

12. BIOSTRATIGRAPHY OF EOCENE TO OLIGOCENE DEEP-WATER AGGLUTINATED FORAMINIFERS IN THE RED CLAYS FROM SITE 767, CELEBES SEA¹

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ABSTRACT

Deep-water agglutinated foraminifers were examined from reddish brown claystones comprising lithologic Unit 4 of Ocean Drilling Program Holes 767B and 767C. The biostratigraphy of deep-water agglutinated foraminifers in this unit indicates an Eocene to Oligocene age. The assemblages are cosmopolitan, not endemic, and several species that are useful biostratigraphic indicators in the Atlantic and western Mediterranean region (e.g., *Reticulophragmium amplexans*, *Reophax elongatus*, *Ammodiscus latus*, *Rzehakina epigona minima*, *Hormosina ovulum ovulum*, and *Paratrochamminoides* spp.) are present in the Celebes Sea. Based on biostratigraphic correlations with the North Atlantic and Alpine-Carpathian regions, the base of the sedimentary section in Hole 767C is determined to be of early Eocene, not middle Eocene age as determined by shipboard biostratigraphic analyses. The Eocene/Oligocene boundary is represented by a hiatus or extremely condensed interval.

INTRODUCTION

The Celebes Sea in the western Pacific is a small oceanic basin within the Eurasian Plate in an area of active collisional tectonics. It is an excellent modern analog of the small oceanic basins that are preserved as obducted fragments in the alpine areas of southern and central Europe. The Celebes Sea, together with the Sulu and Banda basins, are thought to represent a trapped fragment of an originally continuous, once-larger ocean basin, while other basins in the area are thought to have originated by back-arc spreading. The primary goal of Leg 124 was to determine the age, stratigraphy, and paleoceanography of the Celebes Sea and the Sulu Basin to the north, to reconstruct the history of tectonic and paleoceanographic events in the area.

Site 767 is located at 4916 m depth in the central portion of the Celebes Sea (Fig. 1). Drilling at the site recovered a complete sedimentary section overlying plagioclase-olivine basalt. The lowermost lithologic unit at Site 767 (lithologic Unit 4) consists of deep-sea reddish claystones that are barren of calcareous planktonic microfossils, but contain a nearly continuous record of deep-water agglutinated foraminifers (DWAF). In this study, we examined samples from lithologic Unit 4 to determine the nature of DWAF assemblages and thereby constrain the chronostratigraphy and paleoecology of the oldest sediments in the Celebes Sea.

PREVIOUS STUDIES

Very little is known about Eocene-Oligocene DWAF assemblages from the western Pacific margin. DWAF assemblages of undoubtedly Paleocene age from DSDP Site 283 were studied by Webb (1975), which was drilled between Tasmania and New Zealand. Webb's study is significant

because it was the first to document the occurrence in the Pacific Basin of DWAF taxa first described from the western Tethys, thereby documenting the cosmopolitan nature of these forms. Additional occurrences of some Paleocene and lowermost Eocene DWAF taxa in southern New Guinea were noted by Haig (1982). Our study is the first report of DWAF taxa in younger sediments from the western Pacific basins.

Fortunately, a large body of information on the biostratigraphy of Paleogene DWAF is available from the western Mediterranean and in the marginal basins of the Atlantic. Although these records are rather distant from the Celebes Sea, they can nevertheless serve as useful comparative material given the absence of any reference sections in the western Pacific. A formal zonation based on first and last occurrences has been developed for the Paleocene to Eocene for the Polish Carpathians by Geroch and Nowak (1984) and Geroch and Koszarski (1988). The succession of DWAF assemblages in the Skole Basin of the Carpathians, based on semiquantitative faunal abundance data, was discussed by Morgiel and Szymkowska (1978). In addition to these localities, there are several studies from the Atlantic margins that can serve as reference sections. The Campanian to lower Eocene biostratigraphy of DWAF in southern Trinidad was studied by Kaminski et al. (1988); the Eocene to Oligocene biostratigraphy of DWAF in Hole 647A in the southern Labrador Sea was reported by Kaminski et al. (1989), and the Eocene to lower Miocene biostratigraphy of DWAF in Hole 643A in the Norwegian Sea was reported by Kaminski et al. (1990). The Cenozoic record of DWAF in the North Sea was investigated by Gradstein et al. (1988), Charnock and Jones (1990) and by Gradstein et al. (in press).

METHODS

A total of 28 samples from lithologic Unit 4 in Holes 767B and 767C (Cores 124-767B-72X through 124-767C-12R) were studied for foraminifers. Samples, averaging 20 cm³ in volume, were dried overnight in a 60° oven, boiled in a 1% Calgon solution, and washed over a 63- μ m sieve. All foraminifers were picked from the whole fraction >63 μ m according to standard micropaleontologic techniques. Specimens were mounted on cardboard reference slides, and specimens were illustrated by scanning electron microscopy (SEM). See Plates

¹ Silver, E. A., Rangin, C., von Breymann, M. T., et al., 1991. *Proc. ODP, Sci. Results*, 124: College Station, TX (Ocean Drilling Program).

