Oligocene Deep-Water Agglutinated Foraminifera from the Congo Fan, Offshore Angola: Palaeoenvironments and Assemblage Distributions

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ABSTRACT

Agglutinated foraminiferal assemblages from the Oligocene section of an exploration well drilled in the distal part of the Congo Fan are fully documented and interpreted for palaeoenvironment. A total of 65 ditch cutting samples were analysed at 10 m intervals, from 3630 to 4270 m below rotary table. An average of 170 specimens were extracted per sample, with over 100 species being documented and described using SEM and light photography. The results reveal the most taxonomically diverse deep-sea Oligocene fauna yet described. Six assemblages have been defined and analysed with Correspondence and 'Morphogroup' Analysis. These are 1. *Nothia robusta* / *Reticulophragmium* Assemblage (4110-4270 m), 2. *Nothia robusta* / *Scherochorella congoensis* / *Discamminoides* sp. 1 Assemblage (4000-4100 m), 3. High diversity *Reticulophragmium* Assemblage (3870-3990 m), 4. *Portatrochammina profunda* Assemblage (3790-3860 m), 5. *Nothia latissima* Assemblage (3730-3780 m) and 6. Low abundance Assemblage (3630-3720 m). Palaeobathymetric estimates range from middle - lower bathyal based on comparison with living taxa and morphogroup distributions.

These results extend the known stratigraphic range (last occurrences) of *Reticulophragmium amplectens* into the Oligocene in the Atlantic, and possibly also *Paratrochamminoides gorayskii*, *Paratrochamminoides olszewskii*, *Trochamminoides* aff. *proteus*, *Trochamminoides subcoronatus*, *Haplophragmoides horridus* and *Haplophragmoides walteri*, although reworking is documented with these species. Results also extend the known first occurrences of *Recurvoides azuaensis*, *Spiropsammina primula*, *Cyclammina* aff. *orbicularis*, *Discamminoides* sp. and *Glaphyrammina americana* into the Oligocene.

Large scale variations within faunas are largely assigned to documented variations in sand content, where higher proportions of sand generally coincide with reduced diversity and abundance along with a dominance of opportunistic species such as *Nothia robusta*, *Nothia latissima* and *Ammodiscus latus*. A major excursion in the infaunal morphogroup, suspension-feeding morphogroup and diversity and abundance within Assemblage 2 is termed the '*Scherochorella* Event', and does not correlate with an increase in sand. This fauna is thought to be the result of lower oxygen conditions allowing the dominance of the low oxygen morphotype *Scherochorella congoensis* and the opportunistic species *Nothia robusta*. Deep-water circulation in the Atlantic at this time is generally thought to have been strong, and this event suggests that there may have been a temporary expansion of the oxygen minimum zone during the Late Oligocene, coinciding with increased benthic $\delta^{18}O$ values, global cooling, and increased upwelling associated with a stronger polar front. The otherwise high diversity of the fauna in the well supports the interpretation of well-oxygenated conditions.

INTRODUCTION

The Congo Fan is the distal component of the second largest delta system in the world covering some 3.7×10^6 km^2 (Anka & Séranne, 2004), draining most of central Africa through the Congo River and its associated tributaries (see Goudie, 2005). The Congo Fan is a terrigenous wedge largely built of Oligocene and Miocene sands and shales organised into thick sedimentary packages containing palaeocanyons, palaeochannels and overbank deposits (Anka & Séranne, 2004, Babonneau *et al.* 2002 and Lavier *et al.* 2000). These unique meandering palaeochannels contain sands that have proven high quality traps for migrating hydrocarbons (Evans, 2002). In this study we analyse the largely agglutinated foraminiferal microfauna from the

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Oligocene section of a well drilled in the distal part of the fan (fig. 1), in an attempt to characterise the sedimentological subfacies and, for the first time, document the foraminifera present.

The Congo Fan has received significant scientific attention in recent years due in part to substantial interest from the oil industry. However the lack of published foraminiferal studies has lead to a need for the documentation and analysis of these faunas. Moreover, Oligocene deep-water agglutinated foraminifera (DWAF) have received globally little attention due largely to the lack of good recovery at these horizons. Preece *et al.* (1999, 2000) recorded Miocene agglutinated foraminifera from an oxygen minimum zone in the Congo Fan, offshore Cabinda. Miller & Katz (1987) recorded Oligocene to Miocene benthic faunas from the Central North Atlantic, but these assemblages were largely calcareous. The northern North Atlantic has a more complete record, with Oligocene DWAF described from ODP Sites 985 (Kaminski & Austin, 1999), 643 (Kaminski *et al.* 1990), 647 (Kaminski *et al.* 1989) and 909 (Kaminski *et al.* 2005; Osterman & Spiegler, 1996), and from Leg 38 of the Norwegian-Greenland Sea (Verdenius & Hinte, 1981). The North Sea also has a good record of Oligocene DWAF (Charnock & Jones, 1990; Gradstein *et al.* 1994; Gradstein & Kaminski, 1989; Gradstein *et al.* 1988). Other locations include Site 767 of the Celebes Sea (Kaminski & Huang, 1991).

The samples studied here contain by far the most extensive and diverse Oligocene DWAF fauna yet described, with over 100 species and 45 genera recorded. The aim of this study is to document and analyse the Oligocene assemblages from the deep-water Congo Fan, and to develop an up-to-date taxonomy and palaeoenvironmental interpretation within a broad palaeoceanographic context.

GEOLOGY OF THE CONGO FAN

The West African margin has been depositionally active since initial rifting took place in the Early Cretaceous (Jansen *et al.* 1984), following the break-up of Gondwana and the opening of the South Atlantic Ocean (see fig. 2 for generalised geological column). Three phases of rifting in the Early

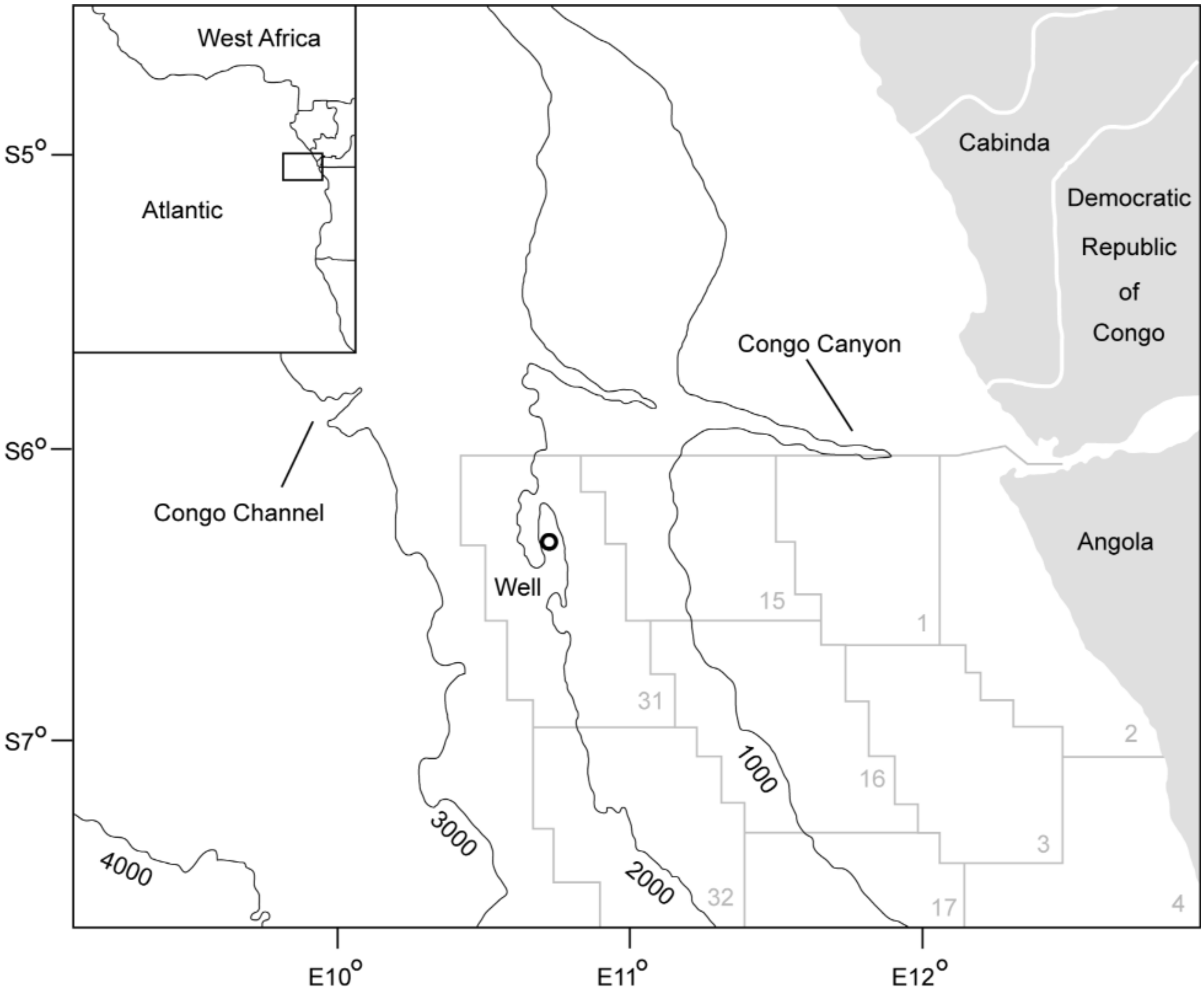


Figure 1. Approximate location of the well analysed in this study. The well penetrated Upper Cretaceous to Middle Miocene sediments. The Oligocene section is analysed in this study.

Cretaceous (De Matos, 1999; Karner & Driscoll, 1999) saw the formation of deep lacustrine basins, and the subsequent deposition of fluvio-lacustrine and lacustrine sands and shales. With the onset of thermal subsidence in the Aptian (Karner *et al.* 1997), fully marine conditions developed for the first time and this period is characterised by the formation of thick evaporite deposits. Today, these evaporites form widespread diapirs throughout the overlying sediments especially in the west. During the Albian, rising sea-levels and thermal subsidence led to basin deepening and the development of a shallow carbonate sea, with associated aggradational carbonate/siliciclastic ramp sediments (Anderson *et al.* 2000). South Atlantic sea-floor spreading and further subsidence in the Late Cretaceous resulted in the onset of deep-marine conditions and the development of deep mudstones. These mudstone deposits record several phases of ocean anoxia in the Cenomanian and Maastrichtian, which led to the formation of thick black shales and ultimately the source rocks for oils in the overlying sands.

During the early-middle Paleogene the Congo Basin region of the African margin received a limited sediment supply, resulting in a condensed sequence of aggrading platform carbonates. A significant unconformity separating the Upper Eocene from the Upper Oligocene follows, and is proceeded by the onset of thick prograding terrigenous turbidite deposits that continue to the Recent forming up to 3 km of sediment (the Congo Fan). Séranne & Abeigne (1999) show that the unconformity before this time affected primarily surface and intermediate waters, causing an erosional surface on the shelf and continental slope, possibly due to changes in oceanic circulation caused by the onset of Antarctic glaciation (Lavier *et al.* 2001). The reason for the subsequent deposition of the Congo Fan during the Oligocene is unclear and has been attributed to several causes. Increased sediment supply feeding an ancient Congo River has been suggested (Bond 1978, Walgenwitz *et al.* 1990, 1992) due to tectonic uplift in the South African region at this time. Anka & Sérranne (2004) has suggested that global cooling may be linked to the stratigraphic shift, while Anderson *et al.* (2000) has linked the event with lowering sea-levels at this time. Most recently, Stankiewicz & Wit (2006) suggested that the Congo River actually flowed east before this time, draining Central Africa into the Indian Ocean, and this appears the most likely explanation. The uplift associated with the East African Rift system in the Oligocene may well have forced central Africa to drain west.

The Congo Fan itself consists of shale and sand overbank and channel-levee deposits, with a well-developed deep canyon cutting the continental shelf and slope (Savoye *et al.* 2000; Babonneau *et al.* 2002; Anka & Séranne 2004). The sedimentation of the fan has been shown by Lavier *et al.* (2001) to increase up to a peak in the Langhian (around 15Ma) in the offshore Angola section of the fan (close to the studied section in this report), with only a steady increase up to the present in the offshore Congo area further to the north. This is probably caused both by climatic changes, and a migrating depocentre from the south to north in the mid-Miocene. Sedimentation of the Congo Fan has continued throughout the late Miocene to Recent as a progradational wedge. The structural evolution of the continental margin has been largely driven by increased sediment load, with down-dip movement of fault blocks along the Aptian salt in the east, and compressional structures and salt diapirism in the west (Anderson *et al.* 2000; Cramez & Jackson 2000; Séranne & Anka, 2005).

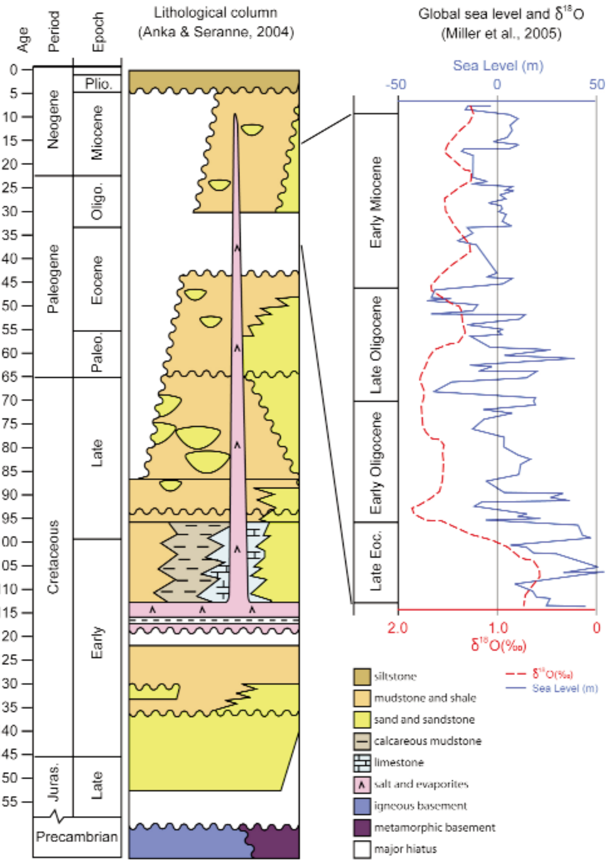


Figure 2. Generalised geological column for the Upper Slope and Shelf of the Congo Fan (after Anka & Séranne, 2004) against global sea-level and δ^{18}O values from benthic foraminifera (Miller *et al.* 2005).

MATERIALS AND METHODS

Sample material for this study consists of 65 ditch-cutting samples from the Upper Oligocene section of an exploration well drilled at a water depth of 2027 m in Block 31, offshore Angola. Samples from the well were collected at 10 m intervals, the Oligocene section (as determined by calcareous nannofossils) occurring over an interval from 3460 - 4270 m (below rotary table). The Oligocene section in the well consists of predominantly black mudstones and siltstones with interbedded sandy horizons. Samples were weighed, disaggregated by boiling in a sodium carbonate solution, sieved over a 63 µm sieve, and all foraminifera were picked from the samples to determine the total abundance per gram. Foraminifera were mounted onto cardboard reference slides. Selected specimens were imaged using a JEOL JSM-648OLV SEM at University College London, and digital plates were made using Adobe Photoshop®.

The percentage of sand was estimated by weighing the washed residues, subtracting the averaged nominal weight of a sample containing no sand, and calculating the remaining percentage weight from the original dried processed weight (which was always >100 g). Abundance was calculated by averaging the total number of specimens by the weight of sediment that was processed (always >100 g), but diversity is given only as the total number of species present within a sample (regardless of the washed weight) as diversity is not merely a function of the amount of sediment processed. The number of specimens obtained average 170 specimens per sample.

Correspondence Analysis (CA) was carried out on the complete data set (fig. 5), with the exception of the single *Valvulina flexilis* data point, using the PAST (Palaeontological Statistics, version 1.36) computer program (Hammer & Harper, 2006). CA is typically used when trying to ascertain ecological patterns in data sets consisting counts of species at differing depths (Kuhnt *et al.* 1999; Hammer & Harper, 2006). The method is a multivariate statistical technique that achieves greater results than principle component analysis because both samples and species can be plotted on the same axes, and the response to environmental parameters is not assumed to be linear. Final 'scores' for both samples and species are reached when the iterative method reaches maximum convergence and there is no further change in the corresponding values. The first eigenvalue is the strongest relationship of how well sample scores correspond to species scores, and is inferred to be a strong signal of environmental gradient. For more detailed information see Teil (1975), Greenacre (1982) and Benzecri (1992).

RESULTS

Agglutinated Foraminifera were recovered from all 65 studied ditch cutting samples. An average of 170 specimens were extracted per sample, with over 100 species being identified and documented using SEM and light photography. The results reveal the most taxonomically diverse Oligocene fauna yet described. Six assemblages have been identified with the help of Correspondence Analysis (CA) and 'Morphogroup' analysis. These are 1. *Nothia robusta / Reticulophragmium* Assemblage (4110-4270 m), 2. *Nothia robusta / Scherochorella congoensis / Discamminoides* sp. 1 Assemblage (4000-4100 m), 3. High diversity *Reticulophragmium* Assemblage (3870-3990 m), 4. *Portatrochammina profunda* Assemblage (3780-3860 m), 5. *Nothia latissima* Assemblage (3730-3770 m) and 6. Low diversity Assemblage (3630-3720 m).

Assemblages

1. *Nothia robusta / Reticulophragmium* Assemblage

Interval: 4110 to 4270 m.

The lowermost interval in the section contains a fauna increasing in diversity and abundance from around 50 up to 300 specimens per sample, with number of species increasing from about 15 up to 30. The bottom of the section is marked by some sandy levels and the occurrence of dark coloured shales up to 4190 m. The most persistent and abundant species are *Nothia robusta* (Grzybowski), *Reticulophragmium rotundidorsatum* (Hantken) and *Reticulophragmium acutidorsatum* (Hantken). Other persistent species are *Discamminoides* sp. 1, *Scherochorella congoensis* Kender, Kaminski and Jones, *Rhabdammina* spp., *Bathysiphon* spp., *Reophax pilulifer* (Brady), *Recurvoides* spp., *Reticulophragmium amplectens* (Grzybowski) and calcareous forms of *Valvulineria* spp. This assemblage contains a variety of other agglutinated specimens, with the tubular forms decreasing in dominance from around 70% near the base to 50% at the top of the assemblage.

2. *Nothia robusta / Scherochorella congoensis / Discamminoides* sp. 1 Assemblage

Interval: 4000 to 4100 m.

This assemblage is marked by a lowering of diversity and an increase in abundance. This is due to the significant domination of the species *Nothia robusta* (up to 233 fragments per sample), *Scherochorella congoensis* (up to 300 fragments per sample) and *Discamminoides* sp. 1. Other diagnostic forms include *Reticulophragmium rotundidorsatum*, *Reticulophragmium amplectens*, *Saccammina spherica* Sars, *Trochammina* spp., *Ammodiscus latus* Grzybowski, *Reophax pilulifer*, *Rhizammina* spp. and *Rhabdammina* spp. Sand content is generally low, with many samples showing a dark colouration.

3. High diversity *Reticulophragmium* Assemblage

Interval: 3870 to 3990 m.

In this interval diversity increases gently up to a maximum of around 40 species per sample. Abundance is lower than in the section below (typically around 130 specimens per sample), whilst sand content is variable but generally low. Tubular forms of *Rhabdammina* spp., *Rhizammina* spp., *Nothia robusta*, *Bathysiphon* spp. and *Nothia* aff. *excelsa* (Grzybowski) dominate over 50% of the assemblage. Persistent species include *Reticulophragmium acutidorsatum*, *Reticulophragmium rotundidorsatum*, *Ammodiscus latus*, *Haplophragmoides* spp., *Portatrochammina profunda* Kender, Kaminski and Jones and *Discamminoides* sp. 1.

4. *Portatrochammina profunda* Assemblage

Interval: 3790 to 3860 m.

This assemblage is characterised by persistently occurring *Portatrochammina profunda*, which reaches a maximum of 31 specimens per 100 g in this interval. Overall diversity remains high, but declines in the upper section as sand content begins to increase. The sediments in many of the samples exhibit a dark colouration. Other persistent forms include *Rhabdammina* spp., *Ammodiscus latus*, *Nothia robusta*, *Rhizammina* spp., *Hormosina globulifera* Brady, *Nothia latissima* (Grzybowski), *Ammosphaeroidina* sp. 1, *Haplophragmoides nauticus* Kender, Kaminski and Jones, *Nothia* aff. *excelsa* and *Psammosphaera* cf. *fusca* Schultze. In general the tubular forms are at their least dominant over the entire studied interval, at around 45% of the assemblage.

5. *Nothia latissima* Assemblage

Interval: 3730 to 3780 m.

These five samples show a decrease in diversity and abundance (typically less than 100 specimens, and less than 20 species). Sand content is variable and high in some samples. *Nothia latissima* is by far the most persistently occurring form, with over 40 fragments at some horizons. *Textularia earlandi* Parker and *Ammodiscus latus* are also persistent, although not abundant, whilst other species occur rarely such as *Glomospira charoides* Jones and Parker, *Nothia robusta*, *Saccammina* spp., *Hormosina globulifera*, *Trochammina* spp., *Portatrochammina profunda*, *Ammosphaeroidina* spp., *Subreophax scalaris* (Grzybowski), *Ammolagena* spp. and *Haplophragmoides* spp.

6. Low abundance Assemblage

Interval: 3630 to 3720 m.

The assemblage in the upper part of the studied interval contains a low diversity and low abundance of foraminifera (typically 7 specimens per sample), and on average a higher sand content. The most persistently occurring specimens are *Nothia robusta* and *Ammodiscus latus*, with occasional *Rhabdammina* spp., *Rhizammina* spp., *Glomospira charoides*, *Reticulophragmium rotundidorsatum* and *Recurvoides* spp.

Morphogroups

Jones & Charnock (1985) first proposed subdividing agglutinated foraminifera into morphogroups based on gross morphology relating to life position and feeding habit, whilst Corliss (1985) found a similar link in live deep sea calcareous forms. This concept has since been developed for agglutinated foraminifera by Jones (1999) and Jones *et al.* (2005) with the use of three groups, and by Nagy (1992), Nagy *et al.* (1995, 1997), van den Akker *et al.* (2000) and Kaminski *et al.* (2005) with an expanded set of morphogroups (see fig. 4). The foraminifera are subdivided on their generic classification alone. Care has been taken however to make sure each individual species matches the morphology (as some genera exhibit significant variation). Morphogroup classification can be viewed as an oversimplification for detailed analysis, but the agreement in results from CA in this report (see Correspondence Analysis below) supports this method. It is worth noting that the link between high infaunal proportions and low oxygen conditions is well documented (e.g., Jorissen *et al.* 1995; Kaminski *et al.* 1995; Preece *et al.* 1999).

Morphogroup analysis of the studied faunas (fig. 3) shows that morphogroups exhibit significant variation within the well, with four large-scale trends visible: 1. The section between 3630 to 3720 m (assemblage 6) contains very low abundances and thus results are noisy and scattered. 2. From about 3730 to 3990 m (assemblages 3-5) the graph levels out and remains relatively stable, with morphogroup M1 making up 35-70% of the fauna. There is a general increase in M1 as we move down this section, and a decrease in M2b. 3. Between 4000 to 4050 m (within assemblage 2) a significant increase in M4b offsets the curve, with M1 reducing slightly and M2-4a reducing significantly. 4. Between about 4060 to 4270 m (assemblages 1 and 2) the proportions return approximately to earlier levels (as in 2 above), dominated by M1 with minor variations within the other groups.

Correspondence Analysis

The data set in this study comprises a total of 163 taxa from 63 samples. Results for the analysis of samples (fig. 5a) show a clear clustering of assemblages 1 to 6, which has been identified independently using morphogroup analysis, and visual comparisons of species fluctuations. These three methods are shown here to be in total agreement with each other. The analysis of species (fig. 5b) shows the corresponding species that have strong correlation to their respective assemblages (i.e., are in similar locations on each graph).

