

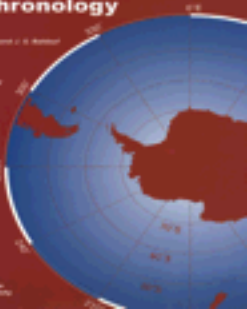
Reassessment of the Southern Ocean Biochronology

A. F. R. Hervey and J. R. Kennen

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A Reassessment of the Southern Ocean Biochronology

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Preface

Numerous biochronological models have been developed for the Southern Ocean based on coring results from the various Deep Sea Drilling Project and Ocean Drilling Program expeditions to this region. These models are based on combining micropalaeontological datums, including the first and last occurrences and sometimes the first common or abundant occurrences of individual species with the record of magnetic polarity reversals.

Previous biostratigraphical age models represent an amalgamation of cruise-specific micropalaeontological datums derived from specific geographical sectors of the Southern Ocean and from other ocean basins. In the development of these models previous workers were constrained by limited sedimentary sequences containing an integrated biostratigraphical (siliceous and calcareous microfossils) and magnetostratigraphical events.

The results presented here integrate data sets generated through previous studies into a Southern ocean-wide perspective. The biostratigraphical (diatoms, radiolarians, and calcareous nannofossils) and magnetostratigraphical data

sets are reviewed, integrated, calibrated, and reinterpreted to the Geopolarity Timescale of Cande & Kent (1995) providing a comprehensive Southern Ocean data base. In doing so, this study identifies inconsistent chronostratigraphical ranges of many previously used biostratigraphical markers thereby questioning the usefulness of these events within the Southern Ocean. The reassessment of previous data sets results in the recognition of 13 primary events which are chronostratigraphically useful throughout the Southern Ocean for the Late Eocene to Recent. Twenty additional events are identified as potentially stratigraphically useful; however further refinement of their spatial and/or temporal distribution is required. The limited number of primary events suggests that the biostratigraphy in the Southern Ocean is less sophisticated than currently assumed.

The integrated approach applied in this study provides a reassessment of the stratigraphy previously established for the 18 holes re-examined. The revised stratigraphy indicates typically more complete sequences compared to previous interpretations.

Acknowledgements

This study was completed with financial support from the National Environmental Research Council, Grant No. NERC-GST/02/698 to the Paleooceanography of the Southern Ocean Working Group (PALSOS) at the University of Wales, Cardiff. The group consisted of Rob Kidd, Tony Ramsay, Tim Sykes (University of Wales, Cardiff), Jack Baldauf and Tom Davies (Texas A&M University, USA) and J.-Y. Royer (Villefranche-sur-Mer, France). Numerous individuals assisted in completing this study and we specifically thank Rosie Sada, Doris Cooley and Tom Parmesen for their dedication, patience and thoroughness.

The manuscript was reviewed by John Barron, Lloyd Burckle and Sherwood Wise, and we are grateful for their critical reviews and constructive comments. We also thank our families who have endured the endless hours focused on this project and who, at times, lived with the flow of the Southern Ocean and the chill of the Antarctic.

Rob Kidd died in June 1996. He was an enthusiastic advocate for the Ocean Drilling Program and for synthesis investigations of ocean drilling data. This study is dedicated to Rob who was a valued colleague and a good friend.

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Introduction

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Introduction

Understanding Earth's climatic history has lead researchers to explore the glacial history of Antarctica and its role in the Earth's climate system. Scientists have used the information recorded both on the continent and from the surrounding marine sediments. Attention to the deep sea record has focused on the use of proxy indicators such as ice-rafted detritus, sedimentological variations, stable-isotope records and changes in faunal and floral assemblages to identify fluctuating ice sheets and changes in continental ice volume. Dating of specific geological events has relied on microfossil biostratigraphy with calibration of specific biostratigraphical datums (e.g. first and last occurrences) to polarity stratigraphies. In the absence of polarity records, dating of biostratigraphical events was based on known calibrations and/or stratigraphical successions of specific species from regions other than the Southern Ocean. For example, Miocene diatom events in the Southern Ocean were typically assigned ages based on the known ranges of the species in the North Pacific. The chronological framework, based on imported microfossil datums, was used to calibrate the ages of datums specific to the Southern Ocean, i.e. a process involving secondary correlation. These approaches assumed isochroneity of events between oceans.

The biochronological framework in this paper is based on the results of the numerous shipboard and shorebased scientists who completed detailed analyses of the sediments recovered at the 59 Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) Southern Ocean sites (Fig. 1; Table 1). Their contributions have made significant advances in the understanding

of species biogeography, evolutionary succession and provide the cornerstone for developing a biochronological framework for the Southern Ocean.

Following 23 years of scientific ocean drilling, it is critical that the current biochronological model be evaluated for overall reliability and usefulness throughout the Southern Ocean and the assumption of isochroneity of specific biostratigraphical events between oceans is tested. This current study incorporates diatom, calcareous nannofossil, radiolarian and palaeomagnetic data sets from numerous Southern Ocean researchers (Table 2) to test the ocean wide isochroneity of currently used biostratigraphical events and ensure a consistent and coherent biochronological model for the Southern Ocean.

Table 1. Latitude and longitude of sites occupied by the Deep Sea Drilling Project and the Ocean Drilling Program position south of 40° southern latitude

Site	Latitude	Longitude
514	46°02.77'S	26°51.29'W
689	64°31.01'S	03°06.00'E
690	65°09.63'S	01°12.30'E
691	70°44.54'S	13°48.66'W
692	70°43.45'S	13°49.21'W
693	70°49.89'S	14°34.41'W
694	66°50.83'S	33°26.79'W
695	62°23.48'S	43°27.10'W
696	61°50.95'S	42°55.98'W
697	61°48.63'S	40°17.27'W
698	51°27.51'S	33°05.96'W
699	51°32.54'S	30°40.62'W
700	51°31.99'S	30°16.70'W
701	51°59.08'S	23°12.74'W
702	50°56.79'S	26°22.13'W
703	47°03.04'S	07°53.68'E
704	46°52.76'S	07°25.25'E
736	49°24.12'S	71°39.61'E
737	50°13.67'S	73°01.97'E
738	62°42.54'S	82°47.25'E
739	67°16.57'S	75°04.91'E
740	68°41.22'S	76°43.25'E
741	68°23.16'S	76°23.02'E
742	67°32.98'S	75°24.27'E
743	66°54.99'S	74°41.42'E
744	61°34.66'S	80°35.46'E
745	59°35.71'S	85°51.60'E
746	59°32.82'S	85°51.78'E
747	54°48.68'S	76°47.64'E
748	58°26.45'S	78°58.89'E
749	58°43.03'S	76°24.45'E
750	57°35.54'S	81°14.42'E
751	57°43.56'S	79°48.89'E

Table 2. Previous shipboard and shorebased studies contributing to the development of the biochronological model presented in this volume

<i>Diatoms</i>	
Baldauf & Barron (1991)	Leg 119
Ciesielski (1983)	Leg 71
Ciesielski (1991)	Leg 114
Fenner (1991)	Leg 114
Gersonde <i>et al.</i> (1990)	Leg 113
Gombos & Ciesielski (1983)	Leg 71
Gombos (1976)	Leg 36
Harwood & Maruyama (1992)	Leg 120
McCollum (1975)	Leg 28
Schrader (1976)	Leg 35
Weaver & Gombos (1981)	Other
<i>Radiolarians</i>	
Abelmann (1990)	Leg 113
Abelmann (1992)	Leg 120
Caulet (1991)	Leg 119
Lazarus (1990)	Leg 113
Lazarus (1992)	Leg 120
Ling (1991)	Leg 114
Takemura (1992)	Leg 120
Weaver (1976)	Leg 35
Weaver (1983)	Leg 71
<i>Calcareous nannofossils</i>	
Aubry (1992)	Leg 120
Chen (1975)	Leg 28
Crux (1991)	Leg 114
Gard & Crux (1991)	Leg 114
Madile & Monechi (1991)	Leg 114
Pospichal & Wise (1990a)	Leg 113
Pospichal & Wise (1990b)	Leg 113
Wei & Thierstein (1991)	Leg 119
Wei & Wise (1990)	Leg 113
Wei & Wise (1992a,b)	Leg 120
Wise & Wind (1977)	Leg 36
Wise (1983)	Leg 71
<i>Magnetics</i>	
Clement & Hailwood (1991)	Leg 114
Hailwood & Clement (1991a)	Leg 114
Hailwood & Clement (1991b)	Leg 114
Heider <i>et al.</i> (1992)	Leg 120
Inokuchi & Heider (1992)	Leg 120
Keating & Saka (1991)	Leg 119
Ledbetter (1983)	Leg 71
Salloway (1983)	Leg 71
Sakai & Keating (1991)	Leg 119
<i>Others</i>	
Barron <i>et al.</i> (1991)	Leg 119
Harwood <i>et al.</i> (1992)	Leg 120

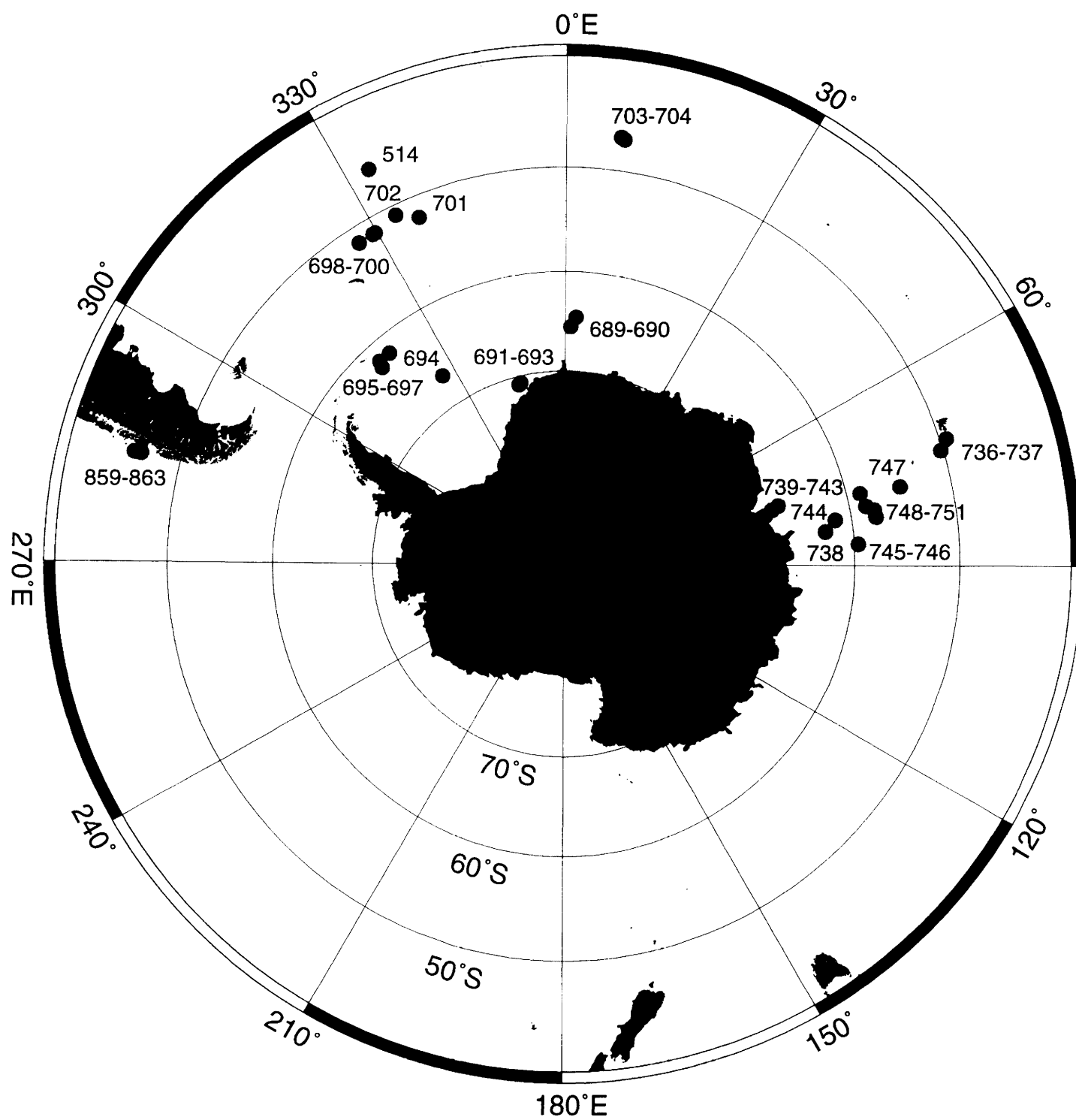


Fig. 1. Geographic location of sites occupied by the Deep Sea Drilling Project and the Ocean Drilling Program South of 40° Southern latitude. Sites used in this study contain both microfossils (diatoms, radiolarians and or calcareous nannofossils) and a polarity record.

Previous work

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Previous work

Biochronological models for the Southern Ocean have developed since the mid 1960s and early 1970s and have accompanied the completion of numerous biostratigraphical studies during the last 30 years. The voluminous bibliographic literature available for discussion has been limited here to selected articles that focus primarily on the development of diatom and radiolarian stratigraphies and the calibration of these stratigraphies to a Geopolarity Timescale (GPTS). This focused discussion reflects the emphasis of these stratigraphies in this current study.

Prior to the DSDP and the ODP expeditions to the Southern Ocean, calibration of microfossil datums to a magnetostratigraphy was limited to stratigraphical successions obtained from relatively short piston cores (generally less than 10 m). This practice established age constraints for microfossil datums within the uppermost sedimentary sequence, i.e. approximately the last 4 million years. Age determination for older sequences was based on estimates derived from secondary and indirect correlations to a magnetostratigraphy. The introduction of DSDP and ODP cruises to the Southern Ocean, commencing with Leg 28 (Hays *et al.* 1975) and continuing through Leg 120 (Wise *et al.* 1992) has both expanded the geographical coverage and the stratigraphical extent of sequences in which direct calibration of biostratigraphical data is possible.

The current Cenozoic biochronological framework results directly from the eight DSDP and ODP Southern Ocean expeditions (DSDP Legs 28, 35, 36, 71; ODP Legs 113, 114, 119, and 120). The biochronological framework has been refined with each expedition, as additional sedimentary sequences with integrated magnetostratigraphical and biostratigraphical records were recovered. Refinement of this framework also continued with advances in species concepts, floral and faunal diversity, and an improved understanding of species biogeography. The Southern Ocean biochronological framework is based predominantly on diatom and radiolarian biostratigraphies for middle Miocene and younger sediments and diatom, radiolarian and calcareous nannofossil biostratigraphies for the lower Miocene and older sediments.

DSDP Leg 28

Deep Sea Drilling Project Leg 28 (Hays *et al.* 1975) was designed to explore the long-term glacial, climatic, biostratigraphical and geological history of Antarctica. Fourteen holes were completed at 11 sites, and Oligocene to Holocene sediments were recovered. Biostratigraphies for most microfossil groups were completed independently of obtaining a magnetostratigraphy. The results of McCollum (1975) and Chen (1975) are pertinent to this study. McCollum (1975) building on the previous work of Jousé *et al.* (1963), Donahue (1970) and Abbott (1972) established a diatom zonation (Fig. 2) consisting of 12 middle Miocene and younger zones based on the first occurrence (FO) or last occurrence (LO) of specific species. Age assignments for specific datums were based on previous calibrations of these datums to a magnetostratigraphy from piston cores (see Donahue 1970; McCollum 1975; Weaver & Gombos 1981) which was applicable for the youngest approximately 4.5 million years interval. The Pliocene and younger diatom zones established were based on the stratigraphical ranges of species endemic to the Southern Ocean. The Miocene zones were based on the stratigraphical ranges of specific species known from the North Pacific and relied on the studies by Burckle (1972), Koizumi (1972) and Schrader (1973). For example, McCollum (1975) equated the LO of *Denticulopsis lauta* (previously referred to as *Denticula lauta*) with the 'A' event of Magnetic Epoch 7 based on a similar placement by Schrader (1973) at DSDP Site 173 which is positioned in the California Current. McCollum (1975) also used the comparative ranges of Miocene diatoms, calcareous nannofossils and foraminifera zonal markers.

Chen (1975) used the previously defined radiolarian stratigraphical framework established by Hays (1965) and Hays & Opdyke (1967) based on piston core data. Zonal definitions, however, were

modified by Chen (1975) to use the last occurrence rather than the last common occurrence (LCO) of specific species. In addition, Chen (1975) established eight new zones based on the stratigraphical ranges of selected species. This stratigraphy was correlated to the Geomagnetic Polarity Time Scale (GPTS) of Opdyke *et al.* (1966) and provided a framework for the youngest c. 4.5 million years.

Burns (1975) described the distribution of nannofossil assemblages, but did not assign these to recognized zones. This omission was deliberate and served to emphasize the sporadic occurrence of low latitude zonal markers defined by Martini (1970), Martini & Worsley (1970) and Bukry (1973b). Bukry (1975) used the results obtained by integrating calcareous nannofossil, silicoflagellate and occasionally diatom data to assign calcareous nannofossil assemblages from Leg 28 samples within a modified version of the low-latitude coccolith zonation which he had established for the Caribbean (Bukry 1973). Bukry attributed the paucity of sphenoliths and discoasters in the calcareous nannofossil assemblages to the reduced tolerance of these forms to cooler conditions.

Leg 35

Leg 35 (Hollister *et al.* 1976) occupied four sites in the Pacific sector of the Southern Ocean to address both the tectonic and palaeoceanographic history of the region. Biostratigraphical studies were completed for most microfossil groups, but unfortunately a palaeomagnetostratigraphy was not obtained. A diatom biostratigraphy (Fig. 2) was established by Schrader (1976), and Weaver (1976) developed a radiolarian biostratigraphy. The diatom stratigraphy developed by Schrader (1976) integrated the Pliocene and Pleistocene zonations of McCollum (1975), but established new or modified zones for the Miocene and Oligocene. Modification of the Miocene zones resulted from differences between McCollum (1975) and Schrader (1976) in the stratigraphical ranges of selected species. The lack of independent age control for the Miocene sediments required that age determination was based on secondary correlations, including known species ranges from non-Antarctic regions. For example, Schrader (1976) defined the Miocene zones based on the known ranges of *Coscinodiscus lewisianus*, *Denticula hustedtii* (now referred to as *Denticulopsis hustedtii*), *Denticula nicobarica* (now referred to as *Crucidenticula nicobarica*) and *Coscinodiscus yabei* (now referred to as *Thalassiosira yabei*) in the North Pacific.

Weaver (1976) used the radiolarian zonation defined by Chen (1975) for DSDP Leg 28. This zonation was modified slightly, based in part on the sporadic occurrence of nominated taxa. For example, Weaver (1976) noted the sporadic occurrence of *Helotholus vema* and replaced this zonal indicator with the FO of *Desmospyris spongiosa*. The absence of radiolarian datums and generally poor preservation of Miocene radiolarians prevented the development of a detailed biostratigraphy for the Leg 35 sites.

Haq (1976) described calcareous nannofossil assemblages for Leg 35 sites. Poor recovery of calcareous sediments, coupled with the poor to moderate preservation of calcareous nannofossils assemblages prohibited the assignment of these assemblages within a zonal framework.

Leg 36

Leg 36 (Barker *et al.* 1976), on the Falkland Plateau examined the gateway history of the Drake passage and the history of the Antarctic bottom water production. The six sites occupied resulted in recovery of Cretaceous through Quaternary sediments. Neogene and Palaeogene microfossil stratigraphies were completed post-cruise for most major microfossil groups, with the exception of radiolarians. Gombos (1976) completed a diatom biostratigraphy and established eight late Palaeocene to early Miocene zones (Fig. 2). A palaeomagnetic stratigraphy was not available for independent age control and Gombos (1976) had to rely on previously

Age Ma	Series	DSDP								ODP				
		Gombos (1976) DSDP Leg 36	McCollum (1975) DSDP Leg 28	Schrader (1976) DSDP Leg 35	Weaver and Gombos 1981	Gombos and Cieselski (1983) DSDP Leg 71	Cieselski (1983) DSDP Leg 71	Fenner (1984,1985)	Cieselski (1986) DSDP Leg 90	NSDZ	Gersonde and Burckle (1991) ODP Leg 113	Baldauf and Barron (1991) ODP Leg 119	NSDZ	Harwood and Maruyama (1992) ODP Leg 120
0	Pleistocene		<i>C. lentiginosa</i>	<i>C. lentiginosa</i>	<i>C. lentiginosa</i>		<i>C. lentiginosa</i>		<i>C. lentiginosa</i>	20	<i>T. lentiginosa</i>	<i>T. lentiginosa</i>	21	<i>T. lentiginosa</i>
2	upper Pliocene	<i>C. elliptopora/ A. ingens</i>	<i>C. elliptopora/ A. ingens</i>	<i>C. elliptopora/ A. ingens</i>		<i>C. elliptopora/ A. ingens</i>		<i>C. elliptopora/ A. ingens</i>	19	<i>A. ingens</i>	<i>A. ingens</i>	20	<i>A. ingens</i>	
		<i>R. barboi</i>	<i>R. barboi</i>	<i>R. barboi</i>		<i>R. barboi</i>		<i>R. barboi</i>	18		<i>R. barboi</i>	19	<i>kerquelensis</i>	
		<i>N. kerquelensis</i>	<i>N. kerquelensis</i>	<i>N. kerquelensis</i>		<i>N. kerquelensis</i>		<i>N. kerquelensis</i>	17	<i>T. kolbei</i>	<i>T. kolbei</i>	18	<i>T. kolbei</i>	
		<i>C. kolbei/ R. barboi</i>	<i>C. kolbei/ R. barboi</i>	<i>C. kolbei/ R. barboi</i>		<i>C. kolbei/ R. barboi</i>		<i>C. kolbei/ R. barboi</i>	16	<i>C. vulnificus</i>	<i>C. vulnificus</i>	17	<i>T. vulnificus</i>	
4	lower Pliocene	<i>C. insignis</i>	<i>C. insignis</i>	<i>C. insignis</i>		<i>C. insignis</i>		<i>C. insignis</i>	15	<i>C. insignis</i>	<i>C. insignis</i>	16	<i>C. insignis</i>	
		<i>N. interfrigidaria</i>	<i>N. interfrigidaria</i>	<i>N. interfrigidaria</i>		<i>N. interfrigidaria</i>		<i>N. interfrigidaria</i>	14	<i>N. interfrigidaria/ C. insignis</i>	<i>N. interfrigidaria/ C. insignis</i>	15	<i>N. interfrigidaria</i>	
		<i>N. praeterfrigidaria</i>	<i>N. praeterfrigidaria</i>	<i>N. praeterfrigidaria</i>		<i>N. praeterfrigidaria</i>		<i>N. praeterfrigidaria</i>	13	<i>N. barronii</i>	<i>N. barronii</i>	14	<i>N. barronii</i>	
		<i>N. angulata</i>	<i>N. angulata</i>	<i>N. angulata</i>		<i>N. angulata</i>		<i>N. angulata</i>	12	<i>T. inura</i>	<i>T. inura</i>	13	<i>T. inura</i>	
6									11					
									10					
									9					
									8					
8	upper Miocene	<i>D. hustedtii</i>	<i>D. hustedtii</i>	<i>D. hustedtii</i>		<i>D. hustedtii</i>		<i>D. hustedtii</i>	7	<i>C. intersectus</i>	<i>C. intersectus</i>	12	<i>T. torokina</i>	
									6					
									5					
									4					
10		<i>D. hustedtii/ D. lauta</i>	<i>D. hustedtii/ D. lauta</i>	<i>D. hustedtii/ D. lauta</i>		<i>D. hustedtii/ D. lauta</i>		<i>D. hustedtii/ D. lauta</i>	3	<i>A. kennettii</i>	<i>A. kennettii</i>	11	<i>A. kennettii</i>	
									2					
									1					
									0					
12		<i>D. dimorpha</i>	<i>D. dimorpha</i>	<i>D. dimorpha</i>		<i>D. dimorpha</i>		<i>D. dimorpha</i>	6	<i>N. praecurta</i>	<i>N. praecurta</i>	10	<i>D. dimorpha</i>	
									5					
									4					
									3					
14	middle Miocene	<i>D. antarctica</i>	<i>D. antarctica</i>	<i>D. antarctica</i>		<i>D. antarctica</i>		<i>D. antarctica</i>	2	<i>D. hustedtii/ N. grossepunctata</i>	<i>D. hustedtii/ N. grossepunctata</i>	7	<i>D. hustedtii/ N. grossepunctata</i>	
									1					
									0					
									0					
16		<i>D. lauta</i>	<i>D. lauta</i>	<i>D. lauta</i>		<i>D. lauta</i>		<i>D. lauta</i>	1	<i>A. ingens/ D. maccollumii</i>	<i>A. ingens/ D. maccollumii</i>	6	<i>A. ingens/ D. maccollumii</i>	
									0					
									0					
									0					
18	lower Miocene	<i>D. antarctica</i>	<i>D. antarctica</i>	<i>D. antarctica</i>		<i>D. antarctica</i>		<i>D. antarctica</i>	0	<i>D. maccollumii</i>	<i>D. maccollumii</i>	5	<i>D. maccollumii</i>	
									0					
									0					
									0					
20														

Fig. 2. Comparison of the numerous Palaeogene to Quaternary diatom zonations defined for the Southern Ocean (modified from Baldauf & Barron 1991).

