For Franco with best memories
of a happy team work

Deep-water arenaceous foraminifera in the Northwest Atlantic Ocean

by

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Submitted in partial fulfillment of the requirements for the degree of

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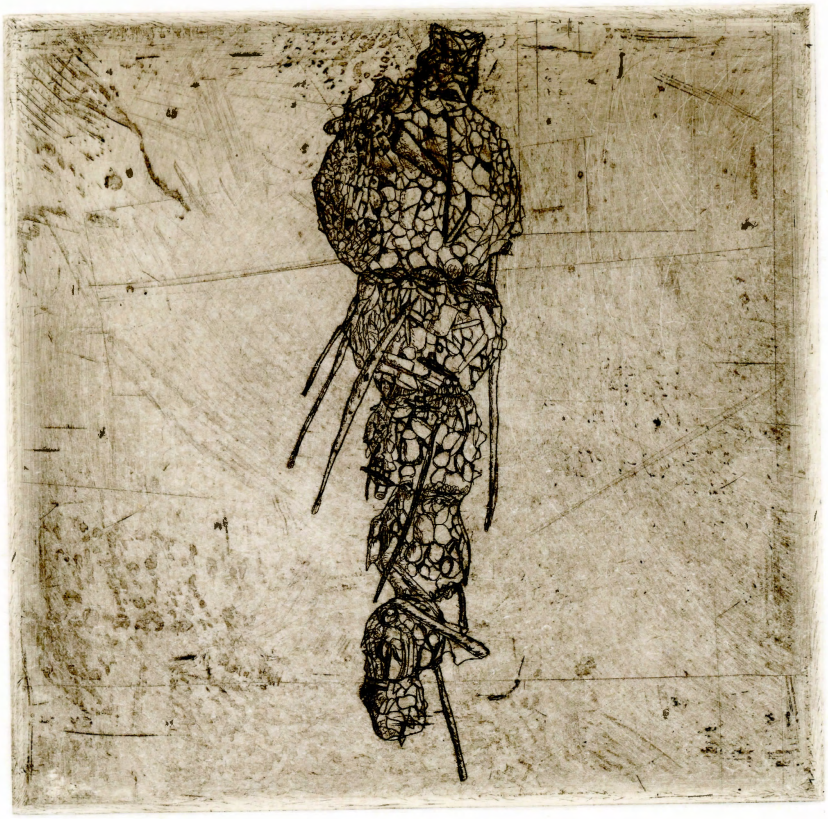

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FACULTY OF GRADUATE STUDIES

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ABSTRACT

Recent deep-water benthonic foraminifera were analysed from 25 box-cores taken on the Continental Rise off Nova Scotia, the Southern Bermuda Rise, and Nares Abyssal Plain. The samples cover a depth range from 2225m to 5779m. Approximately 265 species including 104 arenaceous taxa (related to 10 families) were identified. The arenaceous taxonomy stresses morphotype variability as a function of sediment-type. Classical deep-water collections by H.B. Brady, E. Heron-Allen, A. Earland, and J.A. Cushman served as taxonomic model and were critically reexamined. The percentage of arenaceous foraminifera is increasing progressively with depth. Contour currents strongly influence the nature of substrate which in turn influences the composition of the foraminiferal community. The region below the axis of the Western Boundary Undercurrent (WBUC, 2700-4000m) is subject to winnowing processes which results in an increased Foraminiferal Number and a high species diversity. Fragile arenaceous species such as *Rhizammina algaeformis* seem to prefer zones without major current activity and consequently dominate on the upper Nova Scotia Rise (2200-2500m) above the zone of the WBUC and in abyssal regions. The middle rise arenaceous assemblage, living on a coarse grained substrate, is characterized by coarse grained taxa such as *Hyperammina sp.1*, *Rhabdammina sp.* and *Astrorhiza crassatina* and complemented by species with robust, spherical tests such as *Cribrostomoides subglobosus*, *Recurvoides scitulus*, and *Trochammina cf. globigeriniformis*. Arenaceous species such as *Reophax scorpiurus*, *Reophax bilocularis*, *Psammosphaera fusca*, and *Lagenammina tubulata* are non-selective in their choice of wall material. These species reflect the sediment substrate, resulting in a large intraspecific variability. The arenaceous assemblage on the Nares Abyssal Plain is characterized by a fragile network of delicate species of the family KOMOKIACEA. Other common abyssal species are *Adercotryma glomerata*, *Nodellum membranaceum*, *Ammomarginulina foliacea*, and *Cystammina galeata*. Results suggest that arenaceous foraminifera are more likely controlled by the substrate than by watermasses. Depth ranges, particularly of non-selective taxa, are extended at the lower limit by comparing with published data.

Modern calcareous species form an important component on the Nova Scotia Rise, where 3 assemblages have been identified. The upper continental rise assemblage (2220-2500m) is dominated by *Elphidium excavatum* and *Uvigerina peregrina* associated with the occurrence of the NADW. Increased numbers of *Stainforthia concava* and *Hoeglundina elegans* seem to indicate a transitional mixed watermass of the NADW and the NSOW. The middle continental rise assemblage (2750-3600m) is dominated by *Eponides pusillus* and controlled by NSOW carried southward by the WBUC. With the approach of the lysocline the calcareous assemblage becomes less diverse. Remaining species such *Epistominella umbonifera* and *Epistominella exigua* are abundant and indicate the influence of AABW.

The vertical change in sediment in the upper 30cm is compared with changes in the arenaceous fauna. The effects of selective preservation, chemical solubility of the ferruginous compound in the cement of various species and shifts through transport and reworking processes are reflected in the vertical distribution of the arenaceous assemblages. Based on test construction and depth distribution pattern

arenaceous species are ranked into three major classes reflecting fossilization potential.

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Chapter 1: INTRODUCTION

1.1. GENERAL INTRODUCTION

The deep-sea regions of modern oceans have only recently become objects of extensive study in marine sciences. Special technology had to be developed to obtain reliable oceanographic data and high quality samples from these previously inaccessible areas. Much progress has been made during the last 20 years in the field of physical and chemical oceanography, sedimentology, and deep-sea biology. Among the various components of the deep-sea fauna, foraminifera are a group of special interest to geologists, owing to their evolutionary trends, environmental differentiation and tendency to preserve in large numbers in the fossil record. Early investigations of modern faunas produced descriptive documentations of the foraminifera, based on qualitative studies (e.g. Brady, 1884). The subsequent quantitative investigations of modern deep-sea sediments, their foraminiferal distribution and ecological implications, were based mainly on calcareous foraminiferal assemblages and did not provide sufficient information regarding the arenaceous component. The geological value of fossil arenaceous foraminifera was first recognized by Grzybowski (1898) studying Palaeogene sandstones in Poland and has expanded to many geological basins (e.g. Gradstein & Berggren, 1981). The gap in knowledge of the recent deep water fauna (calcareous vs. arenaceous) has left study of fossil assemblages at a disadvantage. This omission makes it desirable in the present study to focus on the modern arenaceous foraminiferal assemblages.

1.2. PURPOSE AND AREA OF STUDY

The main objective of this study is to examine the live and dead component of the total modern benthonic foraminifera population in deep-sea regions of the NW Atlantic. The analysis is based on three different areas: the Continental Rise off Nova Scotia, the Southern Bermuda Rise, and the Nares Abyssal Plain (Fig. 1). Various deep-sea environments with different benthic habitats which contain distinct faunal assemblages are observed in the area of study. These settings are sufficiently diverse to allow evaluation of ecological parameters which may influence the distribution of foraminiferal species. Ultimately, the study may help to assess controlling factors which differ for the calcareous and arenaceous components.

The samples cover a depth range between 2200m and 5780m. The resulting depth zonation of many benthonic foraminifera species is compared with published depth ranges.

A demonstration of the high degree of intraspecific variability of arenaceous taxa requires a careful taxonomic approach. The available study material of rich, well preserved arenaceous assemblages offers the opportunity to illustrate intergradational series of various species and to document significant features of this important element of the deep-sea meiofaunal community.

The preservation of arenaceous foraminifera and the potential factors which determine the changes in their abundance down core will be assessed. The resulting information about the fossilization potential of arenaceous species may form a link to studies concerning arenaceous foraminiferal assemblages in the fossil record.

1.2.1. Environmental setting

1.2.1.1. Continental Rise off Nova Scotia

The Continental Rise off Nova Scotia ranges in depth from about 2000m to 5000m where it merges seaward with the Sohm Abyssal Plain. The rise is bordered to the northeast by the Laurentian Deep-Sea Channel and to the southwest by the New England Seamounts. The transect (covering a depth range from 2440m to 5000m), from which one part of the sample suite is derived, is located south of a series of smaller canyons which cut the continental slope and rise on the northern side of the area (Fig. 1).

The general distribution of watermasses along the western margin of the North American Basin is controlled by the Western Boundary Undercurrent (WBUC) (Fig. 2). This large contour current ranges between 1000m and 5000m; investigators disagree on its exact position at depth (Bulfinch and Ledbetter, 1983,1984). Within this interval two relatively seperate current systems may exist above and below a more quiet zone at about 4000m on the Continental Rise off Nova Scotia

(Tucholke et al. 1985). Various depth zones with increased current velocity are reported from different areas. Along the slope and rise off Newfoundland major current activity was studied by means of typical geological effects on the ocean floor (Carter et al., 1979; Schafer and Asprey, 1982). The upper and middle continental rise off Nova Scotia between 2500m and 3600m in the region 41°N to 41°53'N, 63°30'W to 65°W was subject to the RISEX Experiment (Lively, 1984). The upper rise showed maximum current speeds of 22cm/sec, increasing towards the middle rise at about 2900m to 63cm/sec and decreasing at 3500m to about 30cm/sec. The lower continental rise southeast of Nova Scotia is studied in detail by various investigators (e.g. Richardson et al., 1981; Bulfinch and Ledbetter, 1983,1984; Hollister and McCave, 1984, Tucholke et al., 1985). The results are mainly derived from the 'High Energy Boundary Layer Experiment (HEBBLE). Current measurements indicate strongest currents below 4500m. The mean current velocity increases between 4100m and 5000m downslope from 8cm/sec to 32cm/sec with maximum speeds of over 70cm/sec (Tucholke et al., 1985). The source of this deep current is in question. According to Bulfinch and Ledbetter (1983, 1984) the current might be correlated to a high velocity core of WBUC. It may also contain a southern source component or a segment of the Deep Gulf Stream Return Flow (DGSRF) near the base of the rise. Whether the described current data are directly transferable to the transect, which was sampled in this study, remains conjectural. If the deep current system is associated with the Gulf Stream then the intensity of the current might decrease above 40°N which is the northern edge of the Gulf Stream between 65° to 50°W

(Hendry, 1982; Hogg and Stommel, 1985).

The initial watermass, transported by the WBUC, is formed by the Norwegian Sea Overflow Water (NSOW), which flows southward from the Denmark Strait and the Iceland-Faeroe Ridge (Stommel, 1958; Stommel and Arons, 1960; Schnitker, 1979) (Fig. 3). The characteristic parameters of this watermass are high dissolved oxygen content, low temperature, and reduced salinity (Worthington and Wright, 1970; Swallow and Worthington, 1961; Schafer and Cole, 1982). As the watermass enters the North American Basin, it mixes with Western North Atlantic Water (WNAW) and North Atlantic Deep Water (NADW), (Emery & Uchupi, 1972). An increased silicate component indicates the inclusion of Antarctic Bottom Water (AABW) on the lower rise (Richardson et al., 1981).

The interaction between the WBUC and the ocean floor was studied in detail on the Continental Slope and Rise off Newfoundland by Carter et al. (1979), Schafer & Asprey (1982), and Carter and Schafer (1983). This area differs from the slope and rise off Nova Scotia in terms of its gentler gradients and the lack of major deep-sea canyons, indicating turbiditic transport of sediment downslope. In the region of the present study, the influence of turbidity currents cannot be totally excluded and the distinction between thin, well sorted turbidites and fine, well sorted contourites is often difficult (Stow, 1979). However, similarities seem to exist between the sediment distributions of both areas. For a complete grain size analysis the reader is referred to the study of Schafer and Asprey (1982). Their data indicate the occurrence of a high current velocity at about 2700m depth. The current erodes the substrate and has a winnowing effect on the underlying sediment. Deposition of fine grained particles and organic supply is inhibited most of the time. A lower content of organic carbon (0.2 %) on the upper rise compared with the upper slope (> 0.4 %) corresponds to a lower flux of organic matter near the WBUC axis. On both sides of this rapidly flowing current - upslope along the transition from rise to slope and seaward towards the lower rise - the rate of deposition increases. The fine silt and clay, carried by the contour current, can settle out in these zones of comparatively low current velocity (i.e. <20cm/sec) (Carter and Schafer, 1983).

These described depositional regimes over the Lower Slope and Rise off Newfoundland are reflected in the sand fraction of the studied depth transect off Nova Scotia. Changes in the various components of the >63um residue are illustrated in Fig. 4. The transitional zone between slope and rise is characterized by an abundant component of light particles such as fragments of planktonic foraminifera, diatom shells and particulate organic matter. Pebble-sized grains are absent. The region under the influence of the upper current system (Lively, 1984) below 2700 is indicated by a compositinal change in the sand fraction. The biogenic component consists of abundant intact tests of planktonic foraminifera, and reduced numbers of diatoms. Coarse detrital sand is present with few iron-coated pebbles. These components form a fraction of a residual sediment, that has been winnowed by currents resulting in a relatively low sedimentation rate. The exact extension of this zone downslope is difficult to determine through lack of detailed current measurements in the interval between 3500m and 4000m. A few current meter stations of the HEBBLE Project suggest lowest current speeds at 4000m (Tucholke et al., 1985). Sedimentological analyses of the area below 4000m on the HEBBLE Site show a slope-parallel zonation in the sediment texture due to contour currents (Driscoll et al., 1985). The silt/clay ratio increases with depth between 4000m and 5100m. A zone rich in clay (>40%) occurs between 4000m and 4800m. A high sand content (>20%) appears between 4800m and 4900m. The coarse fraction in the HEBBLE Area is mainly composed of 2% benthonic foraminifera, 66% planktonic foraminifera, and 32% terrigenous material (Driscoll et al., 1985). Environmental interpretations for the sample transect in this study are based on a generalized picture of the area. Data of the HEBBLE area on the southern Nova Scotia Rise (e.g.Tucholke et al.,1985), of the RISEX Experiment on the upper and middle Nova Scotia Rise (Lively, 1984) and of the Newfoundland slope and rise (e.g. Schafer and Asprey, 1982) are taken into account.

1.2.1.2. Bermuda Rise

In relation to its potential land source area, the Bermuda Rise is a very large topographic feature in the North Atlantic Basin. This is due to an extensive underwater volcanic topography, which is smoothed by deposits of pelagic carbonate (Emery & Uchupi, 1972). The North American Basin below 4000m depth is mainly occupied by the NADW, which overlies a lesser amount of AABW below 4800m depth (Fig. 3) (Worthington & Wright, 1970 and Laine & Hollister, 1981). A clockwise flow of AABW around the Bermuda Rise actively moves the sediments of its western slope in a northward direction.

The surface sediment in the area below 2000m is composed of calcareous silty sand and *Globigerina* ooze. Below the calcium compensation depth (CCD) at around 5000m, brown silty clays are dominant. The Southern Slope and Rise off Bermuda show a steep gradient, leading to downslope transportation of shallow-water sediments to the deep-sea. Turbidites have been supplied by the Bermuda reefs and transport calcareous sediments, consisting of planktonic and shallow-water benthonic foraminifera, fragments of corals and molluscs, pieces of calcareous algae, echinoid spines and sponge spicules, to the deep-sea. These components occasionally form impenetrable layers for sampling devices in the deep-sea. Replicate sampling in this study has shown that the sediment distribution is patchy on the southern part of the rise with locally-distributed turbidites lying adjacent to areas of pelagic sediments.

1.2.1.3. Nares Abyssal Plain

The Nares Abyssal Plain is bordered to the south by the Puerto Rico Trench and to the west by the Hatteras Abyssal Plain. The connection between both abyssal plains is formed by the narrow Vema Gap, through which oceanographic processes take place. Both areas grow progressively deeper eastward, a feature that promotes transport of sediments derived from the North American continent to regions far out on the abyssal plains (Emery & Uchupi, 1972). The Nares Abyssal Plain has a nearly flat floor, dipping slightly to the north and east and is interrupted only by isolated volcanic peaks and basement highs.

The bottom watermass in the Nares area is mainly composed of AABW (Fig. 3). The surface sediment is dominated by pelagic brown clays, which normally contain about 5 % coarse fraction (> 63um) (Shipley, 1978). This fraction consists mainly of arenaceous foraminifera tests, rare sponge spicules, fish teeth, quartz grains, and abundant manganese micro nodules. The scarcity of carbonate in the surface sediment layer results from the overlying position of the CCD and the low productivity in the overlying Sargasso Sea surface water. The remaining carbonate in the sand fraction is formed by corroded fragments of planktonic foraminifera and rare benthonic foraminiferal specimens.

According to Shipley (1978) two different clays can be distinguished by colour on the Eastern Nares Abyssal Plain: a brown clay with less than 5 % coarse fraction and a grey clay which contains 12 % more silt than the pelagic brown clay. Grey clay sediments are interpreted as distal turbidites. The silt layers have increased organic carbon contents and are enriched in calcium carbonate (Kuijpers, 1985). Because of the existence of a surface layer of brown clay on the Nares Abyssal Plain it is assumed that turbidity currents have not been active in Holocene times. It has been suggested by Shipley (1978) that turbidites were transported from the Hatteras Abyssal Plain through the path of the Vema Gap northward across the Nares Abyssal Plain since about Eocene time.

1.3. PREVIOUS STUDIES

Recent calcareous benthonic foraminifera of the North Atlantic Ocean were subjected to many studies during the last 100 years. Numerous investigations examined the details of modern populations on the continental shelf and slope off North America. Benthonic foraminiferal assemblages inhabiting slope environments off Newfoundland were studied by Schafer et al. (1981) and Schafer and Cole (1982). Nova Scotia shelf assemblages have been described by Williamson et al. (1984), by Murray (1969), and Miller and Lohmann (1982) on the eastern shelf of the United States. For a summary of all published data about the Continental Margin of North America I refer to Culver and Buzas (1980, 1981, 1982).

The initial quantitative study of benthonic foraminifera which extended into the deep-sea of the Atlantic was done by Phleger, Parker and Peirson (1953). During the last two decades benthonic foraminifera of deep-sea regions have been investigated extensively for palaeoceanographic determinations. Calcareous foraminiferal assemblages have been used by Streeter (1973), Schnitker (1974, 1979) and Lohmann (1978) as hydrographic indicators for the Recent and through Quarternary times.

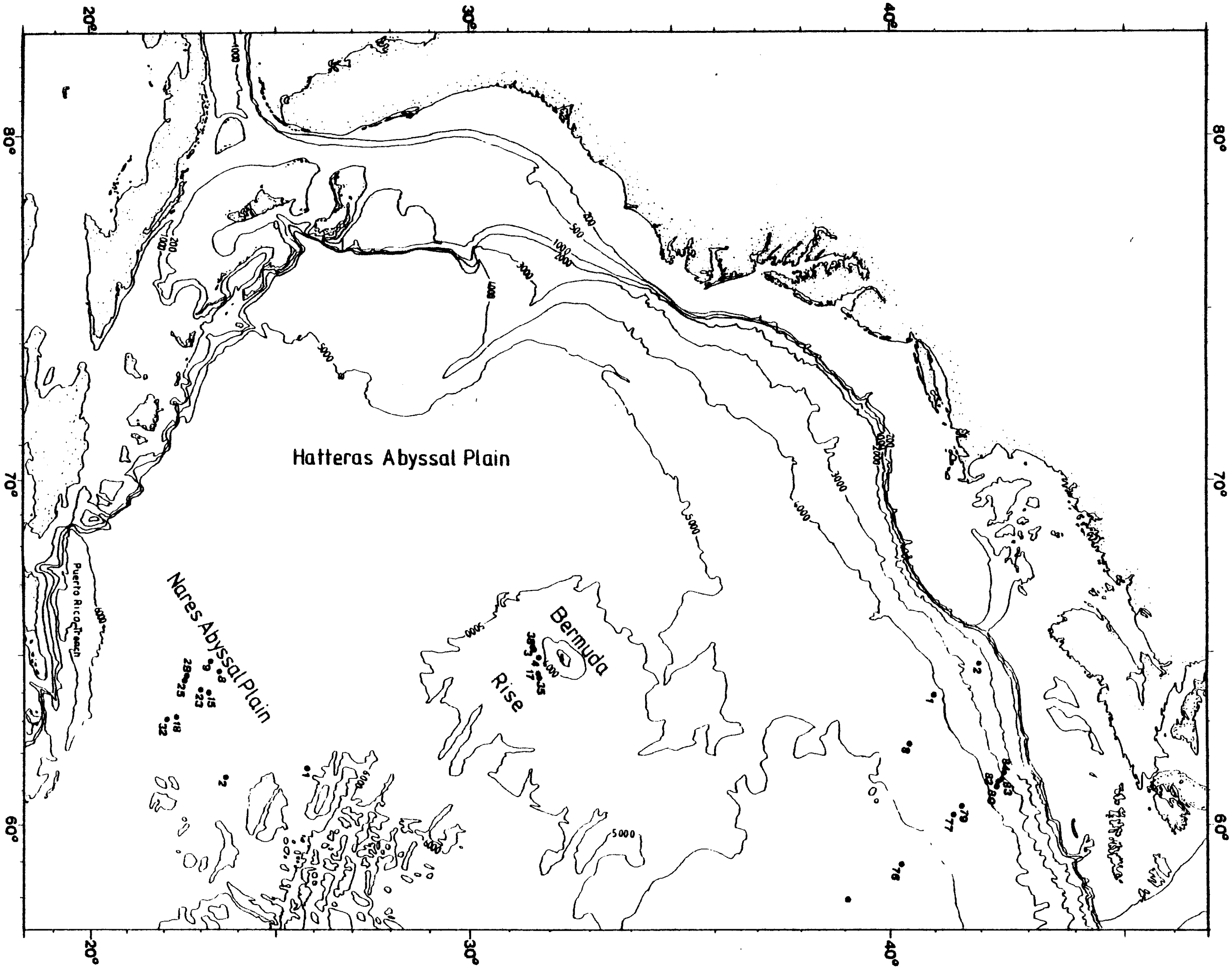
Comparative studies of mid-latitude ocean basins which include the arenaceous deep-sea fauna are scarce. Pioneers in the field such as Brady (1884), Flint (1899), Rhumbler (1913) and Cushman (1918-1923) laid the foundation for future studies through their comprehensive systematic approach and by their excellent illustrations of many species. Quantitative results concerning arenaceous foraminifera are represented to a larger extent in studies of polar regions of the Atlantic. Arctic foraminifera are described by Goes (1894), Cushman (1948), Phleger (1952), Vilks (1969) and Lagoe (1977). The original taxonomic work in the Antarctic region was done by Heron-Allen and Earland (1922), Wiesner (1931), Earland (1933, 1934, 1936) and Parr (1950). Detailed quantitative examinations of various regions in the Southern Atlantic Ocean followed by Bandy and Echols (1964), Pflum (1966), Echols (1971), Herb (1971) and Lindenberg and Auras (1984).

In the Eastern Atlantic foraminifera of continental slope and rise environments off Northwest Africa were studied by Lutze and Coulbourn (1983/1984); off Norway by Sejrup et al. (1981) and Mackensen et al. (1985), and in the Golfe de Gascogne by Caralp et al. (1972). These works also include data on the arenaceous component.

Benthonic foraminifera in abyssal regions were investigated in the Pacific by Saidova (1975), Bernstein et al. (1978), and Walch (1978) and in the Peru Chile Trench by Bandy and Rodolfo (1964) and Ingle et al. (1980).

The recent study extends the knowledge of deep-sea arenaceous foraminifera by revising their taxonomy, establishing depth ranges in the deep-sea realms based on carefully collected box-core samples, and by observing morphological variations of some species within the various environments.

Fig. 1: Index map of stations investigated. Numbers refer to stations of various cruises (see Table 1). Depth contours in meters. Bathymetry after 'General Bathymetric Chart of the Oceans' (GEBCO), Canadian Hydrographic Service, Ottawa.



20°
30°
40°
80°
70°
60°
Hatteras Abyssal Plain
Nares Abyssal Plain
Bermuda Rise
Puerto Rico Trench
200
500
1000
2000
3000
4000
5000
6000

Fig. 2: Blockdiagram showing position of contour currents on the Continental Rise off Nova Scotia. Boldly stippled zones indicate depth ranges of major current interaction (modified after Carter and Schafer, 1983; Ledbetter and Balsam, 1985, Tucholke et al., 1985).

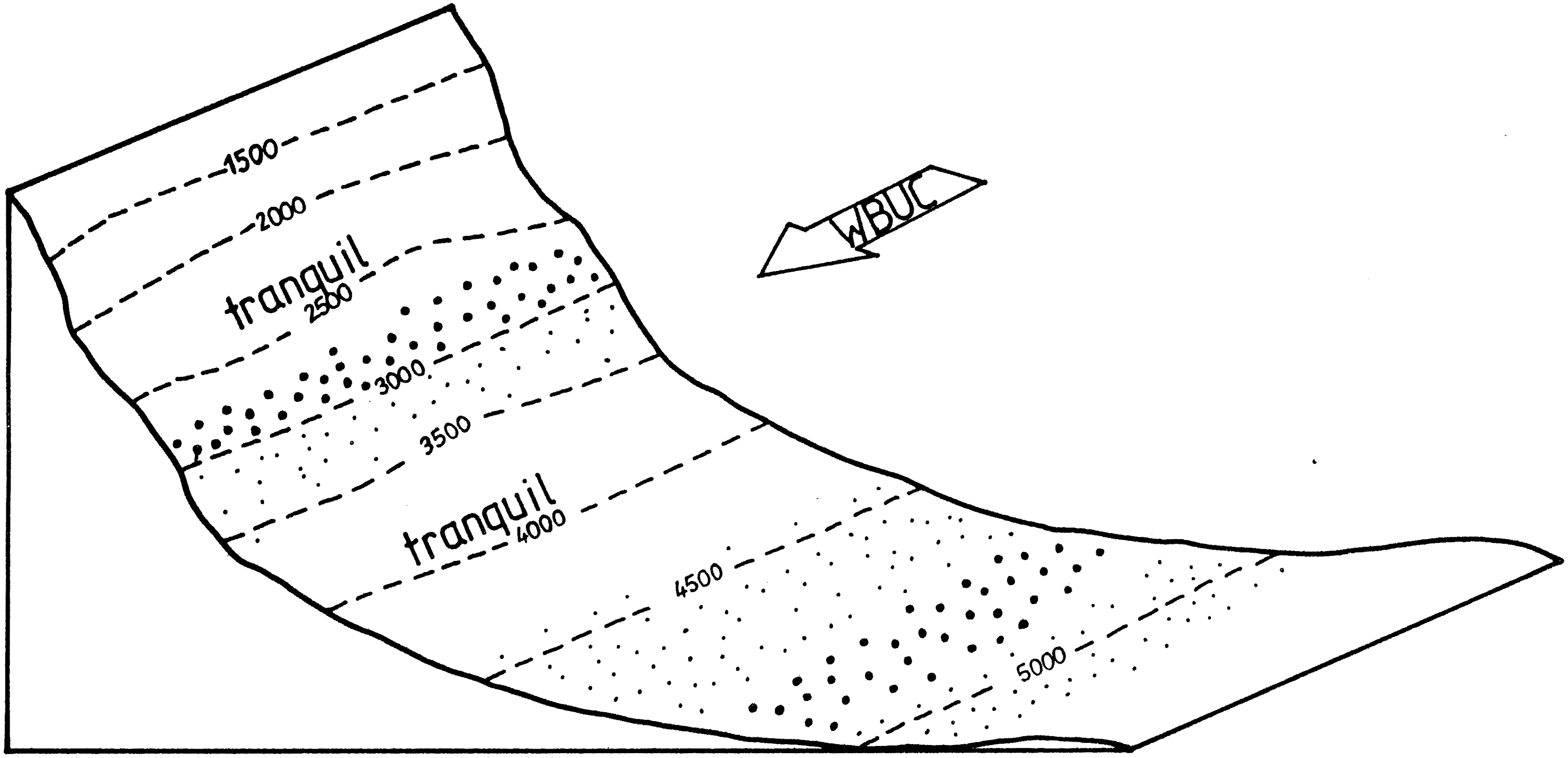

WBUC
1500
2000
tranquil
2500
3000
3500
tranquil
4000
4500
5000

Fig. 3: General distribution of bottom watermasses in the NW Atlantic.

NSOW: Norwegian Sea Overflow Water

NADW: North Atlantic Deep Water

AABW: Antarctic Bottom Water

(modified from Emery and Uchupi, 1972)

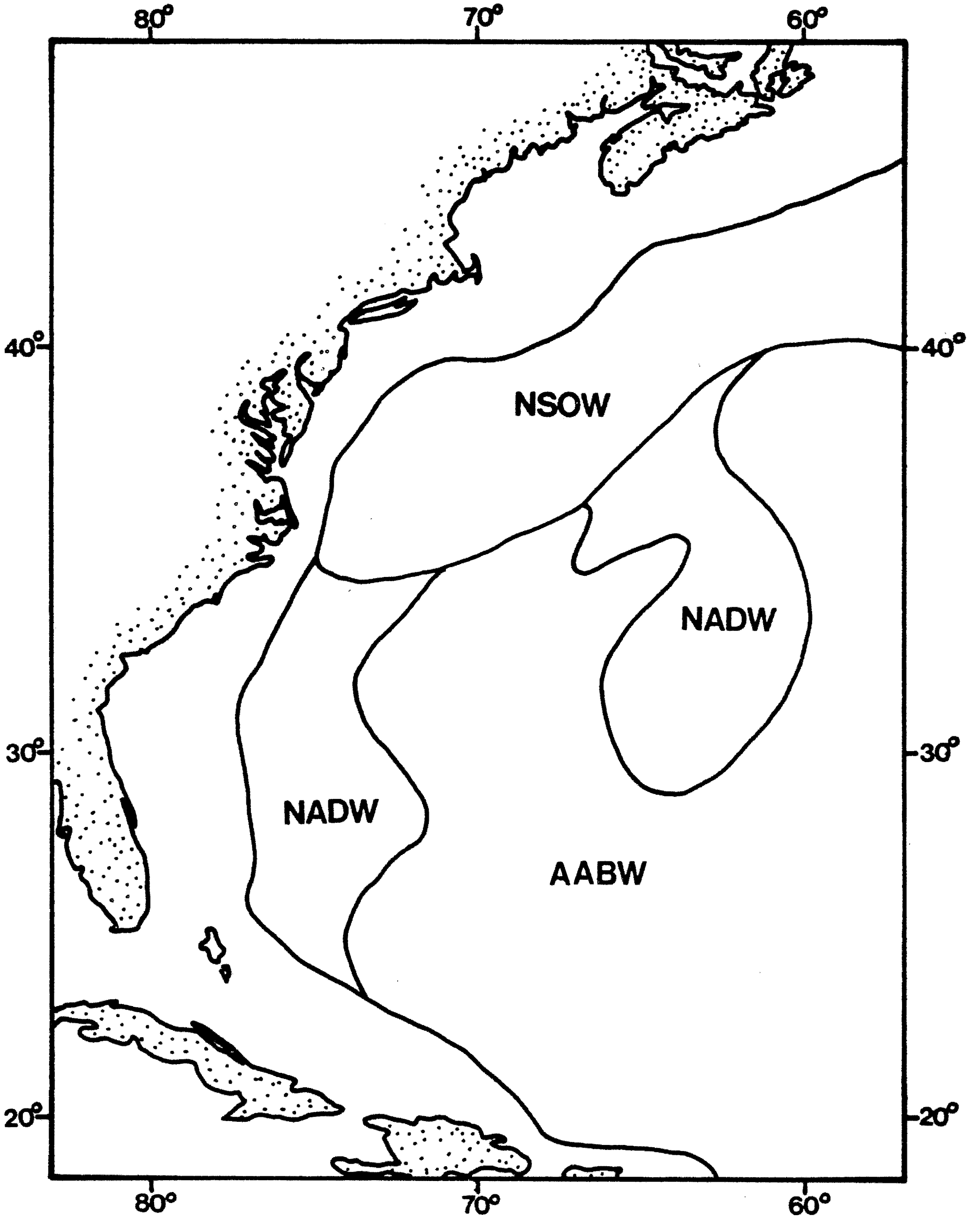

80°
70°
60°
40°
30°
20°
NSOW
NADW
NADW
AABW

Fig. 4: Abundance of main components of the sand fraction in studied box-core samples, and the total number of calcareous benthonic foraminifera. Note the change of composition along the Continental Rise off Nova Scotia, indicating the various depositional regimes of the WBUC.

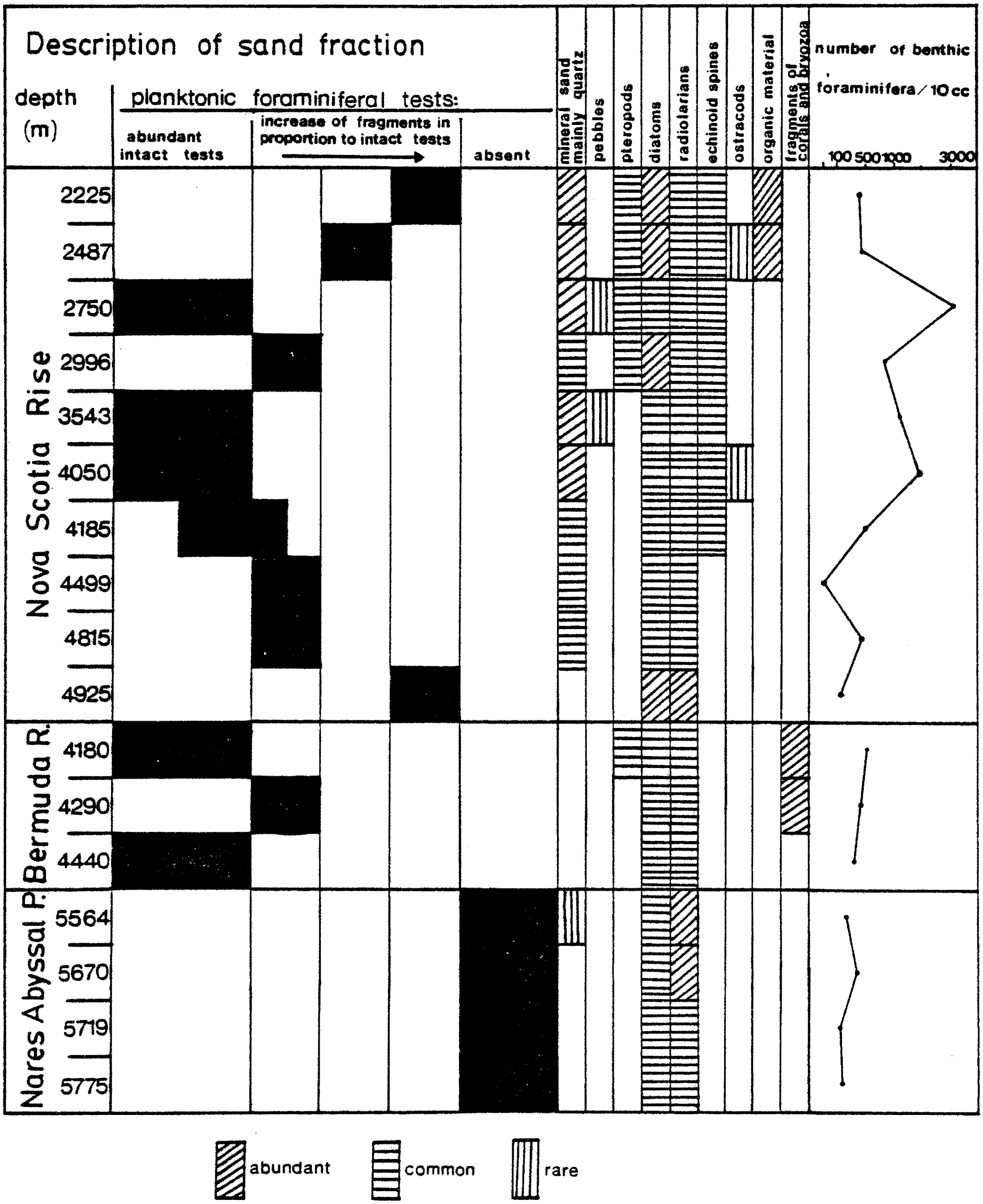

Description of sand fraction
depth (m)
planktonic foraminiferal tests:
abundant intact tests
increase of fragments in proportion to intact tests
absent
mineral sand mainly quartz
pebbles
pteropods
diatoms
radiolarians
echinoid spines
ostracods
organic material
fragments of corals and bryozoa
number of benthic foraminifera / 10 cc
100 500 1000 3000
Nova Scotia Rise
2225
2487
2750
2996
3543
4050
4185
4499
4815
4925
Bermuda R.
4180
4290
4440
Nares Abyssal P.
5564
5670
5719
5775
abundant
common
rare

TABLE 1

LIST OF SAMPLES

area	sample	number of subsamples	depth (m)	Latitude N	Longitude W	total number of benthic foram./10cc		% aggl. species of total benthic foraminifera
NOVA SCOTIA RISE	K104/10BC-2	5	2225	41 59.56	64 39.07	401		25
	82-022-84	5	2487	42 36.98	61 30.36	447		40
	82-022-83	5	2750	42 31.80	61 17.26	3146		45
	82-022-82	5	2996	42 29.73	61 13.80	867		39
	82-022-80	5	3543	42 22.87	60 59.65	1271		60
	82-022-79	5	4050	41 58.58	60 41.91	1934		40
	K103/BC-1	1	4185	40 53.00	63 44.00	505		32
	82-022-77	5	4499	41 37.96	60 19.15	53		69
	K103/BC-8	1	4815	40 27.00	62 20.00	422		60
	82-022-76	5	4925	40 23.87	58 58.09	144		94
Bermuda RISE	83-007-4	5	4180	31 47.50	64 57.50	528		52
	83-007-17	5	4290	31 45.00	64 18.40	410		57
	83-007-35	1	4380	31 45.20	64 11.40	15280	disturbed surface	6
	83-007-38	1	4426	31 36.00	65 11.20	4549	disturbed surface	3
	83-007-3	5	4440	31 36.00	65 10.00	332		74
NARES ABYSSAL PLAIN	80-001-1	1	5664	25 39.00	61 33.40	281		95
	80-001-2	1	5670	23 41.75	61 26.40	355		99
	T84-BC-32	5	5719	22 13.54	63 15.42	117		100
	T84-BC-18	5	5768	22 41.30	63 27.30	53	disturbed surface	90
	T84-BC-25	5	5775	22 57.42	64 10.36	167		99
	T84-BC-9	5	5775	23 12.00	64 45.24	136		98
	T84-BC-8	5	5775	23 32.48	64 30.12	189		99
	T84-BC-28	5	5775	22 42.42	64 20.12	163		100
	T84-BC-23	5	5777.5	23 01.30	64 14.18	190		99
	T84-BC-15	5	5779	23 16.42	63 53.36	103		100

Chapter 2: METHODS

2.1. SHIPBOARD SAMPLING

This study is based on samples collected during three expeditions: CSS HUDSON cruises 82-022 and 83-007 and a the TYRO Expedition in 1984. Additional samples from the Northern Nares Abyssal Plain were kindly provided by G. Vilks of the Bedford Institute of Oceanography, from the HEBBLE area by M. Kaminski, and from the upper rise off Nova Scotia by B. Corliss of the Woods Hole Oceanographic Institute.

All sediment samples selected for foraminiferal analysis are subsamples collected using box-corers using a dimension of 0.25 m^2 (design: Scripps). This device is designed to obtain a large, undisturbed sample of sediment surface. After the box-core was returned to the ship the overstanding surface water has to be drained off. Originally the water was just drained, but it soon became apparent that valuable material was being lost. So a 63 um sieve was employed to retain this component. Depending on the weather conditions and movement of the vessel, the sediment-water interface might be disturbed. Many foraminiferal species, which live loosely attached or spread like a branching network over the sediment surface go into suspension under these conditions. This faunal component is often found in the decanted surface-water of a box-core.

To subsample for the surface component each box-core was subdivided into nine equal squares formed by a partitioning frame and the upper 1 cm layer of up to 9 subsamples was taken and preserved in buffered formalin. The additional surface material of the Northern Nares Abyssal Plain and the HEBBLE area only contain 1 subsample per station (Table 1). After removing the surface layer (1 cm thick), one core of the entire length of the recovered sediment in the box-core (usually 25-35 cm) and 4 short cores (15 cm long) were taken, using plastic coring tubes.

2.2. LABORATORY METHODS

All samples were washed with a fine water spray over a 63 um (230 mesh) sieve to retain the foraminifera. The surface material was stained with Rose Bengal for at least 24 hours to detect individuals living at the time of collection. The samples of box-core K103/BC-1, K103/BC-8, 80-001-1, and 80-001-2 (Table 1) were received in a dry state and unstained. To familiarize oneself with the total variability of forms, it seemed advisable to transfer the entire assemblage to slides. To faciliate this procedure the material from the Nova Scotia Rise, and several samples from the Bermuda Rise, were dried (50° C). All other samples were kept in a bath of alcohol.

From each box-core five subsamples (from each corner and from the center of the box-core), if available, were included in the analysis. For couting each subsample, either wet or dry, was split with a microsplitter into fractions containing at least 300 specimens. The few samples which did not provide the required number were also included in the study. The statistical justification for a count of 300 specimens in ecological studies is discussed by Dennison and Hay (1967). The dried material of the Nova Scotian Slope and Rise and Bermuda Rise were sieved into two fractions: >125 um and 63-125 um, and picked separately on microslides. This method enables the typical fauna occuring abundantly in the small fraction to be observed and to avoid missing small specimens and species.

The short cores (ca 30 cm in length) of selected box-cores were split, described, X-rayed and sampled continously at intervals of 1 or 1.5 cm. The material were treated using the method described above except for the staining procedure. The focus of study for this core material was on the preservation of the arenaceous foraminifera in the live to dead to fossil assemblage.

One of the main problems encountered was the fragility of many arenaceous species. The tubular forms of the family ASTRORHIZIDAE, which are mostly fragmented, comprise one major component of the foraminiferal surface assemblages in all three studied areas and therefore are impossible to neglect. In the present study a fragment was counted as one specimen, identified as precisely as possible, and characterized as a fragment in the resulting illustrations. The same problem was described by Milam and Anderson (1981) with the Antarctic shelf- and slope-fauna. Of course this method creates an overcounting of the tubular species. Therefore a separate calculation was used to show the shifts in percent of calcareous specimens and in percentage occurrences of non-fragmented families, if the ASTRORHIZIDAE are eliminated from the data base (Fig. 5). The largest difference between both plots occurs on the lower rise off Nova Scotia, where the fragile tubular tests of Rhizammina algaeformis, which are highly susceptible to breakage, dominate the fauna.

The photographs of the arenaceous species, illustrated on Plate 1 to 26, include optical micrographs using a Leitz Aristophot instrument incorporating a 35mm camera with Kodak Panatomic X film and scanning electron micrographs, which were taken on a Cambridge S 180 instrument using Polaroid N/P 55 film.

2.3. METHODS AND DATA QUALITY

The influence of the applied shipboard and laboratory methods on the quality of the results in foraminiferal studies is well known. The various controlling factors are discussed in detail by Douglas et al (1978). To provide a useful base for comparisons with other studies the quality of the results described in this work is discussed critically. This study includes three sample sets, collected on various expeditions. The sampling method changed slightly and improved with experience. These changing conditions are reflected in the results and are considered in the interpretation.

The design of the sampling device strongly influences the size and quality of the surface samples. All surface material studied in this project are derived from box-cores. Nevertheless, the richness of total foraminiferal populations and number of living individuals depend on the degree of disturbance of the sediment boundary layer. Weather conditions often stir the supernatant surface water in the box-core and bring many foraminiferal tests into suspension. This faunal component was lost on the Nova Scotia Rise and on the Bermuda Rise by not seiving the surface water. The amount of material lost is impossible to estimate. On the Nares Abyssal Plain the water was drained through a 63um sieve and carefully washed. The residue consisted entirely of arenaceous foraminifera, represented mainly by forms of KOMOKIACEA. This fragile arenaceous group was not discovered in the abyssal regions off Nova Scotia and occurred only as a minor component south of Bermuda. This is probably due to the different sampling procedure. Therefore the KOMOKIACEA are not included in quantitative comparisons. The specific variation of this group was discovered only recently (Tendal and Hessler, 1977; Gooday, 1983; Gooday and Cook, 1984)) through the improvement of sampling methods.

Box-core T84-BC-18 from the Nares Abyssal Plain (Table 1) is an example of a disturbed or missing surficial sediment layer. The percent of total arenaceous foraminifera (Fig. 12) and the live individuals per 10cc (Fig. 17) show a significant decrease at this location, caused exclusively by the loss of the surface sediment layer during shipboard operation. On the Bermuda Rise the surface of box-core 83-007-35 and 83-007-38 were not preserved. The uppermost sediment was part of a turbidite. The extreme high number of benthonic foraminifera per 10cc (Table 1) is the result of the concentration of shallow water calcareous species through downslope transportation. These two box-cores were not included in the comparative diagrams of the results.

Disturbance or loss of the uppermost portion of sediments strongly effects the living foraminiferal assemblage. Different methods used in ecological studies make data comparison difficult. In this study the Rose Bengal method, which was introduced by Walton (1952), was used for staining the live component. The advantage and disadvantage of this method are discussed by Douglas et al (1978). In many thick walled, arenaceous species the stained protoplasm can only be determined by crushing the test. However, this procedure is not advisable in a taxonomic study. Thus the species Aschemonella scabra, for example, is often pink due to stained organic material or bacteria. Crushing of several tests has shown that only a few specimens contained protoplasm. Despite these problems the distinction between the live and dead faunal component was made, but the results illustrated in Fig. 17 should be interpreted with care.

One direct influence of the laboratory methods on the faunal results is given by the choice of the size range of the washed residue (Schröder, Scott and Medioli, in prep.). The present study is based on the fraction >63um. Various larger size ranges have been proposed in analyses concerning deep-sea benthonic foraminifera (Streeter, 1973, >150um; Schnitker, 1974,1979, >125um; and Lohmann, 1978, >250um). The studied samples from the Continental Rise off Nova Scotia have been counted separately in two size fractions: 63-125um and >125um. This method allows the quantitative determination of species which are abundant in the small fraction and often not reported in other studies, that have utilized a larger sieve size. The results for selected common species are illustrated in Fig. 6.

The described influences and uncertainties of various methods affect any diversity measures as well and should be critically considered during interpretations.

2.4. STATISTICAL METHODS

The faunal counts of benthonic foraminifera from the surface samples are expressed in relative abundances, although this method is not totally satisfactory (Murray,1973; Buzas et al, 1977). The study areas show large differences in number of species or number of individuals (Fig. 12) and one species may be represented by the same amount of specimens at various locations, although its percentage may vary substantially.

Species diversity has been computed in ecological studies using several equations. The simplest measure is S; the number of species observed. This number is highly influenced by the sample size, the number of rare species counted, and by the state of preservation of the fragile arenaceous taxa. A commonly used information function which measures the number of species and their proportions is the Shannon-Wiener Index:

$$H = -\sum pi \ln pi,$$

where pi is the proportion of the i^{th} species (Buzas and Gibson, 1969; Buzas et al, 1977). Species with low frequencies contribute little to the value of H. This equation was chosen because the presence or absence of rare taxa may not always reflect actual changes in diversity, but rather changes in sample quality.

A measurement concerning the unequal distribution of species is desirable and given by the following evenness equation (after Buzas and Gibson, 1969) where:

$$E = e^{H}/S$$

S is the number of species observed and H is the Shannon-Wiener information function. In the case where all species are of equal proportion in a sample, the equitability or evenness E equals 1. Values less than 1 are a measure of the degree to which the species proportions in an assemblage differ from a ratio of 1:1.

The living foraminiferal assemblage is expressed by the measure of standing crop which is defined as the number of live individuals based on a standard sample size or area. The results tabulated in this study are normalized to 10cc of wet sediment.

Fig. 5: Percentage of total calcareous specimens and percentage occurrences of the families of arenaceous foraminifera based on two separate calculations:

——— fragmented specimens of ASTRORHIZIDAE included

------ fragmented specimens of ASTRORHIZIDAE not included

One representative sample was chosen for the Nares Abyssal Plain.

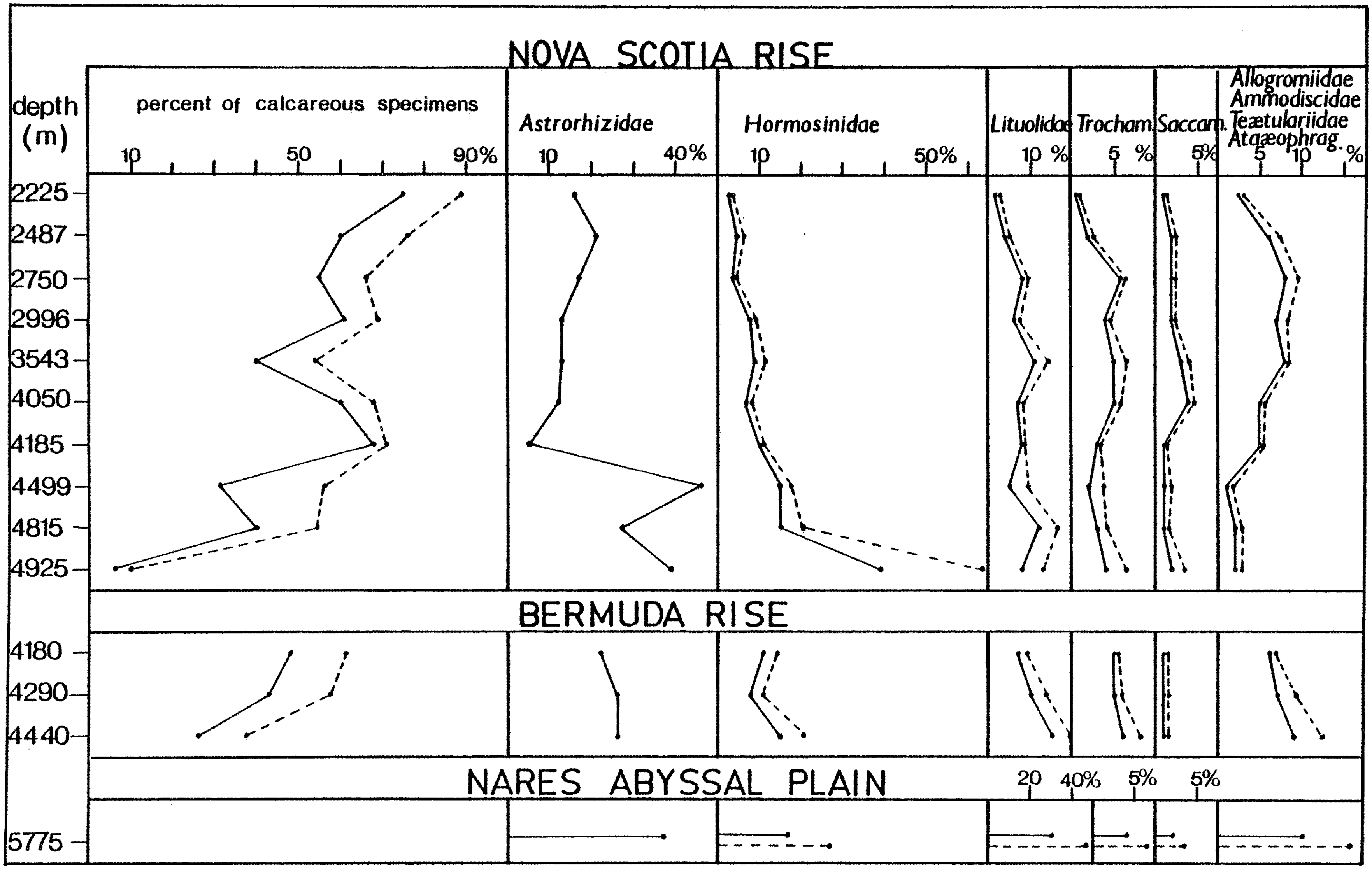
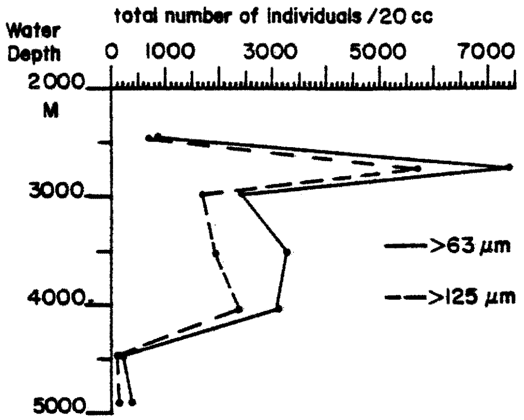
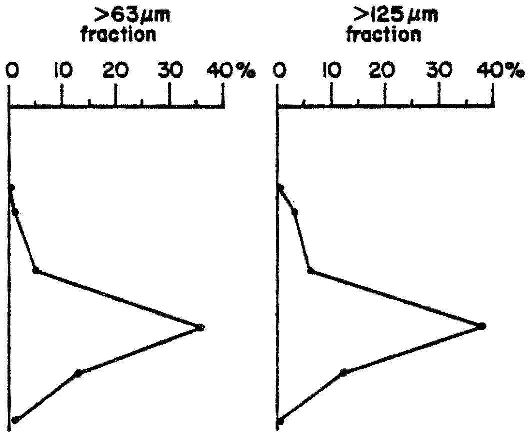
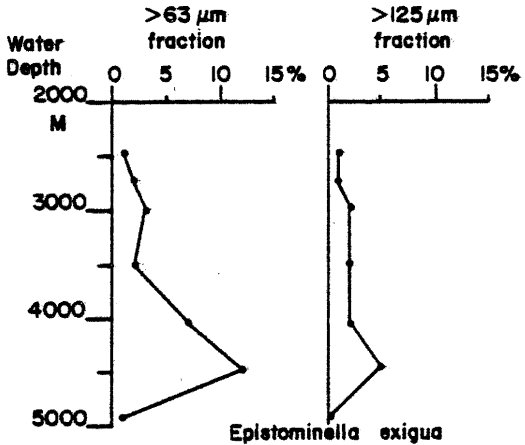

NOVA SCOTIA RISE
depth (m)
percent of calcareous specimens
10 50 90%
Astrorhizidae
10 40%
Hormosinidae
10 50%
Lituolidae
10 %
Trocham.
5 %
Saccam.
5%
Allogromiidae
Ammodiscidae
Textulariidae
Ataeophrag.
5 10 %
2225
2487
2750
2996
3543
4050
4185
4499
4815
4925
BERMUDA RISE
4180
4290
4440
NARES ABYSSAL PLAIN
20 40%
5%
5%
5775

Fig. 6: Percentage occurrences of selected benthonic foraminifera off Nova Scotia relative to water depth using 2 different size fractions.

