Lower Cretaceous Benthic Foraminifera of the Indian Ocean

by

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"Felix qui potuit rerum cognoscere causas"

Virgil, Georgics 2.490

ABSTRACT

A comprehensive documentation of Berriasian to Albian benthic foraminiferal assemblages from Indian Ocean DSDP and ODP sites is compiled, which provides a unified taxonomic data base for the Indian Ocean. The benthic foraminiferal assemblages are strongly cosmopolitan, but differ from typical low latitude Tethyan assemblages by the rarity or absence of some characteristic Tethyan lineages. Marked faunal differentiation or endemism is suggested in the Cuvier Basin by the unique composition of agglutinated assemblages at Site 263, which include five new species and numerous taxa not recorded at other Indian Ocean sites.

The chronostratigraphy of DSDP and ODP Indian Ocean sites is revised. New ages are determined, which considerably improve the stratigraphic resolution of intervals, previously dated as undifferentiated Aptian or Albian. An older Valanginian to Barremian age is also established for the base of Hole 263. None of the existing benthic foraminiferal zonal schemes are found to be applicable in the Lower Cretaceous of the Indian Ocean. A new biostratigraphic scheme is proposed, which enables the correlation of Lower Cretaceous sedimentary sequences in the Indian Ocean.

Palaeoecological interpretations, derived from quantitative analyses of benthic foraminiferal distribution patterns and morphogroup analyses, indicate a marked differentiation in palaeoenvironments along the western and northwestern margins of Australia. Diversity and specific distribution appear strongly influenced by margin subsidence, oceanic circulation patterns, and inferred changes in the depth of the CCD during the Early Cretaceous. Three main transgressive pulses are detected in the Barremian, late Aptian and late early Albian. Productivity fluctuations in the Aptian and Albian probably reflect changes in deep-water circulation and in the nutrient and oxygen budget of an ocean already susceptible to dysoxia. Well ventilated conditions became established during the late early to mid Albian, when a significant drop in CCD occurred, before dysoxic conditions returned to some marginal sites in the late Albian.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

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CHAPTER 1. *Introduction*

Over the last three decades, the Deep Sea Drilling Project (DSDP) and its successor, the Ocean Drilling Program (ODP), have allowed unprecedented access to the sedimentary record of the deep ocean. The scientific study and synthesis of data acquired from this project is a high scientific priority, yet, ODP investigations are often restricted in scope by the limited time schedule available for the preparation of publications and by the need to focus on individual research projects (Lazarus, 1995). Synthetic approaches are, therefore, rarely undertaken, and the vast data set, which has been generated from DSDP and ODP drillholes, remains to be exploited to its full potential.

The biogeographic distribution of various marine organisms in Lower Cretaceous sedimentary sequences has enabled palaeontologists to recognize the existence of two main bioprovinces: a boreal bioprovince in high northern latitudes and a Tethyan bioprovince in low tropical latitudes. The presence of a third main bioprovince, the austral bioprovince, which may have been the southern hemisphere equivalent to the cool boreal bioprovince in the northern hemisphere, is, however, rarely mentioned in the literature, as research traditionally centred on boreal and tropical assemblages. For a long time, the Cretaceous foraminiferal microfaunas from Australia and Madagascar were viewed as unusual and endemic (Crespin, 1944; 1953; 1963; Espitalié and Sigal, 1963; Ludbrook, 1966). Even now, relatively little is known about the microfaunas from the southern oceans and about their relationship to those of the Tethyan and boreal bioprovinces during the Early Cretaceous. The recovery of Lower Cretaceous sedimentary sequences from DSDP and ODP sites in the Indian Ocean has, fortunately, provided new material for studying the distribution of foraminifera in the high southern latitudes. Well-preserved, diversified assemblages have been recovered from Berriasian to Albian sediments in the Indian Ocean, in contrast to the Aptian-Albian impoverished, marginal assemblages previously documented from epeiric basins on mainland Australia (Crespin, 1953; 1963; Ludbrook, 1966; Playford, Haig and Dettmann, 1975; Haig, 1979^{a}; 1979^{b}; 1980; 1982). The foraminifera from Indian Ocean DSDP and ODP sites, therefore, offer a unique insight into the composition of high southern latitude benthic foraminiferal assemblages during the Early Cretaceous.

Unlike planktonic foraminifera, benthic foraminifera showed remarkable diversity during the Early Cretaceous, having radiated since the Palaeozoic to occupy most niches in the marine ecosystem. In the Lower Cretaceous of the Indian Ocean, benthic foraminifera represent one of the few microfossil groups to possess a relatively complete stratigraphic record. However, most previous studies of Lower Cretaceous benthic foraminifera from Indian Ocean DSDP holes were often only preliminary reports or isolated investigations, which lacked and integrative approach. and did not provide a consistent taxonomic data base. Even the more recent ODP foraminiferal studies were quite selective and benthic foraminiferal data from the Lower Cretaceous of Indian Ocean sites are, consequently, fragmentary. Developing a reliable zoological nomenclature and refining the basic biostratigraphic and palaeoenvironmental tools are, therefore, essential prerequisites for correlating sedimentary sequences in an interval, which contains some of the richest hydrocarbon source rocks, but, where other microfossils are often rare or absent, and for monitoring environmental change during a period dramatically affected by climate and sea-level changes.

In modern and ancient environments, the composition of benthic foraminiferal assemblages can provide valuable data on original hydrographic conditions such as depth, salinity, temperature, oxygenation, water chemistry and energy regime (Altenbach *et al.*, 1988; Murray, 1990; 1991; Gooday, 1994). Benthic foraminifera can also be sensitive monitors of environmental parameters such as organic flux (Herguera & Berger, 1991; Altenbach, 1992; Kuhnt, 1992) and quantitative analyses of foraminiferal accumulation rates and population structure can be used to constrain the timing of oceanographic events (Kuhnt and Kaminski, 1989; Kuhnt and Moullade, 1991). Our understanding of the early palaeoenvironments in the Indian Ocean is at present extremely limited, however, and interpretations of the ocean's evolution during the Early Cretaceous are still very tentative. The Early Cretaceous was characterized by global temperature and sea level rises, which had far-reaching consequences for the evolution of marine organisms and for the biosphere as a whole. Although it may be far too simplistic to extrapolate from the Early Cretaceous "Greenhouse" scenario to predict incipient climatic and oceanic changes, it is vital to determine how ancient oceans evolved, in order to understand the interactions between the main parameters regulating climate and oceanic circulation and to devise realistic models of ocean evolution. Benthic foraminifera can offer us invaluable information to retrace past circulation patterns in the deep sea and to constrain relevant evolutionary models.

The Lower Cretaceous foraminiferal assemblages of the Indian Ocean provide, therefore, a unique opportunity to investigate the evolution of the Indian Ocean from its early rifting phase in the late Jurassic, when the supercontinent Gondwana started to fragment, to its mature stage in the late Albian, when it had become a vast ocean, with deep, open connections to other major oceans of the world. No comprehensive synthesis of the Indian Ocean benthic foraminifera has been attempted to-date and there is an urgent need to revise the original biostratigraphic and palaeoenvironmental interpretations of the DSDP holes and to integrate data from the more recently drilled ODP holes.

Objectives

The primary objective of this work is to provide a detailed taxonomic, biostratigraphic and palaeoenvironmental synthesis of the Lower Cretaceous benthic foraminiferal assemblages from Indian Ocean DSDP and ODP sites, in comparison with Tethyan and boreal assemblages, which have been more extensively investigated. This synthesis will help to standardise the taxonomy of benthic foraminifera from Indian Ocean sites, refine the correlations of Lower Cretaceous sedimentary sequences and provide essential palaeoecological data for interpreting the early evolution of the Indian Ocean. The detailed objectives of my research are outlined below.

1. To compile a comprehensive taxonomic documentation of Lower Cretaceous benthic foraminifera from DSDP and ODP holes of the Indian Ocean.

2. To present a biostratigraphic reappraisal of Lower Cretaceous sedimentary sequences from Indian Ocean DSDP and ODP sites, and to investigate the applicability of existing benthic foraminiferal zonal schemes for the Indian Ocean.

3. To derive palaeoenvironmental interpretations from quantitative analyses of benthic foraminiferal distribution patterns, and to define the succession of benthic foraminiferal biofacies at individual DSDP and ODP sites during the Early Cretaceous.

4. Finally, to provide a palaeoceanographic synopsis, based on new benthic foraminiferal data, aiming to retrace the evolution of the Indian Ocean during the Early Cretaceous.

CHAPTER 2. *Background*

2.1. INTRODUCTION

The sedimentary and tectonic evolution of the northwestern Australian margin has been extensively investigated and overviews of its geological development were given most recently by Boote and Kirk (1989), Gradstein and von Rad (1991), Exon *et al.* (1992), Haq *et al.* (1992), von Rad *et al.* (1992^{a}; 1992^{b}), Buffler, 1994, Exon (1994), Exon and Colwell (1994), Exon and von Rad (1994), Gopala Rao *et al.* (1994), Labutis (1994) and Ramsay and Exon (1994). The geology of the western Australian margin is not so well documented, but depositional synopses of the Carnarvon and Perth Basins, off Western Australia, were presented by Hocking (1990) and Cockbain (1990), respectively, and by Baillie *et al.* (1994). Much less is known about the formation of oceanic crust and the accumulation of sediments in the deeper Indian Ocean. Most seismic and sedimentological studies on the Lower Cretaceous of the Indian Ocean are included in the DSDP and ODP Reports by Simpson, Schlich *et al.* (1974), Veevers, Heirtzler *et al.* (1974), Davies, Luyendyk *et al.* (1974), Haq, von Rad, O'Connell *et al.* (1990), Ludden, Gradstein *et al.* (1990), von Rad, Haq *et al.* (1992) and Gradstein, Ludden *et al.*. (1992). The structural and magmatic evolution of the Indian Ocean during the Early Cretaceous was also recently discussed by Duncan and Storey (1992), Hopper *et al.* (1992), Colwell *et al.* (1994) and a middle to Late Cretaceous history of the Indian Ocean was compiled from DSDP and ODP Results by Holmes and Watkins (1992). Palaeoceanographic interpretations, however, remain sketchy and speculative, based on scant knowledge of hydrographic conditions, circulation patterns and sea level change in the nascent Indian Ocean.

2.2. GEOLOGICAL SETTING

2.2.1. Early oceanic evolution

The fragmentation of the Gondwana supercontinent was initiated in the Jurassic and led to the birth of the Indian Ocean in the Early Cretaceous. A narrow seaway first opened between Africa and India in the Callovian (Holmes and Watkins, 1992); two major episodes of rifting followed in eastern Gondwana during the Late Jurassic and Early Cretaceous as the Australian-Antarctic landmass separated from Greater India (Powell *et al.*, 1988; von Rad *et al.*, 1992^{a}). Magnetic anomalies recorded off northwestern Australia document the history of rifting in eastern Gondwana (Figure 2.1).

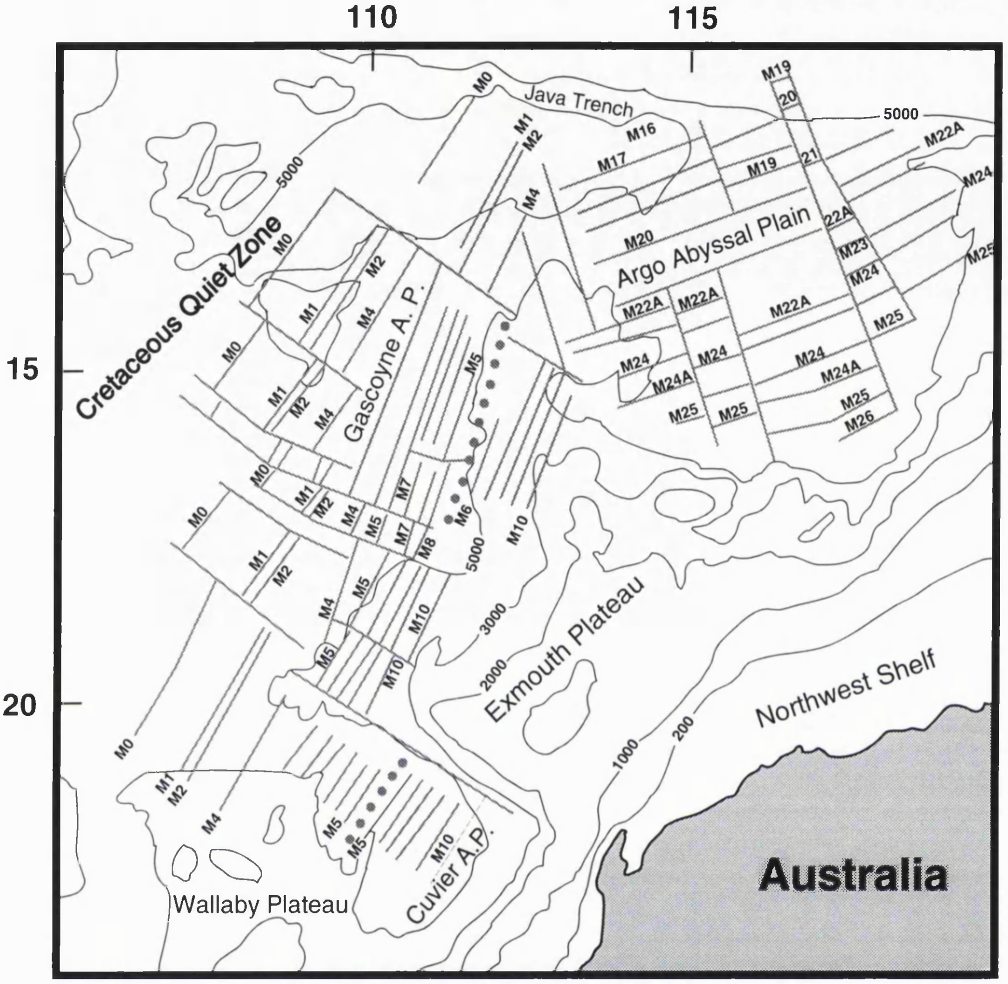


Figure 2.1. Magnetic anomalies along the northwestern Australian continental margin (redrawn after Fullerton *et al.*, 1989). Contours in metres and fossil spreading ridges dotted.

Rifting in eastern Gondwana started during the Late Jurassic, at, or before, Chron M26 (Fullerton *et al.*, 1989; Sager *et al.*, 1992) when several micro-continental plates drifted away from the northern margin of Gondwana, thus forming the Argo Basin (Figure 2.2). Seafloor spreading ceased in the Argo Basin at Chron M16 (Sager *et al.*, 1992; von Rad *et al.*, 1992^{a}) when a worldwide reorganisation of spreading systems appears to have occurred between Chron M16 and Chron M10 (Fullerton *et al.*, 1989). In the earliest Cretaceous the continental margin of northwestern Australia became uplifted, leading to the deposition of the thick, northwards-prograding sequences of the Barrow Delta on the southern Exmouth Plateau from the Berriasian to the early Valanginian (Exon *et al.*, 1992; Ogg *et al.*, 1992^{a}; Ross and Vail, 1994).

During the late Valanginian a second phase of break-up proceeded along the western margin of Australia (Powell *et al.*, 1988). The oldest magnetic anomalies in the Gascoyne, Cuvier and Perth Abyssal Plains, which were dated as Chron M10 (Larson, 1977; Larson *et al.*, 1979; Fullerton *et al.*, 1989; Veevers and Li, 1991), suggest that the initiation of seafloor spreading was virtually synchronous along the western Australian coast. Between Chron M5 and M4 the spreading ridge rotated by about 10°, clockwise, as two major ridge jumps to the west provoked the transfer of two fragments of the Indian Plate to the Australian Plate (Fullerton *et al.*, 1989; Veevers *et al.*, 1991). By late Albian, the Indian Ocean had become a vast, mature ocean with deep, open connections to other major oceans of the world.

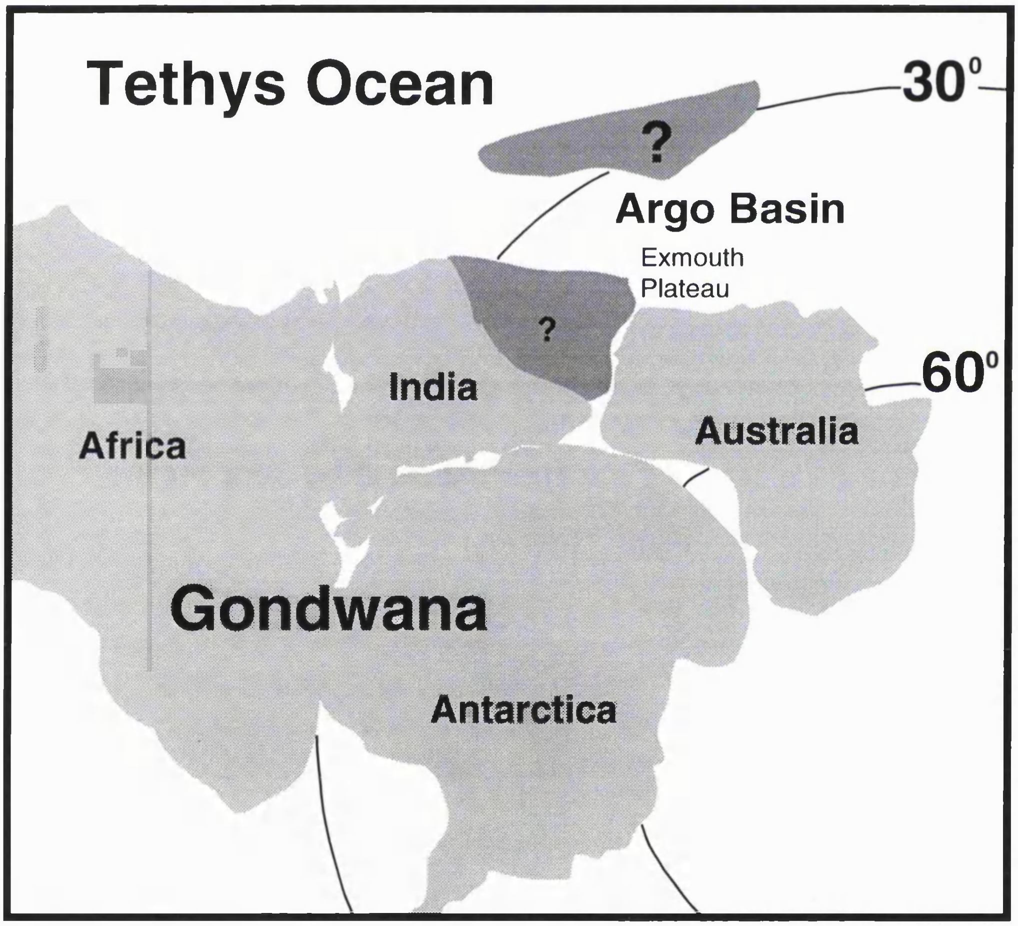


Figure 2.2. Late Jurassic palaeogeographic reconstruction of eastern Gondwana in southern hemisphere (redrawn after Ogg *et al.*, 1992^{a}).

Continental reconstructions are poorly constrained for the Early Cretaceous, mainly due to the lack of a distinctive palaeomagnetic reversal pattern (Ogg *et al.*, 1992^{a}). Two alternative models were proposed for the initial fit of continents in eastern Gondwana. One model was the "classic" du Toit (1937) reconstruction, with the southeast margin of India against Antarctica (Gradstein, 1992); the other hypothesis proposed by Ricou *et al.* (1990) suggested that southeastern India was adjacent to western Australia (Baumgartner *et al.*, 1992). Ogg *et al.* (1992^{a}; 1992^{b}) estimated palaeolatitudes between 35°S and 44°S and a clockwise rotation of about 16° for the Exmouth Plateau during the Early Cretaceous. Baillie *et al.* (1994) reported that the palaeolatitudes of Western Australia remained relatively constant, between 30°S and 50°S, during the Early Cretaceous.

2.3. FIELD AREA

Extensive Lower Cretaceous sedimentary sequences were recovered during two main phases of drilling in the Indian Ocean. The locations of all DSDP and ODP holes which penetrated Lower Cretaceous sediments are shown in Figures 2.3, 2.4 and 2.5 and in Table 2.1.

In the early seventies DSDP Site 249 (Leg 25) was drilled off the East African coast, and seven other DSDP sites were drilled off the western and northern margins of Australia: DSDP Sites 256, 257, 258 (Leg 26) and DSDP Sites 259, 260, 261, and 263 (Leg 27). Most of the Lower Cretaceous sediments recovered from these sites were dated as Aptian-Albian on the basis of microfossils, except for DSDP Sites 249 and 261 where older Valanginian-Barremian and Jurassic-Aptian sequences were also identified.

In the late eighties Berriasian to Albian sedimentary sequences were reported from two sites on the Exmouth Plateau, at ODP Sites 762 and 763 (Leg 122). Upper Jurassic to Albian sequences were recognized from ODP Site 765 (Leg 123) in the Argo Abyssal Plain, and Valanginian to Albian sequences from ODP Site 766 (Leg 123) at the foot of the Exmouth Plateau. Two small condensed intervals of Berriasian-Valanginian and Albian sediments were also recovered from ODP Site 761 (Leg 122) on the Wombat Plateau.

A summary of the lithology and chronostratigraphy of Lower Cretaceous sediments recovered from Indian Ocean DSDP and ODP sites is shown in Figures 2.6, 2.7, 2.8 and 2.9. Exhaustive descriptions are found in the Initial Reports of the DSDP and ODP (Schlich *et al.*, 1974; Veevers, Heirtzler *et al.*, 1974; Davies, Luyendyk *et al.*, 1974; Haq, von Rad, O'Connell *et al.*, 1990; Ludden, Gradstein *et al.*, 1990).

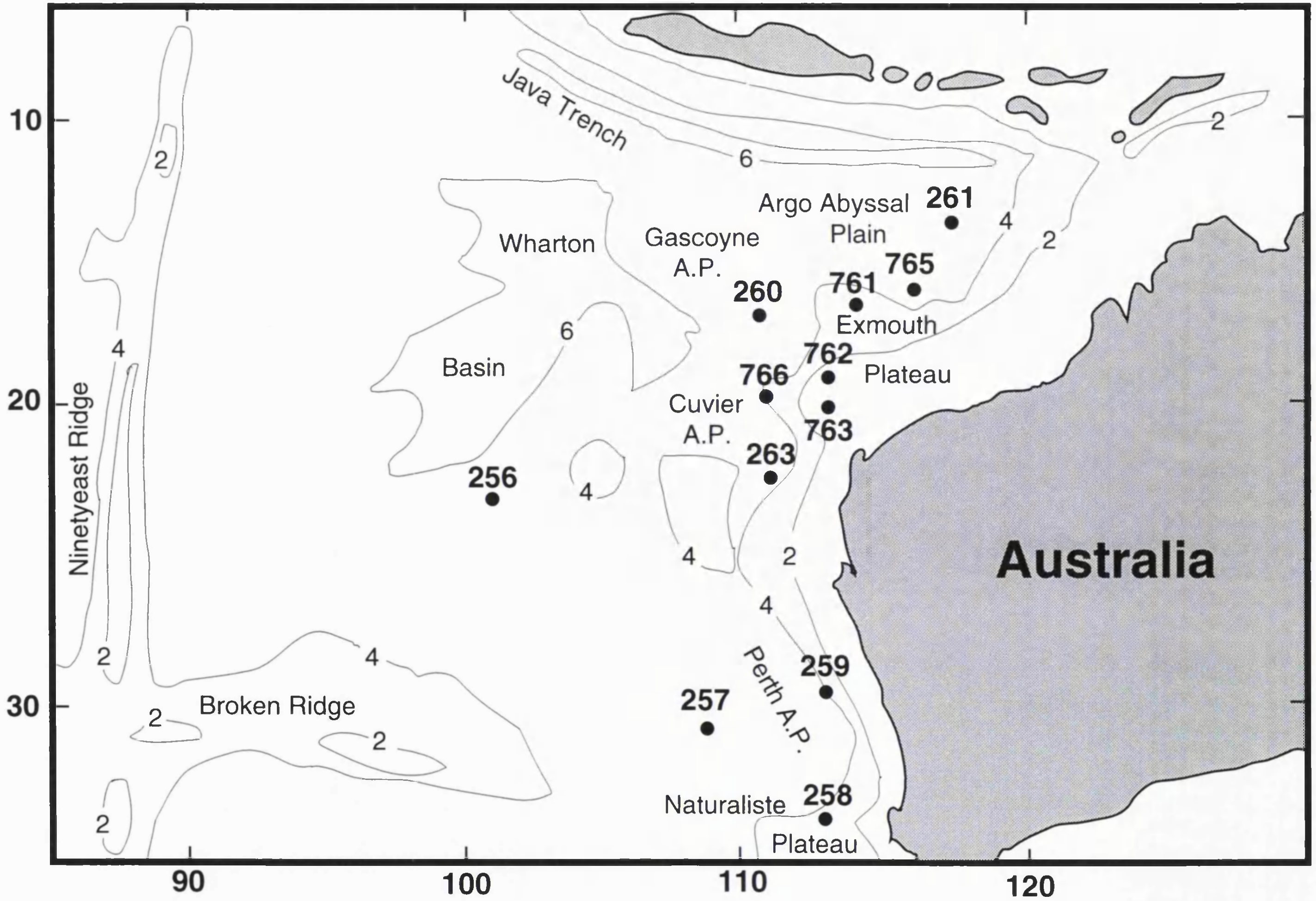


Figure 2.3. Location of DSDP and ODP Sites 256, 257, 258, 259, 260, 261, 263, 761, 762, 763, 765 and 766 (bathymetric contours in km).

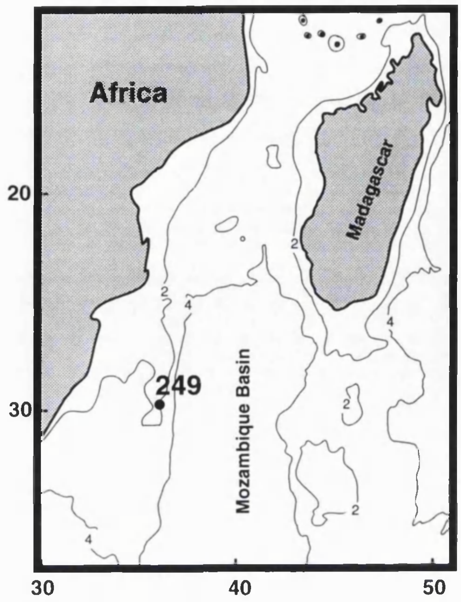


Figure 2.4. Location of DSDP Site 249 (bathymetric contours in km).

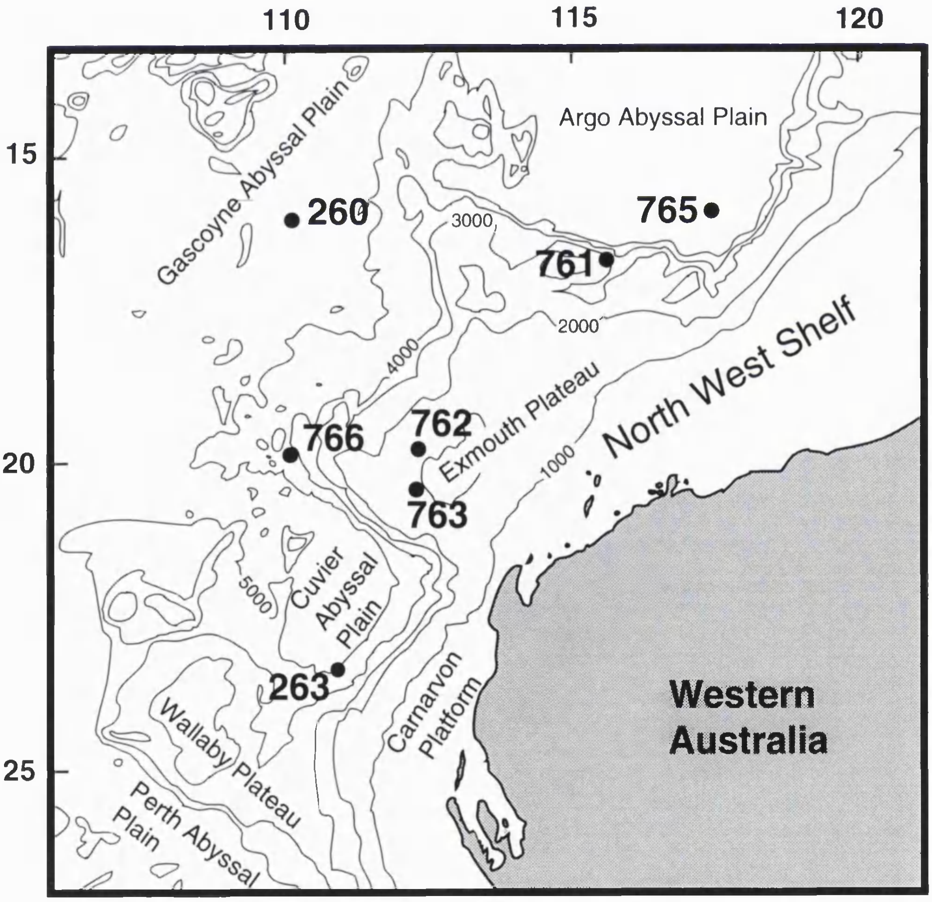


Figure 2.5. Location of DSDP and ODP sites off northwestern Australia (bathymetric contours in m).

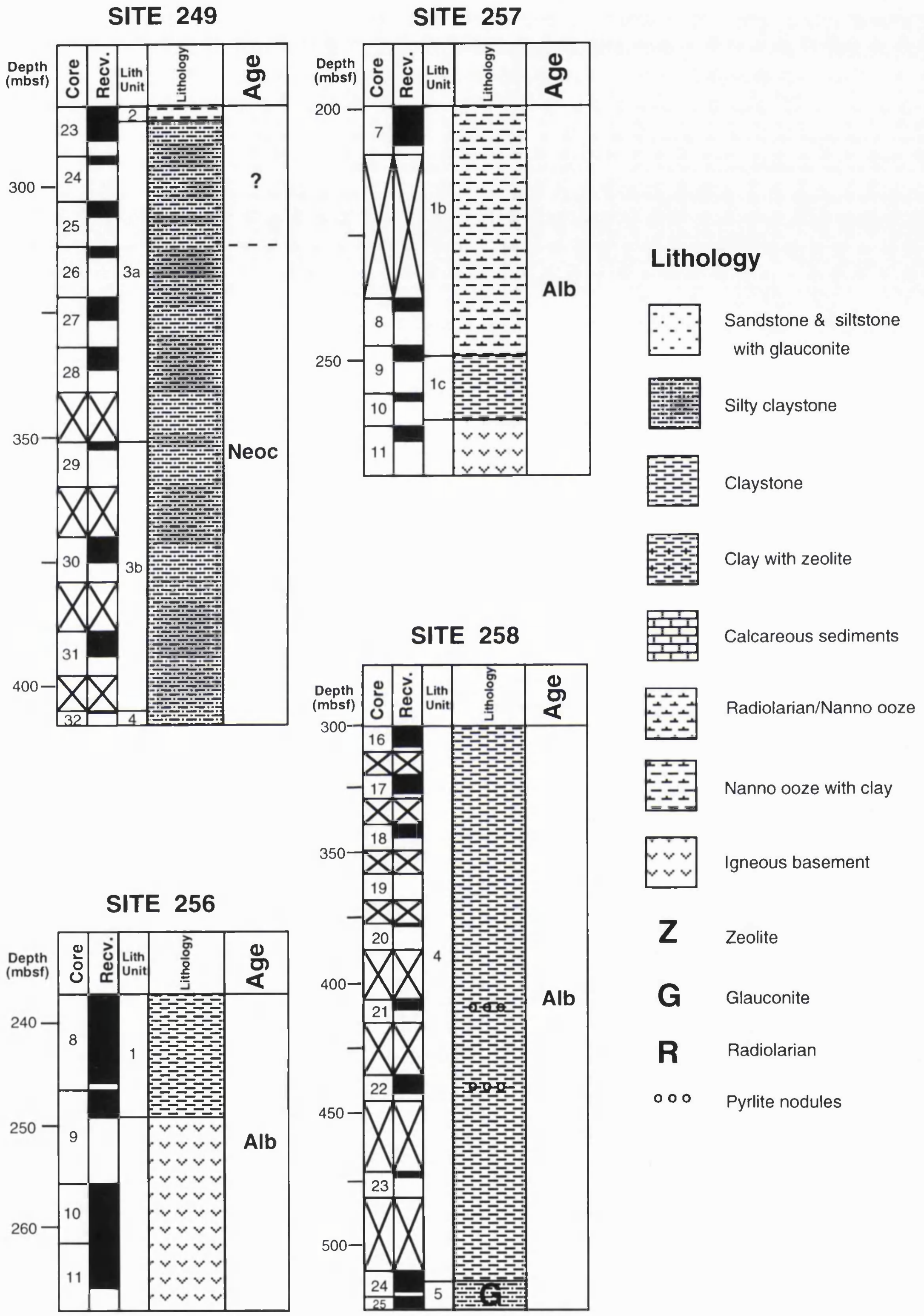


Figure 2.6. Lower Cretaceous lithostratigraphy for Holes 249 (Leg 25), Holes 256, 257, 258 (Leg 26), compiled from Schlich *et al.* (1974) and Veevers, Heirtzler *et al.* (1974).

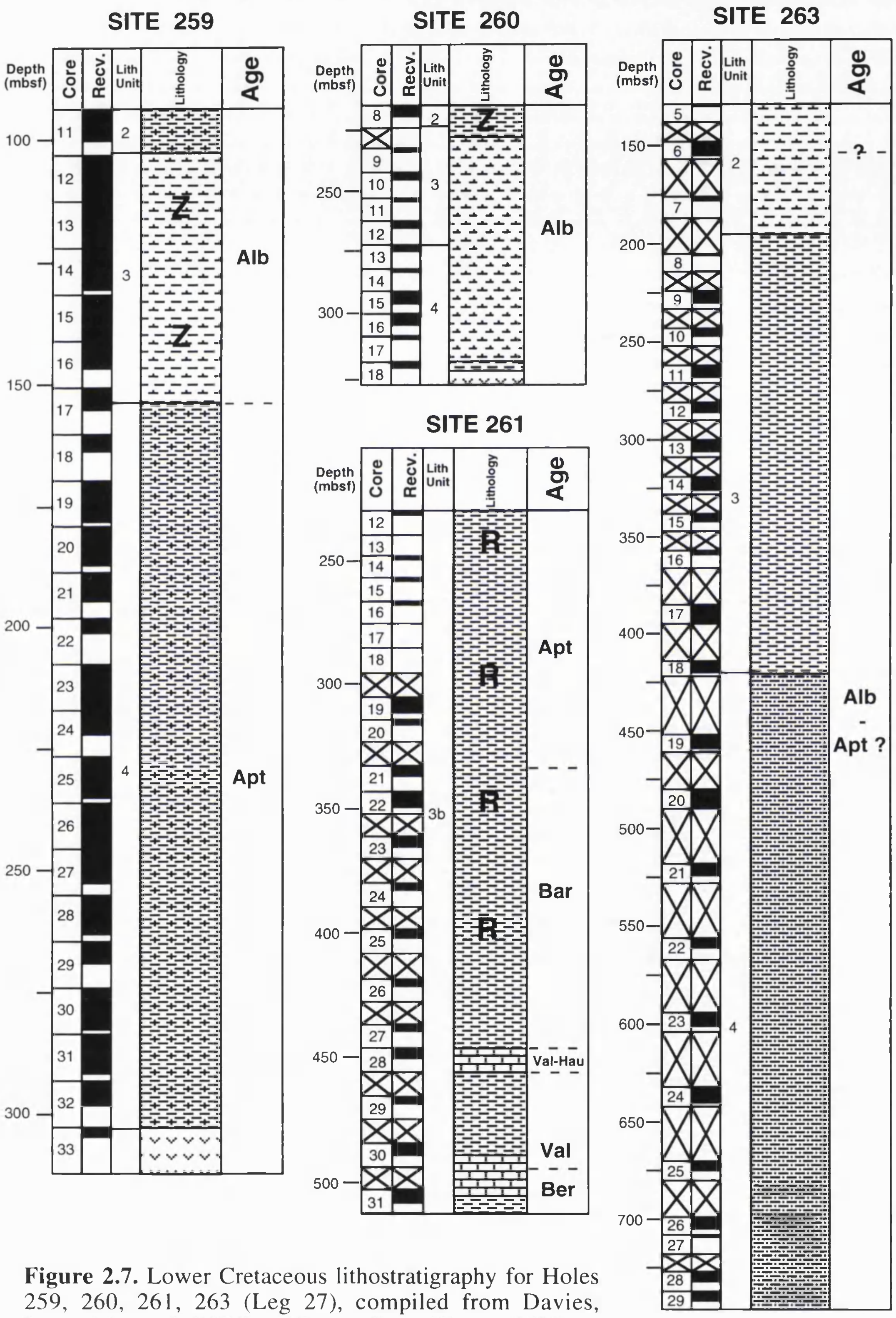


Figure 2.7. Lower Cretaceous lithostratigraphy for Holes 259, 260, 261, 263 (Leg 27), compiled from Davies, Luyendyk *et al.* (1974) and Dumoulin and Bown (1992).

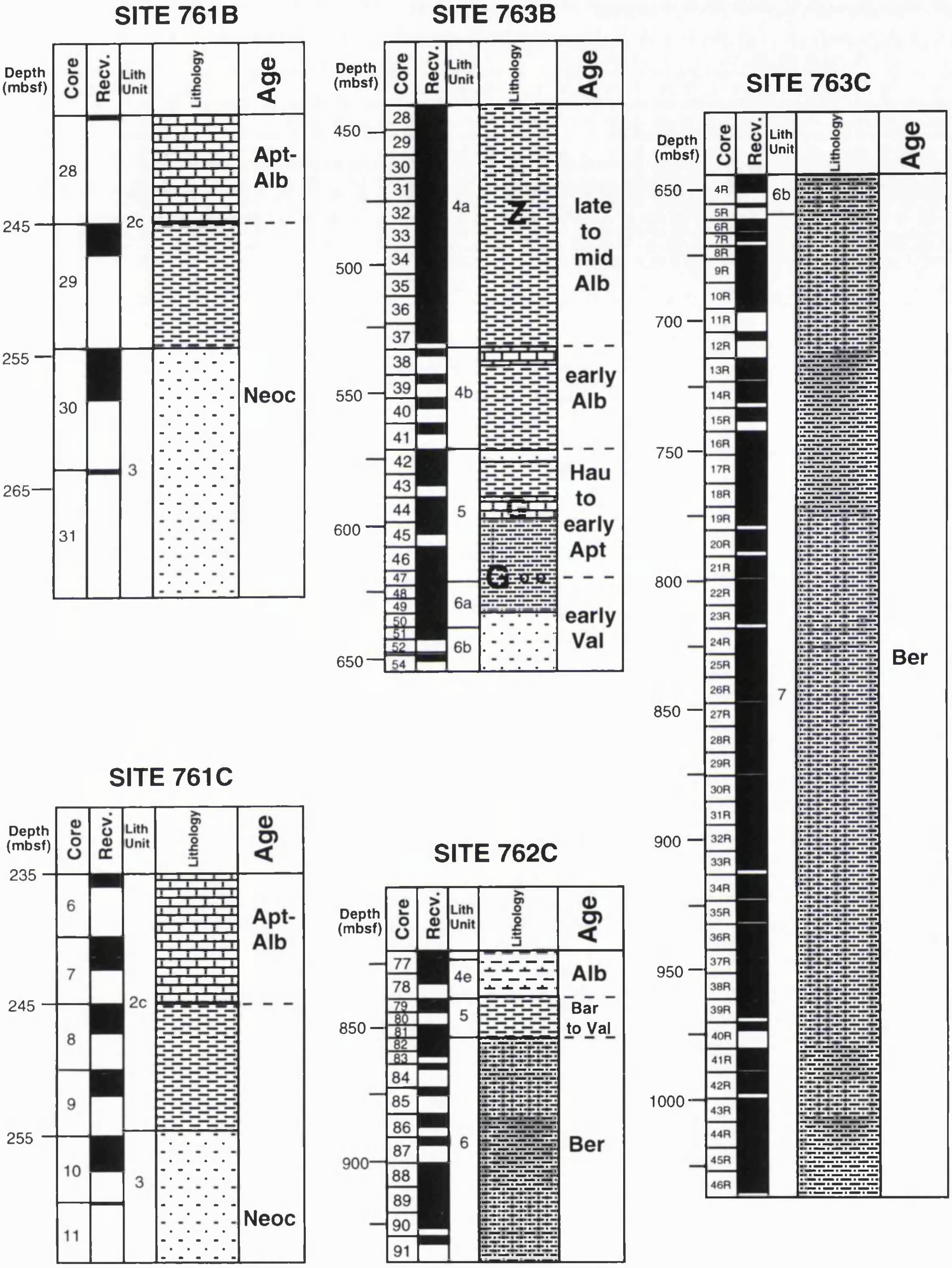


Figure 2.8. Lower Cretaceous lithostratigraphy for Holes 761, 762, 763 (Leg 122), compiled from Haq, von Rad, O'Connell *et al.* (1990).

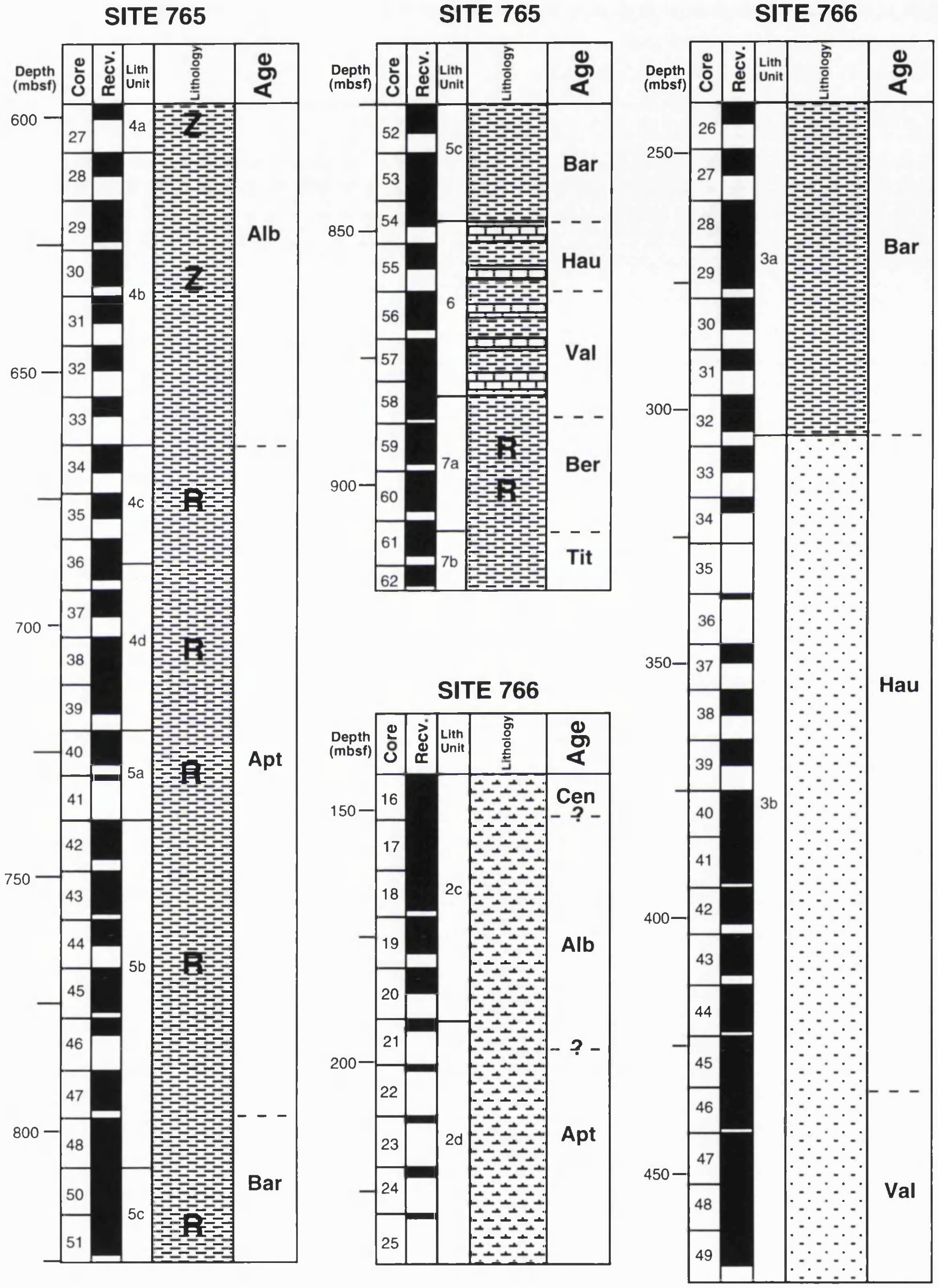


Figure 2.9. Lower Cretaceous lithostratigraphy for Holes 765, 766 (Leg 123), compiled from Ludden, Gradstein *et al.* (1990).

Table 2.1. Indian Ocean DSDP and ODP sites, where Lower Cretaceous sediments have been recovered, compiled from Schlich *et al.* (1974), Veevers, Heirtzler *et al.* (1974), Davies, Luyendyk *et al.* (1974), Haq, von Rad, O'Connell *et al.* (1990) and Ludden, Gradstein *et al.* (1990).

Leg	**Site**	**Position**	**Location**	**Depth** (m)	**Age of Lower Cretaceous sediments recovered**
25	249	29°56.99'S 36°04.62'E	Mozambique Ridge	2088	Neocomian
26	256	23°27.35'S 100°46.46'E	South Wharton Basin	5361	Albian
	257	30°59.16'S 108°20.99'E	Southeastern Wharton Basin	5278	Albian
	258	33°47.69'S 112°28.42'E	Northern flank of Naturaliste Plateau	2793	Albian
27	259	29°37.05'S 112°41.78'E	Perth Abyssal Plain	4706	Aptian-Albian
	260	16°08.67'S 110°17.92'E	Gascoyne Abyssal Plain	5712	Albian
	261	12°56.83'S 117°53.56'E	Argo Abyssal Plain	5677	Berriasian-Aptian
	263	23°19.43'S 110°58.81'E	Cuvier Abyssal Plain	5058	Aptian-Albian
122	761	16°44.23'S 115°32.10'E	Central Wombat Plateau	2179.3	Albian-Neocomian
	762	19°53.23'S 112°15.24'E	Western Exmouth Plateau	1360	Aptian-Albian Berriasian-Valanginian
	763	20°35.20'S 112°12.50'E	Western Exmouth Plateau (South of Site 762)	1367.5	Berriasian-Albian
123	765	15°58.54'S 117°34.49'E	Argo Abyssal Plain	5717.7	Berriasian-Albian
	766	19°55.93'S 110°27.24'E	Foot of Exmouth Plateau	3997.5	Valanginian-Albian

2.4. REVIEW OF BENTHIC FORAMINIFERAL STUDIES

A summary of the benthic foraminiferal studies undertaken on Indian Ocean Lower Cretaceous sediments from DSDP and ODP sites is given in Table 2.2. This table includes a brief description of the foraminiferal assemblages, their ages, the numbers of agglutinated, calcareous and new species recorded and the relevant references. Except for four studies (Scheibnerová, 1978^{c}; Riegraf, 1989; Riegraf and Luterbacher, 1989; Jones *et al.*, 1993), all investigations were originally included in DSDP and ODP Reports.

Table 2.2. Foraminiferal studies of Lower Cretaceous DSDP and ODP sediments from the Indian Ocean.

Leg	Site	Core Sections	Assemblage	Age	No of species				Reference
					Aggl.	Calc.	Total	New	
25	249	31R-26R	Calcareous benthics + "globigerinids"	Neocomian	-	15	15	-	Simpson, Schlich *et al.* (74)
		31R-26R	Calcareous benthics	Valanginian - Hauterivian	4	38	42	-	Riegraf (89)
26	256	9R-7R	Mixed A/C with intermittent planktonics	Albian	15	21	36	1	Scheibnerova (78)[c]
	257	8CC	Mixed A/C with intermittent planktonics	Albian	8	12	20	-	
	258	20R-15R	Mixed A/C with intermittent planktonics	Albian	9	16	27	-	
27	259	17CC-11CC	High diversity mixed A/C with planktonics	late Albian	15	43	58	2	Scheibnerova (74)
		18R-33R	"Primitive" agglutinated	Aptian	No data				Bartenstein (74)
	260	11CC-8CC 18R-12R	High diversity mixed A/C with planktonics at top Low diversity agglutinated only at base	mid-late Albian late Aptian-early Albian	18	24	42	-	Scheibnerova (74)
	261	33R-29R	"Primitive" agglutinated	Barremian-Valanginian	No data				Bartenstein (74)
		35CC?-29CC	High diversity predominantly agglutinated	Valanginian	37	49	86	-	Kuznetsova (74)
		32R-28R	High diversity mixed A/C	Valanginian-Hauterivian	21	14	35	-	Riegraf & Luterbacher (89)
	263	10CC-5CC 29CC-11CC	Low diversity agglutinated only at top High diversity mixed A/C at base	late Aptian-early Albian Aptian	32	30	62	-	Scheibnerova (74)
		17R-5R 29R-18R	Low diversity at top Predominantly agglutinated Very high diversity at base	Aptian-Albian Valanginian-Barremian	66	31	97	5	Holbourn & Kaminski (in press)[b]
122	761	29X-31X 7R-11R	No data	late Berriasian-early Valanginian	No data				Haq, von Rad, O'Connell *et al.* (90)
	762	91X-81X	Low diversity mixed A/C	Berriasian-Valanginian	6	6	12	-	Jones & Wonders (92); Jones *et al.* (93)
	763	45R-4R 54R-46R	High diversity mixed A/C	Berriasian-Valanginian	21	22	43	-	
123	765	62R-47R	High diversity agglutinated at base with rare calcareous	Berriasian-Aptian	66	21	87	-	Kaminski *et al.* (92)[a]
	766	25R-16R	High diversity mixed A/C with planktonics	Aptian-Albian	13	55	68	-	Haig (92)
		49R-24R	Very high diversity mixed A/C (predominantly calcareous)	late Valanginian-Barremian	28	88	116	-	Holbourn & Kaminski (in press)[a]

2.4.1. Taxonomy and biostratigraphy

The initial investigations were originally quite uneven and were followed by few studies, though Bolli and Saunders (1977) and Scheibnerová (1977) both wrote biostratigraphical summaries of DSDP assemblages. In some early works the description of the foraminiferal assemblages is incomplete: for instance, no foraminiferal data were given for some core sections from Sites 257, 258 (Scheibnerová, 1978^{c}) and 259 (Bartenstein, 1974) and the taxa from these and other DSDP sites were only selectively described and illustrated. There are also some inconsistencies: for example, a more recent study of core sections from Site 249 by Riegraf (1989) gave very different results from the original site report (Simpson, Schlich *et al.*, 1974). No planktonics were found by Riegraf, and only one of his 42 species occurred in common with the taxa originally listed in the site report. The findings at Site 261 by Riegraf and Luterbacher (1989) also differed markedly from Kuznetsova's initial results (1974). Thirty-five species were reported by Riegraf and Luterbacher, whereas Kuznetsova listed 86 taxa; only seven species were common to both studies. The discrepancies in the published data can be attributed to several factors:

1) the studies were completed over a twenty-year period during which the taxonomy, biostratigraphy and palaeoecology of foraminifera, especially of agglutinated forms, progressed considerably.

2) many studies were carried out by researchers working in isolation and the taxonomic schemes used may have lacked consistency.

3) some acute problems of systematics still remain, especially among the nodosariids, which show great variability and among the gavelinellids and agglutinated forms, whose taxonomy is very confused.

The genera and species numbers of calcareous and agglutinated foraminifera at all sites, where published data were available, are tabulated in Tables 2.3 and 2.4, respectively. The tables have been compiled from the most comprehensive references listed in Table 2.2, and taxonomic bias has been minimised by using single generic and specific names, where synonymy of taxa can be proven. Tables 2.3 and 2.4 show that the distribution of calcareous and agglutinated taxa varies considerably: calcareous forms are predominant at Site 249, mixed calcareous/agglutinated assemblages at Sites 256, 257, 258, 259, 260, 762, 763 and 766, while agglutinated taxa dominate at Sites 261, 263 and 765. The heterogeneity of previous studies, as well as some unresolved taxonomic dilemmas do not, however, allow direct comparisons of relative diversity and generic/specific distribution between sites.

Table 2.3. Lower Cretaceous agglutinated taxa from Indian Ocean sites, compiled from references cited in Table 2.2.

FAMILY	GENUS	249	256	257	258	259	260	261	263a	263b	762	763	765	766a	766b
Astrorhizidae	*Pelosina*					1	1	1							
Bathysiphonidae	*Bathysiphon*								1	1	1	1	1		1
	Nothia									1					
Rhabdamminae	*Rhabdammina*									1			1		1
	Rhizammina							1					1		1
	Dendrophrya												1		
Psammosphaeridae	*Psammosphaera*		1						1	1			2		
	Sorosphaera							2							
Saccamminidae	*Lagenammina*									1			1		
	Saccammina									2			1		
Hippocrepinidae	*Hyperammina*		1	1	1		1	1	1	1		1	2		
	Saccorhiza							1							
	Hippocrepina							1		2			1		
Ammodiscidae	*Ammodiscoides*												1		
	Ammodiscus		2	1	2	2	2	2	2	4		1	5		2
	Arenoturrispirillina												1		
	Ammolagena							1		1			1		
	Ammovertella							1							
	Glomospira		1	1		1	1	2	1	3		1	5	1a	2
	Glomospirella	1						1		1		1	1	1	1
	Turritellella												1		
Rzehakinidae	*Miliammina*								1						
	Psamminopelta						1		1						
Aschemocellidae	*Aschemocella*									1			1		
	Kalamopsis									1			1		1
Hormosinidae	*Hormosinella*												1		
	Reophax	2						1	1	3			4		
	Subreophax									1			1		
	Hormosina											1	3		
Haplophragmoididae	*Evolutinella*									1					
	Cribrostomoides									1					
	Haplophragmoides		1	1	1	1	2	2	4	3	1	3	6		5
	Labrospira		1	1											
Lituotubidae	*Lituotuba*							1		1			1		
	Trochamminoides												1		
	Paratrochamminoides									1			1		
Lituolidae	*Ammobaculites*	1	1	1	1			1	4	2		1			1
	Ammomarginulina											1			
	Placopsilina							1							
Ammosphaeroidininae	*Ammosphaeroidina*									1				1	
	Praecystammina											1	1		
	Thalmannammina									1					
	Recurvoides		1							2			2		1
Ammobaculinidae	*Bulbobaculites*							3b		2		1b	1		2
Spiroplectamminidae	*Ammobaculoides*									1			1		
	Heterantyx					1c								1	
	Spiroplectammina						1		1			1	1		
	Spiroplectinella													1	
Textulariopsidae	*Aaptotoichus*									2					1
	Textulariopsis									1					
	Bimonilina									2					
Pseudobolivinidae	*Pseudobolivina*														
Trochamminidae	*Paratrochammina*				1								1		
	Trochammina						1	6	3	4		1	3		2
Dorothiidae	*Protomarssonella*										1				
Verneuilinidae	*Pseudoreophax*									1			1		1
	Uvigerinammina												1		
	Verneuilinoides					1		1	1	2		1	2		1
	Gaudryina		1	1	1	1, 1d, 1e	2, 1e		1	1			2	1	
	Gaudryinopsis									1					
	Pseudogaudryinella									1				3	1
	Verneuilina		1	1	1	2	1		1	1					1
	Tritaxia		1			1f	1f							1	
Globotextulariidae	*Remesella*		1			1g	1g			1				1	1
	Verneuilinulla									2					
Eggerellidae	*Dorothia*					1, 1h	1	3	1					1	1
	Marssonella				1			1	1	1				1	1
	Eggerella					1	1						1		
	Karreriella								1						
	Praedorothia												3		
Textulariidae	*Bigenerina*							1	2				1		1
	Textularia		2					2	3	1	1	3	1		1
	Planctostoma								1						
Uncertain Status	*Caudammina*									1					

Table 2.4. Lower Cretaceous calcareous taxa from Indian Ocean sites, compiled from references cited in Table 2.2.

FAMILY	GENUS	249	256	257	258	259	260	261	263a	263b	762	763	765	766a	766b
Hauerinidae	*Quinqueloculina*		1												
	Scutuloris								1						
Robuloididae	*Falsopalmula*							1							
Ichthyolariidae	*Bojarkaella*							1							
	Lingulonodosaria													4	
Nodosariidae	*Laevidentalina*	2i				2i	1i	6i		3		2	1i	4	5
	Dentalinoides					1									
	Nodosaria	1				1			1						1
	Pyramidulina	5j	1j			2j	1j	6j	2j	2		1j	1j	3	7
	Pseudonodosaria	1						1				1		1	3
	Lingulina	5						2	2	1			1	2	1
	Frondicularia					1	1		1	2		2		1	2
	Tristix	1				1k								1l	2
Vaginulinidae	*Lenticulina*	3	1	1	1	2	5	10	4	4	1	1	7	1	12
	Marginulinopsis	2				1	2		2			1			4
	Saracenaria	2							1m	2	1	2		2	11
	Palmula	2				1									1
	Amphicoryna								1						
	Astacolus	2				1n		4	1n	1		1		3	2
	Marginulina	2				1		2	1	1				1	4
	Vaginulinopsis								1	1			2	1	4
	Citharina	3	1		1				1	1			1	3	2
	Planularia					1		1	1o	1				1	2
	Vaginulina													1	1
	Brunsvigella														1
	Psilocitharella	1						4		1		1	1	1	3
Polymorphinidae	*Eoguttulina*	1				1			1						1
	Globulina	1							2					1	3
	Palaeopolymorphina														1
	Pyrulinoides					1			1						
	Pyrulina							2					1		1
	Ramulina	1				1		1	1					1	2
	Glandulopleurostomella								1						
Ellipsolagenidae	*Oolina*					2p	1p	2p		2		4p			6
	Glandulina						1		1						
	Fissurina														1
Ceratobuliminidae	*Reinholdella*										1	1			1
	Pseudolamarckina					1	1								
Epistominidae	*Epistomina*					1		1			1		1		
Conorboididae	*Conorboides*										1	1			
Patellinidae	*Patellina*							1				1			1
	Hergottella													1	
Spirillinidae	*Spirillina*					1	1								1
Bolivinidae	*Neobulimina*					1	1							1	
	Praebulimina		2	2		1	1							2	
	Rectobulimina					1									
	Tappanina													1	
Fursenkoinidae	*Coryphostoma*					1	1							1	
Pleurostomellidae	*Ellipsoglandulina*													1	
	Ellipsoidella					1q									
	Pleurostomella		1	1	2	1				1				1	
Conorbinidae	*Conorbina*						1								
Placentulinidae	*Paalzowella*	1											1		
Bagginidae	*Valvulineria*		2	2	2	2	1								
Osangulariidae	*Osangularia*		1	1	1	1	1							1	
	Globorotalites									1					
	Charltonina		1	1	1									1	
Nonionidae	*Pullenia*		1												
Chilostomellidae	*Gubkinella*			1											
Quadrimorphinidae	*Quadrimorphina*		1r		1r									1	
Alabaminidae	*Alabamina*					1									
Gavelinellidae	*Gyroidinoides*			1		1	1								
	Gyroidina		1		1	1s	1s			1				2t	
	Berthelina					1u	1u							1	
	Gavelinella	1	1	1	1	2,1v	1		1	1			1	4	2
	Lingulogavelinella				2	2	1								
	Orithostella					1									
	Rotaliatina				1										
	Scheibnerova									1				1	
Eponidinae	*Eponides*		1		1	1	1								

Notes for Tables 2.3 and 2.4: Suprageneric classification follows Loeblich and Tappan, 1987, except for *Protomarssonella* Desai and Banner, 1987. and Brunsvigella Meyn and Vespermann, 1994.

a. *Glomospira* as *Repmanina*
b. *Bulbobaculites* as *Haplophragmium*
c. *Heterantyx* as *Spirobolivina*
d. *Gaudryina* as *Remesella*
e. *Gaudryina* as *Migros*
f. *Tritaxia* as *Clavulina*
g. *Remesella* as *Matanzia*
h. *Dorothia* as *Remesella*
i. *Laevidentalina* as *Dentalina*
j. *Pyramidulina* as *Nodosaria*
k. *Tristix* as *Tribrachia*
l. *Tristix* as *Tricarinella*
m. *Saracenaria* as *Lenticulina*
n. *Astacolus* as *Lenticulina*
o. *Planularia* as *Lenticulina*
p. *Oolina* as *Lagena*
q. *Ellipsoidella* as *Nodosarella*
r. *Quadrimorphina* as *?Discorbis*
s. *Gyroidina* as *Gyroidinoides*
t. *Gyroidina* as *Serovaina*
u. *Berthelina* as *Gavelinella*
v. *Gavelinella* as *Anomalina*

263a refers to Scheibnerová, 1974
263b refers to Holbourn and Kaminski in press[b]
766a refers to Haig, 1992
766b refers to Holbourn and Kaminski in press[a]

The disparity of the data has hindered faunal comparisons between sites and most previous studies have lacked an integrative approach. Few comparative studies of Lower Cretaceous foraminifera from the Indian Ocean have been published; three studies are listed in Table 2.5. A synthesis of early DSDP foraminiferal investigations in the Indian Ocean was presented by Scheibnerová in 1977. In her synthesis, Scheibnerová correlated the foraminiferal assemblages from the DSDP sites with coeval assemblages from epeiric basins on mainland Australia. Riegraf and Luterbacher (1989) included only two Indian Ocean DSDP sites (Sites 249 and 261) in their biostratigraphical, taxonomical and palaeoecological overview of Lower Cretaceous foraminifera from DSDP sites in the Atlantic, Indian and Pacific Oceans (Legs 1-80). Kaminski and Geroch (1992) compared the Lower Cretaceous deep-water agglutinated foraminifera (DWAF) from Sites 765 and 261 on the Argo Abyssal Plain.

The chronostratigraphy of most Indian Ocean DSDP sites is poorly defined. This is attributed to the paucity of nannofossil and calcareous foraminiferal index taxa, owing to generally poor carbonate and biosiliceous preservation. In their chronostratigraphic synthesis of the Indian Ocean DSDP sites, based on information from all microfossil groups, Bolli and Saunders (1977) regarded the chronostratigraphic resolution as questionable or poor in seven of the eight sites which recovered Lower Cretaceous. By contrast, a more reliable chronostratigraphy has been established from palynomorphs, nannofossils, radiolaria and foraminifera for Lower Cretaceous sediments from ODP Sites 762, 763, 765 and 766.

Table 2.5. Comparative studies of Lower Cretaceous foraminifera from the Indian Ocean.

Legs	Sites	Study	Reference
25-27	249 256-261	Synthesis of benthic foraminifera from DSDP Sites in the Indian Ocean	Scheibnerova (1977)
25 & 27	263 249 261	Biostratigraphy, taxonomy and palaeoecology of Lower Cretaceous benthic foraminifera from DSDP Legs 1-79	Riegraf and Luterbacher (1989)
27 &123	261 765	Biostratigraphic correlations of deep-water agglutinated foraminifera from the Atlantic, Argo Abyssal Plain and Carpathians	Kaminski and Geroch (1992)

2.4.2. Palaeoenvironments and palaeobiogeography

Scheibnerová (1974; 1977) proposed a shallow provenance for all Lower Cretaceous foraminifera from the Indian Ocean DSDP sites, suggesting that these assemblages were very similar to coeval assemblages from the epeiric seas of the Great Artesian Basin (Scheibnerová, 1976). Scheibnerová's interpretation differed markedly from Kuznetsova's (1974), who assigned an abyssal origin to the assemblages from Site 261. Jones and Wonders (1992) considered the sparse Berriasian-Valanginian assemblages from Sites 762 and 763, which were dominated by Textulariina and Rotaliina, to be diagnostic of a deltaic environment. Kaminski *et al.* (1992[a]) interpreted the Tithonian-Aptian agglutinated assemblages from Sites 765 and 261 as truly abyssal, reflecting deposition below the carbonate compensation depth (CCD). Haig (1992) ascribed an open marine environment of bathyal depth to the diverse Aptian-Albian assemblages with numerous calcareous agglutinated types from Site 766.

Scheibnerová (1971[a]; 1971[b]; 1971[c]; 1973; 1978[a]) also recognized the existence of an "austral biogeoprovince" in the southern hemisphere which included Australia, the epicontinental seas of Gondwana and the Cretaceous southern oceans. She proposed that the austral biogeoprovince supported a distinct microfauna, dominated by agglutinated taxa and small simply-ornamented calcareous forms, and that cool temperature was the main factor controlling faunal distribution. The more recent ODP foraminiferal studies by Haig (1992) and Kaminski and Geroch (1992) pointed out the cosmopolitan elements of the assemblages from Sites 766 and 765 and 261, which, together with the high diversity, supported the existence of open connections with major world oceans, allowing the dispersal of fauna from the Tethys during the Early Cretaceous. Jones and Wonders (1992) recorded many species from Sites 762 and 763, commonly found in coeval, boreal assemblages from northwestern Europe. Haig (1992) suggested that a marked surface water temperature gradient existed along the continental margin between the Exmouth Plateau and the Naturaliste Plateau during the late Albian, which strongly influenced the distribution of planktonic taxa.

CHAPTER 3. *Methods*

3.1. LABORATORY TECHNIQUES

A total of 364 samples from DSDP Sites 249, 256, 257, 258, 259, 260, 263 and ODP Sites 762, 763, 765 and 766 were examined. The number of samples from each site is shown below in Table 3.1.

Table 3.1. Summary of core sections studied from Indian Ocean DSDP and ODP sites.

Leg	Site	Core sections	No of samples
25	249	31R-4 to 25R-2	15
26	256	9R-1 to 8R-1	7
26	257	10R-1 to 7R-1	12
26	258	25R-4 to 14R-1	27
27	259	33R-1 to 11R-3	64
27	260	18R-1 to 6R-4	24
27	263	29R-4 to 4R-4	66
122	762C	91X-CC to 76X-4	17
122	763C 763B	46R-5 to 35R-6 54X-CC to 27X-3	40
123	765	49R-3 to 26R-CC	20
123	766	49R-4 to 16R-1	72

Sediment samples (approximately 20cc) were processed by repeated drying and washing in 1% Calgon solution. The washed residues were randomly divided into fractions with the help of a sample splitter; the fractions were then sieved (>250μm, >125μm and >63μm) and each picked for microfossils. When fossil abundance allowed, a minimum of 300 foraminifera was picked per sample as well as other microfossils (mainly ostracods, bivalve fragments, fish teeth and radiolarians). The picked specimens were then sorted on cardboard slides for identification. These are housed in the Micropalaeontology collections of University College London.

3.2. TAXONOMIC INVESTIGATION

Taxonomic comparisons were made with type material and foraminiferal collections housed at the Senckenberg Museum in Frankfurt (Bartenstein and Brand, 1951; Bartenstein and Kaever, 1973), at the Institute for Palaeontology and Historical Geology in Munich (Weidich, 1990), at the Australian Geological Survey Organisation in Canberra (Crespin, 1953; 1963), at the South Australian Department of Mines in Adelaide (Ludbrook, 1966), at the Geological Survey of New South Wales in Sydney (Scheibnerová 1974; 1976; 1978^c), at the University of Western Australia in Perth (Haig, 1992; Haig and Lynch, 1993; McLoughlin *et al.*, in press), at the University of Queensland in Brisbane (Playford, Haig and Dettmann, 1975; Haig and Barnbaum, 1978; Haig, 1980; 1981; 1982), at the Centre de Recherches Micropaléontologiques "Jean Cuvillier" in Nice (Moullade, 1960; 1966; Guérin, 1981) and with Lower Cretaceous foraminiferal collections from continental Europe and from Atlantic and Pacific DSDP and ODP sites, which are held at Tübingen University, Nice University and University College London. Scanning Electron micrographs were made on a Zeiss-DSM-940 SEM at the Micropalaeontology Unit of University College London.

3.3. PALAEOENVIRONMENTAL ANALYSIS

Benthic foraminiferal distribution patterns were investigated using the following parameters: species frequency, Shannon-Weaver information function, relative abundance of calcareous tests, agglutinated tests with calcareous cement and agglutinated tests with organic cement, distribution of rotaliids, lagenids and of main relevant morphogroups and relative proportion of infaunal to epifaunal/shallow infaunal foraminifera. Additional information was obtained from lithological logs, $CaCO_3$ and TOC content, associated microfossils and from published seismic and geochemical data. Backtracking calculations were applied to compute palaeodepths of sites drilled on oceanic crust. Principal Component Analysis was used to determine benthic foraminiferal biofacies trends in the Indian Ocean during the Early Cretaceous.

3.3.1. Backtracking

The initial ridge-crest depths and successive palaeoseafloor depths of sites situated on oceanic crust are determined using the empirical age/depth equation for the 70Ma to 160Ma interval (Equation 1) proposed by Parsons and Sclater (1977) and modified by Sclater *et al.* (1985) to allow correction for sediment accumulation (Equation 2).

$$d(t) = 6400 - 3200e^{(-t/62.8)}\ \mathrm{m} \qquad (1)$$

where $d(t)$ is the depth of the seafloor in metres at time t.

$$dw_1 = dw_2 + x\,\frac{(ps + pm)}{(pw - pm)}\ \mathrm{m} \qquad (2)$$

where pw, pm, ps are respectively, the water, mantle and sediment densities and dw_1, dw_2 and x are respectively the unsedimented water depth, the sedimented water depth and sediment thickness.

3.3.2. Shannon-Weaver information function

The Shannon-Weaver information function H(S), proposed by Shannon and Weaver (1949) is a measure of heterogeneity, which is frequently used as an index of diversity. It is defined by Equation 3:

$$H(S) = -\sum_{i=1}^{s} p_i \ln p_i \qquad (3)$$

where S is the number of species and p_i the proportion of the ith species (p = per cent divided by 100).

3.3.3. Morphogroup analysis

From analyses of the test shape, the mode of coiling and the presence or absence of surface pores, it has been possible to classify foraminifera into morphogroups with different life positions and feeding strategies within the sediments, reflecting microhabitat preferences related to O_2 and TOC contents (Severin, 1983; Corliss, 1985; Jones and Charnock, 1985; Bernhard, 1986; Corliss and Chen, 1988; Corliss and Fois, 1990; Rey *et al.*, 1993 and Nagy *et al.*, 1995). Infaunal morphotypes appear more tolerant of dysaerobic conditions than epifaunal ones (Kaiho, 1994; Kaminski *et al.*, 1995). They dominate in shallower environments, where sedimentation rates are high, whereas epifaunal taxa are more numerous in the deep sea, where sedimentation rates are low.

Recent studies have indicated that food and oxygen are the most influential factors regulating the distribution of benthic foraminifera (Jorissen, 1987, Jorissen *et al.*, 1992; Sjoersdma and Van der Zwaan, 1992), and it has been suggested by Tyson and Pearson (1991), Barmawidjaja *et al.* (1992) and Jorissen *et al.* (1992) that the depth of the redox potential discontinuity (RPD) affects the microhabitat preferences of benthic foraminifera. Linke and Lutze (1993) considered that the vertical distribution of foraminiferal morphotypes did not represent a static stratification of microhabitats within the sediments, but that it was a dynamic process, reflecting the need to optimize food acquisition. In dysaerobic environments, however, the primary control on foraminiferal distribution and the relative proportion of morphotypes is most probably oxygen availability.

For the purpose of interpreting palaeoenvironments of the Indian Ocean DSDP and ODP sites, benthic foraminifera have been combined into six agglutinated and six calcareous morphogroups, which are described below.

Agglutinated morphogroups

- **Tubes** comprise all tubular genera such as *Rhabdammina, Rhizammina, Hippocrepina, Nothia* and *Bathysiphon*, inferred to be semi-epifaunal suspension feeders.
- **Ammodiscids** represent epifaunal and shallow infaunal detritus feeders mainly belonging to the genera *Ammodiscus* and *Glomospira.*
- **Planispiral/streptospiral involute** morphotypes consist of planispirally and streptospirally coiled forms such as *Haplophragmoides, Recurvoides, Cribrostomoides, Thalmannammina* and *Paratrochamminoides,* which are either epifaunal or shallow infaunal dwellers.

- **Planispiral/streptospiral evolute** morphotypes *(Ammobaculites/Bulbobaculites)* are characterised by an initial planispiral or streptospiral coil, show a tendency to become evolute and generally share an infaunal mode of life.
- **Elongate tapered** forms such as *Reophax, Verneuilinoides, Aaptotoichus, Textulariopsis* and *Verneuilinulla* are regarded as infaunal detritivores.
- **Globular** forms such as *Saccammina* and *Psammosphaera* and **Trochospiral** forms such as *Trochammina,* which are less well represented in Indian Ocean assemblages, are considered to be epifaunal or shallow infaunal dwellers.

Calcareous morphogroups

- **Globular** forms include *Globulina, Ramulina* and *Oolina*, which are characteristically living on or near the sediment surface.
- **Planispiral involute** morphotypes with a planispiral and involute mode of coiling, such as *Lenticulina*, are considered to be epifaunal or shallow infaunal.
- **Planispiral evolute** forms, which have a tendency to become uncoiled and elongate, such as *Vaginulinopsis, Marginulinopsis, Astacolus* and *Saracenaria*, appear to be adapted to an infaunal mode of life.
- **Trochospiral** morphotypes can be divided into biconvex, plano-convex and rounded subgroups, including *Gavelinella, Berthelina, Gyroidina, Charltonina, Scheibnerova* and *Quadrimorphina,* which are all presumed to be epifaunal or shallow infaunal dwellers.
- **Elongate tapered** forms comprise taxa with a variety of coiling modes such as *Laevidentalina, Pyramidulina, Psilocitharella, Coryphostoma* and *Pleurostomella,* which all share an infaunal mode of life.

3.3.4. Principal Component Analysis

Principal Component Analysis has been applied to the benthic foraminiferal data from selected DSDP and ODP sites, in order to determine main biofacies patterns in the Indian Ocean during the Early Cretaceous. The programme SPSS was used on mainframe computers at University College London. This method is discussed further in Chapter 5.

CHAPTER 4. *Biostratigraphy*

4.1. INTRODUCTION

Benthic foraminifera represent one of the few microfossil groups to possess a relatively complete stratigraphic record in the Lower Cretaceous of the Indian Ocean. However, their use in biostratigraphy has previously been greatly limited by the lack of a coherent taxonomy. In the first stage of my research, I undertook detailed taxonomic investigations of the benthic foraminiferal assemblages from DSDP and ODP sites, in order to introduce a standardised nomenclature for the Lower Cretaceous of the Indian Ocean. A systematic documentation of the taxa is presented in Holbourn and Kaminski (in press[a] and [b]) and in Chapter 6, which is complementary to these two studies. A full taxonomic list of agglutinated and calcareous benthic foraminifera recorded from the DSDP and ODP sites studied can be found in Appendices 6.1 and 6.2 of Chapter 6.

The original chronostratigraphy of Lower Cretaceous sediments from Indian Ocean DSDP sites relied predominantly on nannofossils and planktonic foraminifera and was often confused and poorly defined at most sites, owing to the paucity of calcareous index taxa recovered from the cores (Bolli, 1974). In the Initial Reports of the Deep Sea Drilling Project, the age assignments derived from various microfossil groups, including benthic foraminifera, radiolaria, dinoflagellates, spores and pollen, frequently conflicted with the ages determined from nannofossil or planktonic foraminifera. By contrast, a more reliable chronostratigraphy was established mainly from palynomorphs and nannofossils, for the more recently drilled ODP sites in the Argo Abyssal Plain and on the Exmouth and Wombat Plateaux.

The purpose of this chapter is to present a biostratigraphic reappraisal of the Lower Cretaceous sedimentary sequences recovered from individual Indian Ocean DSDP and ODP sites, based primarily on new benthic foraminiferal data, and to establish correlations between all DSDP and ODP sites, which recovered Lower Cretaceous sediments in the Indian Ocean. The applicability of Boreal and Tethyan biostratigraphic zonations for the Indian Ocean sedimentary sequences, deposited in the high southern latitudes during the Early Cretaceous, is also investigated. Stratigraphic assemblages are recognized, based on changes in the composition of dominant taxa and on the occurrences of stratigraphically important species. Whenever possible, benthic foraminiferal data have been calibrated with planktonic foraminifera occurring in the samples studied and with nannofossils recently re-examined by P.R. Bown (pers. comm., 1995). The stratigraphic ranges of relevant planktonic species is plotted in Figure 4.1. Foraminiferal data for each site are given in Appendices 4.1 to 4.11.

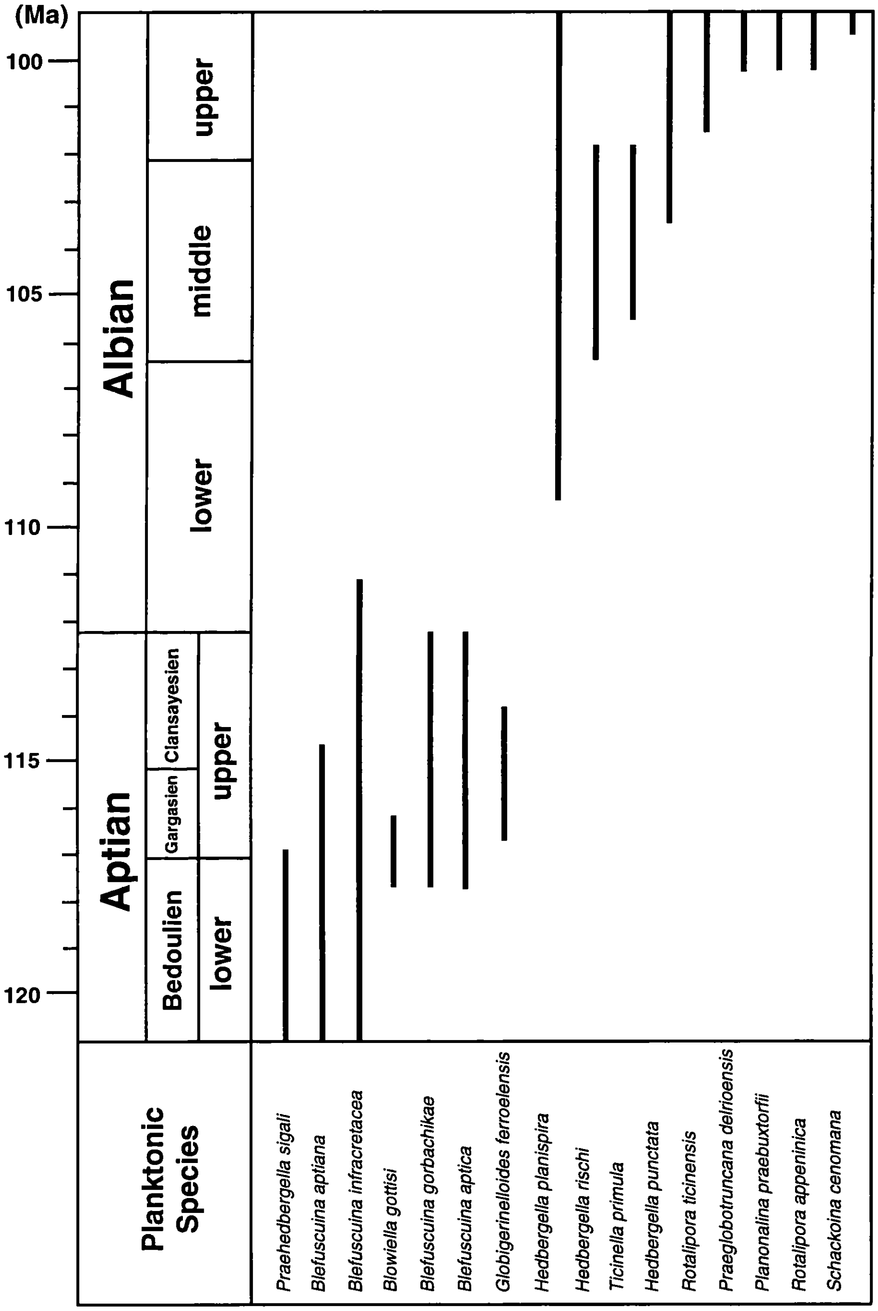


Figure 4.1. Stratigraphic ranges of selected planktonic foraminifera, compiled from Guérin (1981), Banner and Desai (1988) and Moullade (pers. comm., 1995).

4.2. DSDP SITE 249

A Neocomian age (Valanginian or Hauterivian) was assigned to the base of Hole 249 (Cores 249-31R to lower part of -26R) by the Leg 25 Shipboard Scientific Party (Simpson, Schlich *et al.*, 1974). The upper part of Core 249-26R was considered to be Barremian or "Bedoulian", based on the occurrence of small "globigerinid" forms. In a later study, Riegraf (1989) documented 42 benthic foraminiferal taxa from Site 249 and attributed a Valanginian-Hauterivian age to Core sections 249-31R-3 to -26R-2. However, Riegraf was unable to find any planktonic foraminifera in Core 249-26R and his taxonomic inventory included only one of the 14 benthic foraminifera originally listed in the site report (Simpson, Schlich *et al.*, 1974).

I have examined a total of 15 samples from Core sections 249-31R-4 to -25R-2 and distinguished two distinct stratigraphic assemblages. The assemblages and stratigraphic ranges of selected taxa are plotted in Figure 4.2.

1. *Globulina bucculenta - Astacolus* Assemblage
Core sections 249-31R-4 to -28R-3.
Age: late Valanginian to Hauterivian.
This calcareous assemblage, dominated by cosmopolitan polymorphinids and nodosariids, displays the characteristic faunal composition of late Valanginian-Hauterivian shelf assemblages. Distinctive species are *Globulina bucculenta, Globulina prisca, Globulina lacrima, Astacolus parallelus, Lenticulina nodosa, Lenticulina* cf. *schreiterei, Vaginulinopsis excentrica, Psilocitharella recta, Marginulinopsis bettenstaedti, Saracenaria pravoslavlevi, Saracenaria frankei* and *Planularia complanata.* Diversity is generally high (up to 36 species per sample), although abundance fluctuates markedly (from 529 to 12 specimens per sample), as some indurated calcareous samples are either barren or yield low numbers of specimens. Acmes of *Globulina bucculenta* and *Astacolus parallelus* are observed in Sample 249-31R-2; 103-106; the FO of *Gavelinella aff. barremiana* and the LO of *Lenticulina* cf. *schreiterei* are noted in Sample 249-30R-2; 90-93.

2. *Gavelinella barremiana - Planularia crepidularis* Assemblage
Core sections 249-28R-1 to -26R-2.
Age: early Barremian
The base of this assemblage is characterized by the FO of *Gavelinella barremiana.* An acme of *Planularia crepidularis* is also observed in Sample 249-28R-1; 80-83. This calcareous assemblage contains many species, already recorded in Assemblage 1. Nodosariids initially dominate the assemblage as polymorphinids remain low in numbers. However, the number of rotaliids increases dramatically in Sample 249-

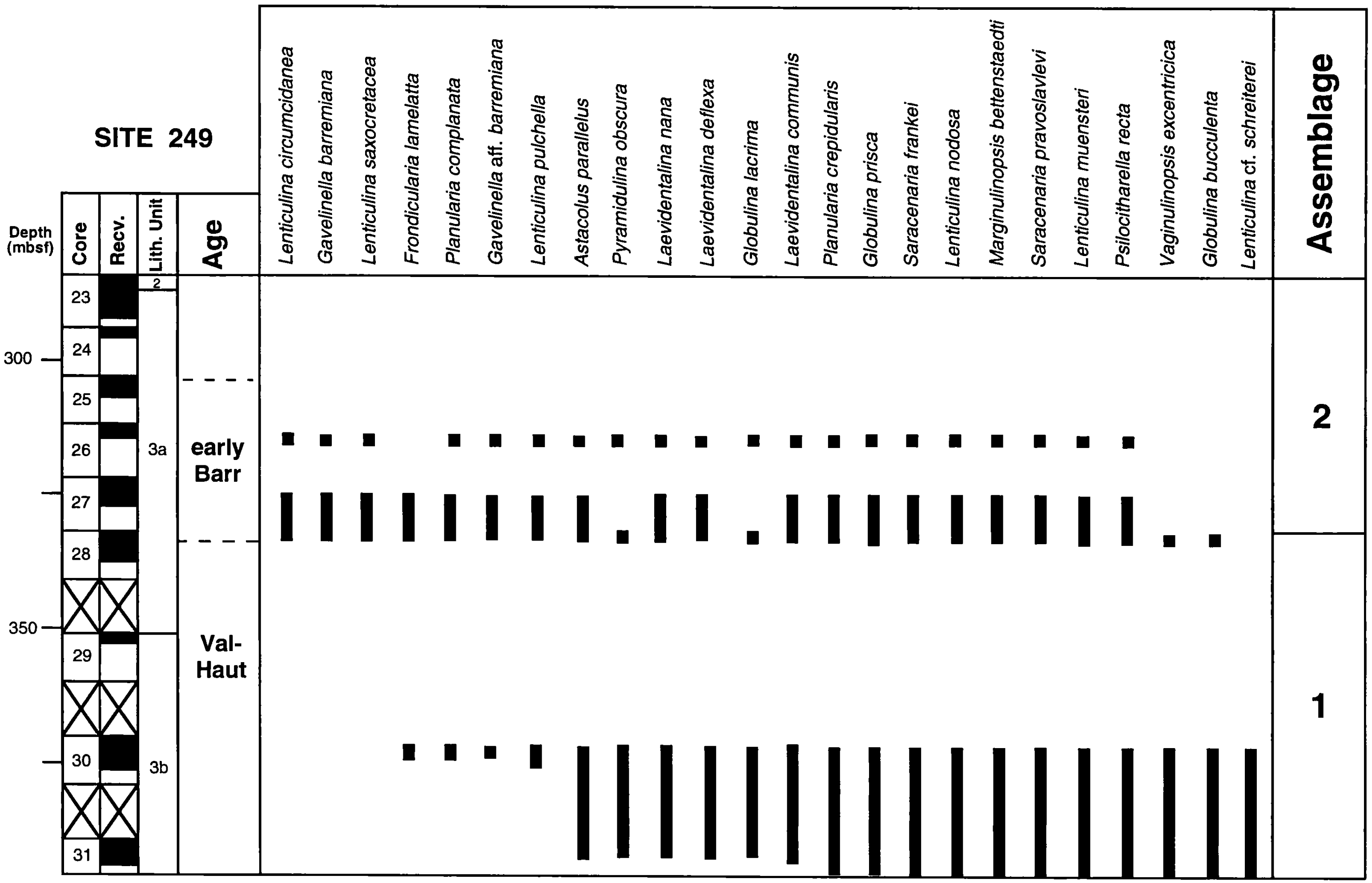


Figure 4.2 . Statigraphic ranges of selected benthic foraminifera from Site 249 (core recovery shaded black).

26R-2; 43-46, where the acme of *Gavelinella barremiana* is observed. Diversity is high, ranging from 32 to 48 species per sample, while abundance fluctuates markedly as several indurated calcareous intervals are devoid of foraminifera.

4.3. DSDP SITE 256

The benthic foraminifera recovered from Cores 256-8R and -9R were initially described as "sparse assemblages of primitive arenaceous foraminifera" and were not considered to be age diagnostic (Davies, Luyendyk *et al.*, 1974). The original age assignment for this interval was based primarily on nannofossils from the *Eiffelithus turriseiffeli* Zone, which indicated an upper Albian age according to Thierstein (1974).

Seven samples from Core sections 256-9R-1 to -8R-1 have been examined and one main benthic foraminiferal assemblage has been recognized. The stratigraphic ranges of selected taxa are plotted in Figure 4.3, which also shows the benthic foraminiferal assemblages.

1. *Heterantyx cretosa* - *Spiroplectinella gandolfii* Assemblage

Core sections 256-9R-1 to -8R-1.

Age: late Albian.

This assemblage contains a mixture of calcareous and agglutinated taxa, which includes many cosmopolitan Albian taxa such as *Tritaxia gaultina, Gyroidina infracretacea, Gyroidina gracillima, Osangularia schloenbachi, Praebulimina nannina, Charltonina australis, Gaudryinopsis gradata, Pleurostomella reussi, Quadrimorphina allomorphinoides, Psilocitharella paucistriata* and *Psilocitharella recta.* The presence of *Scheibnerova protindica*, only recorded in the upper Albian and Cenomanian of the Indian Ocean (Quilty, 1984; Haig, 1992), and of *Berthelina berthelini, Heterantyx cretosa* and *Spiroplectinella gandolfii*, characteristically found in the upper Albian of northeastern Australia (Haig, 1979^{a}; 1981; 1982), allows a late Albian age to be determined for the sequence. The agglutinated taxa include species with calcareous cement, such as *Remesella* sp. 1, *Heterantyx cretosa* and *Spiroplectinella gandolfii*, as well as numerous organically cemented forms such as *Haplophragmoides bulloides, Ammodiscus, cretaceus, Glomospira charoides, Rhabdammina, Paratrochamminoides* spp. Diversity is moderate to high, ranging from 16 to 31 species per sample. Abundance is moderate (typically between about 100 and 300 specimens per sample) but markedly lower in the first two samples at the base of the sequence (below 100 specimens per sample). Most samples also contain a few small planktonic foraminifera, identified as *Hedbergella punctata*, which was

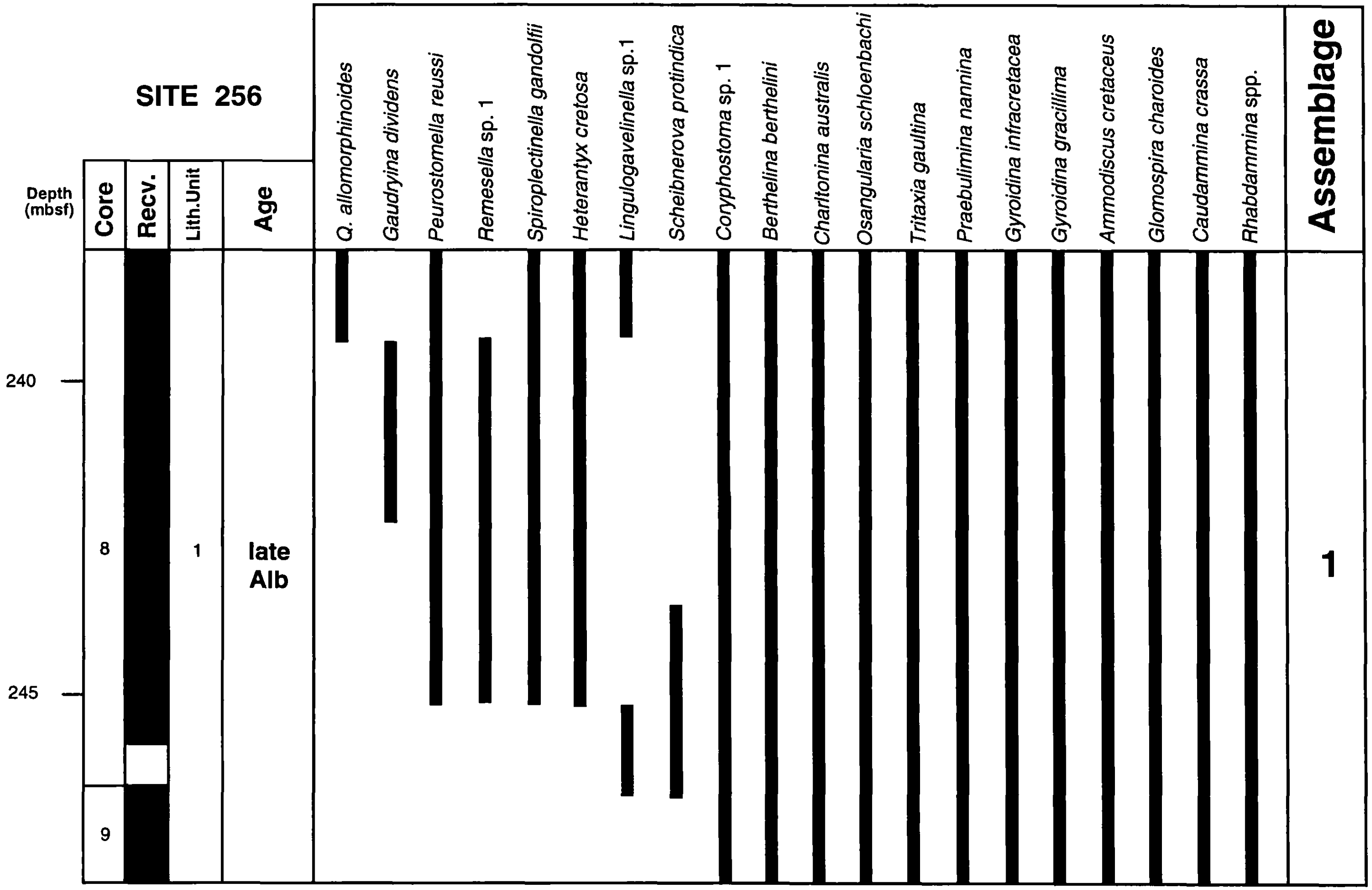


Figure 4.3. Statigraphic ranges of selected benthic foraminifera from Site 256 (% core recovery shaded black).

given a late Albian range by Michael (1972) and two specimens of *Heterohelix* sp. are found in Sample 256-9R-1; 132-135. These planktonic occurrences confirm a late Albian age for the interval.

Nannofossils from Core sections 256-9R-1 to -8R-1 corroborate the foraminiferal age determination, placing the interval in Zone CC 9a, in the uppermost Albian (P.R. Bown, pers. comm., 1995).

4.4. DSDP SITE 257

Three calcareous benthic taxa *(Osangularia utaturensis, Gyroidinoides* cf. *primitiva* and *Gavelinella* ex. gr. *intermedia)* were originally reported from Cores 257-7R to -10R but no age assignment was given. A middle Albian age was determined for this interval by Thierstein (1974) from nannofossils *(Prediscosphaera cretacea* Zone) and confirmed by Herb (1974) from planktonic foraminifera.

I have studied a total of 12 samples from Core sections 257-10R-1 to -7R-1 and have subdivided the sedimentary sequence into three distinct stratigraphic assemblages. The assemblages and stratigraphic ranges of selected taxa are plotted in Figure 4.4.

1. *Glomospira - Ammodiscus* Assemblage

Core sections 257-10R-1 to -9R-2.
Age: Albian?
This assemblage consists exclusively of agglutinated foraminifera. The assemblage is numerically dominated by *Glomospira charoides* and *Ammodiscus cretaceus* but also contains *Caudammina crassa, Glomospirella gaultina, Hippocrepina depressa, Rhabdammina, Rhizammina, Saccammina* and *Haplophragmoides* spp. The age determination remains tentative as planktonic foraminifera are absent from this interval and agglutinated foraminifera are mostly long ranging species. However, the species *Haplophragmoides howardense*, originally recorded from the Cenomanian by McNeil and Caldwell (1981) and *Haplophragmoides* cf. *howardense*, reported from the Albian of Queensland by Haig (1980) may have some stratigraphic significance. Diversity remains low in this interval (12 to 14 species per sample), despite relatively high abundance (between 200 and 250 specimens per sample).

2. *Berthelina intermedia - Osangularia schloenbachi* Assemblage

(Core sections 257-9R-1 to 8R-1).
Age: late early Albian to mid Albian.

This interval contains a mixture of calcareous and agglutinated benthic~~s~~ foraminifera, including many agglutinated forms with calcareous cement. A major faunal turnover occurs at the base of the interval, which is defined by the FOs of the nominate taxa and of *Gyroidina cretacea, Gyroidina gracillima, Pleurostomella reussi, Praebulimina nannina, Lingulogavelinella* sp. 1 and *Lenticulina* spp. Agglutinated species with organic cement are still common but no longer dominate the assemblage. Assemblage 2 includes a large number of cosmopolitan species which have been recorded in the Aptian-Albian. The species *Pleurostomella reussi* (see Haig, 1982), *Gyroidina gracillima* (see Ten Dam, 1950; Weidich, 1990) and *Praebulimina nannina* (see Moullade, 1984) have, however, more restricted Albian ranges. The absence of late Albian markers point to an early to mid Albian age for this interval and a late early to mid Albian age is confirmed by the presence of the planktonic species *Hedbergella planispira* in Samples 257-9R-1; 144-148 and 257-8R-1; 96-100. Diversity is high or moderate (with as many as 36 species per sample). The number of specimens fluctuates from 137 to 402 per sample.

3. *Berthelina cenomanica - Heterantyx cretosa* Assemblage

Core sections 257-7R-6 to -7R-1.

Age: late Albian.

The base of this assemblage is determined by the FOs of *Berthelina berthelini* and *Tritaxia gaultina* in Sample 257-7R-6; 102-106. The FOs of *Berthelina cenomanica* and *Heterantyx cretosa* are observed in Sample 257-7R-5; 46-50 and the FO of *Scheibnerova protindica* is recorded in Sample 257-7R-4; 96-100. Assemblage 3 is assigned a late Albian age, based on the occurrence of *Berthelina cenomanica, Heterantyx cretosa* and *Tritaxia gaultina* and the occurrence of the planktonic species *Hedbergella punctata* in Sample 257R-7-2; 130-134 and of *Hedbergella punctata* with *Schackoina cenomana* in Sample 257-7R-3; 86-90. Diversity and abundance remain moderate in this interval (typically about 25 species and 150 specimens per sample).

On the basis of nannofossils (P.R. Bown, pers. comm., 1995), Core section 257-9R-1 is placed in Zone CC8a (early Albian) and Core sections 257-8R-2 to-7R-1 in Zone CC8b (mid to late Albian), which is in agreement with the ages determined from benthic and planktonic foraminifera.

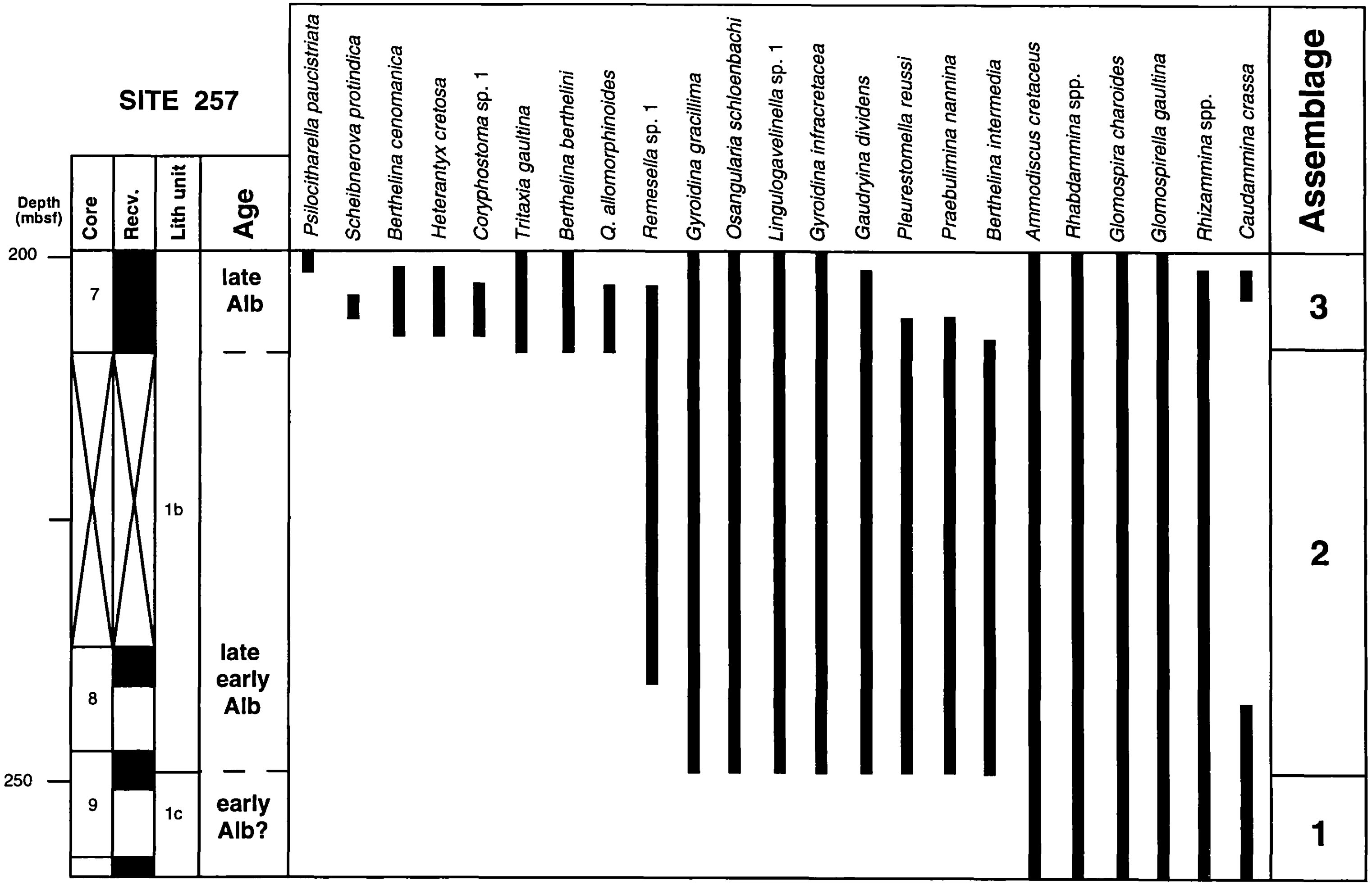


Figure 4.4. Statigraphic ranges of selected benthic foraminifera from Site 257 (% core recovery shaded black)

4.5. DSDP SITE 258

Cores 258-22R to -19R were originally dated from nannofossils as middle Albian *(Prediscosphaera cretacea* Zone) and Cores 258-18R to -13R as upper Albian *(Eiffelithus turriseiffeli* Zone) by Thierstein (1974). Herb (1974) found that the planktonic taxa from these cores indicated an Albian age, but no age assignment was derived from the benthic foraminifera, which were only cursorily described by Scheibnerová (1978^{c}).

A total of 27 samples was examined from Core sections 258-25R-4 to -14R-1 for this study. Above a barren interval at the base of the sequence (Core sections 258-25R-4 to -24R-5) three main stratigraphic assemblages have been recognized. The stratigraphic ranges of selected foraminifera are plotted in Figure 4.5, which also shows the benthic foraminiferal assemblages.

1. *Rhabdammina - Ammodiscus - Glomospira* Assemblage

Core sections 258-24R-3 to -21R-3.

Age: Albian?

This assemblage consists almost exclusively of agglutinated foraminifera with organic cement. Planktonic foraminifera are absent and most of the agglutinated benthic taxa in this interval have extended stratigraphic ranges. The only species with stratigraphic significance are: *"Textulariopsis" wilgunyaensis, Reophax geniculatus, Haplophragmoides minor, Bimonilina engeniensis,* commonly recorded in Aptian-Albian sediments (Ludbrook, 1966; Scheibnerová, 1974; Haig, 1980; 1981) and *Haplophragmoides* cf. *howardense*, known from the Albian of Queensland. Most common species are *Ammodiscus cretaceus, Glomospira charoides, Cribrostomoides nonioninoides, "Textulariopsis" wilgunyaensis, Haplophragmoides minor, Haplophragmoides* cf. *howardense, Bimonilina engeniensis* and *Rhabdammina, Rhizammina, Bathysiphon* spp. Only two calcareous species are recorded (Sample 258-22R-5; 81-85). Diversity is low or moderate (usually below 20 species per sample) and abundance low, except in Sample 258-23R-2; 63-67, where it reaches 280 specimens.

2. *Ammodiscus - Pleurostomella reussi* Assemblage

Core sections 258-21R-2 to -16R-4.

Age: mid Albian to early late Albian.

This assemblage contains a large proportion of agglutinated foraminifera with organic cement, but also includes variable numbers of calcareous species. However, two intervals are completely devoid of calcareous foraminifera (Core sections 258-18R-4 to -18R-3 and 258-17R-3 to -17R-1). The base of the assemblage is characterized by the FOs of *Pleurostomella reussi, Gyroidina infracretacea, Gyroidina gracillima,*

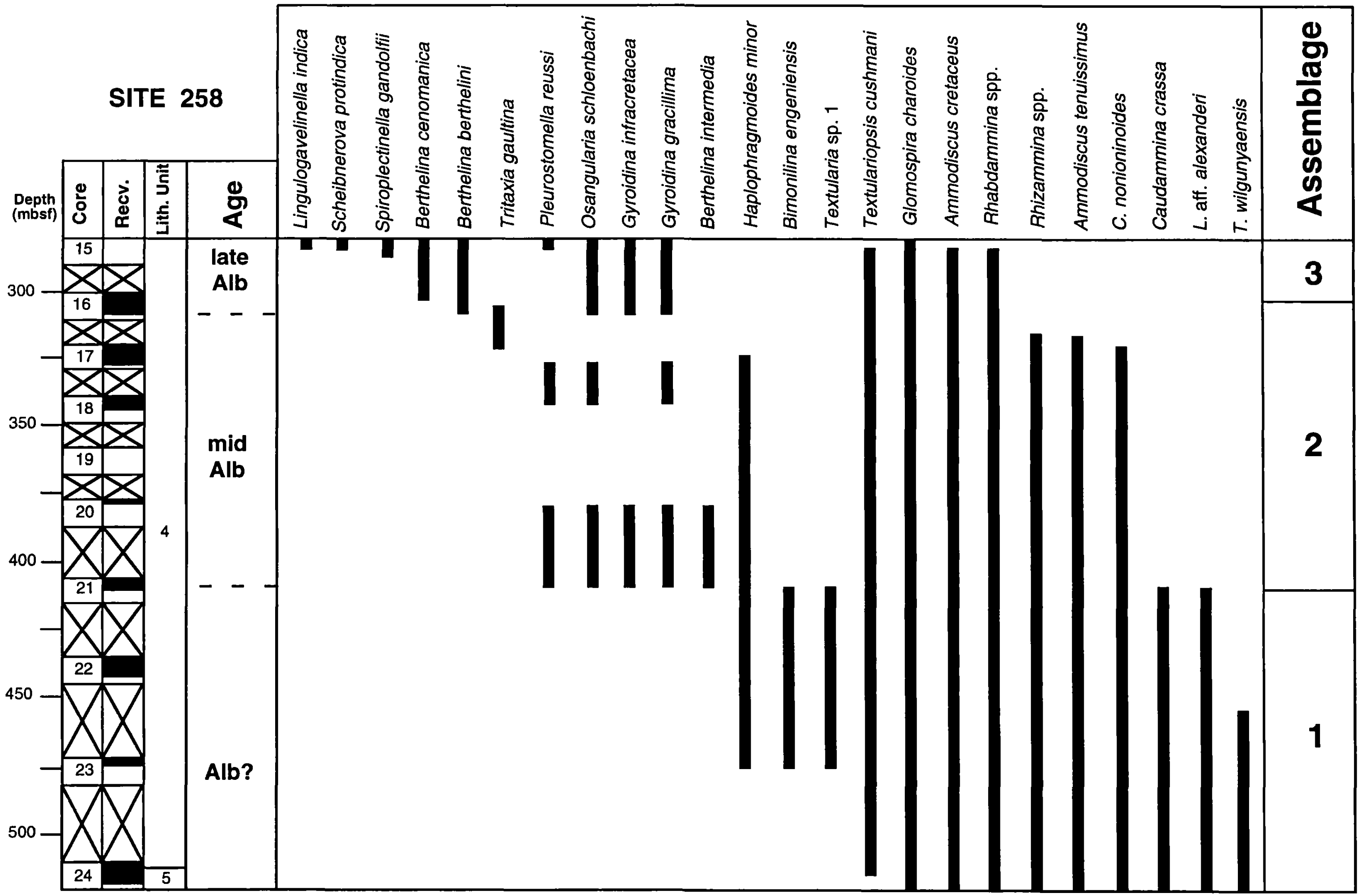


Figure 4.5. Statigraphic ranges of selected benthic foraminifera from Site 258 (% core recovery shaded black).

Osangularia schloenbachi and *Berthelina intermedia*, which indicate an Albian age for the interval. However, sporadic records of *Hedbergella punctata* from Core sections 258-21R-1 to -18R-4, 258-17R-3 and 258-16R-4 place the interval above the mid Albian. Agglutinated benthics with organic cement including *Rhabdammina, Rhizammina, Haplophragmoides* and *Ammodiscus* spp. are also common near the base of the interval, where diversity is quite high (approximately 25 species per sample). Diversity declines markedly above Core section 258-20R-1, where it fluctuates between 5 and 14 species per sample. Abundance is moderate in the lowermost samples (between 150 and 192 specimens per sample in Core sections 258-21R-2 to -20R-1), but becomes low throughout the remainder of the interval (less than 100 specimens per sample).

3. *Berthelina cenomanica - Spiroplectinella gandolfii* Assemblage
Core sections 258-16R-2 to -14R-1.
Age: late Albian.
This assemblage contains a large proportion of calcareous species and agglutinated taxa with calcareous cement. The base of the assemblage is marked by the FO of *Berthelina cenomanica*; the FO of *Spiroplectinella gandolfii* is also observed in Sample 258-15R-4; 35-39. Assemblage 3 is dated as late Albian, based on the occurrence of the benthic species *Berthelina cenomanica* and *Spiroplectinella gandolfii* and planktonic species *Praeglobotruncana delrioensis* and *Hedbergella punctata*. Diversity varies from low to moderate (ranging from 7 to 23 species per sample). Abundance remains low (below 100 specimens per sample), except in Sample 258-15R-2; 42-46, where it reaches 170 specimens.

A discrepancy is observed between the nannofossil and foraminiferal age determinations for Core sections 258-17R-5 to -14R-1, which is assigned to Zone CC9c in the early Cenomanian on the basis of nannofossils (P.R. Bown, pers. comm., 1995). However, benthic foraminiferal diversity and abundance are very low in these core sections and stratigraphic ranges often span the late Albian and early Cenomanian, introducing a significant stratigraphic uncertainty in the dating of this interval.

4.6. DSDP SITE 259

The original age determinations were rather imprecise and confused. Bartenstein (1974) considered that the "primitive" arenaceous foraminifera from Cores 259-25R, -26R and -32R did not contain any age diagnostic species. Scheibnerová (1974) dated

Core sections 259-17R-CC to -11R-CC as upper Albian, after concluding that the benthic foraminiferal assemblages showed close resemblance to those of the Great Artesian and Canning Basins. Planktonic foraminifera from the same cores were given an Albian age by Krasheninnikov (1974) while Bukry (1974) reported nannofossils of a lower Albian age. Dinoflagellates studied by Wiseman and Williams (1974) suggested an early Aptian age for Cores 259-33R to -25R and a late Aptian age for Cores 259-23R to -18R. The palynological data was reassessed by Morgan (1979), who attributed a late Neocomian age to Cores 259-33R to -27R and an early Aptian age to Cores 259-26R to -18R.

I have examined a total of 64 samples from Core sections 259-33R-1 to -11R-3 and have recognized three distinct assemblages. The assemblages and the stratigraphic ranges of selected foraminifera are shown on Figure 4.6.

1. *Psammosphaera fusca - Reophax* sp. 3 Assemblage

Core section 259-33R-1.

Age: undetermined.

This basal assemblage displays very low diversity (8 species per sample), despite high abundance. It contain no age diagnostic foraminifera and is numerically dominated by the very coarsely agglutinated tests of the nominate taxa.

2. *Glomospira charoides - Rhabdammina* Assemblage

Core sections 259-32R-2 to -17R-2.

Age: Aptian-early Albian?

This assemblage is comprised almost exclusively of organically cemented forms with limited stratigraphic value, including *Ammodiscus cretaceus*, *Caudammina crassa*, *Lagenammina lagenoides*, *Recurvoides*, *Bathysiphon*, *Rhizammina* spp. and the nominate taxa. The only significant species are *"Textulariopsis" wilgunyaensis* and *Bimonilina engeniensis*, which have reported Aptian-Albian ranges in eastern Australia (Ludbrook, 1966, Haig, 1980). Diversity is somewhat higher (between 10 and 15 species per sample) near the base of the interval, in Core sections 259-32R-2 to -30R-5, than in the remainder of the interval (1 to 7 species per sample). Foraminiferal abundances are low throughout this interval, rarely exceeding 100 specimens per sample.

3. *Berthelina intermedia - Osangularia schloenbachi* Assemblage

Core sections 259-16R-4 to -11R-3.

Age: late early to early late Albian.

This well diversified assemblage consists predominantly of calcareous and agglutinated taxa with calcareous cement. The base of this assemblage is

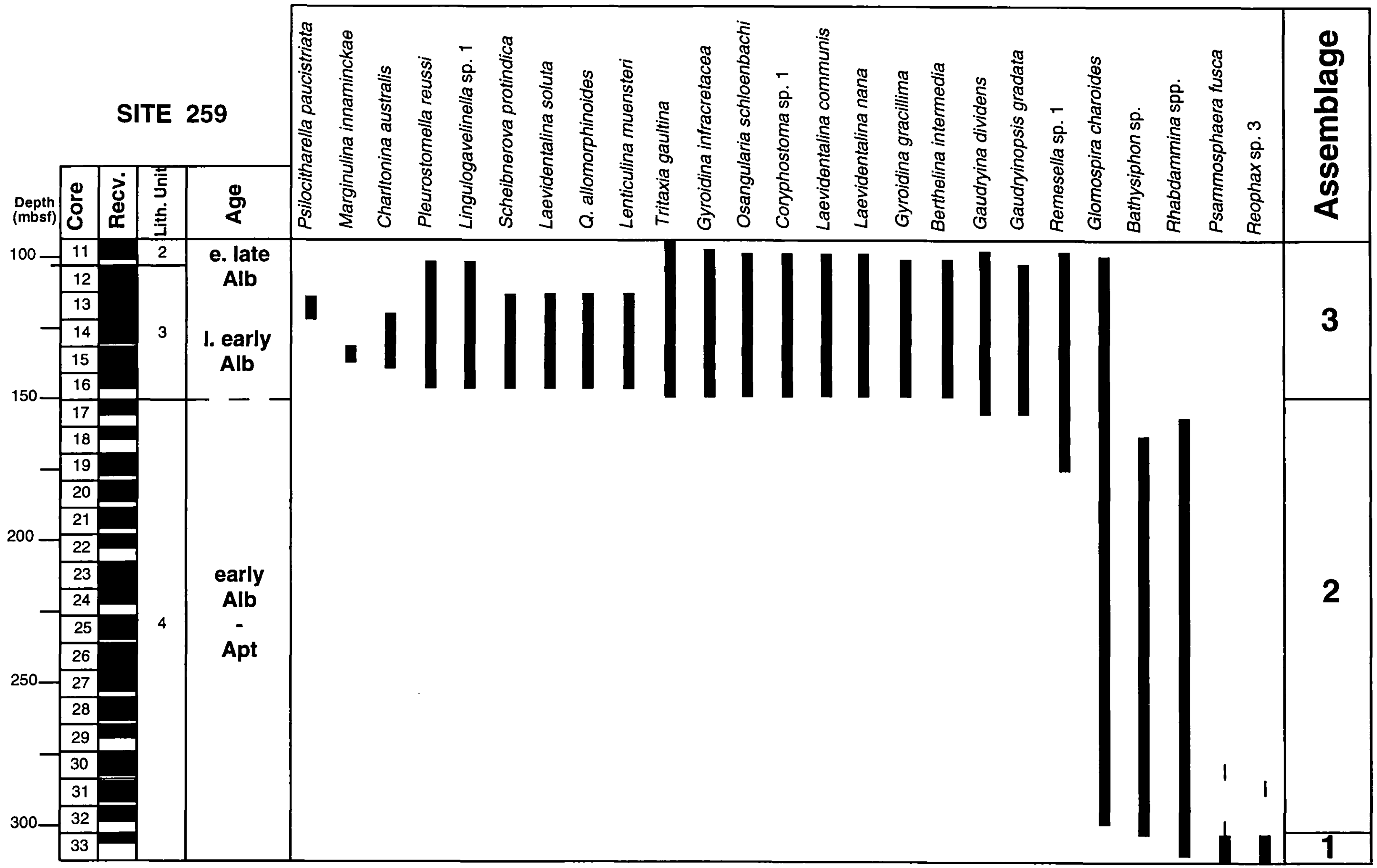


Figure 4.6. Statigraphic ranges of selected benthic foraminifera from Site 259 (% cores recovery shaded black).

characterized by the FOs of *Berthelina intermedia, Osangularia schloenbachi, Gyroidina infracretacea, Gyroidina gracillima, Coryphostoma* sp. 1, *Tritaxia gaultina* and *Laevidentalina* spp. in Sample 259-16R-4; 90-94 and by the FOs of *Pleurostomella reussi, Quadrimorphina allomorphinoides, Lingulogavelinella* sp. 1 and *Lenticulina muensteri* in Sample 259-16R-3; 103-107. The FO of *Scheibnerova protindica* is also noted in Sample 259-15R-3; 135-139. An Albian age is determined for Assemblage 3 from the occurrence of *Pleurostomella reussi, Gyroidina gracillima, Tritaxia gaultina, Psilocitharella paucistriata.* The stratigraphic resolution is improved further by the planktonic marker *Ticinella primula*, which indicates a late early to early late Albian age for Core sections 259-16R-2 to -14R-1. A late Albian age seems to be ruled out for the uppermost part of the sequence (Core sections 259-13R-2 to -11R-3) by the absence of characteristic benthic species such as *Berthelina cenomanica, Spiroplectinella gandolfii* and *Heterantyx cretosa*, which are present at other DSDP and ODP sites. Their non-appearance should, however, be treated with caution, as diversity and abundance are extremely low in this last interval. Diversity increases rapidly at the base of the interval (up to 36 species per sample) but a significant decline is observed above Core section 259-13R-2, where diversity typically remains below 8 species per sample. Abundance initially shows a significant increase (up to 241 specimens per sample), but decreases markedly above Core section 259-13R-4, where it rarely exceeds 20 specimens per sample.

Core Sections 259-33R-1 to -18R-1 are virtually barren of nannofossils but diverse assemblages are found in Core sections 259-16R-4 to -11R-3, which bear out the ages determined from benthic and planktonic foraminifera (P.R. Bown, pers. comm., 1995).

4.7. DSDP SITE 260

The Lower Cretaceous sediments from this site were initially dated as middle Albian on the basis of nannofossils (Proto-Decima, 1974). Benthic foraminifera suggested a middle Albian age for Cores 260-12R to -1R and a late Aptian? to early Albian age for Cores 260-11R to -17R (Scheibnerová, 1974), while planktonic foraminifera in Cores 260-9R- to -11R were considered to be similar to that in Cores 259-12R to -17R at DSDP Site 259 and to indicate a late Albian age (Krasheninnikov, 1974).

I have studied a total of 24 samples from Core sections 260-18R-1 to -6R-4 and recognized two main stratigraphic assemblages above Sample 260-18R-2; 64-68, which was found to contain only rare specimens of *Glomospira, Ammodiscus* and

Rhabdammina spp. Massive influxes of well preserved radiolarians are recorded in the studied interval, which appear to alternate with rich and diverse foraminiferal assemblages. The assemblages and the stratigraphic ranges of selected foraminifera are shown on Figure 4.7.

1. *Praedorothia ouachensis* - *Gavelinella flandrini* Assemblage

Core sections 260-18R-1 to -12R-1.

Age: late early Aptian.