DISCUSSION

Biostratigraphy

The biostratigraphy for the studied section of this well has been carried out using calcareous nanno-

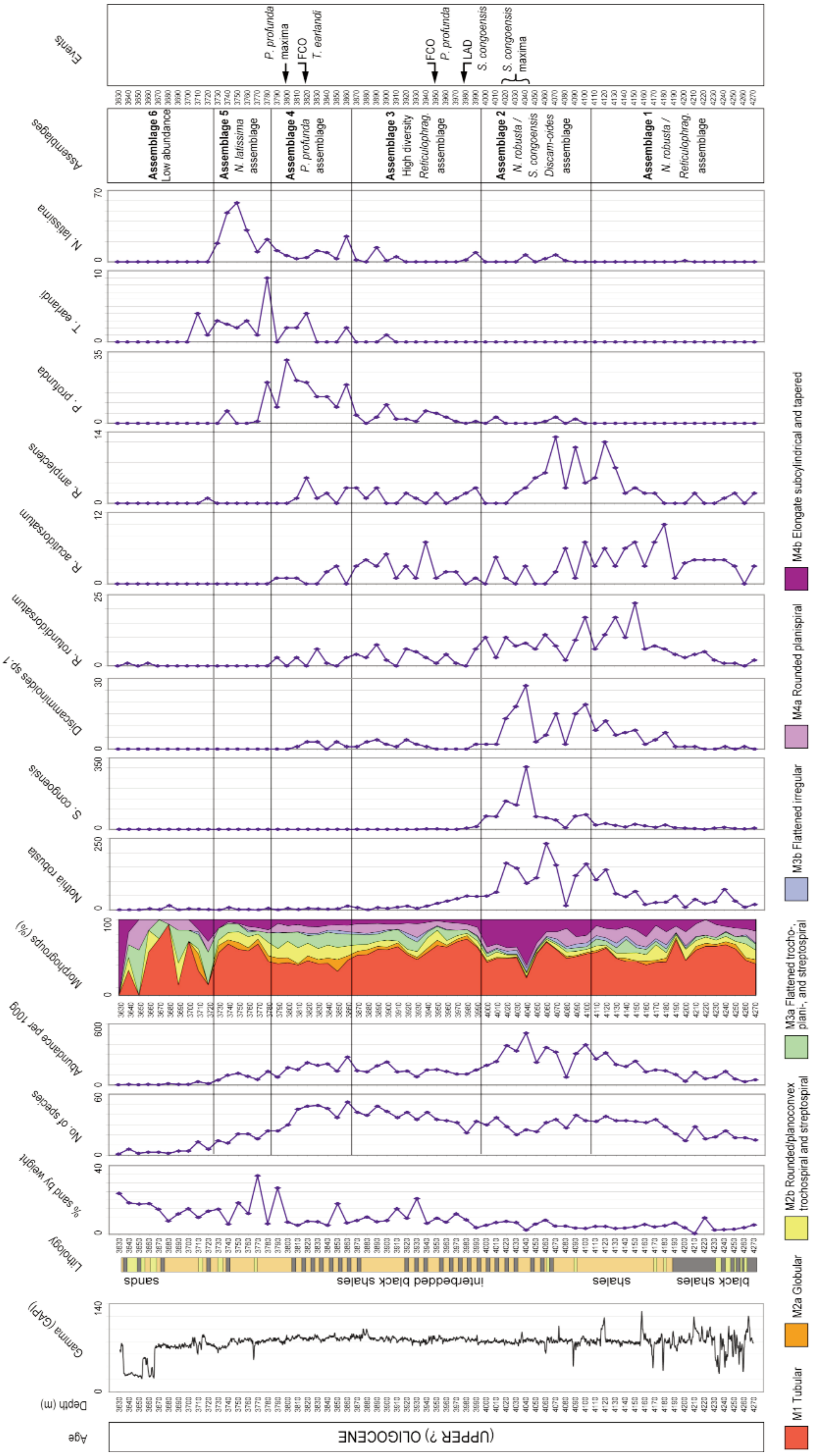
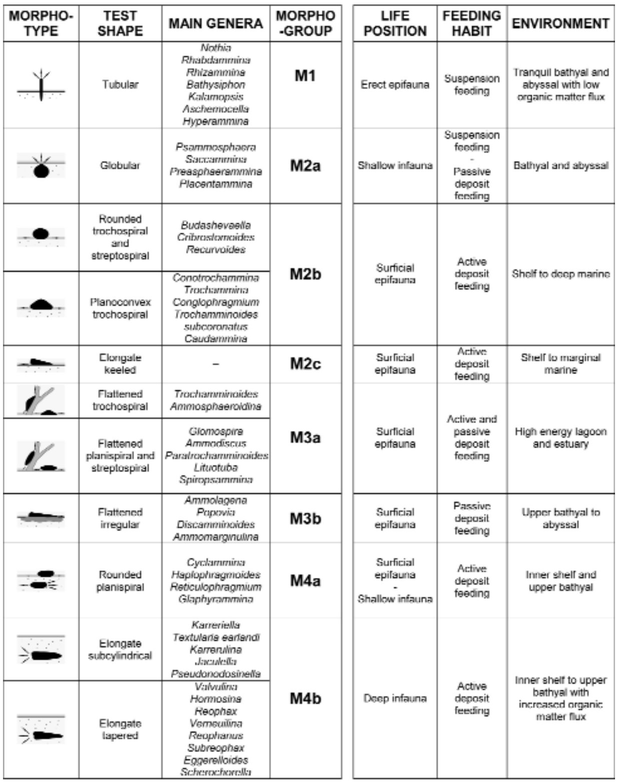


Figure 3. Graphs showing the variation of sand content, diversity, abundance, morphogroups (after van den Akker *et al.*, 2000), and important taxa against wireline data and interpreted lithology. Interpreted foraminiferal assemblages and foraminiferal events are shown on the far right (FCO = first common occurrence, LAD = last appearance datum).



MORPHO-TYPE	TEST SHAPE	MAIN GENERA	MORPHO-GROUP	LIFE POSITION	FEEDING HABIT	ENVIRONMENT
	Tubular	*Nothia* *Rhabdammina* *Rhizammina* *Bathysiphon* *Kalamopsis* *Aschemocella* *Hyperammina*	**M1**	Erect epifauna	Suspension feeding	Tranquil bathyal and abyssal with low organic matter flux
	Globular	*Psammosphaera* *Saccammina* *Preasphaerammina* *Placentammina*	**M2a**	Shallow infauna	Suspension feeding - Passive deposit feeding	Bathyal and abyssal
	Rounded trochospiral and streptospiral	*Budashevaella* *Cribrostomoides* *Recurvoides*	**M2b**	Surficial epifauna	Active deposit feeding	Shelf to deep marine
	Planoconvex trochospiral	*Conotrochammina* *Trochammina* *Conglophragmium* *Trochamminoides subcoronatus* *Caudammina*				
	Elongate keeled	–	**M2c**	Surficial epifauna	Active deposit feeding	Shelf to marginal marine
	Flattened trochospiral	*Trochamminoides* *Ammosphaeroidina*	**M3a**	Surficial epifauna	Active and passive deposit feeding	High energy lagoon and estuary
	Flattened planispiral and streptospiral	*Glomospira* *Ammodiscus* *Paratrochamminoides* *Lituotuba* *Spiropsammina*				
	Flattened irregular	*Ammolagena* *Popovia* *Discamminoides* *Ammomarginulina*	**M3b**	Surficial epifauna	Passive deposit feeding	Upper bathyal to abyssal
	Rounded planispiral	*Cyclammina* *Haplophragmoides* *Reticulophragmium* *Glaphyrammina*	**M4a**	Surficial epifauna - Shallow infauna	Active deposit feeding	Inner shelf and upper bathyal
	Elongate subcylindrical	*Karreriella* *Textularia earlandi* *Karrerulina* *Jaculella* *Pseudonodosinella*	**M4b**	Deep infauna	Active deposit feeding	Inner shelf to upper bathyal with increased organic matter flux
	Elongate tapered	*Valvulina* *Hormosina* *Reophax* *Verneuilina* *Reophanus* *Subreophax* *Eggerelloides* *Scherochorella*				

Figure 4. Morphogroup analysis followed in this study, showing the taxonomic lumpings with associated life position, feeding habit and environment (after Nagy *et al.* 1997; van den Akker *et al.* 2000).

fossils, which constrain the age of the samples to the Late Oligocene. Because the samples are ditch cuttings we can only use last occurrences as bio-events.

The agglutinated foraminifera (see fig. 6) also indicate an Oligocene age when compared with biostratigraphic studies from the Norwegian-Greenland and North Seas. Verdenius & Hinte (1983) recorded *H. walteri*, *B. multicamerata* and *R. acutidorsatum* as terminating at the end of the Oligocene in the Norwegian-Greenland Sea, all of which are present in the studied samples (fig. 3, Appendix 1). However, Verdenius & Hinte (1983) also recorded *R. amplectens* and *K. conversa* as terminating at the end of the Eocene, which are also present in our samples, suggesting possibly a longer stratigraphic range in the Equatorial Atlantic for these species. Gradstein *et al.* (1994) recorded similar last occurrences in the North Sea, whilst Charnock & Jones (1990, 1997) recorded *R. amplectens* ranging to the end of the Oligocene in the Central North Sea. They also listed *L. lituiformis* and *H. globulifera* as terminating at the end Oligocene, with *R. acutidorsatum* and *H. walteri* ranging into the Miocene. It is perhaps worth noting that Kaminski *et al.* (2005) recorded *R. amplectens*, *R. acutidorsatum* and *H. walteri* ranging well into the Middle Miocene at Site 909 in the Fram Strait area.

We regard the samples to be of Oligocene age, as we observe no 'typical' Eocene fauna, in which we would expect to see a wider variety of *Trochamminoides* spp. and *Paratrochamminoides* spp., *Spiroplectammina spectabilis*, *Haplophragmoides stomatus* and higher abundances of *A. peruvianus*. We do, however, observe species not recorded from the Eocene, such as *Paratrochamminoides* ex gr. *challengeri*, *Haplophragmoides carinatus*, *Recurvoides azuaensis*, *Spiropsammina primula*, *Cyclammina* aff. *orbicularis*, *Discamminoides* sp. and *Glaphyrammina americana*. We regard the samples as unlikely to be Miocene in age due to persisting *H. walteri*.

Specimens of *R. amplectens* in our samples appear

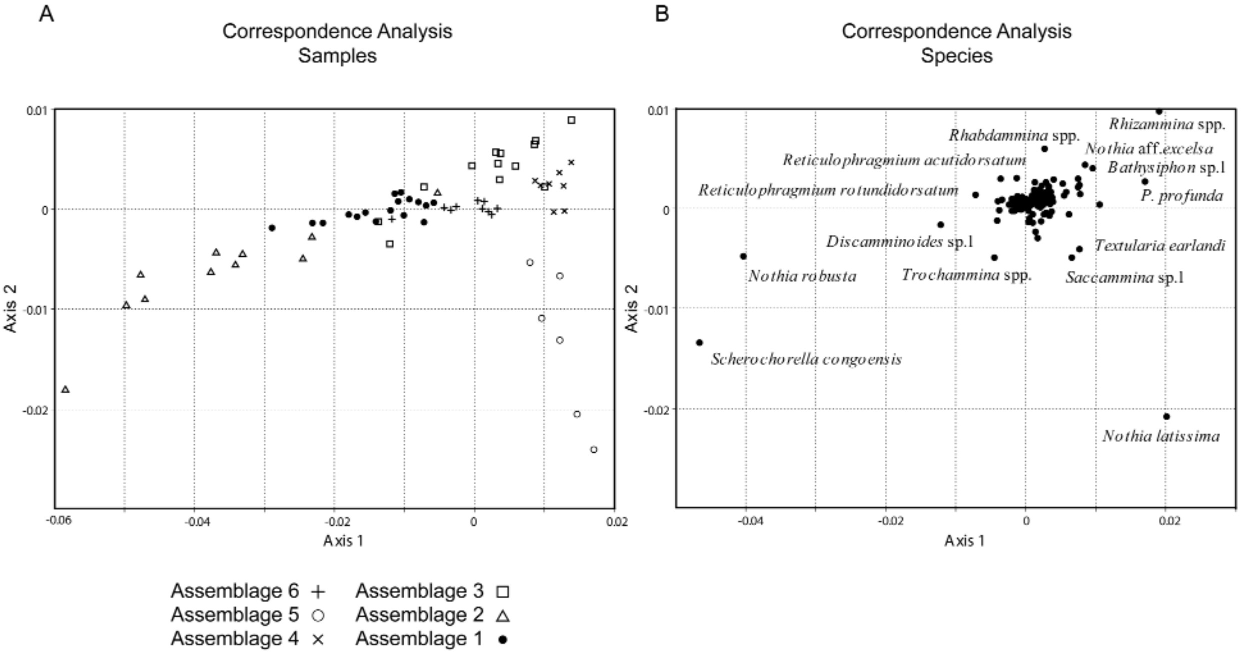


Figure 5. Correspondence analysis for the data analysed in this study. A. axes 1 and 2 eigenvalues plotted for all 65 samples, B. axes 1 and 2 eigenvalues plotted for all 163 species. See text for details. (Graphs obtained from PAST version 1.36).

to have evolved a more acute periphery and larger size than the typical Eocene forms (Plate 12, fig. 11). There are also at least two other forms in the samples similar in appearance to *R. amplectens* but perhaps deriving from a different lineage (we suggest *R. acutidorsatum*). *Reticulophragmium amplectens* ssp. 1 (Plate 12, fig. 12; Plate 15, figs 7,8) exhibits elongated alveoles, but has a larger size and less acute periphery. The *R. amplectens* / *acutidorsatum* transitional form (Plate 15, figs 9,10) shows an acute periphery in accordance with *R. amplectens*, but has a larger size and is transitional between round and elongate alveoles. We have found no reference to specimens with these characteristics before, and presume that the evolution of these forms carried on into the Oligocene in the low latitude South Atlantic.

Caving and Reworking

Caving (down-hole contamination of sediment) occurs in the well and is due to limitations in ditch cutting sample collection. The complete well extends up into ~700 m of Lower and Middle Miocene sediments, and occasional microfossils from these levels appear in the studied samples as specimens with a different wall structure (the amount of silicification increases with depth of burial). This phenomenon can be seen in figure 7, where the white colour of the poorly-silicified specimens from the upper section (3630-3790 m) occur in deeper samples (3800-4010 m) where higher silicification has caused the in situ foraminifera walls to become more brown in colour.

Reworking (re-deposition of stratigraphically older fossils) also occurs and can be seen in figure 7, which shows the percentage of highly-silicified (green-coloured) specimens (believed to be partially Eocene in age) occurring in most of the studied samples. We would expect to see reworking of stratigraphically older fossils as the onset of deposition of the Congo Fan occurs very close to the base of this section (see Geology of the Congo Fan), where Upper Cretaceous - Middle Eocene sediments extend to only about 200 m below the studied interval. The Congo Fan today is fed by the Congo Canyon which stretches from the shelf, near the mouth of the Congo River, to the lower slope at around 2000 m water depth (Babonneau *et al.* 2002). It then reduces significantly in relief as it continues all the way to the abyssal plain (over 4000 m depth). The present day canyon cuts into the underlying sediments by between 1300 m (at the upper slope) to 150 m (at the lower slope).

We do not see Cretaceous or Paleocene species in the samples (Appendix 1), but there are occurrences of small well-silicified *H. walteri*, early *R. amplectens*, *R. intermedium*, *Recurvoides* spp. and *Caudammina* spp., which we may expect from the Eocene. We postulate that these are reworked from older sediments due to their different wall structure, but that the extent of reworking is only from the Eocene at this location.

Palaeobathymetry

The palaeobathymetry of the section is estimated to be middle bathyal (1000-1650m depth) to lower bathyal (1650-2250m) based on morphogroup analysis and comparisons with living species. Caution is needed when analysing palaeobathymetry in this environmental setting as deep-sea fans are turbidite-dominated and therefore transportation of material from higher up the slope is common. The Oligocene section in this well, however, is low in sand content suggesting a minimal input of transported larger particles including foraminifera, and upper slope / shelf species are not found. There are four bathymetrically useful species in the samples that are also known from the Recent. These are *L. lituiformis* (upper - lower bathyal), *A. clavata* (upper bathyal - abyssal), *H. guttifera* (middle - lower bathyal) and *R. rotundidorsatum* (lower bathyal - abyssal), as recorded by Brady (1884) in the Challenger Report (see Jones, 1994). The co-occurrence of these species suggests lower bathyal paleodepths. Morphogroup analysis (fig. 3) shows fluctuations in the gross-morphology of the assemblages, which can be compared to those in modern environments. Jones & Charnock (1985) synthesised such data from various localities on the eastern North Atlantic margin. The major variation between the upper and lower bathyal zone occurs in morphogroup M1 (tubular suspension feeders); upper bathyal containing 50% M1, lower bathyal 70% M1. We find variations within this range (fig. 3), which suggests lower to middle bathyal depths.

Environments on the abyssal plain differ from those on the slope, as recorded by Hart (1988) in the study of Miocene benthic foraminifera from the Bermuda Abyssal Plain (Site 603). Hart reports only a sparse agglutinated fauna, low in abundance and diversity, and contrasting markedly from the highly diverse fauna described in this report.

Palaeoenvironment

Foraminifera can at best only give an indication as to the environment in which they lived and died (see Van der Zwaan *et al.* 1999). There are significant differences in the composition of living and dead assemblages recorded for example in the Adriatic Sea (Jorissen *et al.*, 1992), the Weddell Sea (Murray & Pudsey, 2004), and on the West African continental slope (Licari & Mackensen, 2005). Licari & Mackensen (2005) conclude however that in the West African setting, these differences are not great enough to hide ecological information and suggest that dead assemblages can be used faithfully to

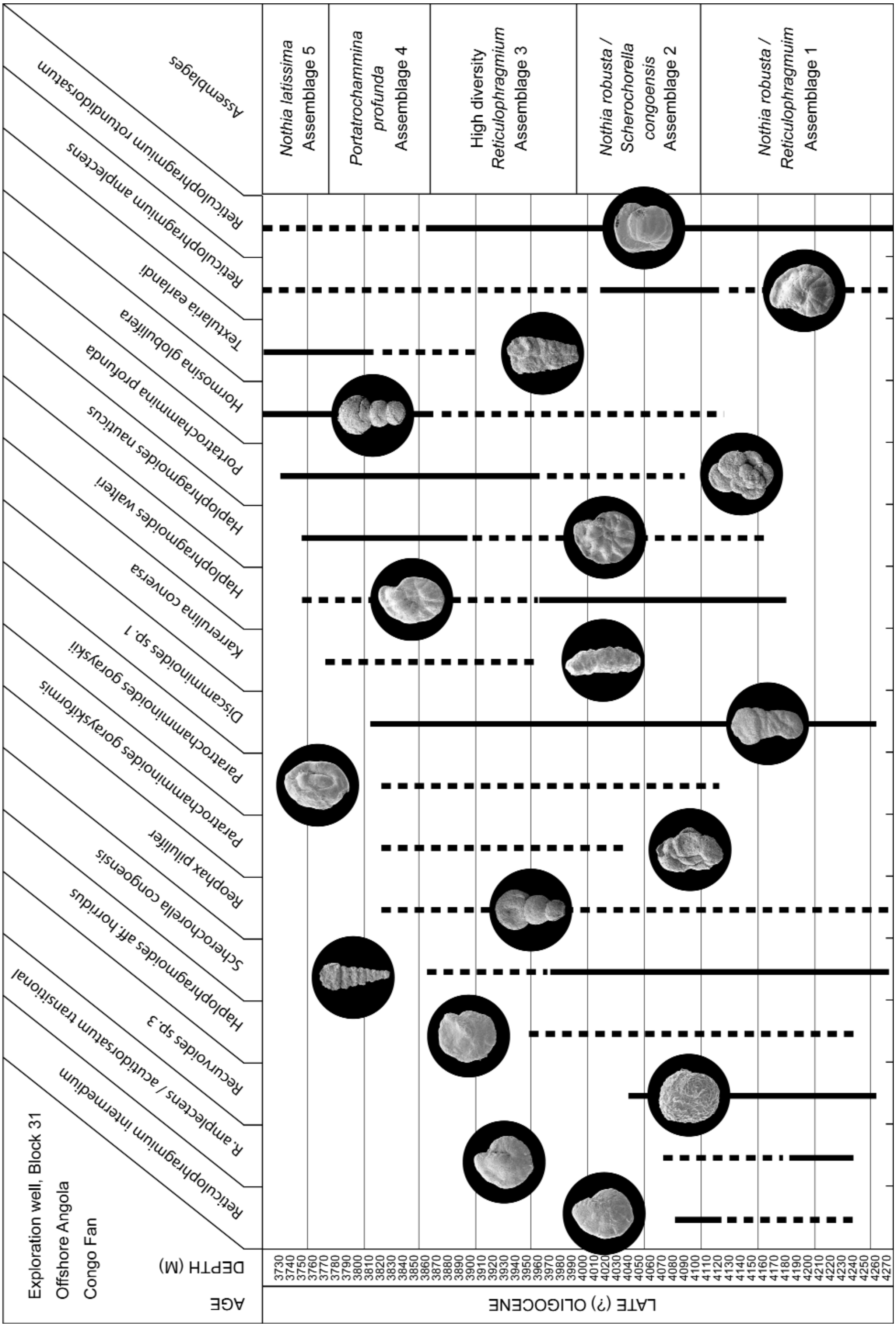


Figure 6. Range chart showing the first and last occurrences of selected foraminifera. Solid lines represent persistent / high abundances, dashed lines sporadic / low.

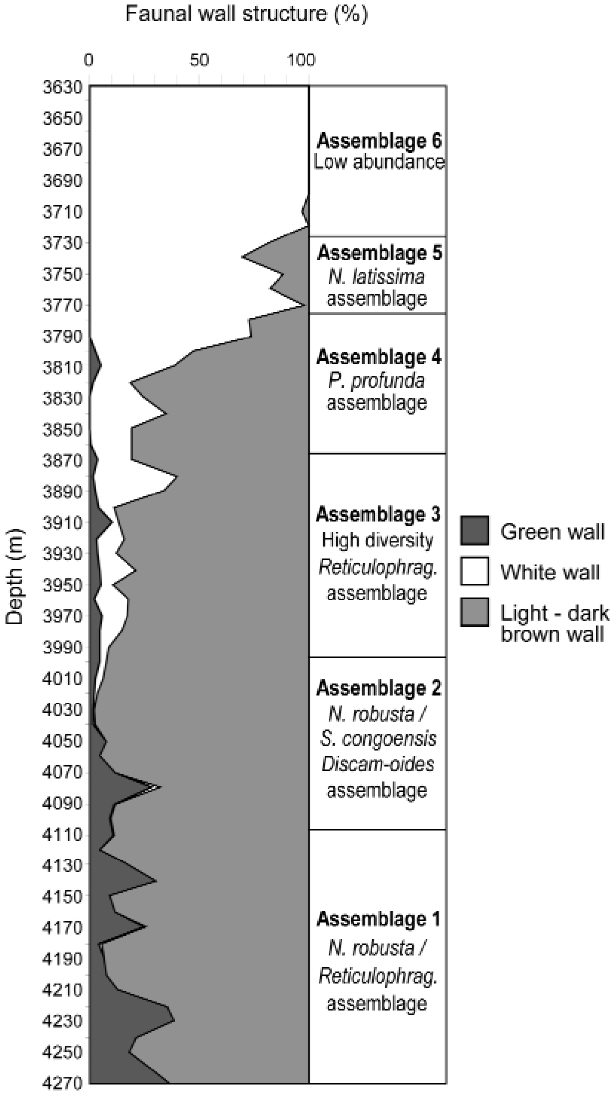


Figure 7. Changes in faunal wall structure with depth. Green wall represents well-silicified cement and can be viewed as percentage of reworked specimens from older (possibly Eocene) strata. White wall represents poorly silicified cement *in situ* at the top of section, with caved specimens at intermediate depths.

reconstruct primary-productivity changes.

The almost entirely agglutinated nature of the studied assemblages is striking. This cannot be entirely explained by deposition below the CCD, as palaeobathymetrical estimates (see above) point to at most lower bathyal depths (maximum 2500 m). There are rare calcareous benthics present in some of the samples (see Appendix 1), although the majority of the samples are composed of entirely agglutinated forms. This phenomenon is not unexpected in turbiditic deep-sea environments (see for example similar findings in the Forties Field, North Sea) where it has been suggested that the oxidation of rapidly deposited organic matter in early diagenesis can release carbonate-dissolving acids (Jones, 1999). The phenomenon may, however, simply be due to high sedimentation rates and low oxygen conditions in which agglutinated forms are able to survive where more specialised and highly adapted calcareous forms cannot.

Near the bottom of the studied section (assemblage 1) the fauna shows low diversity and abundance, probably due to high sand content, and darker colouration (possibly indicating high organic carbon and lower oxygen conditions). The increasing diversity and abundance indicates more favourable conditions (i.e., low energy, low organic flux and oxygenated waters), and this is also supported by the even spread within morphogroups (fig. 3). The following interval (assemblage 2) shows an increase in morphogroup M4b (the '*Scherochorella* Event') along with a decrease in diversity and increase in abundance, probably relating to lowering oxygen levels caused by high productivity and resulting high organic carbon flux. The TROX-model, first proposed by Jorissen *et al.* (1995), links deep-infaunal foraminifera with low oxygen conditions due to high organic carbon flux. Preece *et al.* (1999) observed a correlation between agglutinated foraminiferal morphogroups and organic carbon off Cabinda, West Africa, and we therefore postulate that *S. congoensis* may be a high productivity indicator. The greater abundance of *N. robusta* over this interval supports this interpretation, as this species usually occurs in levels of low diversity in the well and we regard it as an opportunistic species. The possibility that the interval represents dominating hemipelagic shale as opposed to inter-turbiditic shale cannot be ignored, as Jones (1999) records hemipelagic shales in the North Sea as having higher proportions of the infauna morphogroup. We would however expect an increase in diversity with hemipelagic shale, and we record a decrease.

The diversity increase through the following interval (assemblages 3 and 4) probably reflects a return to more stable and favourable conditions, indicated by the low sand content and high abundance. The decrease in the tubular morphogroup M1 and high proportions of *P. profunda* (assemblage 4) indicates perhaps a shallowing of environment (to middle bathyal), which may be expected with the very high sedimentation rate (in the region of 120 m/my).

Conditions probably became more stressed after this interval (assemblage 5), which is indicated by lowering diversity and abundance, and increasing sand and morphogroup M1. The Gamma plot (fig. 3) indicates an increase in sand content from 3770 m upwards, and therefore an increase in energy levels that would have disturbed the foraminiferal community.

Oceanographic Context

Throughout the Late Oligocene sea-levels were fluctuating intensively (fig. 2) after a major sea-level fall at the Early / Late Oligocene boundary (Pekar *et al.*, 2006; Miller *et al.*, 2005; Haq *et al.*, 1987). Kaiho (1991) and Kaiho & Hasegawa (1994) reported falling bottom-water dissolved oxygen levels in the South Atlantic at this time based on benthic foraminiferal morphological proxies, and postulated that this was caused by slower deep-water circulation in response to elevated temperatures. The oxygen isotope record from the Oligocene has been studied in detail by Pekar *et al.* (2006) and generally agrees with Kaiho's interpretation. Pekar *et al.* also found bottom waters to be warmer in the Oligocene in the low latitude Atlantic and Pacific Oceans. However, they also discovered a significant deviation in the isotopic record in the Upper Oligocene between the Antarctic and the lower latitudes, suggesting a large glaciation occurred in the latest Oligocene (26-23Ma), and that transport of these cold waters to the north was prevented owing to a stifled proto-AABW (Antarctic Bottom Water). Prebble *et al.* (2006) and Roberts *et al.* (2003) found miospore floras in the Antarctic Ross Sea that indicate cold temperatures (mean summer 5°C) by the Late Oligocene, whilst Villa & Persico (2005) and Persico & Villa (2004) found nannofossil assemblages from sites in the Southern Ocean (Maud Rise and Kerguelen Plateau) indicating cold waters until the latest Oligocene, when warmer-water taxa began to dominate. The proposed Oligocene glaciation would have been significantly warmer than that of today. Mutti *et al.* (2005) recorded low δ^{18}O values in the Upper Oligocene from Site 999 in the Columbia Basin, with increasing values (probably cooling) by the latest Oligocene. This is in agreement with the Zachos *et al.* (2001) averaged global δ^{18}O levels for this period (fig. 2).

Scherochorella Event

We regard the large excursion in the deep-infaunal morphogroup M4b (termed here the '*Scherochorella* Event') in assemblage 2 (fig. 3) as an ecological response to a change in oceanographic conditions. There is no reason to suggest that a change in sediment supply occurred, as the Gamma plot, lithology and sand content over this interval (fig. 3) show no significant deviations.