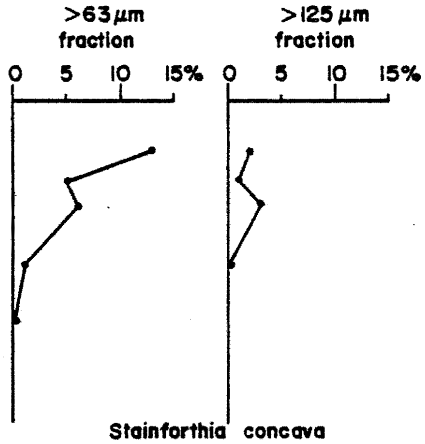




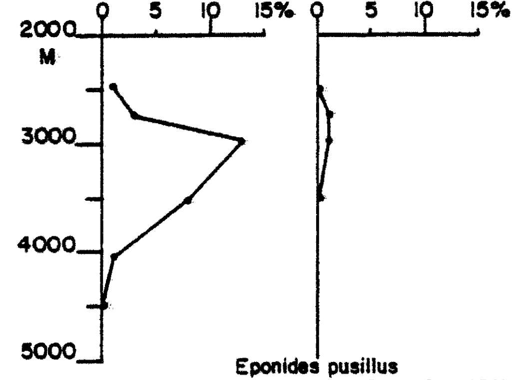
Epistominella umbonifera



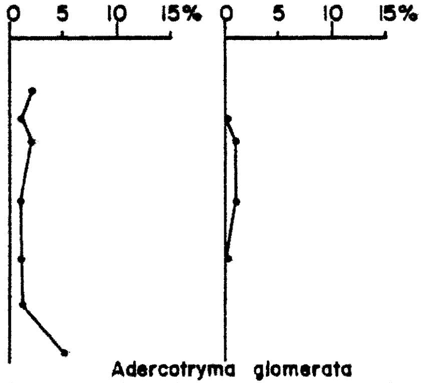
Epistominella exigua



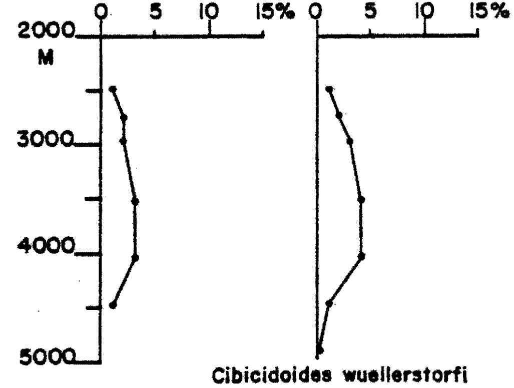
Stainforthia concava



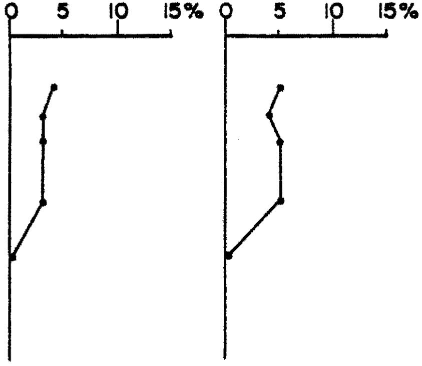
Eponides pusillus



Adercotryma glomerata



Cibicidoides wuellerstorfi



Hoeglundina elegans

Chapter 3: SYSTEMATICS

3.1. GENERAL ASPECTS OF THE USE OF ARENACEOUS FORAMINIFERA

The arenaceous foraminiferal fauna in the deep sea of the modern ocean shows a high species diversity, but most species occur in low numbers. With these forms, the scientist is confronted with a large intraspecific variability probably due to the ability of this group to utilize different particles from local habitats. These conditions complicate the palaeontological taxonomy particularly at population level. Without knowledge of the nature of the sea-bottom one could tend to create a new species, each time a different wall-texture is encountered. As a consequence each sedimentologically differentiated habitat would seem to support its own unique species. In this study, I contend that the sediment type available for the construction of the test is not an important taxonomical criterion. To prove the actual effects of variable sediment on generic and specific determinations, however, further morphological and biological studies involving more taxa in different biotopes, are necessary. The question may be asked what represents a useful method for identification, particularly in quantitative and qualitative studies that are based on many samples. The method developed for this investigation is outlined in the following chapters.

3.2. ECOPHENOTYPIC VARIATIONS OF SOME ARENACEOUS SPECIES

The three sampling areas in the NW Atlantic which are covered by this study are represented by distinctive sedimentary enviroments (see chapter 1). The substrates along the transect of the continental rise off Nova Scotia change from a relatively fine grained sediment (2200-2500m depth) to a winnowed, coarse grained sediment under the axial region of the Western Boundary Undercurrent (2700-3000m depth) to fine grained again on the lower Rise (4500-5000m). The Bermuda Rise contains a large calcareous component formed partly by fragments of shallow water organisms. On the Nares Abyssal Plain the surface sediment is dominated by pelagic brown clays. These regional differences of grain type and grain size in the sediment, available to the arenaceous foraminifera, are reflected in the wall-texture of various species, producing a variety of morphotypes. Not only does the wall-texture change in terms of composition, but it also influences the shape of morphotypes. Features such as the shape of chambers, the shape of a produced neck, and the fragility of the test are often dependent on wall material utilized. Therefore, the question may be asked, which rank does the selectivity in wall particles represent in the species concept.

3.2.1. SELECTIVITY

A perusal of the large body of literature on arenaceous foraminifera reveals that many species are defined on the basis of their agglutinated wall material. Opinions conflict about the significance of this feature.

Avnimelech (1952) and Hofker (1972) give the selectivity in wall particles a high priority in their taxonomical concept. Other authors like Slama (1954), Buchanan & Hedley (1960) and Sliter (1968) have carried out experiments in the laboratory and have shown that the same species are shown to utilize different material to construct their shells. Loeblich and Tappan (1964) reviewed the various conceptions and concluded that selectivity should not be regarded as a feature of taxonomic importance. Many observations in my study support the latter concept.

A convincing example is provided by the genus Reophax. R. scorpiurus is illustrated in Fig. 7 and Plate 23. The form occurs above the Western Boundary Undercurrent in about 2400m depth with tests composed of medium sized quartz-grains. Under the axis of the current (2750m) a different morphotype of this species uses planktonic foraminifera and coarser mineral grains to build the wall. Towards the abyssal regions the test of this form becomes fine grained. South of Bermuda its composition reflects the abundant calcareous fragments or small planktonic foraminifera of the sediment while on the Nares Abyssal Plain it changes again to very fine grained. The exterior shape of the test changes with the different wall material. For instance, a chamber constructed of calcareous fragments is more slender than the one with mineral grains. It is assumed that these various morphotypes are all related to the same species namely R. scorpiurus.

Other species, such as R. bilocularis were found to display a similar variability in wall texture as a function of habitat (Fig. 8 and Plate 24).

How the selectivity has influenced the taxonomic concept of recent taxa of Reophax may be demonstrated with the following three examples, taken from the literature:

(1) Specimens using foraminiferal shells were separated by Cushman (1913) from R. scorpiurus, based on mineral grains, and related to Reophax agglutinatus. (2) A variety of Reophax distans using sponge-spicules and mineral grains, rather than mineral grains only, was described by Parr (1950) as Reophax pseudodistans. (3) Reophax micaceus, described by Earland (1934) seems to be morphological identical with Reophax dentaliniformis; the new species was based on the use of mica flakes.

Various other non-selective species of different families are illustrated on Plates 25 and 26. Hormosina carpenteri was observed in the deep-sea of the Pacific attached to manganese nodules. The test is entirely black due to incorporated manganese. On the Nares Abyssal Plain this taxon displays a test made of fine mineral grains.

Besides these non-selective arenaceous species, forms with a tendency to select one type of wall material exist as well (Lindenberg, 1967). For example Technitella legumen or Saccorhiza ramosa are always found with agglutinated sponge-spicules. However, a preference for a limited range in grain size seems to be more common, a relationship that was made likely in experiments by Sliter (1968). Laboratory tests with Trochammina pacifica have demonstrated the capability of this species to form a fragile test comprising an organic membrane in the absence of agglutinating material. This phenomenon was observed by me in the Nares Abyssal Plain material where organic membrane tests of *Trochammina* and *Thurammina* occurred occasionally without covers of grains or were incompletely covered. These occurrences are probably related to the paucity of suitable wall material in abyssal depth.

More specific observations on the problem of wall material selectivity will be discussed in the next section dealing with systematics.

3.3. FORAMINIFERAL GROUPS REQUIRING SPECIAL TAXONOMIC ATTENTION

3.3.1. Tubular species

An important component of the arenaceous foraminiferal fauna in general is formed by the tubular forms of the family of ASTRORHIZIDAE. The tendency of their tests to fragment renders identification more difficult. In this study identifications are based on visual comparisons of exterior shape and wall texture with a light microscope and SEM photography. Other authors such as Hofker (1972) include observations of thin sections and regard aspects of the inner wall structure such as the number of layers, the existence of thin linings, or the interior of the test as important criteria.

The following distinctive characteristics of morphology have been evaluated (Fig.11):

a. Size

The size of the entire test and the diameter of tubes seem to have only limited value for identification. This feature varies with the ontogenetic stages of the species so that large populations with many age classes are necessary to evaluate these test properties for taxonomic differentiation. The samples taken over a large depth range show that the size of certain arenaceous foraminifera varies with the grain size of the wall material. Several species observed on the rise off Nova Scotia such as _Reophax scorpiurus_, _Reophax bilocularis_, and _Annomarginulina foliacea_ tend to construct larger tests in those instances where their habitat is formed by coarse grained sediment. In abyssal regions the same species form a smaller and more fragile test. The genus _Reophax_ offers an example (Fig. 7-10).

b. shape

The tubular, simple non-branching forms may show the following distinctive shapes:

elongate cylindrical
conical
tapered to one or both ends
fusiform
small central chamber with tubular arms

c. Branching

The existence of branches is an important feature for classification. This cannot be properly assessed in the case of fragments, which are almost always found in fossil assemblages.

d. Number of chambers

In the case of small fragments the number of chambers is of limited value. The proloculus of *Hyperammina*, for example, is often broken, which makes the distinction between *Rhabdammina* and *Hyperammina* almost impossible. A central chamber is a characteristic feature for *Rhabdammina abyssorum*, but the fragments of the broken arms are virtually impossible to identify as such.

e. Growth features

Changes in growth rate resulting in annular contrictions such as in *Rhabdammina discreta* or tranverse rings such as in *Bathysiphon hirundinea* are useful for taxonomy at the species level.

f. Aperture

The number and shape of apertures and their position are important features for identification.

g. Mode of life

Arenaceous foraminifera occur free or attached to other foraminiferal tests or to a variety of other substrates. In the group of tubular species *Dendrophrya*, *Ammolagena* and *Tolypammina* form examples of attached taxa. However, *Tolypammina* occurs attached on the continental slope and as free specimens in abyssal regions.

h. Wall texture

The wall texture can be observed at the outer and inner wall surface. A study of the inner wall texture would require thin sections which were not prepared for the present study. Verdenius and Van Hinte (1983) have studied Tertiary arenaceous foraminifera and have subdivided the outer and inner wall surface into three types by considering the orientation of mineral grains, the smoothness of wall and amount of cement.

The recent material shows that these features can vary within certain species depending on the available grains (as already discussed in section 2.1.). Various species, however, show preferences which may become useful for identification.

3.3.2. Reophax

The genus Reophax DE MONTFORT is an important faunal component in all three areas under study and is represented by numereous species. A detailed revision of the type-species R. scorpiurus DE MONTFORT was done by Brönnimann and Whittaker (1980) who, since the original type seems to be lost, have established a neotype. A ventricose asymmetry of the final chamber and the absence of a produced neck have been proposed as characteristic features for the generic identification. The figures of the neotype show a coarse textured wall made of large angular quartz grains. Consequently, Reophax dentaliniformis BRADY, a fine grained species with a distinct neck, was related by these authors to Hormosina. This classification is not followed in this study, because the material has shown a large variability within Reophax. The distinction of a produced neck, the symmetry of the chambers, and their size, all seem to depend on the wall material utilized.

The variability of R. dentaliniformis in the Baltic Sea was demonstrated by Hermelin (1983). The variation in number and width of chambers and the presence or absence of a produced neck seem to delineate a biogeographic pattern.

Fragmentation of specimens is another cause of identification problems. Tests of Reophax tend to break easily at the junction of chambers, creating single chambered specimens (Fig. 8). Fragments of Reophax ovicula or Reophax bilocularis, both multi-chambered forms, resemble Reophax difflugiformis in morphology, originally described by Brady (1879) as a single, rounded or oval chamber. Therefore in samples with single- and multi-chambered specimens present, a clear cut distinction is often impossible to obtain.

3.3.3. Trochammina

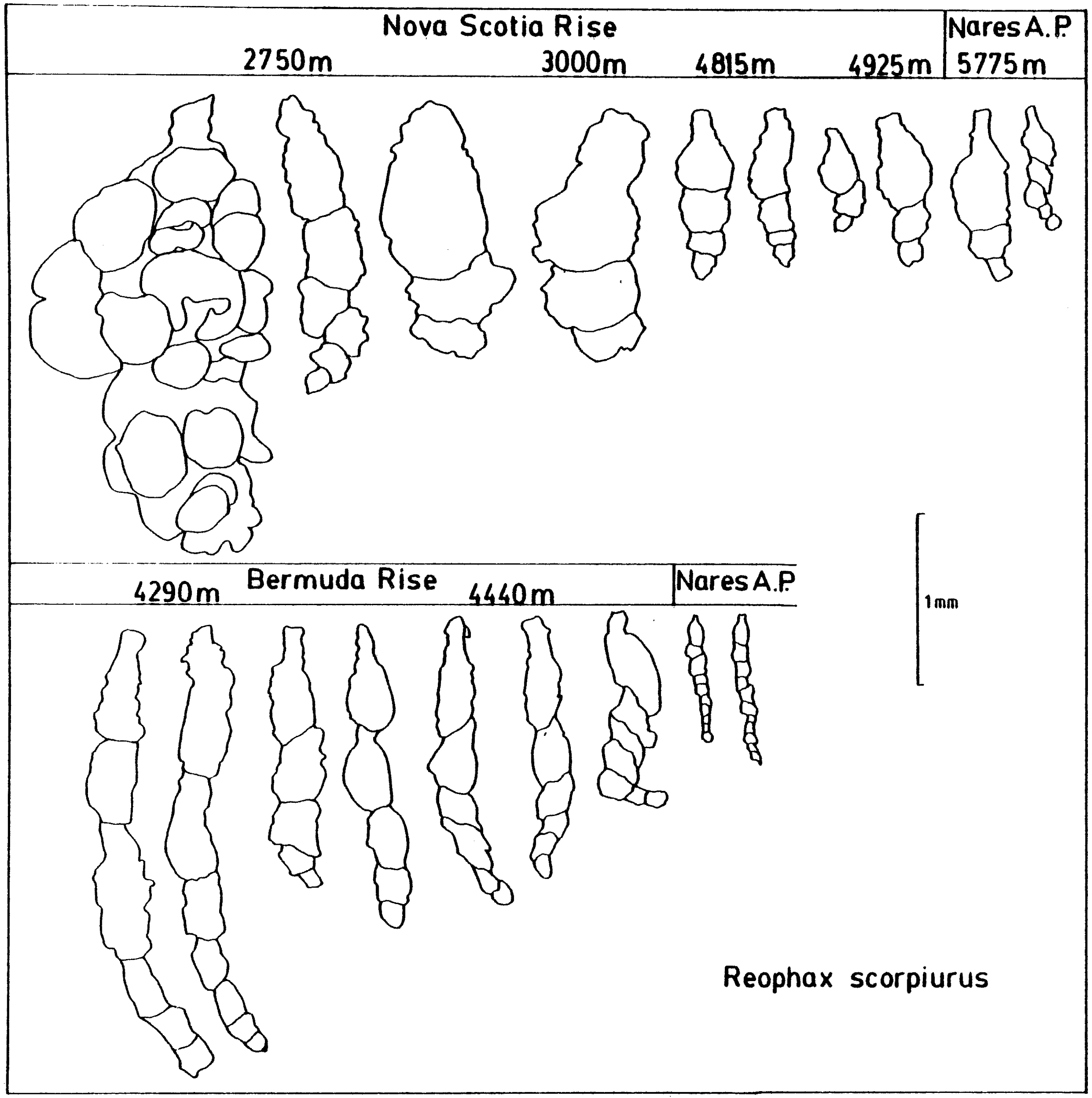
The genus Trochammina poses many problems in classification. This is partly due to variability, but also to the scarcity of individuals per species in the deep-sea. The low abundance in the samples evaluated in this study does not lend itself to the intergradational series technique to determine an exact species concept for this genus.

The family TROCHAMMINIDAE is represented in large numbers in shallow water environments where intergradational series have been used to solve some taxonomic problems (e.g. Scott and Medioli, 1980). Other recent detailed taxonomic studies have resulted in numerous new genera and species (Brönnimann et al. 1983, Brönnimann and Beurlen 1977, Brönnimann 1978). Some of the deep-sea types at present are under study by the same authors (per. comm. P. Brönnimann, 1984).

In this study, five different morphotypes of *Trochammina* have been distinguished. A comparison of these morphotypes with the original types of this genus in the British Museum, London and in the collections at the Smithsonian Institution, Washington D.C. did not show a complete conformity with the discovered taxa. Therefore this study fulfills only the purpose of a distinction of the various deep-sea types, including a description and taxonomic remarks. A detailed revision of this genus seems to be required.

Fig. 7: Variability in size and exterior shape of *Reophax scorpiurus* within the studied areas and depth zones.

Note the decrease in size with increasing water depth.



Reophax scorpiurus

Fig. 8: Variability in size and exterior shape of complete specimens and single chambered fragments of <u>Reophax bilocularis</u>.

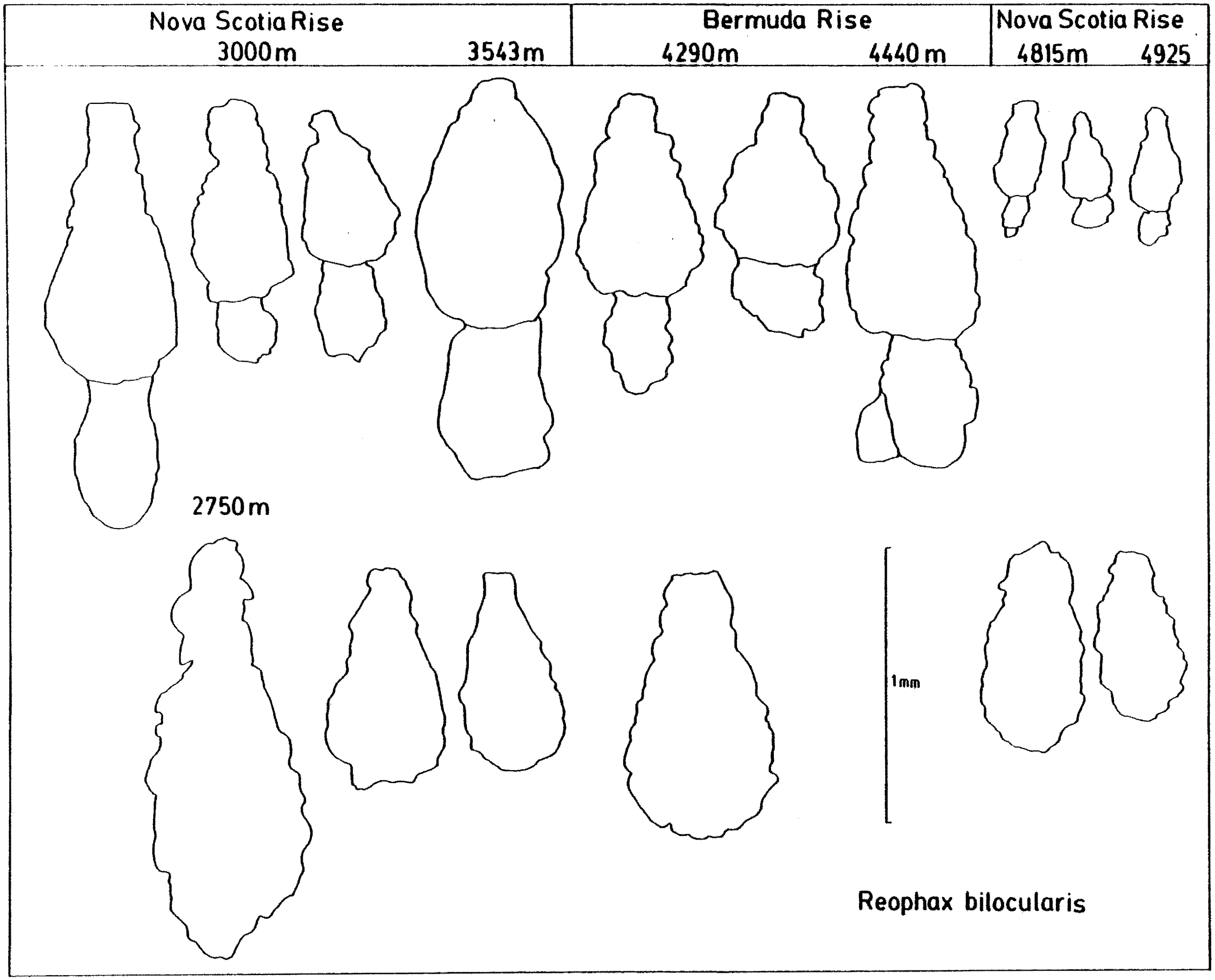

Nova Scotia Rise
3000m
3543m
Bermuda Rise
4290m
4440 m
Nova Scotia Rise
4815m
4925
2750m
1mm
Reophax bilocularis

Fig. 9: Variability in size and exterior shape of Reophax dentaliniformis within the studied areas and depth zones. Note the decrease in size with increasing water depth. Coarse grained wall material often causes irregular sutures which impede the distinction to R. scorpiurus.

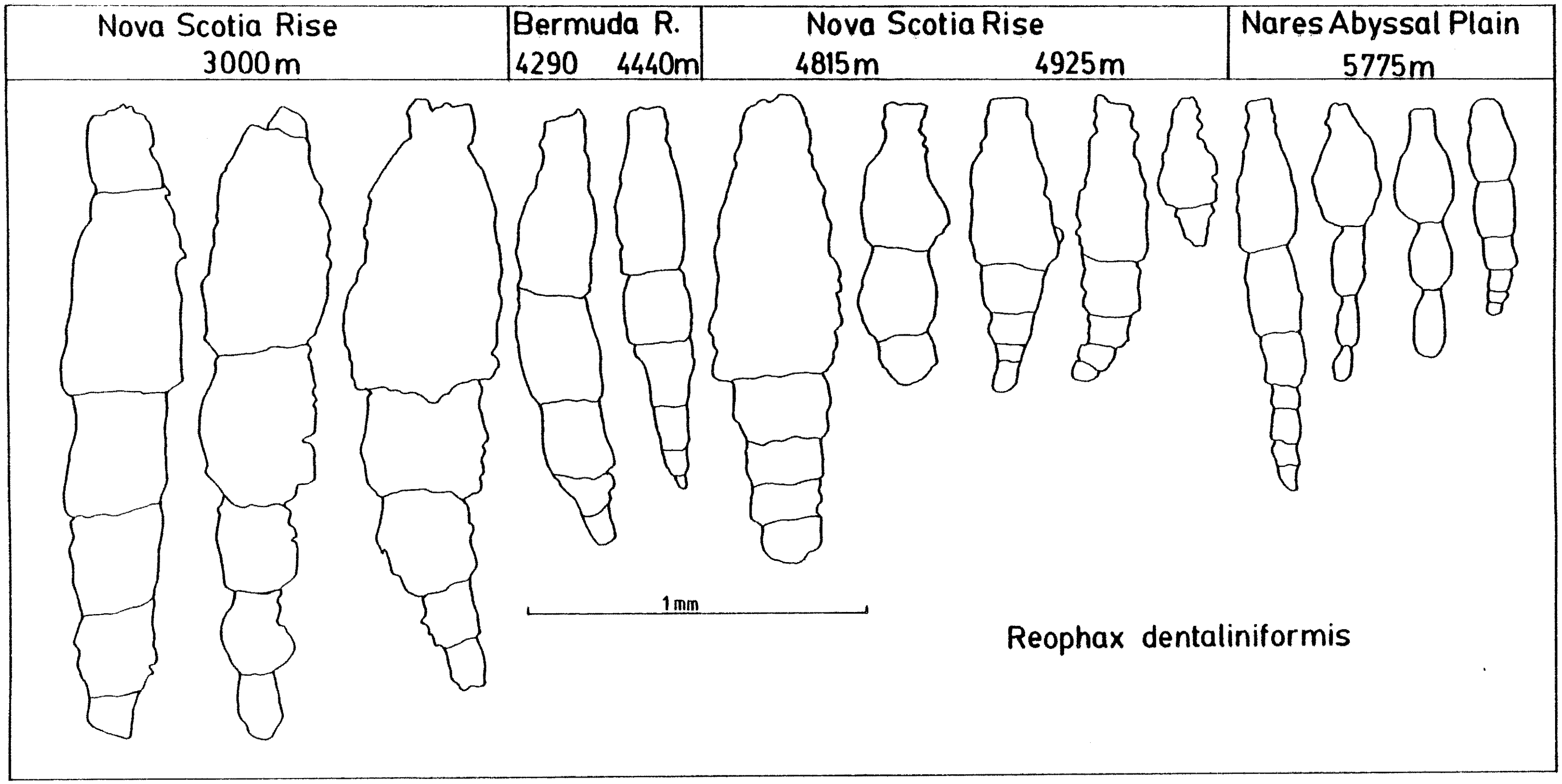

Nova Scotia Rise
3000 m
Bermuda R.
4290 4440m
Nova Scotia Rise
4815m 4925m
Nares Abyssal Plain
5775m
1 mm
Reophax dentaliniformis

Fig. 10: Variability in size and exterior shape of Reophax pilulifer and Reophax horrida within the studied areas and depth zones. The form from 5470m depth and related to R. horrida indicates the high degree of similarity between these types.

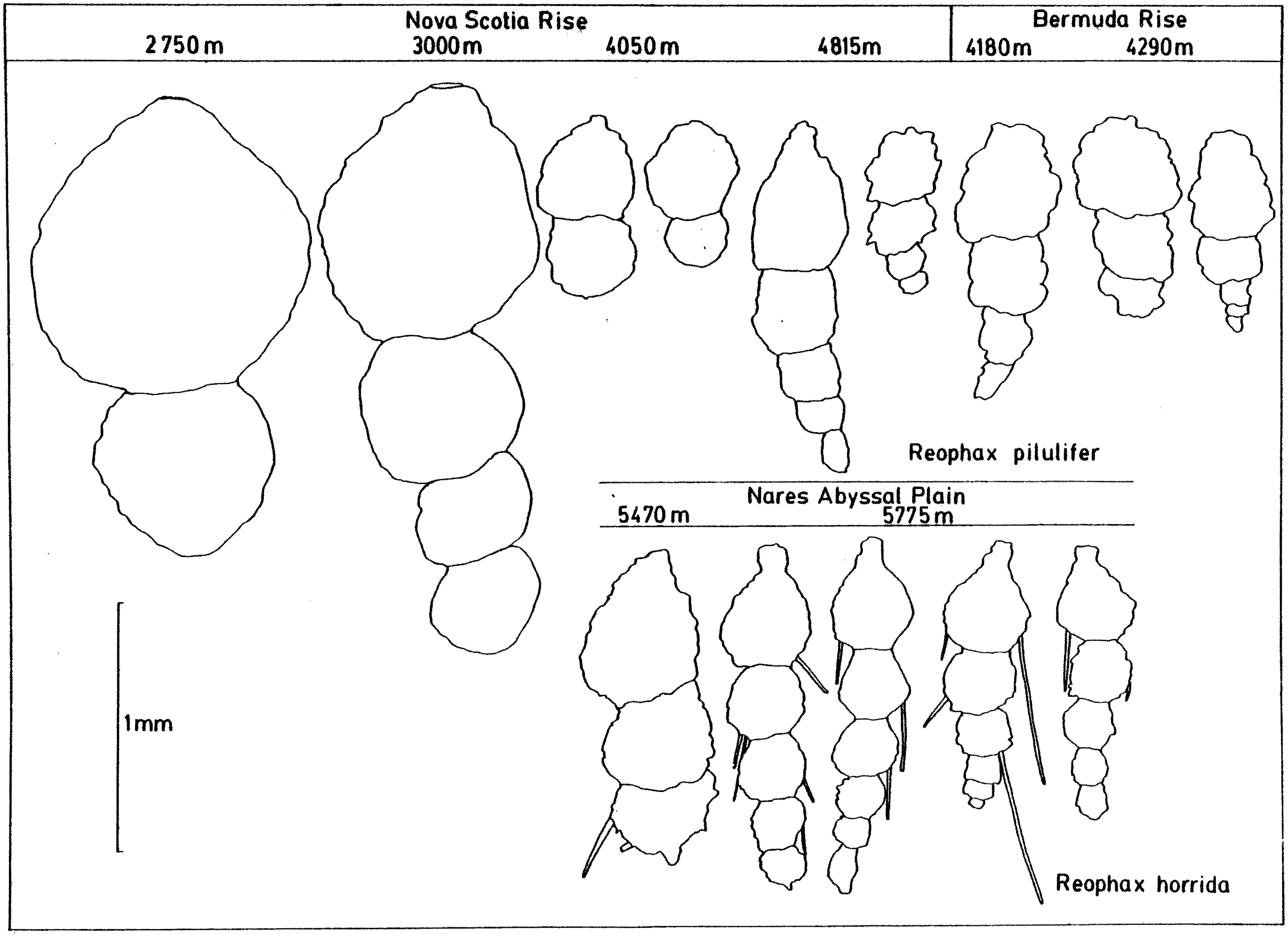

Nova Scotia Rise
2750 m
3000 m
4050 m
4815 m
Bermuda Rise
4180 m
4290 m
Reophax pilulifer
Nares Abyssal Plain
5470 m
5775 m
Reophax horrida
1mm

Fig. 11: Key for identification of tubular, single chambered arenaceous genera. List contains only genera which were found in this material.

	RHABDAMMINA	RHIZAMMINA	BATHYSIPHON	MARSIPELLA	HYPERAMMINA	JACULLELA	SACCORHIZA	DENDROPHRYA
simple tube	X	X	X	X	X	X		
branched tube	X	X					X	X
dichotomous branches							X	
small central chamber with tubular arms	X							
proloculus					X		X	X
elongate cylindrical	X			X	X			
conical						X		
tapered			X					
fusiform				X				
commonly annular constrictions	X		X					
attached with proloculus								X
open only at one end					X			
highly diverse in wall material	X	X						
commonly sponge spicules			X	X			X	
more or less flexible		X						X

3.4. TAXONOMIC NOTES ON THE ARENACEOUS SPECIES

The priority in this study was to point out typical features of each species, their similarities to other forms and to assess the problems of identification created by the high level of intraspecific variability of arenaceous foraminifera. For this reason the taxonomy does not include a full description of each taxon. For reference purpose, the original description and a selection of illustrative studies with characteristic figures are cited. Brief comments and scanning electron microscope and light microscope illustrations complement the systematics.

Most of the species described by H.B. Brady and various species described by E. Heron-Allen & A. Earland and J.A. Cushman were compared with my material by examining original material in the British Museum and the Smithsonian Institution. Some new observations have been added.

The classifications and the concept of genera adopted in this study follow that of Loeblich and Tappan (1964), unless otherwise noted. During the process of this study a new classification was proposed by Loeblich and Tappan (1984). The number of arenaceous families increased substantially by ranking each group higher in the systematic order. At the present time, however, it was more suitable to arrange occurrence data of species according to the old system which allows a comparison with other studies. The original references for all calcareous species are included in the appendix.

ORDER: Foraminiferida EICHWALD, 1830

SUBORDER: Allogromiina LOEBLICH and TAPPAN, 1961

SUPERFAMILY: Lagynacea SCHULTZE, 1854

FAMILY: Allogromiidae RHUMBLER, 1904

GENUS: Nodellum RHUMBLER, 1904

Nodellum membranaceum (BRADY)

Plate 1, Fig. 3

Reophax membranacea, BRADY, H.B., 1879, p. 53, pl. 41, fig. 9.

Nodellum membranaceum (Brady) EARLAND, 1934, p. 84, pl. 2, fig. 41; BARKER, 1960, pl. 32, figs. 1-4; LOEBLICH and TAPPAN, 1964 , fig. 97/4.

Chitinosiphon rufescens THALMANN and BERMUDEZ, 1954, p. 53, textfigs. 1-4.

Remarks: chitinous small test with a series of inflated chambers. Thalmann and Bermudez (1954) established the new genus Chitinosiphon based on the existence of a chitinous wall. Flint (1899) figured a form under the name Bathysiphon rufum (pl. 7) from a depth of approximately 1800m, which appears to be identical in morphology to N. membranaceum, but with a thicker, fine grained wall. This phenomenon might be a matter of a species being capable of constructing a chitinous test in abyssal depth. The chambers in deeper areas are slightly inflated.

My material has been compared with the holotype and paratypes of

H.B.Brady's collection, with which it agrees well.

GENUS: Placopsilinella EARLAND, 1934

Placopsilinella aurantiaca EARLAND

Plate 1, Fig. 1

Placopsilinella aurantiaca EARLAND, A., 1934, p.95, pl. 3, fig. 18; ECHOLS, 1971, pl. 1, fig. 1.

Remarks: chitineous biserial test, attached, found usually on large calcareous foraminiferal tests.

GENUS: Thalamophaga RHUMBLER, 1911

Thalamophaga ramosa RHUMBLER, 1911

Plate 1, Fig. 2

Thalamophaga ramosa RHUMBLER, L., 1911, p. 231; LOEBLICH and TAPPAN 1964, C178 , fig. 6.

Remarks: test attached, chitineous wall.

SUBORDER: Textulariina DELAGE and HEROUARD, 1896

SUPERFAMILY: Ammodiscacea REUSS, 1862

FAMILY: Astrorhizidae BRADY, 1881

SUBFAMILY: Astrorhizinae BRADY, 1881

GENUS: Astrorhiza SANDAHL, 1858

Astrorhiza angulosa BRADY

Plate 1, Fig. 5

Astrorhiza angulosa BRADY, H.B., 1884, p. 234, pl. 20, figs. 10-13; WIESNER, 1931, p. 76, pl. 2, figs. 11,12; BARKER, 1960, pl. 20, figs. 10-13.

Remarks: Test consists of a triangular central chamber with short extensions.

Astrorhiza arenaria CARPENTER

Astrorhiza arenaria CARPENTER M.S., 1877, in Norman, A.M. 1877, p. 213, pl. 19, figs. 1-13; BARKER, 1960, pl. 19, figs. 5-10; HOFKER, 1972, pl. 1, figs 1-5.

Remarks: Test consists of a flat stem with irregular branches which are found often broken. Fragments of tubular arms are difficult to distinguish from other tubular species. Test agglutinates coarse mineral grains with abundant cement.

Astrorhiza crassatina BRADY

Plate 1, Figs. 4a-c

Astrorhiza crassatina BRADY, H. B., 1881, p. 47.

Psammosiphonella crassatina (Brady) BARKER, 1960, pl. 20,figs. 1-9; HOFKER, 1972, p. 25, pl. 4, figs. 9-12.

Remarks: The shape of this large species is irregular, elongate to rounded without uniform breadth. The wall is coarse grained with little cement and without selectivity in size or type of material (mineral grains, calcareous and arenaceous tests of foraminifera). The interior of the wall shows a pseudochitineous lining. The more tubular form should not be confused with *Botelina labyrinthica* BRADY, which has a more regular, smooth wall-texture.

My material has been compared with the holotype and paratypes of H.B. Brady's collection, with which it agrees well.

GENUS: *Astrammina* RHUMBLER in Wiesner, 1931

Astrammina sphaerica (HERON-ALLEN and EARLAND)

Plate 1, Figs. 6a,b

Armorella sphaerica HERON-ALLEN, E. and EARLAND, A., 1932, p. 256; EARLAND, 1933, p. 65, pl. 7, figs. 16-23; EARLAND, 1934, p. 69, pl.2, figs. 12-14.

Remarks: Test consists of a spherical chamber with radiating, tubular extensions. If the wall consists of spicules or coarse grains it becomes irregular in outline; in abyssal regions tests are fine grained and well rounded; a well-preserved test has long flexible arms. My material has been compared with the holotype and paratypes of E. Heron-Allen and A. Earland's collection, with which it agrees well.

GENUS: Rhabdammina M.SARS in Carpenter, 1869

Rhabdammina abyssorum CARPENTER

Plate 2, Figs. 1a-c

Rhabdammina abyssorum CARPENTER, 1869, p. 60; FLINT, 1899, p. 271, pl. 12, fig. 2; HOFKER, 1972, p. 27, pl. 5, figs. 1-6; BARKER, 1960, pl. 21, figs. 1-8, 10-13.

Remarks: Test consist of a central chamber with radiating tubular, straight arms. It differs from Rhabdammina irregularis which shows irregular branches. R. abyssorum can only be clearly identified if the central part is preserved.

In Brady's and Heron-Allen & Earland's collections I have seen tests with different grain sizes and in the collection of Heron-Allen & Earland there are also specimens with constrictions at the arms. Due to this variability a clear cut distinction of fragments of this species from those of other Rhabdammina species is practically impossible.

Rhabdammina agglutissima HOFKER

Plate 3, Figs. 1a-e

Rhabdammina agglutissima HOFKER, J., 1972, p. 28, pl. 5, figs. 7-9.

Remarks: Tests were found only in the form of tubular fragments with coarse grained walls made up of quartz grains or foraminiferal tests, firmly agglutinated with a brown cement. The relation of these fragments to this species is questionable. The name is used because of the distinctive coarseness of the wall. The specimens may be a variety of *Hyperammina* sp.1, but no fragment was preserved with a proloculus.

Rhabdammina cornuta (BRADY)

Plate 3, Fig.2

Astrorhiza cornuta BRADY, H.B., 1879, p. 43, pl. 4, figs. 14-15.
Rhabdammina cornuta (Brady) FLINT, 1899, p. 271, pl. 15, fig. 2; BARKER, 1960, pl. 22, figs. 11-13.

Remarks: A coarse grained test consisting of an inflated chamber of irregular outline and numerous short extensions.

Rhabdammina discreta BRADY

Plate 2, Figs. 3a-c

Rhabdammina discreta BRADY, H.B., 1881, p. 48, BARKER, 1960, pl.22, figs. 7-10; HOFKER, 1972, p. 30, pl. 6, figs. 15-18; LEROY and HODGKINSON, 1975, pl. 1, fig. 1.

Remarks: Test straight, non-branching with annular constrictions at irregular intervals which are the main characteristic feature; sporadically there is a specimen with a swollen chamber which, in case of short fragments, makes the distinction between *R. discreta* and *R. linearis* difficult. The grain size of the wall is highly variable. Specimens covered with shell fragments were found in samples south of Bermuda.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

The Heron-Allen & Earland collection includes specimens with a highly variable wall-texture controlled by grain size and amount of cement.

Rhabdammina irregularis CARPENTER

Plate 2, Figs. 2a-c

Rhabdammina irregularis CARPENTER, W.B., 1869, p. 60; CUSHMAN, 1910, p. 26, text figs. 11,12; BARKER, 1960, pl. 21, fig. 9.

Remarks: A large tubular test, irregularly branched, agglutinating sand grains of different sizes and sometimes sponge-spicules or foraminiferal tests. The distinction between *R. irregularis* and *R. abyssorum* is only possible with well preserved specimens (see *R. abyssorum*). The form differs from *Rhizammina algaeformis* in being less fragile and having a different texture with less cement.

Brady noticed the branched variety and marked it with a question mark in his collection. Heron-Allen & Earland accepted the distinction of this form as an independant species.

Rhabdammina linearis BRADY

Plate 2, Figs. 4a,b

Rhabdammina linearis BRADY, H.B., 1879, p. 37, pl. 3, fig. 10; GOES, 1894, p. 18, pl. 4, figs. 65,66; BARKER, 1960, pl. 22, figs. 1-6; MILAM and ANDERSON, 1981, pl. 1, fig. 2.

Remarks: Test straight or slightly curved, non-branching with a swollen central chamber, wall mostly fine grained. Fragments without the typical central chamber are not distinguishable from other *Rhabdammina* species.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

GENUS: *Vanhoeffenella* RHUMBLER, 1905

Vanhoeffenella gaussi RHUMBLER

Plate 3, Fig. 3

Vanhoeffenella gaussi RHUMBLER, L., 1905, p. 97-106, figs. 1-9, (pl. 1, figs. 14,15); HERON-ALLEN and EARLAND, 1922, pl.1, figs 14,15; WIESNER, 1931, p. 78, pl. 3, figs. 21-26; PARR, 1950, p. 263, pl. 4, fig. 7; HOFKER, 1972, p. 35, pl. 8, figs. 8,9.

Remarks: Living specimens contain a large protoplasm body in the center of an angular, agglutinated tube. The exterior shape varies from discoidal to fusiform.

SUBFAMILY: Rhizammininae RHUMBLER, 1895

GENUS: Rhizammina BRADY, 1879

Rhizammina algaeformis BRADY

Plate 4, Figs. 1a-h

Rhizammina algaeformis BRADY, H.B. 1879, p. 39, pl. 4, figs. 16,17; BARKER, 1960, pl. 28, figs 1-11.

Remarks: A tubular, branching test, more or less flexible, agglutination non-selective, mineral grains, foraminiferal tests and radiolarians loosely cover a thin tube of a fine arenaceous cement. Two different morphotypes often occur together in one sample, differing from each other in size and tube diameter, but similar in wall material utilized. A third morphotype occurs in the abyssal zone, which has a smoother surface and is extremely fragile.
My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

Rhizammina indivisa BRADY

Plate 5, Figs. 1a-c

Rhizammina indivisa BRADY, H.B., 1884, p. 277, pl. 29, figs. 5-7; FLINT, 1899, p. 272, pl. 15, fig. 2; CUSHMAN, 1910, p. 34, text-fig. 24, WIESNER, 1931, p. 79, pl. 4, fig. 31; BARKER, 1960, pl. 29, figs. 5-7.

Remarks: Test cylindrical, non branching, tapering to both ends, flexible, composed of mud with quartz grains and small planktonic foraminiferal shells. Annular constrictions are typical to Brady's (1884) fig. 7.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

Rhizammina sp.

Plate 9, Fig. 1

Remarks: Tests are found as branching and non-branching fragments, fine muddy groundmass with large foraminiferal tests, loosely agglutinated. Short fragments are easy to confuse with coarse grained fragments of Reophax scorpiurus. This is particularly true in those instances where the chambers are not clearly visible.

GENUS: Bathysiphon M. SARS in G.O. Sars, 1872

Remarks: The genus Bathysiphon covers a large variety of forms in the literature and a specific identification of fragments is difficult. The tubular test is straight, sometimes tapering or slightly curved, non-branching, both ends are open. Most species have a smooth wall surface agglutinating small grains and sponge-spicules. The visible features which possibly distinguish this genus from other fine grained tubular species are the annular constrictions, occuring more or less closely spaced.

One distinct species has been identified. Many other specimens were grouped together under Bathysiphon spp..

Bathysiphon hirudinea (HERON-ALLEN and EARLAND)

plate 5, figs. 2a-c

Hippocrepinella hirudinea HERON-ALLEN, E. and EARLAND, A., 1932, p. 258. pl. 1, figs. 7-15.

Bathysiphon hirudinea (Heron-Allen and Earland) LOEBLICH and TAPPAN, 1964, p. C186.

Remarks: Test consisting of an irregular cylindrical chamber, sometimes slightly curved with an aperture at both ends. Wall agglutinates with very fine grains and mud, surface smooth but often transversely wrinkled.

My material has been compared with the holotypes and paratypes of E.Heron-Allen and A.Earland's collection, with which it agrees well.

GENUS: Marsipella NORMAN, 1878

Marsipella elongata NORMAN

Plate 5, Figs. 4a,b

Marsipella elongata NORMAN, A.M., 1878, p. 281, pl. 16, fig. 7; FLINT, 1899, p. 270, pl. 12, fig. 1; BARKER, 1960, pl. 24, figs. 10-19.

Remarks: Test curved or slightly twisted, tapering towards both ends, wall often coarse grained with finer grains or sponge-spicules at both ends. Brady (1884) described a type that consists entirely of sponge-spicules, arranged parallel to the long axis of the tube and for these forms he established the species *M. cylindrica*. Assemblages of the Norwegian Sea show intermediate forms with grains in the central part of the tube and sponge-spicules to both ends (A. Mackensen, per. comm. 1984). In this study both end members are related to *M. elongata*.

SUBFAMILY: Hippocrepininae RHUMBLER, 1895

GENUS: *Hyperammina* BRADY, 1878

Remarks: The test is elongate, cylindrical, consisting of an elongate to round proloculus and a long tubular second chamber, which is normally smaller in diameter than the proloculus. In the case of fragments without the typical proloculus, a differentiation to *Rhabdammina* to the level of species is often difficult.

Several species of this genus exist in the literature based on different coarseness of the wall and slight variation in shape. Looking at a large number of forms it becomes obvious that there are many intermediate specimens which do not conform with the described species. The following descriptions cover the characteristic types in the area under study.

Hyperammina elongata BRADY

Plate 6, Figs. 2a,b

Hyperammina elongata BRADY, H.B., 1878, p. 433, pl. 20, figs. 2a,b; BARKER, 1960, pl. 23, fig. 8.

Remarks: Wall finer grained than in Hyperammina sp.1, grains are well cemented so that the surface appears relatively smooth; black grains are often incorporated. The change in diameter from the proloculus to the second chamber can be abrupt.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

E. Heron-Allen and A. Earland relate fine grained, smooth walled specimens with a large variety in size to H. elongata.

Hyperammina laevigata (WRIGHT)

Plate 6, Figs. 3a,b

Hyperammina elongata BRADY var. laevigata WRIGHT, J., 1891, p. 466, pl. 20, fig. 1.

Hyperammina laevigata (Wright) LEROY and HODGKINSON, 1975, pl. 1, fig. 9.

Remarks: Test extremely fine grained with a smooth shiny surface. Grains cannot be resolved under optical microscopy. Test sometimes contricted above proloculus.

Hyperammina sp. 1

Plate 6, Figs. 1a-c

Remarks: Test agglutinates mostly large, irregularly shaped quartz grains, occasionally sponge-spicules and radiolarians, strongly cemented in a light groundmass. Another coarse grained type was found south of Bermuda with agglutinated foraminiferal tests. Hyperammina sp. 1 is a non-selective form.

Hyperammina sp. 2

Plate 6, Fig. 4

Remarks: Test consisting of a distinct globular proloculus and a second chamber, much smaller in diameter; wall agglutinating fine mineral grains and short fragments of sponge-spicules. This form might resemble the deep-water variety of Hyperammina sp. 1.

GENUS: Jaculella BRADY, 1879

Jaculella acuta BRADY

Plate 8, Fig. 7

Jaculella acuta BRADY, H.B., 1979, p. 35, pl. 3, figs. 12-13; BARKER, 1960, pl. 22, figs. 12-13.

Remarks: A conical, tubular test of variable coarseness.
My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

GENUS: Saccorhiza EIMER and FICKERT, 1899

Saccorhiza ramosa (BRADY)

Plate 7, Figs. 1a-d

Hyperammina ramosa BRADY, H.B., 1879, p. 33, pl. 3, figs. 14,15.

Saccorhiza ramosa (Brady) BARKER, 1960, pl. 23, figs. 15-19.

Remarks: Test consist of a subglobular proloculus and a dichotomously branching second chamber; wall often with agglutinated fragments of sponge-spicules. When the proloculus is broken, a differentiation from R. irregularis is difficult.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

SUBFAMILY: Dendrophryinae HAECKEL, 1894

GENUS: Dendrophrya WRIGHT, 1861

Dendrophrya arborescens (NORMAN)

Plate 7, Fig. 2

Psammotodendron arborescens NORMAN, A.M. in Brady, 1881, p. 98.

Hyperammina arborescens (Norman) GOES, 1894, p. 18, pl. 4, figs. 63-64.

Dendrophrya arborescens (Norman) BARKER, 1960, pl. 28, figs. 12,13.

Remarks: A large, branching test, extremely delicate, and found only in fragments; attached proloculi were found only twice. Wall regularly fine grained with ferruginous cement, which allows the differentiation of fragments of this species from fragments of the non-selective species Rhizammina algaeformis.

My material has been compared with the holotype of A.M. Norman's collection, with which it agrees well.

FAMILY: Saccamminidae BRADY, 1884

SUBFAMILY: Psammosphaerinae HAECKEL, 1894

GENUS: Psammosphaera SCHULZE, 1875

Psammosphaera fusca SCHULZE

Plate 10, Figs. 1a,b

Psammosphaera fusca SCHULZE, F.E., 1875, p. 113, pl. 2, figs. 8a-f; FLINT, 1899, p. 268, pl. 8, fig. 1; ECHOLS, 1971, pl. 1, fig. 3; MILAM and ANDERSON, 1981, pl. 1, fig. 6; HOFKER, 1972, p. 32, pl. 7, figs. 1-3.

Psammosphaera fusca SCHULZE var. testacea FLINT, 1899, p. 268, pl. 8, fig.2.

Psammosphaera testacea (Flint) HOFKER, 1972, p. 32, pl. 7, figs. 6,7.

Psammospharea flintii HOFKER, 1972, p. 33, pl. 7, figs. 8,9.

Remarks: Test consisting of an irregularly globular chamber formed by large agglutinated mineral grains or foraminiferal tests. This form is commonly divided into a number of species on the base of the material agglutinated in the wall. In my samples I have found forms with a variety of different material agglutinated in the test and, because of that, I assume that Psammosphaera is non-selective.

GENUS: Sorosphaera BRADY, 1879

Sorosphaera consociata (RHUMBLER)

Plate 10, Fig. 3

Psammophax consociata RHUMBLER, L., in Wiesner, 1931, p. 81, pl. 4, figs. 38-40, pl. 5, figs. 41-44.

Sorosphaera consociata (Rhumbler) LOEBLICH and TAPPAN, 1964, C197, fig.3 (11).

Remarks: Test consists of globular chambers, in a straight or irregular series, not increasing in size as they do in Hormosina and Reophax. Agglutinated mineral grains are strongly cemented.

SUBFAMILY: Saccammininae BRADY, 1884

GENUS: Saccammina M. SARS in Carpenter, 1869

Saccammina sphaerica BRADY, 1871

Plate 10, Figs. 4a,b

Saccammina sphaerica BRADY, H.B., 1871, p. 183; GOES, 1894, p. 13, pl.

3, figs. 16-18; BARKER, 1960, pl. 18, figs. 11-15, 17.

Remarks: Test consists of a globular chamber with a short, wide neck, agglutinating mineral grains or foraminiferal tests (as found south of Bermuda). This species is coarser grained than Hormosina globulifera which also can occur with a single chamber but with a longer neck and smaller diameter.

GENUS: Lagenammina RHUMBLER, 1911

Lagenammina tubulata (RHUMBLER)

Plate 10, Fig. 2

Saccammina tubulata RHUMBLER, L., in Wiesner, 1931, p. 82, pl. 23, fig. 1.

Proteonina tubulata (Rhumbler) EARLAND, 1933, pl. 1, figs. 30,31.

Saccammina tubulata (Rhumbler) ECHOLS, 1971, pl. 1, fig. 6; RESIG, 1981, pl. 9, fig. 5.

Remarks: Test consisting of one small globular chamber with a thin neck which often extends as far as the length of the chamber. This long neck differentiates Lagenammina from Saccammina. South of Bermuda I found forms with agglutinated foraminiferal shells.

GENUS: Pelosina BRADY, 1879

Pelosina cylindrica BRADY

Plate 10, Fig. 6

Pelosina cylindrica BRADY, H.B., 1884, p. 236, pl. 26, figs 1-3; BARKER, 1960, pl. 26, figs. 1-3.

Remarks: A large, irregularly elongate form, agglutinating mud, occasionally with large cemented particles such as foraminiferal shells and others.

Pelosina variabilis BRADY

Plate 10, Figs. 7a,b

Pelosina variabilis BRADY, H.B., 1879, p. 30, pl. 3, figs. 1-3; BARKER, 1960, pl. 26, figs. 7-9.

Remarks: Test consisting of one or two chambers, irregularly associated and with fine tubular extensions at the ends. The wall agglutinates mud and fine grains.

Pelosina variabilis var. constricta EARLAND

Plate 10, Fig. 8

Pelosina variabilis var. constricta EARLAND, A., 1933, p.42, pl. 1, figs. 13-15.

Remarks: Test consists of several elongate chambers, irregularly constricted, the wall agglutinates mud and is thin and flexible (it collapses when dried out).

GENUS: *Technitella* NORMAN, 1878

Technitella legumen NORMAN

Plate 10, Fig. 5

Technitella legumen NORMAN, A.M., 1878, p. 79, pl. 16, figs. 3,4; CUSHMAN, 1948, p. 13, pl. 1, fig. 10; BARKER, 1960, pl. 25, figs. 8-12.

Remarks: Test consisting of one elongate chamber, agglutinating mainly sponge-spicules, often arranged parallel to each other.

Technitella flexibilis WIESNER

Technitella flexibilis WIESNER, H., 1931, p. 85, pl. 7, fig. 75.

Remarks: Test consisting of a small globular chamber with a short neck, flexible if wet. Wall is fine grained consisting of mud.

GENUS: *Thurammina* BRADY, 1879

Thurammina papillata BRADY

Plate 10, Figs. 9a,b

Thurammina papillata BRADY, H.B., 1879, p. 45, pl. 5, figs. 4-8; WIESNER, 1931, p. 83, pl. 6, figs. 58-60; BARKER, 1960, pl. 36, figs. 7-18; LEROY and HODGKINSON, 1975, pl. 1, figs. 6,8.

Remarks: Test mainly spherical, sometimes elongate or slightly angular, small mammillate protuberances irregularly distributed over the test or in rows. This species was found in abyssal depth with a pseudochitineous test, sometimes with attached fine grains and small fragments of sponge-spicules as well.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

Thurammina cariosa FLINT

Thurammina cariosa FLINT, J.M., 1899, p. 278, pl. 22, fig. 2; EARLAND, A., 1936, pl. 1, figs. 12,13.

Remarks: Test consisting of a globular chamber with a rough outer surface. The apertures are non-tubular, which distinguishes T. cariosa from T. papillata.

FAMILY: Ammodiscidae REUSS, 1862

SUBFAMILY: Ammodiscinae REUSS, 1862

GENUS: Ammodiscus REUSS, 1862

Ammodiscus incertus (D'ORBIGNY)

Plate 10, Figs. 10a,b

Operculina incerta D'ORBIGNY, A., 1839, p. 49, vol. 8, pl. 6, figs. 16-17.

Ammodiscus incertus (d'Orbigny) FLINT, 1899, p. 278, pl. 23, fig. 2;

CUSHMAN, 1910, p. 73, figs. 95-96; BARKER, 1960, pl. 23, figs. 1-3; INGLE, KELLER and KOLPACK, 1980, pl. 9, fig. 9.

Remarks: Tests vary in the width of the coiling chambers. This feature may indicate a sexual dimorphism. Cushman (1909) described the same species showing an involute center and created the new genus *Ammodiscoides* and named the species *A. turbinatus*. This feature is not distinct in the small-sized specimens found at abyssal depth, therefore I kept the species in *Ammodiscus*.

GENUS: *Glomospira* RZEHAK, 1885

Glomospira charoides (JONES and PARKER)

Plate 11, Figs. 3,4

Trochammina squamata charoides JONES, T.R. and PARKER, W.K., 1860, p. 304.

Glomospira charoides (Jones and Parker) BARKER, 1960, pl. 38, figs. 10-16.

Remarks: Test is streptospirally coiled and spherical in shape.

Glomospira gordialis (JONES and PARKER)

Plate 11, Figs. 1,2

Trochammina squamata gordialis JONES, T.R. and PARKER, W.K., 1860, p. 304.

Glomospira gordialis (Jones and Parker) BARKER, 1960, pl. 38, figs.

7-9.

Remarks: Test shows an irregularly coiling with whorls changing plane of coiling.

SUBFAMILY: Tolypammininae CUSHMAN, 1928

GENUS: Tolypammina RHUMBLER, 1895

Tolypammina vagans (BRADY)

Plate 11, Figs. 7-9

Hyperammina vagans BRADY, H.B., 1884, p. 33, pl. 5, fig. 3; FLINT, 1899, p. 270, pl. 15, fig. 2; HOFKER, 1972, p. 55, pl. 16, figs. 8-10.
Tolypammina vagans (Brady) BARKER, 1960, pl. 34, figs. 1-5.