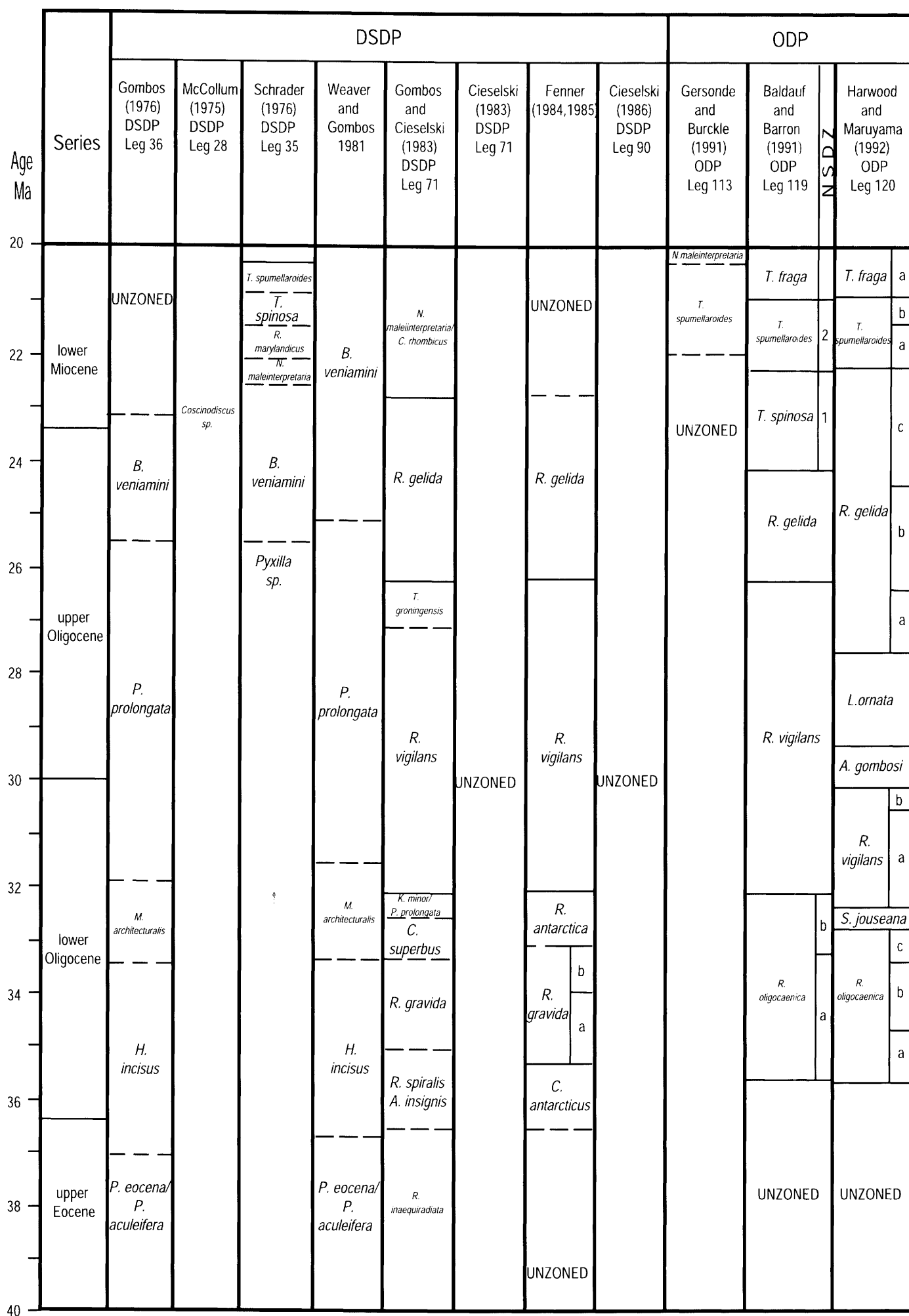


Fig. 2. (continued)

described ranges and secondary correlations to establish age estimates. He integrated diatom assemblages data with data derived from shipboard studies of calcareous nannofossils, radiolarians and silicoflagellate stratigraphies.

Wise & Wind (1976) used the standard low- or middle-latitude zonations of Bukry (1973a,b) for DSDP Leg 36. These workers discussed the influence of cooler climates on the geographical distribution of tropical guide species and the impact of their paucity, absence on biostratigraphical resolution in the higher latitudes. Wise & Wind (1976) recorded the highly restricted nature of Oligocene calcareous nanofloras and the increased restriction in the diversity of Miocene assemblages. Consequently they questioned the usefulness of low-latitude calcareous nannofossil zonations for Oligocene and post-Oligocene Leg 36 material. In addition to using the cooler water form *Isthmoithus recurvus* as a high-latitude, late Eocene zonal marker Wise & Wind (1976) proposed the establishment of two new high-latitude provincial zones (*Fasciculithus involutus* Zone and *Helioithus universus* Zone) for the late Palaeocene. These zones were considered to be of regional importance only.

The completion of DSDP Leg 36 culminated two seasons (Legs 28–29, 35–36) of Southern Ocean exploration and provided the opportunity to synthesize the established biochronological framework. Weaver & Gombos (1981), focusing on diatom biostratigraphical results, synthesized the results from the previous four cruises and re-examined sediments from DSDP Sites 266 and 328 to resolve taxonomic and stratigraphical differences between McCollum (1975) and Schrader (1976). They concluded that these differences, in part, reflected the occurrence of a hiatus that McCollum (1975) did not recognize. Based on these analyses, Weaver & Gombos (1981) established a new diatom zonation (Fig. 2) that incorporated portions of the zonation identified by McCollum (1975) for the Miocene through Pleistocene interval. Portions of these zones were modified, for example the *Nitzschia interfrigidaria* zone was changed because the last occurrence (LO) of *Nitzschia praeinterfrigidaria* was difficult to recognize due to the co-occurrence of several closely related taxa. They replaced this datum with the first occurrence (FO) of *Nitzschia interfrigidaria*. Similarly, Weaver & Gombos (1981) modified the Oligocene and early Miocene zones of Schrader (1976) based on stratigraphical ranges of diatoms from DSDP Site 328 in the Malvinas Outer Basin. Age estimates for the Miocene and older datums were based on secondary correlation or on extrapolation of average sedimentation rates at DSDP Site 278. This later method was used to derive ages for the LOs of *Denticulopsis lauta*, *Nitzschia denticuloides*, and *Nitzschia gressopunctata*.

Leg 71

Leg 71 (Ludwig *et al.* 1983) occupied two sites on the Falkland Plateau within the present-day Antarctic Convergence and two sites on the Mid-Atlantic Ridge, north of the present-day Antarctic Convergence. A good palaeomagnetic stratigraphy was obtained (Ledbetter 1983; Salloway 1983) for the last 4.0 million years, i.e. the interval represented by C4A–C5 (Opdyke *et al.* 1974) or the end of Anomaly 5a (La Breque *et al.* 1977). Identification of the polarity sequence was based primarily on the FO of the planktonic foraminifer *Globorotalia acostaesis* in DSDP Hole 512. Diatom biostratigraphies (Fig. 2) were completed by Ciesielski (1983) and Gombos & Ciesielski (1983) and a radiolarian biostratigraphy was completed by Weaver (1983).

Gombos & Ciesielski (1983) improved the Eocene to Miocene diatom biostratigraphy for the Southwest Atlantic and provided initial comparisons of the stratigraphical ranges of species between the high southern and lower latitudes. In this study, Gombos & Ciesielski (1983) identified 12 early Miocene to late Eocene zones with age estimates inferred from other microfossil biostratigraphies. Fenner (1984) proposed an alternative Palaeogene diatom zonation for the Southern Ocean in order to resolve inconsistent stratigraphical ranges between her study and that of Gombos & Ciesielski (1983). These differences reflect the different methodologies

employed. Correlation of Fenner's (1984) zonation with that of the low-latitudes is based on the first occurrences of cosmopolitan species (Fenner 1985).

Ciesielski (1983) substantially redefined the Neogene and Quaternary diatom zonation previously used by McCollum (1975) and Weaver & Gombos (1981). He established 15 diatom zones, of which five remained unchanged from previous definitions (Fig. 2). The new Pliocene zones were identified in order to improve the overall chronostratigraphical resolution, clarify previous zonal definitions or resolve inconsistent stratigraphical ranges. Ciesielski (1983) introduced several new Pliocene datums, including the LO of *Rhizosolenia barboi* (now referred to as *Simonseniella barboi*) and the LO of *Coscinodiscus vulnificus* (now referred to as *Thalassiosira vulnifica*). Age estimates were generally based on direct calibration to a magnetostratigraphy. Age estimates of datums in intervals lacking a polarity record relied on secondary correlations and age estimates derived at DSDP Site 513 (Ciesielski 1983). One exception was the use of a dated ash layer in Hole 513A which provided an age of 8.7 Ma for the LO of *Denticula lauta* (now referred to as *Denticulopsis lauta*). This age is approximately 0.8 my younger than that obtained by Koizumi (1977) for this event in the North Pacific.

The DSDP Leg 71 radiolarian biostratigraphy was completed by Weaver (1983) using a modified version of the Neogene biostratigraphy established by Chen (1975). Modification to the Pliocene portion consisted of subdividing the *Helotholus vema* zone of Chen (1975) into three zones. With the exception of the *Stichocorys peregrina* zone, datums used to identify these zones were directly calibrated to a polarity record. The age of the FO of *Stichocorys peregrina* was determined based on the relationship of this event to the first occurrence of the diatom *Thalassiosira praeconvexa* calibrated at that time to the upper reversed interval of Chronozone 6 in the low latitudes (see Weaver 1983; Haq *et al.* 1980). The late to mid-Miocene portion of Chen's (1975) zonation was modified to adjust for the inconsistent range of *Actinomma tanyacantha*. Age determinations for the Eocene and Oligocene interval are based on calibration of species ranges from low latitudes.

Wise (1983) described the calcareous nannofossil zonation for DSDP Leg 71. In this report he extends the use of provincial zones to Oligocene sequences and defines six new zones for this time interval. These are: the *Cyclicargolithus abisectus*, *Reticulofenestra bisecta*, *Chiasmolithus altus*, *Reticulofenestra daviesii*, *Clausicoccus fenestratus* and *Blackites spinosus* zones. These zonal units are correlated with the standard low- or middle-latitude Cenozoic zonations of Bukry (1973a,b) and Okada & Bukry (1980) and were erected to be used either in place of or in conjunction with the standard low-latitude zonal schemes. In addition the *Reticulofenestra oamaruensis* zone of Stradner & Edwards (1968) was recorded.

Leg 113

Ocean Drilling Program Leg 113 (Barker *et al.* 1988, 1990) commenced the second generation of exploration of the Southern Ocean and the first expedition by the ODP into the southern high latitudes. Nine sites were occupied in order to investigate the palaeoceanographical history of the Weddell Sea and the glacial history of Antarctica. Shipboard biochronology relied predominantly on diatoms and radiolarians for the Neogene and Quaternary, and calcareous microfossil stratigraphies for Miocene and older sequences. The GPTS of Berggren *et al.* (1985a,b) was used for chronostratigraphical analysis. ODP Leg 113 recovered Neogene sediment at eight sites and detailed palaeomagnetostratigraphies were recovered from Sites 689 and 690 (Spiess 1990). The recovery of a polarity record together with diatoms (Gersonde & Burckle 1990) and radiolarians (Abelmann 1990; Lazarus 1990) provided an opportunity to test and refine the previously established biochronology. Gersonde *et al.* (1990), in their synthesis of the siliceous biostratigraphy for the Leg 113 sites, focused on Holes 689B and 690B.

Gersonde & Burckle (1990) identified 16 diatom zones (Fig. 2) for the Neogene; six of these zones are modified from previous work

based on the inconsistent ranges of *Simonseniella barboi*, *Thalassiosira elliptopora*, *Nitzschia interfrigidaria* and *Nitzschia reinholdii*. They replaced these datums with species such as *Thalassiosira kolbei* and *Thalassiosira inura*. Gersonde & Burckle (1990) also noted that several events such as the FO of *Thalassiosira oestrupii*, the FO of *Denticulopsis praedimorpha* and the LO of *Denticulopsis hustedii* have similar ages between the Southern Ocean and the North Pacific. Specific events are calibrated directly to the polarity record of Spiess (1990) for the entire Neogene with the exception of the interval representing the late Miocene *Cosmiodiscus intersectus* and the late early to early mid-Miocene *Denticulopsis maccollumnii* zones. Ages within these intervals and for the early Miocene interval rely, in part, on the radiolarian biostratigraphy of Abelmann (1990).

Radiolarian biostratigraphies for Leg 113 sediments were completed by Abelmann (1990) for the Oligocene to mid-Miocene, and by Lazarus (1990) for the mid-Miocene to Pleistocene. Abelmann (1990) identified ten new zones, five of which were modified from those of Chen (1975). Modification and/or the replacement of Chen's zones was necessary to accommodate inconsistencies in stratigraphical ranges and differences in species concepts. In addition, Abelmann's (1990) zonation is based only on the first occurrence of radiolarian species, thus eliminating the inconsistent placement resulting from possible reworking of specimens in last occurrences. Datums used as zonal indicators were directly calibrated to the polarity record obtained by Spiess (1990). The mid-Miocene to Pleistocene radiolarian zonation used by Lazarus (1990) was also new and revised the zonations of Hays (1965) and Chen (1975). This new zonation also incorporated some of the datums previously defined by Weaver (1976) and Keany (1979).

The calcareous nannofossil stratigraphy for ODP Leg 113 was completed by Pospichal & Wise (1990) and Wei & Wise (1990). Pospichal & Wise were able to apply the low-latitude, number coded coccolith zonation of Okada & Bukry (1980) to interpret the stratigraphical distribution of Palaeocene to mid-Eocene calcareous nannofossil assemblages. They were, however, unable to achieve the higher biostratigraphical resolution that is obtainable by sub-zone recognition.

Wei & Wise (1990) described the mid-Eocene to Pleistocene calcareous nannofossil assemblages. The absence of calcareous nannofossil assemblages for most of the Neogene sequence prohibited the establishment of a formal calcareous nannofossil zonation for this interval. The calcareous nannofossil zonations proposed for the sub-Antarctic Palaeogene of New Zealand (Edwards 1971) and for the Eocene and Oligocene of the Falkland Plateau (Wise 1983) were shown to have limited value in the Weddell Sea sites. Wei & Wise (1990) recorded a succession of nine calcareous nannofossil zones from the middle Eocene to upper Oligocene sequence and correlated these with the calcareous nannofossil zones used by Okada & Bukry (1980) and Wise (1983). The recorded zones include: the *Reticulofenestra umbilica* and *Reticulofenestra reticulata* Zones, which were new; the *Discoaster saipanensis* and *Chiasmolithus oamaruensis* zones of Martini (1970), which were adopted without amendment as is the *Chiasmolithus altus* Zone of Wise (1983). The *Isthmolithus recurvus* Zone (Martini 1970), *Reticulofenestra oamaruensis* Zone (Stradner & Edwards 1968) *Blackites spinosus* Zone (Wise 1983) and *Reticulofenestra daviesii* Zone (Wise 1983) were emended to eliminate the use of species with variable ranges, time transgressive ranges and uncertain taxonomy. Wei & Wise (1990) also correlated calcareous nannofossil datums (LO *Reticulofenestra umbilica*; LO and FO *Isthmolithus recurvus*; FO and LO *Reticulofenestra oamaruensis*; FO and LO *Reticulofenestra reticulata*; FO and LO *Chiasmolithus oamaruensis*; LO *Chiasmolithus solitus*) with the magnetic time scale of Berggren (1985a, b).

Leg 114

Leg 114 (Ciesielski *et al.* 1988, 1991) investigated the tectonic basement and palaeoceanographic history of the Atlantic sector of the Southern Ocean. Partial polarity records were obtained from

the Miocene and Pliocene section at Site 701, the Eocene sediments at Site 702, Miocene to Eocene interval at Site 703 and the Pleistocene to lower Miocene section at Site 704 (see Hailwood & Clement 1991a, b; Clement & Hailwood 1991). These polarity sequences were correlated with the GPTS of Berggren *et al.* (1985a, b). Calibration of the Pliocene diatom biostratigraphy with the polarity record was completed by Fenner (1991). A radiolarian biostratigraphy for Leg 114 sediments was completed by Ling (1991).

Fenner (1991) completed a quantitative analysis of diatoms from Sites 699, 701 and 704 for the Pleistocene and Pliocene (Bruhnes through Gauss equivalent). Diatom age determinations were based on direct calibration to polarity records. Results from this study questioned the reliability of several previously used datums, including the LO of *Thalassiosira vulnifica*, the range of *Cosmiodiscus insignis*, and the LO of *Simonseniella barboi*. Fenner (1991) suggested that the use of the first abundant appearance (FAAD) and last abundant appearance (LAAD) of species provided more reliable datums than the true first or last occurrences. The isochrony of FAAD and LAAD datums between Sites 699, 701 and 704, during the late Matuyama magnetic epoch, was attributed to migrations of the Polar Front Zone that affected all three sites. Fenner postulated that the diachrony of the FAAD of *Thalassiosira kolbei* and the LAAD of *Thalassiosira vulnifica* between Sites 699 and 701 (isochronous) and 704, during the early Matuyama, resulted from varying palaeoceanographical conditions with stable antarctic conditions at Sites 699 and 701 and stable subantarctic conditions at Site 704.

Ciesielski (1991) investigated and compiled the stratigraphical ranges and relative abundances of selected diatom and silicoflagellate species for Holes 699A and 704A and 704B. His preliminary data for the Site 704 sequences revealed the completeness of the Neogene succession.

Crux (1991) used the calcareous nannofossil zonal scheme of Martini (1970) to interpret the Palaeogene to earliest Miocene succession in Leg 114. In the absence of datums used by Martini (1970), additional datums were imported from the zonal schemes of Edwards (1971), Wise & Constans (1976), Romein (1979), Varol (1981) and Wise (1983). No formal zonal scheme was proposed for the Miocene to Quaternary interval. Madile & Monechi (1991) focused on the upper Eocene to lower Oligocene sequences of Sites 699 and 703. These authors applied the zonal scheme for calcareous nannofossil assemblages proposed by Wise (1983) for the Falkland Plateau region. They assigned calcareous nannofossil assemblages to the *Chiasmolithus oamaruensis* and *Isthmolithus recurvus* Zones.

Wei (1991) described and compared the calcareous nannofossil magnetobiochronology for Sites 699A and 703A and compared these data with results from South Atlantic mid-latitude (Leg 72, Site 516) and other Southern Ocean (Leg 113, Sites 689 and 690; Leg 119, Site 744; Leg 120, Site 748) sites. He recognized the LO of *Reticulofenestra bisecta*, the LO of *Chiasmolithus altus* and the LO of *Isthmolithus recurvus* as consistent, reliable biostratigraphical markers from low to high latitudes. The LOs of *R. bisecta* and *C. altus* are influenced by the presence of hiatuses in the extremely high-latitude Sites 689, 690 and 744 and are therefore unreliable. The LO of *Reticulofenestra oamaruensis* is recorded as isochronous between four Southern Ocean Sites (689, 699, 744 and 748). Wei (1991) recorded an age of 32.9 Ma, i.e. 2.9 million years younger than the age assignment of Berggren *et al.* (1985a) based on mid-latitude data.