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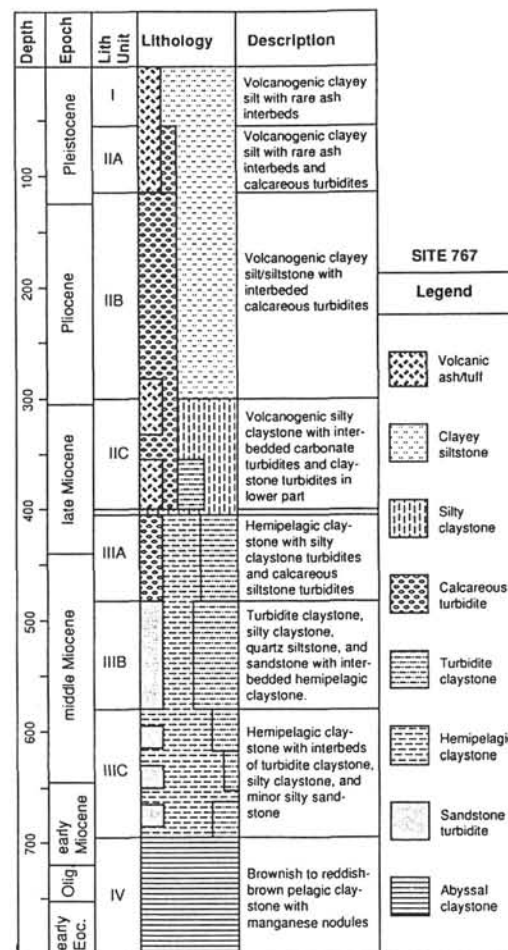
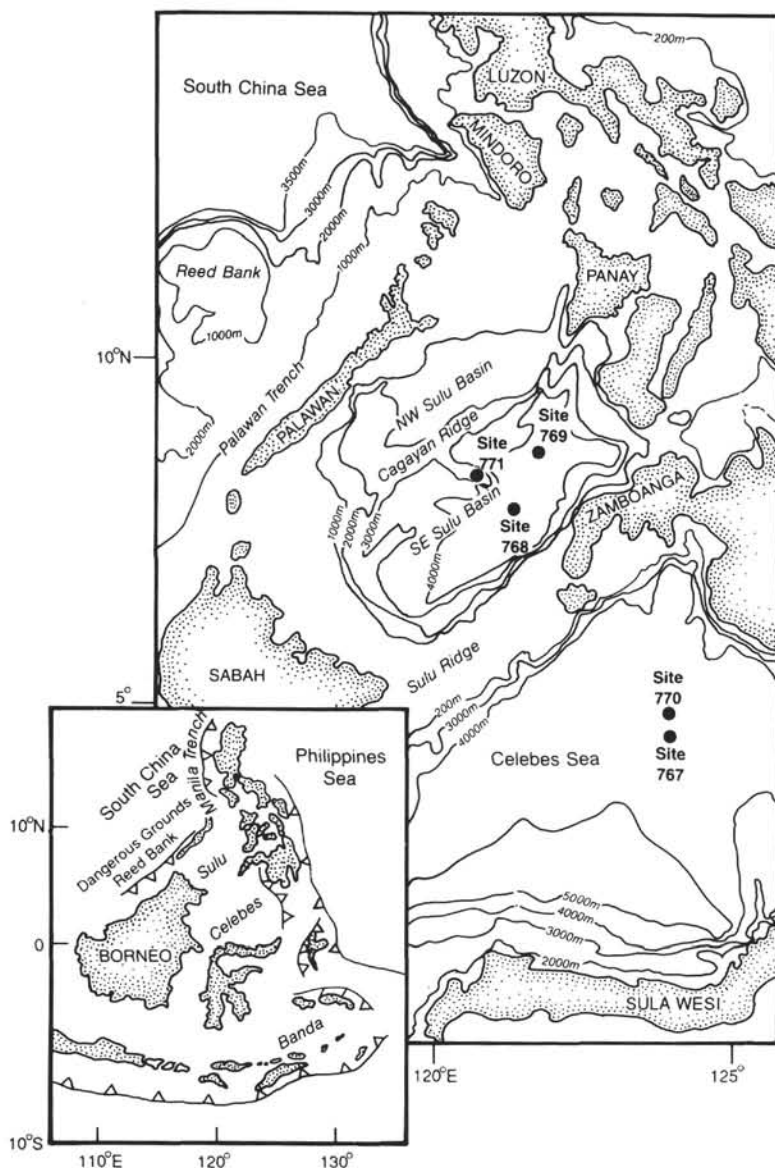


Figure 1. Location of ODP Site 767 in the Celebes Sea, with lithology and chronostratigraphy determined during Leg 124 (modified from Leg 124 Shipboard Scientific Party, 1989a, 1989b).

1-3. Plesiotypes are housed in M.A.K.'s collection at University College London.

LITHOLOGY

Lithologic Unit 4 is composed mainly of dark grayish brown to reddish brown claystone. The claystone is generally homogeneous and structureless in the upper part, becoming more bioturbated downward and finally more laminated near the base of the unit. Laminations are color variations possibly caused by variations in the concentrations of manganese oxides. Sand-size particles consist mainly of biogenic components (agglutinated foraminifers, radiolarians, and fish remains) and small manganese nodules. Zeolites occur as discrete crystals in the lower half of the unit. The carbonate content is very low throughout the section (0.2%). The fine grain size and color of the claystone unit, along with the presence of manganese nodules and fish remains, indicate slow pelagic sedimentation below the calcite compensation depth (CCD).

RESULTS

Biostratigraphy

The red clays from Site 767 are barren of calcareous microfossils, and shipboard biostratigraphy was based solely on radiolarians and ichthyoliths (Site 767, Rangin, Silver, von Breyman, et al., 1990). The benthic foraminifer assemblages and the interpreted chronostratigraphy determined in Site 767 are illustrated in Figure 2; the characteristic assemblages are described below in order from oldest to youngest. For comparison, the shipboard radiolarian and ichthyolith data are also shown. Radiolarian assemblages throughout the interval were found only in isolated samples, but offered the best stratigraphic resolution, especially in the Oligocene. Radiolarian assemblages at the base of Hole 767C were poorly preserved, and only tentatively assigned to the *P. chalara-P. goetheana* Zones (Rangin, Silver, von Breyman, et al., 1990).

