Deep Water Agglutinated Foraminiferal Assemblages across the Gulf Stream: Distribution Patterns and Taphonomy

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ABSTRACT

We studied the distribution of living and dead benthic foraminifera in box-core samples along a transect from the abyssal oligotrophic gyre of the Sargasso Sea to the Gulf Stream and towards the continental rise in the Baltimore Canyon region. Four different faunal assemblages are distinguished. Assemblages from abyssal oligotrophic sites (Sargasso Sea Stations 004, 007) are characterised by small infaunal agglutinated species and small delicate unilocular forms such as *Rhizammina algaeformis* and komokiaceans. Benthic assemblages of the continental rise directly beneath the Gulf Stream (Station 020) have higher standing stocks and are dominated large unilocular astrorhizaceans. Slope assemblages (Stations 021, 025, 027) are characterised by high numbers of *Uvigerina peregrina*, which is generally regarded as an indicator of enhanced organic matter flux to the sea-floor.

Abyssal benthic foraminiferal assemblages underneath the zone of cold core rings south of the Gulf Stream (Station 016) differ from abyssal assemblages of the oligotrophic gyre of the Sargasso Sea and from the Baltimore Canyon continental rise in the following features. (1) The live infauna consists mainly of small, smooth-walled infaunal agglutinated morphotypes. Its taxonomic composition is almost identical to the infauna from stations from the oligotrophic waters of the Sargasso Sea. However, the number of living individuals is about 2 to 3 times higher than in abyssal samples from the Sargasso Sea. (2) Large unilocular astrorhizaceans, which form a major component of the faunal assemblages directly under the Western Boundary Undercurrent, are rare or absent in the zone of cold core rings. (3) Attached agglutinated foraminifera are a characteristic component (10-20% of the total surface population) in the zone of cold core rings. We speculate, that these peculiar features (a higher standing stock of benthic foraminifera than in other abyssal regions of the Northwest Atlantic and a different assemblage composition in comparison to the "oceanic desert" of the Sargasso Sea) are related to two special environmental conditions beneath the Gulf Stream and the zone of cold core rings: (1) the influence of bottom currents, which may be adverse for delicate epifaunal species; (2) for abyssal environments an unusually high and steady supply of nutrients and phytodetritus provided by deep currents.

The number of agglutinated foraminifera drastically decreases in the uppermost 20 cm, and in general, very rare or no agglutinated species are found further downcore. The increasing fragmentation downcore and subsequent loss of first the fragile thin-walled specimens and later the well-cemented thick-walled taxa indicate that this decrease in species abundance is mainly caused by taphonomic processes such as bacterial decay of organic cements. From changing relative abundances of different agglutinated foraminiferal species within the upper part of the sediment column we conclude, that the preservation potential of deep water agglutinated foraminifera is a function of both wall structures (intrisic susceptibility to fragmentation or decay) and habitat preference.

INTRODUCTION

The abundance and community structure of deep water agglutinated foraminifera are strongly affected by the organic flux (Gooday, 1988; Gooday & Lambshead, 1989; Altenbach & Sarnthein, 1989; Altenbach, 1992). A direct relation of several groups of agglutinated foraminifera to surface production has been demonstrated by Gooday (1988), Thiel *et al.* (1989), Gooday & Lambshead (1989), Gooday & Turley (1990), Loubere (1991), and Gooday (1994). Epifaunal, phytodetritus-feeding abyssal agglutinated foraminifera, in particular, seem to be sensitive to seasonal changes in surface productivity and to pulsed inputs of phytodetritus flux to the seafloor (Gooday, 1990b). Several of these forms may have potential to monitor seasonality and palaeoseasonality in oceanic systems.

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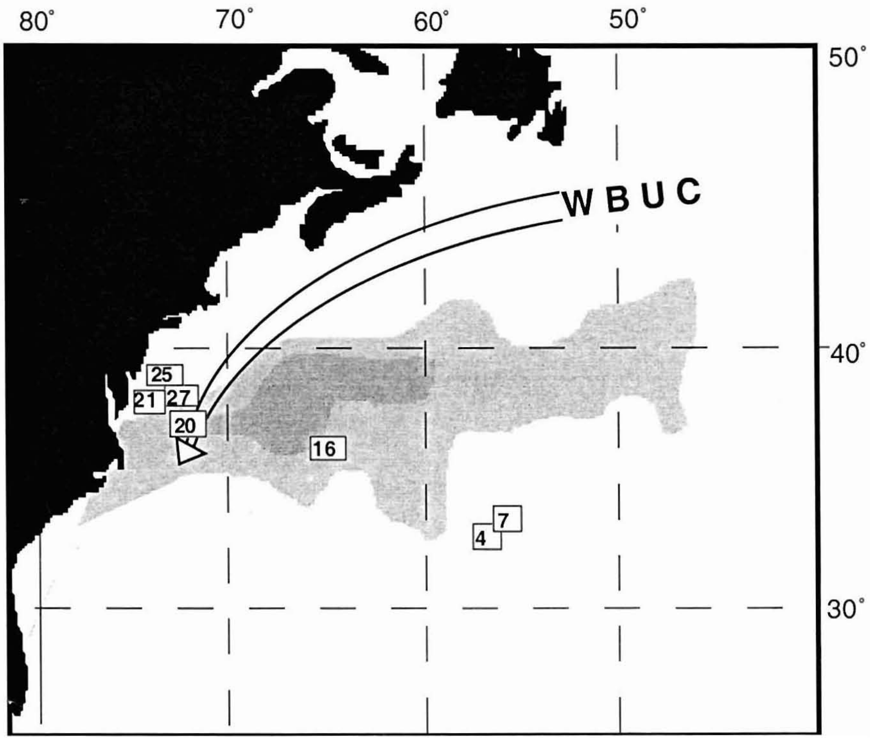

Figure 1. Surface kinetic energy (cm^2 s^{-2}) of the Gulf Stream system on a 2° grid based on drogued-drifter data (after Schmitz *et al.*, 1987), Western Boundary Undercurrent, and location of HUD-89038 stations.

A first attempt to define the characteristics of abyssal agglutinated foraminiferal assemblages underneath oceanic oligotrophic gyres was undertaken by Schröder (1986), Schröder *et al.* (1989) and Gooday (1990a, 1994). Schröder *et al.* (1988) described abyssal agglutinated foraminiferal assemblages from the central Sargasso Sea and compared them to assemblages berneath the oligotrophic gyres of the central North Pacific Ocean.

Deep currents and resulting substrate disturbance have recently been demonstrated as an important controlling factors on deep-water benthic foraminiferal distribution (Kaminski, 1985; Kaminski & Schröder, 1987; Kaminski *et al.*, 1988). Studies of Recent foraminiferal assemblages in current influenced deep-water environments may be a key for the interpretation of late Mesozoic and Paleogene assemblages of "flysch" environments since the flysch basins of the Western Mediterranean, Alpine and Carpathian orogenic belts are generally considered as narrow but deep trenches with strongly influenced by turbidity and contour currents.

In this paper we examine abyssal benthic foraminiferal communities in relation to the distinct oceanographic conditions beneath the Gulf stream system in the western North Atlantic. The transect chosen allows comparison of abyssal benthic foraminiferal assemblages beneath four different water masses: (1) the oligotrophic water masses of the central Sargasso Sea; (2) water masses influenced by cold core eddies in the northern Sargasso Sea; (3) Gulf Stream water masses; (4) cold slope water masses north of the Gulf Stream. One of the objectives of our study is to recognise faunal patterns in abyssal agglutinated foraminifera, which could serve to monitor the influence of water mass boundaries and major current systems in past oceans. A second objective is to determine infaunal and epifaunal species and, in turn, to decide how representative the surface 1 cm is for Recent deep water faunal assemblages. This paper builds on the ealier work of Kuhnt & Collins (1995).

MATERIAL AND METHODS

Surficial sediment samples and replicate push-cores from seven box-cores were sampled in February and March 1990 (C.S.S. Hudson cruise 89038) at a time of low phytoplankton flux to the sea-floor (Table 1). The abyssal sites include sediment traps at the flanks of abyssal hills at the Bermuda Rise in the Sargasso Sea (Stations 004 and 007 at 4418 m and 4437 m water depth), one site in the zone of cold core rings at the southern margin of the Gulf Stream (Station 016 at 4654 m water depth) and one site in a zone of strong abyssal currents at the continental rise beneath the Gulf Stream (Station 020 at 3098 m water depth). The continental slope sites of the Baltimore Canyon area (Stations 021, 025, and 027 at 1614 m, 1256 m and 2330 m water depth) have a

Table 1. Location of HUD-89038 boxcore stations

Station	Latitude	Longitude	Depth	Remarks
BC 004	33° 41.6' N	57° 36.7' W	4418 m	Sargasso Sea, GPC-5 Site
BC 007	33° 41.2' N	57° 38.3' W	4437 m	Sargasso Sea, high sedimentation rates
BC 016	36° 00.40' N	66° 05.40' W	4654 m	beneath cold core rings
BC 020	37° 31.23' N	72° 00.97' W	3098 m	Gulf Stream area
BC 021	38° 24.24' N	73° 14.26' W	1614 m	Baltimore Canyon
BC 025	38° 51.56' N	72° 42.65' W	1256 m	Baltimore Canyon
BC 027	38° 44.58' N	72° 29.67' W	2330 m	Baltimore Canyon

higher terrigenous influx, and the dark greenish gray colour of the sediment indicates depleted oxygen-conditions. The oceanographic setting of the area and the locations of HUD-89038 stations is shown in Figure 1. Schematic lithological descriptions of the box-cores is given in Figure 2.

Station 016 is situated at the southern margin of the Gulf Stream system about 1000 km east of Cape Hatteras. This area lies within the zone of cold core rings in the southern part of the Gulf Stream system between 60° and 70° W, close to the area of preferred formation of cold core rings at 65° W (Schmitz *et al.*, 1987). Cold core rings have a diameter of more than 200 km and a large raised dome in their thermal, salinity, and density fields, extending down near the sea floor. Their movement is characterised by a mean speed of 5 cm/sec for westward moving, isolated rings and 25-75 cm/sec for eastward moving rings, which are attached to the Gulf Stream (Schmitz *et al.*, 1987). Surface speeds within the cyclonic current around the cold slope water core can reach 150 cm/sec, and, at least at the time of their formation, these rings appear to extend to the sea floor (Ring Group, 1981). Consequently deep-sea areas underneath these rings may be occasionally influenced by low velocity bottom currents, which may be enriched in phytodetritus originating from the slope water core. The ring cores have the trophic characteristics of slope water; they are enriched in phytoplankton, planktonic foraminifera and nutrients (Ring Group, 1981). The rings occupy 10 to 15 percent of the surface area of the northern Sargasso Sea at any given time. Rings transport both nutrients and biota from near the coast of North America into the Sargasso Sea, and the nutrients and transported plankton considerably increase the otherwise limited primary productivity of this area (Ring Group, 1981). This area is thus of special interest for our study since the influence of cold core rings undoubtedly increased the phytoplankton flux to the seafloor and thus increased the supply of food particles for detritus and suspension feeding benthic foraminifera. Additionally in areas of high eddy kinetic energy resuspension processes play an important role in organic particle fluxes and may lead to a less pronounced seasonality of food particle supply to benthic communities (Gardner & Richardson, 1992).

Station BC-020 is situated at 3098 m directly underneath the main path of the Gulf Stream not far east of its crossover with the Western Boundary Undercurrent (WBUC). In this area, east of Cape Hatteras, the water depth below the Gulf Stream reaches more than 4000 m. A number of observers have indicated that even at these water-depths the influence of the Gulf Stream extends to the bottom (Fuglister, 1963; Warren & Volkmann, 1968; Knauss, 1969; Schmitz *et al.*, 1970, 1987). Measurements of deep current velocities of the Gulf Stream have been carried out at abyssal depths directly east of Cape Hatteras (Richardson & Knauss, 1971; Richardson, 1977; Watts & Johns, 1982). These measurements indicate that at times the Gulf Stream extends to the seafloor and splits the WBUC. Current measurements at water depths of 2575 m recorded instantaneous velocities of up to 47 cm/sec and mean velocities of 10.8 cm/sec over several weeks (Richardson, 1977).

Foraminiferal samples were taken from the uppermost centimeter of the sediment surface using a 81 cm^2 square grid with 36 squares of 2.25 cm^2 each. Additionally the upper 20 cm of pushcores with a 7 cm diameter were subsampled in 1 cm slices. All samples were immediately fixed in a formaldehyde/sea-water solution buffered with borax and stained with Rose Bengal (Walton, 1952). The pushcore samples were split in eight parts using a wet-splitter as described in Scott & Hermelin (1993). One or two splits for each sample were initially examined in liquid to identify living individuals (Lutze & Altenbach, 1991), then dried, picked and counted quantitatively. For each subsample we counted all living benthic foraminifera and the living and dead agglutinated forms in the fraction > 63 μm. All individuals were mounted in Plummer slides for documentation.

RESULTS

General faunal trends

Calcareous benthic foraminifera are significantly more abundant underneath the Gulf Stream than in oligotrophic sites of the same water depth in the

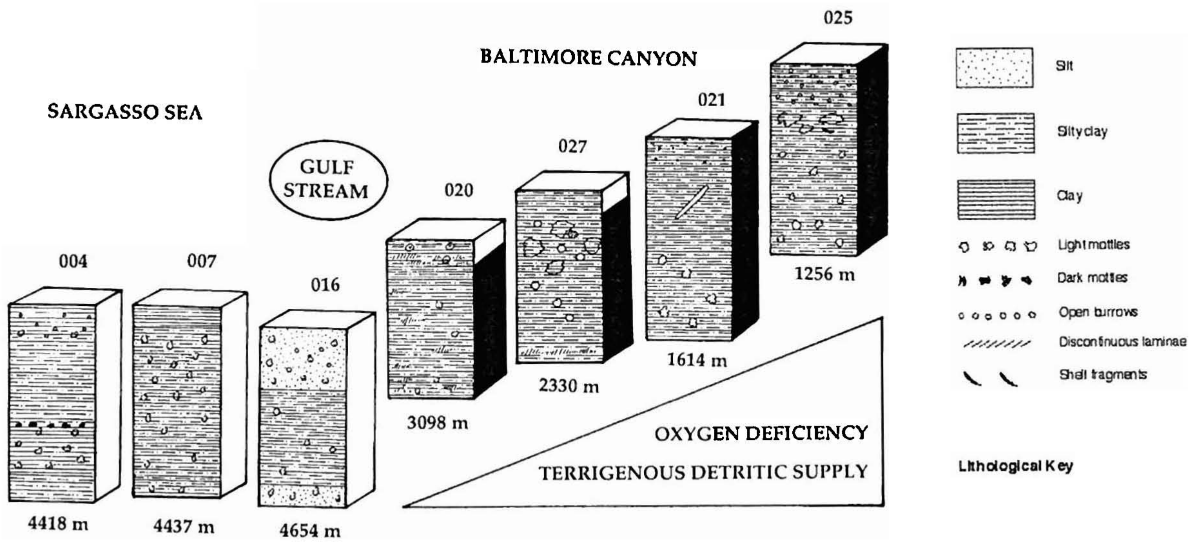

Figure 2. Box cores sampled on C.S.S. Hudson Cruise 89038 along the Sargasso Sea - Baltimore Canyon transect. Black shading indicates oxygen-depleted pore and interstitial waters.

Sargasso Sea (20% of the total benthic population, compared to only about 2-5%). The distribution of selected calcareous benthic foraminifera in surface samples from abyssal and deep bathyal stations is shown in Figure 3. The specific diversity of calcareous benthic foraminifera remains low at Station 016. The following species represent more than 98% of the calcareous benthic forms in surface samples from box-core 89038-016:

Cassidulina subglobosa Brady, 1881
Cibicidoides robertsonianus (Brady, 1881)
Cibicidoides wuellerstorfi (Schwager, 1866)
Epistominella exigua (Brady, 1884)
Eponides tumidulus (Brady, 1884)
Fursenkoina fusiformis (Williamson, 1858)
Gyroidina soldanii d'Orbigny, 1826
Nonion depressulus (Walker & Jacob, 1798)
Nuttallides umbonifera (Cushman, 1933)
Oridorsalis umbonatus (Reuss, 1851)
Pullenia bulloides (d'Orbigny, 1846)
Pullenia subcarinata (d'Orbigny, 1839)
Tosaia hanzawai Takayanagi, 1953

The number of living agglutinated foraminifera in the surface samples is highest at Station 027 (New Jersey slope), where maximum values of more than 8 individuals per cc sediment are observed. At Station 020 beneath the Gulf Stream, values of about 5 individuals per cc are observed in the uppermost centimeters of the sediment column. The values at Station 016 (Northern Sargasso Sea, influenced by cold core rings) are comparable (about 5 individuals at 0-1 cm depth in sediment and close to 4 individuals at 1-2 cm depth). A dramatic decrease in the abundance of living agglutinated foraminifera is observed in cores from within the

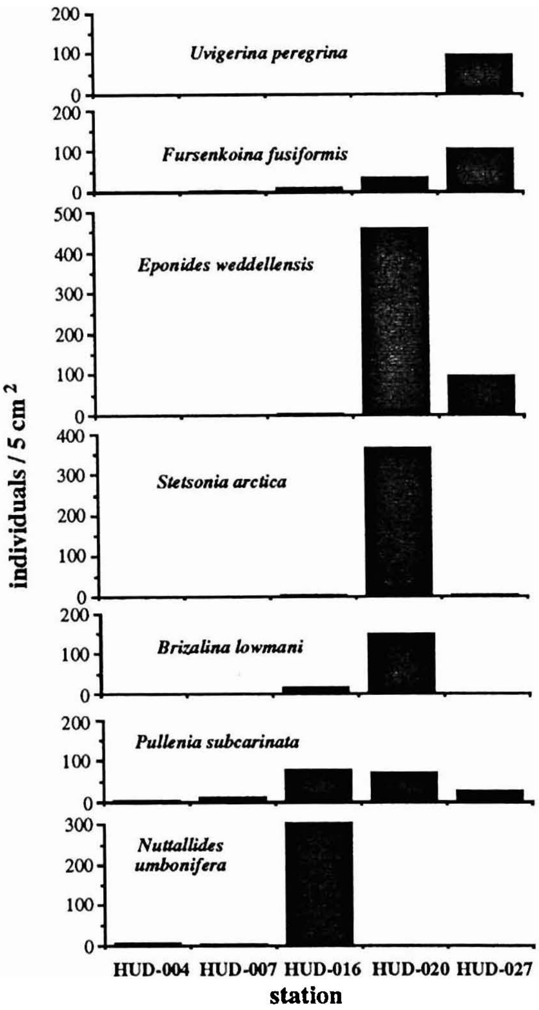

Figure 3. Distribution of ecologically relevant calcareous benthic foraminifera in surface samples from the abyssal and deep bathyal HUD 89038 cores.