Leg 119

Ocean Drilling Program Leg 119 (Barron *et al.* 1989, 1991) addressed the palaeoceanographic history of the Indian Ocean sector of the Southern Ocean, the glacial history of Antarctica, and the tectonic history of the Kerguelen plateau. Eleven sites were occupied and recovered excellent Neogene siliceous microfossils and older siliceous and calcareous microfossils. The high-quality

Table 3. Calculated ages (Ma) for previously used biostratigraphical events using a calibration to the GPTS of Cande & Kent (1995)

Event	514t	514b	689Bt	689Bb	690Bt	690Bb	695At	695Ab	696At	696Ab	697Bt	697Bb	699At	699Ab	701At	701Ab
LO <i>Pterocanium trilobium</i>																
LO <i>Triceraspyris antarctica</i>																
LO <i>Pseudoemiliana lacunosa</i>																
FO <i>Emiliana huxleyi</i>																
LO <i>Thalassiosira elliptopora</i>	0.72	0.84											0.55	0.66		
LO <i>Hemidiscus karstenii</i>													0.00	0.03	0.23	0.26
LO <i>Simonseniella barboi</i>	1.82	1.83			2.93	3.09					3.86	4.05	1.68	1.92	1.48	1.58
FO <i>Nitzschia miocenica</i>																
FO <i>Nitzschia kerguelensis</i>	2.40	2.42			?	?	1.17	1.70	5.13	5.65						
LO <i>Actinocyclus ingens</i>	0.59	0.72	?	?	?	?	0.20	0.64	?	?	0.79	1.10	0.55	0.66	0.81	0.83
LO <i>Thalassiosira kolbei</i>	1.92	2.25	?	?	?	?					1.74	1.95	1.93	2.10	1.73	1.98
LO <i>Thalassiosira inura</i>			?	?	?	?	3.20	3.30	?	?	2.89	2.94				
LO <i>Thalassiosira vulnifica</i>	2.37	2.40					0.64	1.95			2.17	2.40	2.43	2.49	2.12	2.26
LO <i>Thalassiosira insigna</i>	3.20	3.26					2.11	2.77			2.94	3.08	2.68	2.72	2.47	?
LO <i>Nitzschia interfrigidaria</i>	2.91	2.93	?	?	?	?	2.89	3.11			3.08	3.11	2.72	2.82	2.47	?
LO <i>Denticulopsis dimorpha</i>													?	?		
LO <i>Nitzschia barronii</i>			?	?	?	?	3.11	3.12	?	?	1.10	1.25				
LO <i>Helicosphaera sellii</i>																
LO <i>Discoaster browerii</i>																
FO <i>Thalassiosira elliptopora</i>													?	?		
LO <i>Rouxia diploneides</i>																
LO <i>Nitzschia cylindrica</i>																
FO <i>Actinocyclus actinochilus</i>																
LO <i>Antarctissa cylindrica</i>			?	?	?	?	0.00	2.27								
LO <i>Cycladophora pliocenica</i>			?	?	?	?	0.00	2.27								
LO <i>Eucyrtidium calvertense</i>			?	?	?	?										
LO <i>Desmospyris spongiosa</i>	2.42	2.50	?	?	?	?	2.11	2.89			2.39	2.82	2.44	3.26	2.12	2.46
LO <i>Helotholus vema</i>	2.42	2.50	?	?	?	?	2.11	2.89			2.39	2.82	2.44	3.26	2.12	2.46
LO <i>Cycladophora davisiana</i>	2.59	2.63	?	?	?	?	2.11	2.89			3.08	3.34			2.12	2.46
LO <i>Nitzschia weaveri</i>	2.74	2.76					3.11	3.12					2.72	2.89	?	?
LO <i>Nitzschia reinholdii</i>	2.91	2.93											2.53	2.64		
LO <i>Cosmiodiscus intersectus</i>							4.80	4.89								
LO <i>Rouxia heteropolara</i>																
LO <i>Thalassiosira torokina</i>																
LO <i>Rouxia californica</i>																
LO <i>Stephanopyxis grunowii</i>																
LO <i>Nitzschia praeinterfrigidaria</i>			?	?	3.09	?	2.77	2.92	4.52	4.64	3.50	3.66	3.43	3.57		
FO <i>Stephanopyxis grunowii</i>																
FO <i>Thalassiosira lentiginosa</i>	2.91	2.93			?	?					3.40	3.49	?	?		
FO <i>Thalassiosira kolbei</i>	3.24	3.36	4.69	4.75							2.61	2.82				
FO <i>Thalassiosira inura</i>			4.84	4.89	4.76	4.81			6.18	6.77	?	?				
FO <i>Thalassiosira vulnifica</i>							2.89	3.11			2.61	2.82				
FO <i>Nitzschia praeinterfrigidaria</i>	3.24	3.36	6.13	6.54	4.82	4.85	4.83	4.86	4.76				5.25	5.52		
FO <i>Navicula wisei</i>																
FO <i>Nitzschia weaveri</i>	3.37	3.44					4.54	4.60					3.43	3.70		
LO <i>Lampromitra coronata</i>																
FO <i>Nitzschia interfrigidaria</i>	?	?	?	?	?	?	3.30	3.71			4.05	4.35	3.82	4.10		
LO <i>Prunopyle titan</i>			4.27	4.34	?	?	4.60	4.68					3.26	4.64		
LO <i>Nitzschia fossilis</i>																
LO <i>Rhizosolenia miocenica</i>																
FO <i>Helotholus vema</i>			4.44	4.49	?	?										
FO <i>Nitzschia barronii</i>			4.47	4.55	4.52	4.63	4.42	4.48	4.51	4.52	?	?				
LO <i>Thalassiosira complicata</i>									4.52	4.52	3.52	3.53				
LO <i>Denticulopsis hustedtii</i>							4.60	4.68	?	?	2.61	2.82	4.71	4.92		
FO <i>Thalassiosira complicata</i>																
LO <i>Neobrunia mirabilis</i>																
FO <i>Nitzschia praecurta</i>									?	?	?	?				
FO <i>Nitzschia angulata</i>													4.64	4.64		
FO <i>Thalassiosira oestrupii</i>			?	?					?	?	?	?				
LO <i>Thalassiosira burckliana</i>																
LO <i>Thalassiosira miocenica</i>																
LO <i>Hemidiscus cuneiformis</i>													4.98	5.25		
LO <i>Amphymenium challengerae</i>																
LO <i>Stichocorys peregrina</i>																
LO <i>Nitzschia marina</i>																

704Bt	704Bb	737At	737Ab	744At	744Ab	744Bt	744Bb	745Bt	745Bb	746At	746Ab	747At	747Ab	747Bt	747Bb	748Bt	748Bb	751At	751Ab
								0.00	0.09			0.84	0.95						
0.00	0.15											?	?			?	?	?	?
						0.11	1.76	0.79	1.27			0.38	1.70						
												0.85	0.95	0.75	0.80			?	?
0.00	0.07	3.81	3.84			1.76	2.32	0.26	0.44	7.99	8.01			?	?	?	?		
2.12	2.13	3.68	3.76			2.32	3.46	1.57	1.75			1.80	?			?	?	?	?
										6.70	6.74								
		?	?			1.76	2.32	2.12	2.18			?	?	?	?			?	?
0.58	0.64	7.17	7.35			0.11	1.76	0.44	0.61	8.27	8.32	0.37	0.53	0.67	0.75				
2.30	2.34					1.76	2.32	1.75	1.97			?	?	?	?	?	?	?	?
												0.69	0.85	?	?	?	?	?	?
3.00	3.13					1.76	2.32	2.23	2.33			?	?	?	?	?	?	?	?
4.42	4.57	3.28	3.60			1.76	2.32	2.18	2.23			?	?	?	?	?	?	?	?
		?	?			1.76	2.32	1.97	2.12			?	?	?	?	?	?	?	?
9.05	9.37					1.76	2.32	0.61	0.79	6.60	6.65	?	?	?	?	?	?	?	?
												1.17	1.32	3.60	?	?	?	?	?
2.47	2.65																		
2.96	3.13																		
						2.32	3.46	1.57	1.75			1.32	1.48	?	?	?	?	?	?
												?	?						
								2.23	2.33									?	?
												?	?	?	?			?	?
								0.61	0.65			0.84	0.95					?	?
						1.33	1.69	1.57	1.58			1.64	1.80			?	?	?	?
						1.76	3.46	0.61	0.62			?	?			?	?	?	?
		3.24	3.25			1.76	3.46	2.50	2.53			?	?			?	?	?	?
						1.76	3.46	2.48	2.50			?	?			?	?	?	?
								2.66	2.72			?	?			?	?	?	?
		?	?			3.46	?	1.75	1.97			?	?					?	?
4.42	4.57							2.71	2.83			?	?						
4.52	4.57																		
								2.18	2.23										
								2.12	2.18										
								2.33	2.43										
								2.71	2.83										
		?	?			2.32	3.46	2.71	2.83			?	?	3.30	?	?	?	?	?
		4.08	4.13			1.76	2.32					?	?	?	?				
		3.12	3.23			2.32	3.46	2.90	2.96			?	?	3.30	?	?	?	?	?
		4.72	4.77			2.32	3.46	4.80	4.89			5.89	6.14	4.17	?	?	?	?	?
3.31	3.32					2.32	3.46	2.71	2.83			?	?			?	?	?	?
		4.70	4.72			?	?	4.72	4.87			?	?	?	?	?	?	?	?
3.48	3.66	3.32	3.60			?	?	3.06	3.13			?	?	0.75	0.80			?	?
												?	?	3.30	?	?	?	?	?
		3.98	4.03			?	?	3.71	3.80			?	?	3.30	?	?	?	?	?
						1.76	3.46	3.44	3.52			?	?		?	?	?	?	?
4.57	4.63							3.95	4.08							?	?	?	?
								3.95	4.08										
		4.32	4.66					4.57	4.60			?	?	3.75	?	?	?		
		4.32	4.57			?	?	4.22	4.27			?	?	4.17	?	?	?	?	?
4.18	5.42																		
												?	?			?	?		
												?	?			?	?		
																		6.49	6.65
4.05	4.18																		
5.99	6.04	5.01	5.08			3.46	?	5.38	5.56			?	?	?	?	?	?	?	?
		6.93	7.08							6.81	6.86								
4.18	4.25	5.41	5.12			?	?	?	?					?	?			6.47	6.50
4.18	4.25							1.57	1.75										
5.42	6.42																		
5.42	6.42	5.07	5.12																
4.57	4.63																		

(continued)

Event	514t	514b	689Bt	689Bb	690Bt	690Bb	695At	695Ab	696At	696Ab	697Bt	697Bb	699At	699Ab	701At	701Ab
LO <i>Thalassiosira praeconvexa</i>																
LO <i>Thalassiosira convexa</i> v. <i>aspinosa</i>																
LO <i>Lamprocyclus aegles</i>																
FO <i>Thalassiosira praeconvexa</i>																
LO <i>Nitzschia porteri</i>																
FO <i>Lamprocyclus aegles</i>																
LO <i>Diartus hughesi</i>																
FO <i>Stichocorys peregrina</i>																
FO <i>Nitzschia reinholdii</i>			4.67	4.69									?	?		
FO <i>Thalassiosira insignia</i>							3.13	3.16								
FO <i>Nitzschia marina</i>																
LO <i>Denticulopsis lauta</i>													?	?		
FO <i>Navicula wisei</i>													?	?		
FO <i>Thalassiosira inura</i>																
FO <i>Rouxia heteropolara</i>									6.18	6.77	?	?				
LO <i>Cycladophora spongothorax</i>			8.28	8.51	4.88	?										
LO <i>Hemiaulus triangularis</i>																
FO <i>Simonseniella barboi</i>													?	?		
LO <i>Raphidodiscus marylandicus</i>																
FO <i>Cestodiscus peplum</i>																
LO <i>Thalassiosira convexa</i>																
FO <i>Thalassiosira convexa</i> v. <i>aspinosa</i>																
LO <i>Trinacria excavata</i>																
FO <i>Hemidiscus karstenii</i>													?	?		
LO <i>Asteromphalus kennettii</i>			7.02	7.68	?	?										
LO <i>Reticulofenestra pseudumbilica</i>																
LO <i>Amphymenium challengerii</i>																
LO <i>Thalassiosira burckliana</i>																
LO <i>Hemidiscus ovalis</i>																
LO <i>Actinocyclus ingens</i> v. <i>nodus</i>			7.68	8.07												
LO <i>Acrosphaera australis</i>																
FO <i>Cosmiodiscus intersectus</i>			8.23	8.32	?	?					?	?				
FO <i>Acrosphaera labrata</i>			8.28	8.51												
LO <i>Reticulofenestra gelida</i>			8.88	9.66	12.12	12.51										
FO <i>Acrosphaera australis</i>			10.02	10.13												
LO <i>Calcidiscus macintyreii</i>																
FO <i>Thalassiosira torokina</i>													?	?		
LO <i>Cycladophora humerus</i>			10.02	10.13	4.89	4.98										
FO <i>Eucyrtidium pseudoinflatum</i>			10.31	10.39	10.00	10.58										
FO <i>Nitzschia fossilis</i>																
LO <i>Diartus hughesi</i>																
LO <i>Hemidiscus cuneiformis</i>	2.60	2.62											?	?		
LO <i>Thalassiosira miocenica</i>																

704Bt	704Bb	737At	737Ab	744At	744Ab	744Bt	744Bb	745Bt	745Bb	746At	746Ab	747At	747Ab	747Bt	747Bb	748Bt	748Bb	751At	751Ab
5.69	5.92					?	?												
6.43	6.69																		
6.70	6.78																		
6.97	7.01									6.60	6.65								
8.04	8.12																		
8.10	8.25																		
8.39	8.46																		
8.39	8.46																		
8.79	8.81	?	?			?	?							5.19	5.49	?	?	6.49	6.65
8.79	8.81							2.90	2.96					3.30	?	?	?	?	?
8.79	8.81									8.12	8.18								
7.12	7.31					10.76	10.88												
																?	?	?	?
		6.36	6.41					3.95	4.08			?	?			?	?	?	?
										9.11	9.13	?	?	5.38	6.45			9.23	9.30
												?	?						
16.77	?																		
?	?			20.69	?														
								5.98	6.09										
								6.09	6.18										
								6.09	6.18										
										?	?								
										9.17	?	?	?	5.49	?	?	?	6.42	6.47
3.83	4.00					10.33	10.45					16.51	16.75			18.02	18.29	10.14	10.21
6.70	6.78																		
										9.17	?								
												?	?			11.51	11.54	6.49	6.65
11.90	12.18					?	?			6.60	6.65	?	?					12.17	?
						10.41	10.65												
8.79	8.81	?	?							8.44	8.48								
												6.20	?	5.19	5.38			?	?
														10.73	10.93	?	?	10.54	10.61
2.96	3.13					10.45	10.56					9.68	9.85			?	?		
		?	?			?	?			8.38	8.39	6.14	?	9.77	9.87	?	?	?	?
				8.23	8.27					8.23	8.27					?	?	10.79	10.84
						16.45	17.20			?	?	?	?	10.82	10.93	?	?	10.79	10.84
9.16	9.25																		
9.25	9.96																		
10.05	10.15					10.52	10.64					?	?						
10.15	10.30	6.57	6.68			?	?			?	?			5.19	5.49			6.49	6.65
				?	?	2.36	3.46			6.60	6.65			?	?	?	?	?	?
						10.76	11.12					?	?	10.53	10.62			10.90	10.97
10.51	10.60					10.13	10.24			?	?			8.88	9.77	?	?	9.63	9.69
		?	?			10.99	11.05												
10.57	10.62																		
						11.38	11.44					?	?	?	?	11.33	11.40	11.72	11.84
						?	?					?	?			?	?	11.83	11.89
						17.55	17.92					?	?					6.49	6.55
												?	16.73						
11.30	11.76																		
11.90	12.18					?	?	0.79	1.27			?	?			?	?	12.17	?
						?	?												
						11.32	?					?	?	?	?	?	?	12.03	12.08
14.16	15.05					?	?					?	?			?	?	12.78	?
						?	?					?	?			?	?	12.78	?
12.18	?																		
						?	?					?	?			?	?	13.66	14.40
15.06	15.13					15.21	15.55					13.41	13.60			?	?	13.67	13.84
?	15.05					?	?					14.31	14.49			?	?	?	?
?	?	?	?			?	?					14.13	14.31			?	?	14.08	14.15
						?	?			?	?								

(continued)

Table 3. (continued)

Event	514t	514b	689Bt	689Bb	690Bt	690Bb	695At	695Ab	696At	696Ab	697Bt	697Bb	699At	699Ab	701At	701Ab
FO <i>Dendrospyrus megaloccephalis</i>			14.13	?												
LO <i>Synedra jouseana</i>			?	?		14.51	14.74									
FO <i>Actinocyclus ingens</i> v. <i>nodus</i>			?	?		14.51	14.74									
LO <i>Coscinodiscus lewisianus</i>			15.07	15.11												
FO <i>Simonseniella barboi</i>																
LO <i>Coscinodiscus rhombicus</i>			15.11	15.16												
FO <i>Eucyrtidium punctatum</i>			15.16	?												
LO <i>Nitzschia maleinterpretaria</i>			?	?		14.51	14.74									
LO <i>Crucidenticula kanayae</i>			?	?	?	?										
FO <i>Denticulopsis lauta</i>																
FO <i>Nitzschia grossepunctata</i>			?	?	?	?										
FO <i>Nitzschia maleinterpretaria</i>					?	?										
LO <i>Thalassiosira fraga</i>			?	?	?	?										
FO <i>Calcidiscus macintyreii</i>																
FO <i>Actinocyclus ingens</i>	2.35	2.47	?	?	?	?					3.21	3.34				
FO <i>Denticulopsis maccollumii</i>			?	?	?	?										
FO <i>Calcidiscus leptoporus</i>																
FO <i>Crucidenticula kanayae</i>			?	?	?	?										
FO <i>Cycladophora golli regipileus</i>			18.01	18.15	?	?										
FO <i>Crucidenticula nicobarica</i>			18.18	18.49	?	?										
FO <i>Cyrtocapsella tetrapera</i>			18.02	18.31	?	?										
FO <i>Cyrtocapsella longithorax</i>			18.86	19.41	?	?										
LO <i>Thalassiosira aspinosa</i>					?	?										
FO <i>Coscinodiscus lewisianus</i>																
LO <i>Thalassiosira spumellaroides</i>			24.91	25.05	?	?										
FO <i>Raphidodiscus marylandicus</i>			19.51	19.74	?	?										
FO <i>Thalassiosira fraga</i>			19.51	19.74	?	?										
LO <i>Chiasmolithus altus</i>			19.76	20.29	?	?							26.54	26.80		
LO <i>Reticulofenestra bisecta</i>			19.76	20.29	?	?							24.22	24.30		
FO <i>Thalassiosira aspinosa</i>					?	?										
LO <i>Rocella gelida</i>			20.05	?	?	?							23.49	23.51		
LO <i>Rocella schraderi</i>																
LO <i>Rocella vigilans</i>			24.91	25.05	?	?										
LO <i>Bogorovia veniamini</i>													?	?		
LO <i>Lisitzina ornata</i>					?	?										
FO <i>Thalassiosira spumellaroides</i>			?	24.91	?	?										
FO <i>Rocella vigilans</i>			26.07	26.13	25.93	26.01										
FO <i>Rocella gelida</i>			26.07	26.13	25.93	26.01							25.33	25.71		
LO <i>Thalassiosira primalabiata</i>																
FO <i>Lisitzina ornata</i>					26.34	26.43										
LO <i>Reticulofenestra umbilica</i>			30.74	31.03	?	?							31.75	31.87		
LO <i>Isthmolitus recurvus</i>			31.83	32.35	?	?							32.31	32.38		
LO <i>Reticulofenestra oamaruensis</i>			33.58	33.78									33.48	?		
FO <i>Reticulofenestra oamaruensis</i>			34.55	34.59												
FO <i>Isthmolitus recurvus</i>			34.83	34.88	36.36	36.39										
FO <i>Cyclicargolithus abisectus</i>					30.75	?							30.99	31.49		
LO <i>Reticulofenestra reticulata</i>																
LO <i>Rhizosolenia oligocenica</i>																
LO <i>Synedra jouseana</i>																

Emboldened events are primary stratigraphical indicators based on this study. ? indicates the occurrence of undated specific biostratigraphical events. Dating these events was prohibited either by the absence of magnetic data and or the presence of an unconformity.

palaeomagnetostatigraphical record recovered from Sites 744–746, represents a nearly continuous sequence for the last 39 million years (see Keating & Sakai 1991; Sakai & Keating 1991). Barron *et al.* (1991) summarize the biochronological and magnetostratigraphical results correlated with the GPTS of Berggren *et al.* (1985a, b). The Leg 119 diatom biostratigraphy was completed by Baldauf & Barron (1991) and the radiolarian biostratigraphy was completed by Caulet (1991). Baldauf & Barron (1991) identified 24 diatom zones (Fig. 2). The Pliocene and Quaternary portion of this zonal scheme integrates the previous zones of Ciesielski (1983) and Gersonde & Burckle (1990). The Miocene portion is modified from the zonation of Gersonde & Burckle (1990). The Oligocene zones

are new. In this study, Baldauf & Barron (1991) questioned the reliability of *Asteromphalus kennettii* as a stratigraphical marker. These workers considered that the valves of this species were prone to dissolution and that its low preservation potential would impact the reliable stratigraphical placement of the FO and LO datums for this species. Baldauf & Barron (1991) elected to use the FO of *Denticulopsis dimorpha* rather than the FO of *Asteromphalus kennettii* as a zonal marker.

The radiolarian biostratigraphy for Leg 119 (Caulet 1991) incorporated the zones of Chen (1975), Weaver (1983) and Caulet (1982, 1985 and 1986). Although this zonation differs from zonal schemes previously used in the Southern Ocean, the principal

704Bt	704Bb	737At	737Ab	744At	744Ab	744Bt	744Bb	745Bt	745Bb	746At	746Ab	747At	747Ab	747Bt	747Bb	748Bt	748Bb	751At	751Ab
						?	?									?	?		
						?	?					14.49	14.80					14.52	14.59
14.16	15.05					15.55	15.89		8.07	8.12		14.49	14.68					14.29	14.36
?	15.05					1.76	2.32					?	?			?	?		
11.90	11.99																		
17.09	17.16																		
						16.40	16.80									?	?	16.42	16.53
12.18	?											14.56	14.80			11.51	11.54	16.53	16.56
?	?					16.95	17.02					?	?			11.51	11.54	?	?
?	15.05					16.95	17.02					?	?			?	?	?	?
18.68	19.28			25.98	26.22											?	?	17.64	17.94
?	?					16.80	16.95					17.97	18.38			?	?	?	?
?	16.84					?	?					17.17	17.38			11.51	11.54	16.03	16.53
?	15.05					15.89	16.40	2.23	2.33			?	?			?	?	?	?
16.77	16.85					16.95	17.02					16.74	17.14			?	?	16.53	16.66
						?	?					17.52	17.68			?	?	17.58	17.67
17.03	17.09					17.49	17.69					17.43	17.51			?	?	17.64	17.94
						17.20	?												
17.51	17.6					17.49	17.69											14.41	14.45
11.89	12.04																		
				19.61	19.78														
17.17	17.21																		
17.21	17.51																		
20.05	20.45			19.61	19.78											18.85	?		
				20.69	?	17.02	17.18					21.68	22.19						
20.75	21.54			19.85	20.02							20.33	20.57			?	?		
				26.04	26.11							25.96	25.97			25.93	?		
				25.93	25.76							23.80	?			?	?		
19.86	20.05																		
18.68	19.28			20.55	20.70							22.68	23.50						
18.68	19.28			20.01	20.24														
18.68	19.28							5.38	5.56			?	?			?	?		
20.75	21.54			20.69	?							20.79	21.26			?	?		
				25.80	25.86							23.41	23.78			?	?		
				20.55	20.70											?	?		
				30.69	30.83			?	?			26.53	?			30.29	30.52		
?	?			26.23	26.38							25.89	25.92			?	?		
				25.53	25.60							23.78	24.14			?	?		
				26.29	26.44							26.53	?						
				31.21	31.38														
				31.72	31.93											32.11	32.94		
				33.64	33.75											33.74	33.76		
				35.86	35.92														
				36.03	36.15														
				31.39	31.50											30.89	31.25		
				36.03	36.15														
				33.56	33.66														
				30.27	30.56														

stratigraphical datums recognized in the Leg 119 sediments can be correlated to the earlier stratigraphies including those of Abelmann (1992) and Lazarus (1992). Pliocene and Pleistocene radiolarian datums were directly calibrated to the polarity records obtained from Sites 744–746.

The upper Cretaceous and Cenozoic calcareous nannofossil biostratigraphy was completed by Wei & Thierstein (1991). These authors record the Neogene calcareous nannofossil zonation as unworkable. Zonal assignments for the middle Eocene to Oligocene sequence were based on the standard low-latitude zonation of Okada & Bukry (1980) including marker species that are recorded in the zonation of Martini (1970). In addition the zonation adopted

for the Weddell Sea (Leg 113) was modified to accommodate the common occurrence of some cool water marker species and the absence of some marker species in the zonations of (Martini 1970) and Okada & Bukry (1981).