Oligocene cooling and glaciation probably caused the strength of bottom currents in the Atlantic to increase, and could explain the generally low recovery of Oligocene sediments (due to bottom water erosion) from many sites in the Atlantic. Tucholke (1979) and Tucholke & Mountain (1986) synthesised data from western North Atlantic DSDP Sites and found major unconformities of Oligocene age, which they interpreted as erosional surfaces from strong deep-water flow. Similarly, none of the ODP sites drilled off West Africa during ODP Leg 159 recovered any sediment of Oligocene age, indicating that submarine erosion was not confined to the western Atlantic.

The low latitude warming that occurred during the late Oligocene (fig. 2) could have caused expansion of the warm water masses and deepening of the thermocline, resulting in a deeper oxygen minimum zone. Furthermore, glacial conditions and cooling in the Southern Ocean would have caused increased temperature differential between the poles and low latitudes. Consequently, an increase in wind strength would be observed in the subtropics and temporate latitudes that would in turn lead to increased upwelling strength and elevated productivity offshore West Africa. Carbon isotope records from DSDP sites in the Atlantic Ocean (Miller & Fairbanks, 1985) show a broad minimum in δ^{13}C values, suggesting slower production of North Atlantic Deep Water and elevated nutrients in the Atlantic during the late early Oligocene to early late Oligocene (32-26 Ma). During the mid Oligocene, nutrient concentrations in Atlantic deep water were more similar to those of deep water in the South Pacific, which would have conspired to further increase productivity in the Atlantic upwelling zones. We hypothesise, therefore, that the origin of the apparently low-oxygen '*Scherochorella*' Event may be linked to downward expansion of the oxygen minimum zone off West Africa. We also speculate that the low-oxygen conditions in the mid Oligocene provided a habitat that resulted in the evolution of alveolar wall structure in different lineages of agglutinated foraminifera. This idea is supported by our finding of alveolar species of *Discammina* and *Cyclammina*, as well as the appearance of very flat discoidal forms such as *Spiropsammina* in our samples. This proposed relationship between global climate change, dysoxic conditions in the ocean, and the evolution of the alveolar lineages requires further study.

CONCLUSIONS

Analysis of all agglutinated foraminifera within the studied section has revealed a unique and extremely diverse Oligocene fauna that is described for the first time.

1. This study extends the known stratigraphic range of *Reticulophragmium amplectens* at least into the Oligocene in the Atlantic, and revealed some evolutionary oddities within this lineage. We also report new Oligocene occurrences of the species *Paratrochamminoides gorayskii*, *Paratrochamminoides olszewskii*, *Trochamminoides* aff. *proteus*, *Trochamminoides subcoronatus*, *Haplophragmoides horridus* and *Haplophragmoides walteri*, species that are known from the Eocene at other localities. We note the oldest first occurrences of *Recurvoides azuaensis*, *Spiropsammina primula*, *Cyclammina* aff. *orbicularis*, *Discamminoides* sp. and *Glaphyrammina americana* as

Oligocene.

2. The deposition of the Congo Fan began in the Oligocene, and its inception coincides with the base of the studied section. Reworking has been detected from stratigraphically older sediments (Eocene) but this is not extensive. Caving has been detected from stratigraphically younger sediments (Miocene) in the shallower samples.

3. Comparison of the fauna with equivalent living species (*Lituotuba lituiformis*, *Ammolagena clavata*, *Hormosina guttifera* and *Reticulophragmium rotundidorsatum*), and comparison with morphogroup changes with depth in modern and ancient settings, leads us to conclude that the studied section was deposited at middle to lower bathyal palaeodepths.

4. The microfauna has been analysed using both Correspondence and 'Morphogroup' Analysis, and these results, together with abundance and diversity plots, has lead to the identification of 5 assemblages. These assemblages are associated with fluctuations in sand content, caused by the lateral movement of palaeochannels through time that carried large quantities of terrigenous material, and the associated high energy and inhospitable conditions. This is reflected in the reduction of both abundance and diversity with increased sand in the upper and lower parts of the studied section.

5. One faunal signal in the studied section cannot be explained by changing sedimentary influence alone, and is here termed the '*Scherochorella* Event'. Over this interval we observe a marked acme in the infaunal species *Scherochorella congoensis*, along with a marked increase in the opportunistic species *Nothia robusta*. This is coupled with a decline in diversity and an increase in foraminiferal abundance. We have interpreted this as a response to lowered oxygen conditions, driven by slower circulation of nutrient-rich proto-North Atlantic Deep Water during the mid-Oligocene, combined with stronger upwelling and expansion of the oxygen minimum zone caused by increased wind strength during a time of Antarctic glaciation. We hypothesize that the late Oligocene evolution of "infaunal" and alveolar taxa was ultimately driven by the intensification of the oxygen minimum zones in subtropical upwelling areas.

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TAXONOMY

The following taxa are listed according to the Kaminski (2004) classification of agglutinated foraminifera.

Family RHABDAMMINIDAE Brady, 1884
Subfamily RHABDAMMINININAE Brady, 1884
Genus *Rhabdammina* M. Sars in Carpenter, 1869

Rhabdammina linearis Brady, 1879
Plate 1, fig. 1

Rhabdammina linearis Brady, 1879, p. 37, pl. 3, figs 10-11.
Rhabdammina linearis Brady. -Kaminski & Gradstein, 2005, p. 124, pl. 7, figs 1a-8.

Occurrence. 6 specimens from 3 samples.

Rhabdammina spp.
Plate 1, figs 2a-10

Occurrence. 792 specimens from 56 samples.
Description. We include all tubular fragments with thick wall, so that they generally form a circular or elliptical cross-section. Test size small to large, grain size fine to coarse, occasionally branching.
Remarks. We distinguish at least six different forms of *Rhabdammina* from the well, which may prove to be different species. We have listed them all under the same name for the purpose of this study, as the fragmentary pieces are not sufficient to identify species. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Subfamily BATHYSIPHONINAE Avnimelech, 1952
Genus *Bathysiphon* Sars, 1872

Bathysiphon spp.
Plate 1, figs 11-13

Occurrence. 92 specimens from 27 samples.
Description. All tubular fragments with thick wall, straight and unbranching. Small to medium size. Generally smooth wall and annular constrictions.
Remarks. We distinguish at least four different forms of *Bathysiphon* from the well, which may prove to be different species. Their fragmentary nature does not allow us to identify species.

Subfamily BATHYSIPHONINAE Avnimelech, 1952
Genus *Nothia* Pflaumann, 1964

Nothia* aff. *excelsa (Grzybowski, 1898)
Plate 1, figs 14-16

Dendrophrya excelsa Grzybowski, 1898, p. 272, pl. 10, figs 2-4.
Nothia excelsa (Grzybowski, 1898). -Geroch & Kaminski, 1992, p. 255, pl. 1, figs 1-4, pl. 2, figs 1-11.

Occurrence. 248 specimens from 32 samples.

Nothia latissima (Grzybowski, 1898)
Plate 1, fig. 17, Plate 2, fig. 1

Dendrophrya latissima Grzybowski, 1898, p. 273, pl. 10, fig. 8.
Nothia latissima (Grzybowski, 1898). -Kaminski & Geroch, 1993, p. 245, pl. 1, figs. 1a-c, 14a,b.
Nothia latissima (Grzybowski). -Kaminski & Gradstein, 2005, p. 113, pl. 3, figs 1-4b.
Occurrence. 311 specimens from 25 samples.

Nothia robusta (Grzybowski, 1898)
Plate 2, figs 2,3

Dendrophrya robusta Grzybowski, 1898, p. 273, pl. 10, fig. 7.
Nothia robusta (Grzybowski, 1898). -Geroch & Kaminski, 1992, pl. 1, figs. 1-4, pl. 2, figs. 1-11.
Nothia robusta (Grzybowski). -Kaminski & Gradstein, 2005, p. 116, pl. 4, figs 1-8.
Occurrence. 2407 specimens from 57 samples.
Remarks. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Nothia spp.
Plate 2, fig. 4

Occurrence. 114 specimens from 33 samples.
Description. We include all tubular fragments with a thin and therefore much flattened wall. Grain size fine to coarse, finish usually rough. Specimens small to large.
Remarks. We have distinguished at least three differing forms of *Nothia* from the well, which may prove to be different species. We list them all under the same name owing to their fragmentary nature. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Family RHIZAMMINIDAE Brady, 1879
Genus *Rhizammina* Brady, 1879

Rhizammina spp.
Plate 2, figs 5-7

Occurrence. 504 specimens from 44 samples.
Description. We include all tubular fragments exhibiting a very thin and delicate wall with irregular outline. Grain size medium to coarse. Wall shows a rough finish, very small to small size, occasionally branching.
Remarks. We have distinguished at least 5 different forms of *Rhizammina* from the well, which may prove to be different species. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Family SACCAMMINIDAE Brady, 1884
Subfamily SACCAMMININAE Brady, 1884
Genus *Placentammina* Thalmann, 1947

Placentammina placenta (Grzybowski, 1898)
Plate 2, fig. 8

Reophax placenta Grzybowski, 1898, p. 276-277, pl. 10, figs 9-10.
Saccammina placenta (Grzybowski). -Kaminski & Geroch, 1993, p. 249, pl. 2, figs 5-7.
Placentammina placenta (Grzybowski). -Kaminski & Gradstein, 2005, p. 139, pl. 11, figs 1-6.
Occurrence. 12 specimens from 9 samples.

Genus *Saccammina* Carpenter, 1869

Saccammina* cf. *sphaerica Sars, 1872
Plate 2, figs 9,10

Saccammina sphaerica Sars, 1872, p. 250.
Saccammina sphaerica Sars. -Brady, 1884, p. 253, pl. 18, figs 11-15.
Occurrence. 72 specimens from 28 samples.
Remarks. In this group we include single chambered forms with medium test size, small apertural neck, thin to medium wall thickness, and a medium to coarse grain size. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Saccammina sp. 1
Plate 2, fig. 11

Occurrence. 44 specimens from 17 samples.
Description. Single chamber, medium to large in size, thick wall, medium grain size with a fine finish. Aperture a small neck.
Remarks. Differs from *S. sphaerica* by having a much thicker wall.

Saccammina sp. 2

Occurrence. 2 specimens from 2 samples.
Description. Single chamber, very large in size, thick wall, medium grain size with a fine finish. Aperture a small neck.
Remarks. Similar to *Saccammina* sp. 1, but with a much larger size.

Saccammina sp. 3
Plate 2, fig. 12

Occurrence. 8 specimens from 6 samples.
Description. Single chamber, very large in size, thick wall, coarse grain size. Aperture a small neck.

Saccammina spp.

Occurrence. 38.5 specimens from 21 samples.
Description. We include all single chambered fragments, small to large in size, fine to medium grained.
Remarks. Generally indistinguishable fragments. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Family PSAMMOSPHAERIDAE Haeckel, 1894
Subfamily PSAMMOSPHAERINAE Haeckel, 1894
Genus *Psammosphaera* Schulze, 1875

Psammosphaera* cf. *fusca Schultze, 1875
Plate 2, figs 14a,b

Psammosphaera fusca Schultze, 1875, p. 113, pl. 2, figs 8a-f.

Occurrence. 67 specimens from 20 samples.

Remarks. This group includes single chambered forms with small to medium test size, thin to medium wall thickness, and a medium to coarse grain size. Aperture is merely a depression or gap between sand grains.

Psammosphaera sp. 1
Plate 2, fig. 13

Occurrence. 24 specimens from 10 samples.

Description. Single chamber, small to medium in size, wall thick, grain size medium. Finish sometimes smooth. Aperture is a depression or gap between sand grains.

Psammosphaera sp. 2

Occurrence. 1 specimen.

Description. Single chamber, very large test size, thin to medium wall thickness, and a medium to coarse grain size. Aperture is merely a depression or gap between sand grains.

Remarks. Similar to *Psammosphaera fusca* Schultze but with a much larger test size.

Psammosphaera spp.

Occurrence. 9 specimens from 6 samples.

Description. Single chambered, small to large, coarse grained.

Remarks. Generally indistinguishable fragments.

Family HIPPOCREPINIDAE Rhumbler, 1895
Subfamily HIPPOCREPININAE Rhumbler, 1895
Genus *Jaculella* Brady, 1879

Jaculella sp. 1
Plate 2, fig. 15

Occurrence. 2 specimens from 2 samples.

Description. Test tubular, tapering, conical. Wall medium thickness, coarse grained, roughly finished.

Remarks. Both specimens are fragmentary.

Family HYPERAMMINIDAE Eimer & Fickert, 1899
Subfamily HYPERAMMININAE Eimer & Fickert, 1899
Genus *Hyperammina* Brady, 1878

Hyperammina cylindrica Parr, 1950
Plate 2, fig. 16

Hyperammina cylindrica Parr, 1950, p. 254, pl. 3, fig. 5.

Occurrence. 1 specimen.

Hyperammina spp.
Plate 3, figs 1,2

Occurrence. 9 specimens from 9 samples.

Description. Forms with a large proloculus followed by an undivided tube, fine to medium grained, small to large in size.

Remarks. Specimens generally fragmentary.

Family AMMODISCIDAE Reuss, 1862
Subfamily AMMODISCINAE Reuss, 1862
Genus *Ammodiscus* Reuss, 1862

Ammodiscus cretaceus (Reuss, 1845)
Plate 3, fig. 3a

Operculina cretacea Reuss, 1845, p. 35, pl. 13, figs 64-65.
Ammodiscus cretacea (Reuss). -Cushman, 1934, p. 45.
Ammodiscus cretaceus (Reuss). -Kaminski & Gradstein, 2005, p. 147, pl. 14, figs 1a-10.

Occurrence. 42.5 specimens from 20 samples.

Remarks. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Ammodiscus latus Grzybowski, 1898
Plate 3, figs 4-6

Ammodiscus latus Grzybowski, 1898, p. 282, pl. 10, figs 27-28.
Ammodiscus latus Grzybowski. -Kaminski & Gradstein, 2005, p. 152, pl. 16a, figs 1-8, p. 153, pl. 16b, figs 1-6.

Occurrence. 187 specimens from 51 samples.

Ammodiscus peruvianus (Berry, 1928)

Ammodiscus peruvianus Berry, 1928, p. 342, pl. 27.
Ammodiscus peruvianus Berry. -Kaminski & Gradstein, 2005, p. 159, pl. 18, figs 1a-6.

Occurrence. 2 specimens from 2 samples.

Ammodiscus tenuissimus Grzybowski, 1898
Plate 3, fig. 7

Ammodiscus tenuissimus Grzybowski, 1898, p. 282, pl. 10, fig. 35.
Ammodiscus tenuissimus Grzybowski. -Kaminski & Gradstein, 2005, p. 163, pl. 20, figs 1a-7.

Occurrence. 1 specimen.

Remarks. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Ammodiscus sp. 1
Plate 3, figs 8,9

Occurrence. 12 specimens from 7 samples.

Description. Test small, planispiral, strongly compressed along the long axis so that the test forms an elongated shape. Chamber increasing only gradually in size, aperture terminal. Wall fine grained with a smooth finish.

Ammodiscus sp. 2
Plate 3, figs 10,11

Occurrence. 4 specimens from 3 samples.

Description. Test medium to large in size, planispiral sometimes becoming uncoiled, slightly elongated. Chamber increasing rapidly in size, rounded, inflated, 'sausage-like', thick. Wall thick, medium grain size with a smooth finish.

Ammodiscus spp.

Plate 3, figs 12,13

Occurrence. 32.5 specimens from 20 samples.
Description. We include all planispiral forms with one chamber coiling around an initial proloculus.
Remarks. Usually unidentified due to poor preservation.

Subfamily TOLYPAMMININAE Cushman, 1928
Genus *Ammolagena* Eimer & Fickert, 1899

Ammolagena clavata (Jones & Parker, 1860)

Plate 2, fig. 15, Plate 3, fig. 3b

Trochammina irregularis (d'Orbigny) var. *clavata* Jones & Parker, 1860, p. 304.
Ammolagena clavata (Jones & Parker). -Kaminski & Gradstein, 2005, p. 165, pl. 21, figs 1-6.
Occurrence. 12 specimens from 9 samples.

Subfamily USBEKISTANIINAE Vyalov, 1977
Genus *Glomospira* Rzehak, 1885

Glomospira charoides (Jones & Parker, 1860)

Plate 3, fig. 14

Trochammina squamata Jones & Parker var. *charoides* Jones & Parker, 1860, p. 304.
Glomospira charoides (Jones & Parker). -Berggren & Kaminski, 1990, pl. 1, fig. 2.
Glomospira charoides (Jones & Parker). -Kaminski & Gradstein, 2005, p. 173, pl. 22, figs 1-16.
Occurrence. 45 specimens from 24 samples.

Glomospira glomerata (Grzybowski, 1898)

Plate 3, fig. 15

Ammodiscus glomeratus Grzybowski, 1898, p. 285, pl. 11, fig. 4.
"*Glomospira*" *glomerata* (Grzybowski). -Kaminski & Gradstein, 2005, p. 179, pl. 24, figs 1-6.
Occurrence. 4 specimens from 3 samples.

Glomospira gordialis (Jones & Parker, 1860)

Plate 4, fig. 1

Trochammina squamata Jones & Parker var. *gordialis* Jones & Parker, 1860, p. 304.
Glomospira gordialis (Jones & Parker). -Berggren & Kaminski, 1990, pl. 1, fig. 1.
Glomospira glomerata (Jones & Parker). -Kaminski & Gradstein, 2005, p. 184, pl. 25, figs 1-8.
Occurrence. 13 specimens from 9 samples.

Glomospira irregularis (Grzybowski, 1898)

Plate 4, fig. 2

Ammodiscus irregularis Grzybowski, 1898, p. 285, pl. 11, figs 2, 3.
Glomospira irregularis (Grzybowski). -Kaminski & Geroch, 1993, p. 256, pl. 6, fig. 6-8b.
Glomospira irregularis (Grzybowski). -Kaminski & Gradstein, 2005, p. 187, pl. 26, figs 1a-7.
Occurrence. 27 specimens from 13 samples.

Glomospira* aff. *irregularis (Grzybowski, 1898)

Plate 4, figs 3,4

Occurrence. 6 specimens from 3 samples.
Remarks. Similar to *G. irregularis*, but with a larger tube, coarser wall, and less convolutions. The specimens are all fragmentary however.

Glomospira sp. 1

Plate 4, figs 5,6

Occurrence. 5 specimens from 3 samples.
Description. Test small, initially glomospirally enrolled, becoming planispiral. Test flattened. Single chamber increasing in size only gradually. Wall thin, fine grained, with a smooth finish.

Glomospira sp. 2

Plate 4, fig. 7

Occurrence. 3 specimens from 3 samples.
Description. Test medium to large in size, single chambered. Initial coiling irregular to glomospiral, later planispiral. Chamber large, thin, slightly flattened, and increasing only gradually in size. Wall coarse with a rough finish.

Glomospira spp.

Occurrence. 29 specimens from 13 samples.
Remarks. All fragmentary and as yet unidentifiable specimens with single coiled chamber.

Family HORMOSINELLIDAE Rauser & Reitlinger, 1986
Genus *Caudammina* Montanaro-Gallitelli, 1955

Caudammina* aff. *ovuloides (Grzybowski, 1901)

Plate 4, fig. 8

Reophax ovuloides Grzybowski, 1901, p. 223, pl. 8, fig. 3.
Caudammina ovuloides (Grzybowski). -Kaminski & Gradstein, 2005, p. 240, pl. 42, figs 1-7.
Occurrence. 2 specimens from 2 samples.
Description. Test flask shaped, originally multichambered, tubular aperture at one end on a protruding neck, similar aperture at opposite end. Wall medium to thick, grain size medium.
Remarks. Very similar to *Caudammina ovuloides*, known from the Cretaceous and early Paleogene only. Specimens show a highly-silicified wall and may be reworked.

Family HORMOSINELLIDAE Rauser & Reitlinger, 1986
Genus *Hormosinella* Shchedrina, 1969

Hormosinella carpenteri (Brady, 1884)

Plate 4, fig. 9

Trochammina (*Hormosina*) *carpenteri* Brady, 1881, p. 51 [no figure given].

Hormosina carpenteri Brady, 1884, pl. 31, figs 16-22 [earliest figure].

Occurrence. 1 specimen.

Genus *Reophanus* Saidova, 1970

Reophanus berggreni Gradstein & Kaminski, 1997

Plate 4, fig. 10

Reophanus berggreni Gradstein & Kaminski, 1997, p. 220, textfig. 4, fig. 5, 1-7b.

Reophanus berggreni Gradstein & Kaminski. -Kaminski & Gradstein, 2005, p. 265, pl. 50, figs 1-7.

Occurrence. 3 specimens from 2 samples.

Family HORMOSINELLIDAE Rauser & Reitlinger, 1986

Genus *Subreophax* Saidova, 1975

Subreophax pseudoscalaris (Samuel, 1977)

Plate 4, fig. 11

Reophax pseudoscalaria Samuel, 1977, p. 36, pl. 3, figs 14a,b.

Subreophax pseudoscalaris (Samuel). -Kaminski & Gradstein, 2005, p. 282, pl. 56, figs 1-6.

Occurrence. 4 specimens from 2 samples.

Subreophax scalaris (Grzybowski, 1896)

Plate 4, figs 12,13

Reophax guttifera Brady var. *scalaria* Grzybowski, 1896, p. 277, pl. 8, fig. 26.

Subreophax scalaris (Grzybowski). -Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 187, pl. 2, figs 16-17.

Reophax scalaris (Grzybowski). -Kaminski & Gradstein, 2005, p. 279, pl. 55, figs 1-7.

Occurrence. 11 specimens from 8 samples.

Family ASCHEMOCELLIDAE Vyalov, 1966

Genus *Aschemocella* Vyalov, 1966

Aschemocella grandis (Grzybowski, 1898)

Plate 4, figs 14,15

Reophax grandis Grzybowski, 1898, p. 277, pl. 10, figs 13-15.

Aschemocella grandis (Grzybowski). -Kaminski & Geroch, 1993, p. 249, pl. 2, figs 8-10.

Aschemocella grandis (Grzybowski). -Kaminski & Gradstein, 2005, p. 229, pl. 39, figs 1-8b.

Occurrence. 15 specimens from 8 samples.

Aschemocella spp.

Plate 4, fig. 16

Occurrence. 4 specimens from 4 samples.

Description. We include all unidentified fragments of large multichambered forms, where chambers do not increase in size with growth.

Genus *Kalamopsis* de Folin, 1883

Kalamopsis spp.

Plate 4, fig. 17

Occurrence. 19 specimens from 9 samples.

Description. All forms with a rectilinear series of tubular chambers, thick wall, generally smooth finish. Forms unbranching, medium in size.

Family REOPHACIDAE Cushman, 1927

Genus *Hormosinelloides* Saidova, 1975

Hormosinelloides guttifer (Brady, 1884)

Plate 5, fig. 1

Reophax guttifer Brady, 1881, p. 49 [no figure given].

Reophax guttifer Brady, 1884, pl. 31, figs 10-15 [earliest figure].

Hormosinelloides guttiferus (Brady). -Zheng & Fu, 2001, p. 278, pl. 16, figs 16-22 [n.comb.].

Occurrence. 5 specimens from 3 samples.

Genus *Reophax* de Montfort, 1808

Reophax duplex Grzybowski, 1896

Plate 5, fig. 2

Reophax duplex Grzybowski, 1896, p.276, pl. 8, figs 23-24.

Reophax duplex Grzybowski. -Kaminski & Gradstein, 2005, p. 268, pl. 51, figs 1-9.

Occurrence. 5 specimens from 4 samples.

Reophax pilulifer (Brady, 1884)

Plate 5, figs 3,4

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

Reophax pilulifer Brady. -Kaminski & Gradstein, 2005, p. 273, pl. 53, figs 1a-9.

Occurrence. 51.5 specimens from 24 samples.

Reophax pyrifer Rhumbler, 1905

Plate 5, figs 5,6

Reophax pyrifer Rhumbler, 1905, p. 103, text-fig. 4.

Occurrence. 4 specimens from 3 samples.

Reophax sp. 1

Plate 5, figs 7,8

Occurrence. 4 specimens from 3 samples.

Description. Test small, uniserial, consisting of up to three rectilinear chambers increasing in size rapidly. Aperture terminal. Wall thin. Test collapsed. Grainsize coarse, texture of the test rough.

Reophax sp. 2

Plate 5, fig. 9

Occurrence. 5 specimens from 2 samples.

Description. Test large in size, consisting of at least two globular chambers attached in a rectilinear series increasing only slightly in size. Wall very thick and coarse. Chambers overlapping about 20% of previous chambers.

***Reophax* spp.**
Plate 5, fig. 10

Occurrence. 29 specimens from 14 samples.
Remarks. We include all unidentified fragmentary specimens of multichambered unilocular foraminifera.

Family HORMOSINIDAE Haeckel, 1894
Subfamily HORMOSININAE Haeckel, 1894
Genus *Hormosina* Brady, 1879

Hormosina glabra Cushman & Stainforth, 1945
Plate 5, fig. 11

Hormosina glabra Cushman & Stainforth, 1945, p. 14, pl. 1, fig. 9.
Occurrence. 4 specimens from 1 sample.

Hormosina globulifera Brady, 1879
Plate 5, fig. 12

Hormosina globulifera Brady, 1879, p. 60, pl. 4, figs 4-5.
Occurrence. 70 specimens from 24 samples.

***Hormosina* spp.**

Occurrence. 1 specimen from 1 sample.
Remarks. Fragmentary specimen of *H. globulifera* with unidentified aperture.

Genus *Pseudonodosinella* Saidova, 1970

Pseudonodosinella elongata (Grzybowski, 1898)
Plate 5, fig. 13

Reophax elongata Grzybowski, 1898, p. 279, pl. 10, figs 19-20.
Pseudonodosinella elongata (Grzybowski). -Kaminski & Geroch, 1993, p. 295, pl. 3, figs 1-5.
Occurrence. 2 specimens from 1 sample.

Family KUNKLERINIDAE Rauser & Reitlinger, 1986
Genus *Scherochorella* Loeblich & Tappan, 1984

Scherochorella congoensis Kender, Kaminski & Jones 2006
Plate 5, figs 14-16

Scherochorella congoensis Kender, Kaminski & Jones, 2006, p. 467, pl. 1, figs 1-6.
Occurrence. 1214 specimens from 32 samples.

Family LITUOTUBIDAE Loeblich & Tappan, 1984
Genus *Lituotuba* Rhumbler, 1895

Lituotuba lituiformis (Brady, 1879)
Plate 5, fig. 17, Plate 6, fig. 1

Trochammina lituiformis Brady, 1879, p. 59, pl. 5, fig. 16.
Occurrence. 14 specimens from 9 samples.

Genus *Paratrochamminoides* Soliman, 1972

Paratrochamminoides* ex gr. *challengeri (Rögl, 1995)
Plate 6, fig. 2

Trochamminoides challengeri Rogl, 1995, p. 256.
Paratrochamminoides challengeri (Rögl). -Kaminski & Kuhnt, 2004, p. 280.
Occurrence. 2 specimens from 2 samples.