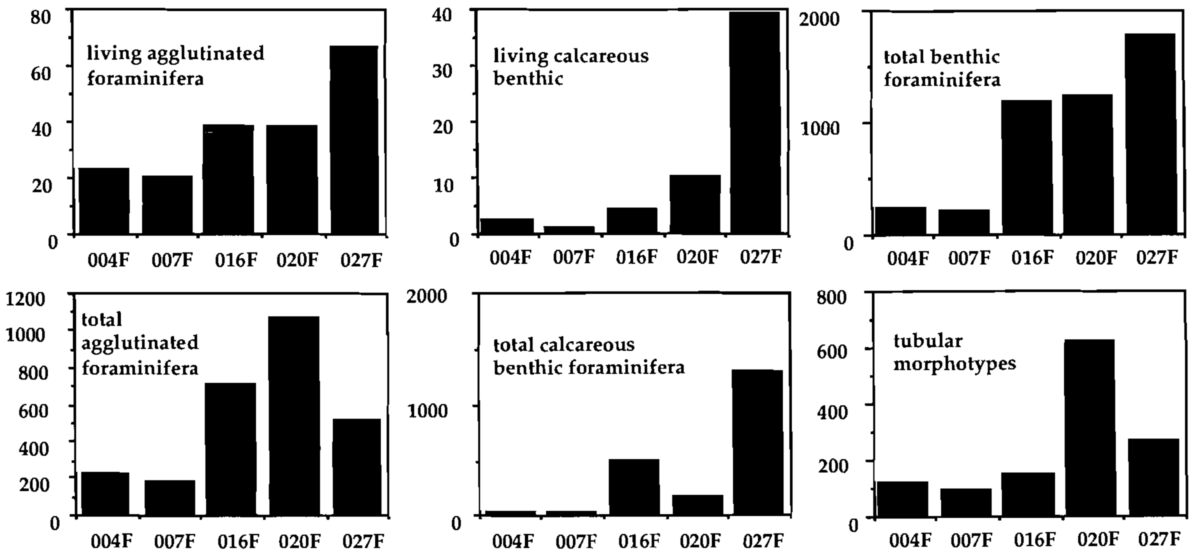

Figure 4. Relative numbers of total benthic foraminifera, living and dead calcareous benthic foraminifera, living and dead agglutinated foraminifera and tubular astrorhizaceans in surface sediments of the Sargasso Sea, beneath the Gulf Stream and slope sites.

central gyre of the Sargasso Sea, where the maximum number of living agglutinated foraminifera are around to be 1- 2 individuals per cc sediment.

The total assemblage counts of the near-surface samples are somewhat different. The highest abundance of agglutinated foraminifera (about 170 individuals/cc) is observed in the upper 1-2 cm at Station 020, beneath the Gulf Stream. The total numbers of agglutinated forminifera are still high at Station 027 (about 80 individuals/cc) and 016 (88 individuals/cc). The total numbers of agglutinated foraminifers within the uppermost 2-3 cm of the sediment column at Stations 004 and 007 decrease dramatically (about 5 individuals/cc at Station 007 and up to 30 individuals/cc at Station 004).

The most significant difference in faunal abundance is thus observed between the abyssal Station 016 in the Northern Sargasso Sea and the abyssal Stations 004 and 007 at the Bermuda Rise. On average the numbers of both living and total agglutinated foraminifers are about 3 to 4 times higher at Station 016 than at the two control stations at the Bermuda Rise (Figure 4). These striking differences in living and total populations within abyssal stations in the Sargasso Sea are somewhat surprising, since Stations 004, 007 and 016 are situated at the same water depth and topographic situation.

Other fundamental differences between agglutinated foraminiferal assemblages beneath the central gyre of the Sargasso Sea and assemblages from the northern Sargasso Sea, which is influenced by cold core rings, are:

(1) the highest numbers of agglutinated foraminiferal tests are observed close to the sediment surface at Station 016 but within about 3–10 cm sediment depth in the other abyssal samples from the Sargasso Sea (Figure 5).

(2) attached agglutinated foraminifera are common (10-20% of the total surface population) at the northern Sargasso Sea station.

(3) epifaunal forms such as *Rhizammina algaeformis*, other epifaunal komokiaceans and unilocular astrorhizaceans form only a minor component of the faunal assemblage in the northern Sargasso Sea.

We relate these differences in faunal abundance and composition to the influence of cold core rings and resulting higher phytodetritus supply to abyssal stations in the northern Sargasso Sea.

Microhabitats and life positions

Most of the observed species of agglutinated foraminifera can be assigned to four groups according to their microhabitat:

(1) epifaunal attached agglutinated foraminifera

(2) fragile, soft and flexible epifaunal and shallow infaunal forms (i.e., komokiaceans).

(3) shallow infaunal forms (living forms are not observed deeper than 3-4 cm in the sediment)

(4) deep infaunal forms (living forms occur below 4 cm in the sediment)

The distribution of representatives of these faunal groups is discussed below. For details on the distribution of komokiaceans in the Gulf Stream area see Kuhnt & Collins (1995).

Attached agglutinated foraminifera

Attached agglutinated foraminifera of abyssal areas (deep-sea hard-substrate communities) have been commonly recorded from surfaces of manganese nodules (Dugolinsky *et al.*, 1977; Mullineaux, 1987, 1988a,b). Less attention was paid to attached deep-

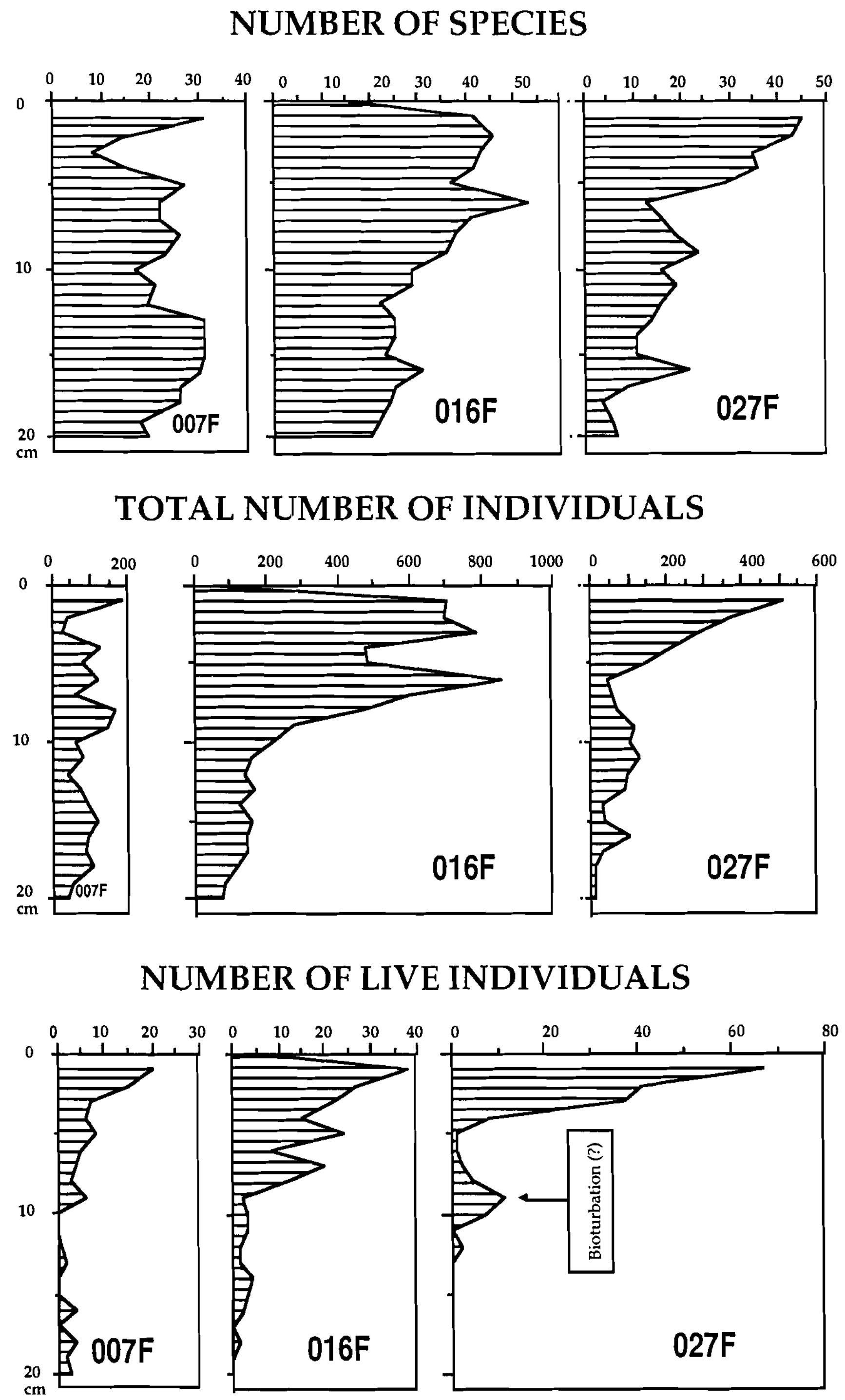

Figure 5. Downcore changes of diversity and abundance of total and living agglutinated foraminifera within pushcores from the central and northern Sargasso Sea, beneath the Gulf Stream and the Baltimore Canyon slope area.

sea agglutinated foraminifera on biogenic substrates such as shells of molluscs and planktonic foraminifera or agglutinated tests since these forms are generally very small and easily overlooked. Gooday (1990a) mentions encrusting forms of the genera *Eggerella, Iridea, Textularia* and *Tritaxis* on the shells of bivalves, pteropods and scaphopods which were very abundant at some bathyal stations at the Porcupine Seabight. Small abyssal attached foraminifers were recorded from inner surfaces of *Bathysiphon rusticus* tubes at 4000 m off northwest Africa (Gooday & Haynes, 1983). Small attached forms (*Placopsinella aurantiaca*) have also been noted in the deep-sea Arctic Ocean (Scott & Vilks, 1991).

Feeding types of attached deep-sea agglutinated foraminifers include suspension and deposit-feeders (Mullineaux, 1987 & 1988b; Gooday, 1990a). Christiansen (1958, 1971) was the first to observe large tubular forms standing up in the sediment

Table 2. Morphotypes of attached agglutinated foraminifers in surface material from boxcore HUD 89038-016. SF = suspension feeders; DF = deposit feeders

morphotype	species	relative abundance	feeding type
1	*Placopsilinella aurantiaca* *Placopsilinella confusa*	abundant	deposit feeder
2	*Saccammina* sp.	common	deposit feeder
3	*Lagenammina tubulata*	rare-few	deposit feeder
4	*Tholosina bulla* *Tholosina vesicularis* *Hemisphaerammina* sp.	few	deposit feeder
5	*Subreophax aduncus*	few	suspension feeder (?)
6	*Ammolagena clavata* *Tolypammina vagans*	common	deposit feeder
7	*Dendrophrya* (?) sp.	common-abundant	suspension feeder

Morphotype 1: multichambered chitineous forms without larger agglutinated grains (Plate 9)
Morphotype 2: single chambered with large agglutinated grains and a terminal aperture protruding on a short neck (Plate 10, Figs 2, 4-6)
Morphotype 3: single chambered subspherical forms with a free test (?) agglutinating or attached to large tests of planktonic foraminifera (Plate 10, Figs 1 and 3)
Morphotype 4: hemispherical or irregular attached forms, finely to medium agglutinated, with basal, hardly visible apertures. These forms often cover the apertures of planktonic tests (Plate 11, Figs 1-4)
Morphotype 5: multichambered forms which protrude from the attaching surface (Plate 11, Figs 5-8)
Morphotype 6: smooth tube-shaped forms, which are attached throughout, with a spherical proloculus (Plate 12, Figs 5-9)
Morphotype 7: Tubular forms, often erect and branching, with finely, medium and coarsely agglutinated walls (Plate 12, Figs 1-4)

with the base of the test anchored in the sediment and the pseudopodia extended in the current like a net. Gooday (1990a) observed large tubular attached suspension feeding agglutinated foraminifera at a depth of 3900 m in the Northeast Atlantic. These suspension feeders preferably occur on the summit of seamounts were currents and hence suspended food particles are likely to be enhanced (Mullineaux, 1987; Gooday, 1990a).

At Station 016 small attached agglutinated foraminifera on larger tests of planktonic foraminifera are very abundant (up to 20 specimens per square cm in surface samples). The downcore distribution and preservation of these forms suggest an epifaunal habitat for these forms (Figure 6). In general, most of the specimens are well-preserved and do not show fragmentation or corrosion of the test only in the uppermost 2-3 cm of the sediment core. However, no identification of living individuals was possible using the Rose Bengal staining method. Probably these tiny forms do not contain enough protoplasm to produce an identificable stained body.

Seven morphotypes were distinguished in surface material from boxcore HUD 89038-016. (Table 2, Plates 9-12).

Shallow infaunal calcareous and agglutinated benthic foraminifera

Living individuals of the following species are more or less consistently observed within the uppermost 1-4 cm of the sediment at Stations 004, 007, 016 and 020:

Adercotryma glomerata
Ammobaculites agglutinans
Ammobaculites cf. filiformis
Eratidus foliaceus
Buzasina galeata
Buzasina ringens
Cystammina pauciloculata
Discammina sp.
Glomospira charoides
Glomospira gordialis
Haplophragmoides bradyi
Haplophragmoides sphaeriloculus
Hormosinella distans
Pseudonodosinella nodulosa
Recurvoides spp.

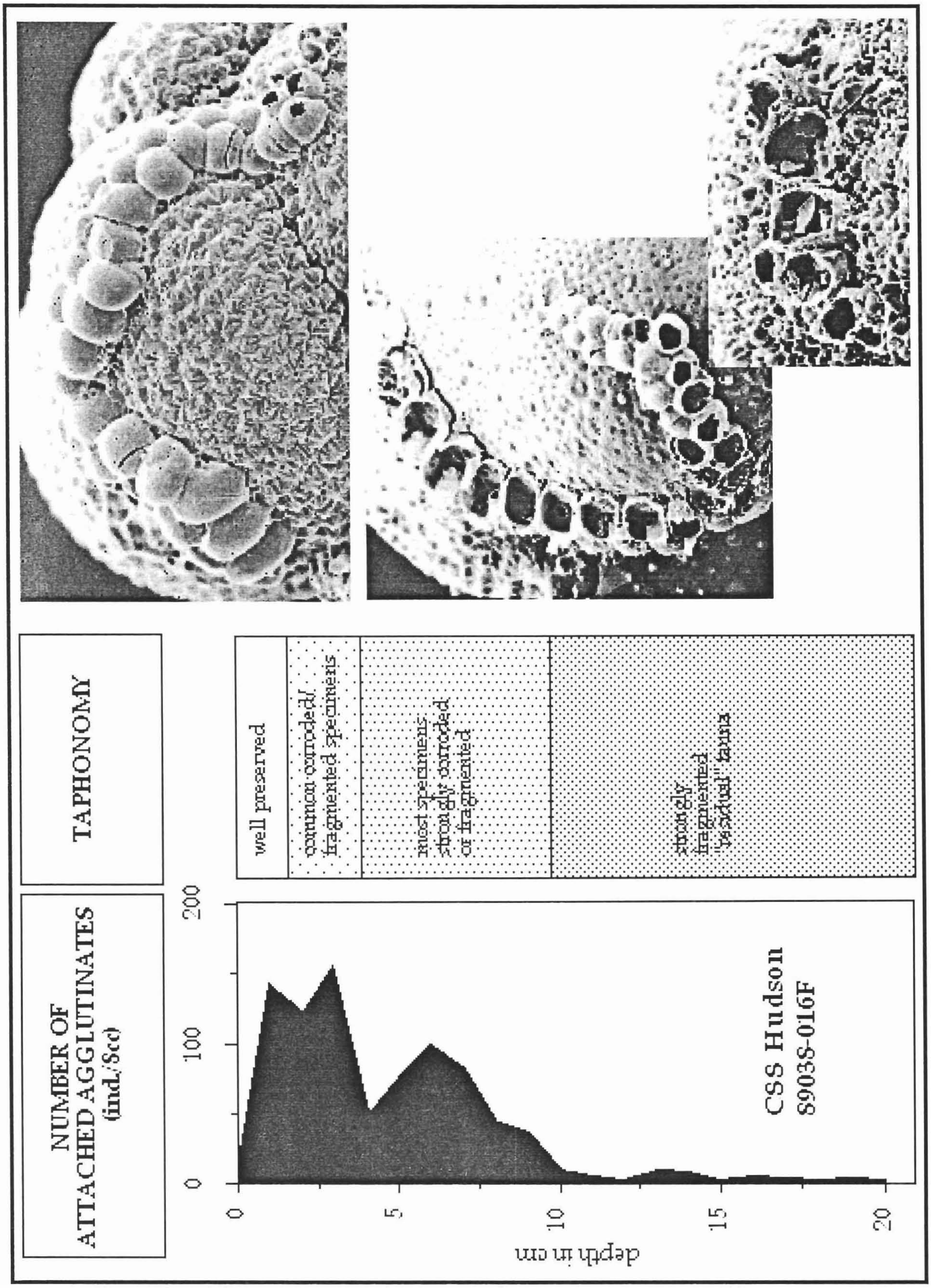

Figure 6: Downcore distribution and taphonomy of attached agglutinated foraminifera in subcore HUD 89038-016F.

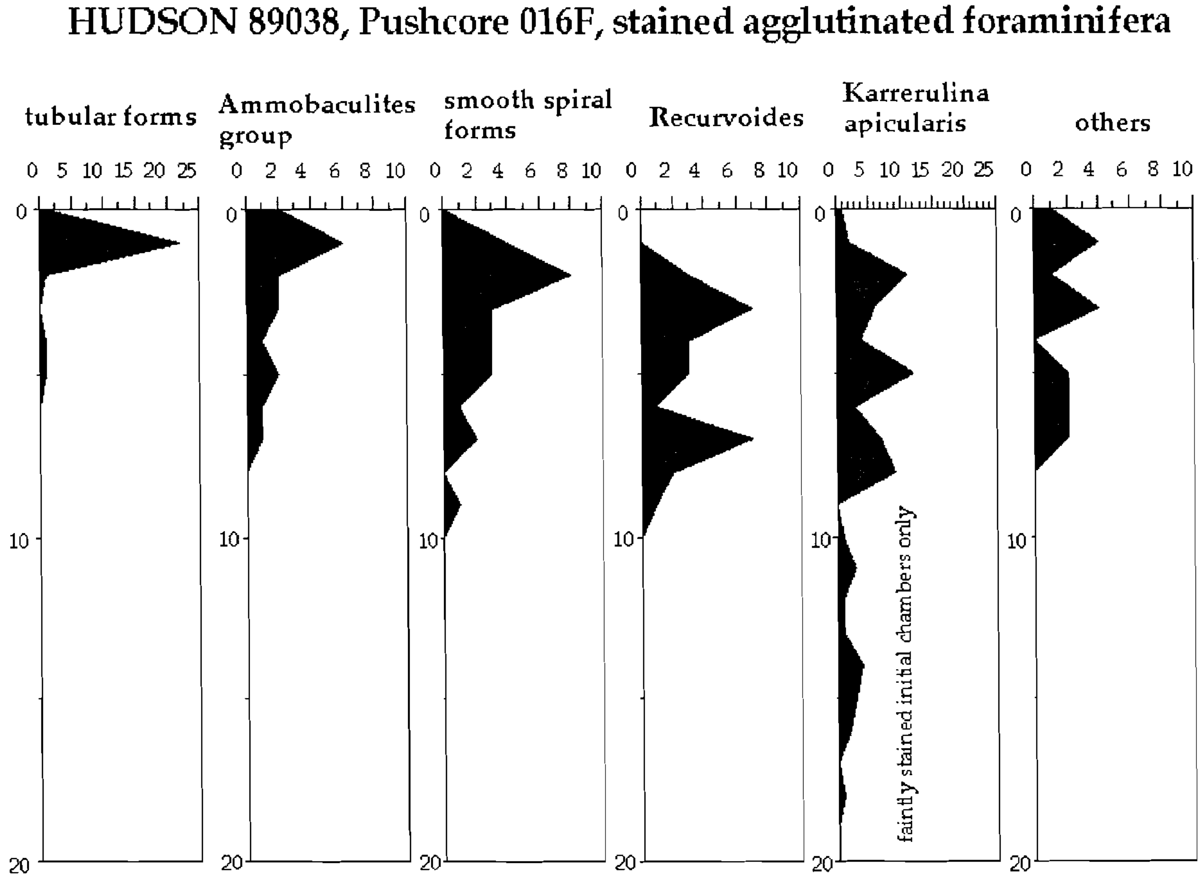

Figure 7. Downcore distribution of stained (living) agglutinated foraminifers at Station 016, pushcore 016F

Reophax bilocularis
Reophax dentaliniformis
Reophax helenae
Reophax scorpiurus
Rhabdammina sp.
small trochamminids

In addition to these, at the Baltimore Canyon slope Station 027, living specimens of *Eggerella bradyi* and *Uvigerina peregrina* are observed in the upper part of the sediment column. Some of these shallow infaunal forms also occur deeper in the sediment column at the abyssal stations. However most of these forms seem to be restricted to the uppermost soupy part of the sediment column with significantly higher water content than below approximately 4 cm. The distribution within this zone is not consistent: living individuals of virtually all species were observed from the sediment/water interface down to the base of the soupy layer. We suggest that many of these species are most probably mobile within this zone and may have their optimum ecological niche close to the sediment/water interface.