This diverse assemblage comprises numerous nodosariids and fluctuating numbers of *Rhabdammina* spp., *Praedorothia ouachensis*, *Gavelinella flandrini, Glomospira charoides, Gyroidina* aff. *infracretacea* and *Praedorothia praeoxycona.* The LO of *Praedorothia ouachensis* is observed at the top of the interval in Sample 260-12R-1; 83-87. Two useful Tethyan markers are *Praedorothia ouachensis* and *Gavelinella flandrini*, which have a late Hauterivian to early Aptian and an early "Gargasian" to early Albian range, respectively (Moullade, 1960; 1984). A late early Aptian age for this assemblage is, thus, indicated by the co-occurrence of these two species in Assemblage 1.

A sudden increase in diversity is observed at the base of this interval, in Sample 260-18R-1; 127-131, where elongated morphotypes, such as *Laevidentalina, Astacolus* spp. and *Praedorothia ouachensis,* become numerically dominant. Core sections 260-16R-2 to -13R-1 contain only very impoverished foraminiferal assemblages but include abundant radiolaria (particularly in Sample 259-15R-3; 141-145, where a massive radiolarian influx is observed). A diversified benthic foraminiferal assemblage is once again recorded in Core sections 260-12R-2 to-12R-1, where the acme of *Gavelinella flandrini* is also noted.

2. *Gaudryinopsis gradata* - *Saracenaria spinosa* Assemblage

Core sections 260-10R-2 to -10R-1.

Age: late Aptian.

A near barren interval separates this assemblage from the one previously described. The base of this assemblage is marked by the FOs of *Gaudryinopsis gradata*, *Gaudryina* cf. *dividens* and *Saracenaria spinosa* (forms similar to morphotypes from Germany). The occurrence of these species and the absence of *Praedorothia ouachensis* point to a late Aptian age for this interval. An early late Aptian age (*cabri* or *ferreolensis* zones) is confirmed by the presence of well preserved planktonics: *Blefuscuiana aptica* and *Blowiella gottisi* are recorded in Sample 260-10R-1; 34-38. A sharp decrease in the number of *Gavelinella flandrini* in this interval is matched by a corresponding increase in *Gyroidina* aff. *infracretacea.* Diversity and abundance fluctuate markedly in this assemblage. Above this interval, Core sections 260-8R-6 to

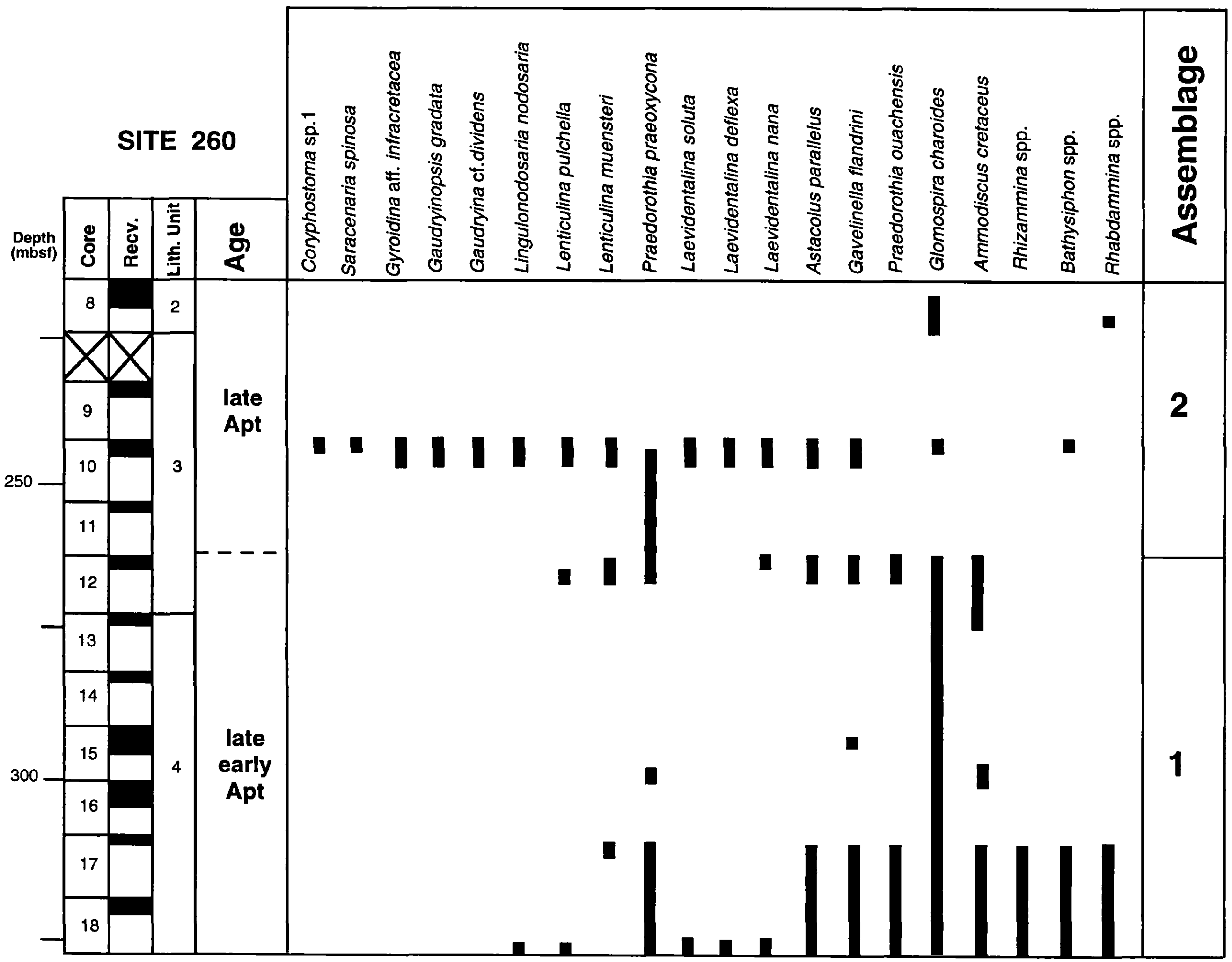


Figure 4.7. Statigraphic ranges of selected benthic foraminifera from Site 260 (%core recovery shaded black).

-6R-4 are virtually barren of foraminifera but contain well defined radiolarian horizons.

Nannofossils are extremely rare between Core sections 260-18R-2 to -13R-1, giving only a tentative Valanginian-Barremian age determination (P.R. Bown, pers. comm., 1995). However, higher up in the sequence, more abundant nannofossil assemblages indicate an early Aptian age for Core sections 260-12R-2 to -11R-1 and a mid to late Aptian age for Core sections 260-10R-2 to -9R-1, which is in good agreement with the foraminiferal age determinations.

4.8. DSDP SITE 263

Scheibnerová (1974) assigned an "Aptian or older" age to Cores 263-11R to -29R and a late Albian age to Cores 263-5R to -10R. However, the ages attributed to the same cores on the basis of other microfossils differed markedly. Pollen and spores suggested a late Neocomian to late Aptian age for Cores 263-11R to -28R and a Neocomian age for Core 263-29R (Wiseman and Williams, 1974). Cores 263-22R to -27R were determined as upper Albian, Core 263-28R as middle Albian, and Core 263-29R as "undifferentiated Lower Cretaceous" on the basis of original nannofossil studies (Bukry, 1974). By contrast, a recent re-examination of nannofossils from Cores 263-4R to -29R failed to confirm any Albian index species and suggested a Valanginian to early Hauterivian age for Cores 263-22R to-29R and a Hauterivian-Albian age for Cores 263-4R to -21R (P.R. Bown, pers. comm., 1994). This was based on the occurrence of *Eiffelithus striatum*, the marker for the *T. striatum* zone of Mutterlose, 1992 (Valanginian-early Hauterivian). This species also occurs in a similar stratigraphic position at nearby ODP Sites 765 and 766.

A total of 66 samples from Core sections 263-29R-4 to -4R-4 have been examined for this study. Three main stratigraphic assemblages are identified. The assemblages and stratigraphic ranges of selected benthic foraminifera are shown in Figure 4.8.

1. *Bulbobaculites - Recurvoides* Assemblage

Core sections 263-29R-4 to -18R-5.

Age: Valanginian to Barremian.

This high diversity assemblage (with up to 30 species per sample) is characterized by *Ammobaculites crespinae, Bulbobaculites humei, Lagenammina* aff. *alexandrei, Aaptotoichus challengeri, "Textulariopsis" elegans, "Gaudryina" cuvierensis, Paratrochamminoides, Recurvoides, Reophax* and *Verneuilinoides* spp. with rare nodosariids and variable numbers of *Rhabdammina, Rhizammina, Ammodiscus* and

Glomospira spp. This assemblage can be subdivided into two sub-assemblages (1A and 1B), based on the disappearance of *Cribrostomoides nonioninoides, Bulbobaculites humei, "Gaudryinopsis" pseudobettenstaedti* and *Verneuilinulla* sp. 1 above Core 263-22R and on the occurrence of *Bulbobaculites* cf. *inconstans* and *Bimonilina* cf. *variana* in Core 263-22R. Abundance varies markedly in this interval.

2. *Rhizammina - Ammodiscus - Glomospira* Assemblage
Core sections 263-18R-4 to -7R-2.
Age: Aptian to Albian.
This moderately diverse assemblage is characterized by highly fluctuating numbers of *Rhizammina* and *Rhabdammina* spp., *Ammodiscus tenuissimus, Ammodiscus cretaceus, Glomospira charoides* and *Glomospira gordialis.* Other common species recorded in this interval are *Haplophragmoides, Recurvoides* and *Reophax* spp., *Bathysiphon brosgei, Trochammina ribstonensis, Hippocrepina gracilis, Glomospirella gaultina* and *Verneuilina howchini.* Abundance remains highly variable throughout this interval (ranging from 36 to 292 specimens per sample).

3. *Pleurostomella - Glomospira* Assemblage
Core sections 263-6R-6 to -4R-4.
Age: Albian or younger.
This very low diversity assemblage contains rare specimens of *Rhizammina, Rhabdammina, Glomospira* and *Ammodiscus* spp. with scarce *Gyroidina infracretacea, Lingulina* sp., *Pleurostomella* sp. and *Gavelinella* spp., indicative of an Albian or younger age.

There are few stratigraphically significant species among the agglutinated taxa in assemblages 1 and 2. The main diagnostic species are: *Verneuilina howchini* in Core sections 263-16R-1 to -6R-6, which has a reported range from the Aptian to the Albian in Australia and the Indian Ocean (Haig, 1980), *Cribrostomoides nonioninoides* in Cores sections 263-29R-3 to -22R-2, which was recorded in the Hauterivian-Barremian of the Carnarvon Basin (McLoughlin *et al.*, in press) and is cosmopolitan in the Barremian-Aptian (Haig, 1980) and *Aaptotoichus challengeri* in Core sections 263-25R-2 to -16R-1, which is also found in the Berriasian-Valanginian and Valanginian-Hauterivian at ODP Sites 765 and 766, respectively (Kaminski *et al.*, 1992[a]; Holbourn and Kaminski, in press[a]). The calcareous species, found intermittently between Core sections 263-29R-3 and -18R-5, indicate a Valanginian-Barremian age (*Oolina* cf. *caudata, Lenticulina subangulata, Citharina harpa, Frondicularia hastata, Lenticulina heiermanni* and abundant polymorphinids). No planktonic foraminifera is recorded in any of the assemblages described above.

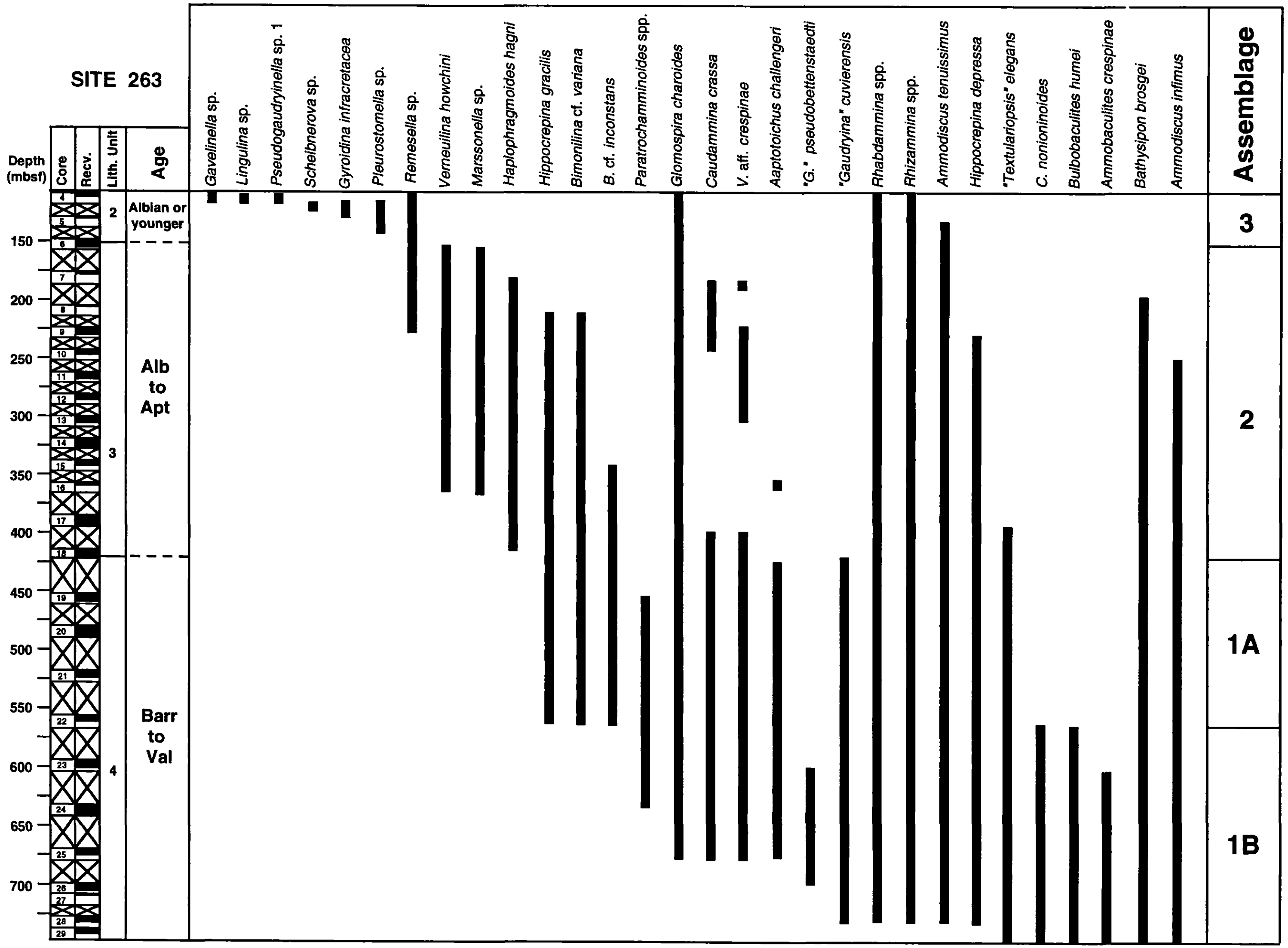


Figure 4.8. Stratigraphic ranges of selected benthic foraminifera at DSDP Site 263 (% core recovery shaded black).

Although the agglutinated foraminiferal assemblages from DSDP Site 263 are diverse, many of the index taxa that are used in the foraminiferal assemblages of the boreal Lower Cretaceous are absent. The stratigraphically important *Falsogaudryinella* and *Praedorothia* lineages are not present, even though the index species *Praedorothia praehauteriviana* has been observed at other Indian Ocean sites (Riegraf and Luterbacher, 1989; Kaminski *et al.*, 1992^{a}). Of the seven Lower Cretaceous Deep Water Agglutinated Foraminifera (DWAF) zonal markers in the scheme of Geroch and Nowak (1984) only *Cribrostomoides nonioninoides* [=*Haplophragmoides nonioninoides* of Geroch and Nowak (1984)] and an atypical species of *Pseudoreophax*, differing from *Pseudoreophax cisownicensis* Geroch, have been observed. Among the 24 index species used in the Boreal Lower Cretaceous zonations of King *et al.* (1989), only one species tentatively identified as *Bulbobaculites* cf. *inconstans* (Bartenstein and Brand, 1951) was found at DSDP Site 263.

Nannofossil recovery was very poor, only permitting tentative age determinations (P.R. Bown, pers. comm., 1995). A Valanginian-early Hauterivian age was attributed to Core sections 263-29R-2 to -22R-2 and a Hauterivian-Albian age to Core sections 263-22R-1 to -4R-4.

4.9. ODP SITES 762 & 763

The Early Cretaceous biostratigraphy of these closely located sites (Hole 763 is situated about 84km south of Hole 762) relied essentially on nannofossils and dinoflagellates (Bralower and Siesser, 1992; Brenner, 1992). Berriasian-Valanginian benthic foraminifers from the Barrow Group deltaic sequences of Hole 762 (Cores 762C-91X to -81X) and Hole 763 (Cores 763B-54X to -46X and 763C-46R to -4R) were documented by Jones and Wonders (1992). In the biostratigraphic summary included in the site reports (Haq, von Rad, O'Connell *et al.*, 1990), two benthic and five planktonic foraminiferal species were reported from Core sections 762C-78X-CC to -77X-4 and three planktonic and four benthic species from Core sections 763B-44X to -27X, but no detailed foraminiferal data were given.

4.9.1. ODP Site 762

I have examined a total of 17 samples from Core sections 762C-91X-CC to -76X-4 and divided the faunal succession into five assemblages. The assemblages and stratigraphic ranges of selected benthic foraminifera are shown in Figure 4.9.

1. *Textularia bettenstaedti* - *Evolutinella perturbans* Assemblage

Core sections 762C-91X-CC to -82X-2.

Age: Berriasian to early Valanginian.

This predominantly agglutinated assemblage is characterized by fluctuating numbers of *Evolutinella perturbans, Haplophragmoides* spp. and *Bulbobaculites* spp. Calcareous taxa including *Lenticulina, Globulina* and *Saracenaria* spp. also occur intermittently. Diversity and abundance remain generally low (usually below 10 species and 100 specimens per sample).

2. *Lenticulina* - *Vaginulinopsis* spp. Assemblage

Core sections 762C-81X-1 to 79X-CC.

Age: latest Hauterivian? to Barremian

Sample 762C-81X-1; 93-96, at the base of the interval, contains only a few agglutinated foraminifera and abundant fish teeth (76 specimens). However, a diverse calcareous assemblage is found in Core section 762C-79X-CC with *Astacolus parallelus, Astacolus calliopsis, Vaginulinopsis excentrica, Planularia crepidularis, Saracenaria forticosta, Saracenaria pravoslavlevi* and various *Lenticulina* and *Laevidentalina* spp.

3. *Gavelinella flandrini* - *Gaudryinopsis gradata* Assemblage

Core section 762C-78X-CC.

Age: late Aptian.

This moderately diverse mixed calcareous/agglutinated assemblage in Core 762C-78X-CC includes *Gyroidina* aff. *infracretacea, Gaudryinopsis gradata* and *Gaudryina* cf. *dividens* but is numerically dominated by *Gavelinella flandrini* and *Lingulogavelinella* sp. 1.

4. *Berthelina intermedia* - *Osangularia schloenbachi* Assemblage

Core section 762C-77X-6.

Age: mid Albian.

This diverse mixed calcareous/agglutinated assemblage, which contains *Berthelina intermedia, Charltonina australis, Globorotalites aptiensis, Gyroidina infracretacea, Gyroidina gracillima, Remesella* sp. 1, *Tritaxia gaultina, Gaudryina dividens, Gaudryinopsis gradata* as well as various nodosariids, is numerically dominated by *Osangularia schloenbachi.* A mid Albian age is also supported by the occurrence of the planktonic species *Hedbergella rischi* and *Hedbergella planispira.*

5. *Berthelina cenomanica* - *Tritaxia gaultina* Assemblage

Core sections 762C-77X-1 to -76X-4.

Age: late Albian.

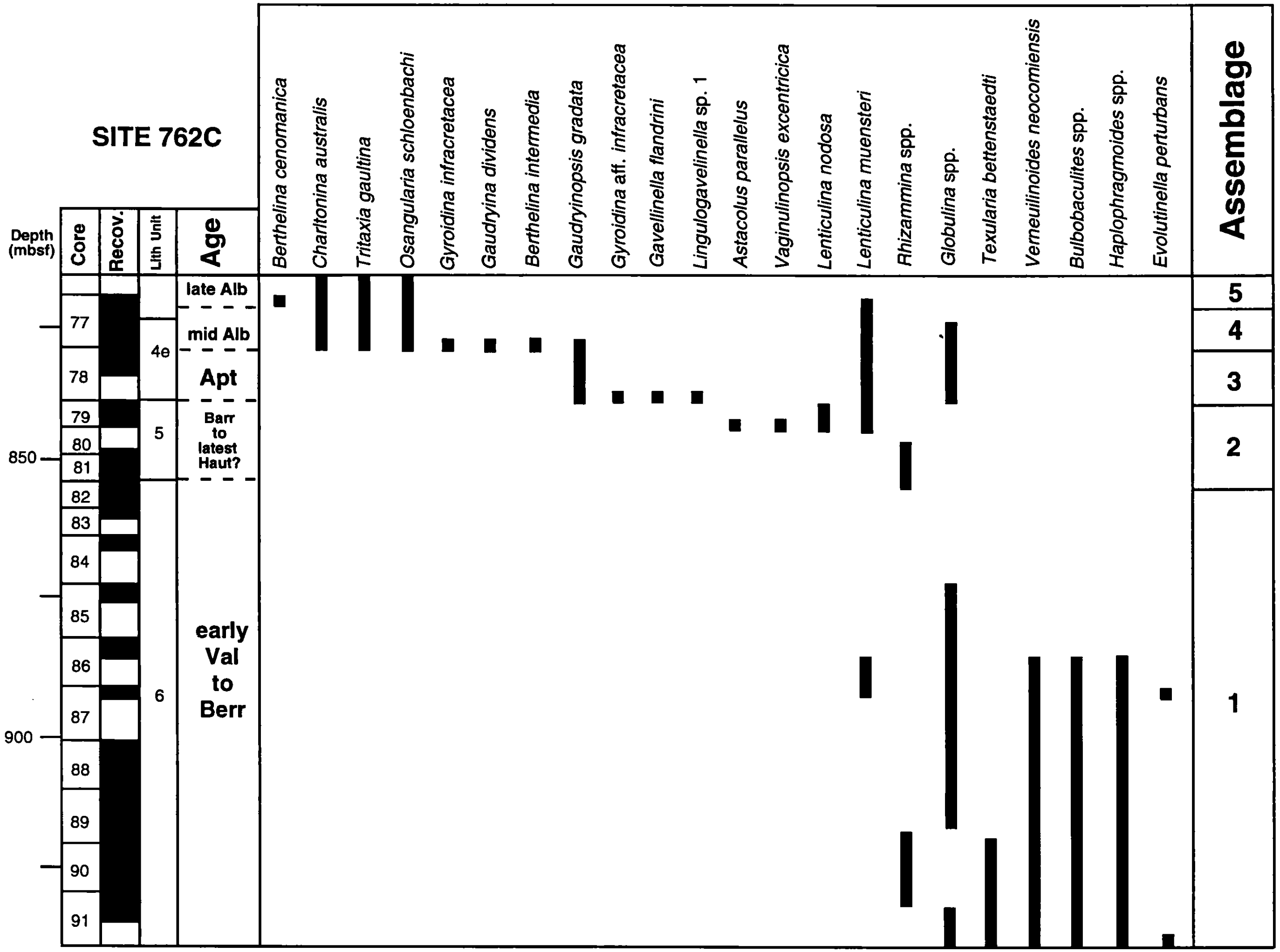


Figure 4.9. Statigraphic ranges of selected benthic foraminifera from Site 762C (% core recovery shaded black)

The base of this mixed calcareous/agglutinated assemblage is marked by the FO of *Berthelina cenomanica* in Core section 762C-77X-1. Benthic diversity and abundance remain relatively low and planktonics (*Rotalipora* spp.) dominate the assemblage.

4.9.2. ODP Site 763

I have analysed a total of 40 samples from Core sections 763C-46R-5 to -35R-6 and Core sections 763B-54X-CC to -27X-3, and have identified five distinct stratigraphic assemblages. The assemblages and the stratigraphic ranges of selected benthic foraminifera are shown in Figures 4.10 and 4.11.

1. *Bulbobaculites humei* - *Evolutinella perturbans* Assemblage
Core sections 763C-46R-5 to -35R-6 and 763B-54X-CC to -48X-5.
Age: Berriasian to early Valanginian.
A predominantly agglutinated assemblage with fluctuating numbers of *Evolutinella perturbans, Haplophragmoides* and *Bulbobaculites* spp. and sporadic occurrences of *Lenticulina, Saracenaria, Globulina* and *Laevidentalina* spp. Diversity and abundance are generally low.

2. *Gavelinella barremiana* - *Lenticulina* spp. Assemblage
Core sections 763B-47X-3 to -43X-2.
Age: latest Hauterivian? to Barremian.
The base of this predominantly calcareous assemblage contains numerous nodosariids. The occurrence of *Gavelinella barremiana* from Core sections 763B-44X-2 to -43X-2 indicate a Barremian age. A dramatic increase in the number of rotaliids is noted higher up in the sequence, where 334 specimens of *Gavelinella barremiana* are recorded in Sample 763B-43X-2; 111-114.

3a. *Gavelinella flandrini* - *Lenticulina* spp. Assemblage
Core sections 763B-41X-5 to -40X-2.
Age: early Aptian?
This very low diversity assemblage, situated above a radiolarian rich sample, which is barren of foraminifera, contains a few nodosariids and agglutinated foraminifera as well as rare specimens of *Gavelinella flandrini.*

3b. *Gavelinella flandrini* - *Gaudryina* cf. *dividens* Assemblage
Core sections 763B-39X-1 to -38X-1.
Age: late Aptian.
This is primarily a calcareous assemblage, dominated by *Gavelinella flandrini, Lingulogavelinella* sp. 1 and *Gyroidina* aff. *infracretacea.* A few specimens of

Gaudryina cf. *dividens* are noted in Sample 763B-38X-1; 112-115. The planktonic species *Globigerinelloides ferreolensis* and *Blefuscuiana* spp. are also recorded within this interval. Diversity is moderate (over 20 species per sample), while abundance remains high (over 300 specimens per sample).

4. *Berthelina intermedia - Osangularia schloenbachi* Assemblage

Core sections 763B-37X-6 to -30X-4.

Age: late early to mid Albian.

This well diversified assemblage is characterized by *Berthelina intermedia, Osangularia schloenbachi*, *Gyroidina infracretacea, Gyroidina gracillima, Coryphostoma* sp. 1, *Gaudryina dividens, Pleurostomella reussi, Marssonella oxycona* and various nodosariids. A mid Albian age is supported by the planktonic species *Hedbergella rischi* and *Hedbergella planispira*, which are abundant in samples from Core sections 763B-36X-3 to -30X-4. Diversity is moderate to high, ranging from 18 to 44 species per sample. Abundance, initially high (over 300 specimens per sample), declines slightly further up in the interval (around 200 specimens per sample).

5. *Berthelina cenomanica* Assemblage

Core sections 763B-29X-6 to -27X-2.

Age: late Albian.

This predominantly calcareous assemblage is characterized by *Berthelina cenomanica, Berthelina berthelini, Gyroidina gracillima, Gyroidina infracretacea, Tritaxia gaultina, Marssonella oxycona, Osangularia schloenbachi, Pleurostomella reussi, Gaudryina dividens* as well as various nodosariids. The base of the assemblage is marked by the FO of *Berthelina cenomanica.* Diversity and abundance are initially quite high (31 species and over 280 specimens in Sample 763B-29X-6; 147-150), but decrease significantly higher up, where assemblages become dominated by planktonics (*Rotalipora* ooze).

The upper Hauterivian to upper Albian intervals at both sites represent a succession of condensed sequences, which can be correlated across the two holes, although sequences are more expanded at Site 763, which is the most proximal of the two sites. Nannofossil ages, determined by Bralower and Siesser (1992) for the Albian interval, agree well with the foraminiferal ages.

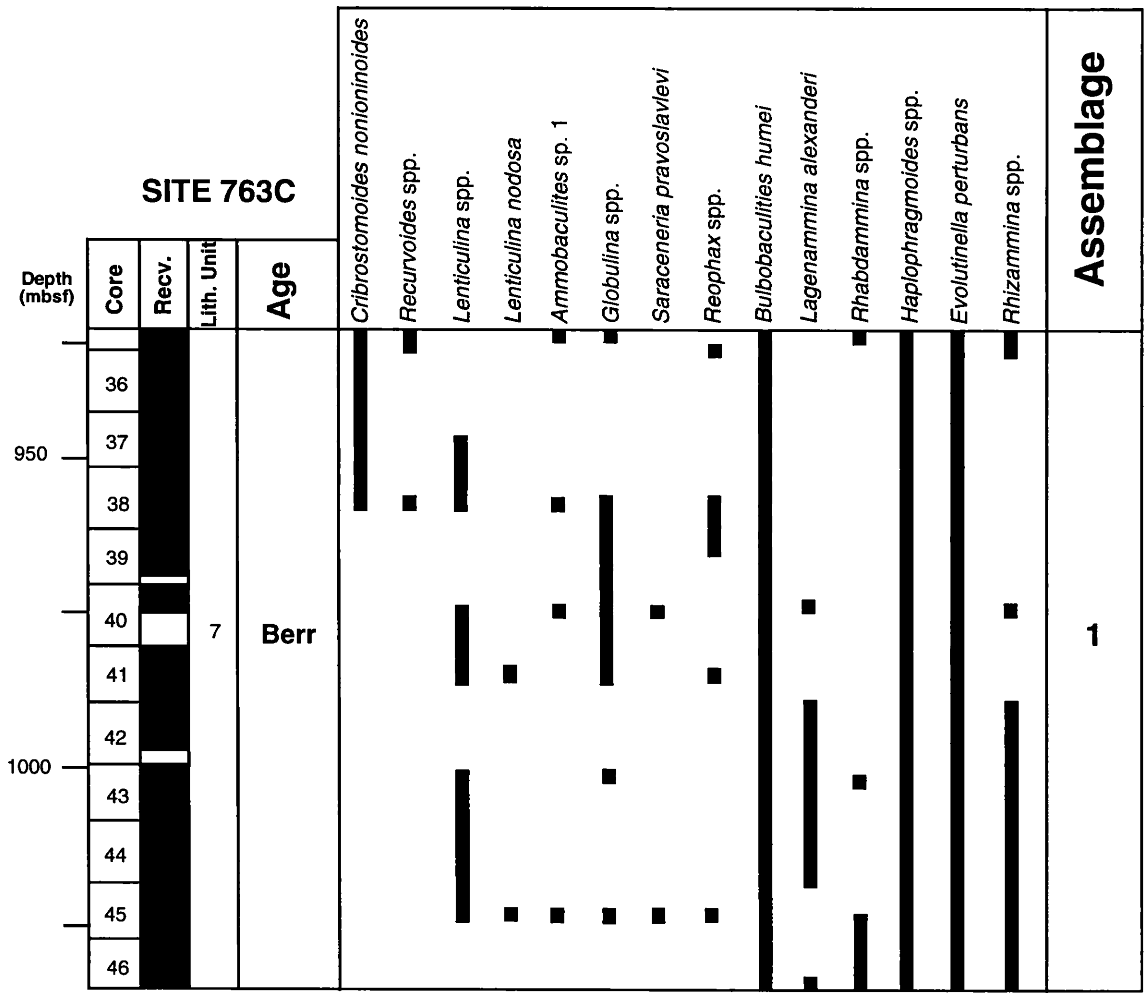


Figure 4.10 . Statigraphic ranges of selected benthic foraminifera from Site 763C (% core recovery shaded black).

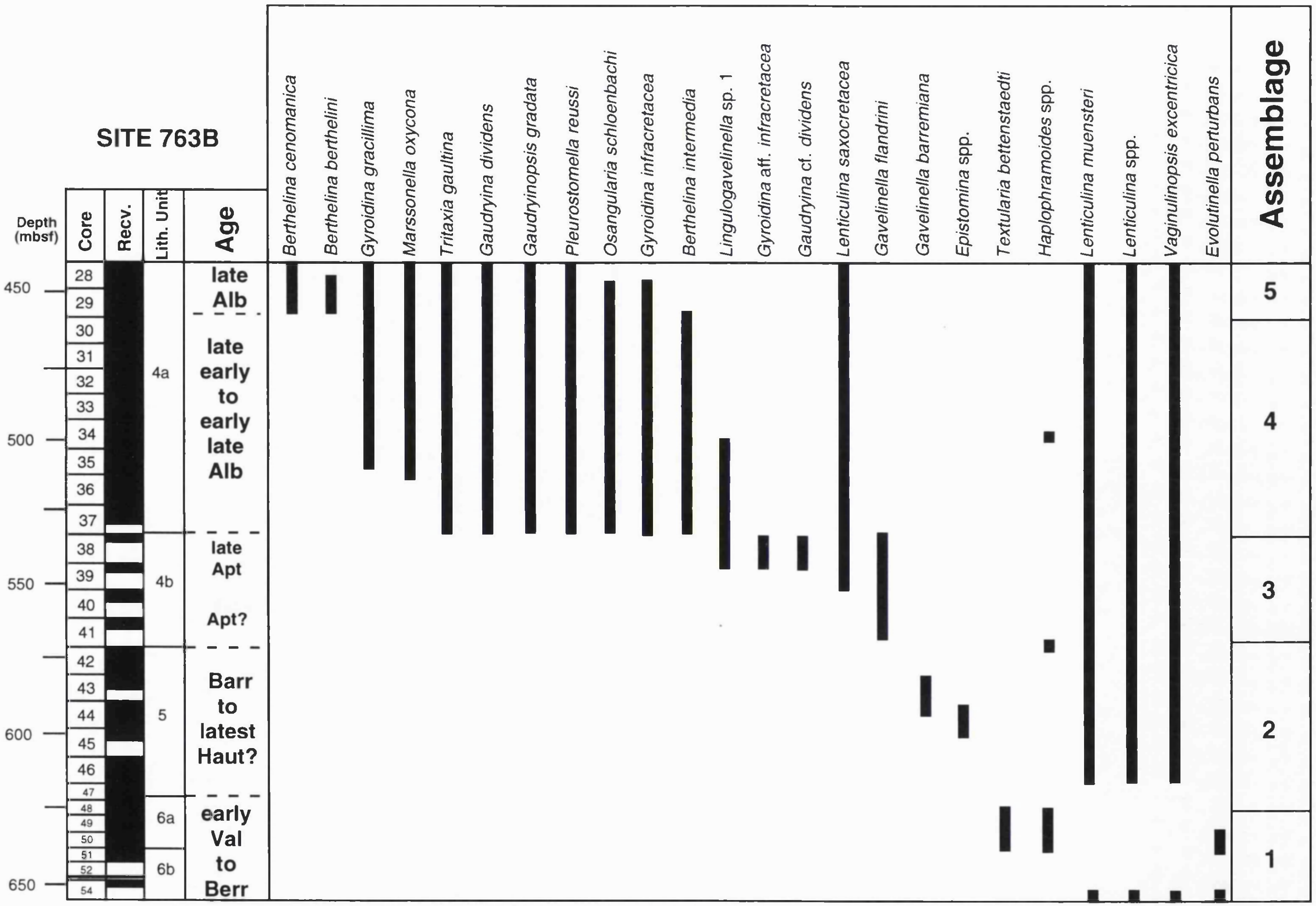


Figure 4.11. Statigraphic ranges of selected benthic foraminifera from Site 763B (% core recovery shaded black).

4.10. ODP SITE 765

Kaminski *et al.* (1992^{a}) documented the Tithonian to Aptian benthic foraminiferal assemblages from Core sections 765-62R-4 to -47R-3 and a summary of the chronostratigraphy, based on calcareous nannofossil, foraminiferal, radiolarian, and palynological biostratigraphy and magnetostratigraphy, was presented by Kaminski *et al.* (1992^{b}). It was noted, however, that some of the planktonic foraminiferal datums given for Cores 765-47R to -27R by Kaminski *et al.* (1992^{b}) did not correspond to datums recorded in other parts of the Indian Ocean and 20 samples from Core sections 49R-3 to 26-CC were, therefore, re-examined. An updated synthesis of the magnetobiostratigraphy and chronostratigraphy of Hole 765 is shown in Figure 4.12.

Many samples within that interval are rich in radiolarians and are either barren or consist of impoverished agglutinated assemblages, although some planktonic foraminifera and a few calcareous benthic species are found intermittently, which are useful for biostratigraphy. Sample 765-45-CC contains the planktonic species *Praehedbergella sigali*, indicating an early Aptian age in agreement with radiolarian, nannofossil and palynological data (Kaminski *et al.*, 1992^{b}; P.R. Bown, pers. comm., 1995). The planktonic~~s~~ species *Blefuscuiana aptica* and *Blefuscuiana* spp. occur in Sample 765-40R-1; 10-12 and also in Samples 765-38R-3; 32-37 and 765-37R-1; 5-4, together with *Globigerinelloides ferreolensis*, pointing to a Gargasian age for these two samples. A late Aptian age is further supported by the presence of the benthic species *Gavelinella flandrini, Gyroidina* aff. *infracretacea, Coryphostoma* sp. 1 and *Gaudryina* cf. *dividens* in Sample 765-37R-1; 5-4. In Sample 765-29R-3; 108-112, the stratigraphically important benthic species *Osangularia schloenbachi* and the planktonic markers *Hedbergella planispira and Hedbergella rischi* suggest a mid Albian age for this sample. Core sections 765-28-CC to 27R-1 are assigned a late Albian age, based on the occurrence of *Hedbergella punctata* and *Tritaxia gaultina.* Finally, Core section 765-26-CC is determined as uppermost Albian or early Cenomanian from the presence of *Rotalipora appenninica* and *Praeglobotruncana delrioensis.*

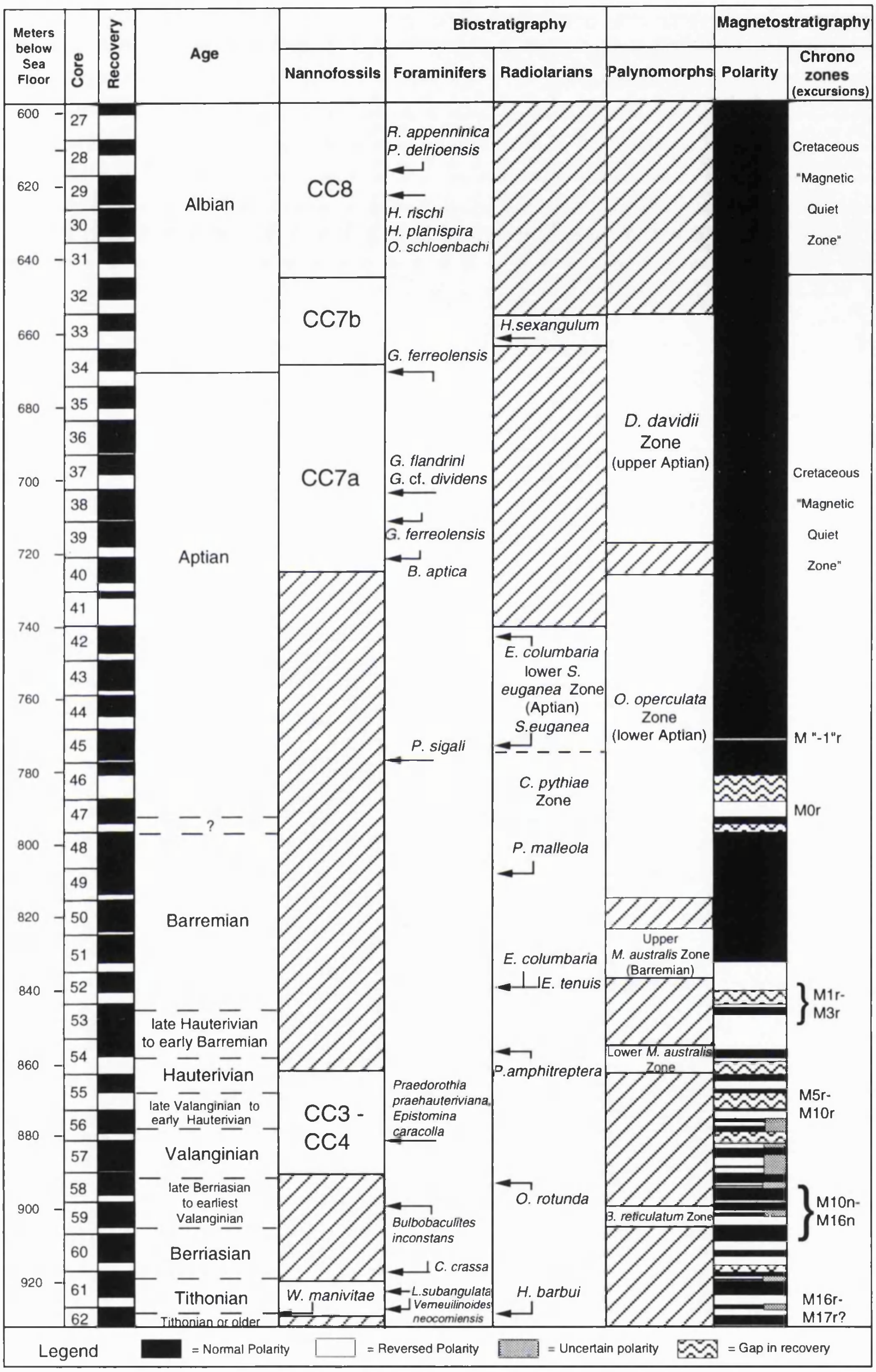


Figure 4.12. Updated magnetobiostratigraphic synthesis and chronostratigraphy of Hole 765 (modified after Kaminski *et al.*, 1992b).

4.11. ODP SITE 766

The biostratigraphy of Lower Cretaceous sediments from Hole 766 was based primarily on nannofossils and planktonic foraminifera for the Aptian-Albian and on radiolaria and palynomorphs for the Valanginian-Barremian (Kaminski *et al.*, 1992^{b}). Magnetostratigraphy was also used to constrain the palaeontological data. The age determinations derived from various microfossil groups were found to be in good agreement, except for the placement of the Hauterivian/Barremian boundary, where nannofossil evidence conflicted with palynological data.

Seventy two samples from Core sections 766-49R-4 to -16R-1 have been analysed for this study. The foraminiferal succession has been divided into seven stratigraphic assemblages. The assemblages and stratigraphic ranges of selected benthic foraminifera are shown in Figures 4.13 and 4.14. An updated synthesis of the magnetobiostratigraphy and chronostratigraphy of Hole 766 is shown in Figure 4.15.

1. *Lenticulina ouachensis - Textularia bettenstaedti* Assemblage

Core sections 766-49R-3 to -43R-5.

Age: late Valanginian to early Hauterivian.

This mixed calcareous/agglutinated assemblage is characterized by *Lenticulina ouachensis, Saracenaria forticosta* and *Frondicularia hastata, Textularia bettenstaedti, Bulbobaculites* sp. 1, *Ammodiscus tenuissimus, Aaptotoichus clavellatus, Rhizammina* spp. and *Haplophragmoides* spp. Diversity is high with up to 49 species per sample. Foraminiferal abundances are low only at the base of the succession (Core sections 766-49R-3 to -48R-6). Fluctuating numbers of coarsely agglutinated *Bulbobaculites* sp. 1 and *Ammobaculites* sp. 1 are noted between Core sections 766-47R-1 and -44R-1 and point to the coarse clastic origin of lithologic subunit IIIB. The upper part of this assemblage is marked by the disappearance of agglutinated taxa.

2. *Lenticulina heiermanni - Saracenaria forticosta* Assemblage

Core sections 766-43R-4 to -40R-3.

Age: early Hauterivian.

This undiagnostic interval assemblage is characterized by *Lenticulina heiermanni, Saracenaria forticosta, Globulina* spp., *Oolina* spp. and is dominated by diverse nodosariids, which have little stratigraphic significance. Both diversity (maximum number of species is 28) and abundance decrease in comparison to the previous assemblage and samples within Cores 766-42R and -41R are barren.

3. *Planularia crepidularis - Patellina subcretacea* Assemblage

Core sections 766-40R-2 to -32R-2.

Age: late Hauterivian.

The base of this assemblage is marked by the FOs of *Saracenaria valanginiana* and *Gavelinella aff. barremiana* and by a massive influx of *Patellina subcretacea.* The foraminiferal abundances increase at the base of the interval, then fluctuate markedly from Core section 766-37R-3 to the top. Diversities remain moderate (with up to 28 species per sample). Agglutinated foraminifera are also absent from this assemblage. At four levels (Core sections 766-40R-2, 766-38R-2 to -37R-3, 766-35R-1, and 766-32R-5), the assemblages become strongly dominated by *Patellina subcretacea* and to a lesser extent by *Gavelinella aff. barremiana.* Highly fluctuating numbers of *Patellina subcretacea* are found in lithologic subunit IIIB from Core sections 766-45R-5 to -32R-5.

4. *Gavelinella barremiana - Praedorothia ouachensis* Assemblage

Core sections 766-30R-4 to- 26R-3.

Age: Barremian.

The base of this assemblage is marked by a faunal turnover corresponding to a major lithological change above an unconformity. The base of the assemblage is characterized by the LO of *Patellina subcretacea*, and the FOs of *Saracenaria spinosa*, *Lenticulina macrodisca*, *Lingulina* sp. 1, *Glomospirella gaultina* and *Glomospira* spp. The FOs of *Gavelinella barremiana* and *Praedorothia ouachensis* are observed in Sample 766-29R-3, 54-55. This faunal change probably reflects a depositional hiatus between the late Hauterivian and Barremian represented by a major discontinuity at the boundary between lithological subunits IIIA and IIIB. Diversity is very high in this interval (with up to 55 species per sample), except at the very top of the section (Core sections 766-27R-3 to 26R-3), where the samples examined are virtually barren of foraminifera. *Glomospira* spp. are more numerous in this interval than in the assemblage below and calcareous agglutinated are recorded for the first time.

5. *Saracenaria spinosa - Gavelinella* sp. 1 Assemblage

Core sections 766-25R-1 to -24R-1.

Age: Aptian.

The assemblage, which occurs above the near barren Core sections 766-27R-3 to 26R-1, is dominated by calcareous species including many nodosariids and rotaliids. The base of the interval is characterized by the FOs of *Gyroidina infracretacea, Gavelinella* sp. 1 and *Lingulogavelinella* sp. 1. The occurrences of *Saracenaria spinosa,* closely resembling European morphotypes (see systematic description in Chapter 6) and of *Gyroidina infracretacea*, known from the Aptian-lower Albian and Aptian-Albian, respectively, together with the lack of diagnostic Albian species

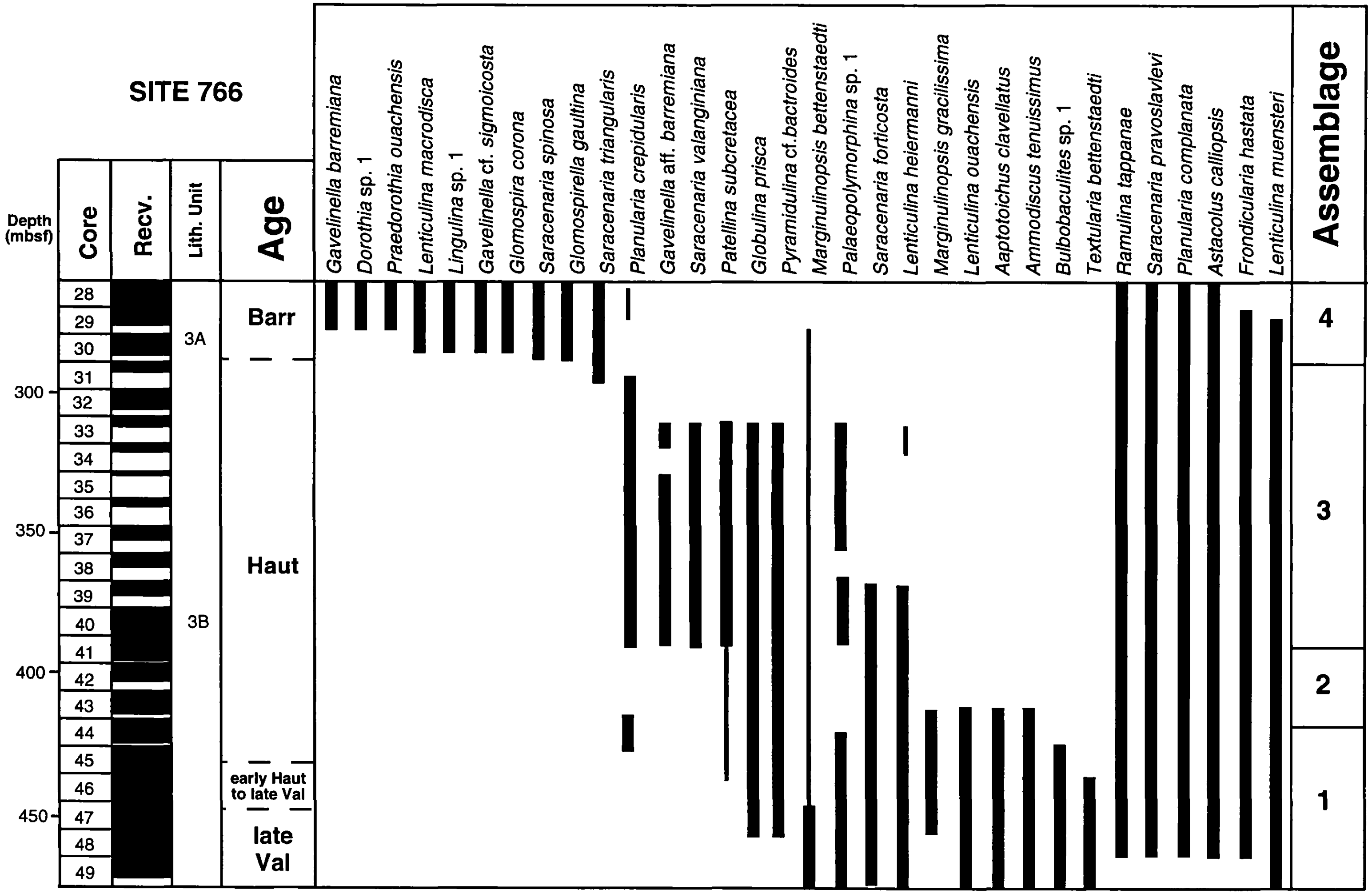


Figure 4.13. Stratigraphic ranges of selected benthic foraminifera at Site 766, Cores -49R to -28R (% core recovery shaded black).

indicate an Aptian age for the interval. An Aptian age is confirmed by the presence of the planktonic species *Praehedbergella sigali* in Sample 766-25R-1; 3-5 and *Blefuscuiana infracretacea, Blefuscuiana aptiana* and *Blefuscuiana gorbachikae* in Sample 766-24R-1; 111-113. Diversity is initially low but increases markedly (to 35 species) in Sample 766-24R-1; 111-113. Abundance remains high throughout the interval (over 350 specimens per sample).

6. *Berthelina intermedia - Osangularia schloenbachi* Assemblage

Core sections 766-21R-2 to -19R-1.

Age: late early Albian to mid Albian.

Due to poor core recovery, no data are available for Cores 766-23R to -22R, which represent a siliceous interval. However, a marked faunal change is observed above this interval. The base of Assemblage 5 is characterized by the FOs of many new taxa, including *Coryphostoma* sp. 1, *Charltonina australis, Quadrimorphina allomorphinoides, Gyroidina gracillima, Gaudryinopsis gradata, Berthelina intermedia* and *Osangularia schloenbachi.* The FOs of *Tritaxia gaultina* and *Pleurostomella reussi* are also noted in Samples 766-21R-1; 39-43 and 766-20R-3; 20-24, respectively and the LO of *Saracenaria spinosa* is noted in Sample 766-20R-1; 39-43. The calcareous benthics point to an Albian age for Assemblage 6 (Core sections 766-21R-1 to -19R-1), although the LO of *Saracenaria spinosa* in Sample 766-20R-1; 39-43 suggests that this part of the interval can be no younger than early mid Albian. Abundant planktonics corroborate a late early to mid Albian age for Assemblage 6 (*Hedbergella* cf. *planispira* is recorded in Core sections 766-21R-2 to -21R-1, *Hedbergella planispira* in Core sections 766- 20R-3 to -19R-1 *Hedbergella rischi* and rare *Hedbergella punctata* in Core sections 766-19R-3 to -19R-1). Diversity is high initially (with up to 39 species per sample), becoming moderate while abundance remains high.

7. *Heterantyx cretosa - Spiroplectinella gandolfii* Assemblage

Core sections 766-18R-5 to -16R-1.

Age: late Albian.

This assemblage is dominated by calcareous species and includes many taxa already recorded in Assemblage 6. However, the FOs of *Heterantyx cretosa* and of *Spiroplectinella gandolfii*, which are observed in Sample 766-18R-5; 78-81 in Sample 766-18R-3; 58-61, respectively, place the interval in the upper Albian. This age determination is supported by the presence of several planktonic index taxa: *Planomalina praebuxtorfii* in Core Section 766-17R-2, *Praeglobotruncana delrioensis* in Core sections 766-16R-5 to -16R-3, *Schackoina cenomana, Rotalipora ticinensis* and *Rotalipora appenninica* in Core section 766-16R-3. Diversity is

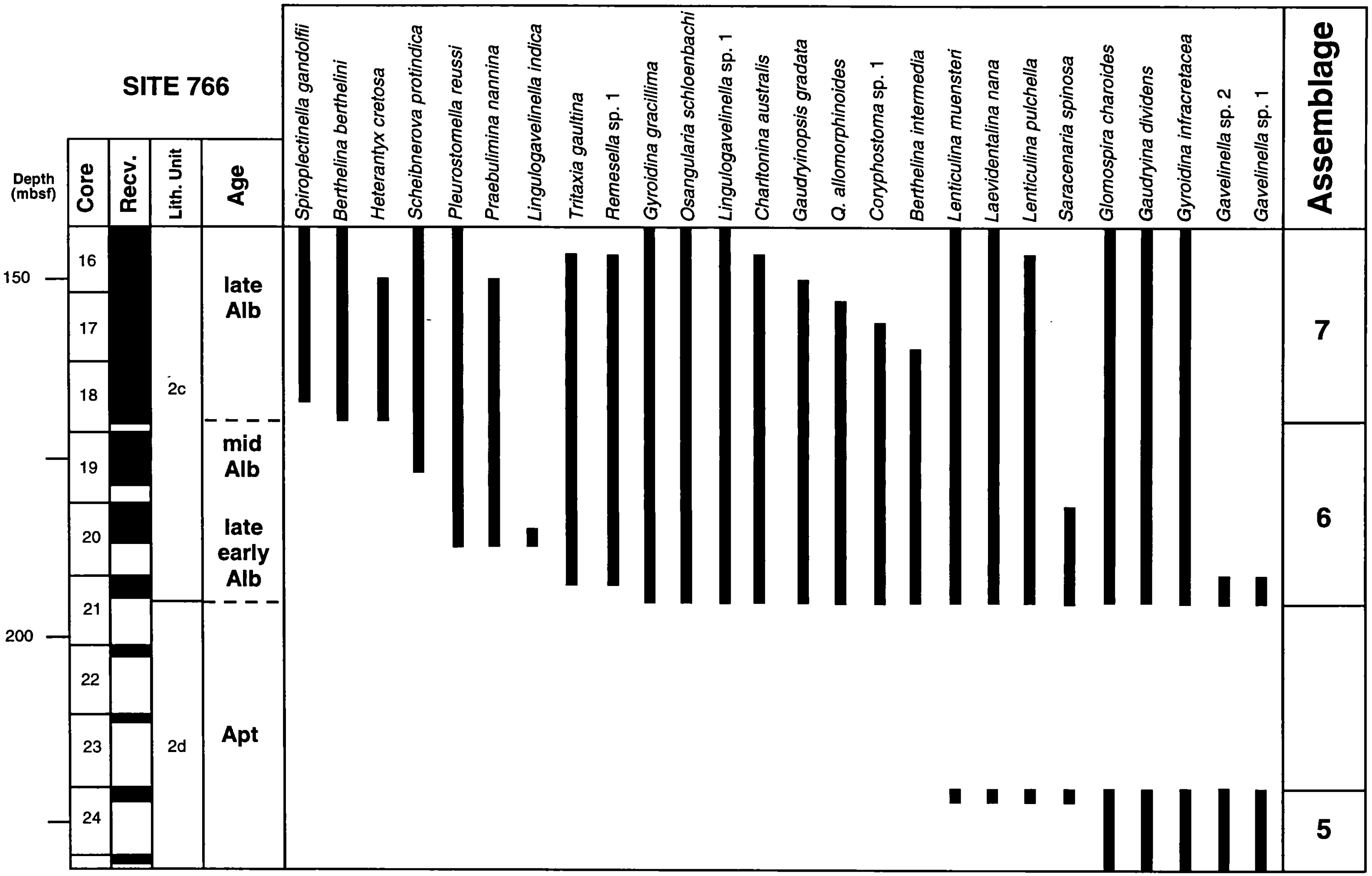


Figure 4.14. Statigraphic ranges of selected benthic foraminifera from Site 766, Cores -25R to -16R (% core recovery shaded black).

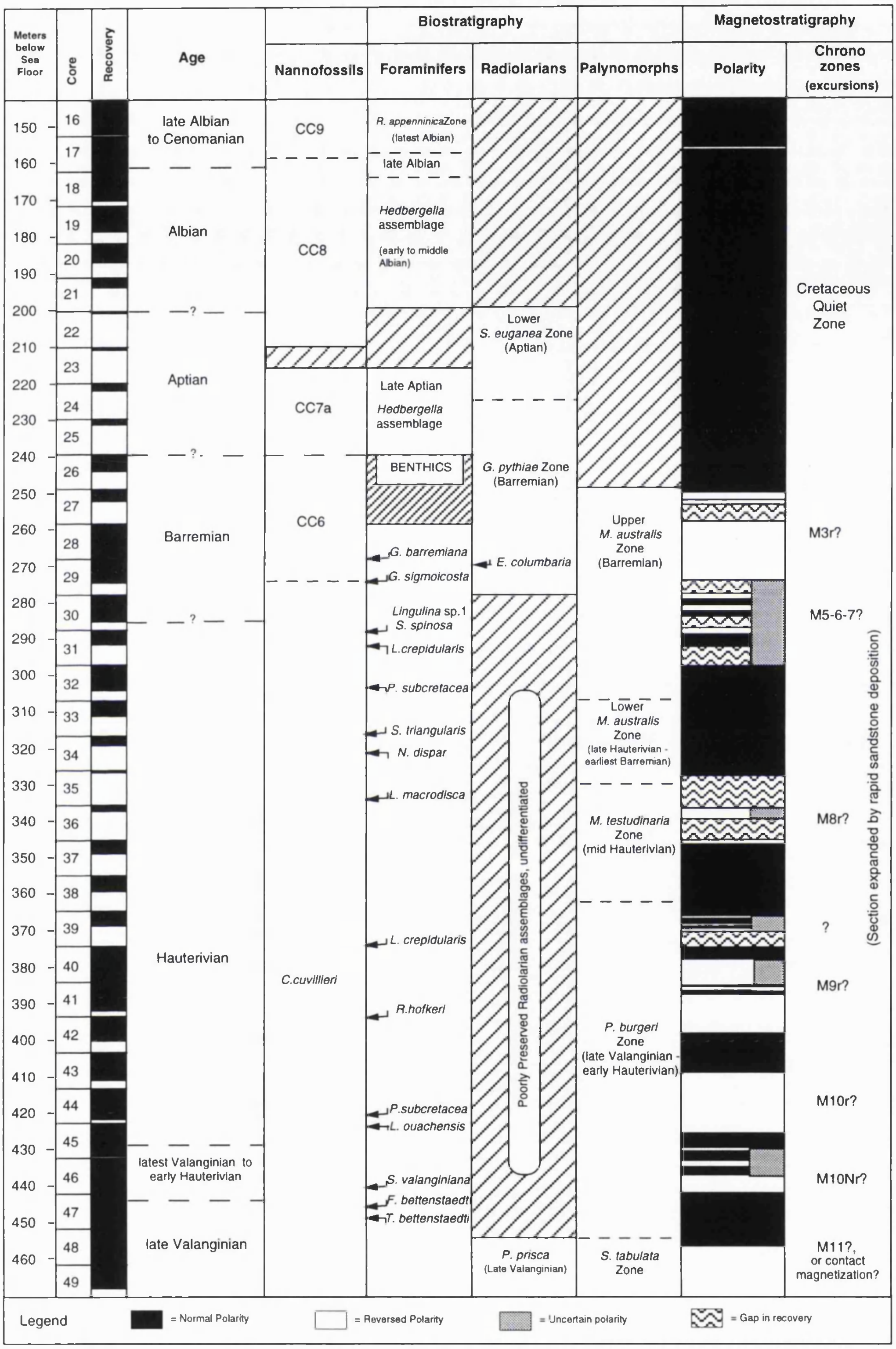


Figure 4.15. Updated magnetobiostratigraphic synthesis and chronostratigraphy of Hole 766 (modified from Kaminski *et al.*, 1992^b).

initially high for this assemblage (with up to 40 species per sample), but decreases near the top of the interval; abundance remains high throughout.

Nannofossil age assignations are in close agreement with the ages determined from benthic and planktonic foraminifera. (P.R. Bown, pers. comm., 1995).

4.12. BENTHIC FORAMINIFERAL ZONATIONS

4.12.1. Review of Early Cretaceous zonal schemes

The biostratigraphy of Lower Cretaceous benthic foraminifera has been studied by a number of authors. The work of Bartenstein and co-workers on the benthic foraminifera of the Saxony Basin has led to a local biostratigraphic scheme for NW Germany (Bartenstein and Bettenstaedt, 1962). This zonation was based on the stratigraphic succession of 75 foraminifera and 12 ostracod species in the middle Valanginian to lowermost Cenomanian of Saxony. The stratigraphic ranges of benthic foraminifera were calibrated to the standard ammonite zones. The zonation of NW Germany has been later refined in numerous publications by Bartenstein and co-workers, and formed the basis of a proposal for a general biostratigraphic zonation for the worldwide Lower Cretaceous using cosmopolitan species (Bartenstein, 1979). This worldwide zonation was based on comparing the stratigraphic ranges of species on both sides of the North Atlantic. Bartenstein used the study of Ascoli (1976) as a standard reference for the Canadian offshore wells. In this zonal scheme, Bartenstein extended the stratigraphic ranges of some of the NW German species to older (Berriasian or Tithonian) horizons, but the first occurrences (FO) of many forms were still recorded with a question mark. The upper limits of the stratigraphic ranges remain largely unchanged from the earlier study.

The stratigraphic ranges of 152 boreal, shallow water Cretaceous foraminifera from southern and eastern England were reported by Hart *et al.* (1989). Data for the Berriasian to Albian were based mainly on studies of the Speeton Clay Formation in north-east England, Atherfield Clay Formation in the Isle Of Wight and Gault Clay Formation in Kent. Hart *et al.* (1989) did not erect a formal zonation for the Lower Cretaceous, but provided extensive range charts. This work on the Lower Cretaceous benthic foraminifera from mainland England can be extended by including the deeper boreal assemblages of the Viking and Central Grabens of the North Sea (King *et al.*, 1989). Two zonal schemes were proposed by King *et al.* (1989): one applicable to the shallower "shelf" facies of the southern and the other to the deeper outer sublittoral and bathyal facies of the northern North Sea.

Moullade (1984) reviewed the importance of small, cosmopolitan, benthic foraminifera from the Oxfordian to the Cenomanian for stratigraphy, palaeoecology and palaeogeography, and proposed a formal zonation for the Upper Jurassic-Lower Cretaceous based on benthic foraminifera. This was the first formal zonation of the northern Tethyan margin, and was based to a large extent on comparison of North Atlantic low-latitude DSDP sites with the Vocontian Trough. Moullade (1974) had previously developed a Lower Cretaceous zonal scheme for the pelagic facies of the Mediterranean Province based on the Vocontian Basin and several other stratotypes and Moullade (1979) had also proposed a zonation for the Valanginian in southeastern France based on benthic foraminifera which was correlated with ammonites.

A zonal scheme for the Tithonian to Cenomanian of the northern Tethyan margin, published by Weidich (1990), was based on the occurrence of over 400 foraminiferal species from the Northern Calcareous Alps in Bavaria and Austria. This monograph provides the most complete taxonomic data set for the northern Tethys. Weidich's biostratigraphic scheme subdivided the Lower Cretaceous into 10 zones, based on first occurrences or acmes of primarily calcareous benthic foraminifera. For the interval of interest for this study, Weidich recognized only three zones, in contrast to the 10 zones defined by Moullade. However, Weidich's zonal scheme is only tentatively correlated to the standard chronostratigraphy (therefore zonal boundaries are indicated by dashed lines), and further calibration of Weidich's samples by means of planktonic microfossils is needed to refine the age of his zones.

Geroch and Nowak (1984) proposed a zonation for the late Tithonian-late Eocene, which was based entirely upon agglutinated foraminifera from the Polish Outer Carpathians. Geroch and Nowak (1984) recognized six partial range zones for the Lower Cretaceous and suggested that their zonal scheme might have wider applicability, as many of the index taxa were also known to occur in deep sea sediments outside the Carpathians.

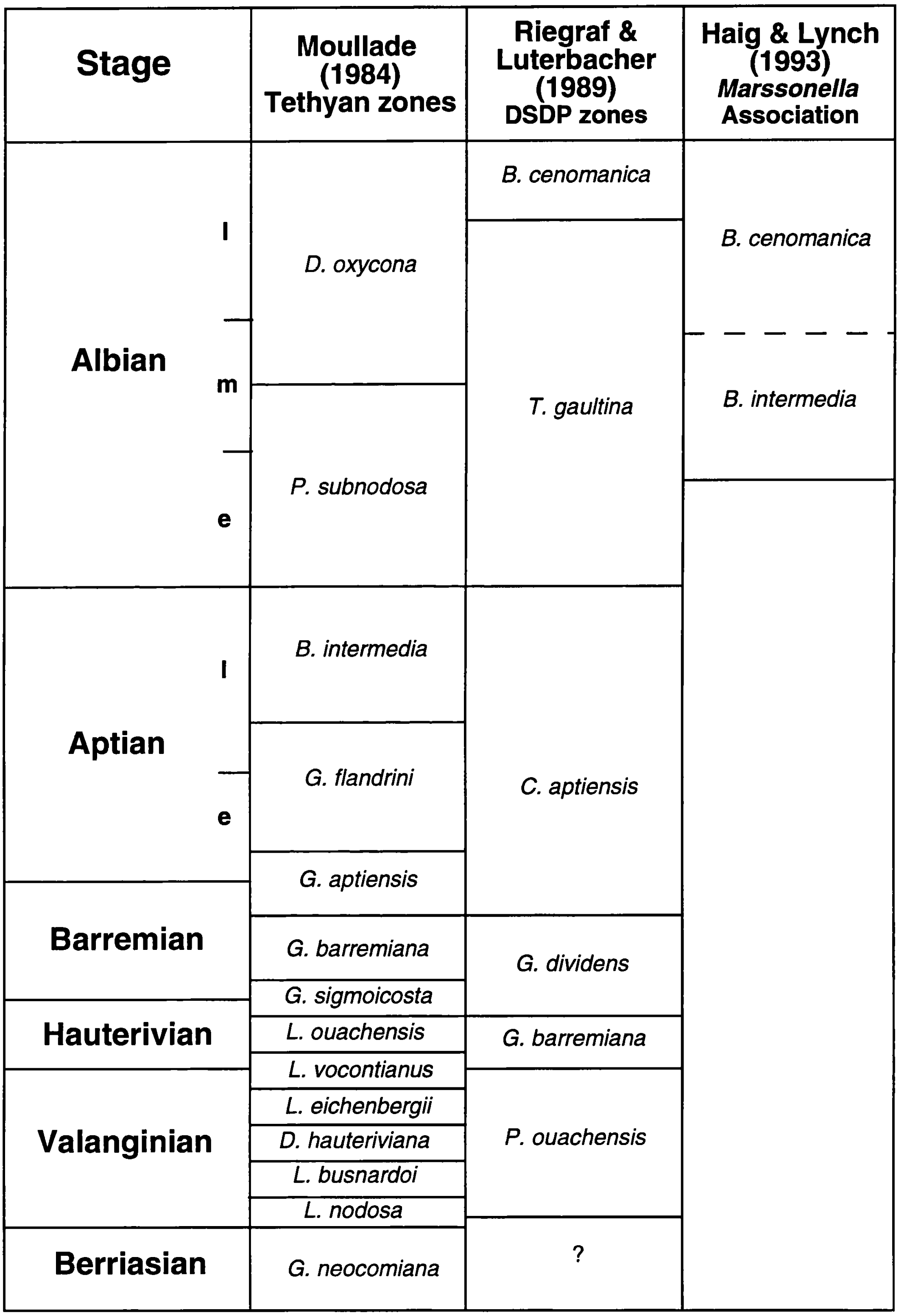
Riegraf and Luterbacher (1989) studied 22 low latitude sites situated in the northern hemisphere, but three sites from higher southern latitudes were also investigated: Sites 249 and 261 in the Indian Ocean and Site 330 in the Atlantic Ocean. These authors devised an Early Cretaceous benthic foraminiferal zonation that subdivided the Berriasian to Cenomanian into six zones, based on the first occurrences of certain taxa. The authors also reported the stratigraphic ranges of 31 cosmopolitan deep-sea species in both deep sea and continental margin sequences. They extended the known stratigraphic range of several other deep-sea taxa into older levels. Among them is the species *Gavelinella barremiana* which was reported from the base of Hauterivian, and is the nominate taxon for their Hauterivian zone. Moullade (pers. comm., 1994) has suggested, however, that the form reported by Riegraf and Luterbacher may be a precursor of *G. barremiana* which is known to have ancestors with FO at the Hauterivian-Barremian boundary (cf. *G.* aff. *barremiana* p. 73 in Moullade, 1966).

Haig (1979[a]) recognized two main faunal associations in the Aptian-Albian of Queensland: the low diversity *Ammobaculites* Association characteristic of shallow epicontinental seas and the *Marssonella* Association reflecting open shelf conditions. The faunal composition of these two benthic foraminiferal associations differed so markedly that Haig (1979[a]) devised two appropriate zonal schemes. The zonation for the *Ammobaculites* Association was based on local index taxa and its regional applicability extended to the Great Artesian Basin. By contrast, the zonation derived for the *Marssonella* Association used cosmopolitan key species and was shown by Haig (1981; 1992) and Haig and Lynch (1993) to have wider geographical relevance in the Papuan Basin and on the western Australian margin. Haig's zonation is the only scheme to be directly based on foraminiferal assemblages from the austral region.

The schemes of Moullade (1984), Riegraf and Luterbacher (1989) and Haig (1979[a]), which are most relevant to this work, are shown for comparison in Figure 4.16.

4.12.2. Discussion

Most of the Early Cretaceous benthic foraminiferal zonations were originally erected for well-delineated sedimentary basins either in the Boreal realm or along the Tethyan margin. The schemes often reflected the paramount influence of particular sets of environmental parameters over the distribution of benthic foraminifera in relatively shallow or semi-enclosed marginal basins. Consequently, the zonations were only applicable on a limited regional scale (e.g. Ascoli, 1988; Kemper, 1989; King *et al.*, 1989). During the last few decades, however, the DSDP and ODP drillings have allowed unprecedented access to the deep-sea sedimentary record of major oceans and it has become imperative to develop cosmopolitan zonations enabling global correlations across ocean basins. This synoptic approach has been encouraged by the growing awareness that "endemism" was often anthropomorphic, expressing taxonomic bias rather than real biological differences, and that deep oceans represented less transient environments than marginal basins. This approach was followed by Bartenstein (1979), Moullade (1984) and Riegraf and Luterbacher (1989), who all proposed Early Cretaceous cosmopolitan zonations. However, some



Stage		Moullade (1984) Tethyan zones	Riegraf & Luterbacher (1989) DSDP zones	Haig & Lynch (1993) *Marssonella* Association
Albian	l	*D. oxycona*	*B. cenomanica*	*B. cenomanica*
			T. gaultina	
	m			*B. intermedia*
		P. subnodosa		
	e			
Aptian	l	*B. intermedia*	*C. aptiensis*	
	e	*G. flandrini*		
		G. aptiensis		
Barremian		*G. barremiana*	*G. dividens*	
		G. sigmoicosta		
Hauterivian		*L. ouachensis*	*G. barremiana*	
		L. vocontianus		
Valanginian		*L. eichenbergii*	*P. ouachensis*	
		D. hauteriviana		
		L. busnardoi		
		L. nodosa	?	
Berriasian		*G. neocomiana*		

Figure 4.16. Comparison between benthic foraminiferal zonations of Moullade (1984), Riegraf and Luterbacher (1989) and Haig and Lynch (1993, updated from Haig, 1979^{a}).

major difficulties arise when attempts are made to apply these zonations to the Lower Cretaceous of the Indian Ocean as none of the three schemes are found to be directly relevant.

The worldwide zonation proposed by Bartenstein (1979) included some benthic foraminiferal species such as *Citharina, Epistomina,* and ornamented *Lenticulina*, which were well known from shallow marine boreal and Tethyan deposits, but are rare or absent in Indian Ocean DSDP and ODP sediments. Out of the 77 species listed by Bartenstein (1979), only 34 are found in DSDP and ODP samples studied. In addition, many of the stratigraphic ranges reported by Bartenstein had undefined FOs and LOs, leading to unreliable biostratigraphic comparisons.

Moullade (1984) subdivided the Berriasian to Albian into 14 zones. Unfortunately, most of the zonal markers are either absent or extremely rare in the Indian Ocean sites investigated. Furthermore, *Gavelinella intermedia* [=*Berthelina intermedia* in this work], the nominate taxon of Moullade's uppermost Aptian zone, and *Gavelinella cenomanica* [=*Berthelina cenomanica* in this work], the nominate taxon for the lowermost Cenomanian zone, are not found in corresponding stratigraphic positions to allow correlation with Moullade's zonal scheme.

Although Riegraf and Luterbacher (1989) included observations based on Indian Ocean DSDP sites, only nine of the 24 Valanginian to Aptian taxa listed in Riegraf and Luterbacher's range chart are found at the sites studied. These are *Laevidentalina debilis, Lingulina loryi, Citharina harpa, Praedorothia ouachensis, Marginulinopsis bettenstaedti, Lenticulina nodosa, Lenticulina quenstedti* [=*L. ouachensis* in this work], *Gaudryina dividens* and *Gavelinella barremiana.* Significant differences are also noted in the reported stratigraphic ranges of several species such as *Gavelinella barremiana, Praedorothia ouachensis* and *Gavelinella intermedia* [=*Berthelina cenomanica* in this work].

The discrepancies between the zonal schemes of Bartenstein (1979), Moullade (1984) and Riegraf and Luterbacher (1989) and their inapplicability for the Lower Cretaceous of the Indian Ocean were probably due to the following factors:

1) The main standards used in the zonations of Bartenstein (1979) and Moullade (1984) were low latitude Tethyan assemblages, which were probably unrepresentative in the higher latitudes of the Indian Ocean during the Early Cretaceous.

2) Some of the stratigraphic discrepancies arise from complex taxonomic conundrums. *Praedorothia ouachensis*, for instance, is reported by Riegraf and Luterbacher (1989) to have an early Valanginian to early Aptian range, while Moullade (1984) distinguished three distinct species: *Praedorothia praehauteriviana*,

Praedorothia hauteriviana and *Praedorothia ouachensis*, with discrete stratigraphic ranges between the early Valanginian and early Aptian. The gavelinellid lineage used by Moullade (1984) and Riegraf and Luterbacher (1989), as the basis for some of their zones, is also controversial. Riegraf and Luterbacher (1989) placed *Gavelinella flandrini*, the index taxon for Moullade's middle Aptian zone, in synonymy with *Gavelinella intermedia*, which they considered to have an extended Aptian-early Cenomanian range. These authors also attributed a prolonged ?Hauterivian-early Cenomanian range to *Gavelinella barremiana*, using the species as an index taxon for their Hauterivian zone, despite recording its Hauterivian occurrence as uncertain in their taxonomic compilation. By contrast, the range of *Gavelinella barremiana* is given as early late Barremian-early Aptian in Moullade's zonation, which is in broad agreement with other records in the literature (e. g. Bettenstaedt, 1952; Michael, 1966; Neagu, 1975).

3) Provincialism may also have affected foraminiferal distribution patterns in the Early Cretaceous, leading to arbitrary occurrences and disjunct ranges. It should be noted, however, that the Albian zones defined by Riegraf and Luterbacher (1989) and Haig (1979^{a}), shown in Figure 4.16, show strong faunal similarity, suggesting that provincialism had certainly faded in the Indian Ocean by the late Aptian or early Albian.

The Albian zonation devised by Haig (1979^{a}) for the *Marssonella* Association of Queensland is the only zonation, which can be applied, without considerable modification, to the Albian of the Indian Ocean. Haig partitioned the Albian into two main zones, the *Berthelina intermedia* zone and the *Berthelina cenomanica* zone, encompassing the early late Albian-middle Albian and the late Albian, respectively (see Figure 4.16). These two zones are found to occur in corresponding stratigraphic positions in the Indian Ocean. Detailed descriptions of the characteristic foraminiferal assemblages in each zone were not, however, provided by Haig (1979a).

4.12.3. Early Cretaceous benthic foraminiferal zonation for the Indian Ocean

In the absence of an appropriate benthic foraminiferal zonation for the Lower Cretaceous of the Indian Ocean, a zonal scheme is proposed here, which is based on foraminiferal data from the DSDP and ODP sites. Six main zones are recognized, which are described below and tabulated in Figure 4.17. The age of stage boundaries and magnetic reversals has been defined using the Mesozoic time scale of Gradstein *et al.* (1994). Dating of the zones has been constrained with calcareous nannofossil, planktonic foraminiferal, radiolarian, and palynological biostratigraphy and magnetostratigraphy (Kaminski *et al.*, 1992^{b}). Zonal terminology follows Berggren and Miller (1988).

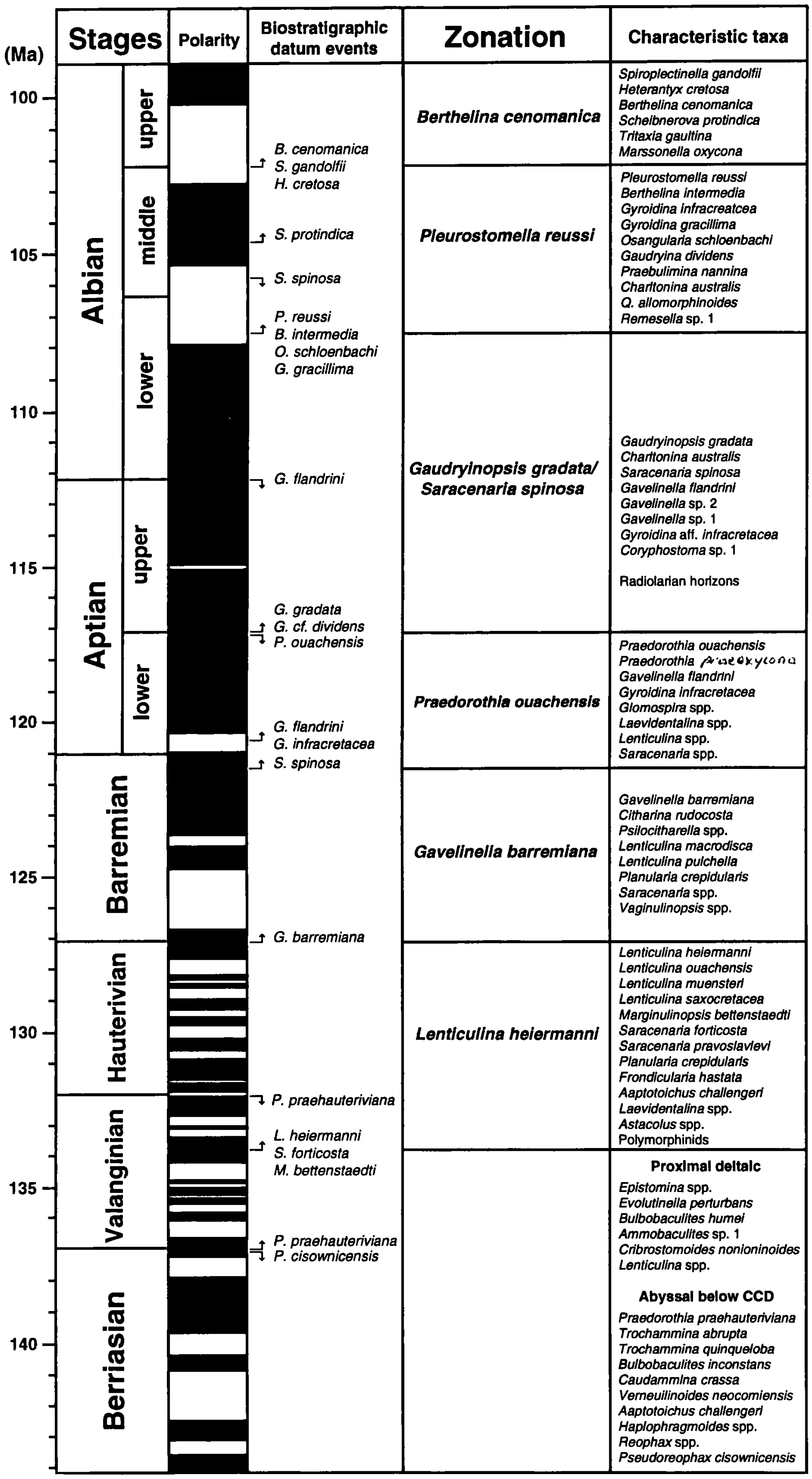


Figure 4.17. Proposed benthic foraminiferal zonation for the Lower Cretaceous of the Indian Ocean (magnetic data provided for reference).

Spiroplectinella gandolfii Zone.

Interval zone: base defined by FO of *Spiroplectinella gandolfii.*

Age: late Albian to early Cenomanian.

Assemblage: dominated by calcareous taxa and calcareous cemented agglutinants, including *Scheibnerova protindica, Tritaxia gaultina, Marssonella oxycona, Pleurostomella reussi, Gyroidina gracillima* and *Berthelina berthelini.* Principal index markers are *Berthelina cenomanica, Heterantyx cretosa* and *Spiroplectinella gandolfii*, which have late Albian to early Cenomanian ranges.

Pleurostomella reussi Zone.

Interval zone: base defined by FO of *Pleurostomella reussi,* top defined by FO of *Spiroplectinella gandolfii.*

Age: late early Albian to early late Albian.

Assemblage: highly diverse assemblage, characterized by calcareous and calcareous agglutinated taxa, including *Gyroidina infracretacea, Gyroidina gracillima, Osangularia schloenbachi, Pleurostomella reussi, Charltonina australis, Praebulimina nannina, Quadrimorphina allomorphinoides, Gaudryina dividens, Remesella* sp. 1 and *Coryphostoma* sp. 1. The ratio of *Gyroidina gracillima/Gyroidina infracretacea* increases towards the top of the zone. Tests of *Gaudryina dividens* exhibit a tendency to become biserial or even uniserial. The occurrence of *Scheibnerova protindica* is first recorded in the mid Albian.

Gaudryinopsis gradata/Saracenaria spinosa Zone.

Partial range zone: base defined by LO of *Praedorothia ouachensis*, top defined by FO of *Pleurostomella reussi.*

Age: late Aptian to late early Albian.

Assemblage: comprises large numbers of calcareous and agglutinated species, including *Gavelinella flandrini, Gavelinella* sp. 1, *Gaudryinopsis gradata, Gyroidina* aff. *infracretacea, Praedorothia praeoxycona, Glomospira* spp. and numerous nodosariids. *Saracenaria spinosa* specimens show close resemblance to European morphotypes. Radiolarian horizons, usually barren of foraminifera, often alternate with diversified foraminiferal assemblages.

Praedorothia ouachensis Zone.

Partial range zone: base defined by FO of *Saracenaria spinosa*, top defined by LO of *Praedorothia ouachensis*

Age: latest Barremian to early Aptian.

Assemblage: characterized by a mixed assemblage of calcareous and agglutinated taxa, including *Praedorothia ouachensis, Praedorothia praeoxycona, Glomospira* spp., *Rhabdammina* spp., *Gavelinella flandrini, Gyroidina infracretacea* with abundant nodosariids. The first appearance of *Saracenaria spinosa* is observed in the latest Barremian, which is slightly earlier than the reported FO from the northern hemisphere.

Gavelinella barremiana Zone.
Interval zone: base defined by FO of *Gavelinella barremiana*, top defined by FO of *Saracenaria spinosa.*
Age: early to late Barremian.
Assemblage: dominated by calcareous taxa (mainly nodosariids) with variable numbers of agglutinants (with organic or calcareous cement). Distinctive species are *Gavelinella barremiana, Planularia crepidularis, Planularia complanata, Lenticulina pulchella, Praedorothia ouachensis* and numerous *Vaginulinopsis* and *Laevidentalina* spp.

Lenticulina heiermanni Zone.
Partial range zone: base defined by FO *Lenticulina heiermanni;* top defined by FO of *Gavelinella barremiana.*
Age: Valanginian to Hauterivian.

Assemblage: predominantly calcareous with subordinate agglutinant component. Polymorphinids are abundant near the base of the assemblage; nodosariids associated with organically cemented agglutinants become numerically dominant above. Characteristic taxa are *Lenticulina ouachensis, Lenticulina heiermanni, Frondicularia hastata, Saracenaria forticosta, Saracenaria pravoslavlevi, Aaptotoichus challengeri, Marginulinopsis bettenstaedti.*

This zonation applies to mixed calcareous/agglutinated benthic foraminiferal associations from outer shelf and bathyal environments above the CCD *(Marssonella* Association of Haig, 1979[a]). Bathyal and abyssal associations from sub-CCD environments in the Indian Ocean are often very impoverished ("Biofacies B" of Kuhnt and Kaminski, 1989) and do not include any age diagnostic taxa. However, diversified "flysch-type" agglutinated Berriasian to early Valanginian assemblages were found at the base of Holes 261 and 765 in the Argo Abyssal Plain (Kaminski *et al.*, 1992[a]), which contained cosmopolitan species with a correlative value. The species *Pseudoreophax cisownicensis*, used by Geroch and Nowak (1984) as the nominate taxon for their late Tithonian-Berriasian zone, was recorded in the correct stratigraphic position at Site 765 (Cores 765-61R to -59R) by Kaminski *et al.* (1992[a]). The stratigraphic distribution of *Praedorothia praehauteriviana* in the Valanginian of Site 765 (Cores 765-58R to -56R), was also found to be consistent with published records from the North Atlantic, Tethys and Pacific Ocean (Kaminski *et al.*, 1992[a]).

These biostratigraphic events, applicable for sub-CCD environments off the northern margin of Australia, have also been included in Figure 4.17.

4.13. CORRELATION OF INDIAN OCEAN DSDP AND ODP SITES

The proposed biostratigraphic scheme has been used to correlate Lower Cretaceous sequences from all DSDP and ODP sites in the Indian Ocean. Most of the sedimentary successions contain stratigraphically significant foraminifera, except for intervals, which are characterized by a very impoverished foraminiferal biofacies, dominated by *Glomospira* and *Ammodiscus*. The correlation of Lower Cretaceous sediments from Indian Ocean DSDP and ODP sites is shown in Figure 4.18.

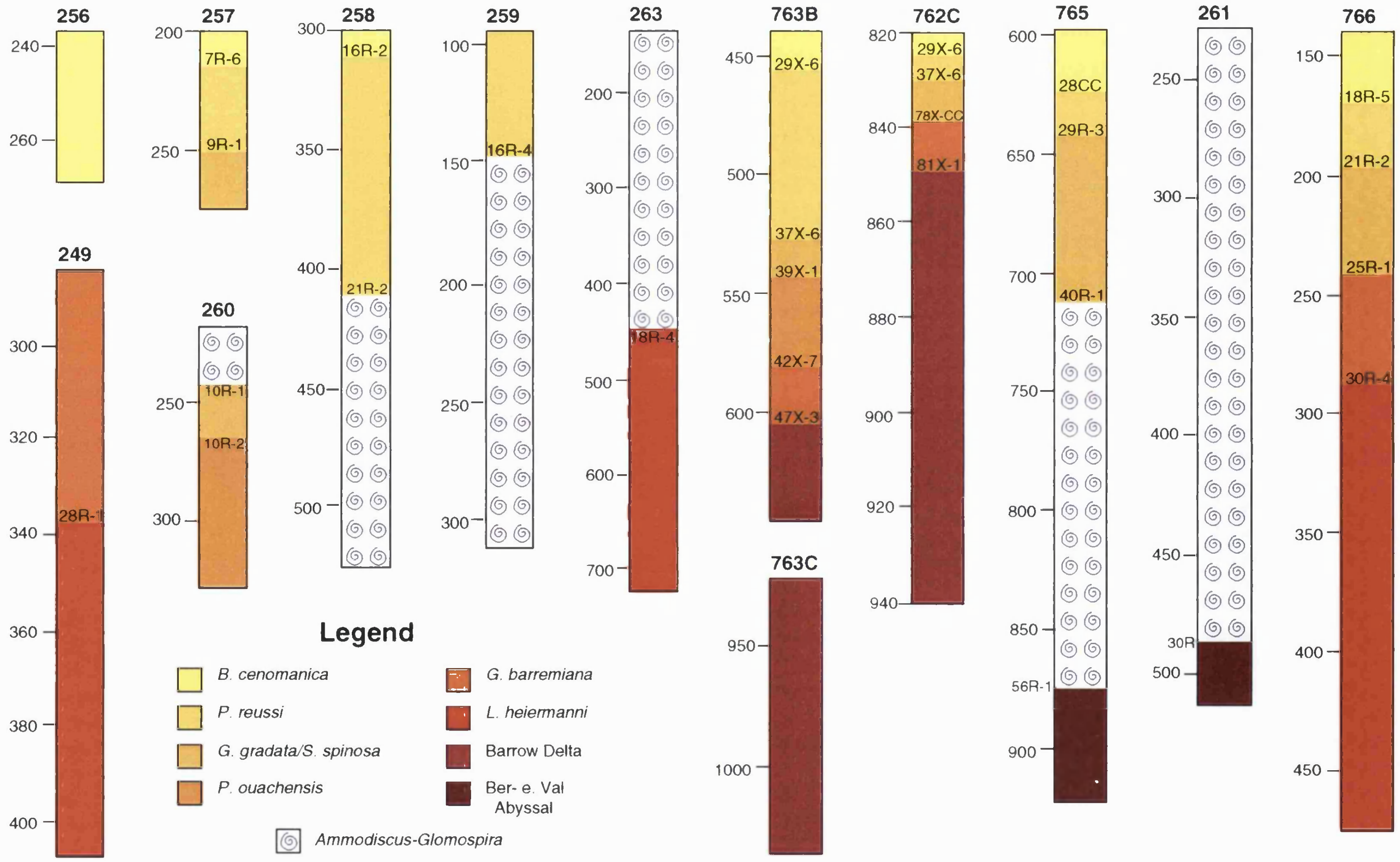


Figure 4.18. Biostratigraphic correlation of Lower Cretaceous sediments from DSDP and ODP holes in the Indian Ocean.

Appendix 4.1. Benthic foraminiferal data for Site 249.

Samples (core, section, interval)	*Globulina* spp.	*Globulina prisca*	*Globulina bucculenta*	*Ramulina tappanae*	*Vaginulinopsis excentricica*	*Lenticulina* spp.	*Astacolus* spp.	*Psilocitharella recta*	*Lenticulina muensteri*	*Saracenaria pravoslavlevi*	*Marginulinopsis bettenstaedti*	*Marginulina pyramidilis*	*Laevidentalina* spp.	*Rhabdammina* spp.	*Saracenaria* spp.	*Lenticulina nodosa*	*Saracenaria frankei*	*Vaginulinopsis reticulosa*	*Lenticulina* cf. *schreiterei*	*Planularia crepidularis*	*Citharina harpa*
26-2; 43-46	2	2		6		39	4	2	3	4	15		8		6	6	3		1	13	
27-3; 115-118	4	10				17	3	2	8	8	7		20		6	2				2	
28-1; 80-83	27	16	14	6	26	97	1	1	62	22	22		40		9	17	8			68	
28-3; 58-61	3	1			4	5	8		1						2						
30-2; 90-93	20	14	36	15	62	36			16	16	28		12	4	15	12	24		13	7	
30-3; 65-68	4	4	48	9	13	24		1	8	11	8	5	5		7	1	4	2	2		
30-4; 5-8			4	1	5								12								1
31-2; 103-106	48	27	112		42	17	18	6	6			1	13		17	1			3	2	
31-3; 80-83			3		2	2			1						2	1					
31-4; 90-94	11	12	16	1	18	13	4	1	9	2	3	1	9	9	7	15	3	3	1	5	2

Samples (core, section, interval)	*Laevidentalina communis*	*Globulina lacrima*	*Laevidentalina deflexa*	*Laevidentalina nana*	*Pyramidulina obscura*	*Astacolus parallelus*	*Astacolus calliopsis*	*Saracenaria forticosta*	*Tristix acutangula*	*Lingulina loryi*	*Oolina sulcata*	*Oolina globosa*	*Vaginulinopsis* spp.	*Lingulina* spp.	*Lenticulina pulchella*	*Marginulina* spp.	*Frondicularia simplicissima*	*Pyramidulina sceptrum*	*Laevidentalina oligostegia*	*Gavelinella* aff. *barremiana*	*Planularia complanata*
26-2; 43-46	3	3	1	4	1	1	1	3		8	1	2		1	8	1		2	3	43	6
27-3; 115-118	8		4	2		3	6	2	2				2		5	4		1	5	4	2
28-1; 80-83	21	11	7	3	4	25	23	8				4	31		21	4		2	2	25	24
28-3; 58-61	1												4			3		1	5		
30-2; 90-93		17	1	5	2	14		4	1		6	5	40		62	16		1	1	3	10
30-3; 65-68	3	10	3		4	8					2	3	1	2	5	1	1	3			
30-4; 5-8		1		1	1	4			1	4	1	2	6								
31-2; 103-106	7	13	2	6	1	60	12	1	3	16											
31-3; 80-83	1																				
31-4; 90-94																					

Samples (core, section, interval)	*Pyramidulina* cf. *bactroides*	*Laevidentalina soluta*	*Frondicularia lamelatta*	*Patellina* spp.	*Laevidentalina distincta*	*Marginulina bullata*	*Lenticulina saxocretacea*	*Lenticulina subangulata*	*Lenticulina nimbifera*	*Pseudonodosaria mutabilis*	*Saracenaria* cf. *valanginiana*	*Gavelinella barremiana*	*Lenticulina circumcidanea*	*Frondicularia dydima*	*Palmula malakialinensis*	*Saracenaria erlita*	*Laevidentalina debilis*	*Pyramidulina obscura*	*Pyramidulina* spp.	*Trocholina* spp.	Diversity	Number of specimens
26-2; 43-46	16	4		8			4			3		228	10			1			3	2	43	485
27-3; 115-118			5			2	1					6	3					5			32	161
28-1; 80-83	6	4	21	1		8	5	3	3	7	3	44	14	2	2	4	7				48	785
28-3; 58-61					1	1															14	40
30-2; 90-93	4	2	4	5																	36	533
30-3; 65-68																					30	202
30-4; 5-8																					14	44
31-2; 103-106																					24	434
31-3; 80-83																					7	12
31-4; 90-94																					21	145

Appendix 4.2. Benthic foraminiferal data for Site 256.

Samples (core, section, interval)	*Rhabdammina* spp.	*Ammodiscus cretaceus*	*Glomospira irregularis*	*Glomospira charoides*	*Ammodiscus infimus*	*Tritaxia gaultina*	*Gaudryina* spp.	*Caudammina crassa*	*Laevidentalina communis*	*Coryphostoma* sp. 1	*Gyroidina infracretacea*	*Gyroidina gracillima*	*Osangularia schloenbachi*	*Berthelina berthelini*	*Charltonina australis*	*Gavelinella* spp.	"*Textulariopsis*" sp. 2	*Praebulimina nannina*
8-1; 132-136	33	45		29	2	9		5		2	3	19	3	2	9	7	3	9
8-2; 116-120	20	10		9				1			6	13	7	5	9	4		2
8-3; 141-145	28	38		21	1	10		6			11	16	9	16	7	1	2	8
8-4; 127-131	40	18		12	1						4	10	13		3	2		
8-5; 32-36	47	34	2	22	1	5	4	1		3	4	16	5	4	2	3		7
8-6; 100-104	21	10		4				1			1	2				4		
9-1; 132-135	21	4	2	2	1	6	2	2	2	1	10	5	1	2	1	4	5	3

Samples (core, section, interval)	*Gaudryinopsis gradata*	*Globulina prisca*	*Ammodiscus tenuissimus*	*Glomospirella gaultina*	*Pleurostomella* spp.	"*Textulariopsis*" spp.	*Bimonilina engeniensis*	*Laevidentalina* spp.	*Pyrulinoides* sp.	*Lingulogavelinella* sp. 1	*Scheibnerova protindica*	*Rhizammina* spp.	*Heterantyx cretosa*	*Spiroplectinella gandolfii*	*Remesella* sp. 1	*Verneuilina* sp.	*Verneuilinoides* spp.	*Pleurostomella reussi*
8-1; 132-136				2	4	8		1		4		2	9	4			1	1
8-2; 116-120								1						3	1			
8-3; 141-145					1									7	5			3
8-4; 127-131						2						3		2				
8-5; 32-36			2	1		3					1	3	1	1	2	1	2	1
8-6; 100-104			3	2	1	2	1	1	1	1	1							
9-1; 132-135	3	1																

Samples (core, section, interval)	*Gyroidinoides* sp.	*Lenticulina muensteri*	*Laevidentalina nana*	*Bathysiphon* sp.	*Glomospira gordialis*	*Ammopshaeroidina* sp.	*Haplophragmoides* sp. 2	*Paratrochamminoides* spp.	*Gaudryina dividens*	*Lenticulina* spp.	*Marginulina bullata*	*Citharina* sp.	*Laevidentalina debilis*	*Pyramidulina sceptrum*	*Psilocitharella recta*	*Psilocitharella* sp.	*Q. allomorphinoides*	Diversity	Number of specimens
8-1; 132-136	7	3					9	18								1	1	31	255
8-2; 116-120	20						4	3	2							2		19	122
8-3; 141-145	18	3	1				16	11	19	4	1	1	1	1	1	3		31	270
8-4; 127-131	13	1		3	1	1	3	1										19	133
8-5; 32-36	5	1	1															30	185
8-6; 100-104																		16	56
9-1; 132-135																		20	78

Appendix 4.3. Benthic foraminiferal data for Site 257.

Samples (core, section, interval)	*Rhizammina* spp.	*Rhabdammina* spp.	*Caudammina crassa*	*Saccammina* sp.	*Kalamopsis* aff. *grzybowskii*	*Saccammina crespinae*	*Saccammina lagenoides*	*Glomospirella gaultina*	*Amodiscus cretaceus*	*Glomospira gordialis*	*Glomospira charoides*	*Haplophragmoides minor*	*Haplophragmoides* spp.	*"Textulariopsis"* spp.	*Ammodiscus infimus*	*Haplophragmoides* cf. *howardense*	*Bathysiphon* sp.	*Ammodiscus tenuissimus*	*Hippocrepina depressa*	*Ammodiscus* spp.	*Glomospira irregularis*	*Ammosphaeroidina* sp.	*Evolutinella perturbans*
7-1; 116-120		3				1		3	29		6		2	1									
7-2; 130-134	1	7						3	24		5		5	1	1						1	3	
7-3; 86-90		5						2	24		10	1	2	3							1		
7-4; 96-100		11							20		6	2	2								3	1	
7-5; 46-50		8						4	17		1			2			2	2			2	3	
7-6; 102-106		9	4			4		3	19		5	2	1	1	1		1	3					
8-1; 96-100		16	1					2	13		4	2	6	2	2	2					1		
8-2; 114-118	2	26				2		7	23		40	2	9	3	1	3	3	1			1	3	
9-1; 144-148	2	21	2	1		1		3	42		74		11	5	1	2	2	2	1	3	1	5	1
9-2; 136-140	1	11	9					5	66		82	6	17	3			4	4	1				
9-3; 92-96	2	21	6			2		9	83		106	6	15	1	2	3							
10-1; 119-123	24	39	20	5	2	2	2	5	82	3	57	4	10	1									

Samples (core, section, interval)	*Gaudryina dividens*	*"Textulariopsis"* sp. 2	*Verneuilinoides* spp.	*Pleurostomella reussi*	*Laevidentalina communis*	*Gyroidina infracretacea*	*Gyroidina gracillima*	*Osangularia schloenbachi*	*Berthelina intermedia*	*Lingulogavelinella* sp. 1	*Gavelinella* spp.	*Lenticulina* spp.	*Vaginulinopsis* spp.	*Globulina prisca*	*Praebulimina nannina*	*Remesella* sp. 1	*Gaudryinopsis gradata*	*Bulbobaculites humei*	*Globulina* sp.	*Berthelina* sp.	*Berthelina berthelini*	*Nothia robusta*	*Tritaxia gaultina*
7-1; 116-120					1	13	33	2		1	1										11		15
7-2; 130-134	9					11	24	12			1	1									19	1	19
7-3; 86-90	5					13	26	15		2	2					2					12		10
7-4; 96-100	8			1		15	22	11							2	1					6		14
7-5; 46-50	14					11	22	13		1		1			5	4					9		16
7-6; 102-106	12			1	1	6	20	10	5		2	1			10	5					15	1	3
8-1; 96-100	20					12	8	21	4	1	2	3			1	5		3	1	5			
8-2; 114-118	76					73	48	48	21			2	1			6	1						
9-1; 144-148	21	14	1	1	3	13	17	11	2	2	8	2	1	1	3								
9-2; 136-140																							
9-3; 92-96																							
10-1; 119-123																							

Samples (core, section, interval)	*Laevidentalina* spp.	*Quadrimorphina allomorphinoides*	*Heterantyx cretosa*	*Coryphostoma* sp. 1	*Pleurostomella* spp.	*Berthelina cenomanica*	*Lenticulina muensteri*	*Glomospira* sp.	*Pseudonodosaria* sp.	*Scheibnerova protindica*	*Gyroidinoides* spp.	*Ammobaculites* spp.	*Bimonilina* spp.	*Arenobulimina* sp..	*Pyramidulina sceptrum*	*Paratrochamminoides* sp.	*Reophax* sp.	*Laevidentalina oligostegia*	*Ramulina* sp.	*Oolina apiculata*	*Psilocitharella paucistriata*	Diversity	Number of specimens
7-1; 116-120					2		1						4				1	1	1	1	2	23	135
7-2; 130-134			3			3	4						4			1						24	163
7-3; 86-90		1		7			1					1	2	1	1							24	149
7-4; 96-100	1			5			2	1	1	2	3											23	140
7-5; 46-50	2		2	3	1	1	2															25	148
7-6; 102-106	1	1																				28	147
8-1; 96-100																						24	137
8-2; 114-118																						24	402
9-1; 144-148																						34	280
9-2; 136-140																						12	209
9-3; 92-96																						12	256
10-1; 119-123																						14	256

Appendix 4.4. Benthic foraminiferal data for Site 258.

Samples (core, section, interval)	*Rhabdammina* spp.	*Rhizammina* spp.	*Caudammina crassa*	*Hippocrepina depressa*	*Bathysiphon* sp.	*Lagenammina* aff. *alexanderi*	*Ammodiscus cretaceus*	*Ammodiscus tenuissimus*	*Glomospira charoides*	*Evolutinella perturbans*	*Haplophragmoides* spp.	*Cribrostomoides nonioninoides*	*Trochammina* spp.	*Verneuilinulla* spp.	"*Textulariopsis*" spp.	*Bimonilina* sp.	"*Textulariopsis*" *wilgunyaensis*	*Reophax geniculatus*	*Recurvoides* spp.	*Bulbobaculites humei*	"*Textulariopsis*" sp. 2	*Psammosphaera* sp. 1	*Glomospira* spp.	*Ammodiscus infimus*	*Glomospira gordialis*	*Aaptotoichus* sp.	*Paratrochamminoides* spp.	*Haplophragmoides* sp. 1	*Haplophragmoides minor*	*Haplophragmoides* cf. *howardense*	*Bimonilina engeniensis*	*Dorothia* sp.	*Verneuilinoides* aff. *crespinae*	*Textulariopsis* sp. 1	*Lenticulina* spp.	*Pleurostomella* spp.	*Haplophragmoides kirki*	*Hyperammina* sp.	*Ammodiscus* spp.	*Glomospirella gaultina*	*Lagenammina* spp.	*Reophax* spp.	*Berthelina intermedia*	*Gyroidina infracretacea*	*Gyroidina gracillima*	*Osangularia schloenbachi*	*Pseudoreophax* sp.	*Pleurostomella reussi*	*Vaginulinopsis* sp.	*Gavelinella* sp.	*Laevidentalina* spp.	*Laevidentalina oligostegia*	*Tritaxia gaultina*	*Berthelina berthelini*	*Praebulimina nannina*	*Psiliocitharella* sp.	*Astacolus* sp.	*Pyramidulina sceptrum*	*Lenticulina muensteri*	*Ramulina* sp.	*Gaudryina dividens*	*Berthelina cenomanica*	*Spiroplectinella gandolfii*	*Lingulogavelinella indica*	*Berthelina* sp.	*Scheibnerova protindica*	*Globulina lacrima*	*Marssonella oxycona*	*Marginulina bullata*	*Lingulogavelinella* sp. 1	*Saracenaria* spp.	*Saracenaria erlita*	*Vaginulinopsis* spp.	*Marginulina* sp.	*Tristix excavata*	*Planularia* sp.	*Ellipsoidella* cf. *cuneata*	*Patellina africana*	Diversity	Number of specimens
14-1; 79-83																																												16						5				4								3		3							2		1	1	1	1	3	5	12	45
15-2; 42-46									2																										5									18	10	19		6		7				11					7		31	2	1	25	2	8	2	2	1	6	1	1	1	1	1				24	170
15-4; 35-39	7						19		9												15																							2										2									2																		7	56
15-6; 52-56	1						6		2												1																							1		1				1				4																									8	17
16-2; 18-22	3						2		13																										2	3								11		12				1				6			1	1	1	1	4	10																	15	71
16-4; 32-36	14																																		1	1								13	12	13				11			1		1	1																							10	68
16-6; 55-59	16						29		14												8																																	5																									5	72
17-1; 81-85	2				1		5		1																															1													1																										6	11
17-3; 104-108	41						23	3	6												4		2		7															2																																							8	88
17-5; 138-142	11	2					16		5		2	1																	3							1									14	1						1																											11	57
18-2; 60-64	18	2			1		28	2	2		5										1								3	1									1						10			1			1																												14	76
18-3; 6-10	33	1					17	2	2		2																													1																																							7	58
18-4; 111-115	6	1			1		23	1	4		3				2									1	1																																																						10	43
20-1; 128-133	15	13			6		32	1	16		43				1	1			1			3		1					6	1					3					2	1	1	5	2	2	2		2			1																												24	161
21-1; 97-101	30	14	1		1		22	6			15	3		1	4				2			2		3	1				6							1				1			16	1	5	5	3	2		2	3																												25	150
21-2; 61-65	24	13	2		7		31	2	6		27	5		1					7	2					1				10							1		1		1		3	38	2	1	3	1	2	1																														25	192
21-3; 140-144	13	6				1	10				20	4																	7		1		2	2				1	1	1	1	3																																					15	73
22-1; 130-134	17	12			2		9	1		1	21	3			8						4	7							3	2	6			2				1																																									16	99
22-3; 92-96	7	7	1		1		5		1		54	8		2			5	6	3	3	4	2							4	10	8	1	2	2			1																																										22	137
22-5; 81-85	4	6			4		7		1		37	7	2		3					6				1	1			4	8	1	7				1	1																																											18	101
23-2; 63-67	27	26	4	2	8	1	42	7	28		14	14			8					2	4	1	1	6	2	3	4	14	23	3	11	6	1	18																																													27	280
24-1; 119-123	33	3			3	1					8	4			8		2	2	9	1	2																																																											12	76
24-3; 55-59	8	28	2	1	2	4	28	2	22	9	10	14	5	4	2	1	14																																																																17	156

Appendix 4.5. Benthic foraminiferal data for Site 259.

Samples (Core, section, interval)	*Psammosphaera fusca*	*Reophax* sp. 3	"*Gaudryina*" spp.	*Caudammina crassa*	*Lagenammina* spp.	*Rhabdammina* spp.	*Rhizammina* spp.	*Ammodiscus* spp.	*Glomospira* spp.	*Bathysiphon* sp.	"*Dorothia*" sp.	*Bimonilina* sp.	*Haplophragmoides* spp.	"*Textulariopsis*" spp.	*Hippocrepina depressa*	*Haplophragmoides kirki*	*Recurvoides* spp.	"*Textulariopsis*" *wilgunyaensis*	*Bimonilina engeniensis*	*Lagenammina lagenoides*	*Glomospira charoides*	*Hyperammina* spp.	*Saccammina crespinae*	*Evolutinella perturbans*	*Psammosphaera* sp. 1	*Hyperammina gaultina*	*Haplophragmoides concavus*	*Vaginulinopsis harpa*	*Paratrochamminoides* spp.	*Marssonella* sp.	*Globulina* spp.	*Saccammina* spp.	*Cribrostomoides nonioninoides*	*Ammosphaeroidina* sp.	*Remesella* sp. 1	*Gaudryinopsis gradata*	*Gaudryina dividens*	*Ramulina tetrahedralis*	*Ramulina* cf. *tetrahedralis*	*Tritaxia gaultina*	*Berthelina intermedia*	*Osangularia schloenbachi*	*Gyroidina infracretacea*	*Gyroidina gracillima*
11-3; 15-17																																								2				
11-3; 125-129																					1														1		1			9			1	
11-4; 94-98																																			1		1			2		1		
11-5; 95-99																					3														10	2	3			22		4	5	4
12-1: 122-126																					1														1		1			5	1			
12-3; 39-43																																			1							1		
12-5; 129-133																					2																			1				
13-2; 54-58								1													2														8	5	5		1	14	3	10	7	5
13-4; 56-60								2																											9	2	9			17	1		1	
13-6; 44-48								1																											9	5	23	1		9		1	2	
14-1; 63-67								1																				2							10	5	8			28	2	2	6	
14-2; 114-118								2																				4							23	5	42			11		6	16	3
14-5; 130-134																																			11	4	9			10		2	8	2
15-1; 86-90								4													3							2							35		50			18	12	12	13	9
15-3; 135-139																																			29		64			5	4	15	19	8
15-5; 40-44																					1														32	1	71	1		1	9	10	21	17
16-2; 33-37								2													4														12	3	53	1		5	3	7	10	4
16-3; 103-107								1								1					6							2							25	5	83	1		4	4	17	17	12
16-4; 90-94																					1														19	5	32			6	3	4	8	2
17-2; 10-14																					6															4	13	1	3					
17-3; 110-114																					1																							
17-4; 24-28						2							3								71															1								
18-1; 121-125																					16																							
18-2; 116-120								2		3											27																							
18-3; 15-19						1															14																							
19-1; 90-94						1				1											14														1									
19-3; 119-123										2											50																							
19-4; 103-107										2											5													1										
20-1; 33-37																					85																							
20-3; 64-68						4				2											46																							
20-5; 103-107																					14																							
21-2; 77-81																					3																							
21-3; 97-101								2													74																							
21-6; 142-146										2											18																							
22-2; 103-107																					34																							
23-2; 70-74						8		1		4											77																							
23-3; 16-20						7		3													68																							
23-5; 116-120						5		4		2											##																							
24-1; 77-81																					35																							
24-2; 44-48			2			5		3		6											86																							
24-3; 63-67								4		1											25																							
25-1; 45-49						3		4													18																							
25-2; 34-38						15		26						8			1				63												1											
25-4; 34-38						2		6		5											46											1												
26-2; 124-128								13		5			1								45									1	1													
26-4; 19-23						1		3		3							2	1			56																							
26-5; 62-66								1		8											28																							
27-1; 44-48						4		5		5											25																							
27-2; 122-126						9		10		14			2				4				46																							
27-5; 86-90						3		8		7							4				44																							
28-1; 21-25						4		15		9								1			40																							
28-3; 52-56						19		3		22								1			51		1																					
28-4; 103-107						2		1		2											7																							
29-1; 43-47										6											5																							
29-2; 96-100						3		6		6											11												1											
29-3; 65-69						4	3	11		4											23				3			3																
30-1; 38-42								5		4											12																							
30-3; 120-124						1		1		4											12												1											
30-5; 33-37	1			5		12		4		14			1					1			15				10			2	1															
31-1; 38-42		1				22		9		16			6				1				6		3			1	1																	
31-3; 36-40						33	6	11		13			1					2			2	1	1	7	2																			
32-1; 90-94				1		23	4	17		9		7	10	1	1	6	6	7	1	1	20																							
32-2; 68-72	4		1			4	5	2	2	4	1	1	2	1																														
33-1; 66-70	##	64	2	2	2	10	4	1																																				

Appendix 4.5. Benthic foraminiferal data for Site 259.

Samples (Core, section, interval)	*Laevidentalina communis*	*Coryphostoma* sp. 1	*Laevidentalina nana*	*Brunsvigella augustissima*	*Ramulina tappanae*	*Quadrimorphina allomorphinoides*	*Lingulogavelinella* sp. 1	*Gavelinella* spp.	*Globulina prisca*	*Pyrulina cylindroides*	*Margulina* sp.	*Oolina globosa*	*Lenticulina muensteri*	*Lenticulina* aff. *nodosa*	*Lenticulina* spp.	*Astacolus calliopsis*	*Laevidentalina legumen*	*Pyramidulina sceptrum*	*Laevidentalina soluta*	*Laevidentalina gracilis*	*Laevidentalina oligostegia*	*Pleurostomella reussi*	*Laevidentalina distincta*	*Lenticulina pulchella*	*Pyrulinoides acuminata*	*Pseudonodosaria humilis*	*Tristix excavata*	*Planularia complanata*	*Vaginulinopsis* spp.	*Laevidentalina* cf. *distincta*	*Lingulonodosaria nodosaria*	*Charltonina australis*	*Astacolus* sp.	*Marginulina innaminckae*	*Scheibnerova protindica*	*Pleurostomella subnodasa*	*Saracenaria* spp.	*Astacolus schloenbachi*	*Pleurostomella* spp.	*Ramulina* sp.	*Pyrulinoides* sp.	*Psilocitharella paucistriata*	*Vaginulina recta*	Diversity	Number of specimens
11-3; 15-17																																												1	2
11-3; 125-129								2																															1					7	16
11-4; 94-98																																												4	5
11-5; 95-99	3	1	3				2								4							1																						14	67
12-1; 122-126																																												5	9
12-3; 39-43																																												2	2
12-5; 129-133							1																																					3	4
13-2; 54-58	4	17	1			2	2						1		4				1			1		1		1			1		1				2				1			1	2	28	104
13-4; 56-60		1	2					1																															2					11	47
13-6; 44-48	6	6	7				1			2			2		1					1												1				2			1			1		20	82
14-1; 63-67	2	7	2												4																													13	79
14-2; 114-118	7	9	4					1		3		3	1		5				1	1	6				1						2	1						1	1	1	1			27	161
14-5; 130-134	4	7	4				2			5			2		2										2		1		1	1		2				2	1							21	82
15-1; 86-90	7	13	5			2	3	2		2		1			4				1	2		6		1	1				3	3	2			2	3									29	221
15-3; 135-139	8	15	2				2	4		1			2		5				1	4		3		2		2			1					1	2									23	199
15-5; 40-44	6	1	4			9	2	3		2		2	10		2				2	2	3	4		4		1	1	2	1	1	2	1	1											33	230
16-2; 33-37	6	18	3		2		1			2			1		3				2				1	1	3	1																		24	148
16-3; 103-107	3	7	5	5	1	1	2	3	4	2	1	2	4	1	10	1	2	1	3	1	2	2																						35	241
16-4; 90-94	4	7	2																																									12	93
17-2; 10-14																																												5	27
17-3; 110-114																																												1	1
17-4; 24-28																																												4	77
18-1; 121-125																																												1	16
18-2; 116-120																																												3	32
18-3; 15-19																																												2	15
19-1; 90-94																																												4	17
19-3; 119-123																																												2	52
19-4; 103-107																																												3	8
20-1; 33-37																																												1	85
20-3; 64-68																																												3	52
20-5; 103-107																																												1	14
21-2; 77-81																																												1	3
21-3; 97-101																																												2	76
21-6; 142-146																																												2	20
22-2; 103-107																																												1	34
23-2; 70-74																																												4	90
23-3; 16-20																																												3	78
23-5; 116-120																																												4	134
24-1; 77-81																																												1	35
24-2; 44-48																																												5	102
24-3; 63-67																																												3	30
25-1; 45-49																																												3	25
25-2; 34-38																																												6	114
25-4; 34-38																																												5	60
26-2; 124-128																																												6	66
26-4; 19-23																																												6	66
26-5; 62-66																																												3	37
27-1; 44-48																																												4	39
27-2; 122-126																																												6	85
27-5; 86-90																																												5	66
28-1; 21-25																																												5	69
28-3; 52-56																																												6	97
28-4; 103-107																																												4	12
29-1; 43-47																																												2	11
29-2; 96-100																																												5	27
29-3; 65-69																																												7	51
30-1; 38-42																																												3	21
30-3; 120-124																																												5	19
30-5; 33-37																																												11	66
31-1; 38-42																																												10	66
31-3; 36-40																																												11	79
32-1; 90-94																																												15	114
32-2; 68-72																																												11	27
33-1; 66-70																																												8	279

Appendix 4.6. Benthic foraminiferal data for Site 260.

Samples (core, section, interval)	*Rhabdammina* spp.	*Bathysiphon* spp.	*Rhizammina* spp.	*Lagenammina* spp.	*Ammodiscus cretaceus*	*Glomospirella gaultina*	*Glomospira charoides*	*Praedorothia ouachensis*	*Gavelinella flandrini*	*Gyroldinia* spp.	*Gavelinellia* spp.	*Saracenaria* spp.	*Lenticulina* spp.	*Astacolus parallelus*	*Astacolus calliopsis*	*Astacolus* spp.	*Globulina prisca*	*Pyrulinoides acuminata*	*Pyrulina cylindroides*	*Globulina* spp.	*Laevidentalina nana*	*Laevidentalina deflexa*	*Laevidentalina olgostegia*	*Laevidentalina communis*	*Laevidentalina soluta*	*Laevidentalina* cf. *deflexa*	*Laevidentalina* spp.	*Psilocitharella arguta*	*Haplophragmoides* spp.	*Praedorothia praeoxycona*	*Ramulina tappanae*	*Marginulina bullata*	*Lenticulina muensteri*	*Lenticulina pulchella*	*Laevidentalina distincta*	*Pyramidulina sceptrum*	*Lingulonodosaria nodosaria*	*Lingulina* spp.	*Laevidentalina debilis*	*Patellina africana*	*Marginulinopsis* spp.	*Pyrulina* sp.	*Othokarstenia shastaensis*	*Gaudryina* aff. *dividens*	*Gaudryinopsis gradata*	*Gyroldina* cf. *infracretacea*	*Vaginulinopsis* spp.	*Saracenaria spinosa*	*Coryphostoma* sp. 1	"*Gaudryina*" spp	Diversity	Number of specimens
7-2; 22-26										2																																									1	2
8-3; 22-26							2																																												1	2
8-5; 115-119	1																																																		1	1
8-6; 115-118							9																																											1	2	10
10-1; 34-38									6				5	5				1	1		2	1	2		3	1	2			33			1	7			2	3	1					55	35	90	2	5	13		23	276
10-2; 132-136		2					4		20			2		2			1	1		1	3	1			1	2	2						2	3	3		3	2						10	29	22					21	116
11-1; 116-120										13																				2																					2	15
12-1; 83-87								41	86			2	3	1			2				2						3			58			1						1			1	2								13	203
12-2; 132-135					1		1	72	108			4	2	1			1													60		2	5	8							1										13	266
13-1; 43-47					3		4																																												2	7
15-1; 138-140							1		4				1																																						3	6
15-2; 125-129							1																																												1	1
15-3; 141-145					2		5																																												2	7
15-4; 124-128					2		5			4																				3				1																	5	15
16-2; 80-84							1			1																														1											3	3
17-1; 134-138	19	1	1		5		24	28	1			2	4	3					1								2			2	1	1	4	5	1	1	1	2	1												22	110
18-1; 127-131	12	8	5	1	10	4	69	86	3	1	1	3	5	1	10	11	4	1	5	3	8	4	3	8	1	1	15	1	3	1																					30	288

Appendix 4.7. Benthic foraminiferal data for Site 263.