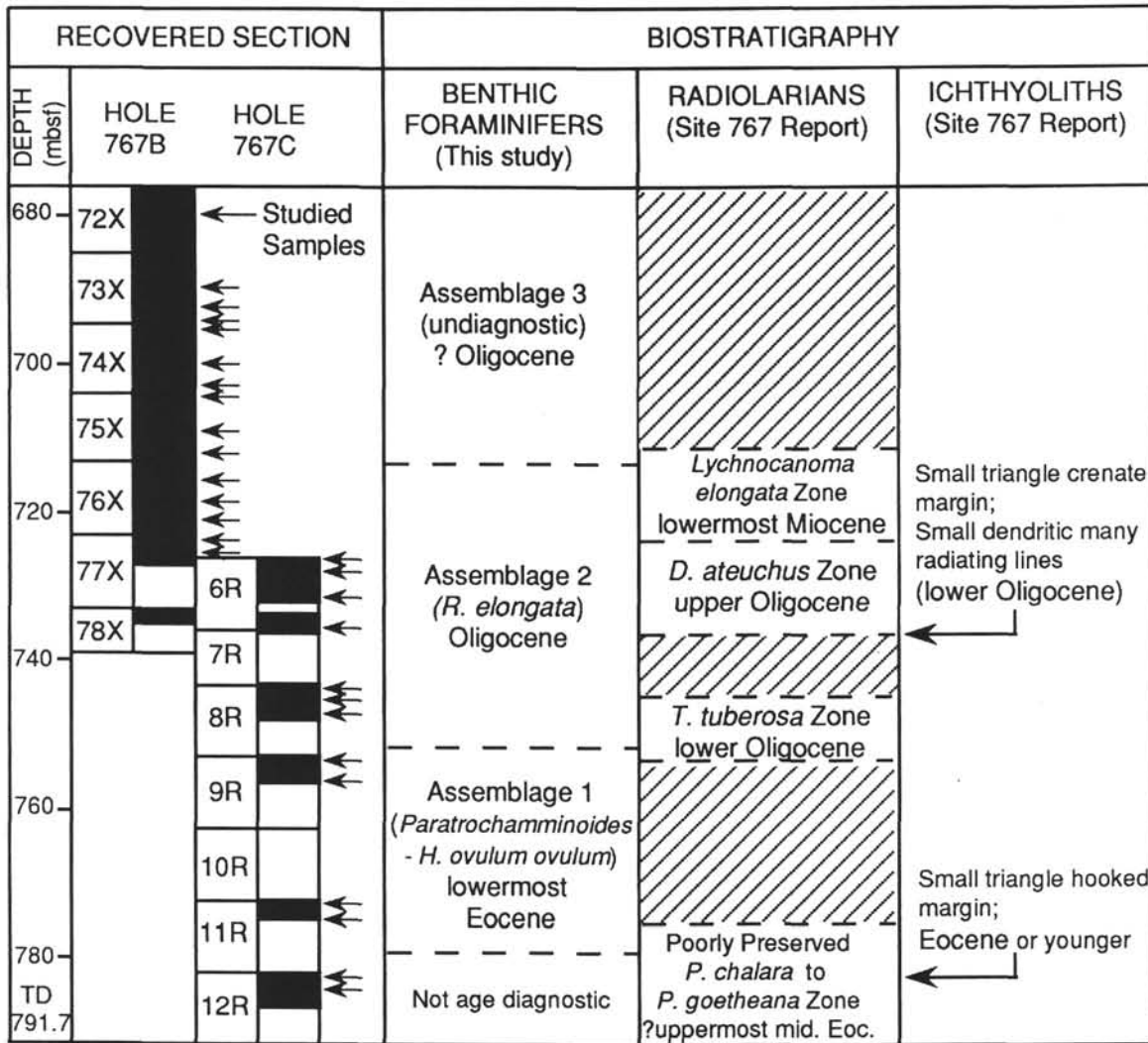


Figure 2. Core recovery, studied samples, and chronostratigraphy of microfossil assemblages from the red clays (lithologic Unit 4) at ODP Site 767. Radiolarian and ichthyolith data were compiled from the Site 767 Chapter (Rangin, Silver, von Breymann et al. 1990). Barren intervals are indicated by diagonal lines.

1. Assemblage 1 (*Paratrochamminoides*—*Hormosina ovulum ovulum*)

Interval: Core 124-767C-11R—Core 124-767C-9R
Age: early Eocene

Sediments directly overlying basement in Core 124-767C-12R are nearly barren of benthic foraminifers, and our two samples from this core contain only fragments of *Rhizammina*. Above this interval, however, the samples from Cores 124-767C-11R and 124-767C-9R contain abundant DWAf assemblages comprised of about 36 taxa (Table 1). The assemblages are dominated by fragments of tubular genera, such as *Rhizammina*, *Rhaddammina*, and *Bathysiphon*. However, some very distinctive species that are useful biostratigraphic indicators also occur in this assemblage, including *Spiroplectammina spectabilis* (Grzybowski), *Reophax nodulosus* Brady, *Kalamopsis grzybowskii* (Dylazanka), *Hormosina ovulum ovulum* (Grzybowski), *Hormosina ovuloides* (Grzybowski), *Rzehakina epigona minima* Cushman and Renz, *Hyperammina rugosa* Verdenius and Van Hinte, *Praecystammina* sp., and *Paratrochamminoides* spp. The occurrence of most of these species is rare and sporadic, but allows us to determine the age of the interval

as early Eocene (see below). The top of this assemblage is determined by the last occurrence of these species in Core 124-767C-9R.

2. Assemblage 2 (*Reophax elongatus*)

Interval: Core 124-767C-8R—Section 124-767B-75X-4
Age: latest early Eocene to early Oligocene

This assemblage corresponds to the total range of *Reophax elongatus* (Grzybowski) in the studied section (Tables 1, 2). The first occurrence (FO) of *R. elongatus* is coincident with the FO of *Reticulophragmium amplexens* in Sample 124-767C-8R-2, 30–34 cm. The last occurrence (LO) of *Reophax elongatus* in Sample 124-767B-75X-4, 45–48 cm also coincides with the LO's of *Haplophragmoides walteri walteri* (Grzybowski) and *Ammodiscus latus* (Grzybowski). The abundance of DWAf in samples from this interval is markedly lower than in the underlying assemblage, but the diversity across the whole interval is only slightly lower (31 vs. 36 taxa). This assemblage contains several taxa that are typical of middle to upper Eocene sediments in the Atlantic and western Tethys, such as *R. amplexens*, *R. elongatus*, *Haplophragmoides walteri walteri*, *Haplophragmoides horridus* (Grzybowski) and *Karrerulina conversa* (Grzybowski).

Table 1. Benthic foraminifers abundance data from ODP Hole 767B. R = 1-3 specimens; F = frequent, 4-9 specimens; C = common, 10-29 specimens; A = abundant, 30 or more specimens.