Leg 120

Leg 120 (Wise *et al.* 1989, 1992) returned to the Kerguelen Plateau region to improve the understanding of the tectonic history of the plateau. Secondary objectives were to obtain continuous

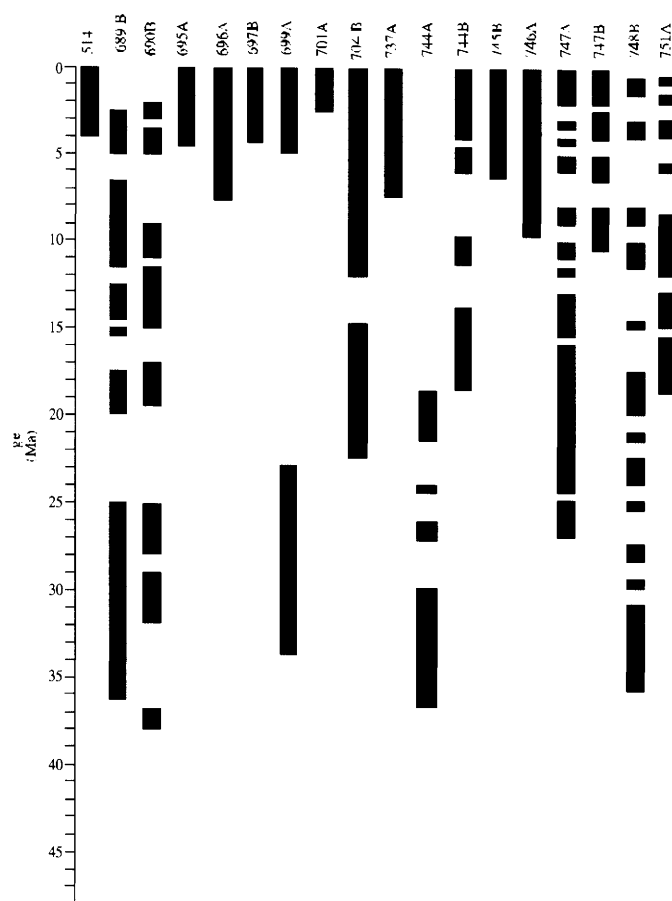


Fig. 3. Chronostratigraphical assignment of sediments recovered from the DSDP and ODP holes based on previous work (Table 2). The age-model used for each hole is based on the shipboard and subsequent shorebased investigations (see text for discussion). Solid bars represent intervals containing diatoms, radiolarians, or calcareous nannofossils and a polarity record.

stratigraphical sequences for biostratigraphical and palaeoceanographic analyses. This leg cored 12 holes at five sites and recovered an excellent polarity sequence from Sites 747, 748 and 751 (Heider *et al.* 1992; Inokuchi & Heider 1992). The biochronological results for the leg are discussed in Harwood *et al.* (1992) using the GPTS of Berggren *et al.* (1985a,b). The diatom biostratigraphy was completed by Harwood & Maruyama (1992) and the radiolarian stratigraphy by Takemura (1992), Abelmann (1992) and Lazarus (1992). The involvement of the same radiolarian workers with Legs 113, 119 and 120 minimized the potential for applying different species concepts.

Harwood & Maruyama (1992) defined 35 Oligocene to Pleistocene diatom zones (Fig. 2) based on the comparison of Leg 120 results with previous stratigraphies of Weaver & Gombos (1981), Ciesielski (1983, 1986), Gersonde & Burckle (1990) and Baldauf & Barron (1991). Diatom datums were calibrated directly to the polarity sequence of Heider *et al.* (1992) and Inokuchi & Heider (1992) for the last 31 million years (see also Harwood *et al.* 1992). The Pleistocene to mid-Miocene portion of the diatom zonation represented an integration between the zonations of Gersonde & Burckle (1990) and Baldauf & Barron (1991). The late Miocene diatom zones were newly defined and the early Miocene and Oligocene zones reflected a modified version of that presented in Baldauf & Barron (1991). Harwood & Maruyama (1992) expressed concern with several taxa based on their diachronous occurrences (*Thalassiosira vulnifica*, *Thalassiosira torokina*) and taxonomic uncertainties (*Thalassiosira inura*, *Thalassiosira jacksonii*, and *Thalassiosira gracilis*).

The Leg 120 radiolarian studies include an analysis of the Palaeogene (Takemura 1992), Miocene (Abelmann 1992) and Neogene (Lazarus 1992). Takemura (1992) elected not to use the

previous late Oligocene zonations of Abelmann (1990) based on the taxonomic uncertainty of the *Stylosphaera* group and stratigraphical uncertainties in the previously recorded species ranges. Instead, Takemura (1992) established three new zones for the upper Eocene and Oligocene sediments. Abelmann (1992) and Lazarus (1992) used previously established Leg 113 zonations for the Neogene sediments. Modifications to these zones including both redefinition of zonal boundaries, replacing zones or re-calibrating datums to the GPTS, were completed based on comparisons of Leg 113 and Leg 120 data. Lazarus (1990) made minor modifications to his previous zones and established three new zones. These modifications were completed based on the rare occurrence of the nominated taxa (e.g. *Acrosphaera australis*). The *A. australis* Zone of Lazarus (1990) is subdivided into three zones (*Amphymenium challengerii*, *Siphonospaera vesuvius* and *Acrosphaera australis*).

The stratigraphy of the Palaeogene calcareous nannofossils was described by Aubry (1991). Calcareous nannofossil assemblages were assigned within Martini's (1970) standard zonation scheme, which was chosen in preference to Bukry's biozonation (1973a, 1975) for its supposed broader geographical applicability.

Wei & Wise (1992a) considered the Oligocene to Quaternary calcareous nanoplankton assemblages. They were unable to assign Neogene assemblages to a zonal scheme, but suggested that non-traditional datums, which include the LO of *Reticulofenestra gelida*, the LO of *Reticulofenestra hesslandii* and the FO of *Calcidiscus leptoporus*/*C. macintyreii*, were potentially useful datums in Leg 120 sites. Neogene Zones (defined tentatively) are correlated with the zonation of Okada & Bukry (1980). Wei & Wise (1992a) applied the high-latitude zonation of Wei & Thierstein (1991) to interpret the upper Oligocene sequence. Wei & Wise (1992b) correlated selected calcareous nannofossil datums (LO and FO *Reticulofenestra perplexa*; LO *Cyclicargolithus floridanus*; and FO *C. leptoporus*/*C. macintyreii*) from Legs 113, 119 and 120 sites with the palaeomagnetic time scale of Berggren *et al.* (1985a).

Wei *et al.* (1992) investigated, in detail, the relationship between the Eocene to Oligocene calcareous nannofossil datums at Site 748B and the preliminary magnetostratigraphy of Schlich *et al.* (1989). This investigation resulted in a reinterpretation of the preliminary magnetostratigraphy which deviates significantly from the magnetostratigraphy presented by Harwood *et al.* (1992).

Wei (1992) addressed the problem of using numerical ages, derived from calibrating calcareous nannofossil and planktonic foraminiferal biostratigraphical datums with magnetostratigraphy at mid-latitudes, to interpret the magnetostratigraphy and construct age-depth curves for Southern Ocean sites. Many of these microfossil datums are shown to be diachronous from mid- to high latitudes. Wei (1992) used direct biomagnetostratigraphical correlations for Southern Ocean sites to eliminate the affects of diachroneity and provided an update on the Palaeogene chronology of eight ODP sites (690, 699, 700, 702, 703, 737, 738 and 748) in the Southern Ocean. The published magnetostratigraphies for some intervals from Sites 690, 699, 700, and 703 are reinterpreted.

The above discussion outlines the evolution of the Southern Ocean siliceous (diatom and radiolarian) and calcareous nannofossil biochronology and provides an understanding of the limitations of the current biochronological model. Age constraints (standardized to the GPTS of Cande & Kent 1995) of the datums used by each worker to construct this model are shown in Table 3. Of the 59 sites drilled south of 40° south, 18 holes at 16 sites contain sediment with both a polarity record and siliceous microfossils. Nine of these holes contain calcareous nannofossils. The chronostratigraphical assignment of sedimentary sequences, used in this study, based on previously published age models is shown in Fig. 3. The Pliocene–Pleistocene interval is represented at all sites and eight holes contain a continuous sequence for the last 5 million years; three holes have a continuous sequence for the last 10 million years. The interval from 10 to 20 Ma is recorded in the sediments of 11 sites and only seven sites contain sediment representing the interval older than 20 Ma. Figure 3 also illustrates the discontinuous nature and limited geographic coverage of the currently available data used to develop the biochronological framework presented here.

The development of the current biochronological model benefited from the improved core recovery achieved by the ODP. The limitations inherent in the model include:

- (1) the geographically and temporally limited nature of continuous stratigraphical sections containing both well preserved biota and a polarity record;
- (2) differences in taxonomic concepts used by different workers;
- (3) the lack of a consistent biostratigraphical framework for each microfossil group that is uniformly applied to all Southern Ocean sites (see Fig. 2 as an example);
- (4) inconsistencies in chronozone nomenclature (see discussion below);
- (5) the use of qualitative versus quantitative data in the definition of datums (e.g. the last occurrence compared with the last common occurrence of a species);
- (6) problems in defining species ranges introduces uncertainty concerning the reliability of datums used to interpret the polarity record.

The advances made in the Southern Ocean biochronology during the last 30 years are significant and reflect the ever increasing data sets and refinement in stratigraphical resolution. The requirement to evaluate the current biochronological framework has been noted for sometime with initial efforts being completed by Thierstein *et al.* (1995) for the Neogene world ocean and by Wei (1992) and Wei *et al.* (1992) for the Palaeogene Southern Ocean. Thierstein *et al.* (1995) integrated published biostratigraphical data for Neogene intervals from 94 DSDP and ODP sites. Data sets obtained for diatoms, radiolarians, calcareous nannofossils and planktonic foraminifers were reviewed and compared with palaeomagnetic data sets correlated to the GPTS of Berggren *et al.* (1985a, b). The

age model derived for each hole generally assumed that the original assignment of the polarity reversals to specific chronozones was accurate and the original assignment of palaeomagnetic reversals was rarely reassessed. The global approach employed focused on numerous microfossil assemblages with significant compositional differences between high and low latitudes and between the primary ocean basins. The stratigraphical potential of previously used microfossil datums was re-evaluated and compared between sites to determine the most reliable datums. Once this was completed, a new age-depth model was generated for each hole.

Wei (1992) used data sets for calcareous nannofossils and planktonic foraminifera and Wei *et al.* (1992) utilized data sets for calcareous nannofossils. These data sets were reviewed, compared with palaeomagnetic data sets, and also correlated to the GPTS of Berggren *et al.* (1995a, b). Wei (1992) and Wei *et al.* (1992) reinterpreted the magnetostratigraphies and constructed new age models for some Southern Ocean sites.

This study has used the pioneering studies of Wei (1992), Wei *et al.* (1992) and Thierstein *et al.* (1995) as its foundation and has adopted several of the same premises used by these workers. The approach used here differs from the studies of Wei (1992) and Wei *et al.* (1992) by including Palaeogene and Neogene data sets for calcareous and siliceous plankton and by the use of the GPTS of Cande & Kent (1995). The methodology, however, is similar to that employed by these investigators. This investigation differs from that of Thierstein *et al.* (1995) in scale and in methodology. This study develops a revised age model for data sets derived only from the Southern Ocean. The reassessment of the age model is based only on diatom, radiolarian and calcareous nannofossil data sets which are integrated with reinterpreted polarity records correlated to the GPTS of Cande & Kent (1995).

Methods

Site selection

Data sets obtained from 59 DSDP and ODP sites located south of 40°S were examined and 16 sites containing palaeomagnetic, diatom and calcareous nannofossil stratigraphies were selected for this study (see Table 1). All sites except DSDP Site 514 (Leg 71) were occupied during two campaigns (ODP Legs 113–114 and 119–120) into the Southern Ocean during 1987 and 1988. The majority of the sites are located between 46°02.77S and 65°9.63S degrees latitude (see Fig. 1). The one exception is Site 693 at 70°49.892S. The quality of the magneto-polarity history varies at each site as a consequence of either core recovery, disturbance, sampling or the scattered nature of the magnetization directions.

Calcareous nannofossils are common to abundant in sediments of Oligocene to Miocene age and are less common, rare or absent from the Pliocene through Pleistocene sequences. Exceptions include Holes 695A, 697B, 701A, 746A in which calcareous nannofossils are extremely rare or not recorded. Calcareous nannofossils are recorded in the upper Miocene sediments in Hole 696A. Diatoms are generally present throughout the Oligocene to Pleistocene sequences.

Palaeontological data sets

This study concentrates on the spatial and temporal distributions of the phytoplankton, diatoms and calcareous nannofossils. Both of these groups belong to the botanical Division Chrysophyta (Tappan 1980) and inhabit the photic zone of the world's ocean. These organisms respond to changing surface water conditions directly linked to changes in climate, surface ocean circulation and upwelling. The difference in the skeletal composition (diatoms – opaline silica; calcareous nannofossils – calcite) affects their preservation and fossilization. The temporal distribution of these organisms in the Southern Ocean is directly related to global cooling associated with increased ice volume and intensified thermal gradients during the late Neogene and Quaternary.

The siliceous zooplankton, represented by the radiolarians, live throughout the water column (Funnell & Riedel 1971) and respond to changes in surface, intermediate and deep water conditions. Their spatial and temporal distributions were used to test the biochronological model developed in this study. The preservation of their skeletal remains and their abundance in the Southern Ocean Pliocene and Pleistocene sediments confers a distinct advantage when compared to the sporadic distribution of the calcareous zooplankton (planktonic foraminifera) within sediments of similar age. In addition, the limited number of radiolarian stratigraphers analysing the faunas from the selected sites minimizes errors introduced by differences between specialists in taxonomic concepts or methodologies. For these reasons we have incorporated radiolarian rather than planktonic foraminiferal data sets into this study.

This study relies on data sets derived from the literature (Table 2) and no additional samples were examined. This approach was adopted to evaluate current biochronologies and to integrate these into a single Southern Ocean biochronology. In adopting this approach we recognize the following limitations.

Species concept

The data sets included in this study result from exploratory drilling spanning nine years between 1983 (Leg 71) and 1992 (Leg 120). Results from four of these expeditions were published between July 1990 and April 1992. Species concepts for the microfossil groups used in this study have advanced during this time resulting in refinement of species definition and identification of outliers within a population. These advances have resulted in the modification of

previous species concepts by segregation into several species, the identification of varieties or grouping of species.

The application of a species concept is influenced by an individual's interpretation and consistency in applying that concept. Difficulties arise when different concepts are applied to the same species. This issue may be magnified by an increased number of researchers applying non-uniform concepts. Differences in species concepts pertaining to the microfossil groups used in this study from the Southern Ocean were potentially minimized by the few specialists completing the biostratigraphies. Several of the later Southern Ocean studies, i.e. Wei (1991, 1992) and Wei & Wise (1992) for calcareous nannofossils; Baldauf & Barron (1991) and Harwood & Maruyama (1992) for diatoms; Lazarus (1992) for radiolarians have incorporated the species concepts used in earlier studies.

In our own effort the potential consequences of differing species concepts is reduced by the typical traits of stratigraphically useful indicators. These include: ease of identification, wide distribution, skeletal size and robustness and minimal intra-specific variation.

Taxonomic nomenclature

Modifications to taxonomic nomenclature have evolved as new information concerning species similarities and differences are identified. Advances in this field result primarily from use of the Scanning Electron Microscope (SEM) to define primary and secondary morphological characteristics used to identify genera and species. This particularly applies to diatoms and is best exemplified by subdivision of the genus *Denticula* into *Denticulopsis*, *Crucidenticula*, and *Neodenticula* (Yanagisawa & Akiba 1985) and by the incorporation of several forms of *Coscinodiscus* into *Thalassiosira* (Akiba & Yanagisawa 1985) or *Azpeitia* (Fryxell *et al.* 1986). We have applied the currently used nomenclatural concepts to data sets in this study.

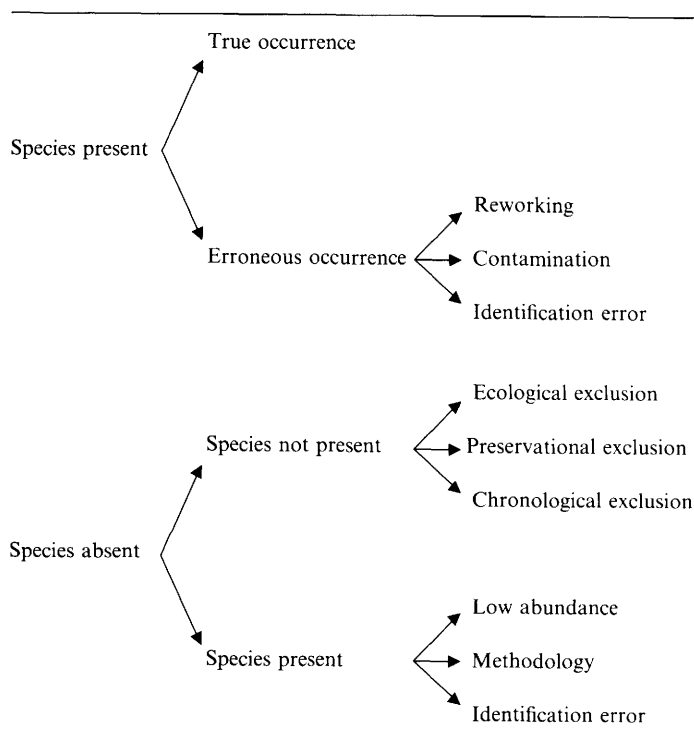
Data quality

Current biochronologies rely on datums, i.e. the first or last occurrence (FO or LO) of a species which has been calibrated to an independent age control such as magnetostratigraphy. Accuracy in the placement of an event (FO/LO) and the age calibration of the event dictates the accuracy and reliability of any given datum. Factors controlling the placement of each event are summarized in Table 4 which is modified from Gradstein *et al.* (1985). We use the stratigraphical placement of each event as identified by each worker and are unable to address most of the factors outlined in Table 4. This study, however, is especially sensitive to potential errors introduced by each worker and has required the careful scrutinizing of each data set to eliminate any inconsistencies.

We have eliminated informally designated species such as *Rouxia* species 1 of Gersonde & Burckle (1990) or *Rhizosolenia* species B of Harwood & Maruyama (1992). An exception to this is our use of the radiolarian species *Acrosphaera labrata* (Lazarus 1992), which is equivalent to *Acrosphaera* sp. 'conical pore' collo-sphaerid (Lazarus 1990). We have also eliminated any uncertain assignments such as *Nitzschia* aff. *porteri* (Gersonde & Burckle 1990) and *Nitzschia* cf. *praeinterfrigidaria* (Baldauf & Barron 1991). Group assignments were also removed from the data sets, for example the *Azpeitia tabularis* group of Gersonde & Burckle (1990). In cases where morphological forms of species were segregated, only the primary species designation was incorporated into the data set. Thus the stratigraphical occurrences of *Thalassiosira oliverana* (coarse and umbonatus), Harwood & Maruyama 1992, were not incorporated.

Typically we adhered to the stratigraphical occurrences of species as assigned by the investigators including their assessment

Table 4. Factors controlling the stratigraphical placement of biostratigraphical events (modified from Gradstein *et al.* 1985)



of reworking of specimens. In rare cases we have adjusted placement of first and last occurrences of selected species (e.g. when a single occurrence is isolated by numerous samples from its continuous stratigraphical range).

Previous workers have recognized the stratigraphical usefulness of abundance data and have defined datums based either on the first or last common occurrence or on the first or last abundance appearance of selected species. In regional settings such datums may prove reliable. We have not considered datums based on the first or last common occurrence or first or last abundance appearance in this study in order to minimize the subjectivity of the data set and also to avoid the influence of environmental factors on relative species abundance. Quantitative studies of diatom species distribution in the Southern Ocean indicate that relative abundances of diatom species were particularly sensitive to water-mass properties. Fenner (1991) speculated that temporal changes in water-mass dynamics of the Southern Ocean, particularly with respect to the position of the Polar Front Zone, influenced the isochroneity/diachroneity of quantitatively determined first and last abundance appearances of diatom species during the Matuyama magnetic epoch. Barron (1996) demonstrated that the relative percentages of diatom taxa, during a Pliocene warm interval (3.1–2.9 Ma) was related to a shift of the Polar Frontal Zone to a position 6° of latitude further to the south.

Calculation of the depths, in hole, of the first and last occurrence of a species represents the range between the sample in which the species is present and the adjacent sample.

Biostratigraphical zonations

Biostratigraphical zonations were continually refined with the addition of new data sets from the Southern Ocean. This holds true for the calcareous nannofossil, diatom and radiolarian biostratigraphies. Zonations are a convention that allow the placement of specific stratigraphical sequences into discrete arbitrary intervals and convey critical biochronological information to specialists and non-specialists. This study does not focus on zones, but uses FOs and LOs for stratigraphical evaluation and the establishment of an age model.

Magnetic data sets

Magnetic data sets obtained from the sites used in this study exhibit varying degrees of quality. These range from records with clear normal and reverse polarity, with directions close to the expected geocentric axial dipole directions, without excessive scatter (Category 1 of Clement *et al.* 1996), to records with a coherent and apparently stable remnant magnetization (Category 4 of Clement *et al.* 1996). In this latter category the dispersion is generally too great to allow polarity assignment. At most Southern Ocean sites, the correlation of the polarity directions is complicated by core recovery, drilling disturbance or sampling. Most Southern Ocean polarity records equate to Category 3 or 4 of Clement *et al.* (1996) as polarities appear to have been recorded, with unusually large amounts of scatter. In some cases, short polarity chrons may not be identified. An exception to this is the Palaeogene to Quaternary records in Holes 689B and 690B (Spiess 1990) and the Pliocene–Pleistocene record from Site 745 (Barron *et al.* 1991), which exhibit excellent polarity sequences.

Data collection. In the Southern Ocean the existence of few sedimentary records with recorded polarity histories is the primary limiting factor in the selection of sites. Of the potential factors influencing polarity history we have focused on inconsistencies in the magnetic history resulting from core disturbance, core recovery and sample frequency. We re-examined polarity records from each site concentrating on variations in the natural remnant magnetization (NRM) intensity and inclination. This was implemented in order to assess the placement of polarity reversals as identified by the various investigators. We are aware that other factors such as alternating field (AF) demagnetization levels, remagnetization of the drillstring, lithology and diagenesis may affect the quality of the magnetic data. With few exceptions, we have adhered to the stratigraphical placement previously identified polarity reversals.

Polarity calibration. Polarity timescales have evolved during and following the period of time represented by the acquisition of the data sets. On Leg 71, Salloway (1983) used the geomagnetic polarity timescale of La Brecque *et al.* (1977). Spiess (1990), Leg 113, applied the GPTS of Berggren *et al.* (1985a, b). During Leg 114, Hailwood & Clement (1991a; Site 699), Clement & Hailwood (1991; Site 701) and Hailwood & Clement (1991b; Site 704) also used the GPTS of Berggren *et al.* (1985a, b). Sakai & Keating (1991) and Barron *et al.* (1991) used the Berggren *et al.* (1985a, b) GPTS during Leg 119, but incorporated modifications proposed by Mankinen & Cox (1988). During Leg 120, Heider *et al.* (1992) and Inokuchi & Heider (1992) used the GPTS of Berggren *et al.* (1985a, b).

Nomenclature, identification of chronozones and sub-chronozones were all in a state of flux and workers who applied the Berggren *et al.* (1985a, b) geomagnetic time scale often modified the chronozone nomenclature of Berggren *et al.* (1985a, b) to more readily identify specific chrons or sub-chrons (Fig. 4). One example is that of Clement & Hailwood (1991) who used the GPTS of Berggren *et al.* (1985a, b) and the zonal nomenclature of La Brecque *et al.* (1983).

Cande & Kent (1992, 1995) proposed a new GPTS for the late Mesozoic and Cenozoic. This time scale reassesses the sea-floor anomalies from profiles obtained throughout the ocean and establishes a polarity sequence using a composite approach. The identification of new events and the assignment of new ages for polarity intervals required re-examination of all data sets used in this study for standardization of these data sets to the Cande & Kent (1995) time scale. The application of this new GPTS has required reassessing previous zonal interpretations to address the critical chronostratigraphical control, and to adjust for changes in the polarity pattern introduced by increased or decreased rates of sediment accumulation. In addition, the polarity pattern was modified by the newly interpreted continuity of the stratigraphical record.