Deep infaunal agglutinated foraminifera

The most characteristic and abundant taxa of deep infaunal agglutinated foraminifera are *Karrerulina apicularis* and *Recurvoides* spp. Besides these forms rare occurrences of stained *Ammobaculites* ex gr. *agglutinans, Buzasina wiesneri, Haplophragmoides bradyi, H. sphaeriloculus Adercotryma glomerata, Buzasina galeata* and *Cystammina pauciloculata* have been observed below 4 cm sediment depth.

All these forms are characterised by extremely small cytoplasm bodies and a differentation of more or less decayed organic material is extremely difficult. Especially in *Karrerulina apicularis* an unbiased identification of living specimens with the Bengal Rose staining method seems to be almost impossible. None of the 67 stained specimens of this species in pushcore 016F showed a clear cytoplasm body in the last chambers. Staining was generally restricted to the earlier chambers and the stained material was identified as an organic meshwork filling most of the extremely small cavities of the massive and thick agglutinated test. Almost 20% of the total number of *K. apicularis* in pushcore 016F were stained (Figure 7), which is an unusually high number for forms with thick-walled tests where a preservation of almost 100% of the tests can be assumed at least for the uppermost 20 cm of the sediment column. Other thick-walled infaunal species with high fossilization potential such as *Recurvoides* spp. and *Adercotryma glomerata* show 3% to 7% stained specimens, which is still far above the values for most other agglutinated and calcareous benthics which are far below 1%. A pos

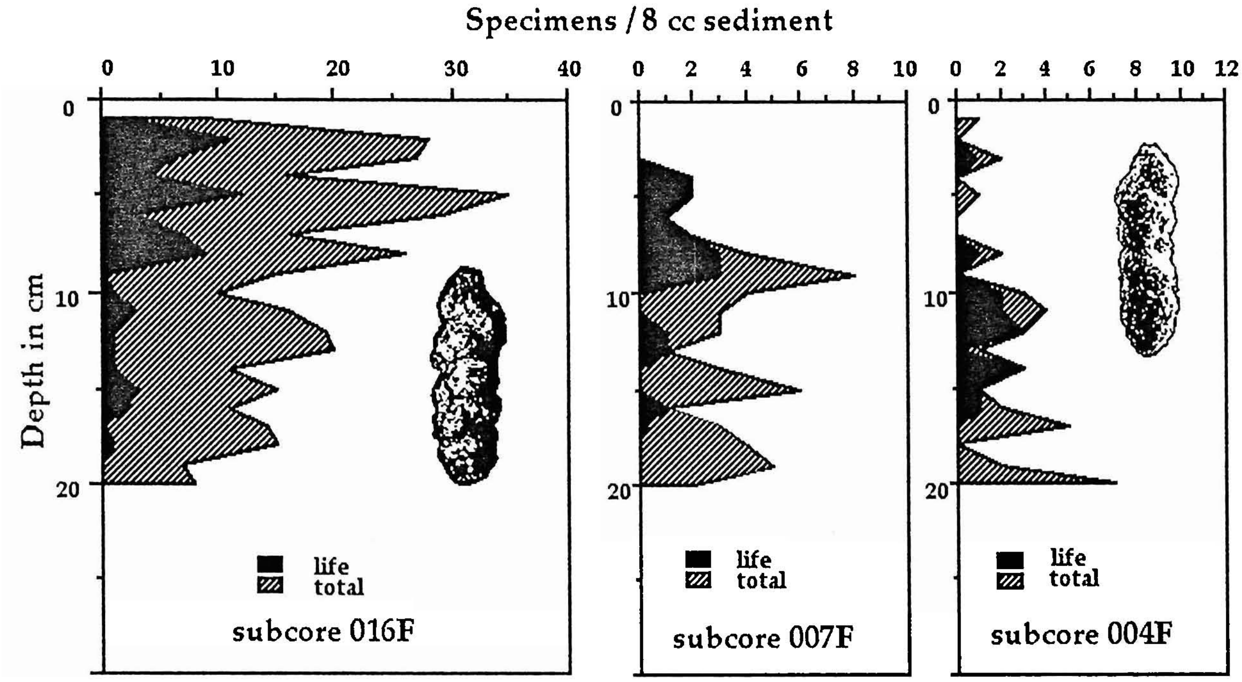

Figure 8. Downcore distribution of the abyssal deep infaunal species *Karrerulina apicularis.*

sible explanation for these differences may be a different adaption to seasonal food supply of deep infaunal agglutinated foraminifera. Epifaunal forms reproduce immediately after the phytodetritus of the spring bloom reaches the seafloor and living forms occur in abundance in the phytodetritus fluff (Thiel *et al.*, 1989). Most of these forms probably do not survive the winter period and at the time we sampled (just before the spring bloom) standing stocks of these forms are low and empty shells strongly dominate even in the surface samples.

We speculate that the deep infaunal forms may have a lower reproduction rate, but may be able to survive the winter season with the given resources. Consequently, the living/dead ratios of these forms are more constant throughout the year. These observations are in accordance with the generally strongly reduced cytoplasm bodies of these forms, which may indicate that parts of the cytoplasm may have been metabolised during the winter. A less probable explanation would be a slow organic decay of the cytoplasm of infaunal agglutinated foraminifers, possibly in the order of several months. Our "living" communities may then include the populations of the previous summer which actively moved downward the sediment column. The sedimentation rates at the sites studied are undoubtedly low enough to exclude a burial of epifaunal forms into depths of several centimeters by sedimentation processes. A more important role may have been played by transport of infaunal agglutinated species by burrowing organisms (e.g., polychaete worms). However, the density of observed polychaete burrows in core 016 is low, and probably did not change the quantitative distribution of stained infaunal agglutinates.

Another possible seasonal aspect of life habitat in this deeper infaunal group is observed in *Adercotryma glomerata*. This species has been described by Gooday (1988) as a form which typically inhabits the fluffy phytodetritus layer above the sediment surface after the spring bloom. We observed living individuals of the same species commonly in sediment depths of more than 4 cm. Thus, this form may be able to seasonally move up and down the sediment column. It consequently can be regarded as an epifaunal detritus feeder after the spring-bloom and as an infaunal form during the rest of the year.

Downcore distribution of agglutinated foraminifera and Taphonomy

The processes controlling the transformation of living to fossil assemblages during the earliest part of their burial history are still poorly understood. The downcore distribution of total assemblages of benthic foraminifera are controlled by three factors: (1) changing environmental conditions at the sediment surface, such as changes in organic matter fluxes and resulting changes in the composition of living populations; (2) the different habitat depth of populations, (3) taphonomic processes and the different fossilisation potential of the tests.

The influence of the different habitat depth on fossil abundances has been theoretically discussed by Loubere (1989). He concludes, that under the conditions of constant habitat occupancy epifaunal species would have constant abundances in the entire sediment column, while infaunal species will have abundances in the sediments that increase down to their maximum habitat depth and then remain constant below that depth. An instructive example for the resulting distribution pattern of a deep infaunal species is the downcore distribution of total individuals of *Karrerulina apicularis* in the box-cores 004, 007 and 016 (Figure 8) since this species builts a very robust, thick-walled test, with high fossilization potential and no specimen loss or fragmentation is observed within the studied intervals. However, this abyssal species is absent at the slope Station 027 and numbers at Station 020 are too low to reconstruct a meaningful downcore distribution.

At all sites studied this species is rare or absent in surface samples and within the uppermost centimeter of the sediment column. Numbers of both living and dead individuals increase down to about 5 cm at Station 016, to about 9 cm at Station 007 and to at least 11 cm at Station 004. These depths correspond closely to the most common occurrence levels of stained specimens at these repective sites. Consequently, these distribution patterns are mainly controlled by the habitat behaviour of *K. apicularis* populations.

Taphonomic processes may significantly modify the theoretical species abundance patterns. Loubere & Gary (1990) observed substantial specimen loss among calcareous benthic foraminifera in the bioturbated interval just below the surface which is especially significant for the fraction of the species populations living at or near the surface. The situation is even worse for fragile, loosely agglutinated foraminifera, where the decay of the organic cement may selectively destroy many individuals during the earliest diagenetic history (Schröder, 1986).

Loubere (1989) proposed that the preservation potential of deep water benthic foraminifera is a function of both wall structures (intrisic susceptibility to dissolution or decay) and habitat preference. The importance of habitat preferences for the preservation potential of benthic foraminifera is further supported by studies of downcore abundances by Denne & Sen Gupta (1989) and Loubere & Gary (1990).

We use downcore plots of percentage values for different species to examine the contributions of selected groups of agglutinated foraminifera to downcore changes in agglutinated forminiferal assemblages within different environments (Figures 9-12). These plots show the following important features:

(1) Downcore abundance profiles of the abyssal Stations 004, 007 and 016 differ significantly from Station 020 and the slope Station 027. Generally the distribution profiles at the Sargasso Sea stations are more continuous, most species are preserved within the whole section of the sediment column and fossil assemblages largely reflect the living populations. Fossil assemblages at Stations 020 and 027 are significantly different from the living populations; agglutinated forms which use organic cement are largely destroyed and the residual assemblages are strongly dominated by agglutinated forms which use calcareous cement such as *"Reophax" bacillaris, Sigmoilopsis schlumbergeri,* and *Eggerella bradyi.*

(2) Within the Sargasso Sea stations infaunal forms generally increase downcore in relative abundance. Important constituents of assemblages below 10 cm sediment depth are in order of decreasing relative abundance: *Karrerulina apicularis, Hormosinella distans, Recurvoides* spp., *Haplophragmoides sphaeriloculus* and *H. bradyi, Buzasina ringens, Buzasina galeata, Ammobaculites agglutinans, Bulbobaculites* of the *B. filiformis* group.

(3) Tubular morphotypes, attached forms, *Aschemonella* spp. and *Subreophax aduncus* are generally most abundant in the uppermost few centimeters of the pushcores and decrease rapidly downcore in abundance. The habitat of these forms is epifaunal and their abundance in fossil assemblages is mainly controlled by their susceptibility to decay. Consequently, thick-walled forms with multilayered walls made up by well-sorted quartz grains such as *Rhabdammina abyssorum, R. linearis* and *R. discreta* generally have higher preservation potential than fragile thin-walled forms such as komokiaceans, *Rhizammina algaeformis, R, indivisa,* attached *Placopsilinella* spp. and *Subreophax aduncus.* However, inner linings of *Rhizammina algaeformis* have been reported in fossil deposits (Scott *et al.*, 1989; Scott & Leger, 1991).

(4) Somewhat surprising is the distribution pattern of *Saccorhiza ramosa* in pushcore 027F (fig. 12), which has maxima of abundance in the surface samples and at a distinct level as deep as 16 cm. This peak in abundace may result from primary high abundances of this species, which were not levelled out by diagenetic decay.

Summing up, our data do not support the model proposed by Schröder (1986) in which the preservation potential of deep water benthic foraminifera is only a function of wall structures in respect to susceptibility to dissolution or decay. There is evidence that the habitat preference is an equally important factor for the preservation potential of agglutinated deep-water foraminifera (Figure 13). Especially in abyssal communities underneath the oligotrophic gyre of the Sargasso Sea fossil communities are dominated by deep infaunal forms. Many of these forms do not even possess especially thick agglutinated walls, but are tiny, thin-walled sometimes even with single-layered walls (e.g., *Haplophragmoides sphaeriloculus, H. bradyi, Buzasina* spp., *Hormosinella distans*). This observation is in good accordance with the composition of fossil abyssal communities from Late Cretaceous and Palaeogene oceans, which are almost exclusively formed by small infaunal agglutinated forms of even the same genera as in modern abyssal oceans (Kuhnt & Kaminski, 1990).

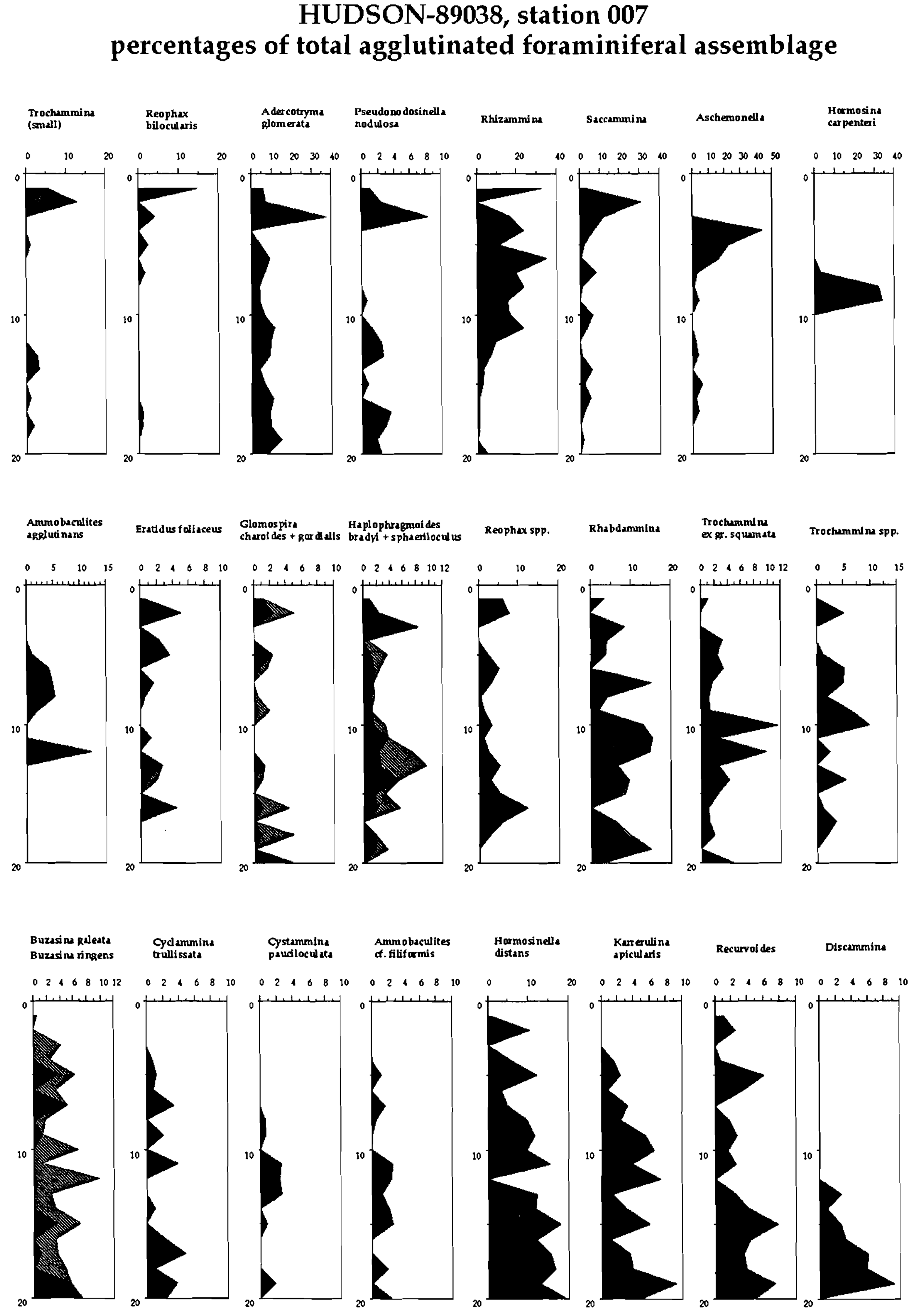

Figure 9. Downcore distribution of significant groups of agglutinated foraminifera within the uppermost 20 cm of the sediment column in Core 007.

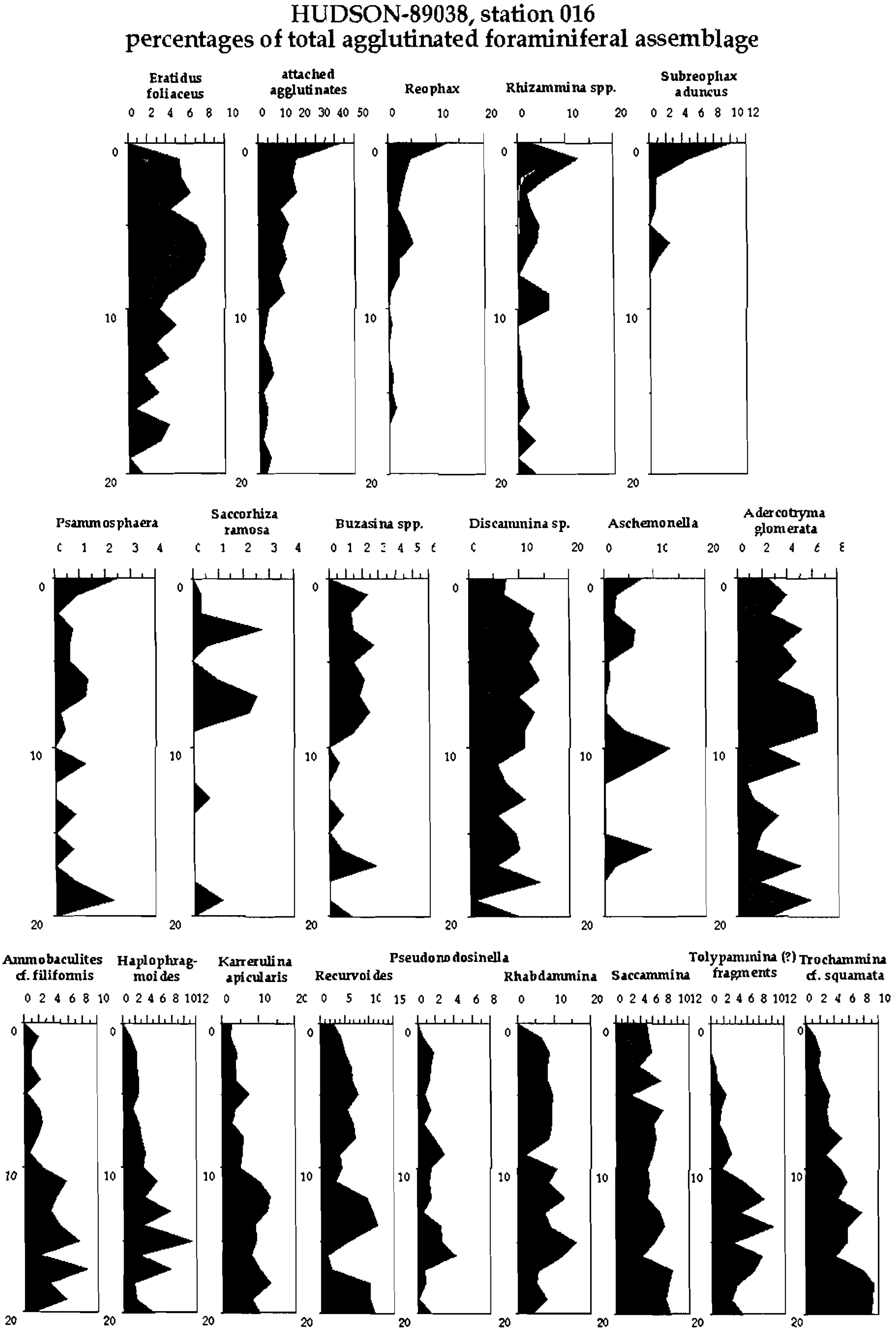

Figure 10. Downcore distribution of significant groups of agglutinated foraminifera within the uppermost 20 cm of the sediment column in Core 016.