Samples (core, section, interval)	*Ammobaculites crespinae*	*Bulbobaculites humei*	*Haplophramoides* spp.	*Hyperammina gaultina*	*Lagenammina* spp.	*Psammosphaera* sp. 1	*Recurvoides obskiensis*	*Recurvoides* spp.	*Trochammina abrupta*	*Trochammina* spp.	*Pseudoreophax* sp. 1	*Cribrostomoides nonioninoides*	*"Textulariopsis" elegans*	*Verneuilinoides neocomiensis*	*Verneuilinulla* sp. 1	*Ammodiscus infimus*	*Spiroplectammina* sp. 1	*Lenticulina* spp.	*Laevidentalina* spp.	*Globulina prisca*	*Bathysiphon brosgei*	*Ammodiscus cretaceus*	*Evolutinella perturbans*	*Haplophragmoides concavus*	*Ammobaculites* sp. 1	*Reophax* cf. *geniculatus*	*Trochammina subinflata*	*Vaginulinopsis excetricica*	*Pyramidulina sceptrum*	Polymorphinids	*Oolina* cf. *caudata*	*Lenticulina subangulata*	*Verneuilinoides* spp.	*Ammodiscus tenuissimus*	*"Gaudryina" cuvierensis.*	*Rhabdammina* spp.	*Rhizammina* spp.	*Hippocrepina depressa*
4-4; 63-67																						3														7	6	
4-5; 64-68																						3														6	5	
4-6; 46-50			1																			10														10	2	
5-1; 131-135																		2				1												1		3		
6-2; 24-28			1																			1												2				
6-4; 67-71			3																			3														1	3	
6-6; 135-139			3							2												6														2	1	
7-2; 14-18			15							3											3	1					8						3				11	
7-3; 91-95			3	1																		1					12						1				6	
8-1; 83-87			3		1																						3						1			4	28	
9-1; 96-100			8	1																	1	4					7						6			1	15	1
9-3; 45-49			6																			4					5						4			3	20	2
9-4; 105-109			24	5						15												7											1	1		9	57	
10-1; 131-135			8		4																4	5					7						4				31	4
10-2; 84-89			10	3						3						1					1	5					10						3	2		20	70	
10-3; 67-71			15	1	1					1						2					3	5											3	1		19	71	
11-2; 92-96			14																		2	4		9									4	4		10	30	1
11-3;105-109			11	1				6		1	1			7		3											1							7		12	55	5
11-4; 67-71			11	3				3		1						3																	3	1		10	50	
12-1; 124-128			8					2			1					1						7											2	9		7	21	
12-3; 79-83			6	3				9		1	2										5												1	6		18	49	
12-4; 70-74			8		1			4			2					2						1												5		9	23	
13-1; 99-103			25	1	4			11			2					2																		2		15	68	
13-3; 34-38			13	6												1					3	1											1	6		4	31	
13-6; 111-115			6	2							1										3												3	1		7	24	
14-1; 41-45			3	1				3								1					5												2	2		13	44	2
14-3; 72-76			3																																	2	18	1
14-5; 127-131			2		1																															4	51	
15-1; 106-110			26	1				10		1						2					1													13			41	
15-2; 113-117			10	2				19								2						2												8		11	46	
15-3; 71-75			6					18																									9	14				
16-1; 93-97			16	2	1	4		10						9							1													15		10	64	6
17-1; 118-122			19			1							12														2						3	4			32	
17-3; 9-13			11								1		3																					2			7	
17-5; 76-80			8					3			1		12	5		6						10												7			9	
18-2; 85-89			13		6	2					8		12			18					12	1												2		14	74	2
18-4; 92-96			2		1			1					2	4								1					1									2	16	
18-5; 101-105			2		1			5					25	2				20	22	7		2						4	2	17		1			2	1	4	
19-2; 86-90			1	1				42			9		2								6	1					4								1	3	8	8
19-4; 102-106					2	1		65					2	2		1					10	2														1	8	6
19-6; 61-65			3					58								1		1			2									2				2			7	
20-2; 15-19					9			24													8					14									2	7	81	1
20-4; 127-131			1		10			40		1				3		1					5	7				4								2	1		52	4
20-6; 132-136				1	1			11					2								1												1			3	9	
21-2; 36-40								20						4										2														
21-3; 90-94			3			1		71						3		1		1			3	5		1				1					6	15		14	26	
21-4; 120-124			2	6				43		1				3								1					1							34		8	5	2
22-1; 66-70			1	2				18					15	26		5			1		3														7	11	23	8
22-2; 91-95		21	7	7	5	1		43		1	4	4	39								4														13	18	62	4
22-3; 117-121			5	2				37					6	3							9	1												8	30	26	15	3
23-2; 139-143			9	1		1		39				6	2										1										1			15		
23-4; 74-78	63		9	1	6	3		66				6	4			1			1	1	1		3			2										25	6	
23-5; 130-134	15		13		9			64		2		6	2			3					4	1	12			1										16	19	
24-2; 30-34	23	2	6	1	28	4		54		1		6	25		15	4							1			14	2									6	16	
24-4; 62-68				1	1			54		2					6	1		1							3								2				6	
24-6; 102-106			1		3			20													2																1	
25-2; 36-40	25	2	4	1	15	1		28		23	1		2		4			1			1				3	19	10						1	1	1		21	2
25-4; 100-103	10	5			3				1	8	1				4						4			2		6	11										27	3
26-2; 60-64	6	2	4		14		8	39		4		4	1		2							12	3		8	7	4	2		7			2				1	3
26-4; 31-35	24	4	4		11	3		3				4	2			1						1	3			2	3	1		1				1	1	4		
26-5; 126-130	9	39	10		12	3		5		11		16				2			2	1					17	2										1	4	
28-1; 36-40	2	2		4	9	2		5		1	1	2	2			13	1				2				2		6								2	2	34	1
28-3; 103-107			1	2	2	1		4					2		1		1				4	1											1	1	1			
29-2; 76-80	21	15	4		11			13		10		4			3			2	1		1	1	2	1	2	6	5	1	1	16	1	1						
29-3; 71-75	19		5		3	4		5		6	1	1	6	1	1	2	4	1	1	1																		
29-4; 140-144	14	2	1	1	10	1	2	3	2																													

Appendix 4.7. Benthic foraminiferal data for Site 263.

Samples (core, section, interval)	*Trochammina depressa*	*Saracenaria forticosta*	*Saracenaria* spp.	*Bullopora* sp.	*"Gaudryinopsis" pseudobettenstaedti*	*Aschemocella* sp.	*Frondicularia hastata*	*Verneuilinoides crespinae*	*Lituotuba* sp.	*Caudammina crassa*	*Saccamnina lagenoides*	*Saccammina* spp.	*Glomospira gordialis*	*Aaptotoichus clavellatus*	*Reophax* sp. 2	*Aaptotoichus challengeri*	*Ammodiscus* spp.	*Glomospirella gaultina*	*Glomospira charoides*	*Subreophax* sp. 1	*Paratrochamminoides* spp.	*Ammosphaeroidina* sp.	*? Arenobulimina* sp.	*Reophax* spp.	*THalmannamina* spp.	*"Gaudryina"* spp.	*Saracenaria erlita*	*Astacolus calliopsis*	*Verneuilinulla* sp. 2	*Kalamopsis grzybowskii*	*Bimonilina variana*	*"Textularia"* spp.	*Bulbobaculites* spp.	*Hippocrepina gracilis*	*Caudammina* spp.	*Bulbobaculites* cf. *inconstans*	*Spiroplectammina* spp.	*Glomospira irregularis*
4-4; 63-67																			3																			
4-5; 64-68																		1	4											1								
4-6; 46-50													5																									
5-1; 131-135																		2	10									1							1			
6-2; 24-28																			1																			
6-4; 67-71													3					1																				
6-6; 135-139													7						19																			
7-2; 14-18								1		3			4					2	5																			
7-3; 91-95								2										1																			1	
8-1; 83-87																	4	1	2												1			3			1	
9-1; 96-100										1			5					2	10					1							2							
9-3; 45-49												1						2	2					5								13						
9-4; 105-109								12					3				1		29					2								9		1				
10-1; 131-135								7		6		3	6				1		10					2						1		10						
10-2; 84-89								4		1							1	2	59					4						1		14	6	4				1
10-3; 67-71								3		1			3				1	2	58			1				1						2	19	4				
11-2; 92-96								9				2	5				1	4	25					2									30	4				
11-3;105-109								1					7					2	33											1		10		7				
11-4; 67-71								2					12				2	2	44													18	2	3				
12-1; 124-128													5					4	11													8		3				
12-3; 79-83								3					17						2													1						
12-4; 70-74													2					2	10													6						
13-1; 99-103								27					3						12					2										5				
13-3; 34-38								13										26	51														6					
13-6; 111-115								2										1	8					1								6						
14-1; 41-45																			7					8								1	1	5				
14-3; 72-76													1				2		4					1										5				
14-5; 127-131										3								1	3					1										3				
15-1; 106-110								2											14															4				
15-2; 113-117										12								3	37					6								5						
15-3; 71-75										1									28					1		2					10	7	2	3		1		
16-1; 93-97									2	3						4		2	34					18								2		1				
17-1; 118-122								6		1									4	1				3								10	2			1		
17-3; 9-13										1									1					1								12						
17-5; 76-80								2									16		6					11						3		2		8		1	2	
18-2; 85-89								5		6									3					7		5						6		3		4		
18-4; 92-96								1				1																				2						
18-5; 101-105		5	3					1								1								1				12					8					
19-2; 86-90								6											4		16			7								3	3					
19-4; 102-106										1						1			4		33			6							2	2		3		20		
19-6; 61-65								13											2		7			2									4			9		
20-2; 15-19								4		2						3		1			11			5						1								
20-4; 127-131								11		3	2	2						7	4		19			12														
20-6; 132-136								3								2					2											2						
21-2; 36-40								5											6		5			3								3				1		
21-3; 90-94								13		1							6	7	35		27			6		2						2						
21-4; 120-124								66		2		1				11		6	51		9			11									23			##		1
22-1; 66-70								20								12		5	8					10									4		7		3	
22-2; 91-95								11		3		2	3			6		3	15					5						5	1		18	7	2	17		
22-3; 117-121								4				1				21		14	79		14	1		7	6	1				1	2	6	6					
23-2; 139-143					16			4																					1									
23-4; 74-78					45	3		2		1		1			11	1					1					1	1	1										
23-5; 130-134					18																4			4	1													
24-2; 30-34	1				5			12				8				1				2	8	1	2															
24-4; 62-68					6																6																	
24-6; 102-106								1				2				4			1	2	2																	
25-2; 36-40					12	2		5		2		3				2	1	1	2	1																		
25-4; 100-103					7			3	1	1	1	2	6	6	1																							
26-2; 60-64	5	1			17	1	2																															
26-4; 31-35			1	2																																		
26-5; 126-130	3	1																																				
28-1; 36-40																																						
28-3; 103-107																																						
29-2; 76-80																																						
29-3; 71-75																																						
29-4; 140-144																																						

Appendix 4.7. Benthic foraminiferal data for Site 263.

Samples (core, section, interval)	*Reophax* sp. 3	*Lenticulina muensteri*	*Nothia robusta*	*Trochammina ribstonensis*	*Lenticulina heiermanni*	*Laevidentalina communis*	*Cithatina harpa*	*Psilocitharella recta*	*Marginulina bullata*	*Planularia compacta*	***Pyrulina*** sp.	*Ramulina* sp.	*Pseudonodosaria* sp.	*Haplophragmoides hagni*	*Verneuilina howchini*	*Marssonella* sp.	*Ammolagena clavata*	*Remesella* sp.	*Gyroidina infracretacea*	*Globorotalites* sp.	*Scheibnerova* sp.	*Gaudryina dividens*	*Laevidentalina debilis*	*Lingulina* sp.	*Frondicularia* sp.	*Gavelinella* sp.	*Oolina* spp.	Diversity	Number of specimens
4-4; 63-67																						4	1	1	1	1	1	10	28
4-5; 64-68																						1						7	21
4-6; 46-50																			2		1							7	31
5-1; 131-135				1														1	1	1								12	25
6-2; 24-28				2												2												6	9
6-4; 67-71																												6	14
6-6; 135-139				7											4	9		6										11	66
7-2; 14-18				31											12	1		1										16	104
7-3; 91-95				14										6	18													12	66
8-1; 83-87				7											11			1										15	71
9-1; 96-100														5	21													17	91
9-3; 45-49														3	14			1										15	85
9-4; 105-109														18	8													17	202
10-1; 131-135														24	23													19	160
10-2; 84-89				1										13	2													25	241
10-3; 67-71			2											9	19	3	2											27	252
11-2; 92-96			1											34	20													21	215
11-3;105-109			3												15													21	189
11-4; 67-71			2											2	16													20	190
12-1; 124-128			2												9													16	100
12-3; 79-83			1	1										1	9													18	135
12-4; 70-74															5													14	80
13-1; 99-103															40													15	219
13-3; 34-38			3												33													15	198
13-6; 111-115			3											9	13													16	90
14-1; 41-45														1	12	1												18	112
14-3; 72-76			1												6													11	44
14-5; 127-131			3												3													11	75
15-1; 106-110			3	19											3													14	140
15-2; 113-117				2											24	1												16	190
15-3; 71-75				3										1	44													16	150
16-1; 93-97														5	39	1												22	249
17-1; 118-122														5														16	106
17-3; 9-13														4														10	43
17-5; 76-80														12														19	124
18-2; 85-89														4														21	207
18-4; 92-96														2														13	36
18-5; 101-105		1			4	1	1	2	1	1	2	3	1															33	165
19-2; 86-90				2																								19	127
19-4; 102-106																												20	172
19-6; 61-65			1																									15	114
20-2; 15-19																												15	173
20-4; 127-131																												21	191
20-6; 132-136	6																											13	44
21-2; 36-40																												9	49
21-3; 90-94	18	1																										25	269
21-4; 120-124	35																											23	448
22-1; 66-70																												20	189
22-2; 91-95																												29	331
22-3; 117-121																												26	308
23-2; 139-143																												12	96
23-4; 74-78																												27	266
23-5; 130-134																												18	194
24-2; 30-34																												26	248
24-4; 62-68																												12	89
24-6; 102-106																												11	39
25-2; 36-40																												31	197
25-4; 100-103																												22	113
26-2; 60-64																												25	159
26-4; 31-35																												20	76
26-5; 126-130																												17	138
28-1; 36-40																												19	93
28-3; 103-107																												13	22
29-2; 76-80																												22	122
29-3; 71-75																												16	61
29-4; 140-144																												9	36

Appendix 4.8. Benthic foraminiferal data for Site 762C.

Samples (core, section, interval)	*Evolutinella perturbans*	*Haplophragmoides* spp.	*Rhabdammina* spp.	*Bulbobaculites inconstans*	*Bulbobaculites* spp.	*Verneuilinoides neocomiensis*	*Textularia bettenstaedti*	*Globulina* spp.	*Laevidentalina* spp.	*Textulariopsis* spp.	*Rhizammina* spp.	*Pseudoreophax* spp.	*Reophax* spp.	*Lenticulina muensteri*	*Lenticulina* spp.	*Saracenaria forticosta*	*Astacolus calliopsis*	*Ammodiscus tenuissimus*	*Saccammina* spp.
76X-4; 81-84															1				
77X-1; 141-144								2						5	2				1
77X-6; 10-13								2						11	1				
78X-CC; 13-15						6		6						24	39				
79X-CC; 5-8									14					38	57	3	16		
80X-4; 72-75											2								
81X-1; 93-96		17	5		3	9				12	24	4							
82X-2; 27-30	16	127	2			72					2	2							
84X-CC; 15-18		3													1				
85X-1; 78-81		8			1	1		3											
86X-2; 29-32		9		1	1		1	5						4	3		1	1	1
87X-1; 109-112				1				2						8	4	1			
89X-5; 29-32		39	2	2	4	5	1				1	2	2						
90X-1; 5-8		32			2	6	17			6	6								
91X-CC	3	39	1	2	3	2	1	16	1										

Samples (core, section, interval)	*Cribrostomoides nonioninoides*	*Bimonilina* spp.	*Psammosphaera* spp.	*Ammobaculites* spp.	*Lenticulina nodosa*	*Lenticulina heiermanni*	*Vaginulinopsis excentricica*	*Astacolus parallelus*	*Laevidentalina oligostegia*	*Pyramidulina sceptrum*	*Laevidentalina nana*	*Laevidentalina communis*	*Laevidentalina deflexa*	*Planularia crepidularis*	*Citharina harpa*	*Planularia* sp.	*Ramulina tappanae*	*Globulina prisca*	*Laevidentalina soluta*	*Marginulina bullata*
76X-4; 81-84											1									
77X-1; 141-144																1				
77X-6; 10-13										1							1	1		
78X-CC; 13-15					2													1		
79X-CC; 5-8					5	3	42	18	1	8	3	4	3	1	1	1	4	5	2	2
80X-4; 72-75																				
81X-1; 93-96																				
82X-2; 27-30	14	1	2	1																
84X-CC; 15-18																				
85X-1; 78-81																				
86X-2; 29-32																				
87X-1; 109-112																				
89X-5; 29-32																				
90X-1; 5-8																				
91X-CC																				

Samples (core, section, interval)	*Saracenaria frankei*	*Saracenaria pravoslavlevi*	*Saracenaria* sp.	*Saracenaria compacta*	*Astacolus* spp.	*Marginulinopsis comma*	*Pyrulina cylindroides*	*Lenticulina saxocretacea*	*Lingulogavelinella* sp. 1	*Gavelinella flandrini*	*Gavelinella* spp.	*Gyroidina* aff. *infracretacea*	*Gaudryina* cf. *dividens*	*Gaudryinopsis gradata*	*Berthelina intermedia*	*Osangularia schloenbachi*	*Patellina africana*	*Charltonina australis*	*Globorotalites aptiensis*	*Gyroidina infracretacea*
76X-4; 81-84							2									2		1		
77X-1; 141-144							1									18				
77X-6; 10-13														7	41	126	2	7	8	12
78X-CC; 13-15							1	12	70	61	17	22	12	12						
79X-CC; 5-8	8	3	15	1	9	1														
80X-4; 72-75																				
81X-1; 93-96																				
82X-2; 27-30																				
84X-CC; 15-18																				
85X-1; 78-81																				
86X-2; 29-32																				
87X-1; 109-112																				
89X-5; 29-32																				
90X-1; 5-8																				
91X-CC																				

Samples (core, section, interval)	*Gyroidina gracillima*	*Ellipsoidella* cf. *cuneata*	*Marginulina* sp.	*Remesella* sp. 1	*Tritaxia gaultina*	*Gaudryina dividens*	*Marssonella oxycona*	*Tristix acutangula*	*Psilocitharella recta*	*Glomospira charoides*	*Berthelina cenomanica*	*Gyroidinoides* sp.	*Pseudonodosaria* sp.	*Ammosphaeroidina* sp.	*Dorothia* sp.	*Gaudryina* sp.	*Spiroplectinata* sp.	Diversity	Number of specimens
76X-4; 81-84					9				1			1					1	9	19
77X-1; 141-144				4	15			1			3	5	1	1	1	1		16	62
77X-6; 10-13	2	1	1	13	8	28	1	1	1	1								23	277
78X-CC; 13-15																		14	285
79X-CC; 5-8																		27	268
80X-4; 72-75																		1	2
81X-1; 93-96																		7	74
82X-2; 27-30																		10	239
84X-CC; 15-18																		2	4
85X-1; 78-81																		4	13
86X-2; 29-32																		10	27
87X-1; 109-112																		5	16
89X-5; 29-32																		9	58
90X-1; 5-8																		6	69
91X-CC																		9	68

Appendix 4.9. Benthic foraminiferal data for Site 763B&C.

Samples (core, section, interval)	*Rhizammina* spp.	*Evolutinella perturbans*	*Haplophragmoides* spp.	*Rhabdammina* spp.	*Lagenammina alexanderi*	*Saccammina* spp.	*Bulbobaculites humei*	*Hippocrepina depressa*	*Bathysiphon* spp.	*Saccammina crespinae*	*Reophax* spp.	*Astacolus calliopsis*	*Saracenaria forticosta*	*Globulina* spp.	*Ammobaculites* sp. 1	*Saracenaria pravoslavlevi*	*Laevidentalina* spp.	*Vaginulinopsis excentricica*	*Marginulina* spp.	*Lenticulina nodosa*	*Lenticulina* spp.	*Vaginulinopsis neopachynota*	*Ammobaculites* spp.	*Pyramidulina sceptrum*	*Ammodiscus* spp.	*Saracenaria compacta*	*Astacolus* spp.	*Verneuilinoides neocomiersis*	*Trochammina* spp.	*Saracenaria* spp.	*Planularia* spp.	*Vaginulinopsis* spp.	*Recurvoides* spp.	*Cribrostomoides nonioninoides*	*Haplophragmoides minor*	*Laevidentalina communis*	*Planularia complanata*	*Astacolus denudata*	*Lenticulina muensteri*	*Globulina prisca*	*Textularia bettenstaedti*	*Verneuilinoides neocomiensis*	*Bulbobaculites* spp.	*Pseudoreophax* spp.	*Oolina globosa*	*Laevidentalina deflexa*	*Globulina lacrima*	*Oolina* spp.	*Epistomina* spp.	*Lenticulina heiermanni*	*Laevidentalina nana*	*Astacolus parallelus*	*Saracenaria triangularis*	*Saracenaria frankei*	*Lenticulina pulchella*	*Lenticulina circumcidanea*	*Textulariopsis* spp.	*Gaudryinopsis* spp.
27X-2; 65-68	3																	2			1																2		7																			
28-3; 45-48																					1																																					
29X-6; 147-150												2					3	2	1		3			1													5		13	1					2						2							
30X-4; 103-106												1					2				8									2									12									1							5			
31X-1; 141-144																	7	2			4															3			21						3						4							
32X-1; 32-35																	3	2	1		7			3															14																2			
33X-5; 99-102																		6			4									1									20									1										
34X-3; 132-135	2		3	1				1	1			3									6									1		1				3			7	2						2		1			1				7	1	1	
35-5; 135-138	2											1					2				5									2		1							12						2	1										1		
36X-3; 115-118	1																6	5	1		12															2	1		10						3					1	2							
37X-6; 21-24												1					2				24																		32																			
38X-1; 112-115	1											7					8	4			24			1												5			11	8															6			
39X-1; 79-81	1											2		5				7		2	43			1						1									25	1												3			17	2		
40X-2; 28-31												1						2			20																		21																			
41X-1; 136-139																					3																		3																			
41X-5; 41-44			4				7							4		2					4						2																												1			
43X-2; 111-114	3											1				3	3				28			2						4									9											3		2				4	122	
44X-2; 134-137	7											2				1				1	23									4		2							14										5						2		18	9
45X-1;16-19	8													3		3	9	29			41			1						5						3	2		2	3						1	4	1	4	2	1	2	1	2	7	8	12	6
47X-3; 18-21														2						3																			3						1													
48X-5; 56-59			24																																						2		6															
49X-4; 141-144		2	39																															2							6	2	1	4														
50CC; 27-30		5	55												1																			7							5																	
51X-5; 97-100													1																											2																		
53X-1; 113-115		1										3		2			1	3			16															1	2	1	8																			
35-6; 84-87	3	4	7	1			15					1		2	2																		8	5	2																							
36-1; 127-130	2	12	22				66				1												4										3	6						1																		
37-3; 62-65		3	20				7														2								1					4					1	1																		
38-4; 9-12		1					22				2			2	2						1												8	8																								
39-2; 27-30		3	46				37			1	4			1																									1	15																		
40-2; 106-109	32	9	33		1		86						2	6	1		1		2		7		3				3	1	2	2	1	1																										
41-5; 41-44			4				6				1			4						2	3					2	2																															
42-1; 35-38	11	10	5		1		4																		1																																	
43-1; 69-72	1	24	15	1	1		116							1							1		1	1																																		
44-6; 2-5	9	37	16		2		146														4		1																																			
45-4; 34-37	33	52	17	4		1	22	1	1	3	3	3	4	2	6	1	4	4	1	4	6	1																																				
46-5; 136-139	2	10	27	1	2	1	63																																																			

Appendix 4.9. Benthic foraminiferal data for Site 763B&C

Samples (core, section, interval)	*Verneuilinoides* spp.	*Gavelinella barremiana*	*Ramulina tappanae*	*Lenticulina* cf. *schreiterei*	*Marginulinopsis bettenstaedti*	*Bimonilina* spp.	*Gavelinella flandrini*	*Lenticulina saxocretacea*	*Pseudonodosaria* spp.	*Marginulina bullata*	*Lingulogavelinella* sp. 1	*Gyroidina* aff. *infracretacea*	*Charltonina australis*	*Gaudryina* cf. *dividens*	*Laevidentalina oligostegia*	*Laevidentalina distincta*	*Tristix acutangula*	*Laevidentalina debilis*	*Ammodiscus cretaceus*	*Psilocitharella recta*	*Lingulonodosaria nodosaria*	*Pleurostomella reussi*	*Gyroidina infracretacea*	*Osangularia schloenbachi*	*Bertehlina intermedia*	*Gaudryinopsis gradata*	*Globorotalites aptiensis*	*Remesella* sp. 1	*Gaudryina dividens*	*Tritaxia gaultina*	*Pyramidulina obscura*	*Coryphostoma* sp. 1	*Marssonella oxycona*	*Glomospira charoides*	*Glomospirella gaultina*	*Tristix excavata*	*Gyroidina gracillima*	*Brunsvigella augustissima*	*Glomospira gordialis*	*Lingulina simplicima*	*Spiroplectammina* spp.	*Frondicularia dydima*	*Pseudonodosaria mutabilis*	*Pyrulina cylindroidres*	*Lenticulina subangulata*	*Dorothia* spp.	*Bertehlina cenomanica*	*Berthelina berthelini*	*Berthelina* spp.	*Gyroidinoides* spp.	Diversity	Total number of specimens
27X-2; 65-68			1					1												1		3				2			4	7			2				2				1		1	2		2	1			3	20	48
28-3; 45-48																			3	1		7	2	7					1	2			6				16										41	21	6		13	114
29X-6; 147-150									1	1					3					1	1	8		102	7		7		2	2	1		2			1	20							1		2	73	2.1			30	272
30X-4; 103-106								2							1				2	3		1	5	55	74	3			21	5				1			16								1						21	221
31X-1; 141-144			4						1	1					1		1			1			2	49	58	3	7		4	5			11	1			4						2	4							25	203
32X-1; 32-35									1										3			2		114	37				37	7	1		7	3		4	4	3				1									21	256
33X-5; 99-102									2						1		1	1		1			19	115	101				19		2		9		2	7	6														19	318
34X-3; 132-135			2					1	1	1	11				2			1	9	5		4	7	182	93		3		9	1	3		14	13	3	3	10	1	3	1	1										44	428
35-5; 135-138								2							2				4	1	1	5	12	76	31				52		1		47	2		1	2														25	268
36X-3; 115-118			1					3	1										7	3		9	27	100	75	3			25			1	4	6	2																26	311
37X-6; 21-24								11	3		14										1	5	39	76	84	5	2	10	63	5	3																				18	380
38X-1; 112-115			3				88	6	1		97	49		13	1		1	1	3	1																															22	339
39X-1; 79-81							66	11	2	1	1	70	30	16	1	1																																			23	309
40X-2; 28-31							2	10																																											6	56
41X-1; 136-139							1																																												3	7
41X-5; 41-44						1																																													8	25
43X-2; 111-114		334	3	1	2																																														16	524
44X-2; 134-137	3	75																																																	14	166
45X-1;16-19	2																																																		26	162
47X-3; 18-21																																																			4	9
48X-5; 56-59																																																			3	32
49X-4; 141-144																																																			7	56
50CC; 27-30																																																			5	73
51X-5; 97-100																																																			2	3
53X-1; 113-115																																																			10	38
35-6; 84-87																																																			11	50
36-1; 127-130																																																			9	117
37-3; 62-65																																																			8	39
38-4; 9-12																																																			8	46
3R-2; 27-30																																																			8	100
40-2; 106-109																																																			18	193
41-5; 41-44																																																			8	24
42-1; 35-38																																																			6	32
43-1; 69-72																																																			10	162
44-6; 2-5																																																			7	215
45-4; 34-37																																																			21	173
46-5; 136-139																																																			7	106

Appendix 4.10. Benthic foraminiferal data for Site 766 (Cores -49R to -26R).

Samples (core, section, interval)	*Oolina sulcata*	*Palaeopolymorphina* sp. 1	*Textularia bettenstaedti*	*Trochammina* sp. 1	*Trochammina* spp.	*Recurvoides* spp.	*Haplophragmoides* sp. 1	*Ammodiscus cretaceus*	*Verneuilinoides subfiliformis*	*Globulina* spp.	*Laevidentalina* spp.	*Lenticulina heiermanni*	*Tristix acutangula*	*Lenticulina* spp.	*Astacolus calliopsis*	*Ammobaculites* sp. 1	*Kalamopsis grzybowskii*	*Saracenaria* spp.	*Citharina* sp. 1	*Globulina bucculenta*	*Lenticulina ouachensis*	*Lenticulina muensteri*	*Aaptotoichus clavellatus*	*Lenticulina pulchella*	*Oolina* spp.	*Laevidentalina communis*	*Psilocitharella* spp.	*Oolina* aff. *oxystoma*	*Haplophragmoides* cf. *vocontianus*	*Saracenaria erlita*	*Saracenaria forticosta*	*Vaginulinopsis excentrica*	*Lenticulina* cf. *subgaultina*	*Saracenaria pravoslavlevi*	*Saracenaria compacta*	*Pyramidulina sceptrum*	*Ramulina tappanae*	*Ammodiscus tenuissimus*	*Rhizammina algaeformis*	*Rhabdammina cylindrica*	*Pseudoreophax* sp. 1	"*Textularia*" spp.	*Bulbobaculites inconstans erectum*	*Planularia* spp.	*Marginulinopsis bettenstaedti*	*Psilocitharella arguta*	*Frondicularia hastata*	*Marginulinopsis comma*	*Oolina laevis*	*Ramulina* spp.	*Lenticulina nodosa*	*Saracenaria frankei*	*Vaginulinopsis neopachynota*	*Palmula* spp.	*Pyramidulina* spp.	*Brunsvigella thoerensis*	*Rhizammina* spp.	*Trochammina* sp. 2	*Fissurina* cf. *laevigata*	*Lenticulina saxocretacea*	*Glomospira gordialis*	*Planularia complanata*	*Glomospira* spp.	*Haplophragmoides* spp.	*Citharina rudocosta*	*Globulina lacrima*	*Bulbobaculites* sp. 1	*Haplophragmoides concavus*	*Haplophragmoides kirki*
26-3; 68-72																																																																					
28-1; 21-25										3					1			3														1		2			1					1											2							4	2								
28-3; 116-120														1																				1																					2					1	2								
28-5; 133-138											3			10				3									1					2		1			1														3				1					4		1							
29-3; 54-55										2	11	5		40	5			4				15		2	6	4				2	1			3	1		5			1		1		1	1		2		4		3		6				1			26	1	1				1			
30-3; 44-47	1									8	16			16				1				7		3			1					2		9	1	1	10		3	5											2		3				2				2								
30-4; 100-102								1		8	9			19	1							4		1	1									1			2		3	4							1		1		2	4	1	1			1			13	2	1							
32-2; 104-108								1		2	4			4	1			4				7		1	1						1								2						1										2					2		1							
32-5; 5-8											7			11				7	4	1		2		8		3	4					2		3			1							2		1		1	6		1			2	2					6		15				7			
33-2; 15-18		22								8	13	4		15								10		1		1						2					18										2		1		1		3		1					2		6				3			
33-3; 34-38		1								1				5	1			2																			3										1							1															
34-1; 122-125	2	8								3	3			4																1							1										2		3					1								5							
34-2; 30-33		25									6			17				6				3		2								1		4			2												3				1							3		6				1			
35-1; 1-4		13								10				17					1			3		5			3			1		1					3				1								3	3	1				1		2			5		6							
36-1; 70-74		12												6				2				1		1										1										2					1											2									
37-1; 29-33		1							1	2								4																															1								2							1					
37-3; 0-3													1	6				1				4			9																				1				9	2			1		1					4		8							
38-1; 112-116										2				5										2								1												2					2		2									1									
38-2; 108-111										2				6				3		2		1			1		2					1					7												6		1		2		1							10							
38-3; 111-113	1									3	2			9				1				1		1	2												3										1		3		4									6		1							
39-1; 47-51		4									1			3										2	2		2										2												4				1													3			
39-2; 9-14	3	15												16								1			5		4				1	1		5			1								1		1		10		3				2					10		7							
39-3; 86-90		5								1	4	1		20								4			3						3	1		2			2										3		2		4		2							8		5				2			
40-1; 84-88											3			2								2		4	1						2	2		1			1												1											2		7							
40-2; 46-50		1								4	3			2	2					1		1			1						2	1		2			2							3					3						3					4						4			
40-3; 33-38										1				1								2												1																																			
43-2; 46-50										1	3	4	1	6										2	3									4			2									1			2	5		1	3		3							7							
43-4; 36-40		3								1	1			9										3	1		2				1			3															2				2		2					3		14							
43-5; 131-135		1					3			3	9	4		20		2					1	3		5							2			5	1				3		3								3		3	2	3				3			1		9		10		4	5	2	
44-1; 43-48		15					1			17	3	5		14	2						2	9	2		3		1				2	5		2			5		7			1			1		2					3			1		4			17				4			33		
44-3; 47-52		32					1			5				19		1						7		2		3					3	4		4			2		9										4		10	1			1					19		8		4	1	1	48	1	
44-5; 102-106	1	29					3			8				11	1							3	2			4		1				6		1		2															6	1	5							19				4		1	27		
45-2; 109-113		30			1		1			10	7	1		10	2	2					1	8			1		3				4	6		5		1	3		9						2		1	2	1		7	5		1			5			8		4		1		12	1		
45-4; 115-120		5					5	1			4	1		11	1	23		15		4		6									2	6		2	1			1	1									1				4	11							8		4		26		4	34	6	4
46-3; 122-125		21	5	1			2			8	8			10	4	1		2				7	6			1					1	12		5			4					2					1		1		1	1			3	2				11		4		11		3	69	3	2
46-4; 105-110		10					1		2	6	1	2		15	1	2						5	4			5		1				2	1	4		1	9		3			1							1		2	5					7			7		5		2			33		
46-5; 20-24		12	8				4			3	5	1		14				3				11	5		2			1			2						2		6		1	2					1	2		1	1		1				6			12		1		14		1	36	4	1
47-1; 98-103	1	20		1	4		1				3	1		10	3	3					1	17	5	4						1	4	8	2	3			1		2						1		6		2	2		1						1				8		12		3	38	2	1
47-3; 25-30		5	1				2			5	2	1		14						3	1	29			3		3					1	6	21	1		1		8					1	2		3					2	3							2	1	5		6		1	1	1	
47-4; 114-119	1	16	2	4			8			2	3	2		14	2						1	6	4								1	2	1	3				1	11	7	2				1		1		1								8	2		8	1	2		1		6	1	1	1
48-2; 95-98	1	6	2	1			2				2	3		4		2		1			4	10	2		2					1	2	4		6	1	2	1		9						3		4			2	2		4				4			19	1	1	2	6	1				
48-4; 51-54		30							1	3	8	1		2	6							4					2	1					3	17		2		4	9	5	1			1	3				2	4	1	3	10	1	3	1	2	1	1	1	1								
48-6; 100-104		3									1			7	1							1		1						1				2						2						1		1																					
49-1; 124-128	1	36	5			1			1		6			4								4								2	4	3	5	4	2	2	2	2	4	3	5	1	1	1	2	1	2																						
49-2; 42-46					1		1		1	5				2	1		1			1	2	1	5	1	1	5	2	2	1																																								
49-3; 43-45	1	13	5	1	2	5	1	1	1	5	1	7	1	2	1	1	1	1	1																																																		

Appendix 4.10. Benthic foraminiferal data for Site 766 (Cores -49R to -26R).

Samples (core, section, interval)	*Glomospira charoides*	*Vaginulinopsis reticulosa*	*Pyrulina cylindroides*	*Globulina prisca*	*Pyramidulina* cf. *bactriodes*	*Marginulinopsis gracilissima*	*Astacolus schloenbachi*	*Pyramidulina obscura*	*Laevidentalina oligostegia*	*Frondicularia bettenstaedti*	*Pyramidulina lagenoides*	*Pyramidulina zippei*	*Laevidentalina soluta*	*Lenticulina circumcidanea*	*Marginulina inaequalis*	*Vaginulinopsis* spp.	*Lenticulina subangulata*	*Astacolus* spp.	*Psilocitharella kochii*	*Ramulina aptiensis*	*Eoguttulina ichnusae*	*Ammodiscus* spp.	*Pseudonodosaria* spp.	*Pseudonodosaria humilis*	*Pseudonodosaria mutabilis*	*Spirillina minima*	*Patellina subcretacea*	*Oolina* cf. *sulcata*	*Laevidentalina debilis*	*Planularia crepidularis*	*Glomospirella gaultina*	*Marginulina* sp. 1	*Lenticulina* cf. *schreiterei*	*Psilocitharella recta*	*Marginulina bullata*	*Lenticulina guttata*	*Saracenaria valanginiana*	*Gavelinella* aff. *barremiana*	*Laevidentalina nana*	*Tristix excavata*	*Vaginulinopsis humilis precursoria*	*Oolina hauteriviana cylindracea*	*Oolina caudata*	*Saracenaria* sp. 1	*Vaginulina petila*	*Saracenaria triangularis*	*Nodosaria* cf. *regularis*	*Saracenaria spinosa*	*Lenticulina macrodisca*	*Marginulinopsis parkeri*	*Saracenaria* sp. 2	*Lingulina* sp. 1	*Bathysiphon brosgei*	*Marginulina pyramidilis*	*Lingulina* spp.	*Glomospira charoides corona*	*Gavelinella sigmoicosta?*	*Praedorothia ouachensis*	*Dorothia* sp. 1	*Remesella* sp.	*Marssonella* sp.	*Gavelinella barremiana*	*Trochammina* spp.	*Verneuilinulla* sp. 1	*Pyramidulina* cf. *corallina*	*Pseudonodosaria* cf. *tenuis*	Diversity (S)	Number of Specimens
26-3; 68-72																															1																																				1	1
28-1; 21-25	3						1									1															1				1				1							2			7			3						3								1	21	44
28-3; 116-120	1																														1																					2				3		3				1					11	18
28-5; 133-138							1											1				1									4				1											4			13		3	10	1			2		28			2	5		1	1		27	108
29-3; 54-55	16								1				1	2	1	1	5	1				1									11				4				1							6	1	1		1	5	8				10	1	33	2	1	2	2	1	1			55	275
30-3; 44-47	8													1			4														13							1								3			12	1	1	6		1	1	11	1										33	157
30-4; 100-102														2	1	1	1														2								2		1					1		2	2	2	1	2	1														36	102
32-2; 104-108					1					1				2		1																														2	1																				21	42
32-5; 5-8				7	30					25				7	2	9		2			1		5				35		1	1						7	1	45		1	2			1	1	5																					42	284
33-2; 15-18					11					7		1			1	1		3		1							15			4					1			4	1		2																										31	165
33-3; 34-38																																			1																																9	16
34-1; 122-125					4					1										1																							1																								15	40
34-2; 30-33				1	5					3													1				11														1																										20	102
35-1; 1-4				2	10					5																	20			3									1																												24	120
36-1; 70-74										1																							1																																		11	30
37-1; 29-33					1																																1																														9	14
37-3; 0-3					14					4			1	3												1	43			2								37																													20	152
38-1; 112-116				1	11									1									3			1	110			2							1	15			2																										18	164
38-2; 108-111					8					4						2							1			1	255														5																										21	321
38-3; 111-113					5	1				1				1													31										2	2			1																										22	82
39-1; 47-51				1	2					3						2											66			3								4			2																										18	107
39-2; 9-14					2					10			1	3													6			5				1																																	24	114
39-3; 86-90				2								1		4			1													1				1			2	1	1			1																									28	87
40-1; 84-88				1	3					7				2		1							1		1		62									1	1	4	2	1	1																										26	116
40-2; 46-50				2	9									3													111			1							2	3	1																												25	171
40-3; 33-38					1									2				1																																																	7	9
43-2; 46-50		3			5	1				3				3		1							2				4							1	1	1																															27	73
43-4; 36-40		5			4					3						3																	1	1																																	20	64
43-5; 131-135				2	1									1		2		2															2																																		32	120
44-1; 43-48				1	2	2																					1			1																																					31	168
44-3; 47-52			1	1	6	2					1			3	1	3							1				1			2	4	1																																			37	217
44-5; 102-106								2		4	1		2			7	2						1		1		5	1	1																																						31	162
45-2; 109-113				6	2				1	8				1	1	3	1	2				1	1	1	2	3	2	1																																							48	191
45-4; 115-120													1																																																						28	192
46-3; 122-125										3			1						2	1	1																																														36	220
46-4; 105-110				4									1						1																																																31	144
46-5; 20-24						3									1	1	1	1																																																	35	170
47-1; 98-103				2	1					2	1	1	1	1			1																																																		41	182
47-3; 25-30				4	4	2	2	2	1	1																																																								37	151
47-4; 114-119	1	1	1																																																																37	130
48-2; 95-98																																																																			34	117
48-4; 51-54																																																																			32	134
48-6; 100-104																																																																			11	21
49-1; 124-128																																																																			26	104
49-2; 42-46																																																																			17	33
49-3; 43-45																																																																			19	51

Appendix 4.11. Benthic foraminiferal data for Site 766 (Cores -26R to -16R).

Samples (core, section, interval)	*Rhizammina* spp.	*Ammodiscus cretaceus*	*Globulina prisca*	*Lingulina* sp. 1	*Oolina* sp.	*Glomospira charoides*	*Gavelinella* sp. 1	*Gavelinella* sp. 2	*Gavelinella* spp.	*Patellina africana*	*Gyroidina infracretacea*	*Gaudryina dividens*	*Lingulina* spp.	*Pseudonodosaria humilis*	*Pseudonodosaria* spp.	*Glomospirella gaultina*	*Lenticulina muensteri*	*Lenticulina pulchella*	*Lenticulina* spp.	*Astacolus calliopsis*	*Vaginulinopsis excentricica*	*Lenticulina* aff. *nodosa*	*Vaginulinopsis* spp.	*Saracenaria* spp.	*Laevidentalina communis*	*Pyrulina cylindroides*	*Laevidentalina nana*	*Laevidentalina oligostegia*	*Laevidentalina soluta*	*Laevidentalina* spp.	*Saracenaria spinosa*	*Gaudryinopsis* cf. *gradata*	*Marssonella* sp.	*Psilocitharella recta*	*Bimonilina variana*	*Lingulonodosaria nodosaria*	*Pleurostomella* spp.	*Marginulina bullata*	*Vaginulinopsis harpa*	*Gyroidina gracillima*	*Brunsvigella* sp.	*Globulina* spp.	*Ramulina tappanae*	*Berthelina intermedia*	*Osangularia schloenbachi*	*Astacolus* spp.	*Coryphostoma* sp. 1	*Ellipsoidella* cf. *cuneata*
16-1; 31-36		1				4			7		24	26					1										1					1				1	1			112					49			
16-3; 32-36						1			12		42	11	1				2	1												2									1	80					32			
16-5; 32-36		1	1			5			2		61	15					1																			5				72					21			
17-2; 130-133		2	1			1			1		87	29	1	1	1		2	1							2		3			2		1				6				61		2	4		86	1		
17-3; 43-46				1		2					63	13	2				12	3	2						1	2	6	3	4							3			3	82		1	10		177		5	1
17-5; 2-3			2			2			5		92	24	1		1		12	1	9						2	2	2	5		5						4				49		2	2	29	126	1		
18-3; 58-61						1			5		54	12	1				4	1			1						2	2	1			1							2	31		1		22	197			1
18-4; 98-100						1			7		65	22	1				5	4		5				1		6	5	1									2		2	76		1		19	169		1	
18-5; 78-81						2			11		55	43	1		1		4	3	2				2	1	2		3	1		5						1		1	1	21		2		14	218		2	
19-1; 68-72		1				1			9		40	25					4		3	2	2			1	2		2			5						1		1		36				25	121		2	
19-3; 29-33											52	40					2		2				1	2			1	1	2	2		1				5			6	51		1		37	165			
19-4; 82-86		1				1					79	67					4		2										3			1				1		1		10				38	286	2		
20-1; 39-43			2								52	77	2		1		3	1	3		3		1	3		1	3			2	2	5				1	2			24		1		38	112		1	1
20-2; 87-91				1					5		30	18	1		1		2	2	8			1	1	5	3					4		1	1							4				41	114			1
20-3; 20-24			1	3					2		34	32	1	1			9		5	2		4		1			1				3	5				4		1	3	37				5	192	1	1	2
21-1; 39-43		1	6			1	36	12			111	89			1		7	7	8	2				1	4		1	1		4	1						2	3	7	4		1		40	96			
21-2; 14-18						2	66	17			126	79	1	2	5		7	7	12	2	1			2	6	3	3	1	1	6	1		1					3	7	4	1	1	2	4	106	1	1	2
24-1; 111-113		2	2				48	26	1		119	28	3	2	3	2	9	31	28	4	2	1	4	2	12	1	3	1	1	1	6	21	6	1	1	3	1	1	1									
25-1; 3-5		1	2	4	1	1	181	23	5	32	107	5																																				
26-2; 68-72	1	1																																														

Appendix 4.11. Benthic foraminiferal data for Site 766 (Cores -26R to -16R).

Samples (core, section, interval)	*Charltonina australis*	*Gaudryinopsis gradata*	*Quadrimorphina allomorphinoides*	*Lingulogavelinella* sp. 1	*Pyrulina* sp.	*Ramulina* spp.	*Lenticulina saxocretacea*	*Saracenaria erlita*	*Lenticulina subgaultina*	*Marginulina* sp.	*Remesella* sp. 1	*Tritaxia gaultina*	*Pseudonodosaria* sp.	*Oolina globosa*	*Lenticulina* aff. *nodosa*	*Pleurostomella reussi*	*Lingulina loryi*	*Lingulina lamellata*	*Praebulimina nannina*	*Falsopalmula* sp.	*Lingulogavelinella indica*	*Tristix excavata*	*Astacolus parallelus*	*Planularia* sp.	*Scheibnerova protindica*	*Ammosphaeroidina* sp.	*Berthelina berthelini*	*Astacolus humilis*	*Heterantyx cretosa*	*Fissurina* sp.	*Oolina sulcata*	*Oolina accuminata*	*Spiroplectinella gandolfii*	*Oolina* spp.	*Psilocitharella* sp.	*Pyramidulina sceptrum*	*Glomospirella gaultina*	*Laevidentalina distincta*	*Saracenaria triangularis*	*Globorotalites aptiensis*	*Haplophragmoides* sp, 1	*Pseudobolivina* sp.	*Berthelina* spp.	*Spiroplectinella* sp.	Diversity	Number of specimens
16-1; 31-36				3												1									136		26						13	1						46			12		20	466
16-3; 32-36	30			22			1				25	42											1		79		4						2	1						11			3	1	24	407
16-5; 32-36	18	3					2			1	20	70				5			1						147		3		2				4							5	1	1			25	467
17-2; 130-133	7	4	1				3				26	37				2									69		6		2				1		1	1			1						35	456
17-3; 43-46		8		17							17	67				3							1		169	1	3		4				1				1	3							34	691
17-5; 2-3	8	14				1	3			1	23	27				1			1						138	3			1					1	1	1									37	602
18-3; 58-61	9			10			2				3	40		1											17				2		1	1	1												29	426
18-4; 98-100				24		1	1				9	74		5					20				1					1	4	1															30	534
18-5; 78-81				6			3			1	11	50		1		1	1		3				1				1	1	1																36	477
19-1; 68-72				9			1				7	57					2		8						115																				26	482
19-3; 29-33	5			16							7	19													2	1																			23	421
19-4; 82-86	1			3			1				23	13												1																					20	538
20-1; 39-43				9					1		23					1							2																						29	377
20-2; 87-91	2		1	10						1	8				1		1						1																						28	269
20-3; 20-24	2						1				34		1	3	4	3	3	2	1	1	1	1																							37	407
21-1; 39-43	4	3		12	2	1	1	1	2	2	11	1																																	36	486
21-2; 14-18	1	19	1	4																																									37	508
24-1; 111-113																																													34	377
25-1; 3-5																																													11	362
26-3; 68-72																																													2	2

CHAPTER 5. *Palaeoecology*

5.1. INTRODUCTION

"The composition and nature of the microfaunas proved to be good general indicators of Cretaceous bathymetry in the Indian Ocean..... There is no convincing evidence for great depth before the beginning of the Late Cretaceous. The scarcity of calcareous forms can be attributed to low temperatures, extremely shallow depth and solution of calcitic tests in the sediment (after burial in the sediment) due to reducing conditions" Scheibnerová (1977).

There has not been any reassessment of Scheibnerová's original palaeoenvironmental interpretation of Lower Cretaceous foraminiferal assemblages from Indian Ocean DSDP sites since the publication of her work in the seventies. Scheibnerová's conclusions were based primarily on the similarity between Indian Ocean agglutinated and calcareous assemblages and their coeval counterparts from epeiric basins on mainland Australia. However, biostratigraphic revisions and taxonomic comparisons between Indian Ocean and Australian assemblages, undertaken during the course of this research, suggest that the faunal affinity between the foraminiferal assemblages from DSDP sites and continental Australia may be more tenuous than initially hypothesized by Scheibnerová.

The main objectives of this chapter are to derive palaeoenvironmental interpretations from quantitative analyses of benthic foraminiferal distribution patterns and to describe the succession of benthic foraminiferal biofacies recorded in Lower Cretaceous sedimentary sequences of Indian Ocean DSDP and ODP sites. The diversity, relative proportion of calcareous/agglutinated taxa, rotaliids and lagenids and the morphogroup composition of benthic foraminiferal assemblages are given below for DSDP Sites 249, 256, 257, 258, 259, 260 and 263 and for ODP Sites 762, 763 and 766. These data are combined with seismic, geochemical and sedimentological information, and with backtracking evidence where applicable, to determine Early Cretaceous palaeoenvironments in the Indian Ocean. Principal Component Analysis is also applied to establish benthic foraminiferal biofacies trends in the Lower Cretaceous of the Indian Ocean. Finally, a palaeoceanographic synopsis is presented, which aims to retrace the evolution of the Indian Ocean during the Early Cretaceous and to monitor oceanic productivity fluctuations in relation to sea-level and circulation changes in the nascent ocean. A detailed description of parameters and methods used, can be found in Chapter 3.

5.2. DSDP SITE 249

5.2.1. Results

Figure 5.1 shows that the foraminiferal assemblages from this site consist almost exclusively of calcareous taxa. Lagenids dominate between Core sections 249-31R-4 and -27R-3, while rotaliids increase significantly in Core section 249-26R-2, representing nearly 50% of all tests. This rise reflects the acme of one species *Gavelinella barremiana*, recorded in Sample 263-26R-2; 43-46. H(S) values are generally high, reaching over 3.0 in several samples.

The distribution of morphogroups varies markedly throughout the sequence. Globular forms are initially abundant (attaining over 46% in Sample 249-31R-2; 103-106), then decline significantly between Core sections 249-28R-3 to -26R-2, where they represent only 10% or less of tests. Planispiral evolute forms (about 30% to 45% of tests) are generally more abundant than planispiral involute morphotypes between Core 249-31R-4 and -27R-3. The proportion of elongate tapered tests, normally around 10% in most samples, rises sharply in two samples (to 41% in Sample 249-30R-4; 5-8 and to 28% in Sample 249-27R-3; 115-118). The variations in the infaunal to epifaunal/shallow infaunal ratio reflects changes in the distribution of the main morphogroups.

5.2.2. Environmental significance

The high diversity, virtual absence of agglutinants (Figure 5.1) and the dominance of lagenids with ornamented tests in most samples point to open marine conditions above the CCD, relatively shallow depths and moderately high energy. Several barren intervals correspond to thin limestone turbidites (shown as sharp peaks in $CaCO_3$ on Figure 5.2), which are intercalated within volcanogenic siltstones, rich in reduced iron and carbon. Despite the location of Hole 249 on oceanic crust (Schlich *et al.*, 1974), initial palaeodepths could not be computed from backtracking, since the site rests on a positive structure of the Mozambique Ridge, which was considerably uplifted and faulted during the Pliocene and Pleistocene (Kent, 1974).

Morphogroup distribution appears to reflect variations in %TOC and to be related to changes in organic flux to the seafloor. Figure 5.1 shows that polymorphinids with an epifaunal or shallow infaunal mode of life, are very abundant at the base of the sequence (Cores 249-31R to -30R), where TOC percentages are lower. As TOC values increase, elongate tapered forms, probably better adapted to more dysoxic conditions, become more numerous. The acme of trochospiral epifaunal rotaliids in Sample 249-26R-2; 43-46, appears to coincide with a drop in %TOC, (Figure 5.2)

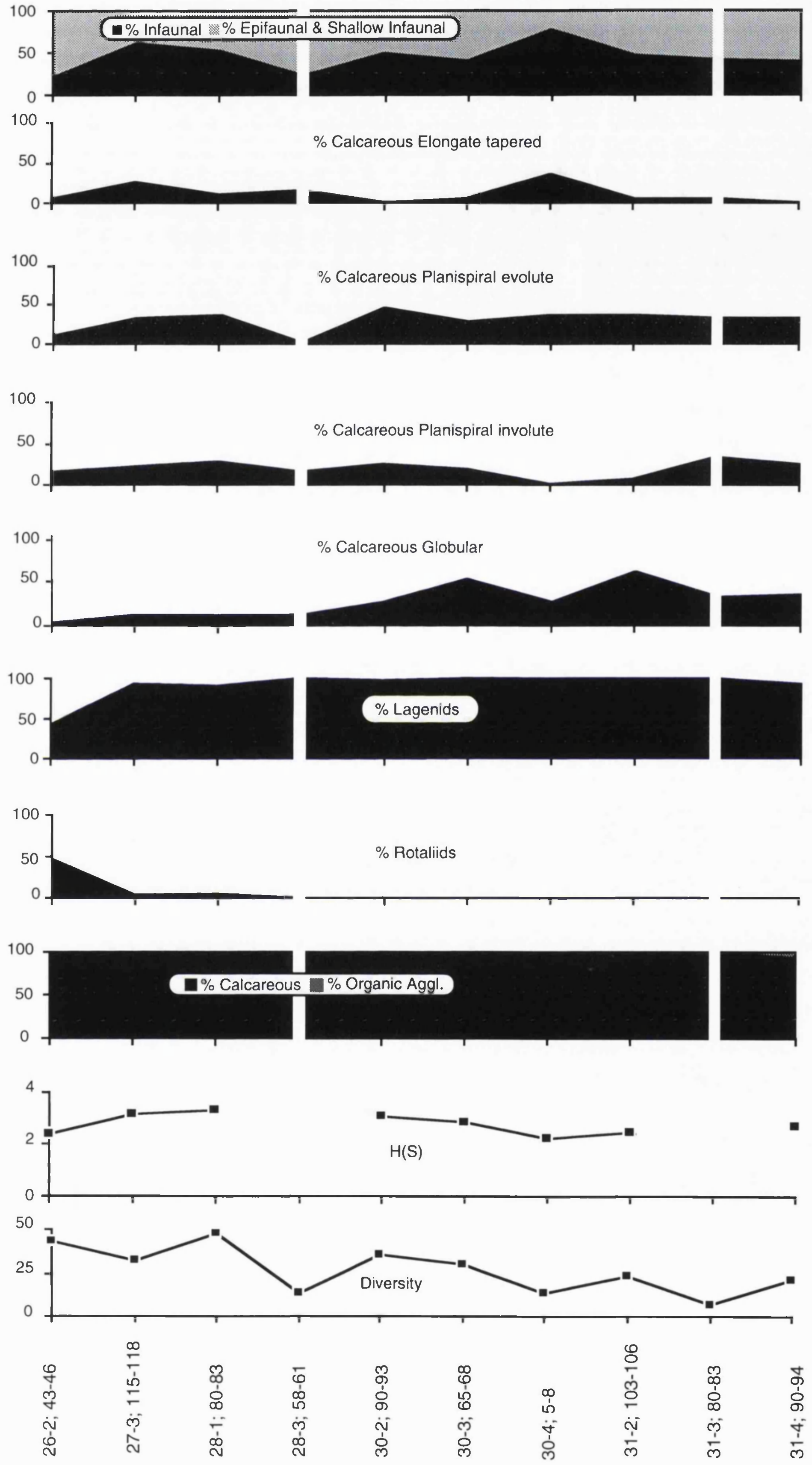


Figure 5.1. Benthic foraminiferal distribution patterns at Site 249 (blanks correspond to statistically insignificant samples).

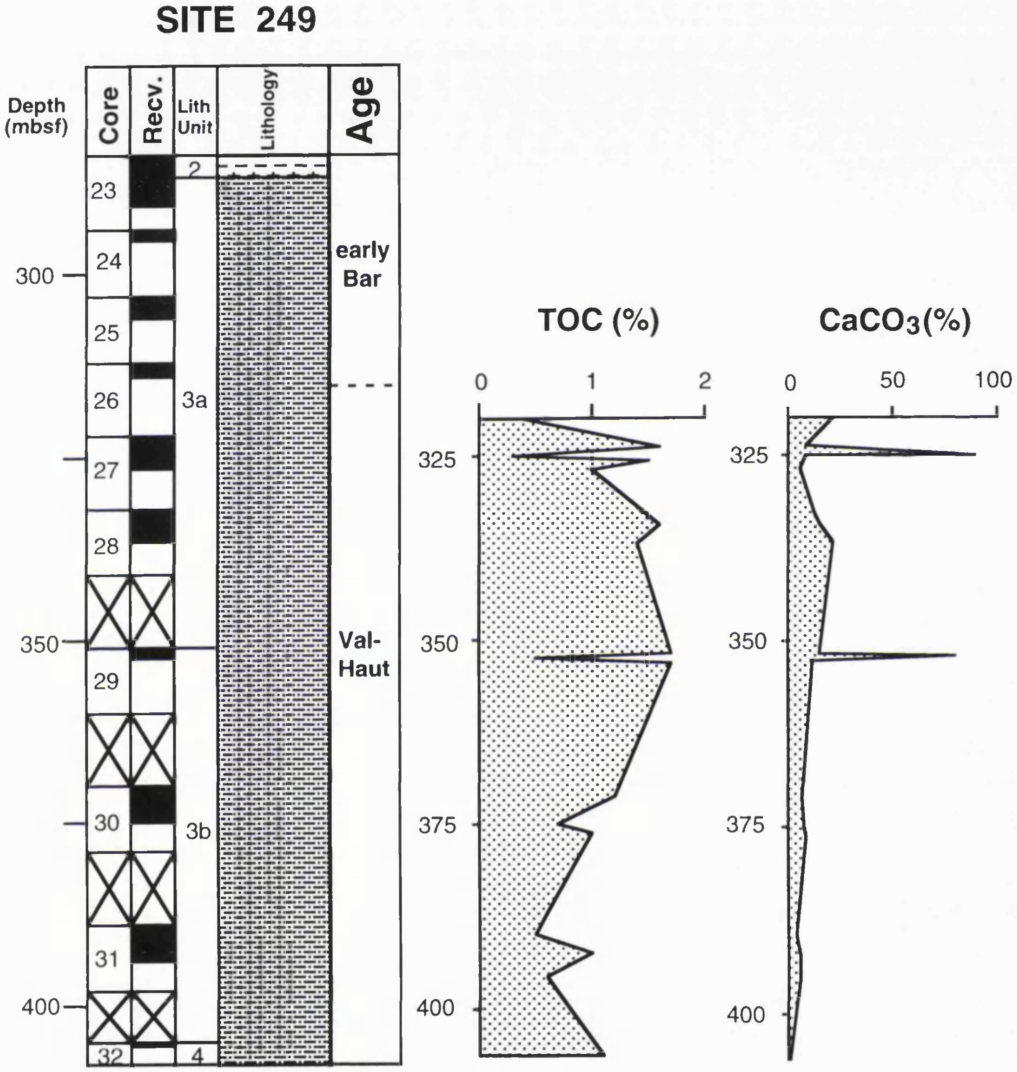


Figure 5.2. Lithology, %TOC, %CaCO$_3$ and grain size distribution at Site 249 (key to lithology in Figure 5.4).
Barren samples 29R-1; 79-81, 27R-2; 100-103, 27R-214-17, 26R-2; 90-93, 25R-2; 130-133.
Compiled from Simpson, Schlich *et al.* (1974).

suggesting a return to improved oxygenation of bottom waters. Marked fluctuations in the proportion of infaunal morphotypes indicates that conditions may occasionally have become restricted in the basin. However, the relatively high foraminiferal diversity and the numerous ostracods, radiolarians, bivalves and echinoderm fragments recorded from many of the samples rule out very eutrophic conditions. A vigorous oceanic circulation (evident from the grain size and sedimentary structures) must have prevented stagnation and allowed the exploitation of abundant food resources at various trophic levels.

The benthic foraminifera from Site 249 are predominantly cosmopolitan, suggesting the existence of open marine connections with Tethys and other major oceans by the late Valanginian and Hauterivian. A few endemic species from Madagascar are also noted, indicating some differentiation from Tethyan faunas.

5.3. DSDP SITE 256

5.3.1. Results

Figure 5.3 shows that the foraminiferal assemblage is relatively diverse: the number of species ranges from 19 to 31 and H(S) varies from 1.96 to 2.96. Calcareous (mainly rotaliids) and organically-cemented agglutinated taxa are predominant, whereas calcareous-cemented agglutinants amount to less than 15% of tests. Ammodiscids and tubes are the most abundant agglutinants, accounting for about 12% to 34% and 10% to 38%, respectively, of all tests. A slight decline in the proportion of these two agglutinated morphogroups is noted above Sample 256-8R-4; 127-131, when rotaliids appear to increase correspondingly. Lagenids are only present in small numbers, representing less than 6% of all tests. The foraminiferal succession is dominated by epifaunal and shallow infaunal morphotypes; the proportion of infaunal forms remains below 18%.

5.3.2. Environmental significance

The assemblages contain a large proportion of tubular forms, considered to be suspension feeders, and, as fragile tests are easily destroyed during fossilisation, the abundance of suspension feeders is probably strongly underestimated. Epifaunal and shallow infaunal morphotypes dominate, suggesting an environment where food is the limiting factor and where the organic flux to the seafloor is mostly consumed by epifaunal and shallow infaunal dwellers so that organic matter rarely becomes

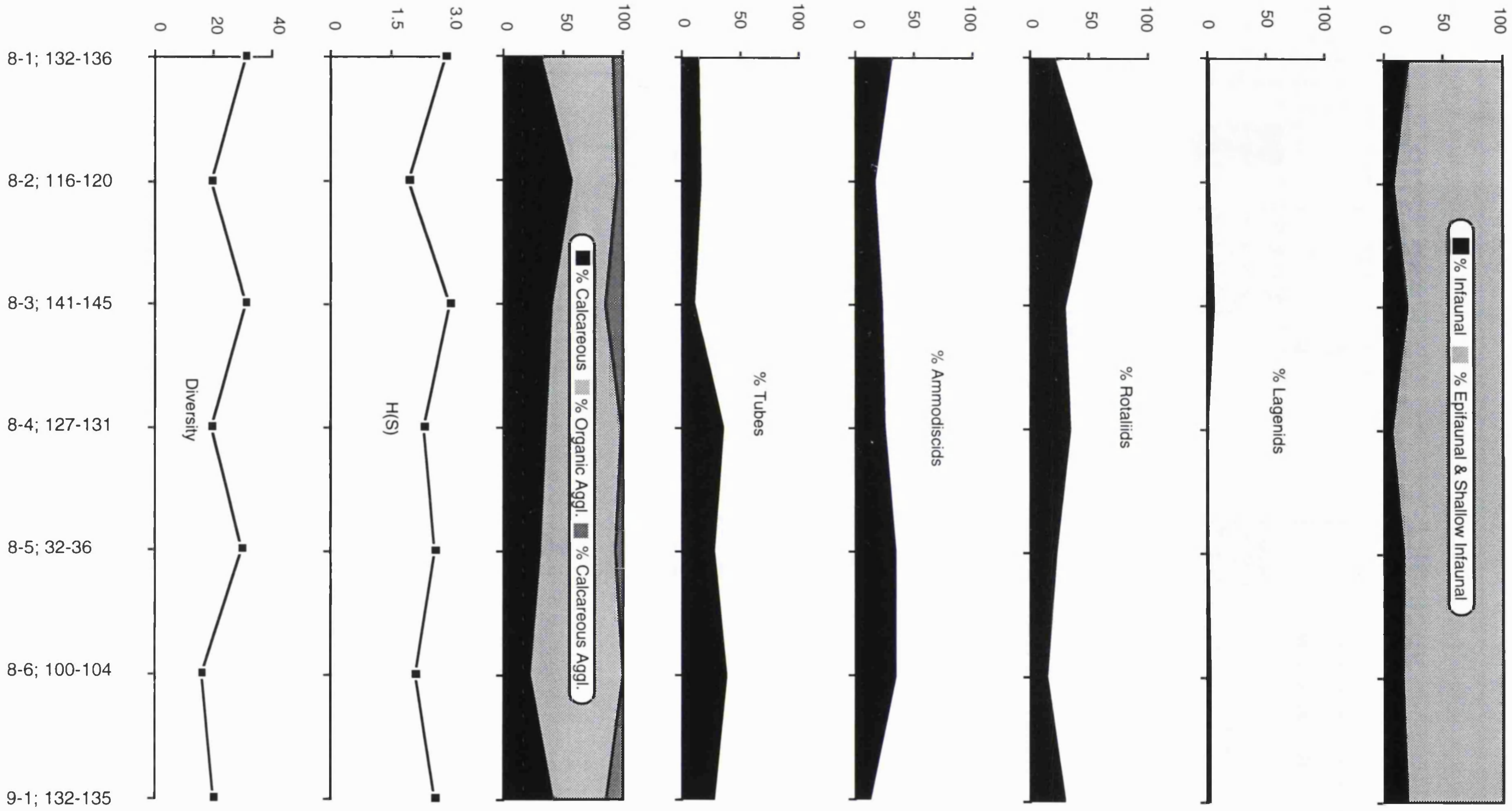
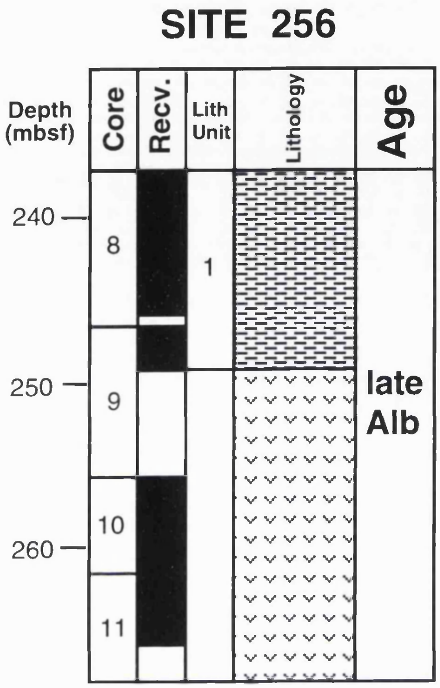
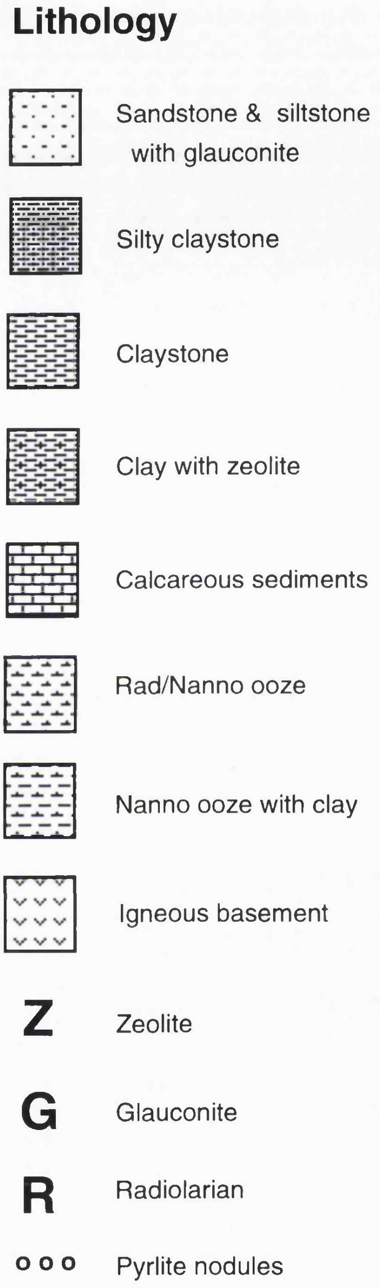


Figure 5.3. Benthic foraminiferal distribution patterns at Site 256.





256-8R-5; 84	%
TOC	0.1
$CaCO_3$	0.1
Sand	0
Silt	24
Clay	76

Figure 5.4. Lithology, %TOC, $\%CaCO_3$ and grain size distribution at Site 256. Compiled from Davies, Luyendyk *et al.* (1974).

preserved within the sediment. Low values of TOC (0.1%) and $CaCO_3$ (0.1%) recorded in Core section 256-8R-5 support this interpretation (Figure 5.4).

In modern oceans such assemblages are characteristically found in central oceanic regions, where food, primarily supplied by the rain of phytodetritus derived from seasonal primary production in the overlying water column, is the main control on foraminiferal distribution (Gooday, 1988; Gooday and Turley, 1990; Lambshead and Gooday, 1990; Murray, 1990; Loubere, 1991; Altenbach, 1992; Sjoerdsma and Van der Zwaan, 1992; Gooday, 1994). In well oxygenated oligotrophic regions epifaunal suspension feeders optimise their ability to obtain food by deploying pseudopodial nets to catch detrital particles before they settle on the seafloor. Komokiaceans and astrorhizids dominate modern deep-water assemblages (Gooday, 1990; Gooday, 1994), although their delicate tests are rarely preserved in the fossil record, which is heavily biased towards robust forms with calcareous or siliceous cement (Schröder, 1988).

In the deep oceans pulses of high particulate organic matter (POM) inputs, such as seasonal algal blooms in higher latitudes, are exploited by opportunistic species which respond rapidly to changing food supply (Graf and Linke, 1992; Linke, 1992). When food supply is very erratic, only non specialists survive and food webs become consequently very short and simple. Food supply exerts, therefore, a direct control on the trophic structure of deep-sea benthic communities. The assemblages from Site 256 also include a large proportion of taxa, which appear to be able to adapt to a wide range of ecological conditions. Most of the calcareous foraminifera are common cosmopolitan taxa, which have broad ecological niches. Ammodiscids are also quite numerous, representing extremely opportunistic taxa, which can survive even in the most hostile environments, for instance, close to hydrocarbon seeps (Kaminski, 1988) or within biosiliceous, radiolarian rich sediments (Kuhnt and Kaminski, 1989; 1990; Kuhnt *et al.*, 1989; Kaminski *et al.*, 1992^a) or in inferred hyposaline prodeltaic environments (Nagy *et al.*, 1990).

The composition of the foraminiferal assemblage, therefore, suggests a pelagic environment, far from terrigenous influences, which received a limited pulsed supply of POM from surface waters. The initial ridge-crest depth of Hole 256, situated on oceanic crust in the southern Wharton Basin, west of the Wallaby Plateau, in present day water depth of 5361m, has been estimated as nearly 3000m from backtracking, and gives further support to this interpretation (Figure 5.5). Variations in the distribution of morphogroups probably reflect changes in surface water fertility and in oceanic circulation. The abundance of calcareous tests and of agglutinants with calcareous cement clearly indicate deposition above the lysocline. Finally, the cosmopolitan character of the fauna points to the existence of deep-water connections between the Indian Ocean and other major oceans.

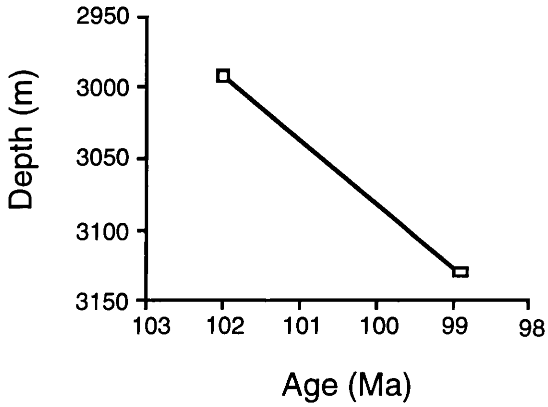


Figure 5.5. Reconstructed palaeodepths for Site 256.

5.4. DSDP SITE 257

5.4.1. Results

Figure 5.6 shows that the foraminiferal succession is initially dominated by ammodiscids between Core sections 257-10R-1 and -9R-2, where both species frequency and H(S) values record low diversity. A major faunal change occurs above Core section 257-9R-2, where diversity increases and organic agglutinants decline significantly in numbers. Calcareous tests and calcareous agglutinants increase markedly, making up approximately two thirds of all tests between Core sections 257-8R-2 and -7R-1. Rotaliids become numerically dominant among calcareous taxa, representing nearly 50% of all tests, whereas lagenids remain a minor constituent of the assemblages (accounting for 5% or less of all tests). The proportion of infaunal morphotypes increases to nearly 20% between Core sections 257-8R-2 and -7R-1.

5.4.2. Environmental significance

The very impoverished foraminiferal assemblage, at the base of the sequence above the basalt, suggests sub-CCD, stressed conditions. This biofacies is a recurrent feature of Cretaceous and Palaeogene DWAF assemblages (Deep Water Agglutinated

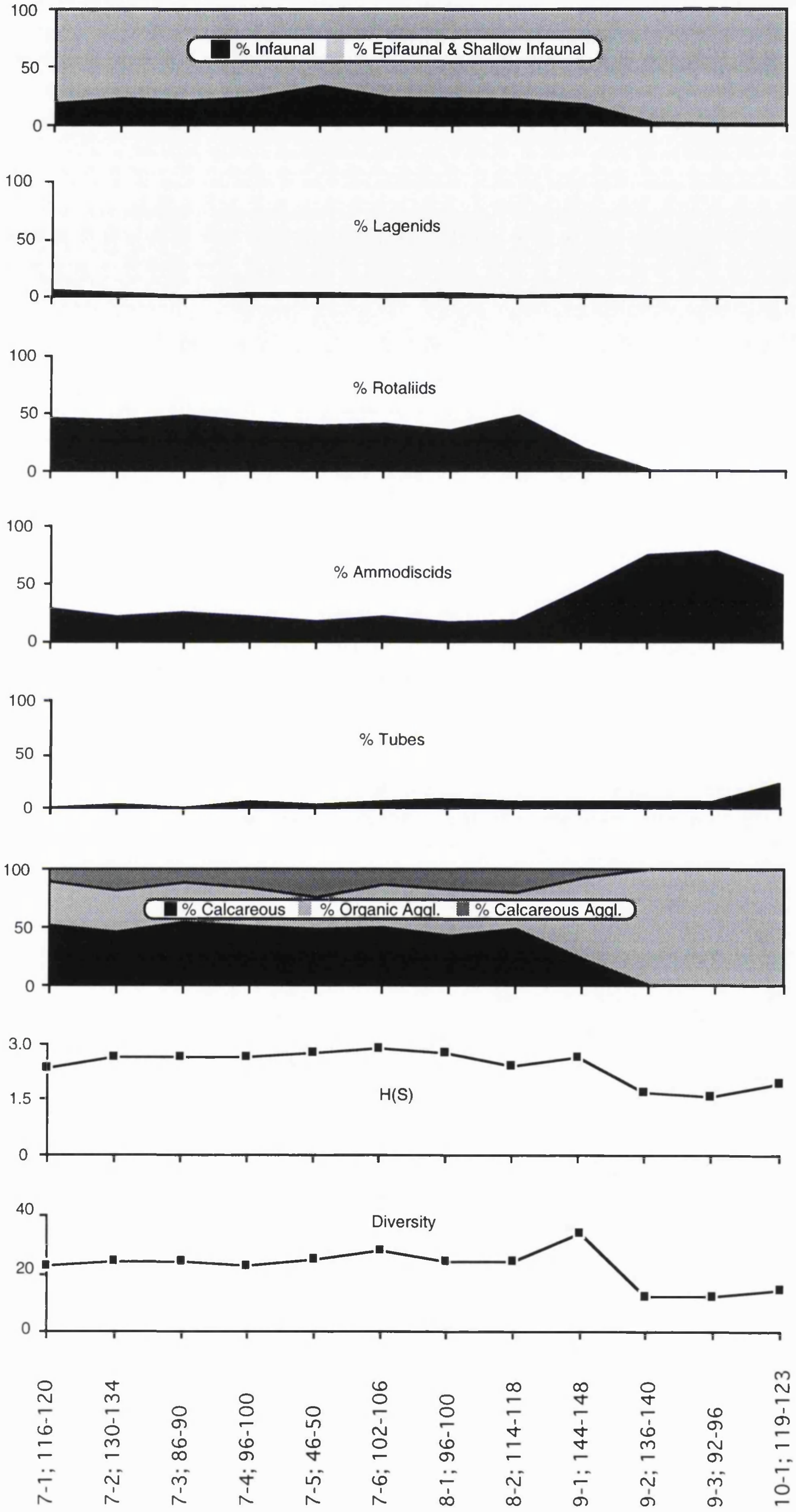


Figure 5.6. Benthic foraminiferal distribution patterns at Site 257.

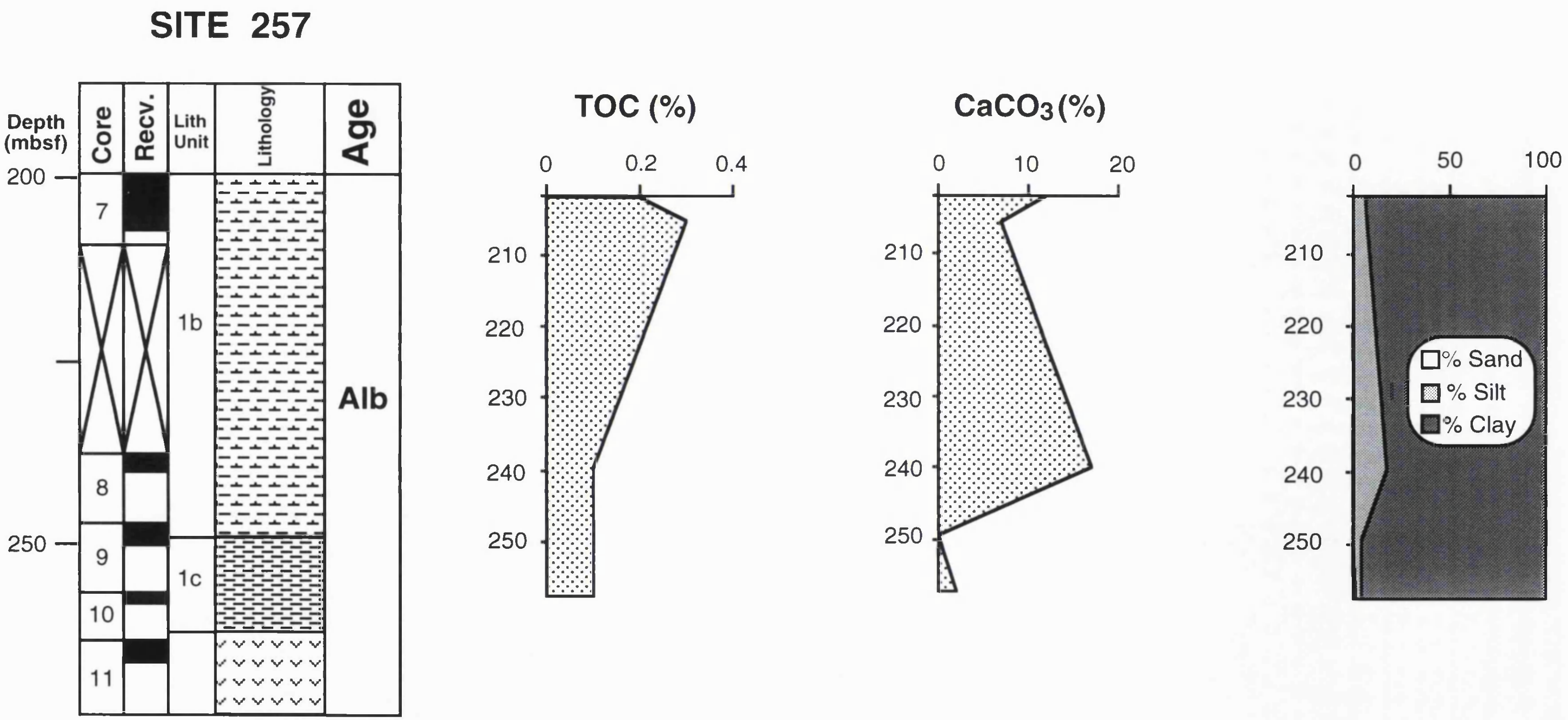


Figure 5.7. Lithology, %TOC, %$CaCO_3$ and grain size distribution at Site 257 (key to lithology in Figure 5.4). Compiled from Davies, Luyendyk *et al.* (1974).

Foraminifera), and is often associated with high biosiliceous productivity (Kuhnt and Kaminski, 1989; 1990; Kuhnt *et al.*, 1989; Kaminski *et al.*, 1992a). Although radiolarians were only reported from the basal clays in Core 257-10R and from a recrystallised limestone layer within the basalt in Core 257-12R (Davies, Luyendyk *et al.*, 1974). their absence from overlying cores may be due to poor preservation.

The increase in diversity and influx of calcareous tests and calcareous agglutinants, recorded from Sample 257-9R-1; 144-148 upwards, corresponds to a lithological change from a detrital clay to a coccolith rich clay (Figure 5.7). The abrupt change in lithology and $CaCO_3$ content suggests that a hiatus may be present at the boundary between the two lithological units. This late early Albian change is also recorded at other DSDP and ODP sites in the Indian Ocean (Sites 259, 762, 763 and 766), suggesting a major shift in oceanic circulation associated with a CCD drop. The diverse assemblages are indicative of well ventilated bathyal conditions. Higher $CaCO_3$ values than at Site 256 probably indicate higher productivity and may explain the relative scarcity of tubes and abundance of rotaliids. An increased supply of POM would lead to more intensive exploitation of surficial sediments and would disrupt the niche of passive suspension feeders. Backtracking also indicates a deep oceanic setting for Site 257, suggesting palaeodepths around 2700m at the start of sedimentation, reaching about 3300m by the late Albian (Figure 5.8). The scarcity of planktonic foraminifera and the absence of keeled taxa point to cool surface waters.

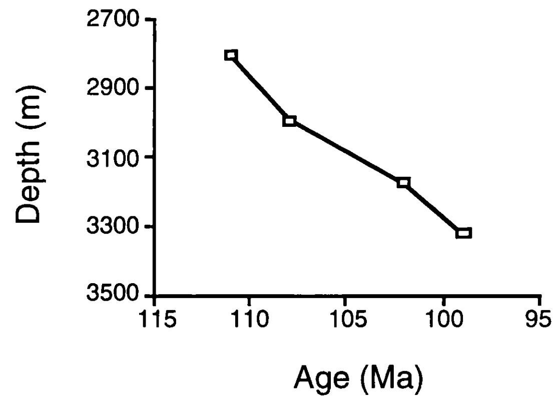


Figure 5.8. Reconstructed palaeodepths for Site 257.

5.5. DSDP SITE 258

5.5.1. Results

The diversity and composition of the foraminiferal assemblages vary considerably (Figure 5.9). Values of H(S) fluctuate between 1.5 and 2.8, while species frequency displays erratic variations between Core sections 258-24R-3 and -14R-1. Organically-cemented agglutinated tests are dominant, except at the top of the interval (Core sections 258-16R-4 to 14R-1), where the proportion of calcareous tests (mainly rotaliids) increases markedly. Sharp changes in the relative proportions of tubes, ammodiscids and planispiral/streptospiral involute morphotypes, which together make up a substantial proportion of the assemblages, are recorded. Planispiral/streptospiral involute morphotypes decline markedly above Core section 258-21R-3 and disappear above Core section 258-17R-5. Epifaunal and shallow infaunal morphotypes dominate over infaunal forms throughout the sequence.

5.5.2. Environmental significance

Site 258 is situated in 2793m of water, on the northern flank of the Naturaliste Plateau. The origin of the Plateau has been the subject of debate for many years and it has been proposed that the Plateau was an epilith extruded after continental break-up (Veevers and Cotterill, 1978; Coffin and Eldholm, 1992; Colwell *et al.*, 1994) or, alternatively, that it was a part of the Gondwana landmass, which had subsided following break-up (Petkovic, 1975; Jongsma and Petkovik, 1977). Drilling was terminated before reaching basement and the basal unit (lithological unit 5) recovered at Site 258 is a detrital silty clay (Figure 5.10), which is barren of foraminifera. It was dated as late Neocomian from palynomorphs and interpreted as a shallow paralic unit by Morgan (1980). According to Morgan (1980), lithological unit 4 represents a shallow marine sequence, which was deposited before the Plateau subsided to oceanic depths in the late Albian-Cenomanian. This interpretation is at odds with the Leg 26 shipboard work, which concluded that lithological units 4 and 5 represented deep-sea sediments, accumulated above and below the lysocline, respectively.

The abundance of tubes and ammodiscids in lithological unit 4 (Figure 5.9) does not support a very shallow origin for this sequence. The occurrence of *Caudammina crassa*, a cosmopolitan species characteristically found in deep sea sediments, also appears to rule out a shallow neritic setting. The presence of *Osangularia schloenbachi* in Core sections 258-21R-2 to -15R-2 (Figure 5.9) points to bathyal conditions, as this species is rarely recorded at shallower depths in the Albian, off northeastern Australia (Haig and Lynch, 1993). Unfortunately,

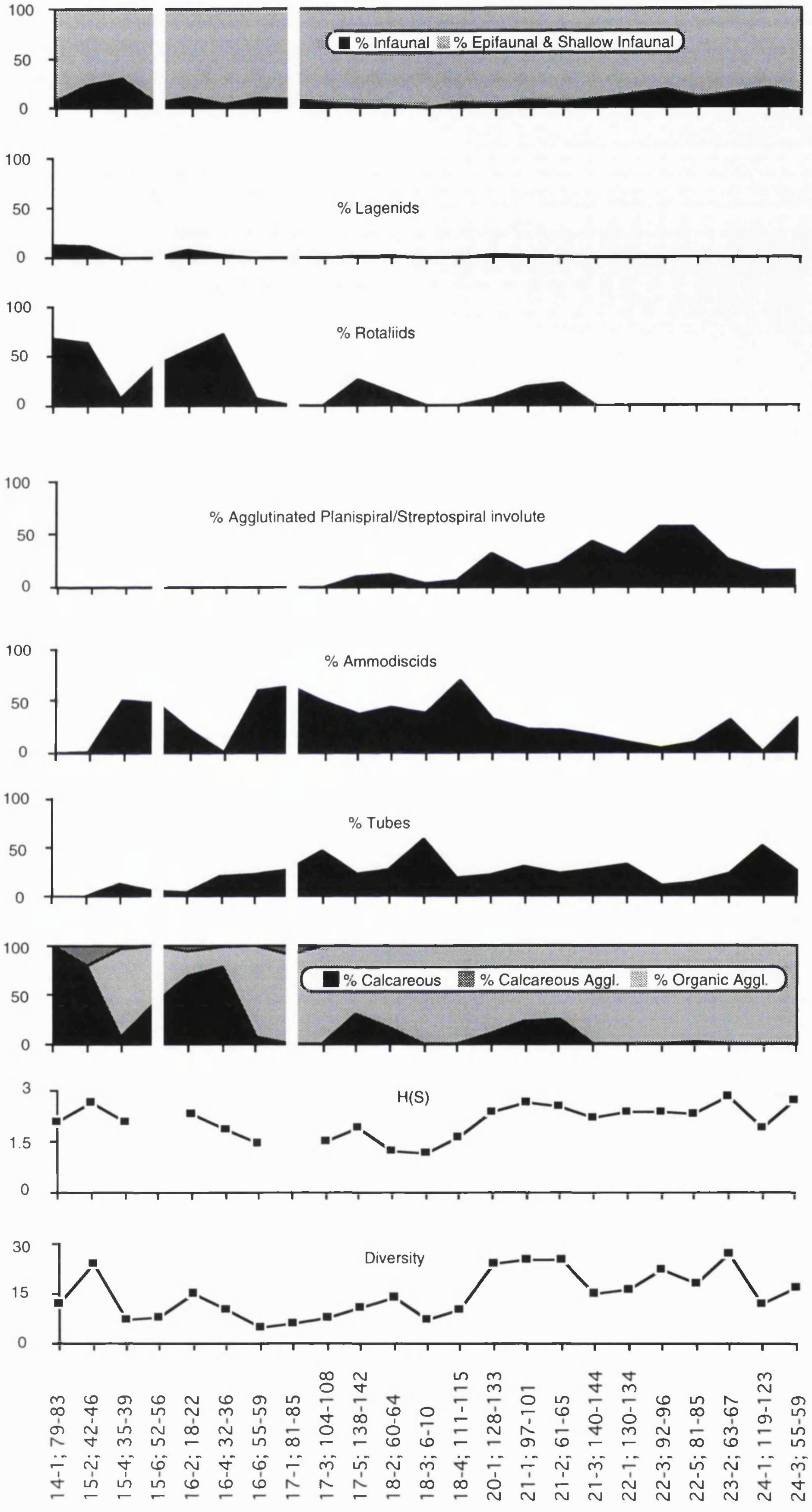


Figure 5.9. Benthic foraminiferal distribution patterns at Site 258 (blanks correspond to statistically insignificant samples).

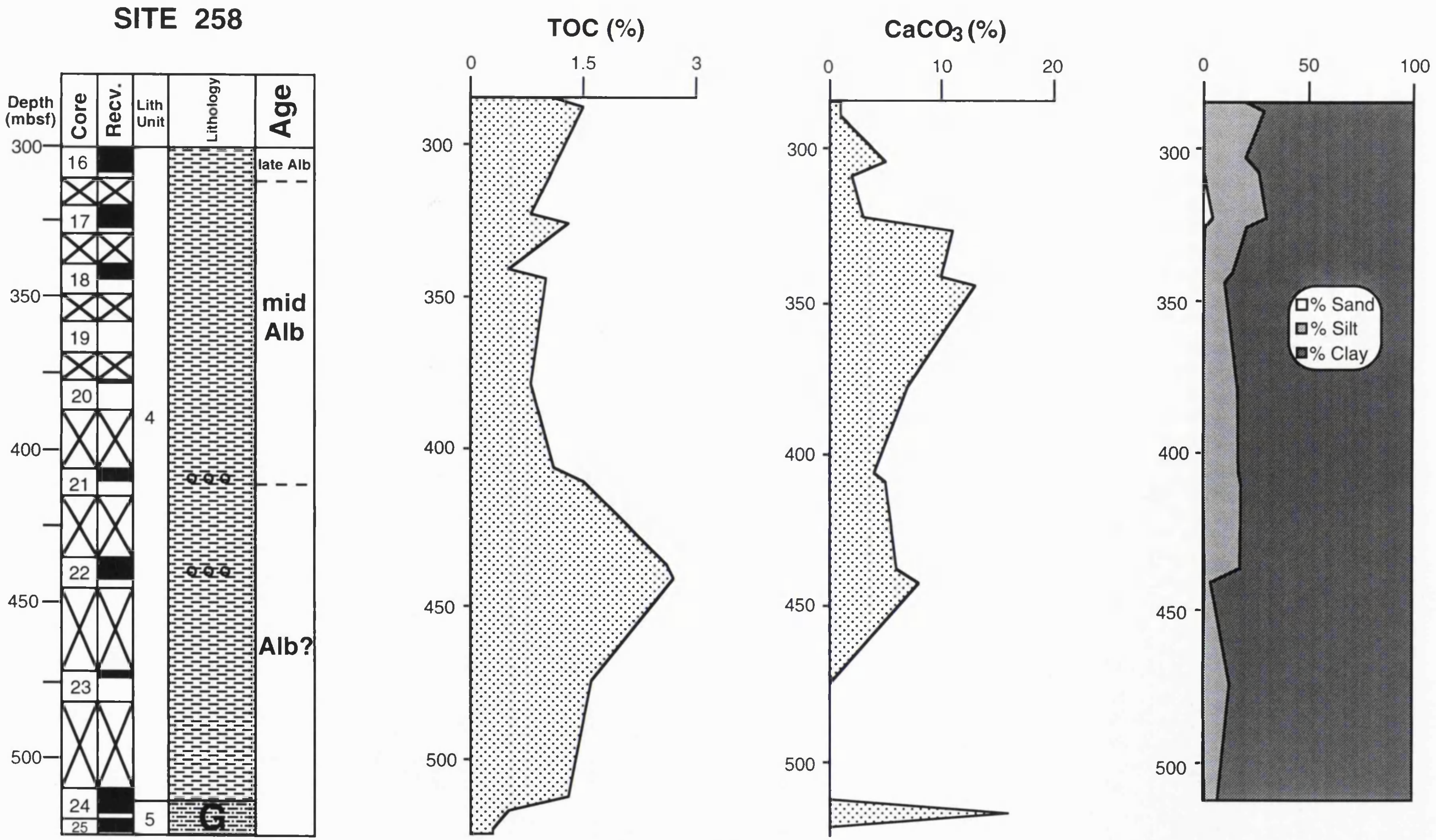


Figure 5.10. Lithology, %TOC, %CaCO3 and grain size distribution at Site 258 (key to lithology in Figure 5.4). Core sections 25R-4 to -2 and 24R-5 are barren.
Compiled from Davies, Luyendyk *et al.* (1974).

backtracking cannot be used, to estimate palaeodepths, since the origin of the Naturaliste Plateau remains ambiguous. However, Petkovic (1975) proposed that the Naturaliste Plateau may have reached its present depth in the mid Albian.

The high proportion of planispiral/streptospiral involute morphotypes, often dominant in organic rich environments (Nagy *et al.,* 1988; 1990), suggests that circulation was initially restricted, when the base of lithological unit 4 was deposited (Core sections 258-24R-3 to -21R-3). This interpretation is supported by the presence of pyrite, elevated %TOC values (Figure 5.10) and the lack of bioturbation at some levels (Davies, Luyendyk *et al.*, 1974). Rises of the RPD within the substrate may have intermittently reduced the depth of the oxygenated layer, leading to marked changes in foraminiferal distribution and diversity. The intermittent increases in calcareous tests above Core section 258-21R-2 suggests temporary improvements in basin circulation in the late Albian. Intense bioturbation in the upper part of lithological unit 4 and in lithological unit 3, where %TOC values are generally lower (Figure 5.10), also points to transient more aerobic conditions (Eksdale and Mason, 1988; Savrda and Bottjer, 1991). Site 258 probably remained above the lysocline during the late Albian; the paucity of calcareous taxa at the base of the sequence possibly being due to diagenetic dissolution in a corrosive environment. The rarity of planktonics and the absence of any keeled taxa indicate cool surface waters at this southerly site.

5.6. DSDP SITE 259

5.6.1. Results

The most salient feature in Figure 5.11 is the dramatic faunal change, which occurs above Core section 259-17R-3. Assemblages are initially composed almost exclusively of organically cemented agglutinated taxa between Core sections 259-33R-1 and 17R-3, where declining values of H(S) and faunal frequency reflect an overall decrease in diversity, as assemblages become increasingly dominated by ammodicisds. Above this interval, calcareous tests and calcareous agglutinants become the dominant elements of the fauna and a sharp rise in diversity is recorded in Sample 259-16R-4; 90-94, where the value of H(S) increases to 2.03. Diversity and abundance remain high from Core sections 259-16R-4 to -13R-2, but a sharp drop in abundance is recorded from Core section 259-12R-5 upwards.

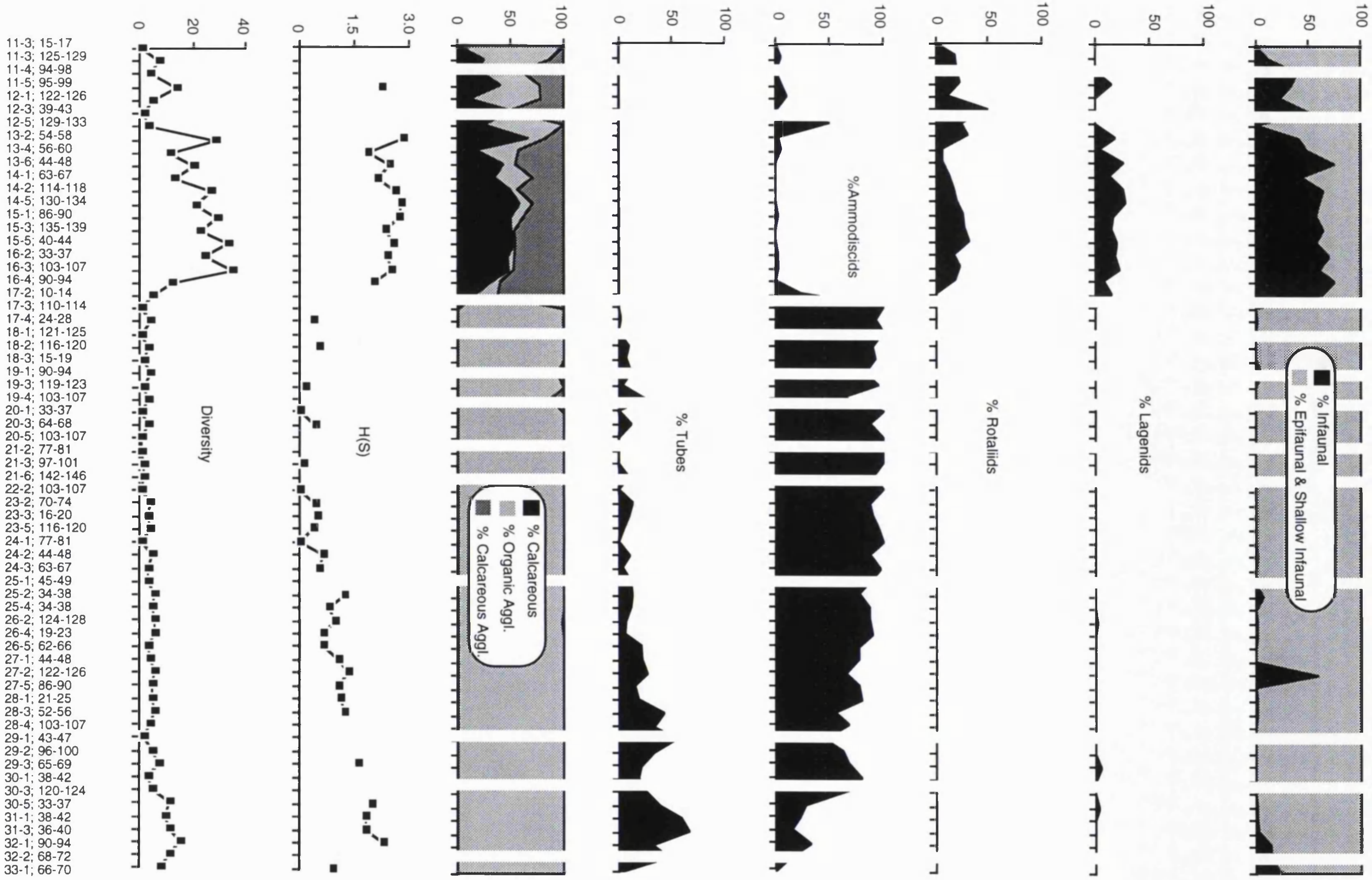


Figure 5.11. Benthic foraminiferal distribution patterns at Site 259 (blanks correspond to statistically insignificant samples).

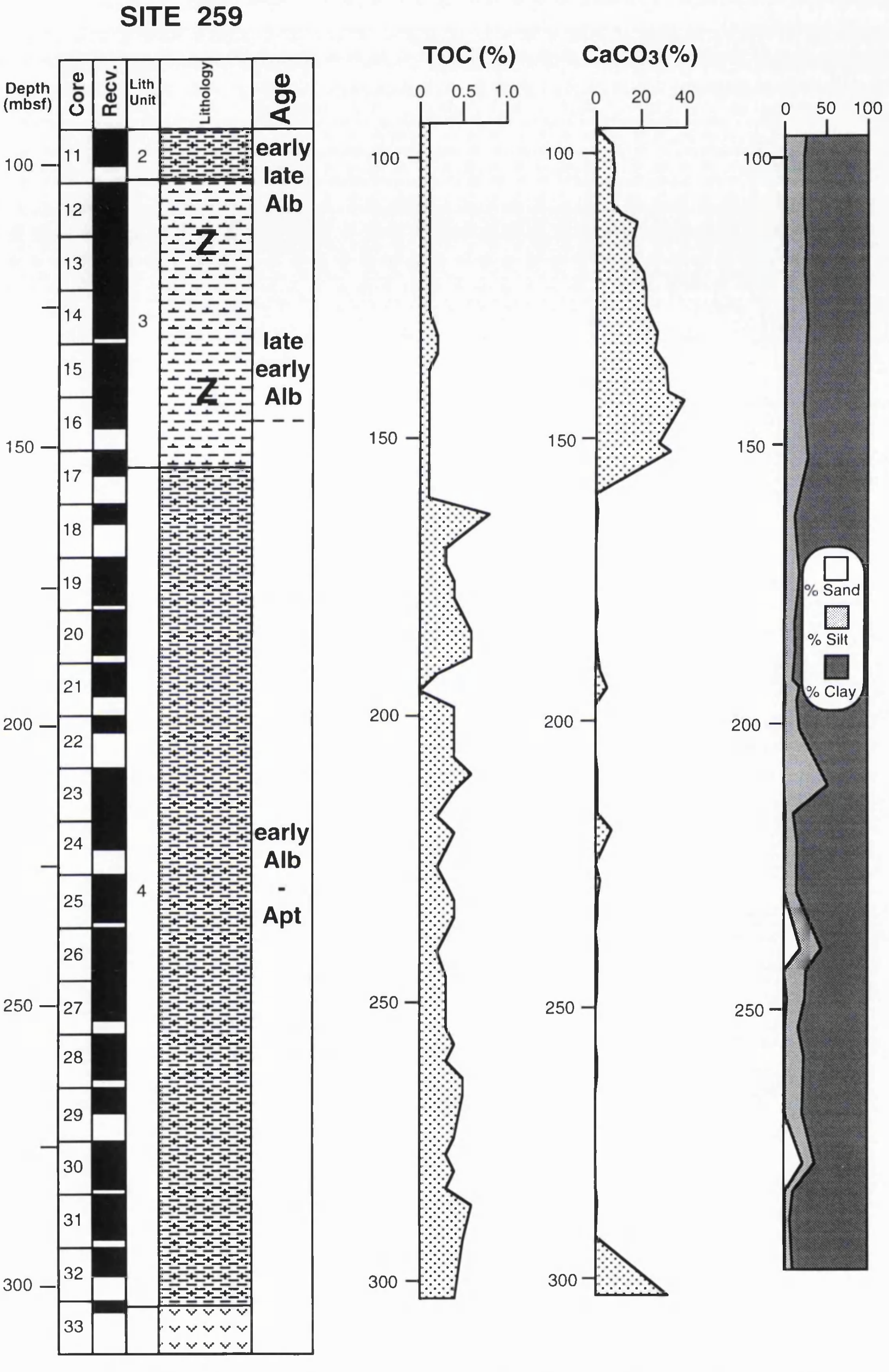


Figure 5.12. Lithology, %TOC, %CaCO$_3$ and grain size distribution at Site 259 (key to lithology in Figure 5.4).
Compiled from Veevers, Heirtzler *et al.* (1974).

5.6.2. Environmental significance

The impoverishment of the agglutinated assemblage from Core sections 259-33R-1 to -17R-3 (Aptian-early Albian) points to deteriorating environmental conditions on the seafloor. The increasing dominance of ammodiscids between Core sections 259-30R-3 and -17R-3 (Figure 5.11) may be linked to high biosiliceous productivity in surface waters. This is supported by the occurrence of poorly preserved radiolarians in this interval. TOC values are also generally higher in lithological unit 4 than in lithological unit 3 (Figure 5.12). The absence of calcareous tests in lithological unit 4 suggests deposition below the lysocline. The silt and sand contents probably reflect the influx of terrigenous sediments at this site, situated in close proximity to the continental margin. Palaeodepths of about 2200m at the beginning of sedimentation in the Aptian, reaching about 2800m by the late Albian, are indicated from backtracking (Figure 5.13).

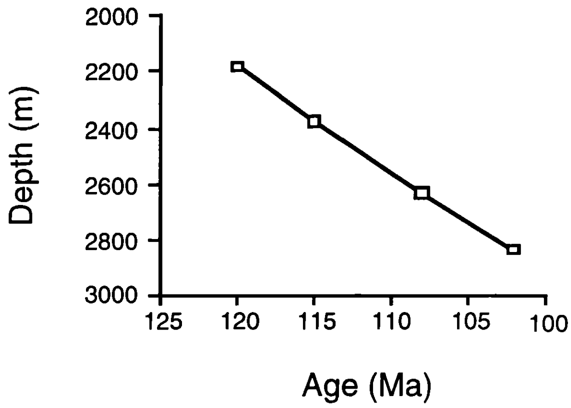


Figure 5.13. Reconstructed palaeodepths for Site 259.

The major faunal change above Sample 259-17R-2; 10-14 coincides with a lithological change from a dark clay in lithological unit 4 to a zeolite rich nannofossil clay in lithological unit 3 with an initially high $CaCO_3$ content (up to 39% $CaCO_3$ in Core section 259-16R-3). The contact between the two lithologies is sharp (Veevers, Heirtzler *et al.*, 1974) and a phosphorite bed is present at the boundary. Cook (1974) suggested that the phosphorite was a replacement deposit, formed by the diagenetic phosphatization of calcareous and siliceous fossil fragments (nannofossils and radiolarians) during a period of very slow deposition. This phosphorite may be interpreted as a hiatus in deep-sea sedimentation during a transgressive event as sediments became sequestered on the shelf (see Haq, 1991). The high diversity calcareous assemblages indicate that the site was well above the CCD during the deposition of unit 3 and that bottom waters were not severely dysoxic. The abundance of nannofossils, planktonic foraminifera and radiolarians and the large proportion of infaunal benthic foraminifera point to high productivity in both surface and bottom waters at this site, which is closely located to the continental margin. The faunal change at the base of litholopical unit 3 reflects an improvement in deep water oxygenation, probably linked to a shift in oceanic circulation and a CCD drop in the late early Albian. Low foraminiferal diversity and abundance at the top of lithological units 3 and 4 indicate a return to less favourable conditions in the late Albian.

The occurrence of large specimens of *Ticinella primula* in Core sections 259-16R-2 to -14R-1 points to the influx of warm surface waters along the western Australian margin in the mid Albian. The cosmopolitan composition of the benthic assemblages reflects open connections between the Indian Ocean and other oceans in the Albian.

5.7. DSDP SITE 260

5.7.1. Results

Changes in diversity and composition are shown in Figures 5.14 and 5.15. The lithological succession at Site 260 consists of yellowish-brown nannofossil ooze with minor nannofossil clay and chert in lithological unit 3 and greenish-grey nannofossil ooze and clay with lesser amounts of radiolarian ooze in lithological unit 4 (Figure 5.16). Abundant and moderately diverse foraminiferal assemblages are recovered only intermittently from carbonate rich nannofossil oozes, in Core sections 260-18R-1 to -17R-1; 260-12R-2 to -12R-1 and 260-10R-2 to-10R-1, whereas clay and radiolarian horizons are either barren or contain very few foraminifera. The diversified assemblages consist predominantly of calcareous taxa and calcareous agglutinants, except for the basal assemblage (Core sections 260-18R-1 to -17R-1), which also comprises approximately 40% of organically cemented agglutinants (mainly tubes and ammodiscids). H(S) values between 1.5 and 2.5 are recorded for these assemblages. Infaunal morphotypes represent about 44% to 66% of all tests.

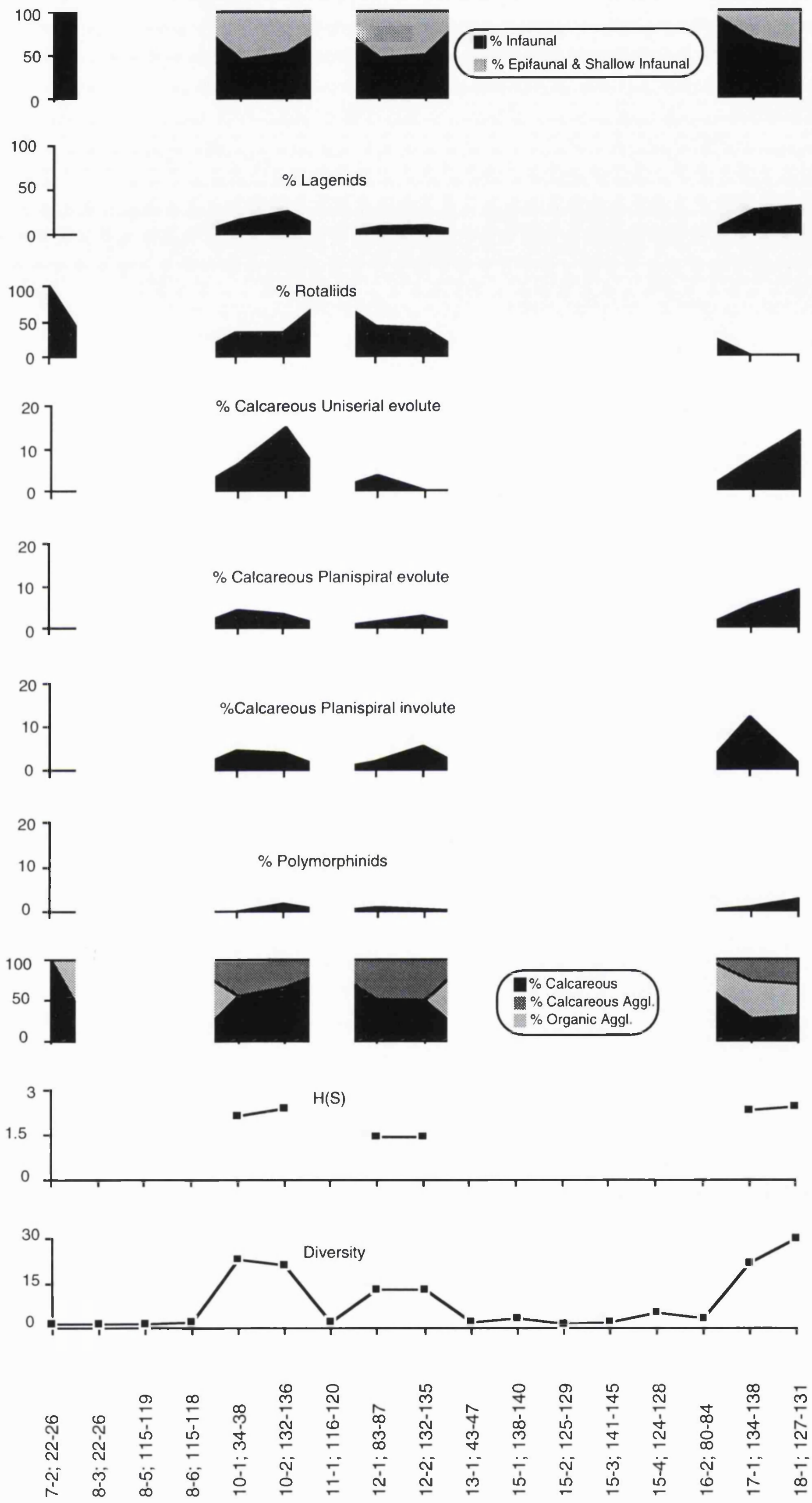


Figure 5.14. Benthic foraminiferal distribution patterns at Site 260 (blanks correspond to statistically insignificant samples).

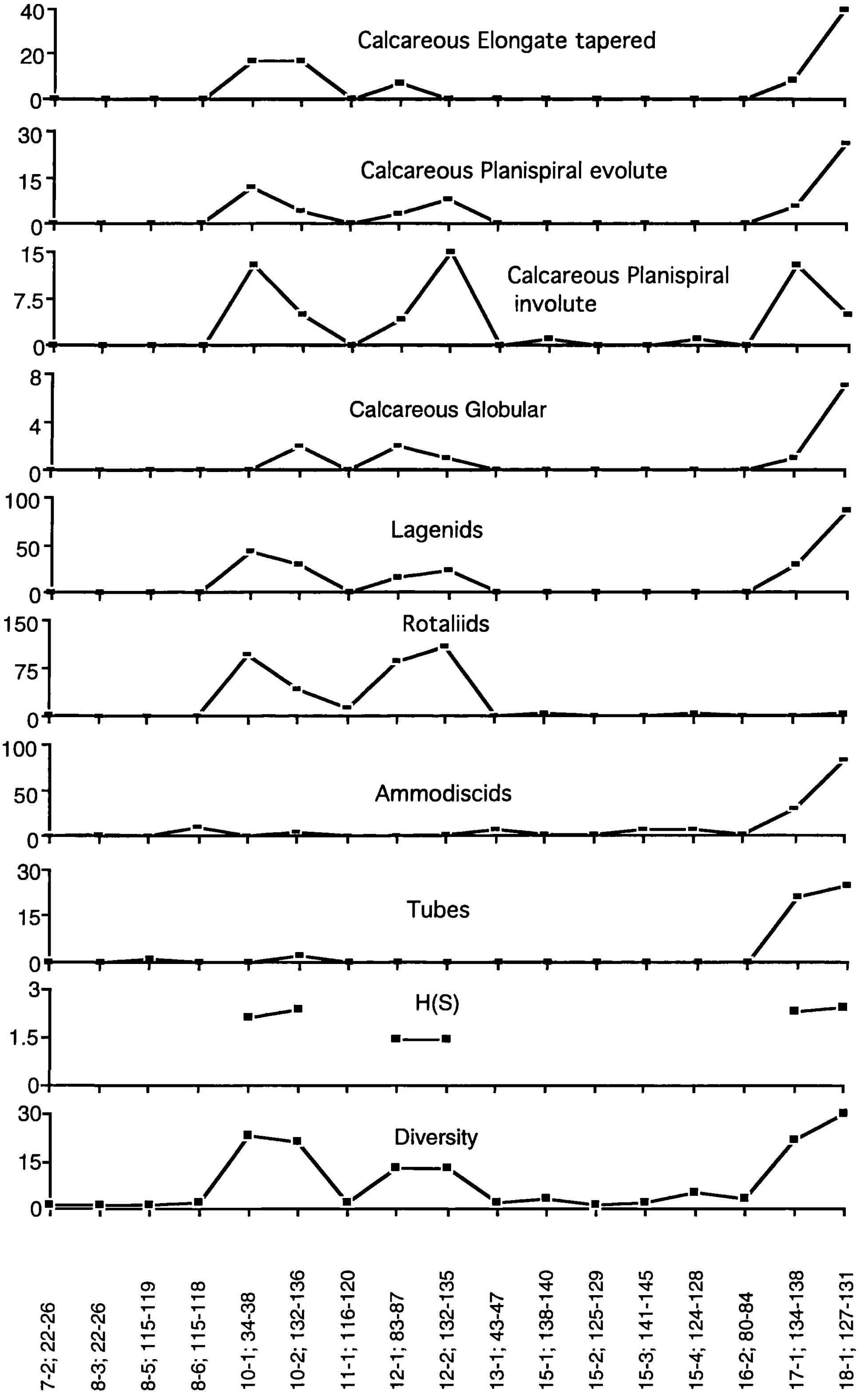


Figure 5.15. Benthic foraminiferal distribution patterns at Site 260 (absolute abundance).

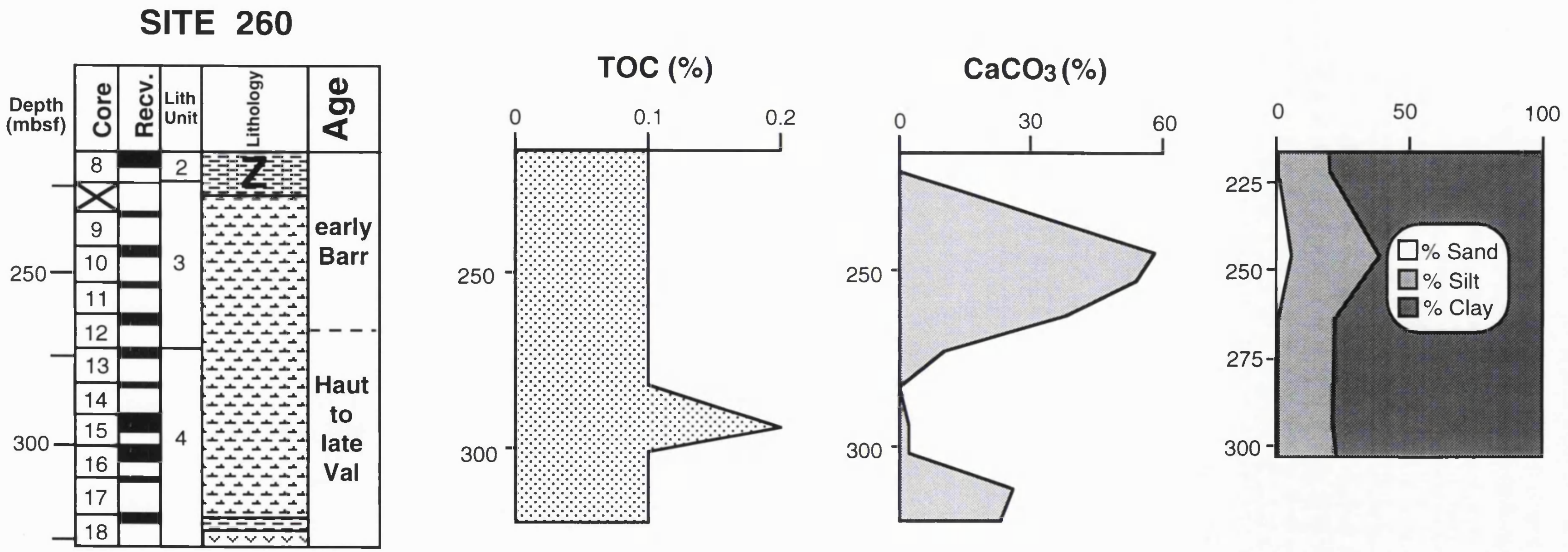


Figure 5.16. Lithology, %TOC, %CaCO$_3$ and grain size distribution at Site 260 (key to lithology in Figure 5.4). Barren samples: 14R-1; 92-96, 7R-5; 122-126, 7R-4; 10-14, 7R-3; 115-119, 7R-1; 23-27, 6R-5; 86-90, 6R-4; 106-110. Compiled from Veevers, Heirtzler *et al.* (1974).