(a)

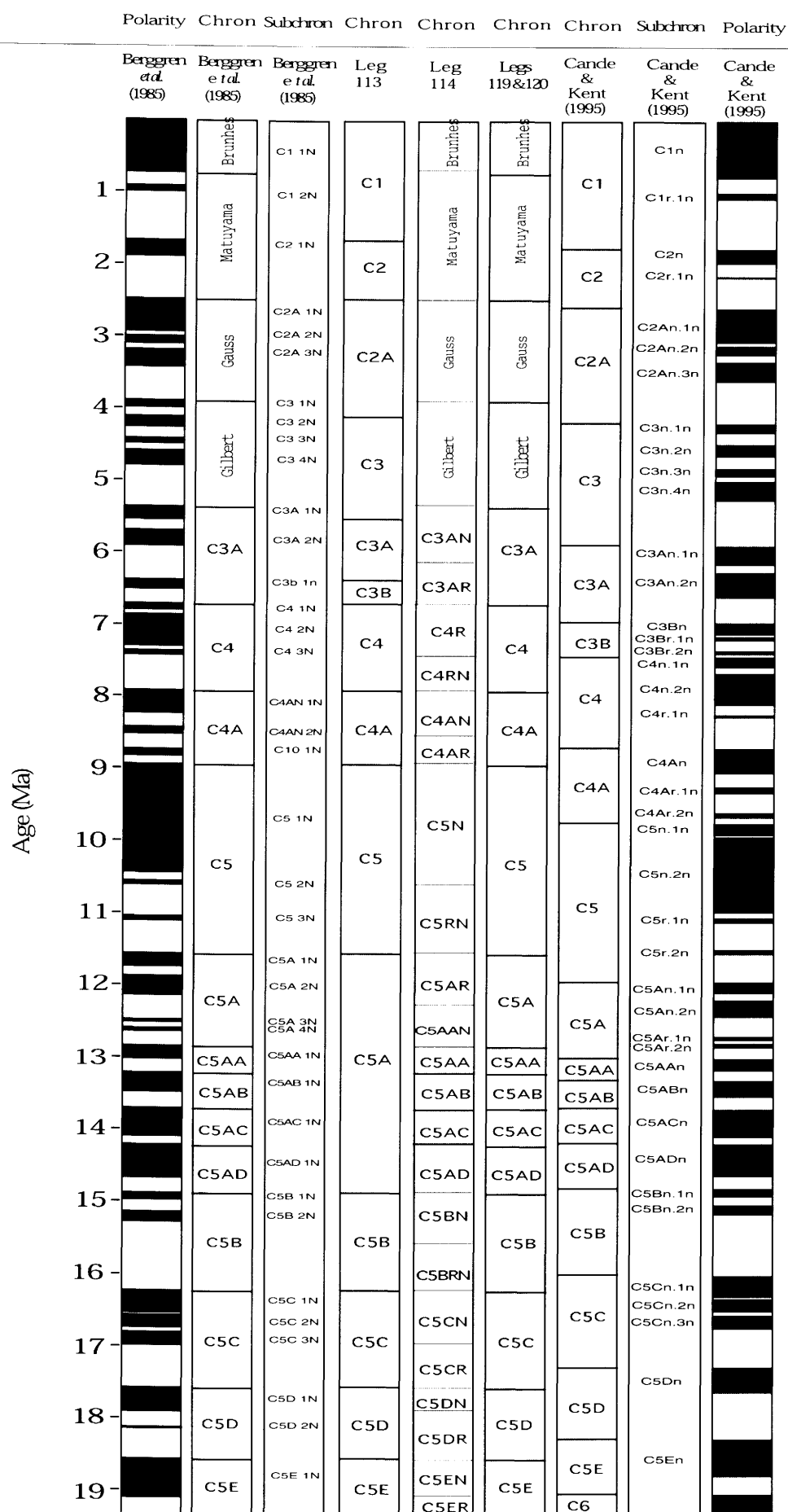
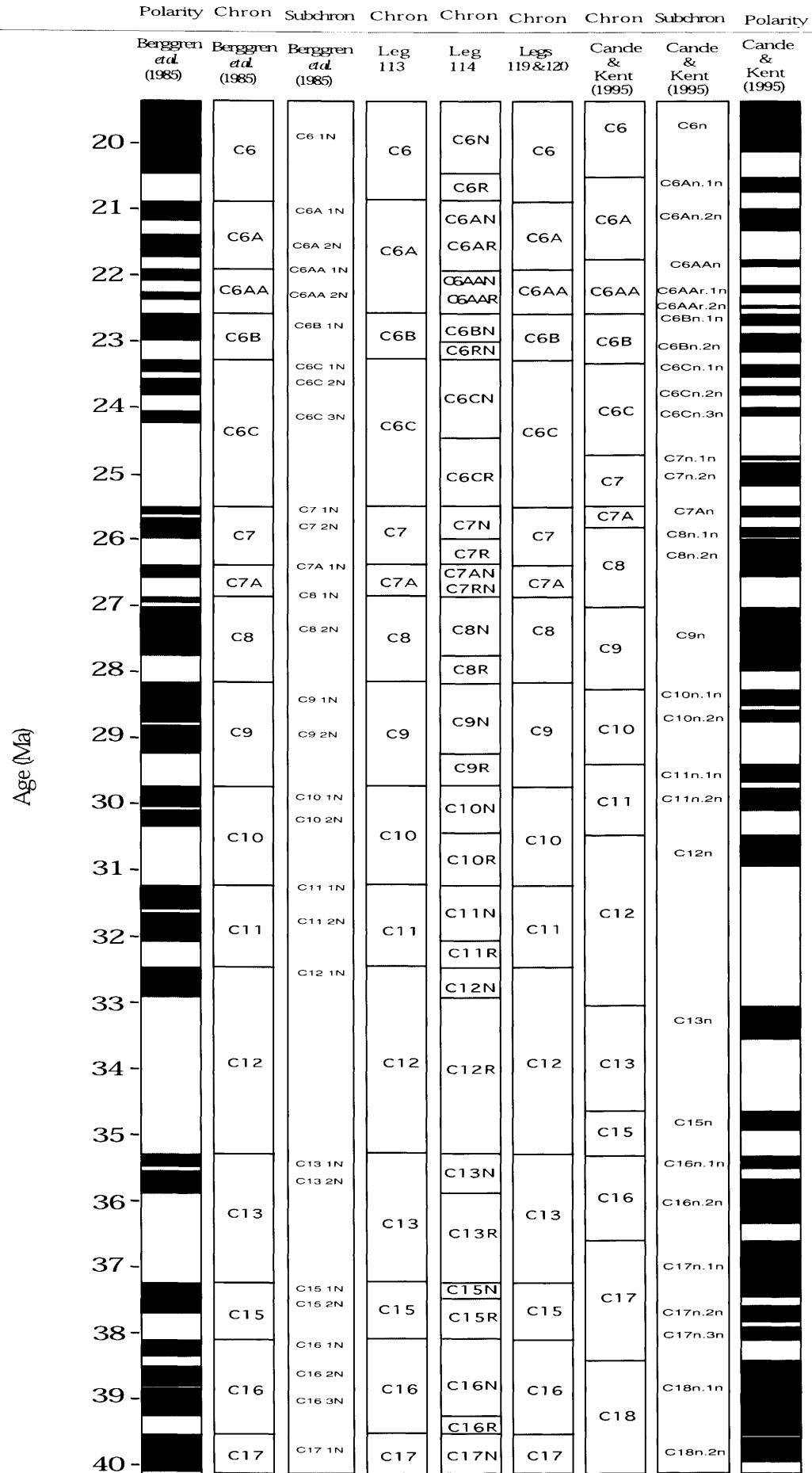


Fig. 4. Comparison of the Geopolarity Timescale (GPTS) of Berggren *et al.* (1985a, b) with the GPTS of Cande & Kent (1995). Shipboard and shorebased studies associated with the DSDP and ODP legs generally used the GPTS of Berggren *et al.* (1985a, b), but elected to modify the chronozonal nomenclature. This study uses the GPTS of Cande & Kent (1995).

(b)



Chronostratigraphical control

A significant objective of this study was to develop a robust biochronological framework in which primary stratigraphical datums were validated and applied consistently throughout the Southern Ocean, when possible. The chronostratigraphical control used in this study is based on the integration of magnetostratigraphical and biostratigraphical data. The assignment of any given chronozone requires accurate identification of the polarity sequence which is achieved by using primary biostratigraphical species in conjunction with the polarity pattern represented in the geopolarity time scale. Each investigation in the Southern Ocean has reassessed previously identified primary datums and augmented these datums to accommodate the biostratigraphical results. This has a minimal impact on the accuracy of chronozonal assignments when the stratigraphical data sets contain numerous events. In the case where few events are present the selection of the primary events will have a significant impact on chronozonal identification.

Sedimentation rates

The reversal sequence provides a polarity pattern that can be compared to the GPTS. The polarity pattern observed at any given site will be affected by temporal variations in the sedimentation rates at that site. Therefore, independent age control (in this study biostratigraphy) is required for identification of the chronozones and to determine the sediment accumulation record. A constant sedimentation rate between chronostratigraphic control points is assumed throughout this study.

Continuity of the stratigraphical record

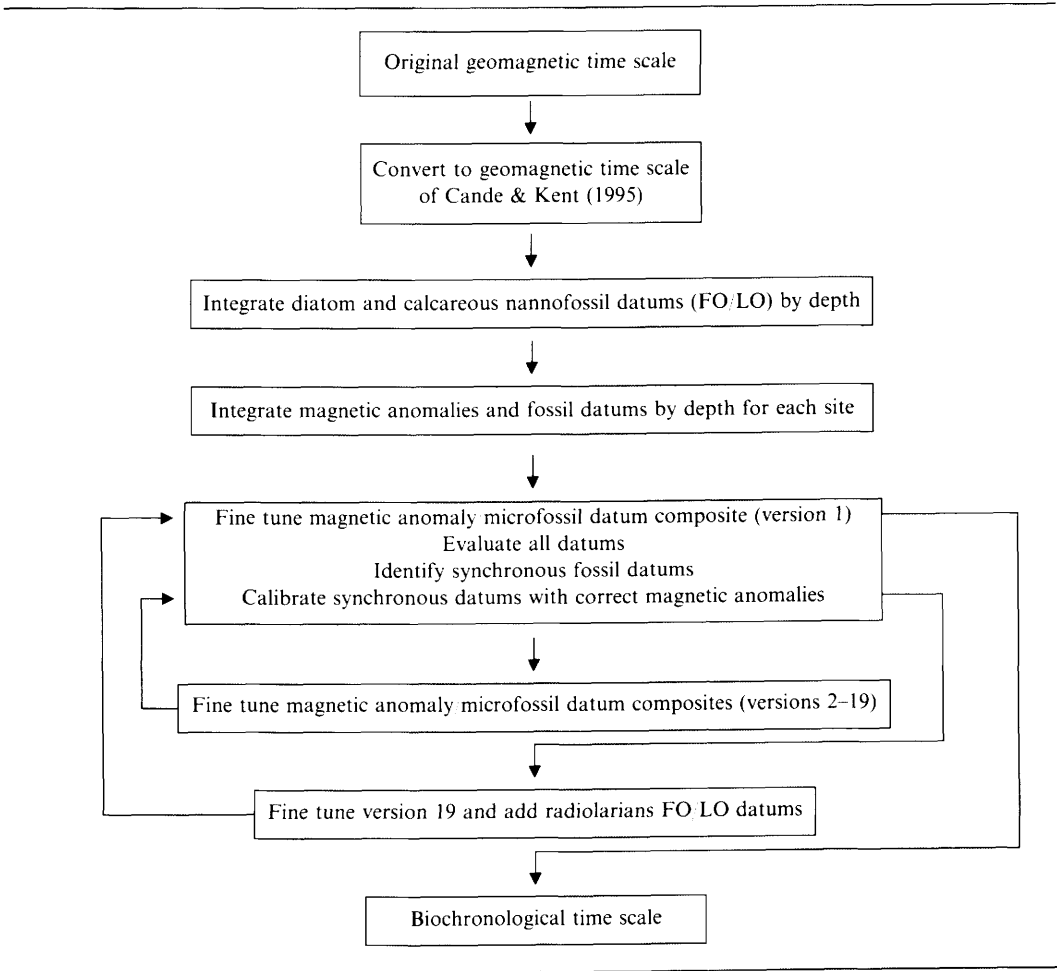
Correlation of any polarity and biostratigraphical data sets to any GPTS will result in the recognition of continuous stratigraphical sequences or in the interpretation of a stratigraphical break in sedimentary successions. The age model developed in this study was initially formulated using an assumption that the sedimentary sequences were continuous. Previously identified unconformities were not taken into consideration during the development of this age model. Stratigraphical breaks were interpreted following careful review of the stratigraphical data sets and an iterative reassessment of the age model.

Data processing

Data sets from previous workers (Table 2) were obtained for calcareous nannofossils, diatoms, radiolarians, and palaeomagnetic events from each site used in this study. The microfossil data sets contain information concerning the first occurrence and last occurrence of all species identified and the stratigraphical position of each event in the sedimentary sequence. Palaeomagnetic data was obtained for each hole and its depth, chronozone identification, and age of the polarity reversals were recorded using the authors calibration to a specific GPTS. These data sets were then combined to provide a composite record for each hole evaluated. Table 3 and Fig. 4 summarize the previously used biostratigraphical and chronostratigraphical indicators calibrated to the GPTS of Berggren *et al.* (1985*a, b*).

Previously identified chronozones were adjusted directly to the GPTS of Cande & Kent (1995) for use in this study. In some cases

Table 5. Methodology used in this study to translate the previously generated datasets from the prior biochronological model to the model presented in this study:



this required combining or subdividing polarity zones and chronozones. As a result, previously determined ages for specific datums were no longer valid and required re-calibration to the Cande & Kent (1995) GPTS and a new age assessment. The previously recognized biostratigraphical events were re-calibrated using the Cande & Kent (1995) GPTS applied to each data set and age-depth plots (designated original) were generated to establish a framework (Table 3).

At this stage we evaluated potentially useful biostratigraphical events and eliminated hole specific events, informally defined taxa and groups or events that failed to meet the criteria discussed above. We also identified polarity intervals requiring reassignment of chrono- or sub-chronozonations. Following this, we initiated an iterative process in which polarity assignments were reassessed and re-calibrated and the ages of microfossil datums were recalculated. Each step in the iterative reassessment of datums involved all sites and proceeded from the initial assumption that the sedimentary sequences at these sites were continuous. During the iterative process the initial age assignments for specific datums, within an individual site, were applied to all other sites in which these datums occurred. When a consistent result was obtained this was accepted. When a result was inconsistent we eliminated the interpretation and instigated a new iteration in which an age from a different hole was selected. We continued the process until either a consistent result was achieved or the datum was eliminated. The influence of this procedure on the assignment of polarity chrons and, on stratigraphical continuity within the sites was observed, where the existence of unconformities was clearly the product of applying a specific datum, we have chosen to maintain stratigraphical continuity at the expense of generating unconformities in order to retain the integrity of a biostratigraphical event. Therefore it was

inevitable that some unconformities, identified on the basis of earlier age models, were eliminated. This process (Table 5) continued until we were confident that primary events were consistent at all sites in which they occur and at this stage, Age Model 1 was established representing the last 65 million years. Model 1 was used to generate age–depth plots for each hole and these were compared graphically to identify inconsistencies in the magnetic and biostratigraphical records from each hole. Biostratigraphical events older than about 36 Ma were eliminated due to the paucity of data. Subsequent iterations, similar to that described above were completed and resulted in establishing Age Model 2.

We applied the radiolarian stratigraphies developed by previous workers and synthesized by Lazarus (1992) as an independent assessment of Age Model 2. Following one additional iteration, diachronous biostratigraphical events were eliminated from the data sets and age–depth plots (designated revised) were reproduced to establish the final age model presented in this paper.

Primary events identified in this study are recorded from the Atlantic and Indian Ocean sectors of the Southern Ocean and are defined as typically having having an age constraint of less than 0.4 million years. This constraint is an artefact of sampling by previous workers and additional samples would have to be examined to refine the age constraint for a specific event. Although 0.4 million years constitutes our threshold we recognize this as an upper limit. In rare instances we have allowed exceptions to accommodate outliers from otherwise consistent data. This occurred occasionally in cases where a specific event occurred in the majority of holes within our established criteria. In addition to the age constraint primary events were identified when the range of a specific event occurred within a less than 0.25 million years tolerance limit in the age ranges of the event in the majority of holes.

Results

The biochronological framework generated by this study is based on re-evaluation of the age model for the holes presented in this report. The results focus on a hole by hole discussion of the age model with a comparison between previous studies and the current results.

Legend

- Diatom (top)
- Radiolarian (top)
- ◇ Nannofossil (top)
- △ Magnetic (top)
- Diatom (base)
- Radiolarian (base)
- Nannofossil (base)
- Magnetic (base)

Fig. 5. Legend of symbols used for age–depth graphs presented in this manuscript.

Hole 514

Thirty-five cores were recovered from a total penetration of 150.8 m below seafloor (mbsf) representing a recovery of 92% of the cored interval. Sediments recovered consist of Quaternary to lower Pliocene diatom ooze with a variable clay component (Ludwig *et al.* 1983). A good polarity record was recovered for the entire stratigraphical sequence. Diatoms and radiolarians are abundant throughout the section. Radiolarians are generally well preserved. Calcareous nannofossils are typically sparse exhibiting poor to moderate preservation (Ludwig *et al.* 1983).

Table 6 presents the integrated biostratigraphical and magnetostratigraphical events previously used (palaeomagnetism: Sallo- way 1983; diatoms: Ciesielski 1983; calcareous nannofossils: none; radiolarians: Weaver 1983) and calibrated to the GPTS of Berggren *et al.* (1985a, b). An age–depth graph for Hole 71-514 using these data is shown in Fig. 6.

Figure 7 compares the polarity chronozones and diatom zones assigned by previous workers with the chronozone assignments in this study. The stratigraphical ranges of diatoms and radiolarians reflect the placement of the FO and LO of stratigraphically useful species. The revised chronozones illustrated are based on

reassessing the data sets of these workers (Table 7). Comparison of the previous chronozone assignments (compare Tables 6 and 7) with those of this study indicates that only minimal revisions were necessary. Modifications reflect in part the differences between the Berggren *et al.* (1985a, b) and Cande & Kent (1995) GPTS.

An age–depth graph for Hole 71-514 using the stratigraphical markers determined in this study is shown in Fig. 8. The section is interpreted to be continuous based on both palaeomagnetic and biostratigraphical control. Palaeomagnetic control consists of a continuous sequence of polarity reversals extending from the base of C1n at 8.43 mbsf to the base of C3n.1n at 133.51 mbsf. Biostratigraphical markers used to calibrate this polarity sequence include the LO of *Thalassiosira kolbei* at 22.26 mbsf, the LOs of *Helotholus vema* and *Desmospyris spongiosa* at 40.8 mbsf and the FO of *Nitzschia praeinterfrigidaria* at 105.96 mbsf. One primary biostratigraphical control point, the FO of *Nitzschia interfrigidaria* occurs at 133.79 mbsf. Unfortunately the absence of palaeomagnetic control points below this depth prevent an age assignment for this biostratigraphical event in this hole.

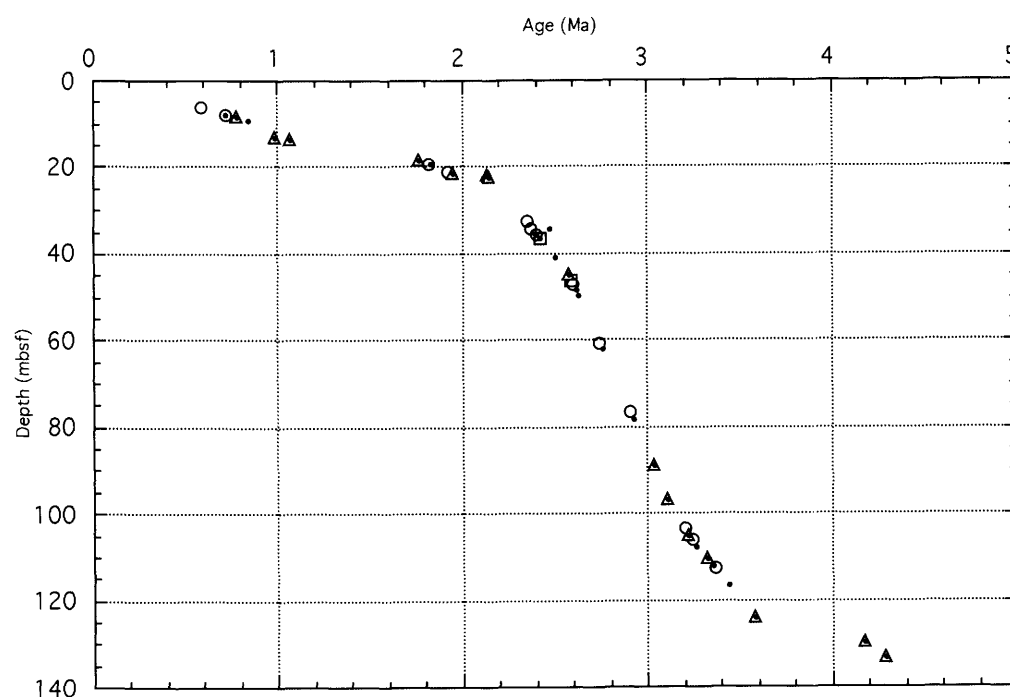


Fig. 6. An age–depth plot for DSDP Hole 514 utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Berggren *et al.* (1985a, b). See Fig. 5 for legend of symbols.

Table 6. Composite dataset for DSDP Hole 514 containing the diatom, radiolarian and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Actinocyclus ingens</i>	3-1, 72-74	3-2, 70-72	6.34	7.82	0.59	0.72
LO <i>Thalassiosira elliptopora</i>	3-2, 70-72	3-3, 49-51	7.82	9.11	0.72	0.84
B C1n			8.43	8.43	0.78	0.78
T C1r.1n			13.06	13.06	0.99	0.99
B C1r.1n			13.55	13.55	1.07	1.07
T C2n			18.52	18.52	1.77	1.77
LO <i>Simonseniella barboi</i>	5-4, 54-56	6-1, 74-79	19.45	19.59	1.82	1.83
LO <i>Thalassiosira kolbei</i>			21.12	22.26	1.92	2.15
B C2n			21.60	21.60	1.95	1.95
T C2r.1n			22.00	22.00	2.14	2.14
B C2r.1n			22.50	22.50	2.15	2.15
FO <i>Actinocyclus ingens</i>	9-1, 86-88	9-2, 70-72	32.74	34.22	2.35	2.47

(continued)

Table 6. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Thalassiosira vulnifica</i>	9-2, 70-72	9-3, 63-65	34.22	35.65	2.37	2.40
FO <i>Nitzschia kerguelensis</i>	9-3, 63-65	10-1, 33-35	35.65	36.75	2.40	2.42
LO <i>Desmospyris spongiosa</i>			36.40	40.80	2.42	2.50
LO <i>Helotholus vema</i>			36.40	40.80	2.42	2.50
T C2An.1n			45.00	45.00	2.58	2.58
FO <i>Cycladophora davisiana</i>			46.20	49.60	2.59	2.63
FO <i>Hemidiscus cuneiformis</i>	35-1, 73-75	35-2, 73-75	47.15	48.63	2.60	2.62
LO <i>Nitzschia weaveri</i>	15-2, 70-72	15-3, 70-72	60.62	62.12	2.74	2.76
LO <i>Nitzschia interfrigidaria</i>	19-1, 72-74	19-1, 72-74	76.74	78.24	2.91	2.93
LO <i>Nitzschia reinholdii</i>	19-1, 72-74	19-1, 72-74	76.74	78.24	2.91	2.93
FO <i>Thalassiosira lentiginosa</i>			76.74	78.24	2.91	2.93
B C2An.1n			89.00	89.00	3.04	3.04
T C2An.2n			97.00	97.00	3.11	3.11
FO <i>Thalassiosira insigna</i>	25-1, 95-97	26-1, 98-100	103.37	107.80	3.20	3.26
B C2An.2n			105.00	105.00	3.22	3.22
FO <i>Thalassiosira kolbei</i>			105.96	112.06	3.24	3.36
FO <i>Nitzschia praeinterfrigidaria</i>			105.96	112.06	3.24	3.36
T C2An.3n			110.57	110.57	3.33	3.33
FO <i>Nitzschia weaveri</i>	27-2, 84-86	28-1, 90-92	112.70	116.52	3.37	3.44
B C2An.3n			124.00	124.00	3.58	3.58
T C3n.1n			129.74	129.74	4.18	4.18
B C3n.1n			133.51	133.51	4.29	4.29
FO <i>Nitzschia interfrigidaria</i>	32-1, 77-79	33-1, 75-77	133.79	138.37	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

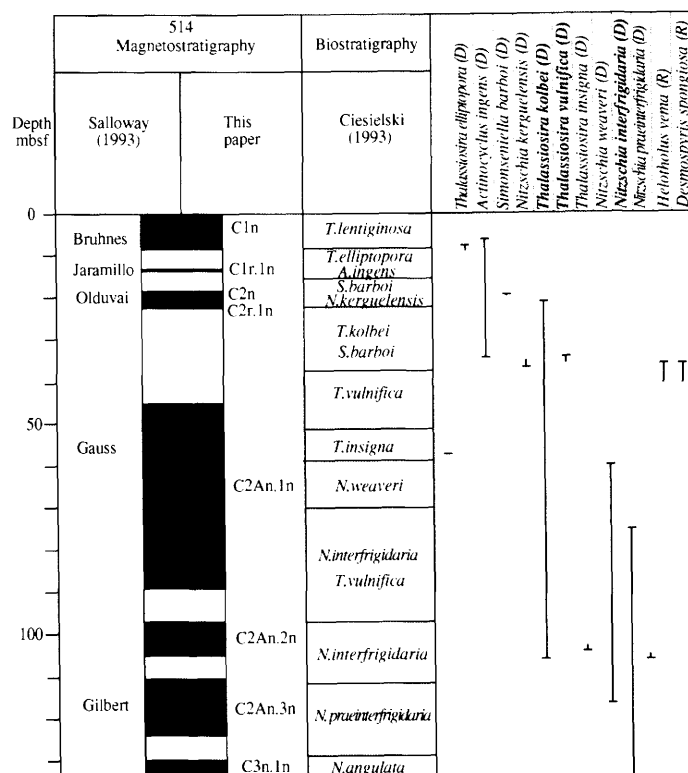


Fig. 7. Comparison of the DSDP Hole 514 polarity chronozones and diatom zonal assignments by previous workers with the chronostratigraphic assignments of this study. The stratigraphical ranges of selected species are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995).