Remarks: Test occurs attached on the slope but was found free in abyssal areas. The second chamber is irregularly twisted and the free test are often contricted above the proloculus. Wall consists mainly of fine grains, reddish brown in colour.
My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

GENUS: Ammolagena EIMER and FICKERT, 1899

Ammolagena clavata (JONES and PARKER)

Plate 11, Figs. 5,6

Trochammina irregularis var. clavata JONES, T.R. and PARKER, W.K., 1860, p. 304.

Ammolagena clavata (Jones and Parker) WIESNER, 1931, p. 11, pl. 11, figs. 131-134; BARKER, 1960, pl. 41, figs. 12-16; LEROY and HODGKINSON, 1975, pl. 2, figs. 5-7.

Remarks: Specimens occur attached on foraminiferal shells or mineral grains, proloculus often broken, wall extremely fine grained.

GENUS: _Lituotuba_ RHUMBLER, 1895

Lituotuba lituiformis (BRADY)

Trochammina lituiformis BRADY, H.B., 1879, p. 52, pl. 5, fig. 16.

Lituotuba lituiformis (Brady) BARKER, 1960, pl. 40, figs 4-7.

Remarks: Early stages irregularly coiled, later stages uncoiled, rectilinear.

SUPERFAMILY: Lituolacea DE BLAINVILLE, 1825

FAMILY: Hormosinidae HAECKEL, 1894

SUBFAMILY: Aschemonellinae EIMER and FICKERT, 1899

GENUS: _Aschemonella_ BRADY, 1879

Aschemonella scabra BRADY

Plate 12, Figs. 1-4.

Aschemonella scabra BRADY, H.B., 1879, p. 44, pl. 3, figs. 12,13; BARKER, 1960, pl. 27, figs. 1,2,4-11.

Remarks: Tests highly variable in size and shape, agglutinating mainly fine material or coarser grains with abundant cement. Individuals, which were dead to the time of collection, occur dark pink in samples stained with Rose Bengal due to either bacteria or an inner organic lining.

Brady (1884) placed this form in synonomy of *A. catenata* Norman, 1878. However, a comparison of both types in the original material makes it more likely that the two are different species.

Aschemonella ramulifera BRADY

Plate 12, Fig. 5

Aschemonella ramulifera BRADY, H.B., 1884, p. 273, pl. 27, figs. 12-15; BARKER, 1960, pl. 27, figs. 12-15.

Remarks: Test more tubular as compared to *A. scabra* and with several openings. Wall thin, fine grained. Specimens from abyssal depth often collapse when dried out.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

SUBFAMILY: Hormosininae HAECKEL, 1894

GENUS: Hormosina BRADY, 1879

Hormosina globulifera BRADY

Plate 13, Figs. 1-3

Hormosina globulifera BRADY, H.B., 1879, p. 60, pl. 4, figs. 4,5; GOES, 1894, p. 29, pl. 6, figs. 218, 219; FLINT, 1899, p. 280, pl. 24, fig. 4; BARKER, 1960, pl. 39, figs. 1-6; LEROY and HODGKINSON, 1975, pl. 3, figs. 1,2; INGLE, KELLER and KOLPACK, 1980, pl. 7, fig. 7.

Remarks: Test mostly fine grained with a long thin neck which distinguishes it from Reophax pilulifera. Specimens consisting of a single chamber are difficult to distinguish from Saccammina sphaerica. My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.
Heron-Allen and Earland's collection includes coarse grained forms, which differ from R. pilulifer only by the long neck.

Hormosina carpenteri BRADY

Plate 13, Fig. 6

Hormosina carpenteri BRADY, H.B., 1884, p. 327, pl. 39, figs. 14-18; BARKER, 1960, pl. 39, figs. 14-18.

Remarks: Test consists of long chains of finely agglutinated, flask-shaped chambers, mostly in an irregular series.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

<u>Hormosina normani</u> BRADY

Plate 13, Fig. 4

<u>Hormosina normani</u> BRADY, H.B., 1881, p. 52; WIESNER, 1931, p. 92, pl. 10, figs. 119-121; PARR, 1950, p. 270, pl. 4, fig. 22; BARKER, 1960, pl. 39, figs. 19-23.

Remarks: Test large, thin walled, chambers are not in rectilinear series like <u>H. globulifera</u>, the aperture occurs laterally in the last chamber.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

GENUS: <u>Reophax</u> MONTFORT, 1808

<u>Reophax scorpiurus</u> MONTFORT

Plate 14, Figs. 1-5

<u>Reophax scorpiurus</u> MONTFORT, D. de, 1808, p. 331, text-fig.; GOES, 1894, p. 24. pl. 5, figs. 158,159, pl. 6, figs. 164-169; FLINT, 1899, pl. 16, fig. 3, pl. 17, fig. 1; CUSHMAN, 1910, p. 83, test-figs. 114-116; WIESNER, 1931, p. 89, pl. 9, fig. 101; LOEBLICH and TAPPAN, 1953, pl. 2, figs. 7-10; BARKER, 1960, pl. 30, figs. 15-17.

<u>Reophax scorpiurus MONTFORT var. testacea</u> PARR, 1950, p. 269. pl. 4,

fig. 19.

Reophax agglutinans LEROY and HODGKINSON, 1975, pl. 3, figs. 3-6.

Remarks: Test consisting of several chambers in an irregularly bent series with oblique sutures. By contrast, the chambers of Reophax nodulosus and Reophax dentaliniformis are in a rectilinear series. This form is non-selective, the wall material consists of mineral grains, calcareous foraminiferal tests and other fragments of various nature. At abyssal depth off Nova Scotia specimens are fragile, consisting of 1 or 2 small initial chambers and a large final one.

This species which is often reported in the literature is common in shallow and deep water. The original figure of de Montfort, however, is inadequate since it shows a peculiar texture for a foraminifer. This species needs a more detailed study (see chapter 3.3.2). Cushman (1913) relates the type made of foraminiferal tests to R. agglutinatus (p. 637, pl.79, fig. 6).

My identifications are based on Brady's delimitation of the species, (which includes R. agglutinatus) because I have found transitional forms with both mineral grains and foraminiferal shells, agglutinated in the test.

Reophax bacillaris BRADY

Plate 16, Figs. 1,2

Reophax bacillaris BRADY, H.B., 1881, p. 49; FLINT, 1899, p. 274, pl. 18, fig. 3; CUSHMAN, 1920, p. 19, pl. 5, fig. 6; BARKER, 1960, pl. 30, figs. 23,14.

Remarks: The size of the initial chambers varies, chambers of the later portion are growing regularly in size.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

Reophax bilocularis FLINT

Plate 14, Figs. 8-13

Reophax bilocularis FLINT, J.M., 1899, p. 273, pl. 17, fig. 2

Reophax agglutinatus CUSHMAN, 1932, pt. 1, p. 4, pl. 1, figs. 1-3.

Reophax sp. A ECHOLS, 1971, pl. 1, fig. 13.

Remarks: Test usually composed of 2 chambers in a straight or curved line; final chamber much larger than the primary. The large final chamber often is the only fragment left, which leads to confusion with species of *Saccammina*. Wall is made of different sized mineral grains or foraminiferal tests.

Reophax cylindricus BRADY

Plate 15, Fig. 10

Reophax cylindricus BRADY, H.B., 1884, p. 299, pl. 32, figs. 7-9; BARKER, 1960, pl. 32, figs. 7-9; MILAM and ANDERSON, 1981, pl. 1, fig. 10.

Remarks: Chambers are increasing in size almost without distinct transition.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

Reophax dentaliniformis BRADY

Plate 14, Figs. 6,7

Reophax dentaliniformis BRADY, H.B., 1881, p. 49; FLINT, 1899, p. 274, pl. 18, fig. 2; EARLAND, 1934, p. 81, pl. 2, figs. 32-35; BARKER, 1960, pl. 30, figs. 21,22; HERMELIN, 1983, pl. 1, figs. 1-16.

Remarks: Test consisting of a series of pyriform chambers with more or less narrow horizontal sutures, chambers increasing regularly in size. Wall agglutinating small mineral grains and occasional foraminiferal tests. Specimens of abyssal areas extremely fragile and almost transparent.
My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

Reophax difflugiformis BRADY

Reophax difflugiformis BRADY, H.B., 1879, p. 51, pl. 4, figs. 3a-b; FLINT, 1899, p. 272, pl. 16, fig. 2; BARKER, 1960, pl. 30, figs. 1-3.
Reophax difflugiformis BRADY var. testacea FLINT, 1899, p. 273, pl. 16, fig. 1.

Remarks: This species is often reported in the literature. The original material of H.B. Brady includes a variety of forms, consisting of a single chamber, but with different agglutinated wall material which varies from fine to coarse mineral grains or sponge-spicules. These types have great similarity with single chambered fragments of R. bilocularis Flint (resembling the coarse grained type) or R. ovicula (Brady) (resembling the fine grained type). Brady (1884) himself noticed the similiarity to single chambered fragments of R. scorpiurus. His foraminiferal collection, however, includes fragments of Hormosina ovicula (considered as Reophax in this study), which are morphologically identical with the original type of R. difflugiformis. Well preserved specimens of R. difflugiformis and isolated initial single chamber of R. ovicula occur at the same localities in the Challenger Report (Brady 1884). Therefore the existence of R. difflugiformis in the deep-sea seems to be questionable.

The coarse grained types can also be confused with Saccammina atlantica (Cushman), a single chamber form, but without neck.

Reophax distans BRADY

Plate 16, Figs. 3-5,9

Reophax distans BRADY, H.B. 1881, p. 50; BARKER, 1960, pl. 31, figs. 18-22.

Reophax pseudodistans CUSHMAN, 1910, p. 85, textfig. 119; PARR, 1950, p. 267, pl. 4, fig. 16.

Remarks: Test consisting of 2 or 3 fusiform to rounded chambers, connected by a thin, fragile neck, so that specimens are mostly found in single chamber fragments. These fragments can be confused with Pelosina didera LOEBLICH and TAPPAN.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

Heron-Allen and Earland's collection includes specimens with abundant agglutinated sponge-spicules, evidently the species is non-selective.

Reophax fusiformis (WILLIAMSON)

Plate 15, Fig. 9

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

Reophax fusiformis (Williamson) BARKER, 1960, pl. 30, figs. 7-11; MILAM and ANDERSON, 1981, pl. 2, fig. 1.

Reophax curtus PHLEGER, 1952, pl. 13, fig. 2.

Remarks: Test consisting of one small initial and a large final chamber, ending in a wide, short neck; wall relatively coarse grained. R. fusiformis is reported as a coarse grained form, typical of shallow water. The type on the Scotian slope shows a more distinct, small initial chamber.

Reophax guttifer BRADY

Plate 15, Figs. 12,13

Reophax guttifer BRADY, H.B., 1881, p. 49; FLINT, 1899, p. 273, pl. 19, fig. 1; CUSHMAN, 1910, p. 88, textfig. 123; BARKER, 1960, pl. 31, figs. 10-15.

Remarks: Test small, variable in wall material and very delicate in abyssal areas.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

Reophax helenae (RHUMBLER)

Plate 15, Fig. 8

Proteonina helenae RHUMBLER, L., 1911, pt. 1, figs. 16,17, pt. 2, 1913, p. 380; CUSHMAN, 1918, pl. 20, pl. 20, figs. 6,7.

Remarks: Test showing a gradual increase in size without a distinct transition between chambers, neck wide and long, increasing in diameter towards the top.

Proteonina was put in synonomy with Reophax by Loeblich and Tappan, 1964. This species is originally described with agglutinated shell fragments as found south of Bermuda in the studied material. I also found a type with fine mineral grains in the Nares Abyssal Plain.

Reophax horrida CUSHMAN

Plate 15, Figs. 6,7

Reophax horrida CUSHMAN, J.A., 1912, p.229, pl. 28, figs. 3,4; UCHIO, 1960, pl. 1, fig. 7.

Remarks: Test consisting of several small, globular chambers, slowly increasing in size with a distinct neck. Test agglutinating fine mineral grains and often long fragments of sponge-spicules.

Reophax nodulosus BRADY

Plate 15, Fig. 11

Reophax nodulosus BRADY, H.B., 1879, p. 52, pl. 4, figs. 7,8; WIESNER, 1931, p. 91, pl. 9, fig. 108; PHLEGER, 1952, pl. 13, figs. 6,7; BARKER, 1960, pl. 31, figs. 1-9; MILAM and ANDERSON, 1981, pl. 1, fig. 7.

Remarks: Test consisting of pyriform chambers, always in rectilinear series. The wall has a variable texture, depending on grain size. Some specimens in abyssal depth show a smooth surface, and are dark brown in colour.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

Reophax ovicula (BRADY)

Plate 13, Fig. 5

Hormosina ovicula BRADY, H.B., 1879, p. 61, pl. 4, fig. 6; WIESNER, 1931, p. 92, pl. 11, figs. 125,126; EARLAND, 1934, p. 85, pl. 3, fig. 1; BARKER, 1960, pl. 39, figs. 7-9; ECHOLS, 1971, pl. 2, figs. 1-3; INGLE, KELLER and KOLPACK, 1980, pl. 9, fig. 13.

Reophax distans BRADY var. gracilis EARLAND, 1933, p. 76, pl. 2, fig. 21.

Reophax ovicula (Brady) MILAM and ANDERSON, 1981, pl. 1, fig. 8.

Remarks: Test consisting of several fusiform chambers in a straight series, each chamber has a produced neck where it is joined to the next chamber which break easily, producing single chambered fragments (see also R. difflugiformis). Wall is fine grained.

Reophax pilulifer BRADY

Plate 15, Figs. 1-5

Reophax pilulifer BRADY, H.B., 1884, p. 292, pl. 30, figs. 18-20; CUSHMAN, 1910, p. 85, textfig. 118; EARLAND, 1934, p. 80, pl. 2, fig. 36; BARKER, 1960, pl. 30, figs. 18-20.

Reophax excentricus CUSHMAN, 1910, p. 92, textfig. 134.

Remarks: Test consisting of large, globular chambers, tapering towards the aperture. Specimens from the continental slope with a thick, coarse grained wall, red-brown in color. South of Bermuda I found tests which incorporate foraminiferal shells into their wall.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

The collection of A.M. Norman (British Museum) also includes specimens with agglutinated foraminiferal tests.

GENUS: *Subreophax* SAIDOVA, 1975

Subreophax adunca (BRADY)

Plate 16, Figs. 6-8

Reophax adunca BRADY, H.B., 1882, p. 715.

Reophax aduncus (Brady) BARKER, 1960, pl. 31, figs. 23-26.

Subreophax adunca (Brady) SAIDOVA, 1975, pl. 11, fig. 6.

Remarks: Test consisting of several chambers in a sinuous series, which do not increase in size. The degree of sinuousity seems to increase towards abyssal depth. This species was established by Saidova (1975) as the type species for *Subreophax*.

FAMILY: Lituolidae DE BLAINVILLE, 1825

SUBFAMILY: Haplophragmoidinae MAYNS, 1952

GENUS: *Haplophragmoides* CUSHMAN, 1910

Haplophragmoides bradyi (ROBERTSON)

Plate 17, Fig. 8

Trochammina bradyi ROBERTSON, 1891, p. 388.

Haplophragmoides bradyi (Robertson) PARKER, 1954, pl. 1, fig. 16.

Remarks: A small inflated test with a smooth wall texture.

Haplophragmoides canariensis (D'ORBIGNY)

Plate 17, Fig. 1

Nonionina canariensis D'ORBIGNY, A., 1839, p. 128, pl. 2, figs 33,34.

Haplophragmoides canariensis (d'Orbigny) WIESNER, 1931, p. 95, pl. 11, fig. 135; BARKER, 1960, pl. 35, figs. 1-3,5.

Remarks: Test inflated, with a wide equatorial-interiomarginal aperture.

Haplophragmoides rotulatum (BRADY)

Plate 17, Figs. 2-4

Haplophragmium rotulatum BRADY, H.B., 1881, p. 50.

Haplophragmoides rotulatum (Brady) CUSHMAN, 1918, pt. 2, pl. 9, figs. 3,4; BARKER, 1960, pl. 34, figs. 5,6.

Remarks: The periphery of the test is often broad and oblique to the plane of coiling.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

Haplophragmoides sphaeriloculus CUSHMAN

Plate 17, Figs. 5-7

Haplophragmoides sphaeriloculus CUSHMAN, J.A., 1910, p. 107, text-fig. 165; WIESNER, 1931, p. 96, pl. 12, fig. 142; EARLAND, 1936, pl.1, figs. 17,18.

Cribrostomoides sphaeriloculus (Cushman) ECHOLS, 1971, pl. 3, figs. 5-7.

Remarks: The holotype of this species shows 5 chambers, but specimens with 4 chambers have been designated as paratypes. The test is often dark brown.

GENUS: Adercotryma LOEBLICH and TAPPAN, 1952

Adercotryma glomerata (BRADY)

Plate 16, Figs. 10,11

Lituola glomerata BRADY, H.B., 1878, p. 433, pl. 20, fig.1.

Adercotryma glomerata (Brady) BARKER, 1960, pl. 34, figs. 15-18.

Remarks: Test elongated in axial direction. The species can be small in size (< 125um), especially in the abyssal areas off Nova Scotia.

GENUS: *Cribrostomoides* CUSHMAN, 1910

Cribrostomoides crassimargo (NORMAN)

Haplophragmium crassimargo Norman, A.M., 1892, p. 17.

Cribrostomoides crassimargo (Norman) BARKER, 1960, pl. 35, fig. 4; HERB, 1971, pl. 11, figs. 1a-c.

Remarks: Wall mostly coarse grained.

Cribrostomoides nitidum (GOËS)

Plate 17, Fig. 9

Haplophragmium nitidum GÖES, A., 1896, p. 30, pl. 3, figs. 8,9.

Cribrostomoides nitidum (Göes) HÖGLUND, 1947, pl. 11, figs. 5a-c; LEROY and HODGKINSON, 1975, pl. 4, figs. 7-9; POAG, 1981, pl. 9, figs. 2a,b.

Remarks: Test fine grained with a smooth surface.

Cribrostomoides ringens (BRADY)

Plate 17, Figs. 13,14

Trochammina ringens BRADY, H.B., 1879, p. 57, pl. 5, fig. 12a,b.

Cribrostomoides ringens (Brady) BARKER, 1960, pl. 40, figs. 17,18; LEROY and HODGKINSON, 1975, pl. 4, fig. 1.

Remarks: Test shows always a smooth, fine grained wall texture. My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

Cribrostomoides subglobosus (G.O. SARS)

Plate 17, Figs. 15,16

Lituola subglobosa SARS, G.O., 1872, p. 252.

Haplophragmium latidorsatum FLINT, 1899, p. 276, pl. 20, fig. 1.

Cribrostomoides bradyi CUSHMAN, 1910, p. 108, textfigs. 167a,b.

Cribrostomoides subglobosus (G.O.Sars) HERB, 1971, pl. 11, figs. 2a-c, 3a-c; MILAM and ANDERSON, 1981, pl. 3, fig. 1.

Remarks: Agglutinated material variable in coarseness. The aperture of large individuals consists of a dentate slit.

Cribrostomoides weddellensis (EARLAND)

Plate 19, Figs. 1-4

Haplophragmoides weddellensis EARLAND, A., 1936, p. 33, pl. 1, figs. 15,16.

Remarks: Test imperfectly bilaterally symmetrical; one umbilical region being more depressed than the other. Test constructed of coarse mineral grains, aperture small on the inner face of the final chamber which relates this form to *Cribrostomoides*.

Cribrostomoides wiesneri (PARR)

Plate 17, Figs. 10-12

Labrospira wiesneri PARR, W.J., 1950, p. 272, pl. 4, fig. 25,26.

Labrospira arctica PHLEGER, 1952, pl. 13, fig. 17.

Alveolophragmium wiesneri (Parr) BARKER, 1960, pl. 40, figs. 14,15.

Cribrostomoides wiesneri (Parr) MILAM and ANDERSON, 1981, pl. 2, fig. 6.

Remarks: A small, fine grained, smooth form with a distinct lip bordering the aperture. No alveolar interior structure was noticed in thin sections.

GENUS: *Discammina* LACROIX, 1932

Discammina compressa (GÖES)

Plate 18, Figs. 7,8

Lituolina irregularis var. compressa GÖES, A., 1882, p. 141.

Discammina compressa (Göes) BARKER, 1960, pl. 33, figs. 26-28.

Remarks: This small form was observed in abyssal areas. The original type has a larger test with more distinct rounded chambers and this identification may be questionable.

GENUS: Recurvoides EARLAND, 1932

Recurvoides scitulus (BRADY)

Plate 18, Figs. 1-4

Haplophragmium scitulum BRADY, H.B., 1881, p. 50.

Haplophragmoides scitulum (Brady) BARKER, 1960, pl. 34, figs. 11-13.

Cribrostomoides scitulus (Brady) LEROY and HODGKINSON, 1975, pl. 4, figs. 5-6.

Recurvoides contortus EARLAND, 1934, p. 91, pl. 10, figs. 7-19; MILAM and ANDERSON, 1981, pl. 3, fig.2.

Remarks: The original figure of Brady shows a planispiral test. The study of the original material, however, has shown that the figures in Brady (1884, pl. 34, figs. 11-13) are not typical for the various forms, related by Brady to this species. Specimens with a slight change in coiling directions were included as well. Earland (1934) established the new genus Recurvoides for forms with the tendency to coil irregularly (with one side flat or slightly convex and the other side forming a deeply depressed umbilicus). The type species of Earland's genus is R. contortus from the Antarctic Ocean. Its differences with Brady's type are discussed in detail by Earland (1934). My material from the North Atlantic contains both types with many transitional forms within one sample. Slightly evolute tests occur as well, a feature also noted by Brady (1884). A clear cut distinction between these various types seems to be doubtful.

Therefore, in the present study the older species name by Brady is regarded as valid, but it is included in *Recurvoides* based on the tendency to streptospiral coiling and the presence of a small areal aperture bordered by a lip. This species should not be confused with *R. turbinatus*.

Recurvoides sp. A

Plate 18, Figs. 5,6

Remarks: Test irregularly coiled, the ventral side resembles *R. turbinatus* (Brady). This species was found only in abyssal depth.

SUBFAMILY: Cyclammininae MARIE, 1941

GENUS: *Cyclammina* BRADY, 1879

Cyclammina pusilla BRADY

Plate 18, Fig. 10

Cyclammina pusilla BRADY, H.B., 1881, p. 53; EARLAND, 1936, pl. 1, figs. 25,26; BARKER, 1960, pl. 37, figs. 20-23; HERB, 1971, pl. 12, figs. 7a,7b.

Remarks: The inner labyrinthic structure is less developed than in *C. cancellata*. Test often agglutinates coarse grains in a fine grained groundmass.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

Cyclammina trullissata (BRADY)

Plate 18, Fig.9

Trochammina trullissata BRADY, H.B., 1879, p. 56, pl. 5, figs. 10,11.

Cyclammina trullissata (Brady) BARKER, 1960, pl. 40, figs. 13a,b, 16.

Cyclammina bradyi CUSHMAN, 1910, p. 113, textfigs. 174a,b.

Remarks: Test fine grained with a smooth surface, equatorial-interiomarginal aperture, inner alveolar structure.

Brady (1884 and collection) relates 3 different types to *T. trullissata*:

1. type completely involute (Brady, 1884, pl. 40, figs. 13,16), identical to some of the forms in the material studied and referred by Cushman (1910) to *C. bradyi*.

2. type not completely involute, 2-3 whorls are visible (Brady, 1884, pl. 40, fig. 14). This morphotype is also found in the material studied and I referred it to *C. trullissata*, while Cushman (1910,1920) placed it in *Haplophragmoides trullissata*.

3. This type differs from the previous two by the presence of an areal aperture bordered by a lip (Brady, 1884, pl. 40, fig. 14) and I refer it to *Cribrostomoides wiesneri*.

The typical characteristics of the genus *Cyclammina* are an inner labyrinthic structure and a cribrate aperture (Loeblich and Tappan, 1964). Neither of these features is developed in *C. trullissata*.

Brady (1879) notices in his original description the marked difference between the poorly developed internal structure of this species compared with the one of C. cancellata and indicates C. pusilla as a transitional species between the other two. Brönnimann (1951) describes the various ontogenetic stages of the inner structure and aperture observed in C. cancellata and concludes that Cyclammina evolved from Haplophragmoides. I assume that C. trullissata represents an intermediate form between Cyclammina and Haplophragmoides.

SUBFAMILY: Lituolinae DE BLAINVILLE, 1825

GENUS: Ammobaculites CUSHMAN, 1910

Ammobaculites agglutinans (D'ORBIGNY)

Plate 21, Figs. 1-4

Spirolina agglutinans D'ORBIGNY, A., 1846, p. 137, pl. 7, figs 10-12.

Ammobaculites agglutinans (d'Orbigny) BARKER, 1960, pl. 32, figs. 19-21,24-26.

Remarks: The initial chambers vary in size, often found with a broken rectilinear part, variable in grain size of wall material.

Ammobaculites agglutinans var. filiformis EARLAND

Plate 21, Figs. 5,6

Ammobaculites agglutinans var. filiformis EARLAND, A., 1934, p. 92, pl. 3, figs. 11-13; BARKER, 1960, pl. 32, figs. 22.

Ammobaculites filiformis (Earland) ECHOLS, 1971, pl. 4, fig. 7.

Remarks: Test consisting of a small initial coil and a long rectilinear later part. Later chambers occasionally increasing in size, obliquely attached together, final chamber tapering to a neck. Grain size of the wall material variable, as noticed also by Earland (1934). A fine grained morphotype shows straight sutures in the uncoiled segment and occurs only in abyssal areas.

My material has been compared with the holotype and paratypes of A.Earland's collection, with which it agrees well.

Ammobaculites agglutinans var. 1

Plate 21, Fig. 7,8

Ammobaculites agglutinans var. filiformis BARKER, 1960, pl. 32, fig. 23.

Ammobaculites filiformis POAG, 1981, p. 36, pl. 7, fig. 3.

Remarks: A small test with a short rectilinear segment, a very smooth surface, grains almost not visible, sutures straight. This form is distinct from Earland's original figure of *A. agglutinans var. filiformis*.

Ammomarginulina foliacea (BRADY)

Plate 21, Figs. 10-13

Haplophragmium foliaceum BRADY, H.B., 1881, p. 50.

Ammomarginulina foliacea (Brady) BARKER, 1960, pl. 33, figs. 20-25.

Remarks: Test flat in comparison to Ammobaculites. Present in abyssal depth with a smaller and finer grained morphotype than that of the slope. The abyssal form agglutinates black mineral grains, often arranged in the sutures.

My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

FAMILY: Textulariidae EHRENBERG, 1838

SUBFAMILY: Spiroplectammininae CUSHMAN, 1927

GENUS: Spiroplectammina CUSHMAN, 1927

Spiroplectammina biformis (PARKER and JONES)

Plate 21, Fig. 14

Textularia agglutinans D'ORBIGNY var. biformis PARKER W.K. and JONES, T.R., 1865, p. 370.

Spiroplectammina biformis (Parker and Jones) BARKER, 1960, pl. 45, figs. 25-27; INGLE, KELLER and KOLPACK, 1980, pl. 5, fig. 9.

Remarks: Test small in abyssal areas.

SUBFAMILY: Textulariinae EHRENBERG, 1838

GENUS: _Textularia_ DEFRANCE in DE BLAINVILLE, 1824

Remarks: The genus _Textularia_ includes a variety of species, which are not always convincingly different from each other. The specimens of _Textularia_ were always rare in the material studied, therefore I could not collect information on the deep-sea types.

Textularia wiesneri EARLAND

Plate 22, Fig. 15

Textularia wiesneri EARLAND, A., 1933, p. 95, pl. 3, figs. 18-20; ECHOLS, 1971, pl. 4, figs. 9,10.

Remarks: Test slightly curved, early chambers may be uniserial, later ones biserially arranged. The long axis of chambers is horizontal. This species is similar to _T. earlandi_ (PARKER) which is found in estuarines.

My material has been compared with the holotype and paratypes of A.Earland collection, with which it agrees well.

FAMILY: Trochamminidae SCHWAGER, 1877

SUBFAMILY: Trochammininae SCHWAGER, 1877

GENUS: _Trochammina_ PARKER and JONES, 1859

Trochammina globulosa CUSHMAN

Plate 19, Figs. 9-11

Trochammina globulosa CUSHMAN, J.A., 1920, p. 77, pl. 16, figs. 3,4; PARKER, 1954, p. 502, pl. 5, figs. 11,12.

Remarks: Test similar to *Trochammina cf. globigeriniformis*, but with a larger final chamber, occupying about one half of the umbilical side, wall more finely agglutinated with a smooth surface, extraumbilical aperture often large and distinct at the inner margin of the last chamber.

Trochammina cf. globigeriniformis PARKER and JONES

Plate 19, Figs. 5-8

Lituola nautiloidea LAMARCK var. *globigeriniformis* PARKER, W.K. and JONES, T.R., 1865, p. 407, pl. 17, fig. 96.

Haplophragmium globigeriniformis (Parker and Jones) FLINT, 1899, p. 277, pl. 21, fig. 1.

Trochammina globigeriniformis (Parker and Jones) BARKER, 1960, pl. 35, figs. 10,11; Poag, 1981, p. 85, pl. 13,14, figs. 1a-c.

Description: test free, trochoid spire, varying from depressed to slightly conical; two or three whorls, chambers rapidly increasing in size, periphery rounded; aperture simple at the inner margin on the umbilical side of the last chamber opening into narrow umbilicus; wall medium to coarsely arenaceous with finer grained matrix, firmly cemented.

Remarks: this species is identical with Brady's form attributed by him to T. globigeriniformis (Parker and Jones). However, the original specimen related to Lituola nautiloidea Lamarck var. globigeriniformis of Parker and Jones is lost and the original figure is poor. Loeblich and Tappan established a lectotype, observed in the British Museum, which is one small specimen, filled with pyrite, poorly preserved. I suggest that this deep-water species should be redescribed. Recent identifications in the literature are mostly related to Brady's figure.

Trochammina cf. squamata PARKER and JONES

Plate 19, Figs. 12-15

Trochammina squamata JONES, T.R. and PARKER, W.K., 1860, p. 304; Brady, 1884, pl. 41, fig. 3.

Description: test free, concavo-convex, low trochoid spire, umbilical side excavated, periphery varies from angular to rounded, two whorls are visible, 4 chambers on umbilical side; aperture extraumbilical indistinct at the inner margin of the umbilical side of the last chamber, wall finely arenaceous with larger grains. The deep-sea types show irregularities in the outer morphology which depend on the coarseness of the wall material.

Remarks: This species is closely related to T. squamata Jones and Parker, 1860. No type figure of the original was given. A detailed study by Hedley, Hurdle and Burdett (1964) includes a redescription of _T. squamata_ and closely related species. Their types were observed in the British Museum including the form attributed by Brady to _T. squamata_ and renamed by Hedley et al. (1964) as _T. challengeri_. None of these species is identical with the studied material.

Trochammina sp. 3

Plate 20, Figs. 5,6

Description: test free, depressed trochoid spire with three whorls; chambers slowly increasing in size, five chambers on umbilical side, periphery rounded, low umbilicus; extraumbilical aperture at the inner margin of the last chamber on the umbilical side; wall finely agglutinated, occasionally with larger grains.

Remarks: This species has a more concave dorsal side than _Trochammina sp. 4_.

Trochammina sp. 4

Plate 20, Figs. 1-4

Description: Test free, dorsal side flat, low trochoid spire with three distinct whorls, chambers gradually increasing in size, 6 chambers on umbilical side, periphery rounded, depressed sutures; aperture a single small slit in equatorial position at the inner margin of the last chamber, wall fine grained, smoothly finished with occasional larger grains.

Remarks: This species differs from *Trochammina sp. 3* in being less concave dorsally and in showing a higher number of chambers on the umbilical side.

GENUS: *Portatrochammina* ECHOLS, 1971

Portatrochammina sp. 1

Plate 20, Figs. 7-9

Description: test free, low trochoid spire; dorsal side from flat to low convex; 3 whorls visible, chambers gradually increasing in size, ventral side convex with 5 chambers; periphery rounded, depressed sutures, umbilicus covered by a series of overlapping flaps, each flap derived from one chamber, the flap of the final chamber often covers completely the umbilicus; slit-like aperture at the lower margin of the final chamber; wall finely arenaceous, smoothly finished; test small and fragile.

Remarks: This form closely conforms to the description of *P. eltaninae* Echols, 1971, described from the Scotian Sea. I did not study the original type material. The original figure and a figure in Brönnimann and Whittaker (1980, p. 184, figs. 32-34) differs slightly from my material.

GENUS: *Cystammina* NEUMEYER, 1889

Cystammina galeata (BRADY)

Plate 18, Figs. 12,13

Trochammina galeata BRADY, H.B., 1881, p. 52.

Cystammina galeata (Brady) BARKER, 1960, pl. 40, figs. 19-23.

Remarks: Test always fine grained with a smooth wall surface.
My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

Cystammina pauciloculata (BRADY)

Plate 18, Figs. 14,15

Trochammina pauciloculata BRADY, H.B., 1879, p. 58, pl. 5, figs. 13,14.

Cystammina pauciloculata (Brady) BARKER, 1960, pl. 41, figs. 1-2; ECHOLS, 1971, pl. 2, figs. 8,9.

Remarks: Test with a smooth fine grained wall texture.
My material has been compared with the holotype and paratypes of H.B.Brady's collection, with which it agrees well.

FAMILY: Ataxophragmiidae SCHWAGER, 1877

SUBFAMILY: Globotextulariinae CUSHMAN, 1927

GENUS: *Eggerella* CUSHMAN, 1933

Eggerella bradyi (CUSHMAN)

Plate 22, Figs. 1-6

Verneuilina bradyi CUSHMAN, J.A., 1911, p. 54, text-figs. 87a,b, pl. 6, fig. 4.

Eggerella bradyi (Cushman) LEROY and HODGKINSON, 1975, pl. 6, fig. 4.

Remarks: On the continental slope the tests are often fine grained with a calcareous, light coloured cement and with a very short triserial test. Below the CCD the tests occur with a ferrugineous cement and clearly visible grains, aperture bordered by a lip in both morphotypes.

Eggerella propinqua (BRADY)

Plate 22, Fig. 7

Verneuilina propinqua BRADY, H.B., 1884, p. 387, pl. 47, figs. 8-14.

Eggerella propinqua (Brady) BARKER, 1960, pl. 47, figs. 8-12.

Remarks: Test coarser grained than *E. bradyi*, aperture not bordered by a lip. The attached variety was transferred by Cushman (1911) to *E. affixa*.

GENUS: *Karreriella* CUSHMAN, 1933

Karreriella apicularis (CUSHMAN)

Plate 22, Fig. 14

Gaudryina apicularis Cushman, J.A., 1911, p. 69, figs. 110a,b.

Karreriella apicularis (Cushman) BARKER, 1960, pl. 46, fig. 17; LEROY and HODGKINSON, 1975, pl. 6, fig. 5.

Remarks: The last chamber is often uniserial.

Karreriella bradyi (CUSHMAN)

Plate 22, Figs. 8,9

Gaudyina bradyi CUSHMAN, J.A., 1911, p. 2, p. 67, figs. 107a,b.
Karreriella bradyi (Cushman) HERB, 1971, pl. 11, figs. 5a,b; LEROY and HODGKINSON, 1975, pl. 6, fig. 6.

Remarks: Test mostly fine grained.

Karreriella novangliae (CUSHMAN)

Plate 22, Figs. 12,13

Gaudryina baccata var. novangliae CUSHMAN, J.A., 1922, p. 76.
Gaudryina novangliae CUSHMAN, 1937, p. 136.
Karreriella novangliae (Cushman) BARKER, 1960, pl. 46, figs. 8-10.

Remarks: Test slightly irregularly twisted, segments are less symmetrical and more inflated than in *K. bradyi*.

SUBFAMILY: Valvulininae BERTHELIN, 1880

GENUS: *Clavulina* D'ORBIGNY, 1826

Clavulina mexicana CUSHMAN

Plate 22, Fig. 10

Clavulina humilis BRADY var. mexicana CUSHMAN, J.A., 1922, p. 83, pl. 16, figs. 1-3.

Pseudoclavulina mexicana (Cushman) PHLEGER and PARKER, 1951, p. 6, pl. 2, figs. 14-16.

GENUS: Martinottiella CUSHMAN, 1933

Martinottiella communis (D'ORBIGNY)

Plate 22, Fig. 11

Clavulina communis D'ORBIGNY, A.D., 1846, p. 196, pl. 12, figs. 1-2; WIESNER, 1931, p. 100, pl. 13, figs. 156,157.

Martinotiella communis (d'Orbigny) BARKER, 1960, pl. 48, figs. 3,4,6-8.

Remarks: Test agglutinates fine mineral grains.

SUBORDER: Miliolina DELAGE and HEROUARD, 1896

SUPERFAMILY: Miliolacea EHRENBERG, 1839

FAMILY: Miliolidae EHRENBERG, 1839

SUBFAMILY: Quinqueloculininae CUSHMAN, 1917

GENUS: Sigmoilopsis FINLAY, 1947

Sigmoilopsis schlumbergeri (SILVESTRI)

Plate 21, Fig. 9

Sigmoilina schlumbergeri SILVESTRI, A., 1904, p. 267,269.

Sigmoilopsis schlumbergeri (Silvestri) BARKER, 1960, pl. 8, fig.1.

PLATE 1

1. *Placopsilinella aurantiaca* Earland, attached to a planktonic foraminiferal test, SEM X104, sample 82-007-83.

2. *Thalamophaga ramosa* Rhumbler, attached to a planktonic foraminiferal test, LM X58, sample 83-007-17.

3. *Nodellum membranaceum* (Brady), SEM X97, sample 84-PCM-33.

4a,b,c. *Astrorhiza crassatina* Brady
(a,b) SEM x17, sample 82-022-82,
(c) LM X15, sample 82-022-82.

5. *Astrorhiza angulosa* Brady, SEM X56, sample 82-022-79.

6a,b. *Astrammina sphaerica* (Heron-Allen and Earland)
(a) SEM X21, sample BC-08-2,
(b) abyssal form, SEM X43, sample 84-PCM-07.

SEM: Scanning Electron Microscope
LM: Light Microscope

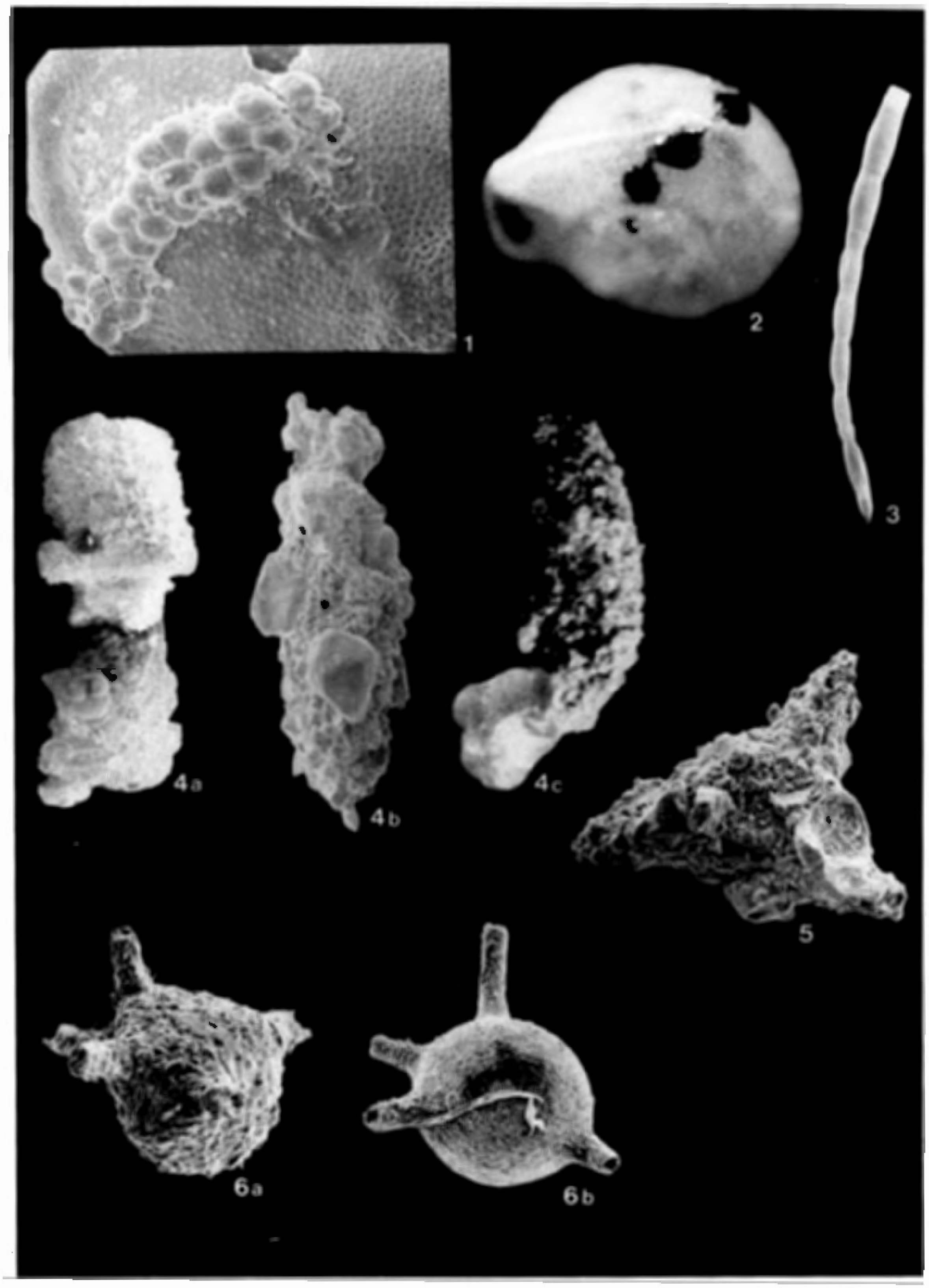

1
2
3
4a
4b
4c
5
6a
6b

PLATE 2

1a,b,c. _Rhabdammina abyssorum_ Carpenter

(a) central chamber with broken arms, SEM X58, sample 82-022-82,

(b) detail of fig. 1a, SEM X129.

(c) SEM X12, sample 82-022-82.

2a,b,c. _Rhabdammina irregularis_ Carpenter

(a) SEM X11, sample 82-022-8,

(b) detail of fig. 2a, SEM X167,

(c) LM X11, sample 82-022-82.

3a,b,c. _Rhabdammina discreta_ Brady

(a) LM X13, sample 82-022-82,

(b) SEM X25, sample 82-022-82,

(c) detail of fig. 3b, SEM X125.

4a,b. _Rhabdammina linearis_ Brady

(a) SEM X38, sample 82-022-80,

(b) detail, SEM X125.

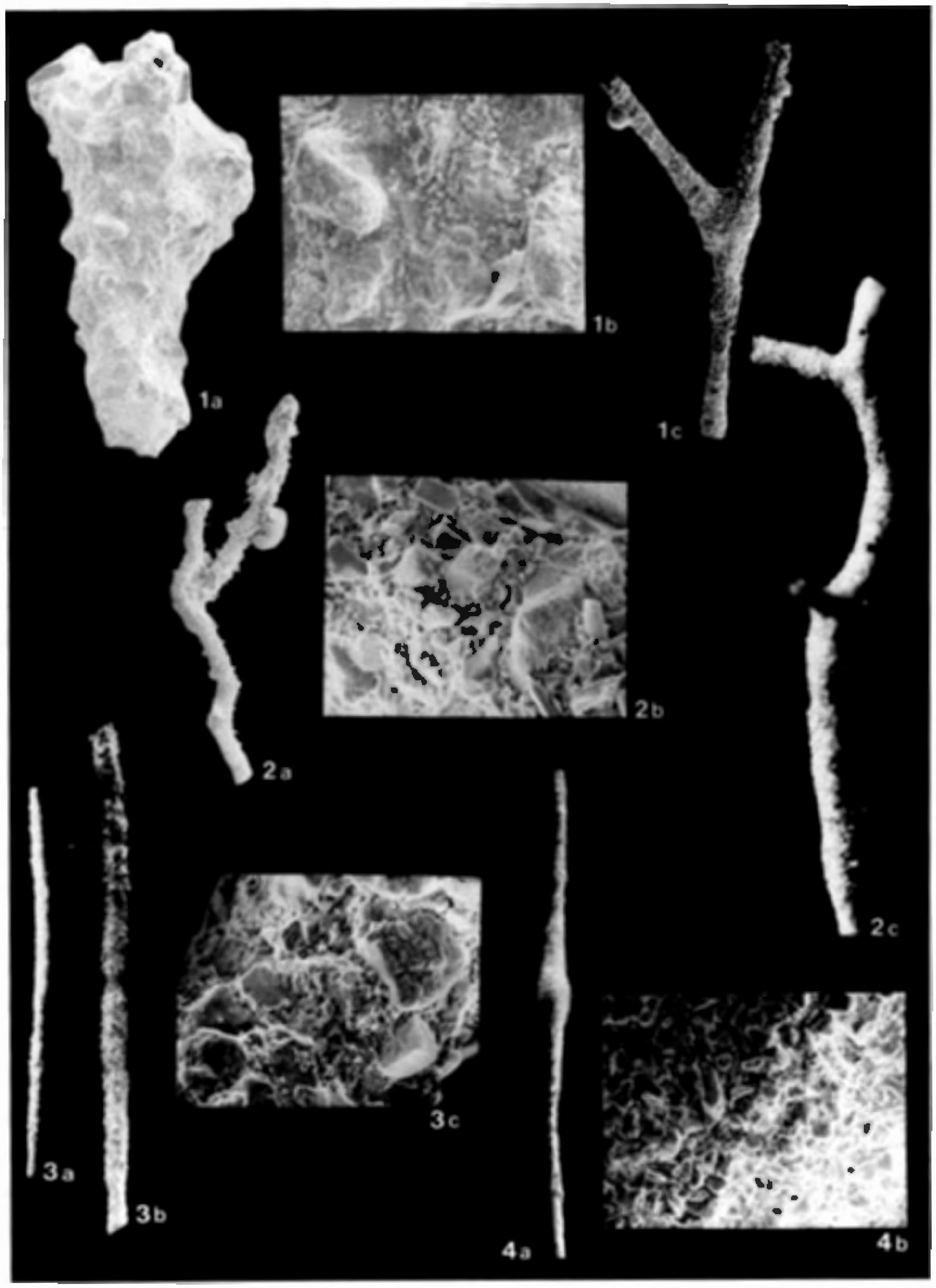

1a
1b
1c
2a
2b
2c
3a
3b
3c
4a
4b

PLATE 3

1a-e. _Rhabdammina agglutissima_ Hofker

(a) test with agglutinated mineral grains,
LM X25. sample 82-022-83,

(b) SEM X10, sample 82-022-83,

(c) detail of fig. 1b, SEM X48,

(d) test with agglutinated mineral grains and
foraminiferal tests,
LM X17, sample 82-022-83,

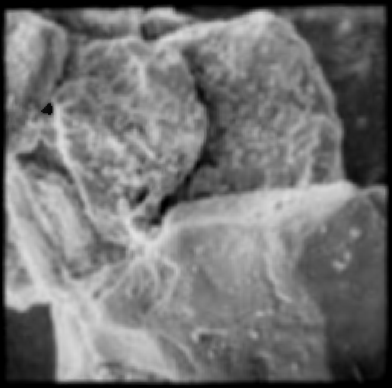
(e) specimen with agglutinated foraminiferal tests,
LM X21, sample 82-022-82.

2. _Rhabdammina cornuta_ (Brady)
LM X28, sample 82-022-83.

3. _Vanhoeffenella gaussi_ Rhumbler
The dark central part contains a large, stained protoplasm body, LM X18, sample 83-007-3.


1a


1b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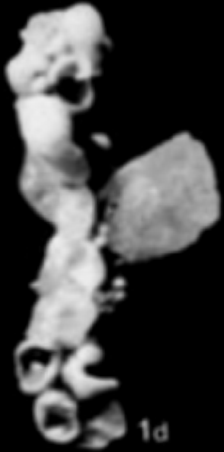
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1e


2

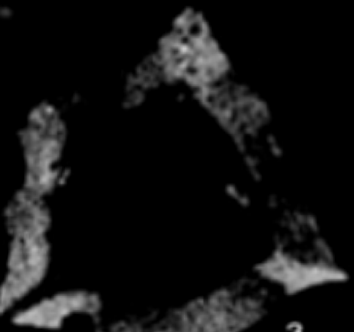
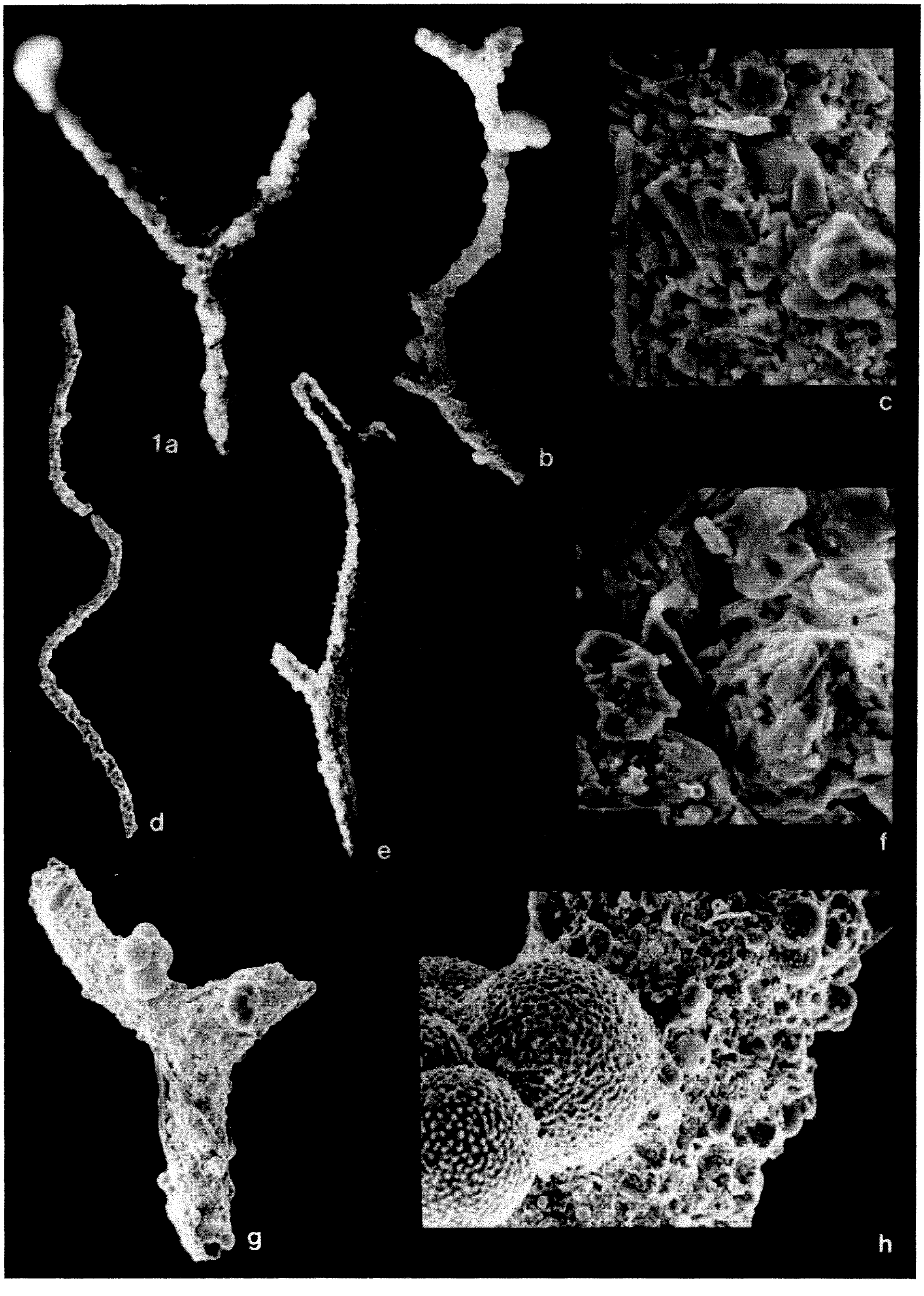

3

PLATE 4

1. *Rhizammina algaeformis* Brady
   - (a) LM X13, sample 82-022-83,
   - (b) SEM X15, sample 82-022-84,
   - (c) detail of fig. 1b, SEM X500,
   - (d) abyssal form, SEM X50, sample 82-022-76,
   - (e) SEM X14, sample 82-022-84,
   - (f) detail of fig. 1e, SEM X500,
   - (g) test with agglutinated shells, SEM X28, sample 83-007-35,
   - (h) detail of fig. 1g, SEM X129.


1a
b
c
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e
f
g
h

PLATE 5

1a,b,c. Rhizammina indivisa Brady

(a) SEM X18, sample 82-022-82,

(b) detail of fig. 1a, SEM X129,

(c) the relation of this specimen to foraminifers might be questionable,

LM X7, sample K104/10 BC-2.

2a,b,c. Bathysiphon hirudinea (Heron-Allen and Earland)

(a) SEM X21, sample 82-022-84,

(b) detail of fig. 2a, SEM X417,

(c) LM X44, sample 82-022-83.

3a,b. Marsipella elongata Norman

(a) SEM X21, sample 82-022-84,

(b) LM X8, sample 82-022-84.


1a
1b
1c
2a
2c
4a
4b
2b

PLATE 6

1a,b,c. Hyperammina sp. 1

(a) SEM X49, sample 82-022-80,

(b) detail of fig. 1a, SEM X190,

(c) SEM X25, sample 82-022-83.

2a,b. Hyperammina elongata Brady

(a) SEM X88, sample 82-022-84,

(b) detail, SEM X388.

3a,b. Hyperammina laevigata Wright

(a) SEM X49, sample 82-022-84,

(b) detail, SEM X634.

4. Hyperammina sp. 2

abyssal form, SEM X27, sample 84-BC-9.


1a
1b
1c
2a
2b
4
3a
3b

PLATE 7

1a-d. Saccorhiza ramosa (Brady)

(a) SEM X51, sample 80-001-002,

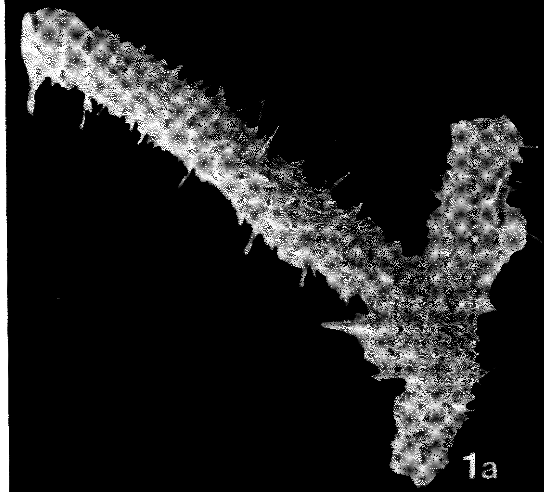
(b) detail of fig. 1a, SEM X209,

(c) SEM X39, sample 84- BC-8,

(d) SEM X27, sample 84-BC-8.