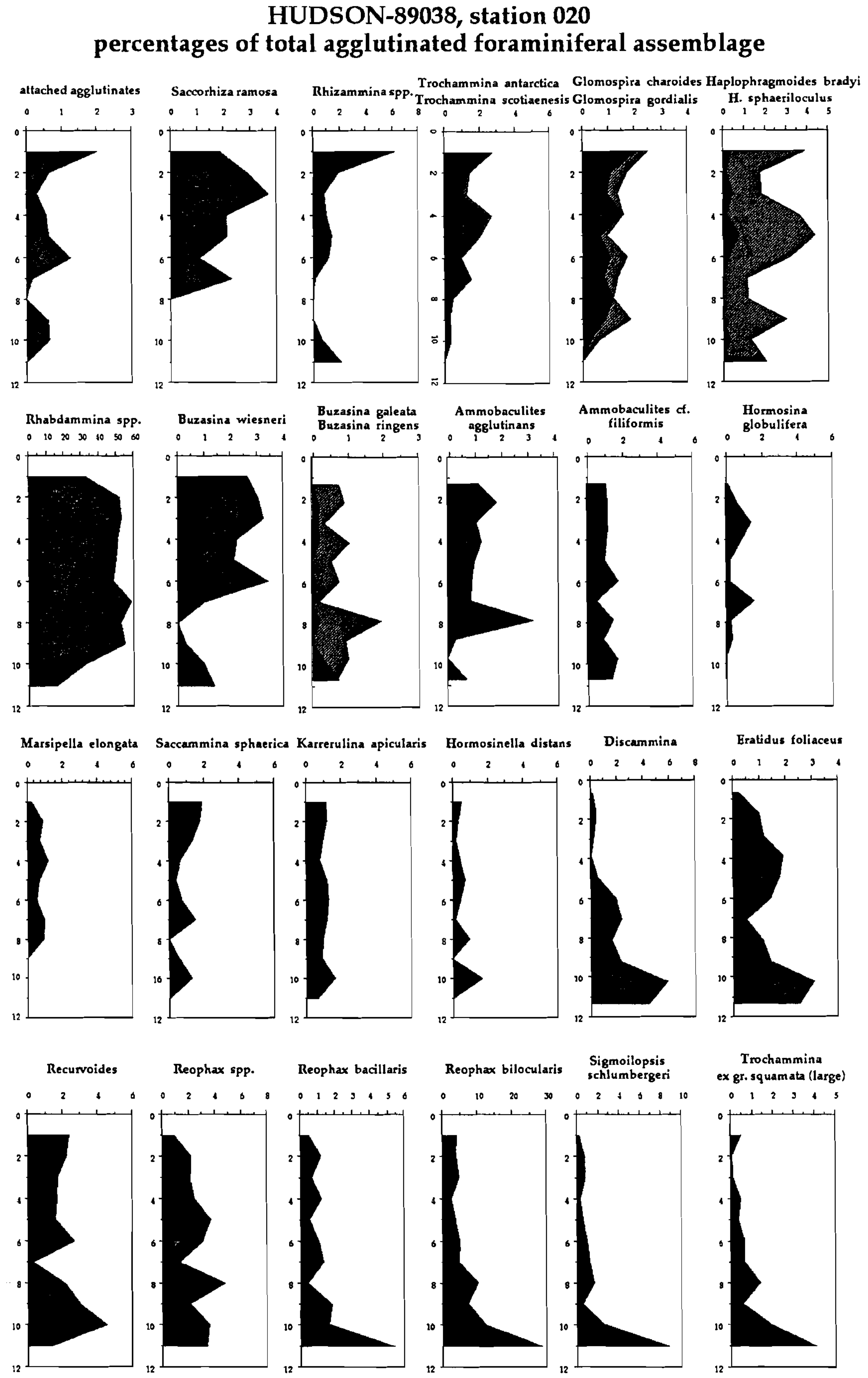

Figure 11. Downcore distribution of significant groups of agglutinated foraminifera within the uppermost 11 cm of the sediment column in Core 020.

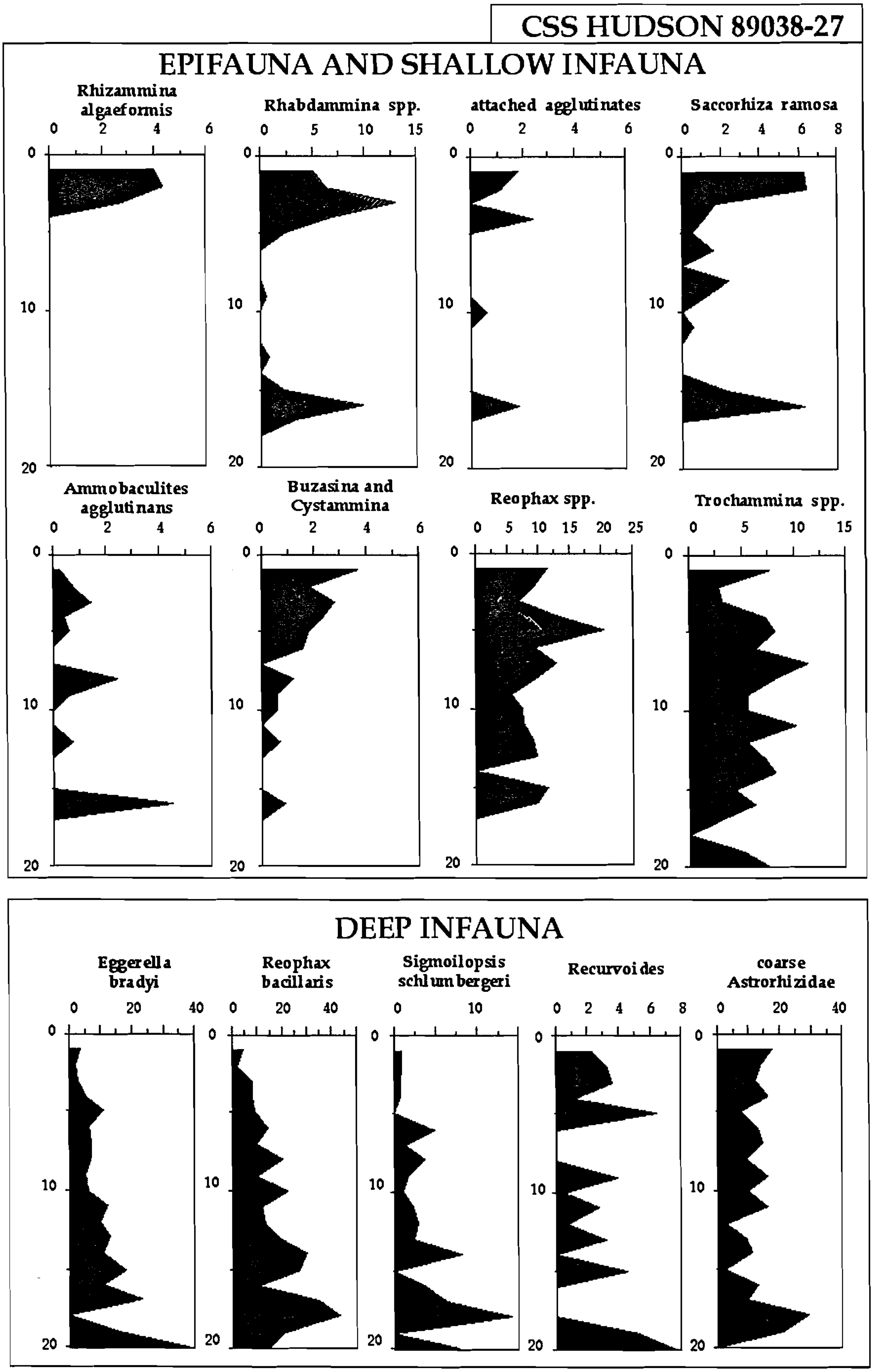

Figure 12. Downcore distribution of significant groups of agglutinated foraminifera within the uppermost 20 cm of the sediment column in Core 027.

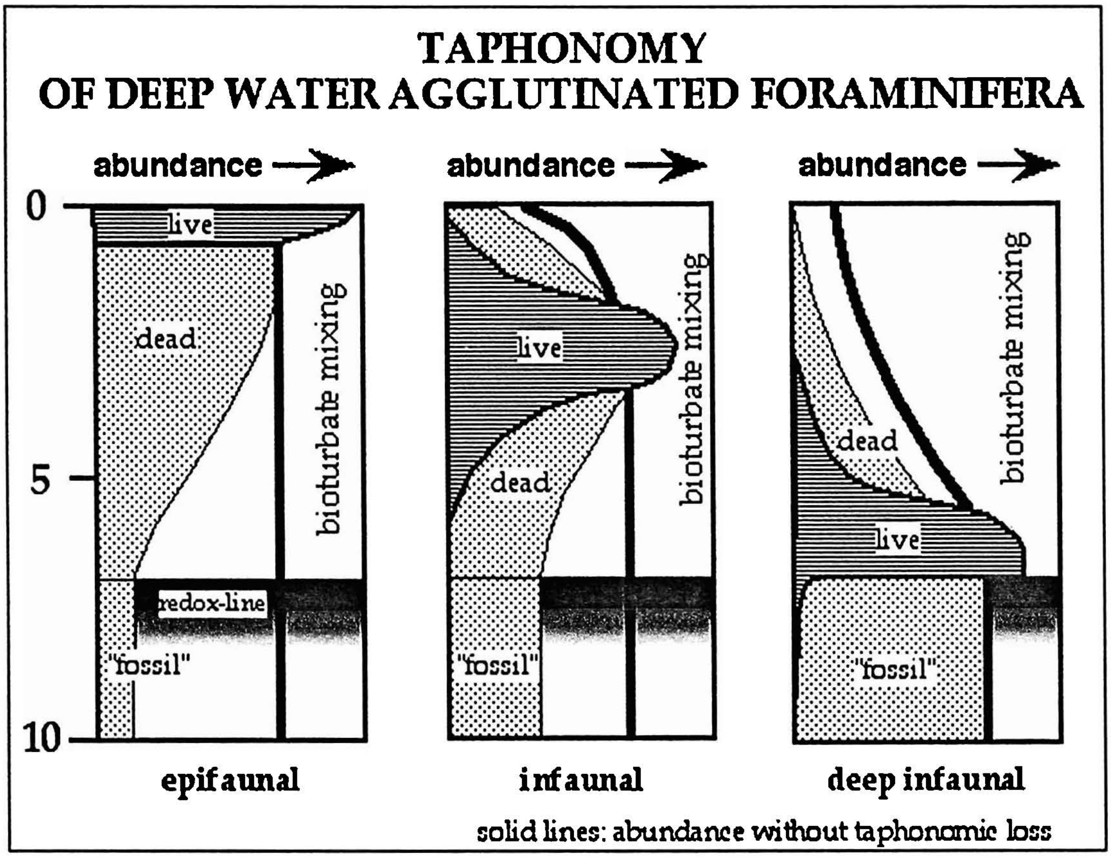

Figure 13. Taphonomic model for the preservation potential of deep water agglutinated foraminifera from various microhabitats (modified after Loubere's model for calcareous benthic foraminifera, 1989). Solid lines: abundance without taphonomic loss. Depth (vertical scale) in cm below sediment surface.

DISCUSSION AND CONCLUSIONS

Benthic foraminiferal assemblages from abyssal water-depths show differences in their taxonomic and quantitative composition which are related to the trophic structure of the overlying surface water masses and the influence of deep currents. Along the transect studied we are able to distinguish three characteristic assemblages:

(1) Benthic foraminiferal assemblages undeneath the oligotrophic water masses of the central Sargasso Sea

(2) Benthic foraminiferal assemblages observed in 4654 m water depth underneath the zone of cold core rings along the southern margin of the Gulf Stream.

The contrasts between these two assemblages are as follows:

- calcareous benthic foraminifers are more abundant under the Gulf Stream than in comparable abyssal areas, which are not current-influenced, although the taxonomic composition of the assemblages remains largely the same
- agglutinated foraminifers with calcareous cement are more common under the Gulf Stream than in abyssal sediments of the Sargasso Sea

the live infauna under the Gulf Stream consists mainly of small, smooth-walled infaunal morphotypes. Its taxonomic composition is almost identical with stations from the oligotrophic waters of the Sargasso Sea. However, the number of living individuals is about 2 to 3 times higher as in abyssal samples from the Sargasso Sea

higher standing stocks of benthic foraminiferal populations under the Gulf Stream may reflect influence of current-transported particulate organic matter.

- most of the observed komokiaceans under the Gulf Stream have been found within the uppermost 2 cm of the sediment and not on the sediment surface. These forms have generally thicker walls and agglutinate larger grains than epifaunal specimens from the underneath the oligotrophic gyre of the Sargasso Sea
- epifaunal attached agglutinated foraminifera are common under the Gulf Stream (10-20% of the total surface population) and include suspension feeding morphotypes. This unusually high number of attached agglutinated foraminifera (mainly attached to large planktonic foraminiferal tests) and the occurrence of unusually coarsely agglutinated Komokiacea which appear to live in the uppermost 2 cm of the sediment column may reflect an influence of low-speed bottom currents

- unilocular astrorhizaceans form only a minor component of the faunal assemblage under the Gulf Stream; large, thick-walled forms, which commonly occur on the rise and slope-sites are virtually absent.

(3) Assemblages underneath the cold and highly productive slope water masses, which are partly influenced by the Western Boundary Undercurrent are highly dominated by tubular agglutinated morphotypes.

Based on these observations we speculate that the general distribution of abyssal agglutinated foraminiferal assemblages is controlled by three main factors in addition to general oceanographic conditions (e.g., position of the CCD):

(1) The low and seasonal supply of nutrients and phytodetritus underneath the central oceanic gyre favors detritus-feeding infaunal forms which prefer closed ecosystems where they do not lose resources to the water column. Recycling of nutrients may be an important process in these oligotrophic benthic communities.

(2) Enhanced and more steady phytodetritus supply to the deep sea underneath large surface current systems like the Gulf Stream and its marginal cold core rings is reflected by generally higher standing stocks and larger proportions of calcareous benthic foraminifera, shallow infaunal, epifaunal and attached agglutinated foraminifers.

(3) The influence of bottom currents favors opportunistic species with high capabilities to recolonise disturbed substrates (e.g., Reophacinae).

The role of major current systems is still poorly understood in reconstructions of paleoproductivity and palaeocirculation patterns using the deep ocean record. One of the reasons is that the conventionally used deep ocean palaeoceanographic tracers such as stable isotopes (∂18O, ∂13C), and geochemical tracers (Cd/Ca and Ba/Ca) generally cannot resolve comparatively narrow features such as the Gulf Stream system. Thus it seems to be worthwile to discuss whether the observed changes in benthic biofacies beneath the Gulf Stream system may have potential as palaeoceanographic tracers.

The following main features may allow to discriminate deep-current influenced benthic foraminiferal assemblages from "normal" abyssal biofacies:

1. higher standing stocks and benthic foraminiferal accumulation rates
2. local occurrence of high organic flux indicator benthic foraminifera
3. reduced importance of "oligotrophic" specialists
4. enlarged test sizes of agglutinated tubular morphotypes (indicators of enhanced biomass)
5. less pronounced influence of seasonality on benthic foraminiferal populations, due to more steady organic flux provided by the current system
6. common occurrence of recolonization opportunists on disturbed substrates following "abyssal storm" events by deep current or eddy activities.

Most of these features also characterise deep-water benthic foraminiferal assemblages underneath high productivity slope waters and in advective zones, where primary production may be enhanced by terrestrial nutrient input or upwelling. However, beneath the Gulf Stream system we did not observe indicators of interstitial water oxygen deficiency and typical indicators of excess organic flux such as *Uvigerina peregrina*, probably because the Gulf Stream continuously supplies highly oxygenated water.

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APPENDIX: TAXONOMIC REFERENCE LIST

We illustrate and provide documentation for agglutinated species only. The taxonomy of calcareous benthic forms mentioned in this study follows Hermelin & Scott (1985).

Agglutinated Foraminifera

Adercotryma glomerata (Brady, 1878)

Plate 6, Figs 10-21

Lituola glomerata Brady, 1878, p. 433, pl. 20, fig. 1a-c

Ammobaculites agglutinans (d'Orbigny, 1846)

Plate 4, Figs 1-2

Spirolina agglutinans d'Orbigny, 1846, p. 137, pl. 7, figs 10-12

Ammobaculites filiformis Earland, 1934

Plate 4, Figs 9-10

Ammobaculites agglutinans var. *filiformis* Earland, 1934, pp. 92-93, pl. 3, figs 11-13

Ammobaculites cf. *filiformis* Earland, 1934

Plate 4, Figs 3-8

Test small with a short rectlinear part; wall finely agglutinated, brownish, surface smooth. Differs from *A. filiformis* in its shorter uniserial part and its typically fine-grained, brownish wall with a smooth surface.

Earland (1934) includes in the variability of his *Ammobaculites agglutinans* var. *filiformis* an "abnormally long specimen with fifteen chambers in the uniserial portion, found at St. WS 472, is very smoothly built, with an excess of cement" (probably the specimen he figures on plate 3, fig. 12). The wall structure of this specimen (described by Earland (1934) as "using cement almost entirely" seems to closely corresond with the forms we call *A.* cf. *filiformis*.

Ammodiscus cretaceus (Reuss, 1845)

Plate 1, Fig. 1

not *Operculina incerta* d'Orbigny, 1839, p. 49, pl. 6, figs 16-17
Operculina cretacea Reuss, 1845, p. 35, pl. 13, figs 64, 65a-b

Brady (1884) used the name *Ammodiscus incertus* (d'Orbigny) for all Recent and fossil species with a test morphology of "a smooth arenaceous planispiral tube". Loeblich & Tappan (1954) have re-examined d'Orbigny's types of *Operculina incerta* from Cuba and figured a lectotype. They found that this species possesses a calcareous, imperforate, porcellaneous wall and placed it in the genus *Cornuspira*. This consequently means that the name *O. incerta* is not available for the undoubtedly agglutinated forms described by Brady under the name *Ammodiscus incertus*.

The first reported deep-water *Ammodiscus* with an undoubtedly agglutinated wall is to our knowledge *O. cretacea* Reuss, 1845, from Upper Cretaceous pelagic marlstones of Bohemia. This name is generally in use for late Cretaceous deep-water forms of the genus *Ammodiscus*. We use this name for the Recent deep-water *Ammodiscus* as well, since we cannot find any diagnostic features which would permit differentiation of late Cretaceous deep-water *Ammodiscus* from the Recent forms.