Table 7. Composite dataset for DSDP Hole 514 containing the diatom, radiolarian and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Actinocyclus ingens</i>	3-1, 72-74	3-2, 70-72	6.34	7.82	0.59	0.72
LO <i>Thalassiosira elliptopora</i>	3-2, 70-72	3-3, 49-51	7.82	9.11	0.72	0.84
B C1n			8.43	8.43	0.78	0.78
T C1r.1n			13.06	13.06	0.99	0.99
B C1r.1n			13.55	13.55	1.07	1.07
T C2n			18.52	18.52	1.77	1.77
LO <i>Simonseniella barboi</i>	5-4, 54-56	6-1, 74-79	19.45	19.59	1.82	1.83
LO <i>Thalassiosira kolbei</i>			21.12	22.26	1.92	2.15
B C2n			21.60	21.60	1.95	1.95
T C2r.1n			22.00	22.00	2.14	2.14
B C2r.1n			22.50	22.50	2.15	2.15
FO <i>Actinocyclus ingens</i>	9-1, 86-88	9-2, 70-72	32.74	34.22	2.35	2.37
LO <i>Thalassiosira vulnifica</i>	9-2, 70-72	9-3, 63-65	34.22	35.65	2.37	2.40
FO <i>Nitzschia kerguelensis</i>	9-3, 63-65	10-1, 33-35	35.65	36.75	2.40	2.42
LO <i>Desmospyris spongiosa</i>			36.40	40.80	2.42	2.50
LO <i>Helotholus vema</i>			36.40	40.80	2.42	2.50
T C2An.1n			45.00	45.00	2.58	2.58
FO <i>Cycladophora davisiana</i>			46.20	49.60	2.59	2.63
FO <i>Hemidiscus cuneiformis</i>	35-1, 73-75	35-2, 73-75	47.15	48.63	2.60	2.62
LO <i>Nitzschia weaveri</i>	15-2, 70-72	15-3, 70-72	60.62	62.12	2.74	2.76
LO <i>Nitzschia interfrigidaria</i>	19-1, 72-74	19-2, 72-74	76.74	78.24	2.91	2.93
LO <i>Nitzschia reinholdii</i>	19-1, 72-74	19-2, 72-74	76.74	78.24	2.91	2.93
FO <i>Thalassiosira lentiginosa</i>			76.74	78.24	2.91	2.93
B C2An.1n			89.00	89.00	3.04	3.04
T C2An.2n			97.00	97.00	3.11	3.11
FO <i>Thalassiosira insigna</i>	25-1, 95-97	26-1, 98-100	103.37	107.80	3.20	3.26
B C2An.2n			105.00	105.00	3.22	3.22
FO <i>Thalassiosira kolbei</i>			105.96	112.06	3.24	3.36
FO <i>Nitzschia praeinterfrigidaria</i>			105.96	112.06	3.24	3.36
T C2An.3n			110.57	110.57	3.33	3.33
FO <i>Nitzschia weaveri</i>	27-2, 84-86	28-1, 90-92	112.70	116.52	3.37	3.44
B C2An.3n			124.00	124.00	3.58	3.58
T C3n.1n			129.74	129.74	4.18	4.18
B C3n.1n			133.51	133.51	4.29	4.29
FO <i>Nitzschia interfrigidaria</i>	32-1, 77-79	33-1, 75-77	133.79	138.37	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

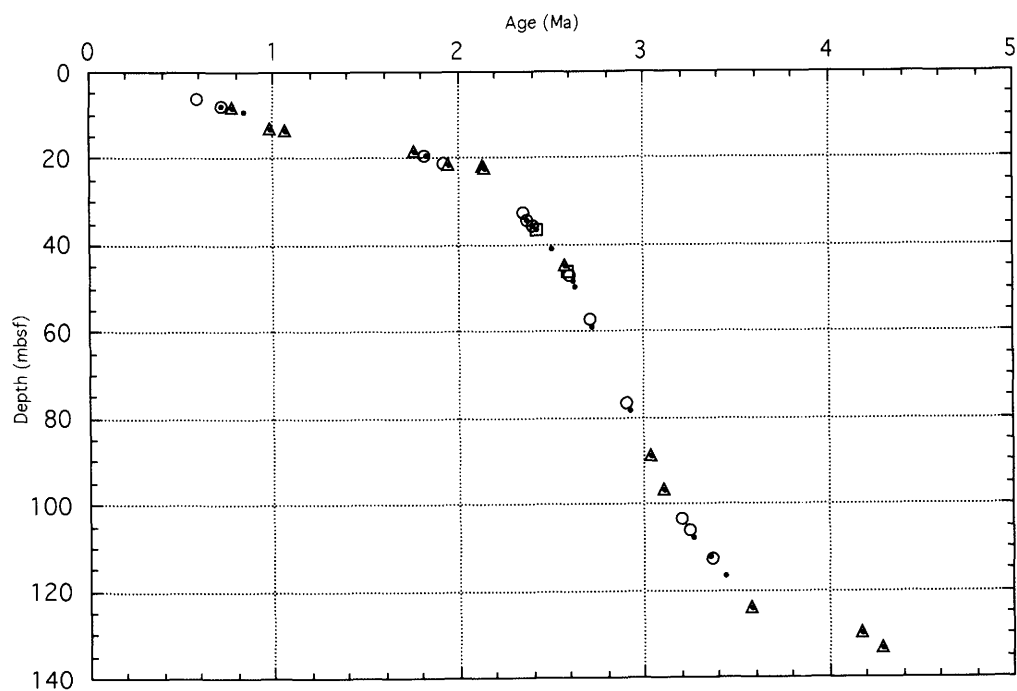


Fig. 8. A revised age–depth plot for DSDP Hole 514 using the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Hole 689B

Thirty-three cores were recovered from a total penetration of 297.3 mbsf representing a recovery of 77% of the cored interval. Sediments recovered consist of Quaternary to upper Miocene diatom ooze, Miocene to Palaeocene calcareous ooze with a variable siliceous component, and Upper Cretaceous chalk. A good palaeomagnetic polarity reversal record was obtained by both shipboard and shorebase analysis (Barker *et al.* 1988; Spiess, 1990). Diatoms, calcareous nannofossils and radiolarians are present throughout the sequence. Moderately preserved, common to abundant diatoms are present throughout the Quaternary to lower Miocene sediments. Diatom abundance decreases with rare and poorly preserved organisms present in this interval (Gersonde & Burckle 1990). Calcareous nannofossils are rare in the Quaternary and upper Pliocene sediments, absent in the middle to lower Pliocene, common to abundant throughout the Miocene and abundant in the Oligocene. Preservation of the calcareous nannofossils varies and is moderate to good in the Miocene and moderate in the Oligocene (Wei & Wise 1990). Well-preserved radiolarians are abundant throughout the upper Pliocene to middle Miocene section. Radiolarian preservation is poor in the lower Miocene and upper Oligocene and good in the lower Oligocene (Barker *et al.* 1988).

Table 8 presents the integrated biostratigraphical and magnetostratigraphical events previously used (palaeomagnetism: Spiess 1990; diatoms: Gersonde & Burckle 1990; calcareous nannofossils: Wei & Wise 1990; radiolarians: Abelman 1990; Lazarus 1990) and calibrated to the GPTS of Berggren *et al.* (1985a, b). An age–depth graph for Hole 113-689B using these data is shown in Fig. 9.

Figure 10 compares the polarity chronozones and diatom zones assigned by previous workers (Spiess 1990; Gersonde & Burckle 1990) with the chronostratigraphical assignments in this study. The stratigraphical ranges of diatoms, radiolarians and calcareous nannofossils reflect the placement of the FO and LO of stratigraphically useful species as recognized by Gersonde & Burckle (1990), Abelman (1990), Lazarus (1990), and Wei & Wise (1990), respectively. The revised chronozones illustrated are based on reassessing the data sets of these workers (Table 9). Comparison of the chronostratigraphical assignments of Spiess (1990; Table 8) with those of this study indicates that only minimal revisions were completed. Modifications reflect in part the differences between the Berggren *et al.* (1985a, b) and Cande & Kent (1995) GPTS.

The integrated biostratigraphical and magnetostratigraphical data used in this study is presented in Table 9. We have limited the data sets to include the Quaternary to latest Eocene stratigraphical interval. The paucity of palaeomagnetic data available for the Eocene and Palaeocene of the Southern Ocean preclude reinterpretation of the data from Eocene or older sediments in this hole.

An age–depth graph for Hole 113-689B, using the stratigraphical markers determined in this study, is shown in Fig. 11. Four hiatuses are noted in the stratigraphical section. The first is placed in the upper 3 m of the section and is identified by the occurrence of older stratigraphical indicators such as the LO of *Desmospyris spongiosa*, the LO of *Helotholus vema* and the LO of *Thalassiosira kolbei* in the upper 0.6 m of the section. The youngest polarity reversal (top of Chron C2An.3n) occurs at a depth of 3.38 mbsf.

The second unconformity occurs between 15.17 and 18.09 mbsf. The upper boundary of this unconformity is constrained by a continuous string of polarity reversal (top of Chron C2An.3n through the top of C3n.4n) from 3.38 through 15.17 mbsf. This magnetic sequence is constrained by the FO of *Helotholus vema* (6.61 mbsf) and the FO of *Nitzschia barronii* (8.59–9.22 mbsf). The lower boundary is constrained by the LO of *Asteromphalus kennettii* at 18.38–19.30 mbsf and a continuous polarity reversal sequence from the top of Chron C4An at 18.09 mbsf to the base of C5ADn at 55.28 mbsf. This magnetic sequence is constrained by the occurrence of the following primary markers: FO *Denticulopsis praedimorpha* (47.45–48.09 mbsf), FO *Nitzschia denticuloides* (50.45–51.09 mbsf), FO *Denticulopsis hustedtii* (52.29–53.19 mbsf) and the LO of *Synedra jouseana* (54.69–55.07 mbsf). Also associated with this interval are the LO of *Cycladophora spongothorax* (20.24–22.16 mbsf) and the FO of *Acrosphaera labrata* (20.26–21.29 mbsf). This second unconformity spans approximately 5 million years.

The third unconformity is situated between 55.28 and 56.19 mbsf and represents about 2 million years. The upper boundary of this event is constrained by the LO of *Synedra jouseana* at and the lower boundary is constrained by a sequence of magnetics from the top of C5Cn.3n (56.53 mbsf) to the top of C6n (61.76 mbsf) and the FO of *Crucidentacula kanayae* (59.19–59.47 mbsf). The last occurrence of *Coscinodiscus rhombicus* (57.06–57.37 mbsf) is a potentially useful marker in this interval. This unconformity replaces two unconformities previously identified by Gersonde & Burckle (1990).

The oldest hiatus is placed between 61.76 and 63.37 mbsf and partitions the top of Chron C6An.1n (67.11 mbsf) from the base of C7n.1n (66.86 mbsf) to the top of C17n.1n (135.77 mbsf). The FO of *Isthmolithus recurvus* and the LO of *Reticulofenestra reticulata* at 131.7–132.73 mbsf occur within the lower part of this sequence. This oldest unconformity corresponds to an unconformity of similar age and depth identified by Spiess (1990) and Gersonde & Burckle (1990).

This study suggests that the stratigraphical section is more continuous than previously recognized. Gersonde & Burckle (1990) and Gersonde *et al.* (1990) identified seven hiatuses in the Quaternary to Oligocene interval based on integrated bio- and magnetostratigraphy. Two of these breaks at 17.8 and 67.0 mbsf approximate hiatuses identified in this study. One hiatus at 58.8 mbsf reflects differences in the interpretation of chronostratigraphical assignment of the polarity reversals. The others at 11.50, 43.80, and 64.7 mbsf reflect differences in biostratigraphical interpretation.

Spiess (1990) identified five hiatuses in the upper 140 m of Hole 113-689B based on pattern recognition of the polarity record. Two of these breaks placed at 17.65 and 66.86 mbsf coincide with those recorded by Gersonde & Burckle (1990), Gersonde *et al.* (1990) and this study. The breaks at 55.28 and 58.75 mbsf approximate breaks at 55.1 and 58.8 mbsf proposed by Gersonde and Burckle (1990) and Gersonde *et al.* (1990). The interpretation of the remaining hiatus at 59.65 mbsf reflects differences in the GPTS and chronostratigraphical assignments used in each study.

Table 8. Composite dataset for ODP Hole 689B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
Unconformity			***	***	***	***
LO <i>Actinocyclus ingens</i>	1H-1, 0	1H-1, 28-29	0.00	0.00	?	?
LO <i>Antarctissa cylindrica</i>	1H-1, 0	1H-1, 25-26	0.00	0.26	?	?
LO <i>Cycladophora pliocenica</i>	1H-1, 0	1H-1, 25-26	0.00	0.26	?	?
LO <i>Eucyrtidium calvertense</i>	1H-1, 0	1H-1, 25-26	0.00	0.26	?	?
LO <i>Desmospyris spongiosa</i>	1H-1, 0	1H-1, 25-26	0.00	0.26	?	?
LO <i>Helotholus vema</i>	1H-1, 0	1H-1, 25-26	0.00	0.26	?	?

Table 8. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO <i>Cycladophora davisiana</i>	1H-1, 0	1H-1, 25-26	0.00	0.26	?	?
LO <i>Nitzschia interfrigidaria</i>	1H-1, 0	1H-1, 28-29	0.00	0.29	?	?
LO <i>Nitzschia barronii</i>	1H-1, 0	1H-1, 28-29	0.00	0.29	?	?
LO <i>Thalassiosira inura</i>	1H-1, 28-29	1H-1, 56-58	0.29	0.58	?	?
LO <i>Thalassiosira kolbei</i>	1H-1, 28-29	1H-1, 56-58	0.29	0.58	?	?
LO <i>Nitzschia praeinterfrigidaria</i>	1H-2, 28-29	1H-2, 50-52	1.79	2.02	?	?
FO <i>Nitzschia interfrigidaria</i>	1H-2, 28-29	1H-2, 50-52	1.79	2.02	?	?
T C3n.1n			3.38	3.38	4.18	4.18
LO <i>Prunopyle titan</i>	1H-3, 118-120	1H-4, 104-105	4.18	5.53	4.27	4.34
B C3n.1n			4.40	4.40	4.29	4.29
LO <i>Denticulopsis dimorpha</i>	2H-1, 31-33	2H-2, 115-116	5.63	6.45	4.34	4.38
FO <i>Helotholus vema</i>	2H-2, 118-120	2H-3, 62-64	7.89	8.92	4.44	4.49
FO <i>Nitzschia barronii</i>	2H-3, 28-29	2H-3, 90-92	8.59	9.22	4.47	4.55
T C3n.2n			8.79	8.79	4.48	4.48
B C3n.2n			9.63	9.63	4.62	4.62
FO <i>Nitzschia reinholdii</i>	2H-4, 28-29	2H-4, 56-58	10.09	10.38	4.67	4.69
FO <i>Thalassiosira kolbei</i>	2H-4, 56-58	2H-4, 115-116	10.38	10.98	4.69	4.75
T C3n.3n			11.45	11.45	4.80	4.80
FO <i>Thalassiosira inura</i>	2H-5, 27-28	2H-5, 55-57	11.58	11.87	4.84	4.89
B C3n.3n			11.72	11.72	4.89	4.89
T C3n.4n			15.17	15.17	4.98	4.98
Unconformity			***	***	***	***
FO <i>Thalassiosira oestrupii</i>	3H-2, 56-58	3H-2, 118-120	16.88	17.50	?	?
T C3Bn			18.09	18.09	6.94	6.94
LO <i>Asteromphalus kennettii</i>	3H-3, 56-58	3H-3, 148-150	18.38	19.30	7.02	7.68
B C3Bn			18.67	18.67	7.09	7.09
T C4n.1n			18.92	18.92	7.43	7.43
LO <i>Actinocyclus ingens</i> v. <i>nodus</i>	3H-3, 148-150	3H-3, 56-58	19.30	19.88	7.68	8.07
FO <i>Cosmiodiscus intersectus</i>	3H-5, 80-82	3H-5, 114-115	20.12	20.45	8.23	8.32
B C4r.1n			20.17	20.17	8.26	8.26
LO <i>Cycladophora spongothorax</i>	3H-4, 94-96	3H-5, 136-138	20.24	21.29	8.28	8.51
FO <i>Acrosphaera labrata</i>	3H-4, 94-96	3H-5, 136-138	20.26	21.29	8.28	8.51
T C4An			22.15	22.15	8.70	8.70
LO <i>Reticulofenestra gelida</i>	5H-2, 30-32	5H-3, 30-32	22.60	24.30	8.88	9.66
B C4Ar.1n			23.65	23.65	9.31	9.31
T C4Ar.2n			23.81	23.81	9.58	9.58
B C4Ar.2n			24.17	24.17	9.64	9.64
T C5n.1n			24.67	24.67	9.74	9.74
LO <i>Cycladophora humerus</i>	4H-2, 117-119	4H-3, 56-58	26.97	27.86	10.02	10.13
FO <i>Acrosphaera australis</i>	4H-2, 117-119	4H-3, 56-58	26.97	27.86	10.02	10.13
FO <i>Asteromphalus kennettii</i>	4H-3, 31-32	4H-3, 114-115	27.62	28.45	10.10	10.20
FO <i>Eucyrtidium pseudoinflatum</i>	4H-4, 56-58	4H-4, 116-118	29.36	29.96	10.31	10.39
B C5n.2n			34.55	34.55	10.95	10.95
B C5r.2n			37.93	37.93	11.53	11.53
LO <i>Actinomma golownini</i>	5H-5, 56-58	5H-5, 117-118	40.36	40.97	11.65	11.69
LO <i>Nitzschia denticuloides</i>	5H-6, 28-29	5H-6, 114-115	41.59	42.45	11.72	11.76
FO <i>Cycladophora spongothorax</i>	5H-CC	6H-1, 59	43.30	43.89	11.81	11.83
LO <i>Dendrospyrus megaloccephalis</i>	5H-CC	6H-1, 59	43.30	43.89	11.81	11.83
FO <i>Denticulopsis dimorpha</i>	6H-1, 27-28	6H-1, 114-115	43.58	44.45	11.82	11.86
LO <i>Reticulofenestra hesslandii</i>	6H-1, 30-32	6H-2, 29-31	43.60	45.09	11.82	11.90
FO <i>Dendrospyrus megaloccephalis</i>	6H-2, 58-60	6H-3, 91-93	45.38	47.21	11.91	12.41
T 5An.1n			45.93	45.93	11.94	11.94
LO <i>Crucidenticula nicobarica</i>	6H-2, 114-115	6H-3, 28-29	45.95	46.59	11.95	12.15
B 5An.1n			46.41	46.41	12.08	12.08
LO <i>Nitzschia grossepunctata</i>	6H-3, 28-29	6H-3, 114-115	46.59	47.45	12.15	12.51
T 5An.2n			46.68	46.68	12.18	12.18
B 5An.2n			47.18	47.18	12.40	12.40
LO <i>Denticulopsis praedimorpha</i>	6H-3, 114-115	6H-4, 28-29	47.45	48.09	12.51	12.76
T C5AAn			48.68	48.68	12.99	12.99
FO <i>Actinomma golownini</i>	6H-4, 108-110	6H-5, 31-33	48.90	49.63	13.06	13.28
C5AAn			49.18	49.18	13.14	13.14
T C5ABn			49.68	49.68	13.30	13.30
FO <i>Antarctissa deflandrei</i>	6H-5, 84-86	6H-5, 117-119	50.16	50.49	13.38	13.44
FO <i>Nitzschia denticuloides</i>	6H-5, 114-115	6H-6, 28-29	50.45	51.09	13.43	13.54
B C5ABn			50.91	50.91	13.51	13.51
T C5ACn			51.93	51.93	13.70	13.70
FO <i>Denticulopsis hustedii</i>	6H-7, 28-29	7H-1, 28-29	52.29	53.19	13.99	14.26
LO <i>Denticulopsis maccollumii</i>	6H-7, 28-29	7H-1, 28-29	52.29	53.19	13.99	14.26

(continued)