5.7.2. Environmental significance

This very patchy distribution may reflect recurrent, adverse conditions at the sediment/water interface. Foraminifera may have been periodically excluded during radiolarian blooms and when stagnant conditions induced dysoxia in bottom waters. Intermittent improvements in bottom water circulation or changes in productivity would have led to carbonate deposition and to the establishment of transient benthic foraminiferal communities. The abundance of elongated, infaunal morphotypes such as *Praedorothia ouachensis, Praedorothia praeoxycona*, *Gaudryinopsis gradata*, *Gaudryina* cf. *dividens, Laevidentalina* spp. and *Astacolus* spp. suggests that conditions remained somewhat dysoxic on the seafloor after episodes of very severe oxygen depletion.

Alternatively, the patchy distribution of benthic foraminifera in lithological units 3 and 4 may be interpreted as the selective dissolution of calcareous tests by corrosive pore waters after burial. Poorly preserved calcareous tests in some of the samples certainly show evidence of partial dissolution. However, close proximity to the lysocline may also be responsible for their poor preservation since palaeodepths between about 3200m and 3500m for the Aptian seafloor are estimated from backtracking for this site (Figure 5.17). A much greater depth for the lysocline is unlikely, as sub-CCD conditions are recorded in the Aptian at Site 765, where palaeodepth estimates are around 4000m.

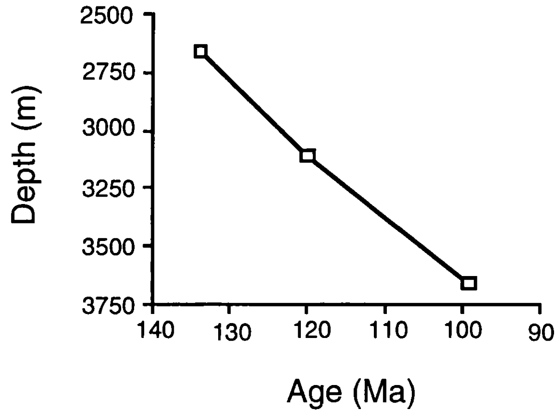


Figure 5.17. Reconstructed palaeodepths for Site 260.

The composition of the assemblages differs markedly from that found at other oceanic sites, which recovered Aptian sediments (Sites 263, 762, 763, 765 and 766). The assemblages contain abundant characteristic Tethyan taxa such as *Praedorothia ouachensis, Praedorothia praeoxycona* and *Gavelinella flandrini*, which are only rarely recorded at other Indian Ocean sites. Their presence at this northerly site demonstrates that the Gascoyne Abyssal Plain maintained deep connections with the Tethys during the Aptian.

5.8. DSDP SITE 263

5.8.1. Results

Figure 5.18 shows that the foraminiferal succession is overwhelmingly dominated by organically cemented agglutinants. After an initial rise in diversity at the base of the interval (Core 263-29R), marked fluctuations in the species frequency and in the Shannon-Weaver index are recorded between Cores 263-28R and -19R. H(S) values range from 2.8 to 1.5 between Cores 263-29R and -19R, reach a maximum of 2.9 in Sample 263-18R-5; 101-105, then remain steadier at approximately 2.0 between Cores 263-17R and -7R. Figure 5.18 shows that the distribution of agglutinated morphogroups varies considerably in the sedimentary sequence. Between Cores 263-33R and -23R the proportion of involute and evolute planispiral and streptospiral morphogroups fluctuate markedly from 0% to 67% and 0% to 47%, respectively. In the upper part of the succession these two morphogroups become much less abundant, in contrast to tubes and ammodiscids, which show a distinct increase. The infaunal to epifaunal/shallow infaunal ratio is quite variable, although epifaunal and shallow infaunal forms are generally more abundant than infaunal ones, particularly in the upper part of the sequence.

5.8.2. Environmental significance

The marked fluctuations in involute and evolute planispiral and streptospiral morphogroups and the changes in diversity, observed in lithological unit 4 (Figure 5.18), suggest a fluvial or deltaic influence. Wightman (1990) demonstrated in his study of estuarine and marsh foraminifera from the Lower Cretaceous of the Lusitanian Basin in West Portugal, that virtually monospecific assemblages of *Ammobaculites* thrived in estuarine environments where particulate matter was abundant. Nagy *et al.* (1990) also showed that *Haplophragmoides* became strongly dominant in the organic rich transgressive shelf facies of the Brora Shale during the Callovian. Intermittent increases in the proportion of involute and evolute Planispiral

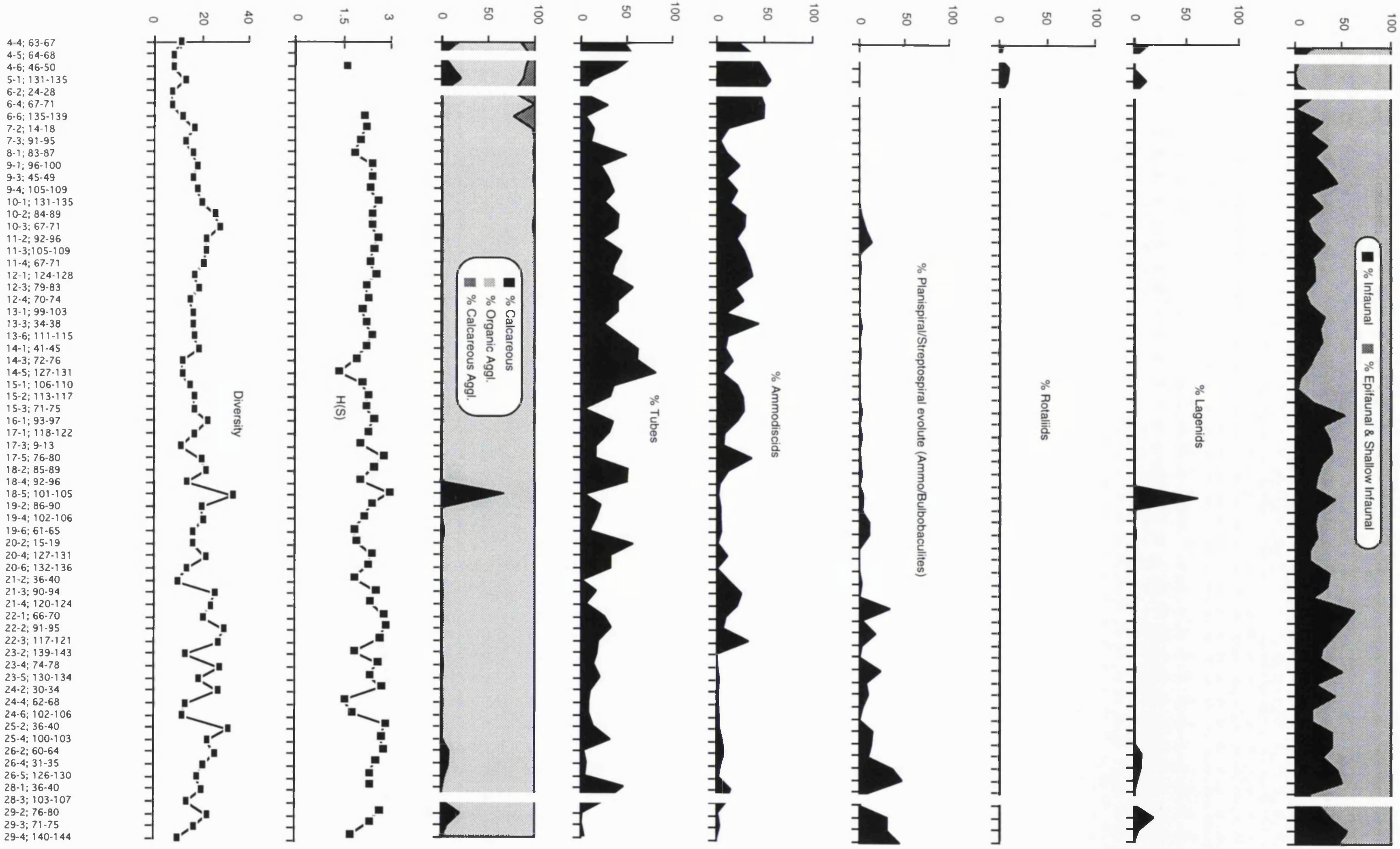


Figure 5.18. Benthic foraminiferal distribution patterns at Site 263 (blanks correspond to statistically insignificant samples).

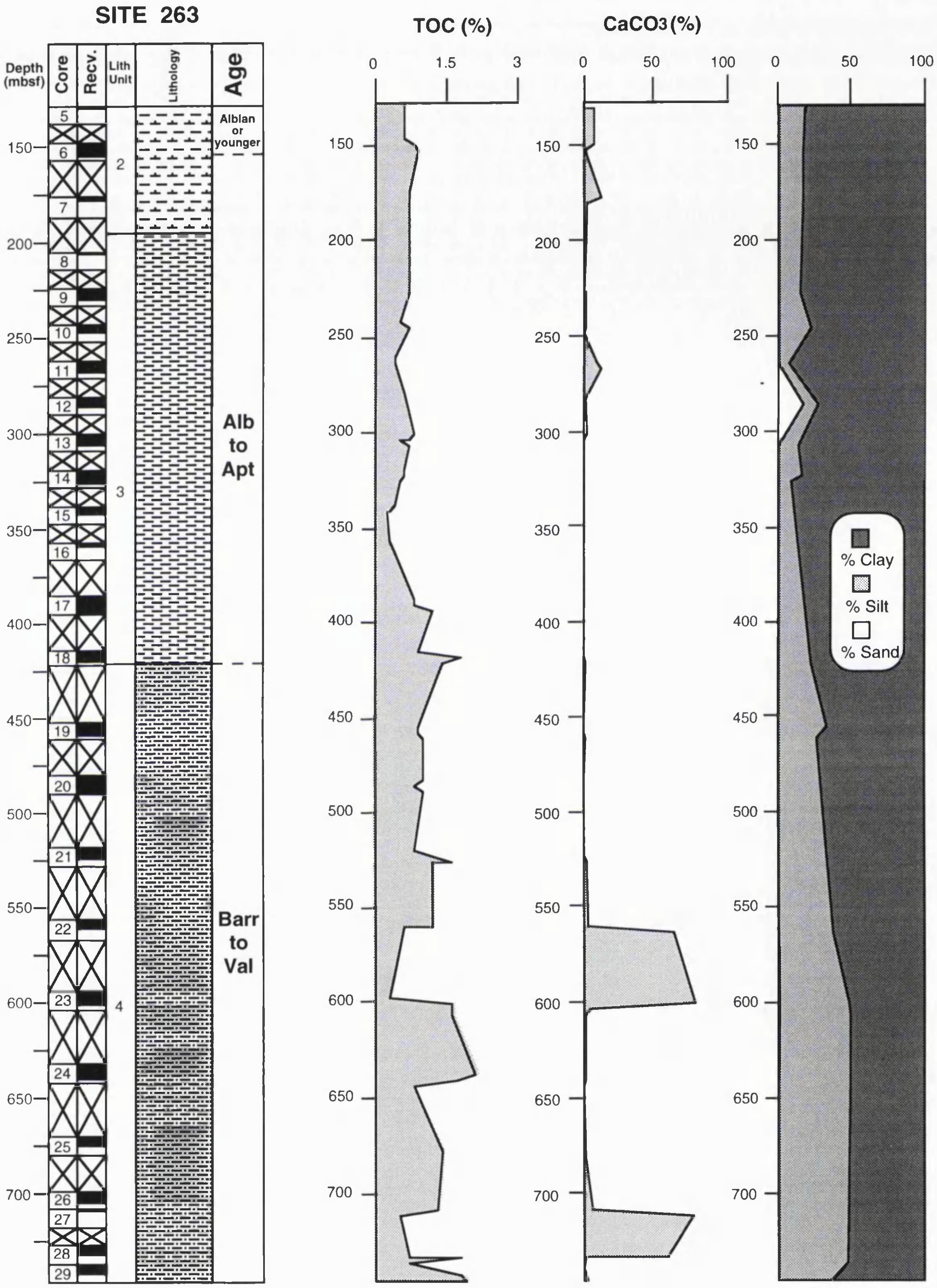


Figure 5.19. Lithology, %TOC, %CaCO3 and grain size distribution at Site 263 (key to lithology in Figure 5.4).

Compiled from Veevers, Heirtzler *et al.* (1974).

and streptospiral morphogroups may, therefore, correspond to cycles of higher organic loading from a fluvial or deltaic source. A distal setting is suggested from the predominance of clay and silt (Figure 5.19). Mineralogical evidence indicates that sediments from lithological unit 4 were predominantly terrestrially derived with minor pelagic input (Compton *et al.*, 1992), giving further support to this interpretation.

Lithological unit 4 was originally interpreted as having been deposited in shallow water, whereas lithological unit 3 indicated deeper conditions, perhaps below the lysocline (Veevers, Heirtzler, *et al.*, 1974). Scheibnerová (1974) suggested that the foraminiferal assemblages from lithological units 3 and 4 were, in fact, of very shallow water origin (less than 100m) and that calcareous tests had been dissolved after burial within the sediment. There are difficulties in interpreting the palaeobathymetric setting of Site 263: the predominantly agglutinated assemblages may either result from the diagenetic dissolution of calcareous tests buried in muddy sediments with corrosive interstitial pore fluids, at relatively shallow depths as proposed by Scheibnerová (1974). Alternatively, the agglutinated assemblages may be primary with the sporadic occurrence of rare calcareous specimens in lithological unit 4 reflecting the episodic deposition of calcareous turbidites in a deepening environment, comparable to that of Site 765 (Kaminski *et al.*, 1992^{a}) at the base of the continental slope.

The presence of discrete calcitic layers with irregular or erosive base recorded within the bioturbated silty clay laminae of lithological unit 4 and the occurrence of flame structures in Core section 263-20R-2 (Veevers, Heirtzler, *et al.*, 1974) may be taken to indicate turbiditic intercalations at ~~to~~ the base of the continental slope, in bathyal or abyssal depths below the lysocline. Unfortunately, the sedimentological reports in Veevers, Heirtzler, *et al.* (1974) are too succinct to allow more than tentative interpretations of the lithologies. Nevertheless, the backtracking data (Figure 5.20) do suggest that depths of over 2500m had been attained at the start of sedimentation in the Cuvier Basin.

The high faunal diversity in the sequence, despite the relatively high organic carbon content of the sediments (Figure 5.19), certainly rules out brackish or very restricted, stagnant conditions. Comparisons with assemblages from the Great Artesian Basin (Crespin, 1953; 1963; Ludbrook, 1966; Playford, Haig and Dettmann, 1975; Haig and Barnbaum, 1978; Haig, 1980; 1981; 1982), where restricted circulation and shallow depths prevailed during most of the Aptian and Albian, highlight significant differences in faunal composition. Large, coarsely agglutinated tests of *Ammobaculites, Bimonilina, Textulariopsis, Haplophragmoides, Lagenammina* and *Hyperammina* dominate with *Lingulogavelinella* and *Neobulimina* spp. in the inner neritic and outer neritic biofacies of the epeiric basins, whereas oceanic assemblages from Site 263 are more diverse and mostly comprised of smaller and finely agglutinated forms, including several new species. From Core section 263-25R-4 upwards, the occurrence of *Caudammina crassa*, a species often recorded in deep-sea cores, is another indicator of a deeper marine setting.

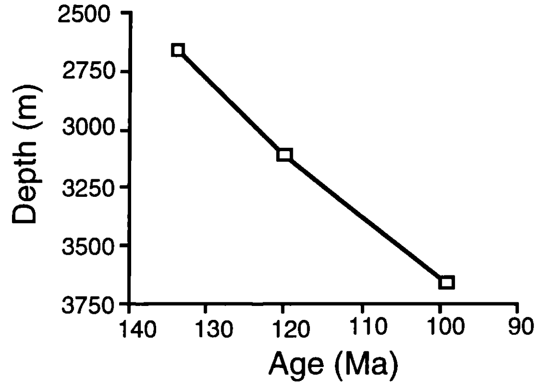


Figure 5.20. Reconstructed palaeodepths for Site 263.

An increase in the clay fraction, matched by a decrease in the %TOC of the sediments (Figure 5.19) and an increase in tubes and ammodiscids signal increasing water depths for lithological unit 3 (Figure 5.18). Sample 263-18R-5; 101-105, at the base of lithological unit 3, displays the highest values of faunal diversity (over 50% of tests are calcareous) and of H(S) recorded at Hole 263 (Figure 5.18) and appears to be a strong candidate for a transgressive surface. The absence of calcareous tests in lithological unit 3 also suggests deposition below the lysocline. However, the occurrence of rare rotaliids and agglutinants with calcareous cement in lithological unit 2, points to a subsequent CCD drop in the Albian.

The Valanginian-Barremian assemblages in lithological unit 4 contain several species of foraminifera that have been described as new, as well as others that have been provisionally left in open nomenclature. The absence of many cosmopolitan forms, despite high diversity, either suggests endemism within the Cuvier Basin or may be a reflection of the generally strong faunal provinciality between the boreal, Tethyan and austral realms during the Neocomian. The palaeocirculation reconstruction of Baumgartner (1992) also indicated that DSDP Site 263 was influenced by cooler water from higher latitudes than ODP Site 765 where a cosmopolitan agglutinated fauna was established since the Tithonian. The combination of cooler waters, clastic sedimentation and more restricted circulation in a newly open seaway may have conspired to produce a unique faunal composition at DSDP Site 263 during the Valanginian-Barremian, in contrast to that of the more pelagic, oceanic ODP Sites 765 and 766.

5.9. ODP SITES 762 & 763

5.9.1. Results

The foraminiferal successions from the Barrow Delta sequences at the base of Holes 762C and 763B and C (Core sections 762C-91R-CC to -82X-2; 763B-54X-CC to -48X-5 and 763C-46R-5 to -35R-6) show marked variations in diversity and composition: H(S) values fluctuate between 0.7 and 2.3 and abundance is also extremely variable, some intervals being virtually barren of foraminifera (Figures 5.21 to 5.24). The assemblages are generally dominated by organically agglutinated taxa (mainly planispiral/streptospiral involute and planispiral/streptospiral evolute morphotypes); however, lagenids are also abundant at some levels. The epifaunal/shallow infaunal to infaunal ratio varies considerably: the proportion of infaunal fluctuates from about 3% to 68% at Site 763 (Figures 5.23 to 5.24) and from about 13% to 45% at Site 762 (Figure 5.21).

By contrast, the Barremian to Albian assemblages in overlying cores (Core sections 762C-81X-1 to -76X-4 and 763B-47X-3 to -27X-2) are generally well diversified (H(S) values are over 2.0 in most samples), except for a few barren or nearly barren samples in Core sections 762C-80X-4, 762C-76X-4, 763B-47X-3 to -46X-7 and 763B-42X-7 to -41X-1 (Figures 5.21 to 5.27). Calcareous tests, comprised mainly of rotaliids and lagenids, dominate the assemblages. The epifaunal/shallow infaunal to infaunal ratio remains very high at both sites (Figures 5.21, 5.23 and 5.24).

5.9.2. Environmental significance

The basal sequences (lithological unit 6) at both sites have been interpreted as a prograding deltaic wedge, deposited in relatively shallow water (less than 400m) during the Berriasian-early Valanginian (Haq, von Rad, O'Connell *et al.*, 1990; Exon and von Rad, 1994). The sequence penetrated at Site 762 is much thinner than at Site 763, reflecting the more distal setting of Hole 762 (Haq *et al.*, 1992). The predominance of low diversity agglutinated assemblages, primarily composed of *Haplophragmoides, Ammobaculites* and *Bulbobaculites* spp. in Cores 762C-91R to

82X, 763B-54X to -48X and 763C-46R to -35R, corresponding to lithological unit 6, points to turbid conditions and reduced oxygenation on the seafloor and correspondingly high %TOC and low %$CaCO_3$ values (Figures 5.25 and 5.26) give support to this interpretation. Wightman (1990) and Nagy *et al.* (1988; 1990) also considered similar assemblages to be characteristic of organic rich environments receiving high terrigenous influx and Haig (1979^b) recognized the *Ammobaculites* Association as diagnostic of shallow, slightly brackish environments with dysoxic bottom waters. Rises in diversity and in the number of calcareous tests may reflect periods of reduced clastic sedimentation, when oxygenation improved on the sea floor. For instance, Sample 763B-53X-1; 113-115, which contains over 97% of lagenids, has high %$CaCO_3$ (66%) and relatively low %TOC (0.6%) contents. Nagy (1985^a; 1985^b) and Nagy *et al.* (1990) also interpreted high diversity Jurassic assemblages dominated by lagenids as indicators of well ventilated environments with little clastic input. Changes in diversity and abundance may also be influenced by dilution rates during periods of increased or reduced terrigenous sedimentation. Jones *et al.* (1993) suggested that the decline in diversity and abundance observed in the upper Barrow Delta sequences was due to increased terrigenous dilution as the delta continued to prograde.

The Barremian intervals (Core sections 762C-81X-1 to -79CC and 763B-47X-3 to -43X-2) at both sites represent condensed sequences deposited during a transgressive pulse, which was also widely recorded over most of northwestern Australia and led to the deposition of the Muderong Shale. Sample 762C-81X-1; 93-96 at the base of the sequence in Hole 762C contains 76 specimens of fish teeth and is interpreted as a transgressive surface. Exon *et al.* (1992) also reported that the base of the sequence was unconformable and gave rise to a regional seismic reflector. Sparse, low diversity assemblages and high %TOC values at the base of the condensed sequences of Holes 762C and 763B where TOC values are high (Figures 5.21 to 5.23, 5.25 and 5.26) suggest shallow depths, restricted circulation and low oxygenation. Well diversified calcareous assemblages recovered from the upper part of the sequences point to improved ventilation. The dominance of epifaunal lagenids and rotaliids in the latter assemblages suggests relatively well oxygenated outer shelf conditions.

The Aptian intervals (Core sections 762C-78X-CC and 763B-41X-5 to -38X-1) at both sites are interpreted as further transgressive sequences, related to a transgression, which established the base of the epeiric basins on mainland Australia and reached its peak in the late Aptian when nearly 50% of the Australian continent became submerged (Frakes *et al.*, 1987; Haig and Lynch, 1993). The sequence at Site

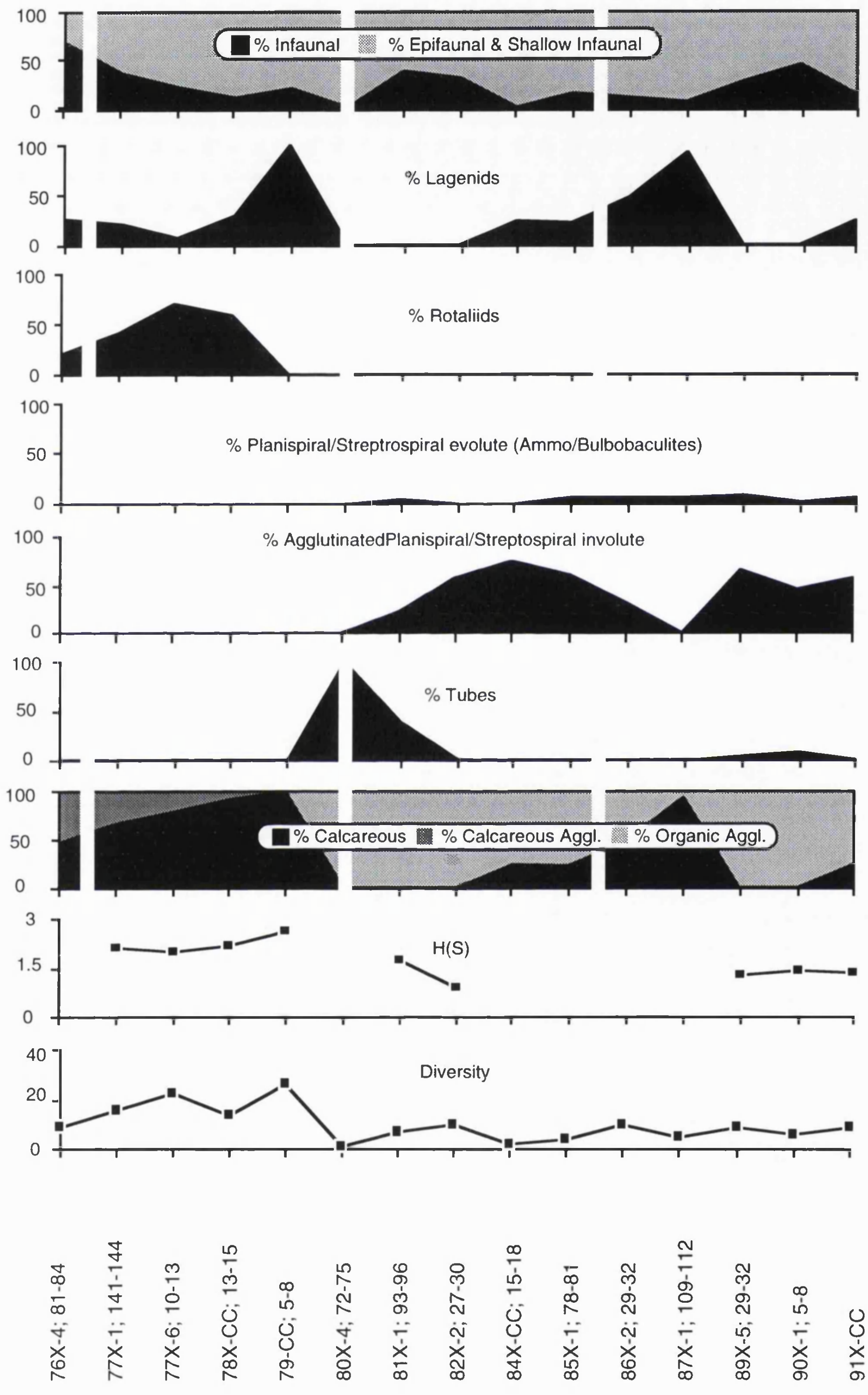


Figure 5.21. Benthic foraminiferal distribution patterns at Site 762C (blanks correspond to statistically insignificant samples).

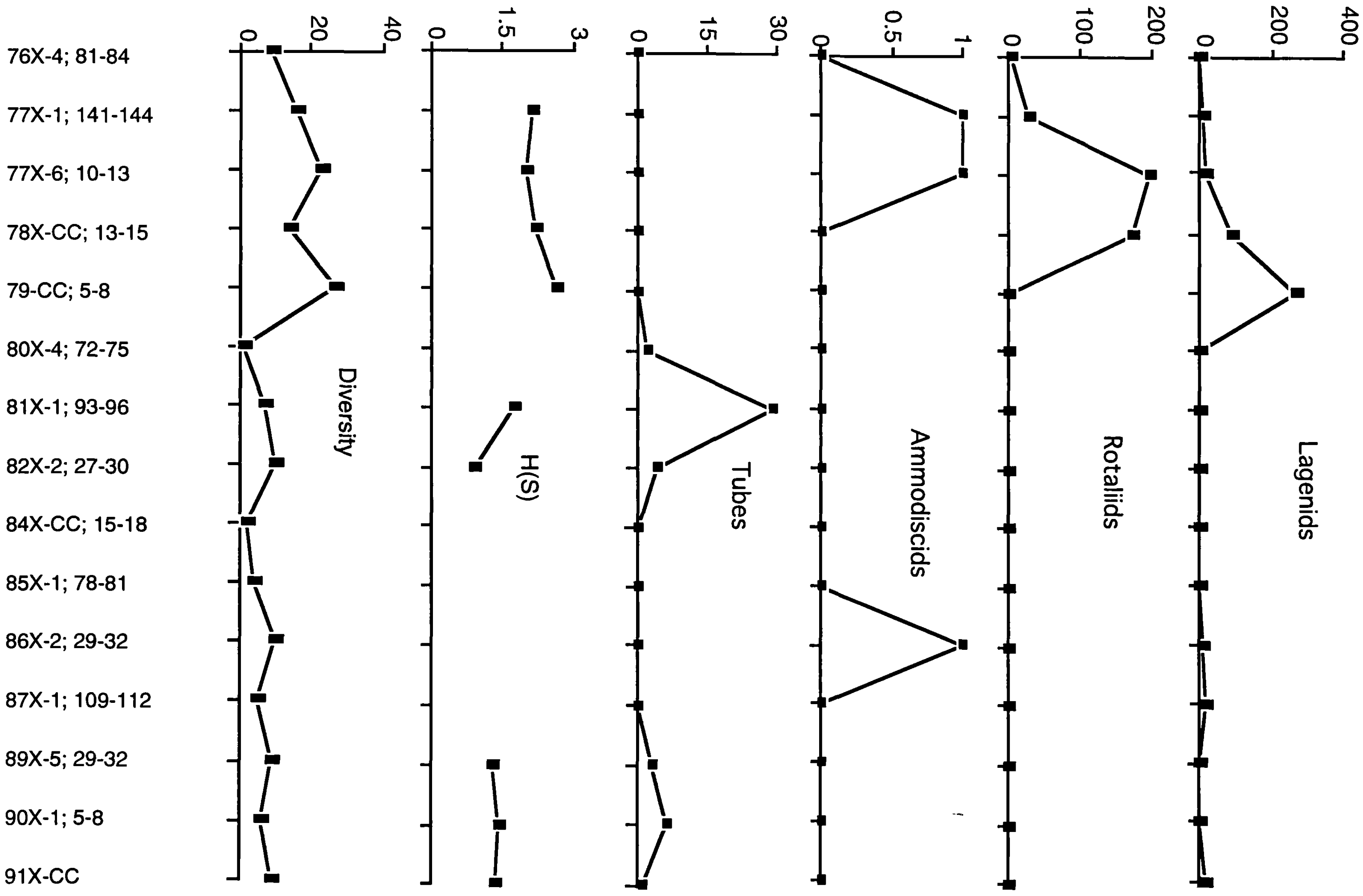


Figure 5.22. Benthic foraminiferal distribution patterns at Site 762C (absolute abundance).

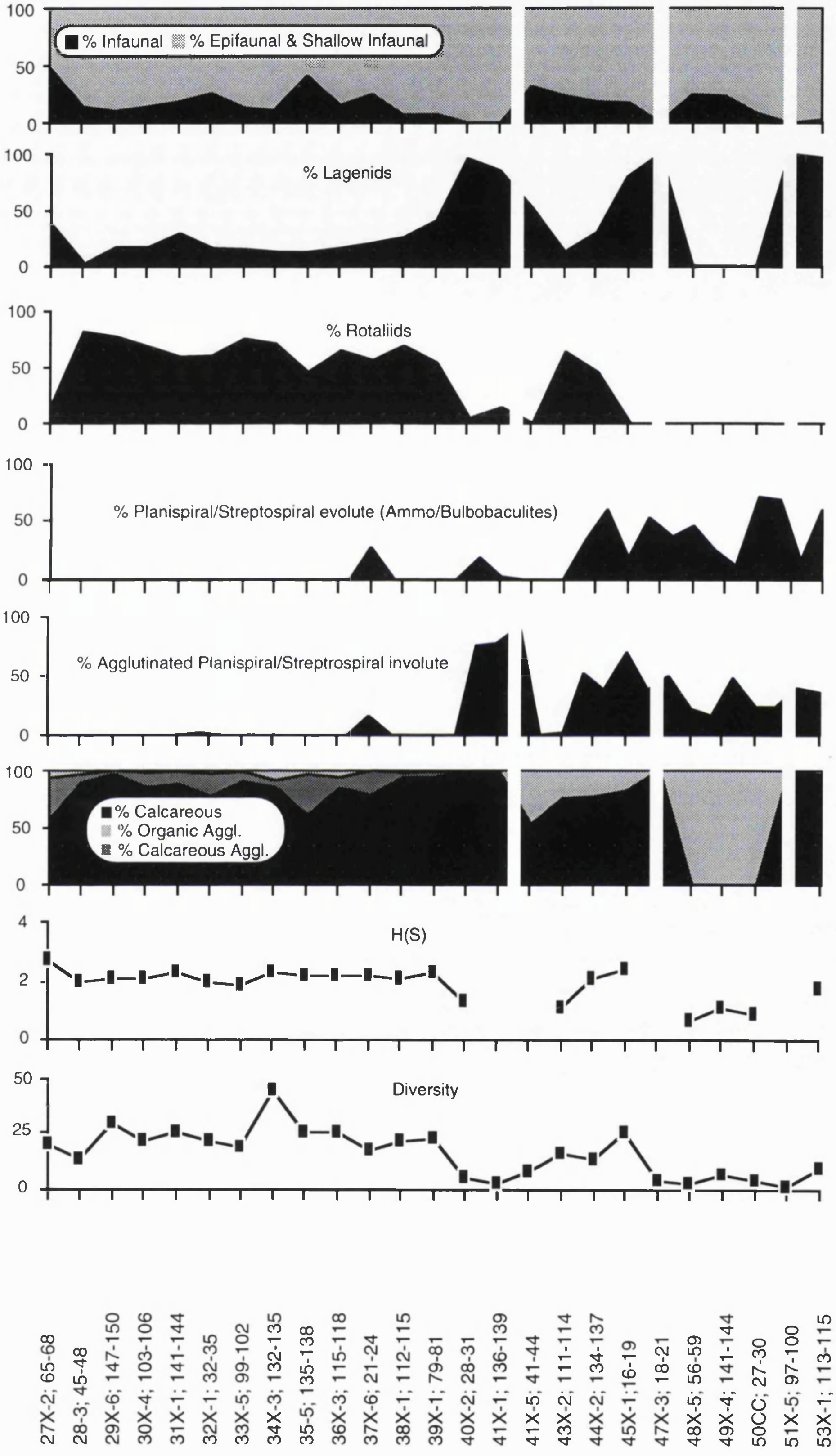


Figure 5.23. Benthic foraminiferal distribution patterns at Site 763B (blanks correspond to statistically insignificant samples).

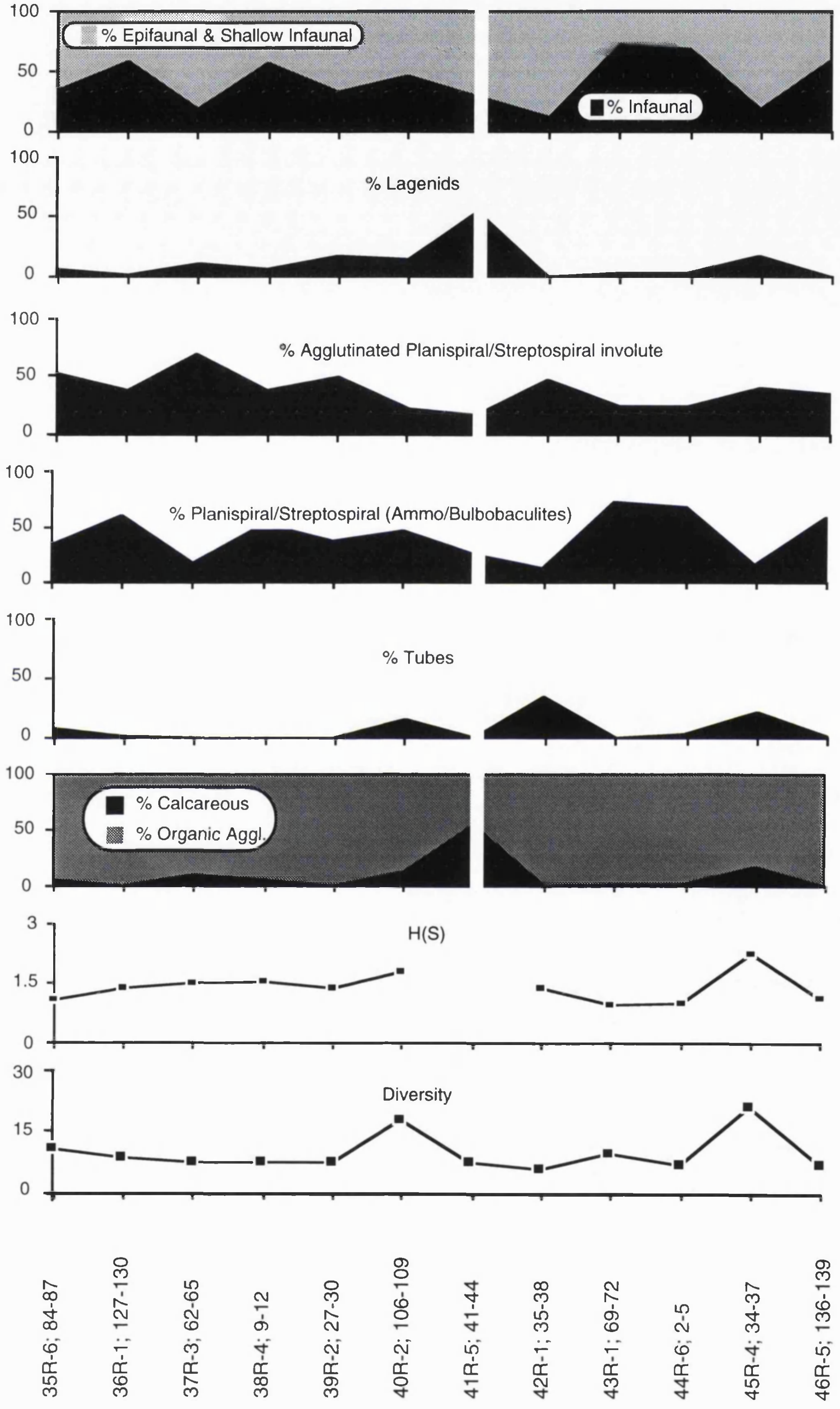


Figure 5.24. Benthic foraminiferal distribution patterns at Site 763C (blanks correspond to statistically insignificant samples).

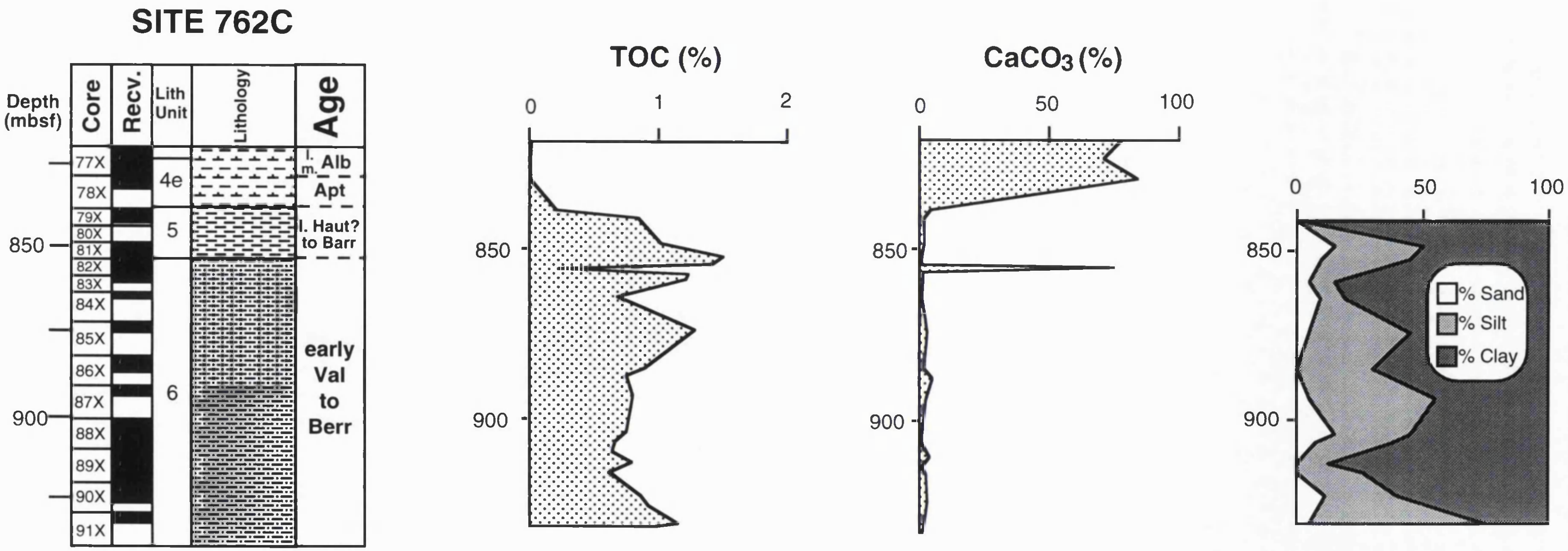


Figure 5.25. Lithology, %TOC, %CaCO$_3$ and grain size distribution at Site 762C (key to lithology in Figure 5.4). Barren samples: 88X-4; 72-75, 83X-1; 36-42.

Compiled from Haq, von Rad, O'Connell *et al.* (1990).

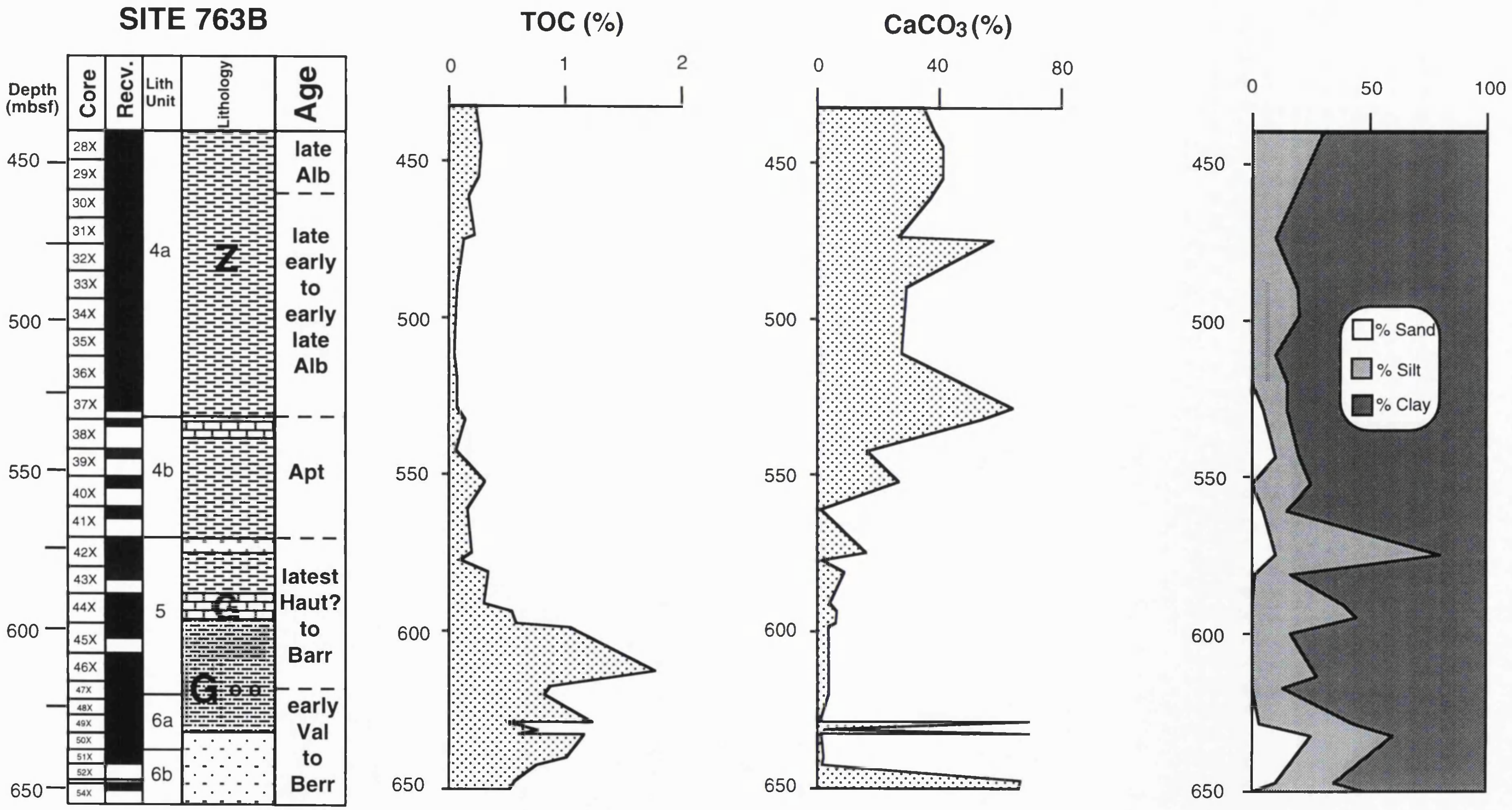


Figure 5.26. Lithology, %TOC, %CaCO3 and grain size distribution at Site 763B (key to lithology in Figure 5.4).
Barren samples: 42X-7; 61-64, 46X-7; 43-46, 54CC; 4-7.
Compiled from Haq, von Rad, O'Connell *et al.* (1990).

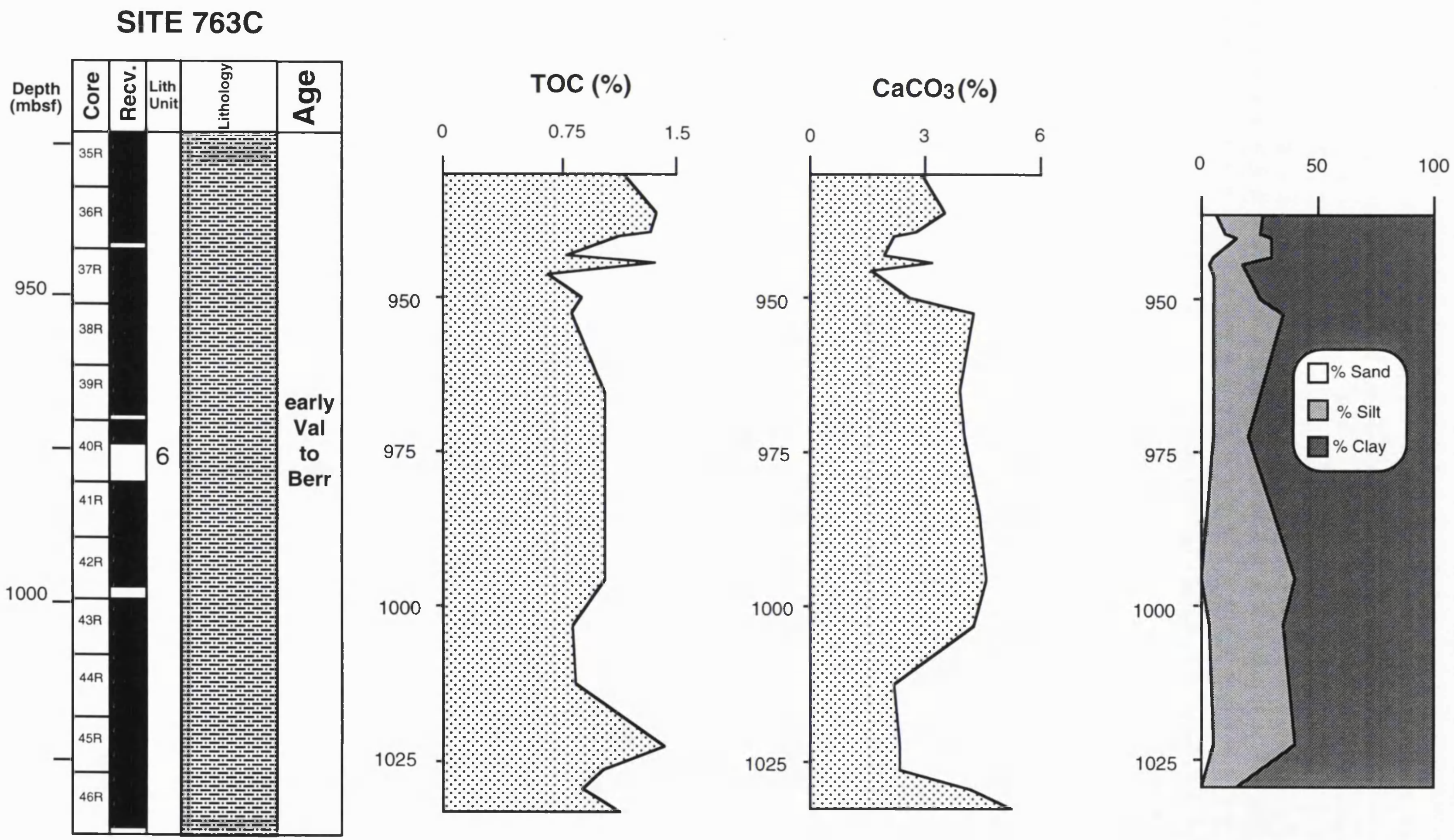


Figure 5.27. Lithology, %TOC, %CaCO$_3$ and grain size distribution at Site 763C (key to lithology in Figure 5.4). Compiled from Haq, von Rad, O'Connell *et al.* (1990).

762C, which is the most distal of the two sites, is extremely condensed. At Site 763B some higher frequency abrupt claystone/chalk variations (Exon *et al*, 1992) are reminiscent of the sedimentation pattern encountered in coeval sediments at Site 260. These cyclic variations may reflect productivity fluctuations linked to climate or circulation changes. The clays at the base of the transgressive sequence contain only impoverished agglutinated assemblages, suggesting restricted conditions, whereas the carbonate rich intervals comprise well diversified calcareous assemblages. A similar faunal pattern was observed at Site 260. The calcareous assemblages are dominated by epifaunal rotaliids (Figures 5.21 and 5.23) and include numerous planktonic foraminifera, ostracods and bivalve fragments indicating intermittent, well ventilated conditions, probably in an outer shelf or upper slope setting.

The uppermost sequence, which is well developed at Site 763B (Core sections 763B-37X-6 to -27X-2) but very condensed at Site 762C (Core sections 762C-77X-1 to -76X-4), can be related to a late early Albian transgressive pulse, recognized by Haig and Lynch (1993) in northeastern Australia as a change from the restricted *Ammobaculites* Association to the open marine *Marssonella* Association. The abundant and very diverse early late to mid Albian assemblages at Site 762C and 763B are dominated by epifaunal rotaliids (Figures 5.21 to 5.23) and include numerous planktonic foraminifera, ostracods, radiolaria and bivalve fragments, indicating a well ventilated environment. They also contain some characteristic deep water species such as *Gaudryina dividens* and *Marssonella oxycona* and large numbers of *Osangularia schloenbachi*, suggesting upper or middle bathyal depths. The low abundance and the increase in the proportion of infaunal taxa, observed at the top of the sequences (Core section 762C-76X-4 and 763B-28X-3 to -27X-2); probably indicate a decrease in ventilation during the late Albian. Haig and Lynch (1993) recorded a regression and increasing dysoxia in most mainland basins during the late Albian.

5.10. ODP SITE 766

5.10.1. Results

Figures 5.28 and 5.29 show that the foraminiferal succession at Site 766 is generally dominated by calcareous taxa. Diversity is initially high near the base of the hole (Core sections 766-49R-3 to -43R-5), where H(S) values fluctuate between 2.5 and 3.4 (Figure 5.28). Lagenids and organically cemented agglutinants are the main constituents of these upper Valanginian to Hauterivian assemblages. Diversity becomes very variable between Core sections 766-43R-4 and -32R-2, reflecting marked variations in abundance and composition in upper Hauterivian assemblages (Figure 5.28). High diversity, indicated by H(S) values around 3.0, is recorded once more in basal samples from the Barremian sequence (Core sections 766-30R-4 and 766-28R-1), where calcareous-cemented agglutinants make their first appearance (Figure 5.28). The Aptian interval (Core sections 766-26R-3 to -22R-1) is virtually barren of foraminifera, except for Core sections 766- 25R-1 to -24R-1, which contain calcareous assemblages with numerous rotaliids (Figure 5.29). Diversity increases markedly in Core section 766-21R-2, above a barren siliceous interval, which spans the Aptian-Albian boundary. Late early to late Albian assemblages in Core sections 766-21R-1 to -16R-1 (Figure 5.29) are dominated by epifaunal rotaliids and have H(S) values between 2.0 and 2.5, except in Sample 766-19R-4; 82-86, where the acme of *Osangularia schloenbachi* is recorded.

5.10.2. Environmental significance

The change from diversified, mixed calcareous and agglutinated assemblages to wholly calcareous assemblages with very variable diversity corresponds to a lithological change from sandy siltstones in Cores 766-49R to -43R to sandstones in Cores 766-43R to -32R (Figure 5.30). The basal siltstones contains abundant pyrite and volcaniclastic grains (Ludden and Gradstein *et al.*, 1990) and have higher TOC values (between 0.5% and 0.8%), which suggests slightly restricted conditions at the onset of spreading and may account for the high proportion of organically cemented agglutinated taxa and the higher percentage of infaunal tests in this interval (Figure 5.28). Strongly dysoxic conditions are ruled out, however, by the high foraminiferal diversity and pervasive bioturbation. Foraminiferal abundance is low in some samples from Cores 766-49R and -48R, containing ash layers, and Sample 766-45R-6; 36-40, which originates from a layer of altered ash (Ludden and Gradstein *et al.*, 1990), is barren of foraminifera. Marked changes in foraminiferal composition and diversity as well as major shifts in %TOC, %$CaCO_3$ and grain size (Figures 5.28 and 5.30) suggest that the upper part of lithological unit 3b (Cores 766-43R to -32R) consists of redeposited material from various origins. The aberrant fluctuations in *Patellina infracretacea* within this interval indicate that sediments were intermittently derived from a proximal, shallow source.

Well diversified assemblages at the base of lithological unit 3a (Cores 766-32R to -28R) indicate a return to more stable conditions, although the increase in infaunal morphotypes (Figure 5.28) and elevated %TOC values (Figure 5.30) suggest a slightly restricted environment. Assemblages become very impoverished in the upper part of the sequence, where radiolarians are very abundant. Lithological subunit

3a is interpreted here as a transgressive sequence, correlatable with the Barremian condensed sequences recognized at Sites 762 and 763. This interpretation is supported by the seismic data, which show that the lower boundary corresponds to an unconformity, characterized by truncation below and onlap above (Buffler *et al.*, 1992) and by the lithological change from coarse clastics in lithological subunit 3b to hemipelagic clays in lithological subunit 3a (Figure 5.30), reflecting the drowning of the adjacent margin.

The strong dominance of *Lingulogavelinella* sp. 1 and *Gyroidina infracretacea* in Sample 766-25R-1; 3-5, above a barren clay at the base of the Aptian sequence, suggests a stressed ecosystem. The well diversified assemblage in Sample 766-24R-1; 111-113 (Figure 5.29) signals a brief improvement, before the deposition of a siliceous interval containing up to 55% radiolarians. Haig (1992) proposed that this upper interval may be correlative of the upper Aptian-lower Albian Windalia Radiolarite in the Carnarvon Basin. The subunit is interpreted as a transgressive sequence, correlatable with the Aptian condensed sequences of Sites 762 and 763. The lower boundary of subunit 2d is an unconformity marked by a prominent reflector with onlap and channel fill above (Buffler *et al.*, 1992). The upper boundary, arbitrarily placed in Core section 766-20R-1 by the Shipboard Party (Ludden and Gradstein *et al.*, 1990), is taken here as the base of Core 766-21R (Figure 5.31), where a major faunal change occurs. Buffler *et al.* (1992) also identified an additional unconformity, characterized by local erosional truncation and onlap at approximately the same level. The overall sedimentation and faunal patterns in the Aptian of Site 766 are reminiscent of changes recorded at Sites 260, 762 and 763, which pointed to cyclic environmental disturbances.

The major faunal change and unconformity at the base of the nannofossil ooze and chalk in lithological subunit 2c (Figures 5.29 and 5.31) can be related to the late early Albian transgressive pulse, documented by Haig and Lynch (1993) in northeastern Australia, and also recorded at Sites 257, 259, 762 and 763. High diversity and a high epifaunal/shallow infaunal to infaunal ratio in upper lower to lower upper Albian assemblages indicate well ventilated conditions, also supported by low %TOC, high %$CaCO_3$ values (Figure 5.31) and by evidence of strong bottom current activity from seismic data (Buffler *et al.*, 1992). No significant change in diversity is apparent in upper Albian assemblages (Figure 5.29), in contrast to Sites 762 and 763. A vigorous bottom circulation probably maintained well oxygenated conditions and supplied abundant food throughout the Albian at Site 766. The high numbers of *Osangularia schloenbachi, Gaudryina dividens, Remesella* sp. 1 and

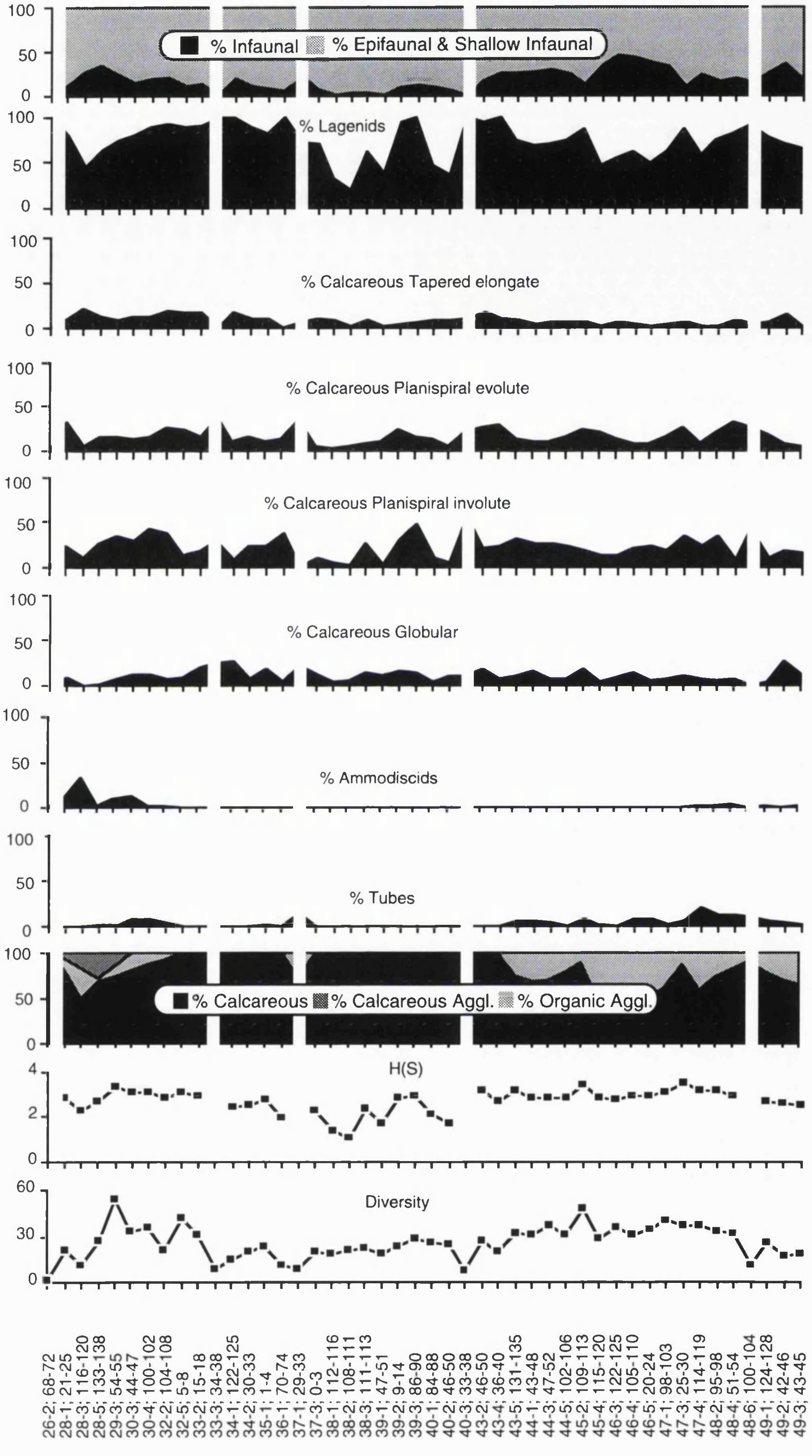


Figure 5.28. Benthic foraminiferal distribution patterns at Site 766, Cores -49R to -36R (blanks correspond to statistically insignificant samples).

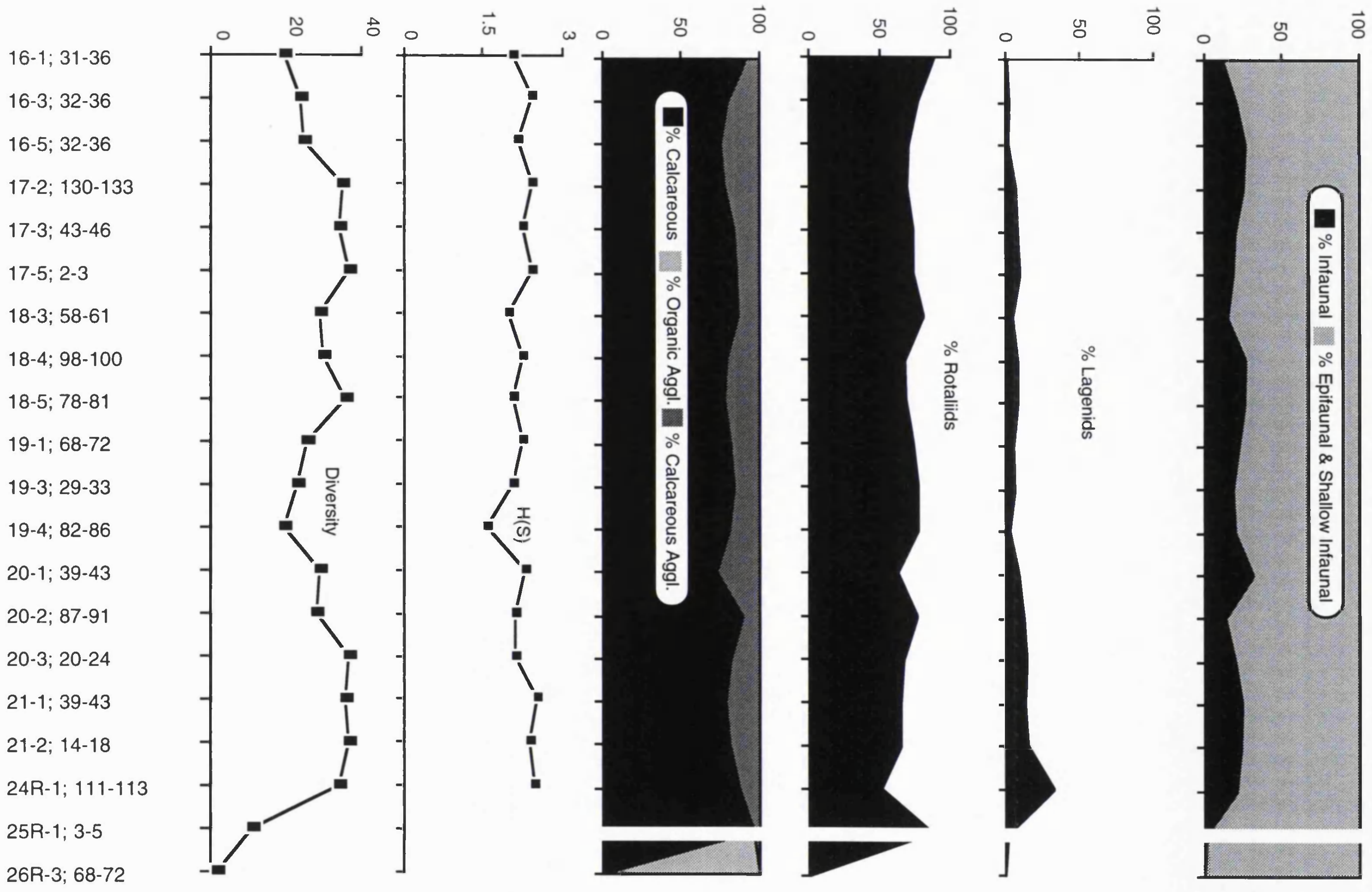


Figure 5.29. Benthic foraminiferal distribution patterns at Site 766, Cores -25R to -16R (blanks correspond to statistically insignificant samples).

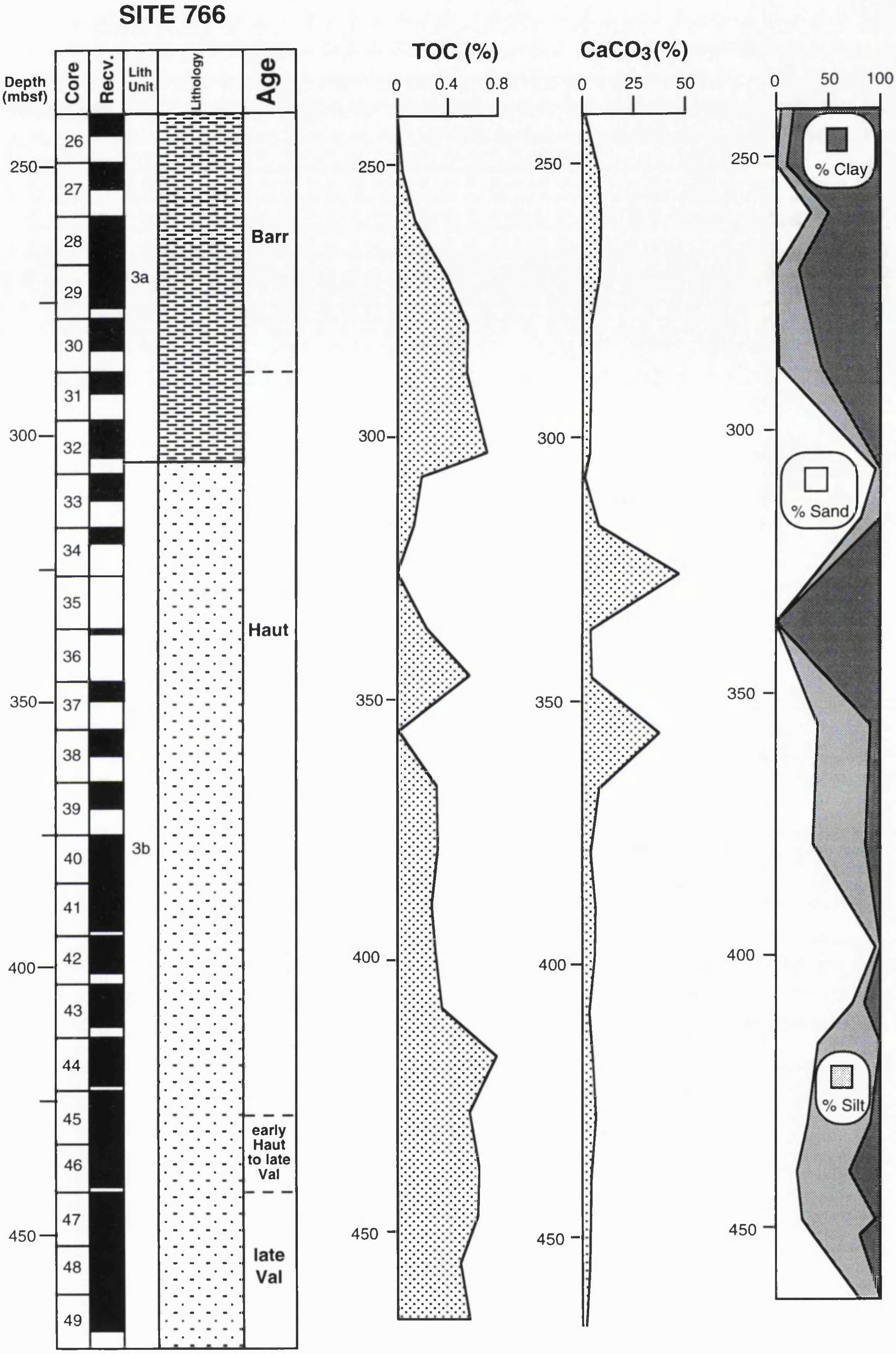


Figure 5.30. Lithology, %TOC, %CaCO3 and grain size distribution at Site 766, Cores -49R to -26R (key to lithology in Figure 5.4).
Barren samples: 26R-1; 14-18, 27R-2; 57-61, 27R-3; 10-14, 29R-1; 59-63, 29R-5; 5-9, 45R-6; 36-40.
Compiled from Ludden, Gradstein *et al.* (1990).

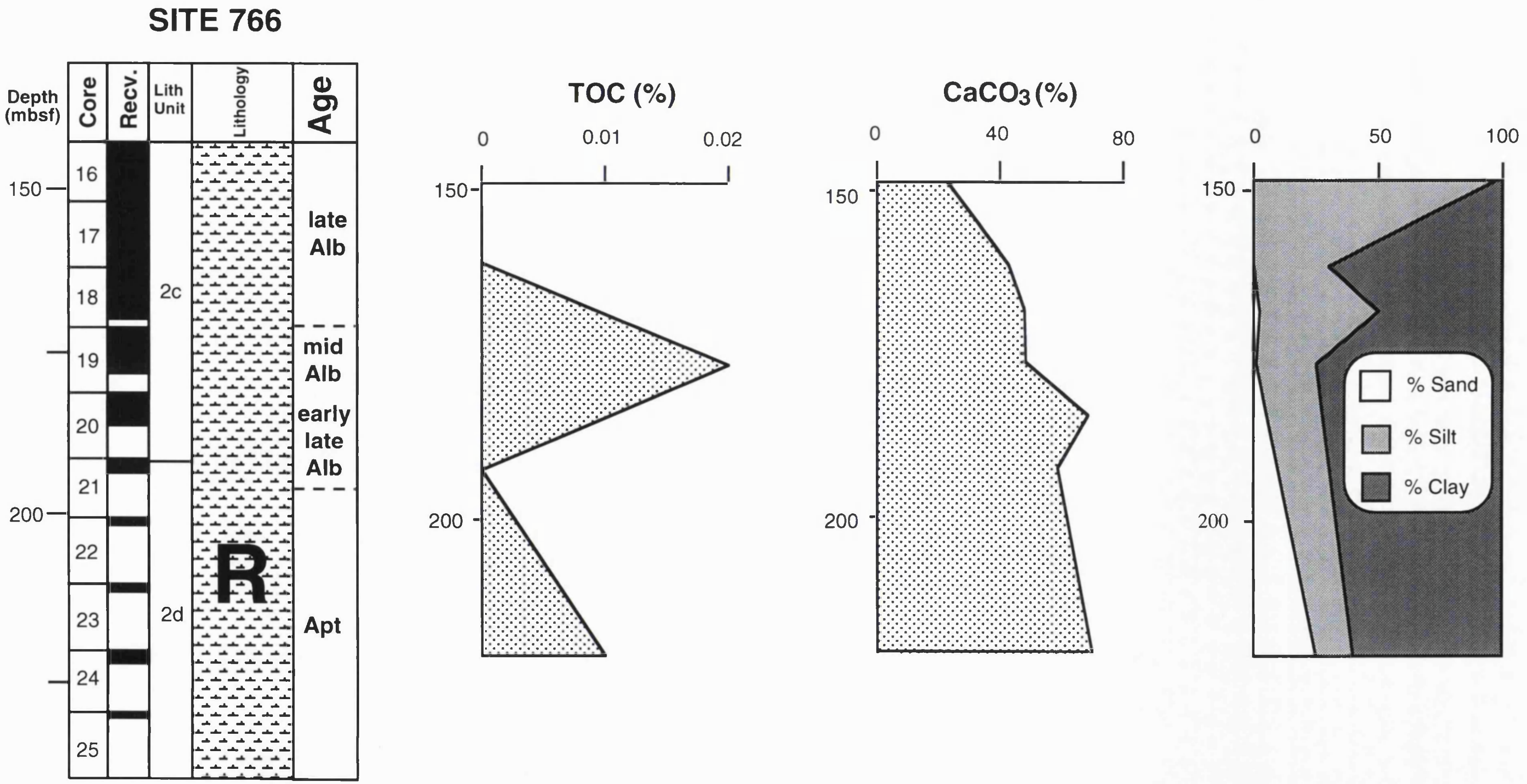


Figure 5.31. Lithology, %TOC, %$CaCO_3$ and grain size distribution at Site 766, Cores -25R to -16R (key to lithology in Figure 5.4). Compiled from Ludden, Gradstein *et al.* (1990).

Tritaxia gaultina in the assemblages point to lower bathyal depths at the foot of the continental slope.

Initial water depths at this site were originally estimated to be approximately 800m from backtracking (Ludden and Gradstein, *et al.*, 1990). However, new computations of palaeoseafloor depths at Sites 765 and 766, using the age/depth equation for the 70Ma to 160Ma interval (Sclater *et al.*, 1985), yield significantly different results (Appendix 5.1). The results for Sites 765 and 766 in Ludden and Gradstein *et al.* (1990) can only be replicated by applying the age/depth equation for 0Ma to 70Ma, which is inappropriate for Lower Cretaceous sediments. New estimated palaeoseafloor depths for Site 766 are about 1500m in the late Valanginian, reaching about 2600 m in the late Albian (Figure 5.32).

The assemblages consist predominantly of cosmopolitan taxa; however, the rarity or absence of characteristic Tethyan species such as *Lenticulina nodosa Lenticulina eichenbergi* and of large, ornamented, palmate morphotypes such as *Citharina* spp., *Flabellina* spp. and *Frondicularia* spp. in upper Valanginian to Barremian assemblages point to some faunal differentiation. The presence of distinctive Indian Ocean taxa such as *Lingulogavelinella* sp. 1 and *Scheibnerova protindica* also suggests some differentiation from Tethyan faunas in the Aptian and Albian. The low diversity of planktonic foraminiferal assemblages and the lack of keeled taxa until the late Albian are indicative of cool surface waters at Site 766. Powell *et al.* (1988) and Baumgartner *et al.* (1992) suggested that the palaeogeography favoured the influx of colder southern waters rather than warmer Tethyan waters during the Early Cretaceous. The cosmopolitan nature of the fauna at Site 766 points to the existence of open connections with major world oceans, which allowed the dispersal of many taxa during the Early Cretaceous.

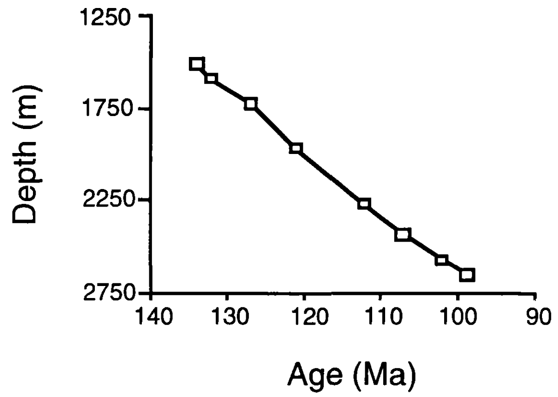


Figure 5.32. Reconstructed palaeodepths for Site 766.

5.11. BENTHIC FORAMINIFERAL BIOFACIES

5.11.1. Principal Component Analysis

Principal Component Analysis was used to investigate the main benthic foraminiferal biofacies trends in the Indian Ocean during the Early Cretaceous. The generic and morphogroup distribution data from selected sites were processed by a Principal Component Analysis using the programme SPSS. In order to provide statistically significant data sets, sites were chosen, where a variable to sample ratio close to 1:3 could be obtained. Rare taxa (with a frequency of less than six occurrences per site) were eliminated on account of their statistical insignificance.

DSDP Site 258

A total of 11 benthic foraminiferal taxa from 23 samples were analysed. Three factors were distinguished by the Principal Component Analysis (Table 5.1).

1. Factor 1 represents an association of calcareous taxa, which includes *Gyroidina, Osangularia, Berthelina, Gavelinella, Pleurostomella* and *Lenticulina*. This association is found above Core section 258-21R-2.
2. Factor 2 characterizes a mixed association dominated by organically-cemented agglutinated taxa such as *Rhabdammina, Rhizammina, Ammodiscus, Glomospira, Haplophragmoides* and *Recurvoides* and Gavelinellids.
3. Factor 3 singles out the *Ammodiscus - Glomospira* association, which occurs sporadically throughout the sampled interval.

DSDP Site 259

A total of 25 benthic foraminiferal taxa from 64 samples were analysed. Six factors were identified from the Principal Component Analysis (Table 5.2); the first three factors are the most important.

1. The dominant factor (Factor 1) represents a diverse mixed calcareous and calcareous-cemented agglutinated association, found exclusively in the upper part of the sedimentary sequence (Core sections 259-16R-4 to -11R-3). Factor 1 comprises *Remesella, Gaudryina, Tritaxia, Berthelina, Osangularia, Gyroidina, Gavelinella, Lenticulina, Laevidentalina* and *Coryphostoma.*
2. Factor 2 corresponds to an organically-cemented agglutinated association, including *Rhabdammina, Rhizammina, Ammodiscus, Bathysiphon, Bimonilina, Recurvoides, Haplophragmoides, Textularia* and *Saccammina*, which is found in Core sections 259-32R-1 to -29R-2.
3. Factor 3 characterizes a low diversity organically-cemented agglutinated association, dominated by two coarsely agglutinated species: *Psammosphaera fusca*

Table 5.1. Principal Component Analysis factor score matrix for foraminiferal data from Hole 258.

	Communality	Factor 1	Factor 2	Factor 3	Factor	Eigenvalue	% Var
Tubes	0.77292	-0.63498	0.596	-0.12045	1	4.96084	45.1
Ammodiscus	0.79198	-0.60923	0.52049	0.38718	2	2.47291	22.5
Glomospira	0.8769	-0.47316	0.5684	0.57441	3	1.18487	10.8
Haplophragmoides	0.57186	-0.50019	0.49219	-0.28182			
"Textularia"	0.5811	-0.65244	0.38948	0.061			
Recurvoides	0.8586	-0.28679	0.47154	-0.74432			
Lenticulina	0.79897	0.76729	0.4381	0.13531			
Pleurostomella	0.87401	0.7888	0.49841	-0.05833			
Gyroidina	0.75709	0.84749	0.16883	0.10175			
Osangularia	0.84654	0.83666	0.37465	0.07863			
Gavelinelliids	0.88865	0.7585	0.54608	-0.12297			

Table 5.2. Principal Component Analysis factor score matrix for foraminiferal data from Hole 259.

	Communality	Factor 1	Factor 2	Factor 3	Factor	Eigenvalue	% Var
Pssammosphaera	0.9762	-0.07774	0.06113	0.94592	1	9.68392	38.7
Reophax	0.97223	-0.07774	0.06173	0.94345	2	4.33768	17.4
Rhabdammina	0.85556	-0.39639	0.751139	0.10984	3	2.32094	9.3
Rhizammina	0.67932	-0.23645	0.58352	0.47995	4	1.47729	5.9
Ammodiscus	0.71833	-0.31745	0.65111	-0.20513	5	1.30209	5.2
Bathysiphon	0.80249	-0.41214	0.46806	-0.10357	6	1.01115	4
Bimonilina	0.85126	-0.18603	0.73416	-0.11068			
Haplophragmoides	0.85893	-0.25114	0.84273	-0.0596			
Recurvoides	0.65006	-0.28365	0.66241	-0.22898			
"Textulariopsis"	0.79706	-0.2568	0.75407	-0.17327			
Glomospira	0.72271	-0.39371	-0.07858	-0.29774			
Saccammina	0.69866	-0.22152	0.42485	0.23194			
Remesella	0.93381	0.94224	0.18312	-0.00152			
Gaudryinopsis	0.7939	0.61765	0.0058	0.00395			
Gaudryina	0.85359	0.88673	0.1902	-0.00313			
Tritaxia	0.57916	0.60067	-0.00179	0.00646			
Berthelina	0.86197	0.80245	0.19823	-0.00649			
Osangularia	0.88941	0.91088	0.19484	-0.00294			
Gyroidina	0.92889	0.91991	0.20062	-0.00197			
Laevidentalina	0.88675	0.88441	0.15041	0.00068			
Coryphostoma	0.75999	0.80176	0.12995	-0.00038			
Lenticulina	0.81523	0.8641	0.19128	-0.00187			
Gavelinella	0.84459	0.85074	0.1847	-0.00505			
Pyrulina	0.66608	0.6694	0.11721	0.00004			
Pleurostomella	0.7369	0.81268	0.1661	-0.00227			

Table 5.3. Principal Component Analysis factor score matrix for foraminiferal data from Hole 766.

	Communality	Factor 1	Factor 2	Factor	Eigenvalue	% Var
Ammodiscus	0.79022	-0.04	0.36	1	7.57849	29.1
Gavelinella	0.72735	0.32	0.17	2	2.73039	10.5
Gaudryina	0.88745	0.69	0.27	3	2.10754	8.1
Laevidentalina	0.80625	0.17	0.68			
Gyroidina	0.95632	0.92	0.21			
Berthelina	0.7495	0.68	0.05			
Osangularia	0.86394	0.79	0.1			
Charltonina	0.55889	0.49	-0.09			
Gaudryinopsis	0.79026	0.45	0.47			
Lenticulina	0.76544	-0.47	0.62			
Remesella	0.7837	0.76	0.06			
Tritaxia	0.8407	0.72	-0.01			
Pleurostomella	0.64892	0.7	0.1			
Praebulimina	0.87571	0.34	-0.01			
Sheibnerova	0.82027	0.65	0.03			
Spiroplectammina	0.61435	0.56	-0.06			
Trochammina	0.63443	-0.26	0.24			
Globulina	0.64449	-0.6	0.2			
Vaginulinopsis	0.78229	-0.38	0.53			
Saracenaria	0.63282	-0.6	0.25			
Oolina	0.5602	-0.37	-0.39			
Tubes	0.75373	-0.42	0.35			
Haplophragmoides	0.81545	-0.37	0.5			
Bulbobaculites	0.7481	-0.36	0.45			
Pyramidulina	0.8198	-0.49	-0.37			
Frondicularia	0.81365	-0.45	-0.2			

and *Reophax* sp. 3. This association is only recorded in the basal core of Hole 259 (Core 259-33R).

ODP Site 766

A total of 26 benthic foraminiferal taxa from 66 samples were analysed. Eight factors were extracted from the Principal Component Analysis (Table 5.3); the first two factors are the most important

1. Factor 1 represents a diverse mixed calcareous and calcareous-cemented agglutinated association, which is found from Core sections 766-21R-2 to -16R-1 and is composed of *Gaudryina, Gyroidina, Berthelina, Osangularia, Remesella Tritaxia* and *Scheibnerova.*
2. Factor 2 corresponds to a mixed association dominated by *Lenticulina, Laevidentalina* and *Vaginulinopsis.*

5.11.2. Biofacies patterns

Six main benthic foraminiferal biofacies can be distinguished from the results of the Principal Component Analysis and the palaeoenvironmental analyses of individual sites.

1. The *Gyroidina-Gaudryina* biofacies corresponds to Factor 1 identified at Sites 258, 259 and 766. Characteristic taxa are *Gavelinella, Lingulogavelinella, Gyroidina, Coryphostoma, Praedorothia, Gaudryina, Remesella* and *Praedorothia* spp. in the Aptian (Sites 260, 762, 763 and 766) and *Gavelinella, Berthelina, Osangularia, Gyroidina, Scheibnerova, Quadrimorphina, Charltonina, Pleurostomella, Gaudryina* and *Remesella* spp. in the Albian (Sites 256, 257, 258, 259, 762, 763 and 766). This diverse association of calcareous taxa and calcareous-cemented agglutinants is typical of open marine, well ventilated environments above the CCD. The ratio of calcareous to agglutinants is variable, probably reflecting changes in productivity. Regression analysis indicates a positive correlation between Factor 1 and the $CaCO_3$ content of sediments at Sites 259 and 766 (Figures 5.33 and 5.34). In both cases the degree of confidence of the correlation coefficient (R^2) is high for the number of samples studied, with a margin of error below 5%.

2. The *Lenticulina-Laevidentalina* biofacies (Factor 2 at Site 766) is a diversified association, containing numerous lagenids and a variable agglutinated component. Common genera are *Lenticulina, Vaginulinopsis, Astacolus, Frondicularia, Saracenaria, Marginulinopsis, Marginulina, Laevidentalina, Pyramidulina* and *Psilocitharella.* This association is typical of open marine, relatively well ventilated shelf to slope environments in the Valanginian to Barremian (Sites 249 and 766).

3. The *Aaptotoichus-"Textulariopsis"* biofacies (Factor 2 at Site 259) corresponds to a diversified "flysch-type" association (Gradstein and Berggren, 1981) composed entirely of organically-cemented agglutinants. Distinctive taxa are *Caudammina crassa, Aaptotoichus challengeri, Rhabdammina, Rhizammina, Hippocrepina, Lagenammina, Recurvoides, Paratrochamminoides, Haplophragmoides, Bimonilina, "Gaudryinopsis"* and *Textulariopsis"* spp. This biofacies is characteristic of sub-CCD environments where oxygen is not severely depleted and food is not a limiting factor (for instance, in abyssal plains at the foot of the continental slope: Sites 259, 263 and 765).

4. The *Ammodiscus-Glomospira* biofacies (Factor 3 at Site 258) is a very impoverished association, comprised almost exclusively of representatives from these two genera. These extremely opportunistic, r-selected taxa are able to withstand even the most adverse environmental conditions (Kaminski, 1988; Nagy *et al.*, 1990) and this biofacies, often associated with high biosiliceous productivity in the Cretaceous and Palaeogene, was considered by Kuhnt and Kaminski (1989; 1990), Kuhnt *et al.* (1989) and Kaminski *et al.* (1992^{a}) to be diagnostic of sub-CCD, highly stressed, unstable ecosystems. The *Ammodiscus-Glomospira* biofacies is recognized at Sites 257, 259, 260, 261, 263 and 765.

5. The *Psammosphaera-Reophax* biofacies is a low diversity association dominated by coarse grained morphotypes (Factor 3 at Site 259). This biofacies is recognized in the basal core of Site 259, which directly overlies the basalt, where it probably represents the early stage of faunal succession. Results from a recolonisation experiment at a 3900m station in the Panama Basin have shown that *Psammosphaera* and *Reophax* spp. were the first colonisers of abiotic sediment trays (Kaminski *et al.*, 1988). These opportunistic taxa are also found to dominate assemblages below the oxygen minimum zone off Oman (Hermelin, 1992) and in seasonally dysoxic environments off California (Kaminski *et al.*, 1995). It is most likely that these r-strategists with non-specialised feeding habits and conservative morphologies occupied similar ecological niches in the Early Cretaceous.

6. The *Bulbobaculites-Haplophragmoides* biofacies represents a low diversity association, consisting predominantly of organically-cemented agglutinated taxa. The dominance of *Bulbobaculites* and *Haplophragmoides* spp. in the assemblages points to a deltaic setting, characterized by a high terrigenous influx and depressed oxygenation levels (Wightman, 1990; Nagy *et al.*, 1990; 1995). This biofacies is recorded at the base of Sites 263, 762 and 763.

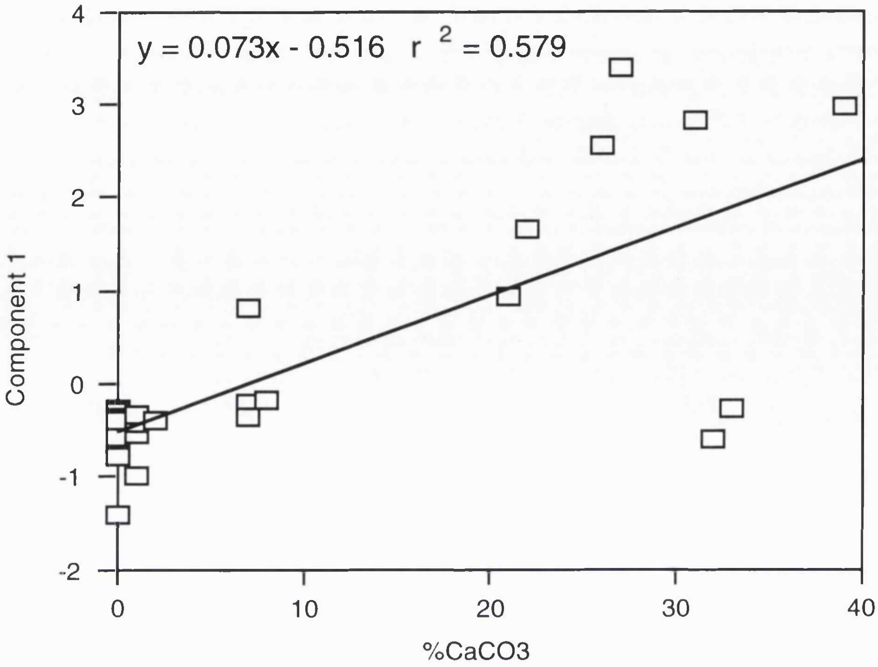


Figure 5.33. Regression analysis between Factor 1 and $CaCO_3$ content for Site 259.

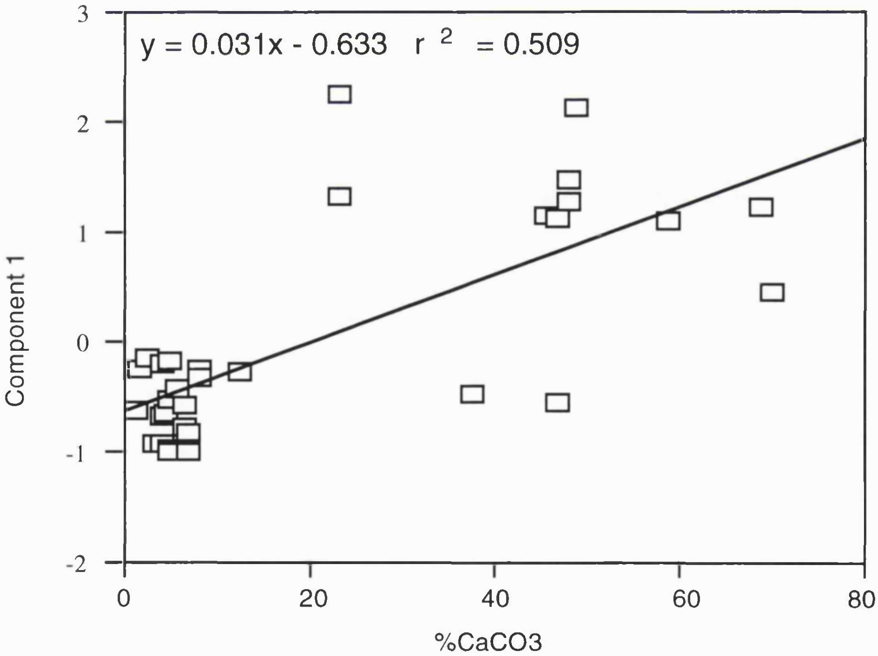


Figure 5.34. Regression analysis between Factor 1 and $CaCO_3$ content for Site 766.

5.12. PALAEOCEANOGRAPHIC SYNTHESIS

An extensive phase of rifting in the Late Jurassic led to the formation of the Argo Basin between the northern Exmouth Plateau and some continental terrranes, which started to drift northwards, away from the Gondwana margin (Boote and Kirk, 1989; Görür and Sengör, 1992). A second rifting episode was initiated in the earliest Cretaceous during a period of renewed crustal stretching between western Australia and Greater India. During the Berriasian and early Valanginian, subsidence of the Cuvier and Gascoyne rifts was associated with uplift and rapid erosion of the Carnarvon Platform and southeastern Exmouth Plateau (Boyd *et al.*, 1992), which provided abundant clastic sediments to the northwards prograding delta lobes of the Barrow Delta (Figure 5.35A). Thick deltaic wedges from the distal part of the delta recovered at Sites 762 and 763, contain impoverished agglutinated foraminiferal assemblages, indicating a very high organic influx and restricted conditions in the Barrow sub-basin during the Berriasian and early Valanginian. At the foot of the continental slope in the Argo Abyssal Plain, calcareous turbidites derived from the uplifted margin and bentonitic pelagic clays were being deposited below the CCD at depths over 3000m at Sites 261 and 765. The cosmopolitan nature of the foraminiferal assemblages at these two sites points to the existence of deep connections between the Argo Basin and the Tethys.

Following break-up in the late Valanginian between Greater India and western Australia, further uplift along transform margins of separating plates led to the emergence of the Barrow Delta platform and to clastic sedimentation into the widening western abyssal plains (Fullerton *et al.*, 1989; Exon *et al.*, 1992). This relative sea level fall may also have been accentuated by a eustatic fall (Haq *et al.*, 1988). Sediments began to accumulate at Site 263 in the Cuvier Abyssal Plain and at Site 766 in the Gascoyne Abyssal Plain. (Figure 5.35B) The unique composition of agglutinated foraminiferal assemblages at Site 263 indicates that circulation within the Cuvier Basin remained relatively restricted during the Early Cretaceous, despite rapid deepening. The foraminiferal assemblages at Site 766 reflect the change from slightly restricted marginal conditions at the foot of a rapidly subsiding margin to a well ventilated pelagic bathyal setting. Recent seismic reflection data revealed that the Cuvier and Exmouth Plateau margins had very different rifting and magmatic developments during the Early Cretaceous. Rapid rifting associated with emplacement of exceptionally large volumes of magma occurred in the Cuvier Basin, whereas the Exmouth Plateau underwent slow extensional deformation through faulting with moderate magmatism (Fullerton *et al.*, 1989; Hopper *et al.*, 1992; Colwell *et al.*, 1994). As a result the Cuvier Abyssal Plain evolved into a small, semi-enclosed oceanic basin (approximately 200km by 400km), bounded by igneous ridges to the south and west and the Exmouth Plateau to the north, while the Gascoyne Abyssal Plain remained open with deep connections to adjacent basins.

Following a ridge jump in the late Hauterivian-early Barremian (Fullerton *et al.*, 1989), widespread subsidence of the northwestern margin (Boyd *et al.*, 1992) and a eustatic sea level rise (Haq *et al.*, 1988) led to a major transgressive pulse over northwestern Australia in the early Barremian. Clays were deposited on the shelf at Sites 762 and 763, in initially shallow, restricted environments and in low energy, deep bathyal settings at Sites 263 and 766 (Figure 5.35C). Impoverished foraminiferal assemblages at Sites 261 and 765 are indicative of sluggish deep water circulation in the Argo Abyssal Plain.

A further transgressive pulse in the Aptian led to widespread submergence of the northwestern margin and flooding of the mainland intracratonic basins (Frakes *et al.*, 1987; Haig and Lynch, 1993). A combination of high surface water fertility and dysoxic bottom waters was probably responsible for the very impoverished foraminiferal assemblages recovered from oceanic sites (Sites 257, 259, 260, 261, 263, 765 and 766) and from marginal sites (Sites 762 and 763) in the Aptian and earliest Albian. Diversified assemblages are, however, intermittently recorded at Sites 260, 762, 763 and 766 in the late early and late Aptian, which suggest periodic improvements in deep water oxygenation. The alternance of barren clays and radiolarian or foraminifera rich oozes at these sites points to cyclic changes in climate and/or productivity.

Schlanger *et al.* (1981), Vogt (1989), Larson (1991) and Kaiho and Saito (1994) correlated the deposition of Cretaceous black shales with periods of intense intraplate volcanism. Increased volcanism appears to have led to elevated sea level, high atmospheric CO_2 concentrations and to generally warm and equable climates without major ice caps and with flatter equator to pole gradients than today's (Arthur *et al.*, 1991; Bralower *et al.*, 1993; 1994). During warm periods the focus of deep water formation switched from the poles to the mid and low latitudes, where shallow seas with high evaporation rates became the sources of warm, oxygen depleted, saline bottom waters (Brass *et al.*, 1982; Hay, 1988; Barron and Peterson, 1990; Spicer and Corfield, 1992). In the eastern Indian Ocean the emplacement of large igneous provinces (LIPs) such as the Wallaby Plateau, Naturaliste Plateau?, Bunbury Basalt and Kerguelen Plateau from about 118Ma to 110 Ma (Duncan and Storey, 1992; Colwell *et al.*, 1994) coincided with maximum flooding of the Australian continent (Figure 5.35D) and with major fluctuations in oceanic productivity. The foraminiferal distribution patterns during that period suggest that conditions became periodically hostile to benthic life during eutrophic intervals. Roth (1989) proposed that periodic intensification of atmospheric circulation enhanced coastal upwelling, terrigenous run off and the production of warm, saline bottom water with low oxygen content, leading to increased fertility in surface waters and oxygen deficiency in bottom waters. Oligotrophic conditions prevailed when mixing in the upper ocean and evaporation of shallow subtropical seas became less intense. Roth (1989) suggested that these fluctuations occurred at Milankovitch frequencies and were superimposed on larger tectonically driven Fischer cycles, which affected halothermal circulation and predisposed mid Cretaceous oceans to oxygen deficit.

Marked fluctuations in productivity in the Aptian and earliest Albian of Indian Ocean DSDP and ODP sites may be interpreted as shifts in the nutrient and oxygen balance of surface and bottom waters in an ocean already prone to dysoxia. A major oceanic change occurred, however, in the late early Albian when rich, diverse, calcareous assemblages were present at Sites 257, 259, 762, 763 and 766 above intervals, which are either barren or contain very impoverished assemblages. Haig and Lynch (1993) traced a transgressive pulse, which significantly altered the composition of foraminiferal assemblages in the western Papuan Basin, the Laura and northern Carpentaria Basin, off northeastern Australia and in the intracratonic Eromanga and Surat Basins in the late early Albian. This transgressive episode led to the deposition of the Gearle Siltstone in the Carnarvon Basin. At Sites 257 and 259 hiatuses in deposition marks the boundary between the underlying detrital clay and the carbonate rich clay, where the faunal change occurs, and provides further evidence of a transgressive episode. The late early Albian diversified benthic assemblages and the abundant planktonic foraminifera, ostracods, radiolaria and bivalve fragments recorded at most Indian Ocean sites indicate a vital improvement in surface and bottom water ventilation. It may be speculated that a major change in oceanic circulation coincided with the waning of volcanic activity in the western Indian Ocean around 110 Ma ago, leading to a decrease in run off and upwelling and to the influx of colder, well oxygenated bottom waters from higher latitudes and a significant CCD drop (see Figure 5.36).

Recent studies have indicated that Cretaceous climates may not have been uniformly warm and equable. Sellwood *et al.* (1994) proposed a cooler Cretaceous climate. The oxygen isotope measurements of *Hedbergella* sp. and *Rotalipora* sp. from the upper Albian and Cenomanian of the Pacific and Atlantic, obtained by these authors, pointed to a latitudinal temperature gradient flatter than today's with polar temperatures close to 0°C and equatorial temperatures equivalent to present values. Frakes and Francis (1988) presented evidence that ice may have formed at sea level in Central Australia during the Early Cretaceous. Frakes and Francis (1990) interpreted growth rings in fossil wood from southern Australia as indicative of cool, seasonal Early Cretaceous climates. Barron and Washington (1982) estimated an annual temperature range of approximately -18°C to 27°C for central Australia during the mid Cretaceous. Barron *et al.* (1995) proposed that higher atmospheric CO_2 and greater oceanic poleward heat flux due to the formation of warm deep water in the subtropics, may have been the main controlling factors of mid-Cretaceous climates. These authors suggested that changes in atmospheric CO_2 and perturbations of the thermohaline circulation may have led to climate variability during the mid-Cretaceous. Oxygen isotope measurements of dimitobelid belemnites from the Albian Gearle Siltstone in the Carnarvon Basin, a transgressive sequence deposited on mainland Australia in the late early Albian, which is correlatable with transgressive deposits recorded at Sites 257, 259, 762, 763 and 766, indicated cool sea temperatures close to 10°C (Pirrie *et al.*, 1995). These records of cooler temperatures suggest that the high southern latitudes may have become the locus of deep water formation during the late early Albian, when volcanic activity declined in the Indian Ocean. A decrease in atmospheric CO_2 may have reduced the intensity of the hydrological cycle (Barron and Washington, 1985), lessening coastal upwelling, terrestrial run off and low latitude evaporation. The palaeogeography of the Indian Ocean would also have favoured the influx of high latitude waters from a southern source.

Fluctuations in benthic foraminiferal diversity, abundance and morphogroups at Sites 258, 259, 762 and 763 during the late Albian suggest further variations in productivity and oxygenation. However, no significant changes are apparent at oceanic sites distant from the continental margin (Sites 256 and 257) and at Site 766, where strong bottom current activity is evident throughout the Albian (Buffler *et al.*, 1992). Regional geography appears to have strongly influenced the extent of dysoxic episodes during the late Albian. The influx of large, keeled planktonics such as *Rotalipora* spp. and *Planomalina* spp. at Sites 762, 763 and 766 in the latest Albian also indicates the inflow of warmer, low latitudes surface waters along the northwestern Australian margin (Figure 5.35E) and may reflect a general warming trend.

The benthic foraminiferal assemblages from DSDP and ODP sites in the Indian Ocean reflect a wide range of palaeoenvironments and provide new insights into the evolution of the Indian Ocean. The palaeoenvironmental interpretation presented here contrasts sharply with the views expressed by Scheibnerová in her syntheses of Leg 27 (1974, 1977), in which she concluded that the foraminiferal assemblages were diagnostic of very shallow, restricted conditions and that there was no evidence for deep-water environments until the Santonian in the Indian Ocean.

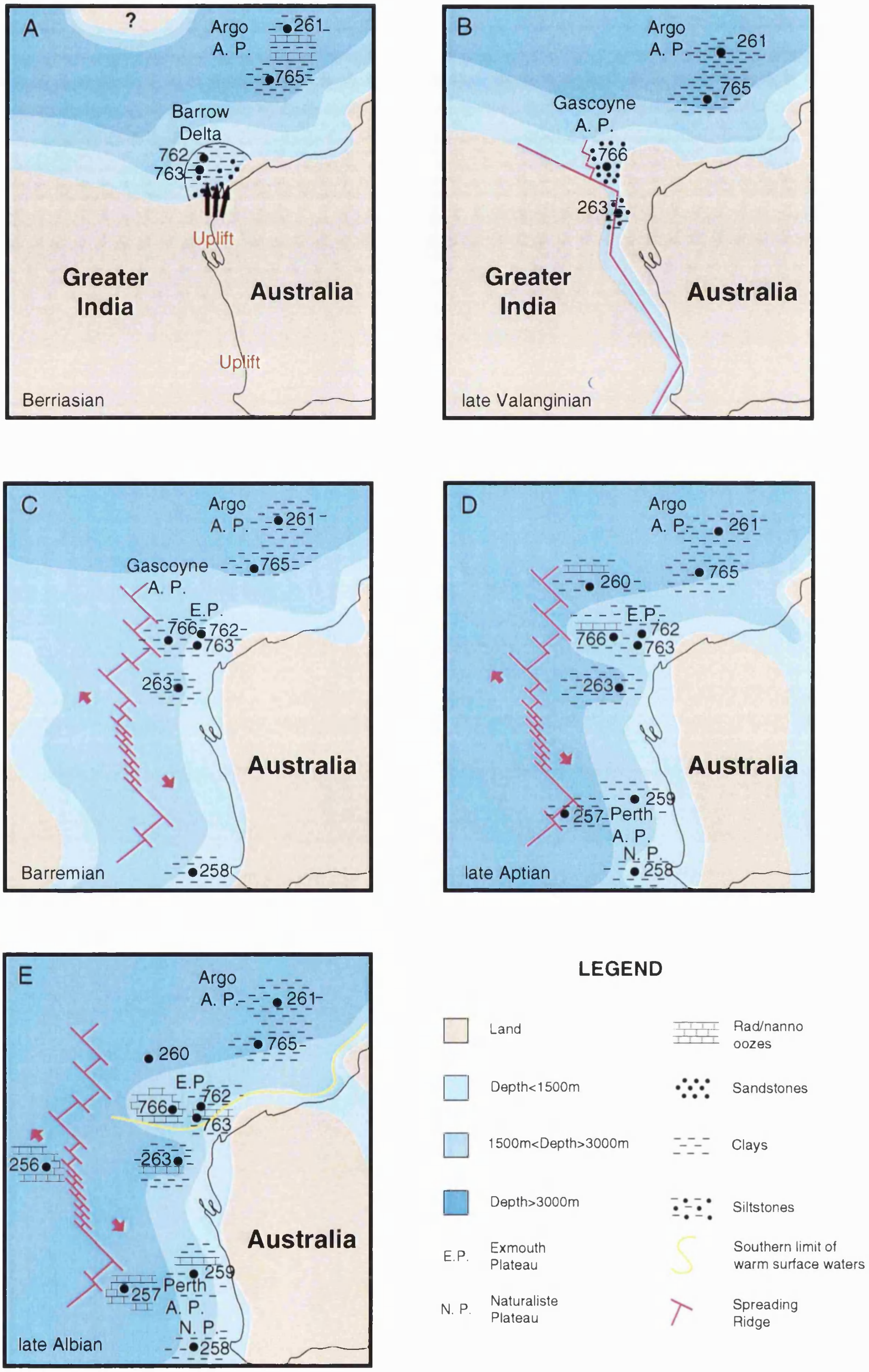
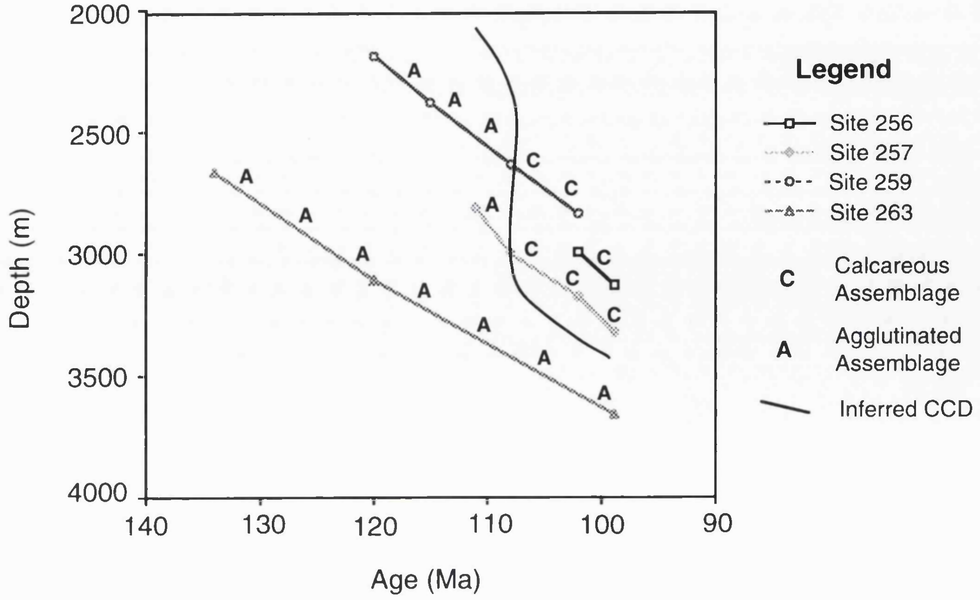
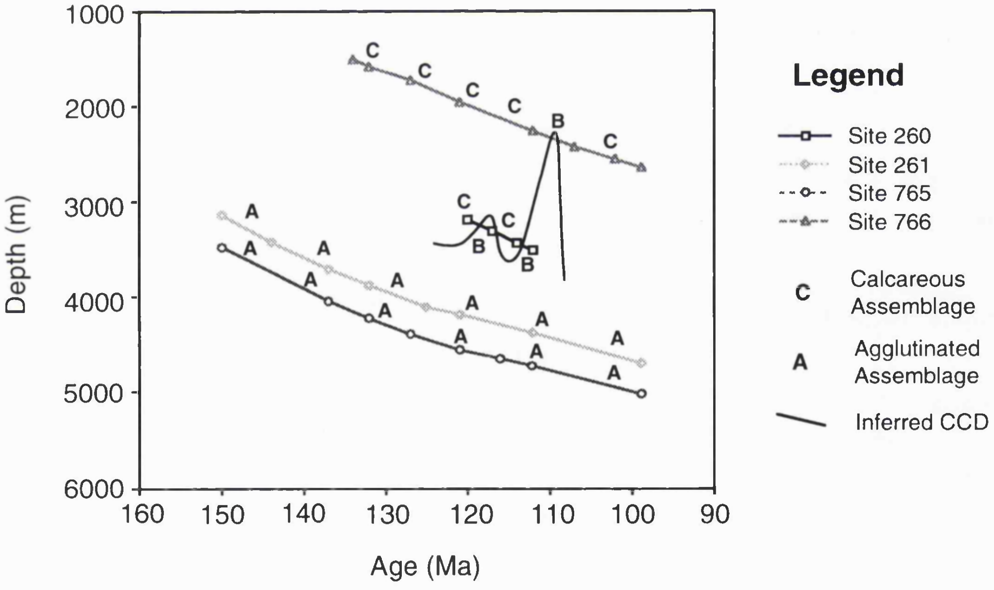


Figure 5.35. Evolution of the Indian Ocean during the Early Cretaceous.



A. Western Indian Ocean



B. Northwestern Indian Ocean

Figure 5.36. Estimated palaeoseafloor depths of DSDP and ODP sites, situated on oceanic crust and inferred CCD curve.

Appendix 5.1. Backtracking data for palaeodepths computations (ages have been defined using the Mesozoic time scale of Gradstein *et al.*, 1994).

Input and output data for backtracking at Site 256

Input data
Present water depth: 5361m
Basement depth: 251m
Average sediment density: 1.5g/cc
Age of basement: 102?Ma

Output data
Present unsedimented water depth: 5561m
Theoretical present unsedimented water depth: 5769m
Offset: -208m

		Palaeodepth (m)	
Time (Ma)	Sediment thickness (m)	Unsedimented	Sedimented
98.9	13.5	3141	3130
102	0	2992	2992

Input and output data for backtracking at Site 257

Input data
Present water depth: 5278m
Basement depth: 262m
Average sediment density: 1.6g/cc
Age of basement: 111Ma

Output data
Present unsedimented water depth: 5475m
Theoretical present unsedimented water depth: 5854m
Offset:-379m

		Palaeodepth (m)	
Time (Ma)	Sediment thickness (m)	Unsedimented	Sedimented
98.9	63	3367	3322
102	24	3193	3176
107	15	3007	2996
111	0	2810	2810

Input and output data for backtracking at Site 259

Input data
Present water depth: 4696m
Basement depth: 304m
Average sediment density: 1.9g/cc
Age of basement: 120?Ma

Output data
Present unsedimented water depth: 4885m
Theoretical present unsedimented water depth: 5927m
Offset: -1042m

		Palaeodepth (m)	
Time (Ma)	Sediment thickness (m)	Unsedimented	Sedimented
102	206	2981	2835
108	153	2741	2632
115?	70	2429	2379
120?	0	2184	2184

Input and output data for backtracking at Site 260

Input data
Present water depth: 5702m

Basement depth: 323m
Average sediment density: 1.9g/cc
Age of basement: 120Ma

Output data
Present unsedimented water depth: 5903m
Theoretical present unsedimented water depth: 5927m
Offset: -24m

		Palaeodepth (m)	
Time (Ma)	Sediment thickness (m)	Unsedimented	Sedimented
112	97	3587	3518
114	78	3495	3440
117	58	3353	3312
120	0	3204	3204

Input and output data for backtracking at Site 261

Input data
Present water depth: 5667m

Basement depth: 538.5m
Average sediment density: 1.7g/cc
Age of basement: 150Ma

Output data
Present unsedimented water depth: 6049m
Theoretical present unsedimented water depth: 6106m
Offset: -57m

		Palaeodepth (m)	
Time (Ma)	Sediment thickness (m)	Unsedimented	Sedimented
98.9	320	4927	4700
112	291	4596	4390
121	196	4326	4187
125	111	4194	4115
132	92	3940	3875
137	44	3741	3710
144	10	3435	3428
150	0	3143	3143

Input and output data for backtracking at Site 263

Input data
Present water depth: 5048m

Basement depth: 760?m
Average sediment density: 2.0g/cc
Age of basement: 134Ma

Output data
Present unsedimented water depth: 5487m
Theoretical present unsedimented water depth: 6021m
Offset: -534m

		Palaeodepth (m)	
Time (Ma)	Sediment thickness (m)	Unsedimented	Sedimented
98.9?	650	4033	3657
120?	340	3305	3108
134	0	2666	2666

Input and output data for backtracking at Site 765

Input data

Present water depth: 5723m

Basement depth: 932m
Average sediment density: 1.7g/cc
Age of basement: 150Ma

Output data

Present unsedimented water depth: 6384m
Theoretical present unsedimented water depth: 6106m
Offset: 278m

		Palaeodepth (m)	
Time (Ma)	Sediment thickness (m)	Unsedimented	Sedimented
98.9	332	5260	5025
112.2	272	4925	4732
116	230	4816	4653
121	135	4661	4565
127	85	4459	4398
132	65	4275	4228
137	39	4076	4048
150	0	3478	3478

Input and output data for backtracking at Site 766

Input data

Present water depth: 4008m

Basement depth: 459m
Average sediment density: 1.7g/cc
Age of basement: 134Ma

Output data

Present unsedimented water depth: 4333m
Theoretical present unsedimented water depth: 6021m
Offset: -1688m

		Palaeodepth (m)	
Time (Ma)	Sediment thickness (m)	Unsedimented	Sedimented
98.9	316	2882	2658
102	305	2790	2574
107	271	2630	2438
112	256	2458	2277
121	206	2110	1964
127	171	1850	1729
132	30	1612	1590
134	0	1512	1512

CHAPTER 6. *Systematic Taxonomy*

6.1. INTRODUCTION

The systematics of Lower Cretaceous foraminifera from the Indian Ocean DSDP and ODP sites are poorly defined. Most previous studies of Indian Ocean DSDP material were completed during the first phase of drilling in the early 1970's and were either preliminary reports or isolated studies of individual holes. Even some of the subsequent reports of Lower Cretaceous benthic foraminifera from the Indian Ocean do not provide a consistent taxonomic data base, and no comprehensive synthesis of the benthic foraminifera from the Indian Ocean has been attempted to date. This chapter presents a systematic documentation of Lower Cretaceous benthic foraminifera from Indian Ocean DSDP and ODP holes, and complements two taxonomic monographs on the Valanginian-Barremian foraminifera from ODP Site 766 and on the Valanginian-Albian foraminifera from DSDP Site 263, published separately (Holbourn and Kaminski, in press [a] and [b]). Species already documented in these two monographs are not repeated here. Systematic references are also given for planktonic foraminifera, which have been used to calibrate benthic foraminiferal data. In the course of this research, a total of 100 agglutinated and 132 calcareous benthic taxa has been described from the DSDP and ODP sites in the Indian Ocean. A complete taxonomic list is provided in Appendices 6.1 and 6.2. Distribution and biostratigraphic ranges are shown in Figures 4.2 to 4.11 and 4.13 to 4.14 and Appendices 4.1 to 4. 11.

6.2. SYSTEMATIC NOMENCLATURE

The benthic foraminiferal classification employed follows the taxonomic classification of Loeblich and Tappan (1987) except for the genus *Praedorothia*, proposed by Desai and Banner, 1987. The revised classification of the Globigerinina by Banner and Desai (1988) is adopted for planktonic taxa. Open nomenclature has been used for taxa which do not closely match published descriptions. The following abbreviations have been used: **cf.** for taxa similar to a known species but different in some detail; **aff.** for taxa showing close affinity to a well-defined taxonomic group; **sp. 1, 2...** for species which do not match published descriptions; **sp.** for taxa not determinable at the specific level.

Phylum PROTOZOA
Class SARCODINA
Order FORAMINIFERIDA Eichwald, 1830
Suborder TEXTULARIINA Delage and Hérouard, 1896
Superfamily ASTRORHIZACEA, Brady, 1881
Family PSAMMOSPHAERIDAE Haeckel, 1894
Genus Psammosphaera Schulze, 1875

Psammosphaera fusca Schulze, 1875
Plate 1, Figures 1-2.

Psammosphaera fusca SCHULZE, 1875, pl. 2, fig. 8a-f.

Description: The test is spherical to sub-spherical with a very coarsely agglutinated wall. No distinct aperture is visible.

Remarks: Weidich (1990) suggested that this species is characteristic of clastic sediments, deposited in bathyal depths.

Range and Occurrence: A cosmopolitan species, widely recorded in the Cretaceous.

Psammosphaera sp. 1
Plate 1, Figure 3.

Description: The test is spherical to sub-spherical, often deflated, with a finely agglutinated wall. No distinct aperture is visible.

Remarks: Differs from *Psammosphaera fusca* by the smaller size of its agglutinated particles.

Family SACCAMMINIDAE Brady, 1884
Subfamily SACCAMMININAE Brady, 1884
Genus *Saccammina* Carpenter, 1869

Saccammina crespinae Holbourn and Kaminski, 1995

Remarks: The original name *Psammosphaera parva* Crespin, 1963 proved invalid (Holbourn and Kaminski, 1995).

Superfamily HORMOSINACEA Haeckel, 1894
Family HORMOSINIDAE Haeckel, 1894
Genus *Reophax* de Montfort, 1808

Reophax geniculatus (Ludbrook, 1966)

Reophax geniculatus LUDBROOK, 1966, pl. 1, figs. 3-4.

Reophax deckeri Tappan.--HAIG, 1980, pl. 2. figs. 2-15 & pl. 9, fig. 7.

Description: The test is large, elongate and uniserial with inflated chambers increasing rapidly in size. The chambers are separated by distinct, depressed sutures. The wall is coarsely agglutinated with a rough texture. The aperture is terminal, at the end of a long, broad neck.

Remarks: Tests are often compressed or broken.

Range and Occurrence: Reophax geniculatus was recorded in the Aptian-Albian of the Great Artesian Basin by Ludbrook (1966), in the Aptian-Albian of Queensland (as *Reophax deckeri*) by Scheibnerová (1976) and Haig (1980) and in the Albian of Papua New Guinea (as *Reophax deckeri)* by Haig (1981).

Reophax sp. 3

Plate 1, Figures 4-5.

Description: The test is small, elongate and uniserial with irregular pyriform chambers separated by short stolons. The wall is very coarsely agglutinated from large, angular particles held in little cement. The aperture is terminal at the end of a short neck.

Remarks: This species is found in association with *Psammosphaera fusca* in basal sediments at DSDP Site 259.

Superfamily LITUOLACEA de Blainville, 1827
Family HAPLOPHRAGMOIDIDAE Maync, 1952
Genus *Haplophragmoides* Cushman, 1910

Haplophragmoides sp. 2

Plate 2, Figure 1.

Haplophragmoides bulloides (Beissel).--MOULLADE 1984, pl. 1, fig. 7.

Description: The test is planispiral, closely involute and very inflated; its thickness is nearly equal to its diameter. The chambers are separated by flush or slightly depressed sutures and the aperture is a slit at the base of the last chamber. The wall is agglutinated with medium to coarse particles held in little cement.

Range and Occurrence: Frequent at lower bathyal and abyssal depths in the Aptian-Albian of the North Atlantic (Guérin, 1981).

Remarks: Differs from *Haplophragmoides bulloides*, illustrated by Beissel (1891) in pl. 4, figs. 24-30, but closely resembles the species figured by Moullade (1984). Also resembles *Haplophagmoides impensus* Martin, 1964, illustrated by McNeil and Caldwell (1981) in pl. 11, fig. 9, but has a coarser wall texture.

Haplophragmoides minor Nauss, 1947

Plate 1, Figures 8-9.

Haplophragmoides minor NAUSS, 1947, pl. 49, fig. 10.

Haplophragmoides minor Nauss.--GEROCH and NOWAK, 1984, pl. 2, fig. 24.

Haplophragmoides gigas minor Nauss.--WEIDICH, 1990, pl. 7, fig. 4 & pl. 36, figs. 11-12.

Description: The test is biumbilicate and planispiral with six to seven chambers in the last whorl. The chambers are inflated in the umbilical region and separated by distinct, depressed, radial sutures. The periphery is lobulate and acute and the aperture is a slit at the base of the last chamber. The wall is finely agglutinated and smoothly cemented.