Core-Section: Interval in cm: AGE: No. of species:	72X-3 23-25 ?Olig. 8	73X-4 92-95 ?Olig. 0	73X-5 126-130 ?Olig. 0	73X-6 51-57 ?Olig. 0	74X-1 108-113 ?Olig. 0	74X-4 69-74 ?Olig. 5	74X-6 79-82 ?Olig. 0	75X-1 45-48 Olig. 6	75X-4 45-48 Olig. 10	75X-6 80-83 Olig. 9	76X-2 111-113 Olig. 7	76X-4 94-96 Olig. 0	76X-6 6-9 Olig. 6	77X-1 88-90 Olig. 5	77X-2 30-34 Olig. 7
SPECIES:		Barren	Barren	Barren	Barren		Barren						Barren		
<i>Rhizammina indivisa</i>	C					R				F				C	
<i>Ammosphaeroidina pseudopauciloculata</i>	F														
<i>Hyperammina</i> spp.	R										R				
<i>Lituotuba lituiformis</i>	R														
<i>Trochammina</i> sp.	R														
<i>Reticulophragmium amplexens</i>	F							R		R					F
<i>Reophax nodulosus</i>	R					R									
<i>Hormosinella</i> sp.	R														
<i>Glomospira charoides</i>						R		F	F	F					
<i>Glomospira gordialis</i>						F		F	F	F					
<i>Glomospira glomerata</i>						R		R							
<i>Ammodiscus tenuissimus</i>								R	R	R	R				
<i>Rhabdammina</i> spp.								F	C	C	C			F	F
<i>Ammodiscus latus</i>									F	R				R	
<i>Reophax elongatus</i>									R						R
<i>Bathysiphon</i> spp.									F	F	F			F	F
<i>Haplophragmoides walteri walteri</i>									R		R				
<i>Glomospira irregularis</i>									R	F					
<i>Ammodiscus peruvianus</i>									R	R					
<i>Hormosina velascoensis</i>											R			R	
<i>Trochamminoides variolarius</i>														R	
<i>Saccammina grzybowskii</i>														R	
<i>Haplophragmoides walteri excavatus</i>														R	
<i>Psammosphaera</i> sp.														R	
<i>Haplophragmoides eggeri</i>														R	
<i>Hyperammina</i> sp. (large, coarse)															R
<i>Cyclammina placenta</i>															R

3. Assemblage 3 (undiagnostic)

Interval: Sample 124-767B-75X-1, 45-48 cm—Sample 124-767B-72X-3, 23-25 cm

Age: ? Oligocene

This assemblage at the top of the studied section displays much lower diversity than the underlying assemblages (only 12 taxa), and five of the eight samples studied were barren. The foraminifer assemblage is characterized by scattered occurrences of mostly long-ranging forms, such as *Rhizammina*, *Lituotuba*, *Reophax nodulosus*, and species of *Glomospira*. However, the occurrences of *Reticulophragmium amplexens* in the uppermost sample suggest an age no younger than Oligocene for this interval.

DISCUSSION

The Age of Basement in the Celebes Sea

In a geophysical survey of the Celebes Sea, Weissel (1980) determined an Eocene age for the oceanic crust preserved in the area using three lines of evidence. (1) using an average crustal depth of 6-7 km and a sediment thickness of 2 km, Weissel estimated an age of 50-55 Ma based on a comparison with the empirical oceanic age vs. depth relationship of Sclater et al. (1971); (2) a compilation of the available heat-flow data collected in the Celebes Sea yielded (after ignoring two anomalously low values) an average observed mean heat flow of 1.58 HFU ($\mu\text{cal cm}^{-2} \cdot \text{s}^{-2}$). A comparison with the cooling half-space model of Parsons and Sclater (1977) yielded an estimated age of about 51 Ma (3) a marine magnetic anomaly survey in the southwestern part of the basin yielded an anomaly pattern that was tentatively interpreted as Anomalies 18, 19, and 20 (42-47 Ma). This age of 42 Ma was accepted for the formation of the Celebes Sea by the Leg 124 Shipboard Scientific Party (1989a).

Evidence for an Early Eocene Age for the Base of Hole 767C

All lines of benthic faunal evidence converge in indicating an Early Eocene age for the base of the sedimentary section at Site 767. This age assignment is based on correlations with the biostratigraphic record in the Carpathians, Trinidad, Labrador, and the North Sea, using the following criteria:

1. *Reophax nodulosus*—This species has its FO near the Paleocene/Eocene boundary, according to Geroch and Nowak (1984). In the Atlantic, it is predominantly an abyssal taxon and occurs commonly in the Eocene at Sites 647 and 643. The occurrence of this species and the absence of any Paleocene taxa in Hole 767C rules out a Paleocene age.

2. *Rzehakina epigona minima*—Cushman and Renz (1946) first described *Rzehakina epigona minima* from the "upper zone" of the Lizard Springs Formation (i.e., the lower Eocene portion), but we have not been able to verify this occurrence. We have observed *R. epigona minima* in the upper Campanian to upper Paleocene (Zone P4) in the Guayaguayare and lower Lizard Springs Formations in Trinidad (Kaminski et al., 1988). In the central North Sea, it is always found below the lowermost Eocene tuff marker, and its LO is generally in the middle part of the upper Paleocene (Gradstein and Kaminski, unpublished data).

3. *Hormosina ovulum ovulum*—In the Carpathian region the LO of this species is generally understood to occur at the top of the Paleocene (Geroch and Nowak, 1984), but in the Skole basin Morgiel and Szymakowska (1978) have reported it to occur in the lowermost Eocene. We have observed its LO in the abyssal North Atlantic within an undated interval between nannofossil Zones NP13 and NP15 in ODP Hole 647 and in an interval of roughly equivalent age in Hole 643A.

Table 2. Benthic foraminifer abundance data from ODP Hole 767C. R = rare, 1-3 specimens; F = frequent, 4-9 specimens; C = common, 10-20 specimens; A = abundant, 30 or more specimens.