Table 8. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
B C5ACn			52.41	52.41	14.08	14.08
FO <i>Cycladophora humerus</i>	6H-7, 32-34	7H-1, 32-34	52.64	53.24	14.13	?
FO <i>Dendrospyrus megalcephalis</i>	6H-7, 32-34	7H-1, 32-34	52.64	53.24	14.13	?
T C5ADn			52.85	52.85	14.18	14.18
LO <i>Synedra jouseana</i>	7H-2, 28-29	7H-2, 65-67	54.69	55.07	?	?
LO <i>Thalassiosira spumellaroides</i>	7H-2, 65-67	7H-2, 115-116	55.07	55.56	?	?
Unconformity			***	***	***	***
FO <i>Actinocyclus ingens</i> v. <i>nodus</i>	7H-3, 28-29	7H-3, 86-88	56.19	56.19	?	?
T C5Bn.2n			56.53	56.53	15.03	15.03
LO <i>Coscinodiscus lewisianus</i>	7H-3, 86-88	7H-3, 114-115	56.78	57.06	15.07	15.11
LO <i>Coscinodiscus rhombicus</i>	7H-3, 115-116	7H-3, 145-147	57.06	57.37	15.11	15.16
FO <i>Eucyrtidium punctatum</i>	7H-3, 145-147	7H-4, 148-150	57.37	58.90	15.16	?
B C5Bn.2n			57.40	57.40	15.16	15.16
LO <i>Crucidentacula kanayae</i>	7H-4, 28-29	7H-4, 88-86	57.60	58.18	?	?
LO <i>Nitzschia maleinterpretaria</i>	7H-4, 28-29	7H-4, 86-88	57.69	58.28	?	?
FO <i>Nitzschia grossepunctata</i>	7H-4, 28-29	7H-4, 86-88	57.69	58.28	?	?
LO <i>Thalassiosira fraga</i>	7H-4, 86-88	7H-4, 115-116	58.28	58.56	?	?
FO <i>Actinocyclus ingens</i>	7H-4, 115-116	7H-5, 28-29	58.60	59.19	?	?
FO <i>Denticulopsis maccollumnii</i>	7H-4, 115-116	7H-5, 28-29	58.60	59.19	?	?
Unconformity			***	***	***	***
FO <i>Crucidentacula kanayae</i>	7H-5, 28-29	7H-5, 55-57	59.19	59.47	?	?
B C5Dn			60.40	60.40	17.62	17.62
FO <i>Cycladophora golli regipileus</i>	7H-5, 89-91	7H-6, 117-119	61.21	61.49	18.01	18.15
FO <i>Crucidentacula nicobarica</i>	7H-6, 115-116	7H-7, 28-29	61.56	62.19	18.18	18.49
FO <i>Cyrtocapsella tetrapera</i>	7H-7, 21-23	7H-7, 56-58	61.23	61.87	18.02	18.31
T C5En			61.76	61.76	18.28	18.28
FO <i>Cyrtocapsella longithorax</i>	8H-1, 57-59	8H-2, 56-58	63.37	64.88	18.86	19.41
FO <i>Raphidodiscus marylandicus</i>	8H-2, 114-115	8H-3, 28-29	65.15	65.79	19.51	19.74
FO <i>Thalassiosira fraga</i>	8H-2, 114-115	8H-3, 28-29	65.15	65.79	19.51	19.74
LO <i>Chiasmolithus altus</i>	8H-3, 30-32	8H-4, 30-32	65.85	67.32	19.76	20.29
LO <i>Reticulofenestra bisecta</i>	8H-3, 30-32	8H-4, 30-32	65.85	67.32	19.76	20.29
LO <i>Rocella gelida</i>	8H-3, 115-116	8H-3, 146-148	66.65	66.96	20.05	?
FO <i>Thalassiosira spumellaroides</i>	8H-3, 144-146	8H-4, 28-29	66.96	67.29	?	24.91
B C6n			66.86	66.86	20.13	20.13
Unconformity			***	***	***	***
T C7n.2n			67.11	67.11	24.84	24.84
LO <i>Rocella vigilans</i>	8H-4, 28-29	8H-4, 57-59	67.29	67.59	24.91	25.05
B 7n.2n			67.88	67.88	25.18	25.18
T C7An			68.61	68.61	25.50	25.50
B C7An			68.88	68.88	25.65	25.65
T C8n.1n			69.38	69.38	25.82	25.82
B C8n.1n			70.11	70.11	25.95	25.95
T C8n.2n			70.38	70.38	25.99	25.99
FO <i>Rocella gelida</i>	8H-5, 114-115	8H-6, 28-29	71.15	71.79	26.07	26.13
FO <i>Rocella vigilans</i>	8H-5, 114-115	8H-6, 28-29	71.15	71.79	26.07	26.13
B C8n.2n			75.98	75.98	26.55	26.55
T C9n			79.46	79.46	27.03	27.03
B C9n			85.05	85.05	27.97	27.97
T C10n.1n			89.82	89.82	28.28	28.28
B C10n.1n			90.07	90.07	28.51	28.51
T C10n.2n			91.01	91.01	28.58	28.58
B C10n.2n			91.93	91.93	28.75	28.75
T C11n.2n			100.23	100.23	29.77	29.77
B C11n.2n			103.38	103.38	30.10	30.10
T C12n			104.38	104.38	30.48	30.48
LO <i>Reticulofenestra umbilica</i>	12H-4, 29-31	12H-5, 29-31	105.81	107.31	30.74	31.03
B C12n			106.88	106.88	30.94	30.94
LO <i>Isthmolithus recurvus</i>	13H-1, 130-132	13H-2, 130-132	111.02	113.42	31.83	32.35
T C13n			116.71	116.71	33.06	33.06
B C13n			119.70	119.70	33.55	33.55
LO <i>Reticulofenestra oamaruensis</i>	13H-7, 28-30	14H-1, 130-132	119.90	121.50	33.58	33.78
FO <i>Reticulofenestra oamaruensis</i>	14H-5, 130-132	14H-6, 130-132	127.50	127.70	34.55	34.59
T C15n			128.33	128.33	34.66	34.66
FO <i>Isthmolithus recurvus</i>	15H-2, 30-32	15H-2, 131-132	131.70	132.73	34.83	34.88
LO <i>Reticulofenestra reticulata</i>	15H-2, 30-32	15H-2, 131-132	131.70	132.73	34.83	34.88
B C15n			134.02	134.02	34.94	34.94

Data sets are integrated from the work of numerous authors (see Table 2).

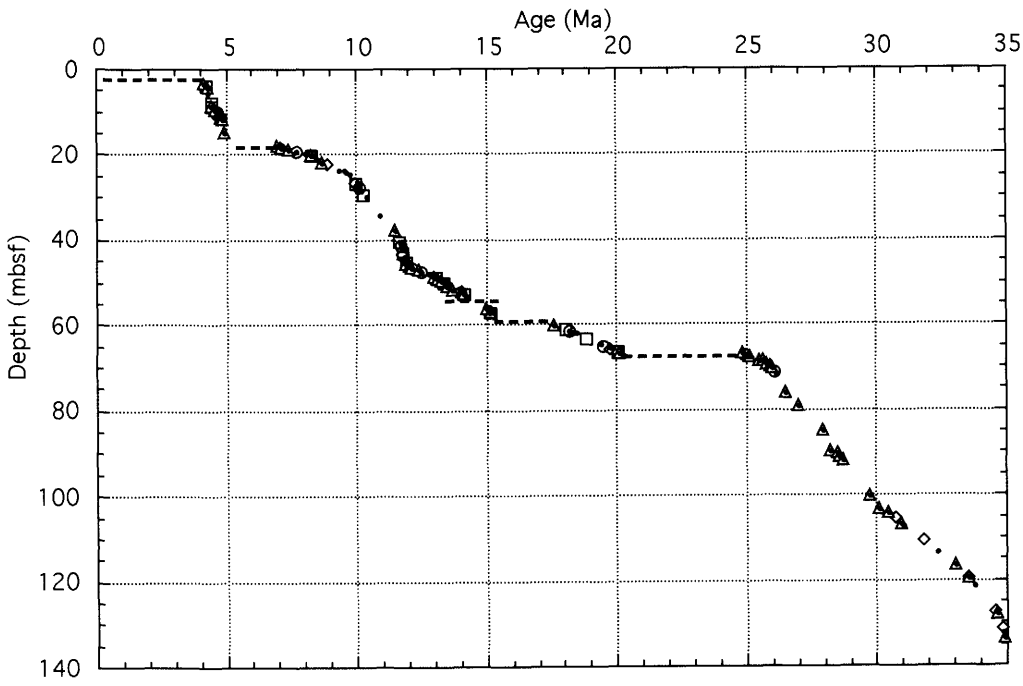


Fig. 9. An age–depth plot for DSDP Hole 689B utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols. Five stratigraphical breaks (dashed line) are based on Spiess (1990).

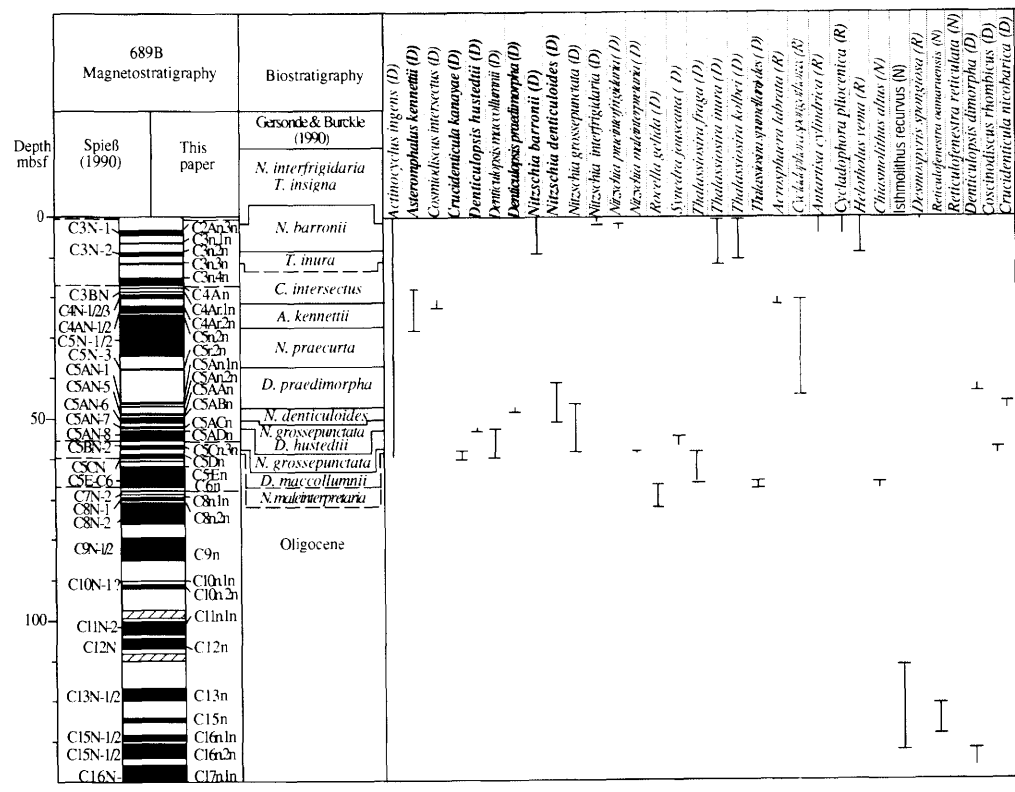


Fig. 10. Comparison of the ODP Hole 689B polarity chronozones and diatom zonal assignments by previous workers with the chronozonal assignments of this study. The stratigraphical ranges of selected stratigraphical indicators are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995). Diagonal lines indicate intervals of uncertainty.

Table 9. Composite dataset for ODP Hole 689B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
Unconformity			***	***	***	***
LO <i>Actinocyclus ingens</i>	1H-1, 0	1H-1, 28-29	0.00	0.00	?	?
LO <i>Antarctissa cylindrica</i>	1H-1, 0	1H-1, 25-26	0.00	0.26	?	?
LO <i>Cycladophora plicocenic</i>	1H-1, 0	1H-1, 25-26	0.00	0.26	?	?
LO <i>Eucyrtidium calvertense</i>	1H-1, 0	1H-1, 25-26	0.00	0.26	?	?
LO <i>Desmospyris spongiosa</i>	1H-1, 0	1H-1, 25-26	0.00	0.26	?	?
LO <i>Helotholus vema</i>	1H-1, 0	1H-1, 25-26	0.00	0.26	?	?
FO <i>Cycladophora davisiana</i>	1H-1, 0	1H-1, 25-26	0.00	0.26	?	?
LO <i>Thalassiosira oestrupii</i>	1H-1, 0	1H-1, 28-29	0.00	0.29	?	?
LO <i>Nitzschia interfrigidaria</i>	1H-1, 0	1H-1, 28-29	0.00	0.29	?	?
LO <i>Nitzschia barronii</i>	1H-1, 0	1H-1, 28-29	0.00	0.29	?	?
LO <i>Thalassiosira inura</i>	1H-1, 28-29	1H-1, 56-58	0.29	0.58	?	?
LO <i>Thalassiosira kolbei</i>	1H-1, 28-29	1H-1, 56-58	0.29	0.58	?	?
LO <i>Nitzschia praeinterfrigidaria</i>	1H-2, 28-29	1H-2, 50-52	1.79	2.02	?	?
FO <i>Nitzschia interfrigidaria</i>	1H-2, 28-29	1H-2, 50-52	1.79	2.02	?	?
T C2An.3n			3.38	3.38	3.33	3.33
LO <i>Prunopyle titan</i>	1H-3, 118-120	1H-4, 104-105	4.18	5.53	3.53	3.92
B C2An.3n			4.40	4.40	3.58	3.58
T C3n.1n			6.41	6.41	4.18	4.18
B C3n.1n			6.61	6.61	4.29	4.29
LO <i>Denticulopsis dimorpha</i>	2H-1, 31-33	2H-1, 115-116	5.63	6.45	3.95	4.02
FO <i>Helotholus vema</i>	2H-2, 118-120	2H-3, 62-64	7.89	8.92	4.40	4.50
FO <i>Nitzschia barronii</i>	2H-3, 28-29	2H-3, 90-92	8.59	9.22	4.46	4.55
T C3n.2n			8.79	8.79	4.48	4.48
B C3n.2n			9.63	9.63	4.62	4.62
FO <i>Nitzschia reinholdii</i>	2H-4, 28-29	2H-4, 56-58	10.09	10.38	4.67	4.69
FO <i>Thalassiosira kolbei</i>	2H-4, 56-58	2H-4, 115-116	10.38	10.98	4.68	4.75
T C3n.3n			11.45	11.45	4.80	4.80
FO <i>Thalassiosira inura</i>	2H-5, 27-28	2H-5, 55-57	11.58	11.87	4.84	4.89
B C3n.3n			11.72	11.72	4.89	4.89
T C3n.4n			15.17	15.17	4.98	4.98
FO <i>Thalassiosira oestrupii</i>	3H-2, 56-58	3H-2, 118-120	16.88	17.50	?	?
Unconformity			***	***	***	***
T C4An			18.09	18.09	8.70	8.70
LO <i>Asteromphalus kennettii</i>	3H-3 56-58	3H-3, 148-150	18.38	19.30	8.55	9.25
B C4An			18.67	18.67	9.03	9.03
T C4Ar.1n			18.92	18.92	9.23	9.23
LO <i>Actinocyclus ingens</i> v. <i>nodus</i>	3H-3, 148-150	3H-3, 56-58	19.30	19.88	9.25	9.29
FO <i>Cosmiodiscus intersectus</i>	3H-5, 80-82	3H-5, 114-115	20.12	20.45	9.31	9.35
B C4Ar.1n			20.17	20.17	9.31	9.31
FO <i>Acrosphaera labrata</i>	3H-4, 94-96	3H-5, 136-138	20.26	21.29	9.32	9.46
LO <i>Cycladophora spongothorax</i>	3H-4, 94-96	3H-5, 136-138	20.24	22.16	9.32	9.58
T C4Ar.2n			22.15	22.15	9.58	9.58
LO <i>Reticulofenestra gelida</i>	5H-2, 30-32	5H-3, 30-32	22.60	24.67	9.60	9.92
B C4Ar.2n			23.65	23.65	9.64	9.64
T C5n.1n			23.81	23.81	9.74	9.74
B C5n.1n			24.17	24.17	9.88	9.88
T C5n.2n			24.67	24.67	9.92	9.92
LO <i>Cycladophora humerus</i>	4H-2, 117-119	4H-3, 56-58	26.97	27.86	10.16	10.25
FO <i>Acrosphaera australis</i>	4H-2, 117-119	4H-3, 56-58	26.97	27.86	10.16	10.25
FO <i>Asteromphalus kennettii</i>	4H-3, 31-32	4H-3, 114-115	27.62	28.45	10.23	10.31
FO <i>Eucyrtidium pseudoinflatum</i>	4H-4, 56-58	4H-4, 116-118	29.36	29.96	10.41	10.47
B C5n.2n			34.55	34.55	10.95	10.95
B C5r.2n			37.93	37.93	11.53	11.53
LO <i>Actinomma golownini</i>	5H-5, 56-58	5H-5, 117-118	40.36	40.97	11.77	11.79
LO <i>Nitzschia denticuloides</i>	5H-6, 28-29	5H-6, 114-115	41.59	42.45	11.80	11.83
FO <i>Cycladophora spongothorax</i>	5H-CC	6H-1, 59	43.30	43.89	11.86	11.87
FO <i>Denticulopsis dimorpha</i>	6H-1, 27-28	6H-1, 114-115	43.58	44.45	11.87	11.89
LO <i>Reticulofenestra hesslandii</i>	6H-1, 30-32	6H-2, 29-31	43.60	45.09	11.87	11.91
FO <i>Dendrospyris megalcephalis</i>	6H-2, 58-60	6H-3, 91-93	45.38	47.21	11.92	12.37
T C5An.1n			45.93	45.93	11.94	11.94
LO <i>Crucidenticula nicobarica</i>	6H-2, 114-115	6H-3, 28-29	45.95	46.59	11.95	12.14
B C5An.1n			46.41	46.41	12.08	12.08
LO <i>Nitzschia grossepunctata</i>	6H-3, 28-29	6H-3, 114-115	46.59	47.45	12.15	12.51
T C5An.2n			46.68	46.68	12.18	12.18
B C5An.2n			47.18	47.18	12.40	12.40
FO <i>Denticulopsis praedimorpha</i>	6H-3, 114-115	6H-4, 28-29	47.45	48.09	12.51	12.76
T C5AAn			48.68	48.68	12.99	12.99

Table 9. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO <i>Actinomma golownini</i>	6H-4, 108-110	6H-5, 31-33	48.90	49.63	13.06	13.28
B C5AAn			49.18	49.18	13.14	13.14
T C5ABn			49.68	49.68	13.30	13.30
FO <i>Antarctissa deflandrei</i>	6H-5, 84-86	6H-5, 117-119	50.16	50.49	13.38	13.43
FO <i>Nitzschia denticuloides</i>	6H-5, 114-115	6H-6, 28-29	50.45	51.09	13.43	13.54
B C5ABn			50.91	50.91	13.51	13.51
T C5ACn			51.93	53.19	13.70	13.70
FO <i>Denticulopsis hustedtii</i>	6H-7, 28-29	7H-1, 28-29	52.29	53.19	13.99	14.24
LO <i>Denticulopsis maccollumnii</i>	6H-7, 28-29	7H-1, 28-29	52.29	53.19	13.99	14.24
B C5ACn			52.41	52.41	14.08	14.08
FO <i>Cycladophora humerus</i>	6H-7, 32-34	7H-1, 32-34	52.64	53.24	14.13	14.25
FO <i>Desmospyris megalcephalis</i>	6H-7, 32-34	7H-1, 32-34	52.64	53.24	14.13	14.25
T C5ADn			52.85	52.85	14.18	14.18
LO <i>Thalassiosira spumellaroides</i>	7H-2, 65-67	7H-2, 115-116	55.07	55.56	15.57	?
LO <i>Synedra jouseana</i>	7H-2, 28-29	7H-2, 65-67	54.69	55.07	14.51	14.57
B C5ADn			55.28	55.28	14.61	14.61
Unconformity			***	***	***	***
FO <i>Actinocyclus ingens v. nodus</i>	7H-3, 28-29	7H-3, 86-88	56.19	56.19	?	?
T C5Cn.3n			56.53	56.53	16.56	16.56
LO <i>Coscinodiscus lewisianus</i>	7H-3, 86-88	7H-3, 114-115	56.78	57.06	16.61	16.66
LO <i>Coscinodiscus rhombicus</i>	7H-3, 115-116	7H-3, 145-147	57.06	57.37	16.66	16.72
FO <i>Eucyrtidium punctatum</i>	7H-3, 145-147	7H-4, 148-150	57.37	58.90	16.72	17.33
B C5Cn.3n			57.40	57.40	16.73	16.73
LO <i>Crucidentacula kanayae</i>	7H-4, 28-29	7H-4, 88-86	57.60	58.18	16.81	17.05
LO <i>Nitzschia maleinterpretaria</i>	7H-4, 28-29	7H-4, 86-88	57.69	58.28	16.85	17.09
FO <i>Nitzschia grossepunctata</i>	7H-4, 28-29	7H-4, 86-88	57.69	58.28	16.85	17.09
LO <i>Thalassiosira fraga</i>	7H-4, 86-88	7H-4, 114-115	58.28	58.56	17.09	17.20
FO <i>Actinocyclus ingens</i>	7H-4, 115-116	7H-5, 28-29	58.60	59.19	17.22	17.45
FO <i>Denticulopsis maccollumnii</i>	7H-4, 115-116	7H-5, 28-29	58.60	59.19	17.22	17.45
T C5Dn			58.75	58.75	17.28	17.28
FO <i>Crucidentacula kanayae</i>	7H-5, 28-29	7H-5, 55-57	59.19	59.47	17.45	17.55
B C5Dn			59.65	59.65	17.62	17.62
T C5En			60.03	60.03	18.28	18.28
B C5En			60.40	60.40	18.78	18.78
FO <i>Cycladophora golli regipileus</i>	7H-5, 89-91	7H-6, 117-119	61.21	61.49	18.94	19.00
FO <i>Crucidentacula nicobarica</i>	7H-6, 115-116	7H-7, 28-29	61.56	62.19	19.01	19.14
FO <i>Cyrtocapsella tetrapera</i>	7H-7, 21-23	7H-7, 56-58	61.23	61.87	18.94	?
T C6n			61.76	61.76	19.05	19.05
Unconformity	***	***	***	***	***	***
FO <i>Cyrtocapsella longithorax</i>	8H-1, 57-59	8H-2, 56-58	63.37	64.88	?	?
FO <i>Raphidodiscus marylandicus</i>	8H-2, 114-115	8H-3, 28-29	65.15	65.79	?	?
FO <i>Thalassiosira fraga</i>	8H-2, 114-115	8H-3, 28-29	65.15	65.79	?	?
LO <i>Chiasmolithus altus</i>	8H-3, 30-32	8H-4, 30-32	65.85	67.32	?	?
LO <i>Reticulofenestra bisecta</i>	8H-3, 30-32	8H-4, 30-32	65.85	67.32	?	24.93
LO <i>Rocella gelida</i>	8H-3, 115-116	8H-3, 146-148	66.65	66.96	?	24.84
B C7n.1n			66.86	66.86	24.78	24.78
T C7n.2n			67.11	67.11	24.84	24.84
FO <i>Thalassiosira spumellaroides</i>	8H-3, 144-146	8H-4, 28-29	66.96	67.29	24.77	24.92
LO <i>Rocella vigilans</i>	8H-4, 28-29	8H-4, 57-59	67.29	67.59	24.91	25.05
B 7n.2n			67.88	67.88	25.18	25.18
T C7An			68.61	68.61	25.50	25.50
B C7An			68.88	68.88	25.65	25.65
T C8n.1n			69.38	69.38	25.82	25.82
B C8n.1n			70.11	70.11	25.95	25.95
T C8n.2n			70.38	70.38	25.99	25.99
FO <i>Rocella vigilans</i>	8H-5, 114-115	8H-6, 28-29	71.15	71.79	26.07	26.13
FO <i>Rocella gelida</i>	8H-5, 114-115	8H-6, 28-29	71.15	71.79	26.07	26.13
B C8n.2n			75.98	75.98	26.55	26.55
T C9n			79.46	79.46	27.03	27.03
B C9n			85.05	85.05	27.97	27.97
T C10n.1n			89.82	89.82	28.28	28.28
B C10n.1n			90.07	90.07	28.51	28.51
T C10n.2n			91.01	91.01	28.58	28.58
B C10n.2n			91.93	91.93	28.75	28.75
T C11n.1n			100.23	100.23	29.40	29.40
B C11n.2n			103.38	103.38	29.66	29.66
T C12n			104.38	104.38	30.48	30.48
LO <i>Reticulofenestra umbilica</i>	12H-4, 29-31	12H-5, 29-31	105.81	107.31	30.74	31.03

(continued)

Table 9. (continued)

	Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
B	C12n			106.88	106.88	30.94	30.94
LO	<i>Isthmolithus recurvus</i>	13H-1, 130-132	13H-2, 130-132	111.02	113.42	31.83	32.35
T	C13n			116.71	116.71	33.06	33.06
B	C13n			119.70	119.70	33.55	33.55
LO	<i>Reticulofenestra oamaruensis</i>	13H-7, 28-30	14H-1, 130-132	119.90	121.50	33.60	34.01
T	C15n			124.09	124.09	34.66	34.66
B	C15n			125.07	125.07	34.94	34.94
FO	<i>Reticulofenestra oamaruensis</i>	14H-5, 130-132	14H-6, 130-132	127.50	127.70	35.24	35.26
T	C16n.1n			128.33	128.33	35.34	35.34
B	C16n.1n			129.70	129.70	35.53	35.53
T	C16n.2n			130.05	130.05	35.69	35.69
FO	<i>Isthmolithus recurvus</i>	15H-2, 30-32	15H-2, 131-132	131.70	132.73	35.82	36.01
LO	<i>Reticulofenestra reticulata</i>	15H-2, 30-32	15H-2, 131-132	131.70	132.73	35.82	36.01
B	C16n.2n			134.02	134.02	36.34	36.34
T	C17n.1n			135.77	135.77	36.20	36.20

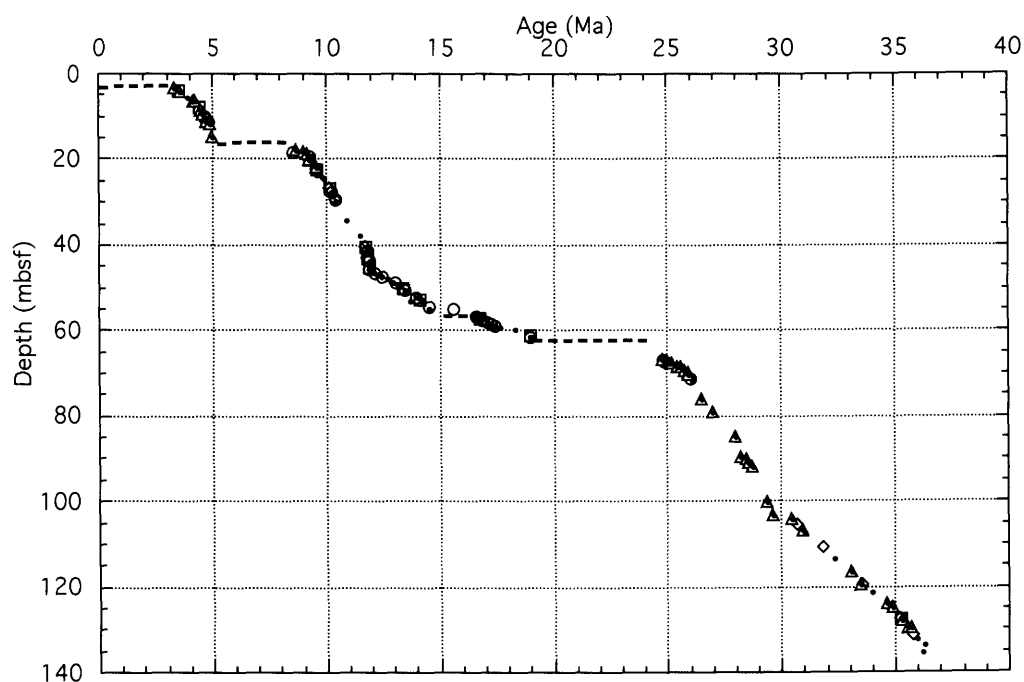


Fig. 11. A revised age-depth plot for DSDP Hole 689B utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols. Four stratigraphical breaks (dashed line) are based on the results of this study.