Range and Occurrence: Reported from the Aptian-Albian of Queensland (Haig, 1980) and worldwide in Lower Cretaceous sediments (Weidich, 1990).

Haplophragmoides cf. ***howardense*** Stelck and Wall, 1954

Plate 1, Figure 11.

Haplophragmoides howardense STELCK and WALL, 1954, pl. 1, fig. 20 & pl. 2, figs. 5-6.

Haplophragmoides howardense Stelck and Wall.--McNEIL and CALDWELL, 1981, pl. 11, figs. 7-8.

Haplophragmoides cf. *howardense* Stelck and Wall.--HAIG, 1980, pl. 2, figs. 21-22, pl. 3, figs. 1-7 & pl. 9, fig. 8.

Description: The test is biumbilicate and planispiral with six to seven chambers in the last whorl. The umbilicus is deep and narrow, the chambers inflated with straight, depressed sutures and the periphery lobulate. The aperture forms an elongate slit at the base of the last chamber. The wall is finely agglutinated, usually white.

Remarks: Differs from *Haplophragmoides howardense*, illustrated by McNeil and Caldwell (1981), by its fewer, more inflated chambers.

Range and Occurrence: Haplophragmoides howardense was reported from the Cenomanian to the Santonian in North America (McNeil and Caldwell, 1981). *Haplophragmoides* cf. *howardense* was recorded in the Albian of Queensland by Haig (1980).

Superfamily HAPLOPHRAGMIACEA Eimer and Fickert, 1899

Family AMMOSPHAEROIDININAE Cushman, 1927

Subfamily RECURVOIDINAE Alekseychik-Mitskevich, 1973

Genus *Recurvoides* Earland, 1934

Recurvoides sp. 1

Plate 1, Figures 12a-12b.

Description: The test is streptospirally enrolled, usually with few chambers per whorl. Medium to coarse agglutinated particles give the external wall of the test a rough texture. The aperture is areal with a lip.

Remarks: The aperture of some specimens is basal rather than areal.

Superfamily SPIROPLECTAMMINACEA Cushman, 1927
Family SPIROPLECTAMMINIDAE Cushman, 1927
Genus *Heterantyx* Loeblich and Tappan, 1982

Heterantyx cretosa (Ten Dam, 1950)
Plate 2, Figures 4-7 & 10.

Spiroplectammina rectangularis var. *cretosa* TEN DAM, 1950, pl. 1, fig. 9.

Heterantyx cretosa (Ten Dam).--HAIG, 1992, pl. 1, figs. 5-6.

Description: The test is elongate, lozenge-shaped and flattened with truncated margins. Initially planispiral, it becomes biserial with approximately 12 pairs of low chambers, separated by prominent elevated intercameral and median sutures. The aperture is a low arch at the base of the last chamber. The wall is smoothly cemented with calcareous cement.

Remarks: This species is distinctly dimorphic: only microspheres bear well-developed planispires.

Range and Occurrence: Commonly recorded in the Albian of the Netherlands (Ten Dam, 1950) and Indian Ocean (Haig, 1992).

Genus *Spiroplectinella* Kisel'man, 1972

Spiroplectinella gandolfii (Carbonnier, 1952)
Plate 2, Figures 8-9.

Spiroplectammina gandolfii CARBONNIER, 1952, pl. 5, fig. 2.

Spiroplectammina gandolfii (Carbonnier).--WEIDICH, 1990, pl. 17, figs. 7-41, pl. 18, figs. 1-16 & pl. 38, figs. 22-25.

Spiroplectinella gandolfii (Carbonnier).--HAIG, 1992, pl. 1, fig. 7.

Description: The test is elongate, flattened and markedly flaring. Initially planispiral, it becomes biserial with very low, broad chambers separated by depressed sutures. The aperture is a low arch at the base of the last chamber. The wall is smoothly cemented with calcareous cement.

Remarks: The planispiral coil is only developed in microspheric tests.

Range and Occurrence: Recorded in the mid-Albian-Cenomanian of the northern Alps (Weidich, 1990) and in the upper Albian of the Papuan Basin and Indian Ocean (Haig, 1992).

Spiroplectinella sp.
Plate 2, Figures 11a-11b.

Description: The test is elongate, flaring, initially planispiral becoming biserial with a sharp periphery increasing markedly in thickness. The low and broad chambers are separated by depressed sutures, which curve strongly downwards. The aperture is an arch at the base of the last chamber. The wall is finely agglutinated and smoothly cemented with calcareous cement.

Remarks: This species selectively used the coccolith *Watzaunaria barnesae* to build its test. The coccoliths are found in a preferred orientation with the convex, distal side of the coccolith directed outwards on the surface of the test. Widmark and Henriksson (1995) described the species *Gaudryina cribrosphaerellifera* from the Upper Cretaceous of the Central Pacific Ocean, which used an analogous technique to construct its test with the coccolith species: *Cribrosphaerella ehrenbergii.* They suggested that the central areas of the coccoliths may have acted as a sieve-plates, to protect the pore entrances of the test.

Family TEXTULARIOPSIDAE Loeblich and Tappan, 1982

Genus *Bimonilina* Eicher, 1960

Bimonilina engeniensis (Ludbrook, 1966)

Plate 4, Figures 5-6.

Pseudobolivina engeniensis LUDBROOK, 1966, pl. 4, figs. 12-14.

Pseudobolivina manitobensis (Wickenden).--HAIG and BARNBAUM, 1978, fig. 2D.

Pseudobolivina manitobensis (Wickenden).--HAIG, 1980, pl. 5, figs. 15-22 & pl. 10, fig. 4.

Description: The test is elongate, initially biserial becoming loosely biserial with inflated chambers, increasing markedly in size. The aperture is a terminal slit, often bordered by a narrow lip. The wall is agglutinated from fine to medium particles held in siliceous cement.

Remarks: Specimens are often distorted and compressed through diagenesis.

Range and Occurrence: Common within the *Ammobaculites australis* biofacies in the Aptian-Albian of Queensland (Haig, 1980).

Bimonilina variana Eicher, 1960

Plate 4, Figure 8.

Bimonilina variana EICHER, 1960, pl. 4, figs. 15-19.

Pseudobolivina variana (Eicher).--HAIG, 1980, pl. 5, figs. 23-26.

Pseudobolivina parvula LUDBROOK, 1966, pl. 4, figs. 18-20.

Description: The test is small, elongate, biserial, showing a slight tendency to become uniserial, as later chambers increase in size and overlap preceding ones. The chambers are inflated and separated by distinct, depressed sutures. The aperture is a terminal slit. The wall is finely agglutinated and smoothly cemented.

Range and Occurrence: Bimonilina variana has been widely recorded in North America in the Albian-Cenomanian. *Pseudobolivina parvula* has been found in Aptian-Albian sediments of South Australia (Ludbrook, 1966).

Genus *Textulariopsis* Banner and Pereira, 1981

"*Textulariopsis*" *wilgunyaensis* Crespin, 1963

Textularia wilgunyaensis CRESPIN, 1963, pl. 14, figs. 5-11.

Textularia wilgunyaensis Crespin.--LUDBROOK, 1966, pl. 4, figs. 9-10.

Textularia wilgunyaensis Crespin.--HAIG, 1980, pl. 5, figs. 12-14 & pl. 10, fig. 8.

Description: The test is elongate, flaring and flattened with sub-rounded periphery and chambers in a biserial arrangement. The chambers increase rapidly in size and are separated by distinct, depressed, oblique sutures. The aperture is an arch at the base of the last chamber. The wall is agglutinated with medium to coarse particles held in siliceous cement.

Remarks: The wall is not calcareous and this species cannot be assigned to *Textulariopsis* as currently defined by Loeblich and Tappan (1987).

Range and Occurrence: Recorded as *Textularia wilgunyaensis* in the upper Aptian-lower Albian of the Great Artesian Basin by Ludbrook (1966) and in the Albian of Queensland by Haig (1980).

"*Textulariopsis*" sp. 1

Description: The test is elongate, flaring and flattened with six to eight pairs of low, broad chambers separated by distinct, depressed sutures. The last two chambers are more inflated than the previous ones. The aperture is a small arch at the base of the last chamber. The wall is agglutinated from fine particles held in a siliceous cement.

Remarks: The wall is not calcareous and this species cannot be assigned to *Textulariopsis* as currently defined by Loeblich and Tappan (1987).

"*Textulariopsis*" sp. 2

Plate 2, Figure 12.

Description: The test is small, elongate and narrow, with rounded periphery and chambers arranged biserially. The chambers (usually 10-12 pairs), increase slowly in size and are separated by fine, slightly depressed, oblique sutures, often forming a distinctive zig-zag pattern. The aperture is an arch at the base of the last chamber. The wall is agglutinated with fine to medium particles held in siliceous cement.

Remarks: The wall is not calcareous and this species cannot be assigned to *Textulariopsis* as currently defined by Loeblich and Tappan (1987). Resembles the Aptian species *Textularia anacooraensis* Ludbrook, 1966, which Haig (1980) considered to be a junior synonym of *Spiroplectammina cushmani* Crespin, 1944.

Superfamily VERNEUILINACEA Cushman, 1911

Family VERNEUILINIDAE Cushman, 1911

Genus *Gaudryinopsis* Podobina, 1975

Gaudryinopsis gradata (Berthelin, 1880)

Plate 3, Figure 2.

Gaudryina gradata BERTHELIN, 1880, pl. 1, fig. 6.

Dorothia cf. *conula* (Reuss).--BARTENSTEIN, BETTENSTAEDT and BOLLI, 1966, pl. 1, figs. 83-93.

Dorothia gradata (Berthelin).--RISCH, 1970, pl. 3, figs. 1-2.

Dorothia gradata (Berthelin).--BARTENSTEIN and BOLLI, 1986, pl. 1, figs. 38-39.

Gaudryinopsis gradata (Berthelin).--HAIG and LYNCH, 1993, pl. 1, fig. 21.

Description: The test is elongate and gently flaring, initially trochospiral, then becoming biserial. The last two chambers of the test are larger and markedly inflated. The aperture is an arch at the base of the last chamber. The wall is smoothly cemented with calcareous cement.

Remarks: Several of the specimens illustrated by Weidich (1990), which lack a biserial stage, appear to be juvenile forms.

Range and Occurrence: Cosmopolitan from the early Albian, according to Bartenstein and Bolli (1986); recorded in the upper Aptian-Cenomanian of the northern Alps by Weidich (1990).

Gaudryinopsis cf. ***gradata*** (Berthelin, 1880)

Remarks: Differs from *Gaudrina gradata* by having less inflated last two chambers, giving the test a less flaring appearance.

Genus *Gaudryina* d'Orbigny, 1839

Gaudryina dividens Grabert, 1959

Plate 3, Figures 8-10.

Gaudryina dividens GRABERT, 1959, pl. 1, fig. 35, pl. 2, figs. 16-30 & pl. 3, figs. 53-59.

Gaudryina compacta GRABERT, 1959, pl. 1, figs. 6-8 & pl. 3, figs. 38-52.

Migros sp. SCHEIBNEROVÁ, 1974, pl. 1, fig. 24 & pl. 9, fig. 13.

Spiroplectinata mendrisiensis (Gandolfi).--GUÉRIN, 1981, pl. 1, fig. 1.

Gaudryina barnardi SHAKIB, 1990, pl. 18, figs. 13-15.

Pseudogaudryinella sp. A HAIG, 1992, pl. 1, figs. 10-11.

Pseudogaudryinella sp. B HAIG, 1992, pl. 1, fig. 12.

Pseudogaudryinella sp. C HAIG, 1992, pl. 1, figs. 13-14.

Description: The morphology of the test shows considerable variation: initially triserial and triangular in shape with sharp to rounded corners, the test may become biserial or biserial and uniserial with a variable number of chambers separated by distinct, depressed sutures. The aperture is an interiomarginal arch at the base of the

last chamber in triserial tests, which tends to become circular and terminal in biserial and uniserial tests. The wall is thick and smoothly cemented with calcareous cement.
Remarks: The variability of the test and its tendency to become biserial or even uniserial through time have led to considerable taxonomic confusion. Grabert (1959) distinguished three species with different morphologies and discrete stratigraphic ranges: *Gaudryina dividens* and *Gaudryina compacta*, from the late Aptian-early Albian, and *Gaudryina richteri*, a precursor from the late Hauterivian. Haig (1992) documented three morphotypes of *Pseudogaudryinella* from the Aptian-Albian of ODP Site 766 but gave no detailed taxonomic descriptions of these taxa. The substantial overlap in shapes observed in Aptian-Albian specimens from DSDP and ODP sites of the Indian Ocean (from triangular to trapezoidal or rectangular and from rounded to angular), precludes the use of Grabert's classification (1959). The range of variability suggests that these forms belong to a broad, evolving plexus, described here under the name of *Gaudryina dividens.* This plexus displays a consistent trend to reduce its coiling arrangement from triserial to biserial and even uniserial, and this tendency is of stratigraphic significance in the Indian Ocean.
Range and Occurrence: This cosmopolitan taxon was widely recorded under various names in DSDP holes in the Atlantic and Pacific (Gradstein, 1978; Riegraf and Luterbacher, 1989) and in Europe (Grabert, 1959; Weidich, 1990). Investigations of cores containing large number of *Gaudryina dividens* from DSDP Site 259 and ODP Site 766 indicate that triserial and triserial-biserial tests with one pair of chambers are dominant in the lower Albian, while triserial-biserial tests with two or three pairs of chambers and triserial-biserial-uniserial forms increase in number in the middle Albian.

Gaudryina cf. ***dividens*** Grabert, 1959
Plate 3, Figure 10.

Gaudryina aff. *richteri* Grabert.--HAIG, 1992, pl. 1, figs. 8-9.
Remarks: The test is consistently more angular in shape than *Gaudryina dividens.* The triserial part is well developed with sharper corners and slightly concave sides. Recorded in the upper Aptian of DSDP Site 260 and ODP Sites 763 and 766.

Family TRITAXIIDAE Plotnikova, 1979
Genus *Tritaxia* Reuss, 1860

Tritaxia gaultina (Morozova, 1948)
Plate 3, Figures 11-15.

Clavulina gaultina MOROZOVA, 1948, pl. 1, fig. 4.
Clavulina gabonica Le Calvez *et al.*--SCHEIBNEROVÁ, 1974, pl. 2, figs. 5-9.
Tritaxia gaultina (Morozova).--HAIG, 1992, pl. 1, fig. 15.

Description: The test is elongate, initially triserial and triangular in shape with sharp carinate angles, becoming uniserial in adult tests. The low chambers in the uniserial portion are inflated and separated by distinct, depressed sutures. The aperture is round and terminal in adult specimens. The wall is thick and smoothly cemented with calcareous cement.

Range and Occurrence: This cosmopolitan species was commonly recorded in the Albian-Cenomanian of the Atlantic, Pacific, Alps and Carpathians (Riegraf and Luterbacher, 1989).

Superfamily ATAXOPHRAGMIACEA Schwager, 1877
Family GLOBOTEXTULARIIDAE Cushman, 1927
Subfamily LIEBUSELLINAE Saidova, 1981
Genus *Remesella* Vasicek, 1947

Remesella sp. 1
Plate 3, Figure 1.

Remesella sp. HAIG, 1992, pl. 2, figs. 1-2.

Mantazia sp. SCHEIBNEROVÁ, 1974, pl. 9, fig. 15.

Arenobulimina conoidea (Perner) MOULLADE, 1984, pl. 1, fig. 15.

Description: The test is elongate, subconical, initially trochospiral, then biserial with inflated chambers separated by slightly depressed sutures. The aperture is an interiomarginal arch. The wall is finely agglutinated and smoothly cemented.

Range and Occurrence: Commonly recorded in Albian sediments from the Indian Ocean (Scheibnerová, 1974; Haig, 1992). Guérin (1981) considered *Arenobulimina conoidea* to be typical of lower bathyal depths in the Tethys and North Atlantic.

Superfamily TEXTULARIACEA Ehrenberg, 1838
Family DOROTHIIDAE Balakhmatova, 1972
Subfamily DOROTHINAE Balakhmatova, 1972
Genus *Praedorothia* Desai and Banner, 1987

Praedorothia praeoxycona (Moullade, 1966)
Plate 3, Figures 6-7.

Dorothia praeoxycona MOULLADE, 1966, pl. 3, figs. 8-11 & pl. 10, figs. 7-9.

Marssonella praeoxycona (Moullade).--BARTENSTEIN and BOLLI, 1973, pl. 2, figs. 57-61.

Marssonella praeoxycona (Moullade).--BOLLI *et al.*, 1994, figs. 7.26-29.

Remarks: Differs from *Marssonella oxycona* by its less regular conical shape and its more rounded apertural face. Only found at DSDP Site 260.

Range and Occurrence: Recorded by Moullade (1966) in the Barremian-lower Aptian of Tethys and in the upper Hauterivian-lower Barremian at DSDP Sites 49 and 50 in the North Pacific by Douglas and Moullade (1972). In Europe it ranges from the Barremian to the middle or upper Aptian, according to Bolli *et al.* (1994).

Praedorothia ouachensis (Sigal, 1952)
Plate 3, Figures 4-5.

Marssonella ouachensis SIGAL, 1952, fig. 16.

Dorothia ouachensis (Sigal).--RISCH, 1971, pl. 1, fig. 15.

Dorothia ouachensis (Sigal).--MOULLADE, 1984, pl. 7, fig. 11, pl. 9, figs. 1-4, ?5, 6-7, ?8-10, 11 & pl. 10, figs. 1-9.

Description: The test is elongate, initially trochospiral, then biserial with a rounded periphery and sub-parallel sides. The chambers are slightly inflated and separated by distinct, depressed sutures. The last two chambers are rounded and the aperture is an arch at the base of the last chamber. The wall is finely agglutinated with calcareous cement.

Remarks: Shows some resemblance to *D. praehauteriviana* (late Valanginian-early Hauterivian), but differs by having a more rounded apertural face and more inflated chambers separated by thicker sutures. The last few chambers of the test also show a tendency to become uniserial. This species is very abundant at DSDP Site 260 where most of the tests are small (less than 0.5mm in length), although a few specimens exceed 1.0mm in length.

Range and Occurrence: Recorded in the Hauterivian-lower Aptian of the Alps by Risch (1971), in the late Hauterivian-early Barremian at DSDP Sites 49 and 50 in the North Pacific by Douglas and Moullade (1972) and in the upper Hauterivian-lower Aptian of Tethys by Moullade (1984).

Genus *Marssonella* Cushman, 1933

Marssonella oxycona (Reuss, 1860)

Gaudryina oxycona REUSS, 1860, pl. 12, fig. 3.

Dorothia oxycona (Reuss).--MOULLADE, 1966, pl. 3, figs. 5-7.

Marssonella oxycona (Reuss).--HAIG and LYNCH, 1993, pl. 1, fig. 20.

Description: The test is elongate, conical, initially trochospiral becoming biserial with a circular cross-section. The chambers are inflated and separated by flush or slightly depressed sutures. The terminal face is flat or slightly concave and the aperture is an arch at the base of the last chamber. The wall is smoothly cemented with calcareous cement.

Range and Occurrence: Recorded by Moullade (1966) in the mid-Albian of Tethys and by Haig and Lynch (1993) in the mid or upper Albian of the Carpentaria Basin.

Suborder SPIRILLININA Hoenegger and Piller, 1975
Family PATELLINIDAE Rhumbler, 1906
Subfamily PATELLININAE Rhumbler, 1906
Genus *Patellina* Williamson, 1858

Patellina africana Lambert and Scheibnerová, 1974
Plate 5, Figure 1.

Patellina africana LAMBERT and SCHEIBNEROVÁ, 1974, pl. 3, fig. 4 & textfig. 11.

Patellina africana Lambert and Scheibnerová.--SCHEIBNEROVÁ, 1974, pl. 4, figs. 8-10 & pl. 9, fig. 15.

Patellina africana Lambert and Scheibnerová.--MOULLADE, 1984, pl. 4, figs. 10-11.

Description: The test is conical, planoconvex, evolute on the spiral side and involute on the ventral side with two chambers per whorl. All the chambers are visible on the dorsal side and are separated by weakly carinate, spiral sutures. The aperture forms an arch on the ventral side of the test. The wall is perforated with numerous pores.

Remarks: The aperture is usually indistinct due to poor preservation.

Range and Occurrence: First described from the middle-upper Albian of Zululand by Lambert and Scheibnerová (1974); it was also recorded by Scheibnerová (1974) at Site 259 in the Indian Ocean and by Moullade (1984) in the South Atlantic.

Suborder LAGENINA Delage and Hérouard, 1896
Superfamily ROBULOIDACEA Reuss, 1963
Family ICHTHYOLARIIDAE Loeblich and Tappan, 1986
Genus *Lingulonodosaria* A. Silvestri, 1903

Lingulonodosaria nodosaria (Reuss, 1863)
Plate 5, Figures 2-3.

Lingulina nodosaria REUSS, 1863, pl. 5, fig. 12.

Lingulina nodosaria Reuss.--SCHEIBNEROVÁ, 1976, pl. 36, fig. 1.

Lingulonodosaria nodosaria (Reuss).--MEYN and VESPERMANN, 1994, pl. 5, figs. 8-11 & pl. 6, figs. 1-3.

Description: The test is small, rectilinear and uniserial with an elliptical cross-section. The chambers, which are usually broader than high, are separated by straight, slightly depressed sutures. The aperture is a slit at the end of the last chamber.

Range and Occurrence: Aptian-Albian in eastern Australia (Scheibnerová, 1976) and Valanginian to Albian in northwestern Germany (Meyn and Vespermann, 1994).

Superfamily NODOSARIACEA Ehrenberg, 1836
Family NODOSARIIDAE Ehrenberg, 1838
Subfamily NODOSARIINAE Ehrenberg, 1838
Genus *Laevidentalina* Loeblich and Tappan, 1986

Laevidentalina distincta (Reuss, 1863)
Plate 5, Figure 4.

Dentalina distincta REUSS, 1863, pl. 2, fig. 17.

Dentalina distincta Reuss.--TAPPAN, 1962, pl. 45, fig. 18.

Laevidentalina distincta (Reuss, 1863).--MEYN and VESPERMANN, 1994, pl. 9, figs. 5-10.

Description: The test is elongate and uniserial, usually with four inflated chambers separated by inclined, slightly depressed sutures. The proloculus is large with a basal spine.

Range and Occurrence: Hauterivian to early late Albian in northwestern Germany (Meyn and Vespermann, 1994), Albian in Alaska (Tappan, 1962).

Laevidentalina cf. ***distincta*** (Reuss, 1863)

Remarks: Differs from *Laevidentalina distincta* by its less prominent proloculus which has no basal spine.

Laevidentalina gracilis (d'Orbigny, 1840)

Nodosaria gracilis D'ORBIGNY, 1840, pl. 1, fig. 7.

Dentalina gracilis (d'Orbigny).--SLITER, 1980, pl. 7, fig. 1.

Dentalina gracilis (d'Orbigny).--HAIG, 1982, pl. 1, figs. 11-12.

Description: The test is uniserial, elongate and narrow, with numerous inflated chambers separated by distinct, depressed sutures.

Range and Occurrence: Recorded in the Albian of Queensland by Haig (1982).

Laevidentalina legumen (Reuss, 1845)

Nodosaria legumen REUSS, 1845, pl. 13, Figs. 23-24.

Dentalina legumen (Reuss).--WEIDICH, 1990, pl. 39, Figs. 19, 27.

Description: The test is uniserial, elongate and very narrow, with numerous elongated chambers separated by slightly depressed sutures.

Range and Occurrence: Aptian to Late Cretaceous in the northern Alps (Weidich, 1990).

Genus *Lingulina* d'Orbigny, 1826

Lingulina lamellata Tappan, 1940

Lingulina lamellata TAPPAN, 1940, pl. 16, fig. 19.

Frondicularia lamellata (Tappan).--BARTENSTEIN and BRAND, 1951, pl. 8, figs. 200-201.

Lingulina lamellata Tappan.--HAIG, 1982, pl. 3, figs. 25-29.

Description: The test is flattened and irregularly palmate with low chambers, which are often of uneven growth in the initial part of the test. The chambers widen rapidly and are separated by curved and slightly depressed sutures. The aperture is a small, terminal slit.

Range and Occurrence: Originally described from the Cenomanian of the Gulf Coast, USA by Tappan (1940) and recorded in the Albian of Queensland by Haig (1982).

Lingulina loryi (Berthelin, 1880)

Plate 5, Figures 5-7.

Frondicularia loryi BERTHELIN, 1880, pl. 4, fig. 5.

Lingulina loryi (Berthelin).--BARTENSTEIN, BETTENSTAEDT and BOLLI, 1966, pl. 3, figs. 243-245.

Lingulina loryi (Berthelin).--RIEGRAF and LUTERBACHER, 1989, pl. 4, Figs. 1-10.

Description: The test is uniserial, elongate, compressed with lenticular cross-section. The chambers are overlapping and separated by slightly curved, depressed sutures. The aperture is an elongate, terminal slit.

Range and Occurrence: Recorded in the upper Aptian and Albian of Trinidad by Bartenstein, Bettenstaedt and Bolli (1966) and in the Lower Cretaceous of the eastern North Atlantic by Sliter (1980).

Family VAGINULINIDAE Ehrenberg, 1838

Subfamily LENTICULININAE Chapman, Parr and Collins, 1934

Genus *Lenticulina* Lamarck, 1804

Lenticulina nimbifera Espitalié and Sigal, 1963

Lenticulina nimbifera ESPITALIÉ and SIGAL, 1963, pl. 17, figs. 3-4.

Description: The test is compressed, planispiral and carinate, with a tendency to become evolute. Eight to ten chambers in the last whorl are separated by limbate, curving sutures.

Range and Occurrence: First described by Espitalié and Sigal (1963) from the Valanginian-Barremian of Majunga Basin, Madagascar.

Lenticulina subgaultina Bartenstein, 1962

Plate 5, Figure 9.

Lenticulina subgaultina BARTENSTEIN, 1962, pl. 15, figs. 1-2.

Lenticulina subgaultina Bartenstein.--BARTENSTEIN and BOLLI, 1973, pl. 4, figs. 30-31.

Lenticulina subgaultina Bartenstein.--NEAGU, 1975, pl. 49, figs. 3-17, 19, 21-22, 24, 27-28, 32.

Description: The test is planispiral, slightly evolute with an elongated last chamber. The periphery is acute and an umbonal boss is present on both sides of the test.

Range and Occurrence: A good index fossil for the Aptian-early Albian of the Boreal and Tethyan realms, according to Bartenstein and Kovatcheva (1982) and Bartenstein (1987).

Genus *Saracenaria* Defrance, 1824

Saracenaria spinosa (Eichenberg, 1935)
Plate 5, Figures 13-14.

Lenticulina spinosa EICHENBERG 1935, pl. 4, fig. 5.

Saracenaria spinosa (Eichenberg).--TAPPAN 1962, pl. 41, figs. 18-19.

Saracenaria spinosa (Eichenberg).--BARTENSTEIN and KAEVER 1973, pl. 6, fig. 94.

Saracenaria spinosa (Eichenberg).--WEIDICH 1990, pl. 42, figs. 14-15.

Remarks: Barremian specimens from Site 766 (illustrated in Holbourn and Kaminski, in press a: plate 10, figure 2) are smaller and more involute, with sharp, needle-like spines, than the Aptian-early Albian forms from Sites 766 and 260. These Aptian-early Albian forms resemble more closely Aptian specimens from Germany and from the northern Alps, illustrated by Bartenstein and Kaever (1973) and by Weidich (1990), respectively.

Range and Occurrence: The species is used by Bartenstein (1987) as a cosmopolitan index for the Aptian and earliest Albian and by King *et al.* (1989) as an index marker for the Aptian of the North Sea. Moullade (1961) and Flandrin *et al.* (1962) recorded the species from the top of the Bedoulian (rare) and through the Gargasian (common) in the Vocontian Trough.

Subfamily PALMULINAE Saidova, 1981
Genus *Palmula* Lea, 1833

Palmula malakialinensis (Espitalié and Sigal, 1963)

Neoflabellina (Falsopalmula) malakialinensis ESPITALIÉ and SIGAL, 1963, pl. 26, figs. 7-9.

Palmula malakialinensis (Espitalié and Sigal).--RIEGRAF, 1989, pl. 2, fig. 12.

Description: The test is flattened and rhomboid, initially planispiral, becoming uniserial and rectilinear. The chambers are broad and low and are separated by flush, chevron-shaped sutures. The periphery is rounded or finely carinate.

Range and Occurrence: Kimmeridgian-Barremian in California, Madagascar and western Indian Ocean (Riegraf, 1989).

Subfamily MARGINULININAE Wedekind, 1937
Genus *Astacolus* de Montfort, 1808

Astacolus parallelus (Reuss, 1863)

Plate 5, Figure 8.

Cristellaria parallela REUSS, 1863, pl. 7, figs. 1-2.

Astacolus parallelus (Reuss).--MEYN and VESPERMANN, 1994, pl. 42, figs. 16-20 & pl. 43, figs. 1-2.

Description: The test is elongate, flattened with straight or gently curved axis and near parallel sides. In the evolute portion of the test six to ten chambers are separated by straight, inclined sutures.

Remarks: Specimens from Indian Ocean sites vary in width and in degree of inflation of last chambers.

Range and Occurrence: First described from Hauterivian-Barremian of northwestern Germany by Reuss (1863).

Genus *Marginulina* d'Orbigny, 1826

Marginulina innaminckae Ludbrook, 1966

Plate 5, Figure 11.

Marginulina innaminckae LUDBROOK, 1966, pl. 9, fig. 4.

Marginulina innaminckae Ludbrook.--SCHEIBNEROVÁ, 1976, pl. 30, figs. 2-9 & textfigs. 59-60.

Marginulina innaminckae Ludbrook.--HAIG, 1982, pl. 5, figs. 1-3.

Description: The test is elongate, straight and uniserial with a large, cylindrical proloculus bearing a basal spine. There are four to six inflated chambers, which are separated by distinct, depressed sutures. Approximately 16 prominent, continuous, longitudinal costae ornament the test. The aperture is terminal, slightly offset to one side at the end of a short neck.

Remarks: Some specimens from the Great Australian Basin, illustrated by Scheibnerová (1976), have a small proloculus and a slightly coiled initial portion, probably representing a different generation of the same species. The ornamentation on these tests also appears more irregular and discontinuous.

Range and Occurrence: Rarely found in the Aptian-Albian of the Great Artesian Basin (Ludbrook, 1966). Recorded in the upper Aptian-Albian of Queensland by Haig (1982).

Genus *Vaginulinopsis* Silvestri, 1904

Vaginulinopsis harpa (Reuss, 1860)

Cristellaria harpa REUSS, 1860, pl. 10, figs. 1-2.

Lenticulina harpa (Reuss).--BARTENSTEIN, BETTENSTAEDT and BOLLI, 1966, pl. 2, figs. 1139-141.

Astacolus howchini LUDBROOK, 1966, pl. 7, fig. 27.

Vaginulinopsis harpa (Reuss).--WEIDICH, 1990, pl. 22, figs. 8, 15.

Description: The test is elongate, flattened with an elliptical cross-section and a curved axis. The last four chambers are evolute and are separated by limbate, gently curving sutures.

Range and Occurrence: Vaginulinopsis harpa was recorded in the lower to middle Albian of the northern Alps by Weidich (1990). *Astacolus howchini* was first described from the Aptian of the Great Artesian Basin by Ludbrook (1966).

Subfamily VAGINULININAE Reuss, 1860

Genus *Psilocitharella* Loeblich and Tappan, 1986

Psilocitharella paucistriata (Reuss, 1863)

Plate 5, Figures 15-16.

Vaginulina paucistriata REUSS, 1863, pl. 3, fig. 16.

Vaginulina strigillata Reuss.--CHAPMAN, 1894, pl. 8, figs. 3-4.

Vaginulina mediocarinata TEN DAM, 1950, pl. 3, fig. 3.

Psilocitharella paucistriata Reuss.--MEYN and VESPERMANN, 1994, pl. 59, figs. 11-12 & pl. 60, figs. 1-10.

Description: The test is elongate, flattened, gently flaring, with approximately seven to eight low chambers separated by oblique, limbate sutures. The test is ornamented with irregular, longitudinal ribs which are more prominent in the early portion. The test is sharply carinate along the dorsal and ventral margins.

Remarks: This species exhibits a wide range of variability (Meyn and Vespermann, 1994). The specimens from the Indian Ocean sites are generally broad, with a slightly convex dorsal margin.

Range and Occurrence: Late early Albian to late Albian in northwestern Germany (Meyn and Vespermann, 1994); late Albian in the northern Alps (Weidich, 1990).

Genus *Brunsvigella* Meyn and Vespermann, 1994

Brunsvigella angustissima Reuss, 1863

Vaginulina angustissima REUSS, 1863, pl. 3, fig. 3.

Citharina sp. B HAIG, 1982, pl. 6, figs. 18-19

Citharina sp. B HAIG and LYNCH, 1993, pl. 3, fig. 23.

Brunsvigella angustissima Reuss.--MEYN and VESPERMANN, 1994, pl. 47, figs. 1-10.

Description: The test is very long and narrow with a concave dorsal margin, a convex ventral margin and a trapezoidal cross-section. The chambers are low, inflated ventrally and separated by distinct, depressed slanting sutures. The spherical or oval proloculus bears a basal spine and the wall is ornamented by fine, longitudinal ribs.

Range and Occurrence: Citharina sp. B was recorded from the upper lower-upper Albian of Queensland (Haig, 1982). *Brunsvigella angustissima* was recorded in the upper Barremian-lower Albian of northwestern Germany (Meyn and Vespermann, 1994).

Family POLYMORPHINIDAE d'Orbigny, 1839
Subfamily POLYMORPHININAE d'Orbigny, 1839
Genus *Pyrulinoides* Marie, 1941

Pyrulinoides acuminata (d'Orbigny, 1840)

Pyrulina acuminata d'ORBIGNY, 1840, pl. 4, figs. 18-19.

Pyrulinoides acuminata (d'Orbigny).--HOFKER, 1966, pl. 4, fig. 70 & pl. 10, fig. 64.

Pyrulinoides acuminata (d'Orbigny).-- McNEIL and CALDWELL, 1981, pl. 17, fig. 17.

Description: The test is elongate, fusiform and markedly tapered at both ends. The strongly overlapping chambers increase rapidly in size and are separated by flush, oblique sutures. The aperture is terminal and radiate.

Subfamily RAMULININAE Brady, 1884
Genus *Ramulina* T.R. Jones, 1875

Ramulina tetrahedralis Ludbrook, 1966
Plate 4, Figures 7 & 10.

Ramulina tetrahedralis LUDBROOK, 1966, pl. 8, figs. 27-28.

Description: The test is globular with four stolonlike projections in a tetrahedral arrangement. The wall is hispid.

Remarks: Similar to one specimen from Guérin's collection (1981), referred to as *Ramulina laevis* Jones in Wright (1875), thereby suggesting that this taxon is not purely endemic to Australia and Indian Ocean.

Range and Occurrence: Aptian-Albian in the Great Artesian Basin (Ludbrook, 1966).

Ramulina cf. ***tetrahedralis*** Ludbrook, 1966
Plate 4, Figure 11.

Polymorphinid SCHEIBNEROVÁ, 1978^c, pl. 2, fig. 7.

Remarks: Differs from *Ramulina tetrahedralis* by having more stolons arranged irregularly. This taxon closely resembles *Ramulina globotubulosa* Cushman, 1938 (illustrated in Ten Dam, 1950: pl. 4, fig. 1).

Family ELLIPSOLAGENIDAE A. Silvestri 1923
Subfamily OOLININAE Loeblich and Tappan 1961
Genus *Oolina* d'Orbigny, 1839

Oolina globosa (Montagu, 1803)
Plate 5, Figure 10.

Vermiculum globosum MONTAGU, 1903, p. 523.

Lagena globosa (Montagu).--FUCHS, 1971, pl. 4, figs. 16, 19.

Lagena globosa (Montagu).--WEIDICH, 1990, pl. 45, figs. 9. 13.

Description: The test is unilocular, spherical to ovate, with an apicular base and a terminal aperture at the end of a short neck.

Range and Occurrence: Rare in the Lower Cretaceous of northwestern Germany (Bartenstein and Brand, 1951) and in the upper Aptian-upper Albian of the northern Alps (Weidich, 1990).

Suborder ROTALIINA Delage and Hérouard, 1896
Superfamily TURRILINACEA Cushman, 1927
Family TURRILINIDAE Cushman, 1927
Genus *Praebulimina* Cushman and Wickenden, 1928

Praebulimina nannina (Tappan, 1940)
Plate 6, Figure 6.

Bulimina nannina TAPPAN, 1940, pl. 19, fig. 4.

Praebulimina nannina (Tappan).--TAPPAN, 1962, pl. 49, figs. 6-9.

Praebulimina nannina (Tappan).--MOULLADE, 1984, pl. 3, figs. 25-26.

Praebulimina cf. *nannina* (Tappan).--HAIG, 1992, pl. 2, fig. 17.

Description: The test is small, flaring and triserial. The chambers are inflated and separated by distinct, depressed sutures. The aperture is an arch at the base of the last chamber, with a simple internal toothplate.

Range and Occurrence: Albian in Alaska (Tappan, 1962) and in the Atlantic (Moullade, 1984).

Superfamily BULIMINACEA Jones, 1875
Family SIPHOGENERINOIDIDAE Saidova, 1981
Subfamily TUBULOGENERININAE Saidova, 1981
Genus *Orthokarstenia* Dietrich, 1935

Orthokarstenia shastaensis Dailey, 1970
Plate 6, Figure 7.

Orthokarstenia shastaensis DAILEY, 1970, pl. 12, figs. 8-10.

Orthokarstenia shastaensis Dailey.--MOULLADE, 1984, pl. 4, figs. 3-4.

Description: The test is elongate, initially triserial then biserial and uniserial with a circular cross-section. The chambers are separated by distinct, depressed sutures. The aperture is terminal and round at the end of a short neck.

Range and Occurrence: Aptian-Cenomanian in California (Dailey, 1970) and in the northern Alps (Weidich, 1990).

Superfamily FURSENKOINACEA Loeblich and Tappan, 1961
Family FURSENKOINIDAE Loeblich and Tappan, 1961
Genus *Coryphostoma* Loeblich and Tappan, 1962

Coryphostoma sp. 1
Plate 6, Figure 1.

Coryphostoma sp. A HAIG, 1982, pl. 12, figs. 19-22.

Coryphostoma sp. HAIG, 1992, pl. 2, fig. 18.

Description: The test is elongate, flattened and biserial with later chambers becoming more elongated and showing a tendency to become uniserial. The sutures are distinct and slightly depressed. The aperture is areal and terminal.

Range and Occurrence: Coryphostoma sp. A was recorded in the Albian of Queensland by Haig (1982).

Superfamily PLEUROSTOMELLACEA Reuss, 1860
Family PLEUROSTOMELLIDAE Reuss, 1860
Subfamily PLEUROSTOMELLNAEA Reuss, 1860
Genus *Ellipsoidella* Heron-Allen and Earland, 1910

Ellipsoidella cf. ***cuneata*** (Loeblich and Tappan, 1946)
Plate 6, Figure 5.

Nodosarella cuneata LOEBLICH and TAPPAN, 1946, pl. 37, fig. 9.

Ellipsoidella cf. *cuneata* (Loeblich and Tappan).--HAIG, 1992, pl. 3, fig. 1.

Description: The test is elongate, initially biserial becoming uniserial with alternating chambers separated by curved, depressed sutures. The aperture is a terminal slit.

Remarks: Uncommon and often poorly preserved.

Genus *Pleurostomella* Reuss, 1860

Pleurostomella subnodosa Reuss, 1860
Plate 6, Figure 2.

Pleurostomella subnodosa REUSS, 1860, pl. 8, fig. 2.

Pleurostomella subnodosa Reuss.--BARTENSTEIN, 1978, fig. 9.

Pleurostomella gr. *subnodosa* Reuss.--MOULLADE, 1984, pl. 4, figs. 13-14.

Description: The test is elongate, with a short biserial stage and a circular cross-section. The alternating chambers of the uniserial portion are separated by straight or slightly inclined, depressed sutures. The aperture is terminal with a pair of triangular teeth and is partially covered by a hood.

Remarks: Differs from *Pleurostomella reussi* by its shorter biserial stage and straighter sutures.

Range and Occurrence: Albian and Late Cretaceous in the northern Alps; close forms are also recorded in the upper Aptian (Weidich, 1990).

Pleurostomella reussi Berthelin, 1880

Plate 6, Figures 3-4.

Pleurostomella reussi BERTHELIN, 1880, pl. 1, figs. 10-12.

Pleurostomella obtusa BERTHELIN, 1880, pl. 1, fig. 9.

Pleurostomella obtusa Berthelin.--SCHEIBNEROVÁ, 1978^c, pl. 1, figs. 25-26.

Pleurostomella reussi Berthelin.--HAIG and LYNCH, 1993, pl. 4, figs. 14-15.

Description: The test is elongate, initially biserial becoming loosely uniserial with alternating chambers. The chambers are inflated and separated by oblique, depressed sutures. The aperture is terminal with a pair of triangular teeth and is partially covered by a hood.

Range and Occurrence: Mid to late Albian in the northern Alps (Weidich, 1990). Late early to late Albian in Queensland (Haig, 1982).

Superfamily CHILOSTOMELLACEA Brady, 1881

Family QUADRIMORPHINIDAE Saidova, 1981

Genus *Quadrimorphina* Finlay, 1939

Quadrimorphina allomorphinoides (Reuss, 1860)

Plate 6, Figure 10.

Valvulina allomorphinoides REUSS, 1860, pl. 10, fig. 20.

?Discorbis sp. SCHEIBNEROVÁ, 1978^c, pl. 2, fig. 14 & pl. 3, figs. 1-3.

Conorboides minutissima (Tappan).--HAIG, 1981, pl. 2, figs. 32-33.

Quadrimorphina allomorphinoides Reuss.--MOULLADE, 1984, pl. 4, figs. 15-16.

Quadrimorphina allomorphinoides Reuss.--HAIG, 1992, pl. 3, fig. 6.

Description: The test is trochospiral, biconvex with four inflated, broad chambers in the last whorl and a lobulate periphery. The sutures are depressed, nearly radial on the umbilical side and curving back on the spiral side. The aperture is an interiomarginal slit, which extends from the umbilicus to the periphery and is covered by a large lip.

Range and Occurrence: Late Albian in the Papuan Basin (Haig, 1981), Albian at Site 766 (Haig, 1992).

Family OSANGULARIIDAE Loeblich and Tappan, 1964
Genus *Charltonina* Bermúdez, 1952

Charltonina australis Scheibnerová, 1978
Plate 6, Figures 8-9 & 11-12.

Charltonina australis SCHEIBNEROVÁ, 1978^{C}, pl. 5, figs. 2-5.

Charltonina australis Scheibnerová.--HAIG, 1992, pl. 3, figs. 12-13.

Charltonina australis Scheibnerová.--BOLLI *et al.*, 1994, figs. 43.14-16.

Description: The test is biconvex and trochospiral with a lobulate, carinate periphery and closed umbilicus. Six to eight chambers in the last whorl are separated by depressed sutures, which are curved on the umbilical face and oblique on the spiral side. The aperture is an interiomarginal slit extending from the umbilicus to the periphery.

Remarks: The umbilical and spiral sides show some variation in convexity: tests range from symmetrically biconvex to near plano-convex with flattened dorsal side.

Range and Occurrence: First described from the Cenomanian of Site 258 by Scheibnerová, (1978^{C}). Recorded in the Albian of Site 766 by Haig (1992) and in the lower Cenomanian and possibly Turonian of Trinidad (Bolli *et al.*, 1994). The occurrence of *Charltonina australis* in the upper Aptian of ODP Site 763 considerably extends the known stratigraphic range of this species.

Genus *Osangularia* Brotzen, 1940

Osangularia schloenbachi (Reuss, 1863)
Plate 6, Figures 13-15 & Plate 7, Figure 1.

Rotalia schloenbachi REUSS, 1863, pl. 10, fig. 5.

Eponides utaturensis SASTRY and SASTRI, 1966, pl. 19, fig. 6.

Osangularia californica DAILEY, 1970, pl. 13, figs. 3-4.

Osangularia utaturensis Sastry and Sastri.--SCHEIBNEROVÁ, 1978^{C}, pl. 4, figs. 5-7.

Notoplanulina? schloenbachi (Reuss).--MEYN and VESPERMANN, 1994, pl. 64, figs. 10-11 & pl. 65, figs. 1-6.

Description: The test is trochospiral, biconvex or planoconvex with a flattened ventral side and with a sharp, carinate periphery. The chambers increase gradually in size and are slightly inflated, except for the last chamber, which is generally larger and more inflated than the previous ones. The sutures are thickened, strongly curved backwards on the spiral side, but sinuate, or gently curving on the ventral face. The areal aperture is situated above a murus reflectus on the apertural face.

Remarks: Crittenden (1983) noted considerable variation in the shape of tests, the number of chambers in the last whorl, the degree of thickening along the sutures and the occurrence of an umbonal boss. He considered that these morphological variations fell within the normal range of specific variation and did not justify splitting the taxon into separate species. A similar range of morphological variations has been found in specimens from the Indian Ocean sites.

Range and Occurrence: This species is cosmopolitan in the Aptian-Albian but its distribution is strongly controlled by facies (Crittenden, 1983). For instance, it is restricted to the upper Albian in the northern North Sea and to the lower-middle Albian in the southern and central North Sea (King *et al.*, 1989). *Osangularia schloenbachi* is rarely recorded in neritic settings. It is very common in middle and lower bathyal depths (Haig and Lynch, 1993).

Family GAVELINELLIDAE Hofker, 1956
Subfamily GYROIDINOIDINAE Saidova, 1981
Genus *Gyroidinoides* Brotzen, 1942

Gyroidinoides sp.

Description: The test is trochospiral and planoconvex with a rounded periphery. The chambers are extended by apertural flaps, which partially cover the umbilicus, and are separated by radial and slightly depressed sutures. The aperture is an interiomarginal slit extending underneath the apertural flap, from the periphery to the umbilicus.

Subfamily GAVELINELLINAE Hofker, 1956
Genus *Berthelina* Malapris, 1965

Berthelina berthelini (Keller, 1935)
Plate 7, Figures 4-5.

Anomalina berthelini KELLER, 1935, pl. 3, figs. 25-27.
Anomalina berthelini TEN DAM, 1950, pl. 4, fig. 9.
Gavelinopsis berthelini (Keller).--MICHAEL, 1966, pl. 50, figs. 18-19.
Anomalinoides berthelini (Keller).--HAIG, 1982, pl. 13, figs. 6-8.

Description: The test is trochospiral, asymmetrically involute with a rounded or slightly angled periphery and approximately 10-12 chambers in the last whorl. The chambers are moderately inflated and separated by slightly depressed sutures. The chambers are extended by relict apertural flaps, partially covering the umbilicus. There is a large, elevated umbonal boss on the umbilical side, which gives the test an unequally convex appearance. A smaller umbo may also develop on the dorsal side. The aperture is interiomarginal with a lip, which extends from the periphery to the umbilicus.

Remarks: The size and prominence of the umbonal boss show some variation, suggesting the occurrence of intermediary forms between *Berthelina berthelini* and *Berthelina intermedia.*

Range and Occurrence: Late Albian in Queensland (Haig, 1982).

Berthelina cenomanica (Brotzen, 1945)

Plate 7, Figures 7-11.

Cibicides (Cibicidoides) cenomanica BROTZEN, 1945, pl. 2, fig. 2.

Gavelinopsis cenomanica (Keller).--MICHAEL, 1966, pl. 50, figs. 16-17.

Gavelinella cenomanica (Brotzen).--CARTER and HART, 1977, pl. 1, figs. 27-28.

Anomalinoides cenomanica (Brotzen).--HAIG, 1982, pl. 13, figs. 12-15.

Berthelina cenomanica (Brotzen).--HAIG and LYNCH, 1993, pl. 5, figs. 1-3.

Description: The test is trochospiral, biconvex and asymmetrically involute, with an acute periphery and approximately 10-12 chambers in the last whorl. The chambers are separated by raised, limbate sutures, which curve backwards. Both umbilical and dorsal sides may be slightly depressed in the centre. The umbilicus is only partially covered by relict apertural flaps extending from the chambers. The aperture is interiomarginal with a lip, which extends from the periphery to the umbilicus.

Remarks: On close inspection, specimens described as *Gavelinella (Berthelina)* aff. *complanata* (Reuss) by Moullade (1966) and *Gavelinella complanata* (Reuss) by Guérin (1981) were found to be very similar to *Berthelina cenomanica.* Moullade (1966) stated a late Albian range for *Gavelinella (Berthelina)* aff. *complanata* in the Vocontian Trough.

Range and Occurrence: Late Albian in Germany (Bartenstein, 1978), Queensland (Haig, 1982) and in the southern and central North Sea (King *et al.*, 1989).

Berthelina intermedia (Berthelin, 1880)

Plate 7, Figures 2-3.

Anomalina intermedia BERTHELIN, 1880, pl. 4, fig. 14.

Gavelinella intermedia (Berthelin).--BARTENSTEIN, 1954, pl. 1, figs. 21-28.

Gavelinella intermedia (Berthelin).--MICHAEL, 1966, pl. 50, figs. 4-13.

Gavelinella ex. gr. *intermedia* (Berthelin).--SCHEIBNEROVÁ, 1974, pl. 5, figs. 18-24 & pl. 6, figs. 1-4.

Gavelinella intermedia (Berthelin).--HART *et al.*, 1989, pl. 7.11, figs. 7-9.

Berthelina intermedia (Berthelin).--HAIG and LYNCH, 1993, pl. 4, figs. 26-28.

Description: The test is trochospiral, asymmetrically involute and either biconvex or plano-convex with a flattened umbilical side and approximately 10-12 chambers in the last whorl. The chambers are moderately inflated and separated by slightly depressed sutures. Relict apertural flaps extending from the chambers partially obscure the umbilicus. The aperture is interiomarginal with a lip, which extends from the periphery to the umbilicus.

Remarks: Bartenstein (1978) considered *B. intermedia* to be the precursor of *Berthelina berthelini* and *Berthelina cenomanica.*

Range and Occurrence: Aptian to Cenomanian worldwide (Bartenstein, 1977; Riegraf and Luterbacher, 1989), Albian to Cenomanian in Britain (Hart *et al.*, 1989) and Albian in the North Sea (King *et al.*, 1989) and northeastern Australia (Haig and Lynch, 1993).

Genus *Gavelinella* Brotzen, 1942

Gavelinella flandrini Moullade, 1960

Plate 7, Figure 12 & Plate 8, Figures 1-2.

Gavelinella flandrini MOULLADE, 1960, pl. 2, figs. 10-14.

Gavelinella flandrini Moullade.--FLANDRIN *et al.*, 1962, pl. 3, figs. 11-13.

Gavelinella flandrini Moullade.--MOULLADE, 1984, pl. 6, figs. 1-3.

Gavelinella flandrini Moullade.--COCCIONI and GALEOTTI, 1993, pl. 2, fig. 11.

Description: The test is trochospiral, compressed with a rounded periphery. There are usually 9 to 12 chambers in the last whorl, separated by depressed, limbate sutures, which are gently curved on the dorsal side and sinuate or more strongly curved on the ventral side. The ventral side is flattened with fused umbilical flaps partially obscuring the umbilicus. The dorsal side is slightly convex and evolute. The aperture is an interiomarginal slit bordered by a lip, which extends from the umbilicus to the periphery.

Remarks: The holotype has 12 chambers in the last whorl and is distinctly evolute on the dorsal side. Moullade (1966) noted a gradation from flattened tests in the Gargasian to more plano-convex morphotypes in the late Aptian-early Albian. Moullade (1960) proposed that *Gavelinella flandrini* evolved from *Gavelinella barremiana* in the early Aptian and gave rise to *Gavelinella intermedia* in the late Aptian.

Range and Occurrence: Gavelinella flandrini is recorded at Sites 763 and 765 and at Site 260 in the Indian Ocean, where it is relatively abundant from Core sections 260R-12-2 to 10-1. *Gavelinella flandrini* was originally described from the Drôme in France by Moullade (1960), with a stratigraphic range extending from the early Gargasian to the early Albian.

Gavelinella aff. ***barremiana*** Bettenstaedt 1952

Gavelinella barremiana BETTENSTAEDT 1952, pl. 2, figs. 26-29.

Remarks: Differs from *Gavelinella barremiana* by having fewer chambers in its last whorl (usually six to eight chambers) and by a more convex spiral side, which gives the test its distinctive plano-convex profile. This species is recorded in the upper Hauterivian at Sites 249 and 766, where it appears to precede *Gavelinella barremiana.*

Gavelinella sp. 1

Plate 8, Figures 3 & 6.

Planulina sp. HAIG, 1981, pl. 3, figs. 12-13.

Gavelinella cf. *andersoni* (Church).--HAIG, 1992, pl. 4, figs. 1-2.

Description: The test is trochospiral with gently convex, evolute, dorsal side and flattened, involute, ventral side. There are eight to ten moderately inflated chambers in the last whorl, which are separated by slightly raised, curved sutures. The aperture is an interiomarginal slit bordered by a lip, which extends from the umbilicus to the periphery.

Remarks: Differs from *Gavelinella andersoni,* originally described by Church (1968), by its smaller size and more numerous chambers, which are separated by curving sutures.

Range and Occurrence: Planulina sp. was recorded from the upper Albian of the Papuan Basin by Haig (1981) and *Gavelinella* cf. *andersoni* from the Aptian-Albian of Site 766 by Haig (1992).

Gavelinella sp. 2

Plate 8, Figures 4-5.

Oristhotella sp. A HAIG, 1982, pl. 3, figs. 9-11.

Gavelinella sp. B HAIG, 1992, pl. 4, figs. 11-12.

Description: The test is trochospiral, planoconvex with a rounded periphery. The dorsal side is gently convex, evolute with a central depression. The ventral side is flat with fused apertural flaps partially covering the umbilicus. The chambers are moderately inflated and separated by slightly depressed sutures, curved on the dorsal side and radial on the umbilical face. The aperture is an interiomarginal slit bordered by a lip, which extends from the umbilicus to the periphery.

Range and Occurrence: Late early to late Albian in Queensland (Haig, 1982), late Aptian to mid Albian at Site 766 (Haig, 1992).

Genus *Gyroidina* d'Orbigny, 1826

Gyroidina gracillima (Ten Dam, 1947)

Plate 8, Figures 9 & 12.

Valvulineria gracillima TEN DAM, 1947, textfig. 4.

Pullenia sp. SCHEIBNEROVÁ, 1978^{c}, pl. 4, fig. 1.

Valvulineria sp. A HAIG, 1982, pl. 12, figs. 31-32.

Valvulineria gracillima Ten Dam.--WEIDICH, 1990, pl. 46, figs. 13-15.

Valvulineria infracretacea (Morozova).--WEIDICH, 1990, pl. 46, figs. 7-9, 19-21.

Serovaina gracillima (Ten Dam).--HAIG, 1992, pl. 3, fig. 7.

Description: The test is trochospiral, fully evolute and flattened on the spiral side, involute and convex on the umbilical side with a faintly lobulate, rounded periphery. Six to eight chambers in the last whorl are moderately inflated and separated by radial, slightly depressed sutures. The last chamber is higher than the previous ones, making the test slightly longer than broad. The aperture is an interiomarginal slit with a narrow lip, which extends from the periphery to about halfway to the umbilicus.

Remarks: There is some variation in the convexity of the test and the length of the apertural slit.

Range and Occurrence: Common in the Albian of the Netherlands, France and England (Ten Dam, 1950) and in the upper Albian of Queensland (Haig, 1982), the northern Alps (Weidich, 1990) and Site 766 (Haig, 1992).

Gyroidina infracretacea Morozova, 1948

Plate 8, Figures 10-11.

Gyroidina nitida Reuss var. *infracretacea* MOROZOVA, 1948, pl. 2, figs. 12-14.

Valvulineria crespinae LUDBROOK, 1966, pl. 12, figs. 1-6.

Gyroidinoides cf. *primitiva* Hofker.--SCHEIBNEROVÁ, 1974, pl. 5, figs. 10-12 & pl. 11, fig. 6.

Valvulineria loetterlei Tappan.--SCHEIBNEROVÁ, 1978^{c}, pl. 3, figs. 5-6.

Gyroidina sp. SCHEIBNEROVÁ, 1978^{c}, pl. 9, fig. 9.

Valvulineria crespinae Ludbrook.--HAIG, 1981, pl. 3, figs. 10-11.

Gyroidinoides aff. *nitida* (Reuss).--RIEGRAF and LUTERBACHER, 1989, pl. 5, figs. 7-9.

Valvulineria loetterlei Tappan.--RIEGRAF and LUTERBACHER, 1989, pl. 5, figs. 3-6, 10-12.

Gyroidina aff. *nitida* (Reuss).--WEIDICH, 1990, pl. 27, figs. 22-35 & pl. 46, figs. 27-29.

Serovaina infracretacea (Morozova).--HAIG, 1992, pl. 3, figs. 8-9.

Gyroidinoides infracretaceus (Morozova).--HAIG and LYNCH, 1993, pl. 4, figs. 16-18.

Description: The test is trochospiral, fully evolute and flattened on the spiral side, involute and strongly convex on the umbilical side with angled periphery and round outline. There are six to seven inflated chambers in the last whorl, which are separated by gently curved, depressed sutures radiating from a closed umbilicus. The last chamber is larger and more inflated than the previous ones. The aperture is an interiomarginal slit, with a narrow lip and extends from the periphery to about halfway to the umbilicus.

Remarks: A broad taxonomic definition is adopted here as the taxon encompasses a range of morphotypes, which vary in size, degree of inflation of the last chamber and length of the apertural slit. This wide range of variation probably accounts for the confused taxonomic status of this species in the literature. Some morphotypes may be stratigraphically useful within limited geographical areas.

Range and Occurrence: This is a cosmopolitan species widely recorded from the Aptian to the Cenomanian.

Gyroidina aff. ***infracretacea*** Morozova, 1948

Plate 8, Figures 7-8.

Remarks: The test is gently convex dorsally, less inflated ventrally than *G. infracretacea.* with more distinct and thickened sutures. This taxon is recorded in Aptian sediments at Sites 260, 762 and 763.

Genus *Lingulogavelinella* Malapris, 1965

Lingulogavelinella indica (Scheibnerová, 1974)

Plate 9, Figures 1-4.

Oristhotella indica SCHEIBNEROVÁ, 1974, pl. 7, figs. 4, 8-13, pl. 8, figs. 1-9 & pl. 11, fig. 9.

Oristhotella indica Scheibnerová.--SCHEIBNEROVÁ, 1978^b pl. 3, figs. 9-10, 14-16.

Lingulogavelinella indica (Scheibnerová).--HAIG and LYNCH, 1993, pl. 5, figs. 7-9.

Description: The test is trochospiral, biconvex to plano-convex, slightly evolute dorsally and involute ventrally. The periphery is rounded and faintly lobulate. Six to eight chambers in the last whorl are separated by slightly depressed radial sutures. The umbilicus is masked by large umbilical flaps, which are strongly overlapping and form a distinctive stellate pattern on the ventral side. The aperture is an interiomarginal arch which is bordered by a narrow lip and extends underneath the apertural flap, from the periphery to the umbilicus.

Range and Occurrence: Originally described from the Albian of the Indian Ocean by Scheibnerová (1974), it was subsequently recorded in the Albian-Cenomanian of India by Narayanan and Scheibnerová (1975), the Albian of the Atlantic by Scheibnerová (1978^b) and the upper lower-lower middle Albian of Queensland by Haig (1982).

Lingulogavelinella sp. 1

Plate 9, Figures 5-6.

Planulina sp. QUILTY, 1984, fig. 6A, B.

Gavelinella sp. 1 MOULLADE, 1984, pl. 6, figs. 4-5.

Gavelinella sp. A HAIG, 1992, pl. 4, figs. 6-8.

Description: The test is trochospiral, very flattened with 10-14 chambers in the last whorl, separated by limbate sutures, which curve strongly backwards. Large, imbricate, umbilical flaps form a distinctive stellate pattern on the ventral side. The aperture is an interiomarginal slit bordered by a narrow lip, which extends from the umbilicus to the periphery.

Range and Occurrence: Planulina sp. was recorded in the Aptian? and Cenomanian of the Exmouth Plateau by Quilty (1984). *Gavelinella* sp. 1 occurred in the upper

Albian of the South Atlantic (Moullade, 1984) and *Gavelinella* sp. A in the upper Aptian-mid Albian of Site 766 (Haig, 1992).

Genus *Scheibnerova* Quilty, 1984

Scheibnerova protindica Quilty, 1984
Plate 9, Figures 7-10.

Scheibnerova protindica QUILTY, 1984, figs. 5A-K.

Scheibnerova protindica Quilty.--HAIG, 1992, pl. 4, figs. 5, 9-10.

Description: The test is trochospiral with a gently curved ventral face, strongly convex spiral side and faintly lobulate periphery. There are five to six chambers in the last whorl bearing some large, irregular pores on the ventral side. The chambers are extended by umbilical flaps, which form a stellate pattern over the umbilicus. They are separated by slightly depressed sutures, which are gently arched ventrally but curve strongly backwards on the dorsal side. The spiral face is ornamented by dense, short, blunt spines; a hispid peripheral band may also surround the test. The aperture is an interiomarginal slit extending halfway from the umbilicus to the periphery.

Range and Occurrence: First described from the lower Cenomanian of the Exmouth Plateau by Quilty (1984). Recorded in the upper Albian of Site 766 by Haig (1992).

Suborder GLOBIGERININA Delage and Hérouard, 1896
Genus *Praehedbergella* Gorbachik and Moullade, 1973

Praehedbergella sigali (Moullade, 1966)

Hedbergella sigali MOULLADE, 1966, pl. 7, figs. 20-25.

Hedbergella sigali Moullade.--CARON, 1985, pl. 25, figs. 21-22.

Genus *Blefuscuiana* Banner and Desai, 1988

Blefuscuiana aptiana (Bartenstein, 1965)

Hedbergella aptiana BARTENSTEIN, 1965, text-figs. 3-6.

Blefuscuiana aptiana (Bartenstein).--BANNER and DESAI, 1988, pl. 5, figs. 1-3.

Blefuscuiana aptica (Agalarova, 1951)

Globigerina aptica AGALAROVA (in Dzhafarov*et al.*, 1951). pl. 8, figs. 9-11.

Globigerina infracretacea Glaessner subsp. *gargasiana*.--MOULLADE, 1961, p. 214.

Blefuscuiana aptica (Agalarova).--BANNER and DESAI, 1988, pl. 5, figs. 4-7.

Blefuscuiana gorbachikae (Longoria, 1974)

Hedbergella gorbachikae LONGORIA, 1974, pl. 15, figs. 1-16.

Blefuscuiana gorbachikae (Longoria).--BANNER and DESAI, 1988, pl. 5, figs. 8-12.

Blefuscuiana infracretacea (Glaessner, 1937)

Hedbergella infracretacea GLAESSNER, 1937, text-fig. 1.

Hedbergella infracretacea Glaessner.--RISCH, 1971, pl. 4, figs. 1-3.

Genus *Blowiella* Kretzchmar and Gorbachik, 1971

Blowiella gottisi (Chevalier, 1961)

Globigerinella gottisi CHEVALIER, 1961, pl. 1, fig. 9.

Globigerinelloides gottisi (Chevalier).--LONGORIA, 1974, pl. 7, figs. 10-13.

Genus *Globogerinelloides* Cushman and Ten Dam, 1948

Globigerinelloides ferreolensis (Moullade, 1961)

Biticinella ferreolensis MOULLADE, 1961, pl. 1, figs. 1-5.

Globigerinelloides ferreolensis (Moullade).--CARON, 1985, pl. 29, 12-13.

Globigerinelloides ferreolensis (Moullade).--BANNER and DESAI, 1988, pl. 9, fig. 9.

Genus *Hedbergella* Brönnimann and Brown, 1958

Hedbergella planispira (Tappan, 1940)

Globigerina planispira TAPPAN, 1940, pl. 9, fig. 12.

Hedbergella planispira (Tappan).--BANNER and DESAI, 1988, pl. 3, figs. 8-9

Hedbergella punctata Michael, 1972

Hedbergella punctata MICHAEL, 1972, pl. 3, figs. 1-3 & pl. 7, figs. 1-2.

Hedbergella punctata Michael.--PLAYFORD *et al.*, 1975, pl. 2, figs. 6-9.

Hedbergella rischi Moullade, 1974

Hedbergella aff.*infracretacea* MOULLADE, 1966, pl. 8, figs. 6-7.

Hedbergella rischi MOULLADE, 1974, p. 1815.

Hedbergella rischi Moullade.--GUERIN, 1981, pl. 7, figs. 16-18.

Genus *Ticinella* Reichel, 1950

Ticinella primula Luterbacher, 1963

Ticinella primula LUTERBACHER (in Renz *et al.*, 1963), text-fig. 4.

Ticinella primula Luterbacher.--WEIDICH, 1990, pl. 61, figs. 12-14, 20--22.

Genus *Rotalipora* Brotzen, 1942

Rotalipora appenninica (Renz, 1936)

Globotruncana appenninica RENZ, 1936, text-fig. 2.

Rotalipora appenninica (Renz).--CARON, 1985, pl. 31, figs. 1-4.

Rotalipora ticinensis (Gandolfi, 1942)

Globotruncana ticinensis GANDOLFI, 1942, pl. 2, fig. 3, pl. 4, figs. 10-11, 23, pl. 5, figs. 2, 4, pl. 8, figs. 4-7, pl. 12, fig. 1 & pl. 13, figs. 11, 12, 14.

Rotalipora ticinensis (Gandolfi).--CARON, 1985, pl. 31, figs. 3-4.

Genus *Praeglobotruncana* Bermudez, 1952

Praeglobotruncana delrioensis (Plummer, 1931)

Globotruncana delrioensis PLUMMER, 1931, pl. 13, fig. 2.

Praeglobotruncana delrioensis Plummer.--CARON, 1985, pl. 30, figs. 1-2.

Genus *Planomalina* Loeblich and Tappan, 1946

Planomalina praebuxtorfii Wonders, 1975

Planomalina praebuxtorfii WONDERS, 1975, pl. 1, figs. 1-2.

Planomalina praebuxtorfii Wonders.--WEIDICH, 1990, pl. 53, figs. 7-8.

Genus *Schackoina* Thalmann, 1932

Schackoina cenomana (Schacko, 1897)

Siderolina cenomana SCHACKO, 1897, pl. 4, figs. 3-5.

Schackoina cenomana (Schacko).--CARON, 1985, pl. 35, figs. 5-9.

Appendix 6.1. Agglutinated taxa from DSDP and ODP sites of the Indian Ocean.

Aaptotoichus challengeri (b)
Aaptotoichus clavellatus (b)
Ammobaculites crespinae (b)
Ammobaculites sp. 1 (b)
Ammobaculoides sp. (b)
Ammodiscus cretaceus (a)
Ammodiscus infimus (b)
Ammodiscus tenuissimus (a)
Ammodiscus sp. 1 (b)
Ammosphaeroidina sp. (b)
?Arenobulimina sp. (b)
Aschemocella sp. (b)
Bathysiphon brosgei (a)
Bimonilina engeniensis
Bimonilina variana
Bimonilina cf. *variana* (b)
Bulbobaculites humei (b)1
Bulbobaculites inconstans (a)
Bulbobaculites cf. *inconstans* (b)
Cribrostomoides nonioninoides (b)
Dorothia sp. 1 (a)
Evolutinella perturbans (b)
Gaudryina dividens 2
Gaudryina cf. *dividens*
"Gaudryina"cuvierensis (b)
Gaudryinopsis gradata
Gaudryinopsis cf. *gradata*
"Gaudryinopsis" pseudobettenstaedti (b)
Gaudryinopsis cf. *gradata*
Glomospira charoides (a)
Glomospira gordialis (a)
Glomospira irregularis
Glomospirella gaultina (a)
Haplophragmoides hagni (b)
Haplophragmoides minor
Haplophragmoides concavus (a)
Haplophragmoides kirki (a)
Haplophragmoides cf. *vocontianus* (a)
Haplophragmoides cf. *howardense*
Haplophragmoides sp. 1
Haplophragmoides sp. 2
Heterantyx cretosa
Hippocrepina depressa (b)
Hippocrepina gracilis (b)
Hyperammina gaultina (b)
Kalamopsis grzybowskii (a)
Kutsevella implanus (a)3
Lagenammina aff. *alexanderi* (b)
Lituotuba sp. (b)
Marssonella oxycona
Nothia robusta (b)
Paratrochamminoides spp. (b)
Praedorothia ouachensis 4
Praedorothia praeoxycona
Psammosphaera fusca
Psammosphaera cf. *fusca* (b)5
Psammosphaera sp. 1
Pseudoreophax sp. 1 (b)
Recurvoides cf. *obskiensis* (b)
Recurvoides sp. 1
Recurvoides spp. (b)
Remesella sp. 1
Reophax geniculatus
Reophax cf. *geniculatus*
Reophax sp. 1 (b)
Reophax sp. 2 (b)
Reophax sp. 3
Rhabdammina cylindrica (a)
Rhabdammina spp. (b)
Rhizammina algaeformis (a)
Rhizammina spp. (b)
Saccammina crespinae (c)
Saccammina lagenoides (b)
Saccammina scruposa (b)
Spiroplectammina sp. 1 (b)
Spiroplectinella gandolfii
Spiroplectinella sp.
Subreophax sp. 1 (b)
"Textularia" bettenstaedti (a)
"Textularia" sp. 1 (b)
"Textulariopsis" cushmani
"Textulariopsis" elegans (b)
"Textulariopsis" wilgunyaensis
"Textulariopsis" sp. 1
"Textulariopsis" sp. 2
Tritaxia gaultina
Thalmannammina spp. (b)
Trochammina abrupta (b)
Trochammina depressa (b)
Trochammina ribstonensis (b)
Trochammina subinflata (b)
Trochammina sp. 1 (a)
Trochammina sp. 2 (a)
Verneuilina howchini (b)
Verneuilina sp. 1 (a)
Verneuilinoides neocomiensis (b)
Verneuilinoides subfiliformis (a)
Verneuilinoides aff. *crespinae* (b)
Verneuilinulla sp. 1 (b)
Verneuilinulla sp. 2 (b)

Notes for Appendix A:
(a) described in Holbourn and Kaminski, in press a
(b) described in Holbourn and Kaminski, in press b
(c) described in Holbourn and Kaminski, in press c
1 as *Bulbobaculites* sp. 1 in (a)
2 as *Pseudogaudryinella* sp. 1 in (b)
3 as *Ammobaculites* sp. 1 in (a)
4 as *Pseudogaudryinella* sp. 1 in (a)
5 as *Psammosphaera* sp. 1 in (b).

Appendix 6.2. Calcareous taxa from DSDP and ODP sites of the Indian Ocean.

Astacolus calliopsis (a)
Astacolus parallelus
Astacolus schloenbachi (a)
Berthelina berthelini
Berthelina cenomanica
Berthelina intermedia
Brunsvigella angustissima
Brunsvigella thoerensis (a)
Bullopora sp. (b)
Charltonina australis
Citharina harpa (b)
Citharina rudocosta (a)
Citharina sp. 1 (a)
Coryphostoma sp. 1
Ellipsoidella cf. *cuneata*
Eoguttulina ichnusae (a)
Fissurina cf. *laevigata* (a)
Frondicularia bettenstaedti (a)
Frondicularia hastata (a)
Gavelinella aff. *barremiana* 1
Gavelinella barremiana (a)
Gavelinella flandrini
Gavelinella sigmoicosta? (a)
Gavelinella sp. 1
Gavelinella sp. 2
Globulina bucculenta (a)
Globulina lacrima (a)
Globulina prisca (a)
Gyroidina gracillima
Gyroidina infracretacea
Gyroidina aff. *infracretacea*
Gyroidinoides sp.
Laevidentalina communis (a)
Laevidentalina debilis (a)
Laevidentalina distincta
Laevidentalina cf. *distincta*
Laevidentalina gracilis
Laevidentalina legumen
Laevidentalina nana (a)
Laevidentalina oligostegia (a)
Laevidentalina soluta (a)
Lenticulina circumcidanea (a)
Lenticulina guttata (a)
Lenticulina heiermanni (a)
Lenticulina macrodisca (a)
Lenticulina muensteri (a)
Lenticulina nimbifera
Lenticulina nodosa (a)
Lenticulina ouachensis (a)
Lenticulina pulchella (a)
Lenticulina saxocretacea (a)
Lenticulina subangulata (a)
Lenticulina subgaultina
Lenticulina cf. *schreiterei* (a)
Lenticulina cf. *subgaultina* (a)
Lingulina lamellata
Lingulina loryi
Lingulina sp. 1 (a)
Lingulogavellinella indica
Lingulogavelinella sp. 1
Lingulonodosaria nodosaria
Marginulina bullata (a)
Marginulina inaequalis (a)
Marginulina innaminckae
Marginulina pyramidilis (a)
Marginulina sp. 1 (a)
Marginulinopsis bettenstaedti (a)
Marginulinopsis comma (a)
Marginulinopsis gracilissima (a)
Marginulinopsis parkeri (a)
Nodosaria cf. *regularis* (a)
Oolina apiculata
Oolina caudata (a)
Oolina aff. *oxystoma* (a)
Oolina globosa
Oolina hauteriviana (a)
Oolina laevis (a)
Oolina sulcata (a)
Oolina cf. *sulcata* (a)
Orthokarstenia shastaensis
Osangularia schloenbachi
Palaeopolymorphina sp. 1 (a)
Palmula malakialinensis
Palmula sp. 1 (a)
Patellina africana.
Patellina subcretacea (a)
Planularia complanata (a)
Planularia crepidularis (a)
Pleurostomella reussi
Pleurostomella subnodosa
Praebulimina nannina
Pseudonodosaria humilis (a)
Pseudonodosaria mutabilis (a)
Pseudonodosaria cf. *tenuis* (a)
Psilocitharella arguta (a)
Psilocitharella kochii (a)
Psilocitharella recta (a)
Psilocitharella paucistriata
Pyramidulina lagenoides (a)
Pyramidulina obscura (a)
Pyramidulina sceptrum (a)
Pyramidulina zippei (a)
Pyramidulina cf. *bactriodes* (a)
Pyramidulina cf. *corallina* (a)
Pyramidulina sp. (a)
Pyrulina cylindroides (a)
Pyrulinoides acuminata
Quadrimorphina allomorphinoides
Ramulina aptiensis (a)
Ramulina tappanae (a)
Ramulina tetrahedralis
Ramulina cf. *tetrahedralis*
Saracenaria compacta (a)
Saracenaria erlita (a)
Saracenaria forticosta (a)
Saracenaria frankei (a)
Saracenaria pravoslavlevi (a)
Saracenaria spinosa
Saracenaria triangularis (a)
Saracenaria valanginiana (a)
Saracenaria sp. 1 (a)
Saracenaria sp. 2 (a)
Scheibnerova protindica
Spirillina minima (a)
Tristix acutangula (a)
Tristix excavata (a)
Vaginulina petila (a)
Vaginulinopsis excentrica (a)
Vaginulinopsis harpa
Vaginulinopsis humilis (a)
Vaginulinopsis neopachynota (a)
Vaginulinopsis reticulosa (a)

Notes for Appendix B: (a) described in Holbourn and Kaminski, in press a
(b) described in Holbourn and Kaminski, in press b
1 as *Reinholdella hofkeri* in (a).

PLATE 1

1 *Psammosphaera fusca* Schulze, (x95), Sample 259-33R-1; 66-70cm.

2 *Psammosphaera fusca* Schulze, (x100), Sample 259-33R-1; 66-70cm.

3 *Psammosphaera* sp. 1, (x110), Sample 258-10R-1; 119-123cm.

4 *Reophax* sp. 3, (x70), Sample 259-33R-1; 66-70cm.

5 *Reophax* sp. 3, (x115), Sample 259-33R-1; 66-70cm.

6 *Bulbobaculites humei* (Nauss), (x100), Sample 258-23R-2; 63-67cm.

7 *Bulbobaculites humei* (Nauss), (x100), Sample 257-8R-1; 96-100cm.

8 *Haplophragmoides minor* (Nauss), (x105), Sample 258-20R-1; 128-132cm.

9 *Haplophragmoides minor* (Nauss), (x130), Sample 258-21R-2; 61-65cm.

10 *Cribrostomoides nonioninoides*, (Reuss), (x105), Sample 258-21R-1; 97-101cm.

11 *Haplophragmoides* cf. *howardense* Stelck and Wall, (x150), Sample 258-9R-3; 92-96cm.

12a, 12b *Recuvoides* sp., (x130, x130), Sample 256-8R-1; 132-136cm.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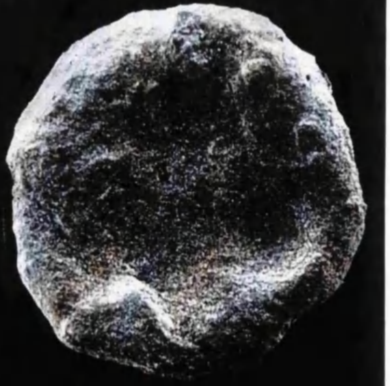
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PLATE 2

1	*Haplophragmoides* sp. 2, (x105), Sample 256-8R-1; 132-136cm.
2	*Ammosphaeroidina* sp., (x105), Sample 257-7R-2; 130-134cm.
3	*Ammosphaeroidina* sp., (x130), Sample 258-23R-2; 63-67cm.
4	*Heterantyx cretosa* (Ten Dam), (x105), Sample 257-7R-5; 46-50cm.
5	*Heterantyx cretosa* (Ten Dam), (x110), Sample 766-17R-3; 43-46cm.
6	*Heterantyx cretosa* (Ten Dam), (x100), Sample 766-18R-4; 98-100cm.
7	*Heterantyx cretosa* (Ten Dam), (x100), Sample 766-18R-4; 98-100cm.
8	*Spiroplectinella gandolfii* (Carbonnier), (x130), Sample 256-8R-3; 141-145cm.
9	*Spiroplectinella gandolfii* (Carbonnier), (x130), Sample 256-8R-3; 141-145cm.
10	*Heterantyx cretosa* (Ten Dam), (x85), Sample 766-19R-1; 68-72cm.
11a, 11b	*Spiroplectinella* sp., (x170), Sample 766-16R-3; 32-36cm.
12	*"Textulariopsis"* sp. 2, (x130, x130), Sample 257-9R-1; 144-148cm.


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PLATE 3

1 *Remesella* sp. 1, (x80), Sample 766-20R-1; 39-42cm.

2 *Gaudryinopsis gradata* (Berthelin), (x100), Sample 260-10R-2; 132-136cm.

3 *Gaudryinopsis* sp., (x115), Sample 258-23R-2; 63-67cm.

4 *Praedorothia ouachensis* (Sigal), (x50), Sample 260-18R-1; 127-131cm.

5 *Praedorothia ouachensis* (Sigal), (x110), Sample 260-18R-1; 127-131cm.

6 *Praedorothia praeoxycona* (Moullade), (x130), Sample 260-12R-2; 132-135cm.

7 *Praedorothia praeoxycona* (Moullade), (x65), Sample 260-12-1; 83-87cm.

8 *Gaudryina dividens* Grabert, (x130), Sample 766-19R-3; 29-33cm.

9 *Gaudryina dividens* Grabert, (x65), Sample 766-19R-1; 68-72cm.

10 *Gaudryina* cf. *dividens* Grabert, (x50), Sample 260-10R-1; 34-38cm.

11 *Tritaxia gaultina* (Morozova), (x65), Sample 259-15R-1; 86-90cm.

12 *Tritaxia gaultina* (Morozova), (x65), Sample 766-17R-3; 43-46cm.

13 *Tritaxia gaultina* (Morozova), (x65), Sample 766-19R-3; 29-33cm.

14 *Tritaxia gaultina* (Morozova), (x85), Sample 766-17R-2; 130-133cm.

15 *Tritaxia gaultina* (Morozova), (x50), Sample 257-7R-5; 46-50cm.


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PLATE 4

1 *Ammodiscus infimus* Franke, (x85), Sample 256-8R-3; 141-145cm.

2 *Ammodiscus cretaceus* (Reuss), (x45), Sample 258-23R-2; 63-67cm.

3 *Glomospira charoides* (Jones and Parker), (x130), Sample 259-28R-3; 52-56cm.

4 *Glomospira irregularis* (Grzybowski), (x100), Sample 258-21R-2; 61-65cm.

5 *Bimonilina engeniensis* (Ludbrook), (x105), Sample 257-7R-3; 86-90cm.

6 *Bimonilina engeniensis* (Ludbrook), (x65), Sample 258-23R-2; 63-67cm.

7 *Ramulina tetrahedralis* Ludbrook, (x140), Sample 259-16R-2; 33-37cm.

8 *Bimonilina variana* Eicher, (x130), Sample 766-24R-1; 111-113cm.

9 *Pseudoreophax* sp., (x130), Sample 258-21R-2; 61-65cm.

10 *Ramulina tetrahedralis* Ludbrook, (x130), Sample 259-20R-1; 33-37cm.

11 *Ramulina* cf. *tetrahedralis* Ludbrook, (x75), Sample 259-17R-2; 10-14cm.

12 *Ramulina tappanae* Bartenstein and Brand (x65), Sample 259-16R-2; 33-37cm.


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PLATE 5

1 *Patellina africana* Lambert and Scheibnerová., (x65), Sample 766-25R-1; 3-5cm.

2 *Lingulonodosaria nodosaria* (Reuss), (x100), Sample 766-17R-2; 130-133cm.

3 *Lingulonodosaria nodosaria* (Reuss), (x55), Sample 259-15R-1; 86-90cm.

4 *Laevidentalina distincta* (Reuss), (x100), Sample 259-15R-5; 40-44cm.

5 *Lingulina loryi* (Berthelin), (x160), Sample 766-20R-3; 20-24cm.

6 *Lingulina loryi* (Berthelin), (x130), Sample 766-20R-3; 20-24cm.

7 *Lingulina loryi* (Berthelin), (x130), Sample 766-19R-1; 68-72cm.

8 *Astacolus parallelus* (Reuss), (x65), Sample 766-18R-4; 98-100cm.

9 *Lenticulina subgaultina* Bartenstein, (x130), Sample 766-21R-1; 39-43cm.

10 *Oolina globosa* (Montagu), (x110), Sample 259-14R-2; 114-118cm.

11 *Marginulina innaminckae* Ludbrook, (x65), Sample 259-15R-3; 135-139cm.

12 *Laevidentalina debilis* (Berthelin), (x65), Sample 260-10R-1; 34-38cm.

13 *Saracenaria spinosa* (Eichenberg), (x70), Sample 260-10R-1; 34-38cm.

14 *Saracenaria spinosa* (Eichenberg), (x65), Sample 227-7R-1; 116-120cm.

15 *Psilocitharella paucistriata* (Reuss), (x65), Sample 227-7R-1; 116-120cm.

16 *Psilocitharella paucistriata* (Reuss), (x65), Sample 227-7R-1; 116-120cm.


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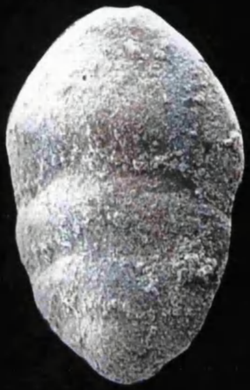
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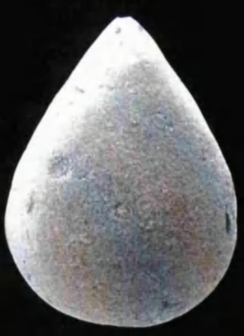
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PLATE 6

1 *Coryphostoma* sp. 1, (x130), Sample 259-15R-3; 135-139cm.

2 *Peurostomella subnodosa* Reuss, (x55), Sample 259-15R-3; 135-139cm.

3 *Peurostomella reussi* Berthelin, (x45), Sample 766-20R-1; 39-43cm.

4 *Peurostomella reussi* Berthelin, (x60), Sample 766-20R-1; 39-43cm.

5 *Ellipsoidella* cf. *cuneata* Loeblich and Tappan, (x100), Sample 766-20R-3; 20-24cm.

6 *Praebulimina nannina* Tappan, (x300), Sample 256-8R-3; 141-145cm.

7 *Orthokarstenia shastaensis* Dailey, (x160), Sample 260-12R-1; 83-87cm.

8 *Charltonina australis* Scheibnerová, (x165), Sample 766-16R-5; 32-36cm.

9 *Charltonina australis* Scheibnerová, (x165), Sample 766-16R-5; 32-36cm.

10 *Quadrimorphina allomorphinoides* (Reuss), (x130), Sample 259-15R-5; 40-44cm.

11 *Charltonina australis* Scheibnerová, (x170), Sample 766-16R-3 32-36cm.

12 *Charltonina australis* Scheibnerová, (x165), Sample 766-17R-5; 2-3cm.

13 *Osangularia schloenbachi* (Reuss), (x120), Sample 259-16R-3; 103-107cm.

14 *Osangularia schloenbachi* (Reuss), (x120), Sample 258-15R-2; 42-46cm.

15 *Osangularia schloenbachi* (Reuss), (x120), Sample 258-15R-2; 42-46cm.

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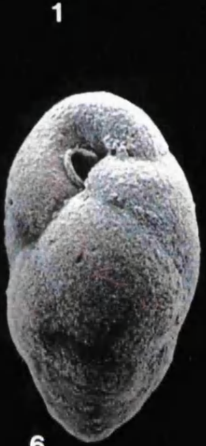

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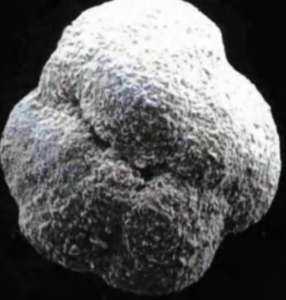

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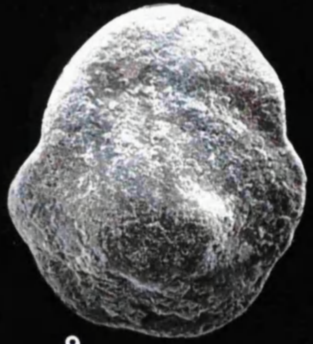

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PLATE 7

1 *Osangularia schloenbachi* (Reuss), (x150), Sample 766-20R-1; 39-43cm.

2 *Berthelina intermedia* (Berthelin), (x100), Sample 256-8R-5; 32-36cm.

3 *Berthelina intermedia* (Berthelin), (x130), Sample 259-16R-2; 33-37cm.

4 *Berthelina berthelini* (Keller), (x120), Sample 258-15R-2; 42-46cm.

5 *Berthelina berthelini* (Keller), (x105), Sample 258-15R-2; 42-46cm.

6 *Berthelina cenomanica* (Brotzen), (x110), Sample 258-14R-1; 79-83cm.

7 *Berthelina cenomanica* (Brotzen), (x105), Sample 258-14R-1; 79-83cm.

8 *Berthelina cenomanica* (Brotzen), (x160), Sample 766-19R-2; 29-33cm.

9 *Berthelina cenomanica* (Brotzen), (x110), Sample 258-14R-1; 79-83cm.

10 *Berthelina cenomanica* (Brotzen), (x80), Sample 259-13R-2; 54-58cm.

11 *Berthelina cenomanica* (Brotzen), (x85), Sample 258-15R-2; 42-46cm.

12 *Gavelinella flandrini* Moullade, (x170), Sample 260-12R-1; 83-87cm.


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PLATE 8

1 *Gavelinella flandrini* Moullade, (x130), Sample 260-10R-2; 132-136cm.

2 *Gavelinella flandrini* Moullade, (x130), Sample 260-10R-2; 132-136cm.

3 *Gavelinella* sp. 1, (x115), Sample 766-25R-1; 3-5cm.

4 *Gavelinella* sp. 2, (x65), Sample 766-21R-1; 39-43cm.

5 *Gavelinella* sp. 2, (x100), Sample 766-21R-1; 39-43cm.

6 *Gavelinella* sp. 1, (x115), Sample 766-25R-1; 3-5cm.

7 *Gyroidina* aff. *infracretacea* Morozova, (x115), Sample 260-10R-1; 34-38cm.

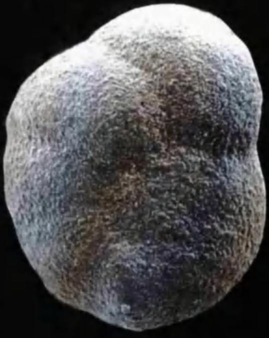
8 *Gyroidina* aff. *infracretacea* Morozova, (x130), Sample 260-10R-1; 34-38cm.

9 *Gyroidina gracillima* (Ten Dam), (x200), Sample 259-15R-3; 135-139cm.

10 *Gyroidina infracretacea* Morozova, (x65), Sample 257-18R-2; 114-118cm.

11 *Gyroidina infracretacea* Morozova, (x85), Sample 259-15R-3; 135-139cm.

12 *Gyroidina gracillima* (Ten Dam), (x180), Sample766-16R-1; 32-36cm.



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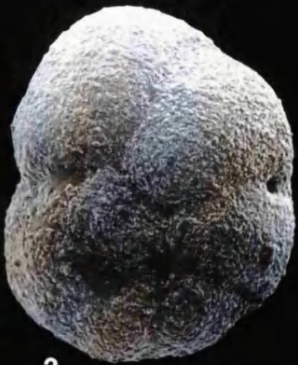

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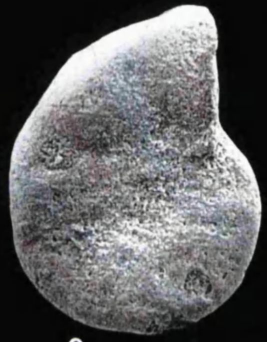

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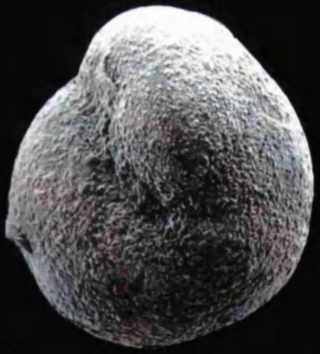

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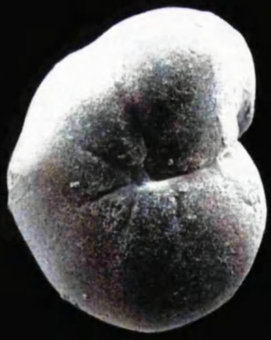

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PLATE 9

1a, 1b	*Lingulogavelinella indica* Scheibnerová, (x200, x95), Sample 258-15R-2; 42-46cm.
2	*Lingulogavelinella indica* Scheibnerová, (x105), Sample 258-15R-2; 42-46cm.
3	*Lingulogavelinella indica* Scheibnerová, (x80), Sample 258-15R-2; 42-46cm.
4	*Lingulogavelinella indica* Scheibnerová, (x150), Sample 258-15R-2; 42-46cm.
5	*Lingulogavelinella* sp. 1, (x130), Sample 766-19R-1; 68-72cm.
6	*Lingulogavelinella* sp. 1, (x115), Sample 766-19R-1; 68-72cm.
7	*Scheibnerova protindica* Quilty, (x125), Sample 258-15R-2; 42-46cm.
8	*Scheibnerova protindica* Quilty, (x130), Sample 766-16R-5; 32-36cm.
9	*Scheibnerova protindica* Quilty, (x170), Sample 766-16R-5; 32-36cm.
10	*Scheibnerova protindica* Quilty, (x160), Sample 766-16R-1; 32-36cm.

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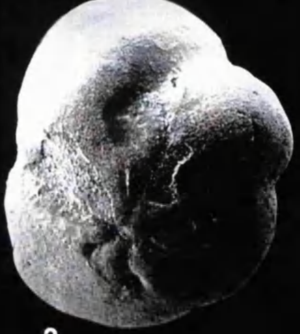

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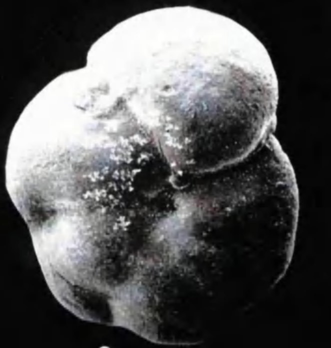

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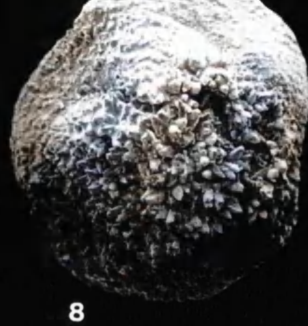

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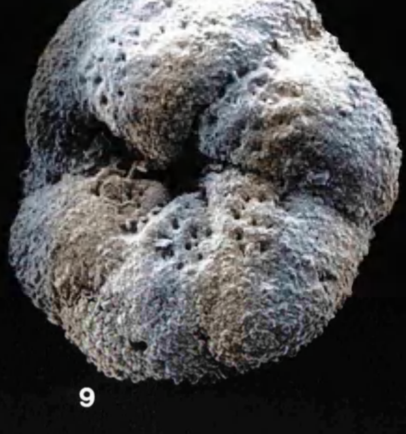

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CHAPTER 7. *Conclusions*

7.1. TAXONOMY

A comprehensive documentation of the Lower Cretaceous benthic foraminifera from Indian Ocean sites has been compiled, which provides a unified taxonomic data base for the Indian Ocean. A total of 100 agglutinated and 132 calcareous taxa, belonging to 90 genera, has been systematically described from DSDP Holes 249, 256, 257, 258, 259, 260 and 263 and from ODP Holes 762, 763, 765 and 766.

The benthic foraminiferal assemblages from Indian Ocean DSDP and ODP sites include some of the most diverse and well preserved assemblages ever documented from the Lower Cretaceous of southern oceans. They contain a high proportion of cosmopolitan taxa, but differ from typical low latitude Tethyan assemblages by the rarity or absence of characteristic Tethyan lineages such as *Epistomina, Marssonella, Falsogaudryinella,* and *Praedorothia.* Some degree of faunal provinciality, probably reflecting the high-latitude position of the sites during the Early Cretaceous, is, therefore, present in the Indian Ocean, manifested by the distinctive composition of foraminiferal assemblages. Strong faunal differentiation or endemism within the Cuvier Basin is suggested at Site 263 by the unique composition of agglutinated assemblages, which includes five new species and a significant number of taxa, that are not recorded at other sites.

7.2. BIOSTRATIGRAPHY

The chronostratigraphy of DSDP Holes 249, 256, 257, 258, 259, 260 and 263 and ODP Holes 762, 763, 765 and 766 has been revised. New ages have been determined from benthic foraminiferal data, which considerably improve the biostratigraphic resolution of Lower Cretaceous DSDP and ODP cores, particularly for intervals, which had previously been dated as undifferentiated Aptian or Albian. An older Valanginian to Barremian age has also been established for the base of Hole 263, in sharp contrast with the original chronostratigraphic interpretations based on benthic foraminifera and nannofossils, which correlated the base of the recovered interval with the Aptian. A summary of the revised chronostratigraphy of Indian Ocean DSDP and ODP holes is presented in Tables 7.1 and 7.2.

Table 7.1. Revised chronostratigraphy of DSDP Holes 249, 256, 257, 258, 259, 260 and 263.

Leg	Site	Previous age determinations based on foraminifera		This study	
		Core Sections	Age	Core Sections	Age
25	249	31R-26R	Valanginian-Hauterivian	**31R-28R**	**Valanginian-Hauterivian**
				28R-26R	**early Barremian**
26	256	9R-7R	Albian	**9R-8R**	**late Albian**
	257	8CC	Albian	**7R**	**late Albian**
				9R-8R	**late early-mid Albian**
				10R-9R	**early Albian?**
	258	20R-15R	Albian	**16R-14R**	**late Albian**
				21R-16R	**early late Albian**
				24R-21R	**Albian?**
27	259	17CC-11CC	late Albian	**16R-11R**	**late early-early late Albian**
		18R-33R	Aptian	**32R-17R**	**Aptian-early Albian**
				33R	**undetermined**
	260	11CC-8CC	mid-late Albian	**10R**	**late Aptian**
		18R-12R	?late Aptian-early Albian	**18R-12R**	**late early-mid Aptian**
	263	10CC-5CC	late Aptian-early Albian	**17R-5R**	**Aptian-Albian**
		29CC-11CC	Aptian	**29R-18R**	**Valanginian-Barremian**

Table 7.2. Revised chronostratigraphy of ODP Holes 762, 763 and 766.

Leg	Site	Previous age determinations based on foraminifera		This study	
		Core Sections	Age	Core Sections	Age
122	762			**77X-76X**	**late Albian**
				77X	**mid Albian**
				78X	**late Aptian**
				81X-79X	**latest Haut?-Barr**
		91X-81X	Berriasian-early Valanginian	**91X-82X**	**Berriasian-early Valanginian**
	763			**29X-27X**	**late Albian**
				37X-30X	**late early-mid Albian**
				39X-38X	**late Aptian**
				42X-40X	**early Aptian?**
				47X-43X	**latest Haut?-Barr**
		54X-46X 46R-4R	Berriasian-early Valanginian	**54X-48X** **46R-35R**	**Berriasian-early Valanginian**
123	766	18R-16R	late Albian	**18R-16R**	**late Albian**
		21R-19R	early-mid Albian	**21R-19R**	**late early-early late Albian**
		25R-24R	Aptian	**25R-24R**	**Aptian**
				30R-26R	**Barremian**
				40R-32R	**late Hauterivian**
				43R-40R	**early Hauterivian**
				49R-43R	**late Valanginian-early Hauterivian**

None of the existing Tethyan and cosmopolitan benthic foraminiferal zonal schemes have been found to be applicable in the Lower Cretaceous of Indian Ocean DSDP and ODP sites. An appropriate Early Cretaceous benthic foraminiferal zonation is, therefore, proposed, which is based on new foraminiferal data from the DSDP and ODP sites (see Figure 4.17). The following six main zones have been recognized:

1) a late Albian to early Cenomanian *Spiroplectinella gandolfii* Zone
2) a late early Albian to early late Albian *Pleurostomella reussi* Zone
3) a late Aptian to late early Albian *Gaudryinopsis gradata/Saracenaria spinosa* Zone
4) a latest Barremian to early Aptian *Praedorothia ouachensis* Zone
5) an early to late Barremian *Gavelinella barremiana* Zone
6) a Valanginian to Hauterivian *Lenticulina heiermanni* Zone.

This new zonal scheme provides a powerful tool to correlate Lower Cretaceous sedimentary sequences in the Indian Ocean. Most of the DSDP and ODP cores from the Indian Ocean contain stratigraphically important benthic foraminifera, except for some intervals, which are characterized by a very impoverished foraminiferal biofacies, dominated by *Glomospira* and *Ammodiscus* spp. A correlation of DSDP and ODP sites, where Lower Cretaceous sediments have been recovered in the Indian Ocean, is presented in Figure 4.18 .

7.3. PALAEOECOLOGY

Benthic foraminiferal assemblages give a unique insight into the succession of palaeoenvironments at Indian Ocean DSDP and ODP sites during the Early Cretaceous. Palaeoecological interpretations, derived from quantitative analyses of benthic foraminiferal distribution patterns and morphogroup analyses, indicate a marked differentiation in palaeoenvironments along the western and northwestern margins of Australia. The benthic foraminiferal assemblages from DSDP and ODP sites reflect a wide range of conditions from neritic to truly abyssal, as shown by the palaeoenvironmental summary presented in Table 7.3. Diversity and specific distribution appear strongly influenced by margin subsidence, oceanic circulation patterns, and inferred changes in the depth of the CCD. The interpretation presented here contrast markedly with Scheibnerová's original hypothesis (1974; 1977) of a shallow-water origin for all Lower Cretaceous foraminiferal assemblages from DSDP sites of the Indian Ocean.

Virtually all the marginal sites display faunal changes that may be linked to deepening palaeobathymetry, as the Australian margin subsided following continental

Table 7.3. Summary of palaeoenvironments in the Lower Cretaceous of the Indian Ocean.

Leg	Site	Core Section	Age	Palaeoenvironment
25	249	31R-4 to 26R-2	late Val to early Bar	Shallow, open marine, mod. high energy
26	256	9R-1 to 8R-1	late Albian	Lower bathyal above CCD, well ventilated
	257	9R-2 to 7R-1	l. early to late Alb	Lower bathyal above CCD, well ventilated
		10R-1 to 9R-2	Albian ?	Bathyal above CCD, restricted
	258	21R-2 to 14R-1	late Albian	Bathyal above CCD, intermittently restricted
		24R-3 to 21R-2	mid to early late Albian	Upper bathyal? restricted
27	259	17R-2 to 14R-1	l. early to late Alb	Lower bathyal above CCD, well ventilated
		33R-1 to 17R-3	Aptian -Albian	Bathyal below CCD, restricted
	260	18R-1 to 7R-2	l. early to late Apt	Lower bathyal above CCD, intermitt. restricted
	263	18R-4 to 7R-2	Aptian-Albian	Lower bathyal below CCD, restricted
		29R-4 to 18R-5	late Val to Bar	Bathyal below CCD? restricted. High clastic input
122	762	77X-1 to 76X-4	l. early to late Apt	Upper-middle bathyal above CCD
		78X-CC	Aptian	Upper bathyal, intermitt. restricted above CCD
		81X-1 to 79-CC	Barremian	Outer shelf above CCD, intermitt. restricted
		91X-CC to 82X-2	Ber to early Val	Restricted, distal delta
	763	37X-6 to 27X-2	l. early to late Alb	Upper-middle bathyal above CCD, slightly restricted in late Albian
		41X-5 to 38X-1	Aptian	Upper bathyal above CCD, intermitt. restricted
		47X-3 to 43X-2	Barremian	Outer shelf, above CCD, initially restricted
		54X-CC to 48X-5 46R-5 to 35R-6	Ber to early Val	Restricted shallow prodelta
123	766	21R-2 to 16R-1	early to late Alb	Lower bathyal above CCD, well ventilated
		26R-2 to 24R-1	Aptian	Lower bathyal above CCD, intermitt. restricted
		30R-4 to 26R-3	Barremian	Lower bathyal above CCD, slightly restricted
		43R-1 to 32R-2 49R-3 to 43R-2	late Val to late Hau	Middle to lower bathyal above CCD, initially slightly restricted. High clastic input

break-up. There is evidence of coarse terrigenous influence in the basal assemblages from Sites 259, 263, 762, 763 and 766, which is followed by a change to more pelagic sediments with "oceanic" foraminiferal assemblages. Oceanic events of the mid-Cretaceous resulted in generally lowered diversities, as demonstrated by the occurrence of impoverished *Glomospira* faunas at Sites 257, 258, 259, 261, 263 765, and of barren horizons rich in radiolarians, alternating with diversified calcareous benthic foraminiferal assemblages at Sites 260, 762, 763 and 776. In the late early and mid Albian, an improvement in deep water ventilation and a deepening of the CCD appear to have contributed to the disappearance of organically-cemented agglutinated assemblages and to the expansion of calcareous assemblages. Six main benthic foraminiferal biofacies have been distinguished, which characterize distinctive environments in the Lower Cretaceous of the Indian Ocean. The benthic foraminiferal biofacies have been summarized in Table 7.4.

Benthic foraminiferal data have been integrated with seismic, geochemical and sedimentological evidence to compile a palaeoceanographic synthesis, retracing the evolution of the Indian Ocean during the Early Cretaceous. In the Berriasian and early Valanginian thick deltaic lobes were deposited on the rapidly eroding uplifted continental margin, while turbidites and clays accumulated at abyssal depths below the CCD in the Argo Abyssal Plain. Clastic sedimentation started at bathyal depths in rifted western basins during the late Valanginian. Circulation remained restricted, however, in the Cuvier Abyssal Plain throughout the Early Cretaceous, while pelagic sediments accumulated in the Gascoyne Abyssal Plain from the Barremian. Three main transgressive pulses in the Barremian, late Aptian and late early Albian led to the drowning of the subsiding Australian margin. Productivity fluctuations in the Aptian and Albian reflected changes in deep-water circulation and in the nutrient and oxygen budget of an ocean already susceptible to dysoxia. Well ventilated conditions became established during the late early to mid Albian, when a significant drop in CCD occurred. Dysoxic conditions developed regionally in the late Albian, when a marked surface temperature gradient along the western Australian margin is recorded by the influx of large, keeled planktonic foraminifera at northern sites. A palaeoceanographic summary is given in Figure 7.1.

Table 7.4. Summary of benthic foraminiferal biofacies in the Lower Cretaceous of the Indian Ocean.

Biofacies	Environment	Characteristic taxa
1. Gyroidina-Gaudryina	open marine, well ventilated above the CCD (Aptian to Albian)	*Berthelina, Charltonina, Coryphostoma, Gavelinella, Gyroidina, Lingulogavelinella, Gaudryina, Osangularia, Pleurostomella, Quadrimorphina, Remesella , Scheibnerova*
2. Lenticulina-Laevidentalina	open marine, relatively well ventilated above the CCD (Valanginian to Barremian)	*Astacolus, Frondicularia, Laevidentalina, Lenticulina, Marginulina, Marginulinopsis, Psilocitharella, Pyramidulina,, Saracenaria, Vaginulinopsis* with variable agglutinated component
3. Aaptotoichus-"Textulariopsis"	sub-CCD, receiving abundant food but not severely dysoxic	*Aaptotoichus challengeri, Caudammina crassa, Bimonilina, Gaudryinopsis", Haplophragmoides, Hippocrepina, Lagenammina, Paratrochamminoides, Recurvoides, Rhabdammina, Rhizammina, Textulariopsis"*
4. Ammodiscus-Glomospira	sub-CCD, highly stressed and unstable	*Ammodiscus, Glomospira*
5. Psammosphaera-Reophax	newly colonized, in the first stage of faunal succession	*Psammosphaera, Reophax*
6. Bulbobaculites-Haplophragmoides	deltaic, poorly oxygenated with high terrigenous influx	*Bulbobaculites, Haplophragmoides* with variable agglutinated component

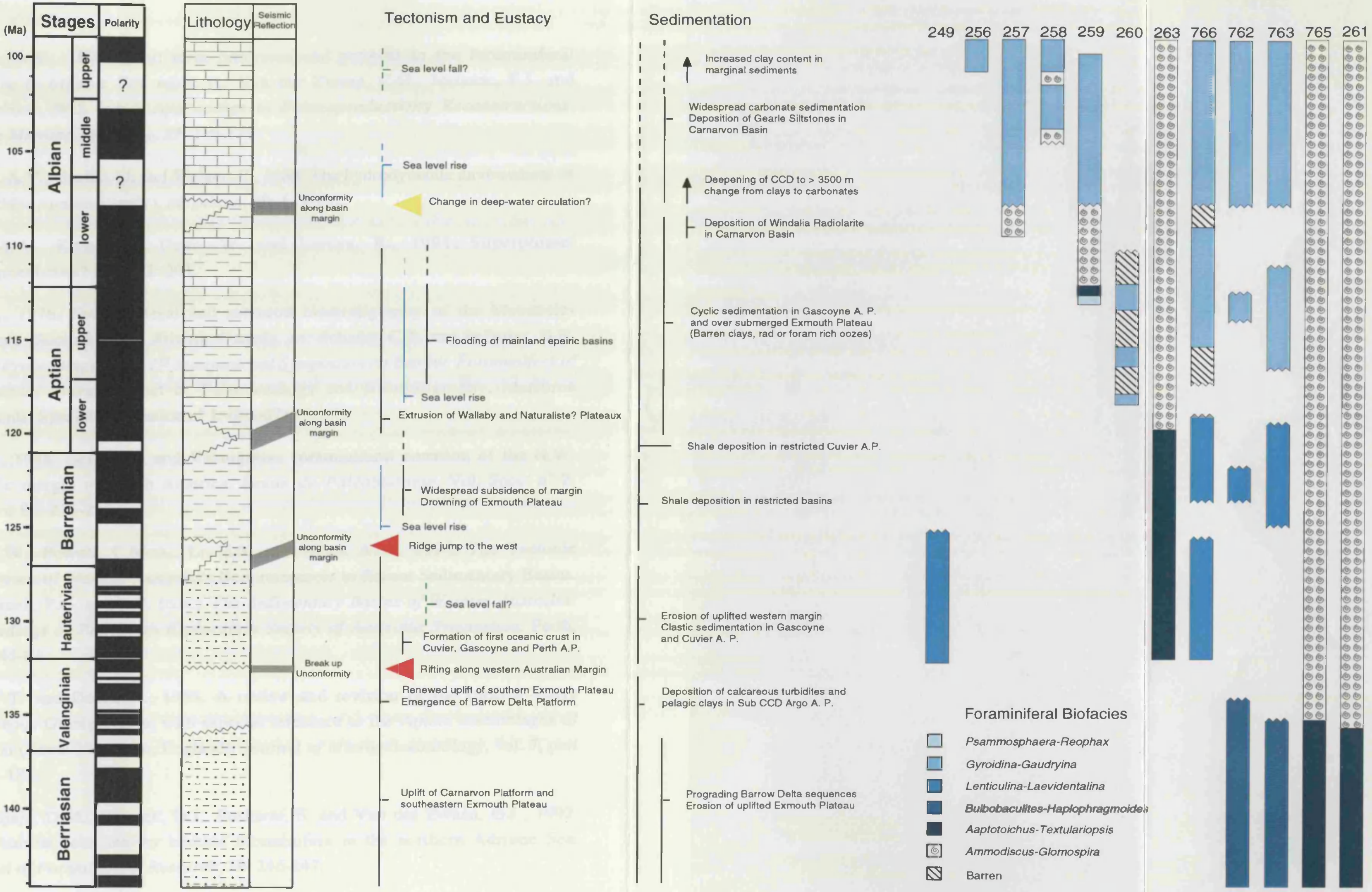

Figure 7.1. Palaeoceanographic evolution of the Indian Ocean during the Early Cretaceous.

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PUBLICATIONS

Valanginian to Barremian benthic foraminifera from ODP Site 766 (Leg 123, Indian Ocean)

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ABSTRACT: A Valanginian to Barremian bathyal foraminiferal assemblage (118 taxa belonging to 51 genera) is documented from ODP Site 766, drilled near the foot of the Exmouth Plateau off northwest Australia. The majority of taxa are cosmopolitan species previously described from the boreal assemblages of northern Europe and the northern margins of the Tethys, but 32 taxa could not be assigned to previously described species and are left in open nomenclature. The chronostratigraphy of this section is based upon nannofossils, palynomorphs, and radiolarians. The foraminiferal succession is divided into four assemblages based on the first and last occurrences of characteristic benthic foraminifera: 1) An upper Valanginian *Lenticulina ouachensis - Textularia bettenstaedti* assemblage with *Ammodiscus tenuissimus, Bulbobaculites* sp., and *Aaptotoichus clavellatus.* The last occurrences of these taxa are observed near the transition between the Valanginian and Hauterivian. 2) A lower Hauterivian assemblage is characterized by *Lenticulina heiermanni* and *Saracenaria forticosta.* 3) An upper Hauterivian assemblage contains *Planularia crepidularis, Patellina subcretacea,* and *Reinholdella hofkeri.* A major faunal discontinuity is observed at the top of this assemblage between Cores 766A-32R and 766A-30R, probably associated with a depositional gap between the late Hauterivian and the Barremian. 4) The overlying Barremian assemblage is characterized by *Gavelinella barremiana, Glomospira* spp., and *Pseudogaudryinella* sp. This record enables long-distance comparisons of the stratigraphic ranges of benthic foraminiferal species in the austral bioprovince with their reported ranges in the North Atlantic region and the northern Tethys. Although the assemblages at Site 766 consist of ca. 74% cosmopolitan species, they differ from Tethyan assemblages in the rarity or absence of index taxa such as *Praedorothia* spp., *Lenticulina nodosa* and *L. eichenbergi,* as well as ornamented, palmate morphotypes such as *Citharina* spp., *Flabellina* spp., and *Frondicularia* spp. They differ from the typical boreal assemblages by the lack of diverse agglutinated taxa. As a result, benthic foraminiferal zonations established for the Lower Cretaceous of the northern Tethys and Tethyan DSDP sites could not be applied at Site 766. Taxonomic and biostratigraphic differences at Site 766 support the existence of a taxonomically distinct Early Cretaceous austral bioprovince.

INTRODUCTION

The biogeographic distribution of various marine organisms in Lower Cretaceous sequences has enabled paleontologists to recognize the existence of two main bioprovinces during Early Cretaceous time: a boreal bioprovince in high northern latitudes and a Tethyan bioprovince in low tropical latitudes. The presence of a third main bioprovince in the southern hemisphere — the austral bioprovince, which was the southern hemisphere equivalent to the cool boreal bioprovince — is, however, rarely mentioned in the literature as research has traditionally focused on boreal and tropical assemblages. For a long time, the Cretaceous foraminiferal microfaunas from Australia and New Zealand were viewed as unusual and endemic. Even now, relatively little is known about the microfaunas from the austral bioprovince and about their relationship to those of the other two bioprovinces during the Early Cretaceous.

The recovery of Lower Cretaceous sedimentary sequences from ODP sites in the Indian Ocean has, fortunately, provided new material for studying the distribution of foraminifera in the high southern latitudes. At ODP Site 766 diverse, well-preserved, bathyal assemblages have been recovered from sediments as old as Valanginian, in contrast to the predominantly marginal assemblages previously described from epeiric basins in Australia and the Indian Ocean. The foraminifera from ODP Site 766, therefore, offer a unique insight into the composition of deep-water benthic assemblages during the Early Cretaceous. These assemblages also provide the opportunity to retrace the evolution of one of the oldest continental margins in the world from its early rifting phase early in the Cretaceous, when the supercontinent Gondwana fragmented and the Indian Ocean started to open, to its mature position in the Albian at the edge of a vast ocean.

The main objective of this work is to conduct a detailed taxonomic and biostratigraphic survey of the lesser-known Valanginian to Barremian benthic foraminifera at Site 766 and to compare them with better-documented assemblages from the Tethyan and boreal bioprovinces. Benthic foraminifera are particularly useful for stratigraphy during this interval because planktonic species are absent. They are also important for paleogeographic and paleoceanographic reconstructions and for worldwide stratigraphic correlations (e.g. Bartenstein 1979).

PREVIOUS WORK

Taxonomy and distribution of southern hemisphere benthic foraminifera

A detailed study of Aptian-Albian benthic foraminifera at ODP Site 766 was carried out by Haig (1992). The Valanginian-Barremian assemblages at this site were examined on board ship: eight species were mentioned in the ODP Site 766 Site report (Ludden and Gradstein et al. 1990). No further work has followed these initial investigations.

The taxonomy and paleoecology of Lower Cretaceous benthic assemblages from high southern latitudes have been studied by several authors, mainly over the past 30 years. Crespin (1944, 1953, 1963) described the Aptian-Albian assemblages from epicontinental seas of mainland Australia. Espitalié and Sigal (1963) compiled a detailed taxonomic and stratigraphic study of foraminifera from Upper Jurassic and Lower Cretaceous deposits of the Majunga Basin (Madagascar) that recognized 189 species, 54 of them new. Ludbrook (1966) documented the foraminiferal assemblages from the Great Artesian Basin. Global distribution patterns were investigated by Sigal et al. (1970), who showed similarities between foraminifera from Upper Jurassic and Lower Cretaceous Gondwana continental margin deposits of Madagascar, India and Chile.

In a series of papers, Scheibnerová (1971a, 1971b, 1972, 1974a, 1974b, 1976, 1977) described Lower Cretaceous assemblages from the Great Artesian Basin and from DSDP Sites in the Indian Ocean. Scheibnerová recognized the existence of an austral biogeoprovince in the southern hemisphere. According to Scheibnerová, austral assemblages (in common with cool boreal assemblages) typically lacked planktonic species and were dominated by agglutinated foraminifera and small simply ornamented calcareous forms. Scheibnerová (1973, 1978) proposed that the austral biogeoprovince, that included Australia, the epicontinental seas of Gondwana and the Cretaceous southern oceans, supported a distinctive cool-water microfauna and that episodic south-north migrations caused similarities between austral and boreal faunas. Lambert and Scheibnerová (1974) compared Albian foraminifera from Zululand (South Africa) and the Great Artesian Basin (Australia) and concluded that they represented a typical, cool-water, austral fauna from shallow environments. Scheibnerová (1974b) described the Aptian-Albian benthic foraminifera from DSDP Sites 259, 260 and 263 and compared them with coeval assemblages from India, Australia and South Africa. Kuznetsova (1974) interpreted the predominantly agglutinated assemblage from the Upper Jurassic and Lower Cretaceous of ODP Site 261 in the eastern Indian Ocean as of deep-water origin, while Scheibnerová (1977) ascribed to the same assemblage a shallow-water origin in a cool, stagnant basin, despite its location on Oxfordian oceanic crust.

Bartenstein (1974a, 1977, 1978, 1979) investigated the stratigraphic range and distribution of *Lenticulina nodosa* (and subspecies) and other index species in Lower Cretaceous sediments worldwide, and Aubert and Bartenstein (1976) extended the range and distribution of *L. nodosa* and related species throughout the north and south temperate realms and the Tethyan realm. Bartenstein (1974b) also documented the "primitive" agglutinated assemblages from Upper Jurassic and Lower Cretaceous deposits at ODP Sites 259 and 261 in the eastern Indian Ocean.

Haig (1979) distinguished three main benthic associations, differentially distributed in tropical and cool-temperate climatic belts from the Barremian to the Cenomanian: 1) the neritic *Ammobaculites* Association dominated by organically cemented forms was extensively developed in epicontinental seas of cool-temperate belts; 2) the predominantly bathyal *Marssonella* Association dominated by calcareous forms lacked "larger" foraminifera and was characteristic of continental slope environments above the CCD (carbonate compensation depth); and 3) the *Recurvoides* Association which was found in abyssal areas beneath the CCD showed no change in tropical and cool-temperate belts. Haig (1980, 1982) described 54 textulariine species and 143 milioline and rotaliine species from the Aptian-Albian of Queensland and assigned the foraminifera to the *Ammobaculites* and *Marssonella* Associations. Haig (1981) also recorded diverse textulariine-rotaliine assemblages with many cosmopolitan forms from the Aptian-Albian of Papua New Guinea, which he attributed to the *Marssonella* Association. Moullade and Guérin (1982) showed that provincialism was much less marked than previously thought in southern latitudes and that foraminiferal evidence from DSDP Sites and Tethyan locations supported the existence of relatively deep connections between the south and central Atlantic Oceans in the middle Albian. Haig and Lynch (1993) related changes in foraminiferal biofacies during the late early Albian (from low diversity agglutinated assemblages to high diversity calcareous assemblages) to a transgressive pulse over northeastern Australia.