Core-Section: Interval in cm: AGE: No. of species:	6R-1 22-25 Olig 8	6R-2 34-37 Olig 5	6R-5 13-17 Olig 20	7R-2 40-45 Olig 4	8R-1 61-65 Olig 6	8R-2 30-34 Olig 8	8R-3 15-18 Olig 6	9R-1 72-77 E. Eoc. 21	9R-3 69-74 E. Eoc. 19	11R-1 54-57 E. Eoc. 15	11R-2 57-60 E. Eoc. 14	12R-1 59-63 E. Eoc. 2	12R-2 110-114 E. Eoc. 1
SPECIES:													
<i>Rhizammina indivisa</i>	C	C	C	F	F	F	F	C	C	C	C	F	F
<i>Ammosphaeroidina pseudopauciloculata</i>					R			R	R				
<i>Hyperammina</i> spp.	R								F	R	R		
<i>Lituotuba lituiformis</i>								R			R		
<i>Reophax nodulosus</i>						R		R		R	R		
<i>Hormosinella</i> sp.													
<i>Glomospira charoides</i>			R	R				F	R	R	R		
<i>Glomospira gordialis</i>		R	R										
<i>Glomospira glomerata</i>			R					R					
<i>Ammodiscus tenuissimus</i>								R	R				
<i>Rhabdammina</i> spp.			C	R	C	R			F	C	C		
<i>Ammodiscus latus</i>	R	R	R		F	R		R	R	R			
<i>Reophax elongatus</i>	F		F			R							
<i>Bathysiphon</i> spp.	F	F	C		F		R	C	C	F	F		
<i>Haplophragmoides walteri walteri</i>	R		R					F	F	R	R		
<i>Glomospira irregularis</i>			R		R			F	F	R	R		
<i>Ammodiscus peruvianus</i>													
<i>Hormosina velascoensis</i>							R		R				
<i>Trochamminoides variolarius</i>													
<i>Saccammina grzybowskii</i>			R					F					
<i>Haplophragmoides walteri excavatus</i>			R								R		
<i>Psammosphaera</i> sp.										R	R		
<i>Cyclammina placenta</i>								R	R				
<i>Reticulophragmium amplectens</i>	F		F	R		R							
<i>Hormosinella distans</i>	F		F							R			
<i>Dendrophrya robusta</i>		F	F			R		R	F	F	R		
<i>Reophax pilulifer</i>			F					R					
<i>Haplophragmoides horridus</i>			R							R			
<i>Bathysiphon microtraphidus</i>			F							R			
<i>Recurvoides walteri</i>			F										
<i>Karrerulina conversa</i>			R										
<i>Tolypammina</i> sp.							R						
<i>Dendrophrya latissima</i>							R						
<i>Kalamopsis grzybowskii</i>								R					
<i>Trochamminoides subcoronatus</i>								R					
<i>Hormosina ovulum ovulum</i>								R					
<i>Karrerulina horrida</i>								R					
<i>Spiroplectammina spectabilis</i>								R					
<i>Hormosina ovuloides</i>								R			R		
<i>Glomospira</i> sp.									R				
<i>Subreophax scalaris</i>									F				
<i>Hyperammina rugosa</i>									R				
<i>Rzehakina epigona minima</i>									R				
<i>Praecystammina</i> sp.									R				
<i>Psammosphaera fusca</i>									R				
<i>Paratrochamminoides</i> spp.										R	R	R	

4. *Praecystammina* sp.—This is a distinctive form first described by Krasheninnikov (1973) from the Upper Cretaceous of the western Pacific. In the abyssal red clays of the North Atlantic region, the LO of this genus is generally within the Upper Cretaceous, but it persists into the Paleocene in bathyal areas (Kuhnt and Kaminski, 1989). It has a consistent LO within the lowermost Eocene tuff sequence in the central North Sea (Gradstein and Kaminski, unpublished data), and near the lower/middle Eocene boundary in the Norwegian Sea (Kaminski et al., 1990).

5. *Cyclammina placenta*—This species is the immediate ancestor of the Holocene species *Cyclammina cancellata* Brady, and first evolved during the early Eocene. This species evolved from a *Haplophragmoides* ancestor and displays an evolutionary trend toward larger size and a more complex aperture (Berggren and Kaminski, 1990). The ancestral populations of *C. placenta* from the lower Eocene in the North

Atlantic are small, display no visible holes in the apertural face, and have only a single, interiomarginal aperture. Specimens from Hole 767C (Pl. 3, Fig. 6) are primitive morphotypes, similar to the ancestral populations from the North Atlantic. The specimens from Core 124-767C-9R are even smaller than lower Eocene specimens from the sediments directly overlying basement at Site 643 in the Norwegian Sea, which was drilled on marine magnetic Anomaly 23 (and correlates with the middle part of the early Eocene).

6. *Paratrochamminoides* spp.—Throughout the flysch basins of the Polish Carpathians, a distinct horizon of reddish sediments contains common to abundant specimens of *Trochamminoides* and *Paratrochamminoides*. Jurkiewicz (1967) regarded this assemblage to be lower Eocene. In their detailed study of the Skole Basin of the Carpathians, Morgiel and Szymakowska (1978) subdivided the lower Eocene into three characteristic assemblages, the lowermost of which they

termed the "Recurvoidea-Trochamminoides" assemblage. In the central North Sea, the LO of *Trochamminoides* is observed in the lowermost Eocene *Coscinodiscus* Zone of Gradstein et al. (1988), and this also is usually an interval of reddish sediments. Although the occurrence of *Trochamminoides* and *Paratrochamminoides* in Hole 767C is not abundant, these forms are not found above Core 124-767C-9R.

7. *Reticulophragmium ampletens*—The FO of this species was observed in Sample 124-767C-8R-2, 30–34 cm, and its occurrence characterizes the overlying assemblage. The common occurrence of species is regarded as a good indicator of middle Eocene in the Carpathian flysch basins, although it occurs sporadically in older strata. Its oldest well-calibrated occurrence in the Carpathians is within nannofossil Zone NP12 (Olszewska and Smagowicz, 1977). We have documented its FO in the southern Labrador Sea in the upper portion of Zone NP11 (Kaminski et al., 1989).

In summary, using the benthic foraminifer data in isolation yields an early Eocene age for the base of the sediment section for the interval of Cores 124-767C-9R to 124-767C-11R. If anything, the section correlates with the earliest Eocene (older than Zone NP12) DWAF assemblages in the Carpathians and North Atlantic. Our early Eocene age assignment (approx. 55 Ma) is in general agreement with the age of 50–55 Ma that Weissel (1980) estimated using the empirical age-depth curve, but remains in conflict with the interpreted magnetic anomalies in the basin (Weissel, 1980) and the middle Eocene age determined by shipboard analysis of radiolarians (Leg 124 Shipboard Scientific Party, 1989a, 1989b). The benthic foraminifer assemblages at Site 767 consist of cosmopolitan deep-water forms. Because the sequence of benthic foraminifer FO's and LO's at Site 767 is so similar to the Atlantic-Mediterranean record, we have no reason to assume that the Celebes Sea contained a relict or peripherally isolated fauna that may have contained species that survived extinction in the main population. We urge reassessment of the available geophysical and micropaleontologic data to resolve this apparent conflict.