2. Dendrophrya arborescens (Norman)

LM X44, sample 83-007-3.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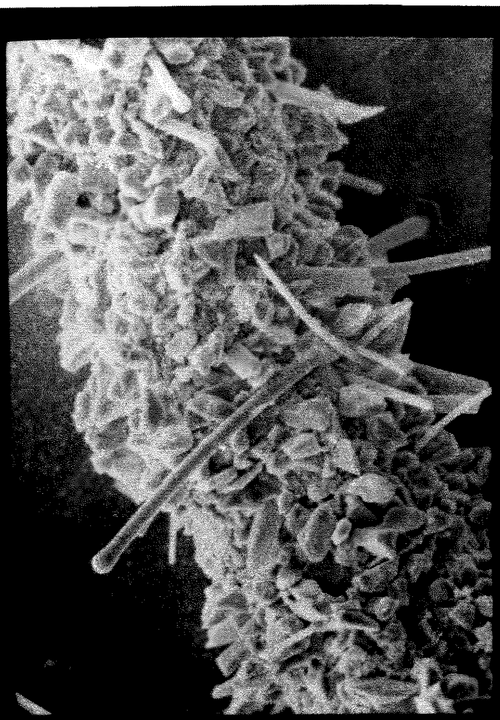
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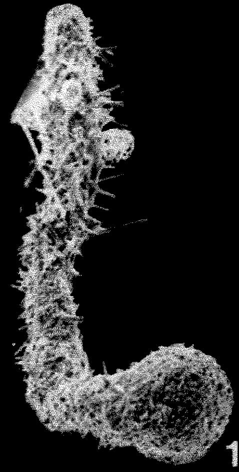
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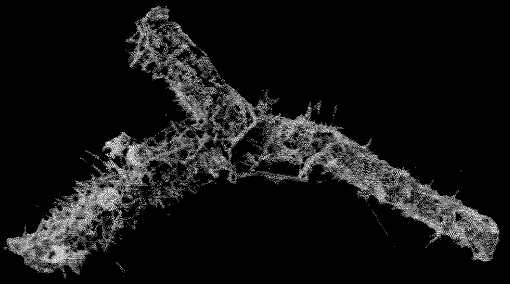
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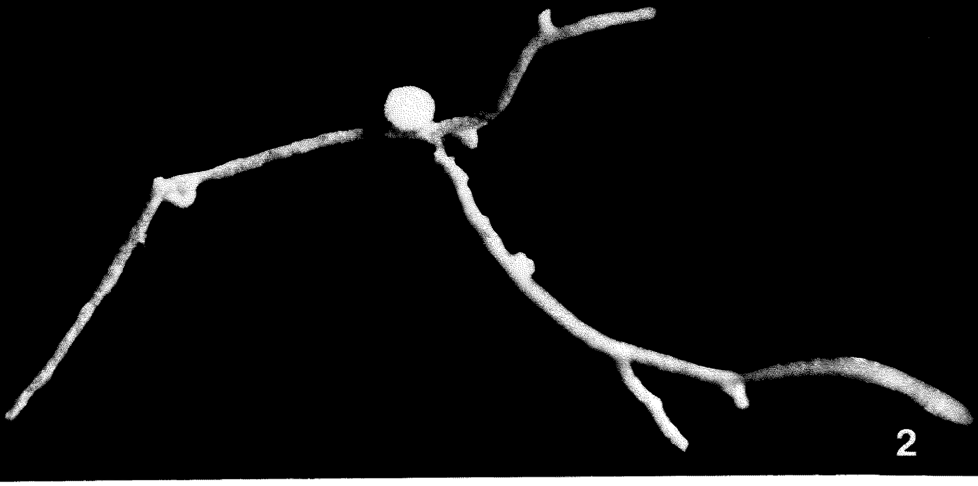
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PLATE 8

This plate shows just an example of the problem of unbranched tubular fragments of foraminiferal tests lacking the necessary features for identification.

1. ?Rhabdammina sp. SEM X37, sample 82-022-82.

2,3. ?Rhabdammina sp. (2) SEM X56, sample 82-022-83,
(3) detail of fig. 2, SEM X117.

4. ?Astrorhiza sp. LM X12, sample 82-022-83.

5. Hyperammina or Rhabdammina SEM X61, sample 82-022-84.

6. Hyperammina or Rhabdammina LM X49, sample 82-022-82.

7. ?Jaculella sp. SEM X55, sample 83-007-17.

8. Hyperammina or Rhabdammina SEM X37, sample 82-022-82.

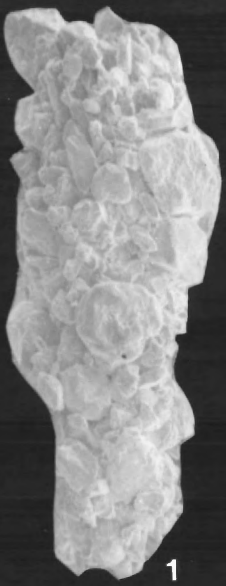
9. Hyperammina or Rhabdammina SEM X61, sample 82-022-84.

10. Hyperammina or Rhabdammina SEM X43, sample 82-022-77.

11. Hyperammina or Rhabdammina SEM X25, sample 82-022-82.

12. ?Bathysiphon sp. SEM X20, sample 82-022-82.

13. ?Bathysiphon sp. SEM X18, sample 82-022-84.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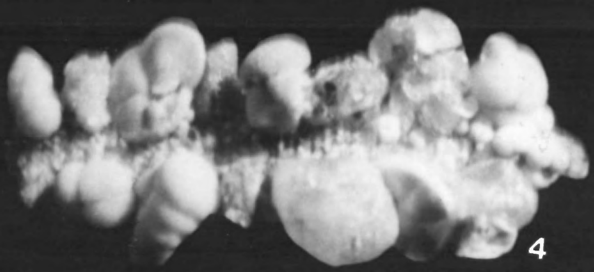
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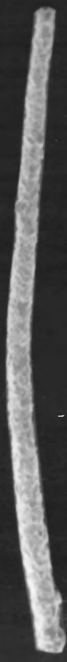
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12


13

PLATE 9

This plate shows an example of tubular fragments probably related to branching species. The necessary features for identification are lacking.

1. _?Rhizammina sp._ SEM X25, sample 82-022-82.

2. _?Rhizammina sp._ LM X18, sample 82-022-82.

3. _?Rhabdammina sp._ LM X21, sample 82-022-82.

4. _?Rhabdammina sp._ LM X25, sample 83-007-17.

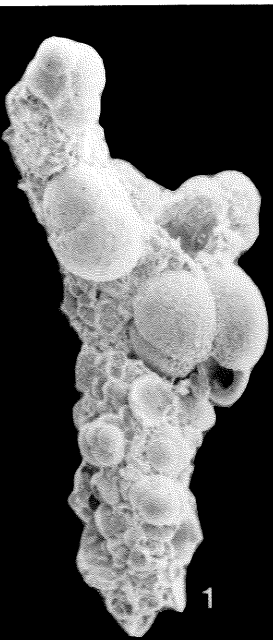
5. _?Rhizammina sp._ SEM X49, sample 82-022-82.

6. _?Rhizammina sp._ SEM X37, sample 82-022-84.

7. _?Rhabdammina sp._ LM x28, sample 82-022-79.

8. _?Rhabdammina sp._ LM X25, sample 82-022-79.

9. _?Rhabdammina sp._ LM X49, sample 82-022-82.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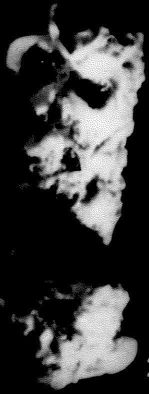
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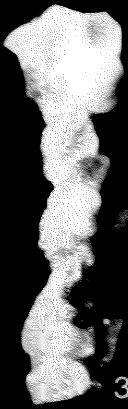
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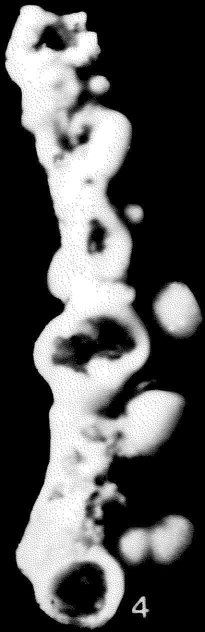
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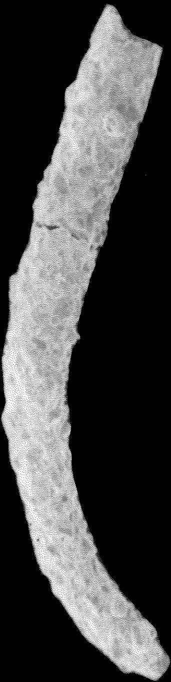
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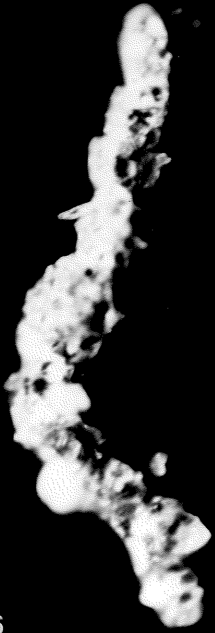
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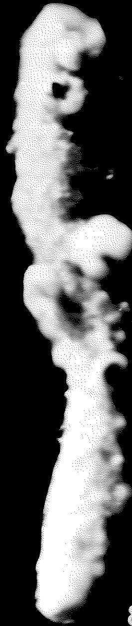
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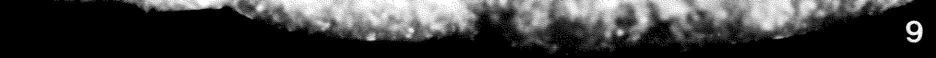
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PLATE 10

1a,b. *Psammosphaera fusca* Schulze

(a) SEM X25, sample 82-022-83,

(b) SEM X19, sample 83-007-35.

2. *Lagenammina tubulata* (Rhumbler)

attached to Globorotalia, SEM X26, sample 83-007-17.

3. *Sorosphaera consociata* (Rhumbler)

SEM X40, sample 84-PCM-39.

4a,b. *Saccammina sphaerica* Brady

(a) SEM X30, sample 82-022-79,

(b) SEM X25, sample 82-022-83.

5. *Technitella legumen* Norman

SEM X13, sample 82-022-80.

6. *Pelosina cylindrica* Brady

LM X4, sample 82-022-83.

7a,b. *Pelosina variabilis* Brady

(a) SEM X23, sample 82-022-80,

(b) detail, SEM X80.

8. *Pelosina variabilis var. constricta* Earland

LM X23, sample 84-BC-15.

9a,b. *Thurammina papillata* Brady

(a) SEM X44, sample 84-BC-15,

(b) LM X45, sample 84-Bc-15.

10a,b. *Ammodiscus incertus* (D'Orbigny)

(a) small abyssal form, SEM X77, sample 84-BC-8,

(b) LM X23, sample DSDP Leg 96- 619-1-1/Top.

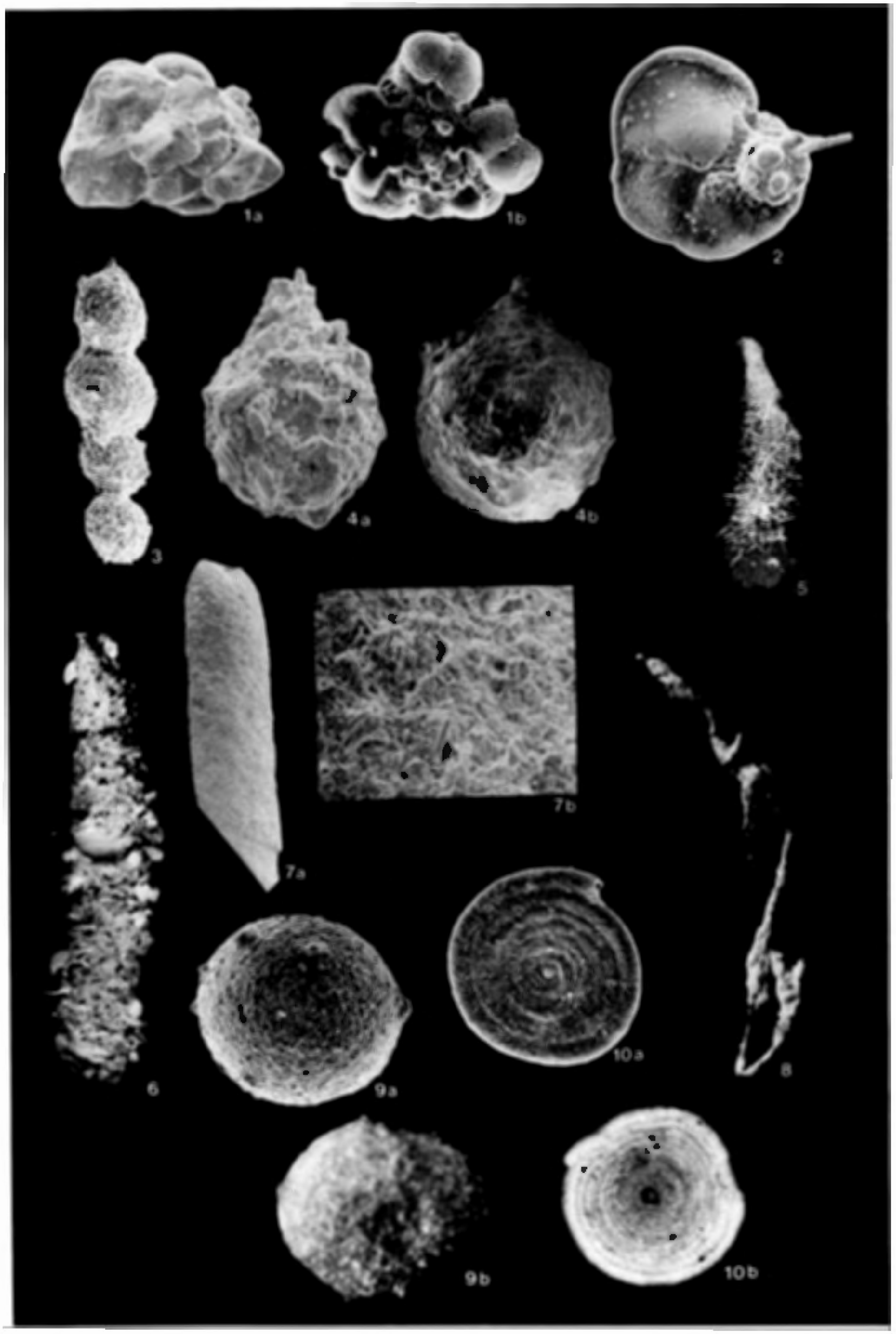

1a
1b
2
3
4a
4b
5
7a
7b
6
9a
10a
8
9b
10b

PLATE 11

1,2. Glomospira gordialis (Parker and Jones)

(1) top view, SEM X125, sample 82-022-84,

(2) side view, SEM X133, sample 82-022-80.

3,4. Glomospira charoides (Parker and Jones)

(3) top view, SEM X65, sample 82-022-83,

(4) top view, LM X71, sample 82-022-83.

5,6. Ammolagena clavata (Parker and Jones)

attached to planktonic foraminifers,

(5) SEM X63, sample 82-022-80,

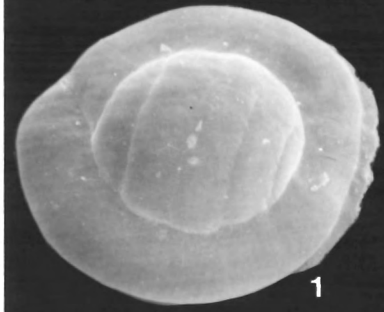
(6) LM X40, sample 82-022-80.

7-9. Tolypammina vagans (Brady)

(7) test attached, SEM X50, sample 82-022-83,

(8) test tightly coiled, SEM X33, sample 84-BC-8,

(9) test free, SEM X47, sample 84-BC-25.



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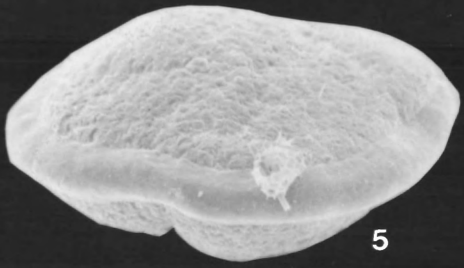

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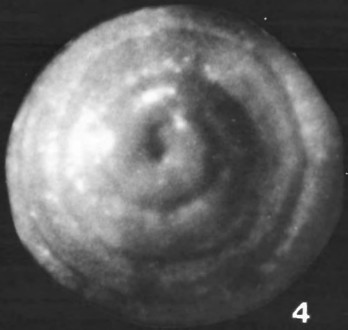

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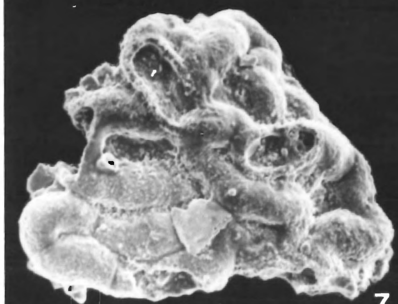

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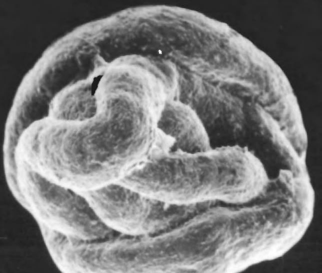

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PLATE 12

1-4. *Aschemonella scabra* Brady

(1) SEM X67, sample 82-022-82,

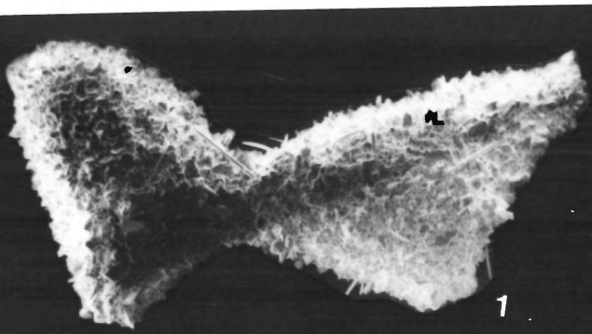
(2) wall detail of fig. 1, SEM X184,

(3) SEM X41, sample 82-022-82,

(4) LM X57, sample DSDP Leg 96-622-1-1/Top.

5. *Aschemonella ramulifera* Brady

SEM X33, sample 84-BC-8.



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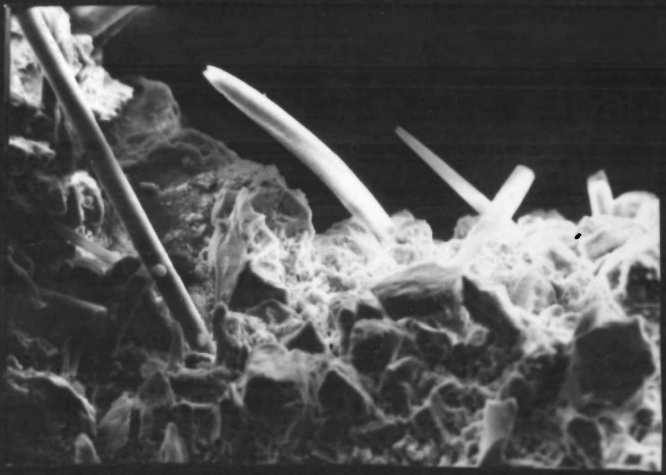

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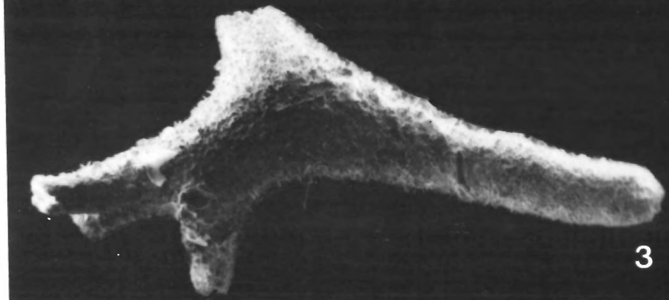

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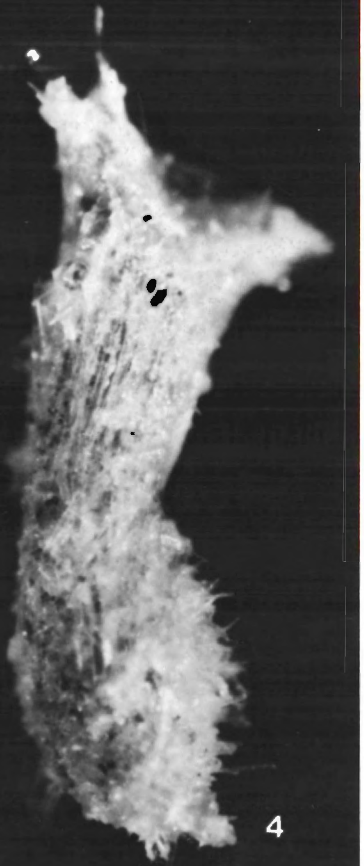

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PLATE 13

1-3. *Hormosina globulifera* Brady

(1) SEM X25, sample 82-022-80,

(2) SEM X74, sample 82-022-84,

(4) LM X29, sample K104/10 BC-2.

4. *Hormosina normani* Brady

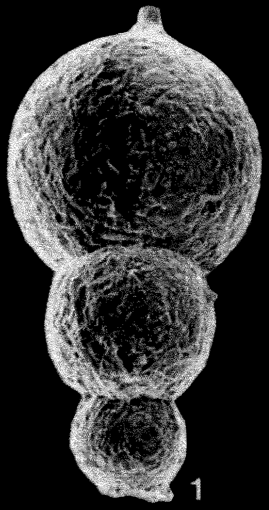
LM X56, sample 84-BC-25.

5. *Reophax ovicula* (Brady)

SEM X59. sample 84-BC-15.

6. *Hormosina carpenteri* Brady

LM X10, sample 84-BC-9.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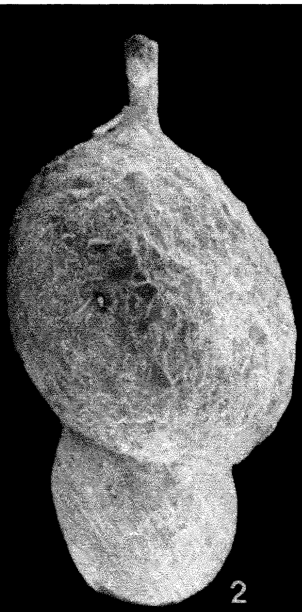
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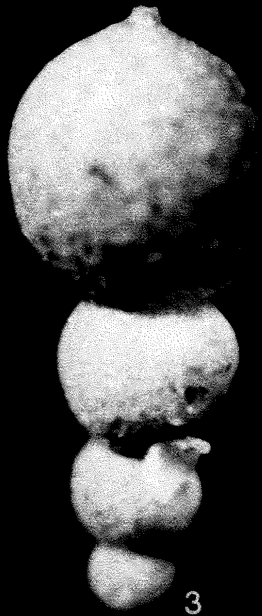
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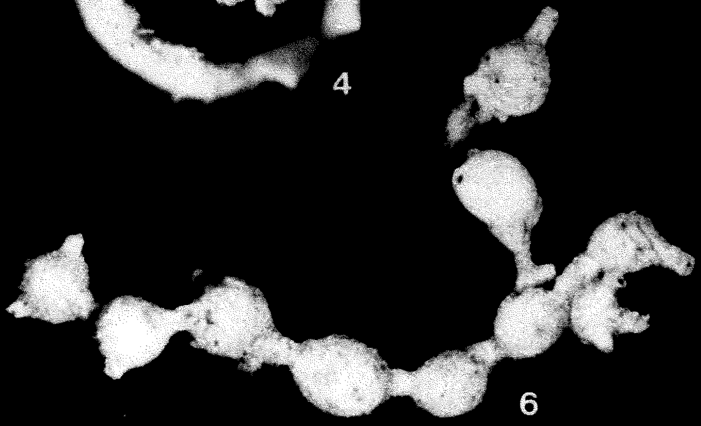
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PLATE 14

Figs. 1-5 show how the morphological changes of *Reophax scorpiurus* are a function of the changing nature of the agglutinated wall material.

1-5. *Reophax scorpiurus* Montfort

(1) SEM X55, sample 82-022-82,

(2) SEM X25, sample 82-022-83,

(3) SEM X37, sample 83-007-17,

(4) SEM X51, sample 83-007-35,

(5) SEM X46, sample 84-BC-25.

6,7. *Reophax dentaliniformis* Brady

(6) SEM X33, sample 82-022-84,

(7) SEM X31, sample 82-022-83.

8-10. *Reophax bilocularis* Flint, complete specimens,

(8) SEM X63, sample 82-022-80,

(9) LM X58, sample 82-022-80,

(10) abyssal form, SEM X117, sample 82-022-76.

11-13. *Reophax bilocularis* Flint, single chamber fragments,

(11) SEM X65, sample 82-022-80,

(12) SEM X67, sample 83-007-17,

(13) SEM X83, sample 82-022-82.

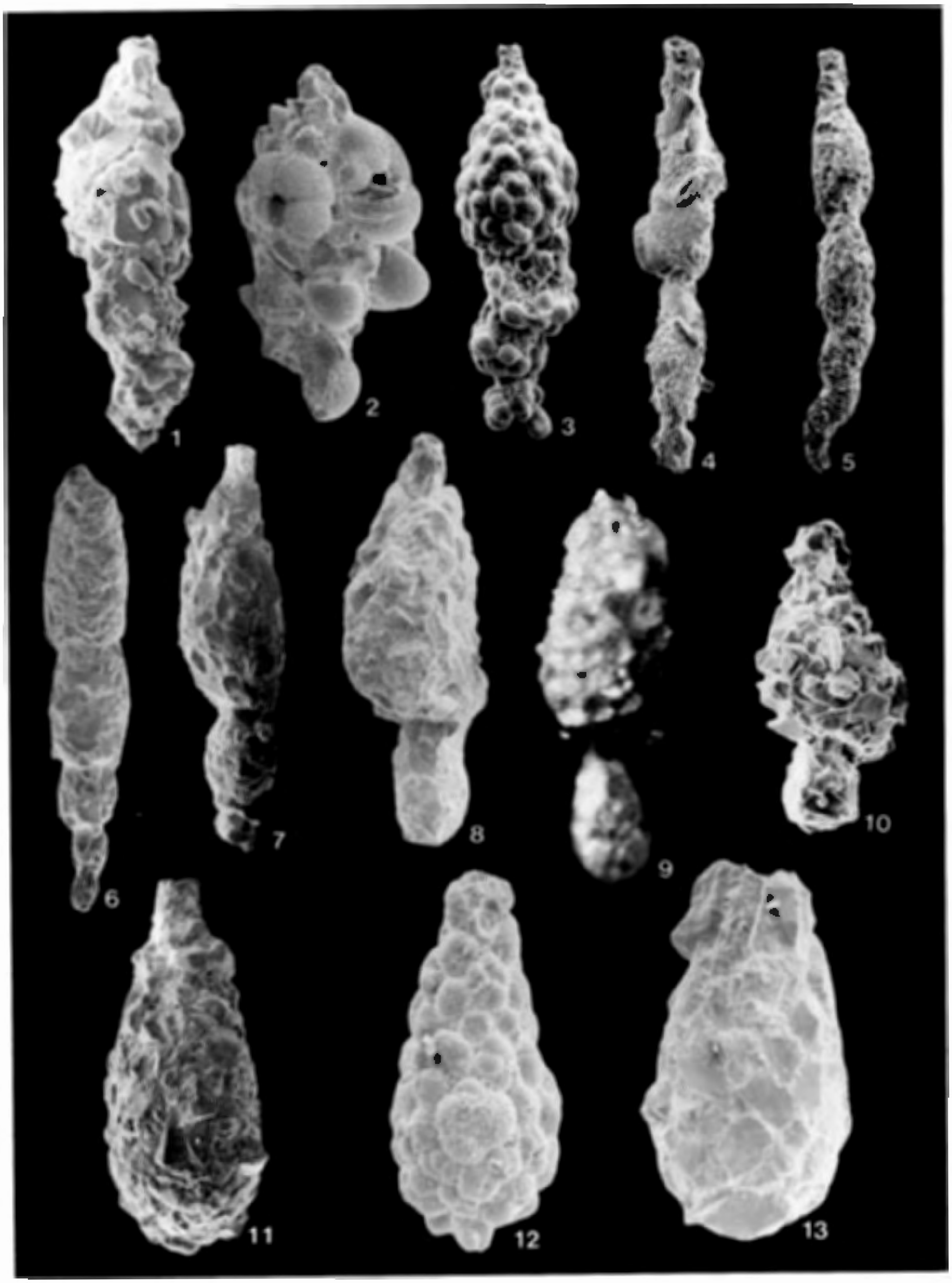
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PLATE 15

Figs. 1-5 show the morphological variability of Reophax pilulifer related to the nature of agglutinated material (from coarse to finer grained and with agglutinated foraminiferal tests).

1-5. Reophax pilulifer Brady

(1) LM X11, sample 82-022-83,

(2) SEM X21, sample 82-022-82,

(3) SEM X20, sample 82-022-82,

(4) SEM X11, sample DSDP Leg-622-1-1/Top,

(5) LM X15, sample 82-022-83.

6,7. Reophax horrida Cushman

(6) SEM X42, sample 80-001-001,

(7) SEM X38, sample 84-BC-15.

8. Reophax helenae (Rhumbler)

SEM X38, sample 84-BC-25.

9. Reophax fusiformis (Williamson)

SEM X70, sample 82-022-84.

10. Reophax cylindricus Brady

SEM X59. sample 82-022-82.

11. Reophax nodulosus Brady

SEM X46, sample 84-BC-15.

12,13. Reophax guttifer Brady

(12) SEM X58, sample 82-022-83,

(13) LM X42, sample 83-007-17.


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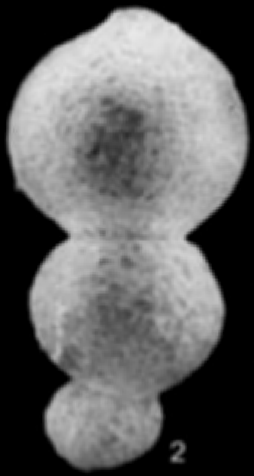
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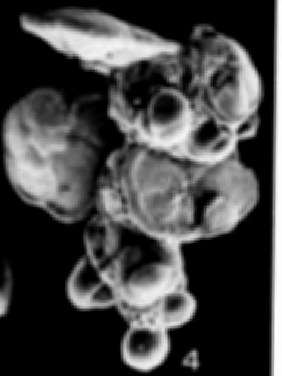
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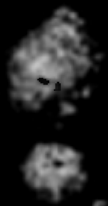
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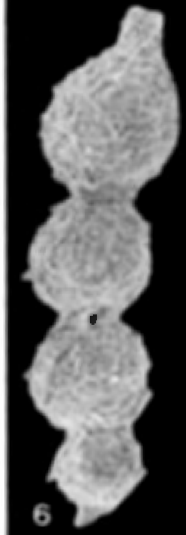
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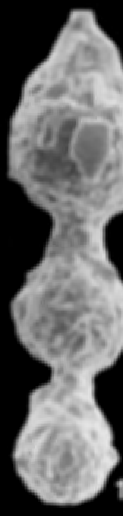
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PLATE 16

1,2. Reophax bacillaris Brady

(1) SEM X65, sample 82-022-83,

(2) LM X58. sample 82-022-83.

3-5,9. Reophax distans Brady

(3) SEM X52, sample 82-022-80,

(4) fragment, single chambered,
SEM X83, sample 82-022-82,

(5) LM X58. sample 82-022-82,

(9) fragment, single chambered,
SEM X65, sample 82-022-80.

6-8. Subreophax aduncus (Brady)

(6) SEM X88, sample 82-022-82,

(7) SEM X65, sample 82-022-84,

(8) abyssal form, SEM X56, sample 84-BC-9.

10,11. Adercotryma glomerata (Brady)

(9) SEM X46, sample 82-022-80,

(10) top view, SEM X118, sample 84-BC-2B.


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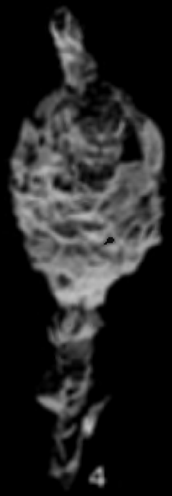
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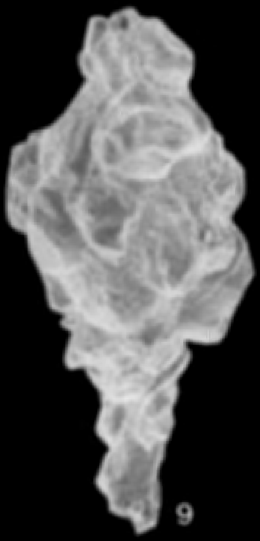
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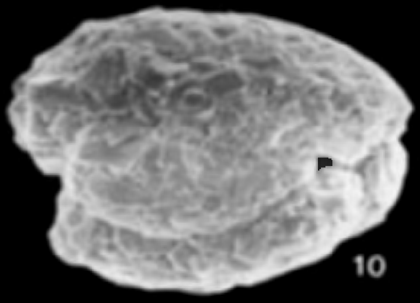
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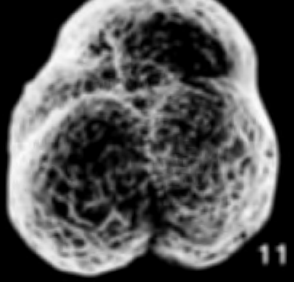
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PLATE 17

1-4. *Recurvoides scitulum* (Brady)

(1) SEM X26, sample 82-022-83,

(2) LM X30, sample 82-022-82,

(3) SEM X 30, sample 82-022-83

(4) aperture view, SEM X29.

5,6. *Recurvoides sp. a*

(5) dorsal side, SEM X50, sample 84-BC-25,

(6) ventral side, SEM X50, sample 84-BC-25.

7,8. *Discammina compressa* (Göes)

(7) SEM X32, sample 82-022-76,

(8) Lm X30, sample 82-022-80.

9. *Cyclammina trullissata* (Brady)

SEM X51, sample 80-001-002.

10. *Cyclammina pusilla* Brady

LM X32, sample 82-022-82.

11. *Cyclammina sp.*

SEM X25, sample 82-022-83.

12,13. *Cystammina galeata* (Brady)

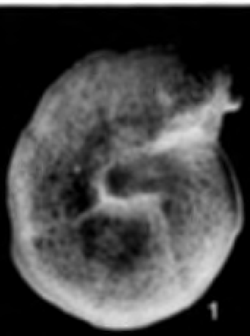
(12) side view, SEM X61, sample 84-BC-25,

(13) aperture view, SEM X75.

14,15. *Cystammina pauciloculata* (Brady)

(14) SEM X58. sample 82-022-83,

(15) LM X30, sample 82-022-83.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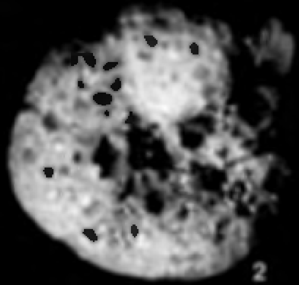
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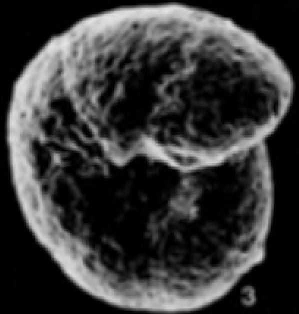
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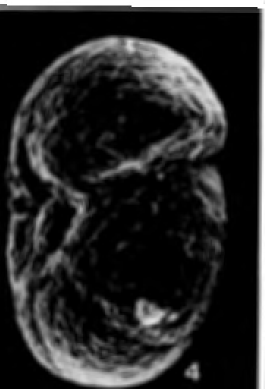
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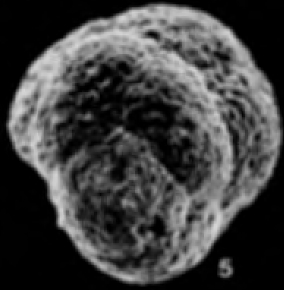
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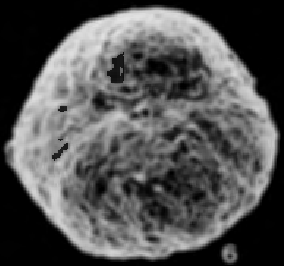
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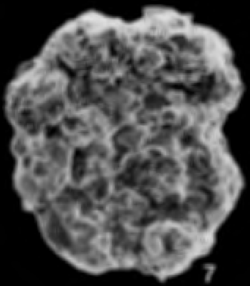
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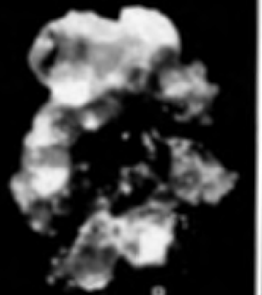
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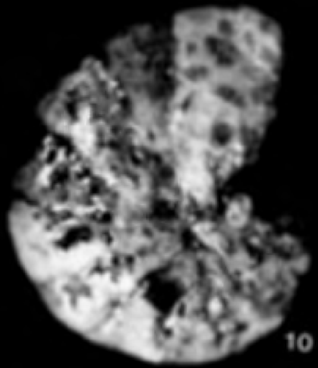
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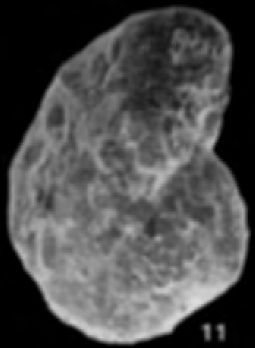
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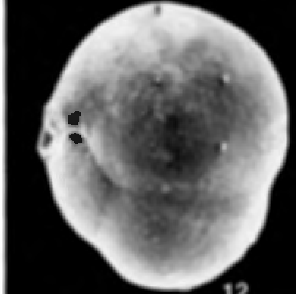
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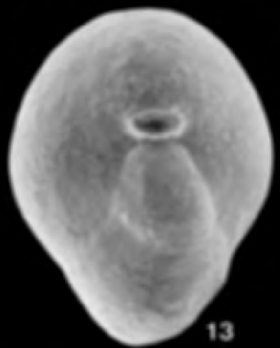
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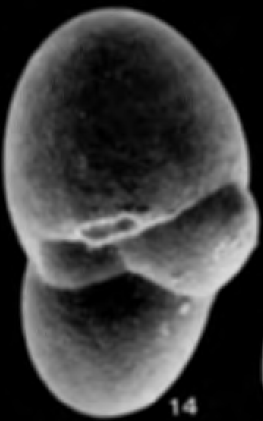
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PLATE 18

1. Haplophragmoides canariensis (D'Orbigny)

SEM X50, sample DSDP Leg 96-619-1-1/Top.

2-4. Haplophragmoides rotulatum (Brady)

(2) SEM X59, sample 84-BC-15,

(3) aperture view, SEM X69,

(4) LM X63, sample 84-BC-9.

5-7. Haplophragmoides sphaeriloculus Cushman

(5) SEM X48, sample 84-BC-8,

(6) SEM X45, sample 82-022-80,

(7) LM X63, sample 82-022-80.

8. Haplophragmoides bradyi (Robertson)

SEM X88, sample 82-022-83.

9. Cribrostomoides nitidum (Göes)

LM X31, DSDP Leg 96-619-1-1/Top.

10-12. Cribrostomoides wiesneri (Parr)

(10) SEM X32, sample 82-022-83,

(11) aperture view, SEM X63,

(12) LM X47, sample 82-022-83.

13,14. Cribrostomoides ringens (Brady)

(13) SEM X32, sample 82-022-80,

(14) LM X38, sample 82-022-80.

15.16. Cribrostomoides subglobosus (G.O.Sars)

(15) SEM X25, sample 82-022-80,

(16) aperture view, SEM X31.

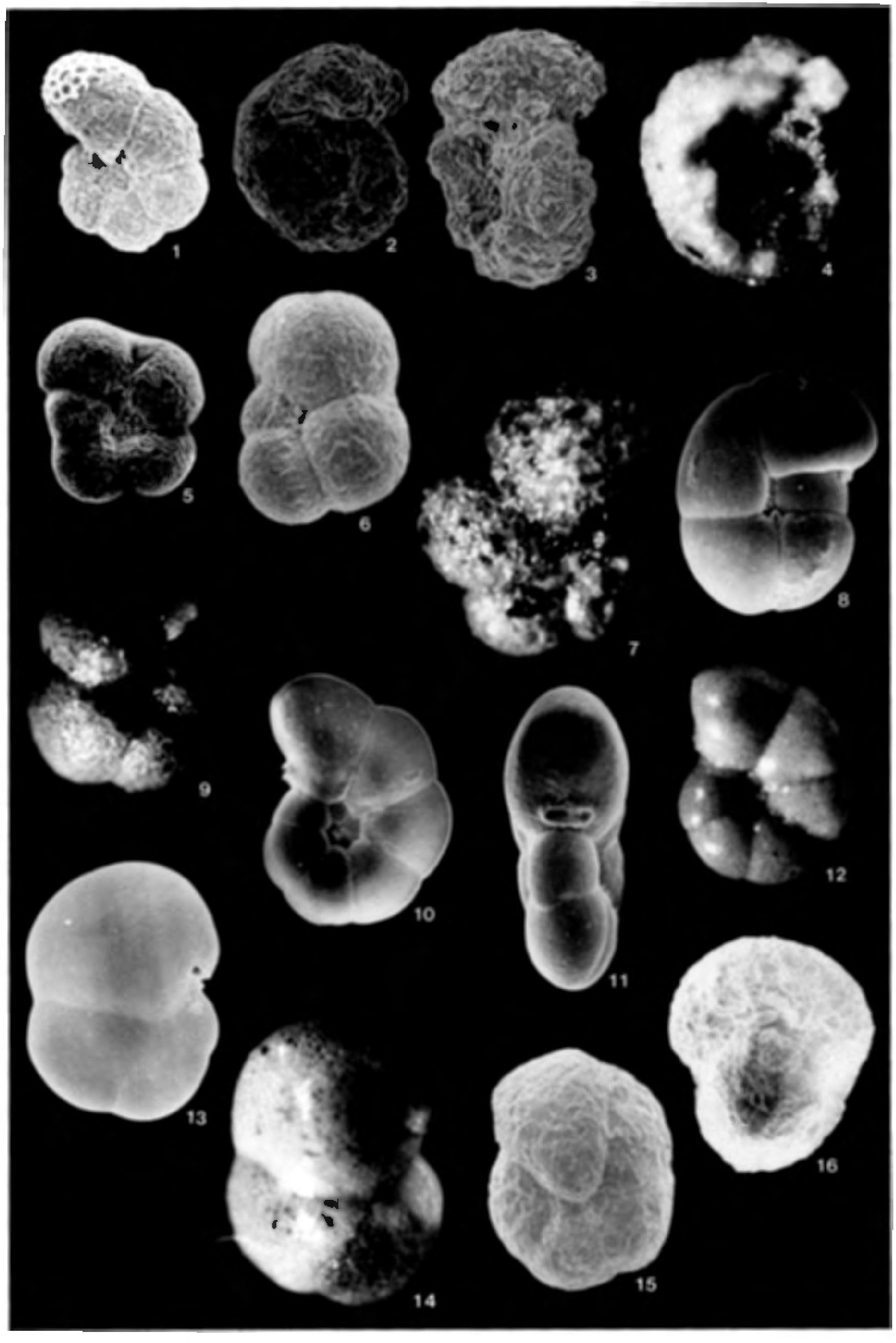
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PLATE 19

1-4. Cribrostomoides weddellensis (Earland)

(1) dorsal side, SEM X26, sample 82-022-79,

(2) ventral side, SEM X23, sample 82-022-79,

(3) aperture view, SEM X41,

(4) ventral side, LM X33, sample 82-022-79.

5-8. Trochammina cf. globigeriniformis (Parker and Jones)

(5) dorsal side, SEM X26, sample 82-022-83,

(6) ventral side, SEM X27, sample 82-022-80,

(7) dorsal side, LM X35, sample 82-022-83,

(8) ventral side, LM X35, sample 82-022-83.

9-11. Trochammina globulosa Cushman

(9) dorsal side, SEM X40, sample 82-022-83,

(10) ventral side, SEM X40, sample 82-022-83,

(11) ventral side, LM X45, sample 82-022-83.

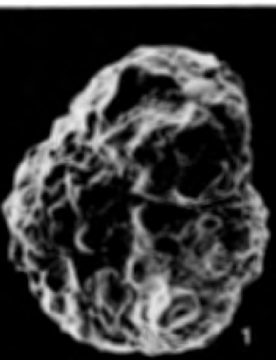
12-14. Trochammina cf. squamata Parker and Jones

(12) dorsal side, SEM X30, sample 82-022-80,

(13) ventral side, SEM X33, sample 82-022-82,

(14)dorsal side, SEM X36, sample 82-022-80,

(15) ventral side, SEM X35, sample 82-022-80.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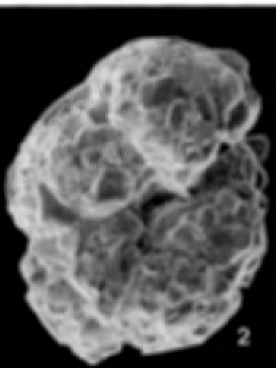
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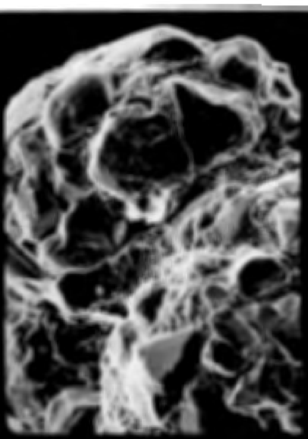
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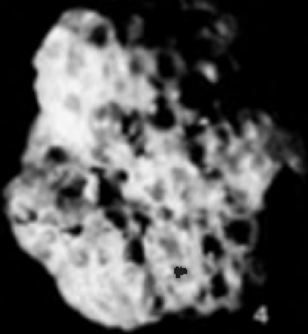
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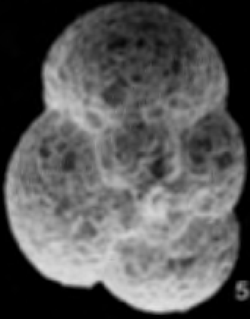
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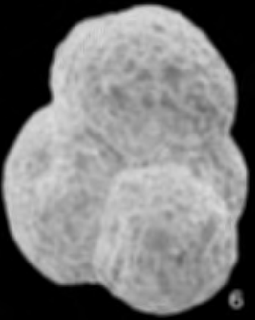
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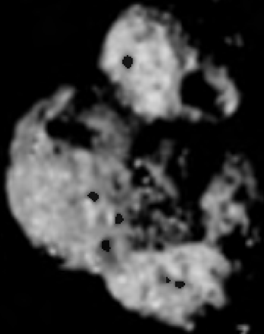
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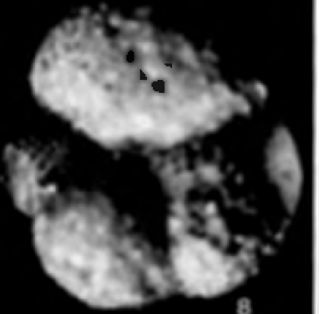
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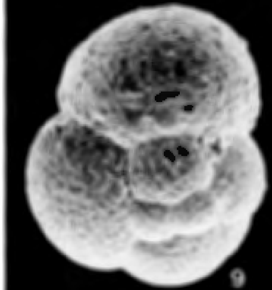
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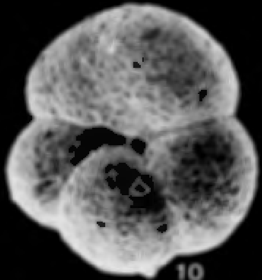
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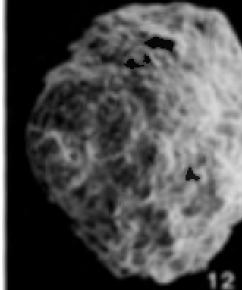
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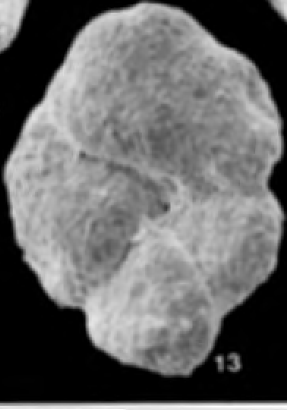
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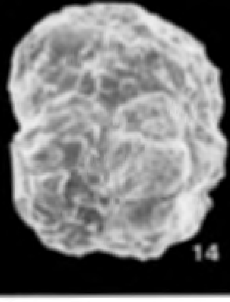
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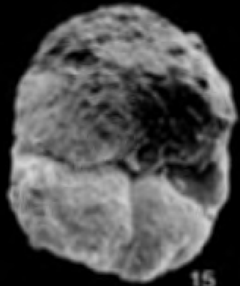
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PLATE 20

1-4. <u>Trochammina sp. 3</u>

(1) dorsal side, SEM X150, sample 82-022-83,

(2) ventral side, SEM X85, sample 82-022-82,

(3) aperture view, SEM X102, sample 82-022-82,

(4) dorsal side, LM X85, sample 82-022-82.

5,6. <u>Trochammina sp. 4</u>

(5) dorsal side, SEM X110, sample 82-022-80,

(6) ventral side, SEM X100, sample 82-022-80.

7-9. <u>Portatrochammina sp. 1</u>

(7) dorsal side, SEM X205, sample 82-022-80,

(8) ventral side, SEM X200, sample 82-022-80,

(9) ventral side, SEM X280 sample 82-022-80.


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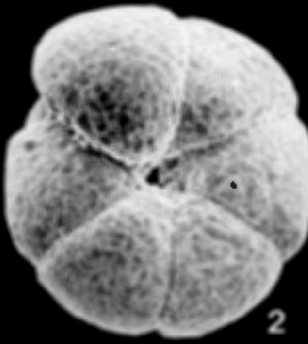
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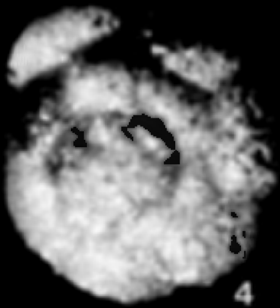
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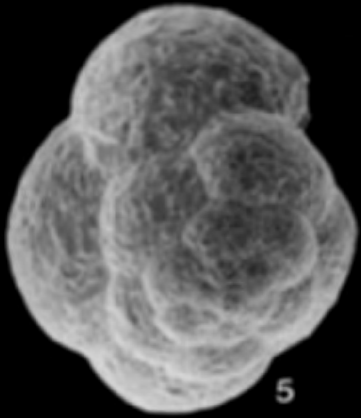
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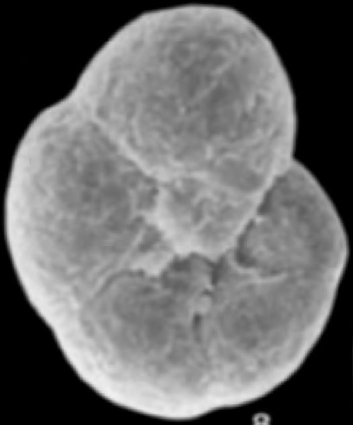
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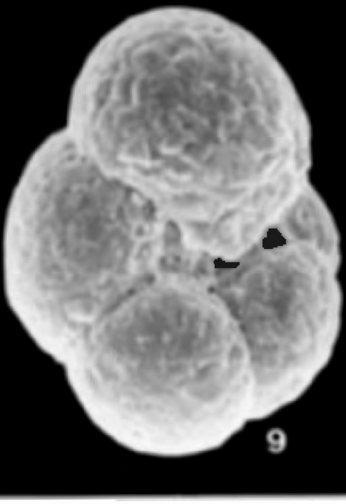
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PLATE 21

1-4. Ammobaculites agglutinans (D'Orbigny)

(1) SEM X17, sample 82-022-82,

(2) SEM X42, sample 82-022-80,

(3) LM X28, sample 82-022-83,

(4) test with broken rectilinear part,

SEM X63, sample 82-022-82.

5,6. Ammobaculites agglutinans var. filiformis Earland

(5) SEM X62, sample 84-BC-9,

(6) SEM X58, sample 84-BC-9.

7,8. Ammobaculites agglutinans var. 1

(7) SEM X53, sample 82-022-82,

(8) LM X45, sample 82-022-82.

9. Sigmoilopsis schlumbergeri (Silvestri)

SEM x33, sample 82-022-83.

10-13. Ammomarginulina foliacea (Brady)

(10) SEM X35, sample 82-022-83,

(11) SEM X25, sample 82-022-82,

(12) abyssal form, LM X28, sample 82-022-76,

(13) abyssal form, SEM X39, sample 84-BC-8.

14. Spiroplectammina biformis (Parker and Jones)

SEM X133, sample 84-BC-25.

15-17. Ammomarginulina recurva Earland,

(15) SEM X36, sample 84-BC-8,

(16) SEM X51, sample 84-BC-9,

(17) LM X38, sample 84-BC-9.


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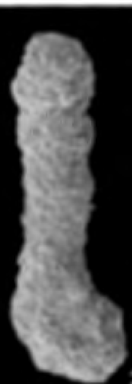
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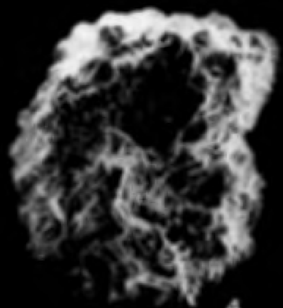
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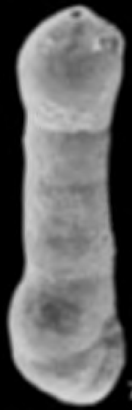
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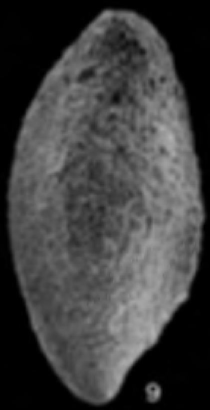
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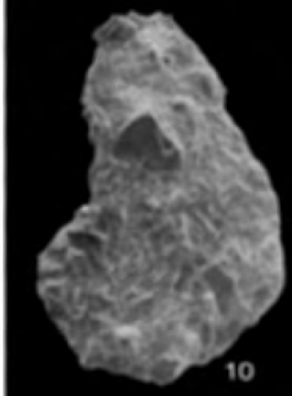
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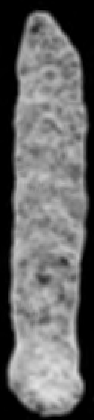
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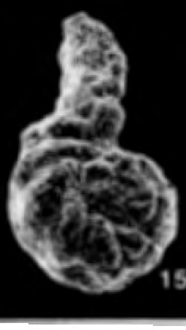
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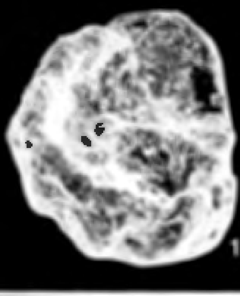
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PLATE 22

1-6. *Eggerella bradyi* (Cushman)

(1) LM X33, sample 82-022-83,

(2) SEM X25, sample 82-022-83,

(3) SEM X33, sample 82-022-79,

(4) aperture view, SEM X50,

(5) abyssal type, SEM X63, sample 84-BC-25,

(6) SEM X56, sample 84-BC-25.

7. *Eggerella propinqua* (Brady)

SEM X16, sample 82-022-83.

8,9. *Karreriella bradyi* (Cushman)

(8) SEM X27, sample 82-022-83,

(9) SEM X25. sample 82-022-83.

10. *Clavulina mexicana* Cushman

SEM X19, sample DSDP Leg 96-619-1-1/Top.

11. *Martinotiella communis* (D'Orbigny)

(11) SEM X15, sample Leg 96-619-1-1/Top.

12,13. *Karreriella novangliae* (Cushman)

(12) LM X23, sample 82-022-80,

(13) SEM X28, sample 82-022-80.

14. *Karreriella apicularis* (Cushman)

SEM X34, sample 82-022-82.

15. *Textularia wiesneri* Earland

SEM X58. sample 82-022-80.