Ammolagena clavata (Jones & Parker, 1860)

Plate 12, Figs 5-8

Trochammina irregularis (d'Orbigny) var. *clavata* Jones & Parker, 1860, p. 304

Aschemonella catenata (Norman, 1876)

Plate 2, Fig. 22

Astrorhiza catenata Norman, 1876, p. 213
Aschemonella catenata (Norman). - Brady, 1884, p. 271, pl. 27, fig. 3; pl. 27A, figs 1-3

Aschemonella ramuliformis Brady, 1884

Plate 2, Fig. 20

Aschemonella ramuliformis Brady, 1884, p. 273, pl. 27, figs 12-15

Aschemonella scabra Brady, 1884

Plate 2, Fig. 21

Aschemonella scabra Brady, 1879, p. 44, pl. 3, figs 6, 7

Astrammina rara Rhumbler in Wiesner, 1931

Plate 1, Fig. 15

Astrammina rara Rhumbler in Wiesner, 1931, p. 78, pl. 2, fig. 19

Astrorhiza crassatina Brady, 1881

Astrorhiza crassatina Brady, 1881, p. 47
Astrorhiza crassatina Brady. - Brady, 1884, pp. 233-234, pl. 20, figs 1-9

Buzasina galeata (Brady, 1881)

Plate 5, Figs 3-6

Trochammina galeata Brady, 1881, p. 52
Trochammina galeata Brady. - Brady, 1884, p. 344, pl. 40, figs 19-23

Buzasina ringens (Brady, 1879)

Plate 5, Figs 1-2

Trochammina ringens Brady, 1879, p. 57, pl. 5, fig. 12a, b
Trochammina ringens Brady. - Brady, 1884, p. 343, pl. 40, figs 17-18

Buzasina wiesneri (Parr, 1950)

Plate 5, Figs 7-8

Labrospira wiesneri Parr, 1950, p. 272, pl. 4, figs 25-26

Cribrostomoides subglobosus (G.O. Sars, 1872)

Plate 6, Figs 1-4

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

Cystammina pauciloculata (Brady, 1879)

Plate 8, Figs 1-2

Trochammina pauciloculata Brady, 1879, p. 58, pl. 5, figs 13-14

Discammina (?) *compressa* (Goes, 1882)

Plate 4, Figs 15-16, 18

Lituolina irregularis var *compressa* Goës, 1882, p. 141, pl. 12, figs 421-423

Eggerella (?) *advena* (Cushman, 1922)

Plate 8, Fig. 5

Verneuilina advena Cushman, 1922, p. 141

Eggerella bradyi (Cushman, 1911)

Plate 8, Figs 13-15

Verneuilina pygmaea (Egger). - Brady, 1884, pp. 385-386, pl. 47, figs 4-7
Verneuilina bradyi Cushman, 1911, p. 54, text-figs 87a, b, pl. 6, fig. 4

Eratidus foliaceus (Brady, 1881)

Plate 4, Figs 11-12

Haplophragmium foliaceum Brady, 1881, p. 50
Haplophragmium foliaceum Brady. -Brady, 1884, pp. 304-305, pl. 33, figs 20-25

Eratidus foliaceus recurvus (Earland, 1934)

Plate 4, Figs 13-14

Ammobaculites foliaceus var. *recurva*, Earland, 1934, pp. 93-94, pl. 3, figs 14-17

Glomospira charoides (Jones & Parker, 1860)

Plate 1, Figs 5-6

Trochammina squamata Jones & Parker var. *charoides* Jones & Parker, 1860, p. 304

Glomospira gordialis (Jones & Parker, 1860)

Plate 1, Fig. 4

Trochammina squamata Jones & Parker var. *gordialis* Jones & Parker, 1860, p. 304

Glomospirella biedai Samuel, 1977

Plate 1, Figs 2-3

Glomospirella biedai Samuel, 1977, p. 29, pl. 3, fig. 16, pl. 21, fig. 3
Ammodiscus anguillae Höglund. - Hermelin & Scott, 1985, p. 202, pl. 1, fig. 1

Haplophragmoides bradyi (Robertson, 1891)

Plate 5, Figs 14-15

Trochammina bradyi Robertson, 1891, p. 388

Haplophragmoides rotulatum (Brady, 1881)

Plate 5, Fig. 13

Haplophragmium rotulatum Brady, 1881, p. 50

Haplophragmoides sphaeriloculum Cushman, 1910

Plate 5, Figs 16-18

Haplophragmoides sphaeriloculum Cushman, 1910, p. 107, text-fig. 165

Hormosina carpenteri Brady, 1884

Plate 3, Fig. 19

Hormosina carpenteri Brady, 1884, p. 327, pl. 39, figs 14-18

Hormosina globulifera Brady, 1879

Plate 3, Figs 17-18

Hormosina globulifera Brady, 1879, p. 60, pl. 4, figs 4,5

Hormosinella distans (Brady, 1881)

Plate 3, Fig. 15

Reophax distans Brady, 1881, p. 50

Hyperammina elongata Brady, 1878

Plate 2, Figs 15-18

Hyperammina elongata Brady, 1878, p. 433, pl. 20, fig. 2a, b

Hyperammina laevigata Wright, 1891

Plate 2, Fig. 19

Hyperammina elongata Brady var. *laevigata* Wright, 1891, p. 466, pl. 20, fig. 1

Jaculella cf. **acuta** Brady, 1879

Plate 2, Fig. 5

cf. *Jaculella acuta* Brady, 1879, p. 35, pl. 3, figs 12-13

Kalamopsis sp.1

Plate 2, Figs 7-10

? *Kalamopsis vaillanti* de Folin. - Loeblich & Tappan, 1988, p. 55, pl. 42, figs 12-13

Karreriella bradyi (Cushman, 1911)

Plate 8, Figs 16, 18

Gaudryina pupoides d'Orbigny. - Brady, 1884, p. 378, pl. 46, figs 1-4
Gaudryina bradyi Cushman, 1911, p. 67, text-fig. 107a, b

Karreriella novangliae (Cushman, 1922)

Plate 8, Fig. 17

Gaudryina novangliae Cushman. - Cushman, 1937b, p. 136, pl. 16, figs 12-13

Karrerulina apicularis (Cushman, 1911)

Plate 8, Figs 6-9

Gaudryina apicularis Cushman, 1911, pp. 69-70, text-fig. 110

Lagenammina difflugiformis (Brady, 1879)

Plate 1, Fig. 13

Reophax difflugiformis Brady, 1879, p. 51, pl. 4, fig. 3a-b

We do not include coarsely agglutinated forms like the one figured by Cole (1981) from the offshore Northeast Newfoundland which are probably single chambered specimens of *Reophax bilocularis.*

Lagenammina tubulata (Rhumbler, 1931)

Plate 1, Fig. 14; Plate 10, Fig. 2

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

Lituotuba lituiformis (Brady, 1879)

Trochammina lituiformis Brady, 1879, p. 59, pl. 5, fig. 16

Marsipella elongata Norman, 1878

Plate 2, Fig. 1

Marsipella elongata Norman, 1878, p. 281, pl. 16, fig. 7

Nodellum membranaceum (Brady, 1879)

Plate 2, Fig. 11

Reophax membranacea Brady, 1879, p. 53, pl. 41, fig. 9

Placopsilinella aurantiaca Earland, 1934

Plate 9, Figs 1-6

Placopsilinella aurantiaca Earland, 1934, p. 95, pl. 3, fig. 18

Placopsilinella confusa (Cushman, 1920)

Plate 9, Figs 7-8

Placopsilina confusa Cushman, 1920, p. 71, pl. 14, fig. 6

Psammosphaera fusca **Schulze, 1875**

Plate 1, Fig. 10

Psammosphaera fusca Schulze, 1875, p. 113, pl. 2, fig. 8a-f

Psammosphaera parva **Flint, 1899**

Plate 1, Fig. 12

Psammosphaera fusca Schulze (pars). - Brady, 1884, pp. 249-251, pl. 18, figs 2-4

Pseudonodosinella (?) bacillaris **(Brady, 1881)**

Plate 8, Fig. 12

Reophax bacillaris Brady, 1881, p. 49

Pseudonodosinella nodulosa **(Brady, 1879)**

Plate 3, Fig. 16

Reophax nodulosa Brady, 1879, p. 52, pl. 4, figs 7, 8

Recurvoides contortus **Earland, 1934**

Plate 6, Figs 7-9

Recurvoides contortus Earland, 1934, pp. 91-92, pl. 10, figs 7-19

Recurvoides scitulus **(Brady, 1881)**

Plate 6, Figs 5-6

Haplophragmium scitulum Brady, 1881, p. 50
Haplophragmium scitulum Brady. - Brady, 1884, pl. 34, figs 11-13

Reophanus oviculus **(Brady, 1879)**

Plate 3, Figs 20-21

Hormosina ovicula Brady, 1879, p. 61, pl. 4, fig. 6
Hormosina ovicula Brady. - Brady, 1884, p. 327, pl. 39, figs 7-9

Reophax bilocularis **Flint, 1899**

Plate 3, Figs 9-10, 11(?)

Reophax bilocularis Flint, 1899, p. 273, pl. 17, fig. 3

Reophax gracilis **Kiaer, 1900**

Plate 3, Fig. 1

Nodulina gracilis Kiaer, 1900, p. 24, text-figs (without number)

Reophax dentaliniformis **Brady, 1881**

Plate 3, Fig. 5

Reophax dentaliniformis Brady, 1881, p. 49

Reophax helenae **(Rhumbler, 1911)**

Plate 3, Figs 2-3

Proteonina helenae Rhumbler, 1911, text-figs 16, 17

Reophax horridus **Cushman, 1912**

Plate 3, Fig. 6

Reophax horrida Cushman, 1912, p. 229, pl. 28, figs 3-4

Reophax pilulifer **Brady, 1884**

Plate 3, Fig. 4

Reophax pilulifera Brady, 1884, p. 292, pl. 30, figs 18-20

Reophax scorpiurus **Montfort, 1808**

Plate 3, Figs 7-8

Reophax scorpiurus Montfort, 1808, p. 330

Reticulophragmium pusillum **(Brady, 1881)**

Plate 5, Figs 11-12

Cyclammina pusilla Brady, 1881, p. 53

Reticulophragmium trullissatum **(Brady, 1879)**

Plate 5, Figs 9-10

Trochammina trullissata Brady, 1879, p. 56, pl. 5, figs 10-11

Rhabdammina abyssorum **Carpenter, 1869**

Rhabdammina abyssorum Carpenter, 1869, p. 60

Rhabdammina agglutissima **Hofker, 1972**

Plate 2, Fig. 3

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

Rhabdammina discreta **Brady, 1881**

Rhabdammina discreta Brady, 1881, p. 48
Rhabdammina discreta Brady. - Brady, 1884, pp. 268-269, pl. 22, figs 7-10.

Rhabdammina linearis **Brady, 1879**

Rhabdammina linearis Brady, 1879, p. 37, pl. 3, fig. 10
Rhabdammina linearis Brady. - Brady, 1884, pp. 269-270, pl. 22, figs 1-6

Rhabdammina **(?) sp. coarse**

We include in this group all fragments of tubular agglutinated morphotypes with the following common features:
- generally straight or only slightly curved tubular fragments with a ± circular cross-section
- no branching visible
- coarsely agglutinated walls, with generally better sorted grains as in *Rhizammina* (?) sp. coarse, quartz grains dominate, planktonic foraminiferal tests are generally not agglutinated
- wall thick with a multilayered structure.

Rhizammina algaeformis **Brady, 1879**

Plate 2, Fig. 4; Plate 14, Figs 6-11 (?)

Rhizammina algaeformis Brady, 1879, p. 39, pl. 4, figs 16-17

Rhizammina indivisa **Brady, 1884**

Plate 2, Fig. 2(?); Plate 14, Figs 6-11 (?)

Rhizammina indivisa Brady, 1884, p. 277, pl. 29, figs 5-7

Rhizammina **(?) sp. coarse**

We include in this group all fragments of tubular agglutinated morphotypes with the following common features:
- irregular curved outline

- occasionally visible branching
- coarsely agglutinated walls, with poorly sorted grains, which may include planktonic foraminiferal tests
- wall structure generally single-layered

Saccammina sphaerica Sars, 1872

Plate 1, Fig. 11

Saccammina sphaerica Sars, 1872, p. 250

Saccorhiza ramosa (Brady, 1879)

Plate 2, Figs 13-14

Hyperammina ramosa Brady, 1879, p. 33, pl. 3, figs 14-15

Sigmoilopsis schlumbergeri (Silvestri, 1904)

Plate 8, Fig. 10

Sigmoilina schlumbergeri Silvestri, 1904, pp. 267-269

Siphotextularia rolshauseni Phleger & Parker, 1951

Plate 8, Fig. 11

Siphotextularia rolshauseni Phleger & Parker, 1951, p. 4, pl. 1, figs 23, 24a,b

Sorosphaera cf. *confusa* Brady, 1879

Plate 2, Fig. 26

cf. *Sorosphaera confusa* Brady, 1879, p. 28, pl. 4, figs 18, 19

Sorosphaera consociata (Rhumbler, 1931)

Plate 2, Figs 23-25, 27

? *Saccammina consociata* Flint, 1899, p. 269, pl. 9, fig. 3
Psammophax consociata Rhumbler (in Wiesner), 1931, p. 81, pl. 4, figs 38-40, pl. 5, figs 41-44

Spiroplectammina biformis Parker & Jones, 1865

Plate 8, Fig. 4

Textularia agglutinans d'Orbigny var. *biformis* Parker & Jones, 1865, p. 370

Subreophax aduncus (Brady, 1882)

Plate 3, Figs 22-23

Reophax adunca Brady, 1882, p. 715
Reophax adunca Brady. - Brady, 1884, pp. 296-297, pl. 31, figs 23-2

Subreophax guttifer (Brady, 1881)

Plate 3, Figs 12-14

Reophax guttifer Brady, 1881, p. 49
Reophax guttifer Brady. - Brady, 1884, p. 295, pl. 31, figs 10-15

Technitella legumen Norman, 1878

Plate 2, Fig. 6

Technitella legumen Norman, 1878, p. 79, pl. 16, figs 3-4

Tholosina bulla (Brady, 1881)

Plate 1, Fig. 9; Plate 11, Fig. 1

Placopsilina bulla Brady, 1881, p. 51
Placopsilina bulla Brady. - Brady, 1884, p. 315, pl. 35, figs 16, 17

Tholosina vesicularis (Brady, 1879)

Plate 11, Figs 2-4

Placopsilina vesicularis Brady, 1879, p. 51, pl. 5, fig. 2

Thurammina papillata Brady, 1879

Plate 1, Figs 16-17

Thurammina papillata Brady, 1879, p. 45, pl. 5, figs 4-8

Tolypammina vagans (Brady, 1879)

Plate 2, Fig. 12

Hyperammina vagans Brady, 1879, p. 33, pl. 3, fig. 5

Trochammina antarctica Parr, 1950

Plate 7, Figs 12, 22-23

Trochammina antarctica Parr, 1950, p. 280, pl. 5, figs 1-2

Trochammina ex gr. *globigeriniformis* (Parker & Jones, 1865)

Plate 7, Figs 11, 13

Lituola nautiloidea Lamarck var. *globigeriniformis* Parker & Jones, 1865, p. 407, pl. 15, figs 46, 47

Brönnimann & Whittaker (1988) regarded *Trochammina globigeriniformis* (Parker & Jones, 1865) as nomen nudum, despite the fact that a lectotype established by Loeblich & Tappan (1964) and illustrated in the Treatise of Invertebrate Paleontology (figs 173-2a-c). For practical reasons we lump under the informal name *Trochammina* ex gr. *globigeriniformis* all specimens of *Trochammina* with globular inflated chambers, four chambers in the last whorl, rather low trochospiral chamber arrangement and an interiomarginal aperture.

Trochammina ex gr. *squamata* Parker & Jones, 1860

Plate 7, Figs 1-7

cf. *Trochammina squamata* Parker & Jones, 1860, p. 304

We observe two distinctly different morphotypes in our material. Specimens from abyssal stations in the Sargasso Sea (Pl. 7, Figs 1-5) are very small, with a finely agglutinated wall with much pseudochitineous cement and a typically dark brownish color. Specimens from bathyal stations in the Baltimore Canyon area are much larger, more coarsely agglutinated, gray with somewhat inflated chambers (Pl. 7, Figs 6-7).

Trochammina scotiaensis (Brönnimann & Whittaker, 1988)

Plate 7, Figs 8, 20-21

Paratrochammina (Paratrochammina) scotiaensis Brönnimann & Whittaker. - Brönnimann & Zaninetti, 1984, p. 68 (nomen nudum)

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PLATES

The illustrated specimens have not been removed from the SEM stubs; the stubs are deposited in the collection of the Centre for Marine Geology at Dalhousie University, Halifax N.S. (stub numbers 5/92-1 to 5).

Plate 1. 1. *Ammodiscus cretaceus*, 004F, 2-3 cm, st. no. 5/92/1-1, x470; **2.** *Glomospirella* sp., 016A, #18, st. no. 91/1-28, x245; **3.** *Glomospirella* sp., 016A, #16, st. no. 91/1-29, x185; **4.** *Glomospira gordialis*, 020F, 1-2 cm, st. no. 5/92/1-8, x235; **5.** *Glomospira charoides*, 020F, 1-2 cm, st. no. 5/92/1-9, x185; **6.** *Glomospira charoides*, 016, 0-2 cm (bulk), st. no. 91/1-37, x130; **7.** *Glomospira irregularis*, 016F, 2-3 cm, st. no. 5/92/3-19, x220; **8.** *Psammosphaera parva* (attached to *Hyperammina elongata*), 020F, 1-2 cm, st. no. 5/92/4-12, x180; **9.** *Tholosina bulla* (attached to *Rhabdammina*), 020F, 0-2 cm (bulk-sample), st. no. 5/92/2-16, x95; **10.** *Psammosphaera fusca*, 027F, 0-1 cm, st. no. 5/92/4-10, x90; **11.** *Saccammina sphaerica*, 004F, 0-1 cm, st. no. 5/92/1-30, x225; **12.** *Psammosphaera parva*, 016F, 4-5 cm, st. no. 5/92/5-7, x100; **13.** *Lagenammina difflugiformis*, 016F, 0-2 cm (bulk sample), st. no. 5/92/3-6, x155; **14.** *Lagenammina tubulata*, 004F, 0-1 cm, st. no. 5/92/1-16, x270; **15.** *Astrammina rara*, 004F, 4-5 cm, st. no. 5/92/2-8, x165; **16.** *Thurammina papillata*, 004F, 4-5 cm, st. no. 5/92/2-9, x145; **17.** *Thurammina papillata*, 020F, 0-2 cm (bulk-sample), st. no. 5/92/2-17, x75.