The Eocene-Oligocene Hiatus

In localities where special studies of Eocene to Oligocene DWAF have been carried out, the Eocene/Oligocene boundary is usually represented by an abrupt taxonomic turnover and a reduction in abundance and diversity. For example, at ODP Site 647, where the Eocene/Oligocene boundary was continuous, the LO's of 12 species were observed within 3 m of the boundary, and the lowermost Oligocene assemblages consisted mainly of *Ammodiscus* and *Glomospira* (Kaminski et al., 1989). In the marginal basins of the North Atlantic, as well as at Site 647, an important indicator species is *Spiroplectammina spectabilis* (Grzybowski). This species has never been observed above the Eocene/Oligocene boundary. At Site 767, a similar change is observed between benthic foraminifer assemblages 1 and 2, between Cores 124-767C-9R and 124-767C-8R. *Spiroplectammina spectabilis* was not observed above Core 124-767C-9R, and all the remaining species comprising Assemblage 2 are known to range from the Eocene to the lower Oligocene in the Atlantic region. This corroborates the age assignment of early Oligocene for Core 124-767C-8R based on radiolarians (Fig. 2). However, because we interpret the benthic foraminifer assemblages from Core 124-767C-9R as earliest Eocene, a significant hiatus or extremely condensed interval must exist between Sample 124-767C-9R-1, 72–77 cm, and Sample 124-767C-8R, CC, which contains lower Oligocene radiolarians.

CONCLUSIONS

1. Eocene to Oligocene deep-water agglutinated assemblages in lithologic Unit 4 of Holes 767B and 767C consist of cosmopolitan species that display strong affinities to coeval assemblages described from the North Atlantic and western Tethys. The biostratigraphic record at Site 767 appears to reflect global, rather than local events. This observation supports the idea that the Celebes Sea is a trapped fragment of ocean crust that originated in an open ocean setting (e.g., Leg 124 Shipboard Scientific Party, 1989a).

2. The early Eocene age for the base of the sediment section determined in this study is derived from several lines of faunal evidence and is in apparent conflict with the middle Eocene age determined by marine magnetic anomaly survey and shipboard biostratigraphic analyses.

3. A comparison between radiolarian and benthic foraminifer biostratigraphy indicates that a significant hiatus or extremely condensed interval exists between 753.0 and 753.7 mbsf.

ACKNOWLEDGMENTS

We gratefully acknowledge the Ocean Drilling Program for providing samples. Travel support for Z. H. to participate on Leg 124 was provided by an NSERC Strategic Grant to Ron Boyd (Dalhousie University). We thank Herb McDaniel and Danuta Kaminski for help with sample preparation. We are grateful to W. A. Berggren and R. W. Jones for reviewing the manuscript. This is contribution No. 28 of the Deep-Water Agglutinated Foraminifera Project, supported by a consortium of oil companies (BP, Chevron, Marathon, Texaco, UNOCAL) under a grant to W. A. Berggren (Woods Hole Oceanographic Institution).

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Date of initial receipt: 17 July 1990