Paratrochamminoides* aff. *deflexiformis (Noth, 1912)
Plate 6, figs 3,4

Trochammina deflexiformis Noth, 1912, p. 26, figs 10a-b.
Paratrochamminoides deflexiformis (Noth). -Kender, Kaminski & Cieszkowski, 2005, p. 263, fig. 11, K1-2.
Occurrence. 2 specimens from 2 samples.
Remarks. These specimens are poorly preserved, but exhibit the characteristic glomospiral coiling and bead-like chambers increasing in size slowly with 8-10 chambers in the final whorl that defines *P. deflexiformis*.

Paratrochamminoides gorayskiformis Kender, Kaminski & Jones 2006
Plate 6, figs 5-8

Paratrochamminoides gorayskiformis Kender, Kaminski & Jones, 2006, p. 467, pl. 1, figs 7-10.
Occurrence. 15 specimens from 7 samples.

Paratrochamminoides gorayskii (Grzybowski, 1898)
Plate 6, fig. 9

Ammodiscus gorayskii Grzybowski, 1898, p. 283, pl. 11, fig. 5.
Paratrochamminoides gorayskii (Grzybowski). -Kaminski & Geroch, 1993, 255, pl. 5, fig. 8a-d.
Paratrochamminoides gorayskii (Grzybowski). -Kaminski & Gradstein, 2005, p. 297, pl. 61, figs 1a-5.
Occurrence. 7 specimens from 4 samples.

Paratrochamminoides olszewskii (Grzybowski, 1898)
Plate 6, figs 10,11

Trochammina olszewskii Grzybowski, 1898, p. 298, pl. 11, fig. 6.
Paratrochamminoides olszewskii (Grzybowski). -Kaminski & Geroch, 1993, p. 257, pl. 7, figs 1a-2b.
Paratrochamminoides olszewskii (Grzybowski). -Kaminski & Gradstein, 2005, p. 307, pl. 64, figs 1a-7.
Occurrence. 21 specimens from 11 samples.

***Paratrochamminoides* sp. 1**
Plate 7, fig. 1

Occurrence. 2 specimens from 1 sample.
Description. Test large in size, coiling streptospiral, chambers numerous, inflated, increasing in size rapidly so that last whorl makes up a significant proportion of the test. Chambers globular, bead-like

to slightly elongated. Wall thin, chambers collapsed. Wall is made up of medium sized grains, surface of the test is smooth.

Paratrochamminoides spp.

Occurrence. 18 specimens from 13 samples.
Description. All specimens with a streptospirally enrolled test, numerous ovate to globular chambers, thin wall.
Remarks. Unidentified fragmentary and collapsed specimens.

Genus *Conglophragmium* Bermúdez & Rivero, 1963

Conglophragmium irregularis (White, 1928)
Plate 7, fig. 2

Trochamminoides irregularis White, 1928, p. 307, pl. 42, fig. 1.
Conglophragmium irregularis (White). -Kaminski & Gradstein, 2005, p. 286, pl. 57, figs 1-6.
Occurrence. 4 specimens from 3 samples.

Family TROCHAMMINOIDAE Haynes & Nwabufo-Ene, 1998
Genus *Trochamminoides* Cushman, 1910

Trochamminoides folius (Grzybowski, 1898)
Plate 7, fig. 3

Trochammina folium Grzybowski, 1898, p. 288, pl. 11, figs 7-9.
Trochamminoides folius (Grzybowski). -Kaminski & Geroch, 1993, p. 306, pl. 9, figs 1a-4b.
Occurrence. 1 specimen from 1 sample.
Remarks. Specimen shows a highly-silicified wall and may be reworked from the Eocene.

Trochamminoides* aff. *proteus (Karrer, 1866)
Plate 7, figs 4,5

Tochammina proteus Karrer, 1866, pl. 1, fig. 8.
Trochamminoides proteus (Karrer). -White, 1928, p. 308, pl. 42, fig. 2.
Trochamminoides proteus (Karrer). -Kaminski & Gradstein, 2005, p. 317, pl. 67, figs 1a-5b.
Occurrence. 2 specimens from 2 samples.
Description. Test large in size, initially irregularly coiled, later becoming planispiral. Chambers increase in size gradually and are numerous with about 7 in the last whorl. Chambers globular, bead-like, sutures straight. Wall is made up of medium sized grains, with a rough finish. Aperture is terminal and equatorial.
Remarks. Differs from its most similar form T. proteus by having fewer chambers in the last whorl, and larger chambers.

Trochamminoides subcoronatus (Grzybowski, 1896)
Plate 7, fig. 6

Trochammina subcoronata Grzybowski, 1896, p. 283 - 284, pl. 9, fig. 3a-c.
Trochamminoides subcoronatus (Grzybowski). -Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 192, pl. 4, fig. 19.
Trochamminoides subcoronatus (Grzybowski). -Kaminski & Gradstein, 2005, p. 319, pl. 67, figs 1a-6.
Occurrence. 6 specimens from 3 samples.

Trochamminoides spp.

Occurrence. 7 specimens from 6 samples.
Description. Irregularly coiled becoming planispiral, numerous ovate to globular chambers, thin wall.
Remarks. Unidentified fragmentary and collapsed specimens.

Family HAPLOPHRAGMOIDIDAE Maync, 1952
Genus *Buzasina* Loeblich & Tappan, 1985

Buzasina* aff. *pacifica (Krasheninnikov, 1973)
Plate 7, fig. 7

Labrospira pacifica Krasheninnikov, 1973, p. 209, pl. 2, figs 4-5.
Buzasina pacifica (Krasheninnikov). -Kaminski & Gradstein, 2005, p. 337, pl. 73, figs 1-5.
Occurrence. 1 specimen from 1 sample.
Description. Test small, planispiral, with 3 chambers increasing in size rapidly. Last chamber strongly overlapping initial chambers and comprising more than half the test. Wall thick, finely agglutinated and smooth. Specimen shows a highly-silicified wall and may be reworked from the Eocene.

Genus *Evolutinella* Mjatliuk, 1970

Evolutinella rotulata (Brady, 1881)
Plate 9, fig 4

Haplophragmoides rotulatus, Brady, 1881, p. 50.
Occurrence. 1 specimen from 1 sample.
Remarks. Differs from *Budashevaella multicamerata* due to its bi-umbilicate form.

Genus *Haplophragmoides* Cushman, 1910

Haplophragmoides carinatus Cushman & Renz, 1941
Plate 7, figs 8,9

Haplophragmoides carinatus Cushman & Renz, 1941, p. 2, pl. 1, fig. 1.
Occurrence. 4 specimens from 3 samples.

Haplophragmoides* aff. *horridus (Grzybowski, 1901)
Plate 7, fig. 10

Haplophragmium horridum Grzybowski, 1901, p. 270, pl. 7, fig. 12.
Haplophragmoides horridus (Grzybowski). -Kaminski &

Geroch, 1993, p. 318, pl. 15, figs 6-8.
Haplophragmoides horridus (Grzybowski). -Kaminski & Gradstein, 2005, p. 349, pl. 77, figs 1a-6.
Occurrence. 7 specimens from 3 samples.
Remarks. The specimens from this well differ from true *H. horridus* by having a thicker wall and larger final chamber compared to the previous ones. It also exhibits a coarse wall, straight sutures and four triangular inflated chambers.

Haplophragmoides nauticus Kender, Kaminski & Jones 2006
Plate 8, figs 5-6
Haplophragmoides nauticus Kender, Kaminski & Jones, 2006, p. 469, pl. 2, figs 1-3.
Occurrence. 44 specimens from 16 samples.
Remarks. Test usually large, with trapezoidal chambers and evolute coiling. Commonly occurs caved.

Haplophragmoides walteri (Grzybowski, 1898)
Plate 8, fig. 1
Trochammina walteri Grzybowski, 1898, p. 290, pl. 11, fig. 31.
Haplophragmoides walteri (Grzybowski). -Kaminski & Geroch, 1993, p. 263, pl. 10, fig. 3a-7c.
Haplophragmoides walteri (Grzybowski). -Kaminski & Gradstein, 2005, p. 365, pl. 83, figs 1-6.
Occurrence. 39 specimens from 14 samples.
Remarks. This species is invariably compressed due its very thin wall. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Haplophragmoides sp. 1
Plate 8, figs 2,3
Occurrence. 8 specimens from 5 samples.
Description. Test medium to large in size, with 5-6 distinctly globular chambers in the last whorl. Umbilicus depressed, periphery rounded, sutures straight and depressed. Wall simple, composed of medium to coarse grains.

Haplophragmoides sp. 2
Plate 8, fig. 7
Occurrence. 1 specimen.
Description. Test large, planispiral, evolute, with 8 chambers in the final whorl. Umbilicus significantly depressed. Periphery consists of a thick carina, sutures depressed and chambers inflated. Wall simple and very thickened.
Remarks. The thickened nature of this *Haplophragmoides* makes it resemble superficially a *Reticulophragmium*.

Haplophragmoides spp.
Plate 8, fig. 3
Occurrence. 74.5 specimens from 33 samples.
Remarks. All fragmentary and unidentified forms with planispiral chambers.

Family DICAMMINIDAE Loeblich & Tappan, 1984
Genus *Glaphyrammina* Cushman, 1910

Glaphyrammina americana (Cushman, 1910)
Plate 8, fig. 4
Ammobaculites americanus Cushman, 1910, p. 117, figs 1-4.
Glaphyrammina americana (Cushman). -Loeblich & Tappan, 1988, p. 68, pl. 51, figs 7-10.
Occurrence. 2 specimens from 2 samples.

Glaphyrammina spp.

Occurrence. 1 specimen.
Remarks. Similar to *G. americana* but broken and unclear.

Family SPHAERAMMINIDAE Cushman, 1933
Subfamily PRAESPHAERAMMININAE Kaminski & Mikhalevich, 2004
Genus *Praesphaerammina* Kaminski & Filipescu, 2000

Praesphaerammina sp. 1
Plate 8, figs 8-10
Occurrence. 9 specimens from 6 samples.
Description. Test very large in size, planispiral, with 3 to 4 strongly overlapping chambers. Final chamber is so large it makes up the majority of the test. Wall is very thick and coarse, with a rough texture.

Praesphaerammina spp.

Occurrence. 13.5 specimens from 11 samples.
Description. Test large, planispirally enrolled, involute, with about four strongly overlapping chambers per whorl, with the final embracing chamber overlapping over half the test. Wall fine, rough to smooth finish.
Remarks. Usually occurs as fragments of very large specimens.

Family LITUOLIDAE de Blainville, 1827
Subfamily AMMOMARGINULINAE Podobina, 1978
Genus *Ammomarginulina* Wiesner, 1931

Ammomarginulina spp.
Plate 8, fig. 11
Occurrence. 6 specimens from 5 samples.
Description. Test elongate, strongly compressed. Planispiral in early stage, later uncoiled and rectilinear with oblique sutures. Wall agglutinated, roughly finished. Aperture terminal, rounded, at dorsal side of test.

Family LITUOLIDAE de Blainville, 1827
Genus *Discamminoides* Bronnimann, 1951

Discamminoides sp. 1

Plate 9, figs 1,2, Plate 15, figs 1,2

Occurrence. 212 specimens from 38 samples.

Description. Test large, involute, planispiral becoming uniserial, flattened, with 4-5 chambers in last coil and up to 5 chambers in uniserial part. Chambers increase in size steadily. Initial coiled part either large or small depending on micro- or megalo- spheric generation. Periphery acute, sutures straight, seen as slight depression or undulation of test surface, or only visible as internal layer. Aperture a terminal slit. Wall bilamellar, internal layer thicker at peripheral part, coarse and sometimes speculated, with thin tubular alveoles. Outer layer medium to coarse grained and thin.

Family AMMOSPHAEROIDINIDAE Cushman, 1927
Subfamily AMMOSPHAEROIDININAE Cushman, 1927
Genus *Ammosphaeroidina* Cushman, 1910

Ammosphaeroidina pseudopauciloculata (Mjatliuk, 1966)

Plate 9, fig. 3

Cystamminella pseudopauciloculata Mjatliuk, 1966, p. 246, pl. 1, figs 5-7, pl. 2, fig. 6, pl. 3, fig. 3.

Ammosphaeroidina pseudopauciloculata (Mjatliuk). - Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 193, pl. 8, figs 3-5.

Occurrence. 109 specimens from 28 samples.

Description. Test size small to medium, streptospirally enrolled, chambers globular, increasing rapidly in size so that only the last 4 are visible in the final whorl. Wall fine to medium agglutinated, surface smoothly finished. Aperture a low interiomarginal arch.

Ammosphaeroidina spp.

Occurrence. 76 specimens from 18 samples.

Description. Test small to large, streptospirally enrolled, chambers globular, increasing rapidly in size so that only the last 4 are visible in the final whorl. Wall finely to coarsely agglutinated, surface with a smooth to rough finish.

Subfamily RECURVOIDINAE Alekseychik-Mitskevich, 1973
Genus *Budashevaella* Loeblich & Tappan, 1964

Budashevaella multicamerata (Voloshinova & Budasheva, 1961)

Plate 9, figs 5,7

Circus multicamerata Voloshinova, 1961, p. 201, pl. 7, figs 6a-c, pl. 8, 1a-c.

Budashevaella multicamerata Voloshinova. -Kaminski & Gradstein, 2005, p. 388, pl. 90, figs 1a-6b.

Occurrence. 13 specimens from 6 samples.

Budashevaella spp.

Occurrence. 6 specimens from 3 samples.

Description. Test medium to large in size, chambers numerous, later stages nearly planispiral and partly evolute, sutures slightly depressed. Wall thick, aperture interiomarginal.

Genus *Cribrostomoides* Cushman, 1910

Cribrostomoides subglobosus (Cushman, 1910)

Plate 9, fig. 8

Lituola subglobosa Cushman, 1910, p. 253.

Cribrostomoides subglobosus (Cushman). -Jones, Bender, Charnock, Kaminski & Whittaker, 1993, pl. 1, figs 1-5.

Cribrostomoides subglobosus subglobosus (Cushman). - Kaminski & Gradstein, 2005, p. 395, pl. 92, figs 1a-3b.

Occurrence. 19 specimens from 10 samples.

Remarks. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Cribrostomoides spp.

Plate 10, fig. 1

Occurrence. 22 specimens from 16 samples.

Description. Test enrolled and involute, later stage becoming more planispiral. Wall thin to thick, simple in structure, surface smoothly to roughly finished. Aperture simple equatorial slit just above the base of the final chamber face, with a narrow lip present on both margins. Sometimes becoming irregular with fine projections from both margins that may divide the primary aperture into a linear series of irregular to rounded openings near the base of the chamber face.

Genus *Recurvoides* Earland, 1934

Recurvoides azuaensis Bermúdez, 1949

Plate 10, figs 2,3

Recurvoides azuaensis Bermúdez, 1949, pl. 1, figs 35-37.

Occurrence. 45 specimens from 25 samples.

Recurvoides sp. 1

Plate 10, figs 4,5

Occurrence. 9 specimens from 4 samples.

Description. Test small, consisting of 5 to 7 elongated chambers tightly enrolled to form spherical test. Coiling streptospiral becoming just off planispiral. Sutures slightly depressed. Aperture a basal slit. Wall coarse, with a rough finish. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Recurvoides **sp. 2**
Plate 9, fig. 6, Plate 10, fig. 6

Occurrence. 9 specimens from 6 samples.
Description. Test large, consisting of 5 chambers straptospirally enrolled, increasing in size rapidly. Periphery rounded, sutures straight and indistinct. Aperture basal surrounded by a coarse lip. Test wall very coarse. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Recurvoides **sp. 3**
Plate 11, figs 7-9

Occurrence. 47 specimens from 14 samples.
Description. Test medium to large in size, subglobular, tightly enrolled in a streptospiral, becoming almost planispiral. Last whorl consists of about 6 chambers increasing in size gradually. Wall thick, made up of coarsely agglutinated grains. Sutures indistinct from the surface topography, straight when viewed through the test wall. Aperture areal. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Recurvoides **spp.**
Plate 10, fig. 10

Occurrence. 75 specimens from 34 samples.
Description. Subglobular, streptospirally enrolled, generally few chambers per whorl, generally trochospiral to planispiral or may show an abrupt change in plane of coiling. Wall coarsely agglutinated, medium to thick, surface usually roughly finished, aperture areal.

Family AMMOBACULINIDAE Saidova, 1981
Subfamily AMMOBACULININAE Saidova, 1981
Genus *Bulbobaculites* Maync, 1952

Bulbobaculites **sp. 1**
Plate 10, fig. 11

Occurrence. 1 specimen from 1 sample.
Description. Test of medium size, elongate, early stage with streptospirally enrolled globular and inflated chambers. Later chambers uncoiled and rectilinear, sutures distinct, depressed and horizontal. Wall coarsely finished and simple. Aperture terminal, a single small rounded opening.

Family PAVONTINIDAE Loeblich & Tappan, 1961
Subfamily SPIROPSAMMININAE Seiglie & Baker, 1984
Genus *Spiropsammina* Seiglie & Baker, 1984

Spiropsammina primula Seiglie & Baker, 1983
Plate 10, fig. 12, Plate 15, fig. 3

Spiropsammina primula Seiglie & Baker, 1983, pl. 2, figs 7-9.

Occurrence. 4 specimens from 4 samples.

Family TROCHAMMINIDAE Schwager, 1877
Subamily TROCHAMMININAE Schwager, 1877
Genus *Portatrochammina* Echols, 1971

Portatrochammina profunda Kender, Kaminski & Jones 2006
Plate 11, figs 1-5

Portatrochammina profunda Kender, Kaminski & Jones, 2006, p. 469, pl. 2, figs 3-8.

Occurrence. 206 specimens from 26 samples.

Genus *Tritaxis* Schubert, 1921

Tritaxis **sp. 1**
Plate 11, figs 6,7

Occurrence. 8 specimens from 5 samples.
Description. Test large, trochospiral, with 3 chambers in the final whorl making up the adult from. Sutures depressed, chambers globular. Wall thick and coarse, with a rough texture. Aperture interiomarginal, resting on the first chamber of the final whorl.

Genus *Trochammina* Parker & Jones, 1859

Trochammina **sp. 1**
Plate 11, figs 8,9

Occurrence. 6 specimens from 3 samples.
Description. Test of medium size, consisting of 5 to 6 globular chambers trochospirally enrolled and increasing in size gradually. Sutures radial. Wall thin, coarse, with a rough texture. Aperture interiomarginal opening resting on the first chamber of the final whorl.

Trochammina **spp.**
Plate 11, fig. 10

Occurrence. 207 specimens from 35 samples.
Description. We include forms that are trochospiral, chambers increasing gradually in size, sutures radial, periphery rounded. Test small to large, aperture generally unseen. Wall coarse to fine, and thin to thick.

Family PROLIXOPLECTIDAE Loeblich & Tappan, 1985
Genus *Eggerelloides* Haynes, 1973

Eggerelloides **sp. 1**
Plate 12, figs 1,2

Occurrence. 2 specimens from 2 samples.
Description. Test large in size, subfusiform, early stage of growth trochospiral, later triserial. Aperture a high interiomarginal arch in the centre of the apertural face, with a broad lip. Wall simple, thick, coarse, with a rough texture.

Genus *Karrerulina* Finlay, 1940

Karrerulina apicularis (Cushman, 1911)
Plate 12, figs 3,4

Gaudryina apicularis Cushman, 1911, p. 69, text-fig. 110.
Karrerulina apicularis (Cushman). -Murray & Alve, 1994, pl. 1, fig. 13.

Occurrence. 12 specimens from 6 samples

Description. Test elongate and slender, initially trochospiral, later triserial becoming biserial. Chambers slightly inflated. Aperture terminal, at the end of a projected neck.

Karrerulina conversa (Grzybowski, 1901)
Plate 12, figs 5-6

Gaudryina conversa Grzybowski, 1901, p. 285, pl. 7, figs 15, 16.
Gerochammina conversa (Grzybowski). -Kaminski & Geroch, 1993, p. 279, pl. 13, figs 5a-11.
Karrerulina conversa (Grzybowski). -Kaminski & Gradstein, 2005, p. 472, pl. 116, figs 1a-11b.

Occurrence. 6 specimens from 3 samples.

Karrerulina horrida (Mjatliuk, 1970)
Plate 12, fig. 7

Karreriella horrida Mjatliuk, 1970, pl. 5, fig. 9, pl. 33, figs 15-16.
Karrerulina horrida (Mjatliuk) -Kaminski & Gradstein, 2005, p. 474, pl. 117, figs 1-11.

Occurrence. 2 specimens from 1 samples.

Karrerulina spp.

Occurrence. 17 specimens from 9 samples.

Description. We include elongated slender specimens that are trochospirally coiled in the initial part and reduced in the latter stages.

Remarks. Generally not assigned to a species due to breakages or bad preservation.

Family REOPHACELLIDAE Mikhalevich & Kaminski, 2004
Subfamily VERNEUILININAE Cushman, 1911
Genus *Verneuilina* d'Orbigny, 1839

Verneuilina sp. 1
Plate 12, fig. 8

Occurrence. 1 specimen.

Description. Test large, elongate conical in shape, chambers tricerial and triangular increasing rapidly in size. Wall simple, thick, and relatively smooth. Aperture an interiomarginal arch.

Family CYCLAMMINIDAE Marie, 1941
Subfamily ALVEOLOPHRAGMIINAE Saidova, 1981

Genus *Popovia* Suleymanov, 1965

Popovia sp. 1
Plate 15, fig. 4

Occurrence. 10 specimens from 6 samples.

Description. Test large, planispiral, involute, with approximately 7 chambers in the final whorl. Periphery acute, test flattened, sutures indistinct from the outer layer. Wall bilamellar. Inner layer thin, thickened at the periphery, with one hemisepta protruding from the periphery into each chamber. Outer wall simple, thin, coarse grained.

Popovia spp.

Occurrence. 22 specimens from 9 samples.

Description. We include planispiral forms uncoiling in later stages. Generally coarse wall with an alveolar subepidermal layer and simple septae.

Remarks. Generally badly preserved specimens that are as yet unassigned to a particular species.

Genus *Reticulophragmium* Maync, 1955

Reticulophragmium acutidorsatum (Hantken, 1868)
Plate 12, fig. 9, Plate 15, fig. 5

Haplophragmium acutidorsatum Hantken, 1868, p. 82, pl. 1, fig. 1.
Reticulophragmium acutidorsatum (Hantken). -Kaminski & Gradstein, 2005, p. 490, pl. 122, figs 1-7.

Occurrence. 136 specimens from 40 samples.

Remarks. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Reticulophragmium acutidorsatum ssp. 1
Plate 12, fig. 10, Plate 15, fig. 6

Occurrence. 1 specimen.

Description. Test large, involute planispiral, with 12 chambers in the last whorl. Chambers inflated, periphery acute. Sutures depressed at the periphery, straight, and angled away from the direction of coiling. Test wall is composed of two layers. The inner hypodermal layer is thick and perforated by tubular alveoles, the outer layer is thin and fine-grained with a smooth finish.

Reticulophragmium amplectens (Grzybowski, 1898)
Plate 12, fig. 11

Cyclammina amplectens Grzybowski, 1898, p. 292, pl. 12, figs 1-3.
Reticulophragmium amplectens (Grzybowski). -Kaminski & Geroch, 1993, p. 266, pl. 11, figs 5-7c.
Reticulophragmium amplectens (Grzybowski). -Kaminski & Gradstein, 2005, p. 495, pl. 123, figs 1-6.

Occurrence. 119 specimens from 34 samples. Occurs throughout most of the well, maxima between 4050-4130m.

Remarks. We include forms that are medium to large, thick, have an acute (almost carinate) periphery, an umbilical depression, and have elongated radial alveoles. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Reticulophragmium amplectens **ssp. 1**
Plate 12, fig. 12, Plate 15, figs 7,8

Occurrence. 6 specimens from 5 samples.

Description. Large, thick, acute periphery, straight depressed sutures, depressed umbilicus. Alveoles are elongated and radial in appearance. Test smooth.

Remarks. This form differs from *R. amplectens* (Grzybowski) by its larger size and less acute periphery. It appears that *R. amplectens* ssp. 1 may have evolved from a transitional form of *R. acutidorsatum* (Hantken) due to its otherwise close appearance. This would indicate that elongated alveoles have evolved more than once and are thus an example of convergent evolution as *R. amplectens* appears first in the Early Eocene. Some specimens show a highly-silicified wall however, and may be reworked from the Eocene.

Reticulophragmium amplectens / acutidorsatum
transitional form
Plate 13, fig. 1, Plate 15, figs 9,10

Occurrence. 9 specimens from 8 samples.

Description. Test large, involute, planispiral, with 12-14 chambers in the final whorl. Periphery acute (almost carinate), sutures depressed and straight, umbilicus depressed. Test wall is composed of primarily rounded and sometimes elongated alveoles.

Remarks. This form is transitional between rounded and elongated alveoles, showing this test feature has evolved more than once. Forms of *R. amplectens* with elongated alveoles first appear in the Early Eocene. Some specimens show a highly-silicified wall however, and may be reworked from the Eocene.

Reticulophragmium gasparensis (Bermúdez, 1949) emend.
Plate 13, fig. 3

Cyclammina gasparensis Bermúdez, 1949, pl. 1, figs 47,48.

Occurrence. One complete form present, numerous broken cyclamminids throughout the well which may be *Cyclammina gasparensis*.

Remarks. This species is here transferred to the genus *Reticulophragmium* Maync due to its absence of true supplementary apertures. The form is otherwise very similar to *Cyclammina* sp. 1 and *Cyclammina* sp. 2 in size, shape and wall structure.

Reticulophragmium intermedium (Mjatliuk, 1970)
Plate 13, fig. 2, Plate 16, figs 1-3

Cyclammina (?) *intermedia* Mjatliuk, 1970, p. 89, pl. 21, figs 1a-c.

Reticulophragmium intermedium (Mjatliuk). -Kender, Kaminski & Cieszkowski, 2005, p. 267, figs 13I, J.

Reticulophragmium intermedium (Mjatliuk). -Kaminski & Gradstein, 2005, p. 500, pl. 125, figs 1a-5b.

Occurrence. 14 specimens from 5 samples.

Remarks. Specimens generally show a highly-silicified wall and may be reworked from the Eocene.

Reticulophragmium rotundidorsatum (Hantken, 1875)
Plate 13, figs 4,5

Haplophragmoides rotundodorsatum Hantken, 1875, p. 12, pl. 1, fig. 2.