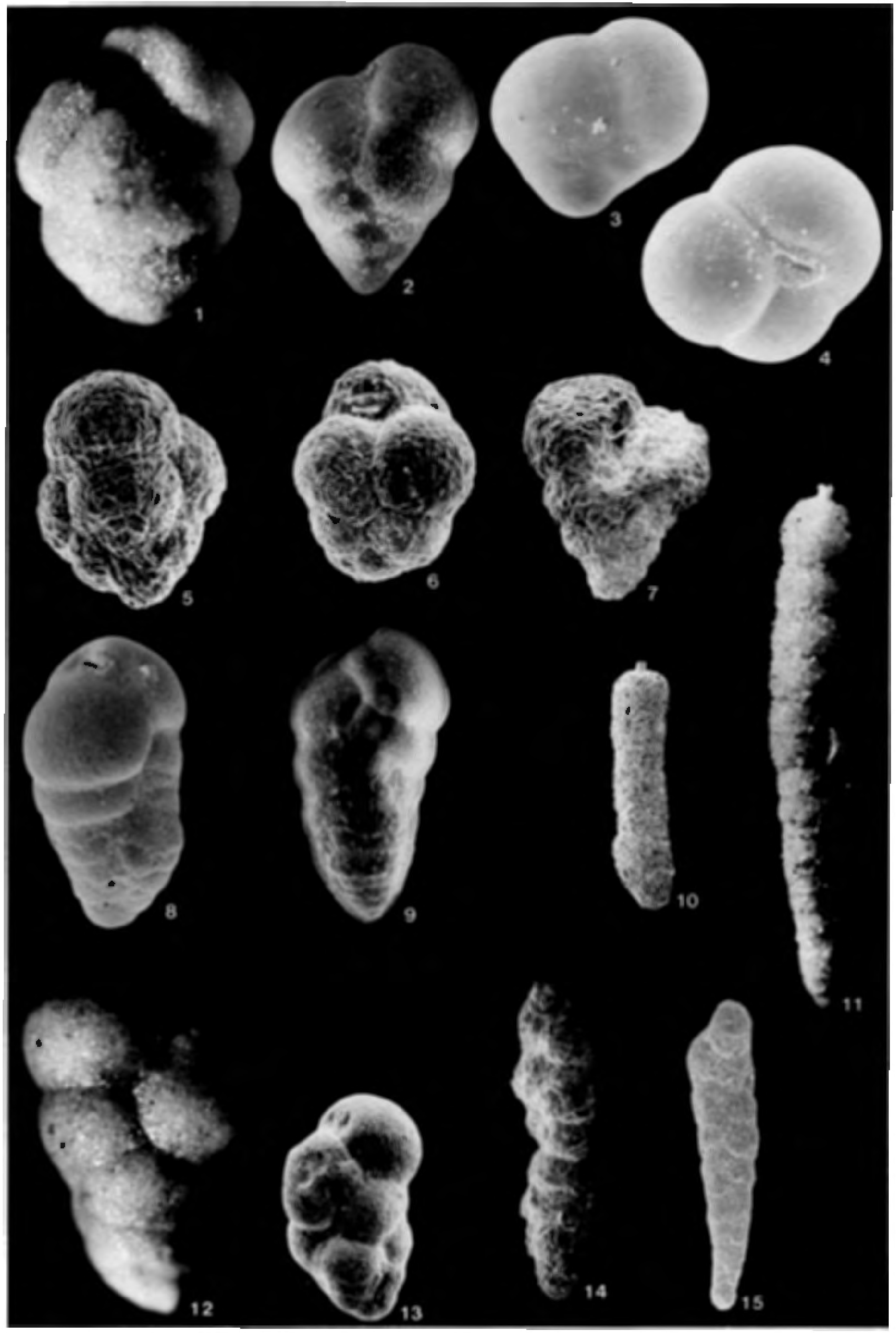
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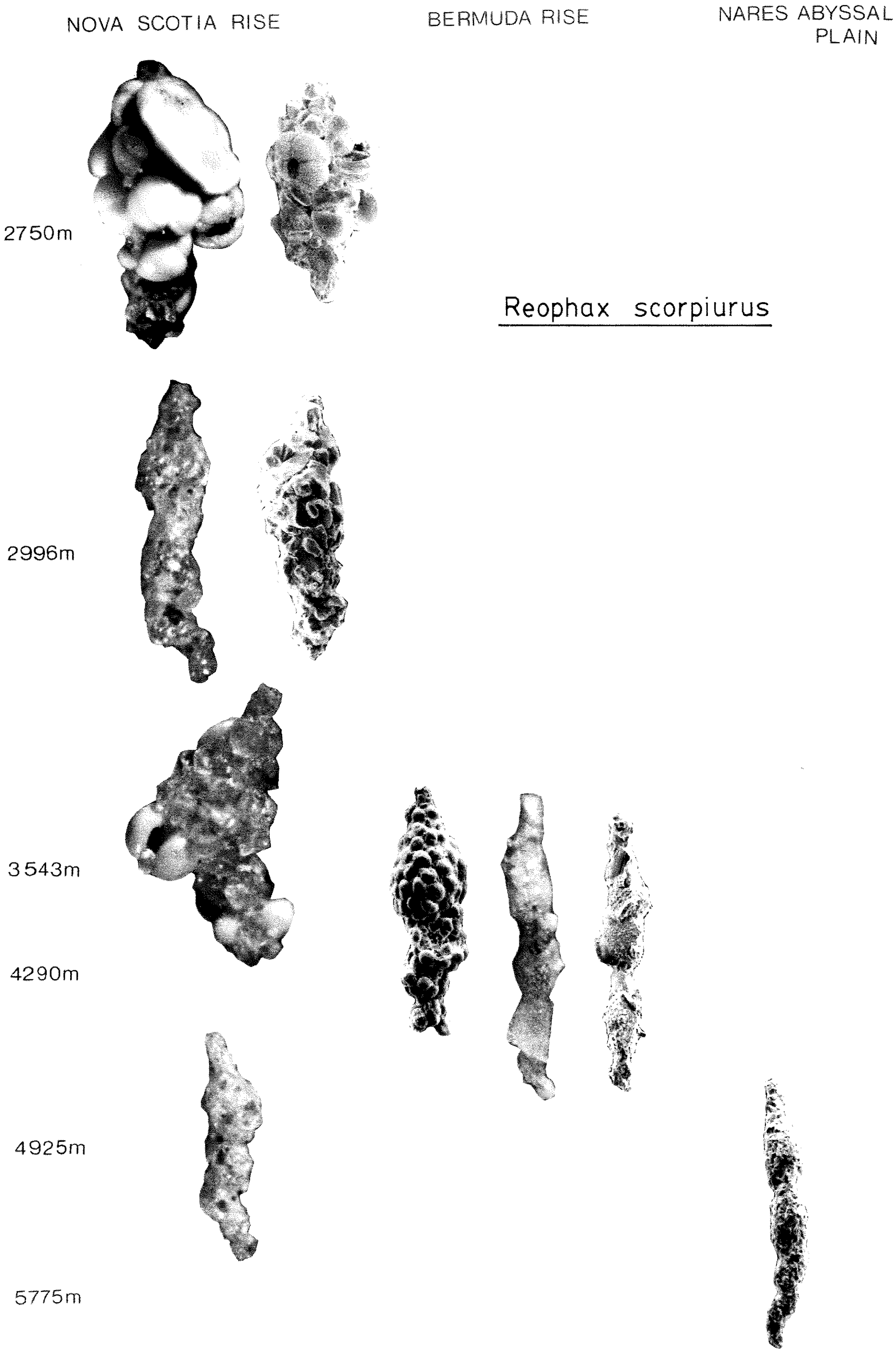
Plate 23

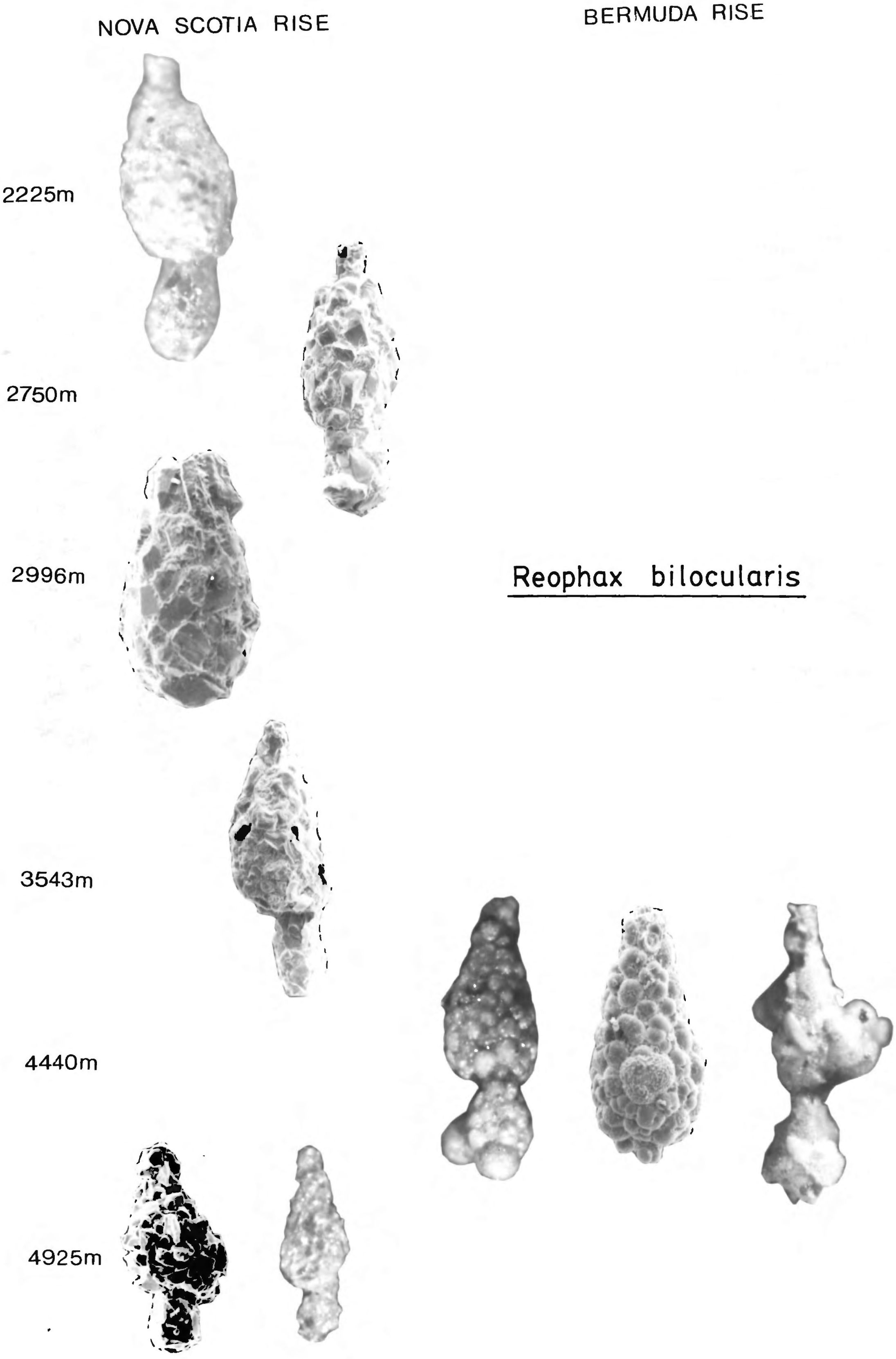
This plate shows the variability of _Reophax scorpiurus_ over the depth range from the slope off Nova Scotia to the Nares Abyssal Plain. The changing exterior shape of chambers seems to depend almost entirely on the agglutinated wall material.



Reophax scorpiurus

Plate 24

This plate illustrates the variability of _Reophax bilocularis_ on the Slope and Rise off Nova Scotia and on the Bermuda Rise. Note the decrease in size and the fragility of the test in abyssal depth.



Reophax bilocularis

Plate 25

This plate shows the variability of *Rhizammina algaeformis* and *Hyperammina sp.* The wall texture and diameter of tubes appears to vary with the wall material utilized.

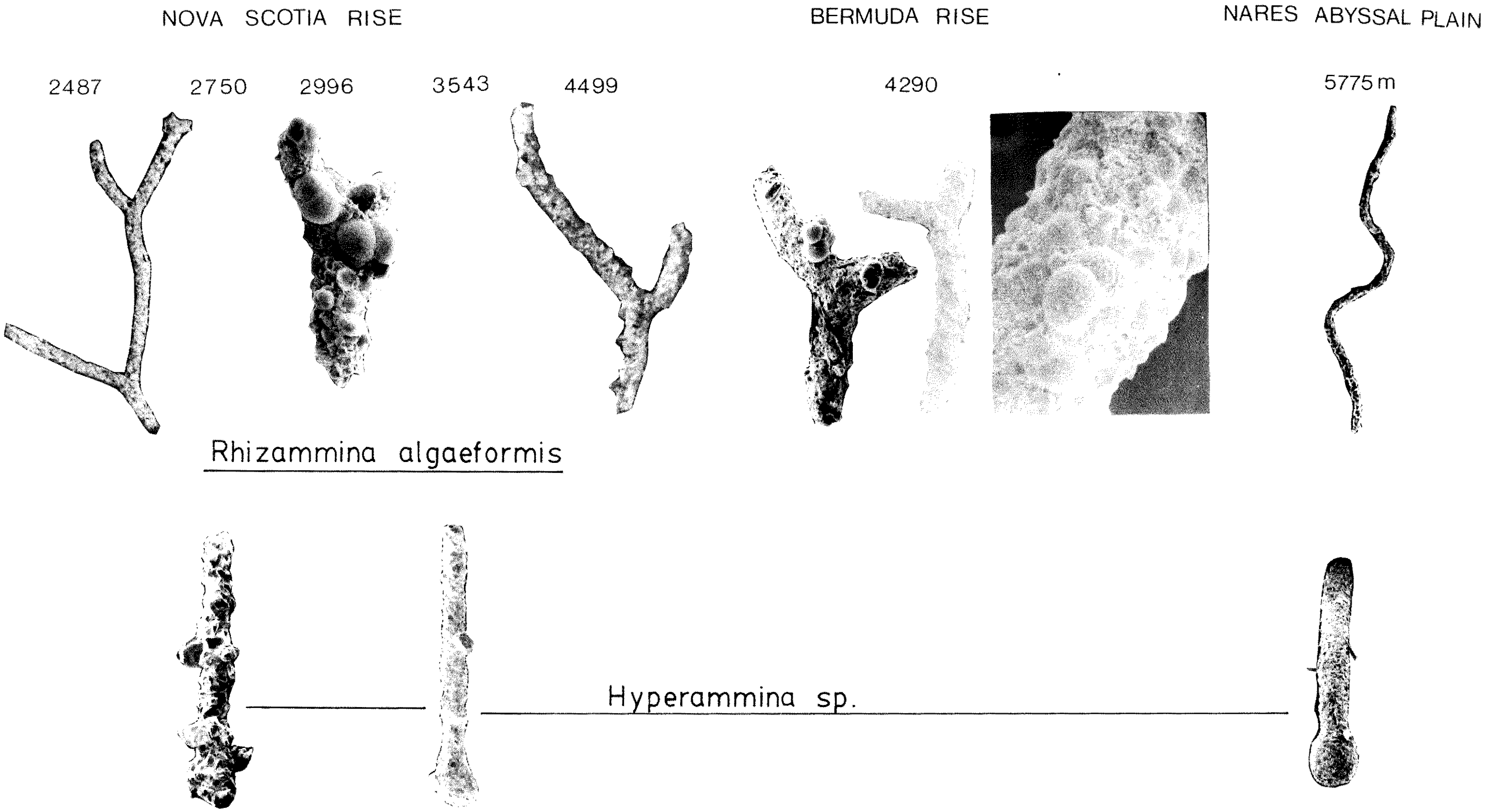
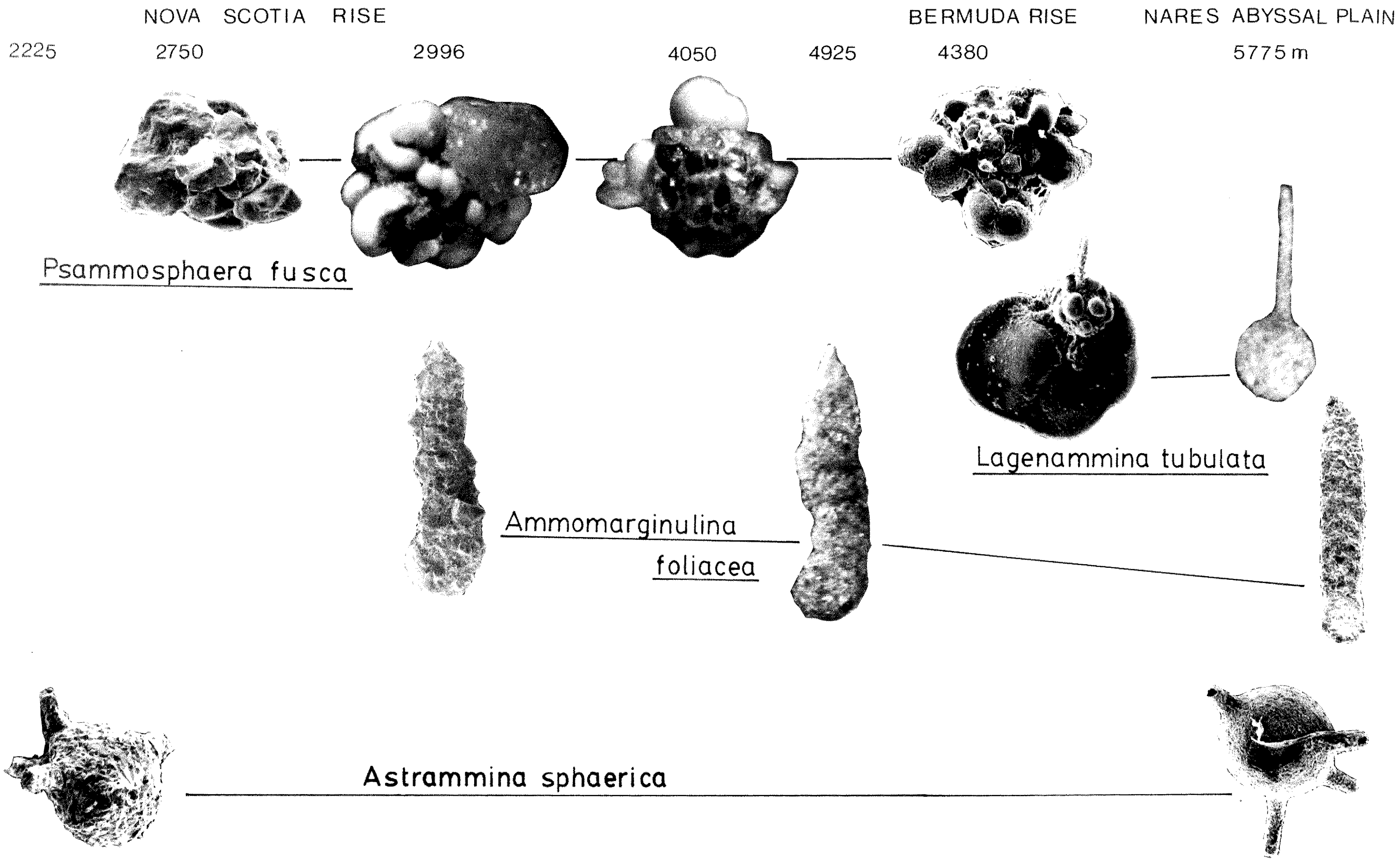

NOVA SCOTIA RISE
BERMUDA RISE
NARES ABYSSAL PLAIN
2487
2750
2996
3543
4499
4290
5775 m
Rhizammina algaeformis
Hyperammina sp.

Plate 26

The species Psammospharea fusca and Lagenammina tubulata are examples of species without a preference in the selection of wall material. They are cabable of agglutinating either mineral grains or foraminiferal tests.

The species Ammomarginulina foliacea and Astrammina sphaerica do not show any preference in the size of agglutinated mineral grains. They agglutinate coarser grained material on the slope than in abyssal regions.


NOVA SCOTIA RISE
BERMUDA RISE
NARES ABYSSAL PLAIN
2225
2750
2996
4050
4925
4380
5775 m
Psammosphaera fusca
Lagenammina tubulata
Ammomarginulina foliacea
Astrammina sphaerica

Chapter 4: FAUNAL PATTERNS IN THE TOTAL FORAMINIFERAL POPULATION

4.1. GENERAL TRENDS

There is little information concerning trends in the distribution of deep-sea arenaceous foraminifera and the factors that control such trends so it appears reasonable to evaluate the samples with respect to their bathymetric orientation. In the following chapters all three study areas are treated together to faciliate comparison of their different environments. In each figure the locations are arranged within each region according to increasing depth.

The quantitative analysis of this project is based on the arenaceous and calcareous foraminiferal fauna, with each group being discussed separately. Percentage occurrences of all identified species are listed in Table 2 and 3 (in back-cover pocket). General benthonic faunal trends and the proportion between the arenaceous and calcareous component are documented in Fig.12. In physically undisturbed environments the Foraminiferal Number decreases with increasing water depth as on the continental margin off NW Africa (Lutze, 1980) and in the Peru-Chile Trench area (Bandy and Rodolfo, 1964). On the Nova Scotia Rise the highest numbers correspond to the zone influenced by the WBUC (2750m - 4050m). The Foraminiferal Number increases from 500 per 10cc in the low energy sedimentary environment of the upper rise to over 3000 on the middle rise at 2750m depth where increased bottom current velocities occur. Erosion of the substrate takes place which probably exposed mid-Holocene sediments on the surface, thus artificially enriching the total fossil assemblage (Carter and Schafer, 1983). This increase is the result of a concentration of empty tests of benthonic and planktonic foraminifera through winnowing processes. The benthonic fauna consists of an "_in situ_" fauna of species resistant to the changing substrate and a relic coarse grained faunal component, that was transported and reworked by the contour current.

The low number of benthonic specimens on the Nares Abyssal Plain does not reflect a true nature of the actual population of this region. One major faunal component of the deepest oceanic realm is formed by species of the family KOMOKIACEA. The developement of their delicate network of tubular arms seems to be supported by the fragile microhabitat of abyssal plains. This component was qualitatively but not quantitatively evaluated in the present study, and is therefore not represented in any calculations.

The significant increase in the concentration of arenaceous foraminifera tests and the increase in fragmented and corroded tests of planktonic foraminifera (Fig. 4) at 4499m on the Nova Scotia Rise indicates the position of the lysocline. The almost entirely arenaceous assemblage in the deepest sample of the Nova Scotia transect at 4925m and on the Nares Abyssal Plain indicates that the area is beneath the calcium compensation depth (CCD).

The lower percentage of arenaceous foraminifera on the Southern Bermuda Rise is caused by a large flux of calcareous shallow-water forms to this environment by turbidity currents. The large supply of calcareous biogenic components may actually depress the depth of the lysocline (Berger, 1976).

4.2. DIVERSITY

Species diversity is a parameter of great interest for biologists. Geologists study recent foraminifera to provide useful information for interpreting fossil assemblages and environments. However, the diversity within a faunal group is controlled by many geological processes during its existence as a living entity as well as during and after fossilization. As soon as post-mortem processes take effect, the original association is difficult to reconstruct. Therefore these indices have to be interpreted with care.

In this study the diversity is expressed by the number of species observed per sample and by the Shannon-Wiener Index (Fig. 13). The equitability indicates how equally species are distributed in a sample. A comparison of the three graphs (Fig. 13) shows a close correlation between all three parameters.

Evidence of a connection between diversity trends within a foraminiferal assemblage and sedimentary processes can be observed along the Continental Rise off Nova Scotia. Highest species diversity ($H=4.2$ and $S=80$) relates to the zone under the influence of increased current velocity between 2750m and 2996m depth. The large number of species in the total population does not correspond to a diverse, living, "in-situ" fauna (Fig. 17), discussed in the following chapter. The effect of increased current speeds on the substrate leads to the accumulation of a death assemblage with a high Foraminiferal Number and species diversity. The number of arenaceous species (Fig. 12, lower graph) also shows an increase that appears to be related to a number of species with robust tests which seem to be resistant to current movement. The same phenomenon occurs at 4815m on the HEBBLE Site, from where strong bottom currents are reported (Tucholke et al., 1985). The significant decrease in species diversity from the HEBBLE Site at 4815m to the deepest sample at 4925m of the sampled transect (see location map, Fig. 1) might indicate that the current regime, investigated in the HEBBLE study, is not directly transferable to the entire Nova Scotia Lower Rise. The decreased number of arenaceous species in 5664m and 5670m depth on the Nares Abyssal Plain is probably caused by examining dried samples in which fragile species may have disintegrated.

A strong dominance of few species prevails, especially on the upper continental rise off Nova Scotia and, to a lesser extent, in abyssal depths (Fig. 13, lower graph). The equitability ranges between 0.2 and 0.4. These regions form an environment where faunal mixing by current reworking processes is less. On the Southern Bermuda Rise the number of species reaches 60 and H varies between 3.0 and 3.5. These high values originate partly as a result of displaced calcareous shallow-water species.

Gibson and Buzas (1969) had already observed that in the Western North Atlantic species diversity generally increases with depth. Values of $H < 2.0$ in 2000m and maximum values of $H = 3.5$ at 4977m were reported. The low values on the slope were explained by environmental instability through downslope transportation of sediment. The increase in diversity in the deep-sea is interpreted by various hypotheses (Sanders, 1968; Dayton & Hessler, 1972; Valentine, 1973; Jumars, 1976). They regard the deep-sea realm as a stable environment which allows a high degree of specialization and the development of microhabitats.

The results show how diversity in the study area, based on the total faunal assemblage, is regulated by fluctuations of various physical factors such as turbity currents, winnowing processes by bottom currents, and sedimentation rate. After burial selective preservation becomes a factor and may reduce species diversity significantly.

4.3. DEPTH ZONATION

4.3.1. Calcareous species

Among the 170 calcareous species identified in the study material, only a few exceed an abundance of 3%. Hence the following discussion only dwells on the common taxa. Percentage occurrences, expressed as the mean of 5 subsamples per box-core, are illustrated in Fig. 14. It should be mentioned that a single depth transect does not form a sufficient base to evaluate the large scale spatial dimensions of faunal assemblages. However, the following associations can be distinguished on the Continental Rise off Nova Scotia:

Upper Continental Rise Assemblage (2200 - 2500m)

The upper rise is represented by two samples, one at 2225m on the southern part and the other at 2487m on the main transect. The calcareous fauna is dominated by *Elphidium excavatum f. clavatum* with *Uvigerina peregrina* and *Stainforthia concava* as subdominant species. Numerous rare species complete the assemblage. *E. excavatum f. clavatum* is reported by Williamson (1983) and Williamson et al. (1984) as an important slope species off Nova Scotia to a depth of 2000m. This species, together with *U. peregrina*, diminishes at the transition to the middle rise, whereas *S. concava* is found down to 3000m.

Middle Continental Rise Assemblage (2500 - 3600m)

The calcareous foraminiferal fauna on the middle rise is comprised of several common species, without distinct dominances. *Eponides pusillus* is the most abundant species with an occurrence of 10 % at 3000m. This small species occurs mainly in the size fraction 63-125um (see Fig. 6) and is therefore not reported in studies based on larger size fractions (Streeter, 1973; Schnitker, 1974,1979). *Hoeglundina elegans* is found down to the upper rise and disappears below 3540m. *Oridorsalis umbonatus*, a species with a wide depth range, shows an increase on the middle rise. Complementing species are *Cibicidoides kullenbergi*, *Eponides regularis*, *Eponides tumidulus*, *Melonis pompilioides*, *Triloculina oblonga*, and *Quinqueloculina sp.*. The genus *Pullenia* is represented by several species, which are difficult to distinguish.

Lower Continental Rise Assemblage (4000 - 4815m)

The calcareous foraminiferal assemblage on the lower rise is clearly dominated by *Epistominella umbonifera*, reaching a maximum abundance of 30 % at 4185m. *Epistominella exigua* shows an increased abundance in this zone, but is rarely distributed over the entire depth range. *Cibicidoides wuellerstorfi* has no distinct bathymetric distribution, showing only a slight increase at 4185m depth. The calcareous component decreases significantly at 4925m, indicating the overlying position of the lysocline.

The Southern Bermuda Rise

The total calcareous foraminifera population varies significantly between the Nova Scotia Rise and the Bermuda Rise. The typical species of the Lower Rise off Nova Scotia also occur on the Southern Bermuda Rise. However, their percentage occurrence is artificially decreased on the Bermuda Rise by the input of shallow-water species through downslope transportation. *Bolivina tortuosa* and *Discorbis bertheloti* are two species described by Phleger et al. (1953) as typical in shallow-water which are in deeper water associated with displaced faunal assemblages. *Bolivina paula* is originally described from the Miocene, but probably extends to the Recent (Phleger et al., 1953).

The important effect of turbidity currents in this area was noticed in two additional box-cores (numbers 83-077-35 and 83-077-38), closely located to the described samples which are included in the illustrations. The results are not listed here because the sediment surface was not preserved. Nevertheless, one subsample of each box-core was studied, and yielded an almost entirely calcareous assemblage in each case mainly composed of shallow-water species (see Table 3 and 4 in the back-cover pocket).

The Nares Abyssal Plain

The total percentage of calcareous specimens on the Nares Abyssal Plain varies from 0 to 2 %. The few calcareous tests may have been transported and deposited recently by bottom currents. This scarce calcareous component reflects deposition well below the CCD.

4.3.2. Arenaceous species

As I have shown before, an important observation is that morphologic changes in size and wall texture of arenaceous species reflect changes in sedimentary environments that can be related to depth. Before discussing the potential causes of these effects, the bathymetric distribution of key arenaceous taxa will be considered.

In the illustrations, the species are classified according to the 10 families as treated in the taxonomic chapter. General trends within each study area such as number of genera and number of species per family are shown in histograms (Fig. 15). The Nova Scotia Rise includes a large depth range compared with the other two regions and therefore typifies a number of different environments, each with a unique species distribution.

ASTRORHIZIDAE and LITUOLIDAE are represented with the largest number of genera in all three areas. On a specific level HORMOSINIDAE are important, represented mainly by 14 species of *Reophax*. ATAXOPHRAGMIIDAE are best represented on the Nova Scotia Rise with 8 taxa. The highest number of genera and species of ALLOGROMIIDAE occurs on the Bermuda Rise. TEXTULARIIDAE form a minor component in all three areas studied. The occurrence of the MILIOLIDAE is based on the arenaceous taxa *Sigmoilopsis schlumbergeri*.

The percentage occurrences of 88 arenaceous species are illustrated in Figs. 16a-c. Bathymetric trends of common species will be emphasized and a division into isobathyal and heterobathyal species follows with special reference to depth ranges established in the literature (chapter 7).

ALLOGROMIIDAE include species with a pseudochitineous test, which often live attached to foraminiferal tests. *Nodellum membranaceum* has a free test and has an abundance of up to 10% on the Nares Abyssal Plain, providing a typical deep-water indicator.

Species of ASTRORHIZIDAE reach a maximum of 15% on the Nova Scotia Rise. *Rhizammina algaeformis* is an exception and occurs over the entire depth range. Two varieties can be distinguished, differing in the diameter of their tubular branches. Fragmented species are indicated and overcounting has to be considered. *Hyperammina* and *Rhabdammina* are dominant on the Nova Scotia Rise, ranging from 2487m to 4185m. *Hyperammina sp. 2* is a fine grained morphotype that occurs at abyssal depths. The common occurrence of *Saccorhiza ramosa* is restricted to the deepest zone (below 4400m).

No species of SACCAMMINIDAE occur with a frequency of more than 1.5%. Thurammina papillata reaches percentages of 2% and prefers regions below 4400 m.

The dominant species of AMMODISCIDAE are Ammodiscus incertus (mainly on the Nares Abyssal Plain) and Ammolagena clavata. This latter species lives attached to planktonic foraminiferal tests, which are particularly abundant on the Southern Bermuda Rise and under the the core of the WBUC (2750m). The increase of A. clavata in both regions may reflect these prefered conditions.

HORMOSINIDAE forms an important family in all three areas. Aschemonella scabra shows increased populations on the Nova Scotia Rise from 4500m to 4800m and on the Southern Bermuda Rise. Species of Reophax such as R. bilocularis, R. dentaliniformis, R. distans, R. guttifer, and R. scorpiurus show no preference for a certain depth range; others are more restricted, like R. bacillaris (2750-4185m), R. fusiformis (2487-4050m), R. helenae (4180-5779m), R. horrida (4180-5779m), and R. ovicula (4185-5779m).

The most dominant species of the LITUOLIDAE is Adercotryma glomerata with a wide depth range and an increased abundance at abyssal depths below 4800m. Ammobaculites is represented by two varieties, one typical for the Middle Nova Scotia Rise and one for the Nares Abyssal Plain. Ammomarginulina foliacea occurs from the upper rise to the abyssal plain. A. foliacea f. recurva represents a variety in the deepest region. Echols (1971) reports a replacement of A. foliacea at about 2350 m by A. foliacea f. recurva in the Scotia Sea, whereas on the Nares Abyssal Plain both varieties coexist. *Cribrostomoides subglobosus* reaches a maximum occurrence of 5% on the middle continental rise. *Cyclammina trullissata* and *Haplophragmoides sphaeriloculus* seem to prefer abyssal regions.

TROCHAMMINIDAE are mainly represented on the middle and lower rise, except *Cystammina galeata*, indicative of water depth below 4000m.

Eggerella bradyi is the most common species of ATAXOPHRAGMIIDAE. This species has a calcareous cement and in the Antarctic Ocean is associated only with calcareous assemblages (Echols, 1971). Another morphotype of this species with a ferrugineous cement was found on the Nares Abyssal Plain.

Sigmoilopsis schlumbergeri, the only representative species of MILIOLIDAE, has a lower depth limit of 3000m.

Arenaceous assemblages of the slope and upper rise environments (300m - 3000m) off Newfoundland are studied by Schafer and Cole (1983). The foraminiferal associations are mainly based on generic level. The depth zone which overlaps with this study (2220m - 3000m) is characterized off Northeast Newfoundland by the dominance of *Trochammina*, *Reophax*, *Rhabdammina*, *Rhizammina*, *Saccorhiza*, and *Saccammina*. The occurrence of these genera confirms results of this study with the exception of *Saccorhiza* which I have only found below 3500m.

Fig. 12: Number of benthonic foraminiferal specimens per 10cc wet sediment, percentage of total arenaceous foraminifera, and the percentage of arenaceous species. Values indicate the mean of 5 subsamples for each box-core.

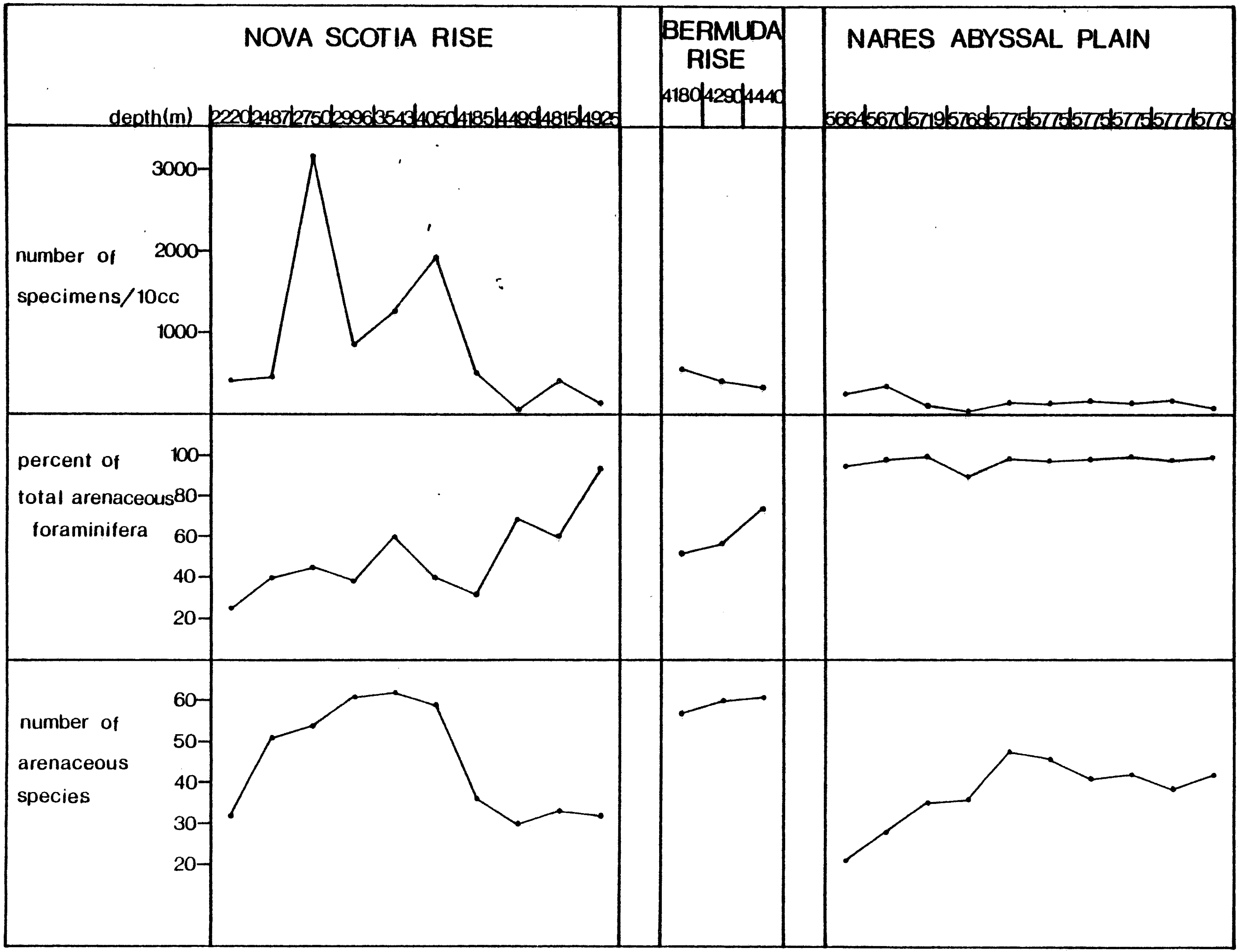

NOVA SCOTIA RISE
BERMUDA RISE
NARES ABYSSAL PLAIN
depth(m)
2220
2487
2750
2996
3543
4050
4185
4499
4815
4925
4180
4290
4440
5664
5670
5719
5768
5775
5775
5775
5775
5777
5779
number of specimens/10cc
3000
2000
1000
percent of total arenaceous foraminifera
100
80
60
40
20
number of arenaceous species
60
50
40
30
20

Fig. 13: Change of diversity indices with depth.

S: number of species observed

H: Shannon-Wiener Index with standard deviation of 5 subsamples per box-core

E: Equitability

⊙ indicates measurements derived from 1 available subsample per box-core.

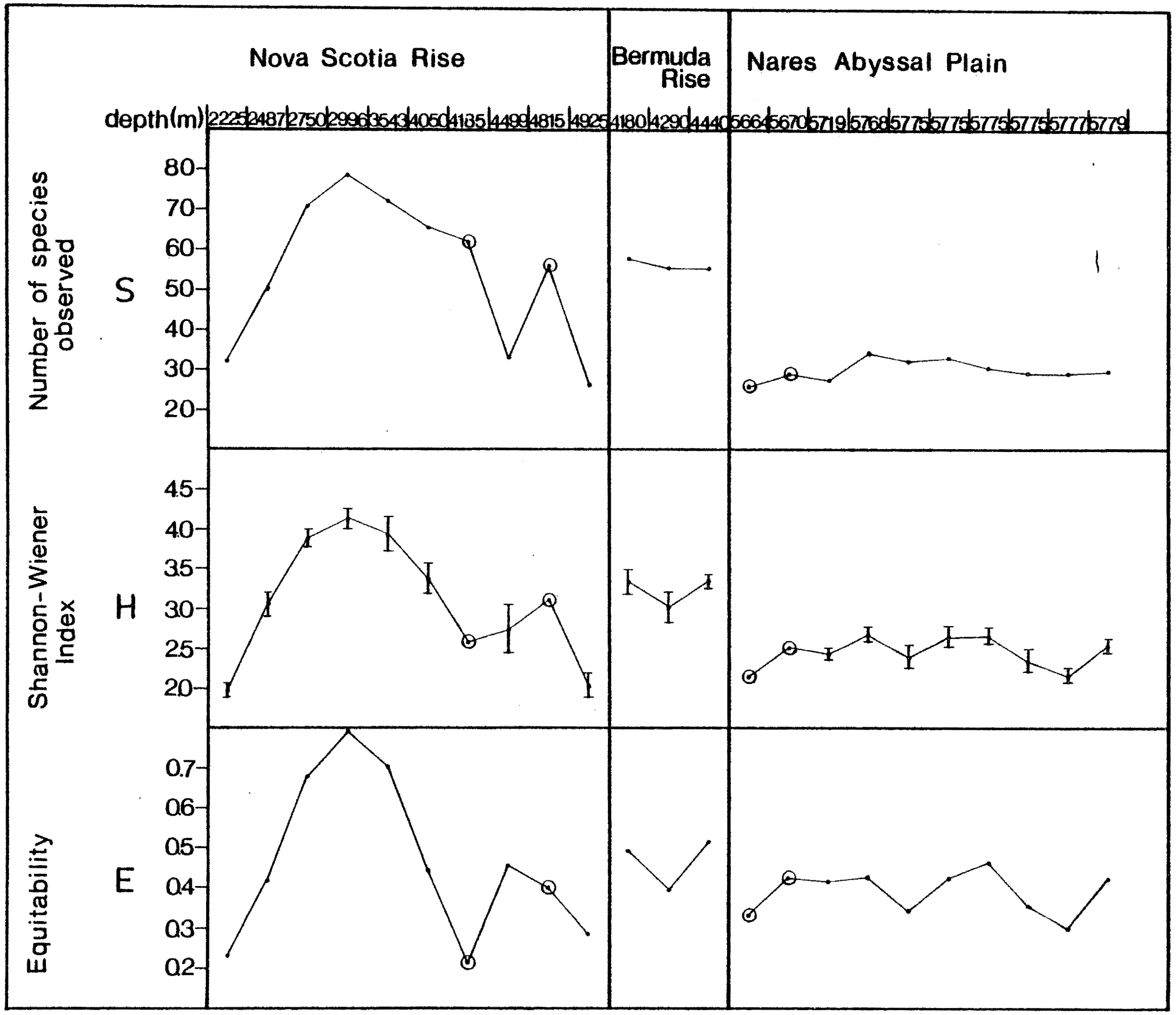

Nova Scotia Rise
Bermuda Rise
Nares Abyssal Plain
depth(m)
2225
2487
2750
2996
3543
4050
4135
4499
4815
4925
4180
4290
4440
5664
5670
5719
5768
5775
5775
5775
5775
5777
5779
Number of species observed
S
80
70
60
50
40
30
20
Shannon-Wiener Index
H
4.5
4.0
3.5
3.0
2.5
2.0
Equitability
E
0.7
0.6
0.5
0.4
0.3
0.2

Fig. 14: Depth distribution of selected calcareous foraminiferal species on the Continental Rise off Nova Scotia, the Southern Bermuda Rise and Nares Abyssal Plain.

Percentages refer to the mean of 5 subsamples per box-core, if available.

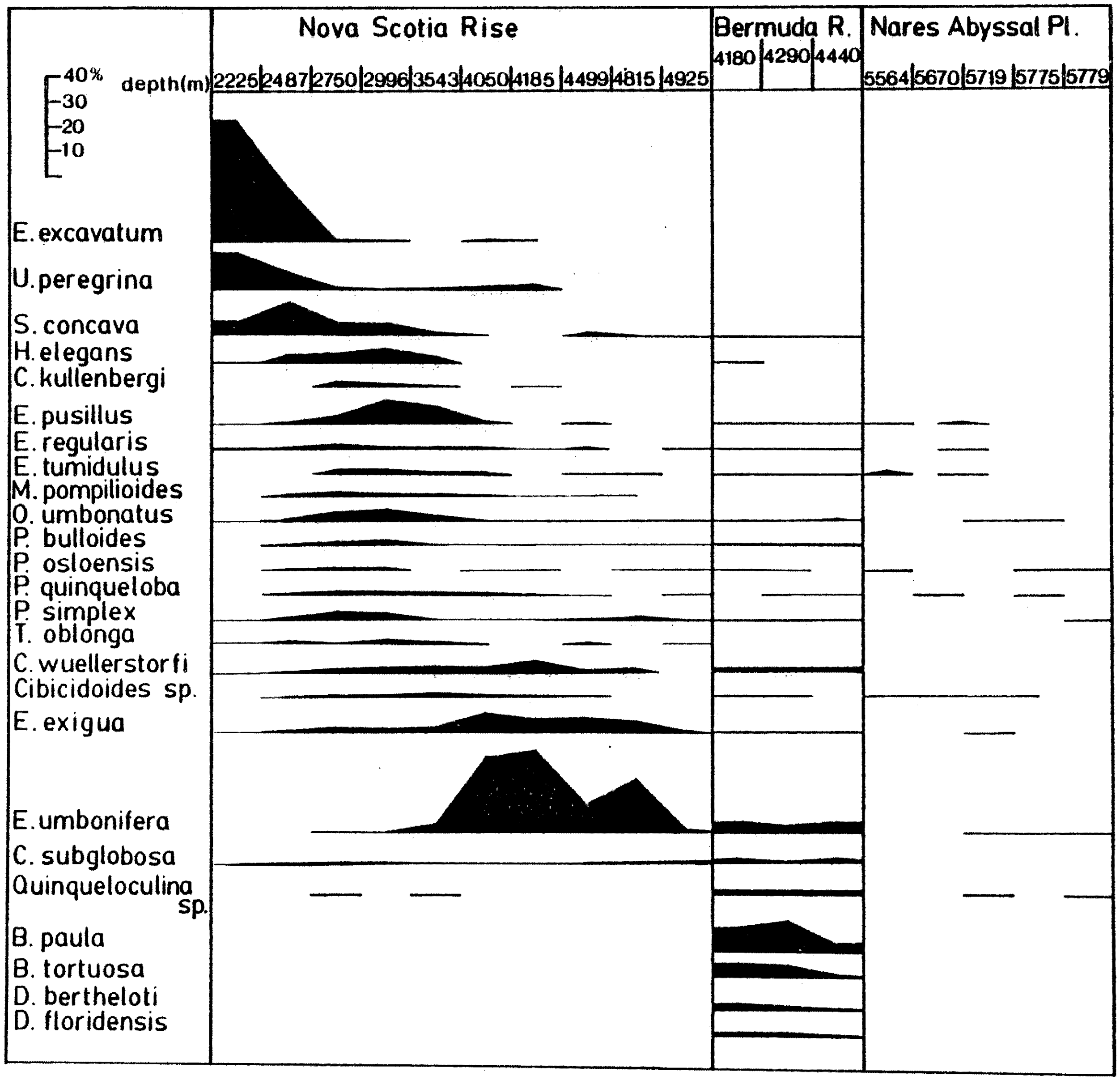
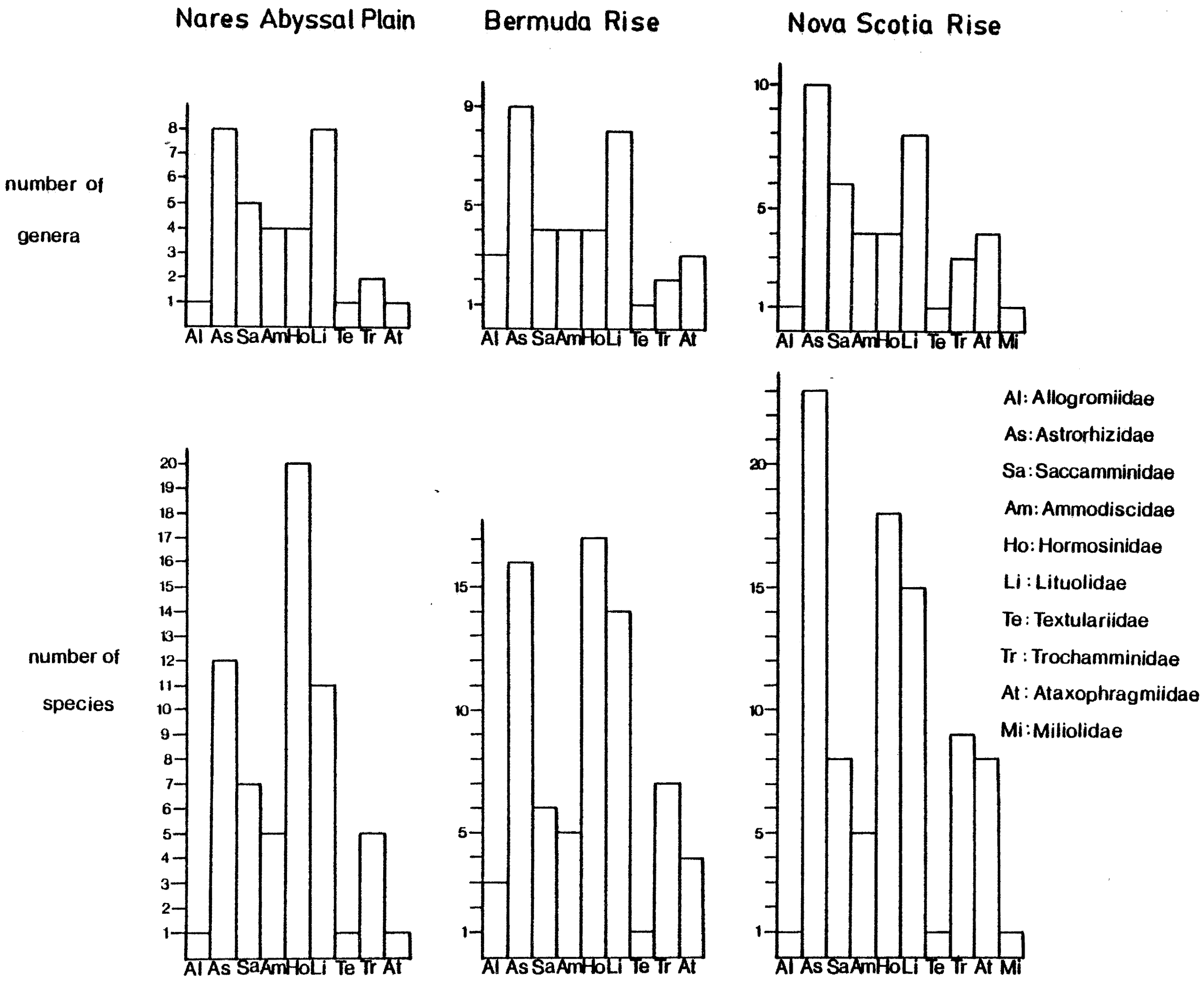

Nova Scotia Rise
Bermuda R.
Nares Abyssal Pl.
40%
30
20
10
depth(m)
2225
2487
2750
2996
3543
4050
4185
4499
4815
4925
4180
4290
4440
5564
5670
5719
5775
5779
E. excavatum
U. peregrina
S. concava
H. elegans
C. kullenbergi
E. pusillus
E. regularis
E. tumidulus
M. pompilioides
O. umbonatus
P. bulloides
P. osloensis
P. quinqueloba
P. simplex
T. oblonga
C. wuellerstorfi
Cibicidoides sp.
E. exigua
E. umbonifera
C. subglobosa
Quinqueloculina sp.
B. paula
B. tortuosa
D. bertheloti
D. floridensis

Fig. 15: Histograms show a regional comparison of the number of genera and the number of species in each arenaceous foraminiferal family.



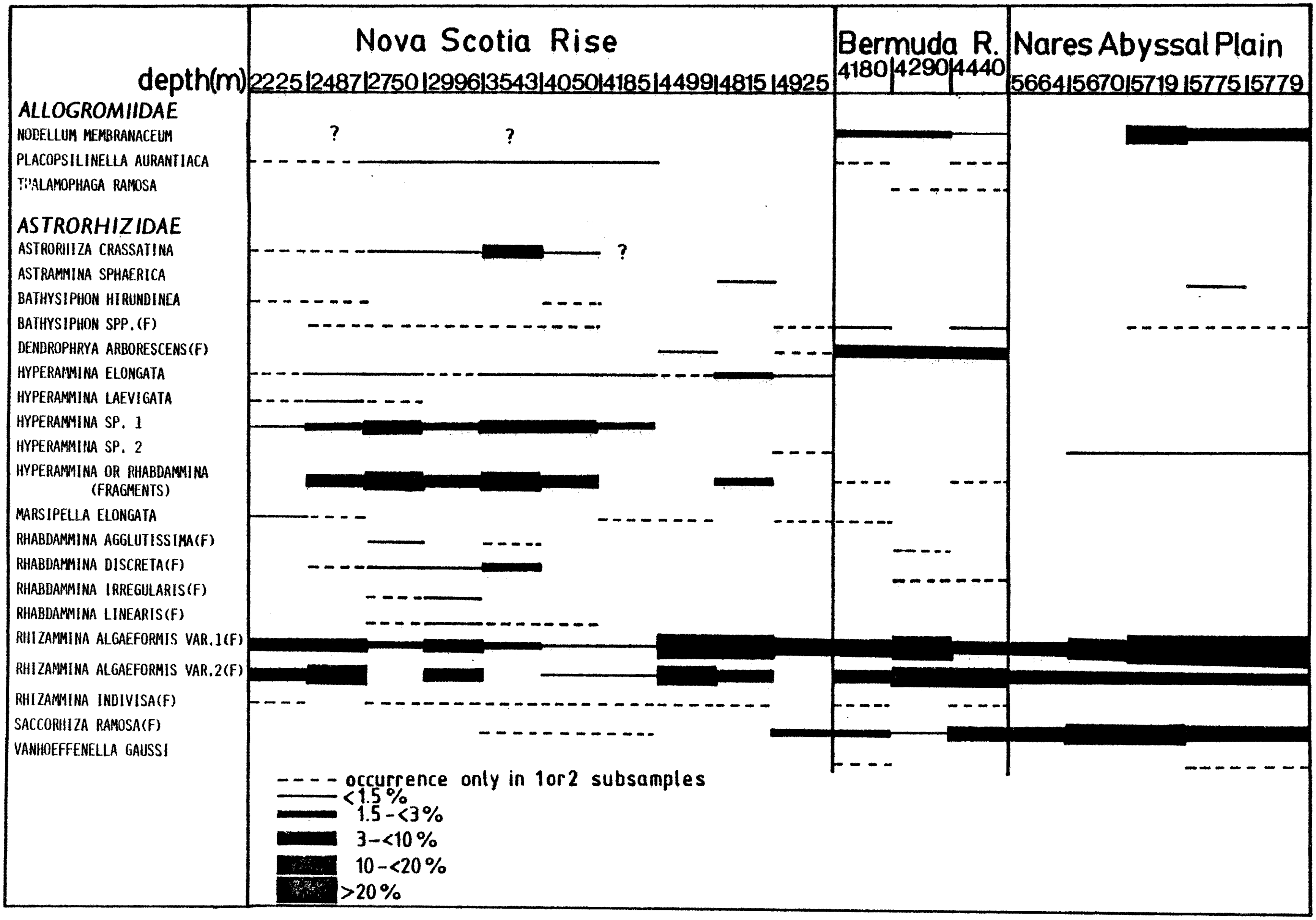
Nares Abyssal Plain
Bermuda Rise
Nova Scotia Rise
number of genera
number of species
Al As Sa Am Ho Li Te Tr At
Al As Sa Am Ho Li Te Tr At Mi
Al: Allogromiidae
As: Astrorhizidae
Sa: Saccamminidae
Am: Ammodiscidae
Ho: Hormosinidae
Li: Lituolidae
Te: Textulariidae
Tr: Trochamminidae
At: Ataxophragmiidae
Mi: Miliolidae

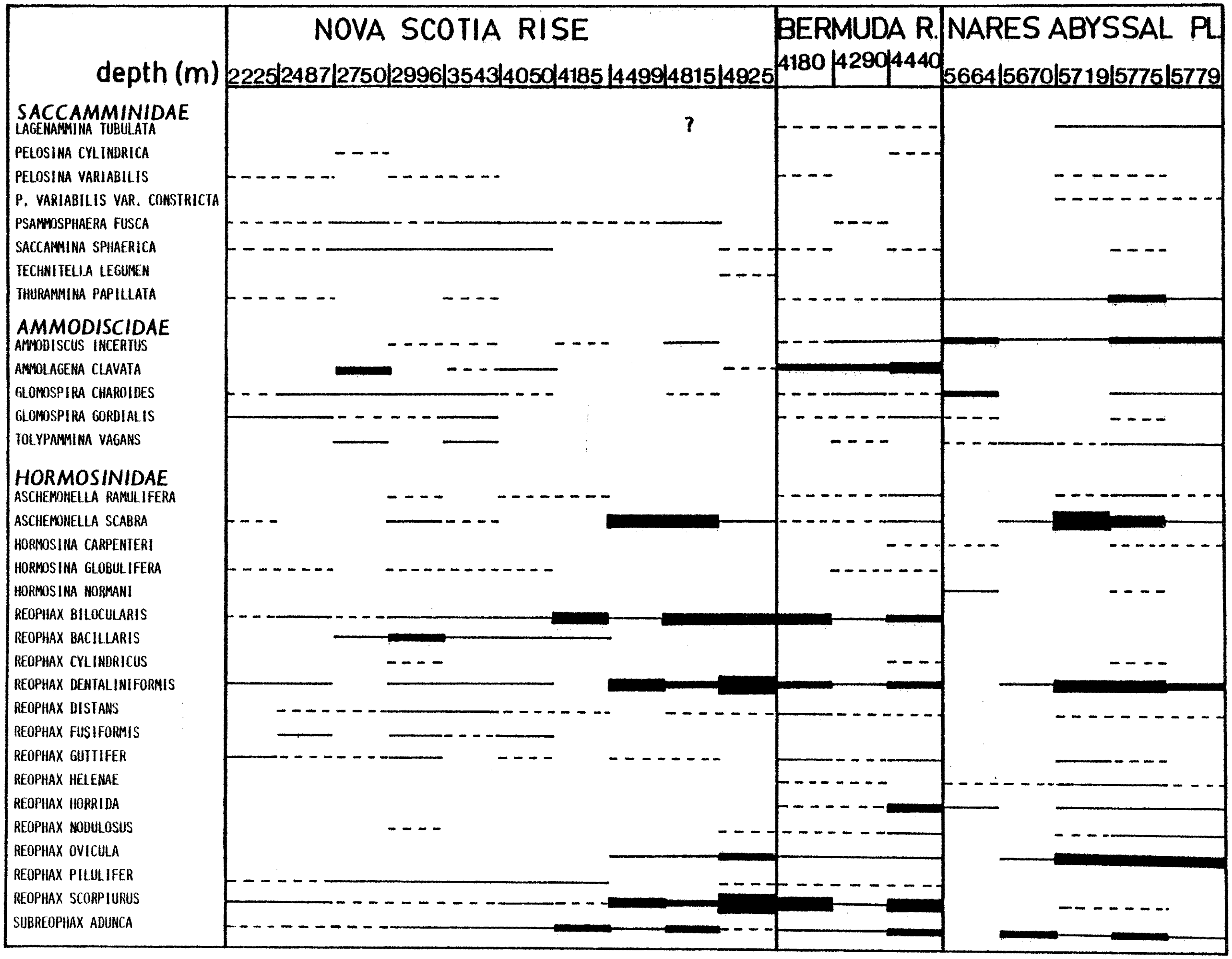
Fig. 16a-c: Depth distribution of arenaceous foraminifera in the three investigated deep-sea regions of the NW Atlantic. Percentages refer to the mean of 5 subsamples per box-core.