Plate 2. 1. *Marsipella elongata*, 020F, 5-6 cm, st. no. 5/92/3-34, x40; **2.** *Rhizammina indivisa* or *R. algaeformis*, 004F, 0-1 cm, st. no. 5/92/1-23, x205; **3.** *Rhabdammina agglutissima*, 027F, 0-1 cm, st. no. 5/92/4-11, x30; **4.** *Rhizammina algaeformis*, 027F, 1-2 cm, st. no. 5/92/4-15, x80; **5.** *Jaculella acuta*, 020F, 5-6 cm, st. no. 5/92/5-1, x55; **6.** *Technitella legumen*, 004F, 1-2 cm, st. no. 5/92/2-6, x130; **7.** *Kalamopsis* sp., 004F, 4-5 cm, st. no. 5/92/2-11, x85; **8.** *Kalamopsis* sp., 027F, 2-3 cm, st. no. 5/92/4-17, x80; **9.** *Kalamopsis* sp., 027F, 2-3 cm, st. no. 5/92/4-16, x65; **10.** *Kalamopsis* (?) sp., 016F, 0-2 cm (bulk sample), st. no. 5/92/3-8, x100; **11.** *Nodellum membranaceum*, 004F, 4-5 cm, st. no. 5/92/2-10, x115; **12.** *Tolypammina vagans* (initial portion with proloculus), 016F, 3-4 cm, st. no. 5/92/4-7, x85; **13.** *Saccorhiza ramosa* (with proloculus), 027F, 0-1 cm, st. no. 5/92/5-13, x110; **14.** *Saccorhiza ramosa* (branching), 027F, 0-1 cm, st. no. 5/92/5-14, x35; **15.-16.** *Hyperammina elongata*, 004F, 0-1 cm, st. no. 5/92/2-2,3, x175 (5.), x85 (6.); **17.** *Hyperammina elongata*, 020F, 1-2 cm, st. no. 5/92/4-12, x50; **18.** *Hyperammina elongata*, 027F, 1-2 cm, st. no. 5/92/4-14, x40; **19.** *Hyperammina laevigata*, 020F, 1-2 cm, st. no. 5/92/4-13, x30; **20.** *Aschemonella ramuliformis*, 004F, 0-1 cm, st. no. 5/92/2-1, x25; **21.** *Aschemonella scabra*, 007F, 8-9 cm, st. no. 5/92/4-4, x30; **22.** *Aschemonella catenata*, 016F, 2-3 cm, st. no. 5/92/4-2, x50; **23.** *Sorosphaera consociata*, 004F, 0-1 cm, st. no. 5/92/1-31, x160; **24.** *Sorosphaera consociata*, 004F, 1-2 cm, st. no. 5/92/2-5, x155; **25.** *Sorosphaera consociata*, 020F, 1-2 cm, st. no. 5/92/1-10, x185; **26.** *Sorosphaera* cf. *confusa*, 004F, 0-1 cm, st. no. 5/92/1-32, x305; **27.** *Sorosphaera consociata*, 020F, 1-2 cm, st. no. 5/92/1-11, x175.

Plate 3. 1. *Reophax gracilis*, 004F, 0-1 cm, st. no. 5/92/1-14, x120; **2.** *Reophax helenae*, 004F, 0-1 cm, st. no. 5/92/1-15, x145; **3.** *Reophax helenae*, 004F, 2-3 cm, st. no. 5/92/1-2, x100; **4.** *Reophax pilulifer*, 020A, #28, st. no. 5/92/5-11, x30; **5.** *Reophax dentaliniformis*, 007F, 1-2 cm, st. no. 5/92/5-10, x50; **6.** *Reophax horridus*, 004F, 1-2 cm, st. no. 5/92/2-4, x60; **7.** *Reophax scorpiurus*, 004F, 0-1 cm, st. no. 5/92/1-33, x85; **8.** *Reophax scorpiurus*, 004F, 0-1 cm, st. no. 5/92/5-12, x65; **9-10.** *Reophax bilocularis*, 004F, 0-1 cm, st. no. 5/92/1-28,29, x65 (9.), x85 (10.); **11.** Proloculus of *Reophax bilocularis* or *Lagenammina* sp., 016F, 0-2 cm (bulk sample), st. no. 5/92/3-7, x260; **12.** *Subreophax guttifer*, 020F, 1-2 cm, st. no. 5/92/4-1, x90; **13.** *Subreophax guttifer*, 004F, 14-15 cm, st. no. 5/92/3-32, x90; **14.** *Subreophax guttifer*, 004F, 18-19 cm, st. no. 5/92/3-31, x70; **15.** *Hormosinella distans*, 004F, 0-1 cm, st. no. 5/92/1-20, x45; **16.** *Pseudonodosinella nodulosa*, 007F, 8-9 cm, st. no. 5/92/4-6, x45; **17.** *Hormosina globulifera*, 020F, 0-2 cm (bulk-sample), st. no. 5/92/2-21, x75; **18.** *Hormosina globulifera* (specimen showing overlapping chamber connections), 020F, 5-6 cm, st. no. 5/92/3-33, x40; **19.** *Hormosina carpenteri*, 007F, 7-8 cm, st. no. 5/92/4-3, x65; **20.** *Reophanus oviculus*, 016F, 0-2 cm (bulk sample), st. no. 5/92/3-5, x145; **21.** *Reophanus oviculus*, 016F, 2-3 cm, st. no. 5/92/3-17, x240; **22.** *Subreophax aduncus*, 004F, 0-1 cm, st. no. 5/92/1-17, x100; **23.** *Subreophax aduncus*, 004F, 0-1 cm, st. no. 5/92/1-19, x95.

Plate 4. **1.** *Ammobaculites agglutinans* (microspheric), 020F, 0-2 cm (bulk-sample), st. no. 5/92/2-25, x25; **2.** *Ammobaculites agglutinans* (megalospheric), 020F, 0-2 cm (bulk-sample), st. no. 5/92/2-26, x50; **3.** *Ammobaculites* cf. *filiformis* (streptospiral initial coil?), 020F, 1-2 cm, st. no. 5/92/1-13, x230; **4.** *Ammobaculites* cf. *filiformis*, 020F, 0-5 cm (bulk-sample), st. no. 5/92/2-15, x175; **5.** *Ammobaculites* cf. *filiformis*, 016A, #16, st. no. 91/1-9, x285; **6.** *Ammobaculites* cf. *filiformis*, 016A, #16, st. no. 91/1-8, x295; **7.** *Ammobaculites* cf. *filiformis*, 016A, #18, st. no. 91/1-11, x280; **8.** *Ammobaculites* cf. *filiformis*, 016A, #18, st. no. 91/1-12, x140; **9.** *Ammobaculites filiformis*, 016F, 3-4 cm, st. no. 5/92/4-8, x100; **10.** *Ammobaculites filiformis*, 016A, #18, st. no. 91/1-10, x95; **11.** *Eratidus foliaceus* (megalospheric ?), 020F, 1-2 cm, st. no. 5/92/1-5, x65; **12.** *Eratidus foliaceus*, 020F, 1-2 cm, st. no. 5/92/1-4, x100; **13.** *Eratidus foliaceus recurvus*, 016F, 0-2 cm (bulk sample), st. no. 5/92/3-1, x105; **14.** *Eratidus foliaceus recurvus*, 016F, 2-3 cm, st. no. 5/92/3-18, x145; **15.** *Discammina* (?) *compressa*, 016F, 0-2 cm (bulk sample), st. no. 5/92/3-14, x145; **16.** *Discammina* (?) *compressa*, 016F, 0-2 cm (bulk sample), st. no. 5/92/3-13, x95; **17.** *Eratidus foliaceus* (small abyssal form), 004F, 2-3 cm, st. no. 5/92/1-3, x165; **18.** *Discammina* (?) *compressa*, 016F, 0-2 cm (bulk sample), st. no. 5/92/3-12, x115; **19.** *Ammobaculites* sp. 3 (=*Discammina* (?) *compressa*), 016F, 2-3 cm, st. no. 5/92/3-20, x75; **20.** *Ammobaculites* sp. 3 (=*Discammina* (?) *compressa*), 016F, 2-3 cm, st. no. 5/92/3-21, x80.

Plate 5. 1. *Buzasina ringens*, 004F, 0-1 cm, st. no. 5/92/1-26, x160; **2.** *Buzasina ringens*, 020F, 0-5 cm (bulk-sample), st. no. 5/92/2-12, x60; **3.** *Buzasina galeata*, 016, 0-2 cm (bulk), st. no. 91/1-39, x70; **4.** *Buzasina galeata*, 016, 0-2 cm (bulk), st. no. 91/1-38, x65; 5. *Buzasina galeata*, 004F, 0-1 cm, st. no. 5/92/1-21, x160; **6.** *Buzasina galeata*, 004F, 0-1 cm, st. no. 5/92/1-22, x285; 7. *Buzasina wiesneri*, 020F, 1-2 cm, st. no. 5/92/1-6, x180; 8. *Buzasina wiesneri*, 020F, 1-2 cm, st. no. 5/92/1-7, x160; 9. *Reticulophragmium trullissatum*, 016F, 0-2 cm (bulk sample), st. no. 5/92/3-4, x120; 10. *Reticulophragmium trullissatum*, 007F, 10-11 cm, st. no. 5/92/3-24, x110; **11-12.** *Reticulophragmium pusillum*, 016F, 0-2 cm (bulk sample), st. no. 5/92/3-2 and 3, x145 (10.), x85 (11.); 13. *Haplophragmoides rotulatum*, 007F, 10-11 cm, st. no. 5/92/3-23, x95; 14. *Haplophragmoides bradyi*, 004F, 0-1 cm, st. no. 5/92/1-27, x280; 15. *Haplophragmoides bradyi*, 016A, #18, st. no. 91/1-21, x180; **16.** *Haplophragmoides sphaeriloculus*, 020F, 1-2 cm, st. no. 5/92/3-26, x215; **17-18.** *Haplophragmoides sphaeriloculus*, 016A, #16, st. no. 91/1-19, 18, x170 (16.), x295 (17.).

Plate 6. 1. *Cribrostomoides subglobosus*, 020F, 0-2 cm (bulk-sample), st. no. 5/92/2-19, x70; **2.** detail of fig. 1, aperture, x340; **3.** *Cribrostomoides subglobosus*, 020F, 0-2 cm (bulk-sample), st. no. 5/92/2-20, x70; **4.** detail of fig. 1, aperture, x455; **5.** *Recurvoides scitulus*, 016F, 0-2 cm (bulk sample), st. no. 5/92/3-9, x133; **6.** *Recurvoides scitulus*, 016F, 0-2 cm (bulk sample), st. no. 5/92/3-10, x150; **7.** *Recurvoides contortus*, 016F, 0-2 cm (bulk sample), st. no. 5/92/3-11, x150; **8.** *Recurvoides contortus*, 016F, 2-3 cm, st. no. 5/92/5-9, x210; **9.** *Recurvoides contortus*, 016F, 2-3 cm, st. no. 5/92/5-8, x110; **10-15.** Dimorphism in abyssal *Adercotryma glomerata* (all specimens are from the same subsample HUD 89038-016A, 4654 m water-depth): **10-13.** Elongate morphotype with distinct "terrazzo-type" agglutinated wall surface (microspheric?), magnifications: x 380 (10.), x 340 (11.), x 260 (12.,13.); **14-15.** Subspheric morphotype with more randomly oriented agglutinated grains (macrospheric?), magnifications: x 320 (14.), x 240 (15.).

Plate 7. 1-7. Abyssal and bathyal morphotypes of the *Trochammina squamata* - group: **1-5.** Small, brownish, thin-walled, finely agglutinated abyssal morphotype (Core HUD 89038-016, 4654 m water depth); **6-7.** Large, gray, medium to coarsely agglutinated bathyal morphotype (Core HUD 89038-027, 2330 water depth); **8.** *Trochammina scotiaensis*, 004F, 1-2 cm, st. no. 5/92/2-7, x385; **9.** *Trochammina* ex gr. *globigeriniformis*, 016F, 5-6 cm, st. no. 5/92/5-19, x140; **10.** *Trochammina antarctica*, 020F, 1-2 cm, st. no. 5/92/3-29, x480; **11.** *Trochammina* ex gr. *globigeriniformis*, 016F, 5-6 cm, st. no. 5/92/5-18, x160; **12.** *Trochammina scotianesis*, 027F, 0-1 cm, st. no. 5/92/5-17, x300; **13.** *Trochammina scotianesis*, 027F, 0-1 cm, st. no. 5/92/5-16, x245; **14.** *Trochammina antarctica*, 020F, 1-2 cm, st. no. 5/92/3-27, x450; **15.** *Trochammina antarctica*, 020F, 1-2 cm, st. no. 5/92/3-28, x480; **16.** *Trochammina* sp. (attached to planktic foraminiferal test), 004F, 0-1 cm, st. no. 5/92/1-34, x210; **17.** *Trochammina* sp. (small), 004F, 0-1 cm, st. no. 5/92/1-24, x330; **18.** *Trochammina* sp. (small), 004F, 0-1 cm, st. no. 5/92/1-25, x230.

Plate 8. **1.** *Cystammina pauciloculata*, 020F, 0-5 cm (bulk-sample), st. no. 5/92/2-13, x225; **2.** *Cystammina pauciloculata*, 020F, 0-5 cm (bulk-sample), st. no. 5/92/2-14, x500; **3.** *Textularia*, 020F, 1-2 cm, st. no. 5/92/1-12, x210; **4.** *Spiroplectammina biformis*, 027F, 0-1 cm, st. no. 5/92/5-15, x280; **5.** *Eggerella* (?) *advena*, 027F, 10-11 cm, st. no. 5/92/3-22, x300; **6.** *Karrerulina apicularis* (megalospheric?), 016F, 7-8 cm, st. no. 5/92/5-6, x240; **7.** *Karrerulina apicularis*, 016A, #18, st. no. 91/1-30, x145; **8.** *Karrerulina apicularis*, 016, 0-2 cm (bulk), st. no. 91/1-33, x70; **9.** *Karrerulina apicularis* (microspheric?), 016F, 7-8 cm, st. no. 5/92/5-5, x65; **10.** *Sigmoilopsis schlumbergeri*, 020F, 10-11 cm, st. no. 5/92/3-30, x65; **11.** *Siphotextularia rolshauseni*, 007F, 10-11 cm, st. no. 5/92/3-25, x140; **12.** *Pseudonodosinella* (?) *bacillaris*, 020F, 0-2 cm (bulk-sample), st. no. 5/92/2-22, x30; **13.** *Eggerella bradyi*, 027F, 2-3 cm, st. no. 5/92/5-4, x170; **14.** *Eggerella bradyi*, 016F, 2-3 cm, st. no. 5/92/3-16, x105; **15.** *Eggerella bradyi*, 016F, 2-3 cm, st. no. 5/92/3-15, x70; **16.** *Karreriella bradyi*, 027F, 2-3 cm, st. no. 5/92/5-3, x65; **17.** *Karreriella novangliae*, 027F, 2-3 cm, st. no. 5/92/5-2, x50; **18.** *Karreriella bradyi*, 020F, 0-2 cm (bulk-sample), st. no. 5/92/2-24, x60.

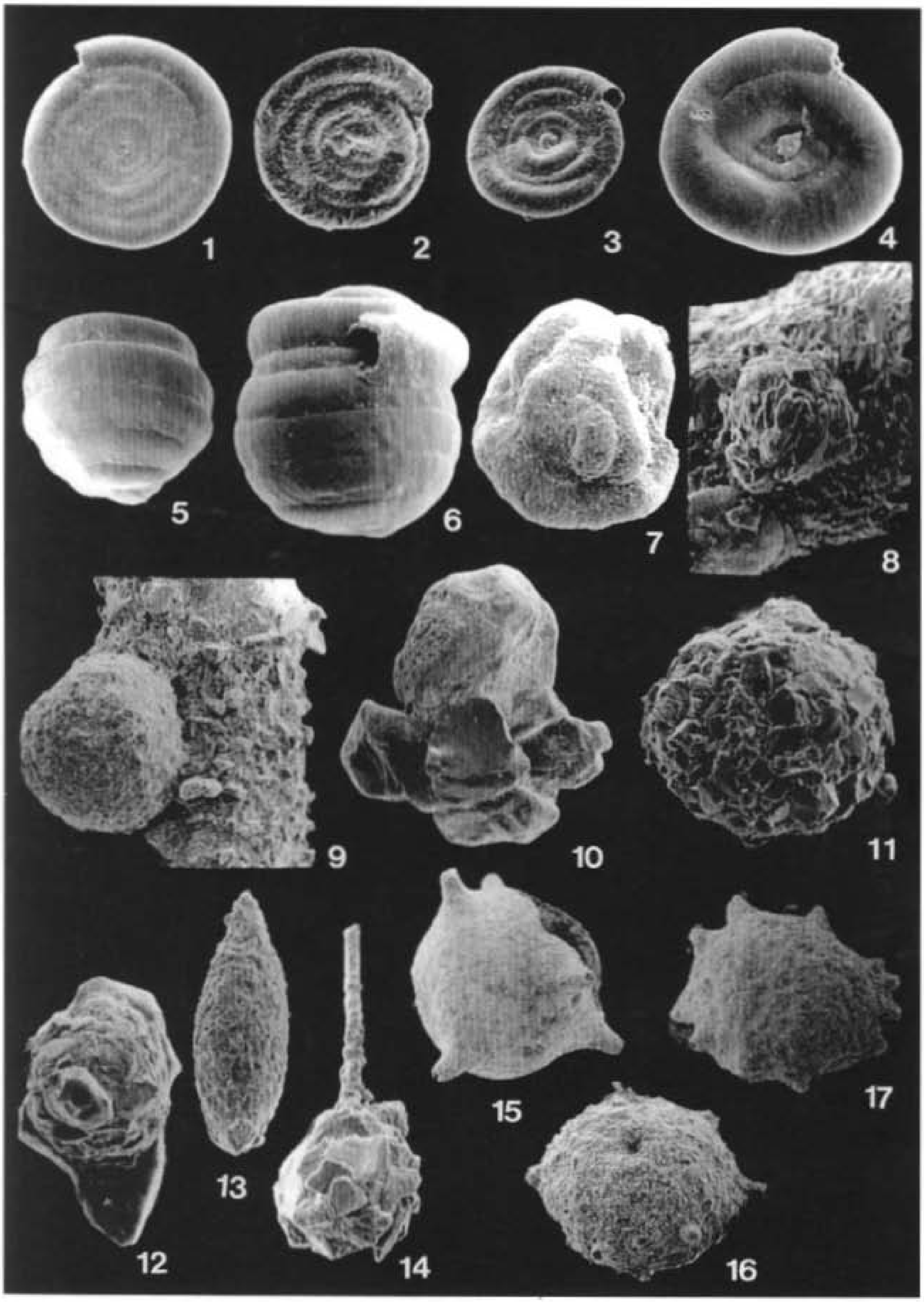
Plate 9. Attached agglutinated foraminifers: morphogroup 1.- **1.** *Placopsilinella aurantiaca*; pushcore HUD 89038-016F, 0-1 cm; **2.** *Placopsilinella aurantiaca*; pushcore HUD 89038-016F, 2-3 cm; **3.** *Placopsilinella* sp., pushcore HUD 89038-016F, 0-1 cm; **4.** *Placopsilinella aurantiaca*, pushcore HUD 89038-016F, 2-3 cm; **5.** *Placopsilinella aurantiaca*; pushcore HUD 89038-016F, 0-1 cm; **6.** *Placopsilinella aurantiaca*; pushcore HUD 89038-016F, 2-3 cm; **7.** *Placopsilinella confusa.*, pushcore HUD 89038-016F, 2-3 cm; **8.** *Placopsilinella confusa*; pushcore HUD 89038-016F, 1-2 cm.

Plate 10. Attached agglutinated foraminifers: morphogroups 2 and 3.- **1.** pushcore HUD 89038-016F, 1-2 cm; **2.** *Lagenammina tubulata*, pushcore HUD 89038-016F, 1-2 cm; **3.** pushcore HUD 89038-016F, 1-2 cm; **4.** pushcore HUD 89038-016F, 2-3 cm; **5.** pushcore HUD 89038-016F, 1-2 cm; **6.** pushcore HUD 89038-016F, 0-1 cm.

Plate 11. Attached agglutinated foraminifers: morphogroups 4 and 5.- **1.** *Tholosina bulla*, pushcore HUD 89038-016F, 2-3 cm; **2.** *Tholosina vesicularis*, pushcore HUD 89038-016F, 1-2 cm; **3.** *Tholosina vesicularis*, pushcore HUD 89038-016F, 2-3 cm; **4.** *Tholosina vesicularis*, pushcore HUD 89038-016F, 2-3 cm; **5.** *Subreophax aduncus*, pushcore HUD 89038-016F, 0-1 cm; **6.** *Subreophax*(?) sp., pushcore HUD 89038-016F, 0-1 cm; **7.** *Subreophax aduncus*, pushcore HUD 89038-016F, 1-2 cm; **8.** *Subreophax aduncus*, pushcore HUD 89038-016F, 0-1 cm.