Cyclammina (*Reticulophragmium*) *rotundidorsatum* (Hantken). -Charnock & Jones, 1990, pl. 7, figs. 13-15, pl. 19, fig. 1.

Reticulophragmium rotundidorsatum (Hantken). -Cicha, Rögl, Rupp & Ctyroka, 1998, pl. 5, fig. 5.

Reticulophragmium rotundidorsatum (Hantken). -Kaminski & Gradstein, 2005, p. 507, pl. 127, figs 1a-5c.

Occurrence. 256.5 specimens from 44 samples.

Remarks. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Reticulophragmium **sp. 1**
Plate 13, fig. 6

Occurrence. 6 specimens from 4 samples.

Description. Test medium to small in size, involute planispiral, with 5 bead-like chambers in the final whorl. Periphery rounded. Sutures straight and depressed. Aperture indistinct. Wall thin, bilamellar, inner wall alveolar. Test usually flattened due to thin wall.

Remarks. *Reticulophragmium* sp. 1 is probably a 'primitive' evolutionary form of the genus, and may have evolved form the *Haplophragmoides* Cushman as it exhibits only a very thin alveolar wall.

Reticulophragmium **spp.**

Occurrence. 73.5 specimens from 34 samples.

Description. We include all forms that are planispiral, with a complex bilamellar wall. Inner wall contains alveoles, outer wall simple, smooth with a fine finish. Apertural a basal lip.

Remarks. Poor preservation did not enable us to assign these forms to particular species.

Family CYCLAMMINIDAE Marie, 1941
Subfamily CYCLAMMININAE Marie, 1941
Genus *Cyclammina* Brady, 1879

Cyclammina **aff.** ***orbicularis*** Brady, 1884
Plate 13, figs 7-8

Cyclammina orbicularis Brady, 1884, p. 353, pl. 37, figs 17-18.

Occurrence. 2 specimens from 2 samples.

Remarks. These specimens resemble *R. orbicularis*, but bad preservation of apertural face hampers identification.

Cyclammina sp. 1

Plate 14, fig. 1

Cyclammina (*Cyclammina*) *acutidorsata* (Hantken). - Charnock & Jones, 1997, p. 188, fig. 6, figs 2a-c.

Occurrence. 2 specimens from 2 samples.

Description. Test large, involute, planispiral, with 12-14 chambers in the final whorl. Test approx. half as thick as it is wide. Megalospheric forms have fewer chambers in the final whorl than the microspheric forms. Periphery acute, sutures depressed and sigmoidal in later stages, umbilicus depressed. Apertural face large, convex, containing coarse grains. Primary aperture is a basal slit covered by a small lip. A single round supplementary aperture is present in the centre of the apertural face, sometimes surrounded by a raised lip. Test wall is composed of two layers. The inner hypodermal layer is thick and perforated by tubular alveoles, the outer layer is thin and fine-grained with a smooth finish.

Remarks. This species is distinct due to its single supplementary aperture in the centre of the apertural face, and differs from *C. cyclops* McNeil (1988) by having a much thicker test, larger apertural face and more involute coiling. Charnock & Jones (1997) also illustrate this species from the North Sea, and class it under the name *Cyclammina acutidorsata* (Hantken), along with other specimens containing more supplementary apertures but with an otherwise similar morphology.

Cyclammina sp. 2

Plate 14, figs 2,3

Cyclammina sp. Kaminski, Silye & Kender, 2005, p. 395, pl. 7, figs 3a-c.

Occurrence. 2 specimens from 2 samples.

Description. Test large, involute, planispiral, with 10-13 chambers in the final whorl. Test approx. half as thick as it is wide. Megalospheric forms have fewer chambers in the final whorl than the microspheric forms. Periphery acute, sutures depressed and sigmoidal in later stages, umbilicus depressed. Apertural face large, convex, containing coarse grains. Primary aperture is a basal slit covered by a small lip. Four round supplementary apertures are present in the centre of the apertural face forming a 'diamond' arrangement, and are surrounded by raised lips. Test wall is composed of two layers. The inner hypodermal layer is thick and perforated by tubular alveoles, the outer layer is thin and fine-grained with a smooth finish.

Remarks. This species is distinct due to its four supplementary apertures on the apertural face, arranged in an oblique 'diamond' pattern. Charnock & Jones (1997) have found similar cyclamminids from the North Sea and generally grouped them under *Cyclammina acutidorsata* (Hantken).

Cyclammina spp.

Occurrence. 22.5 specimens from 12 samples.

Remarks. Most of these specimens strongly resemble either *R. gasparensis*, or *Cyclammina* sp.1 or sp.2. They do not, however, have the apertural face preserved.

Family TEXTULARIELLIDAE Grönhagen & Luterbacher, 1966
Genus *Alveovalvulina* Brönnimann, 1953

Alveovalvulina sp. 1

Plate 14, fig. 5

Occurrence. 1 specimen.

Description. Test large, increasing in size rapidly. Coiling trochospiral in the early stage, becoming triserial. Chambers inflated, sutures depressed. Wall coarse, with complex alveolar inner structure. Aperture a low interiomarginal arch.

Alveovalvulina spp.

Plate 14, fig. 4

Occurrence. 1 specimen.

Description. The form exhibits a trochospiral early stage, becoming triserial. Test large. Wall coarse, with complex alveolar structure. Aperture a low interiomarginal arch.

Genus *Alveovalvulinella* Brönnimann, 1953

Alveovalvulinella crassa (Cushman & Renz, 1941)

Plate 14, figs 6,7

Liebusella pozonensis var. *crassa* Cushman & Renz, 1941, p. 10, pl. 2, figs 3, 4.

Alveovalvulinella pozonensis var. *crassa* (Cushman & Renz). -Bolli et al., 1994, pl. 76, figs 30-31

Occurrence. 2 specimens from 1 sample.

Family EGGERELLIDAE Cushman, 1937
Subfamily EGGERELLINAE Cushman, 1937
Genus *Karreriella* Cushman, 1933

Karreriella spp.

Occurrence. 7 specimens from 4 samples.

Description. Test small to medium in size, elongate, trochospiral becoming biserial. Wall canaliculate, coarse to medium grained, generally with a rough finish. Aperture terminal.

Family VALVULINIDAE Berthelin, 1880
Subfamily VALVULININAE Berthelin, 1880
Genus *Valvulina* d'Orbigny, 1826

Valvulina flexilis Cushman & Renz, 1941

Plate 14, fig. 8

Valvulina flexilis Cushman & Renz, 1941, p. 7, pl. 1, figs 16-17.

Occurrence. 1 specimen.

Valvulina spp. early form

Occurrence. 1 specimen.

Description. Test medium to small in size, triserial, chambers triangular with flattened sides. Wall canaliculate, thin, medium grained with smooth finish. Aperture interiomarginal.

Family TEXTULARIIDAE Ehrenberg, 1838
Subfamily TEXTULARIINAE Ehrenberg, 1838
Genus *Haeuslerella* Parr, 1935

Haeuslerella sp. 1

Plate 14, fig. 9

Occurrence. 3 specimens from 3 samples.

Description. Medium to small in size, elongate, biserial, later alternating in a loose biserial arrangement. Sutures distinct, depressed. Chambers globular. Wall thin, coarse, with a rough texture. Aperture nearly terminal and rounded.

Genus *Textularia* Defrance, 1824

Textularia earlandi Parker, 1952

Plate 14, figs 10,11

Textularia tenuissima Earland, 1933, p. 95, pl. 3, figs 21-30.
Textularia earlandi Parker, 1952, p. 458.

Occurrence. 37.5 specimens from 14 samples.

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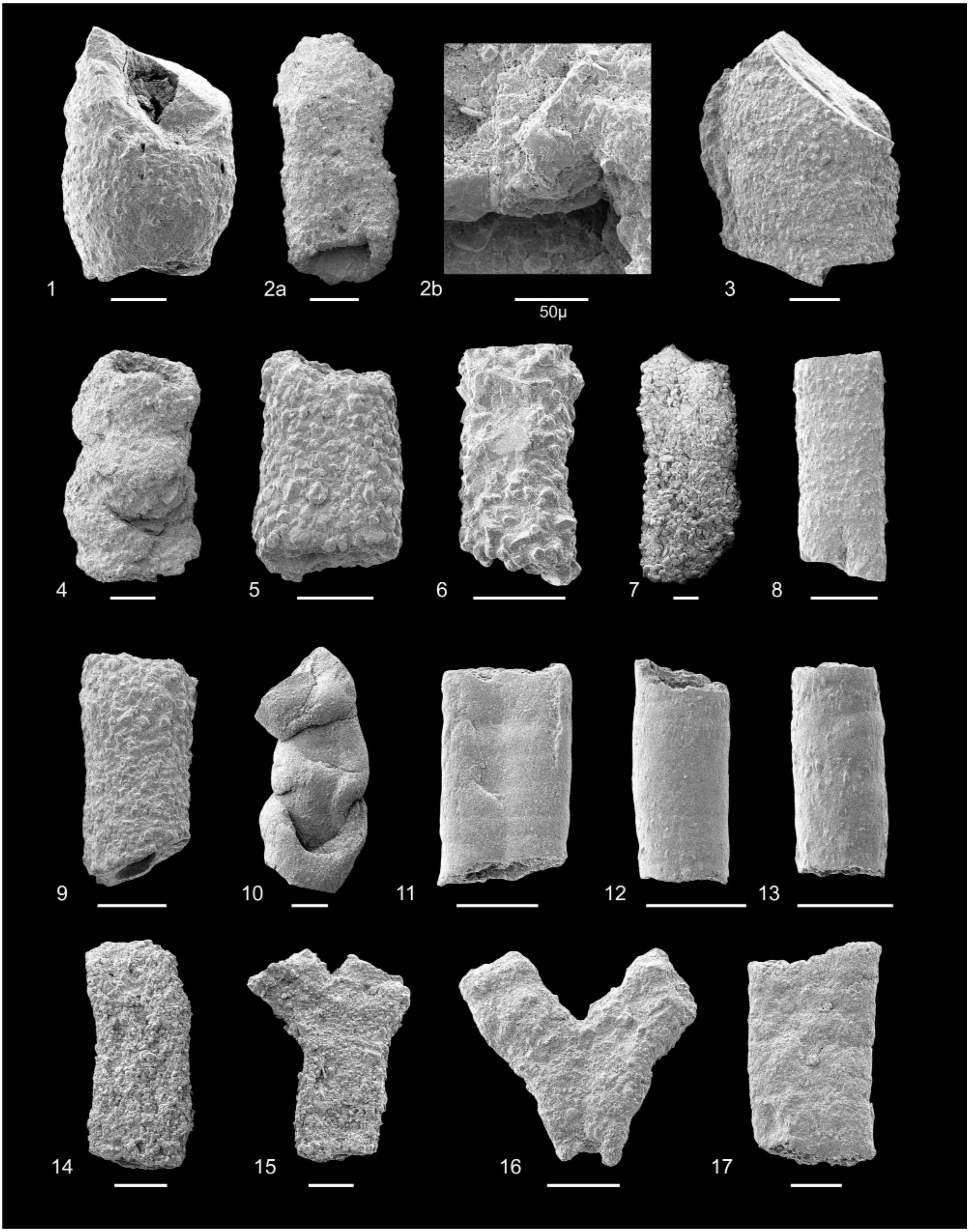

Plate 1. 1. *Rhabdammina linearis*, 3880m. 2. *Rhabdammina* sp., 4170m. 3. *Rhabdammina* sp., 4100m. 4. *Rhabdammina* sp., 4100m. 5. *Rhabdammina* sp., 4100m. 6. *Rhabdammina* sp., 4100m. 7. *Rhabdammina* sp., 3820m. 8. *Rhabdammina* sp., 3800m. 9. *Rhabdammina* sp., 4100m. 10. *Rhabdammina* sp., 3850m. 11. *Bathysiphon* sp., 3780m. 12. *Bathysiphon* sp., 3900m. 13. *Bathysiphon* sp., 3900m. 14. *Nothia* aff. *excelsa*, 3820m. 15. *Nothia* aff. *excelsa*, 3820m. 16. *Nothia* aff. *excelsa*, 4180m. 17. *Nothia latissima*, 3750m. All scale bars 200μm unless otherwise indicated.

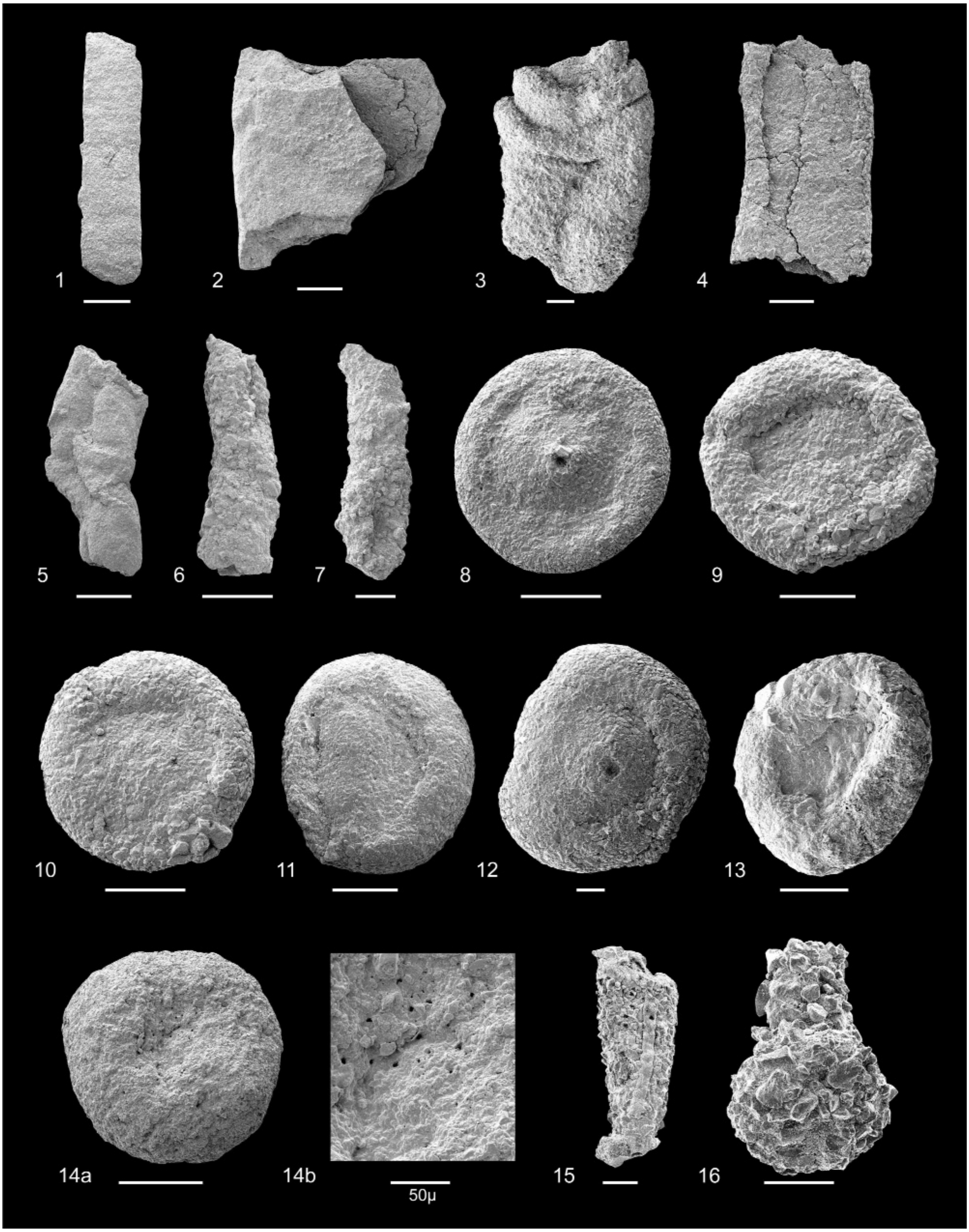

Plate 2. 1. *Nothia latissima*, 3750m. 2. *Nothia robusta*, 3810m. 3. *Nothia robusta*, 3740m. 4. *Nothia* sp., 3800m. 5. *Rhizammina* sp., 3900m. 6. *Rhizammina* sp., 3900m. 7. *Rhizammina* sp., 4100m. 8. *Placentammina placenta*, 3820m. 9. *Saccammina* cf. *spherica*, 3830m. 10. *Saccammina* cf. *spherica*, 3840m. 11. *Saccammina* sp.1, 3810m. 12. *Saccammina* sp.3, 3940m. 13. *Psammosphaera* sp.1, 3800m. 14. *Psammosphaera* cf. *fusca*, 3850m 15. *Jaculella* sp.1 with attached *Ammolagena* sp., 4010m. 16. *Hyperammina cylindrica*, 4010m. All scale bars 200µm unless otherwise indicated.

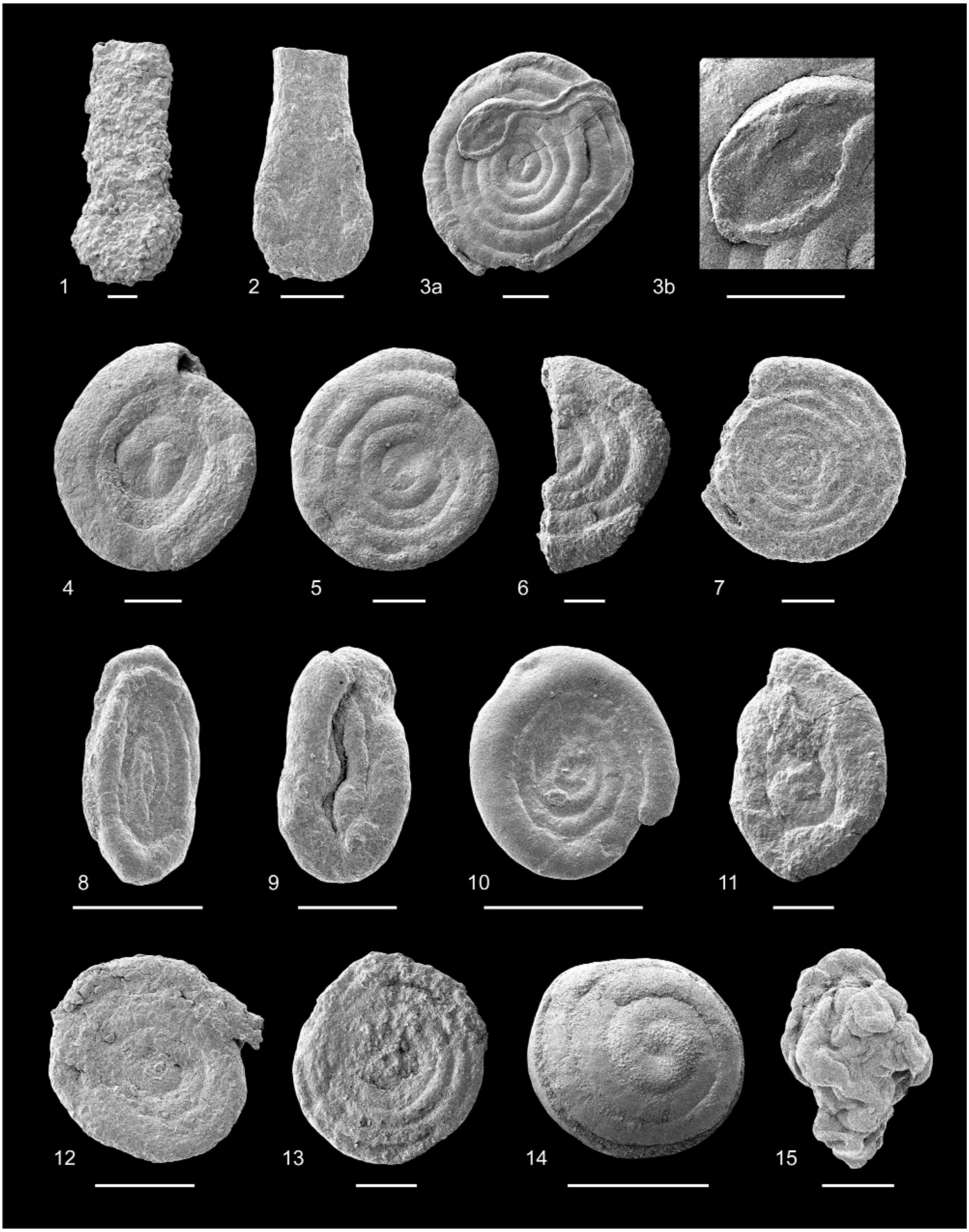

Plate 3. 1. *Hyperammina* sp., 4250m. 2. *Hyperammina* sp., 4170m. 3. *Ammodiscus cretaceous* with attached *Ammolagena clavata*, 3830m. 4. *Ammodiscus latus*, 3840m. 5. *Ammodiscus latus*, 3840m. 6. *Ammodiscus latus*, 3860m. 7. *Ammodiscus tenuissimus*, 4060m. 8. *Ammodiscus* sp.1, 3810m. 9. *Ammodiscus* sp.1, 3850m. 10. *Ammodiscus* sp.2, 3840m. 11. *Ammodiscus* sp.2, 3820m. 12. *Ammodiscus* sp., 3810m. 13. *Ammodiscus* sp., 3840m. 14. *Glomospira charoides*, 2900m. 15. *Glomospira glomerata*, 3820m. All scale bars 200μm unless otherwise indicated.

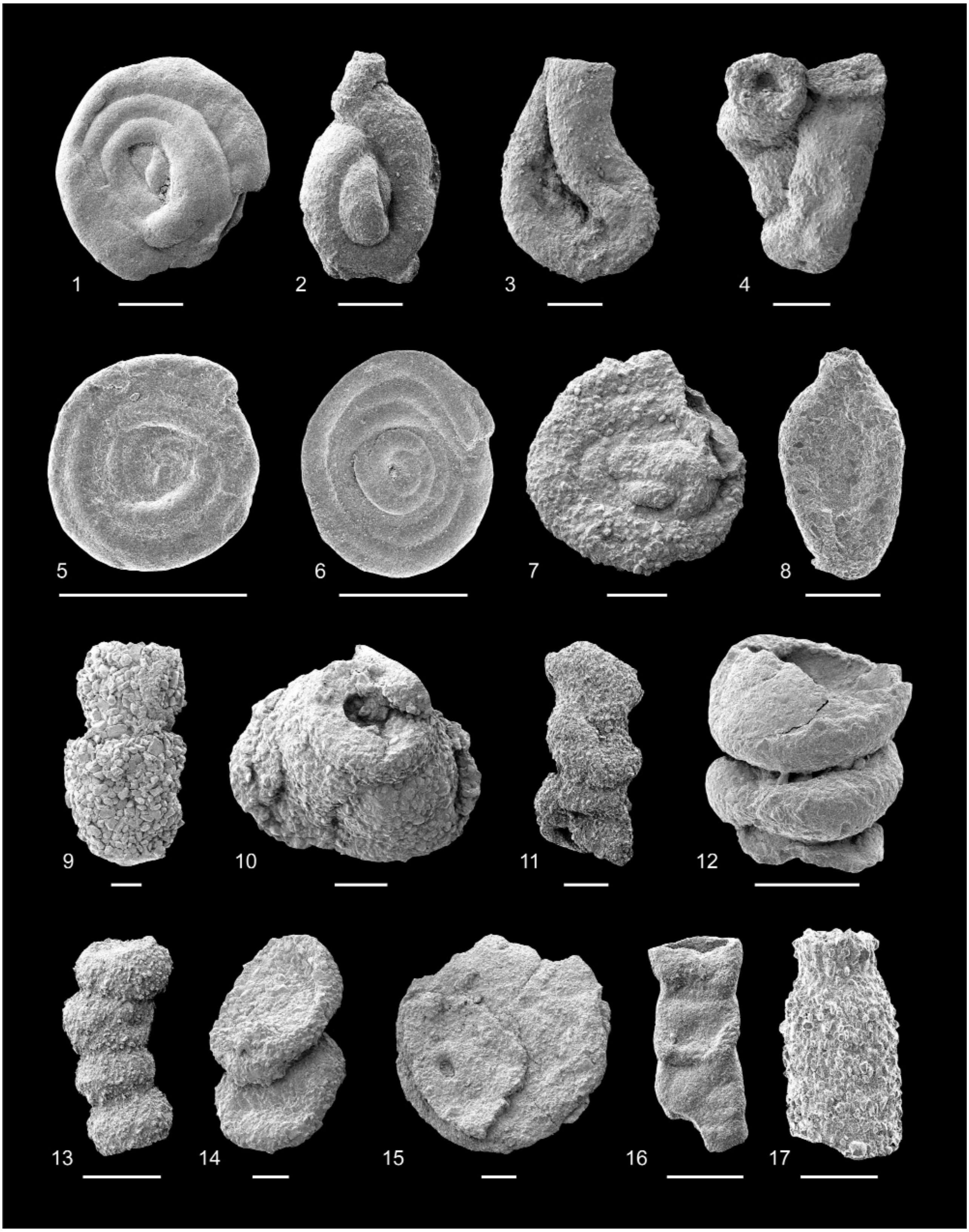

Plate 4. 1. *Glomospira gordialis*, 3860m. 2. *Glomospira irregularis*, 3860m. 3. *Glomospira* aff. *irregularis*, 3840m. 4. *Glomospira* aff. *irregularis*, 3840m. 5. *Glomospira* sp.1, 3810m. 6. *Glomospira* sp.1, 3810m. 7. *Glomospira* sp.2, 3850m. 8. *Caudammina* aff. *ovuloides*, 4150m. 9. *Hormosinella carpenteri*, 3900m. 10. *Reophanus berggreni*, 3850m. 11. *Subreophax pseudoscalaris*, 3910m. 12. *Subreophax scalaris*, 4170m. 13. *Subreophax scalaris*, 3860m. 14. *Aschemocella grandis*, 3960m. 15. *Aschemocella grandis*, 4130m. 16. *Aschemocella* sp., 3830m. 17. *Kalamopsis* sp., 4030m. All scale bars 200μm unless otherwise indicated.