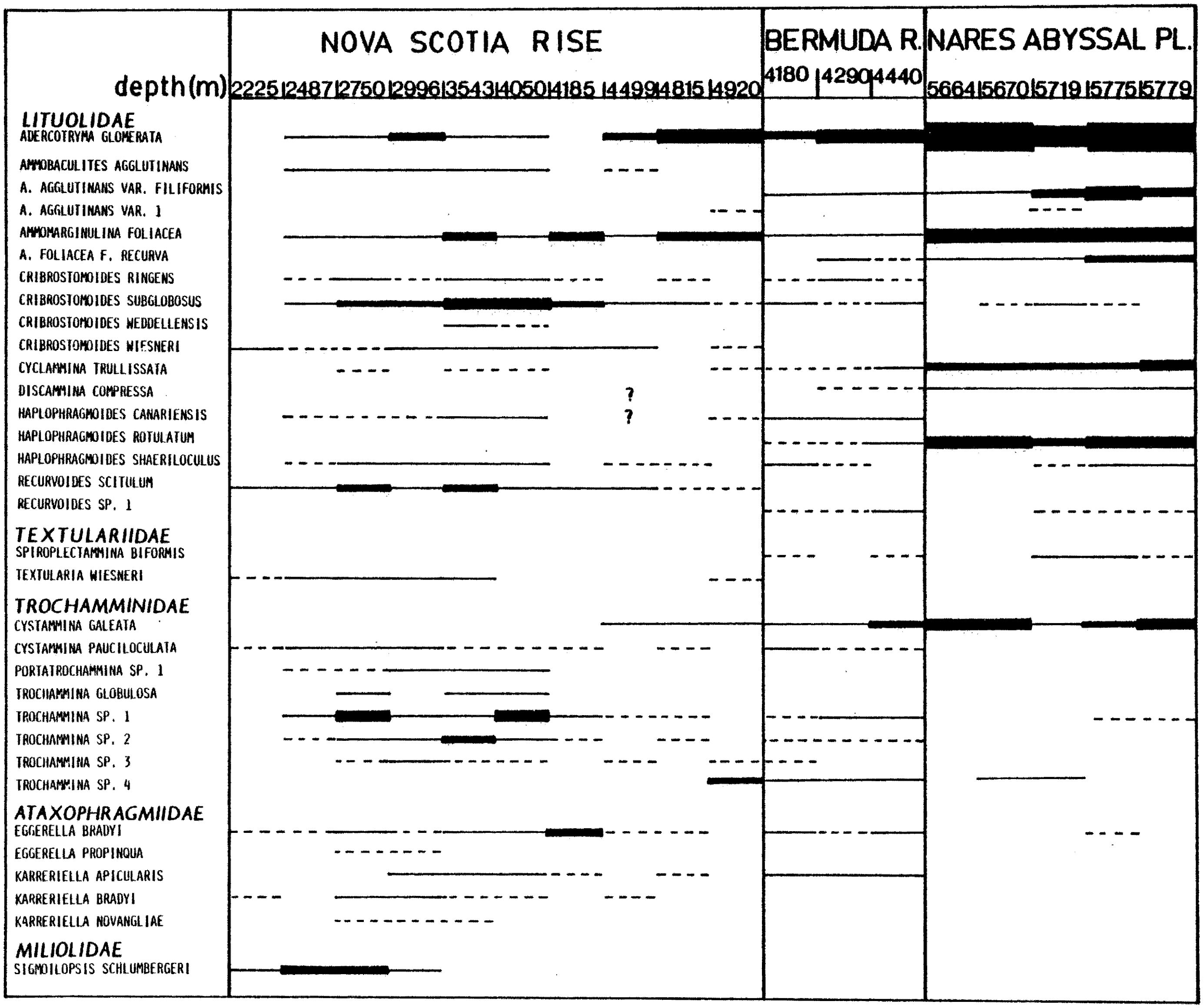
a. ALLOGROMIIDAE and ASTRORHIZIDAE

b. SACCAMMINIDAE, AMMODICIDAE and HORMOSINIDAE

c. LITUOLIDAE, TEXTULARIIDAE, TROCHAMMINIDAE, ATAXOPHRAGMIIDAE and MILIOLIDAE


Nova Scotia Rise
Bermuda R.
Nares Abyssal Plain
depth(m)
2225
2487
2750
2996
3543
4050
4185
4499
4815
4925
4180
4290
4440
5664
5670
5719
5775
5779
ALLOGROMIIDAE
NODELLUM MEMBRANACEUM
PLACOPSILINELLA AURANTIACA
THALAMOPHAGA RAMOSA
ASTRORHIZIDAE
ASTRORHIZA CRASSATINA
ASTRAMMINA SPHAERICA
BATHYSIPHON HIRUNDINEA
BATHYSIPHON SPP.(F)
DENDROPHRYA ARBORESCENS(F)
HYPERAMMINA ELONGATA
HYPERAMMINA LAEVIGATA
HYPERAMMINA SP. 1
HYPERAMMINA SP. 2
HYPERAMMINA OR RHABDAMMINA (FRAGMENTS)
MARSIPELLA ELONGATA
RHABDAMMINA AGGLUTISSIMA(F)
RHABDAMMINA DISCRETA(F)
RHABDAMMINA IRREGULARIS(F)
RHABDAMMINA LINEARIS(F)
RHIZAMMINA ALGAEFORMIS VAR.1(F)
RHIZAMMINA ALGAEFORMIS VAR.2(F)
RHIZAMMINA INDIVISA(F)
SACCORHIZA RAMOSA(F)
VANHOEFFENELLA GAUSSI
?
?
?
occurrence only in 1or2 subsamples
<1.5 %
1.5-<3%
3-<10%
10-<20%
>20%


NOVA SCOTIA RISE
BERMUDA R.
NARES ABYSSAL PL.
depth (m)
2225
2487
2750
2996
3543
4050
4185
4499
4815
4925
4180
4290
4440
5664
5670
5719
5775
5779
SACCAMMINIDAE
LAGENAMMINA TUBULATA
?
PELOSINA CYLINDRICA
PELOSINA VARIABILIS
P. VARIABILIS VAR. CONSTRICTA
PSAMMOSPHAERA FUSCA
SACCAMMINA SPHAERICA
TECHNITELLA LEGUMEN
THURAMMINA PAPILLATA
AMMODISCIDAE
AMMODISCUS INCERTUS
AMMOLAGENA CLAVATA
GLOMOSPIRA CHAROIDES
GLOMOSPIRA GORDIALIS
TOLYPAMMINA VAGANS
HORMOSINIDAE
ASCHEMONELLA RAMULIFERA
ASCHEMONELLA SCABRA
HORMOSINA CARPENTERI
HORMOSINA GLOBULIFERA
HORMOSINA NORMANI
REOPHAX BILOCULARIS
REOPHAX BACILLARIS
REOPHAX CYLINDRICUS
REOPHAX DENTALINIFORMIS
REOPHAX DISTANS
REOPHAX FUSIFORMIS
REOPHAX GUTTIFER
REOPHAX HELENAE
REOPHAX HORRIDA
REOPHAX NODULOSUS
REOPHAX OVICULA
REOPHAX PILULIFER
REOPHAX SCORPIURUS
SUBREOPHAX ADUNCA


NOVA SCOTIA RISE
BERMUDA R.
NARES ABYSSAL PL.
depth(m)
2225
2487
2750
2996
3543
4050
4185
4499
4815
4920
4180
4290
4440
5664
5670
5719
5775
5779
LITUOLIDAE
ADERCOTRYMA GLOMERATA
AMMOBACULITES AGGLUTINANS
A. AGGLUTINANS VAR. FILIFORMIS
A. AGGLUTINANS VAR. 1
AMMOMARGINULINA FOLIACEA
A. FOLIACEA F. RECURVA
CRIBROSTOMOIDES RINGENS
CRIBROSTOMOIDES SUBGLOBOSUS
CRIBROSTOMOIDES WEDDELLENSIS
CRIBROSTOMOIDES WIESNERI
CYCLAMMINA TRULLISSATA
DISCAMMINA COMPRESSA
HAPLOPHRAGMOIDES CANARIENSIS
HAPLOPHRAGMOIDES ROTULATUM
HAPLOPHRAGMOIDES SHAERILOCULUS
RECURVOIDES SCITULUM
RECURVOIDES SP. 1
?
?
TEXTULARIIDAE
SPIROPLECTAMMINA BIFORMIS
TEXTULARIA WIESNERI
TROCHAMMINIDAE
CYSTAMMINA GALEATA
CYSTAMMINA PAUCILOCULATA
PORTATROCHAMMINA SP. 1
TROCHAMMINA GLOBULOSA
TROCHAMMINA SP. 1
TROCHAMMINA SP. 2
TROCHAMMINA SP. 3
TROCHAMMINA SP. 4
ATAXOPHRAGMIIDAE
EGGERELLA BRADYI
EGGERELLA PROPINQUA
KARRERIELLA APICULARIS
KARRERIELLA BRADYI
KARRERIELLA NOVANGLIAE
MILIOLIDAE
SIGMOILOPSIS SCHLUMBERGERI

Chapter 5: LIVING FORAMINIFERAL ASSEMBLAGE

5.1. STANDING CROP

In this material the proportion of the living fauna to the total assemblage is small. The number of live individuals per sample at several locations is below 50 specimens. This number is insufficient to calculate occurrences for each individual species as percentage of the living population. Two samples from the Nova Scotia Rise (at 4185m and 4815m) and two from the Nares Abyssal Plain (at 5664m and 5670m) were not stained with Rose Bengal and therefore not included in the illustrations. Problems with identification of stained protoplasm in thick arenaceous tests is considered in the following discussion. This condition makes comparison with other studies difficult.

The upper graph of Fig. 17 shows the standing crop as live individuals per 10 cc of wet sediment. On the Nova Scotia Rise the largest number (38 stained specimens) are found in the area under the influence of the WBUC with maximum current activity at 2750m. A similar situation was found on the Continental Slope and Rise off Newfoundland (Schafer & Cole, 1982), where this depth zone is indicated by a coarse substrate and a decreased influx of organic matter. It has been argued by those authors that lower organic carbon concentrations may be sufficient for the foraminiferal fauna, but may inhibit the colonization of macro-organisms and consequently creates a lack of predators. Tietjen (1971) also noticed a direct correlation between grain size or sediment type and organic content in regard to population densities of meiofauna observed on the slope of North Carolina. The living population drops significantly at 4500m to only 2 specimens per 10cc, corresponding to a decrease down to 53 specimens in the total population (Fig. 12). These reduced numbers may suggest the presence of an "deep-sea storm event" in this region as described by Hollister and McCave (1984) from the HEBBLE area further south between 4880m and 5000m. Un unfavorable environment for faunal assemblages may be the result of a rapid change between sediment deposition and erosion.

A large spatial heterogeneity within the living foraminiferal distribution is symbolized by the error bars, which are particularly high in the zone of the WBUC. Contradictory results were found by Schafer and Cole (1982) off Newfoundland, where the fine, bioturbated middle-slope substrate is reflected by more of a clumpbed distribution pattern than the occasionally mobilized upper-rise substrate.

The Southern Bermuda Rise area shows a low living population, in most samples less than 10 specimens per 10cc wet sediment.

Since the KOMOKIACEA form a large component of the abyssal community, not included in the quantitative analysis, the standing crop for the Nares Abyssal Plain is actually higher than illustrated. The small live component of 1 to 2 specimens per 10cc at 5768m depth is caused by the loss of sediment surface through shipboard sampling. The patchy distribution of living individuals is a less distinct phenomenon on the abyssal plain compared with the Nova Scotia Rise. The different degrees of patchiness on the relatively physically undisturbed abyssal plain can be explained by biological effects, which will be discussed in more detail in chapter 6.

Differing results regarding the density of living foraminifera are reported from other deep-sea areas and probably relate somewhat to productivity and sedimentation rate. Williamson (1983) found no living individuals on the slope off Nova Scotia, but this may be an artifact of the procedure he used. In the Norwegian Sea a significant decrease in the living population is observed towards 4000m depth (Mackensen et al, 1985) with values reaching a low of 2 specimens per $10cm^2$. On the Continental Rise of NW Africa the living fauna is diminished below 2000m decreasing to values of less than 25 individuals per 10cc wet sediment (Lutze, 1980).

5.2. COMPARISON OF LIVE AND DEAD BENTHONIC ASSEMBLAGES

The proportion between the live and dead or live and total foraminiferal assemblage is a result of factors such as dilution by terrigenous sediments, reworking processes or spatial heterogeneity. Walton (1955) used the ratio between the number of live specimens to number of dead specimens as an indicator for sedimentation rate. Uchio (1960) modified the method and used the live/total ratio. The total living fauna (i.e. living arenaceous plus calcareous specimens) and the arenaceous living fauna is plotted as percent of total specimens (Fig. 17, lower graph). Under the core of the WBUC standing stock reaches a maximum of 38 living specimens per 10cc, but the living component forms only of 1% of the total fauna. Concentration of dead foraminiferal tests through bottom current activity, reflected in the high number of total specimens (over 3000, Fig. 12), enhances a dilution of the living fauna. On the contrary the abyssal regions studied are least affected by erosion and reworking. The high proportion of the living population with a maximum of 13% at 5777m depth may give an unbiased picture of the ratio between the live and dead faunal assemblage, caused by natural mortality. We know that deep-sea species have a longer life span, and standing crop may reflect several years of production instead of yearly fluctuations in shallower waters. The space between the two lines (Fig. 17) represents the portion of the calcareous living population, that is more or less correlated with the percent of total calcareous foraminifera. It is interesting to note that the few live specimens on the Bermuda Rise were almost all arenaceous species. Here, the calcareous foraminiferal component consists of a large amount of displaced species.

In deep-sea regions a very low degree of resemblance exists between live and dead assemblages. This is illustrated in Fig. 18, which shows the number of living species, observed over the entire box-core surface (including 5 subsamples), plotted as percent of the total number of species per box-core. The depth zone under the influence of the contour current is characterized by a high diversity of 71 observed species, of which only 10% are recognized in the living fauna. The fact that 90% of the species in the total assemblage were not found in the live component has impact on the actual environmental interpretation of faunal assemblages. Thus the bathymetric distribution is based on the total fauna and slight shifts in the actual depth zones through reworking cannot be excluded. This phenomenon must be considered on the Continental Rise off Nova Scotia and on the Bermuda Rise.

Table 4 lists the species that were observed 5 or more times in the box-cores. The three calcareous faunal assemblages on the Nova Scotia Rise are not distinct in the living population. The upper rise assemblage is in the total population represented by *Elphidium excavatum f. clavatum*, *Uvigerina peregrina*, and *Stainforthia concava* and living specimens were only recognized of *E. excavatum f. clavatum* and *S. concava*. High numbers of living specimens of *E. excavatum f. clavatum* are reported from the middle slope off Newfoundland between 700 and 2000m (Schafer and Cole, 1982). On the Norwegian continental margin tests of *E. excavatum* are considered to have resulted from winnowing of glacial marine sediments (Mackensen et al, 1985). No stained specimen of *U. peregrina* was found in the studied material. *U. peregrina* is abundant on the slope off Nova Scotia between (800 - 2000m) (Williamson, 1983) and is correlative to a section of the continental slope southeast of Cape Cod that is characterized by a maxima of organic carbon and silt in the substrate between 1600 and 2500m (Miller & Lohmann, 1982). The occurrence of abundant corroded tests of *U. peregrina* and the lack of live specimens implies possible downslope transportation. The living arenaceous assemblage in this zone is represented by *Rhizammina algaeformis*, *Recurvoides scitulus* and *Adercotryma glomerata*.

Among the numerous species of the total assemblage of the middle continental rise (2500 - 3600m) only *Eponides pusillus* occurs with 5 to

10 specimens in the living population. It is therefore the only reliable indicator of the middle rise assemblage. In contrast on the Newfoundland Rise, Schafer and Cole (1982) identified *Cibicidoides lobatulus*, *Eponides tumidulus*, *Oridorsalis umbonatus*, and *Epistominella exigua* as common living species for this depth zone.

The living fauna of the lower continental rise contains no typical taxa. The indicator species of the dead assemblage of that environment such as *Epistominella umbonifera* and *E. exigua* occur only with 1 or 2 live individuals per 5 subsamples.

The highest number of living specimens (11) occurs at 4925m depth in an arenaceous assemblage in which *Reophax dentaliniformis*, *Reophax bilocularis*, *A. glomerata* and *R. algaeformis* are the dominant species. The few stained calcareous tests that were found at this location seem to be resistant to calcium dissolution.

The living population on the Bermuda Rise consists almost entirely of arenaceous species. *Reophax scorpiurus* and *Rhizammina algaeformis* occur with frequencies of more than 5 specimens per 5 subsamples.

The Nares Abyssal Plain assemblage shows the greatest uniformity between the live and dead population, a feature which corresponds closely to observations from the abyssal region off Nova Scotia. The living species form an average proportion of 30 to 40% of the total number of species. Indicator species such as *Rhizammina algaeformis*, *Adercotryma glomerata*, *Saccorhiza ramosa*, *Reophax helenae*, and *Reophax dentaliniformis* are represented in the living fauna by more than 5 or

10 specimens per 5 subsamples.

Fig. 17: Upper graph shows standing crop as living individuals per 10cc of wet sediment and the standard deviation of 5 subsamples within each box-core.

Lower graph shows the total living population (dotted line) and the arenaceous living population as percent of total specimens.

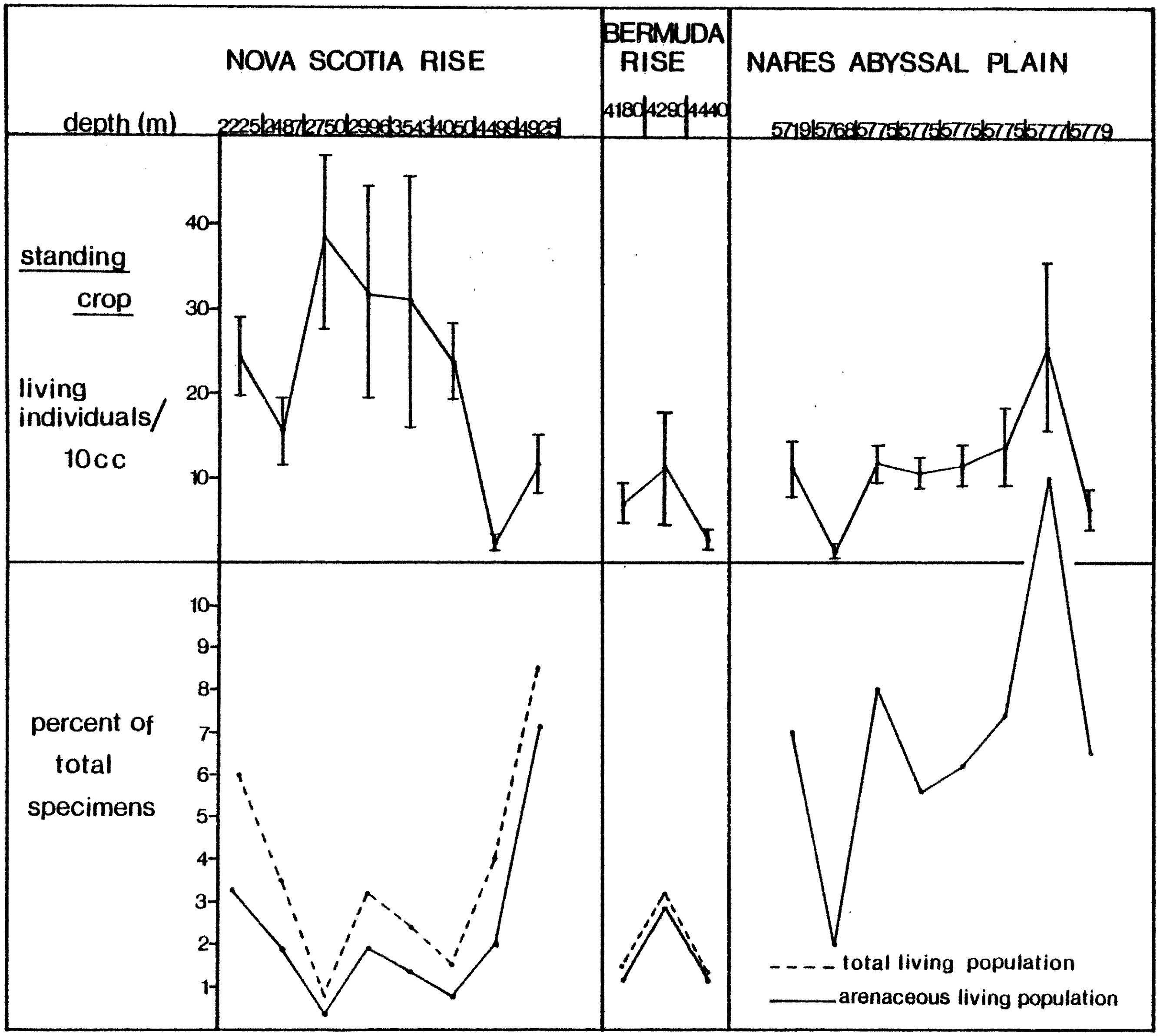

NOVA SCOTIA RISE
BERMUDA RISE
NARES ABYSSAL PLAIN
depth (m)
2225
2487
2750
2996
3543
4050
4499
4925
4180
4290
4440
5719
5768
5775
5775
5775
5775
5777
5779
standing crop
living individuals/ 10cc
40
30
20
10
percent of total specimens
10
9
8
7
6
5
4
3
2
1
total living population
arenaceous living population

Fig. 18: Average number of living species found in 5 subsamples/box-core plotted as proportion of total number of species.

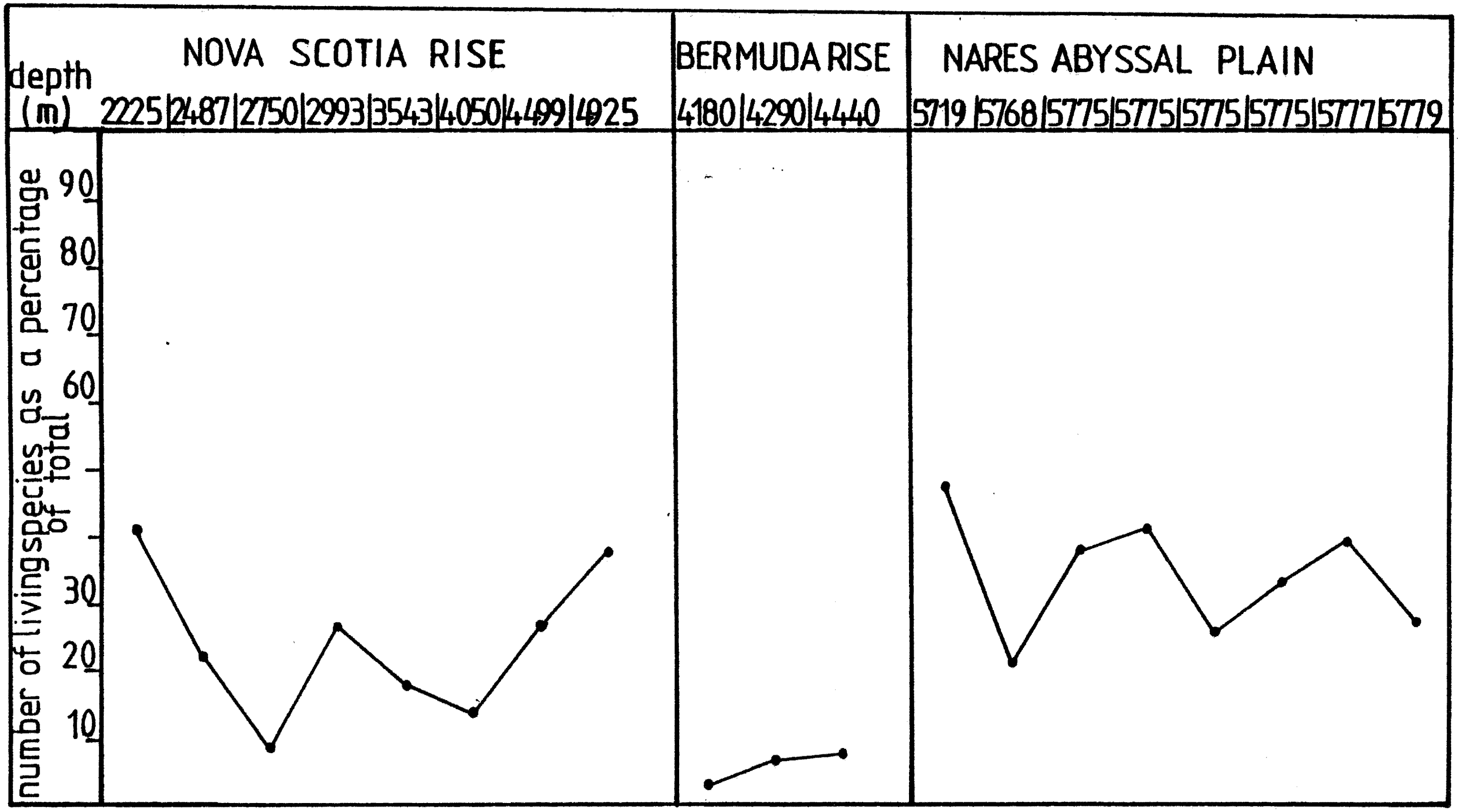

NOVA SCOTIA RISE
BERMUDA RISE
NARES ABYSSAL PLAIN
depth (m)
2225
2487
2750
2993
3543
4050
4499
4925
4180
4290
4440
5719
5768
5775
5775
5775
5775
5777
5779
number of living species as a percentage of total
90
80
70
60
30
20
10

TABLE 4: List of living species that were observed 5 or more times in 5 subsamples per box-core.
* indicates species which were represented with more than 10 living specimens.

NOVA SCOTIA RISE

2225m

Elphidium excavatum f. clavatum*
Stainforthia concava
Rhizammina algaeformis
Recurvoides scitulus

2487m

Elphidium excavatum f. clavatum*
Adercotryma glomerata

2750m

only rare species

2995m

Eponides pusillus
Reophax bilocularis

3543m

Reophax dentaliniformis

4050m

only rare species

4499m

only rare species

4925m

Reophax dentaliniformis*
Reophax scorpiurus*
Reophax bilocularis*
Adercotryma glomerata
Rhizammina algaeformis
Pullenia bulloides

BERMUDA RISE

4180m

only rare species

4290m

Rhizammina algaeformis

4440m

Reophax scorpiurus

NARES ABYSSAL PLAIN

all 8 stations

Rhizammina algaeformis*
Adercotryma glomerata*
Reophax dentaliniformis*
Reophax helenae
Saccorhiza ramosa

Chapter 6: ENVIRONMENTAL PARAMETERS VS ASSEMBLAGE DISTRIBUTION

6.1. WATERMASSES AND BENTHONIC FORAMINIFERAL ASSEMBLAGES

Benthonic foraminifera are often used as indicators of the presence of particular bottom watermasses and to track their changes in the past (e.g. Streeter, 1973; Lohmann, 1978; Schnitker, 1974). Three different watermasses can be identified in this region. The upper zone to about 2500m on the continental slope and rise off Nova Scotia is occupied by the NADW, which is characterized by its relatively high salinity (Schafer and Cole, 1982). This zone is underlain by a mixed watermass of NADW and NSOW, transported southward by the WBUC. Below 4000m the influence of the AABW is first observed. The calcareous foraminiferal assemblages can be related to these various oceanographic conditions. The deepest zone (4000-4814m) is dominated by Epistominella umbonifera, which agrees with other reports of this species as an indicator for AABW (Streeter, 1973; Schnitker, 1980). This species appears to be more resistant to the attack of carbonate undersaturated bottom water than most other calcareous species (Peterson, 1984; Corliss and Honjo, 1982). The high occurrence of this species with increasing depth has invoked two theories to explain its distributional pattern (Bremer and Lohmann, 1982). The distribution is either produced by the post-mortem dissolution of the tests or it is a response of living benthonic foraminifera to carbonate saturation of seawater.

The middle Nova Scotia continental rise assemblage (2500 - 3600m) is dominated by Eponides pusillus. Schnitker (1980) reports Cibicidoides wuellerstorfi and Epistominella exigua as indicator species for the lower NADW and in the area of the WBUC for the NSOW. The present study suggests a different picture. Epistominella exigua occurs most abundantly below 4000m and Cibicidoides wuellerstorfi shows no significant increase in occurrence. My results can be explained by the use of different sieve sizes with resulting size selection. Epistominella exigua has a relatively small test and occurs more frequently if the 63-125um fraction is included, whereas the proportion of Cibicidoides wuellerstorfi, a large species, becomes smaller (Fig. 6).

The transition to the environmental regime of the upper rise is marked by the occurrence of Hoeglundina elegans and Stainforthia concava. These two species extend through the middle and upper rise and may indicate a mixed layer of NADW and NSOW. The NADW population of the upper rise is represented primarily by Elphidium excavatum f. clavatum and Uvigerina peregrina.

A comparison between the calcareous and arenaceous assemblages suggests that these oceanographic boundaries, reflected in the calcareous component, cannot be entirely related to the arenareous faunal pattern. The distinct boundary between 3543 and 4050m, which is reflected by a marked increase of Epistominella umbonifera is a result of selective dissolution of less resistant species (Corliss and Honjo, 1982; Bremer and Lohmann, 1982). Carbonate undersaturation may also control the distribution of arenaceous species with a calcareous cement such as Eggerella bradyi and Karreriella bradyi. Specimens, identical to Eggerella bradyi but with a ferruginous cement, were found on the Nares Abyssal Plain. The relation of these forms to Eggerella bradyi may be questionable due to the different cement. However, most of the species remain uneffected. The dominant arenaceous species on the middle rise (Hyperammina sp. 1, Rhabdammina sp., and C. subglobosus) extend beyond this interval to a depth of 4185m. The boundary between the middle rise and the upper rise is characterized by the transition from the NSOW to the overlying NADW. This change in the oceanographic conditions is related to a change in the sedimentary environment by passing from a current zone on the middle rise into a quiet depositional zone on the upper rise. This transition shows a corresponding response in the composition of arenaceous and calcareous assemblages. Various characteristic trends in the composition of the arenaceous fauna suggest that the substrate exerts a primary control. This aspect will be discussed below.

6.2. SEDIMENT DISTRIBUTION AND THE CHANGING CHARACTERISTICS OF ARENACEOUS ASSEMBLAGES

The taxonomic concept of this study, in which sediment particle selectivity is not regarded as a characteristic feature for identification, has a significant effect on the interpretation of faunal trends. Detailed observations of the total arenaceous assemblage allows the recognition of two groups:

Group A includes those species with preference for a specific sedimentary environment and which consequently have a shorter depth range.

Group B includes species that are non-selective and show a greater adaptation to their habitat which is reflected in a large depth range. Many representative species of both groups reflect the general distribution of available grains for test construction.

Group A will be discussed first. The lower slope and rise off Nova Scotia show sedimentary changes that reflect the regional influence of contour currents. These changes are indicated by the occurrence of characteristic arenaceous species such as i.e. Rhizammina algaeformis, Hyperammina sp.1, Rhabdammina sp., Cribrostomoides subglobosus and Reophax dentaliniformis (illustrated in Fig. 19). Since no consistent bathymetric zonation of the eastern North American continental margin exists in the literature, a slightly different zonation was chosen to allow a division of the zone between 2500m and 4200m.

The zone between 2200m and 2500m is characterized by a tranquil sedimentary environment without major current activity. It lies above the influence of the WBUC, and is characterized by increased deposition rates of abundant fine, light particles. The substrate of the zone between 2700m and 4000m shows a different sediment composition, reflecting winnowing processes. Components such as coarse sand and large intact foraminiferal tests are abundant. Towards the abyssal plain, below 4000m, with the approach of the lysocline the coarse calcareous biogenic component decreases, replaced by more silty sediments. These changes are reflected in the arenaceous assemblage. The lower slope and abyssal region is characterized by an increased abundance of R. algaeformis. This delicate branching form seems to prefer a more fine grained substrate. On the other hand, the more coarse grained substrate of the middle rise is characterized by various taxa with a coarse grained wall texture. Tubular fragments of Hyperammina and Rhabdammina increase significantly in this environment. Fragmentation of these tests may be enhanced by current activity. A typical species is Astrorhiza crassatina which has an extremly coarse grained test. The family ASTRORHIZIDAE is associated with Cribrostomoides subglobosus, Recurvoides scitulus and Trochammina cf. globigeriniformis. These taxa have a finer grained wall texture, but their solid, large tests, spherical in shape, may be more resistant to current movement.

This distributional pattern of arenaceous species is reflected in the equivalent depth zone off Northeast Newfoundland. Rhizammina algaeformis seems to be associated with a low energy, fine sediment substrate also further north (Schafer and Cole, 1983). Other indicators for this environment off Newfoundland are Adercotryma, Astrammina, Hormosina, Rhabdammina, Saccorhiza, Sorosphaera, and Textularia. The described increase in abundance of the coarse grained varieties of Hyperammina and Rhabdammina in the zone below the axis of the WBUC was not observed by Schafer and Cole (1983). Their indicator genera for coarse substrate on the upper continental rise are Haplophragmoides, Saccammina, and Spiroplectammina, three genera which are rare on the Nova Scotia Rise.

On the Norwegian continental slope a large living population of Cribrostomoides subglobosus prefers a foraminiferal ooze as substrate

(Mackenson et al., 1985).

The arenaceous component of the deepest zone off Nova Scotia (4200-4925m) is dominated by species with a fine grained wall texture. Delicate tests of Reophax, Aschemonella scabra, and Ammomarginulina foliacea become abundant in this environment. Other subsamples of the HEBBLE Site box-cores from 4185m and 4815m depth were subject to a study by Kaminsky (1985). The analysis of the foraminiferal fauna based on the coarse fraction >250um resulted in two distinct arenaceous assemblages. The deep site at 4815m, which is strongly influenced by the deep contour current, is dominated by more primitive tubular and single-chambered species with a coarse grained wall texture. The shallow site in a more tranquil environment shows a higher diversity and is represented by a greater proportion of multichambered species of HORMOSINIDAE with a fine grained wall texture. My results show a slightly different picture by including species, which are abundant in the small fraction. The deepassemblage also contains commonly multichambered forms such as small morphotypes of Reophax bilocularis, Reophax scorpiurus, Reophax dentaliniformis, Ammomarginulina foliacea, and Adercotryma glomerata.

The influence of the sediment character (volcanic or terrigenous particles) and texture on the distribution of deep-sea arenaceous species was also noticed in the Scotian Sea. Cribrostomoides umbilicatulus soldanii is restricted to sediments with abundant diatoms and absent in sediments of volcanic composition. Cyclammina pusilla is only present in sediments with few or no diatoms (Echols, 1971).

The second group (B) includes species which occur over a large depth range and reflect in their agglutinated wall material typical detrital components of the ocean floor. The variability of these species is illustrated on Plates 23-26. On the middle rise *Reophax scorpiurus* (Plate 23) incorporates large planktonic foraminiferal tests and changes to small mineral grains towards abyssal depths. The calcareous sediment on the Bermuda Rise is reflected in a wall contructed entirely of small planktonic foraminiferal shells or calcareous fragments. A similar variability is observed in *Reophax bilocularis* (Plate 24). Plate 26 shows 4 different forms adapted to either different grain types (terrigenous or calcareous particles), such as *Psammosphaera fusca* or *Lagenammina tubulata*, or to different grain sizes, e.g. *Ammomarginulina foliacea* and *Astrammina sphaerica*.

Rhizammina algaeformis (Plate 25) may be related to both groups. This species is non-selective in the choice of wall material and occurs consequently over a large bathymetric range. However, the fragile branching specimens prefer the more tranquil environments of the upper rise off Nova Scotia and of the abyssal regions (Fig. 19).

The change in wall material in one species was observed in the fossil record by Carter and Hart (1977). Species of *Tritaxia* were found in the Lower Cenomanian with tests of detrital minerals (eg. glauconite), changing to quartz higher in the succession; in the Maastrichtian, the tests consist of sponge-spicules.

Not every arenaceous species shows a relation between sedimentary environment and wall texture. Certain taxa (e.g. *R. algaeformis*, *P. fusca*, and *Reophax spp.*) are non-selective and adapt to the composition of the substrate; others are consistent in their utilization of wall material (e.g. *Trochammina spp.*, *Ammobaculites agglutinans*, *Haplophragmoides spp.*) and supply therefore no information on substrate conditions.

6.3. GEOGRAPHICALLY RESTRICTED ARENACEOUS SPECIES

Census data for the depth zone below 4200m suggest the existence of some geographically restricted species. Several species were found on the Nares Abyssal Plain and Southern Bermuda Rise, which do not occur on the lower continental rise off Nova Scotia. These include *Nodellum membranaceum*, *Reophax horrida*, *Ammobaculites agglutinans var. filiformis*, *Ammomarginulina foliacea f. recurva*, and *Haplophragmoides rotulatum*. These species occur with an abundance of 1.5 to 10% of the total population. Taxa exclusive to the Nares Abyssal Plain and Bermuda Rise, which occur at frequencies of less than 1.5%, are *Vanhoeffenella gausii*, *Lagenammina tubulata*, *Hormosina carpenteri*, *Reophax helenae*, *Discammina compressa*, and *Spiroplectammmina biformis*.

The limited geographic distribution of the species mentioned may be controlled by environmental conditions, which have an effect on both southern deep-sea regions, but not on the lower Nova Scotia Rise. The Bermuda Rise and Nares Abyssal Plain are occupied by AABW, which, through mixing, is only of minor influence further north. The differences in the sedimentary environments of these regions may also have impact on the distribution of these arenaceous species. The Nares

Abyssal Plain and Southern Bermuda Rise are not effected by major current activities, as is the case on the lower Nova Scotia Rise where contour currents influence the substrate and cause periods of rapid deposition (Hollister and McCave, 1984).

6.4. SPATIAL HETEROGENEITY

Patchiness on a cm-scale has been reported in shallow-water sites, where physical environmental parameters such as salinity, temperature, dissolved oxygen concentrations of sediment pore water are affected by daily temporal and spatial fluctuations (Boltovsky and Lena, 1969; Buzas, 1968, 1970; Olson and Eriksson, 1974; Scott and Medioli, 1980). In deep-sea regions with presumably stable physical conditions the phenomenon of biological patch structure was studied by Bernstein et al (1978), who investigated 5 box-cores collected from the abyssal Central Pacific. The results were based on the total foraminiferal assemblage and later the work was extended by studying the live foraminiferal component of the same material (Bernstein and Meador, 1979). Both studies report that the foraminiferal fauna is significantly patchy on a scale of kilometers and centimeters. The patchiness of the total population reflects the conditions of the living fraction (Bernstein and Meador, 1979).

The documentation of spatial heterogeneity in my samples was carried out by analysing 5 subsamples per box-core, which were collected from each corner and the center of the retained surface layer. The small-scale variation in percentage occurrences of species within one box-core in shown in Fig. 20. Results are based on the relatively abundant species in the total assemblage. Each sample site is represented by 5 data points arranged vertically to visualize the within-core variation and the bathymetric trend of a species. The calcareous species such as *Elphidium excavatum*, *Eponides pusillus*, *Hoeglundina elegans*, and *Stainforthia concava* differ in abundance by about 5 % on the intrabox-core scale. *Epistominella umbonifera* and *Epistominella exigua* show differences of over 10%. However, the general bathymetric trend of species is not affected. A few arenaceous species show a more pronounced heterogeneous distribution. *Adercotryma glomerata* and *Reophax dentaliniformis* are two of the few abundant species which occur with over 10%. They show small-scale differences of up to 15 %. *Cribrostomoides subglobosus* is less common and has a maximum occurrence of 7%. Due to their tendency to break up, the increased patchiness of arenaceous species might reflect partly differences in the state of preservation of subsamples. The trend in specimen abundance for *Rhizammina algaeformis* was plotted to show the large fluctuations within one box-core, which is mainly due to varying degrees of fragmentation.

As previously shown in Fig. 17, the living population of benthonic foraminifera show a large degree of spatial heterogeneity. These results correspond to the observation of Bernstein and Meaodor (1979), who report a patchy living arenaceous assemblage in the Central Pacific.

Various factors have been discussed in the literature to explain spatial dispersion within faunal communities. Because deep-sea regions are perceived as homogenous in regard to physical environmental parameters such as salinity, temperature and dissolved oxygen, biological interaction becomes a more important consideration as an influencing factor (Bernstein et al. 1978). Various types of deposit feeders, the biogenic surface structure and the existence of manganese nodules were correlated with the spatial distribution of foraminiferal genera. The role of large benthonic foraminifera as predators was also evaluated.

The Nares Abyssal Plain, with a homogenous sediment distribution, provides a fragile microhabitat structure. This type of environment favors the formation of a dense network of pseudopodia and tubular arms of species. The abundance of KOMOKIACEA and the occurrence of species having long chains of chambers like Hormosina carpenteri are examples. These modes of foraminiferal life may have a large influence on the structure of the benthonic community. In contrast, on the Continental Slope and Rise off Nova Scotia and Newfoundland the sedimentary environment is affected by bottom currents which create different microhabitats. Examples of this substrate variability are illustrated on bottom photographs by Schafer and Asprey (1982).

The dense coverage of samples in the small area of the Nares Abyssal Plain allows the study of spatial heterogeneity on a larger scale. The largest number of species (28) is represented in all of the 8 box-cores (Fig. 21). The taxa which occur only in 1 single subsample/boxcore are represented by only 1 or 2 specimens per sample and may be considered as rare species. These data indicate a fairly homogenous distribution of the more abundant arenaceous foraminifera on a regional scale.

Fig. 19: Percentage occurrences of selected arenaceous species along the depth transect of the Continental Rise off Nova Scotia. The distribution of these taxa reflects the nature of the substrate in their tests. (f) indicates fragments of *Rhizammina algaeformis*.

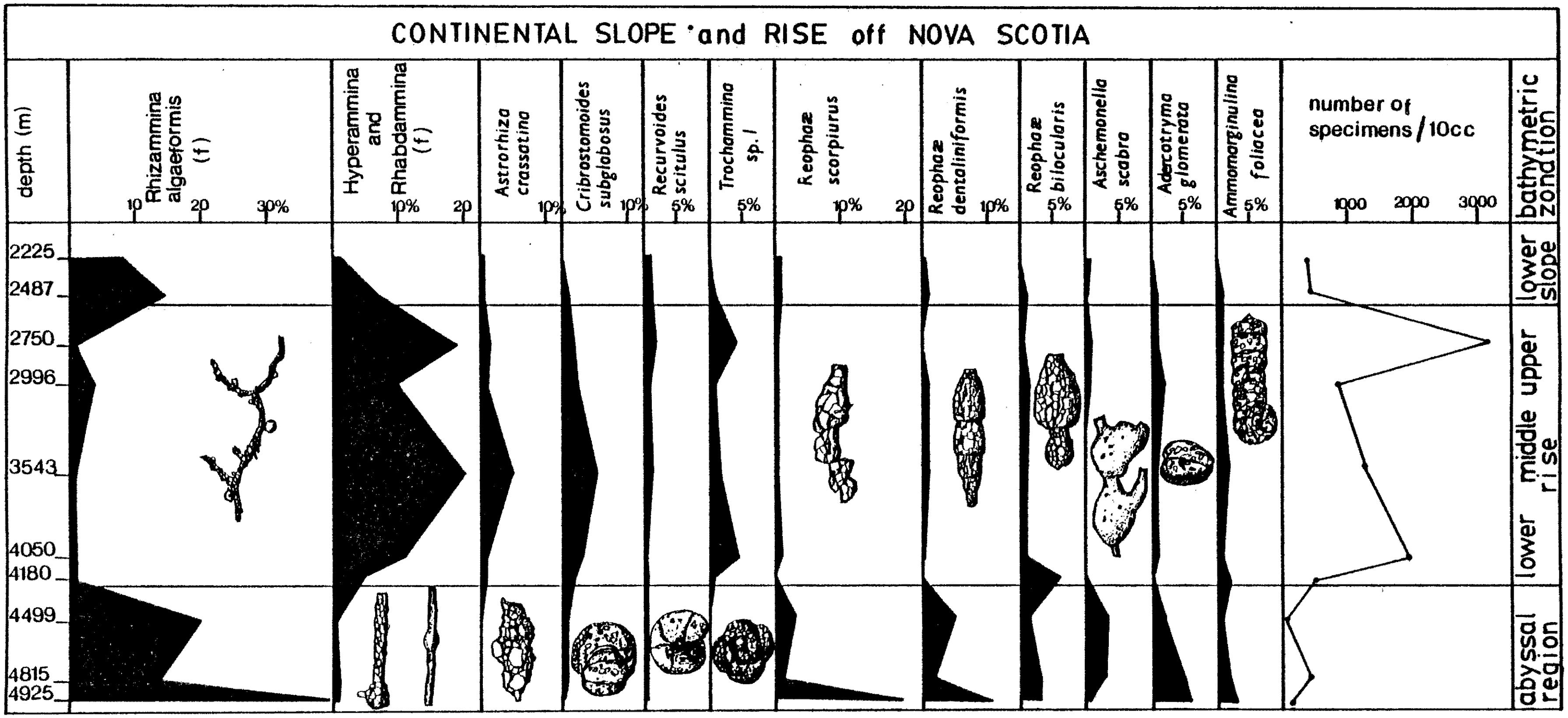

CONTINENTAL SLOPE and RISE off NOVA SCOTIA
depth (m)
Rhizammina algaeformis (f)
10
20
30%
Hyperammina and Rhabdammina (f)
10%
20
Astrorhiza crassatina
10%
Cribrostomoides subglobosus
10%
Recurvoides scitulus
5%
Trochammina sp. I
5%
Reophax scorpiurus
10%
20
Reophax dentaliniformis
10%
Reophax bilocularis
5%
Aschemonella scabra
5%
Adercotryma glomerata
5%
Ammomarginulina foliacea
5%
number of specimens/10cc
1000
2000
3000
bathymetric zonation
2225
2487
2750
2996
3543
4050
4180
4499
4815
4925
lower slope
lower middle upper rise
abyssal region

Fig. 20: Small scale variation in percentage occurrence of selected species in 5 subsamples per box-core.

The number of counted specimens of each subsample is indicated on the left margin.

The drastic fluctuations of Rhizammina algaeformis within one box-core surface is partly due to the varying degree of fragmentation of this taxon.

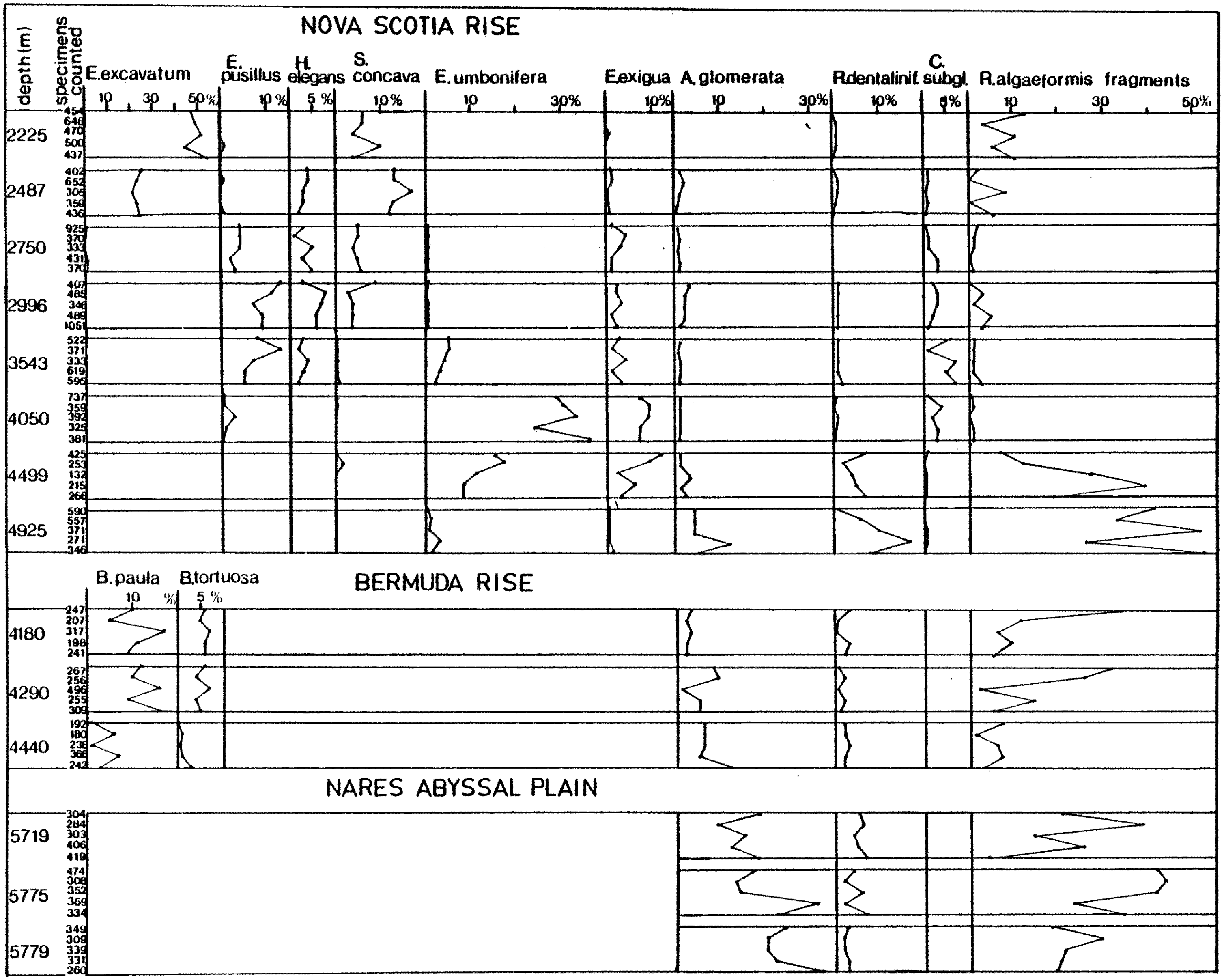
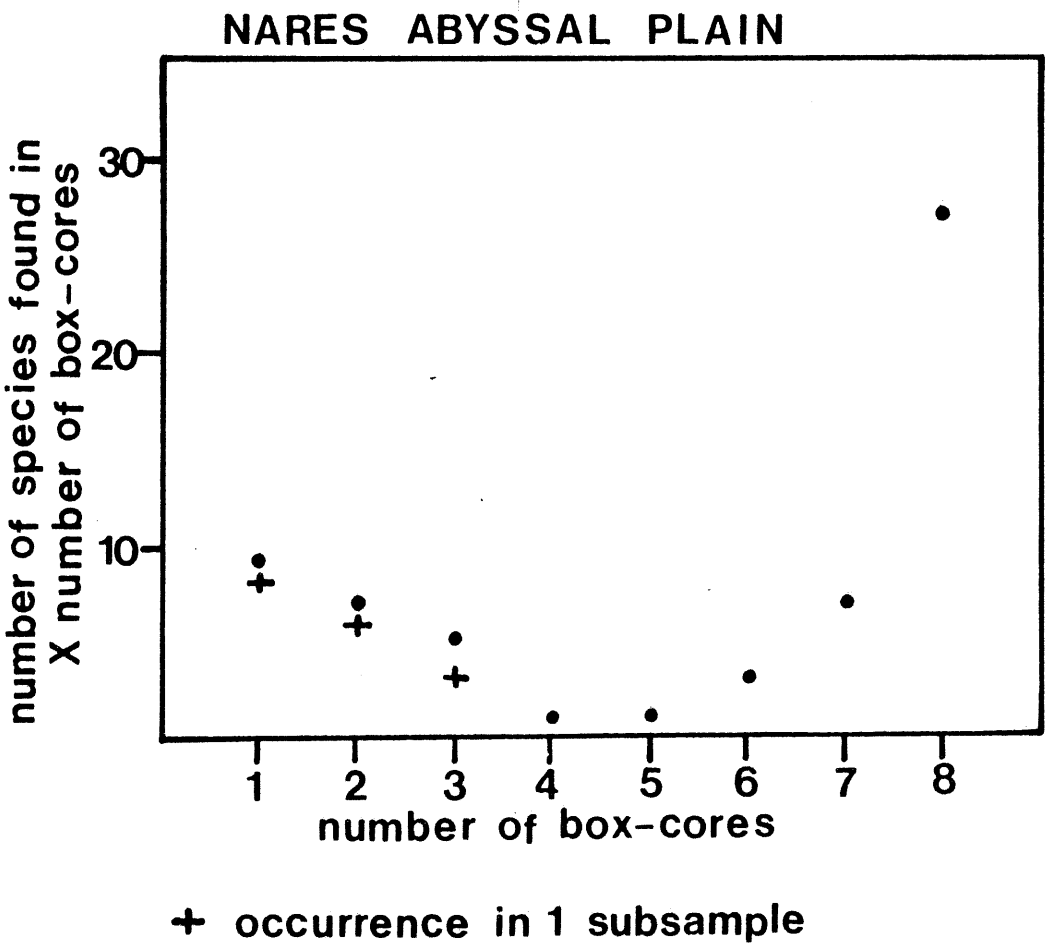

NOVA SCOTIA RISE
depth (m)
specimens counted
E.excavatum
10 30 50%
E. pusillus
10 %
H. elegans
5 %
S. concava
10%
E. umbonifera
10 30%
E.exigua
10%
A. glomerata
10 30%
R.dentalinif.
10%
C. subgl.
5%
R.algaeformis fragments
10 30 50%
2225
454
648
470
500
437
2487
402
652
305
359
436
2750
925
370
333
431
370
2996
407
485
346
489
1051
3543
522
371
333
619
595
4050
737
359
392
325
381
4499
425
253
132
215
266
4925
590
557
371
271
346
BERMUDA RISE
B.paula
10 %
B.tortuosa
5 %
4180
247
207
317
198
241
4290
267
256
496
255
309
4440
192
180
238
366
242
NARES ABYSSAL PLAIN
5719
304
284
303
406
419
5775
474
306
352
369
334
5779
349
309
339
331
260

Fig. 21: Number of species found in X (1 to 8) number of box-cores versus the number of box-cores on the Nares Abyssal Plain. The position of the crosses in each case indicates the number of species which occur only in 1 subsample/box-core and are therefore considered as rare taxa.