Date of acceptance: 10 December 1990

Ms 124B-131

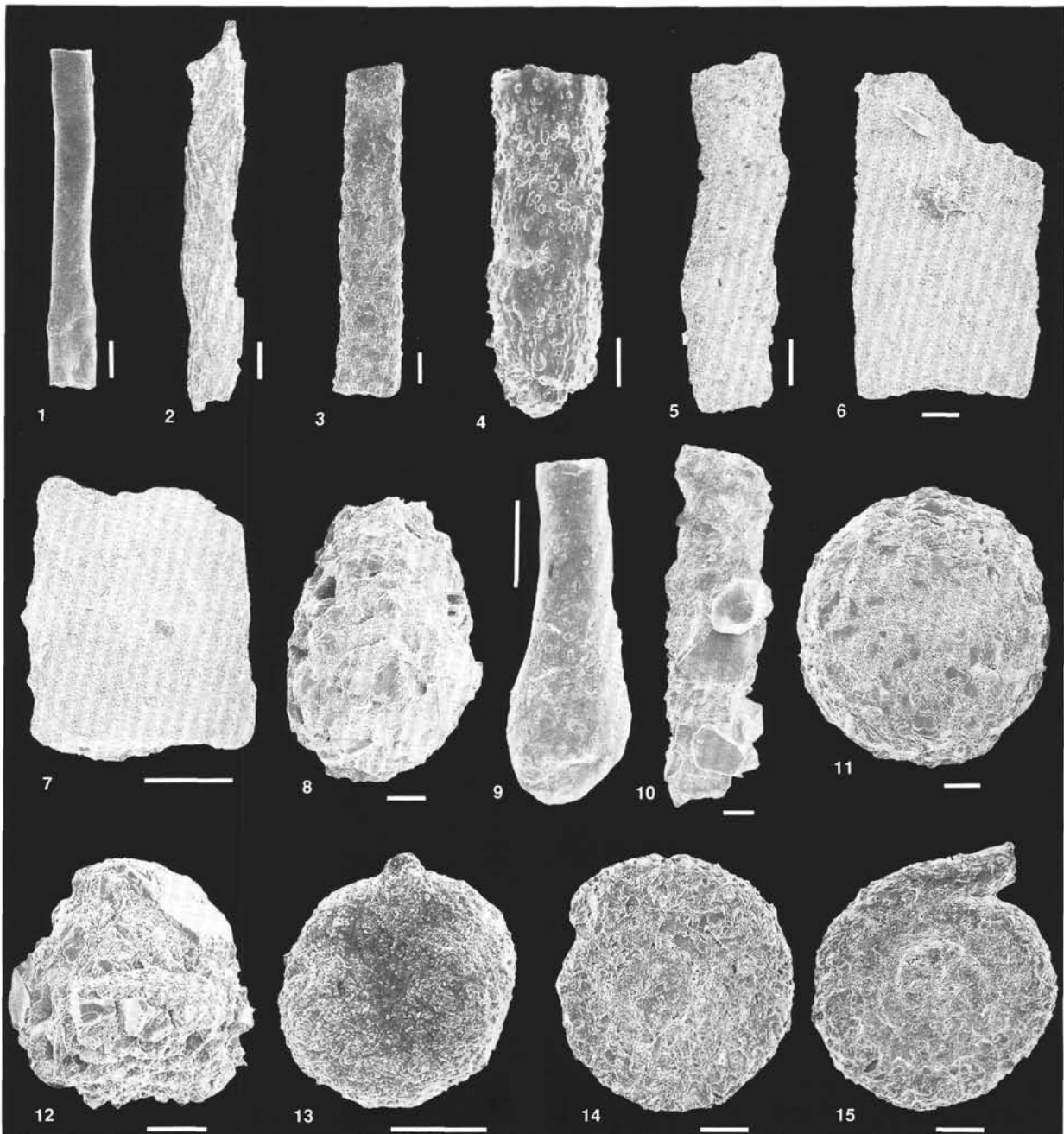


Plate 1. All scale bars are 100 μm , except Figure 7, which is 300 μm . 1. *Bathysiphon* sp., Sample 124-767C-9R-3, 69–74 cm. 2. *Bathysiphon microrhaphidus* Samuel, Sample 124-767C-6R-5, 13–17 cm. 3. *Rhizammina indivisa* Brady, Sample 124-767C-9R-3, 69–74 cm. 4. *Rhabdammina cylindrica* Glaessner, Sample 124-767B-75X-4, 45–48 cm. 5. *Rhabdammina* sp. Sample 124-767C-11R-1, 54–57 cm. 6. *Dendrophrya latissima* Grzybowski, Sample 124-767C-8R-3, 15–18 cm. 7. *Dendrophrya robusta* Grzybowski, Sample 124-767C-8R-2, 30–34 cm; scale bar = 300 μm . 8. *Hyperammina* sp. Sample 124-767B-77X-2, 30–34 cm. 9. *Hyperammina elongata* Brady, Sample 124-767C-11R-1, 54–57 cm. 10. *Hyperammina rugosa* Verdenius and Van Hinte, Sample 124-767C-9R-3, 69–74 cm. 11. *Psammosphaera* sp., Sample 124-767C-11R-2, 57–60 cm. 12. *Psammosphaera fusca* Schultze, Sample 124-767C-9R-3, 69–74 cm. 13. *Saccammina grzybowskii* (Schubert), Sample 124-767C-9R-1, 72–77 cm. 14. *Ammodiscus latus* Grzybowski, megalosphaeric form, Sample 124-767C-8R-2, 30–34 cm. 15. *Ammodiscus latus* Grzybowski, microsphaeric form, Sample 124-767B-75X-4, 45–48 cm.

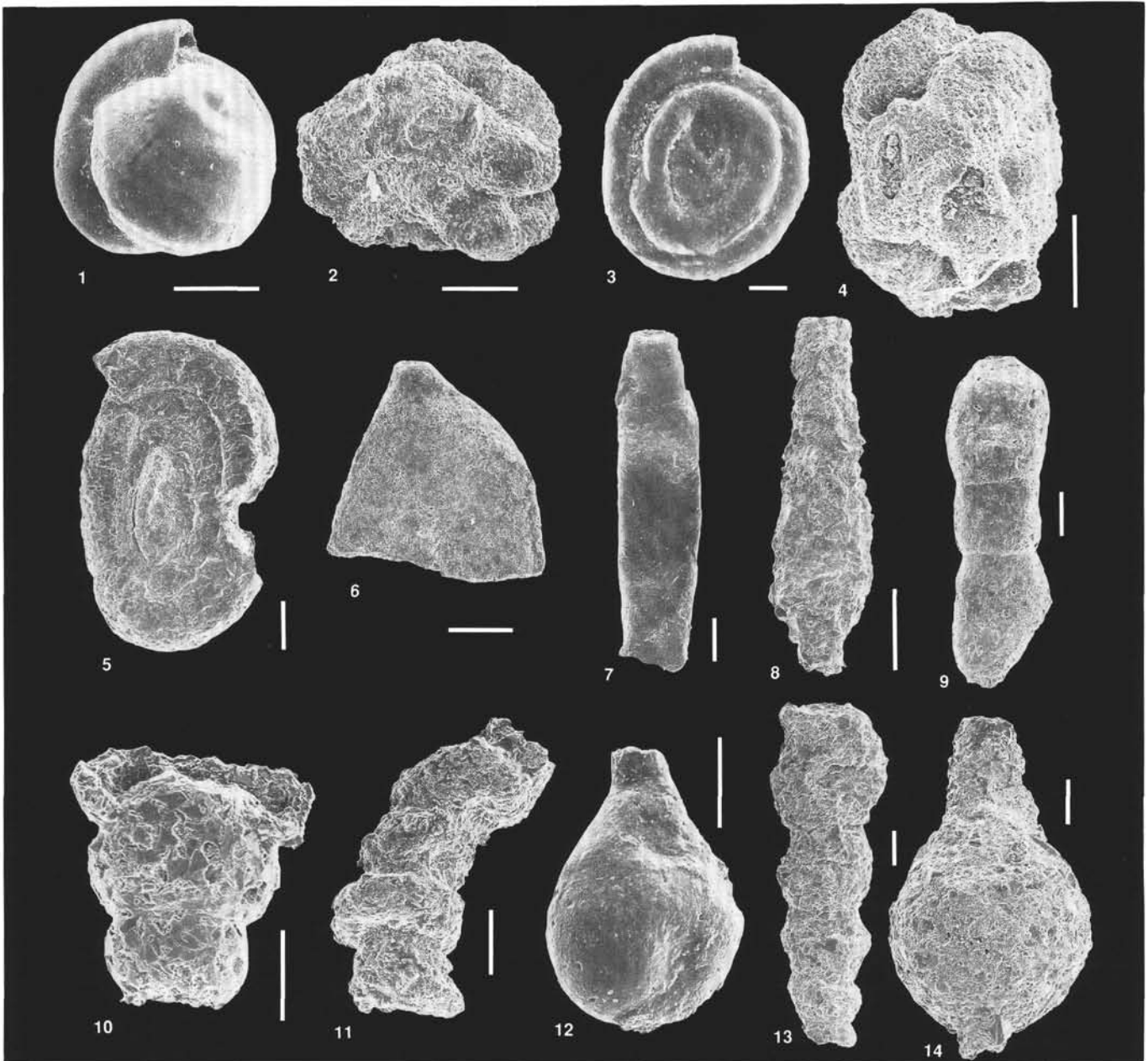


Plate 2. Scale bar in Figure 8 is 300 μm and in Figure 3 is 30 μm ; all others are 100 μm . 1. *Glomospira charoides* (Jones and Parker), Sample 124-767C-8R-2, 30–34 cm. 2. *Glomospira glomerata* (Grzybowski), Sample 124-767C-6R-5, 13–17 cm. 3. *Glomospira gordialis* (Jones and Parker), Sample 124-767B-76X-2, 111–113 cm; scale = 30 μm . 4. *Glomospira irregularis* (Grzybowski), Sample 124-767C-8R-1, 61–65 cm. 5. *Glomospirella* sp., Sample 124-767C-6R-1, 22–25 cm. 6. *Rzehakina epigona minima* Cushman and Renz, Sample 124-767C-9R-3, 69–74 cm. 7. *Kalamopsis grzybowskii* (Dylazanka), Sample 124-767C-9R-1, 72–77 cm. 8. *Reophax elongatus* Grzybowski, Sample 124-767C-8R-2, 30–34 cm; scale = 300 μm . 9. *Reophax nodulosus* Brady, Sample 124-767C-11R-1, 54–57 cm. 10. *Reophax pilulifer* Brady, Sample 124-767C-6R-5, 13–17 cm. 11. *Subreophax scalaris* (Grzybowski), Sample 124-767C-9R-3, 69–74 cm. 12. *Hormosina ovulum ovulum* (Grzybowski), Sample 124-767C-9R-1, 72–77 cm. 13. *Hormosina velascoensis* (Cushman), Sample 124-767C-8R-3, 15–18 cm. 14. *Hormosinella distans* (Brady), Sample 124-767C-6R-5, 13–17 cm.