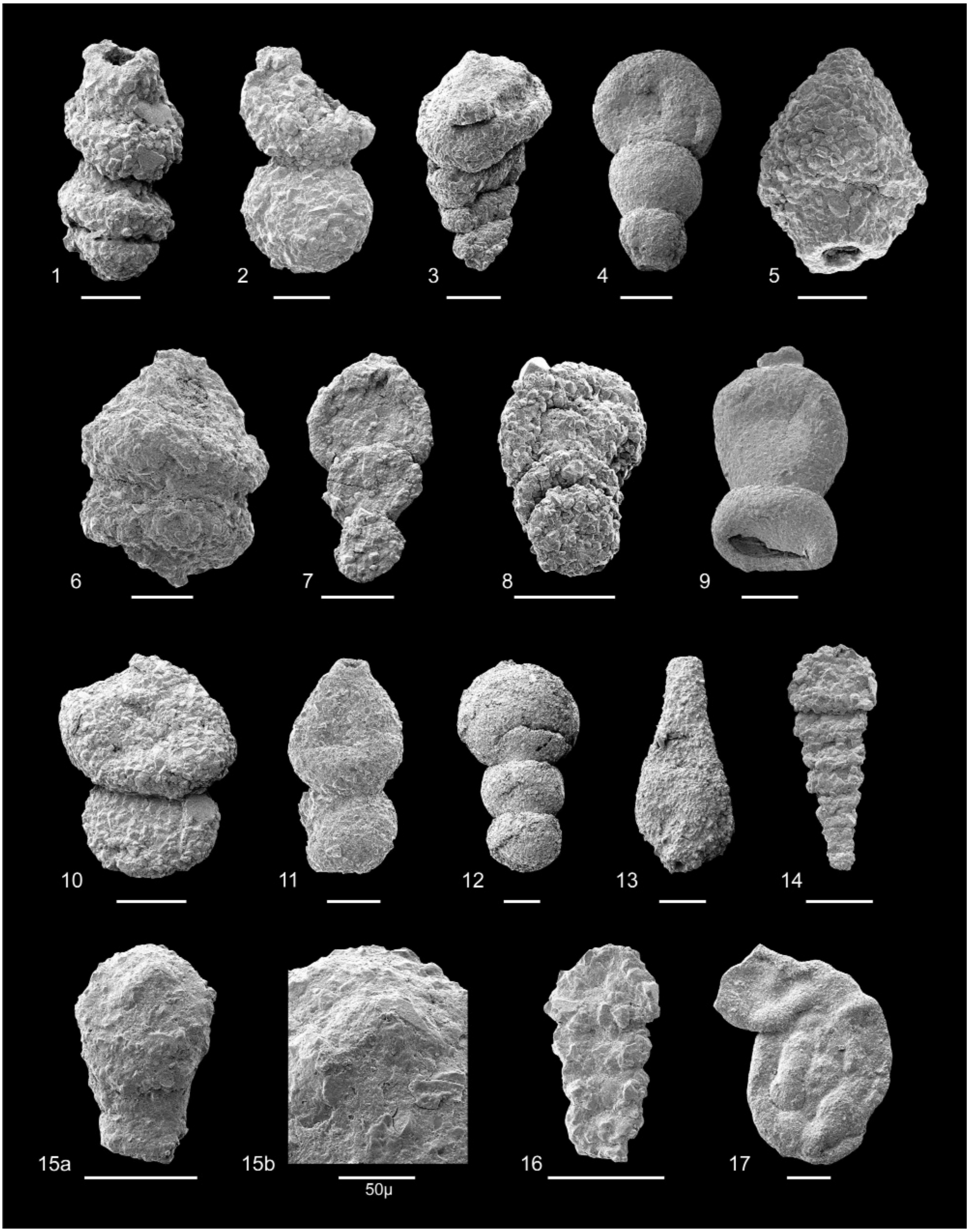

Plate 5. 1. *Hormosinelloides guttifer*, 3840m. 2. *Reophax duplex*, 4000m. 3. *Reophax pilulifer*, 3920m. 4. *Reophax pilulifer*, 3840m. 5. *Reophax pyrifer*, 4120m. 6. *Reophax pyrifer*, 3810m. 7. *Reophax* sp.1, 3830m. 8. *Reophax* sp.1, 3750m. 9. *Reophax* sp.2, 3810m. 10. *Reophax* sp., 3850m. 11. *Hormosina glabra*, 3890m. 12. *Hormosina globulifera*, 2810m. 13. *Pseudonodosinella elongata*, 3820m. 14. *Scherochorella congoensis*, 4040m. 15. *Scherochorella congoensis*, 4020m. 16. *Scherochorella congoensis*, 4040m. 17. *Lituotuba lituiformis*, 3860m. All scale bars 200µm unless otherwise indicated.

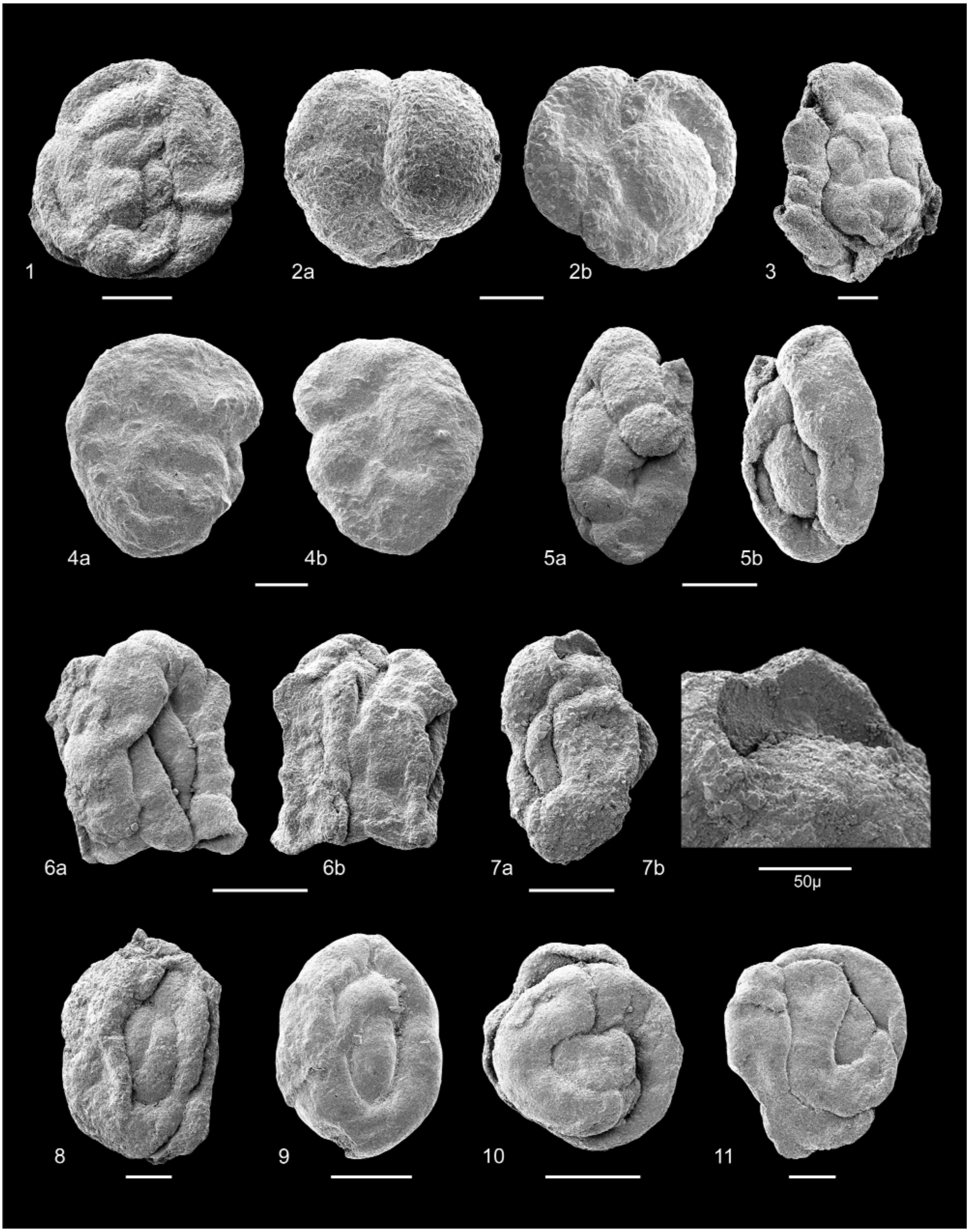

Plate. 6. 1. *Lituotuba lituiformis*, 3860m. 2. *Paratrochamminoides* ex gr. *challengeri*, 4060m. 3. *Paratrochamminoides* aff. *deflexiformis*, 4030m. 4. *Paratrochamminoides* aff. *deflexiformis*, 4240m. 5. *Paratrochamminoides gorayskiformis*, 3850m. 6. *Paratrochamminoides gorayskiformis*, 3830m. 7. *Paratrochamminoides gorayskiformis*, 3830m. 8. *Paratrochamminoides gorayskiformis*, 3870m. 9. *Paratrochamminoides gorayskii*, 3810m. 10. *Paratrochamminoides olszewskii*, 3800m. 11. *Paratrochamminoides olszewskii*, 4170m. All scale bars 200µm unless otherwise indicated.

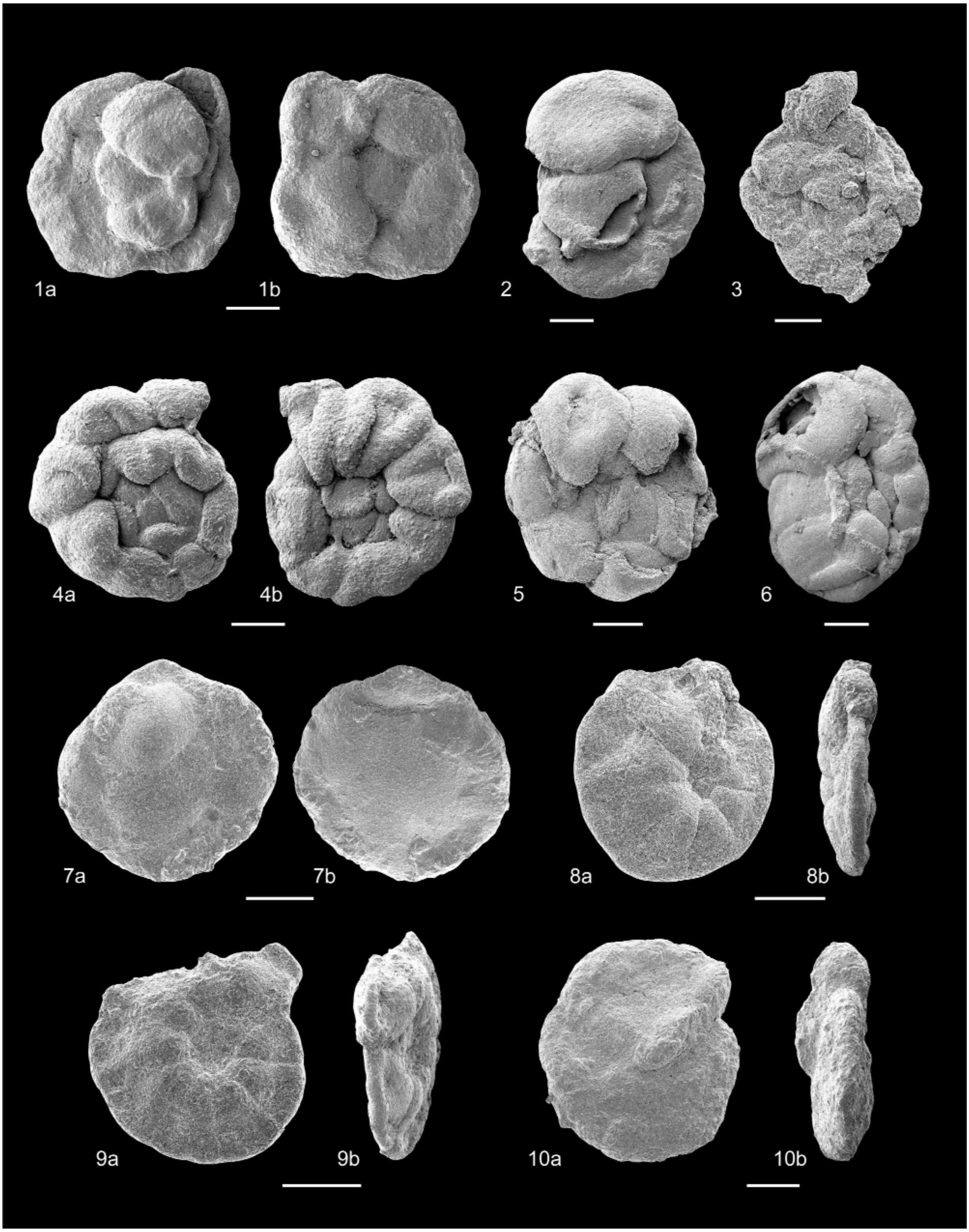

Plate 7. 1. *Paratrochamminoides* sp.1, 3930m. 2. *Conglophragmium irregularis*, 3830m. 3. *Trochamminoides folius*, 3960m. 4. *Trochamminoides* aff. *proteus*, 3820m. 5. *Trochamminoides* aff. *proteus*, 3900m. 6. *Trochamminoides subcoronatus*, 3140m. 7. *Buzasina* aff. *pacifica*, 4130m. 8. *Haplophragmoides carinatus*, 4090m. 9. *Haplophragmoides carinatus*, 4130m. 10. *Haplophragmoides* aff. *horridus*, 4240m. All scale bars 200µm unless otherwise indicated.

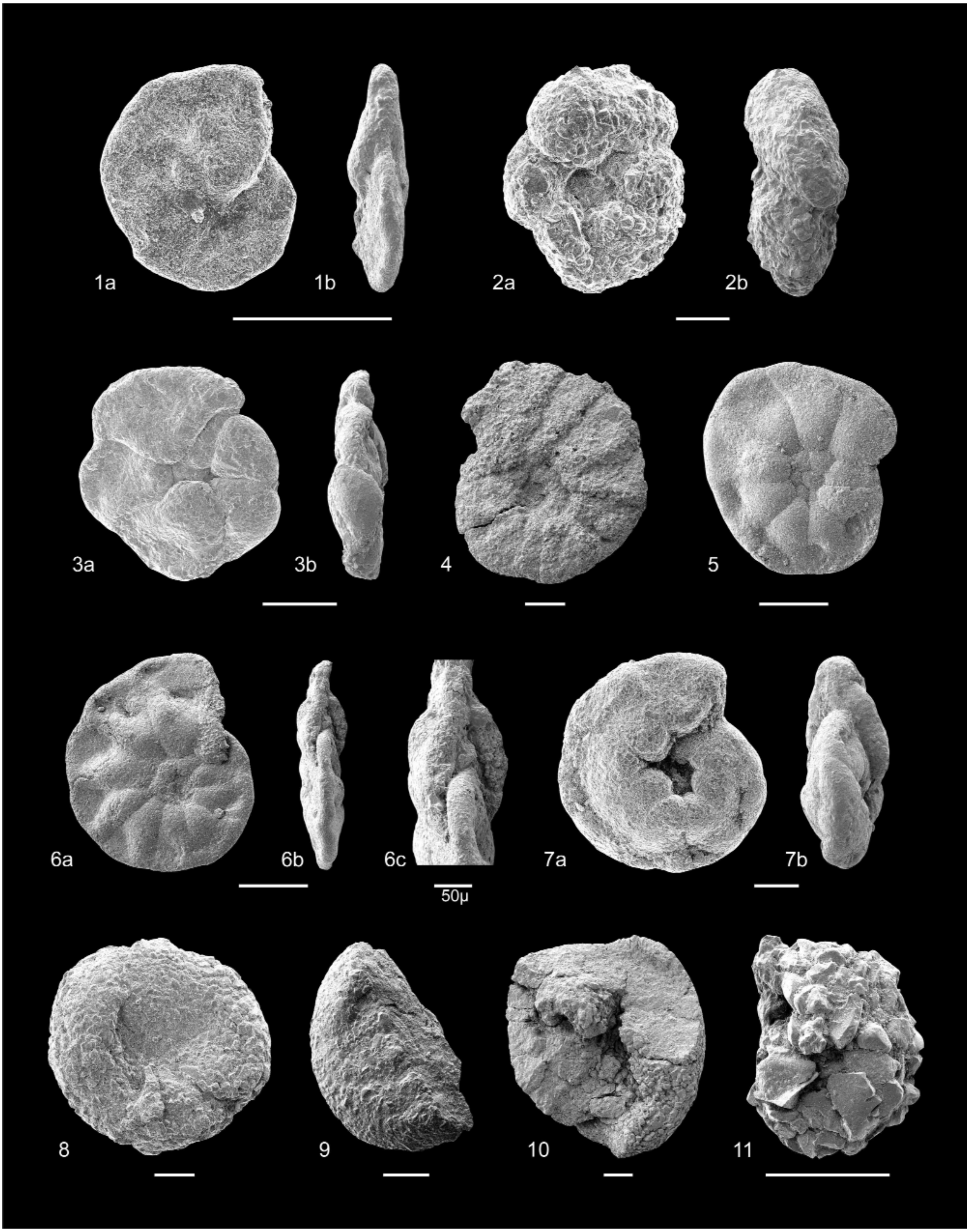

Plate 8. 1. *Haplophragmoides walteri*, 4020m. 2. *Haplophragmoides* sp.1, 3990m. 3. *Haplophragmoides* sp., 3870m. 4. *Glaphyrammina americana*, 3820m. 5. *Haplophragmoides nauticus*, 3800m. 6. *Haplophragmoides nauticus*, 3840m. 7. *Haplophragmoides* sp.2, 4000m. 8. *Praesphaerammina* sp.1, 4240m. 9. *Praesphaerammina* sp.1, 4240m. 10. *Praesphaerammina* sp.1, 3850m. 11. *Ammomarginulina* sp., 3850m. All scale bars 200µm unless otherwise indicated.

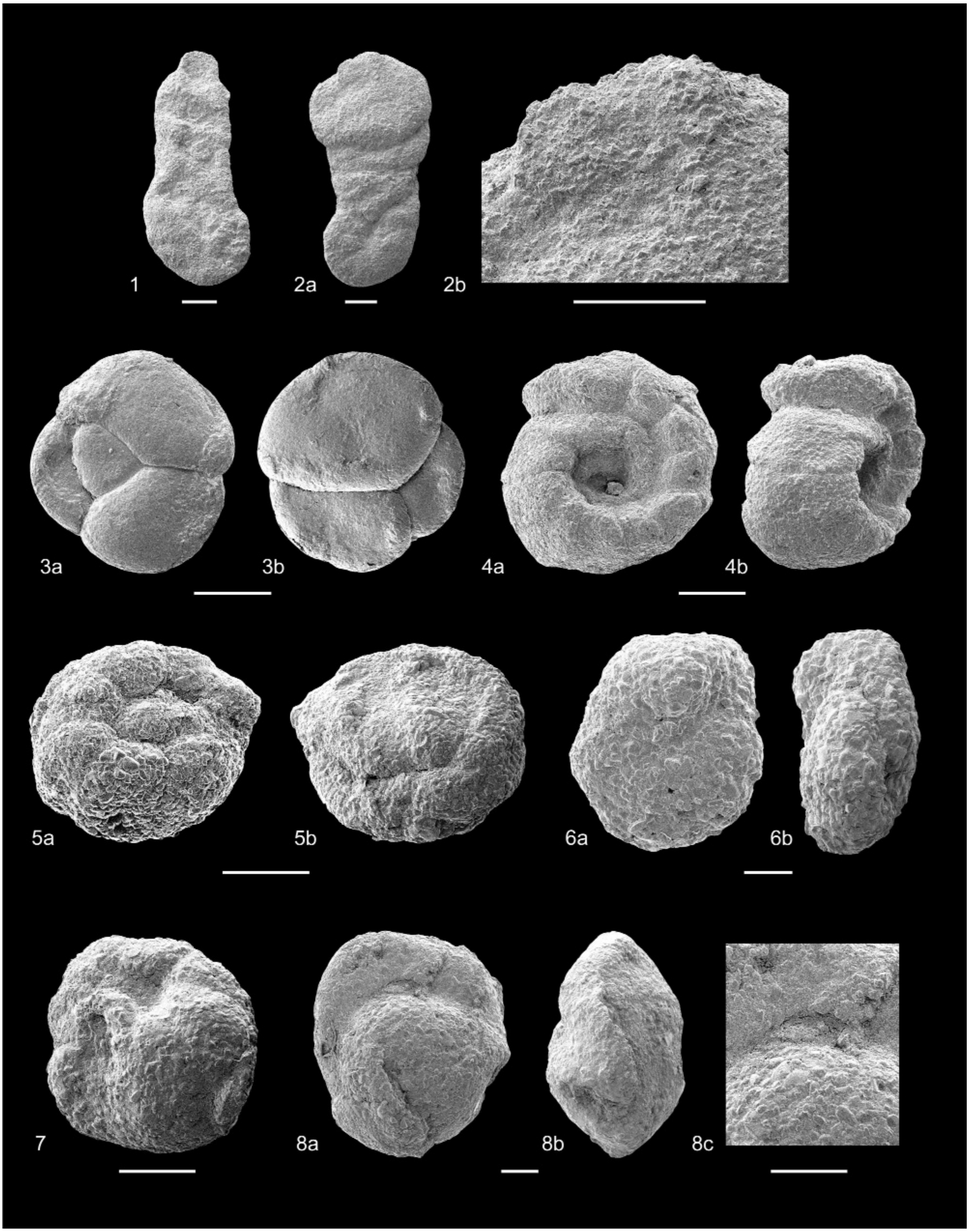

Plate 9. 1. *Discamminoides* sp.1, 4030m. 2. *Discamminoides* sp.1, 4030m. 3. *Ammosphaeroidina pseudopauciloculata*, 3850m. 4. *Evolutinella rotulata*, 3890m. 5. *Budashevaella multicamerata*, 3840m. 6. *Recurvoides* sp.2, 3930m. 7. *Budashevaella multicamerata*, 3860m. 8. *Cribrostomoides subglobosus*, 4120m. All scale bars 200μm unless otherwise indicated.

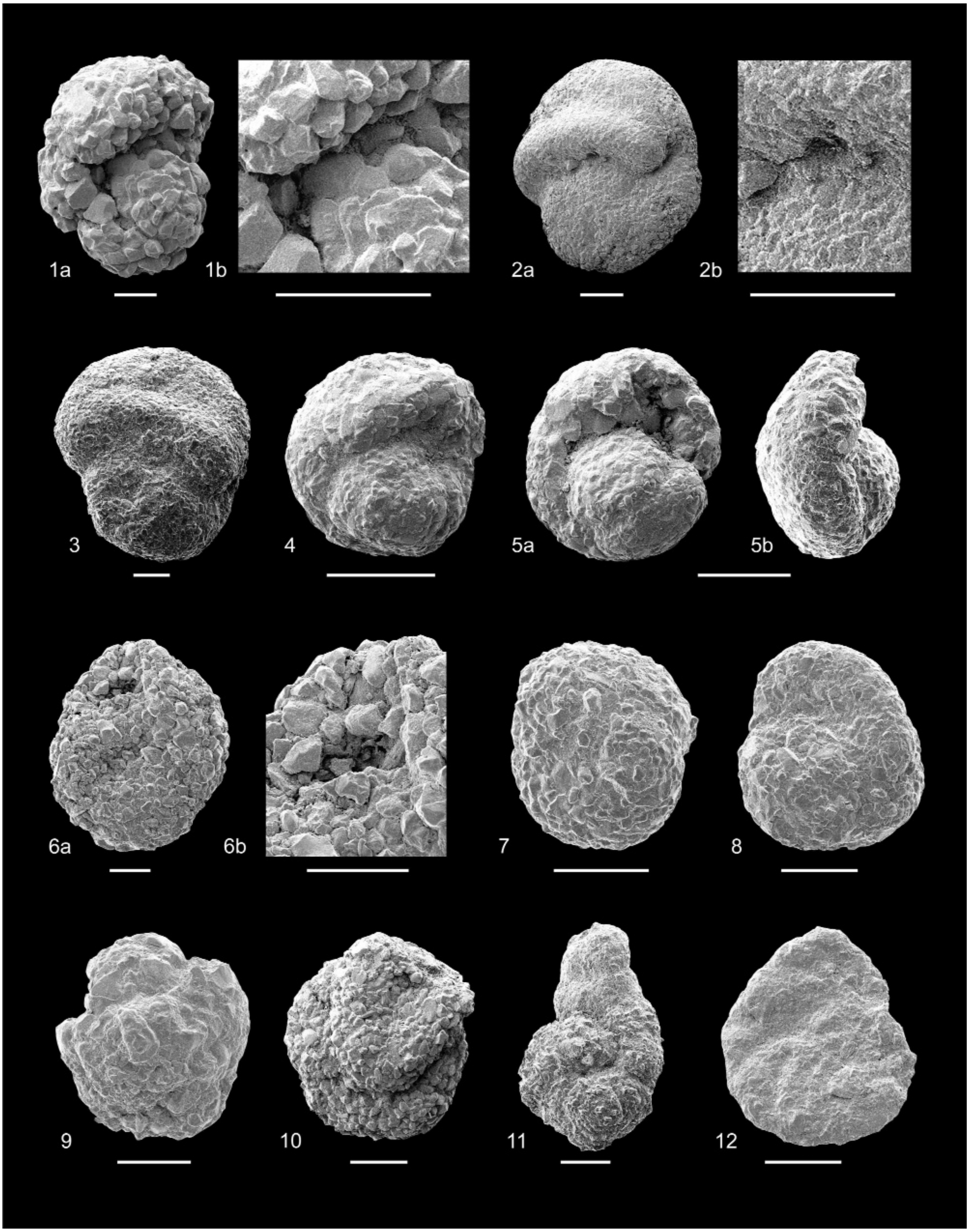

Plate 10. 1. *Cribrostomoides* sp., 3860m. 2. *Recurvoides azuaensis*, 3760m. 3. *Recurvoides azuaensis*, 4090m. 4. *Recurvoides* sp.1, 3860m. 5. *Recurvoides* sp.1, 3860m. 6. *Recurvoides* sp.2, 3940m. 7. *Recurvoides* sp.3, 4090m. 8. *Recurvoides* sp.3, 4090m. 9. *Recurvoides* sp.3, 4170m. 10. *Recurvoides* sp., 3860m. 11. *Bulbobaculites* sp.1, 3910m. 12. *Spiropsammina primula*, 3860m. All scale bars 200μm unless otherwise indicated.