NARES ABYSSAL PLAIN
number of species found in X number of box-cores
30
20
10
1
2
3
4
5
6
7
8
number of box-cores
+ occurrence in 1 subsample

Chapter 7: COMPARISON OF DEPTH RANGES IN ATLANTIC AND ANTARCTIC OCEANS REGIONS

Bathymetric ranges of benthonic foraminifera are often established during investigation of shelf- and slope sediments. Due to sample depth limits species which occur below 2000m depth are frequently considered as deep-water taxa without any reference to their lower depth limit. This study covers the depth range from 2200m to 5800m and provides more detailed information on the depth distribution in the deep-sea. My results are compared with depth-ranges published in other studies. Based on the amount of available literature, a comparison is carried out separately for the moderate latitudes of the Atlantic Ocean and with the southern polar region.

1. MODERATE LATITUDES

For the moderate latitudes of the Atlantic, one has to go back to the classic worldwide expeditions to retrieve distributional data on deep-sea arenaceous foraminifera. The following studies were evaluated and are illustrated in Fig. 22a-c:

AUTHOR	EXPEDITION	SAMPLED DEPTH RANGE
Brady, 1884	Challenger Expedition	shelf to 5775m
Flint, 1899	Albatross Expedition	shelf to 4600m
Cushman, 1918	various expeditions	shelf to 4500m

Localities in the Atlantic and in the Gulf of Mexico were extracted for the comparison. These studies provide absence presence data, except J.A.Cushman, who lists the common abundance of various species which are marked bracketed in Fig. 22a-c. The depth distribution of live and dead foraminiferal assemblages were reported by Lutze (1980) from the continental margin off NW Africa, where the deepest sample is derived from 3500m so that the area of overlap is small.

The following generalized divisions group arenaceous species with preference for a certain depth range within the deep-sea.

Continental Slope to Middle Continental Rise:

Ammobaculites agglutinans
Astrorhiza crassatina
Cribrostomoides ringens
Eggerella bradyi
Karreriella bradyi
Reophax bacillaris
Reophax pilulifer
Rhabdammina abyssorum
Rhabdammina discreta
Rhizammina indivisa
Sigmoilopsis schlumbergeri

Lower Continental Rise and Abyssal Region:

Cystammina galeata

Haplophragmoides rotulatum

Nodellum membranaceum

Heterobathyal species - slope to abyssal depth:

Ammolagena clavata

Aschemonella scabra

Cystammina pauciloculata

Hormosina carpenteri

Hormosina globulifera

Recurvoides scitulus

Reophax distans

Saccammina sphaerica

Saccorhiza ramosa

Subreophax adunca

Heterobathyal species - shelf to abyssal depth

Adercotryma glomerata

Ammodiscus incertus

Ammomarginulina foliacea

Cribrostomoides subglobosus

Glomospira charoides

Glomospira gordialis

Haplophragmoides sphaeriloculus

Hyperammina elongata

Psammosphaera fusca

Reophax dentaliniformis

Reophax nodulosus
Reophax guttifer
Reophax scorpiurus
Thurammina papillata
Tolypammina vagans
Trochammina cf. globigeriniformis

The present study has extended the lower depth limit of several taxa compared with Brady's results. This may be due to the more advanced sampling methods used on the Nares Abyssal Plain, which allowed for the recovery of rare and delicate tests. Another reason originates as a consequence of a different taxonomic approach. Some interesting species should be emphasized:

Adercotryma glomerata shows a bimodal distribution with a high abundance on the shelf and in abyssal depth.

Ammodiscus incertus, which is common on the slope and upper rise with a large test, occurs in the study area only on the Nares Abyssal Plain as a very small, fragile form which can be easily overlooked.

Dendrophrya arborescens was found by Brady (1884) in shallow-water and in this study in deep-water on the Bermuda Rise. The finding of this species depends on the preservation of the material as the test consists of extremely fragile branching tubes and an attached proloculus.

Haplophragmoides rotulatum is reported by Cushman (1918-22) as a rare species between 1500m and 1750m. The most common occurrence seems to be at abyssal depths.

Saccorhiza ramosa shows two maxima. Cushman reports a common abundance between 1000 m and 2800m, whereas in my material the species occurs abundantly at abyssal depths.

The comparison of all four investigations implies wide depth ranges for most of the arenaceous species. Differences between the authors occur particularly at the lower depth limits of taxa.

7.2. SOUTHERN POLAR REGION

A larger volume of more recent literature, based on quantitative data, exists for the southern polar deep-sea region. The following studies provided bathymetric ranges of arenaceous foraminifera and were taken into account for the comparison:

Author	Region	Sampled depth range
Echols, 1971	Scotia Sea	201-7690m
Herb, 1971	Drake Passage	73-4758m
Lindenberg & Auras, 1982	Kerguelen Pl.	329-3509m
Anderson, 1975	Weddell Sea	250-4200m
Pflum, 1966	East. Ross Sea Amundson Sea Bellingshausen Sea	210-3545m

The selected arenaceous species are not represented in every study. The available information for each taxan in each region is combined and illustrated in Fig. 23.

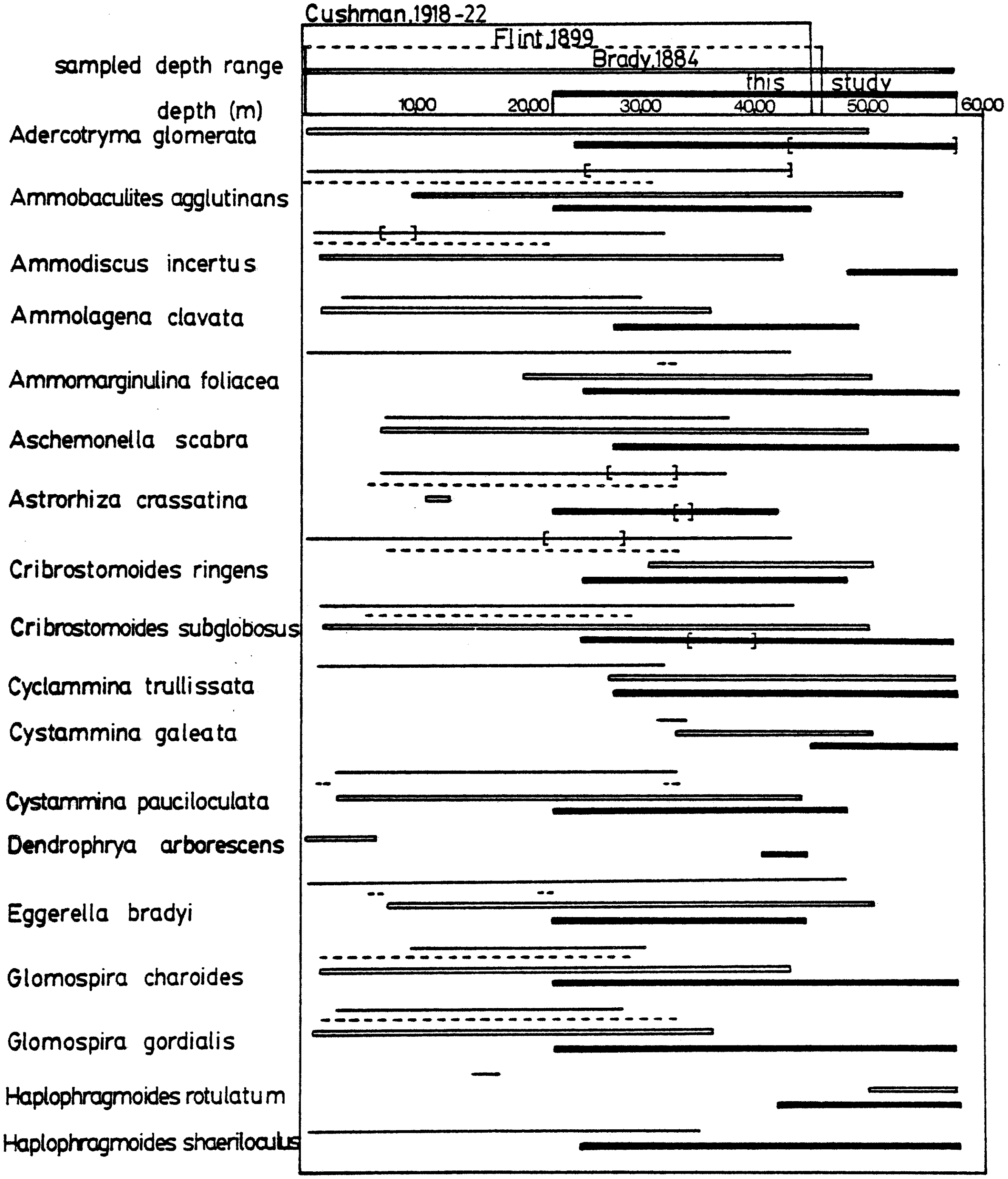
The comparison of distributional data in the mid-latitudes of the Atlantic Ocean has shown that a large number of arenaceous species occur over a wide depth range. Fig. 23 implies, that a.) many of these species occur also in the southern polar region, indicating an ocean wide distribution, and b.) most deep-sea species around Antarctica extend onto the slope and shelf. This is also true in the Arctic, but there is less data available for this area at present. Since the deeper Antarctic region (below 4700m) is only represented in the investigation by Echols of the Scotia Sea (1971), a statement on the comparison of lower depth limits can only be vague.

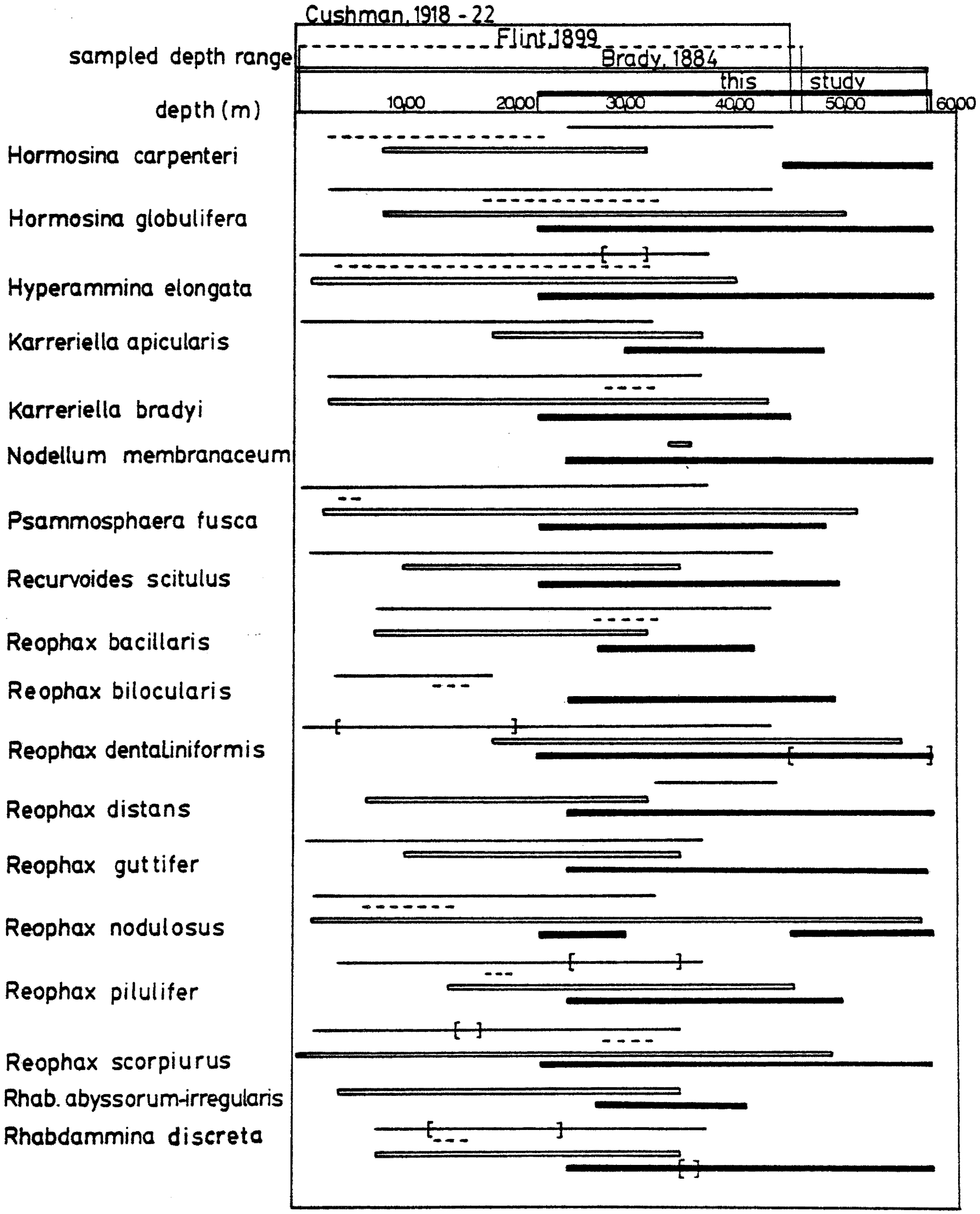
Only three taxa can be described as typical deep-water species in the southern polar region:
Ammomarginulina foliacea f. recurva, a form restricted to abyssal depth in the present study, *Nodellum membranaceum* and *Placopsilinella aurantiaca*. The difference in depth range of *Reophax scorpiurus*, *Rhizammina algaeformis* and *Tolypammina vagans* may originate in the taxonomic approach used in this study. *R. scorpiurus* and *R. algaeformis* are taxa which show a large intraspecific variability in wall texture. This fact may lead other authors to assign these forms to other species. It is interesting to note that *Spiroplectammina* occurs in the Antarctic Ocean exclusively in shallow water, but is found on the Bermuda Rise and Nares Abyssal Plain rarely below 4000m depth and on the Nova Scotia shelf in shallow water (Williamson, 1984). The specimens in deep-water are very small and easy to miss.

The occurrence of Atlantic deep-sea species in shallow-water areas of the Antarctic may be explained by the physical and biotic similarities of both environments (Lipps & Hickman, 1982). Physical parameters such as cold water temperature, salinities and low terrestrial sedimentation rates are similar. Differences exist in seasonal productivity and in the influence of light at Antarctic latitudes compared to deep-sea regions. The existence of an entire arenaceous assemblage below the shallow CCD in this cold water realm resembles arenaceous abyssal faunal associations noted for mid-latitudes. Another similarity may originate in the important watermass of AABW, which is derived from around Antarctica and influences the deep-sea fauna over large areas of the Atlantic Ocean basin. It is argued by Lipps & Hickman (1982) that the morphologic resemblance between species from the two regions may result from their adaptation to similar environmental regimes, assuming that the majority of species in both environments have originated in place. Only a small number of species may have migrated between the two regions. However, my results concerning arenaceous taxa suggest that many species are highly adaptable to various substrates and seem to be independant of watermass characteristics in their distribution. This ability would favor a migration between different regions.

Fig. 22a-c: Comparison of bathymetric ranges of selected arenaceous species in the Atlantic Ocean. Brackets indicate common occurrences.

AUTHOR	SAMPLED DEPTH RANGE
Cushman, 1918-1922	shelf to 4500m
Flint, 1899	shelf to 4600m
Brady, 1884	shelf to 5775m
this study	2225m to 5779m


Cushman,1918-22
Flint,1899
Brady,1884
this study
sampled depth range
depth (m)
1000
2000
3000
4000
5000
6000
Adercotryma glomerata
Ammobaculites agglutinans
Ammodiscus incertus
Ammolagena clavata
Ammomarginulina foliacea
Aschemonella scabra
Astrorhiza crassatina
Cribrostomoides ringens
Cribrostomoides subglobosus
Cyclammina trullissata
Cystammina galeata
Cystammina pauciloculata
Dendrophrya arborescens
Eggerella bradyi
Glomospira charoides
Glomospira gordialis
Haplophragmoides rotulatum
Haplophragmoides shaerilocullus


Cushman, 1918 - 22
Flint, 1899
Brady, 1884
this study
sampled depth range
depth (m)
1000
2000
3000
4000
5000
6000
Hormosina carpenteri
Hormosina globulifera
Hyperammina elongata
Karreriella apicularis
Karreriella bradyi
Nodellum membranaceum
Psammosphaera fusca
Recurvoides scitulus
Reophax bacillaris
Reophax bilocularis
Reophax dentaliniformis
Reophax distans
Reophax guttifer
Reophax nodulosus
Reophax pilulifer
Reophax scorpiurus
Rhab. abyssorum-irregularis
Rhabdammina discreta

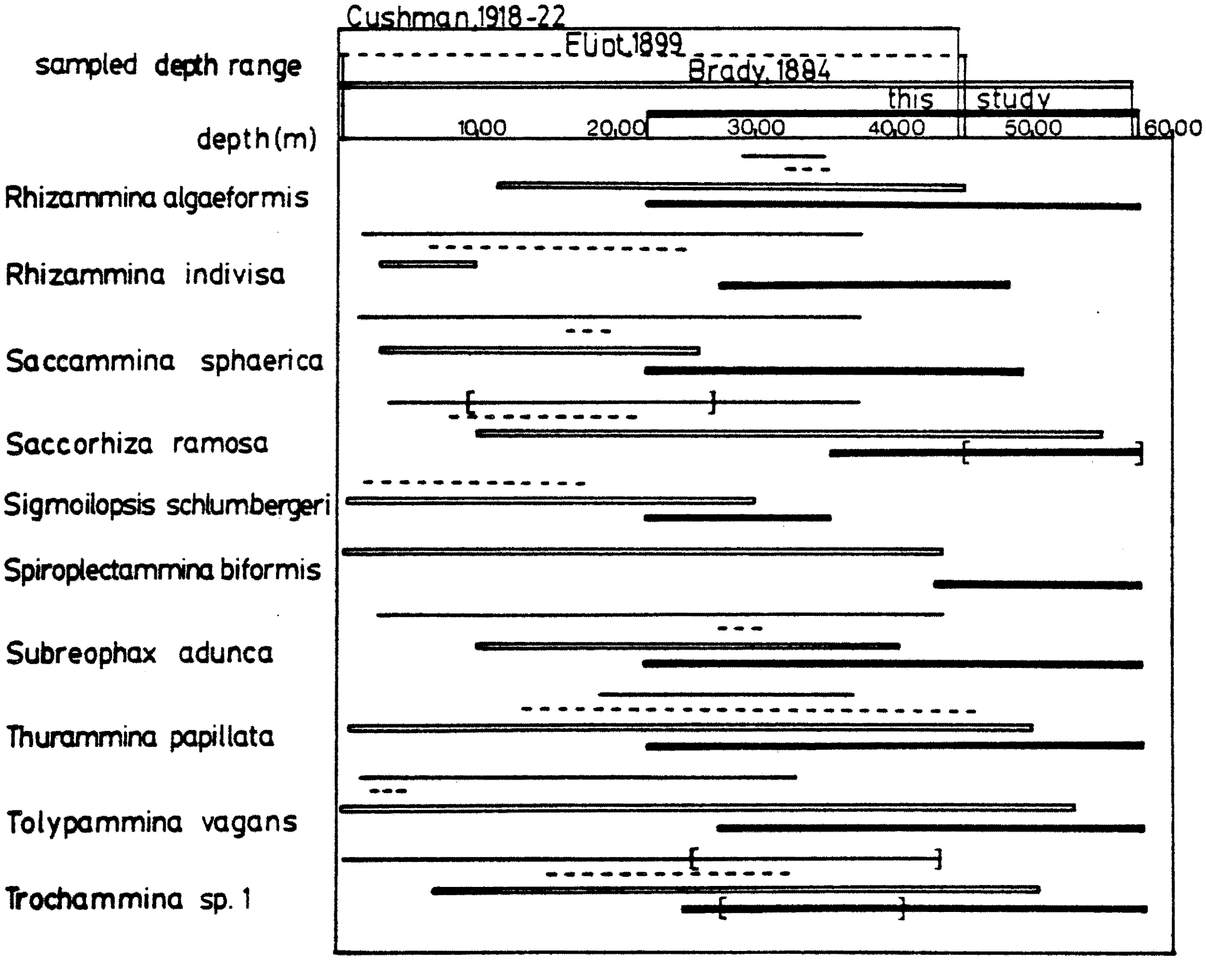
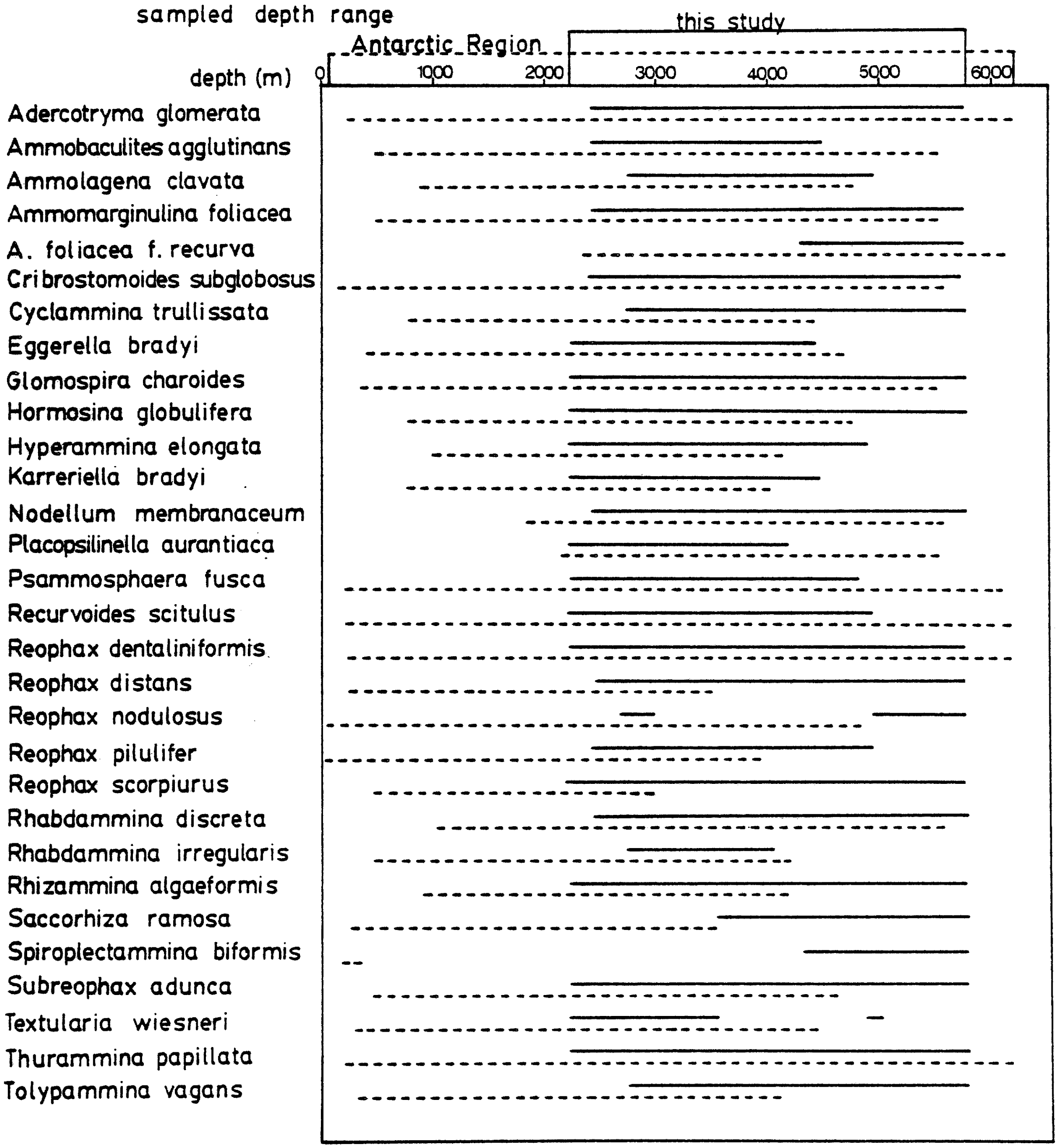

Cushman 1918-22
Eliot 1899
Brady 1884
this study
sampled depth range
depth (m)
1000
2000
3000
4000
5000
6000
Rhizammina algaeformis
Rhizammina indivisa
Saccammina sphaerica
Saccorhiza ramosa
Sigmoilopsis schlumbergeri
Spiroplectammina biformis
Subreophax adunca
Thurammina papillata
Tolypammina vagans
Trochammina sp. 1

Fig. 23: Comparison of depth ranges of selected arenaceous species between the southern polar region and this study.

Data are compiled from Echols, 1971; Herb, 1971; Lindenberg and Auras, 1982; Anderson, 1975; Pflum, 1966.


sampled depth range
this study
Antarctic Region
depth (m)
0
1000
2000
3000
4000
5000
6000
Adercotryma glomerata
Ammobaculites agglutinans
Ammolagena clavata
Ammomarginulina foliacea
A. foliacea f. recurva
Cribrostomoides subglobosus
Cyclammina trullissata
Eggerella bradyi
Glomospira charoides
Hormosina globulifera
Hyperammina elongata
Karreriella bradyi
Nodellum membranaceum
Placopsilinella aurantiaca
Psammosphaera fusca
Recurvoides scitulus
Reophax dentaliniformis
Reophax distans
Reophax nodulosus
Reophax pilulifer
Reophax scorpiurus
Rhabdammina discreta
Rhabdammina irregularis
Rhizammina algaeformis
Saccorhiza ramosa
Spiroplectammina biformis
Subreophax adunca
Textularia wiesneri
Thurammina papillata
Tolypammina vagans

CHAPTER 8: PRESERVATION OF ARENACEOUS FORAMINIFERA

8.1. TRANSITION FROM LIVE TO DEAD TO FOSSIL ASSEMBLAGES

In this chapter I will discuss the transition from live to dead to buried and fossilized assemblages of arenaceous foraminifera. The arenaceous component has often been ignored in studies dealing with recent benthonic deep-sea foraminifera (e.g. Streeter, 1973; Lohmann, 1978). The disappearance just below the sediment surface of various species has been interpreted as an indication that no arenaceous forms are preserved in the fossil record. The geological record contradicts this interpretation and as a consequence the following questions are raised:

1. Which factors modify the assemblage during the life stage, after death, and after burial?
2. How is the diversity and abundance of species influenced by these factors?
3. Which specific components of the modern fauna will survive fossilization?

The suggested factors involved in modification acting on the living population are (after Hart, 1983):

a) life span of taxa
b) growth rate of taxa
c) reproduction rate of taxa
d) intra- and interspecific competition

e) predation

The modification factors initiated after death are:

a) attack of bacteria or scavengers

b) post-mortem movement by currents or bioturbation

The modification factors activated after burial are:

a) compressional effects, especially for species with flexible tests

b) attack by geochemical processes in the porewater

c) surface overgrowth through diagenesis

d) decalcification of a mixed calcareous/arenaceous assemblage, producing an entire arenaceous assemblage or affecting the calcareous cement of some arenaceous forms.

This study focuses on the compositional changes in the arenaceous fauna. The upper 25 to 35cm of sediment of four box-cores from the Nares Abyssal Plain (5775m waterdepth) and two cores from the Continental Rise off Nova Scotia (2750m and 4499m waterdepth) were examined. The upper sediment sequence of the Nares samples is a brown mud, characterized by mottling and bioturbation down to 10-14cm (Fig. 24) with the exception of core 84-BC-2B/5, where the entire sequence is bioturbated. The lower parts of the Nares cores show thin lamination, occasional silt layers and a slightly more greyish colour. In these sequences the carbonate content is increased because of the occurrence of planktonic foraminifera, mainly fragmented or corroded specimens, and benthonic calcareous species. High percentages of these calcareous components below the usual 5000m depth limit of the CCD appear to be the result of sudden large depositional events that allow no opportunity for long periods of solution by seawater undersaturated with respect to calcium carbonate.

The number of arenaceous specimens per 20cc of wet sediment fluctuates throughout the upper sequence of the cores. The surface assemblage has the highest number, varying between 200 and 350 specimens, with the exception of core 84-BC-25/5, where the sample 12cm below the surface exceeds the surface sample in terms of the Foraminiferal Number. In the upper 4cm a drastic decrease from about 300 to 100 specimens per 20cc occurs in three of the studied cores. A second major decrease in the number of arenaceous specimens parallels the sedimentological change from the brown bioturbated mud to the greyish turbiditic sediment. In specific layers of the turbidite sequence, the arenaceous fauna is impoverished in diversity, but represented by a countless number of small tubular fragments, which are difficult to identify. They may be related to <u>Saccorhiza ramosa</u> or <u>Rhabdammina sp.</u>. The concentration of these short fragments in specific layers, which have more or less all the same size, may result from hydrodynamic sorting during turbiditic processes. The same phenomenon was encountered in turbiditic sequences in deeper layers of piston-cores from the Nares Abyssal Plain, and has been noted in known turbiditic areas of the Arctic Ocean (Scott, pers. comm.).

The number of specimens per 20cc of wet sediment of various abundant species of the Nares Abyssal Plain are illustrated in Figs. 25 and 26. The most dominant species is <u>Adercotryma glomerata</u>, a form which has been found in Pleistocene sediments up to 20,000 years old on the continental margin of Eastern Canada (Scott et al., 1984). The vertical changes in abundance of A. glomerata in all four cores are plotted for comparison in Fig. 27. Downcore fluctuations cannot be correlated between localities. However, the zone between 16 and 20cm is marked by a drastic decrease from about 40 to 10 or less specimens per 20cc in all four cores. Less common arenaceous species like Nodellum membranaceum, Ammobaculites filiformis, Haplophragmoides rotulatum, Ammomarginulina foliacea, Reophax dentaliniformis, and Cyclammina trullissata fluctuate randomly downcore and diminish at the upper boundary of the turbidite sequence. At this boundary the calcareous foraminiferal component increases and is dominated by Epistominella umbonifera. This species forms the most abundant taxa of the adjacent deep-sea areas above the CCD, where turbidity currents pick up material and spread it over the Nares Abyssal Plain. Additional less common species are related to the genera Cibicidoides, Pullenia and Eponides. The observed disappearance of the diversified arenaceous assemblage at the turbiditic level and the appearance in this sequence of countless tubular fragments and a calcareous component in this case clearly relates to changes in sedimentation regime and the substrate.

The studied localities represent a relatively restricted area of the Nares Abyssal Plain. It can be assumed therefore that watermass characteristics and sediment distribution are uniform over the study area as factors influencing the distribution of arenaceous foraminifera. However, the changing vertical abundance of the illustrated species (Figs. 25 and 26) does not indicate a uniform pattern within the investigated localities. The differences may have to be explained by factors operating on a small regional scale. Fluctuations in abundance may be due to changes in biological productivity or to the dilution effects resulting from an increased sedimentation rate, which becomes an important factor in the turbidite sequence.

Corliss (1985) studied the depth distribution of living deep-sea calcareous species in response to different physico-chemical conditions within the sediment. Some taxa prefer microhabitats 10cm below the surface. This preference may also be valid for certain arenaceous species. However, such cannot be corroborated by the present study because the core samples were not stained.

Another important explanation for the decrease of arenaceous foraminifera with depth below the sediment/water interface is the great fragility of many taxa. Selective preservation decreases species diversity and creates shifts in species dominance. Many arenaceous species have an iron compound, stabilizing the organic cement which binds the individual detrital grains in the test (Hedley, 1963; Towe, 1967). This iron can be attacked by chemical agents. The vertical distribution of iron-rich arenaceous foraminifera in the Late Quarternary has been studied by Sidner and McKee (1976). Their results indicate that the distribution is controlled more by geochemical factors rather than ecological ones. Arenaceous foraminifera with a ferrugenous cement occur abundantly in the upper oxidized layer which is characterized by a positive redox potential. In the underlying reduced sediment the iron in the organic cement is reduced from the ferric to the ferrous state and subsequently mobilized. This process causes bleaching and the ultimate destruction of the test (Sidner and McKee, 1976).

Geochemical analyses have been carried out on piston cores of the southern Sohm Abyssal Plain (Winters and Buckley, in press). Measurements of the iron content in the porewater indicate an increase several centimeters below the surface at the transition from an oxidizing zone to a reducing sediment. Where arenaceous fauna have an iron compound in their cement, they may be affected by the geochemistry of the porewater. Consequently, this change may be reflected partly in the drastic decrease of the number of arenaceous species below the surface (Fig. 24). Core 84-BC-2B/5 shows a slightly higher number of arenaceous specimens per 20cc throughout the entire column. This occurrence may be the result of a more oxidized sediment, an observation that is supported by visible bioturbation features that extend down to 30cm below the sediment surface.

Among the available box-cores from the Continental Rise off Nova Scotia, two cores were selected to study the vertical change in arenaceous foraminifera. The changing sedimentological regimes over the entire zone of the continental rise are recognizable in core photographs (Fig. 28). A brown, oxidized and bioturbated zone occurs in three regions: (1) on the upper rise in 2487m in the quiet depositional regime; (2) at 2996m in a weakly developed layer below the zone of maximum current velocity; (3) on the lower rise towards the abyssal plain at 4925m depth. The regions under the influence of contour currents, especially at 2750m, show a hard surface layer, more greyish in colour. Most of the fine particles have been removed from this layer by winnowing processes.

The area with the maximum current velocity of the WBUC at 2750m and the region under the influence of the DWBUC at 4499m depth were chosen for the analyses. Both zones represent environments that are exposed to changing sedimentological processes such as turbidity current activity and bottom current sediment surface interactions. Conversely, the Nares Abyssal Plain is an example of a more stable substrate. Shifts in the intensity of factors influencing the sea bottom take place through time and may be reflected in the foraminiferal content. The arenaceous component was studied quantitatively. For an evaluation of the vertical changes of calcareous species from live to dead to fossil assemblages the interested reader is referred to Douglas et al. (1980), which authors studied samples from the Southern California borderland.

A visual estimation of the mineral component in the sand fraction suggests a down core increase at both localities. The average grain size is larger on the upper rise where the sediment also includes many pebbles. This indicates a more activ downslope transportation of terrigenous sediments in the early Holocene. Such allochtonous input in the lower sequence of core 82-022-77/E is reflected in the occurrence of calcareous species usually found on the slope such as Elphidium excavatum, Rutherfordoides tenuis, Nonionella sp., and Globobulimina sp.. In the Monterey deep-sea fan off Central

California, the proportion of shallow water species in deep-sea sediments has been used to distinguish turbidite sequences from hemipelagic muds (Brunner & Normark, 1985). In my material significant differences between both core localities exist in the general trends of number of species and number of specimens per 10cc of wet sediment (Figs. 29 and 30). The surface assemblage of core 82-022-83/E has a rich arenaceous fauna showing a high diversity of 50 species due to a concentration of robust forms, which are resistant to the erosive forces that occur below the WBUC axis. Below the upper centimetre of sediment the arenaceous fauna decreases drastically from over 1000 to 380 specimens per 10cc. This drop is also reflected in the vertical distribution of all dominant species. The decrease in the arenaceous fauna directly below the surface might be caused by current compaction which does not favor the preservation of fragile tests. The arenaceous component disappears almost completely between 12 and 14cm. Slightly bleached specimens occur below 12cm where the sediment colour changes to light grey (Fig. 28). In this sequence the remaining taxa are Eggerella bradyi, Karreriella bradyi, Karreriella novangliae, and Reophax bacillaris - species, which have a calcareous or an organic matrix and therefore are not affected by the solubility of iron in a reducing environment.

Core 82-022-77/E is characterized by a sparse arenaceous fauna of low diversity at the surface, which increases significantly in number of species and specimens towards 4cm level down core. The Foraminiferal Number changes from 20 to 150 specimens and the species number from 10 to 30 species per 10cc. The impoverished surface population is here interpreted as a residual assemblage after erosion of the substrate by bottom currents, described as a deep-sea storm event (Hollister et al., 1984). This current occurs episodically and influences the substrate with varying intensity. These changes may explain some of the vertical differences in species richness of the benthonic foraminiferal populations. The dominant species fluctuate in the upper 10cm. Among these species Rhizammina algaeformis has the most fragile test and does not remain below 9cm. The occurrence of Reophax distans, Trochammina cf. globigeriniformis, and Cribrostomoides subglobosus is unusual at this water depth. These species represent, in the modern assemblage, the middle continental rise. The relatively coarse grained tests of these species, which were found in this core, reflecting a relatively fine grained environment, may imply downslope transportation. No distinct oxidized zone is developed in core 82-022-77/E. In contrast to the Nares Abyssal Plain, bleached arenaceous specimens were found in the upper three samples of the core. The transition to non-bleached specimens occurs gradually with tests showing only a bleached final chamber.

The aforementioned differences in the vertical distribution of arenaceous foraminifera seem to be controlled by various factors such as a changing substrate through time or by preference for a infaunal microhabitat. However, chemical and mechanical destruction of tests blur, through selective removal, the natural changes in the abundance of arenaceous species. Unfortunately, the penetration depth of the box-cores does not extend to a depth that allows a study of the faunal changes below the turbidite sequence. Therefore an evaluation of the actual effects of turbidity currents on the arenaceous fauna is not feasible in context of this study.

8.2. IMPLICATION OF BURIAL MODIFICATION FOR PALEOECOLOGY USING FOSSIL FORAMINIFERAL ASSEMBLAGES

The importance of arenaceous foraminifera in palaeoenvironmental interpretations in the fossil record has been realized for some time. In socalled flysch-type faunas, arenaceous species form the entire foraminiferal assemblage (Pflaumann, 1964; Simpson, 1969; Gradstein & Berggren, 1981). However, only limited use had been made of the distributional data on modern arenaceous species as depth and environmental indicators to produce valuable information for the interpretation of the past. For such an attempt it is of interest to know which component of the modern fauna remains through geological time. The recent deep-sea arenaceous fauna consists to a large extent of fragile species, such as found in the family KOMOKIACEA on the abyssal plains. This component has no potential to survive the fossilization process. The loss of these taxa confronts us with a residual fauna in the fossil record of deep-sea sediments. This assemblage may lack the most dominant or indicative species for the environment at that time. The study of the vertical changes of the arenaceous composition over the upper 30cm of sediment allows some estimation of which taxa may survive processes such as transportation, burial, compaction, and dissolution.

Figure 31a,b groups deep-sea arenaceous species into three categories. I have attempted to arrange the species within each group in vertical order with respect to increasing test stability.

Group A comprises species with a flexible test and with delicate branches of agglutinated clay particles. These forms often collapse if the test dries out, such as the species related to the family of KOMOKIACEA. These taxa are most susceptible to mechanical destruction and slight compaction and have therefore no potential to survive in the fossil record. They were never found below 4 to 5cm in the cores.
Group B includes species with relatively fragile tests, thin walls, and often loosely cemented wall material like the genus Rhizammina. These taxa have only a small chance to survive compaction and show, therefore, a low potential to remain in the fossil record.
Group C is formed by those species which have a firmly cemented arenaceous test and consequently have a high potential to survive fossilization.

The influence of geochemical processes in the sediment column on the various types of cement has not been considered in this classification. Destruction through chemical solution may be a localized effect which is difficult to generalize without quantitative chemical studies.

Species related to Rhizammina were described from Late Cretaceous and Early Tertiary assemblages (Pflaumann, 1964; Gradstein & Berggren, 1981; K.Miller et al., 1982). From comparison with the fragile tests of the recent species, fossilization of this genus appears to be questionable. The majority of the species of Reophax show a tendency to disintegrate rapidly after burial. Exceptions are Reophax bacillaris, R. distans, and R. ovicula. Vilks and Mudie (1983) found Reophax fusiformis together with Saccammina atlantica and Spiroplectammina biformis abundantly preserved in cores of Lake Melville, Labrador, down to 7m below surface. Scott et al (1984) found Reophax arctica (a small fragile test) in sediments of late Pleistocene age (10m below the surface). A.Miller et al (1982) observed Reophax scottii (a very delicate form) fossilized in a fjord at depths up to 4m below the surface. These types of observations make generalized groupings difficult.

As mentioned earlier, in the early Holocene and Pleistocene turbiditic sequences of the Nares Abyssal Plain some layers are characterized by abundant tubular fragments as the only arenaceous component (Fig. 24). The concentration of primitive taxa in restricted zones was also observed in the fossil record. Pflaumann (1964) described from the Upper Cretaceous flysch faunas of Bavaria an alternation of layers dominated by primitive tubular forms and layers with higher developed taxa. Simpson (1969) reported, from the Carpathian flysch, assemblages which mainly consist of Bathysiphon and Hyperammina species. In turbidite sequences of the Tertiary sediments in the Norwegian-Greenland Sea two subfaunas were distinguished by Verdenius and Van Hinte (1983): (1) a frontier-area subfauna, consisting of more primitive forms, which quickly repopulate a substrate affected by a turbidite and (2) a species-rich subfauna of sophisticated forms that fit into narrow ecological niches in the environment.

Since on the Nares Abyssal Plain the assemblage of tubular forms occurs together with a calcareous component, that clearly indicate the allochtonous nature of the sediment, I assume that these arenaceous specimens are transported and have been concentrated through hydraulic sorting during a turbidity current event.

The results of this study suggest that a number of arenaceous species reflect sedimentary regime and the nature of the substrate in their tests. This observation may be of help when using fossil arenaceous assemblages to interpret typical features of their palaeoenvironment.

The data show that the disappearance of arenaceous species below the surface sediment, at least in this area, is a reflection of environmental change and not simple degradation of the tests by depositional factors.

Fig. 24: Figure shows sedimentological observations, changes in number of total benthonic specimens, and changes in the number of total calcareous specimens per 20cc wet sediment in four selected short cores from the Nares Abyssl Plain. The hatched areas indicate sequences with abundant short, tubular arenaceous fragments which were not recorded quantitatively.

NARES ABYSSAL PLAIN

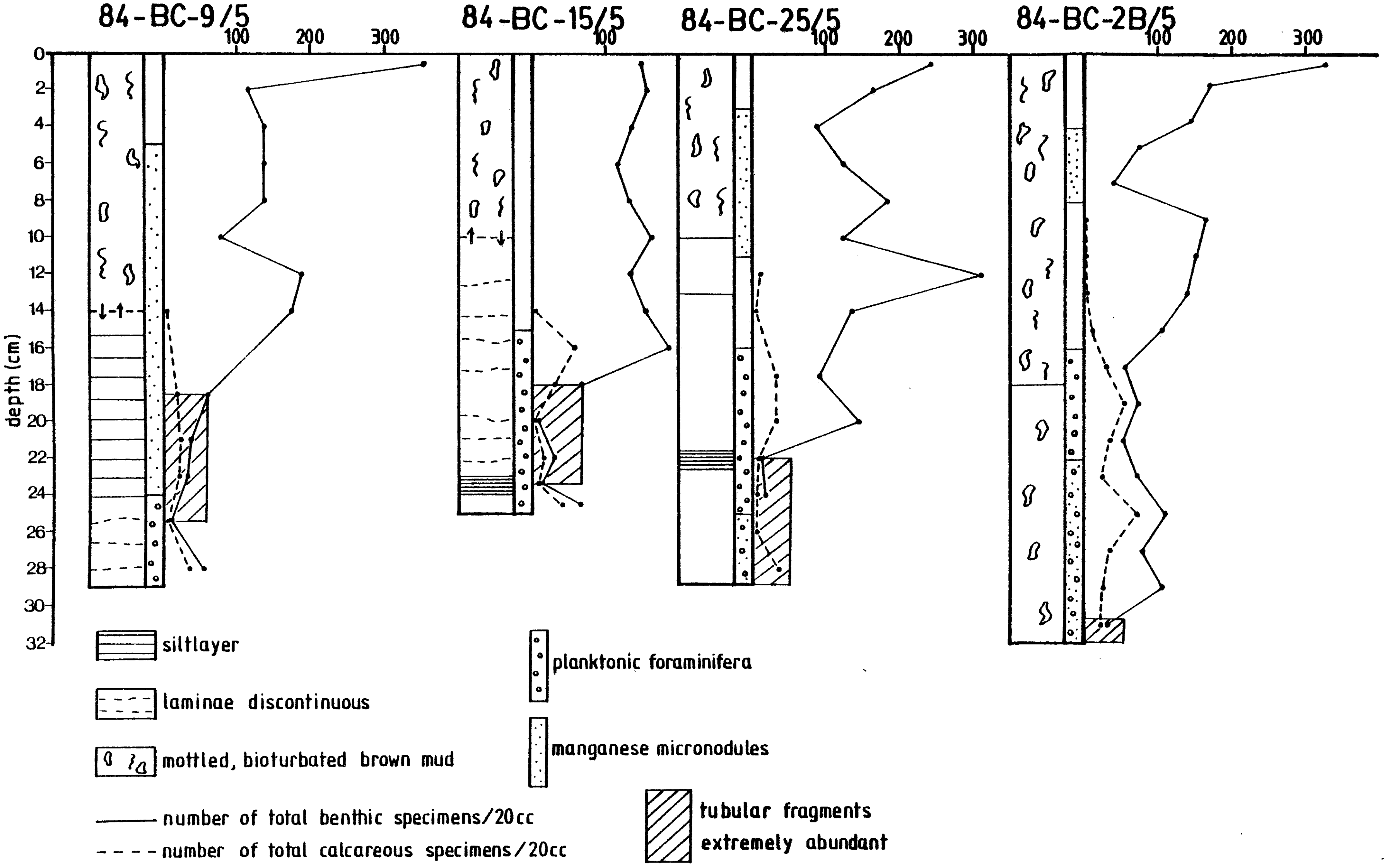


Fig. 25: Vertical changes in actual number of selected species per 20cc wet sediment in cores 84-BC-9/5 and 84-BC-15/5 from the Nares Abyssal Plain.

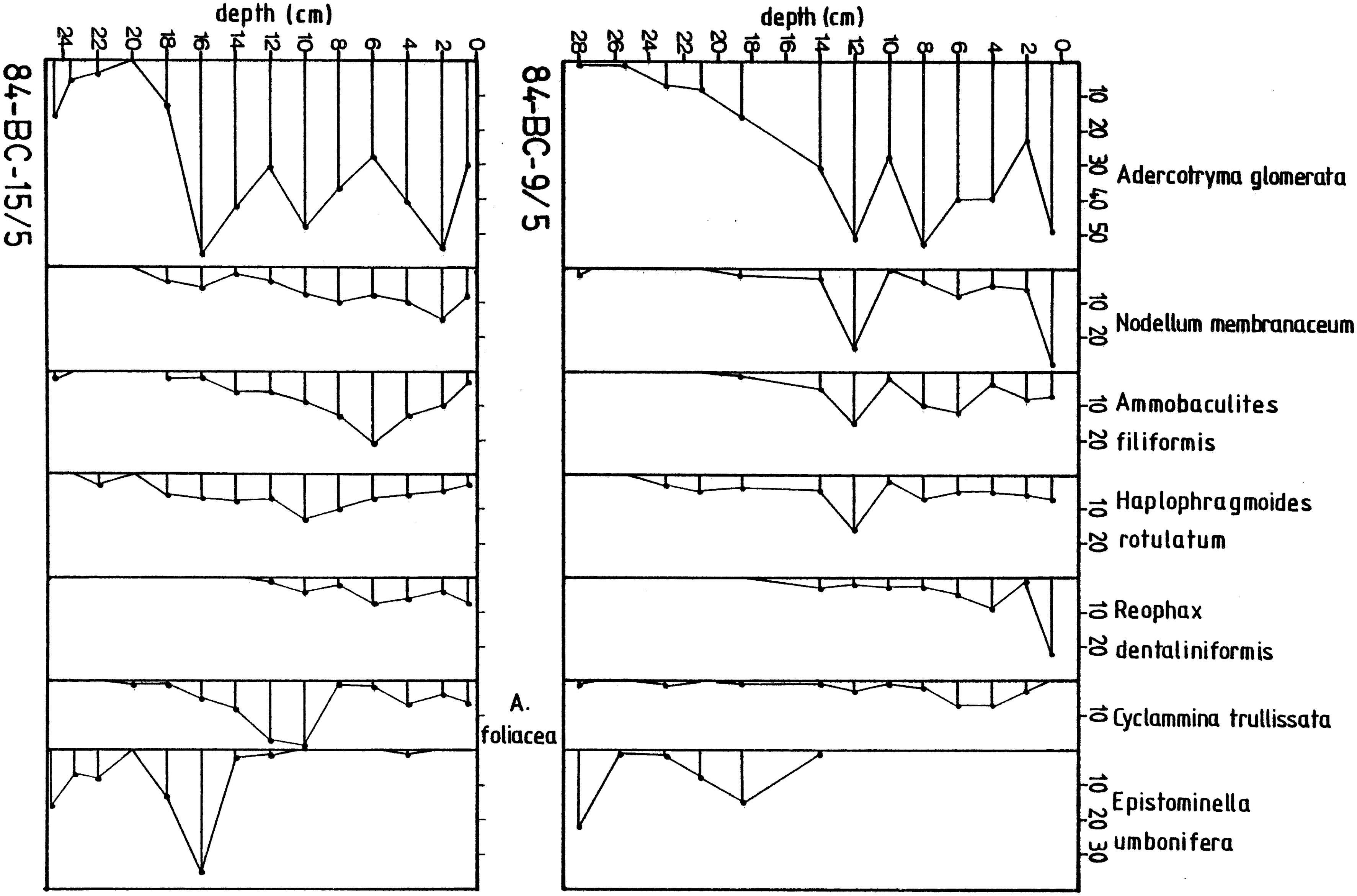
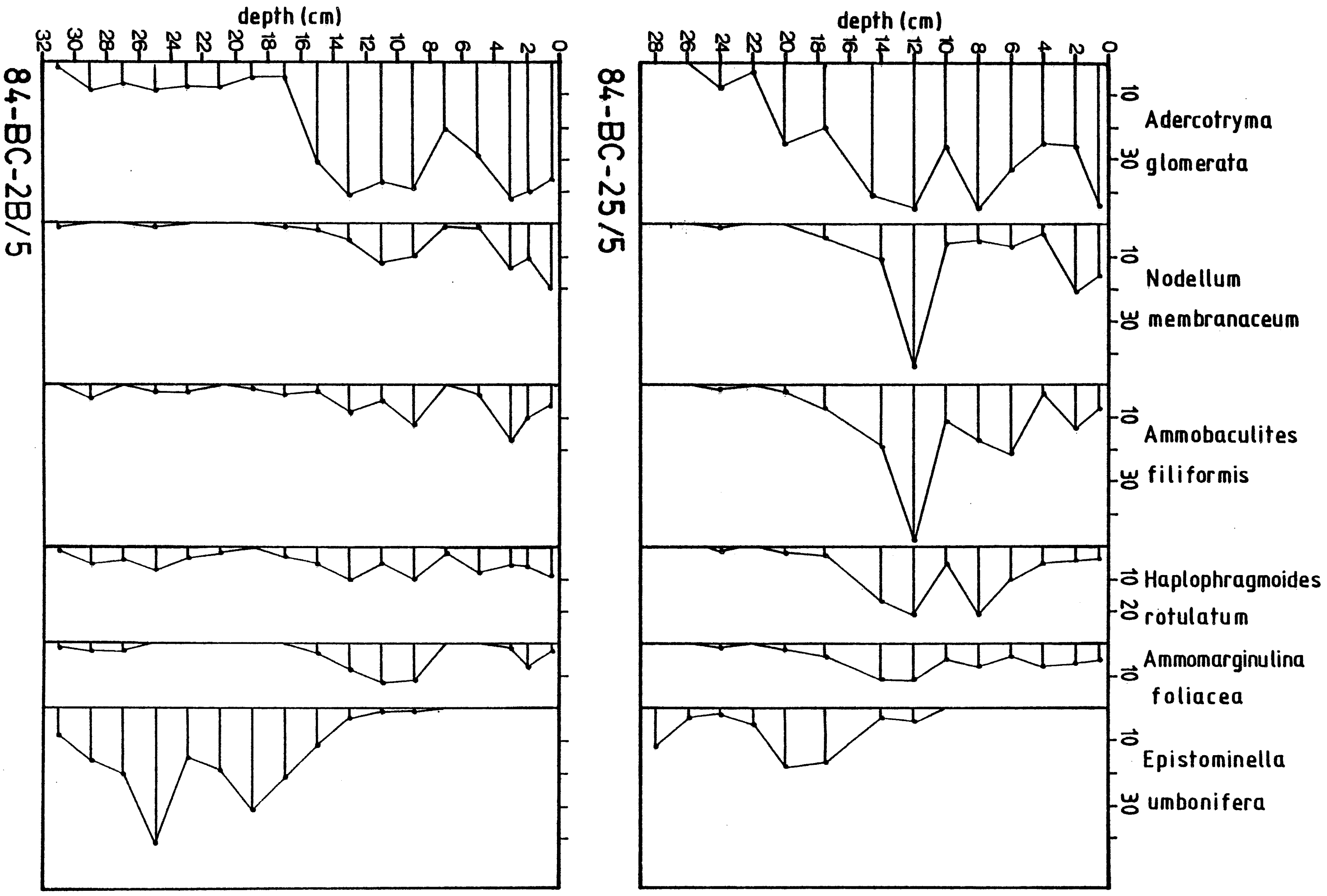

84-BC-15/5
84-BC-9/5
depth (cm)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
10
20
30
40
50
Adercotryma glomerata
Nodellum membranaceum
Ammobaculites filiformis
Haplophragmoides rotulatum
Reophax dentaliniformis
A. foliacea
Cyclammina trullissata
Epistominella umbonifera

Fig. 26: Vertical changes in actual number of selected species per 20cc wet sediment in cores 84-BC-25/5 and 84-BC-2B/5 from the Nares Abyssal Plain.



84-BC-2B/5
84-BC-25/5
depth (cm)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
10
20
30
Adercotryma glomerata
Nodellum membranaceum
Ammobaculites filiformis
Haplophragmoides rotulatum
Ammomarginulina foliacea
Epistominella umbonifera

Fig. 27: Comparison of the vertical changes in actual number per 20cc wet sediment of Adercotryma glomerata in the four studied cores of the Nares Abyssal Plain.