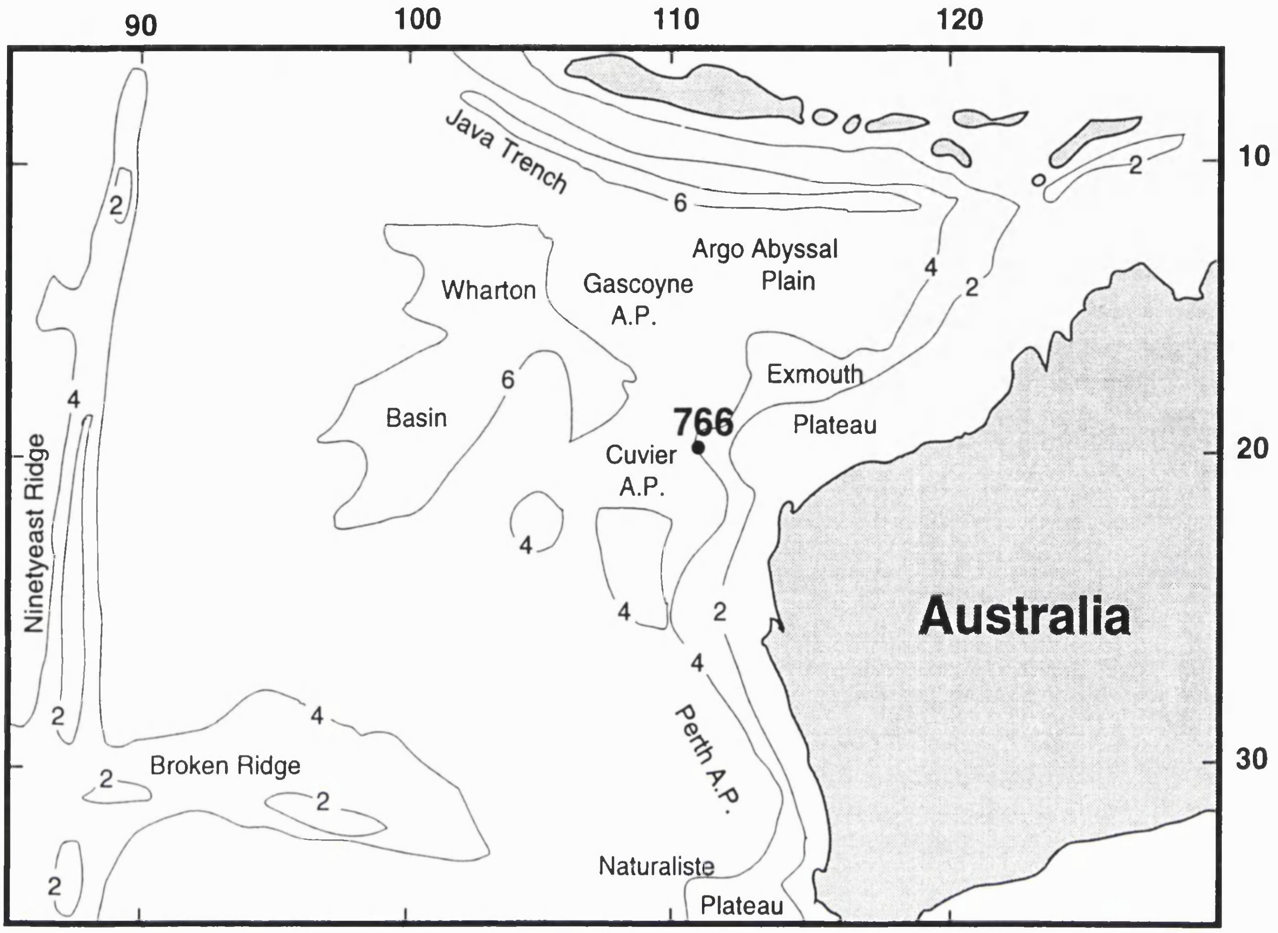
Riccardi (1988) listed Lower Cretaceous foraminifera recovered from the Austral Basin of southern Patagonia and from the Andean Basin. These assemblages were dominated by benthic species that showed varying degrees of endemism. Riegraf (1989) studied Valanginian-Hauterivian benthic assemblages at ODP Site 249 in the Indian Ocean, southwest of Madagascar; the 42 recorded species comprised mainly nodosariids, typical of shelf environments which showed a strong cosmopolitan influence. Riegraf and Luterbacher (1989a) presented a biostratigraphical, taxonomical and paleoecological overview of Lower Cretaceous foraminifera from DSDP Sites in the Atlantic, Indian and Pacific Oceans (Legs 1-80). Kaminski et al. (1992) and Kaminski and Geroch (1992) studied deep-water benthic assemblages from the Tithonian to Aptian at ODP Sites 765 and 261 on the Argo Abyssal Plain in the Indian Ocean. These authors found that the predominantly agglutinated assemblages included many cosmopolitan species known from other sub-CCD environments (Carpathians, North Atlantic) but were taxonomically more diverse than any previously described deep-water assemblages.

Review of zonal schemes for the Lower Cretaceous

The biostratigraphy of Lower Cretaceous benthic foraminifera has been studied by a number of authors. The work of Bartenstein and co-workers on the benthic foraminifera of the Saxony Basin has led to a local biostratigraphic scheme for NW Germany (Bartenstein and Bettenstaedt 1962). This zonation was based on the stratigraphic succession of 75 foraminifera and 12 ostracod species in the middle Valanginian to lowermost Cenomanian of Saxony. The stratigraphic ranges of benthic foraminifera were calibrated to the standard ammonite zones. The zonation of NW Germany has been later refined in numerous publications by Bartenstein and co-workers, and formed the basis of a proposal for a general biostratigraphic zonation for the worldwide Lower Cretaceous using cosmopolitan species (Bartenstein 1979). This worldwide zonation was based on comparing the stratigraphic ranges of species on both sides of the North Atlantic. Bartenstein used the study of Ascoli (1976) as a standard reference for the Canadian offshore wells. In this zonal scheme, Bartenstein extended the stratigraphic ranges of some of the NW German species to older (Berriasian or Tithonian) horizons, but the first occurrences of many forms were still recorded with a question mark. The upper limits of the stratigraphic ranges remain largely unchanged from the earlier study.

The stratigraphic ranges of 152 boreal, shallow water Cretaceous foraminifera from southeast England were reported by Hart et al. (1989). Data for the Berriasian to Barremian are based mainly on studies of the section at Speeton, NE England. Hart et al. did not erect a formal zonation for the Lower Cretaceous, but provided a range chart. This work on the Lower Cretaceous benthic foraminiferal zonations can be extended by including the deeper boreal assemblages of the Viking and Central Grabens of the North Sea (King et al. 1989).

Moullade (1984) reviewed the importance of small, cosmopolitan, benthic foraminifera from the Oxfordian to the Cenomanian for stratigraphy, paleoecology and paleogeography and proposed a formal zonation for the Upper Jurassic-Lower Cretaceous based on benthic foraminifera. This was the first formal zonation of the



TEXT-FIGURE 1
Location of Site 766 on the lower Exmouth Plateau (redrawn after Ludden, Gradstein et al. 1990). Countours in thousands of meters.

northern Tethyan margin, and was based to a large extent on comparison of North Atlantic low-latitude DSDP sites with the Vocontian Trough. Moullade (1974) had previously developed a Lower Cretaceous zonal scheme for the pelagic facies of the Mediterranean Province based on the Vocontian Basin and several other stratoypes and had also proposed (1979) a zonation for the Valanginian in southeastern France based on benthic foraminifera which was correlated with ammonites. A zonal scheme for the Tithonian to Cenomanian of the northern Tethyan margin, published by Weidich (1990), was based on the occurrence of over 400 foraminiferal species from the Northern Calcareous Alps in Bavaria and Austria. This monograph provides the most complete taxonomic data set for the northern Tethys. Weidich's biostratigraphic scheme subdivided the Lower Cretaceous into 10 zones based on first occurrences or acmes of primarily calcareous benthic foraminifera. For the interval of interest for this study, Weidich recognised only three zones, in contrast to the 10 zones defined by Moullade. However, Weidich's zonal scheme is only tentatively correlated to the standard chronostratigraphy (therefore zonal boundaries are indicated by dashed lines), and further calibration of Weidich's samples by means of planktonic microfossils is needed to refine the age of his zones.

Riegraf and Luterbacher (1989a) studied 22 low latitude sites situated in the northern hemisphere, but three sites from higher southern latitudes were also investigated: Sites 249 and 261 in the Indian Ocean and Site 330 in the Atlantic Ocean. These authors devised a Lower Cretaceous benthic foraminiferal zonation that subdivided the Berriasian to Cenomanian into six zones, based on the first occurrences of certain taxa. The authors also reported the stratigraphic ranges of 31 cosmopolitan deep-sea species in both deep sea and continental margin sequences. They extended the known stratigraphic range of several other deep-sea taxa into older levels. Among them is the species *Gavelinella barremiana*, which was reported from the base of Hauterivian and is the nominate taxon for their Hauterivian zone. Moullade (pers. comm., 1994) has suggested, however, that the form reported by Riegraf and Luterbacher may be a precursor of *G. barremiana*, which is known to have ancestors with FO at the Hauterivian-Barremian boundary (cf. *G.* aff. *barremiana* Moullade 1966, p. 73).

LOCATION AND GEOLOGICAL SETTING

ODP Leg 123, Site 766 was drilled at latitude 19°55.92′S and longitude 110°27.24′E at the foot of the Exmouth Plateau, off northwestern Australia (text-fig. 1). This site is located on an ancient continental margin; it formed part of an extensive continental rift zone during the Early Cretaceous when the supercontinent Gondwana fragmented and the Indian Ocean started to open. Approximately 300m of Valanginian to Albian sediments were recovered at Site 766. The chronostratigraphy based on magnetostratigraphy, palynomorphs, radiolarians and benthic foraminifera was compiled by Kaminski et al. (1992). The Lower Cretaceous chronostratigraphy of Hole 766A is shown in text-figure 2. The

Valanginian to Barremian interval (Sections 123-766A-26R-1 to 123-766A-49R-4) consists of approximately 250m dark greenish gray siliciclastics, which have been divided into two main lithological subunits (IIIA and IIIB). A prominent seismic reflector marks the boundary between subunits IIIA and IIIB where the lithology changes from claystones (above) to sandstones and siltstones (below). This unconformable surface, located at 307m below the sea floor, is characterized by onlap above and erosional truncation below and represents a major unconformity between the two subunits (Ludden, Gradstein et al. 1990).

The oldest subunit IIIB (Sections 123-766A-32R, CC to 123-766A-49R-4) thickens to the southwest and is dominated by redeposited sandstones and siltstones with a few intercalated ash layers. It has been interpreted as a prograding syn-rift sedimentary wedge, composed mainly of volcanic and shallow marine grains derived from the outer Exmouth Plateau which had become elevated to the southwest due to thermal uplift of the rifting margin (Ludden, Gradstein et al. 1990). This sedimentary sequence has no equivalent on the Exmouth Plateau where it coincides with an unconformity. Buffler et al. (1992) proposed that it was deposited when the Cuvier Ocean basin opened and "Greater India" drifted past Site 766 in the Valanginian-Hauterivian. High TOC values to about 1.6 wt% were recorded for subunit IIIB and Rock-Eval pyrolysis indicated a terrestrial origin for the organic matter.

Subunit IIIA (Sections 123-766A-26R-1 to 123-766A-32R, CC) is characterized by bioturbated claystones with abundant glauconitic grains and radiolarians, which suggest a lower depositional energy, possibly in a deeper and/or more stable environment. Thermal subsidence of the margin coupled with a sea-level rise and a major ridge jump probably cut off the supply of coarse clastics and led to the abandonment of the prograding wedge system (subunit IIIB) and to the deposition of a more hemipelagic sequence (Subunit IIIA) during the Barremian (Buffler et al. 1992). The characteristic TOC values, which are near 1 wt% for the claystones, are lower than in the basal subunit IIIB.

From backtracking, sedimentation appears to have started at depths of about 800m and the site probably remained near or above CCD level throughout the Early Cretaceous; the calculated sedimentation rates of 60m/my are high for subunit IIIB, but decrease to 10m/m.y. for subunit IIIA (Ludden, Gradstein et al. 1990).

METHODS

Fifty-three samples (20 cc) from Cores 49R-04 to 26R-01 were processed by repeated drying and washing in 1% Calgon solution. The washed residues were randomly divided into fractions with the help of a sample splitter; the fractions were then sieved (>250mm, >125 mm and >63mm) and each picked for microfossils. When fossil abundance allowed, a minimum of 300 foraminifera were picked per sample as well as other microfossils. The picked specimens were then sorted on cardboard slides for identification. These are housed in the Micropaleontology collections of University College London.

Taxonomic comparisons were made with paratypes and holotypes from Early Cretaceous foraminiferal collections at the Senckenberg Museum in Frankfurt (Bartenstein and Brand 1951; Bartenstein and Kaever 1973) and at the Institute for Palaeontology and Historical Geology in Munich (Weidich 1990). Site 766 assemblages were also compared with coeval, Tethyan and boreal assemblages from Atlantic ODP Sites and continental Europe and with high latitude, southern assemblage from Indian Ocean ODP Sites. Scanning electron micrographs were made on a Zeiss-DSM-940 SEM at the Micropaleontology Unit of University College London.

RESULTS

Calcareous foraminifera dominate the assemblages at Site 766, but significant numbers of agglutinated forms are present at the lower and upper portions of the sequence (core sections 766A-49R-03 to -43R-05 and core sections 766A-30R-02 to -26R-01). The microfossil assemblages in the basal part of the succession (core sections 766A-49R-03 to -48R-06) are numerically dominated by radiolarians. In general, preservation is moderate to good in most samples, except for a few diagenetically altered intervals. The benthic foraminiferal data are given in table 1. The stratigraphic ranges of selected benthic foraminifera are given in text-figure 3.

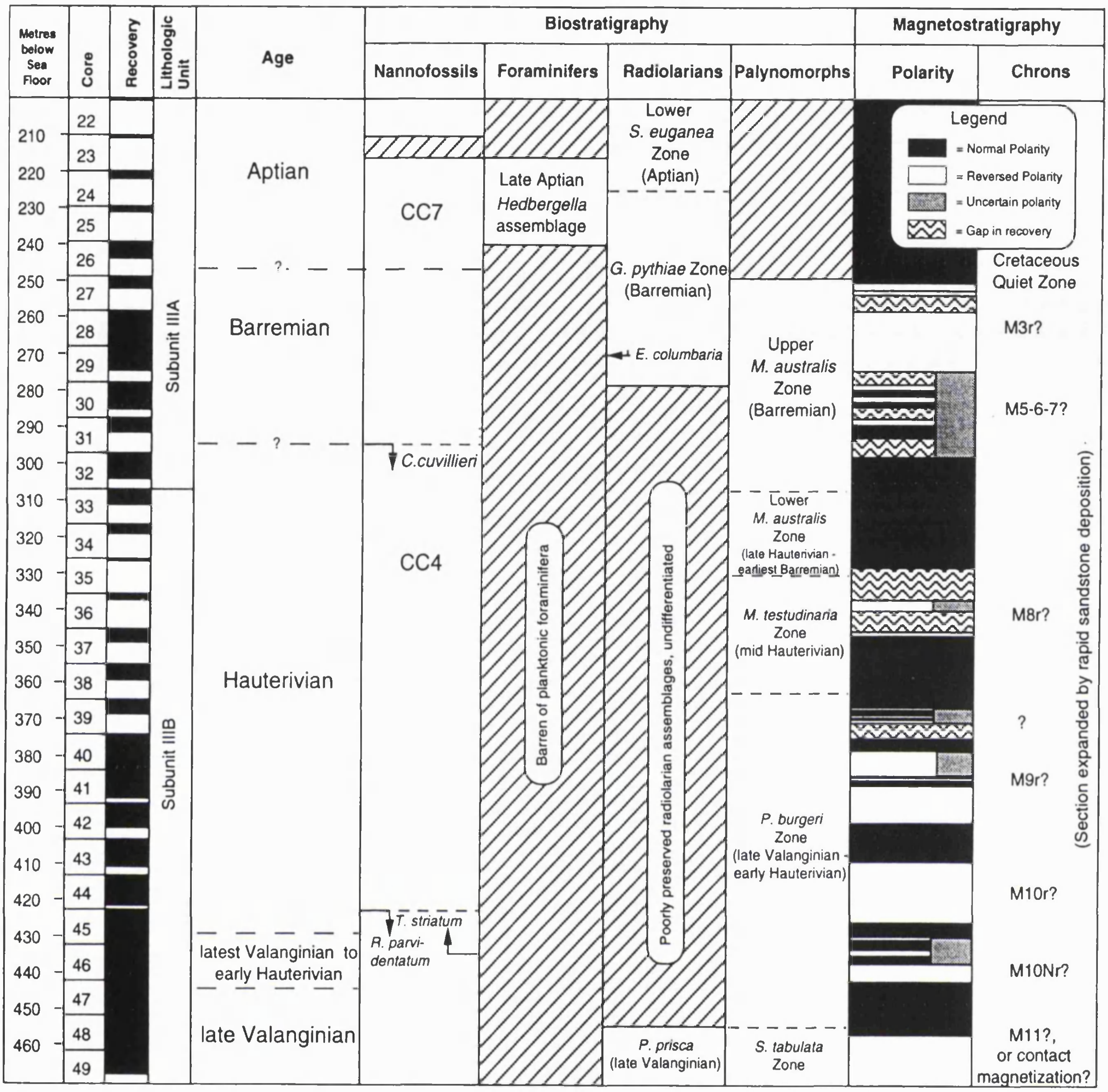
The foraminiferal succession can be subdivided into four assemblages based on changes in the composition of dominant taxa and on occurrences of stratigraphically important species.

1) *Lenticulina ouachensis - Textularia bettenstaedti* assemblage (core sections 766A-49R-03 to -43R-05): This upper Valanginian-lower Hauterivian mixed calcareous/agglutinated assemblage is characterized by *Lenticulina ouachensis, Textularia bettenstaedti, Bulbobaculites* sp. 1, *Ammodiscus tenuissimus, Aaptotoichus clavellatus, Rhizammina* spp. and *Haplophragmoides* spp. Diversity is relatively high with up to 49 species per sample. Foraminiferal abundances are low only at the base of the succession (Cores 766A-49R-03 to -48R-06). Fluctuating numbers of coarsely agglutinated *Bulbobaculites* sp. 1 and *Ammobaculites* sp. 1 are noted between core sections 766A-47R-01 and -44R-01 and point to the coarse clastic origin of lithologic subunit IIIB. The upper part of this assemblage is marked by the disappearance of agglutinated taxa, probably indicating a change to more open oceanic conditions.

2) *Lenticulina heiermanni - Saracenaria forticosta* assemblage (core sections 766A-43R-04 to -40R-03): This is an undiagnostic lower Hauterivian interval assemblage dominated by nodosariids. This typically bathyal assemblage is characterized by *Lenticulina heiermanni, Saracenaria forticosta, Globulina* spp., *Oolina* spp. and diverse nodosariids. Both diversity (maximum number of species is 28) and abundance decrease compared with the previous assemblage, and samples in core sections 766A-42R and -41R are barren.

3) *Planularia crepidularis - Patellina subcretacea* assemblage (core sections 766A-40R-02 to -32R-02): The base of this upper Hauterivian assemblage is marked by the FO of *Saracenaria valanginiana* and *Reinholdella hofkeri* and by a massive influx of *Patellina subcretacea.* The foraminiferal abundances increase at the base of the interval then fluctuate markedly from core section 766A-37R-03 to the top. Diversities remain moderate (with up to 28 species per sample). Agglutinated foraminifera are also absent from this assemblage. At four levels (core sections 766A-40R-02, -38R-02 to -37R-03, -35R-01, and -32R-05), the assemblages become strongly dominated by *Patellina subcretacea* and to a lesser extent by *Reinholdella hofkeri.* Highly fluctuating numbers of *Patellina subcretacea* are found in lithologic subunit IIIB from core sections 766A-45R-05 to 766A-32R-05 .

4) *Gavelinella barremiana - Pseudogaudryinella* sp. 1 assemblage (core sections 766A-30R-04 to- 26R-02): The base of this Barremian assemblage is marked by a faunal turnover corresponding to a major lithological change above an unconformity. The base of the assemblage is characterized by the LO of *Patellina subcretacea* and the FOs of *Saracenaria spinosa, Lenticulina*



TEXT-FIGURE 2
Chronostratigraphy of the Lower Cretaceous of ODP Hole 766, based on calcareous nannofossil, planktonic foraminiferal, radiolarian and palynological biostratigraphy and magnetostratigraphy. Nannofossil zones follow the zonation of Sissingh (1977). Modified from the Leg 123 magnetobiostratigraphic synthesis Kaminski et al. (1992).

macrodisca, *Lingulina* sp. 1, *Glomospirella gaultina* and *Glomospira* spp. The FOs of *Gavelinella barremiana* and *Pseudogaudryinella* sp. 1 were observed in Sample 766A-29R-03, 54-55cm. Diversity is very high in this interval (with up to 55 species per sample), except at the very top of the section (Cores 766A-27-03 to 26R-01) where the samples examined were virtually barren of foraminifera. Large numbers of *Glomospira* spp. and *Pseudogaudryinella* spp. are also found in the samples from this interval, indicative of a deeper water setting compared to the assemblage below.

The stratigraphic ranges of selected benthic foraminifera are shown in text-figure 3. A marked faunal change is observed at the lithostratigraphic boundary between Cores 766A-32R and -30R: the calcareous species *Saracenaria spinosa*, and *Lenticulina macrodisca* make their first appearance in Core 766A-30R along with some calcareous agglutinated forms such as *Pseudogaudryinella* sp. 1 and *Dorothia* sp. 1 in Core 766A-29R. Two useful markers for the latest Hauterivian and Barremian in other parts of the world are also found in Cores 766A-30R and -29R (*Gavelinella sigmoicosta* and *Gavelinella barremiana*). This faunal change probably reflects a depositional hiatus between the late Hauterivian and Barremian represented by a major discontinuity at the boundary between lithological subunits IIIA and IIIB.

DISCUSSION

Biostratigraphy

To test whether cosmopolitan Lower Cretaceous benthic foraminifera can be used for long-distance stratigraphic correlation, we compared the ranges of selected commonly occurring taxa at Site 766 with their reported ranges in the published Tethyan and boreal zonations. These species are listed in table 2.

The zonal scheme of the lower Saxony Basin (Bartenstein and Bettenstaedt 1962) was based mainly on benthic foraminiferal species that are known from shallow marine sediments, such as *Citharina, Epistomina* and ornamented *Lenticulina.* Unfortunately these forms are absent or very rare at Site 766. Only 19 of the NW German index species were encountered in this study. Among these taxa, 11 occur commonly at Site 766 and may be useful for stratigraphic correlation. The worldwide zonation proposed by Bartenstein (1979) was based on comparing the stratigraphic ranges of species on both sides of the North Atlantic. Bartenstein listed 17 species in his zonation which also occur in the studied interval at Site 766 (table 2). In general, the stratigraphic ranges of species found at Site 766 coincide with their ranges reported from the northern hemisphere zonations of Bartenstein and co-workers. However, two stratigraphically important taxa (*Saracenaria spinosa* and *Saracenaria forticosta*) appear earlier at Site 766. Other forms, such as *Reinholdella hofkeri* and *Saracenaria valanginiana,* have an expanded younger stratigraphic range in comparison with NW Europe.

A total of 13 of the 37 Valanginian to Barremian benthic taxa reported by Hart et al. (1989) were found at Site 766. There are two discrepancies in the range of two species: *Gavelinella barremiana* which is recorded by Hart et al. in the lower Aptian, was observed at Site 766 in the Barremian, which is more in accordance with its known range. A more striking disagreement was observed in the range of *Saracenaria valanginiana* which according to Hart et al. is confined to the Valanginian in SE England in agreement with the original Berriasian-Valanginian range defined by Bartenstein and Brand (1951). At Site 766 it is only present in the Hauterivian. However, in the Arctic *Saracenaria valanginiana* is reported by Tappan (1962) to have a much later occurrence (Aptian-Albian) than its normal range in the lower latitudes. Ludbrook (1966) also described the new species *Saracenaria warella* from the Aptian-Albian of the Great Artesian Basin, which shows resemblance to *S. valanginiana.*

Moullade (1984) subdivided the Valanginian to Barremian into nine zones. Unfortunately, this Tethyan zonation could not be applied at Site 766 because of the absence of six of the nine zonal markers. In addition *Gavelinella sigmoicosta,* the nominate taxon of Moullade's uppermost Hauterivian to lowermost Barremian zone, was very rare at Site 766. Only *Gavelinella barremiana* was found in the proper numbers and stratigraphic position to allow correlation with Moullade's zonal scheme. A total of 63 of the species recorded by Weidich in his range charts also occur at Site 766, which emphasizes their cosmopolitan distribution. However, most of these are stratigraphically long-ranging forms. Weidich (1990) recognised only three zones in the Valanginian-Barremian. Several of the index taxa in Weidich's zonation are also found in a similar sequence at Site 766. We list 13 species in common that have meaningful FOs and LOs. However, there are discrepancies beween the occurrences of some taxa at Site 766 and their reported stratigraphic ranges in the Bavarian Alps. The FO of *Lenticulina heiermanni* was correlated with the Valanginian/Hauterivian boundary by Weidich and was used to define the base of his Hauterivian Zone 4 while *Marginulinopsis bettenstaedti* was reported from the Barremian to Aptian. At Site 766, these two species range upwards from the base of the recovered sediment column (upper Valanginian). The range of *Saracenaria forticosta* was reported by Weidich as Barremian to Aptian, but at Site 766 it occurs in the upper Valanginian to mid-Hauterivian. Additional species that occur earlier at Site 766 are *Globulina prisca, Tristix excavata* and *Saracenaria spinosa.* The LOs of *Lenticulina ouachensis* and *Textularia bettenstaedti* were observed in the Aptian of the Bavarian Alps, whereas at Site 766 their ranges are truncated, occurring in the lower Hauterivian.

Although Riegraf and Luterbacher (1989a) included observations based on Indian Ocean DSDP sites, we found that their zonal scheme and biochronology were not applicable at Site 766. Only five of the 22 Valanginian to Barremian taxa listed in Riegraf and Luterbacher's range chart were found at Site 766. These are *Dentalina debilis, Marginulinopsis bettenstaedti, Lenticulina nodosa, Lenticulina quenstedti* [=*L. ouachensis* according to our taxonomy] and *Gavelinella barremiana.* There are differences in the reported stratigraphic ranges; for example the earliest occurrence of *G. barremiana* at Site 766 is within the lower Barremian and the last occurrence of *Lenticulina ouachensis* is in the Hauterivian (Table 2). These observations question the validity of this zonation for the austral bioprovince.

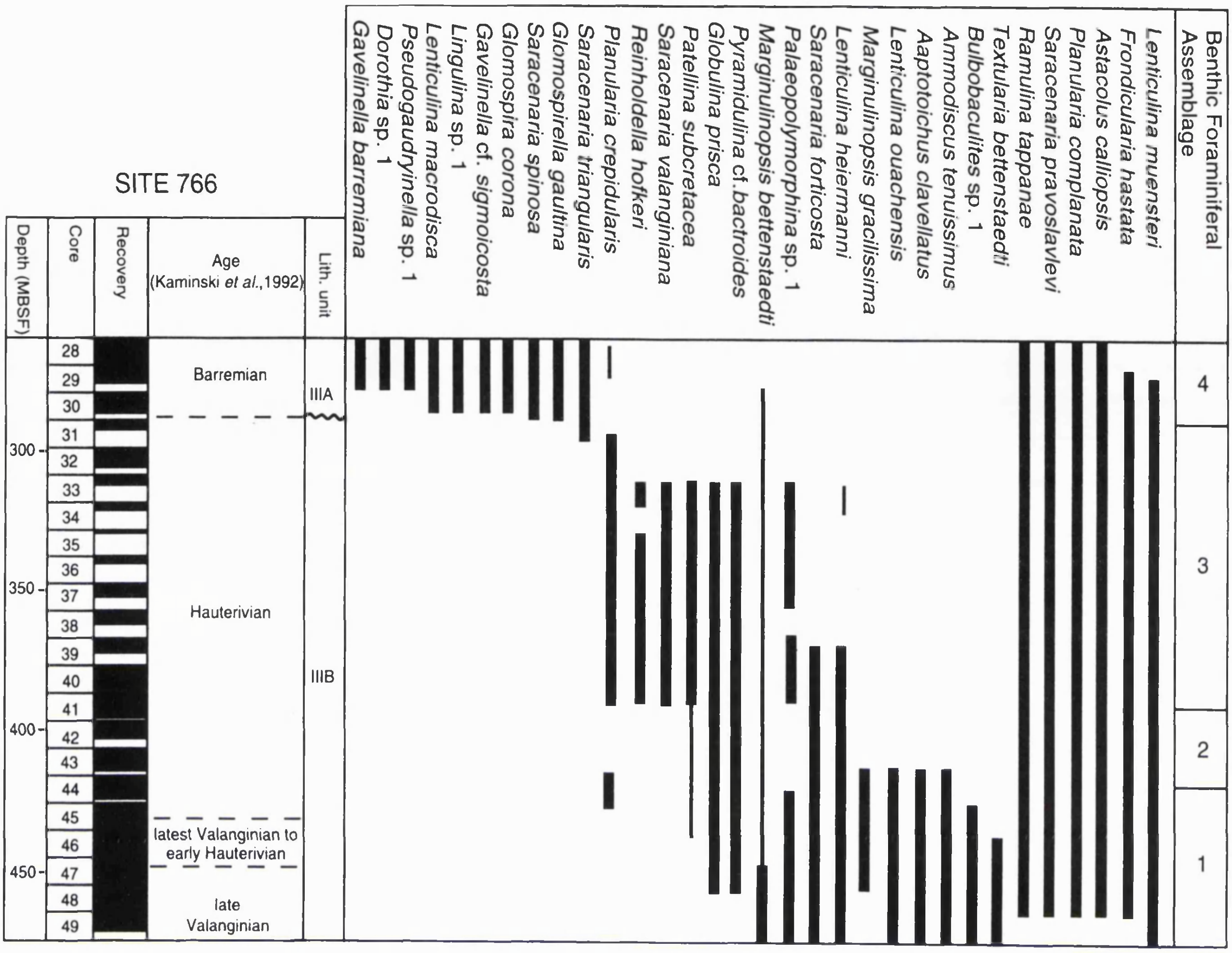
Paleoecology and Paleobiogeography

Some of the faunal distribution patterns observed at Site 766 are useful indicators of environmental and sedimentary changes. For example, the large number of organically cemented agglutinated foraminifera at the base of the section reflects clastic substrate and/or semi-restricted basinal conditions. The occurrence of exclusively calcareous assemblages above Core 766A-44R suggests a change to more open marine conditions as the young Indian Ocean widened. The faunal changes above Cores 766A-41R and -33R most likely record changes in sedimentation patterns linked to sea-floor spreading and/or sea-level changes.

Comparison with ODP Site 249: The assemblages from Site 766 show strong similarities to the shallow shelf calcareous faunas from Site 249 in the Indian Ocean, southwest of Madagascar to which Riegraf (1989) assigned a Valanginian-Hauterivian age. In contrast to Site 766, preservation remains good throughout at Site 249, tests are strongly sculptured and agglutinated forms are virtually absent. A slight endemic bias from nearby Madagascar is also detected at Site 249 by Riegraf (1989), which is not evident at Site 766. The assemblage differences probably reflect different depositional settings: Site 766 was located on a rapidly subsiding margin during the Early Cretaceous, whereas Site 249 remained a shallow, shelf close to the Majunga Basin and farther away from the main rifting center.

Comparison with ODP Sites 259 and 261: The assemblages from Site 766 differ from the flysch-type assemblages recovered at ODP Sites 259 and 261 in the Indian Ocean by the scarcity of agglutinated foraminifera. Scheibnerová (1977) suggested that the flysch-type assemblages at Sites 259 and 261 were a result of a combination of shallow depth, low temperature and reducing conditions after burial, leading to test dissolution, and that the assemblages did not necessarily reflect abyssal deposition, as proposed by Kuznetsova (1974) and Gradstein (1983). Scheibnerová (1977) argued that deep environments had not developed in the nascent Indian Ocean. The marked differences in the agglutinated component at ODP Sites 259 and 261 and at ODP Site 766 may indicate a steep bathymetric gradient along the rapidly collapsing margin of the ocean.

Comparison with Tethyan and boreal assemblages: A high proportion (about 74%) of calcareous foraminifera at Site 766 are cosmopolitan species. The assemblages from Site 766 differ,



TEXT-FIGURE 3
Stratigraphic ranges of selected benthic foraminifera at Site 766.

however, from typical low latitude Tethyan assemblages by the rarity or absence of characteristic Tethyan species such as *Epistomina* spp., *L. nodosa nodosa* Reuss and *L. eichenbergi* Bartenstein and Brand and by the scarcity of large, ornamented, palmate morphotypes such as *Citharina* spp., *Flabellina* spp. and *Frondicularia* spp. The assemblages from Site 766 still show considerable diversity and are very different from the typical Cretaceous cold-water associations dominated by agglutinated forms known from Alaska, the Russian Platform and Canada (Tappan 1962; Azbel and Grigalis 1991; Fowler and Braun 1993). The assemblages at Site 766, in fact, most closely resemble bathyal assemblages from the northern margin of Tethys described by Weidich (1990), which he considered to be cool-water associations.

The paleolatitude of Site 766 during the Valanginian-Barremian was between 50 to 60°S (Baumgartner et al. 1992) and although latitudinal temperature gradients were lower in the Lower Cretaceous oceans, significantly cooler temperatures would have occurred at these high latitudes (Frakes and Francis 1988; Frakes et al. 1992). These lower temperatures may explain the absence or rarity of Tethyan species. The paleogeography would also have favored the influx of colder southern water rather than warmer Tethyan water (Baumgartner et al. 1992, Powell et al. 1988). Scheibnerová (1971a, 1977, 1978) proposed the existence during the Early Cretaceous of a cool austral bioprovince at high southern latitudes that was the equivalent of the boreal bioprovince and that comprised Australia, India, South Africa and South America. Its existence is supported by the distinctive composition of assemblages at Site 766, which lack some of the common Tethyan taxa (instead, the various forms of *Saracenaria* and *Lenticulina* lineages are particularly well developed). It should be stressed, however, that although cool temperature may have strongly influenced the composition of shallow-water benthic foraminiferal assemblages at high latitudes, deep-water benthic foraminifera are affected by many additional factors, such as nutrient flux, substrate composition, and oxygen levels of the deep-water masses. The cosmopolitan character of the fauna at Site 766 and its relatively high diversity point to the existence of open connections with major world oceans (accentuated by the Valanginian-Barremian first order eustatic sea-level rise, Frakes et al. 1992), which allowed the dispersal of many taxa during the Early Cretaceous. Diachrony in the stratigraphic positions of some taxa suggests migration from the Tethyan to the high latitudes and vice-versa. Moullade and Guérin (1982) demonstrated that the common distribution of benthic foraminifera in numerous DSDP Sites and Tethyan outcrops indicated the presence of open marine connections between the south and central Atlantic Ocean in mid Albian time. Open connections between the austral, Tethyan and boreal realms must have been established since the Valanginian to account for the cosmopolitan nature of the microfauna.

TABLE 1
Foraminiferal census data from ODP Hole 766A.

Samples	Oolina sulcata	Palaeopolymorphina sp. 1	Textularia bettenstaedti	Trochammina sp. 1	Trochammina spp.	Recurvoides spp.	Haplophragmoides sp. 1	Ammodiscus cretaceus	Verneuilinoides subfiliformis	Globulina spp.	Laevidentalina spp.	Lenticulina heiermanni	Tristix acutangula	Lenticulina spp.	Astacolus calliopsis	Ammobaculites sp. 1	Kalamopsis grzybowskii	Saracenaria spp.	Citharina sp. 1	Globulina bucculenta	Lenticulina ouachensis	Lenticulina muensteri	Aaptotoichus clavellatus	Lenticulina pulchella	Oolina spp.	Laevidentalina communis	Psilocitharella spp.	Oolina aff. oxystoma	Haplophragmoides vocontianus	Saracenaria erlita	Saracenaria forticosta	Vaginulinopsis excentrica	Lenticulina cf. subgaultina	Saracenaria pravoslavlevi	Saracenaria compacta	Pyramidulina sceptrum	Ramulina tappanae	Ammodiscus tenuissimus	Rhizammina algaeformis	Rhabdammina cylindrica	Pseudoreophax sp. 1.	Textularia spp.	Bulbobaculites inconstans erectum	Planularia spp.	Marginulinopsis bettenstaedti	Psilocitharella arguta	Frondicularia hastata	Marginulinopsis comma	Oolina laevis	Ramulina spp.	Lenticulina nodosa	Saracenaria frankei	Vaginulinopsis neopachynota	Palmula spp.	Pyramidulina spp.	Brunsvigella thoerensis	Rhizammina spp.	Trochammina sp. 2	Fissurina cf. laevigata	Lenticulina saxocretacea	Glomospira gordialis	Planularia complanata	Glomospira spp.	Haplophagmoides spp.	Citharina rudocosta	Globulina lacrima	Bulbobaculites sp. 1	Haplophragmoides concavus
26R-02; 68-72	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
28R-01; 21-25	.	.	.	.	.	.	.	.	.	3	.	.	.	.	1	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	2	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	4	2	.	.	.	.	.	.	.
28R-03; 116-120	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	1	2	.	.	.	.	.	.	.
28R-05; 133-138	.	.	.	.	.	.	.	.	.	.	3	.	.	10	.	.	.	3	.	.	.	.	.	.	.	.	1	.	.	.	.	2	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	1	.	.	.	.	4	.	1	.	.	.	.	.	.
29R-03; 54-55	.	.	.	.	.	.	.	.	.	2	11	5	.	40	5	.	.	4	.	.	.	15	.	2	6	4	.	.	.	2	1	.	.	3	1	.	5	.	.	1	.	1	.	1	1	.	2	.	4	.	3	.	6	.	.	.	1	.	.	26	1	1	.	.	.	1	.	.
30R-03; 44-47	1	.	.	.	.	.	.	.	.	8	16	.	.	16	.	.	.	1	.	.	.	7	.	3	.	.	1	.	.	.	.	2	.	9	1	1	10	.	3	5	.	.	.	.	.	.	.	.	.	.	2	.	3	.	.	.	2	.	.	.	2	.	.	.	.	.	.	.
30R-04; 100-102	.	.	.	.	.	.	.	1	.	8	9	.	.	19	1	.	.	.	.	.	.	4	.	1	1	.	.	.	.	.	.	.	.	1	.	.	2	.	3	4	.	.	.	.	.	.	1	.	1	.	2	4	1	1	.	.	1	.	.	13	2	1	.	.	.	.	.	.
32R-02; 104-108	.	.	.	.	.	.	.	1	.	2	4	.	.	4	1	.	.	4	.	.	.	7	.	1	1	.	.	.	.	.	1	.	.	.	.	.	.	.	2	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	2	.	.	.	.	2	.	1	.	.	.	.	.	.
32R-05; 5-8	.	.	.	.	.	.	.	.	.	.	7	.	.	11	.	.	.	7	4	1	.	2	.	8	.	3	4	.	.	.	.	2	.	3	.	.	1	.	.	.	.	.	.	2	.	1	.	1	6	.	1	.	.	2	2	.	.	.	.	6	.	15	.	.	.	7	.	.
33R-02; 15-18	.	22	.	.	.	.	.	.	.	8	13	4	.	15	.	.	.	.	.	.	.	10	.	1	.	1	.	.	.	.	.	2	.	.	.	.	18	.	.	.	.	.	.	.	.	.	2	.	1	.	1	.	3	.	1	.	.	.	.	2	.	6	.	.	.	3	.	.
33R-03; 34-38	.	1	.	.	.	.	.	.	.	1	.	.	.	5	1	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
34R-01; 122-125	2	8	.	.	.	.	.	.	.	3	3	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	2	.	3	.	.	.	.	1	.	.	.	.	.	.	.	5	.	.	.	.	.	.
34R-02; 30-33	.	25	.	.	.	.	.	.	.	.	6	.	.	17	.	.	.	6	.	.	.	3	.	2	.	.	.	.	.	.	.	1	.	4	.	.	2	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	1	.	.	.	.	.	.	3	.	6	.	.	.	1	.	.
35R-01; 1-4	.	13	.	.	.	.	.	.	.	10	.	.	.	17	.	.	.	.	1	.	.	3	.	5	.	.	3	.	.	1	.	1	.	.	.	.	3	.	.	.	1	.	.	.	.	.	.	.	3	3	1	.	.	.	1	.	2	.	.	5	.	6	.	.	.	.	.	.
36R-01; 70-74	.	12	.	.	.	.	.	.	.	.	.	.	.	6	.	.	.	2	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	2	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.
37R-01; 29-33	.	1	.	.	.	.	.	.	1	2	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	2	.	.	.	.	.	.	1	.	.	.	.
37R-03; 0-3	.	.	.	.	.	.	.	.	.	.	.	.	1	6	.	.	.	1	.	.	.	4	.	.	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	9	2	.	.	1	.	1	.	.	.	.	4	.	8	.	.	.	.	.	.
38R-01; 112-116	.	.	.	.	.	.	.	.	.	2	.	.	.	5	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	2	.	2	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
38R-02; 108-111	.	.	.	.	.	.	.	.	.	2	.	.	.	6	.	.	.	3	.	2	.	1	.	.	1	.	2	.	.	.	.	1	.	.	.	.	7	.	.	.	.	.	.	.	.	.	.	.	6	.	1	.	2	.	1	.	.	.	.	.	.	10	.	.	.	.	.	.
38R-03; 111-113	1	.	.	.	.	.	.	.	.	3	2	.	.	9	.	.	.	1	.	.	.	1	.	1	2	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	1	.	3	.	4	.	.	.	.	.	.	.	.	6	.	1	.	.	.	.	.	.
39R-01; 47-51	.	4	.	.	.	.	.	.	.	.	1	.	.	3	.	.	.	.	.	.	.	.	.	2	2	.	2	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.
39R-02; 9-14	3	15	.	.	.	.	.	.	.	.	.	.	.	16	.	.	.	.	.	.	.	1	.	.	5	.	4	.	.	.	1	1	.	5	.	.	1	.	.	.	.	.	.	.	1	.	1	.	10	.	3	.	.	.	2	.	.	.	.	10	.	7	.	.	.	.	.	.
39R-03; 86-90	.	5	.	.	.	.	.	.	.	1	4	1	.	20	.	.	.	.	.	.	.	4	.	.	3	.	.	.	.	.	3	1	.	2	.	.	2	.	.	.	.	.	.	.	.	.	3	.	2	.	4	.	2	.	.	.	.	.	.	8	.	5	.	.	.	2	.	.
40R-01; 84-88	.	.	.	.	.	.	.	.	.	.	3	.	.	2	.	.	.	.	.	.	.	2	.	4	1	.	.	.	.	.	2	2	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2	.	7	.	.	.	.	.	.
40R-02; 46-50	.	1	.	.	.	.	.	.	.	4	3	.	.	2	2	.	.	.	.	1	.	1	.	.	1	.	.	.	.	.	2	1	.	2	.	.	2	.	.	.	.	.	.	3	.	.	.	.	3	.	.	.	.	.	3	.	.	.	.	4	.	.	.	.	.	4	.	.
40R-03; 33-38	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
43R-02; 46-50	.	.	.	.	.	.	.	.	.	1	3	4	1	6	.	.	.	.	.	.	.	.	.	2	3	.	.	.	.	.	.	.	.	4	.	.	2	.	.	.	.	.	.	.	.	1	.	.	2	5	.	1	3	.	3	.	.	.	.	.	.	7	.	.	.	.	.	.
43R-04; 36-40	.	3	.	.	.	.	.	.	.	1	1	.	.	9	.	.	.	.	.	.	.	.	.	3	1	.	2	.	.	.	1	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	2	.	2	.	.	.	.	3	.	14	.	.	.	.	.	.
43R-05; 131-135	.	1	.	.	.	.	3	.	.	3	9	4	.	20	.	2	.	.	.	.	1	3	.	5	.	.	.	.	.	.	2	.	.	5	1	.	.	.	3	.	3	.	.	.	.	.	.	.	3	.	3	2	3	.	.	.	3	.	.	1	.	9	.	10	.	4	5	2
44R-01; 43-48	.	15	.	.	.	.	1	.	.	17	3	5	.	14	2	.	.	.	.	.	2	9	2	.	3	.	1	.	.	.	2	5	.	2	.	.	5	.	7	.	.	1	.	.	1	.	2	.	.	.	.	3	.	.	1	.	4	.	.	17	.	.	.	4	.	.	33	.
44R-03; 47-52	.	32	.	.	.	.	1	.	.	5	.	.	.	19	.	1	.	.	.	.	.	7	.	2	.	3	.	.	.	.	3	4	.	4	.	.	2	.	9	.	.	.	.	.	.	.	.	.	4	.	10	1	.	.	1	.	.	.	.	19	.	8	.	4	1	1	48	1
44R-05; 102-106	1	29	.	.	.	.	3	.	.	8	.	.	.	11	1	.	.	.	.	.	.	3	2	.	.	4	.	1	.	.	.	6	.	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	1	5	.	.	.	.	.	.	19	.	.	.	4	.	1	27	.
45R-02; 109-113	.	30	.	.	1	.	1	.	.	10	7	1	.	10	2	2	.	.	.	.	1	8	.	.	1	.	3	.	.	.	4	6	.	5	.	1	3	.	9	.	.	.	.	.	2	.	1	2	1	.	7	5	.	1	.	.	5	.	.	8	.	4	.	1	.	12	1	.
45R-04; 115-120	.	5	.	.	.	.	5	1	.	.	4	1	.	11	1	23	.	15	.	4	.	6	.	.	.	.	.	.	.	.	2	6	.	2	1	.	.	1	1	.	.	.	.	.	.	.	.	1	.	.	.	4	11	.	.	.	.	.	.	8	.	4	.	26	.	4	34	6
46R-03; 122-125	.	21	5	1	.	.	2	.	.	8	8	.	.	10	4	1	.	2	.	.	.	7	6	.	.	1	.	.	.	.	1	12	.	5	.	.	4	.	.	.	.	2	.	.	.	.	1	.	1	.	1	1	.	.	3	2	.	.	.	11	.	4	.	11	.	3	69	3
46R-04; 105-110	.	10	.	.	.	.	1	.	2	6	1	2	.	15	1	2	.	.	.	.	.	5	4	.	.	5	.	1	.	.	.	2	1	4	.	1	9	.	3	.	.	1	.	.	.	.	.	.	1	.	2	5	.	.	.	.	7	.	.	7	.	5	.	2	.	.	33	.
46R-05; 20-24	.	12	8	.	.	.	4	.	.	3	5	1	.	14	.	.	.	3	.	.	.	11	5	.	2	.	.	1	.	.	2	.	.	.	.	.	2	.	6	.	1	2	.	.	.	.	1	2	.	1	1	.	1	.	.	.	6	.	.	12	.	1	.	14	.	1	36	4
47R-01; 98-103	1	20	.	1	4	.	1	.	.	.	3	1	.	10	3	3	.	.	.	.	1	17	5	4	.	.	.	.	.	1	4	8	2	3	.	.	1	.	2	.	.	.	.	.	1	.	6	.	2	2	.	1	.	.	.	.	.	1	.	.	.	8	.	12	.	3	38	2
47R-03; 25-30	.	5	1	.	.	.	2	.	.	5	2	1	.	14	.	.	.	.	.	3	1	29	.	.	3	.	3	.	.	.	.	1	6	21	1	.	1	.	8	.	.	.	.	1	2	.	3	.	.	.	.	2	3	.	.	.	.	.	.	2	1	5	.	6	.	1	1	1
47R-04; 114-119	1	16	2	4	.	.	8	.	.	2	3	2	.	14	2	.	.	.	.	.	1	6	4	.	.	.	.	.	.	.	1	2	1	3	.	.	.	1	11	7	2	.	.	.	1	.	1	.	1	.	.	.	.	.	.	.	8	2	.	8	1	2	.	1	.	6	1	1
48R-02; 95-98	1	6	2	1	.	.	2	.	.	.	2	3	.	4	.	2	.	1	.	.	4	10	2	.	2	.	.	.	.	1	2	4	.	6	1	2	1	.	9	.	.	.	.	.	3	.	4	.	.	2	2	.	4	.	.	.	4	.	.	19	1	1	2	6	1	.	.	.
48R-04; 51-54	.	30	.	.	.	.	.	.	1	3	8	1	.	2	6	.	.	.	.	.	.	4	.	.	.	.	2	1	.	.	.	.	3	17	.	2	.	4	9	5	1	.	.	1	3	.	.	.	2	4	1	3	10	1	3	1	2	1	1	1	1	.	.	.	.	.	.	.
48R-06; 100-104	.	3	.	.	.	.	.	.	.	.	1	.	.	7	1	.	.	.	.	.	.	1	.	1	.	.	.	.	.	1	.	.	.	2	.	.	.	.	.	2	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
49R-01; 124-128	1	36	5	.	.	1	.	.	1	.	6	.	.	4	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	2	4	3	5	4	2	2	2	2	4	3	5	1	1	1	2	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
49R-02; 42-46	.	.	.	.	1	.	1	.	1	5	.	.	.	2	1	.	1	.	.	1	2	1	5	1	1	5	2	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
49R-03; 43-45	1	13	5	1	2	5	1	1	1	5	1	7	1	2	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

TABLE 1
(continued)

Samples	*Haplophragmoides kirki*	*Glomospira charoides charoides*	*Vaginulinopsis reticulosa*	*Pyrulina cylindroides*	*Globulina prisca*	*Pyramidulina cf. bactriodes*	*Marginulinopsis gracilissima*	*Astacolus schloenbachi*	*Pyramidulina obscura*	*Laevidentalina oligostegia*	*Frondicularia bettenstaedti*	*Pyramidulina lagenoides*	*Pyramidulina zippei*	*Laevidentalina soluta*	*Lenticulina circumcidanea*	*Marginulina inaequalis*	*Vaginulinopsis spp.*	*Lenticulina subangulata*	*Astacolus spp.*	*Psilocitharella kochii*	*Ramulina aptiensis*	*Eoguttulina ichnusae*	*Ammodiscus spp.*
26R-02; 68-72	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
28R-01; 21-25	.	3	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
28R-03; 116-120	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
28R-05; 133-138	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1
29R-03; 54-55	.	16	.	.	.	.	.	.	.	1	.	.	.	1	2	1	1	5	1	.	.	.	1
30R-03; 44-47	.	8	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	4	.	.	.	.	.
30R-04; 100-102	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	1	1	.	.	.	.	.
32R-02; 104-108	.	.	.	.	.	1	.	.	.	.	1	.	.	.	2	.	1	.	.	.	.	.	.
32R-05; 5-8	.	.	.	.	7	30	.	.	.	.	25	.	.	.	7	2	9	.	2	.	.	1	.
33R-02; 15-18	.	.	.	.	.	11	.	.	.	.	7	.	1	.	.	1	1	.	3	.	1	.	.
33R-03; 34-38	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
34R-01; 122-125	.	.	.	.	.	4	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.
34R-02; 30-33	.	.	.	.	1	5	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.
35R-01; 1-4	.	.	.	.	2	10	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.
36R-01; 70-74	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
37R-01; 29-33	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
37R-03; 0-3	.	.	.	.	.	14	.	.	.	.	4	.	.	1	3	.	.	.	.	.	.	.	.
38R-01; 112-116	.	.	.	.	1	11	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
38R-02; 108-111	.	.	.	.	.	8	.	.	.	.	4	.	.	.	.	.	2	.	.	.	.	.	.
38R-03; 111-113	.	.	.	.	.	5	1	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.
39R-01; 47-51	.	.	.	.	1	2	.	.	.	.	3	.	.	.	.	.	2	.	.	.	.	.	.
39R-02; 9-14	.	.	.	.	.	2	.	.	.	.	10	.	.	1	3	.	.	.	.	.	.	.	.
39R-03; 86-90	.	.	.	.	2	.	.	.	.	.	.	.	1	.	4	.	.	1	.	.	.	.	.
40R-01; 84-88	.	.	.	.	1	3	.	.	.	.	7	.	.	.	2	.	1	.	.	.	.	.	.
40R-02; 46-50	.	.	.	.	2	9	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.
40R-03; 33-38	.	.	.	.	.	1	.	.	.	.	.	.	.	.	2	.	.	.	1	.	.	.	.
43R-02; 46-50	.	.	3	.	.	5	1	.	.	.	3	.	.	.	3	.	1	.	.	.	.	.	.
43R-04; 36-40	.	.	5	.	.	4	.	.	.	.	3	.	.	.	.	.	3	.	.	.	.	.	.
43R-05; 131-135	.	.	.	.	2	1	.	.	.	.	.	.	.	.	1	.	2	.	2	.	.	.	.
44R-01; 43-48	.	.	.	.	1	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
44R-03; 47-52	.	.	.	1	1	6	2	.	.	.	.	1	.	.	3	1	3	.	.	.	.	.	.
44R-05; 102-106	.	.	.	.	.	.	.	.	2	.	4	1	.	2	.	.	7	2	.	.	.	.	.
45R-02; 109-113	.	.	.	.	6	2	.	.	.	1	8	.	.	.	1	1	3	1	2	.	.	.	1
45R-04; 115-120	4	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
46R-03; 122-125	2	.	.	.	.	.	.	.	.	.	3	.	.	1	.	.	.	.	.	2	1	1	.
46R-04; 105-110	.	.	.	.	4	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.
46R-05; 20-24	1	.	.	.	.	.	3	.	.	.	.	.	.	.	.	1	1	1	1	.	.	.	.
47R-01; 98-103	1	.	.	.	2	1	.	.	.	.	2	1	1	1	1	.	.	1	.	.	.	.	.
47R-03; 25-30	.	.	.	.	4	4	2	2	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.
47R-04; 114-119	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
48R-02; 95-98	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
48R-04; 51-54	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
48R-06; 100-104	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
49R-01; 124-128	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
49R-02; 42-46	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
49R-03; 43-45	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Samples	*Pseudonodosaria spp.*	*Pseudonodosaria humilis*	*Pseudonodosaria mutabilis*	*Spirillina minima*	*Patellina subcretacea*	*Oolina cf. sulcata*	*Laevidentalina debilis*	*Planularia crepidularis*	*Glomospirella gaultina*	*Marginulina sp. 1*	*Lenticulina cf. schreiterei*	*Psilocitharella recta*	*Marginulina bullata*	*Lenticulina guttata*	*Saracenaria valanginiana*	*Reinholdella hofkeri*	*Laevidentalina nana*	*Tristix excavata*	*Vaginulinopsis humilis precursoria*	*Oolina hauteriviana cylindracea*	*Oolina caudata*	*Saracenaria sp. 1*	*Vaginulina petila*
26R-02; 68-72	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
28R-01; 21-25	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	1	.	.	.	.	.	.
28R-03; 116-120	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
28R-05; 133-138	.	.	.	.	.	.	.	.	4	.	.	.	1	.	.	.	.	.	.	.	.	.	.
29R-03; 54-55	.	.	.	.	.	.	.	.	11	.	.	.	4	.	.	.	1	.	.	.	.	.	.
30R-03; 44-47	.	.	.	.	.	.	.	.	13	.	.	.	.	.	.	1	.	.	.	.	.	.	.
30R-04; 100-102	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	2	.	1	.	.	.	.
32R-02; 104-108	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
32R-05; 5-8	5	.	.	.	35	.	1	1	.	.	.	.	.	7	1	45	.	1	2	.	.	1	1
33R-02; 15-18	.	.	.	.	15	.	.	4	.	.	.	.	1	.	.	4	1	.	2	.	.	.	.
33R-03; 34-38	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
34R-01; 122-125	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
34R-02; 30-33	1	.	.	.	11	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
35R-01; 1-4	.	.	.	.	20	.	.	3	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
36R-01; 70-74	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
37R-01; 29-33	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
37R-03; 0-3	.	.	.	1	43	.	.	2	.	.	.	.	.	.	.	37	.	.	.	.	.	.	.
38R-01; 112-116	3	.	.	1	110	.	.	2	.	.	.	.	.	.	1	15	.	.	2	.	.	.	.
38R-02; 108-111	1	.	.	1	255	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.
38R-03; 111-113	.	.	.	.	31	.	.	.	.	.	.	.	.	.	2	2	.	.	1	.	.	.	.
39R-01; 47-51	.	.	.	.	66	.	.	3	.	.	.	.	.	.	.	4	.	.	2	.	.	.	.
39R-02; 9-14	.	.	.	.	6	.	.	5	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
39R-03; 86-90	.	.	.	.	.	.	.	1	.	.	.	1	.	.	2	1	1	.	.	1	.	.	.
40R-01; 84-88	1	.	1	.	62	.	.	.	.	.	.	.	.	1	1	4	2	1	1	.	.	.	.
40R-02; 46-50	.	.	.	.	111	.	.	1	.	.	.	.	.	.	2	3	1	.	.	.	.	.	.
40R-03; 33-38	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
43R-02; 46-50	2	.	.	.	4	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.
43R-04; 36-40	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.
43R-05; 131-135	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.
44R-01; 43-48	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
44R-03; 47-52	1	.	.	.	1	.	.	2	4	1	.	.	.	.	.	.	.	.	.	.	.	.	.
44R-05; 102-106	1	.	1	.	5	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
45R-02; 109-113	1	1	2	3	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
45R-04; 115-120	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
46R-03; 122-125	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
46R-04; 105-110	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
46R-05; 20-24	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
47R-01; 98-103	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
47R-03; 25-30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
47R-04; 114-119	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
48R-02; 95-98	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
48R-04; 51-54	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
48R-06; 100-104	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
49R-01; 124-128	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
49R-02; 42-46	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
49R-03; 43-45	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Samples	*Saracenaria triangularis*	*Nodosaria cf. regularis*	*Saracenaria spinosa*	*Lenticulina macrodisca*	*Marginulinopsis parkeri*	*Saracenaria sp. 2*	*Lingulina sp. 1*	*Bathysiphon brosgei*	*Marginulina pyramidilis*	*Lingulina spp.*	*Glomospira charoides corona*	*Gavelinella sigmoicosta?*	*Pseudogaudryinella sp. 1*	*Dorothia sp. 1*	*Remesella sp.*	*Marssonella sp.*	*Gavelinella barremiana*	*Trochammina spp.*	*Verneuilina sp. 1*	*Pyramidulina cf. corallina*	*Pseudonodosaria cf. tenuis*	Diversity (S)	Number of Specimens
26R-02; 68-72	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
28R-01; 21-25	2	.	.	7	.	.	3	.	.	.	.	.	3	.	.	.	.	.	.	.	1	21	44
28R-03; 116-120	.	.	.	.	.	.	2	.	.	.	3	.	3	.	.	.	1	.	.	.	.	11	18
28R-05; 133-138	4	.	.	13	.	3	10	1	.	.	2	.	28	.	.	2	5	.	1	1	.	27	108
29R-03; 54-55	6	1	1	.	1	5	8	.	.	.	10	1	33	2	1	2	2	1	1	.	.	55	275
30R-03; 44-47	3	.	.	12	1	1	6	.	1	1	11	1	.	.	.	.	.	.	.	.	.	33	157
30R-04; 100-102	1	.	2	2	2	1	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	36	102
32R-02; 104-108	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	21	42
32R-05; 5-8	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	42	284
33R-02; 15-18	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	31	165
33R-03; 34-38	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	16
34R-01; 122-125	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15	40
34R-02; 30-33	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	102
35R-01; 1-4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	24	120
36R-01; 70-74	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11	30
37R-01; 29-33	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	14
37R-03; 0-3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	152
38R-01; 112-116	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	18	164
38R-02; 108-111	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	21	321
38R-03; 111-113	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	82
39R-01; 47-51	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	18	107
39R-02; 9-14	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	24	114
39R-03; 86-90	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	28	87
40R-01; 84-88	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	26	116
40R-02; 46-50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	171
40R-03; 33-38	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7	9
43R-02; 46-50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	27	73
43R-04; 36-40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	64
43R-05; 131-135	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	32	120
44R-01; 43-48	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	31	168
44R-03; 47-52	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	37	217
44R-05; 102-106	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	31	162
45R-02; 109-113	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	48	191
45R-04; 115-120	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	28	192
46R-03; 122-125	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	36	220
46R-04; 105-110	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	31	144
46R-05; 20-24	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	35	170
47R-01; 98-103	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	41	182
47R-03; 25-30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	37	151
47R-04; 114-119	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	37	130
48R-02; 95-98	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	34	117
48R-04; 51-54	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	32	134
48R-06; 100-104	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11	21
49R-01; 124-128	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	26	104
49R-02; 42-46	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	17	33
49R-03; 43-45	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	19	51

Barren samples:
766A-26R-01; 14-18
766A-26R-03; 68-72
766A-27R-02; 57-61
766A-27R-03; 10-14
766A-29R-01; 59-63
766A-29R-05; 5-9
766A-45R-06; 36-40

CONCLUSION

The taxonomic study of Valanginian-Barremian samples from ODP Site 766 provides a unique insight into the composition of bathyal foraminiferal assemblages at high southern latitudes during the Early Cretaceous. One hundred eighteen species of benthic foraminifera have been recorded, 88 of them calcareous and 30 agglutinated. Thirty-two taxa that did not closely match published taxonomic descriptions have been described in open nomenclature.

Benthic foraminifera can be used to subdivide the Valanginian-Barremian interval at ODP Site 766 into four assemblages: 1) An upper Valanginian-lower Hauterivian *Lenticulina ouachensis - Textularia bettenstaedti* assemblage characterized by *Lenticulina ouachensis, Textularia bettenstaedti, Bulbobaculites* sp. 1, *Ammodiscus tenuissimus, Aaptotoichus clavellatus, Rhizammina* spp.and *Haplophragmoides* spp. 2) A lower Hauterivian *Lenticulina heiermanni - Saracenaria forticosta* assemblage characterized by *Lenticulina heiermanni, Saracenaria forticosta, Globulina* spp., *Oolina* spp. and diverse nodosariids. 3) An upper Hauterivian *Planularia crepidularis - Patellina subcretacea* assemblage characterized by *Planularia crepidularis, Patellina subcretacea, Saracenaria valanginiana* and *Reinholdella hofkeri.* 4) A Barremian *Gavelinella barremiana - Pseudogaudryinella* sp. 1 assemblage characterized by *Gavelinella barremiana, Pseudogaudryinella* sp. 1, *Saracenaria spinosa, Lenticulina macrodisca, Lingulina* sp. 1, *Glomospirella gaultina* and *Glomospira* spp. The assemblages are important indicators of environmental and sedimentary changes, linked either to regional events or to eustatic sea-level changes and plate tectonics developments on a global scale.

A comparison of the occurrences of biostratigraphically important taxa from Site 766 with their ranges in the published boreal and Tethyan zonations points to the cosmopolitan distribution of many bathyal taxa in the Lower Cretaceous. The assemblages at Site 766 bear closest resemblance to the bathyal faunas from the northern margin of the Tethys described by Weidich (1990), suggesting deep water connections with the world oceans. However, detailed comparisons of their ranges in the northern and southern hemispheres revealed some important discrepancies: some species that are stratigraphical index taxa in both Tethyan and boreal zonations are missing at Site 766 (in particular, *Epistomina* and *Marssonella* lineages), a number of species occur earlier at Site 766 than previously recorded (e.g. *L. heiermanni, S. forticosta and S. spinosa*) and others have truncated stratigraphical ranges. The distinctive composition and stratigraphic ranges of the fauna support the existence of an austral bioprovince during the Early Cretaceous.

Finally, we point out some problems of foraminiferal systematics, especially among the nodosariids, which show great variability. The taxonomic criteria which are used are often highly subjective, leading to arbitrary classification. Such difficulties are compounded by inaccessibility of type specimens and a lack of coordinated effort to reevaluate earlier classifications. There is an urgent need for taxonomic reappraisal to assure the validity of stratigraphic correlations and paleoenvironmental analyses. Further research at other Indian Ocean DSDP and ODP Sites will lead to a better understanding of cosmopolitan faunal distribution and paleocirculation in the austral realm and help unravel the early evolution of the Indian Ocean during the Early Cretaceous.

SYSTEMATIC TAXONOMY

The microfauna recovered from Site 766 consists predominantly of calcareous foraminifera with a rich nodosariid component and variable numbers of agglutinated foraminifera, ostracods, radiolarians, fish teeth and echinoderm fragments. Preservation is generally moderate to good, except for several intervals where fragile calcareous tests are partially dissolved.

The foraminiferal classification follows the classification proposed by Loeblich and Tappan (1987). Open nomenclature has been used for taxa that do not closely match published descriptions. The following abbreviations have been used:

cf. for taxa similar to a known species but different in some detail.
aff. for taxa showing close affinity to a well-defined taxonomic group.
sp. 1, 2... for species that do not match published descriptions.
sp. for taxa not determinable at the specific level.

It should be noted that the suprageneric classification within the Family Nodosariacea is still controversial as their phylogeny remains uncertain. There is also some taxonomic confusion at the specific and generic levels because nodosariids show considerable variability. Many transitional forms transgress boundaries between species making taxonomic criteria difficult to apply and leading to subjective, arbitrary classifications. Another problem is that many studies have been carried out by researchers working in isolation and the taxonomic schemes used often reflect their own brand of "provincialism."

Phylum PROTOZOA
Class SARCODINA
Order FORAMINIFERIDA Eichwald 1830
Suborder TEXTULARIINA Delage and Hérouard 1896
Superfamily ASTRORHIZACEA Brady 1881
Family BATHYSIPHONIDAE Avnimelech 1952
Genus *Bathysiphon* Sars 1872

Bathysiphon brosgei Tappan 1957
Plate 1, figures 1a, 1b

Bathysiphon brosgei TAPPAN 1957, pl. 65, figs. 1-5. — TAPPAN 1962, pl. 29, figs. 1-5. — WEIDICH 1990, pl. 1, fig. 8; pl. 33, figs. 13-14.

Description: Straight, slender, cylindrical test with well cemented, finely agglutinated wall.

Range and Occurrence: A cosmopolitan Cretaceous species found mostly in flysch facies (Weidich 1990).

Family RHABDAMMININAE Brady 1884
Subfamily RHABDAMMININAE Brady 1884
Genus *Rhabdammina* Sars 1869

Rhabdammina cylindrica Glaessner 1937
Plate 1, figures 3-4

Rhabdammina cylindrica GLAESSNER 1937; pl. 1, fig. 1. — WEIDICH 1990, pl. 1, fig. 2; pl. 33, figs. 2-3.

Description: Slender, tubular, straight test, very coarsely agglutinated.

Remarks: Specimens in Site 766 are somewhat flattened.

Range and Occurrence: A cosmopolitan Cretaceous to Paleogene species (Weidich 1990).

Genus *Rhizammina* Brady 1879

Rhizammina algaeformis Brady 1879
Plate 1, figure 5

TABLE 2
A comparison of stratigraphic ranges of index taxa from (1) Bartenstein and Bettenstaedt 1962; (2) Bartenstein 1979; (3) Hart et al. 1989; (4) Weidich 1990; (5) Riegraf and Luterbacher 1989a.

Species name	**Range at Site 766**	**Range in Literature**
Astacolus schloenbachi	upper Val. - Bar.	Val.-lower Apt. (3)
Bulbobaculites inconstans	upper Val. - Haut.	Val. to Haut. (1)
Laevidentalina debilis		Haut. Berr. to Alb. (5)
Frondicularia hastata		upper Val. - Bar.Val.-lower Bar. (3)
		Berr. to Bar. (4)
Gavelinella barremiana	Bar.	mid Bar. to lower Apt. (max. mid Bar.) (1)
		mid Bar.-lower Apt. (2)
		lower Apt. (3)
		Bar. to Apt. (4)
		Haut. to Albian (5)
Gavelinella sigmoicosta	Bar.	upper Haut. to lower Bar. (max. u. Haut.) (1)
		upper Haut.-Bar. (2)
		upper Haut.-lower Bar. (3)
		lower Bar. (4)
Globulina prisca	upper Val. - Haut.	upper Alb. to Cenom. (4)
Lagena hauteriviana		Haut. Berr.-lower Bar. (3)
Lenticulina guttata	Haut.	Berr.-lower Bar. (2)
Lenticulina heiermanni	upper Val. - lower Haut.	Haut.-lower Bar. (3)
		Haut. to Bar. (4)
Lenticulina muensteri		upper Val. - Bar.Berr.-Bar. (3)
Lenticulina nodosa and subspecies	upper Val. - Bar.	upper Val. to lower Haut. (1)
		Berr.-Bar., Apt.? (2)
		mid-Val. to mid-Barr. (5)
Lenticulina ouachensis	upper Val. - lower Haut.	upper Hauteriv. to lower Apt. (max. u.-m. Bar.) (1)
		Val.-lower Apt. (2)
		upper Val.-Haut. (3)
		Berr. to Apt. (4)
		lower Val. to lower Apt. (5)
Lenticulina reticulosa		upper Val. - lower Haut.Val.-lower Apt. (2)
Lenticulina schreiterei		Haut. Val.-Alb. (2)
		upper Val.-Haut., lower Apt. (3)
Marginulinopsis bettenstaedti	upper Val. - Bar.	Berr. to Apt. (4)
		(max. upper Val.)lower Haut. to mid Bar. (max. Haut.) (1)
		mid-Val. to mid-Bar. (5)
Marginulinopsis gracilissima	upper Val. - lower Haut.	mid Val. to lower Apt. (max. u. Haut - m. Bar.) (1)
	Berr.-lower Apt. (3)	
Patellina subcretacea		Haut. Berr. to lower Apt. (4)
Planularia crepidularis	Haut.	upper Val. to mid Bar. (max. u. Haut.) (1)
		Tith.-lower Apt. (2)
		upper Val.- lower Apt. (3)
Reinholdella hofkeri		Haut. Berr.-Val. (2)
Saracenaria forticosta		upper Val. - Haut.lower Bar. to lower Apt. (max. mid Bar.) (1)
		mid Bar.-lower Apt. (2)
		Bar. to Apt. (4)
Saracenaria frankei		upper Val. - Haut.upper Val.-lower Apt. (2)
Saracenaria spinosa		Bar. lower Apt. to lower Alb. (max. u. Apt.) (1)
		Apt.-lower Alb. (2)
		upper Apt. (4)
Saracenaria valanginiana	Haut.	Berr.-Val. (2)
		Val. (3)
Textularia bettenstaedti	upper Val. - lower Haut.	upper Haut. to lower Alb. (max. u. Apt - l. Alb.) (1)
	Berr. to Apt. (4)	
Tristix excavata	Haut.	upper Alb. to Cenom. (4)
Psilocitharella arguta		upper Val. - Haut. upper Val.-Cenom. (2)
		upper Val.-lower Bar. (3)
Psilocitharella kochii		lower Haut.upper Val.-lower Apt. (2)
		Bar. to Apt. (4)
Psilocitharella recta		Haut. mid Bar.-lower Cenom. (2)
Vaginulinopsis humilis precursoria		upper Haut. Val.-lower Apt. (3)
Vaginulinopsis neopachynota	upper Val. - Bar.	Haut.-Bar. (2)

Rhizammina algaeformis BRADY 1879, pl. 4, figs. 16-17. — WEIDICH 1990, pl. 33, figs. 7-8.

Description: Slender, tubular test, quite coarsely agglutinated, flattened in cross-section and markedly bent.

Range and Occurrence: Cosmopolitan Cretaceous species, typical of turbid and cold environment in deep basins (Weidich 1990).

Superfamily AMMODISCACEA Reuss 1862
Family AMMODISCIDAE REUSS 1862
Subfamily AMMOVERTELLININAE Saidova 1981

Genus ***Glomospira*** Rzehak 1885

Finely agglutinated, tubular test with aperture at open end of tube, streptospirally enrolled at least in its early part. Classified into subgroups by Weidich (1990) according to the regularity of coiling.

Glomospira charoides charoides (Jones and Parker 1860)
Plate 1, figure 13

Trochammina squamata var. *charoides* JONES and PARKER 1860, p.304.
Glomospira charoides charoides (Jones and Parker) — WEIDICH 1990, pl. 34, fig. 7, 11.
Glomospira charoides (Jones and Parker) — BERGGREN and KAMINSKI 1990, pl. 1, fig. 2.

Description: Irregularly coiled about an axis.

Remarks: Berggren and Kaminski (1990) designated a lectotype from the W.K. Parker collection at the B.M.N.H.

Range and Occurrence: Cosmopolitan throughout the Early Cretaceous.

Glomospira charoides corona Cushman and Jarvis 1928
Plate 2, figures 1a, 1b, 3a, 3b.

Glomospira charoides var. *corona* CUSHMAN and JARVIS 1928, pl. 12, figs. 9-11.
Glomospira corona Cushman and Jarvis. — TAPPAN 1962, pl. 29, fig. 13-16.
Glomospira charoides corona Cushman and Jarvis. — WEIDICH 1990, pl. 34, fig. 8-9.

Description: Distinctive crown-shaped coiling. May be a growth stage of *Glomospira charoides.*

Range and Occurrence: Cosmopolitan species appearing in the Barremian.

Glomospira gordialis (Jones and Parker 1860)

Trochammina squamata var. *gordialis* JONES and PARKER 1860, p. 304.
Glomospira gordialis (Jones and Parker). — BARTENSTEIN and BRAND 1951, pl. 1, figs. 15-16. — BERGGREN and KAMINSKI 1990, pl. 1, fig. 1.

Description: Test remains irregularly coiled.

Remarks: Berggren and Kaminski (1990) designated a lectotype from the W.K. Parker collection at the B.M.N.H.

Range and Occurrence: Cosmopolitan throughout the Early Cretaceous.

Genus *Glomospirella* Plummer 1945

Glomospirella gaultina (Berthelin 1880)
Plate 1, figures 10-12

Ammodiscus gaultinus BERTHELIN 1880, pl. 1, fig. 3.
Glomospirella gaultina (Berthelin). — RIEGRAF and LUTERBACHER 1989a, pl. 1, figs. 16-17.

Description: Tubular test, glomospiral initially, becomes planispiral. Aperture at open end of tube.

Range and Occurrence: Cosmopolitan in the Early Cretaceous.

Subfamily AMMOVOLUMMINAE Chernykh 1967
Genus *Ammodiscus* Reuss 1862

Ammodiscus cretaceus (Reuss 1845)
Plate 1, figures 7-8

Operculina cretacea REUSS 1845, pl. 13, figs. 64-65.
Ammodiscus cretaceus (Reuss). — TAPPAN 1962, pl. 30, figs. 1-2. — WEIDICH 1990, pl. 1, fig. 15.

Description: Finely agglutinated, tubular test with globular proloculus and planispirally coiled second chamber increasing gradually in diameter. The whorls of the coil are slightly overlapping and the test may be occasionally constricted. Aperture at end of open tube.

Range and Occurrence: Cosmopolitan throughout the Cretaceous.

Ammodiscus tenuissimus (Gümbel 1862)
Plate 1, figure 6a, 6b

Spirillina tenuissimus GÜMBEL 1862, pl. 4, fig. 12a, b.
Ammodiscus tenuissimus (Gümbel). — BARTENSTEIN and BRAND 1951, pl. 1, fig. 14. — NEAGU 1975, pl. 1, figs. 1-4, 7-13, 25; pl. 2, figs. 1-14, 16, 21, 30. — KAMINSKI et al. 1992, pl. 2, fig. 3.

Description: Subcircular, tubular test with small, globular proloculus and thin, planispiral second chamber increasing in size very gradually. Test composed of fine agglutinated particles cemented in a fine siliceous matrix, giving the test a slightly rough appearance. Aperture at end of open tube.

Range and Occurrence: Late Valanginian in northwestern Germany (Bartenstein and Brand 1951), Hauterivian in Rumania (Neagu 1975) and earliest Cretaceous at ODP Site 765 (Kaminski et al. 1992).

Superfamily HORMOSINACEA Haeckel 1894
Family ASCHEMOCELLIDAE Vyalov 1966
Genus *Kalamopsis* de Folin 1883

Kalamopsis grzybowskii (Dylazanka 1923)

Hyperammina grzybowskii DYLAZANKA 1923, p. 65-66.
Kalamopsis grzybowski (Dylazanka). — KAMINSKI and GEROCH 1993, pl. 17, figs. 5a-8.

Description: A narrow tube with constrictions.

Range and occurrence: A single specimen. Reported from the Lower Cretaceous of Site 765 (Kaminski et al. 1992).

Superfamily LITUOLACEA de Blainville 1827
Family HAPLOPHRAGMOIDIDAE Maync 1952
Genus *Haplophragmoides* Cushman 1910

Haplophragmoides concavus (Chapman 1892)
Plate 2, figures 5, 7

Trochammina concava CHAPMAN 1892, pl. 6, fig. 14a, b.
Haplophragmoides concavus (Chapman). — NEAGU 1975, pl. 12, figs. 3-15. — WEIDICH 1990, pl. 7, figs. 2, 11, 19; pl. 36, figs. 5-6.

Description: Biumbilicate, planispiral test, slightly evolute, usually with five or six chambers in last whorl. Straight, depressed sutures, deep umbilicus and finely agglutinated wall. The apertural slit at the base of the last chamber is rarely visible.

Remarks: Specimens at Site 766 show appreciable variability in size, number of chambers and degree of diagenetic compression.

Range and Occurrence: Cosmopolitan species in the Early Cretaceous (Weidich 1990).

Haplophragmoides* cf. *vocontianus Moullade 1966
Plate 2, figure 4

Haplophragmoides vocontianus MOULLADE 1966, pl. 1, figs. 1-2.

Description: Biumbilicate, involute, planispiral test, very compressed with eight quadrate chambers in last whorl. Apertural slit at base of last chamber, wall finely agglutinated.

Remarks: The number of chambers in the last whorl does not usually reach 9-11 as described by Moullade (1966).

Haplophragmoides kirki Wickenden 1932
Plate 2, figure 2

Haplophragmoides kirki WICKENDEN 1932, pl. 1, fig. 1. — KAMINSKI et al. 1992, pl. 4, figs. 1a-2.

Description: Planispiral, involute test with four or five moderately inflated chambers in last whorl.

Remarks: Rare in Site 766; aperture not visible.

Range and Occurrence: Originally described from Upper Cretaceous of Alberta. Also reported from the Upper Jurassic-Lower Cretaceous at Site 765 (Kaminski et al. 1992).

Haplophragmoides sp. 1
Plate 2, figure 6

Description: Biumbilicate, planispiral test, markedly evolute with six chambers in the last whorl. Periphery lobulate, chambers somewhat flattened with straight, depressed sutures. Aperture an elongate slit at the base of the apertural face, wall finely agglutinated.

Remarks: Many tests are distorted by diagenetic compaction.

Haplophragmoides sp.

Description: Biumbilicate, planispiral, involute test with six inflated chambers in last whorl. Periphery rounded, deep, narrow umbilicus and depressed, straight sutures. Aperture not visible.

Family LITUOLIDAE de Blainville 1827
Subfamily AMMOMARGINULININAE Podobina 1978
Genus *Ammobaculites* Cushman 1910

Ammobaculites sp. 1
Plate 2, figure 8a, 8b

Description: Large, robust, very coarsely agglutinated test with large planispiral coil and indistinct sutures.

Remarks: Specimens in Site 766 are mostly closely enrolled without a distinct uncoiled portion. They appear at marked horizons in the sedimentary sequence, probably reflecting the cyclic influx of coarse clasts.

Family AMMOBACULINIDAE Saidova 1981
Genus *Bulbobaculites* Maync 1952

Bulbobaculites sp. 1
Plate 2, figure 9

Description: Elongated test with small, streptospiral, early stage and very coarsely agglutinated wall. Sutures and number of chambers indistinct due to very large agglutinated particles.

Remarks: Found mostly in association with *Ammobaculites* sp.1, also a very coarsely agglutinated species. The occurrence of these two species at specific levels reflects sedimentary pulses of coarser particles.

Bulbobaculites inconstans erectum (Bartenstein and Brand 1951)
Plate 2, figure 10

Haplophragmium inconstans erectum BARTENSTEIN and BRAND 1951, pl. 3, figs. 50-55. — MICHAEL 1974, pl. 1, fig. 7.

Description: Elongated test, cylindrical in cross-section with small streptospiral early stage becoming uniserial. Chambers broader than high and separated by deep sutures, last chamber markedly pointed towards terminal aperture. Wall firmly cemented, with some coarse particles.

Range and Occurrence: Originally described from Valanginian of northwestern Germany by Bartenstein and Brand (1951).

Superfamily HAPLOPHRAGMIACEA Eimer and Fickert 1899
Family AMMOSPHAEROIDININAE Cushman 1927
Subfamily RECURVOIDINAE Alekseychik-Mitskevich 1973
Genus *Recurvoides* Earland 1934

Recurvoides sp.

Description: Small, trochospirally enrolled test.

Remarks: Rare in Site 766. Specimens are often compressed and apertures rarely visible.

Superfamily SPIROPLECTAMMINACEA Cushman 1927
Family TEXTULARIOPSIDAE Loeblich and Tappan 1982
Genus *Aaptotoichus* Loeblich and Tappan 1982

Aaptotoichus clavellatus (Bartenstein and Brand 1951)
Plate 3, figure 2a, 2b

Bigenerina clavellata BARTENSTEIN and BRAND 1951, pl. 4, figs. 75-76.
Aaptotoichus clavellatus (Bartenstein and Brand). — LOEBLICH and TAPPAN 1988, pl. 122, figs. 1-4.

Description: Small, finely agglutinated, compressed test, biserial at first, becoming uniserial and flaring, Last chamber flattened and rounded, small, terminal aperture rarely visible.

Range and Occurrence: Found in upper Valanginian deposits of northwestern Germany (Bartenstein and Brand 1951), upper Valanginian-lower Hauterivian of Rumania (Neagu 1975), Barremian alpine sediments (Weidich 1990) and Lower Cretaceous of Trinidad and Texas (Loeblich and Tappan 1988).

Superfamily TROCHAMMINACEA Schwager 1877
Family TROCHAMMINADAE Schwager 1877
Subfamily TROCHAMMININAE Schwager 1877
Genus *Trochammina* Parker and Jones 1859

Trochammina sp. 1
Plate 3, fig. 3a, 3b.

Description: Trochospiral, planoconvex, flattened test with five chambers in last whorl and lobate periphery.

Remarks: Few, poorly preserved specimens recovered.

Trochammina sp. 2
Plate 3, figure 4a, 4b

Description: Trochospiral, spiroconvex test with two and a half whorls of five chambers and lobate periphery. Chambers inflated, increasing quite rapidly in size; sutures radial and umbilicus markedly depressed.

Remarks: Rare at Site 766.

Superfamily VERNEUILINACEA Cushman 1911
Family VERNEUILINIDAE Cushman 1911
Subfamily VERNEUILINOIDINAE Suleymanov 1973
Genus *Pseudoreophax* Geroch 1961

Pseudoreophax sp. 1
Plate 3, figure 5a, 5b

Description: Slender, elongated, finely agglutinated test with circular cross-section. Trochospiral in early stage becoming uniserial along a twisted axis; aperture terminal, usually indistinct.

Remarks: Only few specimens present. Differs from *Pseudoreophax cisovnicensis* Geroch in possessing more numerous chambers and a more tapered initial part.

Genus *Verneuilinoides* Loeblich and Tappan 1949

Verneuilinoides subfiliformis Bartenstein 1952
Plate 3, figure 6a, 6b

Verneuilinoides subfiliformis BARTENSTEIN 1952, pl. 12a, figs. 1-11. — BARTENSTEIN and BOLLI 1986, pl. 2, figs. 23-25. — WEIDICH 1990; pl. 32, fig. 9.

Description: Elongated, triserial test, subrounded in cross-section with numerous chambers (usually ten or more), separated by distinct sutures. Wall finely agglutinated, interiomarginal arched aperture.

Remarks: Bartenstein and Bolli (1986) suggested that this species evolved from *V. neocomiensis* Mjatliuk and is a precursor to *Dorothia filiformis* Berthelin.

Range and Occurrence: A cosmopolitan species from the Hauterivian to early Albian.

Subfamily VERNEUILININAE Cushman 1911
Genus *Pseudogaudryinella* Cushman 1911

Pseudogaudryinella sp. 1
Plate 3, figure 10

Description: Elongate test, initially triserial, then becoming biserial to uniserial. Aperture interiomarginal in biserial stage or terminal in uniserial stage.

Remarks: Specimens from Site 766 usually lack a uniserial stage. Common in Cores 766A-30R-28R.

Genus *Verneuilina* d'Orbigny 1839

Verneuilina sp. 1
Plate 3, figure 8

Description: Elongate, triangular test with chambers triserially arranged and interiomarginal apertural arch.

Remarks: Present in Cores 766A-30R-28R.

Superfamily ATAXOPHRAGMIACEA Schwager 1877
Family GLOBOTEXTULARIIDAE Cushman 1927
Subfamily LIEBUSELLINAE Saidova 1981
Genus *Remesella* Vasicek 1947

Remesella sp.
Plate 3, figure 7

Description: Elongate, subconical test with chambers trochospirally enrolled initially, then becoming biserial. Well-cemented wall and interiomarginal apertural arch.

Remarks: Present in Cores 766A-30R-28R.

Superfamily TEXTULARIACEA Ehrenberg 1838
Family EGGERELLIDAE Cushman 1932
Subfamily DOROTHINAE Balakhmatova 1972
Genus *Dorothia* Plummer 1931

Dorothia sp. 1
Plate 3, figure 11

Description: Elongated, finely agglutinated test, subcircular in cross-section, with moderately inflated chambers and nearly parallel sides. Trochospiral in early stage, later biserial, with an interiomarginal apertural slit on the last chamber.

Remarks: Common in Cores 766A-30R-28R.

Genus *Marssonella* Cushman 1933

Marssonella sp.

Description: Conical, subcylindrical test with trochospiral early stage, becoming triserial, then biserial. Wall finely agglutinated, aperture interiomarginal.

Remarks: Few, poorly preserved specimens.

Family TEXTULARIDAE Ehrenberg 1838
Subfamily TEXTULARIINAE Ehrenberg 1838
Genus *Textularia* Defrance 1824

Textularia bettenstaedti Bartenstein and Oertli 1977
Plate 3, figure 9

Textularia bettenstaedti BARTENSTEIN and OERTLI 1977, figs. 3, 4. — BARTENSTEIN and KOVATCHEVA 1982, pl. 1, figs. 24-25.

Description: Long, narrow, biserial test with 12 alternating chambers separated by depressed sutures. Agglutinated wall with characteristic "coal dust" grains, especially along the sutures; apertural slit on the inner side of the last chamber,

Range and Occurrence: Cosmopolitan species in temperate and Tethyan facies (Bartenstein and Kovatcheva 1982). Rare in the

Valanginian-middle Barremian and early Aptian, common in the late Aptian-early Barremian (Bartenstein and Oertli 1977). Reported from the upper Hauterivian to lower Albian in the boreal fauna of the Central North Sea (King et al. 1989). Characterizes the basal assemblage (late Valanginian) at Site 766.

Suborder SPIRILLININA Hoenegger and Piller 1975
Family PATELLINIDAE Rhumbler 1906
Subfamily PATELLININAE Rhumbler 1906
Genus *Patellina* Williamson 1858

Patellina subcretacea Cushman and Alexander 1930
Plate 14, figures 7a, 7b and 8a, 8b.

Patellina subcretacea CUSHMAN and ALEXANDER 1930, pl. 3, fig. 1a, b. — BARTENSTEIN and BRAND 1951, pl. 11, fig. 319. — NEAGU 1975, pl. 82, figs. 1-16; pl. 85, figs. 26-29.

Description: Conical test, evolute on spiral side and involute on ventral side. Two chambers per whorl, narrower at the ends and separated by weakly carinate spiral sutures. Scroll-like median septum, radiating grooves and nodes distinct on ventral side of well preserved specimens. Pores are present on outer wall of chambers.

Range and Occurrence: Recorded from the middle and upper Valanginian in northwestern Germany (Bartenstein and Brand 1951), from the Hauterivian, Barremian and lower Aptian in Rumania (Neagu 1975) and in Berriasian-lower Aptian sediments of the Bavarian Alps (Weidich 1990).

Family SPIRILLINIDAE Reuss and Fritsch 1861
Genus *Spirillina* Ehrenberg 1843

Spirillina minima Schacko 1892
Plate 14, figure 9a, 9b

Spirillina minima SCHACKO 1892; pl. 1, fig. 4. — BARTENSTEIN and KOVATCHEVA 1982, pl. 4, figs. 38, 39; pl. 5, figs. 43-44. — WEIDICH 1990, pl. 44, fig. 28.

Description: Discoidal test with small proloculus and gradually increasing tubular second chamber, initially trochospiral, becoming planispiral. Aperture at end of open tube. Numerous pores on test surface.

Range and Occurrence: Widely recorded in the Lower Cretaceous.

Suborder LAGENINA Delage and Hérouard 1896
Superfamily NODOSARIACEA Ehrenberg 1836
Family NODOSARIIDAE Ehrenberg 1838
Subfamily NODOSARIINAE Ehrenberg 1838
Genus *Laevidentalina* Loeblich and Tappan 1986

Laevidentalina communis (d'Orbigny 1826)
Plate 4, figures 1a-3c

Nodosaria communis d'ORBIGNY 1826 p. 254.
Dentalina communis (d'Orbigny). — BARTENSTEIN and BRAND 1951, pl. 9, figs. 228-231. — BARTENSTEIN and BOLLI 1986; pl. 2, figs. 36-37.

Description: Elongated, uniserial test with a slightly curved axis. Variable number of chambers, increasing slowly in size and separated by inclined, slightly depressed sutures.

Range and Occurrence: A cosmopolitan species commonly recorded in the Lower Cretaceous.

Laevidentalina debilis (Berthelin 1880)

Marginulina debilis BERTHELIN 1880, pl. 3, fig. 28.
Dentalina debilis (Berthelin). — BARTENSTEIN and BRAND 1951, pl. 10, fig. 239-240a.
Lenticulina (Vaginulina) debilis (Berthelin). — MOULLADE 1984, pl. 3, fig. 13.

Description: Elongated, uniserial, thin test with sharp dorsal edge and rounded ventral side. Chambers inflated ventrally and separated by strongly depressed, inclined sutures.

Remarks: Only found as fragments.

Range and Occurrence: Cosmopolitan in the Lower Cretaceous (Bartenstein and Brand 1951).

Laevidentalina nana (Reuss 1863)
Plate 4, figure 4a, 4b

Dentalina nana REUSS 1863, pl. 2, figs. 10, 18. — FUCHS and STRADNER 1967, pl. 7, fig. 5. — MOULLADE 1984, pl. 2, fig. 15. — MEYN and VESPERMANN 1994, pl. 7, figs. 8-16; pl. 8, figs. 1-3.

Description: Uniserial, elongated, straight to slightly curved test, subcylindrical in cross-section with very wide chambers (five or more), becoming slightly elongated and inflated. The last chamber tapers towards a terminal, dorsal aperture while the first chamber is markedly rounded. Sutures are oblique and slightly depressed.

Range and Occurrence: Albian in the Netherlands (Fuchs and Stradner 1967) and in Atlantic and Tethys (Moullade 1984). Barremian-Cenomanian in the northern Alps (Weidich 1990).

Laevidentalina oligostegia (Reuss 1845)
Plate 4, figure 5a, 5b

Nodosaria oligostegia REUSS 1845, pl. 13, figs. 19-20.
Dentalina oligostegia (Reuss) MOULLADE 1984, pl. 2, fig. 16. — WEIDICH 1990, pl. 25, fig. 10; pl. 40, fig. 8.

Description: Uniserial, elongated test consisting of two ovate chambers, separated by distinctly depressed sutures. Last chamber elongated towards terminal radiate aperture on dorsal side.

Range and Occurrence: Albian in the Atlantic and Tethys (Moullade 1984). Aptian-Albian in the northern Alps (Weidich 1990).

Laevidentalina soluta (Reuss 1851)
Plate 4, figure 6a, 6b

Dentalina soluta REUSS 1851, pl. 3, fig. 4a, b.
Dentalina soluta (Reuss). — BARTENSTEIN and BRAND 1951, pl. 9, fig. 237. — WEIDICH 1990, pl. 39, figs. 11-12; pl. 40, fig. 7.

Description: Uniserial, elongated test with spherical chambers strongly strangulated by very depressed, wide sutures.

Remarks: Mostly found as fragments, broken off at sutures.

Range and Occurrence: Mid to late Valanginian in northwestern Germany (Bartenstein and Brand 1951). Hauterivian-Cenomanian in the northern Alps (Weidich 1990).

Genus *Nodosaria* Lamarck 1812

Nodosaria* cf. *regularis Terquem 1862
Plate 4, figure 12

Nodosaria regularis TERQUEM 1862, pl. 5, fig. 12.
Nodosaria cf. *regularis* Terquem. — BARTENSTEIN and BRAND 1951, pl. 10, figs. 244-245.

Description: Uniserial, rectilinear test, usually consisting of only two chambers strongly strangulated by a deep suture. The first chamber is more spherical and distinctly pointed at the base, the second is elongated towards a terminal central aperture.

Range and Occurrence: Late Valanginian-early Hauterivian in northwestern Germany (Bartenstein and Brand 1951).

Genus *Pyramidulina* Fornasini 1894

Pyramidulina* cf. *bactriodes (Reuss 1863)
Plate 4, figures 8-9

Nodosaria bactriodes REUSS 1863, pl. 2, fig. 5. — NEAGU 1975, pl. 71, figs. 11-14.

Description: Short, costate test with large, inflated first chamber followed by two or three smaller chambers, gradually decreasing in size and tapering towards central apertural neck. Basal disc may originally have surrounded a spine. Sutures slightly depressed, a variable number of prominent costae ornament the test.

Remarks: Closest to specimen illustrated by Neagu (1975) in pl. 71, fig. 11. Differs from *P. bactriodes* Reuss in the smaller number of chambers, shorter test and variable number of costae. Also close to the Jurassic species *P. dispar* Franke, illustrated by Exton (1979) in pl. 2, fig. 1. This Jurassic species is very variable leading to taxonomic confusion. Bach et al. (1959) established the synonymy between *P. dispar* Franke, *P. hortensis* Terquem, *P. variabilis* Terquem and Berthelin, *P. fontinensis* Terquem and *P. mutabilis* Terquem, renamed *P. reiseckei* Hagenmeyer. Exton (1979), however, retained them as distinct species. The specimens from Site 766 most closely resemble *P. dispar* Franke, described by Exton (1979), although they are slightly more inflated. The two and three chambered specimens of *P. reineckei* described by Hagenmeyer in Bach et al. (1959) are considered to be juvenile stages. The predominance of short tests in Site 766 suggests, however, that they are adult individuals.

Range and Occurrence: Early Hauterivian in Rumania (Neagu 1975).

Pyramidulina* cf. *corallina (Gümbel 1862)
Plate 4, figure 10

Nodosaria corallina GÜMBEL 1862, pl. 3, fig. 10a, b. — RIEGRAF and LUTERBACHER 1989b, pl. 3, figs. 4-5. — WEIDICH 1990, pl. 24, fig. 6.

Description: Uniserial, elongated test with near spherical chambers increasing slowly in size. The chambers are ornamented by longitudinal ribs and separated by deep, straight sutures.

Remarks: The number of ribs (12 in younger chambers) is higher than on the specimen illustrated by Gümbel. Very rare, may not be in situ.

Range and Occurrence: Callovian-Kimmeridgian in the North Atlantic, Germany and in the eastern Indian Ocean (Riegraf and Luterbacher 1989b).

Pyramidulina lagenoides (Wisniowski 1890)
Plate 4, figure 11

Nodosaria lagenoides WISNIOWSKI 1890, pl. 8, fig. 25. — KUZNETSOVA 1974, pl. 2, fig. 22.

Description: Ovate test with prominently inflated, costate first chamber and very reduced second and third chambers, barely visible below apertural neck.

Range and Occurrence: Late Jurassic species, very rare in Site 766, perhaps reworked.

Pyramidulina obscura (Reuss 1845)
Plate 4, figure 13a, 13b

Nodosaria obscura REUSS 1845, pl. 13, figs. 7-9. — BARTENSTEIN and BRAND 1951, pl. 10, figs. 247-248. — WEIDICH 1990, pl. 25, fig. 1; pl. 39, figs. 7-8.

Description: Small, uniserial, cylindrical test with five or six sub-spherical chambers, the first one being slightly pointed. The chambers are ornamented by 12 fine longitudinal ribs and separated by faintly depressed sutures.

Range and Occurrence: Widely recorded in Lower and Upper Cretaceous sediments (Bartenstein and Brand 1951).

Pyramidulina sceptrum (Reuss 1863)

Nodosaria sceptrum REUSS 1863, pl. 2, fig. 3. — NEAGU 1975, pl. 70, figs. 3-5, 7. — HAIG 1982, pl. 2, figs. 29-32.

Description: Elongate test with chambers broader at base and straight, depressed sutures. Test increases slowly in size and is ornamented by fine, longitudinal costae. Simple, terminal aperture.

Remarks: Occurs mostly as fragments.

Range and Occurrence: Barremian in Rumania (Neagu 1975). Aptian-Albian in Queensland (Haig 1982).

Pyramidulina zippei (Reuss 1845)
Plate 4, figure 14a, 14b, 14c

Nodosaria zippei REUSS 1845, pl. 8, figs 1-3. — MICHAEL 1974, pl. 2, fig. 12. — KUZNETSOVA 1974, pl. 2, fig. 13. — WEIDICH 1990, pl. 39, fig. 6.
Nodosaria cf. *zippei* (Reuss). — BARTENSTEIN and BRAND 1951, pl. 10, fig. 249.

Description: Uniserial, rectilinear test with five chambers becoming slightly wider towards the top. The first chamber is spherical and slightly pointed, the last one is flattened with a small apertural neck. Nine prominent, longitudinal costae ornament the test.

Remarks: This species differs somewhat from the original description of Reuss in the number and shape of chambers. It is very similar to Lower Cretaceous specimens illustrated by Bartenstein and Brand (1951), Michael (1974), Kuznetsova (1974) and Weidich (1990).

Range and Occurrence: Late Valanginian-early Hauterivian in northwestern Germany (Bartenstein and Brand 1951), Late Jurassic-Early Cretaceous in the eastern Indian Ocean (Kuznetsova 1974) and Barremian to Aptian in the northern Alps (Weidich 1990). According to Weidich (1990) this is a typical Upper Cretaceous taxon that first appeared in the Early Cretaceous.

Pyramidulina sp.
Plate 5, figures 1-2

Description: Subglobular test with a compressed basal disc (early chamber?), followed by a single, very large chamber. Aperture terminal at the end of a thin short neck. Prominently raised, longitudinal costae, may be broken into knots.

Remarks: Test may be flattened diagenetically (see pl. 5, figs. 1-2) and costae vary in width and regularity.

Genus *Pseudonodosaria* Boomgaart 1949

Pseudonodosaria humilis (Roemer 1841)
Plate 5, figure 3a, 3b

Nodosaria humilis ROEMER 1841, pl. 15, fig. 6.
Pseudoglandulina humilis (Roemer). — BARTENSTEIN and BRAND 1951, pl. 10, figs. 266-271. — NEAGU 1975, pl. 74, figs. 12-13, 15-16, 18-32; pl. 75, figs. 1-4.

Description: Rectilinear test with chambers increasing gradually in size. Straight, flush sutures become depressed in the younger part of test.

Range and Occurrence: Cosmopolitan in the Early Cretaceous (Neagu 1975).

Pseudonodosaria mutabilis (Reuss 1863)
Plate 5, figure 4a, 4b

Glandulina mutabilis REUSS 1863, pl. 5, figs. 7-11.
Pseudonodosaria mutabilis (Reuss). — NEAGU 1975, pl. 73, figs. 32-45; pl. 74, figs. 1-11, 14-15.

Description: Very variable, rectilinear test with inflated chambers of unequal size. Straight sutures flush in the early portion, becoming depressed. Terminal, radiate aperture.

Range and Occurrence: Cosmopolitan in the Early Cretaceous (Neagu 1975).

Pseudonodosaria cf. ***tenuis*** (Bornemann 1854)

Glandulina tenuis BORNEMANN 1854, pl. 2, fig. 3a, b.
Pseudoglandulina tenuis (Bornemann). — BARTENSTEIN and BRAND 1951, pl. 13, fig. 249. — NEAGU 1975, pl. 110, figs. 1-5.
Pseudonodosaria cf. *tenuis* (Bornemann). — WEIDICH 1990, pl. 26, fig. 23.

Description: Elongated, rectilinear test with inflated chambers increasing progressively in size. Flush sutures in early part of test become depressed.

Remarks: Only one well preserved specimen, closest to the form illustrated by Bartenstein and Brand (1951). Species recorded from upper Hauterivian deposits in Rumania (Neagu 1975), from upper Valanginian deposits in northwestern Germany (Bartenstein and Brand 1951), from Albian alpine sediments and from upper Jurassic and Lower Cretaceous deposits in Europe (Weidich 1990).

Subfamily LINGULININAE Loeblich and Tappan 1961
Genus *Lingulina* d' Orbigny 1826

Lingulina sp. 1
Plate 5, figures 7-8b

Lingulina sp. 3, BARTENSTEIN and BRAND 1951, pl. 8, fig. 193.
Lingulina sp. SLITER 1980, pl. 13, fig. 16.

Description: Uniserial, slightly compressed elongated test with small initial chambers increasing very rapidly in size and becoming very broad. The last chamber is quite inflated and has a terminal apertural slit.

Remarks: Very similar to the form illustrated by Bartenstein and Brand (1951) but with a more extended apertural slit and a more inflated last chamber. This species has only been rarely recorded in Valanginian deposits by Bartenstein and Brand (1951).

Subfamily FRONDICULARIINAE Reuss 1860
Genus *Frondicularia* Defrance 1826

Frondicularia hastata Roemer 1842
Plate 5, figures 10a-12b

Frondicularia hastata ROEMER 1842, pl. 7B, fig. 5. — BARTENSTEIN and BRAND 1951, pl. 8, figs. 207-208. — WEIDICH 1990, pl. 25, fig. 21.

Description: Large, narrow, flattened, finely tapered test with very elongated, equitant chambers. Proloculus inflated and rounded with a median carina. Sutures weakly curved and depressed, last chamber strongly tapered towards a terminal, central aperture.

Remarks: Large specimens, often found in fragments.

Range and Occurrence: In northwestern Germany from mid-Valanginian to late Hauterivian (Bartenstein and Brand 1951), in the northern Alps from Berriasian to Barremian (Weidich 1990).

Frondicularia bettenstaedti Zedler 1961
Plate 5, fig. 13; plate 6, figure 1a, 1b

Frondicularia bettenstaedti ZEDLER 1961, pl. 8, figs. 21-22.

Description: Very compressed, lanceolate test with 6-10 low chambers, gradually increasing in width but not changing markedly in height. Small rounded proloculus, distinctly arched, depressed sutures and terminal, slit-like aperture.

Remarks: Very close to *F. simplicissima* Ten Dam 1946. Compared to the specimens of Bartenstein and Kaever (1973), *F. bettenstaedti* Zedler differs by its more regular outline, smaller proloculus, less angled sutures and more numerous chambers. Zedler (1961) argued that *F. bettenstaedti* is not simply the microspheric generation of *F simplicissima* Ten Dam and separated the two species on account of their different distribution and stratigraphic ranges. This species also closely resembles *Lingulina lamellata* Tappan 1940, illustrated by Haig (1982, pl. 3, figs. 25-29).

Range and Occurrence: Used by Zedler (1961) as an index species for the upper Hauterivian in northwestern Germany.

Genus *Tristix* Macfayden 1941.

Tristix acutangula (Reuss 1863)
Plate 6, figure 2a, 2b

Rhabdogonium acutangulatum REUSS 1863, pl. 4, fig. 14a, b.
Tristix acutangulum (Reuss). — NEAGU 1975, pl. 75, figs. 40-49; pl. 76, figs. 7-11, 13-16.
Tristix acutangula (Reuss). — WEIDICH 1990, pl. 44, figs. 11-12.

Description: Elongated, uniserial, rectilinear test, triangular in cross-section with slightly concave lateral faces. Chambers low, separated by very arched, depressed sutures. Last chamber elongated towards terminal circular aperture.

Remarks: Rare at Site 766, the specimens recovered differ from the Aptian form illustrated by Weidich (1990) in having a more elongated last chamber. The specimens from Site 766 only have five or six chambers, unlike the very elongated variations illustrated by Neagu (1975).

Range and Occurrence: Cosmopolitan throughout the Early Cretaceous (Bartenstein and Bolli 1986).

Tristix excavata (Reuss 1863)
Plate 6, figure 3a, 3b

Rhabdogonium excavatum REUSS 1863, pl. 12, fig. 8a-c.
Tribrachia australiana (Reuss). — SCHEIBNEROVÁ 1974b, pl. 2, fig. 16; pl. 10, fig. 6. — SCHEIBNEROVÁ 1976, pl. 37, fig. 1.

Tristix excavata (Reuss). — HAIG 1982, pl. 7, figs. 16-17.

Description: Elongated, uniserial, tapering test, triangular in cross-section with distinctly concave lateral faces. Eight low chambers are separated by strongly arched, depressed sutures which are steeply inclined downwards. Last chamber rounded with simple aperture.

Remarks: The specimens from Site 766 closely resemble *T. excavata* Reuss, illustrated by Haig (1982) and *Tribrachia australiana* Ludbrook illustrated by Scheibnerová (1976). The specimens are also very similar to *Tricarinella excavata* originally described by Reuss (1863) and illustrated by Sliter (1980), Moullade (1984) and Weidich (1990) but are generally narrower, more tapered and lack a drawn-out aperture.

Riegraf and Luterbacher (1989b) did not taxonomically differentiate *Tristix tunassica* Shokhina 1960 and its synonym *Tristix lanceola* Sliter 1980 from the very variable species *T. excavata* Reuss 1863. *Tristix excavata* Reuss 1863, however, clearly possesses a triangular cross-section with three nearly equal sides, while both *T. tunassica* Shokhina 1960 and *T. lanceola* Sliter 1980 are unevenly quadrate (test wider than thick) as illustrated by Weidich (1990). The photograph of *T. tunassica* Shokhina 1960 in Riegraf and Luterbacher (1989b) is, unfortunately, too vague to clarify the matter.

Range and Occurrence: Tristix excavata Reuss has been recorded in the Valanginian-Barremian of the southwestern Atlantic (Sliter 1977), from the mid Albian in the northern Alps (Weidich 1990), in the late Albian-Cenomanian of Papua New Guinea (Haig 1981) and in the late Albian of Queensland (Haig 1982). Scheibnerová also found *Tribrachia australiana* Ludbrook in Aptian-Albian sediments at ODP sites in the eastern Indian Ocean (1974b) and in Albian sediments of the Great Australian Basin (1976).

Family VAGINULINIDAE Ehrenberg 1838
Subfamily LENTICULININAE Chapman, Parr and Collins 1934
Genus *Lenticulina* Lamarck 1804

Lenticulina circumcidanea (Berthelin 1880)
Plate 6, figure 4

Cristellaria circumcidanea BERTHELIN 1880, pl. 3, fig. 1.
Lenticulina circumcidanea (Berthelin). — JENDRYKA-FUGLEWICZ 1975, pl. 13, figs. 5-7.

Description: Involute test, subcircular in outline with 7-8 chambers in the last whorl. Periphery acute with a narrow keel, sutures curved, flush in the early part becoming faintly depressed. Aperture radiate at peripheral angle and small, depressed umbilicus.

Remarks: Keel development varies in specimens from Site 766.

Range and Occurrence: Found in the Valanginian-Hauterivian of Poland and in the Albian of France (Jendryka-Fuglewicz 1975), also in the Albian of the northern Alps (Weidich 1990).

Lenticulina guttata (Ten Dam 1946)
Plate 13, figures 7-8c

Lenticulina guttata TEN DAM 1946, pl. 88, fig. 2. — NEAGU 1975, pl. 50, figs. 1-2; pl. 51, figs. 2-6, 12, 14, 18-19, 23-25.
Lenticulina guttata guttata (Ten Dam). — BARTENSTEIN and BRAND 1951, pl. 5, fig. 116.

Description: Flattened, carinate test with a tendency to become evolute. Sutures are marked by prominent carinae or nodulose rows. Very ornamented forms may be tricarinate with additional longitudinal ornamentation on the chamber walls. Elaborate, phyaline, radiate aperture at end of a narrow protuding neck.

Remarks: Closely resembles more ornamented forms illustrated by Neagu (1975) but generally more flattened with a more elaborate aperture. Less involute and more flattened than specimens illustrated by Bartenstein and Brand (1951).

Range and Occurrence: Late Valanginian-early Hauterivian in northwestern Germany (Bartenstein and Brand 1951). Hauterivian in Rumania (Neagu 1975). Late Valanginian-early Barremian in Tethyan and transitional boreal facies of northern Europe (Bartenstein 1977). Characterizes the upper Hauterivian assemblage at Site 766.

Lenticulina heiermanni Bettenstaedt 1952
Plate 6, figures 5a-8b

Lenticulina heiermanni BETTENSTAEDT 1952, pl. 1, fig. 9-10. — BARTENSTEIN and BETTENSTAEDT 1962, tab. 18, pl. 39, fig. 1. — WEIDICH 1990, pl. 20, figs. 15-16.

Description: Thick, involute test with numerous chambers (usually 10 or more). Sutures are curved, strongly raised and form a thick, irregular umbilical callus. Radiate aperture at the peripheral angle.

Remarks: Number of chambers, prominence of sutures and size of the callus vary significantly.

Range and Occurrence: Cosmopolitan species, widely recorded from the Hauterivian to lower Aptian in the Tethyan and temperate realms (Bartenstein and Kovatcheva 1982).

Lenticulina macrodisca (Reuss 1863)
Plate 6, figures 9-10b

Cristellaria macrodisca REUSS 1863 pl. 9, fig. 5a, b.
Lenticulina macrodisca (Reuss). — NEAGU 1975, pl. 45, figs. 1-16, 20; pl. 47, figs. 25-26. — WEIDICH 1990, pl. 21, figs. 1-2.

Description: Involute, strongly convex, lenticuline test with extremely large, dark, projecting umbilical disc. Sutures are curved backwards and the periphery is very sharp with a narrow keel. Aperture radiate at peripheral angle.

Remarks: Shows considerable variability (see *L. muensteri* Roemer).

Range and Occurrence: A cosmopolitan species, widely distributed in the Early Cretaceous (Weidich 1990)

Lenticulina muensteri (Roemer 1839)
Plate 6, figure 11a, 11b

Robulina muensteri ROEMER 1839, pl. 20, fig. 29a, b.
Lenticulina muensteri (Roemer). — JENDRYKA-FUGLEWICZ 1975, pls. 8, 9, 10, 11, figs. 1-6, pl. 19, pl. 20, figs. 1-2. — BARTENSTEIN and BOLLI 1986, pl. 4, figs. 25-26.

Description: Smooth, involute, convex, lenticuline test with 7-12 chambers in the last whorl. Flush, markedly curved sutures coalesce into a large, dark, slightly projecting umbonal disc. Sharp periphery, radiate aperture at peripheral angle.

Remarks: This very long ranging, cosmopolitan species shows considerable variability. Jendryka-Fuglewicz (1975) has distinguished six morphotypes with stratigraphic significance from the Jurassic to the Albian in Poland. Transitional forms lead to a wide overlap and stratigraphic resolution depends on morphometric analysis. Bartenstein and Bolli (1986) have also emphasized the difficulty in dividing *L. muensteri* Roemer, *L. cultrata* Montfort, *L. rotulata* Lamarck, *L. macrodisca* Reuss, *L. roemeri* Reuss and *L. subalata* Reuss into valid morphological and stratigraphical groups because so many transitional forms exist. Meyn and Vespermann (1994) treat *L. ehrenbergi, L. crassa, L. impressa* and *L. macrodisca* as synonyms. At Site 766 extreme members of the *L. muensteri* and *L. macrodisca* plexus are distinguishable, and more refined morphological and stratigraphical resolution might be achieved with the application of morphometrics.

Range and Occurrence: A cosmopolitan species in the Jurassic-Cretaceous (Jendryka-Fuglewicz 1975).

Lenticulina nodosa (Reuss 1863)
Plate 7, figure 2a, 2b

Robulina nodosa REUSS 1863, pl. 9, fig. 6a, b.
Lenticulina nodosa nodosa (Reuss). — BARTENSTEIN 1974b, pl. 1, figs. 3-17; pl. 2, figs. 5-6, 9-12, 16-17.
Lenticulina nodosa (Reuss). — JENDRYKA-FUGLEWICZ 1975, pl. 12, figs. 4-12.

Description: Small, involute, test with 7-10 chambers in last whorl separated by thick, curved, raised sutures. Peripheral knot-like thickenings give the test a distinctive polygonal appearance. Radiate aperture at peripheral angle.

Remarks: Uncommon at Site 766, most tests only have weak sculpture and faint thickenings at the periphery in comparison with the plesiotypes of Bartenstein and Brand (1951) and Bartenstein and Kaever (1973). The variability of the species and its tendency to uncoil has led to considerable taxonomic confusion. Bartenstein (1974b) and Aubert and Bartenstein (1976) have identified within the *L. nodosa* Reuss plexus several subspecies and closely related species of stratigraphic and/or biogeographic relevance. Some evolute specimens are present at Site 766. Their small number and poor preservation, however, prevent subspecific identification.

Range and Occurrence: Widely distributed, but with very variable stratigraphic occurrence. This species probably embraces several iterative forms that evolved in geographic isolation from a long-ranging common ancestor such as *Lenticulina muensteri* Roemer (Michael 1967, Bartenstein 1974b, Aubert and Bartenstein 1976, Weidich 1990). Occurs from the late Jurassic to the late Aptian in Tethys, generally restricted to the Valanginian and Hauterivian in north and south temperate realms (Bartenstein 1974b, King et al. 1989).

Lenticulina ouachensis (Sigal 1952)
Plate 7, figures 10-12

Lenticulina ouachensis SIGAL 1952, Abb. 10.
Lenticulina ouachensis ouachensis (Sigal). — BARTENSTEIN and BETTENSTAEDT 1962, pl. 38, fig. 11. — WEIDICH 1990, pl. 19, fig. 17-21; pl. 42, fig. 6.

Description: Involute test with 8-10 moderately inflated chambers in last whorl. Carinate periphery; slightly arched, carinate sutures, attenuated near the periphery and joining in the center to form a periumbilical ring. Radiate aperture at peripheral angle.

Remarks: Partial dissolution has obliterated the sculpture on many tests from Site 766. *Lenticulina ouachensis* Sigal was placed in synonymy with *L. quenstedti* Gümbel by Riegraf and Luterbacher (1989b), who believe that the two species cannot be differentiated taxonomically but differ only in their stratigraphic ranges. They also pointed out that this species has been described under many different names (see synonymy list in Riegraf and Luterbacher 1989b).

Range and Occurrence: Lenticulina ouachensis Sigal is a cosmopolitan species with a range from Berriasian to Aptian (Riegraf and Luterbacher 1989a, Weidich 1990). *Lenticulina quenstedti* Gümbel extends from the Bajocian to the late Tithonian.

Lenticulina pulchella (Reuss 1863)
Plate 7, figures 4a-5b

Cristellaria pulchella REUSS 1863, pl. 8, fig. 1.
Lenticulina pulchella (Reuss). — JENDRYKA-FUGLEWICZ 1975, pl. 13, figs. 5-7.

Description: Involute test tending to uncoil, usually, with eight chambers increasing rapidly in size in last whorl. Fine, curved sutures, flush and indistinct in early part, becoming depressed. Last chamber pointed towards terminal, radiate aperture. Small, depressed umbilicus, acute periphery and oval to polygonal outline.

Range and Occurrence: Occurs in the Valanginian-Hauterivian of Poland and in the Albian of Germany and Rumania (Jendryka-Fuglewicz 1975).

Lenticulina saxocretacea Bartenstein 1954
Plate 7, figure 3

Lenticulina saxocretacea BARTENSTEIN 1954, p. 45-46.
Cristellaria subalata REUSS 1863, pl. 8, fig. 10; pl. 9, fig. 1.
Lenticulina saxocretacea Bartenstein. — BARTENSTEIN and BOLLI 1986, pl. 4, figs. 32-34. — WEIDICH 1990, pl. 21, fig. 7, pl. 41, figs. 23-26; pl. 42, figs. 1, 7-8, 11.

Description: Robust involute to slightly evolute test with 7-10 chambers in last whorl and a sharp, carinate periphery. Sutures limbate, raised and curved. Umbilical disc flush and poorly defined. Radiate aperture near dorsal margin.

Remarks: The Early Cretaceous form of *L. subalata* Reuss 1863 was renamed *L. saxocretacea* by Bartenstein (1954) to differentiate it from the Late Cretaceous homonym *L. subalata* Reuss 1854. *Lenticulina subalata* Reuss 1854 differs from *L. saxocretacea* Bartenstein mainly in having a larger, better defined, rounded callus and a more convex profile and narrower keel (see also *L. muensteri* Roemer). *Lenticulina saxocretacea* Bartenstein and *L. subalata* Reuss were both illustrated by Weidich (1990).

Range and Occurrence: Lenticulina saxocretacea Bartenstein ranges from Barremian to Albian in boreal and Tethyan realms (Bartenstein and Bolli 1986). *Lenticulina subalata* Reuss 1854 ranges from the Berriasian to the Late Cretaceous (Weidich 1990).

Lenticulina* cf. *schreiterei (Eichenberg 1935)

Elphidium schreiterei EICHENBERG 1935, pl. 13, fig. 11.
Lenticulina d'Orbigny schreiterei (Eichenberg). — BARTENSTEIN and BRAND 1951, pl. 4, figs. 104-105.
Lenticulina schreiterei (Eichenberg). — BARTENSTEIN and KAEVER 1973, pl. 2, fig. 31.

Description: Involute, relatively flattened test tending to uncoil with prominent, irregular, longitudinal ribs. Sutures indistinct, periphery sharply carinate, aperture at peripheral angle.

Remarks: Very rare at Site 766. Bartenstein and Brand (1951) defined *L. schreiterei* Eichenberg as a subspecies of the Jurassic species *L. d'Orbigny* Roemer, recently redefined by Brand and Ohmert (1992). *Lenticulina schreiterei* Eichenberg is often confused in the literature with the very variable species *V. reticulosa* Ten Dam, the taxonomic parameters separating these two species being rather obscure. Specimens in Site 766 differ from *L. schreiterei* Eichenberg by their heavier, irregular ornamentation and less inflated chambers; the identification of these specimens as *L. schreiterei* Eichenberg remains tentative as a taxonomic and stratigraphic reappraisal of *L. schreiterei* Eichenberg and *V. reticulosa* Ten Dam is needed to clarify the confusion between these two species.

Range and Occurrence: Late Valanginian-early Hauterivian in northwestern Germany (Bartenstein and Brand 1951).

Lenticulina subangulata (Reuss 1863)
Plate 8, figure 1a, 1b

Cristellaria subangulata Reuss 1863; pl. 8, fig. 7.
Lenticulina subangulata (Reuss). — BARTENSTEIN and BRAND 1951, pl. 5, fig. 111. — JENDRYKA-FUGLEWICZ 1975, pl. 13, figs. 8-9. — MOULLADE 1984, pl. 3, fig. 3.

Description: Large, robust, involute, lenticuline test with an acute periphery (no keel). Sutures are fine, inclined backwards and faintly raised. The last two chambers become elongated and sharply angled, giving the test its distinctive angular outline. Radiate aperture at peripheral margin.

Range and Occurrence: Common in the Valanginian-Hauterivian of Europe (Jendryka-Fuglewicz 1975).

Lenticulina cf. ***subgaultina*** Bartenstein 1962
Plate 8, figure 4a, 4b

Lenticulina cf. *subgaultina* BARTENSTEIN 1962, pl. 15, figs. 1-2.
Lenticulina subgaultina Bartenstein. — BARTENSTEIN, BETTENSTAEDT and BOLLI 1966, pl. 2, figs. 128-129. — NEAGU 1975, pl. 49, figs. 3-17, 19, 21-22, 24, 27-28, 32; pl. 50, fig. 20.

Description: Involute test tending to uncoil with an elongated last chamber. Sutures flush or depressed, distinct umbilical disc and sharp periphery with or without carina.

Remarks: Taxonomic descriptions vary significantly. Specimens from Site 766 are poorly preserved and have only been tentatively identified.