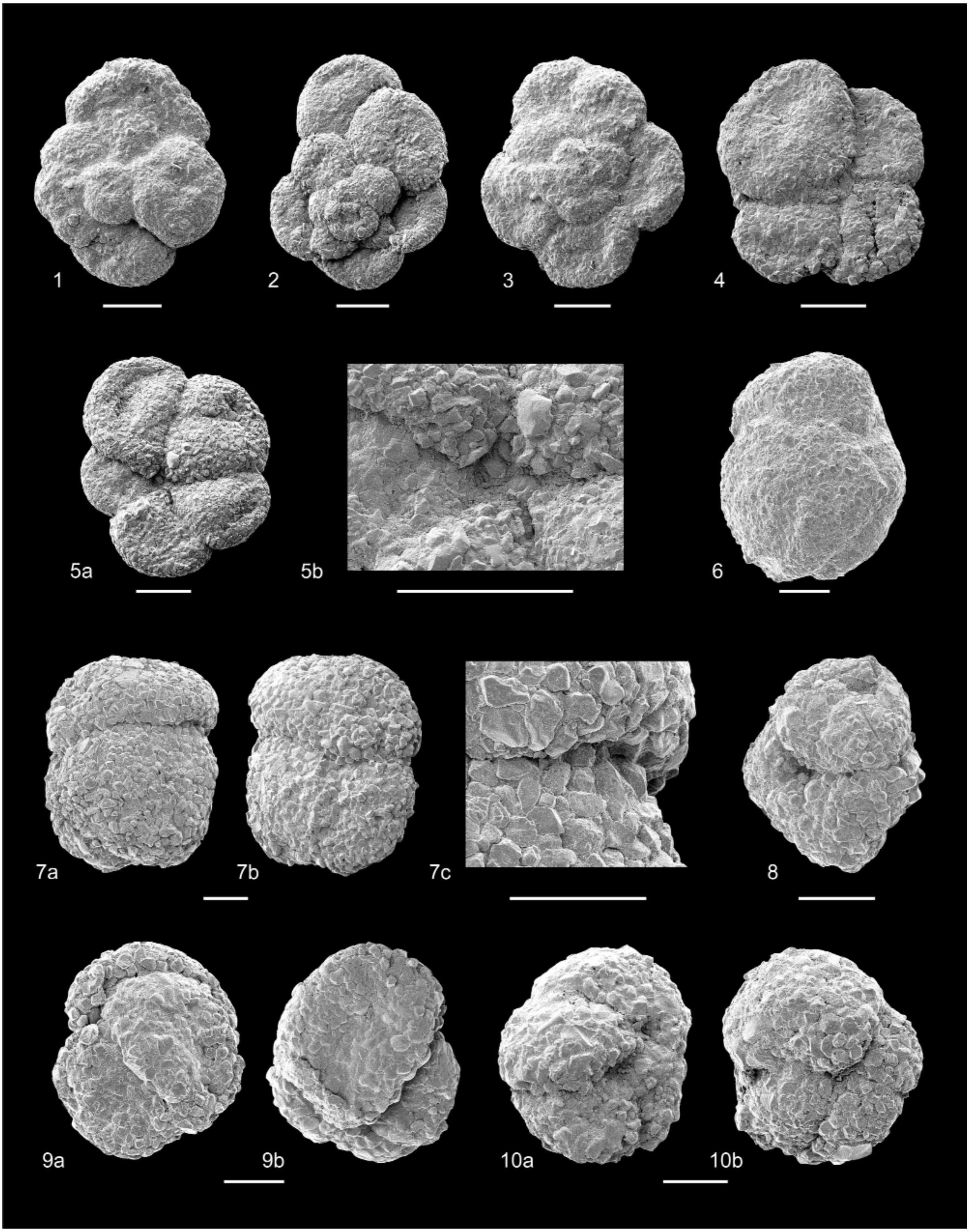

Plate 11. 1. *Portatrochammina profunda*, 3860m. 2. *Portatrochammina profunda*, 3830m. 3. *Portatrochammina profunda*, 3860m. 4. *Portatrochammina profunda*, 3800m. 5. *Portatrochammina profunda*, 3840m. 6. *Tritaxis* sp.1, 4070m. 7. *Tritaxis* sp.1, 3830m. 8. *Trochammina* sp.1, 3820m. 9. *Trochammina* sp.1, 3820m. 10. *Trochammina* sp., 3900m. All scale bars 200μm unless otherwise indicated.

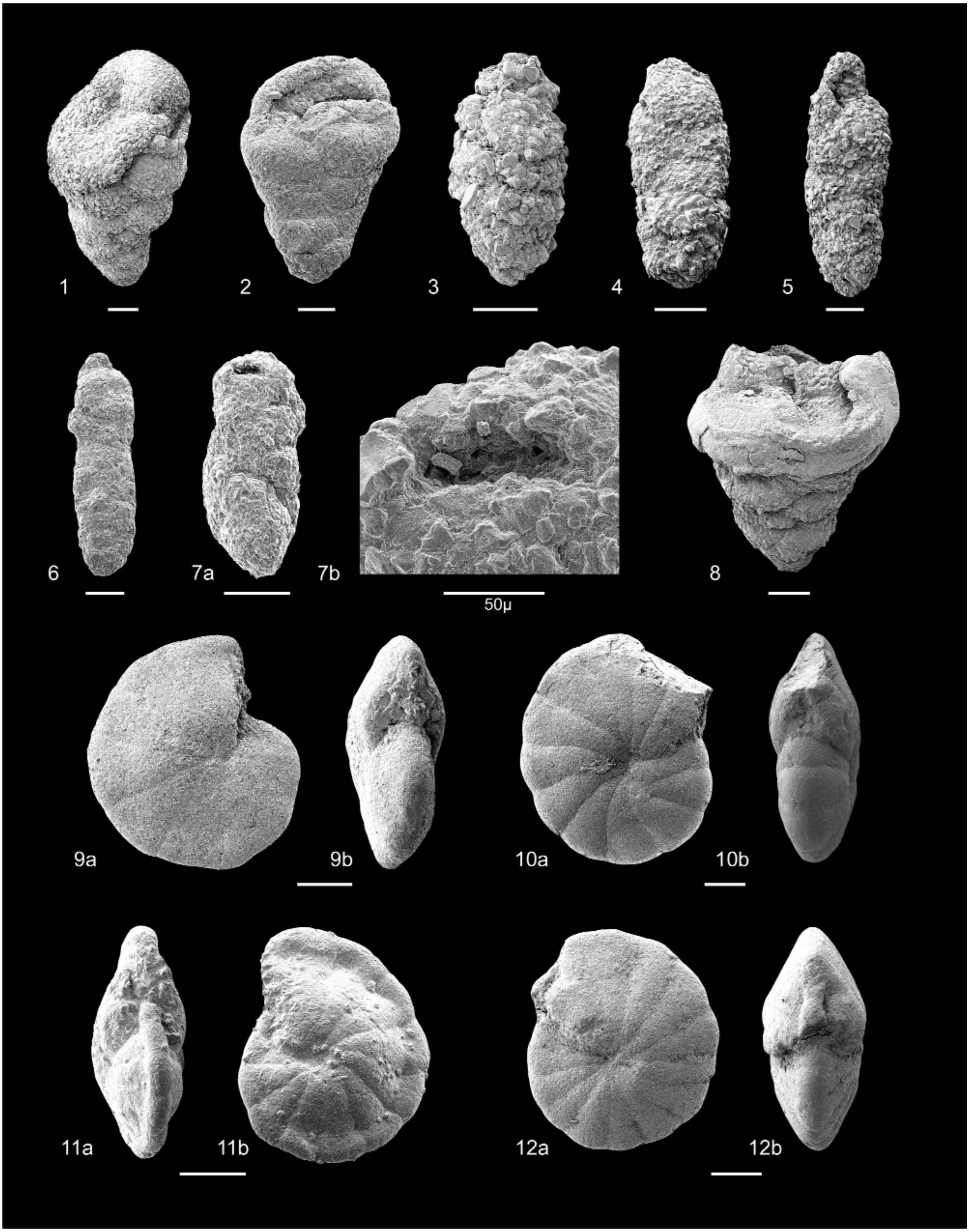

Plate 12. 1. *Eggerelloides* sp.1, 3870m. 2. *Eggerelloides* sp.1, 3850m. 3. *Karrerulina apicularis*, 3780m. 4. *Karrerulina apicularis*, 3860m. 5. *Karrerulina conversa*, 3830m. 6. *Karrerulina conversa*, 3830m. 7. *Karrerulina horrida*, 4090m. 8. *Verneuilina* sp.1, 3770m. 9. *Reticulophragmium acutidorsatum*, 3810m. 10. *Reticulophragmium acutidorsatum* ssp.1, 4100m. 11. *Reticulophragmium amplectens*, 3860m. 12. *Reticulophragmium amplectens* ssp.1, 3860m. All scale bars 200μm unless otherwise indicated.

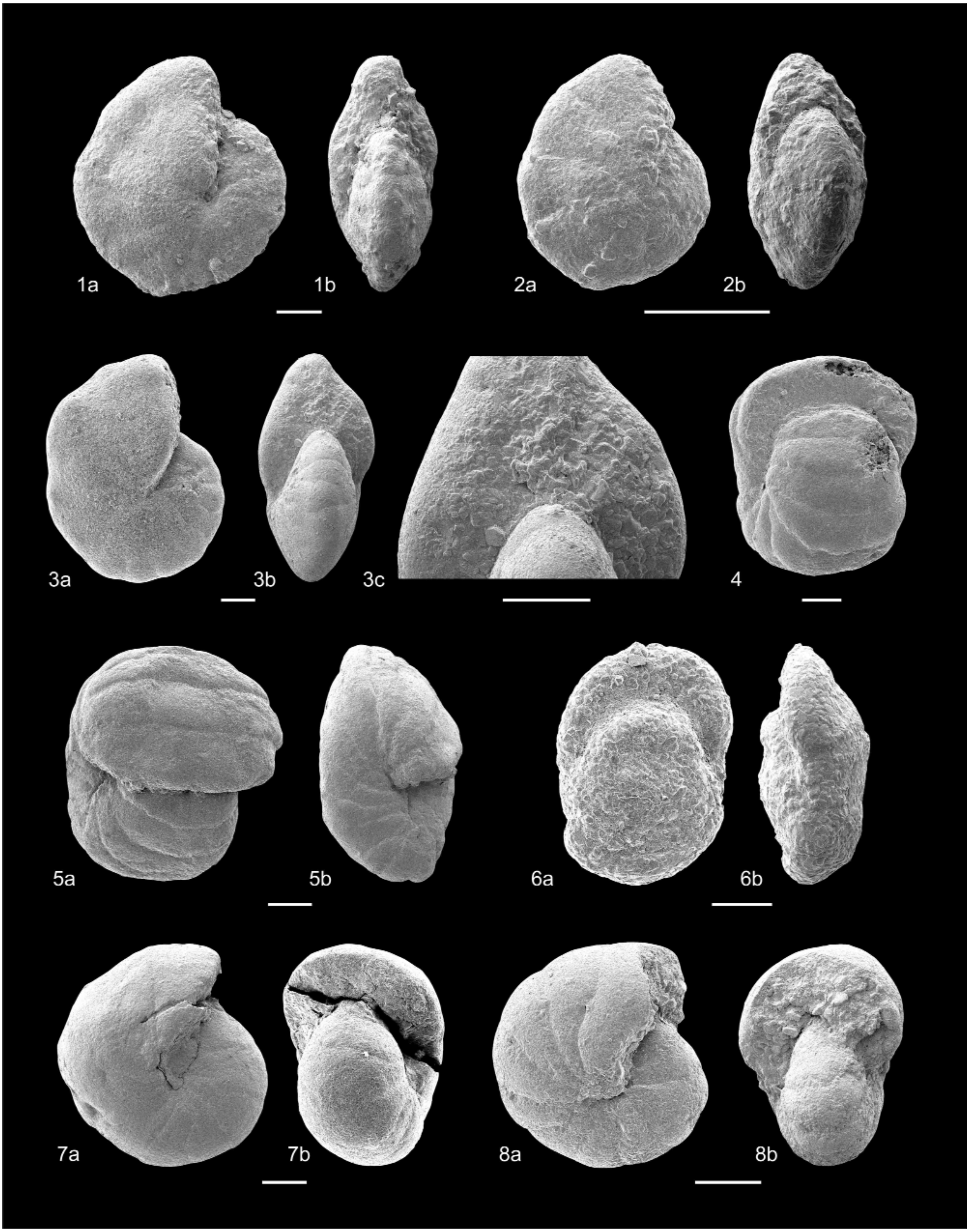

Plate 13. 1. *Reticulophragmium amplectens/acutidorsatum* transitional form, 4090m. 2. *Reticulophragmium intermedium*, 4120m. 3. *Reticulophragmium gasparensis*, 3840m. 4. *Reticulophragmium rotundidorsatum*, 4100m. 5. *Reticulophragmium rotundidorsatum*, 4100m. 6. *Reticulophragmium* sp.1, 3930m. 7. *Cyclammina* aff. *orbicularis*, 4010m. 8. *Cyclammina* aff. *orbicularis*, 3840m. All scale bars 200µm unless otherwise indicated.

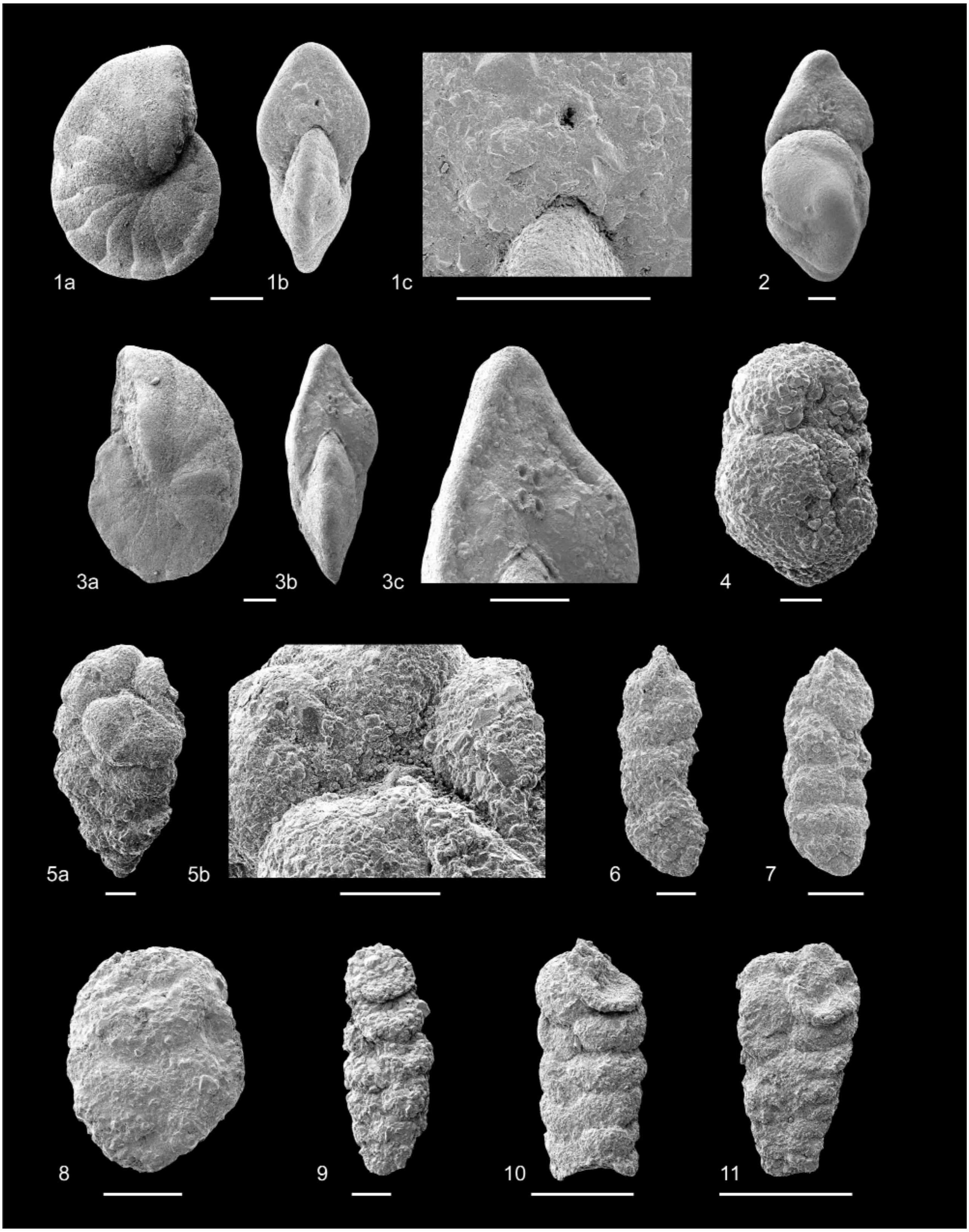

Plate 14. 1. *Cyclammina* sp.1, 3040m. 2. *Cyclammina* sp.2, 3930m. 3. *Cyclammina* sp.2, 3040m. 4. *Alveovalvulina* sp., 3910m. 5. *Alveovalvulina* sp.1, 3810m. 6. *Guppyella crassa*, 3870m. 7. *Guppyella crassa*, 3870m. 8. *Valvulina flexilis*, 3630m. 9. *Haeuserella* sp.1, 3830m. 10. *Textularia earlandi*, 3820m. 11. *Textularia earlandi*, 3860m. All scale bars 200μm unless otherwise indicated.

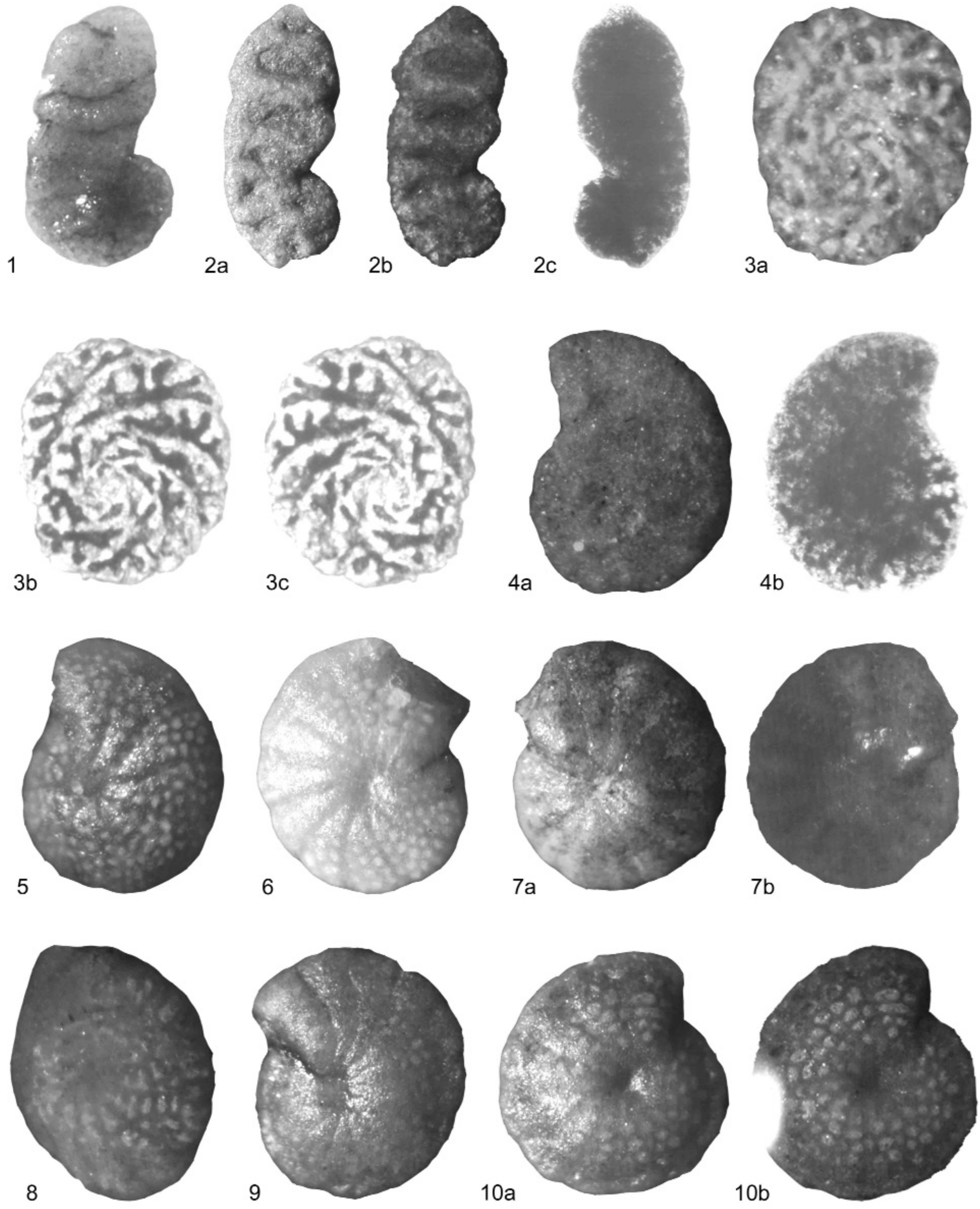

Plate 15. 1. *Discamminoides* sp.1, (818μm width) 4100m, reflected light, water immersed. 2. *Discamminoides* sp.1, (654μm width) 4030m, a. reflected light, b. reflected light, water immersed, c. transmitted light. 3. *Spiropsammina primula*, (473μm width) 4170m, a. reflected light, b,c. transmitted light. 4. *Popovia* sp.1, (654μm width) 3840m, a. reflected light, b. transmitted light. 5. *Reticulophragmium acutidorsatum*, (600μmm width) 4180m, reflected light. 6. *Reticulophragmium acutidorsatum* ssp.1, (1018μm width) 4100m, reflected light. 7. *Reticulophragmium amplectens* ssp. 1, (745μm width) 3860m, a. reflected light, b. reflected light, water immersed. 8. *Reticulophragmium amplectens* ssp. 1, (764μm width) 4170m, reflected light, water immersed. 9. *Reticulophragmium amplectens/acutidorsatum* transitional form, (1000μmm width) 4190m, reflected light. 10. *Reticulophragmium amplectens/acutidorsatum* transitional form, (891μm width) 4180m, a. reflected light, b. reflected light, water immersed.

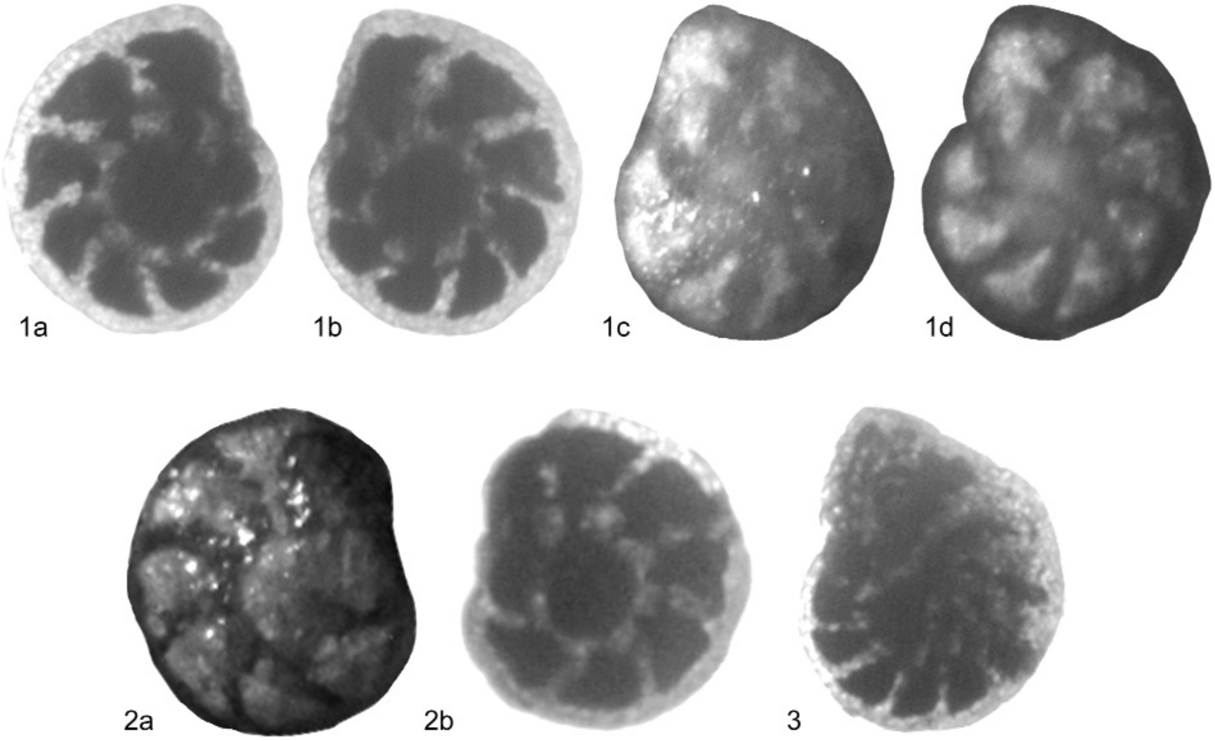

Plate 16. 1. *Reticulophragmium intermedium*, (291µm width) 4110m, a,b. transmitted light, c. reflected light, d. reflected light, water immersed. 2. *Reticulophragmium intermedium*, (309µm width) 4100m, a. reflected light, b. transmitted light. 3. *Reticulophragmium intermedium*, (455 µm width) 4100m, transmitted light.

Appendix 1. Number of specimens from all sample depths (every 10m), with abundance and diversity counts.