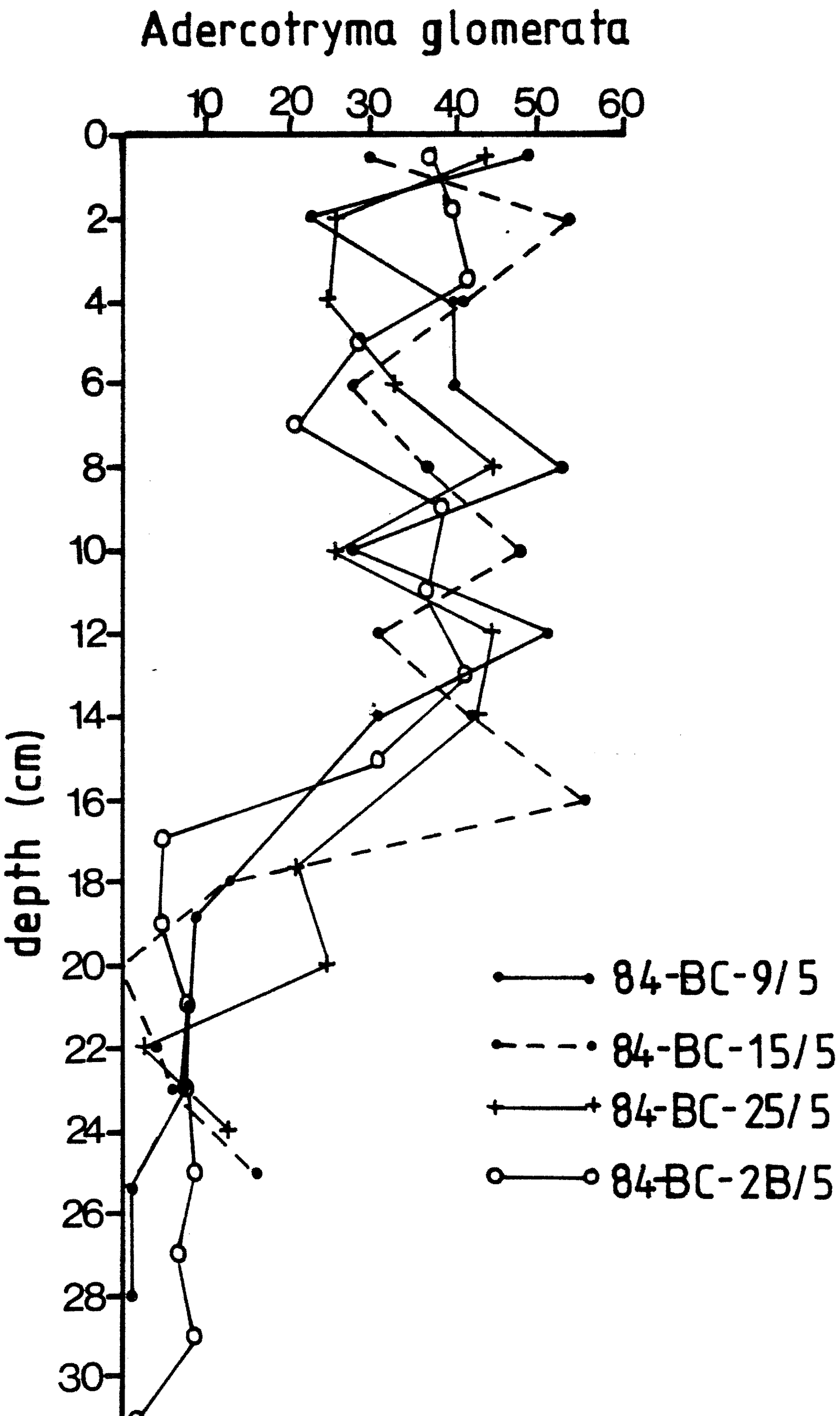
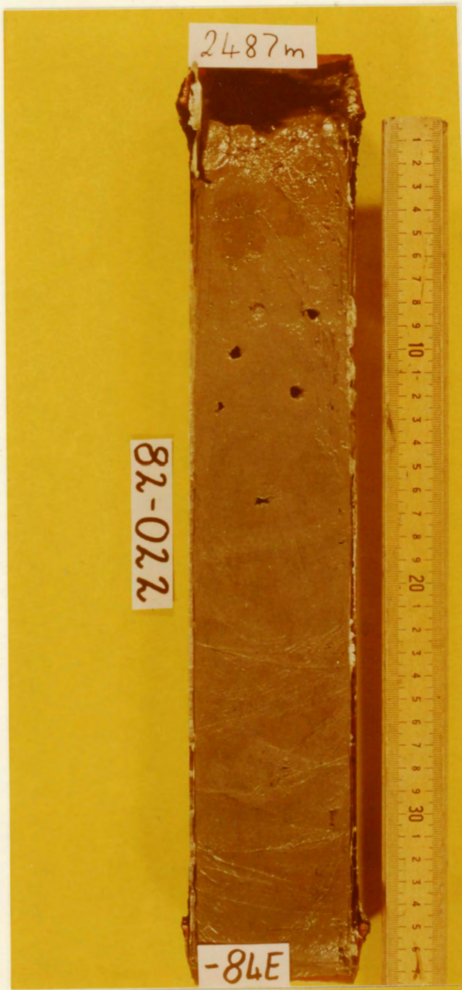

Adercotryma glomerata
10
20
30
40
50
60
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
depth (cm)
84-BC-9/5
84-BC-15/5
84-BC-25/5
84-BC-2B/5

Fig. 28: Photographs of 7 short cores from the sampled transect of the Continental Rise off Nova Scotia. Note the differences in sediment between the quiet depositional regimes (at 2487m and 4925m) and the zones which are under the influence of contour currents (at 2750m and 4490m).


2487m
82-022
-84E


2750m
2996m
82-022
-83E
-82E


3543m
4030m
82-022
-80E
-79E


4490m
4925m
-76E
82-022
-77E

Fig. 29: Vertical changes in number of arenaceous specimens, number of arenaceous species and actual number of selected dominant species per 10cc wet sediment in core 82-022-83/E of the middle Continental Rise off Nova Scotia.

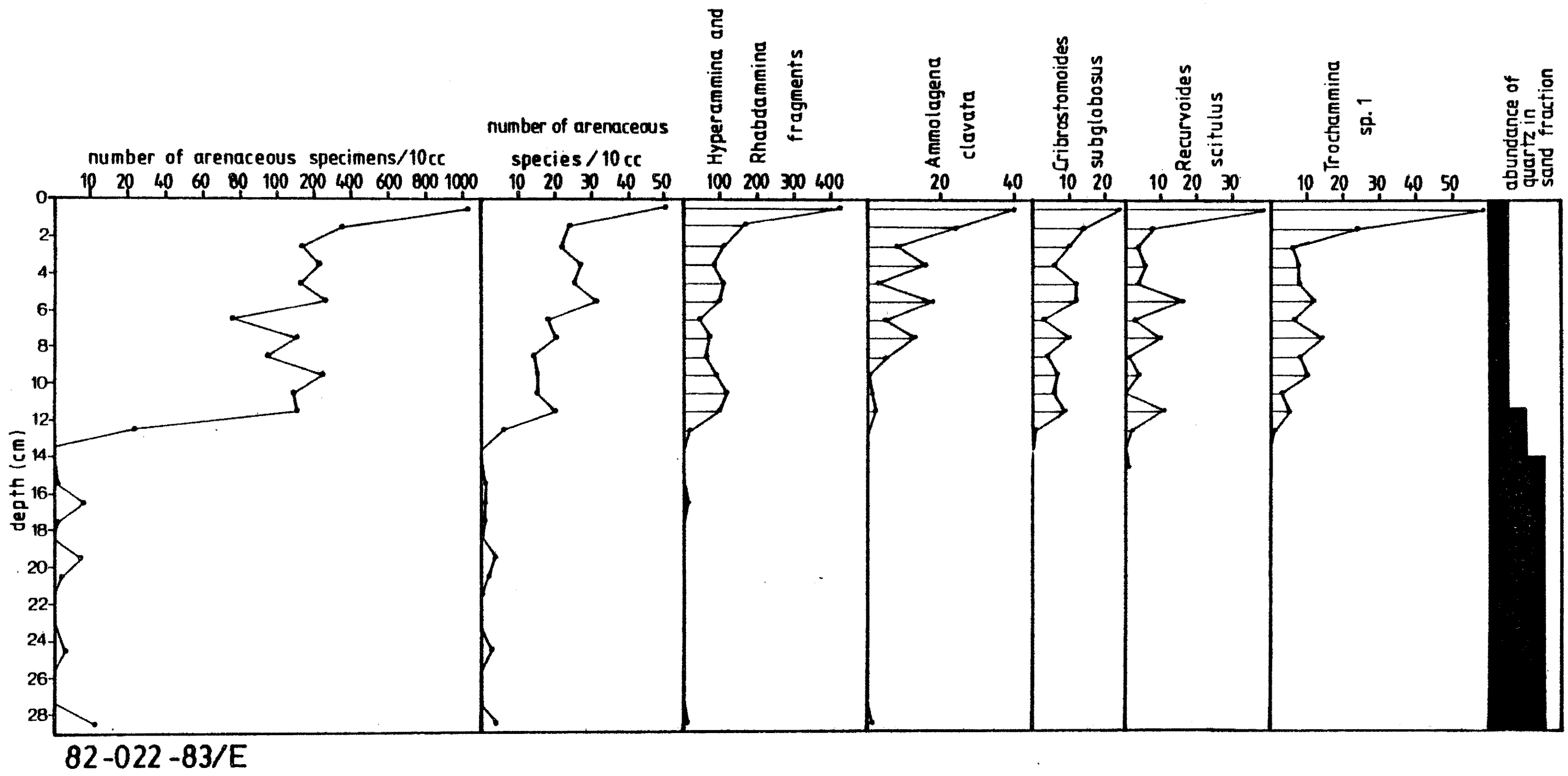

number of arenaceous specimens/10cc
10 20 40 60 80 100 200 400 600 800 1000
number of arenaceous species / 10 cc
10 20 30 40 50
Hyperammina and Rhabdammina fragments
100 200 300 400
Ammolagena clavata
20 40
Cribrostomoides subglobosus
10 20
Recurvoides scitulus
10 20 30
Trochammina sp. 1
10 20 30 40 50
abundance of quartz in sand fraction
depth (cm)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
82-022-83/E

Fig. 30: Vertical changes in number of arenaceous specimens, number of arenaceous species and actual number of selected dominant species per 10cc wet sediment in core 82-022-77/E of the lower Continental Rise off Nova Scotia.

Note the increase in the terrigenous component down core.

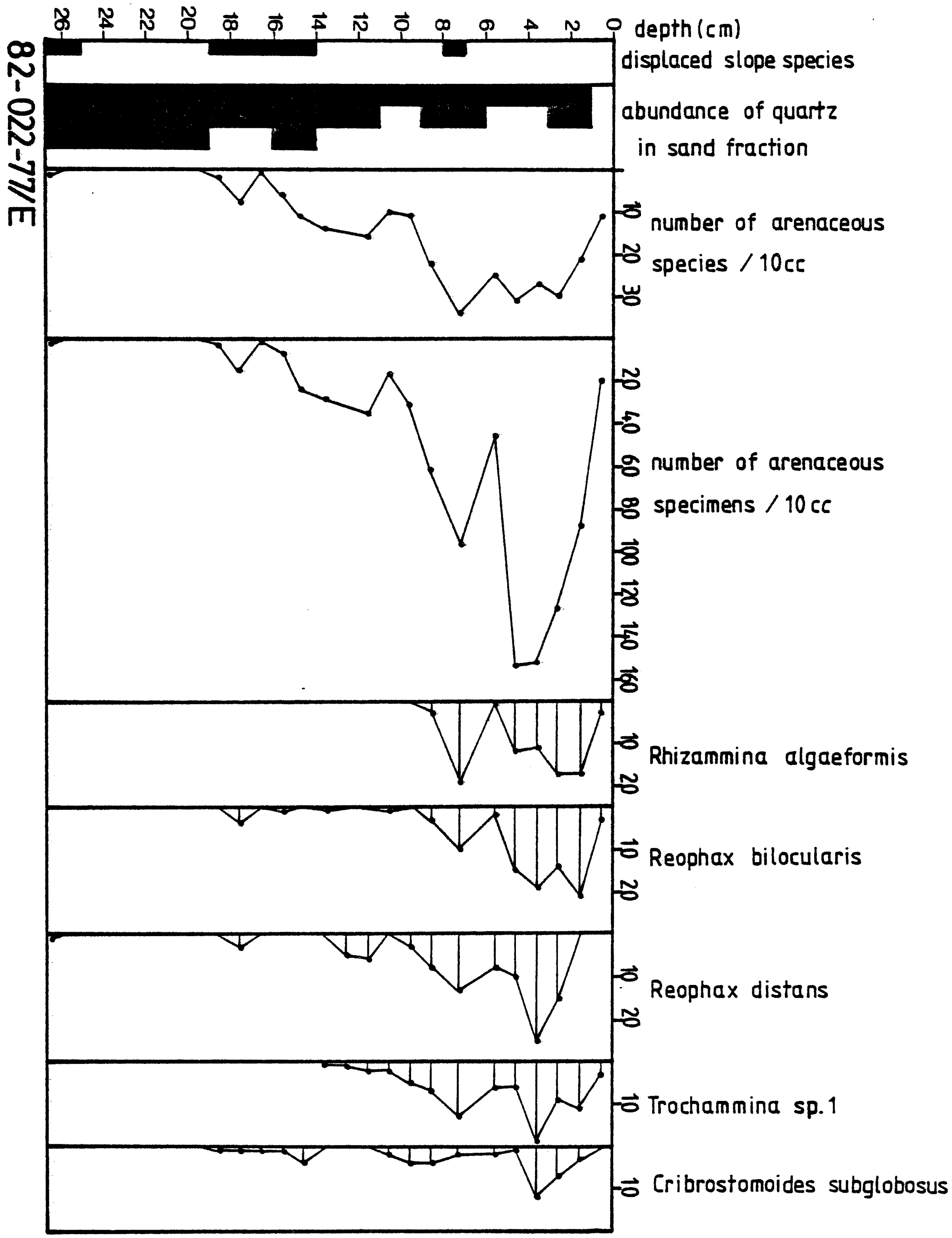
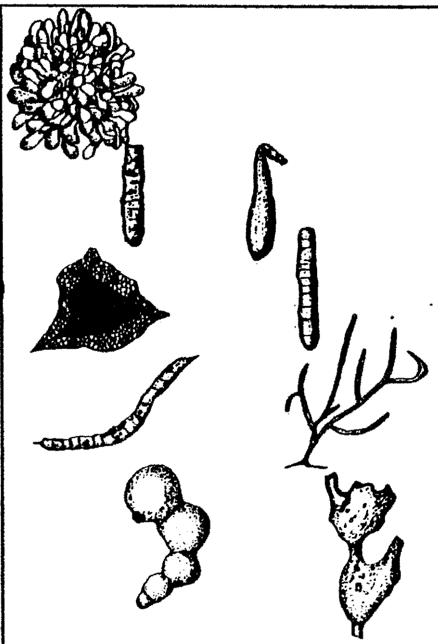
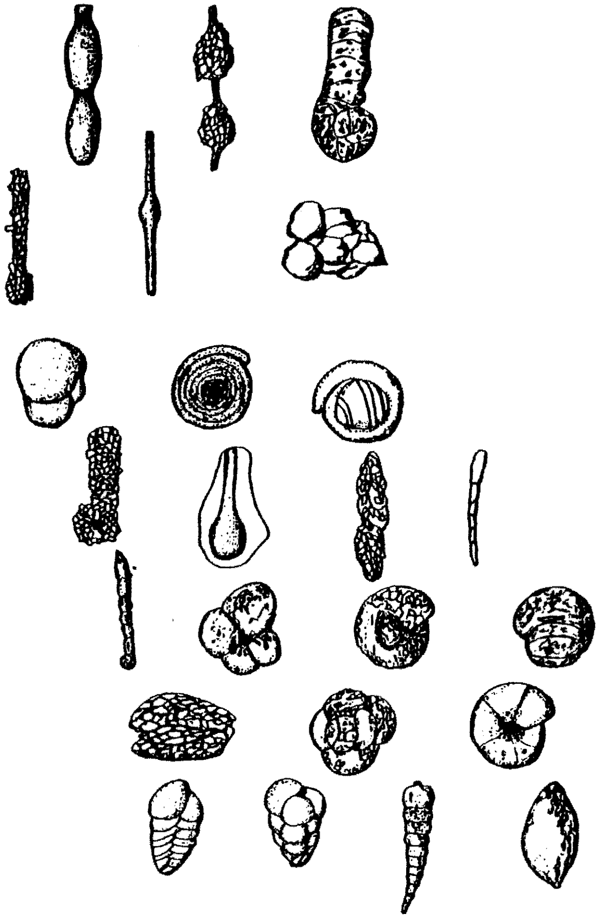

82-022-77/E
depth (cm)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
displaced slope species
abundance of quartz in sand fraction
number of arenaceous species / 10cc
10
20
30
number of arenaceous specimens / 10 cc
20
40
60
80
100
120
140
160
Rhizammina algaeformis
10
20
Reophax bilocularis
10
20
Reophax distans
10
20
Trochammina sp.1
10
Cribrostomoides subglobosus
10

Fig. 31a,b: Potential for fossilization of selected recent arenaceous foraminifera, coordinated in 3 groups. The species are arranged in each category in vertical order of increased test stability with respect to destructive agents.

GROUP A species with flexible tests, most susceptible to mechanical destruction and slight compaction no fossilization potential		KOMOKIACEA *Pelosina cylindrica* *Pelosina variabilis* *Vanhoeffenella gaussi* *Bathysiphon hirundinea* *Rhizammina indivisa* *Dendrophrya arborescens* *Hormosina normani* *Aschemonella scabra*
GROUP B species with loosely cemented wall material, susceptible to compaction low fossilization potential		*Hormosina carpenteri* *Aschemonella ramulifera* *Reophax helenae* *Reophax horrida* *Reophax scorpiurus* *Reophax dentaliniformis* *Reophax bilocularis* *Rhizammina algaeformis* *Hormosina globulifera* *Thurammina papillata*

GROUP C species with firmly cemented tests high fossilization potential	Reophax ovicula Reophax distans Ammomarginulina foliacea Hyperammina spp. Rhabdammina spp. Psammosphaera fusca Cystammina galeata Ammodiscus incertus Glomospira gordialis Ammobaculites agglutinans Ammolagena clavata Karreriella apicularis Nodellum membranaceum Ammobaculites filiformis Haplophragmoides sphaeriloculus Haplophragmoides rotulatum Cribrostomoides subglobosus Adercotryma glomerata Trochammina sp. 1 Recurvoides scitulus Karreriella bradyi Eggerella bradyi Reophax bacillaris Sigmoilopsis schlumbergeri	

Chapter 9: CONCLUSIONS

1. The study of benthonic foraminifera in 25 box-cores collected from the continental rise off Nova Scotia, the Southern Bermuda Rise and the Nares Abyssal Plain, yielded 161 calcareous and 104 arenaceous foraminiferal species. No new taxa were observed.

2. The influence on the substrate of the WBUC and DWBUC along the continental rise of Nova Scotia is reflected in the structure of the foraminiferal community. Under the axis of maximum current velocity of the WBUC, winnowing processes form an artificially concentrated assemblage high in foraminiferal number and species diversity.

3. The area of the DWBUC is characterized by a diminished fauna suggesting a changing substrate through episodic fast sediment deposition and erosion. These conditions seems not to be in favor for a rich benthonic assemblage.

4. The changing substrate over the depth range studied is reflected in the arenaceous assemblage. Fine grained, more fragile taxa prefer tranquil depositional regions, whereas zones with strong bottom current-sediment interactions are dominated by coarse grained, robust tests. This observation may also help by using fossil arenaceous assemblages to interpret typical features of palaeoenvironments.

5. Several arenaceous species such as _Reophax scorpiurus_, _Reophax_

bilocualris, *Psammosphaera fusca* or *Rhizammina algaeformis* are non-selective in their wall material. A large intraspecific variability is shown by comparing specimens of different environments. The size of their tests decreases with increasing water depth. Other arenaceous species such as *Trochammina spp.*, *Recurvoides scitulus* or *Hyperammina elongata* show a stronger preference for certain grain types.

6. The calcareous species form three distinct assemblages on the continental rise off Nova Scotia and appear to be controlled by the regional watermasses:

a. upper continental rise assemblage (2200-2500m), dominated by *Elphidium excavatum*, *Uvigerina peregrina* and *Stainforthia concava* and controlled by the occurrence of NADW.

b. middle continental rise assemblage (2500-3600m), dominated by *Eponides pusillus* and controlled by NSOW.

c. lower continental rise assemblage (4000-4815m), dominated by *Epistominella umbonifera* and *Epistominella exigua* and controlled by AABW.

7. The observation of patchy distribution in benthonic foraminiferal assemblages has implications for the study of fossil assemblages. The analysis of single small sections of an area, derived from cores or wells, might lead to misinterpretations of faunal changes.

8. The species diversity of the living fauna is significantly lower

than in the dead assemblage. The highest degree of resemblance between the live and dead fauna occurs on the abyssal plains as compared to the slope and rise. On the abyssal plains there is less input of reworked species through turbidites and current activity during Recent time.

9. A comparison of the observed depth ranges of arenaceous species in this study with their depth limits known elsewhere in the Atlantic and in the Antarctic Ocean allows the classification of species into heterobathyal and isobathyal groups. The non-selective behaviour of certain taxa implies that there is no restriction on their choice of habitat which consequently results in wide depth ranges for certain forms.

10. The vertical change with depth in the sediment and in the abundance of arenaceous foraminifera illustrates how effects of selective preservation, transport and reworking influence the fossil assemblages. Results also show that significant numbers of arenaceous species do fossilize and can be used as paleoceanographic indicators.

11. A significant decrease in the abundance of species with a ferrigenous cement such as *Adercotryma glomerata*, *Cribrostomoides subglobosus*, and *Trochammina spp.* is correlated with the transition down core from an oxidizing to a reducing sediment.

12. The decrease of arenaceous species in the North Atlantic in subsurface sediments is related to a major change in sedimentation, not

simply non-fossilization of arenaceous species.

APPENDIX

REFERENCE LIST FOR CALCAREOUS FORAMINIFERAL SPECIES

Amphicoryna scalaris (Batsch) = *Nautilus scalaris* Batsch, 1791, Sechs Kupfertafeln mit Conchylien des Seesandes, gezeichnet und gestochen von A.J.G.K. Batsch, Jena, p. 1.

Amphistegina lessonii D'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 304, no. 3, pl. 17, figs. 1-4.

Amphistegina sp.

Angulogerina bella Phleger and Parker, 1951, Geol. Soc. Am. Mem. 46, pt. 2, p. 12, pl. 6, figs. 7,8.

Anomalina globulosa Chapman and Parr, 1937, Australian Antarctic Exped. 1911-14, Scientific Repts., ser. C (Zoology, Botany), vol. 1, pt. 2, p. 117, pl. 9, fig. 27.

Astacolus sp.

Bolivina bradyi Asano, 1938, Geol. Soc. Japan, Journ. 45, no. 538, p. 603, pl. 41, fig. 2.

Bolivina decussata Brady, 1881, Quart. Journ. Micr. Sci., n. ser., vol. 21, p. 58.

Bolivina goesii Cushman, 1922, U.S. Nat. Mus., Bull., no. 104, p. 34, pl. 6, fig. 5.

Bolivina paula Cushman and Cahill, 1932, in: Cushman and Ponton, 1932, Florida State Geol. Survey, Bull. 9, p. 84, pl. 12, fig. 6.

Bolivina pseudopunctata Höglund, 1947, Uppsala Univ., Zoology, Bidr., vol. 16, p. 273, pl. 24, fig. 5, pl. 32, figs. 23, 24, textfigs. 280, 281,287.

Bolivina pulchella D'Orbigny, 1839, in: De la Sagra, Hist. Phys. Pal. Nat. Cuba, "Foraminifères", p. 150, pl. 1, figs. 23.24.

Bolivina pusilla Schwager, 1866, Novara Exped. 1857-59, Geologischer Theil, vol. 2, pt. 2, p. 254, pl. 7, fig. 101.

Bolivina striatula Cushman, 1922, Carnegie Inst. Washington, Publ., no. 311 (Dept. Marine Biol., Papers, vol. 17), p. 27, pl. 3, fig. 10.

Bolivina tortuosa Brady, 1881, Quart. Journ. Micr. Soc., vol. 21, p. 57, fig. Rept. Challenger Exped. 1873-76, Zoology, vol. 9, p. 420, pl. 52, figs. 31,32.

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Cibicidoides spp.

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Dentalina sp.

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Fursenkoina sp.

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Lagena spp.

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Quinqueloculina sp.

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Table 2

	NOVA SCOTIA RISE																																									BERMUDA RISE																	NARES ABYSSAL PLAIN																																									
Sample	2					84					83					82					80					79					1	77					2	76					4					17					35	38	3					1	2	32					18					25					09					08					23					23					15				
Depth (m)	2225					2 87					2750					2996					3543					4050					4185	4499					4815	4925					4180					4290					4380	4426	4440					5664	567	5719					5768					5775					5775					5775					5775					5777					5779				
Subsample	1	2	3	4	5	A	C	E	G	I	A	C	E	G	I	A	C	E	G	I	A	C	E	G	I	A	C	E	G	I	1	A	C	E	G	I	2	A	C	E	G	I	1	3	5	7	9	1	3	5	7	9	2	2	1	3	5	7	9	1	1	1	3	5	7	9	1	3	4	7	9	1	3	5	7	9	1	3	5	7	9	1	3	5	7	9	1	3	5	7	9	1	3	5	7	9	1	3	5	7	9
Total number of specimens/10cc	363	518	376	400	349	402	373	407	287	768	3700	3947	2664	3448	1973	1302	554	692	390	1401	1193	989	1332	1651	1190	3369	957	2091	1733	1524	505	106	32	33	53	44	225	148	139	186	136	115	329	828	634	528	321	356	341	661	340	353	15280	4549	768	180	188	366	161	281	355	116	252	152	135	160		58	41	44	72	222	230	122	106	157	158	154	176	185	111	178	179	177	202	211	88	239	163	148	179	190	274	173	232	81	133	62	75	110	139
ALLOGROMIIDAE																																																																																																									
Nodellum membranaceum																																											3				X	X	3		2	3			X				1			17	11	14	17	5	1	1	1	1	3	4	5	7	6	5	9	6	3	2	3	3	4	6	4	4	8	8	6	7	8	7	3	3	9	3	4	5	6	6	2
Placopsilinella aurantiaca	X						X	X				1	1	X	X	X	X	X	X	X	X	X		X	X	X		X	1	X	X												X													X																																																			
Thalamophaga ramosa																																																		|X|			|X| |X|																																																
ASTRORHIZIDAE																																																																																																											
Astrammina sphaerica		1		X																																	X																																																																		
Astrorhiza arenaria									|1|																																																																																												
Astrorhiza crassatina								X			2	1	1	2	X	1	1	1	1	2	2	5	4	4	10		1	1	1	1	1																																																																										
Bathysiphon hirundinea			X			X	1																						X																																																																											
Bathysiphon spp.							X		X	X	X			X				X	X				X					X											X				2	X											2	X							X	X						X	X	X	X	X			X			X						X		X		X	X	X		X				X				X
Dendrophrya arborescens																													X	X						2						X	4	8	2	10		2	1		2	5			9	4	6	2	3																																										
Dendrophrya sp.																																																													X	1	1	4	2								X	X	X		X	2	2	1	X	X	X				2	3	X	X	4		4			X		X			
Hyperammina elongata				X		2	1	1	1	1	2	1	1		1	X					X	1		1		1	1	1		1	1			2			3		1	1	2	1																																																															
Hyperammina laevigata			X			X	X	X	X		X																																																																																														
Hyperammina subnodosa																																																						X																																																		
Hyperammina sp. 1	X	X	2		2	1	1	4	3	3	2	8	2	3	6	2		2	2	3	6	2	2	1	4	2	2	2	6	4	2																															X		X	X		X		X	X	X	X	X	X	X	X	X	1	X	X	1	X	1	X	1	X		1	X		1		1	1	X		X	1	X	X	X	
Hyperammina sp. 2																																						X				X																				X																	X															X								
Jaculleia obtusa										X																																						X			X																																																					
Rhabdammina abyssorum																		X																																						X																																																			
Rhabdammina agglutissima											X		1	1	1						1			X																																																																															
Rhabdammina cornuta								X															1		1																																																																																
Rhabdammina discreta							X					1	1	X		1	1	1	1		1	3	2	1	2																									X							X																																					X								
Rhabdammina irregularis											X					1			1	X						X				1																																																																									
Rhabdammina linearis						X						X	1	X				1		X			X																																																																															
Hyperammina or Rhabdammina fragments						6	1	3	3		18	8	12	15	13	4	7	4	6	4	11	12	14	18	19	8	7	3	10	6								4			4			X		X									X	X			X																																														
Rhizammina algaeformis	19	10	17	21	20	10	18	26	18	18	2	1	1		1	3	4	4	11	7	1	1	1	1	3	X	3		2	1	1	15	12	41	60	60	17	44	33	51	26	52	37	26	8	15	10	41	42	12	31	15	X	3	28	9	25	24	10	9	5	27	47	15	26	7		15	10	8	2	43	43	41	31	34	16	30	30	9	19	20	27	16	42	42	27	40	54	48	45	49	48	57	42	63	18	38	23	21	21
Rhizammina indivisa			X								X			X		X			X	X					X						X				X		2							X												X																																																		
Saccorhiza ramosa																					X									X	X							1	2	1	1	7		3		1	1		X	X	X	X			7	2	2	2	5	9	26	7	5	13	11	13	18	10	14	8	13	2	3	3	8	3	7	6	5	9	7	5	2	7	4	7	8	4	6	5	3	10	3	6	6	7	10	6	10	7	5
Vanhoeffenella gaussi																																																			X																																						X				X							
SACCAMMINIDAE																																																																																																											
Lagenammina tubulata																																					X						X									X	2				2	X					X	X	X	X	X	3			2	X	X	1	X		X	1	X	X	1	2	X	1	X	X			1	X	X	X	X		X	X	X	1	X	3	X	X
Pelosina cylindrica											X																																												X																																																					
Pelosina variabilis	X					X			X							X					X		X	X																			X																							X																										X								
Pelosina variabilis var. constricta																																																																2																		X						X		X										X		X		
Pelosina sp.		X	X			X			X		X									X			X			1	2			X			X		X		1	1	X										1																																																							
Psammosphaera fusca			X						1		1		1	1	1					X	X		1	1				X	1	1	X	1					2													X																																																							
Saccammina atlantica																			1	1				1						2																																																																									
Saccammina sphaerica	X		X			X			X		1		1		2		X	X	X	X	X		X		1		2	1	1									1		1						X																															1																											
Technitella legumen																																										X																																																																	
Technitella flexibilis																																																																													X			X																										
Thurammina papillata		X								X											X			X																				X		X		X							X	X	X	X	X	X	1	X		1	1	X	2	X	X	X	2	1	X	1	3	5	1	2	2	2	1	X	X	X	X	X	X	X	X	X		X	X	3	2	X	X	X	X	X	X
Thurammina cariosa		X																																																												3																																												
AMMODISCIDAE																																																																																																										
Ammodiscus incertus																				X		X			X						X						1								X			X			X	X					X		1	2	X	X		X	X	X	1	X	2	3	1	1	1	1	X	1	1	1	X	X	X	2	1	2	1	X	1	X	1		1	1	2	1	X	X	1	X	X	X	X
Ammolagena clavata											1	1	2	1	1						X					X		X		X									X				X	X		3	X	X	1	X	1	2		X	1	6	3	X	4																																														
Glomospira charoides		X				1	1	1	2	1	X	1	1	X	1		1	1	X	X	1		2	1	2	X				X							X						1					X		X		X							X	2									1	X	X																															
Glomospira gordialis	X	X	X	X		X	X		1	1	X								X	X	1	1		1	1																			X		1			X			X					1	X	X		X																X		X		X	X		1	X	X			X				X		X			X			X			X	X
Lituotuba lituiformis																																																																																X									X													X				
Tolypammina vagans											X	1	1	1							X	X	X	X	X																								X											X	1	X				X			X	X	X		X	X	2	1			X	X		X	2			X	X	X	X	X		X			X		1	X	X	X	X
HORMOSINIDAE																																																																																																											
Aschemonella catenata																				X																																																											X																	X				
Aschemonella ramulifera																	X												X		X													X							X		X			X			3				X	1								5			X	X		2	1	X	X	1			X	X	X			1	1		X				3	X			X	
Aschemonella scabra																																1	5	5			3		1		2			X			X		X							X			X	X		1	X	2	3	X	27		X	X	2	3	X	X	3	X	X	3	X	2	3	4	3		2	3	4	2	3	1	2	1	3	1	1	X	X	X	X	X	X	2
Hormosina carpenteri																																																									X					X							1		X		X					1	X			X				X	X				X		X		X		1		2			
Hormosina globulifera	X	X					X												1			X			1					1																		X										X	X			X						X		X	1					X		2					X		X	X	X		X			X		X			X		X			
Hormosina normani																																																													1														X																													
Reophax bacillaris											X	1	1	1	1	2	3	1	2	2	1	1	1	1	1	1	1	X	1	1	X																																			X																																								
Reophax bilocularis					X	X	1	X	1	1	X	X			X	1	2	1	1	1	1	2	1	X	1	1		1	2	1	6	2	1	1		2	3	8		1	1	2	2	6	2	3	7	X			X	X	X	X	2	1	4																																																		
Reophax cylindricus																			X																																							X	X																			X																										
Reophax dentaliniformis							1	1	X							1	1	1	1	1	1	1	1	1	2	X		1	X	X		7	2	4	5	7	2	13	6	10	17	8	3	X		3	2	X	2	X	2	1			2	2	3	2	2		1	5	6	4	5	7	6	1	3	2	4	4	3	2	6	1	4	2	6	2	7	5	3	4	3	3	4	5	3	3	2	2	2	3	6	6	3	2	2	3	3
Reophax distans							1				X					1	1		1		1	1	1	1				1		X	1						X	X			X		X	X	X	X			X		X			X				X	1						1												X		1	2		X		3		X									X		X			X				
Reophax fusiformis						X	X		X	X							X	X	X	X		X				1		1	1	1																																																																											
Reophax guttifer	2	X		X			1			1	X					X	X		1	1							1	1				1					X						X	X	X							X			2				X			X			X	X																		X																					
Reophax helenae																																												X				X													X	X	X	X	X	3	X						1	X	X	X		X	X					X			2		X	X	X		X	X	X		2	X			X	X
Reophax horrida																																															1	X				X			1	2	X		X			1	1	X		X			X	X		X	X		X	X	2	X	X		X	1	X	2		X			X	X	X		X		X	1	1	X		1	X
Reophax nodulosus																				X																		X						X	X				X			X			1		X	2							X		X	X	1	X	X			X	X	X	1	X	X	X		X	X	X	X		X	X	X	X		X		X		X	X		1	2	1
Reophax ovicula																																2	1		1	1	1	2		1	1	2	2	X	X	1	X	X			1	X	X		1	X	2		X		1	3	6	6	6	5	4	4	4	6	6	3	3	4	3	3	4	3	6	4	4	6	4	6	1	3	6	2	2	4	4	2	X	3	4	X	2	7	4	5	4
Reophax pilulifer					X	X			X		2	1	1	1	1	1	1	1	1	1	2	1		1	1	X	X			1	1										X		X					X				X	X	X					X																																														
Reophax scorpiurus	X	1	X	1	1	X	1		1	1				X		X					X			X		1	1	1	1	1	X	2	12	14	2	2	2	15	46	20	14	13	3	2	6	3	2	2	X	3	1	1	X		3	5	7	10	7													X					X	X	X										X														
Subreophax adunca	X				X			1		1	1		1				1	1	1	1	1	1		1	X	1	X	1			2	1	1				2			X			2	1		1	1		1	X	1	X	X	X	2	X	3	1	3		2	1	1	1	X	X	X		X	X	X	2	2	1	X	1	2	X	X	X	X	X	2	2	X	1	2	2	X	1	X	X	X	X	X	X	X	X	X	X	X
LITUOLIDAE																																																																																																										
Adercotryma glomerata						1	2	1	X		X	1	X	1	1	3	2	2	2	1	1	X	1	1	1	1	1	1	1	1		1	1	3	1	2	5	4	4	4	12	5	3	2	3	2	2	8	9	1	5	5	1		6	6	6	5	12	32	37	18	8	15	12	18	28	33	32	34	24	16	15	18	16	22	17	13	14	31	22	18	20	21	14	11	20	14	11	10	14	11	7	11	12	19	24	20	20	22	32
Ammobaculites agglutinans						1	1	1	2	2	1	1		1	1	1	2	1	1	2	1	1	1	3	1	2		1	1	1		X																																																																						
Ammobaculites filiformis																																											X	1	1	X	X	2		2				X	2	1		X	1	X	1	2	1	2	3	3	1	3	4	1	3	X	3	2	3	4	1	2	3	2	3	5	3	2	2	3	3	2	2	2	2	1	1	2	2	3	3	2	2	2
Ammobaculites sp.																																											X				X	1	X		X	X				X			X	1	X	X	2	2	6	2	4	3	1	X	2	X	3	2	4	4	4		4	2	3	5	6	2	4	4	3	2	1	2	2	2	1	3	2	3	3	5	4		2
Ammomarginulina foliacea						1		1	1	1	1			1	1	1	1	1	1	1	1	2	2	1	2	1	1	1	1	1	2		1			1	2	1	1	3	3	3	X	X	X		X	X		X	X				2	1	X	1	1	5	4	2	X	3	1	1	5	4	2	5	3	2	2	2	2	3	3	2	2	4	4	3	4	3	1	2	1	1	1	2	1	1	2	2	2	3	5	2	4	5	3
Ammomarginulina foliacea f. recurva																																																	X	X	X					X		X	X	X	X	X			X	1	X	1	X	2	1	1	1	X	X	2	X	1	X	1	2	2	X	2	1	1	1	X		X	2		2	X		2	2	1	2	2
Cribrostomoides crassimargo																							X	X	X		X	X																																																																									
Cribrostomoides ringens										X	1	1	1	1	1				1	1	1	1		1		1		X	X	X	X						X							X				X	X			X				X																																																	
Cribrostomoides subglobosus						1	1	X	1	X	X	1	1	3	3	2	3	3	2	1	6	1	7	5	7	1	4	2	3	3	2	1		X	X	X	1				X	X		X	X	1	X			X		X		X	1		X	1			X						2	X	1	X	1			X		X	X		X																								
Cribrostomoides weddellensis																										X			X		X																																																																										
Cribrostomoides wiesneri	X	X	X	X						X	X		1					1	1	1	1	1	1	1	1	1	1	1			X	1	1	2	1	1				X																																																																			
Cribrostomoides sp.			X																																																																																																							
Cyclammina pusilla										|X|																																																																																											
Cyclammina trullissata		X			X							X			X							X				X	X		X	X	X										X				X	X	X				X	X			2		X	X	X	4	3	X	X	2	1	1	X	4	2	3	2	X	1	2	3	1	1	2	1	3	2	3	3	4	4	2	3	1	2	3	1	2	2	X	X	3	2	2	1	3	5
Discammina compressa																																					1												X								X			X	X	X	X		X	X	X	X		1	2	1	X	X	X		2	2	1			X	X		X	X	X	2		X		2	X	X							
Recurvoides scitulus	X	1	1	1	X	1	1	1	3	1	2	2	2	3	1	1	1	1	X	X	2	1	2	1	1	X		X	X	X	X	X	X			X	X			X	X																																																																
Recurvoides sp. a																																											X				X		X							2		X	X									X			1			X	X				X	X		X		X							X										X	X
Haplophragmoides canariensis										X	X	X							X	X	1	1	X	X	X	1	X	1	X						X					X			X	2	X	X	2	X	X	X	1	2			1		2	X	X																																														
Haplophragmoides coronatum																									X						X													X	X									X	X	2			X																																														
Haplophragmoides rotulatum																																												X						X			X			1	1	X	X	4	5	3	2	3	2	2	4	4	4	3	4	2	4	1	4	2	5	4	2	5	4	6	3	6	5	4	2	2	3	2	2	2	2	2	1	4	4	X	2	8	4
Haplophragmoides sphaeriloculus									X		2	1	1	1	2	X	1	1	1		1	2		1	1	X	X	1	1	1		X	X				X						X		X	X	X			X														X			4	X	X	X	1	X				X				X		X									X	X		X			X		X	X	
TEXTULARIIDAE																																																																																																											
Spiroplectammina biformis																																																X								X			X				X	X	X	X	X	X								X		X		X	X			X	X	X	X	X	X		X	X	X	X	X					X	X	
Textularia wiesneri						X	X		X	X		X		X	X	X	X			X		X	X		X														X																																																																			
TROCHAMMINIDAE																																																																																																											
Cystammina galeata																																X	X	1			X	1	1		3	1	X	X	X	1	2	X	1	X	2	1	1	X	2	2	2	2	2	5	3	2	1	1	1	2	4	2	2	3	2	1	2	X	2	5	2	1	1	2	2	2	3	3	4	2	2	X	1	1	1	2	2	X	X	3	3	X	2	4	5
Cystammina pauciloculata					X	1	2	1	1	1	1	2	1	1	1	X	1	X	1	1	X		X					X			X						X						X	X			X			X				X				X																																															
Portatrochammina sp. 1						X	X							X	X	2	1	1	1		2	1	1	1	2		X	X		1																																																																									
Trochammina globulosa											1	X		1								1		X	X		1																																																																															
Trochammina cf. globigeriniformis						1	1			X	5	3	3	2	5	1	1	1	1	1	1	1	1	1	2	2	3	2	4	1	1		X			X	X									X			X	X	X					1		1	1	X	1																																				X							
Trochammina cf. squamata						X	X				X	X	X		X	X	X	X	X	X	2	2	1	1	2	1	1	X	1	1	X						X								X					X						X																																															
Trochammina sp. 3												1				1	1	1		1			X		X			X								X				X				X																																																															
Trochammina sp. 4																																							X	1	3	1	X	X	1	3			X	2	X	2			1	X	X	X	2																	X					X			X																					
Trochammina spp.							X			X	X	X								2	1							X	X	X	X	X					1	X	X		X	X	X	X	X	1	2			X				X	X		X		X																																														
ATAXOPHRAGMIIDAE																																																																																																												
Clavulina mexicana																															X																			X								X																																																
Eggerella bradyi			X				X				X			X	X				X	X			1		5	1	1	2	3	1	2	X					X								X	2	X			X	X			X		1	2	X	1														X	X							X			X	X																					
Eggerella propinqua															X					X																																																																																				
Eggerella scabra												X						X			X		X	X	X		X		X		X																X			X																																																									
Karreriella apicularis																1	1		1	1	2	1	1	1	1	1	1	1	1		X						X						X	X		X			X		X	X		X	1	X	1		X																																															
Karreriella bradyi			X								1	1	1	2	1	1	1		1						X					X			X																																																																												
Karreriella novangliae											X									X			X	X																																																																																		
Martinottiella communis							X													X																																																																																							
MILIOLIDAE																																																																																																											
Sigmoilopsis schlumbergeri	X	1	X		X	2	2	2	1	1	1		1	2	3	1	2	1	1	1	1	1	1	1	X																																																																																			

Table 3

	NOVA SCOTIA RISE																																										BERMUDA RISE																	NARES ABYSSAL PLAIN									
Depth (m)	2225					2487					2750					2996					3543					4050					4185	4499					4815	4925					4180					4290					4380	4426	4440					5664	5670	5719	5768	5775	5775	5775	5775	5777	5779
Sample		2				84					83					82					80					79					1	77					2	76						4					17				35	38		3				1	2	32	18	25	9	8	23	23	15
Subsample	1	2	3	4	5	A	C	E	G	I	A	C	E	G	I	A	C	E	G	I	A	C	E	G	I	A	C	E	G	I	1	A	C	E	G	I	2	A	C	E	G	I	1	3	5	7	9	1	3	5	7	9	3	2	1	3	5	7	9	1	1	C	C	C	C	C	C	C	C
Amphicoryna scalaris																																													X																								
Amphistegina lesonii																																											X		X									1															
Amphistegina sp.																																													X																								
Angulogerina bella																																																					X	X															
Anomalina globosa																									X																												X																
Astacolus sp.																			X						X																						X	X					X	1											X				
Bolivina bradyi																											X	X																																									
Bolivina decussata		X		X		2		X		X		X	X	X		X	X			X				X				X														X																X											
Bolivina goesii																																					X																																
Bolivina paula																																											10	5	17	11	9	12	10	16	9	16		13	1	6	1	7	3										
Bolivina pseudopunctata		X			X																																X						X	X		2	X	2		X	2	1		1															
Bolivina pulchella																																													X		1			X	2	X	1	2															
Bolivina pusilla											X																																		X																								
Bolivina striatula			X																																																																		
Bolivina tortuosa																																											6	5	7	6	6	6	4	7	4	5	7	10		1	X	1	3										
Bolivina sp.				X									X		X		X				X									X	X		X	2	X							X						X		X			X	1															
Brizalina sp.																																													X			X																					
Bulimina aculeata																																				X																																	
Bulimina elongata																						X			X																																	X											
Bulimina exilis																										X																																											
Bulimina gibba																										X																																											
Bulimina laevigata																																																		X																			
Bulimina pupoides																																																						1															
Bulimina striata var. mexicana	X	X	X	X	X		X		1	X		X																																		X	X						X					X											
Bulimina sp.			X																																																																		
Cancris oblonga																																																		1																			
Cassidulina carinata												X	X		X	X	X	X				1			X				X	1					X											X																							
Cassidulina laevigata																										X																			X									1															
Cassidulina norcrossi																																													X					X																			
Cassidulina subglobosa			X				X				1		1	X	1	X	X		X	X		X			X	X	1	1	X	X	X	1					X	X				X	X	3		1	4		X	1			X	2		3	X	2	1										
Cassidulina sp.											X									X					X																												X																
Cassidulinoides mexicana																																													X					X				X															
Chilostomella oolina		X	X	X	X		1		X	X							X			X					X	X					X				X										X											X													
Cibicidoides bradyi																																											X		1	X				X		X	X			X	X												
Cibicidoides kullenbergi											1	2	1	3	2	X	1	1	X	1	X	1	X	X	X						X																																						
Cibicidoides cf. lobatulus										X	X							X		X	X	2	X		X		X			X		X	X										X		3	2	1							1	1		X	X											
Cibicidoides robertsonianus		X					X	X		X	1	1	2	X	X		1	X	X	1	X	1	1	1	X	X	X	X																		X	1				X																		
Cibicidoides rugosus																																											X	2	3		3							1															
Cibicidoides wuellerstorfi		X			X	X	X	X			2	2	2	1	2	2	2	3	2	2	3	6	3	2	2	3	1	3	2	3	5	X		2			2						X		3	2	2	1	1	X	2	3	X	1	3	6	X	X	2				1						
Cibicidoides cf. wuellerstorfi																											1			2																																							
Cibicidoides spp.									X	X	X	1	2		X	1	2	X	2	X	4	2		1	1	1	1	3		1	1	X	1	X					X		X		X		X					2				2						X	X	X		X		X			
Cyclogyra involvens											X																																																										
Cyclogyra planorbis								X		X																																								X			X	1															
Dentalina filiformis																																																										X											
Dentalina intorta																																																																			X		
Dentalina ittai											X																				X																																						
Dentalina sp.							X					X		X															X				X												X		X				2	X			X	2		2											
Discorbis bertheloti																																											X	4	X	2	6	2		4	X	1	15	15				X											
Discorbis floridensis																																											X	1	1	3	2	X		3	X	1	3	1				X											
Discorbis williamsoni																																																						1															
Ehrenbergina spinea																																												X		X							X	1	X														
Elphidium crispum																																															X																						
Elphidium excavatum	47	48	51	44	54	25	23	21	23	24	X			X	X	X				X						1		X	X	X	X																																						
Elphidium spp.																																													X		X			X			1	2															
Epistominella exigua			X			X	1				1	4	3	1	1	2	2	3	1	2	3	1	4	1	3	7	9	9	7	7	6	12	9	2	6	3	5	X	X	X	X	1	X	1			X	X		X	X	X		1	X		X		X				X						
Epistominella umbonifera											X	X	X	X	X	X		X	X	X	5	5	4	3	2	28	30	33	24	36	34	15	17	11	8	8	22		1	X	3	1	X	4	4	5	9	3	3	2	4	3	X	1	3	4	8	2	7				10	X		X	X	X	X
Eponides punctulatus																										X																																											
Eponides pusillus				X			X			X	4	4	4	2	3	13	11	7	9	9	8	13	7	5	5	X	X	3	1	X							X								X					X				X	X	X		X		X				X					
Eponides regularis			X	X			X			X	2	2	2	2	1	1	1	1	X	3	1		1	1	X	1	X	X		X	X	1			2			X	X	X	X						X		X	X	X	X	X	X		1			X				X		X				
Eponides repandus																																													X					X			X	2															
Eponides tumidulus											1	2	2	4	2	1	3	2	1	1	1	X	1	1	1		X		1			X					X									2						X				3		X		2			X		X				
Fissurina spp.	X		X	X	X	1	1	X	1	1	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	X			X	X	X	X		X					2	1	3			X	X	X	X	1			1	1	1				X						
Francesita advena												X															X				X																																						
Fursenkoina compressa				X																																																	X																
Fursenkoina fusiformis					X	1	X	X	X	X	1	1	2	2	X	X	X	X	1								X			X		2						X					X					X	X			X																	
Fursenkoina sp.																				X				X																																													
Globobulimina auriculata			X				2	X	1	X				X	X	X	X	1	X	X			X	X	X	X	X			X		X		X	2							X																											
Globobulimina pacifica	1	2	X	X	1	X	1	X		X	X					X		X		X		X			X																																												
Globulina sp.																				X							X																																										
Guttulina sp.																																																																					
Gyroidina lamarchiana											X		X	X		X	X	X	X	X	X	X	X	X	X	X	X		X	X	X																																						
Gyroidina neosoldanii												X		X		X	X	X	X	X	X																									X			X																				
Gyroidina orbicularis							X				X	1	X	X	2	1		X	X	1	X	1	1	X	X		X	X	X		X	X	X				X				X	X		X													X												
Hoeglundina elegans	X	X	X		X	4	4	3	3	2	3	1	5	3	5	3	8	7	6	6	3	2	4	3	2																						X																						
Islandiella teretis																														X		X																											X										
Lagena clavata																																X																																					
Lagena gracilis												X			X	X	X	1	X						X							X	X										1														X												
Lagena hispida	X				X								X	X	X	X		X		X					X		X																					X	X									X											
Lagena meridionalis										X	X		X							X										X																																							
Lagena mollis																				X																																																	
Lagena stelligera					X							X		X		X	X		X			X																		X							X			X																			
Lagena sulcata											X															X						X											X													X													
Lagena spp.			X						X		X		X	X	X		X	X						X	X		X	X		X	X		X	X		X	X	X	X			X								X			X																
Laryngosigma hyalascidia																																X																																					
Lenticulina peregrina																																																	X																				
Lenticulina sp.						X	X		X		X	X	X		X					X		X		X	X		X	X															X	X	X	X	X							1															
Loxostomum truncatum																																													X																								
Marginulina obesa																	X				X				X																																												
Marginulina sp.																						X				X																			X						X																		
Marginulopsis bradyi												X												X							X																																						
Melonis barleeanus							X			X	X	X		X	X	X	1	1	X	X	X		X	X	X	1	X			X	X				X																																		
Melonis pompilioides						X	X			X	1	2	2	1	3	X	2	2	1	X	1	1			X	X	X	X	X	X	X	X					X																																
Melonis sp.													X				X	X	X														X													X					X		1																
Miliolinella subrotunda																																																1		2	X		6	6															
Miliolinella sp.																																																						1															
Neoconorbina terquemi																																															X		X		X		5	3			X												
Nodosaria flintii																																													X																								
Nodosaria sp.																																													X																								
Nonion germanicum									X					X				X									X		X				X			X							2																										
Nonion sp.																									X																				X					1						X	X												
Nonionella atlantica										X	1																					4						X					X					X			1	2																	
Nonionella sp.	X	X	X	X	X	X	X	2	2			X	1	X		X	X	X	1	1	1		X			X						X	X		1																																		
Nummoloculina irregularis																																																						1															
Oolina globosa							X			X	X	X	X			1	X	X	X	X	X					X			X																						X	X			X				X										
Oolina hexagona						X	X			1								X		X																																																	
Oolina longispina							X																																																														
Oolina melo																																																										X											
Oolina multicostata																																																					X																
Oolina sp.																																					X																	X															
Ophthalmidium acutimargo																																																																		X		X	
Ophthalmidium pusillum																				X																		X																															
Oridorsalis umbonatus	X	X		X	X	2	1	X	X	X	4	5	4	3	5	4	5	7	5	4	4	2	2	1	1	X	X	1	2	X	1	1	X	X	X	X	1	X		X			X	X	1	X				X					X	2	X	X	X					X		X			
Parafissurina tectulostoma		X					X					X				X					X																																																
Parafissurina sp.													X					X	X			X		X	X				X			1	X				X	X			X	X	X		3	2	X			X	2		X	1	X	1		2	1										
Planorbulina mediterranensis																																																	X	X			4	3															
Pleurostomella sp.																				X																															X				X														
Polymorphina sp.																			X																																	X																	
Pullenia bulloides						X				1	X	3	1	X	X	1	2	2	3	3	X	X	X	X	1	X	X	X	X	X	X	1		X			X	2	X	1	X		X		X	X				X		3		1		2	1	X	X										
Pullenia osloensis						X			X				2	3	2		2	1	2								X	X			1						X		X							X	X				X	X		1						X			X	X		X		X	
Pullenia quinqueloba						X	1				3	3				2		1	X	3	2	2	1	2	1	1	X	2		X	X	X			X			X											X	X				1				X			X				X	X	1		
Pullenia simplex			X			1	2	X		1	3	5	5	5	3	4	3	4	1	4	X	X		X		X	X	1		X	X	2	X	X		1	2	X			X						X	X	X			1	X		X	X	X	X	X										X
Pyrgo depressa																								X																																													
Pyrgo elongata																						X										X	X																																				
Pyrgo murrhina			X								X				X		X	X	X	X	X	1	X	1	X	1	X	2	2	X	2	2	1			1	2	X		1	2		X				X																X						
Pyrgo nasuta																										X																																											
Pyrgo serrata					X																																																																
Pyrgo williamsoni										X		X					X	X			X			X			X	X	X	2				X	X		X								X													X											
Pyrgo sp.																		X																		X																																	
Pyrgoella sphaerica													X	X																																																							
Pyrolina angusta											X	X					X		X								X		X																																								
Pyrolina extensa															X	X	X	X				X								X																																							
Pyrolina sp.							X				X		X	X																																																							
Quinqueloculina bicornis																																																					X																
Quinqueloculina oblonga																																								X																4	X	3	X										
Quinqueloculina seminula		X	X																																								3	1	3	X	2	3	1	23	2	1	26	16	2	X	2		4				X		X		X		
Quinqueloculina tropicalis																																																X	X			X																	
Quinqueloculina venustra																											X					X																																					
Rectoglandulina torrida											X																																																										
Robertina bradyi													X																															X	X		X			X	X	X																	
Robertina tasmanica																							X																																														
Robulus sp.																		X																																																			
Rutherfordoides tenuis																																																		1																			
Siphonina tubulosa																																													X									X															
Sphaeroidina bulloides													X		X															X																				X	X							X											
Spiroloculammina tenuis																																											X						X				X	2															
Spiroloculina sp.																																																					X	1															
Stainforthia concava	6	6	4	10	4	13	13	17	13	12	5	5	4	5	6	9	3	4	4	4	X	X	X	X	1		X						2				X	X					X		X	1		X	X	X	X	X	X	X	X		X	X	X										
Stilostomella bradyi																																													X	X							X	X															
Tosaia hanzawai												X									X									X																					X				X														
Trifarina angulosa							X			X	1	2		1			1	2	1	X	X	X	2		X																		X		X										X								X						
Trifarina bradyi																																																						X															
Trifarina sp.																																																					X																
Triloculina oblonga	X	1	X	X		1	1	2	1	1		1		X	X	3	1	1			1	1	X		X	X	X	X		1		1	1		X	X		X															X																
Triloculina tricarinata				X							X		1		X	X	X		X	2				1			X	X				X																																					
Triloculina trihedra																			2							X																																											
Triloculina sp.														X																																																							
Uvigerina auberiana																						X																																					X										
Uvigerina peregrina-group	13	23	14	16	9	8	7	9	7	6	X	X					X		X		1			X	X	X	X	1	1	2	2																																						
Valvulineria humilis																																																										X											
Valvulineria laevigata																																																		X			X																