Plate 12. Attached agglutinated foraminifers: morphogroups 6 and 7.- **1.** *Dendrophrya*(?) sp., pushcore HUD 89038-016F, 0-1 cm; **2.** pushcore HUD 89038-016F, 0-1 cm; **3.** pushcore HUD 89038-016F, 0-1 cm; **4.** *Dendrophrya*(?) sp., pushcore HUD 89038-016F, 0-1 cm; **5.** *Ammolagena clavata*, pushcore HUD 89038-016F, 0-1 cm; **6.** *Ammolagena clavata*, pushcore HUD 89038-016F, 1-2 cm; **7.** *Ammolagena clavata*, pushcore HUD 89038-016F, 0-1 cm; **8.** *Ammolagena clavata*, pushcore HUD 89038-016F, 2-3 cm; **9.** *Ammolagena clavata*, pushcore HUD 89038-016F, 0-1 cm.

Plate 1



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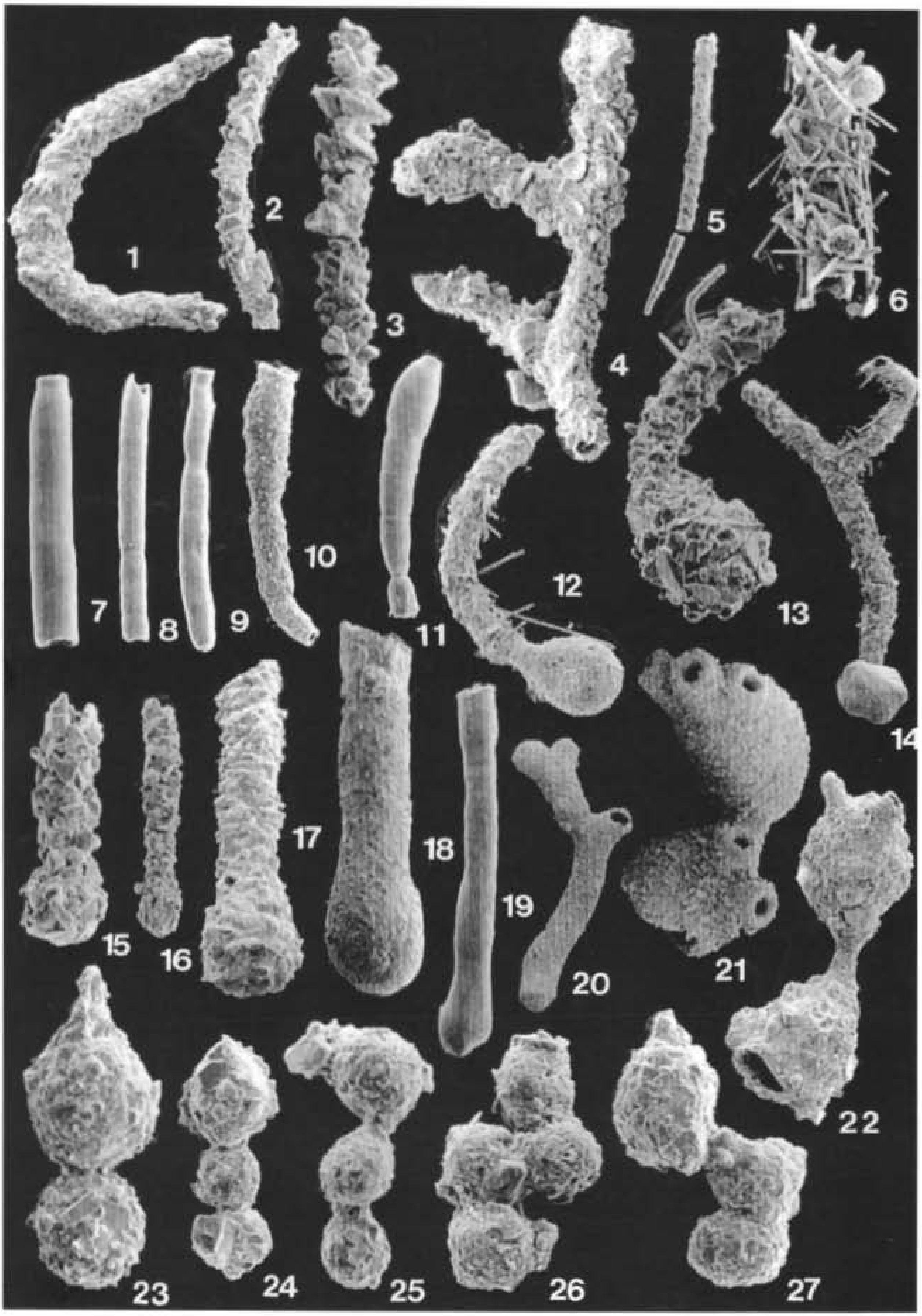

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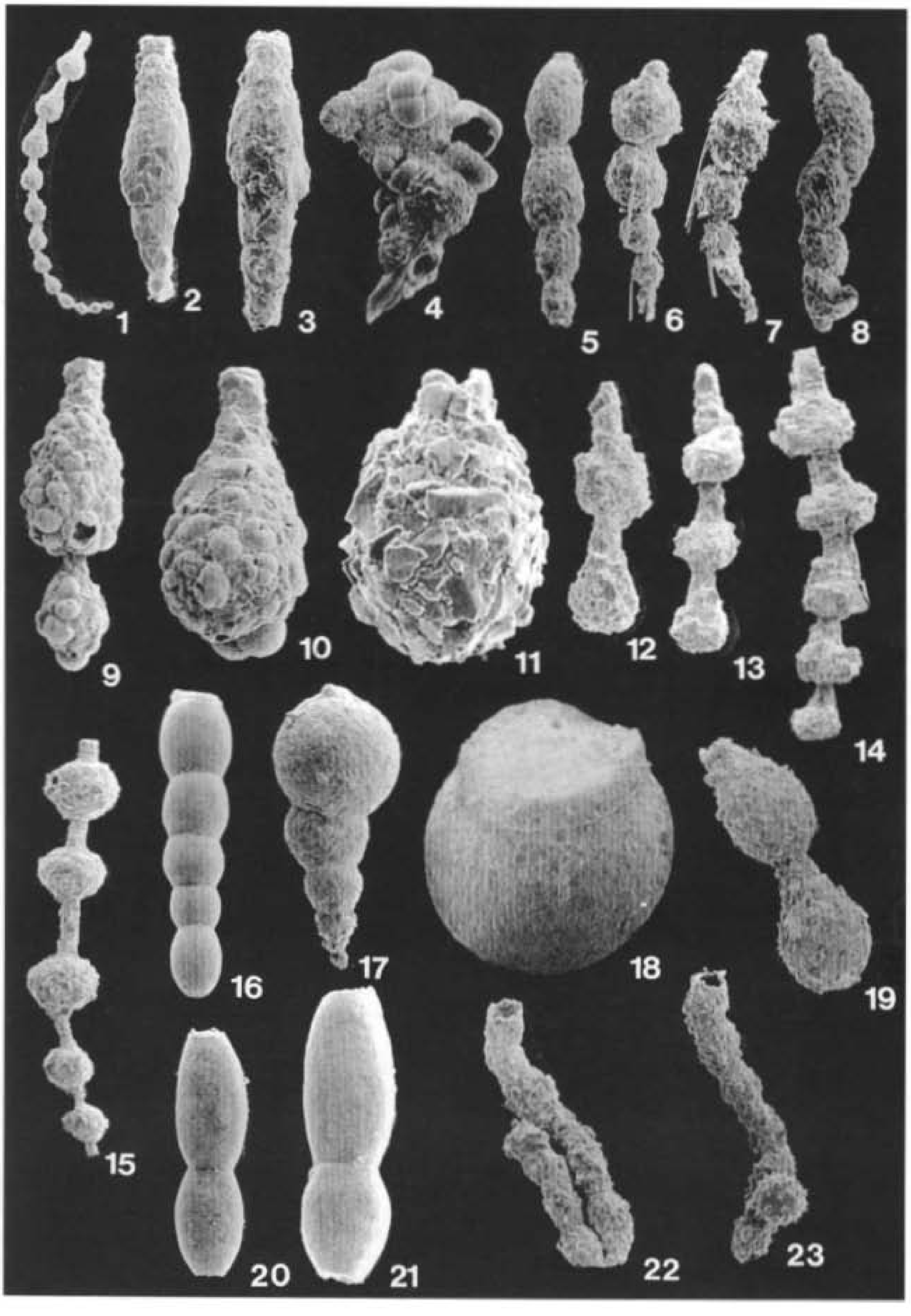

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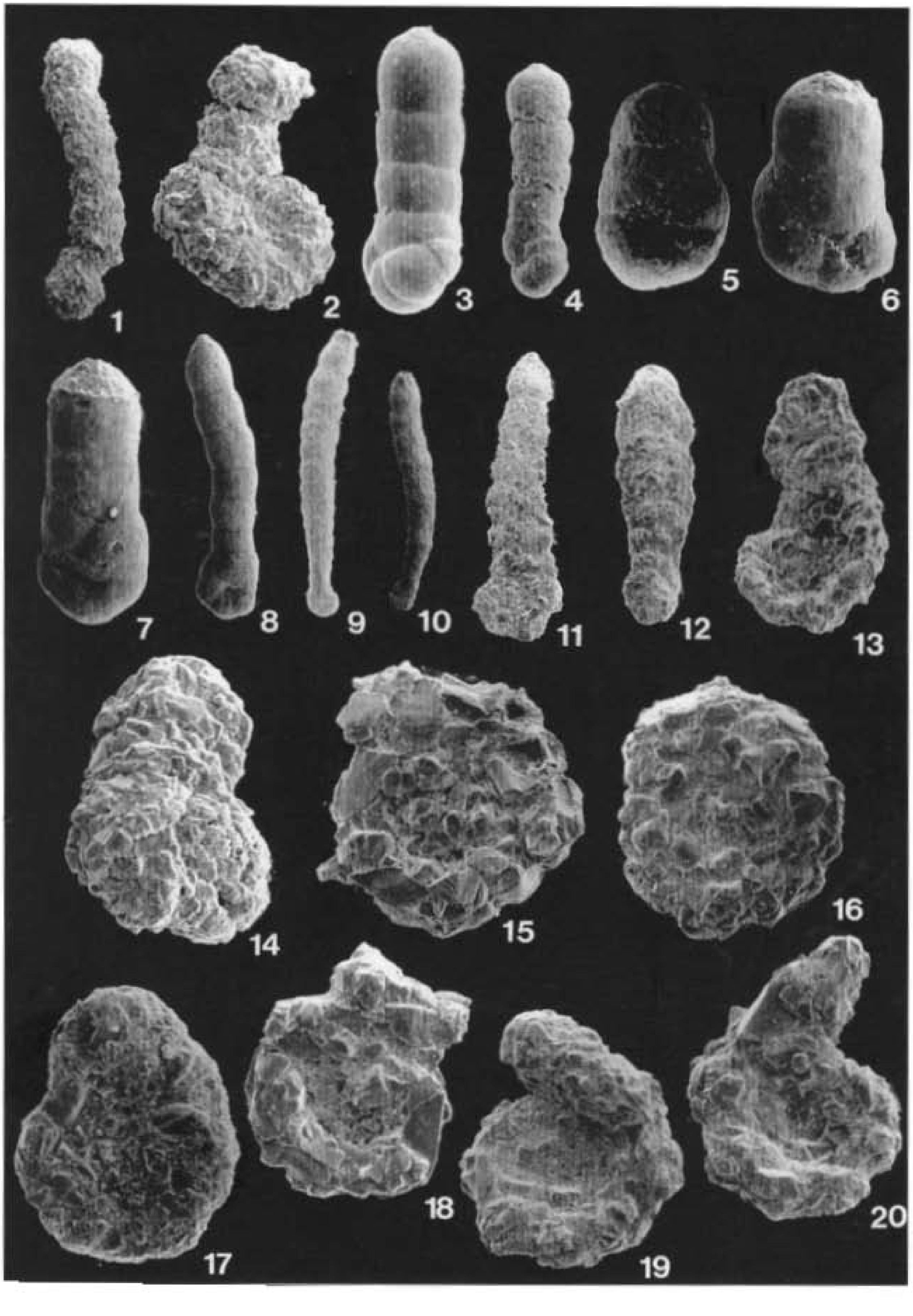

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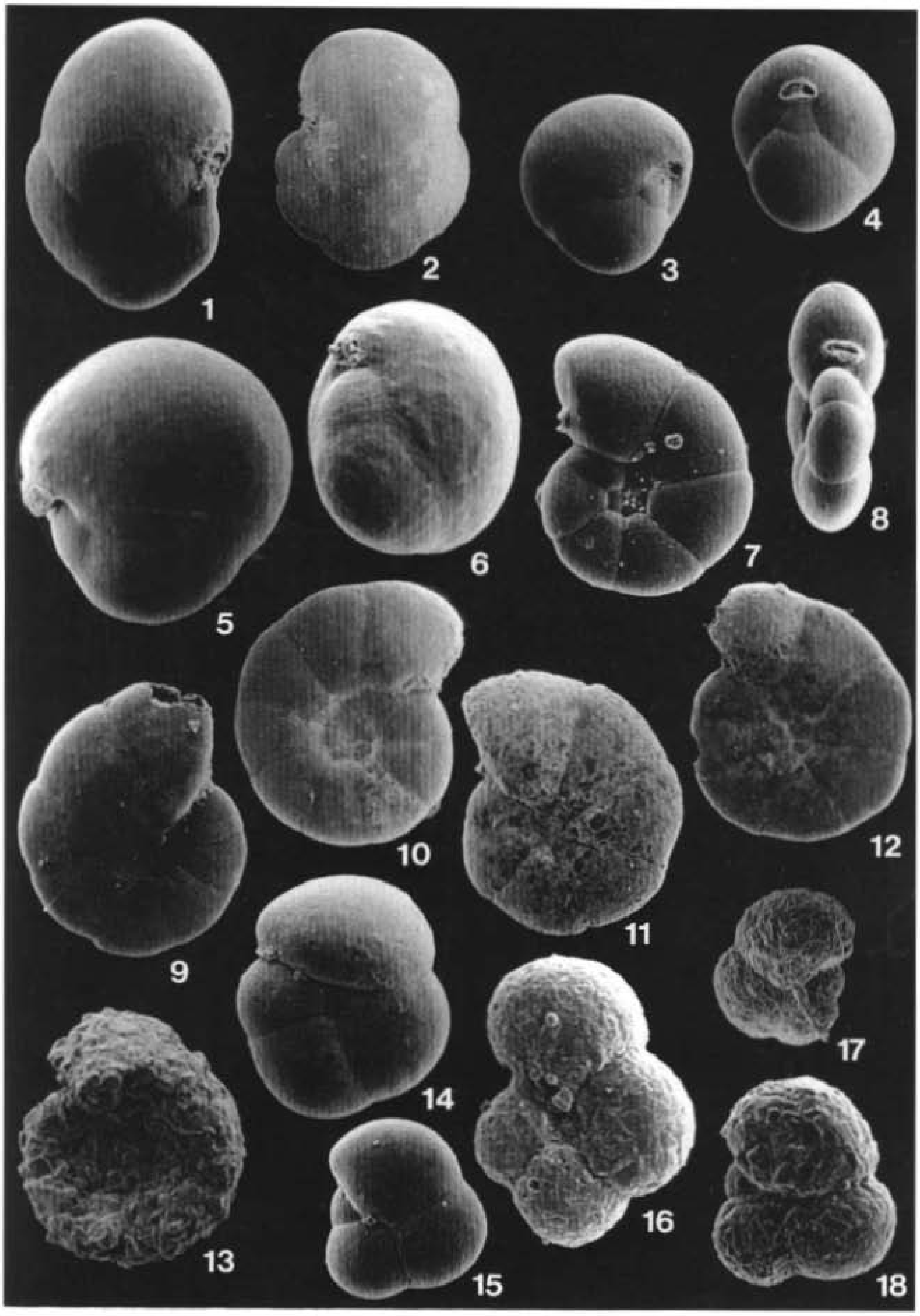

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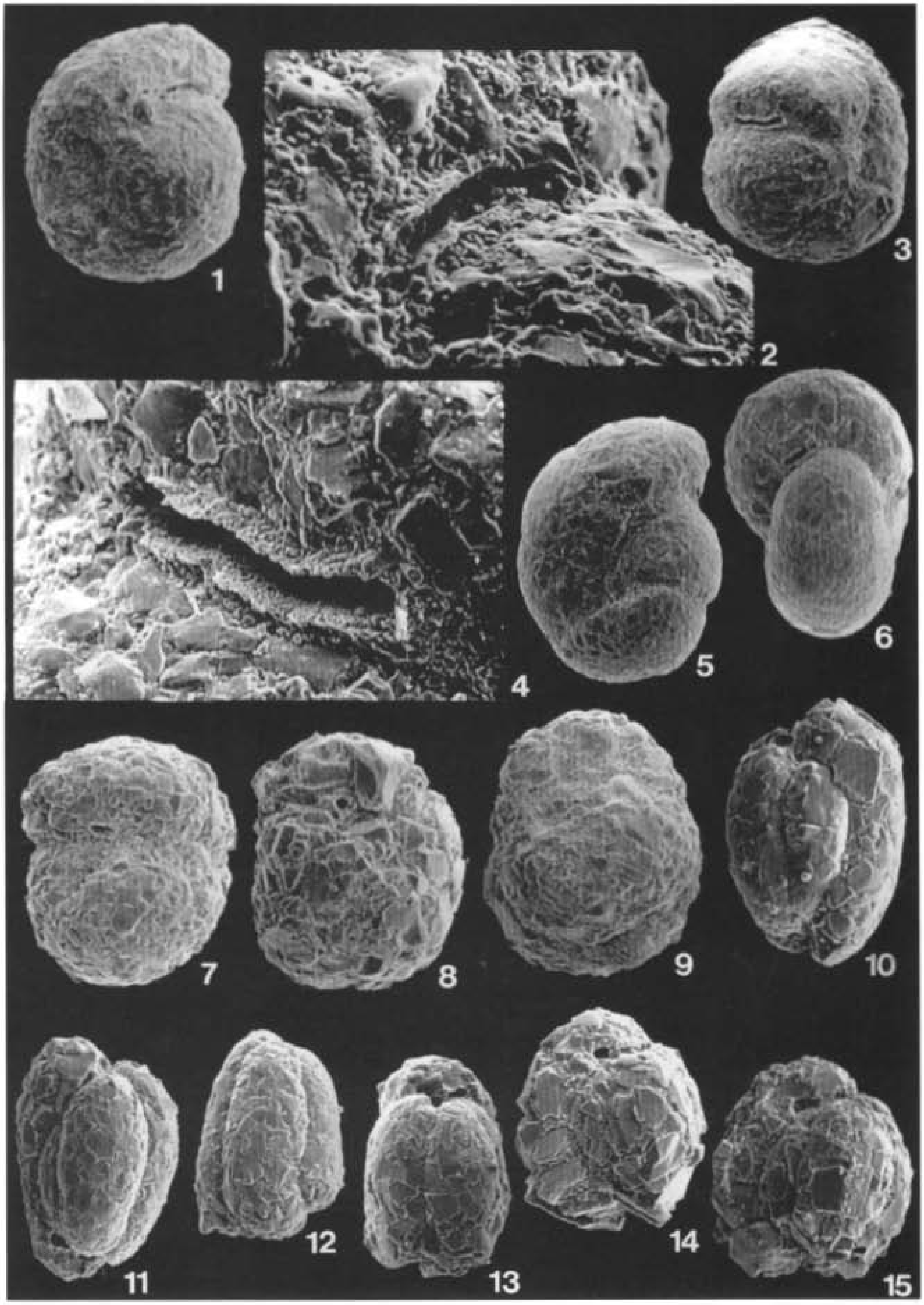