Depth (m)	Diversity	Abundance	Unidentified fragments	Valvulina flexilis	Glomospira charoides	Cribrostomoides spp.	Reticulophragmium rotundidorsatum	Valvulina (early form)	Nothia spp.	Rhabdammina spp.	Ammodiscus latus	Reticulophragmium spp.	Recurvoides spp.	Nothia robusta	Haplophragmiodes spp.	Trochammina sp. 2	Rhizammina spp.	Saccammina sp. 1	Saccammina spp.	Psammosphaera spp.	Ammomarginulina spp.	Textularia earlandi	Paratrochamminoides spp.	Ammodiscus sp. 1	Hormosina globulifera	Reticulophragmium amplectens	Aschemocella spp.	Ammodiscus spp.	Trochammina spp.	Nothia latissima	Nonion spp.	Cibicidoides spp.	Saccammina cf. spherica
3630	1	3.0	2.0	1.0																													
3640	6	6.0			1.0	1.0	1.0	1.0	1.0	1.0																							
3650	2	3.5	1.0								1.5	1.0																					
3660	3	9.0	2.0				1.0						2.0	4.0																			
3670	3	4.0								1.0	1.0			2.0																			
3680	2	16.0												15.0	1.0																		
3690	4	7.0									3.0	1.0				2.0	1.0																
3700	4	7.0			1.0					1.0				4.0	1.0																		
3710	13	35.0	5.0						1.0	1.0	5.0	1.0	1.0	3.0			5.0	3.0	1.0	3.0	1.0	4.0	1.0										
3720	6	14.0	7.0								1.0			1.0								1.0		2.0	1.0	1.0							
3730	14	49.5	5.0						4.0		4.5						1.0		2.0	2.0		3.0	1.0		2.0		1.0	1.0	3.0	18.0	1.0	1.0	
3740	12	96.5	13.0		1.0						7.0			8.0				2.5				2.5							2.0	48.0			2.0
3750	18	113.0	12.0								2.0			2.0	1.0			9.0				2.0							12.0	58.0			
3760	21	86.0	8.0		3.0				1.0	5.0			1.0	1.0			3.0	1.0	2.0			3.0			1.0			1.5	8.0	31.0			
3770	16	55.0	8.0						5.0	2.0								3.0				1.0			1.0					10.0			
3780	23	135.0	17.0						5.0	11.0	1.0	1.0		6.0			1.0	3.0	5.5			9.0			4.0				1.0	22.0			
3790	24	79.5	1.0		1.0		3.0			4.0	3.5		1.0		0.5		18.0				1.0				3.0			2.0		11.0			2.0
3800	27	171.0	21.0		1.0				3.0	22.0	11.5			5.0			10.0	3.0				2.0			7.0					6.0			
3810	39	153.5	12.0		7.0		3.0		2.0	11.0	6.0	1.0	3.0	2.0	1.0		8.0	1.0	1.0			2.0		1.0	3.0	1.0	1.0			3.0			
3820	45	223.0	16.0		5.0				8.0	3.0	1.0	1.0	3.0	5.0	4.0		39.0	7.0			1.0	4.0		1.0	6.0	5.0				4.0			2.5
3830	42	197.0	8.0		2.0		6.0		3.0	22.0	6.5	2.0		4.0	6.0	2.0	21.0						2.0		5.5	1.0	1.0		3.0	11.0			7.0
3840	40	209.5	10.0		3.0	2.0			1.0	27.0	5.5		4.0	3.0			29.0								5.0	2.0		3.0	13.0	9.0			12.0
3850	30	139.5	25.0							15.0	4.0	3.5		4.0	2.0		16.0				2.0		3.0	2.0	1.0				7.0	3.0			4.0
3860	45	276.5	12.0		3.0	1.0	3.0			25.0	6.5	1.0		14.0	3.0		24.0		2.0			2.0		3.0	7.0	3.0		2.0	4.0	25.0			
3870	40	141.0	9.0		1.0		4.0		1.0	13.0	4.0		1.0	8.0	2.0		38.0				1.0				1.0	3.0				2.0			
3880	33	130.0	5.0		1.0	1.0	3.0			14.0	3.0		4.0		2.0		23.0		0.5							1.0		2.0	1.0				
3890	42	189.0	13.0				7.5			29.0	4.0			8.0	4.0		27.0	1.0	1.0			1.0	1.0		2.0	3.0		1.0	2.0	14.0			2.0
3900	36	227.0	23.0		1.0	1.0	2.0			31.0	2.0		2.0	6.0	7.0		53.0					1.0			6.0				3.0	1.0		1.0	2.0
3910	30	129.5	3.0		1.0	1.0				35.0		3.0		9.0	3.0		14.0	1.0							1.5			4.0		5.0			
3920	36	138.5	11.0				6.0		2.0	16.0	7.0		2.0	14.0			16.0						1.0		0.5	2.0		1.0					
3930	29	83.5	13.0		1.0		5.0		8.0	11.0	2.5	2.5	1.0	5.0	1.0		8.0									1.0							1.0
3940	36	147.5	4.0		1.0	3.0	3.0		5.0	23.0	5.5	2.0	5.0	13.0	2.0		17.0						1.0				1.0		3.0				5.0
3950	30	152.0	9.0			3.0	1.0		10.0	21.0	3.0	1.0	5.0	23.0	3.0		29.0	2.0	2.0				2.0			2.0							
3960	31	134.5	13.0		3.0		4.0		2.0	13.0	5.5	2.0	1.0	31.0	3.0		24.0								1.0				1.0				1.0
3970	30	110.5	4.0			1.0	1.0		6.0	12.0	0.5	2.0	1.0	39.0	2.0		10.0		2.5						0.5	1.0						1.0	1.0
3980	17	106.5	7.0						2.0	9.0	2.0	1.0		49.0	2.0		1.0									2.0		2.0		2.0			4.5
3990	31	148.5	4.0				6.0		5.0	17.0	1.0		1.0	47.0			2.0									3.0		1.0	6.0	9.0			1.0
4000	26	195.0	7.0		1.0		10.0		2.0	8.0	3.0	1.0	2.0	48.0	1.0		2.0		2.0										7.0				
4010	34	231.0	3.0			1.0	3.0		2.0	27.0	2.5	4.0		62.0	1.0		9.0			1.0					3.0				9.0				2.0
4020	23	388.0	4.0			1.0	10.0		2.0	19.0	1.0	2.0	1.0	163.0			3.0											1.0	11.0			1.0	1.0
4030	19	336.0	5.0		1.0		7.0			10.0	1.5	4.0		146.0			5.0		2.0							2.0			6.0				
4040	23	512.0	1.0				8.0			10.0	3.0	2.0		93.0	1.0		2.0	1.0							1.0	3.0			25.0	7.0			3.0
4050	19	221.0	1.0			1.0	6.0			7.0	2.0		2.0	112.0			2.0								4.0	5.0			3.0				2.0
4060	28	371.0	1.0		1.0		11.0		3.0	13.0	2.0	2.0	2.0	233.0			1.0		2.0							6.0			4.0	3.0			1.0
4070	29	323.0	10.0				7.0		2.0	15.0	6.0	3.0	3.0	157.0	3.0	2.0	4.0						1.0			13.0			6.0	7.0			1.0
4080	24	81.0	3.0				2.0			8.0	3.0	2.0	3.0	15.0	2.0		8.0		1.0							3.0				1.0			1.0
4090	37	309.5	5.0		1.0		9.0		8.0	15.0	2.0	1.0		120.0	3.0		3.0	2.0	1.0				1.0	2.0		5.0							2.0
4100	31	397.5	7.0				17.0		6.0	36.0	5.0	0.5	2.0	161.0			3.0		5.0				1.0			5.0			11.0				1.0
4110	27	257.0	13.0				6.0			26.0	10.0	6.0	2.0	105.0			1.0						1.0			5.0			5.0				
4120	32	315.5	14.0			2.0	11.0		2.0	29.0	9.0	2.0	1.0	141.0						1.0				1.0	3.0	13.0		1.0					4.0
4130	33	201.0	13.0				17.0		6.0	16.0	3.0		2.0	57.0	4.0		2.0		2.0							7.0		1.0					
4140	29	181.0	4.0		2.0		10.0			20.0	6.5	2.0	1.0	46.0	1.0	1.0	6.0	2.0	1.0														
4150	29	235.0	10.0				22.0			15.0	6.0	1.0	3.0	65.0	3.0	1.0	2.0						2.0			3.0		1.0	8.0				1.0
4160	29	127.0	1.0				6.0		1.0	6.0			2.0	19.0			7.0		1.0	1.0						2.0		2.0	4.0				3.0
4170	30	150.0	2.0			1.0	7.0			24.0	3.0	5.0	5.0	26.0	1.0			2.0								2.0			14.0				
4180	26	140.0	3.0			1.0	6.0		1.0	12.0	3.0		2.0	27.0			3.0			1.0								1.0	6.0				
4190	19	103.0	6.0				4.0			11.0	2.0			49.0	1.0														1.0				
4200	14	38.5	1.0				3.0			3.0	0.5			10.0															4.0	1.0			
4210	25	125.0	5.0		2.0		4.0			12.0	1.5	3.0	3.0	36.0	2.0		3.0									2.0							1.0
4220	15	62.0	10.0				5.0			8.0				22.0				1.0	1.0										1.0				
4230	13	76.5	1.0				2.0			20.0		6.0		28.0					1.0										4.0				
4240	21	133.5	2.0				1.0		1.0	16.0				72.0	1.0													1.5	7.0				
4250	16	58.5	2.0				1.0		3.0	1.0				31.0												2.0		1.5					
4260	15	32.0				1.0				6.0	1.0	1.0	1.0	9.0																			
4270	13	52.0	3.0				2.0			4.0				19.0												2.0		2.0	2.0				2.0

Appendix 1. (Continued).

Depth (m)	Diversity	Abundance	Glomospira spp.	Cyclammina spp.	Portatrochammina profunda	Oridorsalis spp.	Ammosphaeroidina spp.	Glomospira irregularis	Reophax sp. 1	Subreophax scalaris	Trochammina sp. 1	Ammosphaeroidina pseudopauciloculata	Trochamminoides spp.	Globigerina (bulloides?)	Pseudononion spp.	Bulimina spp.	Ammolagena clavata	Reophax spp.	Haplophragmoides nauticus	Karrerulina spp.	Recurvoides azuaensis	Nothia aff. excelsa	Haplophragmoides walteri	Ammodiscus sp. 2	Glomospira gordialis	Congophragmium spp.	Verneuilina sp. 1	Karreriella spp.	Bathysiphon spp.	Bathysiphon sp. 2	Cribrostomoides subglobosus	Ammodiscus cretaceous	Karrerulina conversa
3630	1	3.0																															
3640	6	6.0																															
3650	2	3.5																															
3660	3	9.0																															
3670	3	4.0																															
3680	2	16.0																															
3690	4	7.0																															
3700	4	7.0																															
3710	13	35.0																															
3720	6	14.0																															
3730	14	49.5																															
3740	12	96.5	2.0	1.5	6.0	1.0																											
3750	18	113.0	3.0				1.0	1.0	1.0	2.0	1.0	2.0	1.0	1.0	1.0	1.0																	
3760	21	86.0											1.0				2.0	1.0	1.0	2.0	1.5	5.0	3.0										
3770	16	55.0		2.0	1.0																			1.0	1.0	1.0	1.0	2.0	5.0	10.0	1.0		
3780	23	135.0		2.0	20.0		6.0					4.0						1.0	2.0						2.0							1.5	1.0
3790	24	79.5	1.0	0.5	8.0			4.0				4.0							3.0				1.0		1.0								
3800	27	171.0	1.0	0.5	31.0		2.0					1.0						3.0	5.0		1.0	18.0							1.0				
3810	39	153.5	4.0	1.0	21.0					1.0			2.0						5.0		1.0	9.0			2.0				14.0	6.0		1.5	
3820	45	223.0		6.0	20.0					1.0	4.0	6.0	1.0				1.0	3.0	1.0	2.0	1.0	24.0		2.0					2.0	9.0		2.5	
3830	42	197.0			13.0			3.0	2.0			6.0					1.0	2.0			4.0	9.0						2.0		3.0		7.0	4.0
3840	40	209.5	2.0		13.0			1.0		1.0		13.0					2.0		3.0			10.0		1.0	1.0			1.0					
3850	30	139.5			8.0							3.0	1.0								2.0											1.0	
3860	45	276.5	3.0		19.0			6.0		1.0		13.0							9.0		1.0	20.0			2.0			2.0	1.0				
3870	40	141.0			4.0		3.0	2.0	1.0			2.0	1.0					1.0	3.0		2.0											2.0	
3880	33	130.0						4.0		1.0		3.0						3.0	5.0			14.0			2.0					1.0			
3890	42	189.0	4.0		3.0			1.0											1.0		2.0	5.0							1.0	2.0		2.5	
3900	36	227.0	5.0		9.0			1.0				9.0							1.0	2.0		10.0								8.0		5.0	
3910	30	129.5			2.0		7.0	1.0				2.0								3.0		8.0								4.0		2.0	
3920	36	138.5	1.0	2.0	2.0		4.0										1.0				2.0	6.0			1.0					6.0			
3930	29	83.5			1.0			1.0									2.0	3.0		2.0											1.0	1.5	
3940	36	147.5			6.0		1.0					1.0						1.0		2.0	2.0	13.0											
3950	30	152.0		1.0	5.0																2.0	9.0			1.0	3.0							
3960	31	134.5			3.0		2.0			1.0		4.0						1.0	1.0		1.0								2.0				1.0
3970	30	110.5		1.0	1.0		2.0			1.0		4.0						2.0			1.0		2.0						1.0	3.0			
3980	17	106.5		2.0				1.0														7.0				3.0			4.0				
3990	31	148.5			1.0							1.0				1.0			1.0			6.0	3.0						2.0			1.5	
4000	26	195.0	1.0									2.0										15.0	1.0						7.0				
4010	34	231.0	1.0		3.0		2.0					2.0					1.0				2.0	6.0											
4020	23	388.0										2.0								1.0			5.0										
4030	19	336.0																				3.0				1.0							
4040	23	512.0																				5.0								1.0			
4050	19	221.0		3.0																			1.0									1.0	
4060	28	371.0			1.0		6.0				1.0										1.0	3.0	2.0						2.0			1.0	
4070	29	323.0			3.0																2.0		2.0										
4080	24	81.0																	1.0														
4090	37	309.5			2.0		4.0					1.0									1.0	3.0							4.0		2.0	2.0	
4100	31	397.5					5.0					3.0						1.0		2.0		6.0	7.0								1.0		
4110	27	257.0					11.0														1.0	3.0	5.0						3.0		3.0		
4120	32	315.5																				4.0	2.0						8.0		4.0	4.5	
4130	33	201.0					6.0	1.0										3.0		1.0									1.0		1.0	1.0	
4140	29	181.0					10.0					8.0					1.0	4.0			6.0								3.0			1.5	
4150	29	235.0										7.0									3.0	6.0							4.0		4.0		
4160	29	127.0	1.0									3.0							2.0			4.0							2.0			1.0	
4170	30	150.0								2.0		1.0					1.0				2.0	7.0	3.0						4.0		1.0		
4180	26	140.0					1.0															6.0	2.0						6.0			1.0	
4190	19	103.0																											6.0				
4200	14	38.5																			1.0	2.0											
4210	25	125.0														1.0					1.0								5.0				
4220	15	62.0										1.0																	1.0				
4230	13	76.5																														1.5	
4240	21	133.5					3.0															1.0							1.0				
4250	16	58.5														1.0						1.0							1.0		1.0		
4260	15	32.0																			2.0								1.0				
4270	13	52.0										1.0																					

Appendix 1. (Continued).

Depth (m)	Diversity	Abundance	Karrerulina apicularis	Bathysiphon sp. 1	Psammosphaera cf. fusca	Hormosinelloides guttifer	Praesphaerammina sp. 1	Reticulophragmium acutidorsatum	Reticulophragmium gasparensis	Placentammina placenta	Paratrochamminoides olszewskii	Haplophragmoides sp. 1	Reticulophragmium sp. 1	Glomospira sp. 1	Lituotuba lituiformis	Siphonina tenuicarinata?	Reophax pyrifer	Reophax sp. 2	Recurvoides sp.2	Discamminoides sp.1	Trochamminoides subcoronatus	Glomospira glomerata	Praesphaerammina spp.	Trochamminoides aff proteus	Glaphyrammina americana	Pseudonodosinella elongata	Popovia spp.	Reophax pilulifer	Conglophragmium irregularis	Budashevaella spp.	Stilostomella spp.	Paratrochamminoides gorayskii	Paratrochamminoides gorayskiformis
3630	1	3.0																															
3640	6	6.0																															
3650	2	3.5																															
3660	3	9.0																															
3670	3	4.0																															
3680	2	16.0																															
3690	4	7.0																															
3700	4	7.0																															
3710	13	35.0																															
3720	6	14.0																															
3730	14	49.5																															
3740	12	96.5																															
3750	18	113.0																															
3760	21	86.0																															
3770	16	55.0																															
3780	23	135.0	1.0	8.0																													
3790	24	79.5			3.0	1.0	1.0	1.0																									
3800	27	171.0			6.0			1.0	4.0	1.0	1.0	2.0	1.0																				
3810	39	153.5						1.0			4.0			1.0	2.0	2.0	2.0	2.0	2.0	1.0													
3820	45	223.0			2.0					1.0				2.0			1.0			3.0	3.0	2.0	1.0	1.0	1.0	2.0	4.0						
3830	42	197.0		4.0	3.0	1.0														3.0	2.0				1.0			2.0	1.0	2.0	1.0	4.0	3.0
3840	40	209.5	2.0	5.0	2.0	3.0		2.0	1.0			1.0	3.0		1.0													2.0					
3850	30	139.5		1.0	13.0		1.0	3.0						2.0						3.0													3.0
3860	45	276.5	2.0	12.0	8.0				2.0						2.0					1.0			1.0				6.0	5.0					
3870	40	141.0	3.0	3.0	2.0			3.0		2.0										1.0		1.0	2.0				1.0			2.0			3.0
3880	33	130.0		8.0	4.0			4.0												3.0			0.5					3.0					
3890	42	189.0		16.0	2.0			3.0			2.0				1.0					4.0			1.0					1.0					
3900	36	227.0		12.0				5.0							2.0					2.0				1.0			1.0		2.0				
3910	30	129.5		5.0	3.0			1.0							2.0					1.0													
3920	36	138.5	3.0	8.0				3.0		1.0	4.0	1.0								4.0			1.0					2.0				1.0	
3930	29	83.5						1.0		1.0			1.0						1.0	2.0													1.0
3940	36	147.5		3.0				7.0											1.0	1.0		1.0	1.0										
3950	30	152.0					2.0	1.0		2.0																	2.0	1.0					1.0
3960	31	134.5		4.0				2.0		2.0	1.0																1.0		1.0				
3970	30	110.5	1.0	3.0				2.0																				1.0					
3980	17	106.5																															
3990	31	148.5						1.0			2.0	1.0	1.0		1.0				2.0	2.0													
4000	26	195.0																		2.0			1.0					1.0					1.0
4010	34	231.0		3.0	1.0			4.5										3.0		2.0								2.0				1.0	
4020	23	388.0						1.0												13.0							2.0	2.0					
4030	19	336.0																	1.0	18.0													
4040	23	512.0		1.0	2.0			3.0			1.0	2.0								27.0													3.0
4050	19	221.0																		3.0													
4060	28	371.0			1.0															6.0								3.0					
4070	29	323.0						2.0		1.0										15.0								5.0					
4080	24	81.0						6.0												2.0								1.0					
4090	37	309.5		3.0				1.0			2.0									15.0								1.5		2.0			
4100	31	397.5			2.0			6.0												19.0								4.0					
4110	27	257.0			4.0			3.0				3.0								8.0													
4120	32	315.5						6.0									1.0			12.0			1.0					2.0				1.0	
4130	33	201.0						3.0							1.0					6.0							4.0	2.0					
4140	29	181.0						6.0							2.0					7.0													
4150	29	235.0						7.0												8.0								4.0					
4160	29	127.0						3.0												2.0	1.0						1.0	3.0					
4170	30	150.0			2.0			7.0			2.0									4.0													
4180	26	140.0			4.0			10.0		1.0										7.0				1.0									
4190	19	103.0						1.0												1.0								1.0					
4200	14	38.5						3.5												1.0								0.5					
4210	25	125.0			2.0			4.0			1.0									1.0								1.5					
4220	15	62.0						4.0											2.0														
4230	13	76.5			1.0			4.0			1.0																						
4240	21	133.5					3.0	4.0												1.0			2.0										
4250	16	58.5					1.0	3.0															2.0										
4260	15	32.0					1.0													1.0													
4270	13	52.0						3.0																				1.0					

Appendix 1. (Continued).

Depth (m)	Diversity	Abundance	Haeuslerella sp. 1	Budashevaella multicamerata	Popovia sp.1	Reophanus berggreni	Glomospira aff irregularis	Cyclammina aff. orbicularis	Glomospira sp. 2	Eggerelloides sp. 1	Subreophax pseudoscalaris	Spiropsammina primula	Psammosphaera sp. 1	Reticulophragmium amplectens ssp. 1	Scherochorella congoensis	Recurvoides sp. 1	miliolid	Kalamopsis spp.	radiolarian	Rhabdammina linearis	Caudammina aff. ovuloides	Guppyella crassa	Orthomorphina sp.	scaphopod frag.	Hormosina glabra	Evolutinella rotulata	Aschemocella grandis	Alveovalvulina sp. 1	Planulina spp.	Uvigerina spp.	Hormosinella carpenteri	Saccammina sp. 3	Bulbobaculites sp. 1	Hyperammina spp.
3630	1	3.0																																
3640	6	6.0																																
3650	2	3.5																																
3660	3	9.0																																
3670	3	4.0																																
3680	2	16.0																																
3690	4	7.0																																
3700	4	7.0																																
3710	13	35.0																																
3720	6	14.0																																
3730	14	49.5																																
3740	12	96.5																																
3750	18	113.0																																
3760	21	86.0																																
3770	16	55.0																																
3780	23	135.0																																
3790	24	79.5																																
3800	27	171.0																																
3810	39	153.5																																
3820	45	223.0																																
3830	42	197.0	1.0																															
3840	40	209.5		2.0	3.0	1.0	4.0	1.0																										
3850	30	139.5				2.0			1.0	1.0	2.0	1.0																						
3860	45	276.5		5.0								1.0	4.0	2.0	1.0	4.0	1.0	2.0																
3870	40	141.0								1.0								3.0	1.0	1.0	1.0	2.0												
3880	33	130.0		2.0									3.0			1.0		2.0		4.0			1.0	1.0										
3890	42	189.0			1.0											3.0		1.0	3.0					2.0	4.0	1.0	1.0	1.0						
3900	36	227.0	1.0										5.0																2.0	1.0	1.0			
3910	30	129.5									2.0			1.0														1.0				2.0	1.0	1.0
3920	36	138.5			2.0				1.0											1.0												1.0		
3930	29	83.5														1.0																		1.0
3940	36	147.5			1.0		1.0							1.0	1.0			7.0														1.0		
3950	30	152.0		2.0											1.0			1.0														2.0		
3960	31	134.5																									1.0							
3970	30	110.5																																
3980	17	106.5													6.0																			
3990	31	148.5													14.0			1.0						3.0										
4000	26	195.0			1.0										65.0																	1.0		
4010	34	231.0	1.0												62.0									1.0										1.0
4020	23	388.0											2.0		139.0																			
4030	19	336.0							1.0						120.0			1.0														0.5		
4040	23	512.0													307.0																			
4050	19	221.0													63.0												1.0							
4060	28	371.0													57.0																			
4070	29	323.0										1.0	1.0		45.0												1.0							1.0
4080	24	81.0													7.0			1.0																1.0
4090	37	309.5		2.0											65.0																			
4100	31	397.5											1.0	1.0	72.0																			
4110	27	257.0			2.0								3.0		20.0																			
4120	32	315.5													28.0												2.0							
4130	33	201.0													18.0												7.0		1.0					1.0
4140	29	181.0											3.0	2.0	11.0																			
4150	29	235.0											1.0		25.0						1.0									2.0				
4160	29	127.0													17.0															1.0				
4170	30	150.0										1.0		1.0	9.0																			1.0
4180	26	140.0													20.0																			
4190	19	103.0						1.0					1.0		7.0												1.0							1.0
4200	14	38.5													5.0																			
4210	25	125.0													4.0																			
4220	15	62.0																												1.0				
4230	13	76.5													5.0												1.0							
4240	21	133.5													9.0																			
4250	16	58.5													4.0																			1.0
4260	15	32.0					1.0							1.0	2.0																			
4270	13	52.0													5.0																			

Appendix 1. (Continued).

Depth (m)	Diversity	Abundance	Cyclammina sp. 1	Haplophragmoides carinatus	Cyclammina sp. 2	Paratrochamminoides sp. 1	Saccammina sp. 2	Glaphyrammina spp.	Trochamminoides folius	Haplophragmoides aff. horridus	Ammodiscus peruvianus	Haplophragmoides sp.2	Reophax duplex	Hormosina sp.	Jaculella sp. 1	Hyperammina cylindrica	Paratrochamminoides aff. deflexiformis	Recurvoides sp. 3	Rhabdammina sp. 1	Paratrochamminoides ex gr. challengeri	Cassidulina spp.	Valvulinaria spp.	R. amplectens / acutidorsatum trans.	Reticulophragmium intermedium	Karrerulina horrida	Reticulophragmium acutidorsatum. ssp.	Ammodiscus tenuissimus	Gyroidina spp.	Subbotina eocena (plank)	Buzasina aff. pacifica	Bolivina spp.	Chrysalogonium spp.	Psammosphaera 2
3630	1	3.0																															
3640	6	6.0																															
3650	2	3.5																															
3660	3	9.0																															
3670	3	4.0																															
3680	2	16.0																															
3690	4	7.0																															
3700	4	7.0																															
3710	13	35.0																															
3720	6	14.0																															
3730	14	49.5																															
3740	12	96.5																															
3750	18	113.0																															
3760	21	86.0																															
3770	16	55.0																															
3780	23	135.0																															
3790	24	79.5																															
3800	27	171.0																															
3810	39	153.5																															
3820	45	223.0																															
3830	42	197.0																															
3840	40	209.5																															
3850	30	139.5																															
3860	45	276.5																															
3870	40	141.0																															
3880	33	130.0																															
3890	42	189.0																															
3900	36	227.0																															
3910	30	129.5																															
3920	36	138.5	1.0	1.0																													
3930	29	83.5			1.0	2.0																											
3940	36	147.5					1.0	1.0																									
3950	30	152.0																															
3960	31	134.5							1.0	1.0																							
3970	30	110.5									1.0																						
3980	17	106.5																															
3990	31	148.5					1.0																										
4000	26	195.0										1.0	2.0																				
4010	34	231.0												1.0	1.0	1.0																	
4020	23	388.0								1.0																							
4030	19	336.0															1.0																
4040	23	512.0																															
4050	19	221.0	1.0															1.0															
4060	28	371.0																	1.0	1.0													
4070	29	323.0											1.0					3.0															
4080	24	81.0									1.0							1.0			1.0	6.0	1.0										
4090	37	309.5		2.0														7.0		1.0			1.0	6.0	2.0								
4100	31	397.5											1.0		1.0									4.0		1.0							
4110	27	257.0								3.0								3.0						1.0			1.0						
4120	32	315.5			1.0								1.0											2.0				1.0	1.0				
4130	33	201.0		1.0						1.0								8.0				2.0				1.0				1.0			
4140	29	181.0																4.0			1.0	8.0									1.0		
4150	29	235.0								3.0												16.0									1.0		
4160	29	127.0																1.0			1.0	25.0									4.0		
4170	30	150.0																7.0	2.0			1.0											
4180	26	140.0																			2.0	10.0	2.0									1.0	
4190	19	103.0																2.0				5.0	1.0										1.0
4200	14	38.5																			2.0	1.0											
4210	25	125.0																3.0			6.0	19.0	1.0									1.0	
4220	15	62.0																1.0			1.0	2.0	1.0										
4230	13	76.5																					1.0										
4240	21	133.5								1.0							1.0				2.0	2.0	1.0	1.0									
4250	16	58.5																			2.0												
4260	15	32.0																3.0				1.0											
4270	13	52.0																3.0				3.0											