Genus *Marginulinopsis* A. Silvestri 1904

Marginulinopsis bettenstaedti Bartenstein and Brand 1951
Plate 8, figures 7-9

Marginulinopsis bettenstaedti BARTENSTEIN and BRAND 1951, pl. 6, figs. 144-147. — RIEGRAF 1989, pl. 1, fig. 27.

Description: Elongated test with small, planispirally coiled stage becoming evolute. Uncoiled stage consists typically of three chambers. Chambers increase markedly in size, becoming very inflated ventrally. Sutures are depressed and straight. Aperture terminal. Periphery carinate. Surface of test ornamented by prominent longitudinal costae (usually eight per side), often becoming offset at sutures.

Range and Occurrence: First described from Valanginian deposits of northwestern Germany (Bartenstein and Brand 1951), this species is widely recorded in the Early Cretaceous: from Kimmeridgian to Albian in California, the North Atlantic, the Paris Basin, northern Germany, Sardinia, Madagascar and from the Kimmeridgian to Hauterivian in western Indian Ocean (Riegraf 1989).

Marginulinopsis comma (Roemer 1841)
Plate 8, figure 5a, 5b

Marginulina comma ROEMER 1841, pl. 15, fig. 15.
Marginulinopsis comma (Roemer). — BARTENSTEIN and BRAND 1951, pl. 6, fig. 135. — FUCHS and STRADNER 1967, pl. 11, fig. 7.

Description: Elongated test with clearly defined planispiral early portion and evolute stage, usually consisting of four broad chambers becoming more elongated and inflated distally. The last chamber is drawn out towards a terminal, dorsal aperture. Sutures are deeply depressed, dorsal and ventral margins rounded without keels.

Range and Occurrence: Reported from the middle and upper Valanginian of northwestern Germany by Bartenstein and Brand (1951) and from the Hauterivian of Germany by Roemer (1841).

Marginulinopsis gracilissima (Reuss 1863)
Plate 8, figures 11-13

Cristellaria gracilissima REUSS 1863, pl. 6, figs. 9-10.
Marginulinopsis gracilissima (Reuss). — BARTENSTEIN and BRAND 1951, pl. 6, fig. 139. — FOWLER and BRAUN 1993, pl. 7, figs. 36-39.

Description: Elongated hispid test with curved axis and well defined planispiral early stage. Three chambers in the evolute portion become elongated and inflated, the last one tapering towards an apertural neck on the dorsal side. Sutures are distinctly depressed and periphery round.

Remarks: Closely resemble specimens illustrated by Fowler and Braun (1993).

Range and Occurrence: Widely recorded in the Lower Cretaceous deposits of Europe and the Hauterivian-Barremian of the Mount Goodenough Formation in Canada (Fowler and Braun 1993).

Marginulinopsis parkeri (Reuss 1863)

Marginulina parkeri REUSS 1863 pl. 5, fig. 14.
Marginulinopsis parkeri (Reuss). — BARTENSTEIN and BRAND 1951, pl. 6, figs. 136-137. — NEAGU 1975, pl. 60, figs. 12, 14.

Description: Elongated test, oval in cross-section with planispiral early stage, becoming evolute and rectilinear. Chambers inflated, becoming more elongated with sutures depressed and inclined, periphery rounded without keel, radiate aperture at peripheral angle.

Remarks: Very similar to specimens illustrated by Neagu (1975).

Range and Occurrence: Late Valanginian-early Hauterivian in northwestern Germany (Bartenstein and Brand 1951) and in Rumania (Neagu 1975).

Genus *Saracenaria* Defrance 1824

Saracenaria compacta Espitalié and Sigal 1963
Plate 8, figures 6a, 6b, 10a, 10b.

Saracenaria compacta ESPITALIÉ and SIGAL 1963, pl. 24, figs. 4-5. — SLITER 1980, pl. 12, fig. 4. — KUZNETSOVA and SEIBOLD 1977, pl. 7, fig. 12.

Description: Thick, massive, triangular test with few chambers separated by prominent raised, curved sutures. The ventral and dorsal margins are carinate and the oral face forms an angle of approximately 90° with the ventral face. Radiate aperture at peripheral angle.

Remarks: Espitalié and Sigal (1977) suggested that *S. compacta* evolved from forms of *S. pravoslavlevi* Fursenko and Polenova, or *S. tsaramandrosoensis* Espitalié and Sigal. Transitional forms from *Saracenaria pravoslavlevi* Fursenko and Polenova are observed at Site 766. *Saracenaria compacta* differs from *S. forticosta* Bettenstaedt mainly by the very marked angle between the oral and ventral faces. One of the *S. forticosta* paratypes from the middle Barremian of northwestern Germany (Bettenstaedt 1952) resembles *S. compacta* Espitalié and Sigal very closely and is probably a representative of that species (Espitalié and Sigal 1963).

Range and Occurrence: First described from the Berriasian-Barremian in the Majunga Basin of Madagascar by Espitalié and Sigal (1963). Also recorded in the eastern North Atlantic (Sliter 1980).

Saracenaria erlita Ludbrook 1966
Plate 9, figure 8a, 8b

Saracenaria erlita LUDBROOK 1966, pl. 8, fig. 10. — SCHEIBNEROVÁ 1974b, pl. 2, figs, 25-26. — SCHEIBNEROVÁ 1976, text-figs. 84-85.

Description: Triangular test with rounded ventral edges and sharper dorsal edge (no keel). Six or seven chambers planispirally coiled, except for the last one which becomes strongly inflated ventrally. Sutures curved and slightly depressed, radiate aperture at peripheral angle

Remarks: This species is close to *S. bronnii* Roemer but lacks its longer evolute portion.

Range and Occurrence: Recorded from the Aptian in South Australia and the eastern Indian Ocean (Scheibnerová 1974; 1976).

Saracenaria forticosta Bettenstaedt 1952
Plate 9, figures 1-7

Saracenaria forticosta BETTENSTAEDT 1952, pl. 1, fig. 12; pl. 2, fig. 13.
Saracenaria italica Defrance var. *crassicosta* EICHENBERG 1933, pl. 5, fig. 2a-c.
Saracenaria crassicosta Eichenberg. — RIEGRAF 1989, pl. 1, fig. 18.

Description: Large, broad, triangular test with straight or slightly curved axis and numerous chambers (nine or more). It has a small planispiral stage and a well-developed evolute portion. Low and broad chambers are separated by curved, strongly raised sutures. The dorsal edge is carinate and the ventral edges sharply angled. Last chamber very triangular, slightly inflated ventrally and drawn out towards terminal radiating aperture.

Remarks: This species may be confused with *S. pravoslavlevi* Fursenko and Polenova. Although Bartenstein (1977, 1979) has queried the separation of these two species, their different stratigraphic ranges and morphologies suggest that they should be treated separately. *Saracenaria forticosta* Bettenstaedt may have evolved from *S. pravoslavlevi* Fursenko and Polenova, rather than from *S. frankei* Ten Dam as suggested by Bartenstein (1978).

Range and Occurrence: First described from the middle Barremian of northwestern Germany (Bettenstaedt 1952), it has been widely recorded from Berriasian to Albian in California, the North Atlantic, Europe, Madagascar and the eastern and western Indian Ocean (Riegraf 1989).

Saracenaria frankei Ten Dam 1946
Plate 9, figures 9-10b

Saracenaria frankei TEN DAM 1946, pl. 8, fig. 1a, b. — BARTENSTEIN and BOLLI 1977, pl. 2, figs. 9-10. — SLITER 1980, pl. 12, figs. 8-9. — WEIDICH 1990, pl. 24, fig. 6.

Description: Elongated, triangular test with small, enrolled, early portion and well developed evolute stage. Ventral and dorsal edges of test markedly angular; numerous, low, broad chambers separated by distinct curved sutures; last chamber elongated towards radiating aperture at peripheral angle.

Remarks: Also close to *S. lutanata* Ludbrook recorded from Valanginian to Albian in eastern and western Indian Ocean (Riegraf 1989).

Range and Occurrence: A cosmopolitan species common in Tethyan and temperate facies deposits from the Valanginian to Aptian (Bartenstein 1977), in the eastern North Atlantic (Sliter 1980) and in northern alpine sediments from the Hauterivian to Barremian (Weidich 1990).

Saracenaria pravoslavlevi Fursenko and Polenova 1950
Plate 9, figures 11a-13

Saracenaria pravoslavlevi FURSENKO and POLENOVA 1950, pl. 4, figs. 13-15. — ESPITALIÉ and SIGAL 1963, pl. 23, figs. 4-7; pl. 24, fig. 1. — FOWLER AND BRAUN 1993, pl. 8, figs. 13-15.

Description: Triangular test with very prominent carinae along dorsal and ventral margins. Broad, raised, thickened sutures on dorsal side becoming narrower and slightly depressed on ventral side, aperture radiate at peripheral angle. Tests exhibit considerable variation in length, degree of curvature and spine development. Differences in ornamentation are also observed as keels may be acute and jagged and sutures vary in regularity and convexity.

Remarks: *S. pravoslavlevi* Fursenko and Polenova has many variants and transitional forms to other *Saracenaria* species are found.

Range and Occurrence: First described from lower Volgian deposits of the Emba region in the former U.S.S.R. by Fursenko and Polenova, this is a cosmopolitan species found in Lower Cretaceous deposits of the Majunga Basin, Madagascar (Espitalié and Sigal 1963) and the Mount Goodenough Formation, Aklavik Range, North America (Fowler and Braun 1993).

Saracenaria spinosa (Eichenberg 1935)
Plate 10, figure 2a, 2b

Lenticulina spinosa EICHENBERG 1935, pl. 4, fig. 5a-d.
Saracenaria spinosa (Eichenberg). — TAPPAN 1962, pl. 41, figs. 18-19. — BARTENSTEIN and KAEVER 1973, pl. 6, fig. 94. — WEIDICH 1990, pl. 42, figs. 14-15.

Description: Triangular test, composed of few low chambers (usually six or seven), strongly involute except for the last two chambers. Last chamber inflated and flaring markedly towards a radiate aperture; sutures slightly depressed. Periphery acute with a thin keel along the dorsal margin in the early chambers. Chambers are characteristically extended by needle-shaped spines along the ventral edges of the last two chambers.

Remarks: The specimen illustrated by Bartenstein and Kaever (1973, pl. 6, fig. 94) was found to differ markedly from the specimens from Site 766 in its straighter, longer evolute portion and a reduced planispiral stage. It is also generally less inflated and lacks sharp spines (instead of true spines, it has rounded projections along the ventral edges of the evolute chambers). The specimen illustrated by Weidich (1990) is also more evolute and its spines are not well defined. Moullade (pers. comm., 1994) also found this specimen to differ from the typical Aptian-Albian Tethyan forms.

Range and Occurrence: First described from Aptian deposits in north Germany, this is a cosmopolitan species recorded from the upper Aptian of the northern Alps (Weidich 1990), the upper Aptian-lower Albian of the Vocontian Trough (Moullade 1966) and in many parts of the world from the Aptian to lower Albian (Bartenstein and Kaever 1973; Bartenstein 1979).

Saracenaria triangularis (d'Orbigny 1840)
Plate 10, figure 1a, 1b

Saracenaria triangularis d'ORBIGNY 1840, pl. 2, figs. 21-22. — FUCHS and STRADNER 1967, pl. 12, fig. 3. — MOULLADE 1984, pl. 3, fig. 1.

Description: Involute triangular test with thin dorsal keel and sharp ventral edges. Six or seven chambers, low and wide becoming very inflated, last chamber flaring to pointed radiate aperture, oblique sutures strongly curved and slightly depressed.

Remarks: Also bears some resemblance to *S. brookei* Fowler and Braun from Hauterivian-Barremian of Mount Goodenough Formation of Canada.

Range and Occurrence: A cosmopolitan species recorded from Albian deposits of the Atlantic and Tethys (Moullade 1984) and in Holland (Fuchs and Stradner 1967).

Saracenaria valanginiana Bartenstein and Brand 1951
Plate 10, figures 4a-6.

Saracenaria valanginiana BARTENSTEIN and BRAND 1951, pl. 13, figs. 364-365. — TAPPAN 1962, pl. 42, figs. 7-8.

Description: Triangular test, elongated, with a small planispiral stage. Chambers broader than high, separated by thin, slightly depressed, curved sutures. Characteristic ornamentation consisting of thin, irregular, longitudinal striations on ventral and dorsal sides of test; striations usually reach the base of the last chamber but their number and prominence may vary considerably.

Remarks: Some forms from Site 766 are shorter and squatter with a larger involute stage and stronger costae than the holotype of Bartenstein and Brand (1951, pl. 10, fig. 6) and with a very prominent central parting on the ventral side. The form illustrated by Tappan (1962) from the Albian appears to have much finer ornamentation and may not be similar to the Valanginian form. Ludbrook (1966) also described the new species *Saracenaria warella* from the Aptian-Albian of the Great Australian Basin which resembles *Saracenaria valanginiana.*

Range and Occurrence: First described from Valanginian deposits of northwestern Germany, this is a cosmopolitan species widely recorded in Berriasian to Valanginian Tethyan and temperate facies deposits (Bartenstein 1979) and in Berriasian-Valanginian sediments along the Atlantic margin of North America (Ascoli 1988). In the Arctic it was found by Tappan (1962) in the Albian.

Saracenaria sp.1,
Plate 10, figure 10a, 10b.

Description: Very elongated, slender, triangular test with numerous chambers (more than 12) arranged along a slightly curved axis; enrolled portion very reduced. Distinct, curved sutures on dorsal side, slightly depressed on ventral side, sharp keels along dorsal and ventral edges. Last chamber tapering towards radiate terminal aperture.

Remarks: Only one complete test found plus fragments. The test appears very fragile. Reminiscent of *Saracenaria yalanya* Ludbrook (cf. Ludbrook 1966; pl. 8, fig. 15) but the test of our specimen remains very narrow and has more chambers in its uncoiled portion.

Saracenaria sp. 2,
Plate 10, fig. 11

Description: Elongated, narrow test without a distinct coil and without ornamentation, becoming rectilinear and triangular in cross-section. Chambers low, separated by distinct, strongly oblique sutures. Last chamber tapering towards radiating aperture at dorsal angle.

Remarks: Rare at Site 766. Reminiscent of *Saracenaria* cf. *grandstandensis* Tappan (cf. Tappan 1962; pl. 41, figs. 3-5).

Saracenaria sp.
Plate 10, figures 7-9

PLATE 1

1a,b *Bathysiphon brosgei* Tappan, (×85, ×80), Sample 766A-30R-04; 100-102cm.

2 *Rhizammina* sp., (×65), Sample 766A-48R-04; 51-54cm.

3 *Rhabdammina cylindrica* Glaessner, (×80), Sample 766A-48R-04; 51-54cm.

4 *Rhabdammina cylindrica* Glaessner, (×100), Sample 766A-48R-04; 51-54cm.

5 *Rhizammina algaeformis* Brady, (×50), Sample 766A-46R-03; 122-125cm.

6a,b *Ammodiscus tenuissimus* (Gümbel), (×180, ×180), Sample 766A-48R-04; 51-54cm.

7 *Ammodiscus cretaceus* (Reuss), (×130), Sample 766A-28R-03; 116-120cm.

8 *Ammodiscus cretaceus* (Reuss), (×100), Sample 766A-30R-04; 100-102cm.

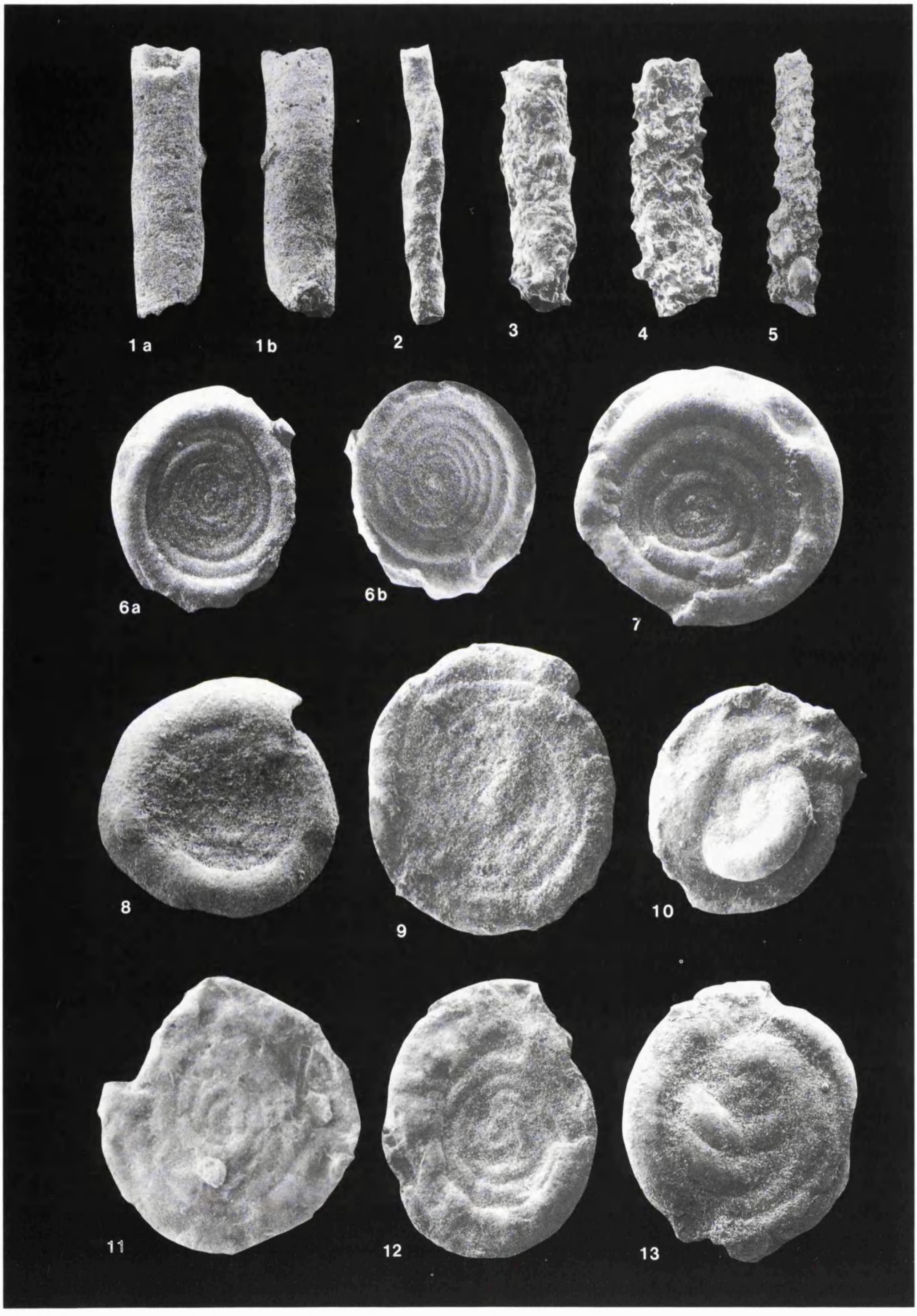
9 *Ammodiscus* sp., (×130), Sample 766A-28R-05; 133-138cm.

10 *Glomospirella gaultina* (Berthelin), (×100), Sample 766A-30R-04; 100-102cm.

11 *Glomospirella gaultina* (Berthelin), (×90), Sample 766A-47R-04; 114-119cm.

12 *Glomospirella gaultina* (Berthelin), (×55), Sample 766A-28R-01; 21-25cm.

13 *Glomospira charoides charoides* (Jones and Parker), (×120), Sample 766A-28R-01; 21-25cm.


1a
1b
2
3
4
5
6a
6b
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11
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13

Description: Elongated, smooth, tapering test but with broader chambers than *Saracenaria* sp. 1. May be a transitional form.

Subfamily PALMULINAE Saidova 1981
Genus *Palmula* Lea 1883

Palmula sp. 1
Plate 11, figure 1a, 1b.

Falsopalmula cf. *obliqua* Terquem. — BARTENSTEIN and BRAND 1951, pl. 8, fig. 197.
Falsopalmula cf. *deslongchampsi* Terquem. — KUZNETSOVA and SEIBOLD 1977, pl. 1, fig. 17.

Description: Large, elongated, flattened test, planispiral initially becoming uncoiled and slightly flaring with a subrounded periphery. Low, broad chambers are separated by strongly arched, thick, flush sutures. Terminal, radiate aperture.

Remarks: Rare at Site 766. Bartenstein and Brand's species has a broader, squatter shape whereas Kuznetsova and Seibold's is longer with more chambers than specimens from Site 766. This species is also reminiscent of *P. primordialis* Terquem, illustrated by Riegraf and Luterbacher (1989b) but lacks its sharper periphery and raised sutures.

Subfamily MARGINULININAE Wedekind 1937
Genus *Astacolus* de Montfort 1808

Astacolus calliopsis (Reuss 1863)
Plate 11, figures 2a-5

Marginulina linearis REUSS 1863, pl. 5, fig. 15.
Astacolus calliopsis (Reuss). — BARTENSTEIN and BRAND 1951, pl. 5, figs. 120-122. — BARTENSTEIN and BOLLI 1986, pl. 4, figs. 9-10.

Description: Elongated test with small planispiral portion and slightly curved axis. Chambers few, compressed dorsally, last one becoming more inflated and tapering towards radiate, terminal aperture. Sutures slightly depressed and strongly inclined.

Remarks: Shows variability in width, height and degree of compression of the chambers.

Range and Occurrence: A cosmopolitan species, widely recorded from the Lower Cretaceous (Bartenstein and Bolli 1986).

Astacolus schloenbachi (Reuss 1863)
Plate 11, figure 6a, 6b

Cristellaria schlönbachi REUSS 1863, pl. 6, figs. 14-15.
Astacolus schlönbachi (Reuss). — BARTENSTEIN and BRAND 1951, pl. 5, figs. 124-125. — BARTENSTEIN and BOLLI 1986, pl. 4, figs. 35-36.

Description: Elongated test with slightly curved axis. Chambers somewhat irregular in size and less compressed than in *S. calliopsis* Reuss; early chambers not forming full spiral, last chamber drawn out towards a radiate terminal aperture, sutures depressed and strongly inclined.

Range and Occurrence: a cosmopolitan species, widely distributed throughout the Lower Cretaceous (Bartenstein and Bolli 1986).

Genus *Marginulina* d'Orbigny 1826

Marginulina bullata Reuss 1860
Plate 11, figure 7a, 7b

Marginulina bullata REUSS 1860, pl. 6, figs. 4-6. — SCHEIBNEROVÁ 1976, pl. 29, fig. 1. — BARTENSTEIN and BOLLI 1986, pl. 5, figs. 17-18.

Description: Elongated, robust test with broad chambers, slightly coiled initially becoming evolute. Last chamber very inflated and bearing a radiate, terminal aperture at the dorsal edge, sutures oblique and slightly depressed.

Remarks: Site 766 specimens differ from those illustrated by Reuss (1860) and Bartenstein and Bolli (1986) in having fewer chambers and more oblique sutures.

Range and Occurrence: Upper part of the Lower Cretaceous and Cenomanian of northern California (Bartenstein and Bolli 1986).

Marginulina inaequalis Reuss 1860
Plate 11, figure 12

Marginulina inaequalis REUSS 1860, pl. 7. fig. 3. — RIEGRAF 1989, pl. 2, figs. 6-7.

PLATE 2

1a,b *Glomospira charoides corona* Cushman and Jarvis, (×200, ×190), Sample 766A-30R-03; 100-102cm.

2 *Haplophragmoides kirki* Wickenden, (×145), Sample 766A-47R-04; 114-119cm.

3a,b *Glomospira charoides corona* Cushman and Jarvis, (×160, ×150), Sample 766A-29R-03; 54-58cm.

4 *Haplophragmoides vocontianus* Moullade, (×130), Sample 766A-49R-02; 42-46cm.

5 *Haplophragmoides concavus* (Chapman), (×105), Sample 766A-47R-01; 98-103cm.

6 *Haplophragmoides* sp. 1, (×140), Sample 766A-48R-02; 95-98cm.

7 *Haplophragmoides concavus* (Chapman), (×130), Sample 766A-47R-04; 114-119cm.

8a,b *Ammobaculites* sp. 1, (×80, ×75), Sample 766A-48R-02; 95-98cm.

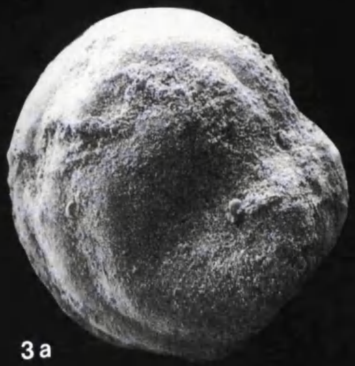
9 *Bulbobaculites* sp. 1, (×75), Sample 766A-44R-05; 102-106cm.

10 *Bulbobaculites inconstans erectum* (Bartenstein and Brand), (×85), Sample 766A-49R-01; 124-128cm.


1a


1b

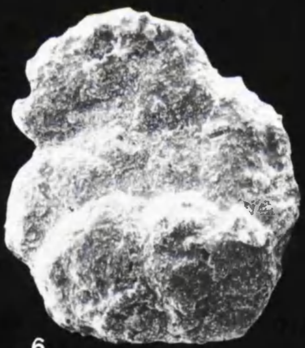

2


3a


3b


4


5


6


7


8a


8b


9


10

Marginulina sp. — KUZNETSOVA and SIEBOLD 1977, pl. 7, fig. 5.

Description: Elongated, straight test, slightly curved initially, with circular cross-section and chambers of irregular shape and size. First chamber rounded, slightly pointed at the proximal end. Ultimate chamber markedly inflated, drawn out towards a radiate, terminal aperture.

Remarks: Specimens from Site 766 most closely resemble forms illustrated by Kuznetsova and Siebold (1977) from the North Atlantic and by Riegraf (1989) from ODP Site 249.

Range and Occurrence: Oxfordian-Albian in the North Atlantic, Paris Basin, northern Germany, western Indian Ocean and Central Pacific (Riegraf 1989).

Marginulina pyramidilis (Koch 1851)
Plate 11, figure 10

Nodosaria pyramidilis KOCH 1851, pl. 24, fig. 8.
Marginulina pyramidilis (Koch). — BARTENSTEIN and BRAND 1951, pl. 9, figs. 221-223. — FOWLER and BRAUN 1993, pl. 7, figs. 18-19.

Description: Elongated, straight test, slightly curved initially, with apiculate or rounded base and six prominent, straight, longitudinal costae. Cross-section subcircular to circular, aperture terminal.

Remarks: Site 766 specimens are similar to plesiotypes illustrated by Bartenstein and Brand (1951) and Bartenstein and Kaever (1973).

Range and Occurrence: Most common in middle Valanginian and upper Hauterivian deposits of the boreal realm, also occurs in Berriasian-Valanginian of Siberia and throughout the Lower Cretaceous in Europe (Fowler and Braun 1993).

Marginulina sp. 1
Plate 11, figure 8a, 8b, 8c

Description: Elongated test with slightly curved axis, few inflated chambers and prominent, wide carinae along the dorsal and ventral edges. Lateral longitudinal rib, may be discontinuous and offset towards the dorsal margin in successive chambers, radiate aperture at the end of a robust, cylindrical neck on dorsal side.

Remarks: Very rare, does not match any described species in the consulted references.

Genus *Vaginulinopsis* Silvestri 1904

Vaginulinopsis excentrica (Cornuel 1848)
Plate 11, figures 9a, 9b, 11a, 11b; pl. 12, figures 1a, 1b, 3.

Cristellaria excentrica CORNUEL 1848, pl. 2, figs. 11-13.
Vaginulinopsis excentrica (Cornuel). — NEAGU 1975, pl. 55, figs. 5, 8-17, 22-26. — SLITER 1980, pl. 12, figs. 21-22; pl. 13, fig. 1.

Description: Elongated test with a well-developed planispiral early portion and evolute later stage. Sutures inclined and slightly depressed, last chamber elongated towards radiate aperture at dorsal margin, periphery subrounded.

Remarks: Width of chambers and degree of evolution vary.

Range and Occurrence: Hauterivian-Aptian in Rumania (Neagu 1975).

Vaginulinopsis humilis precursoria Bartenstein and Brand 1951
Plate 12, figures 7a-8

Vaginulinopsis humilis precursoria BARTENSTEIN and BRAND 1951, pl. 5, figs. 126-127. — BARTENSTEIN 1974a, pl. 2, figs. 28-37. — NEAGU 1975, pl. 57, figs. 28-37; pl. 59, figs. 35-37.

Description: Flattened test with early planispiral portion becoming evolute and extended. Chambers low and broad, separated by curved, strongly raised, irregular sutures. Subacute dorsal margin slightly arched and unkeeled; ventral margin straight and truncated with last chamber very elongated towards a radiate aperture located at dorsal margin.

Remarks: Differs from forms illustrated by Bartenstein (1974a) by its more flattened test and discontinuous sutures (forming nodulose ridge rather than continuous ridges). Rare at Site 766, tests show variation in width and degree of tapering.

Range and Occurrence: A cosmopolitan index marker for the late Valanginian-early Hauterivian (Bartenstein 1974a).

PLATE 3

1a,b *Ammobaculites* sp., (×50, ×50), Sample 766A-44R-03; 47-52cm.

2a,b *Aaptotoichus clavellatus* (Loeblich and Tappan), (×105, ×110), Sample 766A-49R-02; 42-46cm.

3a,b *Trochammina* sp. 1, (×105, ×110), Sample 766A-47R-01; 88-103cm.

4a,b *Trochammina* sp. 2, (×100, ×105), Sample 766A-48R-04; 51-54cm.

5a,b *Pseudoreophax* sp. 1, (×95, ×95), Sample 766A-46R-05; 20-24cm.

6a,b *Verneuilinoides subfiliformis* Bartenstein, (×130, ×120), Sample 766A-49R-01; 124-128cm.

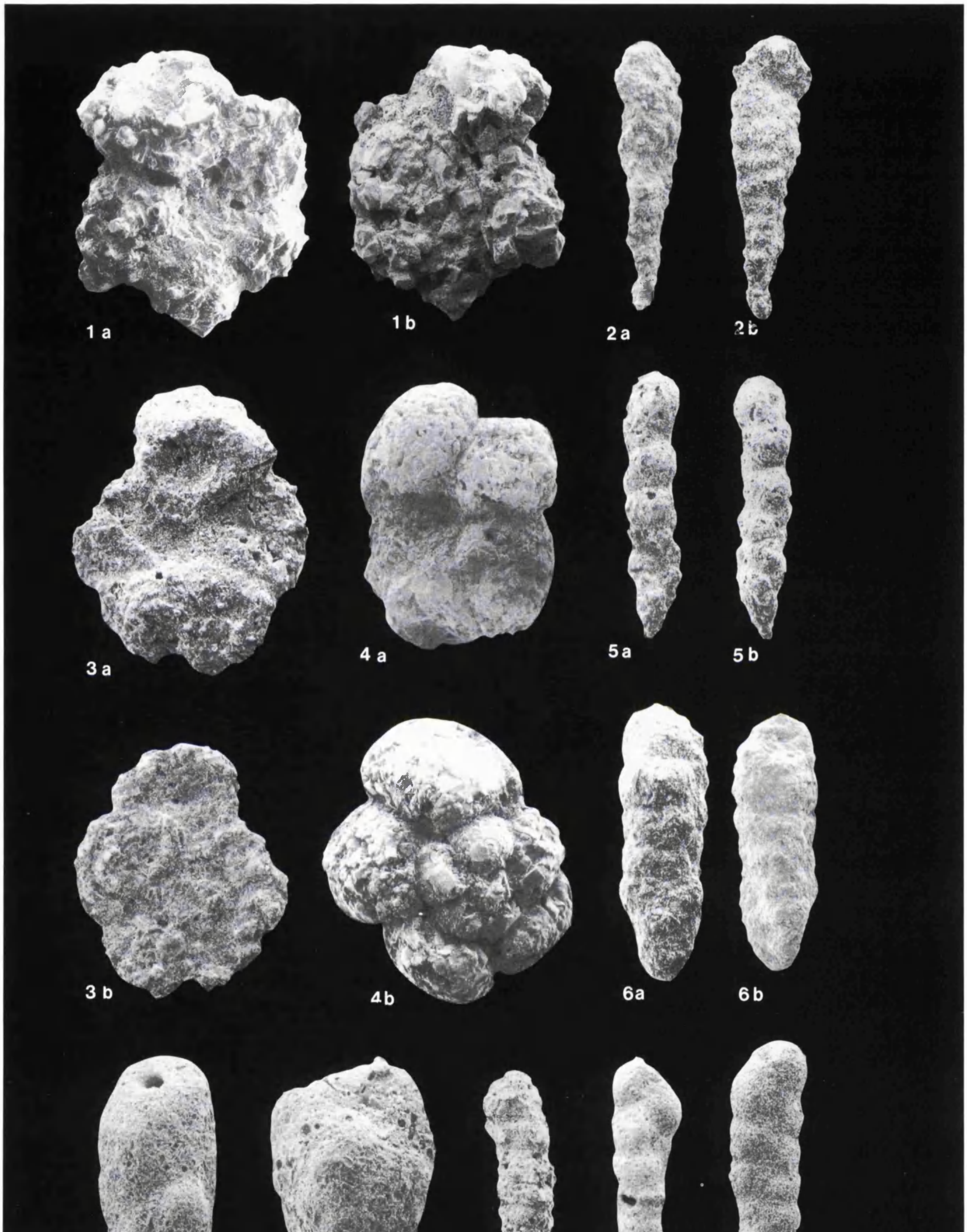
7 *Remesella* sp., (×160), Sample 766A-29R-03; 54-58cm.

8 *Verneuilina* sp. 1, (×160), Sample 766A-29R-03; 54-58cm.

9 *Textularia bettenstaedti* Bartenstein and Oertli, (×100), Sample 766A-46R-05; 20-24cm.

10 *Pseudogaudryinella* sp. 1, (×80), Sample 766A-29R-03; 54-58cm.

11 *Dorothia* sp. 1, (×90), Sample 766A-29R-03; 54-58cm.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Vaginulinopsis neopachynota Bartenstein and Kaever 1973
Plate 12, figures 4a-5

Vaginulinopsis neopachynota BARTENSTEIN and KAEVER 1973, pl. 2, figs. 25-27.
Astacolus neopachynota Bartenstein and Kaever. — BARTENSTEIN 1974a, pl. 2, figs. 22-25.

Description: Elongated, evolute test with planispiral, early portion and prominent, thick, raised sutures. Periphery rounded, aperture terminal at the dorsal margin.

Remarks: Rare at Site 766. Differs from the types by less prominent sutures. Bartenstein (1974a) suggested that *V. neopachynota* Bartenstein and Kaever is a successor to *A. humilis precursoria* Bartenstein and Brand, which belongs to the *L. nodosa* Reuss evolutionary plexus.

Range and Occurrence: A typical Hauterivian species, occuring less frequently in the Barremian (Bartenstein 1974a).

Vaginulinopsis reticulosa Ten Dam 1946
Plate 12, figures 9a-12

Vaginulinopsis reticulosa TEN DAM 1946, pl. 88, fig. 4a, b. — WEIDICH 1990, pl. 22, figs. 1-5.
Marginulinopsis djaffaensis SIGAL 1952, Abb. 9.
Marginulinopsis sigali BARTENSTEIN, BETTENSTAEDT and BOLLI 1957, pl. 5, fig. 99; pl. 6, figs. 130-131.

Description: Test may be planispiral initially or completely evolute. Prominent longitudinal and transverse ribs, often arranged in a patchwork pattern, periphery carinate, convex apertural face with aperture at dorsal margin.

Remarks: This very variable species displays a confusing range of shapes (from involute to evolute) and ornamentation (longitudinal ribs to grid patterns). It has been described under three different names, leading to considerable taxonomic confusion (see also *L. schreiterei* Eichenberg).

Range and Occurrence: Widely recorded in many parts of the world throughout the Early Cretaceous.

Subfamily VAGINULININAE Reuss 1860

Genus *Citharina* d'Orbigny 1839

Citharina rudocosta Bartenstein and Brand 1951
Plate 13, figure 1a, 1b

Citharina rudocosta BARTENSTEIN and BRAND 1951, pl. 2, fig. 183; pl. 12A, fig. 340. — NEAGU 1975, pl. 64, figs. 7-12, 14-17 19-21, 23.

Description: Elongated, compressed test with slightly diverging sides, gently pointed, curved proximal end and dorsally elongated last chamber. Four or five raised, longitudinal costae ornament the test.

Range and Occurrence: First described from the mid-Valanginian of northwestern Germany (Bartenstein and Brand 1951). Late Valanginian to late Hauterivian in Rumania (Neagu 1975).

Citharina sp. 1
Plate 13, figure 2

Description: Flattened, uniserial test with curved dorsal margin and truncate ventral face. Narrow chambers angled at base increasing rapidly in breadth, sutures indistinct. Prominent, raised, bifurcating, sinusoidal costae do not all extend to first and last chambers. Radiate, dorsal aperture.

Remarks: Very rare at Site 766. Some similarity to the Jurassic species *C. inaequistriata* Terquem 1864.

Genus *Planularia* Defrance 1826

PLATE 4

1a,b *Laevidentalina communis* (d'Orbigny), (×65, ×65), Sample 766A-29R-03; 54-58cm.

2a,b *Laevidentalina communis* (d'Orbigny), (×45, ×45), Sample 766A-49R-02; 42-46cm.

3a-c *Laevidentalina communis* (d'Orbigny), (×60, ×60, ×900), Sample 766A-44R-05; 102-106cm.

4a,b *Laevidentalina nana* (Reuss), (×95, ×95), Sample 766A-28R-01; 21-25cm.

5a,b *Laevidentalina oligostegia* (Reuss), (×80, ×80), Sample 766A-32R-02; 104-108cm.

6a,b *Laevidentalina soluta* Reuss, (×85, ×90), Sample 766A-44R-05; 102-106cm.

7 *Laevidentalina* sp., (×95), Sample 766A-40R-01; 84-88cm.

8 *Pyramidulina* cf. *bactriodes* (Reuss), (×160), Sample 766A-40R-01; 84-88cm.

9 *Pyramidulina* cf. *bactriodes* (Reuss), (×90), Sample 766A-33R-02; 15-18cm.

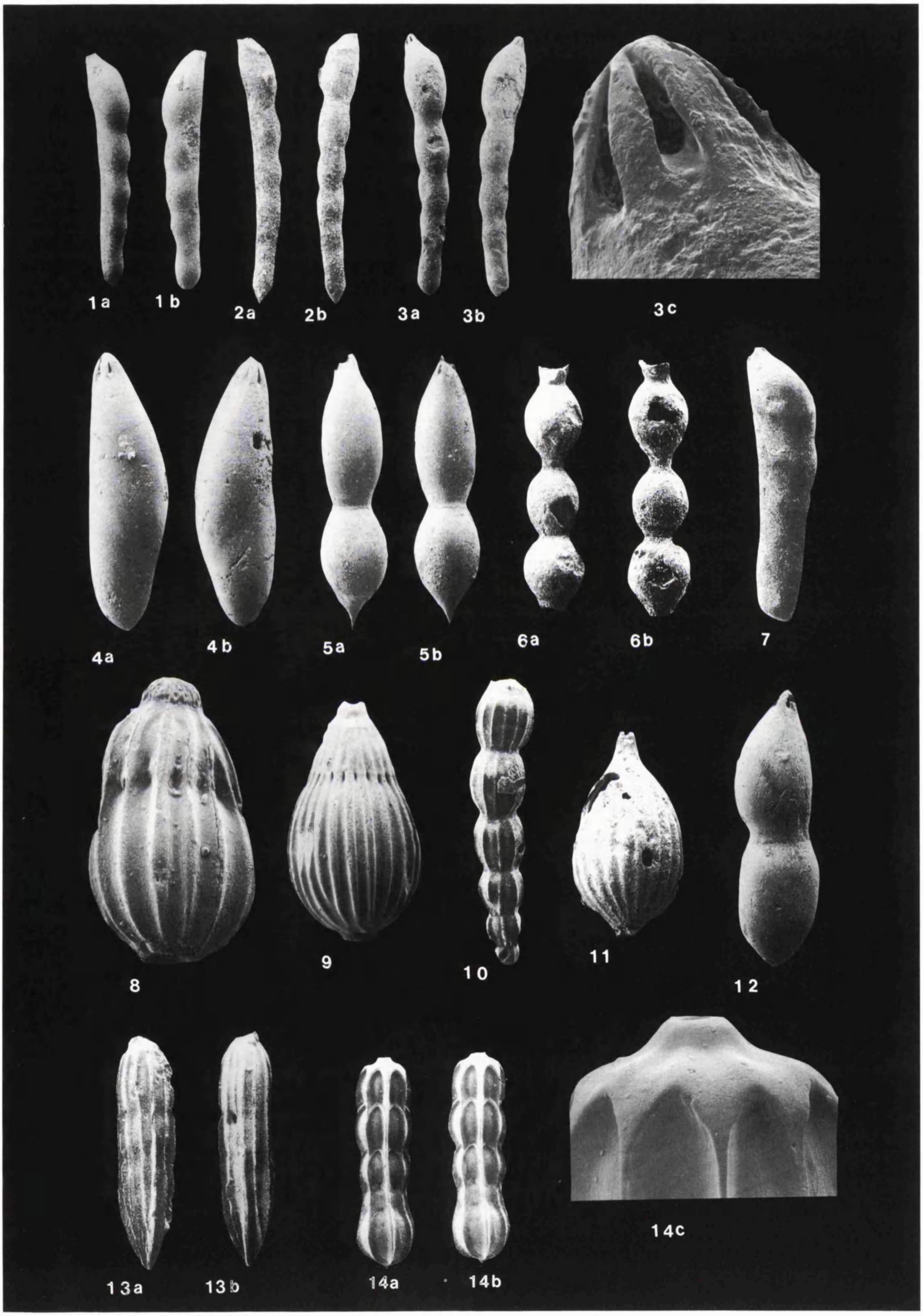
10 *Pyramidulina* cf. *corallina* (Gümbel), (×100), Sample 766A-28R-05; 133-138cm.

11 *Pyramidulina lagenoides* (Wisniowski), (×120), Sample 766A-44R-03; 47-52cm.

12 *Nodosaria* cf. *regularis* Terquem, (×85), Sample 766A-29R-03; 54-58cm.

13a,b *Pyramidulina obscura* (Reuss), (×100, ×100), Sample 766A-44R-05; 102-106cm.

14a-c *Pyramidulina zippei* (Reuss), (×70, ×70), Sample 766A-33R-02; 15-18cm.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Planularia complanata (Reuss 1845)
Plate 13, figures 4-6b

Cristellaria complanata REUSS 1845, pl. 13, fig. 54a, b.
Planularia madagascariensis ESPITALIÉ and SIGAL 1963, pl. 6, figs. 8-11; pl. 24.
Planularia complanata (Reuss). — WEIDICH 1990, pl. 40, figs. 13-14.

Description: Flattened fan-shaped test with numerous low chambers separated by curved, slightly limbate sutures. Shape of test varies quite considerably from open fan to elongated with sub-parallel sides. Initial spire unevenly developed, faint, short lineations may ornament some tests. Dorsal edge mostly sharp and narrowly carinate, radiate aperture at dorsal angle.

Remarks: Espitalié and Sigal (1963) have suggested that this very variable species may have evolved from one of the many Jurassic forms. Although the ornamentation is lacking or very faint on most tests, the specimens from Site 766 are similar to *P. madagascariensis* Espitalié and Sigal.

Range and Occurrence: Planularia madagascariensis Espitalié and Sigal ranges from the Callovian to the Valanginian in the Majunga Basin. *Planularia complanata* Reuss has been recorded in the Hauterivian, Aptian and Albian of the northern Alps (Weidich 1990).

Planularia crepidularis Roemer 1842
Plate 13, figures 9a-10b

Planularia crepidularis ROEMER 1842, pl. 7B, fig. 4.
Lenticulina crepidularis Roemer. — BARTENSTEIN and BRAND 1951, pl. 5, figs. 106-108. — RIEGRAF 1989, pl. 2, figs. 10-11.

Description: Flattened test with early planispiral stage, becoming evolute. Sutures curved, marked by strong carinae which may not extend to the umbilicus. Dorsal periphery tricarinate, ventral periphery usually carinate. Phyaline, radiate aperture at the dorsal periphery.

Remarks: The tests from Site 766 vary in the degree of coiling, keel development and ornamentation (additional ornamentation may be present in the form of irregular, longitudinal, nodulose ribs). Some authors have divided the taxon into several subspecies to account for various morphological and stratigraphical differences (e.g. Bartenstein, Bettenstaedt and Bolli 1957; Weidich 1990). At Site 766 the morphological variability does not appear stratigraphically correlated. Some very ornamented specimens appear to be transitional forms to *L. guttata* Ten Dam.

Range and Occurrence: Late Valanginian-early Barremian in northwest Germany (Bartenstein and Brand 1951). Oxfordian-Aptian in the North Atlantic, northern Germany, southern Sweden and the Indian Ocean (Riegraf 1989).

Genus *Psilocitharella* Loeblich and Tappan 1986

Psilocitharella arguta (Reuss 1860)
Plate 14, figure 6

Vaginulina arguta REUSS 1860, pl. 8, fig. 4.
Vaginulina arguta Reuss. — BARTENSTEIN and KAEVER 1973, pl. 4, figs. 55-56. — NEAGU 1975, pl. 65, figs. 3, 12, pl. 66, figs. 1-2, 7, 12, 16; pl. 67, fig. 3.

Description: Elongated, narrow test with slightly diverging sides. First chamber markedly inflated and last chamber elongated towards terminal, radiate aperture. Sharp, lateral carinae, inclined raised sutures.

Remarks: This species is quite variable. The specimen illustrated on pl. 14, fig. 6, is slightly arched, triangular in cross-section and has few chambers; it is probably a juvenile as described by Neagu (1975).

Range and Occurrence: Hauterivian-Barremian in Rumania (Neagu 1975).

PLATE 5

1 *Pyramidulina* sp., (×70), Sample 766A-34R-02; 30-33cm.

2 *Pyramidulina* sp., (×60), Sample 766A-40R-02; 46-50cm.

3a,b *Pseudonodosaria humilis* (Roemer), (×120, ×120), Sample 766A-45R-02; 109-113cm.

4a,b *Pseudonodosaria mutabilis* (Reuss), (×70, ×70), Sample 766A-44R-05; 102-106cm.

5a,b *Lingulina* sp., (×130, ×130), Sample 766A-30R-03; 100-102cm.

6 *Lingulina* sp., (×85), Sample 766A-28R-03; 116-120cm.

7 *Lingulina* sp. 1, (×130), Sample 766A-28R-05; 133-138cm.

8a,b *Lingulina* sp. 1, (×165, ×160), Sample 766A-28R-05; 133-138cm.

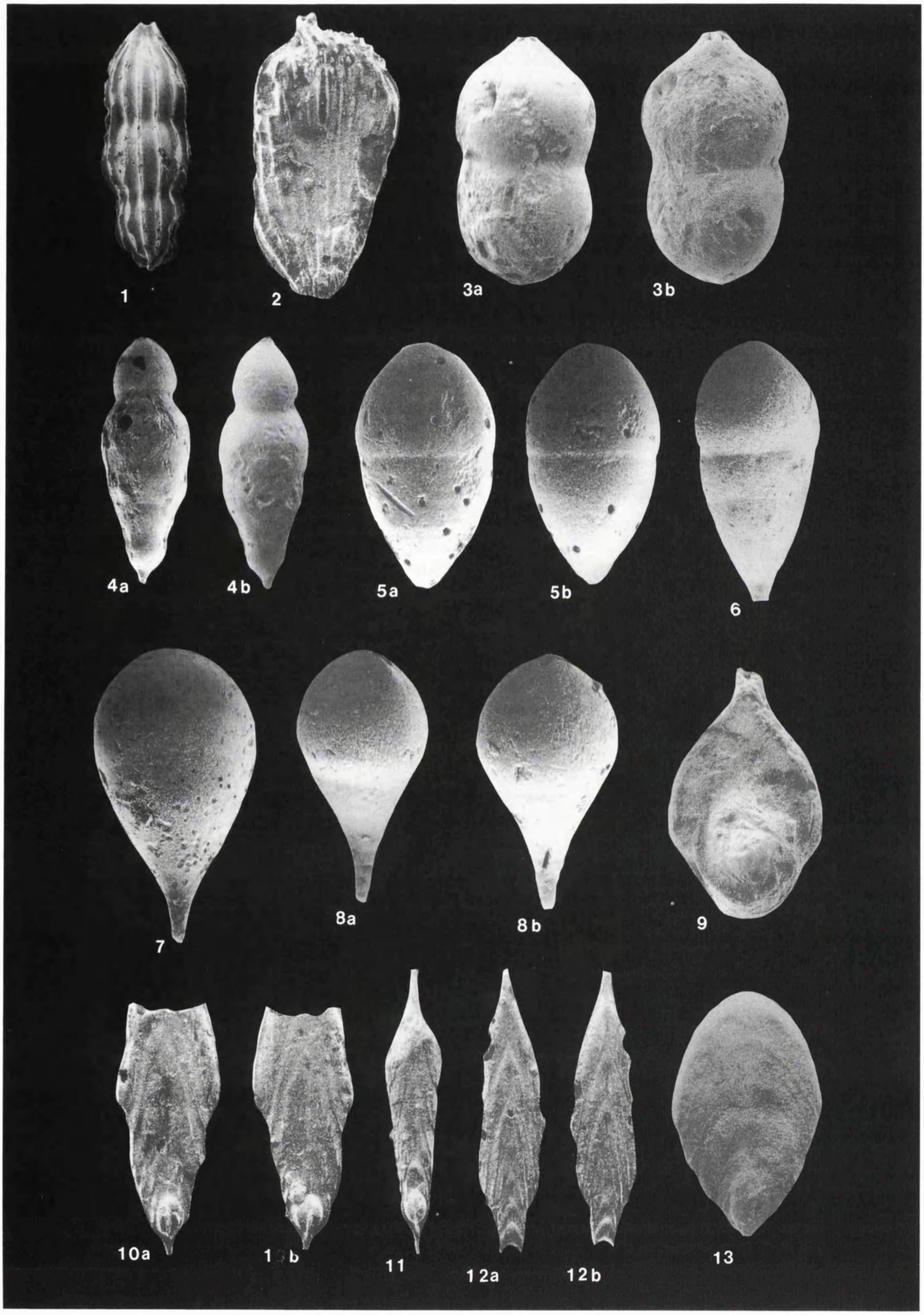
9 *Frondicularia* sp. (juvenile), (×130), Sample 766A-38R-01; 112-116cm.

10a,b *Frondicularia hastata* Roemer, (×40, ×40), Sample 766A-47R-01; 98-103cm.

11 *Frondicularia hastata* Roemer, (×40), Sample 766A-49R-01; 124-128cm.

12a,b *Frondicularia hastata* Roemer, (×32, ×32), Sample 766A-47R-01; 98-103cm.

13 *Frondicularia bettenstaedti* Zedler, (×60), Sample 766A-40R-01; 84-88cm.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Psilocitharella kochii (Roemer 1841)
Plate 14, figure 3a, 3b

Vaginulina kochii ROEMER 1841, pl. 15, fig. 10. — BARTENSTEIN and BRAND 1951, pl. 6, figs. 158-159. — WEIDICH 1990, Abb. 21/2-3.

Description: Compressed, harp-shaped test with strongly diverging sides. Last chamber tapers towards radiate, terminal, dorsal aperture, sutures indistinct.

Range and Occurrence: Index marker for the late Valanginian in northwestern Germany, less frequently in the Hauterivian-Aptian (Bartenstein and Brand 1951). Valanginian to Albian in Tethyan and transitional boreal facies of the northern hemisphere (Bartenstein 1977).

Psilocitharella recta (Reuss 1863)

Vaginulina recta REUSS 1863, pl. 2, figs. 14-15. — BARTENSTEIN, BETTENSTAEDT and BOLLI 1957, pl. 5, fig. 103.
Citharina recta (Reuss). — HAIG 1982, pl. 6, figs. 31-34.

Description: Elongated, narrow test with near parallel carinated sides and raised sutures.

Remarks: Only fragments recovered.

Range and Occurrence: Late early Albian-late Albian in Queensland (Haig 1982). Valanginian-Albian of Texas, England, southern France, northern Germany, western Indian Ocean and Central Pacific (Riegraf 1989).

Genus *Vaginulina* d'Orbigny 1826

Vaginulina petila (Eicher and Worstell 1970)
Plate 14, figure 5a, 5b

Citharina petila EICHER and WORSTELL 1970, pl. 2, figs. 20-21. — HAIG 1982, pl. 6, figs. 7-10.
Vaginulina sp. 3 BARTENSTEIN and BRAND 1951, pl. 6, fig. 153.
Lenticulina sp. LAMBERT and SCHEIBNEROVÁ 1974, pl. 1, fig. 3.

Description: Elongated, compressed test with sharp dorsal edge and rounded ventral side. Seven low chambers, slightly inflated ventrally, are separated by strongly inclined, depressed sutures. Last chamber becomes very elongated towards the terminal, radiate aperture on the dorsal side. Test is ornamented by several fine, slanting, prominent costae which do not extend over the whole test.

Remarks: Very rare. Virtually identical to *C. petila* Eicher and Worstell illustrated by Haig (1982). More slender than the specimen illustrated by Eicher and Worstell (1970). Differs from *Vaginulina* sp. 3 illustrated by Bartenstein and Brand (1951) by its narrower test and more elongated last chamber.

Range and Occurrence: First described from the Cenomanian-Turonian of the Western Interior, U.S.A (Eicher and Worstell 1970), this species has been recorded from the Albian of Queensland (Haig 1982) the Albian of South Africa (Lambert and Scheibnerová 1974), and possibly the Albian of France (Haig 1982). Bartenstein and Brand (1951) described *Vaginulina* sp. 3 from upper Valanginian sediments in northwestern Germany.

Genus *Brunsvigella* Meyn and Vespermann 1994

Brunsvigella thoerensis (Bartenstein and Brand 1951)
Plate 14, figures 1, 2a, 2b, 4a, 4b

Vaginulina thoerensis BARTENSTEIN and BRAND 1951, pl. 7, fig. 170. — NEAGU 1975, pl. 64, figs. 27, 30-31.
Citharina thoerensis (Bartenstein and Brand). — HAIG 1982, pl. 6, figs. 3-6.

Description: Elongated, narrow test, tricarinate on dorsal side and sharply edged with two or three prominent, longitudinal costae on the ventral side. The chambers are slightly inflated ventrally and separated by weakly depressed, inclined sutures. In cross-section the test is roughly rhomboidal. Proloculus is small, inflated, with a median rib and a basal spine.

Remarks: Very similar to the forms illustrated by Neagu (1975). Differs from specimens figured by Bartenstein and Brand (1951) by its smaller, rounded proloculus.

PLATE 6

1a,b *Frondicularia bettenstaedti* Zedler, (×110, ×115), Sample 766A-33R-02; 15-18cm.

2a,b *Tristix acutangula* (Reuss), (×150, ×150), Sample 766A-43R-02; 46-50cm.

3a,b *Tristix excavata* (Reuss), (×120, ×120), Sample 766A-40R-01; 84-88cm.

4 *Lenticulina circumcidanea* (Berthelin), (×100), Sample 766A-30R-04; 100-102cm.

5a,b *Lenticulina heiermanni* Bettenstaedt, (×40, ×40), Sample 766A-45R-02; 109-113cm.

6 *Lenticulina heiermanni* Bettenstaedt, (×40), Sample 766A-46R-04; 105-110cm.

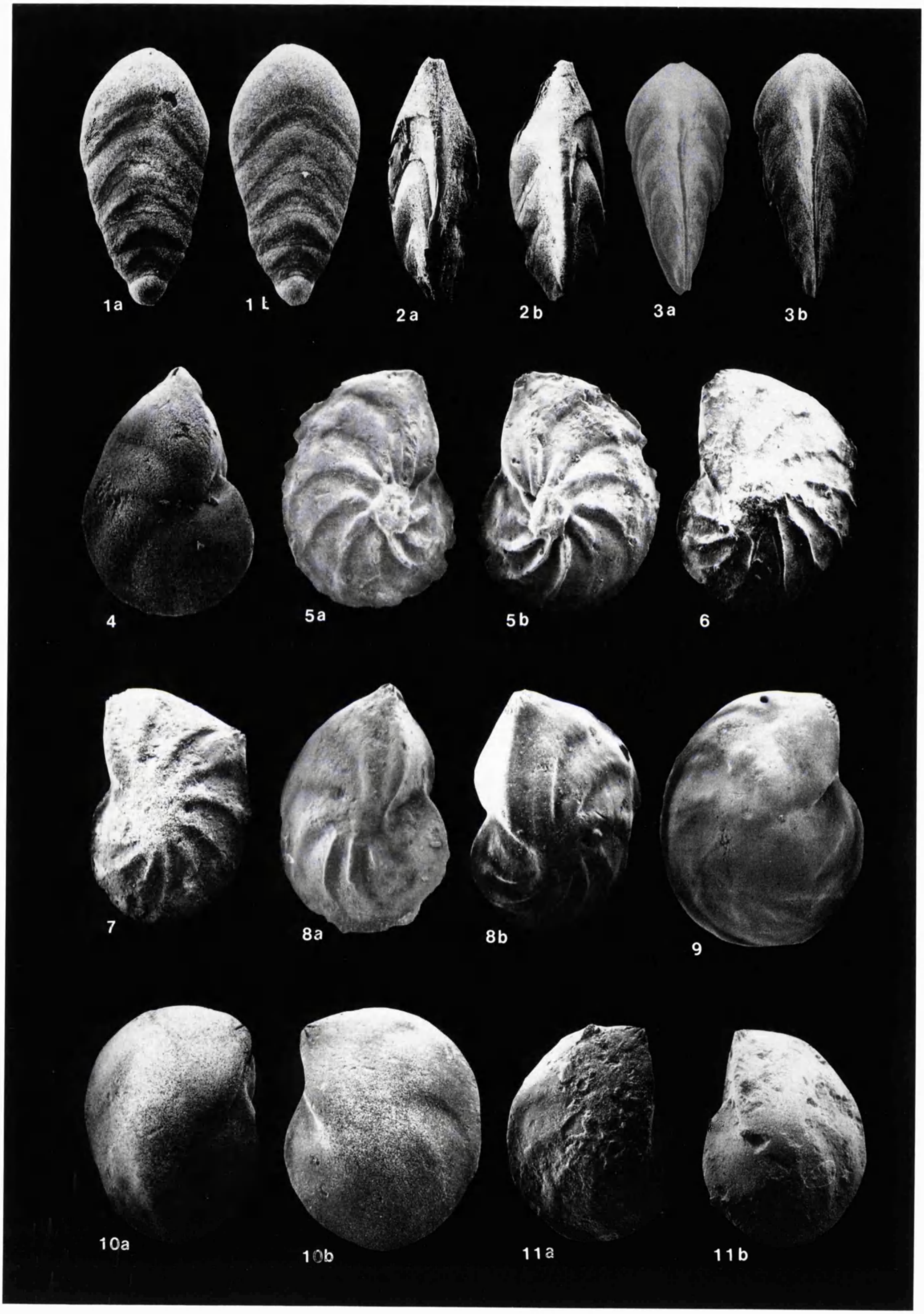
7 *Lenticulina heiermanni* Bettenstaedt, (×40), Sample 766A-46R-04; 105-110cm.

8a,b *Lenticulina heiermanni* Bettenstaedt, (×80, ×85), Sample 766A-45R-04; 115-120cm.

9 *Lenticulina macrodisca* (Reuss), (×50), Sample 766A-29R-03; 54-58cm.

10a,b *Lenticulina macrodisca* (Reuss), (×90, ×90), Sample 766A-30R-03; 100-102cm.

11a,b *Lenticulina muensteri* (Roemer), (×60, ×60), Sample 766A-47R-04; 114-119cm.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Range and Occurrence: A cosmopolitan index species for the upper Valanginian (Bartenstein and Brand 1951) and upper Hauterivian in Rumania (Neagu 1975). Recorded from the Albian of Queensland (Haig 1982).

Family POLYMORPHINIDAE d' Orbigny 1839
Subfamily POLYMORPHININAE d' Orbigny 1839
Genus *Eoguttulina* Cushman and Osawa 1930

Eoguttulina ichnusae (Dieni and Massari 1966)
Plate 16, figure 1a, 1b

Guttulina ichnusae DIENI and MASSARI 1966, pl. 6, figs. 29-31. — NEAGU 1975, pl. 76, figs. 27-30; pl. 108, figs. 28-30.

Description: Slightly compressed, ovate test with elongate chambers added spirally in planes less than 90° apart. Depressed, oblique sutures and fine costate ornamentation.

Remarks: Very rare. Ornamentation most similar to that illustrated by Dieni and Massari (1966),

Range and Occurrence: Upper Valanginian in Sardinia (Dieni and Massari 1966). Upper Hauterivian, Barremian and lower Aptian in Rumania (Neagu 1975).

Genus *Globulina* d' Orbigny 1839

Globulina bucculenta (Berthelin 1880)
Plate 15, figure 6a, 6b

Polymorphina bucculenta BERTHELIN 1880, pl. 4, figs. 17-20.
Globulina bucculenta (Berthelin). — RIEGRAF 1989, pl. 2, figs. 17-20.

Description: Moderately inflated test, pointed at the proximal end with three strongly overlapping chambers arranged along three planes. Sutures depressed and radiating, terminal aperture large and straight.

Remarks: Identical to specimens from ODP Site 249 illustrated by Riegraf (1989) in pl. 2, figs. 17-20.

Range and Occurrence: North Atlantic, eastern Indian Ocean and Central Pacific in Valanginian-Albian sediments (Riegraf 1989).

Globulina lacrima (Reuss 1845)
Plate 15, figures 4a-5b

Polymorphina lacrima REUSS 1845, pl. 12, fig. 6a-c.
Globulina lacrima (Reuss). — WEIDICH 1990, pl. 26, figs. 25-26.
Globulina cf. *lacrima* (Reuss). — FOWLER and BRAUN 1993, pl. 9, figs. 4-5.

Description: Ovate test with rounded base and slightly tapering apertural end. Few rapidly increasing chambers separated by flush indistinct sutures. Aperture large, radiate.

Range and Occurrence: Albian to Late Cretaceous in the northern Alps (Weidich 1990). Cretaceous in Europe and Gulf Cost of USA (Fowler and Braun 1993).

Globulina prisca (Reuss 1863)
Plate 15, figures 7a-9

Polymorphina prisca REUSS 1863, pl. 8, fig. 8.
Globulina prisca (Reuss). — BARTENSTEIN and BRAND 1951, pl. 10, fig. 286. — FOWLER and BRAUN 1993, pl. 9, figs. 8-10.

Description: Elongated test, moderately inflated and slightly pointed at the proximal end with three overlapping chambers arranged along three planes. Sutures slightly depressed and terminal, radiate aperture.

Range and Occurrence: A cosmopolitan species in the Early Cretaceous recorded in Germany, Netherlands, England, Poland, Alaska, France, Norway (Fowler and Braun 1993).

Genus *Palaeopolymorphina* Cushman and Ozawa 1930

Palaeopolymorphina sp. 1
Plate 16, figures 13-15b

Description: Elongated test, broadly rounded at the base and narrower at the top. Five or more overlapping chambers initially

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PLATE 7

1 *Lenticulina muensteri* (Roemer), (×75), Sample 766A-45R-02; 109-113cm.

2a,b *Lenticulina nodosa* (Reuss), (×160, ×160), Sample 766A-46R-05; 20-24cm.

3 *Lenticulina saxocretacea* Bartenstein, (×120), Sample 766A-32R-02; 104-108cm.

4a,b *Lenticulina pulchella* (Reuss), (×140, ×140), Sample 766A-33R-02; 15-18cm.

5a,b *Lenticulina pulchella* (Reuss), (×190, ×190), Sample 766A-30R-03; 100-102cm.

6 *Lenticulina* sp. (transitional), (×120), Sample 766A-30R-04; 100-102cm.

7 *Lenticulina* sp. (transitional), (×90), Sample 766A-45R-02; 109-113cm.

8 *Lenticulina* sp. (transitional), (×75), Sample 766A-45R-02; 109-113cm.

9 *Lenticulina* sp. (transitional), (×75), Sample 766A-45R-04; 115-120cm.

10 *Lenticulina ouachensis* (Sigal), (×80), Sample 766A-43R-05; 131-135cm.

11a,b *Lenticulina ouachensis* (Sigal), (×105, ×100), Sample 766A-47R-01; 98-103cm.

12 *Lenticulina ouachensis* (Sigal), (×95), Sample 766A-47R-03; 25-30cm.


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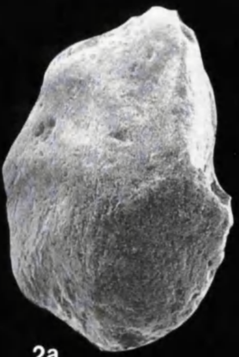
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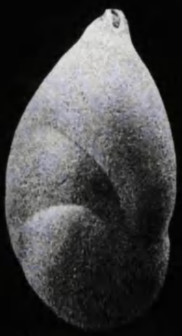
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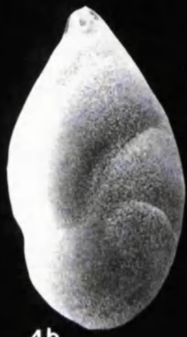
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biserial, then tending to become uniserial. Early chambers small, increasing rapidly in size. Sutures oblique, faintly depressed in early portion, becoming distinctly depressed between younger chambers. In well-preserved specimens the surface of the test appears rough and a distinct spine is present at the base of the first chamber. The last chamber tapers towards a phialine, radiate aperture at the end of a short neck.

Remarks: Tests are variable in shape: some are squat with broad chambers, others more slender and only loosely biserial. This species closely resembles *Palaeopolymorphina inflata* Espitalié and Sigal (1963 pl. 30, fig. 18) and ?*Glandulina aptiensis* Myatlyuk and Vasilenko 1988 (pl. 57, figs. 1-9) although the specimen illustrated by Espitalié and Sigal is more globular, without basal extension and with a smaller, indistinct aperture while the specimens described by Myatlyuk and Vasilenko have simpler aperture and no basal extension. Neagu (pers. comm. 1993) suggests that these forms are polymorphinid gamonts.

Range and Occurrence: Espitalié and Sigal (1963) use *P. inflata* Espitalié and Sigal as a zonal marker for the base of the late Valanginian in the Majunga Basin.

Genus *Pyrulina* d' Orbigny 1839

Pyrulina cylindroides (Roemer 1838)
Plate 15, figure 10

Polymorphina cylindroides ROEMER 1838, pl. 3, fig. 26a, b.
Pyrulina cylindroides (Roemer). — McNEIL and CALDWELL 1981, pl. 17, fig. 16. — RIEGRAF and LUTERBACHER 1989a, pl. 4, figs. 23-24.

Description: Test fusiform, subcircular in cross-section, tapering slightly at both extremities. Overlapping chambers are added spirally and separated by flush sutures. Large radiate, terminal aperture.

Range and Occurrence: A cosmopolitan species recorded from the Cretaceous to Recent (Riegraf and Luterbacher 1989a).

Subfamily RAMULININAE Brady 1884
Genus *Ramulina* T.R. Jones 1875

Ramulina aptiensis Bartenstein and Brand 1951
Plate 16, figure 8

Ramulina aptiensis BARTENSTEIN and BRAND 1951, pl. 11, fig. 332.

Description: Elongated, irregular chambers connected by stolons. Surface ornamented with short, thick spines.

Range and Occurrence: Rare in the Valanginian to Aptian of northwestern Germany but becoming common in the Aptian and Albian (Bartenstein and Brand 1951).

Ramulina tappanae Bartenstein and Brand 1951
Plate 16, figures 9-11

Ramulina tappanae BARTENSTEIN and BRAND 1951, pl. 11, figs. 305-307. — RIEGRAF 1989, pl. 2, figs. 21-22.

Description: Subglobular or irregular chambers joined by stolons. Surface finely or coarsely spinose, aperture at the end of open stolons.

Remarks: Included in this species are tubular, branching fragments which may represent original connecting stolons.

Range and Occurrence: Cosmopolitan from the Valanginian to the the Albian (Riegraf 1989).

Family ELLIPSOLAGENIDAE A. Silvestri 1923
Subfamily OOLININAE Loeblich and Tappan 1961
Genus *Oolina* d'Orbigny 1839

Oolina caudata d'Orbigny 1840
Plate 16, figure 5

PLATE 8

1a,b *Lenticulina subangulata* (Reuss), (×50, ×50), Sample 766A-39R-03; 86-90cm.

2a,b *Lenticulina* sp., (×90, ×100), Sample 766A-44R-03; 47-52cm.

3 *Lenticulina* sp., (×150), Sample 766A-32R-02; 104-108cm.

4a,b *Lenticulina* cf. *subgaultina* Bartenstein, (×60, ×60), Sample 766A-49R-01; 124-128cm.

5a,b *Marginulinopsis comma* (Roemer), (×85, ×90), Sample 766A-45R-02; 109-113cm.

6a,b *Saracenaria compacta* Espitalié and Sigal, (×120, ×120), Sample 766A-47R-03; 27-30cm.

7 *Marginulinopsis bettenstaedti* Bartenstein and Brand, (×150), Sample 766A-47R-03; 27-30cm.

8 *Marginulinopsis bettenstaedti* Bartenstein and Brand, (×130), Sample 766A-29R-03; 54-58cm.

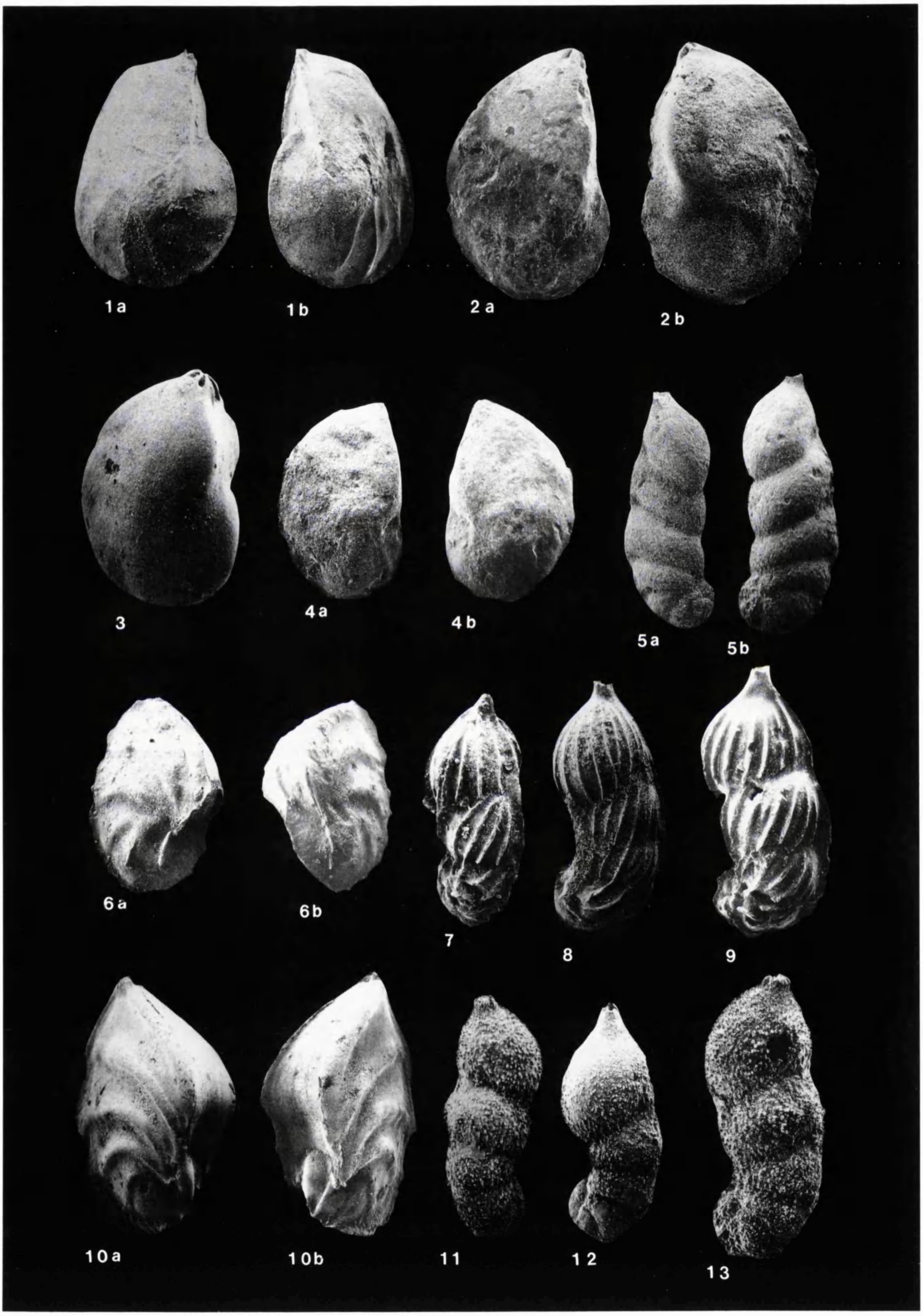
9 *Marginulinopsis bettenstaedti* Bartenstein and Brand, (×140), Sample 766A-49R-01; 124-128cm.

10a,b *Saracenaria compacta* Espitalié and Sigal, (×45, ×45), Sample 766A-29R-03; 54-58cm.

11 *Marginulinopsis gracilissima* (Reuss), (×105), Sample 766A-38R-03; 111-113cm.

12 *Marginulinopsis gracilissima* (Reuss), (×140), Sample 766A-47R-03; 25-30cm.

13 *Marginulinopsis gracilissima* (Reuss), (×115), Sample 766A-38R-03; 111-113cm.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Oolina caudata d'ORBIGNY 1840, pl. 5, fig. 6.
Lagena cf. *caudata* (d'Orbigny). — BARTENSTEIN and BRAND 1951, pl. 10, fig. 282; pl. 13, fig. 352.

Description: Unilocular, pear shaped test with a rounded aperture at the end of a thick tapering neck. Ten thick, longitudinal costae ornament all but the top of the test.

Remarks: Only one specimen found at Site 766.

Range and Occurrence: Recorded by Bartenstein and Brand (1951) from middle and upper Valanginian deposits of northwestern Germany.

Oolina hauteriviana cylindracea (Bartenstein and Brand 1951)
Lagena hauteriviana cylindracea BARTENSTEIN and BRAND 1951, pl. 10, figs. 279-280. — WEIDICH 1990, pl. 45, figs. 11-12.

Description: Unilocular, cylindrical test, tapering at both ends. Rounded aperture at the end of a short neck.

Remarks: Very rare at Site 766.

Range and Occurrence: Bartenstein and Brand (1951) use *O. hauteriviana cylindracea* as an index species for the lower Hauterivian in northwestern Germany. Also recorded by Weidich (1990) in the Berriasian of the northern Alps where its rare occurrence and different range from Germany suggest distinct Tethyan and boreal distributions.

Oolina laevis (Montagu 1803)
Plate 16, figure 4

Vermiculum laeve MONTAGU 1803; Test. Brit., S. 524.
Lagena laevis (Montagu). — BARTENSTEIN and BRAND 1951, pl. 10, fig. 274. — NEAGU 1975, pl. 69, figs. 20, 21, 24.

Description: Unilocular, globular test with rounded aperture on short neck and smooth surface.

Remarks: Shape varies from cylindrical to slightly elongate.

Range and Occurrence: Recorded in the Valanginian of northwestern Germany by Bartenstein and Brand (1951), by Neagu (1975) in the Hauterivian and Barremian of Rumania.

Oolina aff. ***oxystoma*** (Reuss 1858)
Plate 16, figure 6

Lagena oxystoma REUSS 1858, pl. 5, fig. 66.
Oolina aff. *oxystoma* (Reuss). — BARTENSTEIN and BRAND 1951, pl. 10, fig. 33; pl. 13, figs. 354-356. — BARTENSTEIN and BOLLI 1986, pl. 4, figs. 4-6.

Description: Subglobular test, finely to coarsely spinose with rounded or apiculate base. Simple aperture at the end of a thin neck.

Range and Occurrence: Cosmopolitan from Jurassic to Recent (Bartenstein and Bolli 1986).

Oolina sulcata (Walker and Jacob 1798)
Plate 16, figure 3

Serpula sulcata WALKER and JACOB 1798, pl. 14, fig. 5.
Lagena cf. *sulcata* (Walker and Jacob). — BARTENSTEIN and BRAND 1951, pl. 10, fig. 281.
Lagena sulcata (Walker and Jacob). — NEAGU 1975, pl. 69, figs. 18-19.

Description: Unilocular, globular test with rounded aperture on short neck. Ten longitudinal ribs ornament the test.

Remarks: Differs slightly from the species illustrated by Bartenstein and Brand (1951) in having a more pointed proximal end.

Range and Occurrence: Late Valanginian in northwestern Germany (Bartenstein and Brand 1951), late Valanginian-early Hauterivian in Rumania (Neagu 1975).

Oolina cf. ***sulcata*** (Walker and Jacob 1798)
Plate 16, figure 2

Serpula sulcata WALKER and JACOB 1798, pl. 14, fig. 5.
Lagena sulcata (Walker and Jacob). — WEIDICH 1990, pl. 45, figs. 6, 14.

PLATE 9

1 *Saracenaria forticosta* Bettenstaedt, (×50), Sample 766A-47R-01; 98-103cm.

2 *Saracenaria forticosta* Bettenstaedt, (×50), Sample 766A-45R-02; 109-113cm.

3 *Saracenaria forticosta* Bettenstaedt, (×50), Sample 766A-45R-02; 109-113cm.

4 *Saracenaria forticosta* Bettenstaedt, (×55), Sample 766A-47R-01; 98-103cm.

5 *Saracenaria forticosta* Bettenstaedt, (×65), Sample 766A-49R-01; 124-128cm.

6 *Saracenaria forticosta* Bettenstaedt, (×60), Sample 766A-32R-02; 104-108cm.

7 *Saracenaria forticosta* Bettenstaedt, (×90), holotype.

8a, b *Saracenaria erlita* Ludbrook, (×145, ×150), Sample 766A-29R-03; 54-58cm.

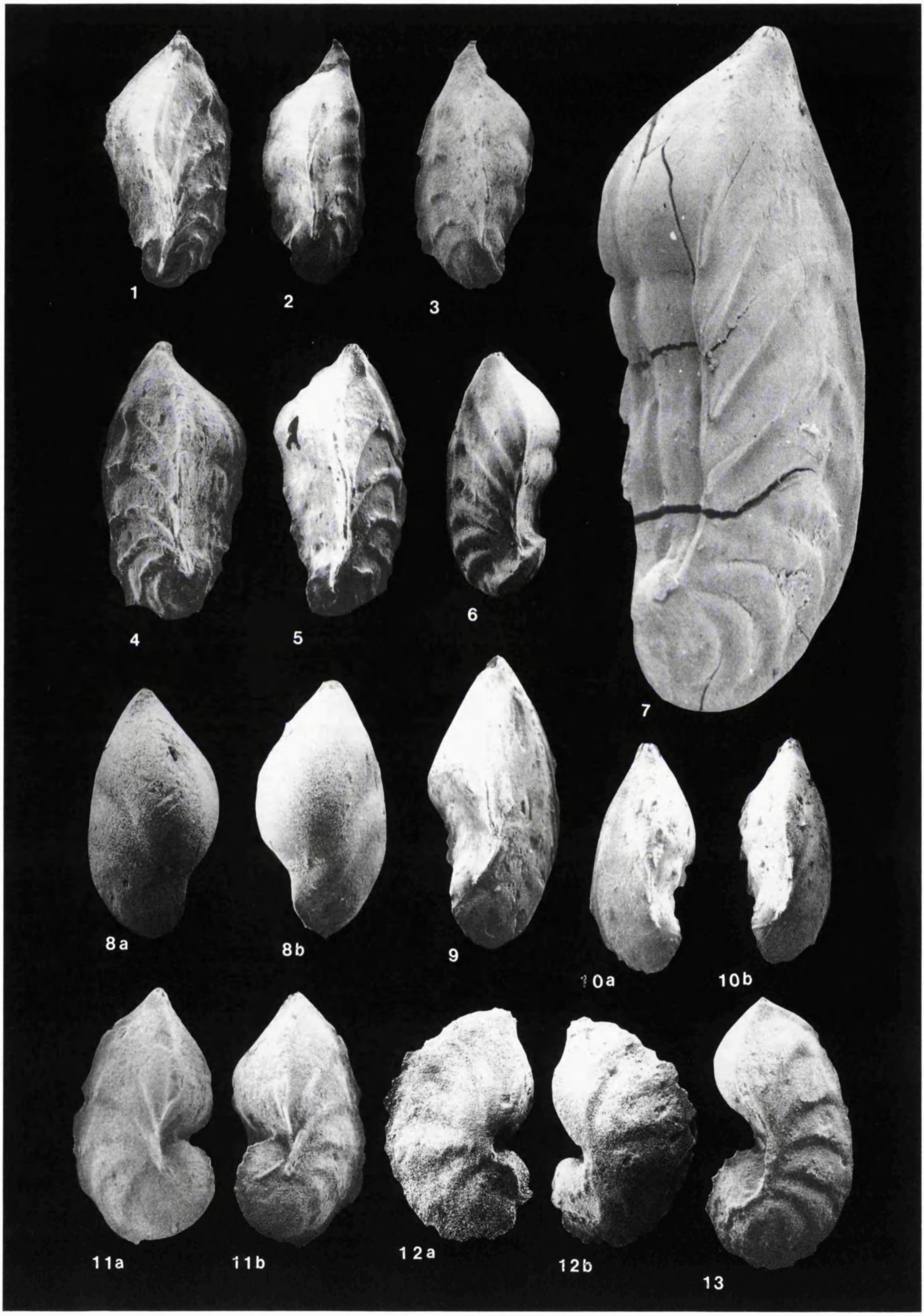
9 *Saracenaria frankei* Ten Dam, (×100), Sample 766A-48R-04; 51-54cm.

10a, b *Saracenaria frankei* Ten Dam, (×75, ×75), Sample 766A-47R-01; 98-103cm.

11a, b *Saracenaria pravoslavlevi* Fursenko and Polenova, (×70), Sample 766A-45R-04; 115-120cm.

12a, b *Saracenaria pravoslavlevi* Fursenko and Polenova, (×75, ×70), Sample 766A-45R-04; 115-120cm.

13 *Saracenaria pravoslavlevi* Fursenko and Polenova, (×95), Sample 766A-48R-04; 51-54cm.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Description: Unilocular, fusiform test, pointed at both ends with six projecting, thin, longitudinal costae reaching a small round aperture.

Remarks: Differs from *O. sulcata* Walker and Jacob by having a less globular test and fewer costae which are more prominently raised.

Range and Occurrence: Late Albian-Cenomanian in the northern Alps (Weidich 1990).

Subfamily ELLIPSOLAGENINAE A. Silvestri 1923
Genus *Fissurina* Reuss 1850

Fissurina* cf. *laevigata Reuss 1850
Fissurina cf. *laevigata* REUSS 1850, pl. 46, fig. 1a, b.
Fissurina laevigata Reuss. — WEIDICH 1990, pl. 45, figs. 7-8.

Description: Ovate test, lenticular in cross section with carinate periphery. Slit-like terminal aperture.

Remarks: Rare at Site 766.

Range and Occurrence: Cretaceous to Holocene (Loeblich and Tappan 1987).

Suborder ROBERTININA Loeblich and Tappan 1984
Superfamily CERATOBULIMINACEA Cushman 1927
Family CERATOBULIMINIDAE Cushman 1927
Subfamily REINHOLDELLINAE Seiglie and Bermúdez 1965
Genus *Reinholdella* Brotzen 1948

Reinholdella hofkeri (Bartenstein and Brand 1951)
Plate 15, figure 2a, 2b

Conorbis hofkeri BARTENSTEIN and BRAND 1951, pl. 11, fig. 320.
Reinholdella hofkeri (Bartenstein and Brand). — NEAGU 1975, pl. 107, figs. 1-6; pl. 108, figs. 19-20.

Description: Trochospiral test with five chambers in last whorl and subacute periphery. Sutures fine, radiate and faintly depressed on concave umbilical face; on convex spiral side, sutures thicker, curved and markedly depressed. Interiomarginal aperture.

Remarks: Secondary apertures are rarely visible.

Range and Occurrence: Late Hauterivian-early Barremian in Rumania (Neagu 1975). Berriasian to Valanginian and possibly Hauterivian-Aptian in Tethyan and transitional boreal facies in the northern hemisphere (Bartenstein 1976).

Suborder ROTALIINA Delage and Hérouard 1896
Superfamily CHILOSTOMELLACEA Brady 1881
Family GAVELINELLIDAE Hofker 1956
Subfamily GAVELINELLINAE Hofker 1956
Genus *Gavelinella* Brotzen 1942

Gavelinella sigmoicosta? (Ten Dam 1948)
Plate 15, figure 1a, 1b

Anomalina sigmoicosta TEN DAM 1948, pl. 32, figs. 23-24.
Gavelinella sigmoicosta (Ten Dam). — BARTENSTEIN and KAEVER 1973, pl. 6, figs. 98-100. — WEIDICH 1990, pl. 28, figs. 21-23.
Lingulogavelinella sigmoicosta (Ten Dam). — NEAGU 1975, pl. 100, figs. 1-29, pl. 101, figs. 1-34, pl. 102, figs. 6-20; text fig. 22.

Description: Small, disc-shaped test with flat, spiral face (two and a half whorls). Eight chambers in last whorl becoming progressively higher and more inflated, separated by arched sutures, slightly depressed in last chamber; large, open umbilicus and extraumbilical-umbilical, interiomarginal slit-aperture.

Remarks: Poor preservation only allowed tentative determination.

Range and Occurrence: Cosmopolitan and earliest representative of the genus, this species is a useful marker for the late Hauterivian-early Barremian (Zedler 1961; Bartenstein and Kaever 1973; Neagu 1975; Weidich 1990).

Gavelinella barremiana Bettenstaedt 1952
Plate 15, figure 3a, 3b

Gavelinella barremiana BETTENSTAEDT 1952, pl. 2, figs. 26-29.

PLATE 10

1a,b *Saracenaria triangularis* (d'Orbigny), (×110, ×110), Sample 766A-30R-04; 100-102cm.

2a,b *Saracenaria spinosa* (Eichenberg), (×115, ×115), Sample 766A-30R-04; 100-102cm.

3a,b *Saracenaria valanginiana* Bartenstein and Brand, (×85, ×85), Sample 766A-32R-05; 5-8cm.

4a,b *Saracenaria valanginiana* Bartenstein and Brand, (×55, ×50), Sample 766A-40R-02; 46-50cm.

5 *Saracenaria valanginiana* Bartenstein and Brand, (×50), Sample 766A-40R-02; 46-50cm.

6 *Saracenaria valanginiana* Bartenstein and Brand, (×280), holotype.

7 *Saracenaria* sp., (×40), Sample 766A-46R-03; 122-125cm.

8 *Saracenaria* sp., (×40), Sample 766A-34R-02; 30-33cm.

9 *Saracenaria* sp., (×45), Sample 766A-45R-04; 115-120cm.

10a,b *Saracenaria* sp. 1, (×55, ×55), Sample 766A-32R-05; 5-8cm.

11 *Saracenaria* sp. 2, (×60), Sample 766A-30R-04; 100-102cm.


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Lingulogavelinella barremiana (Bettenstaedt). — NEAGU 1975, pl. 89, figs. 20-27, pl. 99, figs. 1-26, pl. 102, figs. 1-5; text fig. 22.

Description: Small, disc-shaped test with slightly convex spiral face (two and a half whorls). Twelve chambers in the last whorl becoming progressively larger and more inflated, separated by sutures, more markedly depressed towards the umbilicus. Large, open umbilicus and extraumbilical, interiomarginal slit-aperture with lip extended to the umbilicus.

Remarks: This cosmopolitan species probably evolved from *G. sigmoicosta* in the late Barremian (Neagu 1975). The species reported by Riegraf (1989) from the upper Hauterivian in ODP Sites may be a precursor to *G. barremiana* (Moullade, pers. comm. 1994).

Range and Occurrence: A useful marker for the late Barremian to early Aptian in northern Germany (Bettenstaedt 1952).

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PLATE 11

1a,b *Palmula* sp. 1, (×75, ×75), Sample 766A-32R-05; 5-8cm.

2a,b *Astacolus calliopsis* (Reuss), (×95, ×100), Sample 766A-29R-03; 54-58cm.

3 *Astacolus calliopsis* (Reuss), (×80), Sample 766A-29R-03; 54-58cm.

4 *Astacolus calliopsis* ((Reuss), (×75), Sample 766A-29R-03; 54-58cm.

5 *Astacolus calliopsis* (Reuss), (×85), Sample 766A-29R-03; 54-58cm.

6a,b *Astacolus schlönbachi* (Reuss), (×100, ×100), Sample 766A-28R-01; 21-25cm.

7a,b *Marginulina bullata* Reuss, (×110, ×115), Sample 766A-33R-02; 15-18cm.

8a-c *Marginulina* sp. 1, (×90, ×85, ×900), Sample 766A-44R-03; 47-52cm.

9a,b *Vaginulinopsis excentrica* (Cornuel), (×75, ×80), Sample 766A-45R-04; 115-120cm.

10 *Marginulina pyramidilis* (Koch), (×140), Sample 766A-30R-03; 44-47cm.

11a,b *Vaginulinopsis excentrica* (Cornuel), (×90, ×90), Sample 766A-45R-04; 115-120cm.

12 *Marginulina inaequalis* Reuss, (×60), Sample 766A-33R-02; 15-18cm.

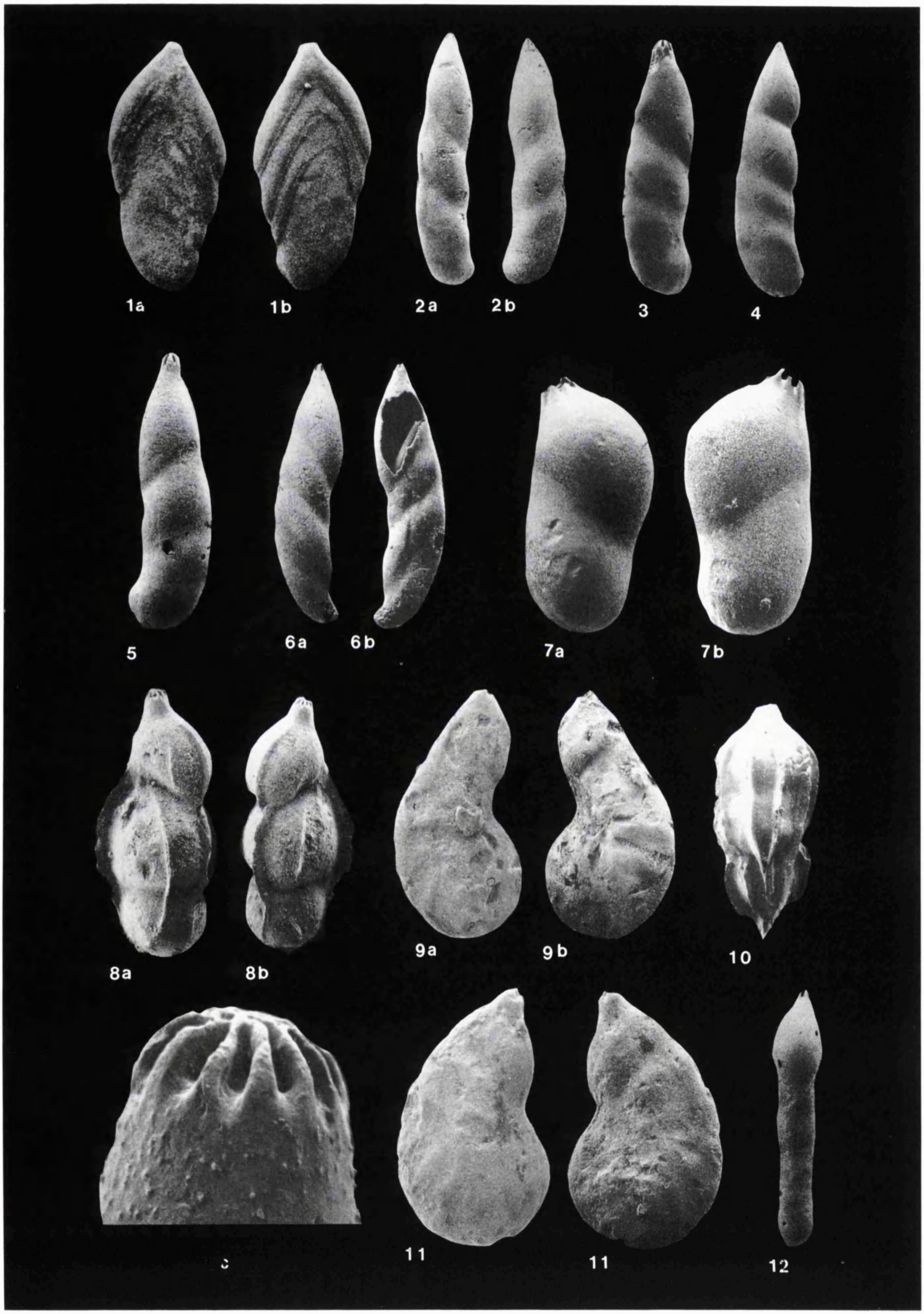
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PLATE 12

1a,b *Vaginulinopsis excentrica* (Cornuel), (×105, ×110), Sample 766A-44R-05; 102-106cm.

2a,b *Vaginulinopsis* sp., (×90, ×90), Sample 766A-45R-04; 115-120cm.

3 *Vaginulinopsis excentrica* (Cornuel), (×60), Sample 766A-32R-05; 5-8cm.

4a,b *Vaginulinopsis neopachynota* Bartenstein and Kaever, (×90, ×90), Sample 766A-32R-02; 104-108cm.

5 *Vaginulinopsis neopachynota* Bartenstein and Kaever, (×65), Sample 766A-28R-01; 21-25cm.

6 *Vaginulinopsis* sp., (× 80), Sample 766A-44R-03; 47-52cm.

7a,b *Vaginulinopsis humilis precursoria* Bartenstein and Brand, (×100, ×105), Sample 766A-32R-05; 5-8cm.

8 *Vaginulinopsis humilis precursoria* Bartenstein and Brand, (×120), Sample 766A-40R-01; 84-88cm.

9a,b *Vaginulinopsis reticulosa* Ten Dam, (×120, ×120), Sample 766A-47R-04; 114-119cm.

10 *Vaginulinopsis reticulosa* Ten Dam, (×75), Sample 766A-43R-04; 36-40cm.

11 *Vaginulinopsis reticulosa* Ten Dam, (×100), Sample 766A-36R-01; 70-74cm.

12 *Vaginulinopsis reticulosa* Ten Dam, (×100), Sample 766A-43R-05; 131-135cm.

13 *Vaginulinopsis* sp., (×150), Sample 766A-47R-03; 25-30cm.


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9a 9b


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PLATE 13

1a,b *Citharina rudocosta* Bartenstein and Brand, (×45, ×45), Sample 766A-48R-02; 95-98cm.

2 *Citharina* sp. 1, (×85), Sample 766A-44R-03; 47-52cm.

3a,b *Planularia complanata* (Reuss), (×80, ×80), Sample 766A-45R-04; 115-120cm.

4 *Planularia complanata* (Reuss), (×75), Sample 766A-40R-01; 84-88cm.

5a,b *Planularia complanata* (Reuss), (×90, ×95), Sample 766A-46R-03; 122-125cm.

6a,b *Planularia complanata* (Reuss), (×95, ×90), Sample 766A-47R-03; 25-30cm.

7 *Lenticulina guttata* (Ten Dam), (×75), Sample 766A-32R-05; 5-8cm.

8a-c *Lenticulina guttata* (Ten Dam), (×100, ×100, ×600), Sample 766A-32R-05; 5-8cm.

9a,b *Planularia crepidularis* Roemer, (×130, ×130), Sample 766A-32R-05; 5-8cm.

10a,b *Planularia crepidularis* Roemer, (×95, ×90), Sample 766A-43R-02; 46-50cm.

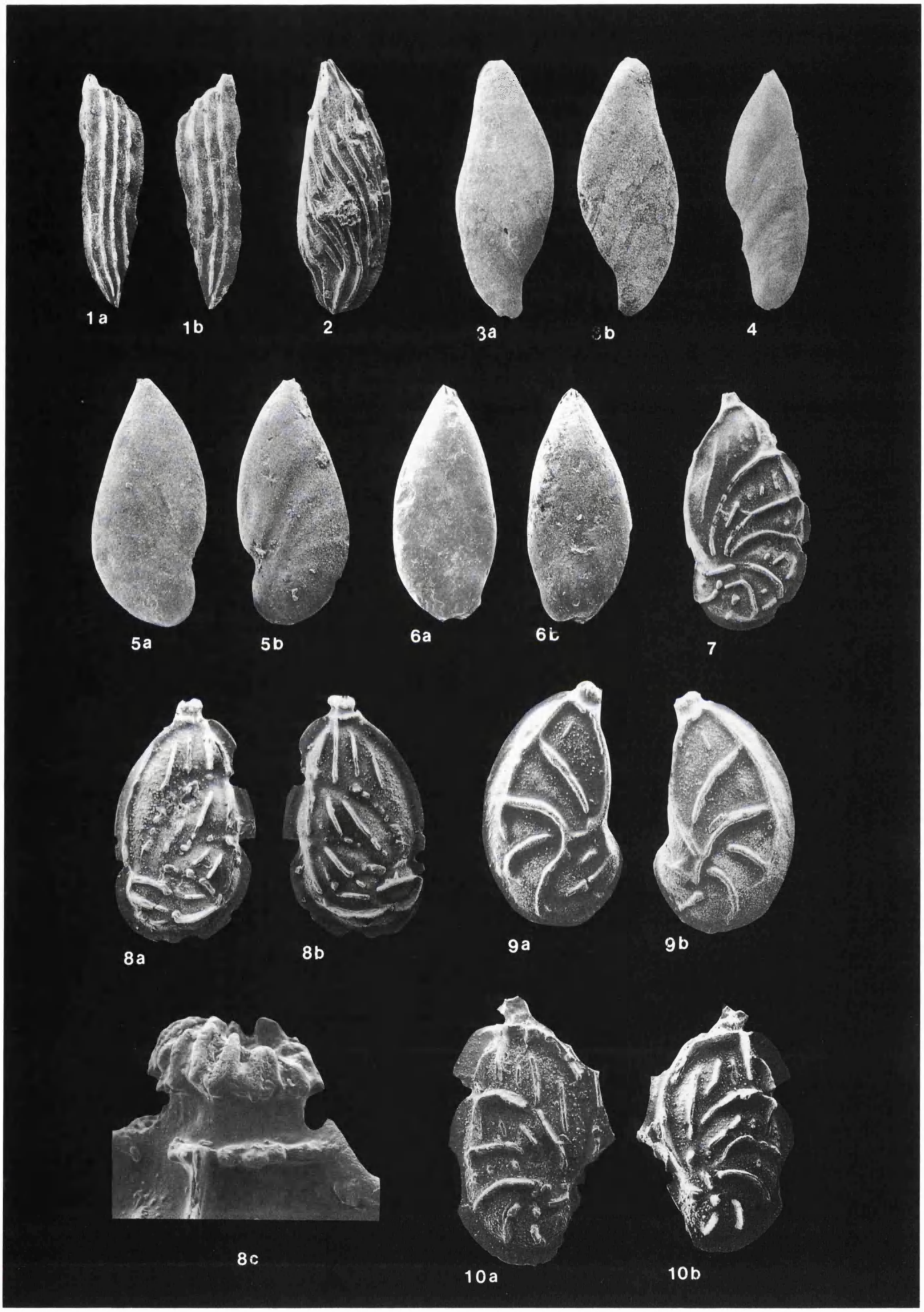
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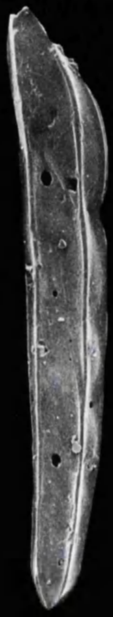
PLATE 14

1	*Brunsvigella thoerensis* (Bartenstein and Brand), (×90), holotype.
2a,b	*Brunsvigella thoerensis* (Bartenstein and Brand) (juvenile), (×120, ×120), Sample 766A-46R-03; 122-125cm.
3a,b	*Psilocitharella kochii* (Roemer), (×130, ×125), Sample 766A-46R-03; 122-125cm.
4a,b	*Brunsvigella thoerensis* (Bartenstein and Brand), (×45, ×45), Sample 766A-46R-03; 122-125cm.
5a,b	*Vaginulina petila* Eicher and Worstell, (×65, ×65), Sample 766A-46R-03; 122-125cm.
6	*Psilocitharella arguta* (Reuss), (×90), Sample 766A-43R-02; 46-50cm.
7a,b	*Patellina subcretacea* Cushman and Alexqander, (×100, ×95), Sample 766A-33R-02; 15-18cm.
8a,b	*Patellina subcretacea* Cushman and Alexander, (×115, ×110), Sample 766A-40R-02; 46-50cm.
9a,b	*Spirillina minima* Ehrenberg, (×120, ×120), Sample 766A-45R-02; 109-113cm.



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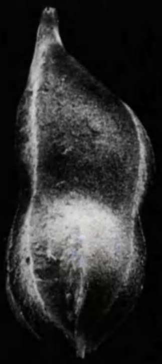

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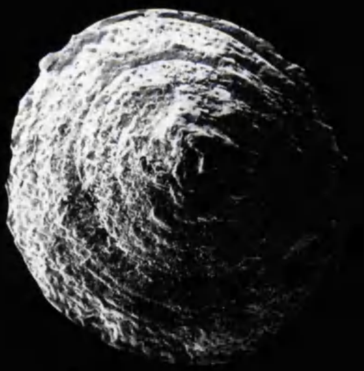

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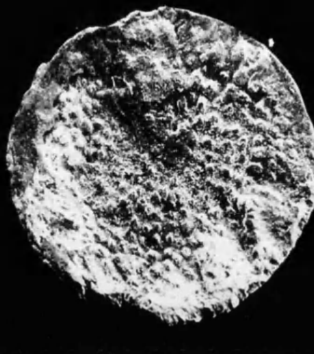

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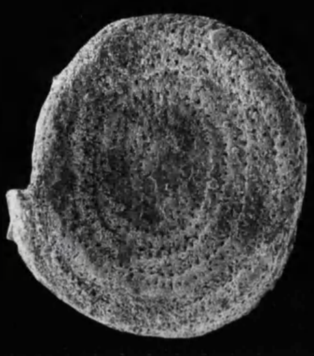

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PLATE 15

1a,b *Gavelinella sigmoicosta?* (Ten Dam), (×190, ×190), Sample 766A-29R-03; 54-55cm.

2a,b *Reinholdella hofkeri* (Bartenstein and Brand), (×150, ×145), Sample 766A-40R-01; 84-88cm.

3a,b *Gavelinella barremiana* Bettenstaedt, (×200, ×195), Sample 766A-28R-03; 116-120cm.

4a,b *Globulina lacrima* (Reuss), (×140, ×150), Sample 766A-46R-03; 122-125cm.

5a,b *Globulina lacrima* (Reuss), (×130, 135), Sample 766A-32R-05; 5-8cm.

6a,b *Globulina bucculenta* (Berthelin), (×100, ×100), Sample 766A-32R-05; 5-8cm.

7a,b *Globulina prisca* Reuss, (×120, ×120), Sample 766A-40R-01; 84-88cm.

8 *Globulina prisca* Reuss, (×70), Sample 766A-32R-05; 5-8cm.

9 *Globulina prisca* Reuss, (×95), Sample 766A-32R-05; 5-8cm.

10 *Pyrulina cylindroides* (Roemer), (×85), Sample 766A-47R-04; 114-119cm.


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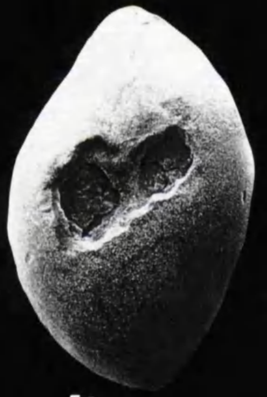
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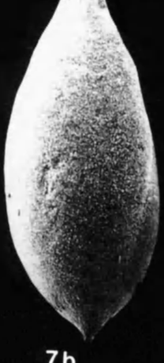
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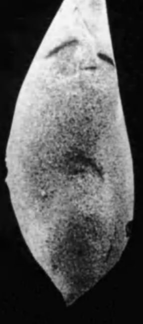
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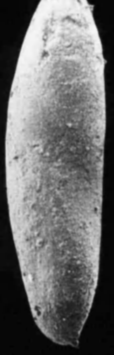
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B., Eds., Palaeoecology, Biostratigraphy, Palaeoceanography and Taxonomy of Agglutinated foraminifera. NATO ASI Series C 327, Kluwer Academic Publishers, pp. 245-265.

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PLATE 16

1a,b *Eoguttulina ichnusae* (Dieni and Massari), (×160), Sample 766A-46R-03; 122-125cm.

2 *Oolina* cf. *sulcata* (Walker and Jacob), (×145), Sample 766A-44R-05; 102-106cm.

3 *Oolina sulcata* (Walker and Jacob), (×155), Sample 766A-47R-01; 98-103cm.

4 *Oolina laevis* (Montagu), (×160), Sample 766A-34R-01; 70-74cm.

5 *Oolina caudata* d'Orbigny, (×100), Sample 766A-34R-01; 122-125cm.

6 *Oolina* aff. *oxystoma* (Reuss), (×170), Sample 766A-48R-04; 51-54cm.

7 *Ramulina* sp., (×110), Sample 766A-43R-02; 46-50cm.

8 *Ramulina* sp., (×65), Sample 766A-33R-02; 15-18cm.

9 *Ramulina aculatea* Wright, (×120), Sample 766A-44R-03; 47-52cm.

10 *Ramulina aculatea* Wright, (×120), Sample 766A-46R-04; 105-110cm.

11 *Ramulina aculatea* Wright, (×60), Sample 766A-39R-01; 47-51cm.

12 *Ramulina* sp., (×100), Sample 766A-46R-03; 122-125cm.

13 *Palaeopolymorphina* sp. 1, (×90), Sample 766A-37R-01; 29-33cm.

14 *Palaeopolymorphina* sp. 1, (×55), Sample 766A-47R-04; 114-119cm.

15a,b *Palaeopolymorphina* sp. 1, (×100, ×105), Sample 766A-46R-03; 122-125cm.


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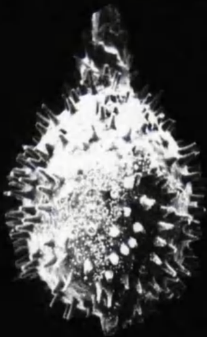
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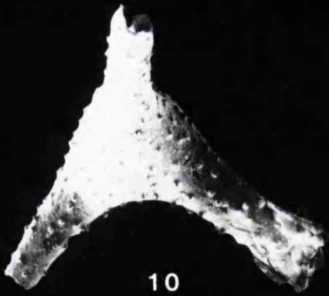
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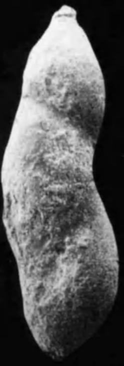
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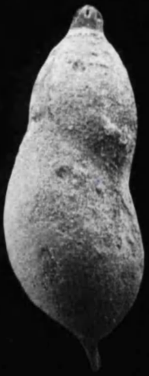
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Lower Cretaceous benthic foraminifera from DSDP Site 263: micropalaeontological constraints for the early evolution of the Indian Ocean

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Abstract

Analysis of 66 samples from DSDP Site 263 (Cores 263-4R-4 to 263-29R-4) reveals a unique faunal composition with a predominance of agglutinated taxa, many of them previously unrecorded from any other DSDP and ODP Indian Ocean sites. A total of 66 agglutinated and 31 calcareous taxa are documented and five new species are described: *Hippocrepina gracilis* n.sp., "*Textulariopsis*" *elegans* n.sp., *Aaptotoichus challengeri* n.sp., "*Gaudryinopsis*" *pseudobettenstaedti* n.sp. and "*Gaudryina*" *cuvierensis* n.sp. Three assemblages are recognized based on changes in the composition of dominant taxa and occurrences of stratigraphically important species: (1) a high-diversity Valanginian to Barremian *Bulbobaculites–Recurvoides* Assemblage (Cores 263-29R to -18R), comprised of numerous elongate agglutinated forms, rare nodosariids, and variable numbers of tubes and ammodiscids; (2) a moderately diverse Aptian to Albian *Rhizammina–Ammodiscus–Glomospira* Assemblage (Cores 263-18R to -7R) with highly fluctuating numbers of the nominate taxa and *Haplophragmoides*, *Trochammina*, *Verneuilinoides* spp., and *Verneuilina howchini*; (3) a very low diversity Albian or younger Assemblage (Cores 263-6R to -4R) containing sparse agglutinated foraminifera, rare nodosariids and rotaliids. We interpret the assemblages as shelf to lower slope and consider them to reflect a deepening palaeobathymetry as the Cuvier margin subsided after the initial breakup of East Gondwana during the Valanginian. Our interpretation is in sharp contrast with initial palaeodepth estimates of less than 100 m, as well as with original chronostratigraphic interpretations based on foraminifera and nannofossils which correlated the base of the recovered interval with the Aptian. The absence of many cosmopolitan forms, despite high diversity, suggests strong faunal differentiation in the Austral realm or endemisn within the Cuvier Basin during the Early Cretaceous.

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1. Introduction

The Deep Sea Drilling Program (DSDP) and the Ocean Drilling Program (ODP) have recovered extensive Lower Cretaceous sedimentary sequences at 12 sites in the Indian Ocean. The Indian Ocean cores contain some of the most diverse benthic foraminiferal assemblages ever recorded from the Lower Cretaceous of the DSDP and ODP sites (e.g. Kaminski et al., 1992; Holbourn and Kaminski, in press). The systematics of Lower Cretaceous foraminifera from high southern latitudes in the Indian Ocean are, however, still not well defined. Indeed, most previous studies of Indian Ocean DSDP material were completed during the first phase of drilling in the early 1970s and were either preliminary reports or isolated studies of individual holes. Even some of the subsequent reports of Lower Cretaceous benthic foraminifera from the Indian Ocean do not provide a consistent taxonomic data base. There is an urgent need for taxonomic reappraisal to ensure the

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validity of stratigraphic correlations and to enable us to use the foraminiferal records for constraining the palaeoenvironment, subsidence history, and palaeoceanography of the Early Cretaceous Tethyan seaways of eastern Gondwana.

The main aims of this study are to fully document the Lower Cretaceous benthic foraminifera from DSDP Site 263 and to provide a data base for understanding the chronostratigraphy and palaeoenvironment of the Cuvier Abyssal Plain. This study is a step towards a comprehensive account of the Lower Cretaceous deep-water benthic foraminiferal assemblages from this region.

2. Previous work

The original description of Lower Cretaceous benthic foraminifera from DSDP Site 263 was carried out by Scheibnerová (1974), who documented selected taxa from several Leg 27 sites in the DSDP Leg 27 *Report* (Veevers et al., 1974). Scheibnerová listed a total of 33 agglutinated taxa from DSDP Site 263 (22 were illustrated with SEM photographs and/or drawings) and 28 calcareous taxa. Scheibnerová (1974) assigned an "Aptian or older" age to Cores 263-11R to -29R and a late Albian age to Cores 263-5R to -10R. However, the ages attributed to the same cores on the basis of other microfossils differed markedly. Pollen and spores suggested a late Neocomian to late Aptian age for Cores 263-11R to -28R and a Neocomian age for Core 263-29R (Veevers et al., 1974). Cores 263-22R to -27R were determined as upper Albian, Core 263-28R as middle Albian, and Core 263-29R as "undifferentiated Lower Cretaceous" on the basis of original nannofossil studies (Veevers et al., 1974). By contrast, a recent re-examination of nannofossils from Cores 263-4R to -29R failed to confirm any Albian index species and suggested a Valanginian to early Hauterivian age for Cores 263-22R to-29R and a Hauterivian–Albian age for Cores 263-4R to -21R (P.R. Bown, pers. commun., 1994). This was based on the occurrence of *Eiffelithus striatum*, the marker for the *T. striatum* zone of Mutterlose, 1992 (Valanginian–early Hauterivian). This species also occurs in a similar stratigraphic position at nearby ODP Sites 765 and 766.

A revision and extension of Scheibnerová's foraminiferal studies have become essential, as considerable changes in the taxonomy and palaeoenvironmental interpretation of agglutinated foraminifera have taken place since her work was completed. Scheibnerová (1974, 1977) interpreted the palaeoenvironment of the foraminiferal assemblages at DSDP Site 263 as shallow to very shallow, with estimated water depths not exceeding 100 m. Scheibnerová considered the assemblages to closely resemble those of the Canning and Great Artesian Basins and attributed the scarcity of calcareous tests to diagenetic solution in a shallow, stagnant, dysaerobic environment.

3. Location and geological setting

3.1. Location

DSDP Site 263 is situated at the eastern edge of the Cuvier Abyssal Plain in the Indian Ocean, at 23°19.43'S and 110°58.81'E (Fig. 1). The Cuvier Abyssal Plain is a small oceanic basin (about 200 km by 400 km), bounded by the Wallaby Plateau to the south, the Exmouth Plateau to the north and the Sonne and Sonja Ridges to the west. Recent seismic reflection data have revealed that the Cuvier and Exmouth Plateau margins had very different rifting and magmatic developments during the Early Cretaceous despite contemporaneous break-up. Rapid rifting associated with emplacement of exceptionally large volumes of magma occurred in the Cuvier Basin, whereas the Exmouth Plateau underwent slow extensional deformation through faulting with moderate magmatism (Fullerton et al., 1989; Hopper et al., 1992; Colwell et al., 1994).

DSDP Site 263 is an abyssal site drilled on oceanic crust close to the base of the western Australian continental rise, in a water depth of 5048 m. Drilling at DSDP Site 263 was terminated before reaching basement, leaving the basal 100–200 m of the sedimentary sequence unrecovered (Veevers et al., 1974). The magnetic anomaly pattern in the Cuvier Abyssal Plain and in the adjacent Gascoyne Abyssal Plain to the north has been identified as encompassing anomalies M10–M5 (Larson, 1977; Fullerton et al., 1989). Continental breakup in this sector of eastern Gondwana, therefore, occurred in Chron M10 (Fullerton et al., 1989) or perhaps in Chron M11 (Veevers and Li, 1991), during the Valanginian. As DSDP Site 263 is located just landwards of anomaly M10 (Fig. 2), it is reasonable to

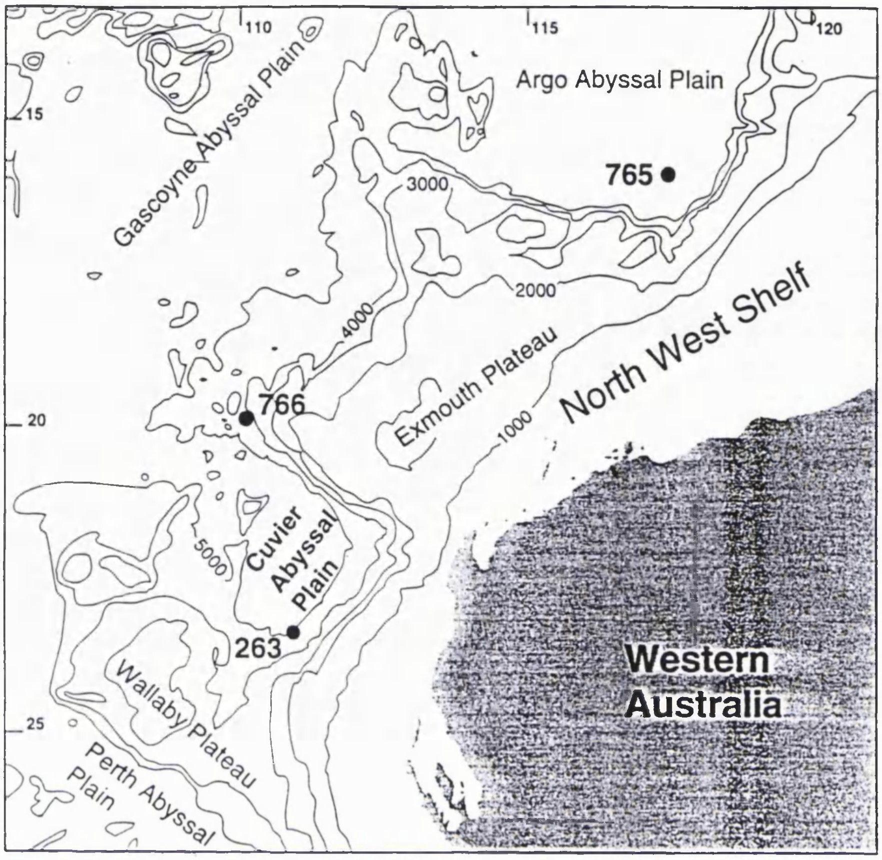

Fig. 1. Location map showing DSDP Site 263, ODP Sites 765 and 766 and bathymetric contours (m).

assume that the base of the sediment column is the age equivalent of the basal sediments recovered at ODP Site 766 on the northern flank of the Cuvier Abyssal Plain, which has been dated as late Valanginian (Kaminski et al., 1992). This interpretation is at odds with the Leg 27 shipboard work as well as the work of Veevers and Johnstone (1974) who correlated the Lower Cretaceous oceanic sequences from DSDP Site 263 with the Aptian–Albian Winning Group sequences of the Carnarvon Basin (Fig. 3).

3.2. Lithology

Approximately 615 m of Lower Cretaceous sediments were recovered at this site. They were subdivided by the Shipboard Scientific Party into three main lithological units.

Unit 2: The base of unit 2 (Cores 263-5R to -6R) consists of dark greenish nannofossil-bearing clay (proportion of nannos is small in the lower part of the unit: ca. 5–10%).

Unit 3: This unit (Cores 263-7R to -18R) consists of a greenish-black claystone with a thickness of about 275 m. Montmorillonite is the dominant clay mineral with some minor quartz, feldspar, pyrite, kaolinite and muscovite, more abundant in the coarser fractions. The sediment has poorly defined bedding of contorted laminae and lenses, up to 1 cm thick. A gradational boundary is observed (Cores 263-16R to -19R) between the clays of unit 3 and the silty layers of unit 4.