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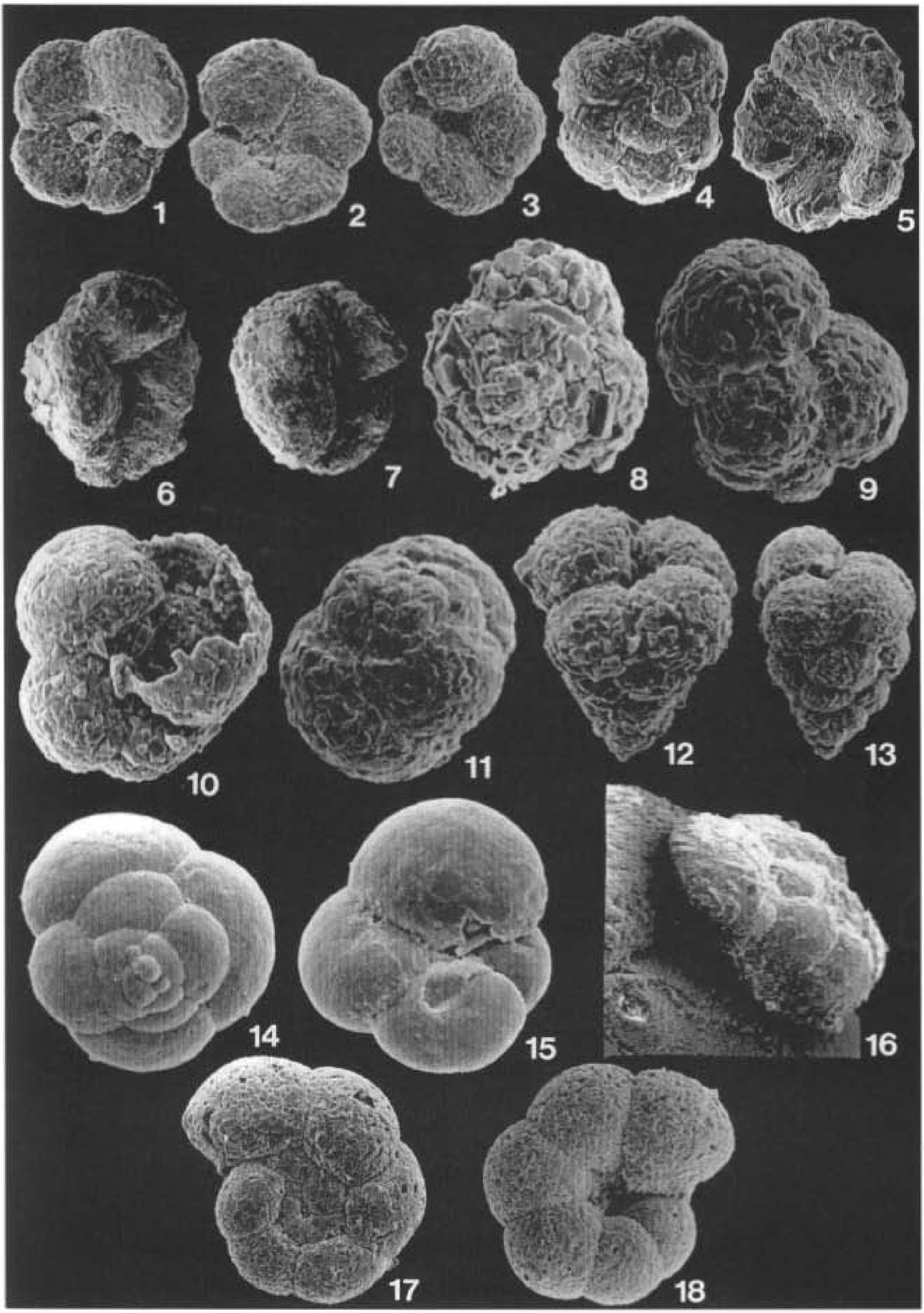

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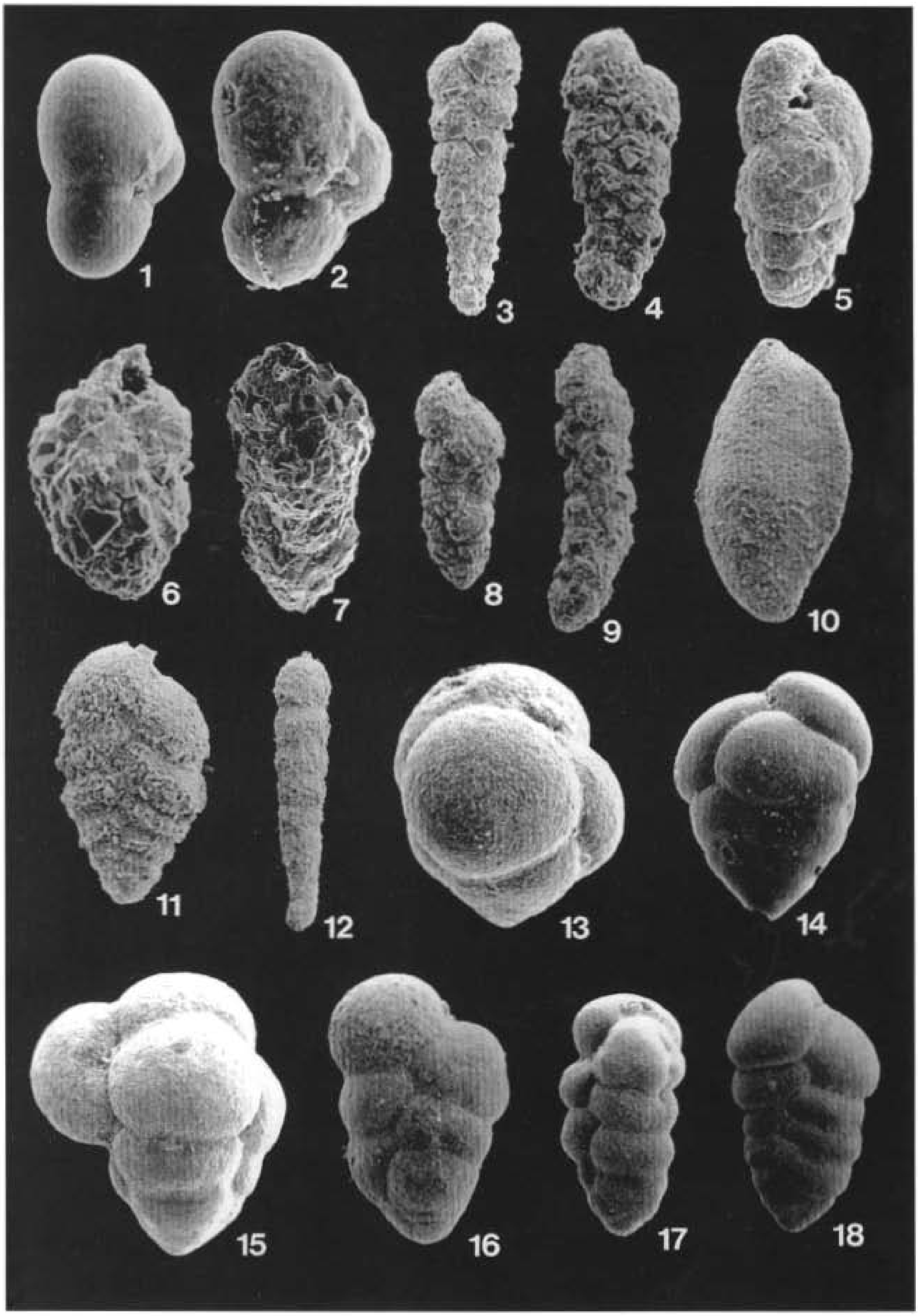

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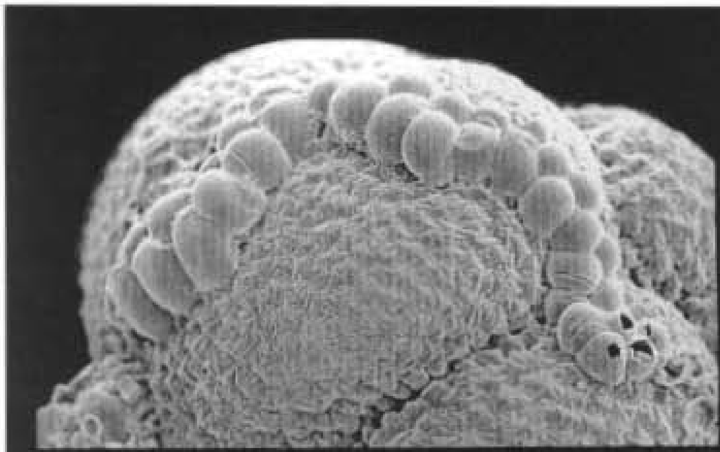
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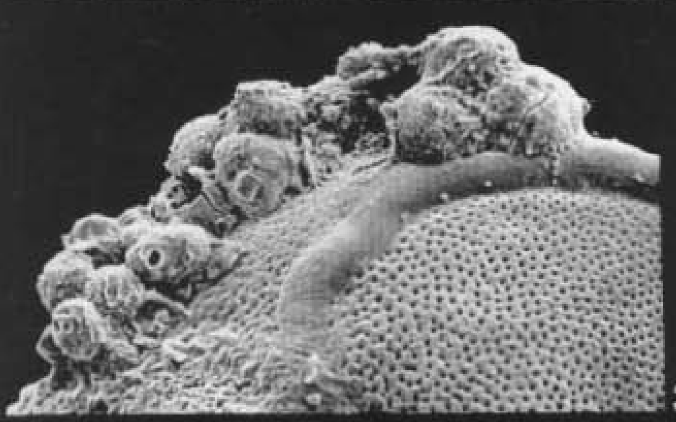
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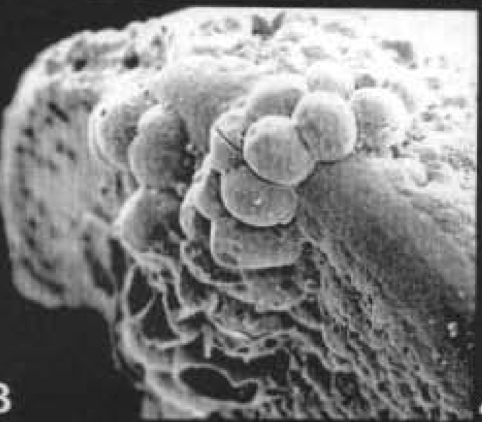
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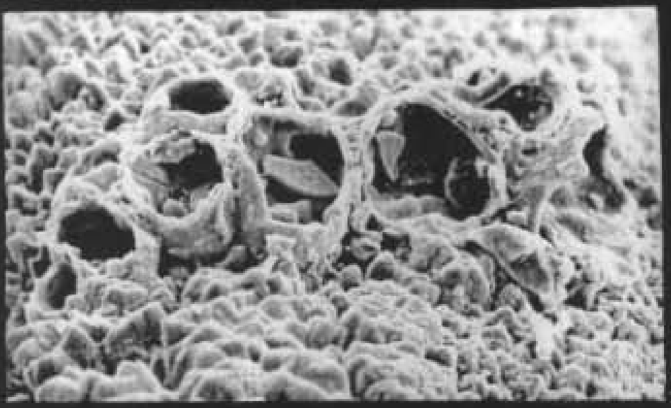
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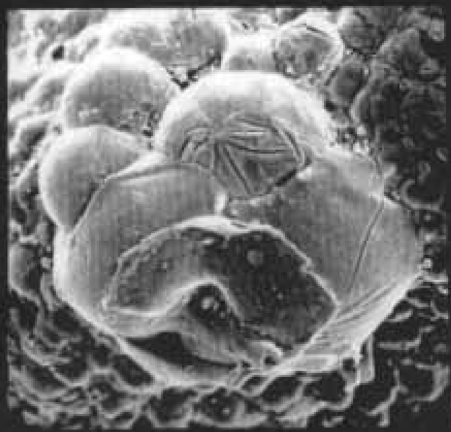
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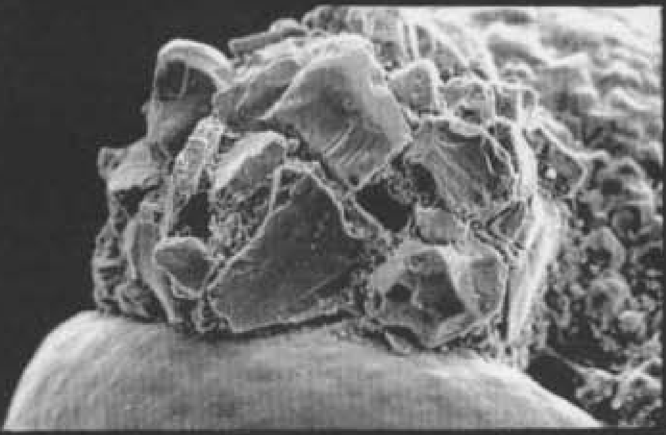
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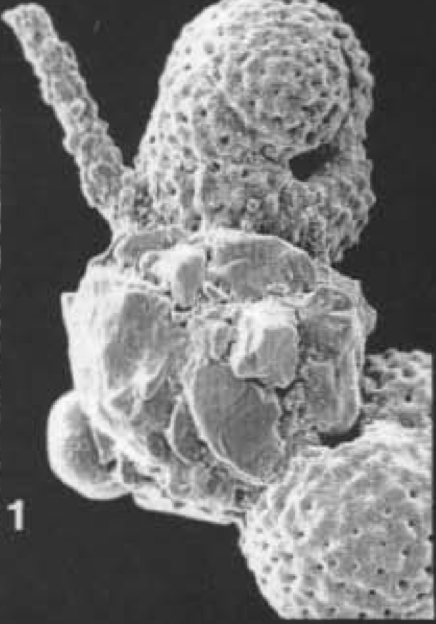
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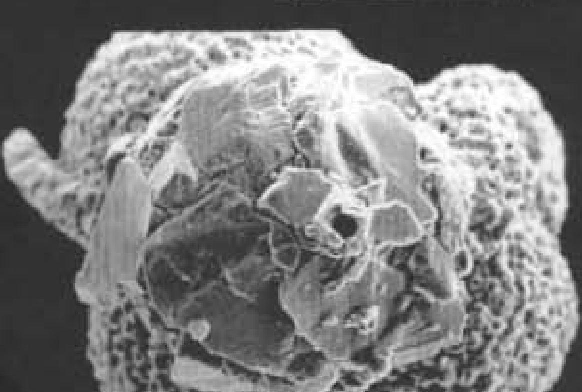
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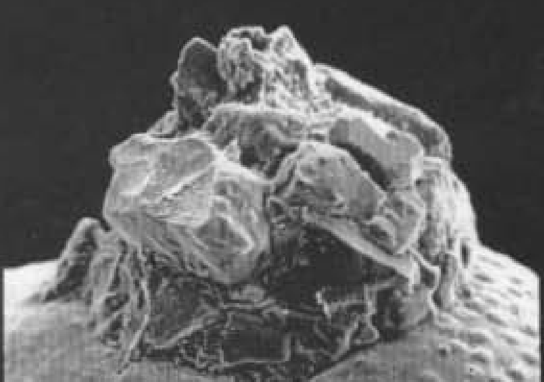
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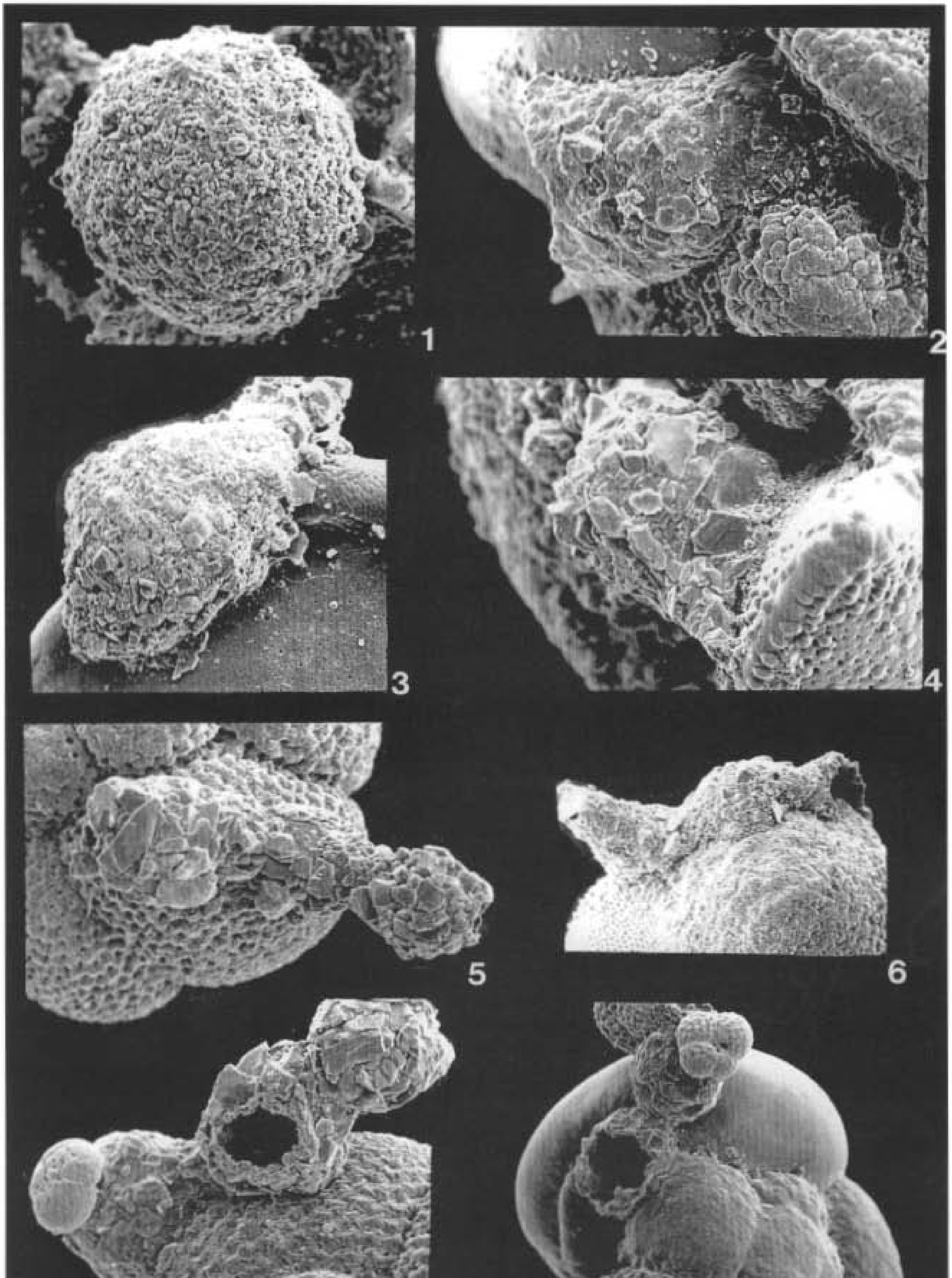

Plate 12