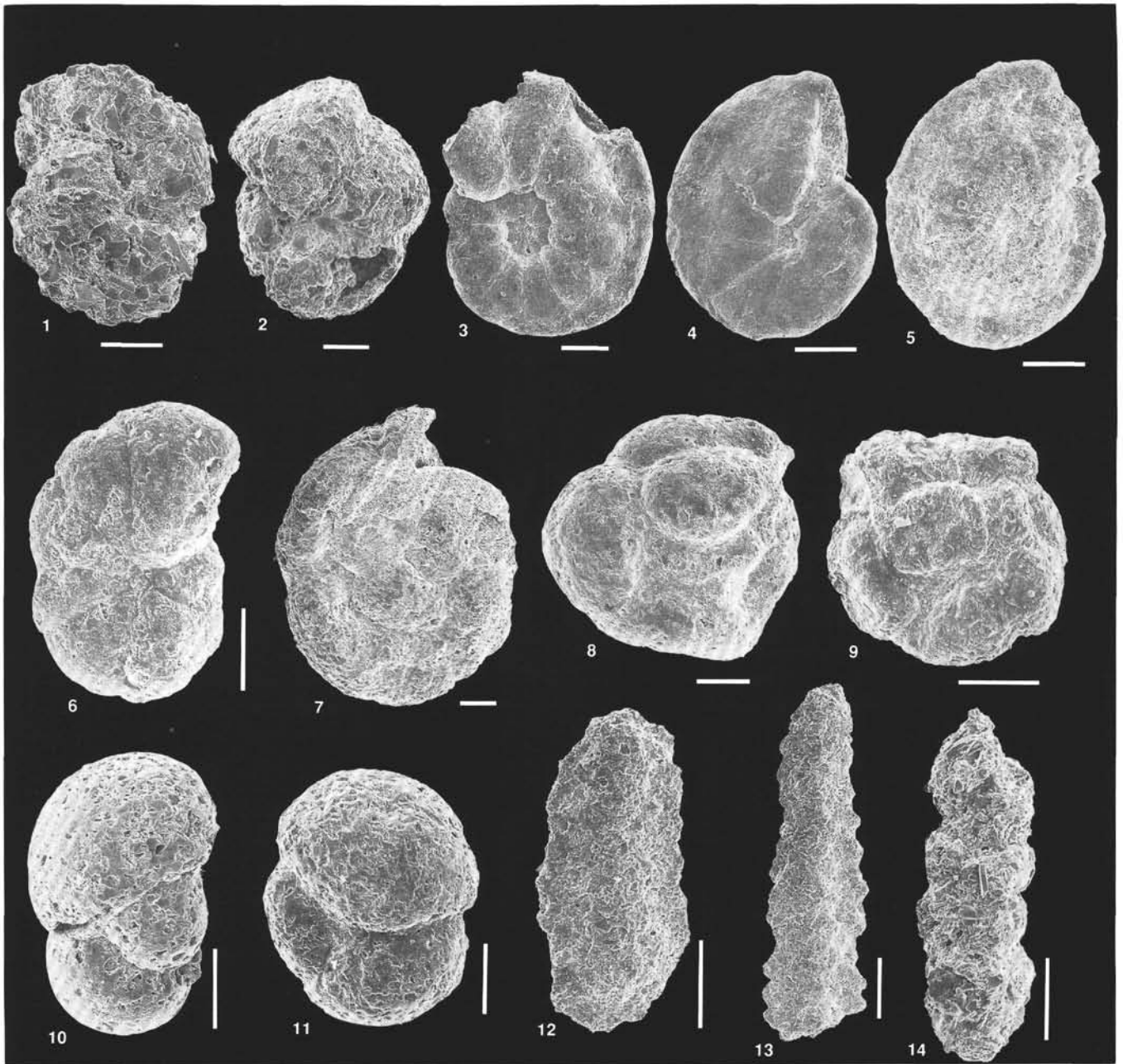


Plate 3. All scale bars = 100 μm . 1. *Cribrostomoides* sp., Sample 124-767B-77X-2, 30–34 cm. 2. *Haplophragmoides horridus* (Grzybowski), Sample 124-767C-6R-5, 13–17 cm. 3. *Haplophragmoides walteri excavatus* Cushman and Waters, Sample 124-767C-11R-2, 57–60 cm. 4. *Haplophragmoides walteri walteri* (Grzybowski), Sample 124-767C-6R-1, 22–25 cm. 5. *Reticulophragmium amplexens* (Grzybowski), Sample 124-767B-75X-1, 45–48 cm. 6. *Cyclammina placenta* (Reuss), Sample 124-767C-9R-1, 72–77 cm. 7. *Paratrochamminoides* sp., Sample 124-767C-11R-1, 54–57 cm. 8. *Paratrochamminoides* sp., Sample 124-767C-11R-1, 54–57 cm. 9. *Trochamminoides variolarius* (Grzybowski), Sample 124-767B-76X-6, 6–9 cm. 10. *Praecystammina* sp., Sample 124-767C-9R-3, 69–74 cm. 11. *Ammosphaeroidina pseudopauciloculata* (Mjatliuk), Sample 124-767C-9R-3, 69–74 cm. 12. *Spiroplectammina spectabilis* (Grzybowski), megalosphaeric form, Sample 124-767C-9R-1, 72–77 cm. 13. *Spiroplectammina spectabilis* (Grzybowski), microsphaeric form, Sample 124-767C-9R-1, 72–77 cm. 14. *Karrerulina conversa* (Grzybowski), Sample 124-767C-6R-5, 13–17 cm.