Unit 4: This unit (Cores 263-19R to -29R) is an olive black silty claystone, approximately 276 m thick. It consists of about 70–80% kaolinitic clay and 10–30% silt-size quartz with minor silt-size feldspar,

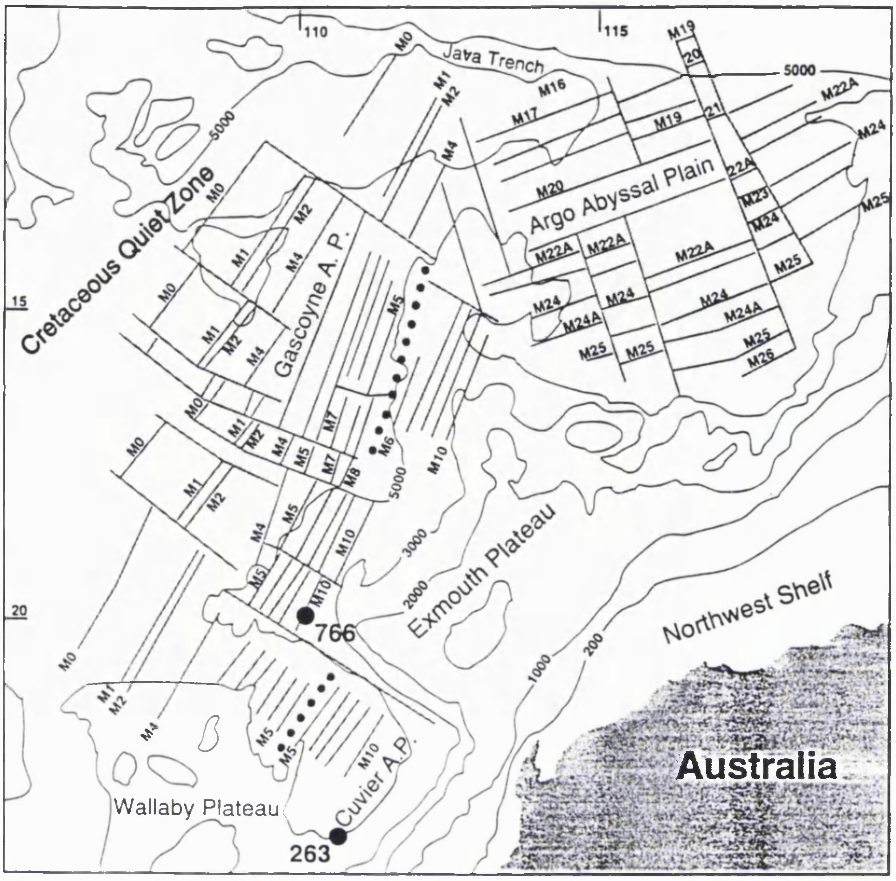

Fig. 2. Magnetic anomalies along the northwest Australian continental margin, showing bathymetric contours (m), fossil spreading ridges (dotted) and location of DSDP Site 263 and ODP Site 766 (after Fullerton et al., 1989).

pyrite, muscovite, heavy minerals and zeolite. Calcite and dolomite nodules are frequent throughout the unit. Cross-bedding is evident in the coarser sandstones at the bottom of the unit while laminae are found in the claystone, higher up in the sequence. This change in lithology probably reflects a decrease in depositional energy from the base to the top of the unit. Alternance of black layers with lighter calcitic bioturbated intervals suggests that there were also significant changes in oxygenation and/or TOC. Bioturbation is evident in the lighter, calcitic mudstones.

4. Methods

Sixty-six samples from Cores 263-4R-4 to 263-29R-4 were processed by repeated drying and washing in 1% Calgon solution. The washed residues were randomly divided into fractions with the help of a sample splitter and picked for microfossils. When fossil abundance allowed, at least 300 foraminifera were picked from each sample. The specimens were mounted onto slides and sorted for identification. Scanning Electron micrographs were made on a Zeiss-DSM-940 SEM at the Micropalaeontology Unit of University College London.

5. Results and discussion

5.1. Taxonomy

The benthic foraminiferal data are given in Tables 1 and 2. A total of 66 agglutinated taxa and 31 calcareous

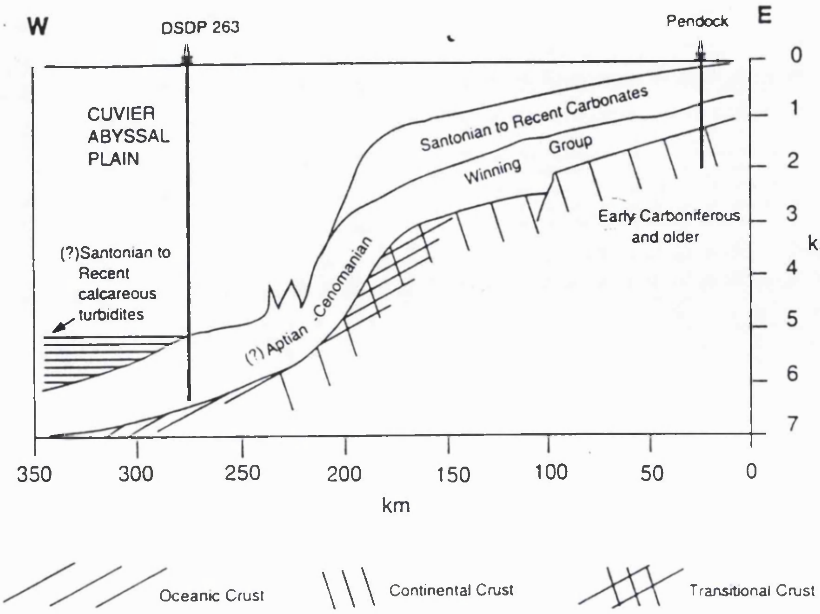

Fig. 3. Tentative correlation of Lower Cretaceous sedimentary sequences at DSDP Site 263 with Aptian–Albian Winning Group sequences (after Veevers and Johnstone, 1974).

taxa were recorded (the samples examined contained no planktic foraminifera, except in Cores 263-5R to -4R). The assemblages in lithological units 3 and 4 exhibit high diversity and consist predominantly of agglutinated species with organic cement that is now preserved as silica. Most common genera are *Rhizammina*, *Rhabdammina*, *Ammodiscus*, *Glomospira*, *Reophax*, *Bulbobaculites*, *Recurvoides*, *Paratrochamminoides*, *Haplophragmoides*, *Trochammina* and *Verneuilinoides*. Some nodosariid tests were found in 12 samples from lithological units 3 and 4 (Table 2); these were often corroded near the base of the sequence. The sparse assemblages in lithological unit 2 contain rare calcareous taxa (mainly rotaliids) as well as a few agglutinated species with calcareous cement.

Five new species are described: *Hippocrepina gracilis* n.sp., "*Textulariopsis*" *elegans* n.sp., *Aaptotoichus challengeri* n.sp., "*Gaudryinopsis*" *pseudobettenstaedti* n.sp. and "*Gaudryina*" *cuvierensis* n.sp. The generic affiliation to the genera *Textularia*, *Textulariopsis*, *Gaudryinopsis* and *Gaudryina* remains tentative because differences in wall composition and mode of coiling have suggested that the present classification is inadequate and needs to be revised.

The assemblages from DSDP Site 263 contain a number of cosmopolitan species that have been widely recorded in areas of the USA, Canada, Siberia, and Europe where environmental conditions favoured agglutinated assemblages during the Early Cretaceous. However, an even greater proportion of taxa remain in open nomenclature or are here described as new. Further taxonomic studies of taxa described under open nomenclature and local names may extend the cosmopolitan affiliations of these assemblages.

5.2. Biostratigraphy

The stratigraphic ranges of selected benthic foraminifera are plotted in Fig. 4. First and last occurrences are shown on Fig. 5. The foraminiferal assemblages are divided into three assemblages (Fig. 4), based on changes in the composition of dominant taxa and occurrences of stratigraphically important species:

(1) A high-diversity Valanginian to Barremian *Bulbobaculites–Recurvoides* assemblage (Cores 263-29R-18R) is characterised by *Ammobaculites crespinae*, *Bulbobaculites humei*, *Lagenammina* aff. *alexandrei*, *Aaptotoichus challengeri* n.sp., "*Textulariopsis*" *elegans*. n.sp., "*Gaudryina*" *cuvierensis* n.sp.,

Table 1
Agglutinated foraminifera at DSDP Site 263

Samples (core, section, interval)	*Ammobaculites crespinae*	*Bulbobaculites humei*	*Haplophragmoides* spp.	*Hyperammina gaultina*	*Lagenammina* spp.	*Psammosphaera* sp. 1	*Recurvoides obskiensis*	*Recurvoides* spp.	*Trochammina abrupta*	*Trochammina* spp.	*Pseudoreophax* sp. 1	*Cribrostomoides nonioninoides*	"*Textulariopsis*" *elegans* n.sp.	*Verneuilinoides neocomiensis*	*Verneuilinulla* sp. 1	*Ammodiscus infimus*	*Spiroplectammina* sp. 1	*Bathysiphon brosgei*	*Ammodiscus cretaceus*	*Evolutinella perturbans*	*Haplophagmoides concavus*	*Ammobaculites* sp. 1	*Reophax* cf. *geniculatus*	*Trochammina subinflata*	*Verneuilinoides* spp.	*Ammodiscus tenuissimus*	"*Gaudryina*" *cuvierensis* n.sp.	*Rhabdammina* spp.	*Rhizammina* spp.	*Hippocrepina depressa*	*Trochammina depressa*	"*Gaudryinopsis*" *pseudobettenstaedti* n.sp.	*Aschemocella* sp.	*Verneuilinoides* aff. *crespinae*	*Lituotuba* sp.	*Caudammina crassa*	*Saccammina lagenoides*	*Saccammina* spp.
4-4; 63-67																			3									7	6									
4-5; 64-68																			3									6	5									
4-6; 46-50			1																10									10	2									
5-1; 131-135																			1							1		3										
6-2; 24-28			1																1							2												
6-4; 67-71			3																3									1	3									
6-6; 135-139			3							2									6									2	1									
7-2; 14-18			15							3								3	1					8	3				11					1		3		
7-3; 91-95			3	1															1					12	1				6					2				
8-1; 83-87			3		1																			3	1			4	28									
9-1; 96-100			8	1														1	4					7	6			1	15	1						1		
9-3; 45-49			6																4					5	4			3	20	2								1
9-4; 105-109			24	5						15									7						1	1		9	57					12				
10-1; 131-135			8		4													4	5					7	4				31	4				7		6		3
10-2; 84-89			10	3						3						1		1	5					10	3	2		20	70					4		1		
10-3; 67-71			15	1	1					1						2		3	5						3	1		19	71					3		1		
11-2; 92-96			14															2	4		9				4	4		10	30	1				9				2
11-3; 105-109			11	1				8		1	1			7		3								1		7		12	55	5				1				
11-4; 67-71			11	3				3		1						3									3	1		10	50					2				
12-1; 124-128			8					2			1					1			7						2	9		7	21									
12-3; 79-83			6	3				9		1	2							5							1	6		18	49					3				
12-4; 70-74			8		1			4			2					2			1							5		9	23									
13-1; 99-103			25	1	4			11			2					2										2		15	68					27				
13-3; 34-38			13	8												1		3	1						1	6		4	31					13				
13-6; 111-115			6	2							1							3							3	1		7	24					2				
14-1; 41-45			3	1				3								1		5							2	2		13	44	2								
14-3; 72-76			3																									2	18	1								
14-5; 127-131			2		1																							4	51							3		
15-1; 106-110			26	1				10		1						2		1								13			41					2				
15-2; 113-117			10	2				19								2			2							8		11	46							12		
15-3; 71-75			6					18																	9	14										1		
16-1; 93-97			16	2	1	4		10						9				1								15		10	64	6					2	3		
17-1; 118-122			19			1							12											2	3	4			32					6		1		
17-3; 9-13			11								1		3													2			7							1		
17-5; 76-80			8					3			1		12	5		6			10							7			9					2				
18-2; 85-89			13		6	2					8		12			18		12	1							2		14	74	2				5		6		
18-4; 92-96			2		1			1					2	4					1		1			1				2	16					1				1
18-5; 101-105			2		1			5					25	2					2								2	1	4					1				
19-2; 86-90			1	1				42			9		2					6	1					4			1	3	8	8				6				
19-4; 102-106					2	1		65					2	2		1		10	2									1	8	6						1		
19-6; 61-65			3					58								1		2								2			7					13				
20-2; 15-19					9			24										8					14				2	7	81	1				4		2		
20-4; 127-131			1		10			40		1				3		1		5	7				4			2	1		52	4				11		3	2	2
20-6; 132-136				1	1			11					2					1							1			3	9					3				
21-2; 36-40								20						4							2													5				
21-3; 90-94			3			1		71						3		1		3	5		1				6	15		14	26					13		1		
21-4; 120-124			2	6				43		1				3					1					1		34		8	5	2				66		2		1
22-1; 66-70			1	2				18					15	26		5		3									7	11	23	8				20				
22-2; 91-95		21	7	7	5	1		43		1	4	4	39					4									13	18	62	4				11		3		2
22-3; 117-121			5	2				37					6	3				9	1							8	30	26	15	3				4				1
23-2; 139-143			9	1		1		39				6	2							1					1			15				16		4				
23-4; 74-78	63		9	1	6	3		66				6	4			1		1		3			2					25	6			45	3	2		1		1
23-5; 130-134	15		13		9			64		2		6	2			3		4	1	12			1					16	19			18						
24-2; 30-34	23	2	6	1	29	4		54		1		6	25		15	4				1			14	2				6	16		1	5		12				8
24-4; 62-68				1	1			54		2					6	1						3			2				6			6						
24-6; 102-106			1		3			20										2											1					1				2
25-2; 36-40	25	2	4	1	15	1		28		23	1		2		4			1				3	19	10	1	1	1		21	2		12	2	5		2		3
25-4; 100-103	10	5			3				1	8	1				4			4			2		6	11					27	3	5	7		3	1	1	1	2
26-2; 60-64	6	2	4		14		8	39		4		4	1		2				12	3		8	7	4	2				1	3		17	1					
26-4; 31-35	24	4	4		11	3		3				4	2			1			1	3			2	3		1	1	4										
26-5; 126-130	9	39	10		12	3		5		11		16				2						17	2					1	4		3							
28-1; 36-40	2	2		4	9	2		5		1	1	2	2			13	1	2				2		6			2	2	34	1								
28-3; 103-107			1	2	2	1		4					2		1		1	4	1						1	1	1											
29-2; 76-80	21	15	4		11			13		10		4			3			1	1	2	1	2	6	5														
29-3; 71-75	19		5		3	4		5		6	1	1	6	1	1	2	4																					
29-4; 140-144	14	2	1	1	10	1	2	3	2																													

Samples (core, section, interval)	*Glomospira gordialis*	*Aaptotoichus clavellatus*	*Reophax* sp. 1	*Aaptotoichus challengeri* n.sp.	*Ammodiscus* spp.	*Glomospira gaultina*	*Glomospira charoides*	*Subreophax* sp. 1	*Paratrochamminoides* spp.	*Ammosphaeroidina* sp.	*?Arenobulimina* sp.	*Reophax* spp.	*Thalmannammina* spp.	"*Gaudryina*" spp.	*Verneuilinulla* sp. 2	*Kalamopsis grzybowskii*	*Bimonilina* cf. *variana*	"*Textularia*" spp.	*Bulbobaculites* spp.	*Hippocrepina gracilis* n. sp.	*Caudammina* spp.	*Bulbobaculites* cf. *inconstans*	*Spiroplectammina* spp.	*Glomospira irregularis*	*Reophax* sp. 2	*Nothia robusta*	*Trochammina ribstonensis*	*Haplophragmoides hagni*	*Verneuilina howchini*	*Marssonella* sp.	*Ammolagena clavata*	*Remesella* sp.	*Pseudogaudryinella* sp. 1	Diversity (s)	Number of specimens
4-4; 63-67							3																										4	5	23
4-5; 64-68						1	4									1																	1	7	21
4-6; 46-50	5																																	5	28
5-1; 131-135						2	10														1						1					1		8	20
6-2; 24-28							1																				2			2				6	9
6-4; 67-71	3					1																												6	14
6-6; 135-139	7						19																				7		4	9		6		11	66
7-2; 14-18	4					2	5																				31		12	1		1		16	104
7-3; 91-95						1																	1				14	6	18					12	66
8-1; 83-87					4	1	2										1			3			1				7		11			1		15	71
9-1; 96-100	5					2	10					1					2											5	21					16	90
9-3; 45-49						2	2					5						13										3	14			1		15	85
9-4; 105-109	3				1		29					2						9		1								18	8					17	202
10-1; 131-135	6				1	2	10					2				1		10										24	23					20	162
10-2; 84-89					1	2	59					4				1		14	6	4				1			1	13	53					25	292
10-3; 67-71	3				1	4	58			1				1				2	19	4						2		9	19	3	2			27	254
11-2; 92-96	5				1	2	25					2							30	4						1		34	20					21	213
11-3; 105-109	7					2	33									1		10		7						3			15					21	191
11-4; 67-71	12				2	4	44											18	2	3						2		2	16					20	192
12-1; 124-128	5						11											8		3						2			9					15	96
12-3; 79-83	17					2	2											1								1	1	1	9					19	137
12-4; 70-74	2						10											6											5					13	78
13-1; 99-103	3					2	12					2								5									40					16	221
13-3; 34-38						6	51												6							3			33					15	180
13-6; 111-115						1	8					1						6								3		9	13					16	90
14-1; 41-45							7					8						1	1	5								1	12	1				18	112
14-3; 72-76	1				2		4					1								5						1			6					11	44
14-5; 127-131						1	3					1								3						3			3					11	75
15-1; 106-110							14													4						3	19		3					14	140
15-2; 113-117						3	37					6						5									2		24	1				16	190
15-3; 71-75							28					1		2			10	7	2	3		1					3	1	44					16	150
16-1; 93-97				4		2	34					18						2		1								5	39	1				22	249
17-1; 118-122							4	1				3						10	2			1						5						16	106
17-3; 9-13							1					1						12										4						10	43
17-5; 76-80					15		6					11				3		2		8		1	2					12						19	124
18-2; 85-89							3					7		5				6		3		4						4						21	207
18-4; 92-96																		2										2						13	36
18-5; 101-105				1								1							8															13	55
19-2; 86-90							4		16			7						3	3								2							19	127
19-4; 102-106				1			4		33			6					2	2		3		20												20	172
19-6; 61-65							2		7			2							4			9				1								13	111
20-2; 15-19				3		1			11			5				1																		15	173
20-4; 127-131						7	4		19			12																						21	191
20-6; 132-136				2					2									2							6									13	44
21-2; 36-40							6		5			3						3				1												9	49
21-3; 90-94					6	7	35		27			6		2				2							18									22	266
21-4; 120-124				11		6	51		9			11							23			126		1	35									23	448
22-1; 66-70				12		5	8					10							4		7		3											19	188
22-2; 91-95	3			6		3	15					5				5	1		18	7	2	17												29	331
22-3; 117-121				21		14	79		14	1		7	6	1		1	2	6	6															26	308
23-2; 139-143															1																			12	96
23-4; 74-78			11	1					1					1																				23	262
23-5; 130-134									4			4	1																					18	194
24-2; 30-34				1				2	8	1	2																							26	248
24-4; 62-68									6																									11	88
24-6; 102-106				4			1	2	2																									11	39
25-2; 36-40				2	1	1	2	1																										30	196
25-4; 100-103	6	6	1																															23	118
26-2; 60-64																																		20	142
26-4; 31-35																																		16	71
26-5; 126-130																																		14	134
28-1; 36-40																																		19	93
28-3; 103-107																																		13	22
29-2; 76-80																																		15	99
29-3; 71-75																																		13	58
29-4; 140-144																																		9	36

Table 2
Calcareous benthic foraminifera at DSDP Site 263

Samples (core, section, interval)	*Lenticulina* spp.	*Laevidentalina* spp.	*Globulina prisca*	*Vaginulinopsis excentrica*	*Pyramidulina sceptrum*	Polymorphinids	*Oolina* cf. *caudata*	*Lenticulina subangulata*	*Saracenaria forticosta*	*Saracenaria* spp.	*Bullopora* sp.	*Frondicularia hastata*	*Saracenaria erlita*	*Astacolus calliopsis*	*Lenticulina muensteri*	*Lenticulina heiermanni*	*Dentalina communis*	*Citharina harpa*	*Vaginulina recta*	*Marginulina bullata*	*Planularia complanata*	*Pyrulina* sp.	*Ramulina* sp.	*Pseudonodosaria* sp.	*Pleurostomella* sp.	*Gyroidina infracretacea*	*Globorotalites* sp.	*Scheibnerova* sp.	*Dentalina debilis*	*Lingulina* sp.	*Frondicularia* sp.	*Gavelinella* sp.	*Oolina* sp.	Diversity (s)	Number of specimens
4-4; 63-67																									1				1	1	1	1	1	6	6
4-6; 46-50																										2		1						2	3
5-1; 131-135	2													1												1	1							4	5
6-4; 67-71																									1									1	1
18-5; 101-105	20	22	7	4	2	17		1	5	3				12	1	4	1	1	2	1	1	2	3	1										20	110
19-6; 61-65	1					2																												2	3
21-3; 90-94	1			1											1																			3	3
22-1; 66-70		1																																1	1
23-4; 74-78		1	1										1	1																				4	4
24-4; 62-68	1																																	1	1
25-2; 36-40	1																																	1	1
26-2; 60-64				2		7			1			2																						4	12
26-4; 31-35				1		1				1	2																							4	5
26-5; 126-130		2	1						1																									3	4
29-2; 76-80	2	1		1	1	16	1	1																										7	23
29-3; 71-75	1	1	1																															3	3

Paratrochamminoides, *Recurvoides*, *Reophax* and *Verneuilinoides* spp. with rare nodosariids and variable numbers of *Rhabdammina*, *Rhizammina*, *Ammodiscus* and *Glomospira* spp. This assemblage can be subdivided into two sub-assemblages (1A and 1B), based on the disappearance of *Cribrostomoides nonioninoides*, *Bulbobaculites humei*, "*Gaudryinopsis*" *pseudobettenstaedti* n.sp. and *Verneuilinulla* sp. 1 above Core 263-22R and on the occurrence of *Bulbobaculites* cf. *inconstans* and *Bimonilina* cf. *variana* in Core 263-22R.

The calcareous species, found intermittently between Cores 263-29R-3 and 263-18R-5, indicate a Valanginian–Barremian age (*Oolina* cf. *caudata*, *Lenticulina subangulata*, *Citharina harpa*, *Frondicularia hastata*, *Lenticulina heiermanni*, abundant polymorphinids).

(2) A moderately diverse Aptian to Albian *Rhizammina–Ammodiscus–Glomospira* assemblage (Cores 263-18R-7R) is characterized by highly fluctuating numbers of the nominate taxa and by *Rhabdammina*, *Haplophragmoides*, *Verneuilinoides* spp., *Trochammina ribstonensis* and *Verneuilina howchini*.

There are few stratigraphically significant species among the agglutinated taxa in lithological units 3 and 4. The main diagnostic species are: *Verneuilina howchini* in Cores 263-16R-1 to 263-6R-6, which has a reported range from the Aptian to the Albian in Australia and the Indian Ocean (Haig, 1980), *Cribrostomoides nonioninoides* in Cores 263-29R-3 to 263-22R-2, which was recorded in the Hauterivian–Barremian of the Carnarvon Basin (McLoughlin et al., in press) and is cosmopolitan in the Barremian–Aptian (Haig, 1980) and *Aaptotoichus challengeri* n.sp. in Cores 263-25R-2 to 263-16R-1, which is also found in the Berriasian–Valanginian and Valanginian–Hauterivian at ODP Sites 765 and 766, respectively (Kaminski et al., 1992; Holbourn and Kaminski, in press).

(3) A very low diversity assemblage (Cores 263-6R-4R) contains rare specimens of *Rhizammina*, *Rhabdammina*, *Glomospira* and *Ammodiscus* spp. with scarce *Gyroidina infracretacea*, *Lingulina* sp., *Pleurostomella* sp. and *Gavelinella* spp., indicative of an Albian or younger age.

Although the agglutinated foraminiferal assemblages from DSDP Site 263 are diverse, many of the index taxa that are used in the foraminiferal assemblages of the Boreal Lower Cretaceous are absent. The stratigraphically important *Falsogaudryinella* and *Praedorothia* lineages are not present, even though the index species *P. praehauteriviana* has been observed at other Indian Ocean sites (Riegraf and Luterbacher, 1989a; Kaminski et al., 1992). Of the seven Lower Cretaceous Deep Water Agglutinated Foraminifera

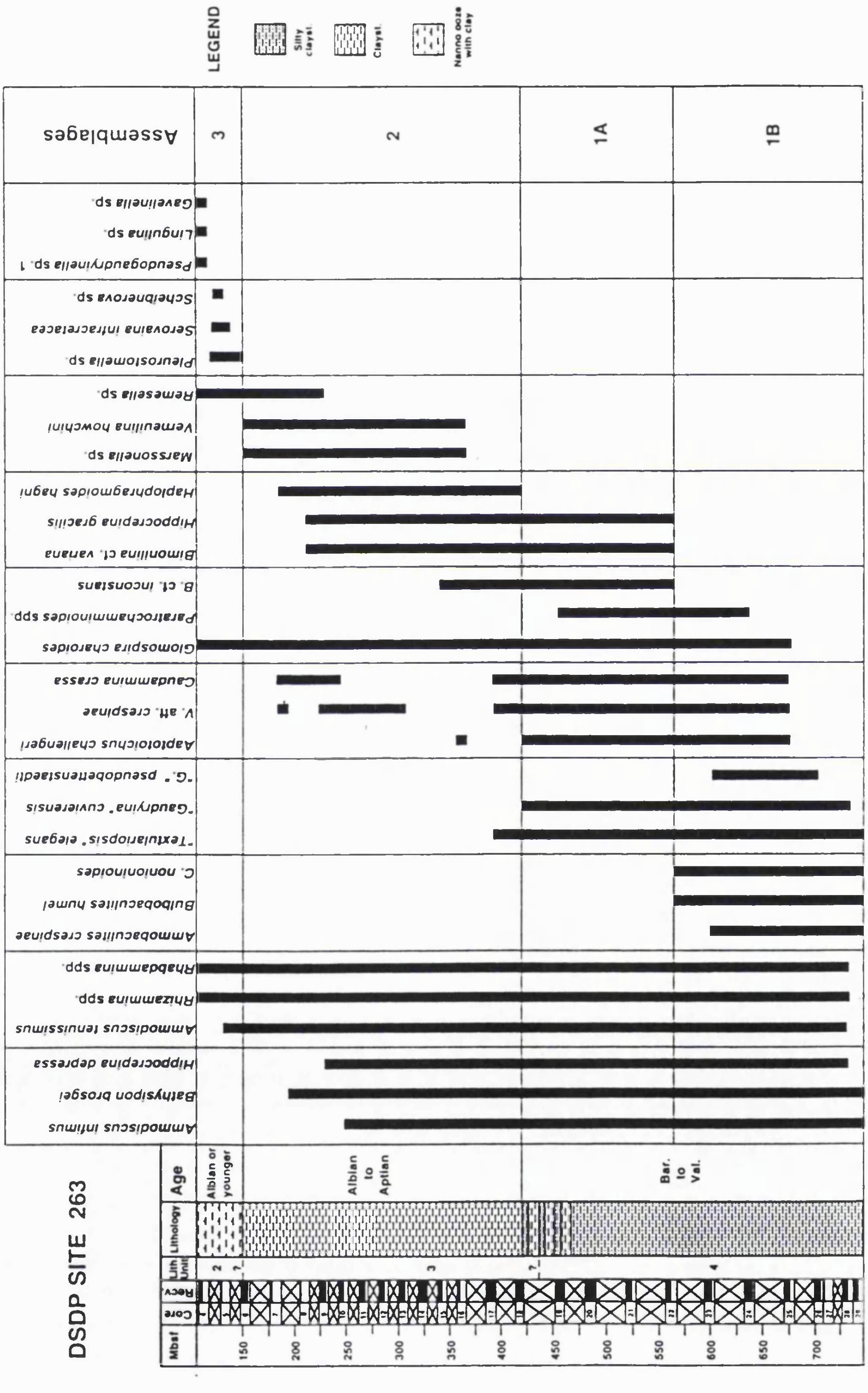

Fig. 4. Stratigraphic ranges of selected benthic foraminifera at DSDP Site 263 (percentage core recovery shaded black, lithological units with gradational boundaries).

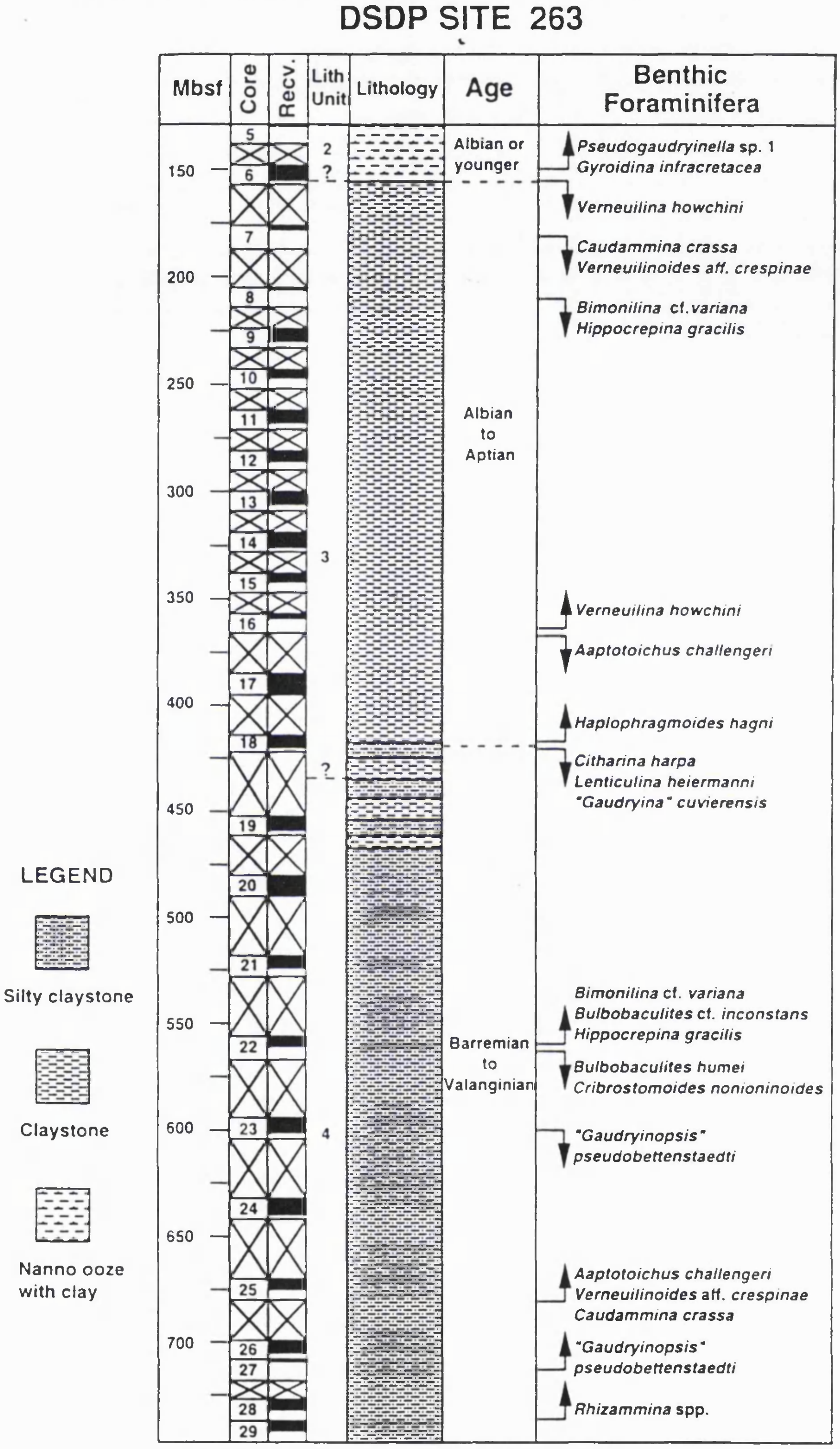

Fig. 5. First and Last Occurrences of benthic foraminifera at DSDP Site 263 (percentage core recovery shaded black).

(DWAF) zonal markers in the scheme of Geroch and Nowak (1984) only *Cribrostomoides nonioninoides* [= *Haplophragmoides nonioninoides* of Geroch and Nowak (1984)] and an atypical species of *Pseudoreophax*, differing from *P. cisownicensis* Geroch, have been observed. Among the 24 index species used in the Boreal Lower Cretaceous zonations of King et al. (1989), only one species tentatively identified as *Bulbobaculites* cf. *inconstans* (Bartenstein and Brand, 1951) was found at DSDP Site 263.

5.3. Palaeoecology

Taxa with organic and siliceous cement and tapered (presumably infaunal) morphologies dominate the assemblages of lithological units 3 and 4, suggesting that dysaerobic environmental conditions were prevalent during the deposition of these units. Mineralogical evidence indicates that sediments from DSDP Site 263 were predominantly terrestrially derived with minor pelagic input (Compton et al., 1992) and the lithologies of dark claystones also point to high organic influx and oxygen depletion. However, a very restricted, stagnant environment is excluded by the high faunal diversity. Conditions appear, nevertheless, to have remained more restricted at DSDP Site 263 than at ODP Sites 765 and 766 during the Early Cretaceous, which may explain the paucity of calcareous benthic taxa and the absence of some cosmopolitan DWAF.

The Valanginian–Barremian assemblages contain several species of foraminifera that are here described as new, as well as others that we have provisionally left in open nomenclature. This may due to endemism in the Cuvier Basin or may be a reflection of the generally strong faunal provinciality between the Boreal, Tethyan and Austral realms during the Neocomian. A high degree of provincialism has been observed among Valanginian–Barremian ammonites in the Boreal realm (Rawson, 1980), whereas provinciality became less marked in the Aptian–Albian owing to generally warmer climates and rising sea levels, leading to increased opportunities for faunal dispersal. Although such a pattern has not yet been observed among Tethyan–Austral invertebrate faunas owing to a lack of published data (P. Rawson, pers. commun., 1994), we do observe this pattern in the benthic foraminiferal assemblages at DSDP Site 263 and ODP Site 766. At both sites, many of the well-known Tethyan Neocomian index forms are missing. However, the Valanginian–Barremian assemblages from ODP Site 766 contain a much higher proportion of cosmopolitan calcareous taxa in comparison with those from DSDP Site 263. This probably reflects distinct sedimentation and circulation regimes at these two sites, which may be linked to their different rifting histories (Colwell et al., 1994).

The overall decrease in coarsely agglutinated species and corresponding increase in finely agglutinated deeper-water forms indicate that although the sediments from DSDP Site 263 were originally deposited in a neritic environment (possibly under deltaic influence), gradual deepening occurred as the rifted Indian Ocean margin subsided. The occurrence of deep-water species such as *Caudammina crassa* from Cores 263-25R-4 to 263-7R-2, the marked upward increase of *Rhabdammina*, *Rhizammina*, *Ammodiscus* and *Glomospira* spp. in lithological units 3 and 4, as well as the scarcity of shallow-water taxa such as *Hyperammina* spp. also point to increasing water depth. Evidence of a deepening palaeobathymetry is reflected in the lithology by a upward decrease in grain size and a change to lower energy bedforms in the lower part of the sequence. Our interpretation contrasts markedly with the views presented by Scheibnerová in her syntheses of Leg 27 (1974, 1977), in which she concluded that water depth did not exceed 100 m at DSDP Site 263 during the Early Cretaceous, and that there was no evidence for deep-water environments before the Santonian at any of the Indian Ocean sites.

6. Summary

DSDP Site 263 is an important taxonomic reference site for the still poorly-known Lower Cretaceous benthic foraminifera of the Indian Ocean: 66 agglutinated and 31 calcareous taxa have been documented in this study. We have been able to confirm 22 of the taxa originally reported by Scheibnerová, and 5 taxa are here described as new.

Although the base of the sedimentary column was not drilled at DSDP Site 263, our findings of sparse Valanginian–Barremian calcareous benthic foraminifera in lithological unit 4 is in general agreement with a Valanginian age for the opening of the Cuvier Basin, as suggested by geophysical evidence. The assemblages at DSDP Site 263 reflect a deepening palaeobathymetry, from shelf to middle or lower slope. Our interpretation contrasts sharply with the views expressed by Scheibnerová (1974), Scheibnerová (1977) who interpreted the foraminiferal assemblages as diagnostic of shallow-water conditions (less than 100 m) in the Indian Ocean, throughout the Early Cretaceous.

The nature of the sediments and the composition of the assemblages indicate that circulation within the Cuvier Basin was relatively restricted during the Early Cretaceous. Except for brief intervals of time, DSDP Site 263 remained below the CCD until the Albian and experienced a much greater influence of clastic deposition than ODP Site 766 on the northern margin of the basin. As a result, the foraminiferal assemblages of these two sites are not comparable. The palaeocirculation reconstruction of Baumgartner et al. (1992) also suggested that DSDP Site 263 was influenced by cooler water from higher latitudes than ODP Site 765 where a cosmopolitan agglutinated fauna was established since the Tithonian. The combination of cooler waters, shallower depths, clastic sedimentation and restricted circulation have conspired to produce a unique faunal composition at DSDP Site 263 during the Valanginian–Barremian in contrast to that of the more pelagic, oceanic ODP Sites 765 and 766.

Our study provides time constraints for the rifting in the Cuvier Basin that are in agreement with recent geophysical evidence and gives new insight into the palaeoenvironments of the Indian Ocean during early opening stage.

7. Systematic taxonomy

Taxa are arranged according to the systematics of Loeblich and Tappan (1988).

Agglutinated foraminifera

Superfamily ASTRORHIZACEA, Brady, 1881

Bathysiphon brosgei Tappan, 1957 (Plate I, 11)

Bathysiphon brosgei Tappan 1957, pl. 65, figs. 1–5.—Tappan 1962, pl. 29, figs. 1–5.—Haig and Lynch, 1993, pl. 1, fig. 1.

Range and occurrence: A cosmopolitan species, widely recorded in the Aptian–Albian (Haig, 1980).

Rhizammina spp. (Plate I, 4–10)

Remarks: We included in this group all finely–medium agglutinated branched or unbranched tubes.

Rhabdammina spp. (Plate I, 1–3)

Remarks: We included in this group all thick-walled, unbranched tubular forms.

Plate I.

1. *Rhabdammina* sp., (× 40), Sample 263-15-6; 111–115 cm.
2. *Rhabdammina* sp., (× 35), Sample 263-13-1; 99–103 cm.
3. *Rhabdammina* sp., (× 17), Sample 263-10-3; 67–71 cm.
4. *Rhizammina* sp., (× 45), Sample 263-23-3; 130–134 cm.
5. *Rhizammina* sp., (× 55), Sample 263-11-2; 92–46 cm.
6. *Rhizammina* sp., (× 45), Sample 263-23-3; 130–134 cm.
7. *Rhizammina* sp. (× 45), Sample 263-21-3; 90–94 cm.
8. *Rhizammina* sp., (× 90), Sample 263-20-2; 15–19 cm.
9. *Rhizammina* sp., (× 40), Sample 263-25-4; 100–103 cm.
10. *Rhizammina* sp., (× 40), Sample 263-22-2; 91–95 cm.
11. *Bathysiphon brosgei* Tappan, (× 35), Sample 263-15-1; 106–110 cm.
12. *Nothia robusta* (Grzybowski), (× 25), Sample 263-15-1; 106–110 cm.
13. *Nothia robusta* (Grzybowski), (× 18), Sample 263-15-1; 106–110 cm.
14. *Hippocrepina depressa* Vašicek, (× 40), Sample 263-25-4; 100–103 cm.
15. *Hippocrepina gracilis* n.sp., (holotype), (× 45), Sample 263-19-2; 86–90 cm.
16. *Hippocrepina gracilis* n.sp., (× 20), Sample 263-17-5; 76–80 cm.
17. *Hyperammina gaultina* Dam, (× 100), Sample 263-10-3; 67–71 cm.
18. *Hyperammina gaultina* Dam, (× 40), Sample 263-22-2; 91–95 cm.
19. *Kalamopsis grzybowskii* (Dylażanka), (× 70), Sample 263-21-3; 90–94 cm.
20. *Kalamopsis grzybowskii* (Dylażanka), (× 45), Sample 263-10-2; 84–89 cm.

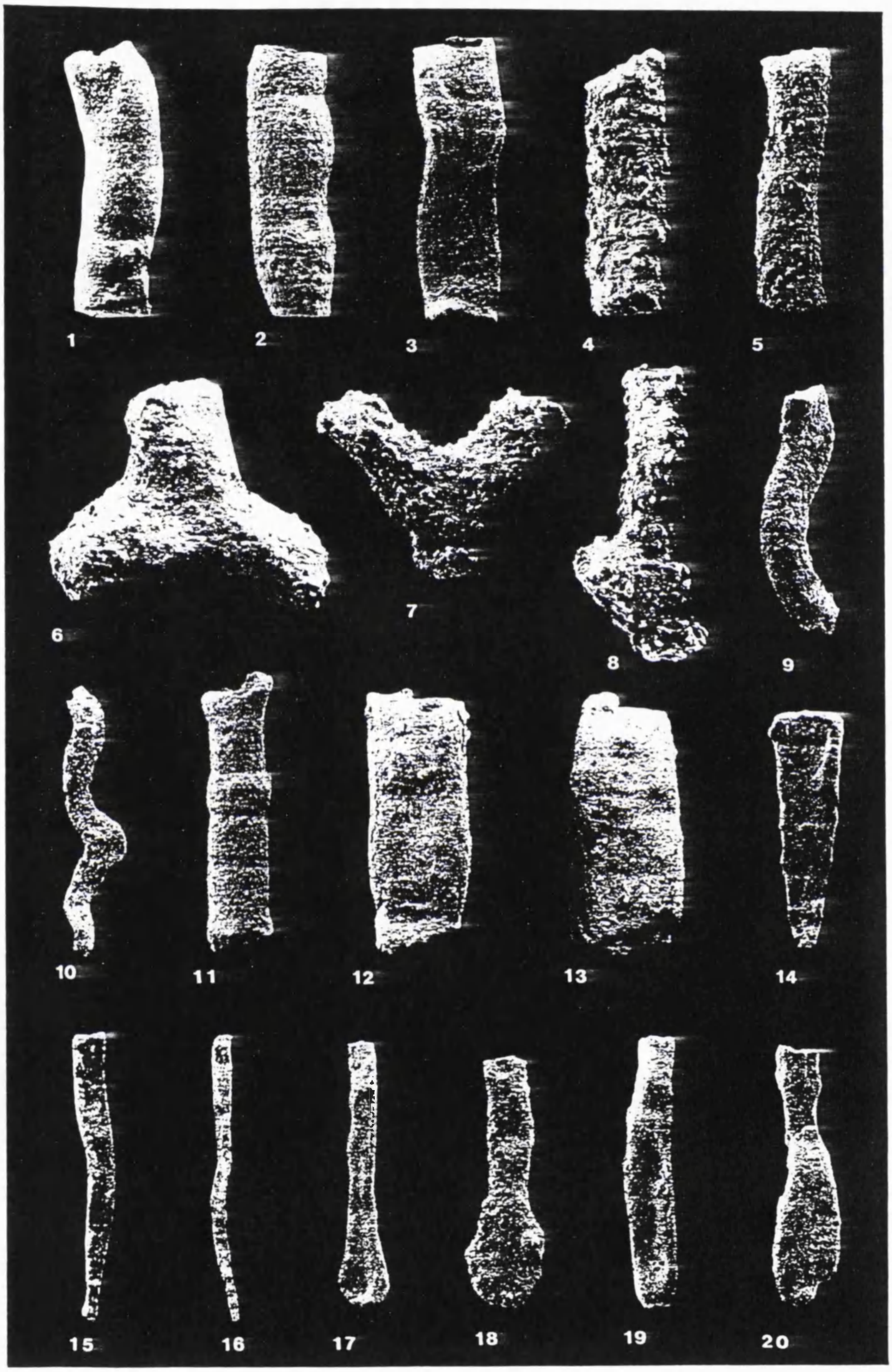

Plate 1.

Please note that the original plates will be returned after printing of the special volume.

Nothia robusta (Grzybowski, 1898) (Plate I, 12–13)

Dendrophyra robusta Grzybowski, 1898, pl. 10, fig. 7.

Rhabdammina robusta (Grzybowski).—Weidich, 1990, pl. 33, fig. 1.

Psammosphaera sp. 1 (Plate II, 4)

Description: Spherical to sub-spherical, well-cemented test with medium to coarse agglutinated particles giving the external wall of the test a rough texture. Aperture indistinct.

Remarks: Differs from *Psammosphaera fusca* Schulze, illustrated by Bartenstein and Brand, 1951 (pl. 1, fig. 2), by the smaller size of agglutinated particles.

Saccammina lagenoides (Crespin, 1953) (Plate II, 9)

Pelosina lagenoides Crespin, 1953, pl. 1, figs. 19–20.

Saccammina lagenoides (Crespin).—Haig, 1980, pl. 1, figs. 18–21.

Range and occurrence: Recorded in the Aptian–Albian of Australia and India (Haig, 1980).

Saccammina scruposa (Berthelin, 1880) (Plate II, 8)

Haplophragmium scruposum Berthelin, 1880, pl. 1, fig. 1.

Description: Sub-globular test with a short, narrow neck. Well-cemented wall with coarser particles.

Lagenammina aff. ***alexanderi*** (Loeblich and Tappan, 1950) (Plate II, 5–7)

Proteonina alexanderi Loeblich and Tappan, 1950, pl. 1, figs. 1–2.

Lagenammina alexanderi (Loeblich and Tappan).—Haig, 1980, pl. 1, figs. 14–17.

Remarks: Differs from *Lagenammina alexanderi* by the more spherical shape of test, without tapering into apertural neck.

Range and occurrence: A cosmopolitan species, widely recorded from the Aptian to the Cenomanian (Haig, 1980).

Superfamily HORMOSINACEA Haeckel, 1894

Aschemocella sp. (Plate VIII, 13)

Remarks: Only a few specimens were found at DSDP Site 263.

Kalamopsis grzybowskii (Dylążanka, 1923) (Plate I, 19–20)

Hyperammina grzybowskii Dylążanka, 1923, pp. 65–66.

Kalamopsis grzybowskii (Dylążanka).—Riegraf and Luterbacher 1989b, pl. 1, figs. 4–5.

Remarks: The Lower Cretaceous specimens of *K. grzybowskii* typically have shorter chambers than the type specimens in the Grzybowski Collection, which can be up to 1 mm in length (Kaminski and Geroch, 1993).

Plate 2.

1. *Caudammina crassa* (Geroch), (× 100), Sample 263-10-2; 84–89 cm.
2. *Caudammina crassa* (Geroch), (× 40), Sample 263-22-2; 91–95 cm.
3. *Caudammina crassa* (Geroch), (× 50), Sample 263-21-3; 90–94 cm.
4. *Psammosphaera* sp. 1, (× 75), Sample 263-29-4; 140–144 cm.
5. *Lagenammina* aff. *alexanderi* (Loeblich and Tappan), (× 70), Sample 263-29-4; 140–144 cm.
6. *Lagenammina* aff. *alexanderi* (Loeblich and Tappan), (× 65), Sample 263-10-1; 131–135 cm.
7. *Lagenammina* aff. *alexanderi* (Loeblich and Tappan), (× 105), Sample 263-22-2; 91–95 cm.
8. *Lagenammina scruposa* Berthelin, (× 65), Sample 263-21-4; 120–124 cm.
9. *Saccammina lagenoides* (Crespin), (× 60), Sample 263-21-4; 120–124 cm.
10. *Reophax* cf. *geniculatus*, (× 50), Sample 263-29-3; 71–75 cm.
11. *Reophax* cf. *geniculatus*, (× 45), Sample 263-29-2; 76–80 cm.
12. *Reophax* sp. 1, (× 35), Sample 263-29-2; 76–80 cm.
13. *Reophax* sp. 2, (× 75), Sample 263-22-3; 117–121 cm.
14. *Pseudoreophax* sp. 1, (× 65), Sample 263-19-2; 86–90 cm.
15. *Pseudoreophax* sp. 1, (× 85), Sample 263-19-2; 86–90 cm.
16. *Subreophax* sp. 1, (× 45), Sample 263-25-2; 36–40 cm.
17. *Ammolagena clavata* (Jones and Parker), (× 60), Sample 263-21-3; 90–94 cm.
18. *Lituotuba* sp., (× 50), Sample 263-25-4; 100–103 cm.

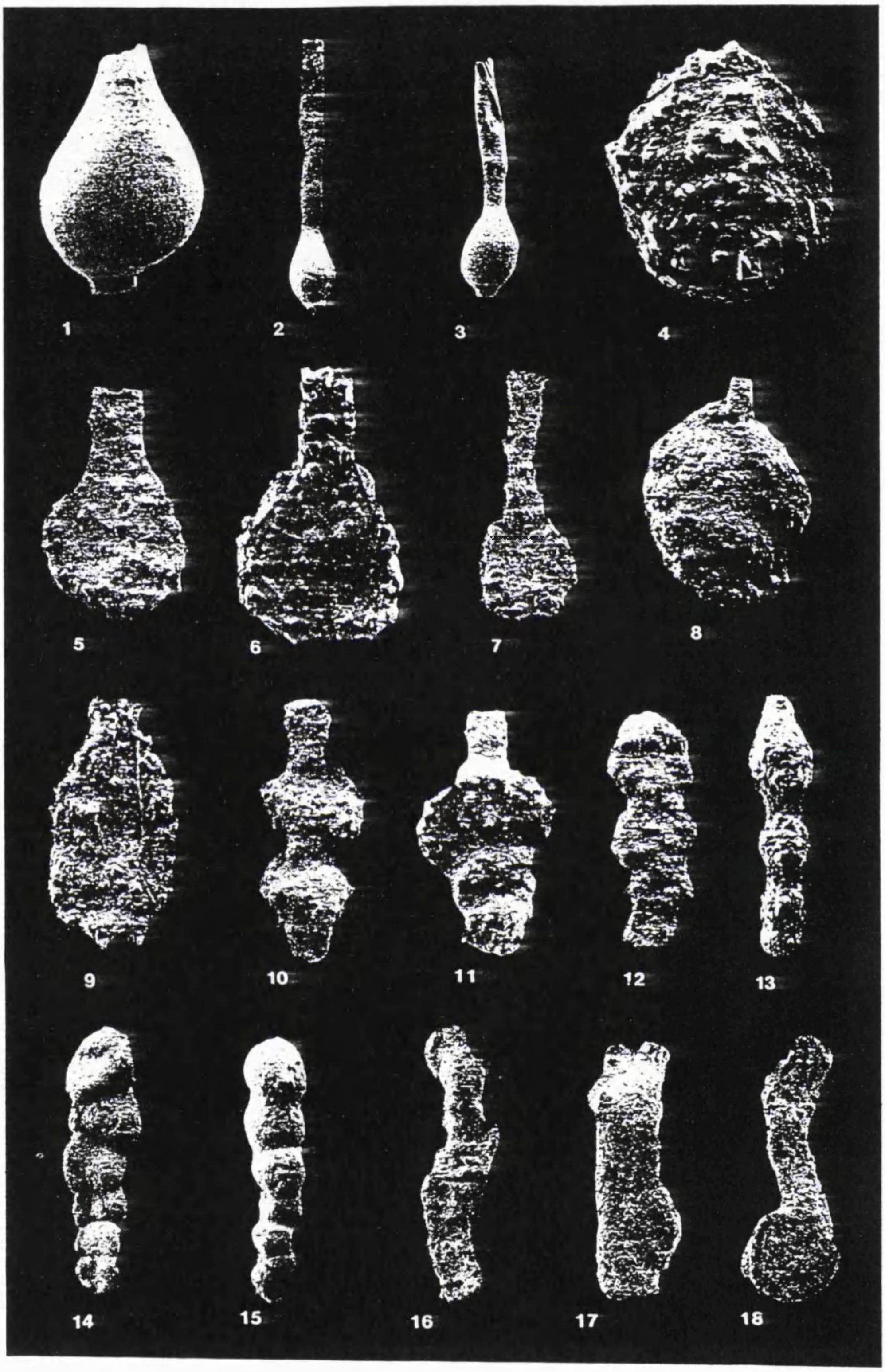

Plate 2.

Caudammina crassa (Geroch, 1966) (Plate II, 1–3)

Hormosina ovulum crassa Geroch, 1966, p. 439, fig. 6.

Hormosina crassa Geroch.—Kaminski et al., 1992, pl. 3, figs. 7–8.

Remarks: We transfer this species to the genus *Caudammina* Montanaro-Gallitelli, 1955, because of the presence of stolons between chambers. We regard the genus *Carpathiella* Myatlyuk, 1966 to be fully synonymous with *Caudammina*. The specimens of *C. crassa* from DSDP Site 263 include ones with extremely long stolons (e.g. Plate II, 2,3), suggesting some link to "more primitive" tubular genera such as *Kalamopsis* or *Hyperammina*. Such a feature has not been observed in specimens from the Carpathians, where the species was first described.

Range and occurrence: Tithonian to Valanginian at ODP Site 765 (Kaminski et al., 1992). Reported by Riegraf and Luterbacher (1989a) as a cosmopolitan species from the Hauterivian to the Campanian.

Reophax cf. ***geniculatus*** (Ludbrook, 1966) (Plate II, 10–11)

Reophax geniculatus Ludbrook, 1966, pl. 1, figs. 3–4.

Reophax deckeri Tappan.—Haig, 1982, pl. 1, fig. 6.

Description: Elongate test with few flattened chambers and coarsely agglutinated wall. Terminal aperture, at the end of a long, broad neck.

Remarks: Close to *Hormosinella* because of the presence of stolons between the chambers. Differs from *Reophax geniculatus* Ludbrook by the presence of these short stolons.

Reophax sp. 1 (Plate II, 12)

Description: Elongate test with flattened chambers increasing slowly in size and coarsely agglutinated wall. Simple aperture is at the end of the last chamber.

Remarks: This species resembles *Scherochorella minuta* (Tappan, 1940) in that it has horizontal sutures and lacks an apertural neck. It differs, however, in having fewer chambers and a coarser wall.

Reophax sp. 2 (Plate II, 13)

Description: Elongate test with initially rounded chambers increasing gradually in size and becoming fusiform. Wall thick, coarsely agglutinated. Terminal aperture at the end of the last chamber which is slightly drawn-out.

Remarks: Close to *Reophax* sp. A (pl. 4, fig. 8 in Crespin, 1963) but has wider, depressed sutures.

Subreophax sp. 1 (Plate II, 16)

Description: Test elongate and irregularly constricted, without distinct chambers. Terminal aperture.

Superfamily HIPPOCREPINACEA Rhumbler, 1895

Hippocrepina depressa Vašiček, 1947 (Plate I, 14)

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Hippocrepina depressa Vašiček, 1947, pl. 1, figs. 1–2.—Kaminski et al., 1992, pl. 1, figs. 7–8.

Remarks: A cosmopolitan species from the Oxfordian to the Cenomanian (Riegraf and Luterbacher, 1989a).

Hippocrepina gracilis n.sp. (Plate I, 15–16)

Derivation of name: latin, meaning thin.

Holotype: Specimen figured in Plate I, fig. 15. Deposited in the micropalaeontological collections of

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Plate 3.

1. *Ammodiscus tenuissimus* (Guembel), (× 85), Sample 263-21-3; 90–94 cm.
2. *Ammodiscus cretaceus* (Reuss), (× 140), Sample 263-21-4; 120–124 cm.
3. *Ammodiscus cretaceus* (Reuss), (× 130), Sample 263-22-3; 117–121 cm.
4. *Ammodiscus infimus* Franke, (× 90), Sample 263-21-3; 90–94 cm.
5. *Ammodiscus infimus* Franke, (× 35), Sample 263-10-3; 67–71 cm.
6. *Ammodiscus* sp. 1, (× 105), Sample 263-26-2; 60–64 cm.
7. *Ammodiscus* sp., (× 105), Sample 263-21-4; 120–124 cm.
8. *Glomospira* sp., (× 105), Sample 263-21-4; 120–124 cm.
9. *Glomospira gordialis* (Jones and Parker), (× 130), Sample 263-22-3; 117–121 cm.
10. *Glomospira charoides* (Jones and Parker), (× 110), Sample 263-10-2; 84–89 cm.
11. *Glomospira charoides* (Jones and Parker), (× 130), Sample 263-21-4; 120–124 cm.
12. *Glomospirella gaultina* (Berthelin), (× 70), Sample 263-10-2; 84–89 cm.

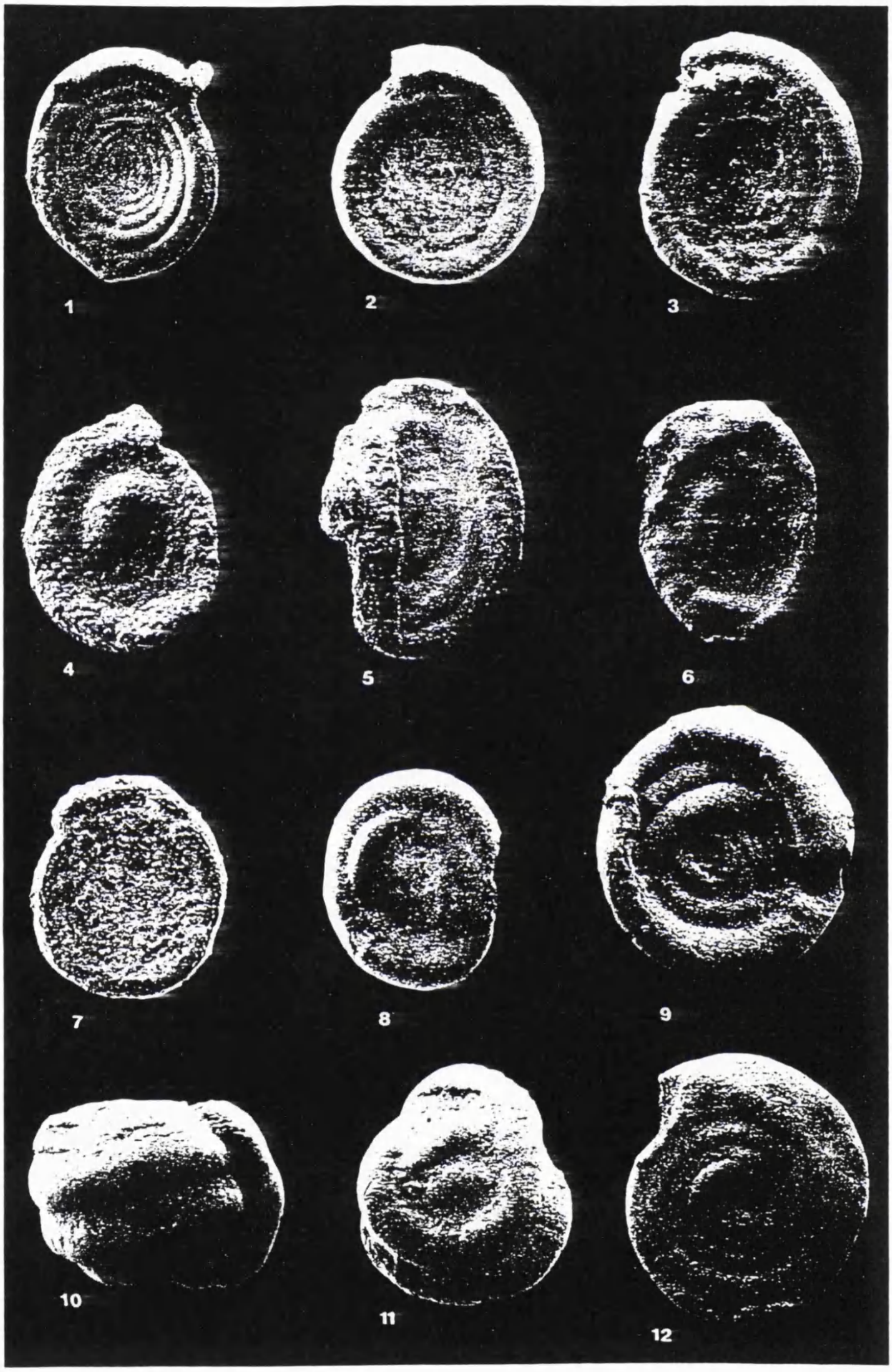

Plate 3.

the British Museum (Natural History), catalog no. PF 53004.

Material: 76 specimens.

Locality and horizon: Sample 263-19R-2, 86–90 cm. *Age*: Valanginian–Barremian.

Description: Test a narrow, elongated, compressed tube, very gently arched, and gently tapered towards the base, with a median furrow. Wall finely agglutinated and smoothly finished. Aperture is the open end of the tube.

Dimensions: Length of Holotype: 0.97 mm.

Remarks: Differs from *H. depressa* by its longer, narrower, more gently arched test and thinner agglutinated wall. Closely resembles *Hyperammina* sp. C figured in pl. 2, fig. 4 by Crespin (1963). The Albian species *Hippocrepina vermicula* Bulatova described from the Albian of Siberia is a much broader, stouter form.

Hyperammina gaultina Ten Dam, 1950

Hyperammina gaultina Ten Dam, 1950, pl. 1, fig. 2.—Haig, 1980, pl. 1, figs. 4–5.

Remarks: Very common in the shallow-water *Ammobaculites* Association of Queensland (D. Haig, pers. commun., 1994). Few specimens are found at DSDP Site 263.

Range and occurrence: A cosmopolitan species in the Aptian–Albian (Haig, 1980).

Superfamily AMMODISCACEA Reuss, 1862

Ammodiscus cretaceus (Reuss, 1845) (Plate III, 2–3)

Operculina cretacea Reuss 1845, pl. 13, figs. 64–65.

Ammodiscus cretaceus (Reuss).—Riegraf and Luterbacher 1989a, pl. 1, fig. 7. ***Ammodiscus infimus*** Franke, 1936 (Plate III, 4–5)

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Ammodiscus infimus Franke, 1936, pl. 1, fig. 14.—Weidich, 1990, pl. 34, fig. 1–3.

Ammodiscus tenuissimus (Gümbel, 1862) (Plate III, 1)

Spirillina tenuissima Gümbel, 1862, pl. 4, fig. 12.

Ammodiscus tenuissimus (Gümbel, 1862).—Kaminski et al., 1992, pl. 2, fig. 3.

Remarks: Close to *Ammodiscus glabratus* Cushman and Jarvis, 1928, except for its smaller size.

Ammodiscus sp. 1 (Plate III, 6)

Description: Tubular test with globular proloculus and very wide, planispirally coiled second chamber which is occasionally constricted. Aperture at end of open tube.

Ammolagena clavata (Jones and Parker, 1860) (Plate II, 17)

Trochammina irregularis var. *clavata* Jones and Parker, 1860, p. 304.

Ammolagena clavata (Jones and Parker).—Loeblich and Tappan, 1988, pl. 36, fig. 16.

Glomospira charoides (Jones and Parker, 1860) (Plate III, 10–11)

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

Glomospira charoides (Jones and Parker).—Berggren and Kaminski, 1990, pl. 1, fig. 2.

Plate 4.

1. *Recurvoides obskiensis* Romanova. (× 140), Sample 263-21-4; 120–124 cm.
2. *Recurvoides* sp., (× 110), Sample 263-20-4; 127–131 cm.
3. *Recurvoides* sp., (× 140), Sample 263-22-3; 117–121 cm.
4. *Recurvoides* sp., (× 140), Sample 263-20-4; 127–131 cm.
5. *Recurvoides* sp., (× 140), Sample 263-19-6; 61–65 cm.
6. *Recurvoides* sp., (× 130), Sample 263-22-3; 117–121 cm.
7. *Thalmannammina* sp., (× 100), Sample 263-10-2; 84–89 cm.
8. *Thalmannammina* sp., (× 180), Sample 263-21-4; 120–124 cm.
9. *Thalmannammina* sp., (× 150), Sample 263-22-3; 117–121 cm.
10. *Paratrochamminoides* sp., (× 130), Sample 263-22-3; 117–121 cm.
11. *Paratrochamminoides* sp., (× 120), Sample 263-19-6; 61–65 cm.
12. *Ammosphaeroidina* sp., (× 160), Sample 263-22-3; 117–121 cm.

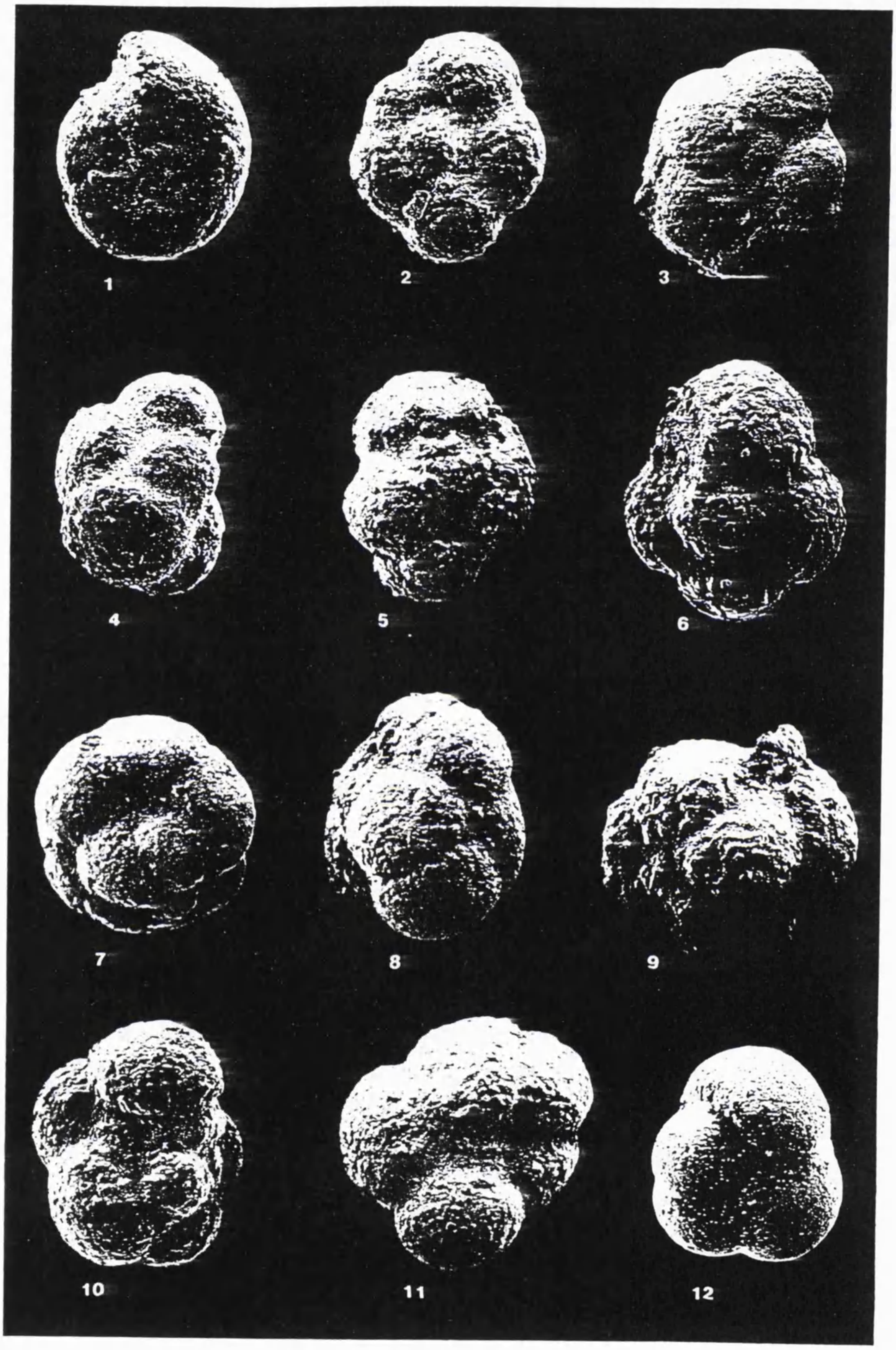

Plate 4

Glomospira gordialis (Jones and Parker, 1860) (Plate III, 9)

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

Glomospira gordialis (Jones and Parker).—Berggren and Kaminski, 1990, pl. 1, fig. 1.

Glomospira irregularis (Grzybowski, 1896)

Ammodiscus irregularis Grzybowski, 1896, pl. 11, figs. 2-3.

Glomospira irregularis (Grzybowski, 1896).—Kaminski et al., 1992, pl. 2, figs. 11–12.

Glomospirella gaultina (Berthelin, 1880) (Plate III, 12)

Ammodiscus gaultinus Berthelin, 1880, pl. 1, fig. 3.

Glomospirella gaultina (Berthelin).—Kaminski et al., 1992, pl. 2, fig. 15.

Superfamily SPIROPLECTAMMINACEA Cushman, 1927

Ammobaculoides sp. (Plate VI, 13)

Remarks: Rare at Site 263.

Spiroplectammina sp. 1 (Plate VI, 11)

Description: Elongate, compressed test with small initial coil. Sutures oblique in biserial part; well-cemented wall, coarsely agglutinated.

Aaptotoichus clavellatus (Loeblich and Tappan, 1946) (Plate VI, 16)

Bigenerina clavellata Loeblich and Tappan, 1946, pl. 35, figs. 7–8.

Bigenerina clavellata (Loeblich and Tappan).—Bartenstein and Brand, 1951, pl. 4, figs. 75–76.

Bigenerina clavellata (Loeblich and Tappan).—Sliter, 1977, pl. 3, figs. 6–7.

Aaptotoichus challengeri n.sp. (Plate VII, 1–6)

Bigenerina loeblichae Crespin.—Scheibnerová, 1974, pl. 9, fig. 7.

cf. *Bigenerina jurassica* Haeusler.—Riegraf and Luterbacher, 1989b, pl. 2, figs. 15–20.

Bigenerina sp. Kaminski et al., 1992, pl. 7, fig. 1.

Derivation of name: after the drilling vessel *Glomar Challenger.*

Holotype: Specimen figured in Plate I, fig. 1. Deposited in the micropalaeontological collections of the British Museum (Natural History), catalog no. PF 53005.

Material: 69 specimens from Site 263, and several specimens from ODP Sites 765 and 766.

Locality and horizon: Sample 263-22R-3, 117–121 cm. *Age*: Valanginian–Barremian.

Description: Elongate, narrow test with short, biserial stage followed by longer, uniserial portion of up to seven chambers. Chambers in the uniserial portion are inflated, with sutures that are horizontal or slightly oblique. Wall finely agglutinated, finely finished. Aperture terminal, a small round opening at the end of a short neck. This species is distinctly dimorphic: the microsphere has a pointed, rapidly expanding biserial stage composed of numerous small chambers, whereas the megalosphere has only a few large round biserial chambers in the initial part of the test.

Dimensions: Length of Holotype: 0.46 mm.

Remarks: The definition of the genus *Aaptotoichus* given by Loeblich and Tappan (1988) makes no mention of a neck. This species differs from the type species *A. clavellatus* (Loeblich and Tappan) in possessing

Plate 5.

1. *Cribrostomoides nonioninoides* (Reuss), (× 100), Sample 263-26-5; 126–130 cm.
2. *Evolutinella perturbans* Ludbrook, (×55), Sample 263-26-5; 126–130 cm.
3. *Haplophragmoides concavus* (Chapman), (× 115), Sample 263-29-3; 71–75 cm.
4. *Haplophragmoides* sp., (×70), Sample 263-26-5; 126–130 cm.
5. *Trochammina depressa* Lozo, (×85), Sample 263-21-4; 120–124 cm.
6. *Trochammina* sp., (×90), Sample 263-21-4; 120–124 cm.
7. *Trochammina subinflata*, (× 130), Sample 263-21-4; 120–124 cm.
8. *Trochammina abrupta* Geroch, (× 100), Sample 263-29-4; 140–144 cm.
9. *Trochammina ribstonensis* Wickenden, (× 170), Sample 263-19-2; 86–90 cm.
10. *Trochammina ribstonensis* Wickenden, (× 150), Sample 263-19-2; 86–90 cm.
11. *Trochammina ribstonensis* Wickenden, (×200), Sample 263-19-2; 86–90 cm.
12. *Trochammina ribstonensis* Wickenden, (× 170), Sample 263-19-2; 86–90 cm.

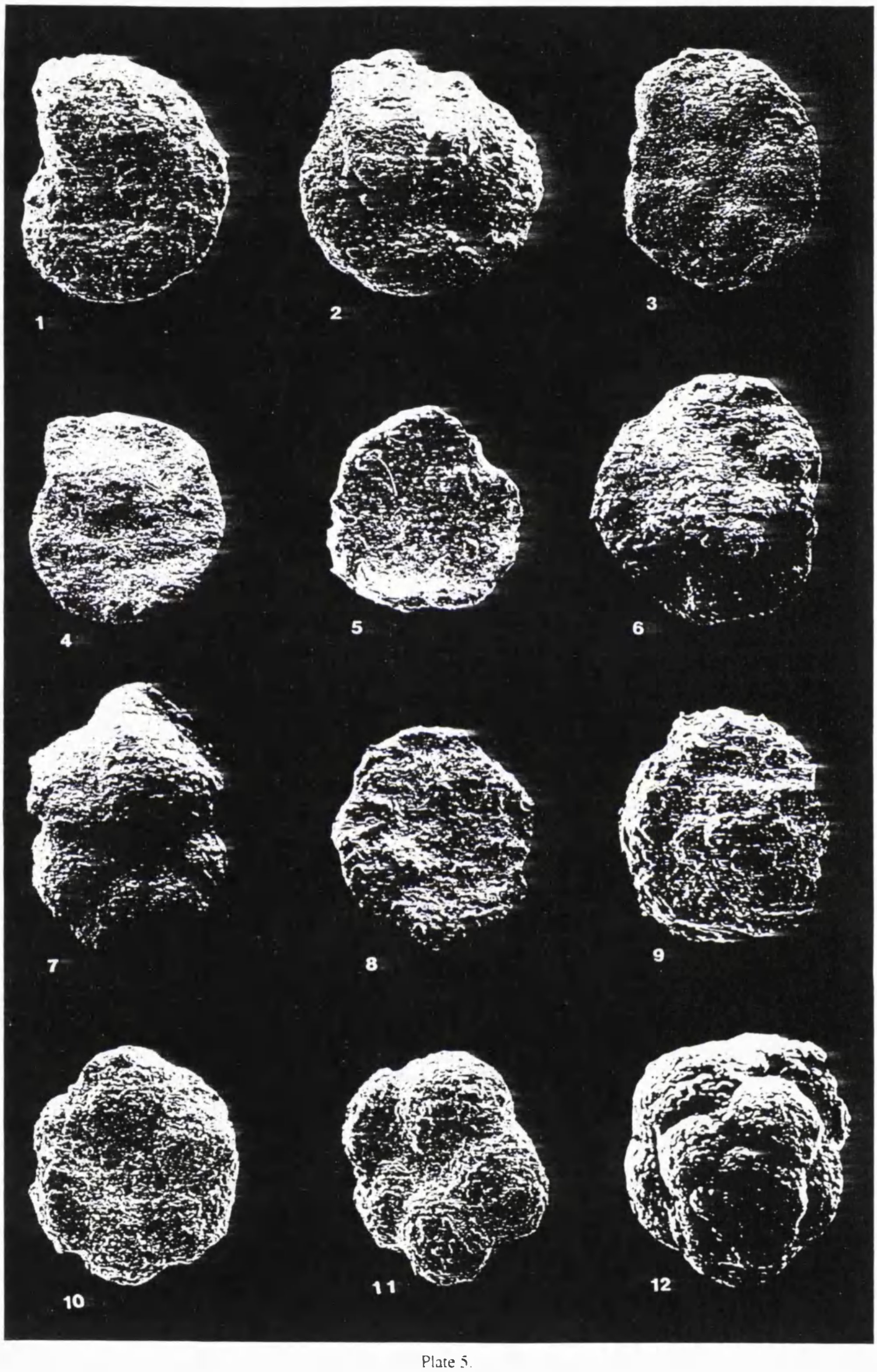

Plate 5.

fewer number of uniserial chambers separated by slightly oblique sutures, and in its short neck. The species *Bigenerina pitmani* (Crespin) of Haig (1980) (which also includes the subjective synonyms *Ammobaculoides romaensis* Crespin, 1953 and *Bigenerina loeblichae* Crespin, 1953), differs from it by its straighter axis and much longer uniserial stage with horizontal sutures, and by the absence of an apertural neck.

Aaptotoichus challengeri n.sp. appears to be the intermediate form between the Upper Jurassic "*Bigenerina*" *jurassica* (Haeusler, 1890) and the Aptian species *Aaptotoichus pitmani* (Crespin, 1953) (=*Bigenerina pitmani*). Evolution in this suspected lineage progresses by a reduction in the relative proportions of the biserial part with respect to the uniserial part, and the addition of numerous low uniserial chambers with horizontal sutures. The typical *B. jurassica* as emended by Oesterle (1968) has a terminal part that is still loosely biserial, with high chambers. In the intermediate stage represented by *A. challengeri*, the biserial part is followed by a more loosely biserial stage, and the terminal chambers may still have slightly oblique sutures. Similar specimens have been illustrated as *Bigenerina jurassica* by Riegraf and Luterbacher (1989a) from the Valanginian of western North Atlantic. In the younger species *Aaptotoichus pitmani*, as well as in *Aaptotoichus clavatellus* (Bartenstein and Brand, 1951), there is no sign of a loosely biserial portion—the initial chambers of the uniserial part are immediately low, with horizontal sutures.

Range and occurrence: This species was found in Cores 60R and 61R at ODP Site 765 and in Cores 49R-43R at ODP Site 766, which have been correlated with the Berriasian–Valanginian and the Valanginian–Hauterivian, respectively.

Bimonilina sp. (Plate VI, 17–18)

Bimonilina cf. ***variana*** Eicher, 1960 (Plate VI, 14–15)

Bimonilina variana Eicher, 1960, pl. 4, figs. 15–19.

Pseudobolivina variana (Eicher).—Haig, 1980, pl. 5, figs. 23–26.

Pseudobolivina parvula Ludbrook, 1966, pl. 4, figs. 18–20.

Range and occurrence: *Bimonilina variana* is widely recorded in North America from the Albian to the Cenomanian. *Pseudobolivina parvula* is found in the Aptian–Albian of South Australia (Ludbrook, 1966).

Remarks: The test does not display the tendency to become uniserial of *B. variana* and *B. parvula*: the last chamber is not so markedly elongated and does not overlap the preceeding pair of chambers.

"***Textulariopsis***" ***elegans*** n.sp. (Plate VIII, 1–2)

Plate 6.

1. *Ammobaculites* sp. 1, (×45), Sample 263-26-5; 126–130 cm.
2. *Ammobaculites* sp. 1, (×45), Sample 263-26-5; 126–130 cm.
3. *Bulbobaculites* cf. *inconstans*(Bartenstein and Brand), (×140), Sample 263-22-2; 91–95 cm.
4. *Bulbobaculites* cf. *inconstans*(Bartenstein and Brand), (×100), Sample 263-21-4; 120–124 cm.
5. *Ammobaculites* sp. 1, (×35), Sample 263-25-2; 60–64 cm.
6. *Bulbobaculites humei* Nauss, (×70), Sample 263-22-3; 117–121 cm.
7. *Bulbobaculites humei* Nauss, (×45), Sample 263-19-4; 102–106 cm.

8a. *Bulbobaculites humei* Nauss, (×70), Sample 263-11-2; 92–96 cm.

8b. *Bulbobaculites humei* Nauss, (×200), Sample 263-19-4; 102–106 cm.

9. *Ammobaculites crespinae* Bhalla, (×45), Sample 263-25-4; 100–104 cm.
10. *Ammobaculites crespinae* Bhalla, (×40), Sample 263-25-2; 60–64 cm.
11. *Spiroplectammina* sp. 1, (×80), Sample 263-19-4; 102–106 cm.
12. *Spiroplectammina* sp., (×45), Sample 263-13-6; 111–115 cm.
13. *Ammobaculoides* sp., (×55), Sample 263-25-4; 100–104 cm.
14. *Bimonilina* cf. *variana* Eicher, (×130), Sample 263-19-4; 102–106 cm.
15. *Bimonilina* cf. *variana* Eicher, (×85), Sample 263-16-1; 93–97 cm.
16. *Aaptotoichus clavellatus* (Loeblich and Tappan), (×95), Sample 263-25-4; 100–104 cm.
17. *Bimonilina* sp., (×95), Sample 263-16-1; 93–97 cm.
18. *Bimonilina* sp., (×55), Sample 263-16-1; 93–97 cm.

Plate 6.

Derivation of name: because of its slender "elegant" shape.

Holotype: Specimen figured in Plate VIII, fig. 2. Deposited in the micropalaeontological collections of the British Museum (Natural History), catalog no. PF 53006.

Material: 128 specimens from Site 263.

Locality and horizon: Sample 263-22R-2, 91–95 cm. *Age*: Valanginian–Barremian.

Description: Test biserial with an adventitious chamber in the initial portion of the test; elongate, narrow, very gently flaring, with numerous chambers gradually increasing in size (usually 17 pairs or more). The test is sub-rounded in cross-section with well-defined, sutures that are oblique in the center and becoming horizontal towards the periphery, forming a distinctive herring-bone pattern down the centre of the test. Wall is solid, noncalcareous, finely agglutinated with a smooth finish. Aperture is a slit at the base of the last chamber.

Dimensions: Length of Holotype: 0.42 mm.

Remarks: The wall is not calcareous. This species cannot, therefore, be placed in *Textularia* as currently defined by Loeblich and Tappan (1988). It differs from *T. anacooraensis* Crespin (Ludbrook, 1966, pl. 4, fig. 6) by its more numerous chambers and by the presence of an adventitious chamber. The wall appears to be thin and tests are often distorted.

Superfamily LITUOLACEA de Blainville, 1827

Cribrostomoides nonioninoides (Reuss, 1863) (Plate V, 1)

Haplophragmium nonioninoides Reuss, 1863, pl. 1, fig. 8.

Labrospira nonioninoides (Reuss).—Haig, 1980, pl. 3, fig. 12–19.

Haplophragmoides nonioninoides (Reuss).—Meyn and Vespermann, 1994, pl. 1, figs. 1–8.

Remarks: Haig (1980) suggested that many of the Australian forms described under *Haplophragmoides* by Crespin (1963) and Ludbrook (1966) closely resemble *C. nonioninoides*, but the poor preservation state prevented precise determination. In most specimens from Site 263 the aperture is indeterminate, but the best-preserved specimens appear to have a small areal aperture in the center of the apertural face. Meyn and Vespermann (1994) assigned this species to the genus *Haplophragmoides* despite the fact that their plates show a distinctly areal aperture. These authors considered the genus *Labrospira* to be a Holocene taxon, following the age reported by Loeblich and Tappan (1988), with no known counterparts in the Cretaceous. This species has now been assigned to the genus *Cribrostomoides* on account of the areal aperture and slightly streptospiral early stage, observed in some specimens (D. Haig, pers. commun., 1994; McLoughlin et al., in press).

Range and occurrence: A cosmopolitan species in the Barremian–Aptian (Haig, 1980), it was recorded in the Hauterivian–Barremian of the Carnarvon Basin (McLoughlin et al., in press).

Evolutinella perturbans (Ludbrook, 1966) (Plate V, fig. 2)

Haplophragmoides perturbans Ludbrook, 1966, pl. 3, figs. 1–4.

Haplophragmoides audax Ludbrook, 1966, pl. 2, figs. 1–4.

Remarks: This species resembles *H. gigas* Cushman, except for its more rounded periphery and straighter sutures.

Range and occurrence: This species ranges from the Aptian to the base of the Albian in South Austalia (Ludbrook, 1966).

Haplophragmoides concavus (Chapman, 1892) (Plate V, fig. 3)

Trochammina concava Chapman, 1892, pl. 6, fig. 14.

Haplophragmoides concavus (Chapman).—Bartenstein and Brand, 1951, pl. 1, figs. 24–25.

Haplophragmoides concavus (Chapman).—Weidich, 1990, pl. 7, figs. 2, 11, 19 and pl. 36, figs. 5–6.

Range and occurrence: A cosmopolitan species throughout the Early Cretaceous (Weidich, 1990).

Haplophragmoides hagni Bhalla, 1965

Haplophragmoides hagni Bhalla, 1965.—Bhalla, 1969, pl. 1, figs. 6–7, text-fig. 3.

Remarks: This species shows close similarity to *Haplophragmoides euryraptum* Fowler and Braun (1993, pl. 3, figs. 11–13).

Haplophragmoides sp. (Plate V, 4)

Remarks: Many tests, are distorted and poorly preserved and can only be tentatively identified.

Lituotuba sp. (Plate II, 18)
Remarks: Only three specimens were found at DSDP Site 263.

Paratrochamminoides spp. (Plate IV, 10–11)
Remarks: Specimens classified under this generic name have a planispiral last whorl. These forms also display affinity to specimens included here as *Recurvoides*.

Ammobaculites crespinae Bhalla, 1969 (Plate VI, 9–10)
Ammobaculites crespinae Bhalla, 1969, pl. 2, figs. 1–3.
Ammobaculites crespinae Bhalla.—Scheibnerová, 1974, pl. 1, fig. 11 and pl. 9, fig. 4.
Remarks: The specimens from DSDP Site 263 have a characteristic dome-shaped last chamber which often bears a very short neck. They show considerable variation in size, number and width of chambers and wall texture.

Ammobaculites sp. 1 (Plate VI, 1–2,5)
Description: Test with large initial planispiral coil, slightly evolute, composed of 6–11 chambers in the last whorl (in presumed megalospheric forms the coil is larger and contains up to 11 chambers). Uniserial portion extends tangentially, is straight or slightly curved, usually narrower than the coil, with as many as 10 (normally four or five) broad, low chambers separated by thin, depressed, horizontal sutures. Aperture indistinct, probably simple and terminal in the uncoiled part. Wall noncalcareous, thick and firmly cemented, medium to finely agglutinated.
Remarks: The size of initial coil and width of uniserial portion vary considerably in our specimens from DSDP Site 263. The specimen from the Muderong Shale illustrated as *Ammobaculites laevigatus* Lozo by Crespin (1963) differs by its curved axis, finer grained wall and more involute, broader initial coil. This species also resembles the Siberian species *Acruliammina pseudolonga* Subbotina, 1964, (Subbotina, 1964, pl. 14, fig. 4), from which it differs in having a single aperture and a greater number of chambers in its coiled part.

Superfamily HAPLOPHRAGMIACEA Eimer and Fickert, 1899

Ammosphaeroidina sp. (Plate IV, 12)
Remarks: Coiling is involute and slightly streptospiral, with four chambers visible from the exterior. The aperture is not visible in our specimens, but it is probably interiomarginal.

Recurvoides cf. *obskiensis* Romanova, 1960 (Plate IV, 1)
Recurvoides obskiensis Romanova (in Glazunova et al., 1960), pl. 4, figs. 1–8.
Recurvoides cf. *obskiensis* Romanova.—Weidich, 1990, pl. 4, figs. 13–17.
Remarks: Our specimens display the characteristic oval outline, recurvoidiform coiling, and thick sutures of this distinctive Siberian species, but differ in their generally smaller dimensions, and in having a fewer number of chambers in the final whorl. *Recurvoides obskiensis* was described as possessing 9–13 chambers, but our specimens generally have 9–10, rarely 11 chambers.
Range and occurrence: *Recurvoides obskiensis* was first described from the Valanginian to Hauterivian of western Siberia (Subbotina, 1964). It has been reported from the Volgian to Ryazenian of Spitsbergen (Nagy et al., 1990).

Recurvoides spp. (Plate IV, 2–6)
Remarks: Specimens from DSDP Site 263 show considerable variability with many transitional forms to *Thalmannammina* and *Paratrochamminoides* spp. A detailed taxonomic study of specimens belonging to all three groups is necessary before speciation can be attempted.

Thalmannammina spp. (Plate IV, 7–9)
Remarks: Specimens grouped under this generic name are typically coiled in a U-shaped manner.

Bulbobaculites humei (Nauss, 1947) (Plate VI, 6–8)
Ammobaculites humei Nauss, 1947, pl. 48, fig. 1.
Ammobaculites humei Nauss.—Haig, 1980, pl. 4, figs. 4–10. [with synonymy]
Remarks: Included under this designation are all the slender forms with numerous chambers. This is a very variable species which has been described under a large number of specific names (Haig, 1980). Haig's syn-

onymy includes the specimens illustrated by Scheibnerová (1974) as *Ammobaculites fisheri* Crespin, 1953 from DSDP Site 263.

Range and occurrence: A cosmopolitan species in the Aptian–Albian (Haig, 1980).

Bulbobaculites **cf.** ***inconstans*** (Bartenstein and Brand, 1951) (Plate VI, 3–4)

Haplophragmium inconstans erectum Bartenstein and Brand, 1951, pl. 3, figs. 50–55.

Bulbobaculites cf. *inconstans* Bartenstein and Brand.—Kaminski et al., 1992, pl. 4, figs. 9–10.

Remarks: Specimens from DSDP Site 263 have a shorter uniserial portion (usually two or three chambers) than the Valanginian species described by Bartenstein and Brand (1951).

Superfamily TROCHAMMINACEA Schwager, 1877

Trochammina abrupta Geroch, 1959 (Plate V, 8)

Trochammina abrupta Geroch, 1959, pl. 12, figs. 1–3.

Trochammina abrupta Geroch.—Kaminski et al., 1992, pl. 5, figs. 14–15 and pl. 6, figs. 1–2.

Range and occurrence: This species was found in the Tithonian to Valanginian at Site 765 (Kaminski et al., 1992). It was described from the Hauterivian to Albian in the Polish Carpathians (Geroch and Nowak, 1984).

Trochammina depressa Lozo, 1944 (Plate V, 5)

Trochammina depressa Lozo, 1944, pl. 2, figs. 4–5.

Trochammina depressa Lozo.—McNeil and Caldwell, 1981, pl. 13, fig. 8.

Remarks: Haig (1980) regarded the species *T. flosculus*, described by Ludbrook (1966, pl. 5, figs. 7–10) as a synonym of *T. depressa*.

Range and occurrence: A cosmopolitan species in the Aptian–Albian (Haig, 1980).

Trochammina ribstonensis Wickenden, 1932 (Plate V, 9–12)

Trochammina ribstonensis Wickenden, 1932, pl. 1, fig. 12.

Trochammina ribstonensis Wickenden.—Tappan, 1962, pl. 39, fig. 15–17.

Trochammina minuta Crespin.—Scheibnerová, 1974, pl. 1, figs. 18–20 and pl. 9, figs. 19–20.

Remarks: This is a small species, described as *T. ribstonensis* by Tappan (1962) and as *T. minuta* by Scheibnerová (1974). It differs from *T. ribstonensis*, illustrated by McNeil and Caldwell (1981, pl. 13, fig. 1), by having fewer chambers in the last whorl (four to six) and in its more conical shape.

Range and occurrence: *Trochammina ribstonensis* has been widely recorded from the Turonian to Campanian of North America (McNeil and Caldwell, 1981). *Trochammina minuta* is common in the Aptian of the Great Artesian and Canning Basins, also, in the lower Albian of the Great Artesian Basin (Scheibnerová, 1974).

Trochammina subinflata (Plate V, 7)

Plate 7.

1a. *Aaptotoichus challengeri* n.sp. (holotype), (× 85), Sample 263-22-3; 117–121 cm.
1b. *Aaptotoichus challengeri* n.sp. (holotype), (× 350), Sample 263-22-3; 117–121 cm.
2a. *Aaptotoichus challengeri* n.sp., (× 95), Sample 263-22-3; 117–121 cm.
2b. *Aaptotoichus challengeri* n.sp, (× 350), Sample 263-22-3; 117–121 cm.
3a. *Aaptotoichus challengeri* n.sp., (× 75), Sample 263-22-3; 117–121 cm.
3b. *Aaptotoichus challengeri* n.sp., (× 275), Sample 263-22-3; 117–121 cm.
4a. *Aaptotoichus challengeri* n.sp, (× 75), Sample 263-22-3; 117–121 cm.
4b. *Aaptotoichus challengeri* n.sp., (× 325), Sample 263-22-3; 117–121 cm.
5. *Aaptotoichus challengeri* sp.n., (× 75), Sample 263-21-4; 120–124 cm.
6. *Aaptotoichus challengeri* n.sp, (× 80), Sample 263-21-4; 120–124 cm.
7. "*Gaudryina*" sp., (× 80), Sample 263-26-2; 60–64 cm.
8. "*Gaudryina*" sp., (× 100), Sample 263-21-4; 120–124 cm.
9a. "*Gaudryinopsis*" *pseudobettenstaedti* n.sp. (holotype), (× 95), Sample 263-25-4; 100–104 cm.
9b. "*Gaudryinopsis*" *pseudobettenstaedti* n.sp. (holotype), (× 275), Sample 263-25-4; 100–104 cm.
10a. "*Gaudryinopsis*" *pseudobettenstaedti* n.sp., (× 110), Sample 263-24-2; 30–34 cm.
10b. "*Gaudryinopsis*" *pseudobettenstaedti* sp.n., (× 425), Sample 263-24-2; 30–34 cm.

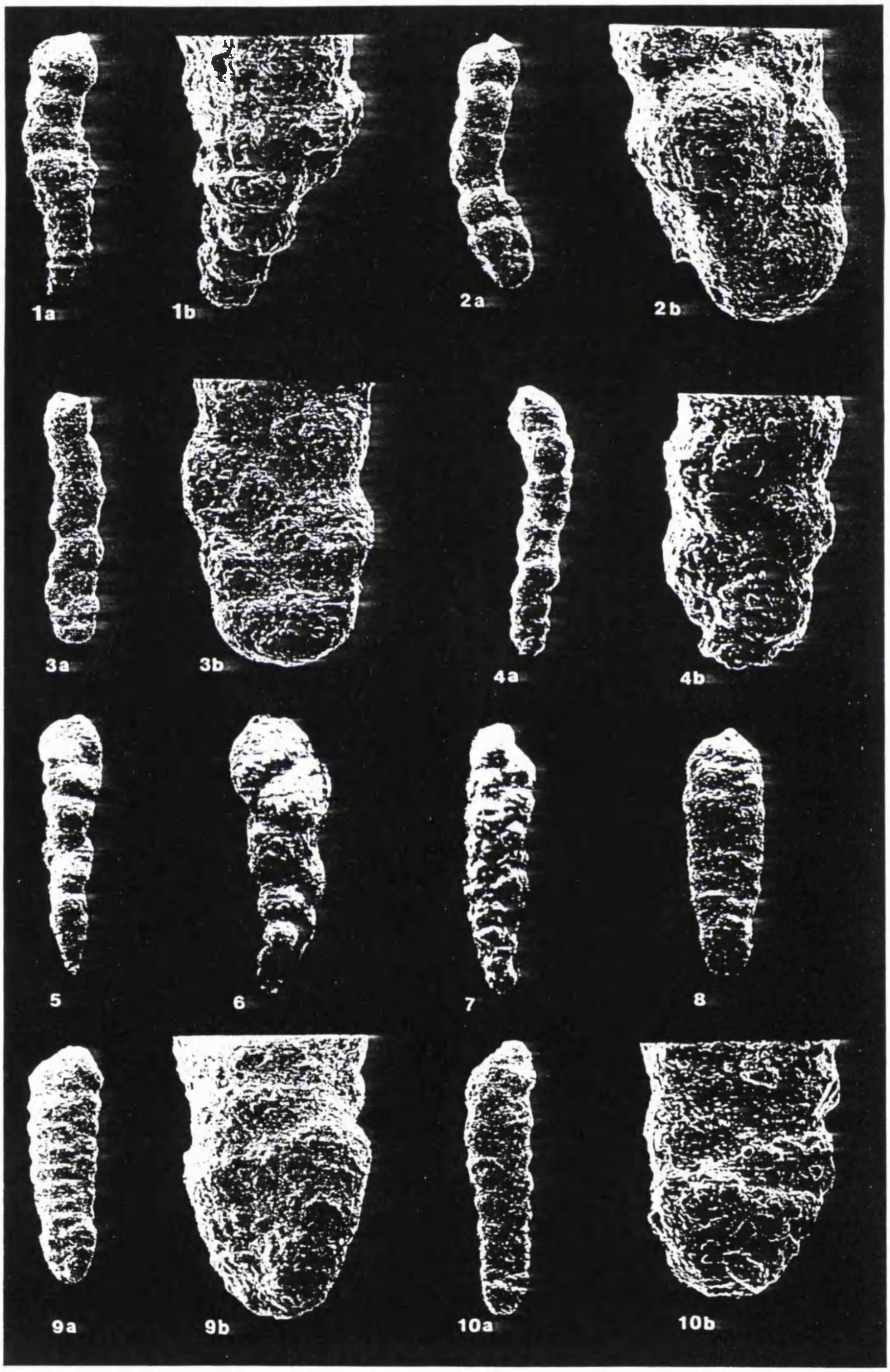

Plate 7.

Trochammina subinflata Crespin, 1963, pl. 18, figs. 11–19.

Trochammina subinflata Crespin.—Ludbrook, 1966, pl. 5, figs. 11–14.

Trochammina subinflata Crespin.—Haig, 1980, pl. 6, figs. 17–18 and pl. 7, figs. 1–2.

Superfamily VERNEUILINACEA Cushman, 1911

"Gaudryinopsis" pseudobettenstaedti n.sp. (Plate VII, 9–10)

Derivation of name: because of its resemblance to *Textularia bettenstaedti* Bartenstein, 1977.

Holotype: Specimen illustrated in Plate VII, fig. 9. Deposited in the micropalaeontological collections of the British Museum (Natural History), catalog no. PF 53007.

Material: 126 specimens from Site 263.

Locality and horizon: Sample 263-25R-4, 100–104 cm. *Age*: Valanginian–Barremian.

Description: Elongate test with a short triserial stage, becoming biserial with near parallel sides (9–14 pairs of chambers) and a sub-circular cross-section. Sutures curved and slightly depressed. Wall noncalcareous, finely agglutinated with distinctive mafic grains along the sutures. Aperture, a low arch at the base of the last chamber.

Dimensions: Length of Holotype: 0.44 mm.

Remarks: The biserial part of the test strongly resembles *Textularia bettenstaedti* because of the mafic grains along the sutures. It differs in the presence of an initial triserial part.

Pseudoreophax sp. 1 (Plate II, 14–15)

Description: Elongate test, initially trochospiral, then uniserial with asymmetric chambers along a twisting axis. Megalosphere is uniserial throughout. Chambers are inflated, wall finely agglutinated, aperture rounded and terminal.

Remarks: Differs from *Pseudoreophax cisownicensis* Geroch, 1966, by its longer size, greater number of chambers and thinner wall.

Verneuilinoides aff. ***crespinae*** Ludbrook, 1966 (Plate IX, 6)

Verneuilinoides crespinae Ludbrook, 1966, pl. 7, figs. 13–14.

Verneuilinoides crespinae Ludbrook—Scheibnerová, 1974, pl. 1, figs. 25–26 and pl. 9, fig. 14.

Remarks: Scheibnerová described this species as *V. crespinae.* However, examination of type material showed that the specimens from DSDP Site 263 differed from *V. crespinae* by their uniform triserial coiling, greater number of whorls and more pronounced flare. The holotype, redescribed by Haig (1980) as *Riyadhella crespinae* (now referred to as *Eomarssonella crespinae* by Haig and Lynch, 1993), and the paratypes, have a distinct trochospire at the beginning of the test, consisting of one to two whorls of four chambers; the remainder of the test is triserial with three to four whorls of chambers. The species from DSDP Site 263 shows some resemblance to *Verneuilinoides implexus* Fowler and Braun, 1993, (pl. 5, figs. 17–19).

Plate 8.

1a. "*Textulariopsis*" *elegans* n.sp., (×75), Sample 263-22-2; 91–95 cm.
1b. "*Textulariopsis*" *elegans* n.sp., (×450), Sample 263-22-2; 91–95 cm.
2. "*Textulariopsis*" *elegans* n.sp. (holotype), (×100), Sample 263-22-2; 91–85 cm.
3. "*Textularia*" sp. 1, (×100), Sample 263-22-2; 91–95 cm.
4. "*Textularia*" sp. 1, (×105), Sample 263-22-3; 117–121 cm.
5. "*Textularia*" sp. 1, (×140), Sample 263-19-4; 102–106 cm.
6. "*Gaudryina*" *cuvierensis* n.sp., (×85), Sample 263-24-2; 30–34 cm.
7a. "*Gaudryina*" *cuvierensis* n.sp., (×75), Sample 263-22-3; 117–121 cm.
7b. "*Gaudryina*" *cuvierensis* n.sp., (×85), Sample 263-22-3; 117–121 cm.
8a. "*Gaudryina*" *cuvierensis* n.sp., (×75), Sample 263-22-3; 117–121 cm.
8b. "*Gaudryina*" *cuvierensis* n.sp., (×275), Sample 263-22-3; 117–121 cm.
9a. "*Gaudryina*" *cuvierensis* n.sp., (×50), Sample 263-22-2; 91–95 cm.
9b. "*Gaudryina*" *cuvierensis* n.sp., (×210), Sample 263-22-2; 91–95 cm.
10. "*Gaudryina*" *cuvierensis* n.sp., (×70), Sample 263-22-2; 91–95 cm.
11. "*Gaudryina*" *cuvierensis* n.sp., (×85), Sample 263-22-2; 91–95 cm.
12. "*Gaudryina*" *cuvierensis* n.sp., (×95), Sample 263-22-2; 91–95 cm.
13. *Aschemocella* sp., (×60), Sample 263-23-4; 74–78 cm.

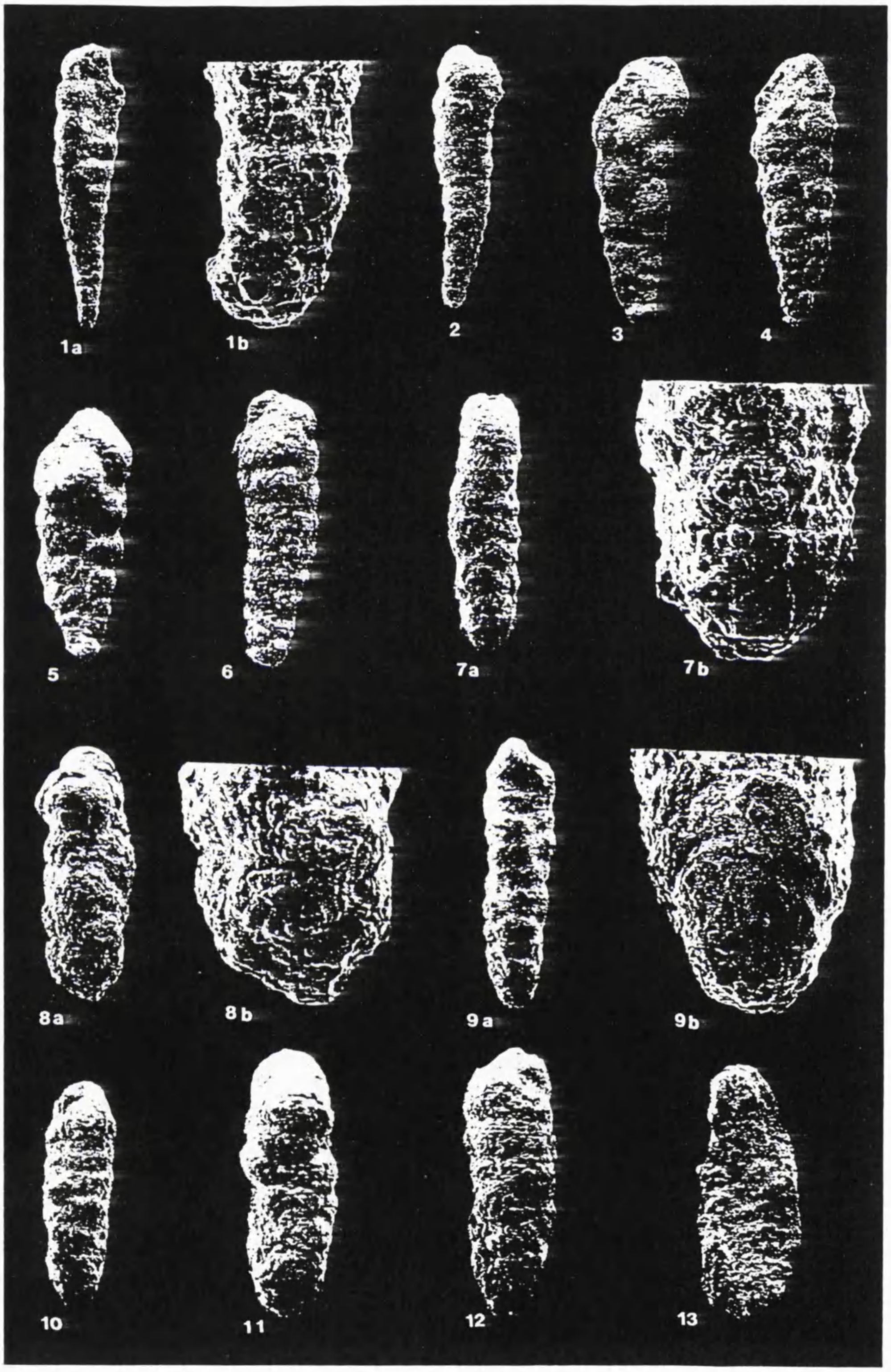

Plate 8.

Range and occurrence: *Eomarssonella crespinae* was found in the Albian of Queensland, Australia. *V. implexus* was recorded from the upper Barremian by Fowler and Braun (1993) in Arctic Canada.

Verneuilinoides neocomiensis (Myatlyuk, 1939) (Plate IX, 5)

Verneuilina neocomiensis Myatlyuk, 1939, pl. 1, figs. 12–13.

Verneuilinoides asperulus Crespin 1963, pl. 15, figs. 8–12.

Verneuilinoides neocomiensis (Myatlyuk).—Kaminski et al., 1992, pl. 7, fig. 15.

Range and occurrence: Cosmopolitan during the Early Cretaceous (Haig, 1980).

Remarks: *Verneuilinoides asperulus* appears to be a coarse-grained morphotype of *V. neocomiensis*.

''Gaudryina''cuvierensis n.sp. (Plate VIII, 6–12)

Derivation of name: after the Cuvier Abyssal Plain.

Holotype: Specimen figured in Plate VIII, fig. 9. Deposited in the micropalaeontological collections of the British Museum (Natural History), catalog no. PF 53008.

Material: 61 specimens from Site 263.

Locality and horizon: Sample 263-22R-3, 117–121 cm. *Age*: Valanginian–Barremian.

Description: Elongate test with circular cross-section, sub-parallel sides and well-developed triserial initial stage, becoming fully biserial in adult tests. The test often has a slightly twisted axis, so that the chambers are not uniformely aligned above each another. The triserial part consists of six to eight whorls of chambers which increase rapidly in size initially. The length of the biserial part varies considerably (from one to five whorls of chambers). Wall finely agglutinated. Aperture, a low arch at the base of the last chamber.

Dimensions: Length of Holotype: 0.77 mm.

Remarks: The wall is not calcareous and therefore, this species cannot be assigned to *Gaudryina* as currently reported by Loeblich and Tappan (1988).

Pseudogaudryinella **sp. 1**

Pseudogaudryinella sp. B Haig and Lynch, 1993, pl. 1, fig. 25–26.

Verneuilina howchini Crespin, 1953 (Plate IX, 3)

Verneuilina howchini Crespin, 1953, pl. 5, fig. 16.

Verneuilina howchini Crespin.—Scheibnerová, 1974, pl. 10, fig. 12.

Verneuilina howchini Crespin.—Haig, 1980, pl. 7, figs. 5–17.

Verneuilina canadensis Cushman.—McNeil and Caldwell, 1981, pl. 14, fig. 3. Superfamily ATAXOPHRAGMIACEA Schwager, 1877

?Areobulimina **sp.**

Description: Subconical, trochospiral test with 5 chambers per whorl. The chambers are inflated and separated by depressed sutures. Aperture, an interiomarginal arch; wall finely agglutinated.

Plate 9.

1. *Marssonella* sp., (×100), Sample 263-26-5; 126–130 cm.
2. *Verneuilinulla* sp. 2, (×55), Sample 263-23-2; 139–143 cm.
3. *Verneuilina howchini* Crespin, (×85), Sample 263-15-2; 113–117 cm.
4. *Verneuilinoides* sp., (×80), Sample 263-12-3; 79–83 cm.
5. *Verneuilinoides neocomiensis* (~~Mjatliuk~~), (×80), Sample 263-21-4; 120–124 cm.
6. *Verneuilinoides* aff. *crespinae* Loeblich and Tappan, (×120), Sample 263-21-4; 120–124 cm.
7. *Verneuilinulla* sp. 1, (×160), Sample 263-29-2; 76–80 cm.
8. *Bullopora* sp., (×45), Sample 263-26-4; 31–35 cm.
9. *Citharina harpa* Roemer, (×70), Sample 263-18-5; 101–105 cm.
10. *Vaginulinopsis excentrica* (Cornuel), (×60), Sample 263-18-5; 101–105 cm.
11. *Oolina* cf. *caudata* (Walker and Jacob), (×100), Sample 263-29-2; 76–80 cm.
12. *Lenticulina subangulata* (Reuss), (×70), Sample 263-29-2; 76–80 cm.
13. *Lingulina* sp. 1, (×105), Sample 263-4-4; 63–67 cm.
14. *Gyroidina infracretacea*, (×100), Sample 263-4-6; 46–50 cm.
15. *Gavelinella* sp., (×110), Sample 263-4-4; 63–67 cm.
16. *Schreibnerova* sp., (×100), Sample 263-4-6; 46–50 cm.

Myatiyuk

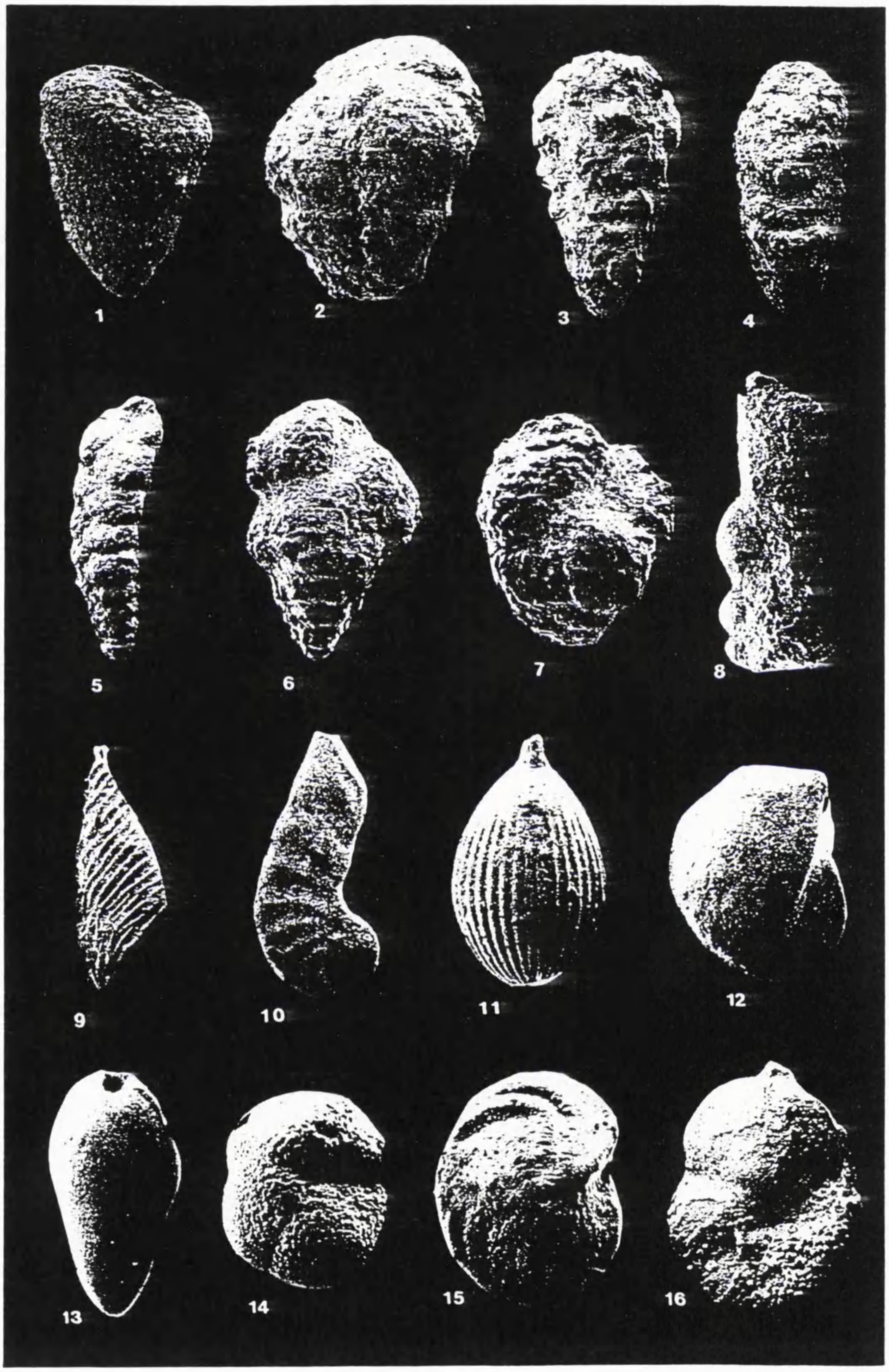

Plate 9.

Remarks: This species was only tentatively identified as the wall structure is unknown. Only two specimens were found.

Verneuilinulla sp. 1 (Plate IX, 7)

Description: Short, conical test, trochospirally coiled with four chambers per whorl. In some specimens the number of chambers reduces to three in last whorls. Slit aperture at the base of the last chamber.

Remarks: A relatively rare species, occurring at the base of Hole 263.

Verneuilinulla sp. 2 (Plate IX, 2)

Description: Subconical test, initially trochospiral, becoming triserial. Chambers are very inflated and separated by markedly depressed sutures (with supporting pillars). Aperture is an interiomarginal arch at the base of the last chamber. Wall finely agglutinated.

Remarks: Only one specimen was found. Scheibnerová (1974) tentatively identified one similar specimen in Core 263-19CC as *Jarvisella* sp.

Remesella sp.

Remarks: This species occurs rarely in Cores 263-9R-3 to -4-R4.

Superfamily TEXTULARIACEA Ehrenberg, 1838

Marssonella sp. (Plate IX, 1)

"*Textularia*" sp. 1 (Plate VIII, 3–5)

Textularia wilgunyaensis Crespin.—Scheibnerová, 1974.

Description: Elongate, tapering, biserial test with 8–11 pairs of chambers increasing gradually in size. Wall finely agglutinated, sutures depressed and slightly oblique. Slit aperture at the base of the last chamber.

Remarks: The wall is not calcareous and this species cannot be assigned to *Textularia* as currently defined by Loeblich and Tappan (1988).

Calcareous benthic foraminifera

Superfamily NODOSARIACEA Ehrenberg, 1838

Laevidentalina communis (d'Orbigny, 1826)

Nodosaria communis d'Orbigny, 1826, p. 254.

Dentalina communis (d'Orbigny).—Bartenstein and Bolli, 1986; pl. 2, figs. 36–37.

Laevidentalina debilis (Berthelin, 1880)

Marginulina debilis Berthelin, 1880, pl. 3, fig. 28.

Lenticulina (*Vaginulina*) *debilis* (Berthelin). Moullade, 1984, pl. 3, fig. 13. ***Frondicularia hastata*** Roemer, 1842

Frondicularia hastata Roemer 1842, pl. 7B, fig. 5.—Weidich, 1990, pl. 25, fig. 21.

Citharina harpa Roemer, 1841 (Plate IX, 9)

Citharina harpa Roemer, 1841, pl. 15, fig. 13.

Citharina harpa Roemer.—Riegraf, 1989, pl. 2, figs. 23–24.

Citharina pseudostriatula.—Bartenstein and Brand, 1951, pl. 7, fig. 182.

Range and occurrence: Valanginian–Barremian in Germany and western Indian Ocean.

Pyramidulina sceptrum (Reuss, 1863)

Nodosaria sceptrum Reuss, 1863, pl. 2, fig. 3.—Haig, 1982, pl. 2, figs. 29–32.

Lenticulina heiermanni Bettenstaedt, 1952

Lenticulina heiermanni Bettenstaedt, 1952, pl. 1, figs. 9–10.—Weidich 1990, pl. 20, figs. 15–16.

Lenticulina muensteri (Roemer, 1839)

Robulina muensteri Roemer, 1839, pl. 20, fig. 29a,b.

Lenticulina muensteri (Roemer).—Meyn and Vespermann, 1994, pl. 23, figs. 12–17 and pl. 24, figs. 1–17.

Lenticulina subangulata (Reuss, 1863) (Plate IX, 12)

Cristellaria subangulata Reuss, 1863; pl. 8, fig. 7.

Lenticulina subangulata (Reuss).—Moullade, 1984, pl. 3, fig. 3.

Saracenaria erlita Ludbrook, 1966

Saracenaria erlita Ludbrook, 1966, pl. 8, fig. 10.—Scheibnerová, 1976, text-figs. 84–85.

Saracenaria forticosta Bettenstaedt, 1952

Saracenaria forticosta Bettenstaedt, 1952, pl. 1, fig. 12 and pl. 2, fig. 13.

Saracenaria crassicosta Eichenberg.—Riegraf, 1989, pl. 1, fig. 18.

Astacolus calliopsis (Reuss, 1863)

Marginulina linearis Reuss, 1863, pl. 5, fig. 15.

Astacolus calliopsis (Reuss).—Meyn and Vespermann, 1994, pl. 10, figs. 15–16 and pl. 41, figs. 1–15.

Marginulina bullata Reuss, 1860

Marginulina bullata Reuss 1860, pl. 6, figs. 4–6.—Scheibnerová, 1976, pl. 29, fig. 1.

Vaginulinopsis excentrica (Cornuel, 1848) (Plate IX, 10)

Cristellaria excentrica Cornuel, 1848, pl. 2, figs. 11–13.

Vaginulinopsis excentrica (Cornuel).—Sliter, 1980, pl. 12, figs. 21–22 and pl. 13, fig. 1.

Planularia complanata (Reuss, 1845)

Cristellaria complanata Reuss, 1845, pl. 13, fig. 54a,b.

Planularia madagascariensis Espitalié and Sigal, 1963, pl. 6, figs. 8–11 and pl. 24.

Planularia complanata (Reuss).—Weidich, 1990, pl. 40, figs. 13–14.

V~~aginulina~~ recta Reuss, 1863

Vaginulina recta Reuss, 1863, pl. 2, figs. 14–15.

Citharina recta (Reuss).—Haig, 1982, pl. 6, figs. 31–34.

Ramulina tappanae Bartenstein and Brand, 1951

Ramulina tappanae Bartenstein and Brand, 1951, pl. 11, figs. 305–307.—Riegraf, 1989, pl. 2, figs. 21–22.

Globulina prisca (Reuss, 1863)

Polymorphina prisca Reuss, 1863, pl. 8, fig. 8.

Globulina prisca (Reuss).—Bartenstein and Brand, 1951, pl. 10, fig. 286.

Oolina cf. *caudata* d'Orbigny, 1840 (Plate IX, 11)

Oolina caudata d'Orbigny, 1840, pl. 5, fig. 6.

Lagena cf. *caudata* (d'Orbigny).—Bartenstein and Brand, 1951, pl. 10, fig. 282 and pl. 13, fig. 352.

Superfamily DISCORBACEA Ehrenberg, 1838 *Gyroidina infracretacea* (Morozova, 1948) (Plate IX, 14)

Gyroidina nitida Reuss var. *infracretacea* Morozova, 1948, pl. 2, figs. 12–14.

Serovaina infracretacea (Morozova).—Haig, 1992, pl. 3, figs. 8–9.

Remarks: The genus *Serovaina* is considered to be a junior synonym of *Gyroidina* (S. Revets, pers. commun., 1994).

Some poorly preserved or single specimens of the genera *Laevidentalina*, *Frondicularia*, *Pyramidulina*, *Lenticulina*, *Lingulina* (Plate IX, 13), *Oolina*, *Bullopora* (Plate IX, 8), *Pleurostomella*, *Gavelinella* (Plate IX, 15), *Schreibnerova* (Plate IX, 16), *Globorotalites* and some *Polymorphinids* were recorded in open nomenclature.

Not in text: Bartenstein and Bolli (1986) and Bartenstein and Oertli (1977).

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