Hole 690B

Twenty-five cores were recovered from a total penetration of 213.4 mbsf representing a recovery of 100% of the cored interval. Sediments recovered consist of Quaternary calcareous ooze, Pliocene to upper Miocene diatom ooze, and Miocene to upper Palaeocene calcareous ooze. A siliceous component varies throughout the Miocene to upper Eocene section (Barker *et al.* 1988). A good palaeomagnetic polarity reversal record was obtained by both shipboard and shorebase analysis (Barker *et al.* 1988; Spiess 1990). Diatoms, calcareous nannofossils and radiolarians are present throughout the sequence. Diatoms are present through the Pleistocene to Oligocene sequence. Abundance and preservation varies with common, moderately preserved diatoms present in the Pleistocene to upper Miocene sediments; few, moderately preserved diatoms recorded in the middle and lower Miocene; and rare, poorly preserved diatoms observed in the Oligocene (Gersonde & Burckle 1990). Calcareous nannofossils are rare in the Pleistocene, absent in the Pliocene to upper Miocene, and abundant throughout the remaining sequence. Preservation of calcareous nannofossils is moderate in the Miocene to Oligocene interval (Wei & Wise 1990). Radiolarians are abundant and well preserved in the Pleistocene to lower Miocene and abundant and poorly preserved in the Oligocene. Radiolarians are absent from the remaining sequence (Barker *et al.* 1988). The previously used biostratigraphical and magnetostratigraphical data (palaeomagnetism: Spiess 1990; diatoms: Gersonde & Burckle 1990; calcareous nannofossils: Wei & Wise 1990; radiolarians: Abelman 1990; Lazarus 1990) integrated and calibrated to the GPTS of Berggren *et al.* (1985a, b) is presented in Table 10. An age-depth graph for Hole 113-690B using this data is shown in Fig. 12.

Figure 13 compares the polarity chronozones and diatom zones assigned by previous workers (Spiess 1990; Gersonde & Burckle 1990, respectively) with the chronozone assignments in this study. The stratigraphical ranges of diatoms, radiolarians and calcareous nannofossils reflect the placement of the FO and LO of stratigraphically useful species as recognized by Gersonde & Burckle (1990), Abelman (1990), Lazarus (1990), and Wei & Wise (1990), respectively. The revised chronozones illustrated are based on reassessing the data sets of these workers (Table 11). Comparison of the chronozone assignments of Spiess (1990; Table 10) with those of this study (Table 11) indicates that significant reinterpretation was completed for the upper 50 m of the section. Within the upper 50 m, differences in chronozone assignments reflect in part differences in the GPTS used in each study.

An age-depth graph for Hole 113-690B using the stratigraphical markers determined in this study is shown in Fig. 14. Four unconformities are identified in this stratigraphical sequence at approximately 18.3, 42.0, 51.5 and 90 mbsf. The youngest unconformity is constrained above by the LO of *Thalassiosira*

kolbei (1.84–2.39 mbsf), the FO of *Nitzschia interfrigidaria* (8.39–9.25 mbsf), the FO of *Helotholus vema* (9.84–11.7 mbsf) and the FO of *Nitzschia barronii* at (11.39–11.98 mbsf). The interval above the unconformity contains the base of C2r.1n (2 mbsf) to the base of C3n.2n (11.78 mbsf). The lower boundary of this unconformity is constrained by the FO of *Denticulopsis praedimorpha* (36.75–37.39 mbsf), the FO of *Nitzschia denticulodes* (38.89–39.75 mbsf), the FO of *Denticulopsis hustedtii* (40.39–41.08 mbsf), the LO of *Synedra jouseana* (41.32–42 mbsf) and a continuous polarity sequence from the top of C4Ar.1n (18.57 mbsf) to the base of C5ADn (41.68).

The second stratigraphical break is placed between 41.68 and 42.16 mbsf. The upper boundary of this unconformity is constrained by the LO of *Denticulopsis hustedtii* and the LO of *Synedra jouseana*. The lower boundary is constrained by a polarity sequence from the top of C5Cn.3n (42.16 mbsf) to the base of C6n (51.28 mbsf) and the FO of *Crucidentacula kanayae* (44.08–44.31) mbsf.

A third unconformity is recognized at a depth of 51.5 mbsf. The upper boundary is constrained by the base of Chron C6n. The lower boundary is constrained by a sequence of magnetic events from the top of C8n.2n (53.25 mbsf) to the base of C12n (84.01 mbsf). No primary biostratigraphical markers occur within the sequence.

The oldest hiatus occurs at approximately 90 mbsf. The upper boundary of this break is constrained by the base of C12n (84.01 mbsf). The lower boundary is constrained by the base of C16n.1n (91.95 mbsf), the top of C16n.2n (92.21 mbsf) and the FO of *Isthmolithus recurvus* (92.41–93.42 mbsf) and LO of *Reticulofenestra reticulata* at 92.41–93.42 mbsf.

This study suggests that the stratigraphical section is more continuous than previously recognized. Gersonde & Burckle (1990) and Gersonde *et al.* (1990) identified 11 hiatuses at 2.0, 7.2, 14.9, 18.8, 21.0, 31.2, 39.0, 43.7, 47.1, 48.7 and 51.2 mbsf. These breaks are based primarily on an integrated bio and magnetostratigraphy. Gersonde *et al.* (1990) identify the hiatuses at approximately 17.5 and 51.2 mbsf as the most important stratigraphical breaks. The unconformities at approximately 18.45 and 51.5 mbsf recognized in this study occur at approximately the same depths in the hole to similar unconformities identified by Gersonde & Burckle (1990).

Spiess (1990) identified nine hiatuses within an interval of approximately 37.8 my. Breaks at 2.0, 7.23, 18.83, 21.07, 31.2, 43.66, 51.28 mbsf coincide with Neogene hiatuses recognized by Gersonde & Burckle (1990) and Gersonde *et al.* (1990). Earlier hiatuses at 72.18 and 91.58 mbsf occur within the upper Eocene to Oligocene sequence, which is not considered by Gersonde & Burckle (1990) and Gersonde *et al.* (1990). The hiatus at approximately 90 mbsf is coincides with the hiatus at 91.58 mbsf recorded by Spiess 1990.

Table 10. Composite dataset for ODP Hole 690B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande and Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO <i>Nitzschia kerguelensis</i>	1H-1, 0	1H-1, 73-75	0.00	0.75	?	?
LO <i>Antarctissa cylindrica</i>	1H-1, 0	2H-2, 0	0.00	2.10	?	?
LO <i>Cycladophora pliocenica</i>	1H-1, 0	2H-2, 0	0.00	2.10	?	?
LO <i>Eucyrtidium calvertense</i>	1H-1, 0	2H-2, 0	0.00	2.10	?	?
LO <i>Desmospyris spongiosa</i>	1H-1, 0	2H-2, 0	0.00	2.10	?	?
LO <i>Helotholus vema</i>	1H-1, 0	2H-2, 0	0.00	2.10	?	?
FO <i>Cycladophora davisiana</i>	1H-1, 0	2H-2, 0	0.00	2.10	?	?
LO <i>Actinocyclus ingens</i>	1H-1, 73-75	1H-2, 32-34	0.75	1.84	?	?
LO <i>Thalassiosira kolbei</i>	1H-2, 32-34	2H-1, 28-29	1.84	2.39	?	?
LO <i>Nitzschia interfrigidaria</i>	1H-2, 32-34	2H-1, 28-29	1.84	2.39	?	?
LO <i>Thalassiosira inura</i>	1H-2, 32-34	2H-1, 28-29	1.84	2.39	?	?
LO <i>Nitzschia barronii</i>	1H-2, 32-34	2H-1, 28-29	1.84	2.39	?	?

(continued)

Table 10. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
Unconformity			***	***	***	***
T ? Reunion			3.45	3.45	?	?
B ? Reunion			3.70	3.70	?	?
T C2An.1n			4.83	4.83	2.58	2.58
T <i>Simonseniella barboi</i>	2H-3, 114-115	2H-4, 28-29	6.25	6.89	2.93	3.09
B 2An.1n			6.71	6.71	3.04	3.04
LO <i>Nitzschia praeinterfrigidaria</i>	2H-4, 28-29	2H-4, 114-115	6.89	7.75	3.09	?
T C2An.2n			6.98	6.98	3.11	3.11
Unconformity			***	***	***	***
FO <i>Thalassiosira lentiginosa</i>	2H-4, 114-115	2H-5, 28-29	7.75	8.39	?	?
FO <i>Nitzschia interfrigidaria</i>	2H-5, 28-29	2H-5, 114-115	8.39	9.25	?	?
LO <i>Prunopyle titan</i>	2H-6, 24	2H-CC	9.84	11.70	?	?
FO <i>Helotholus vema</i>	2H-6, 24	2H-CC	9.84	11.70	?	?
T C3n.1n			10.23	10.23	4.18	4.18
B C3n.1n			10.48	10.48	4.29	4.29
T C3n.2n			11.21	11.21	4.48	4.48
FO <i>Nitzschia barronii</i>	2H-7, 27-29	3H-1, 27-28	11.39	11.98	4.52	4.63
B C3n.2n			11.78	11.78	4.62	4.62
LO <i>Denticulopsis dimorpha</i>	3H-1, 27-28	3H-1, 115-116	11.98	12.86	4.63	4.68
FO <i>Thalassiosira inura</i>	3H-2, 114-115	3H-3, 73-75	14.36	15.21	4.76	4.81
FO <i>Nitzschia praeinterfrigidaria</i>	3H-3, 73-75	3H-3, 125-127	15.45	15.97	4.82	4.85
LO <i>Cycladophora spongothorax</i>	3H-4, 26	3H-6, 26	16.46	19.46	4.88	?
LO <i>Cycladophora humerus</i>	3H-CC	4H-2, 26-28	16.76	18.26	4.89	4.98
T C3n.4n			18.32	18.32	4.98	4.98
FO <i>Nitzschia praeinterfrigidaria</i>	3H-3, 73-75	3H-3, 125-127	18.45	18.87	?	?
LO <i>Asteromphalus kennettii</i>	3H-5, 73-75	3H-5, 114-115	18.45	18.87	?	?
Unconformity			***	***	***	***
B unidentified anomaly			18.57	18.57	5.23	5.23
FO <i>Cosmiodiscus intersectus</i>	3H-5, 114-115	3H-6, 23-25	18.87	19.95	?	?
B C4An			20.07	20.07	9.03	9.03
Unconformity			***	***	***	***
LO <i>Cycladophora humerus</i>	3H-CC	4H-2, 26-28	21.40	23.16	?	10.00
B C5n.1n			22.53	22.53	9.88	9.88
T C5n.2n			22.76	22.76	9.92	9.92
FO <i>Eucyrtidium pseudoinflatum</i>	4H-2, 26	4H-4, 26	23.16	26.16	10.00	10.58
LO <i>Actinomma golownini</i>	4H-2, 26	4H-4, 26	23.16	26.16	10.00	10.58
FO <i>Asteromphalus kennettii</i>	4H-1, 114-115	4H-3, 26-27	24.06	24.67	10.17	10.29
LO <i>Denticulopsis praedimorpha</i>	4H-5, 26-27	4H-5, 114-115	27.67	28.55	10.88	?
B C5n.2n			28.03	28.03	10.95	10.95
Unconformity			***	***	***	***
LO <i>Nitzschia denticuloides</i>	5H-1, 28-29	5H-1, 115-117	31.39	32.27	?	?
T C5An.1n			31.72	31.72	11.94	11.94
B C5An.1n			32.45	32.45	12.08	12.08
FO <i>Cycladophora spongothorax</i>	5H-2, 26	5H-4, 26	32.86	35.86	12.12	12.93
LO <i>Reticulofenestra gelida</i>	5H-1, 30-32	5H-2, 30-32	32.90	34.40	12.12	12.51
LO <i>Reticulofenestra hesslandii</i>	5H-1, 30-32	5H-2, 30-32	32.90	34.40	12.12	12.51
T C5An.2n			33.47	33.47	12.18	12.18
B C5An.2n			33.95	33.95	12.40	12.40
LO <i>Crucidenticula nicobarica</i>	5H-3, 27-29	5H-3, 115-117	34.39	35.25	12.51	12.72
FO <i>Denticulopsis dimorpha</i>	5H-3, 115-117	5H-4, 27-29	35.25	35.89	12.72	12.88
T C5AAn			36.35	36.35	12.99	12.99
FO <i>Denticulopsis praedimorpha</i>	5H-4, 115-117	5H-5, 27-29	36.75	37.39	13.09	13.25
B C5AAn			36.95	36.95	13.14	13.14
T C5ABn			37.20	37.20	13.30	13.30
FO <i>Actinomma golownini</i>	5H-5, 49-51	5H-6, 49-51	37.61	39.11	13.41	13.82
C5ABn			37.97	37.97	13.51	13.51
FO <i>Nitzschia denticuloides</i>	5H-6, 27-29	5H-6, 115-117	38.89	39.75	13.68	14.00
LO <i>Nitzschia grossepunctata</i>	5H-6, 27-29	5H-6, 115-117	38.89	39.75	13.68	14.00
T C5ACn			38.97	38.97	13.70	13.70
FO <i>Cycladophora humerus</i>	5H-6, 49-51	6H-1, 51-52	39.11	41.32	13.75	14.51
FO <i>Antarctissa deflandrei</i>	5H-6, 49-51	6H-1, 51-52	39.11	41.32	13.75	14.51
B C5ACn			39.95	39.95	14.08	14.08
T C5ADn			40.20	40.20	14.18	14.18
LO <i>Denticulopsis maccollumii</i>	5H-7, 27-29	6H-1, 27-29	40.39	41.08	14.24	14.44
FO <i>Denticulopsis hustedtii</i>	5H-7, 27-29	6H-1, 27-29	40.39	41.08	14.24	14.44
LO <i>Nitzschia maleinterpretaria</i>	6H-1, 50-52	6H-1, 115-117	41.32	42.00	14.51	14.74
LO <i>Synedra jouseana</i>	6H-1, 50-52	6H-1, 115-117	41.32	42.00	14.51	14.74
FO <i>Actinocyclus ingens v. nodus</i>	6H-1, 50-52	6H-1, 115-117	41.32	42.00	14.51	14.74
B C5ADn			41.68	41.68	14.61	14.61

Table 10. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
T C5Bn.1n			42.16	42.16	14.80	14.80
B C5Bn.1n			42.41	42.41	14.89	14.89
LO <i>Crucidenticula kanayae</i>	6H-2, 49-51	6H-2, 115-117	42.81	43.45	?	?
FO <i>Nitzschia grossepunctata</i>	6H-2, 115-117	6H-3, 27-29	43.45	44.08	?	?
FO <i>Actinocyclus ingens</i>	6H-2, 115-117	6H-3, 27-29	43.45	44.08	?	?
FO <i>Nitzschia maleinterpretaria</i>	6H-2, 115-117	6H-3, 27-29	43.45	44.08	?	?
Unconformity			***	***	***	***
FO <i>Denticulopsis maccollumii</i>	6H-3, 27-29	6H-3, 49-51	44.08	44.31	?	?
FO <i>Crucidenticula kanayae</i>	6H-3, 27-29	6H-3, 49-51	44.08	44.31	?	?
B In C5Dn			44.68	44.68	?	?
LO <i>Thalassiosira fraga</i>	6H-3, 115-117	6H-4, 27-29	44.95	45.58	?	?
FO <i>Cycladophora golli regipileus</i>	6H-5, 49-51	6H-6, 49-51	45.41	47.31	?	?
B C5Dn			45.68	45.68	17.62	17.62
B In C5En			46.68	46.68	?	?
FO <i>Cyrtocapsella longithorax</i>	6H-6, 49-51	6H-7, 49-51	48.81	50.31	?	?
FO <i>Crucidenticula nicobarica</i>	6H-5, 27-29	6H-5, 114-115	47.09	47.95	?	?
LO <i>Thalassiosira spumellaroides</i>	6H-6, 49-51	6H-6, 115-116	48.59	49.46	?	?
FO <i>Cyrtocapsella tetrapera</i>	6H-6, 49-51	7H-1, 49-51	48.81	50.89	?	?
FO <i>Thalassiosira fraga</i>	6H-7, 27-29	7H-1, 27-29	50.09	50.69	?	?
LO <i>Rocella gelida</i>	6H-7, 27-29	7H-1, 27-29	50.09	50.69	?	?
LO <i>Rocella vigilans</i>	7H-1, 27-29	7H-1, 49-51	50.68	50.91	?	?
FO <i>Thalassiosira aspinosa</i>	7H-1, 27-29	7H-1, 49-51	50.68	50.91	?	?
FO <i>Raphidodiscus marylandicus</i>	7H-1, 27-29	7H-1, 49-51	50.68	50.91	?	?
LO <i>Lisitzina ornata</i>	7H-1, 49-51	7H-1, 114-115	50.91	51.55	?	?
FO <i>Thalassiosira spumellaroides</i>	7H-1, 49-51	7H-1, 114-115	50.91	51.55	?	?
Unconformity			***	***	***	***
LO <i>Chiasmolithus altus</i>			51.72	52.20	?	?
T C8n.1n			53.25	53.25	25.82	25.82
FO <i>Rocella gelida</i>	7H-3, 114-115	7H-4, 27-29	54.55	55.19	25.93	26.01
FO <i>Rocella vigilans</i>	7H-3, 114-115	7H-4, 27-29	54.55	55.19	25.93	26.01
B C8n.1n			54.75	54.75	25.95	25.95
T C8n.2n			55.00	55.00	25.99	25.99
FO <i>Lisitzina ornata</i>	7H-6, 27-29	7H-6, 114-115	58.19	59.05	26.34	26.43
B C8n.2n			60.11	60.11	26.55	26.55
T C9n			60.99	60.99	27.03	27.03
B C9n			68.48	68.48	27.97	27.97
LO <i>Reticulofenestra bisecta</i>	9H-2, 28-30	9H-3, 28-30	71.58	73.10	?	?
Unconformity			***	***	***	***
B C11n.2n			73.93	73.93	30.10	30.10
T C12n			80.76	80.76	30.48	30.48
FO <i>Cyclicargolithus abisectus</i>	9H-6, 28-30	9H-7, 28-30	82.68	84.18	30.75	?
B C12n			84.01	84.01	30.94	30.94
LO <i>Reticulofenestra umbilica</i>	10H-4, 26-28	10H-5, 26-28	84.18	85.68	?	?
LO <i>Isthmolithus recurvus</i>	11H-1, 29-31	11H-1, 130-132	89.39	90.09	?	?
Unconformity			***	***	***	***
B C16n.2n			91.95	91.95	36.34	36.34
FO <i>Isthmolithus recurvus</i>	11H-3, 29-31	11H-3, 130-132	92.41	93.42	36.36	36.39
LO <i>Reticulofenestra reticulata</i>	11H-3, 29-31	11H-3, 130-132	92.41	93.42	36.36	36.39
In C16r			95.7	95.7	?	?
T 17n.1n			96.59	96.59	36.62	36.62
B 17n.1n			99.04	99.04	37.47	37.47

Data sets are integrated from the work of numerous authors (see Table 2).

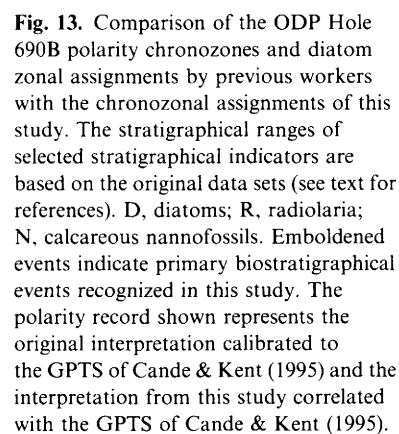
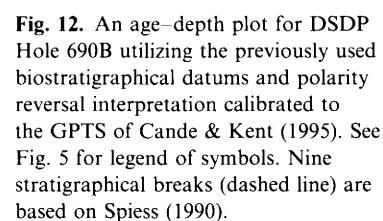


Table 11. Composite dataset for ODP Hole 690B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO <i>Nitzschia kerguelensis</i>	1H-1, 0	1H-1, 73-75	0.00	0.75	0.00	0.81
LO <i>Antarctissa cylindrica</i>	1H-1, 0	2H-2, 0	0.00	2.10	0.00	2.26
LO <i>Cycladophora pliocenica</i>	1H-1, 0	2H-2, 0	0.00	2.10	0.00	2.26
LO <i>Eucyrtidium calvertense</i>	1H-1, 0	2H-2, 0	0.00	2.10	0.00	2.26
LO <i>Desmospyris spongiosa</i>	1H-1, 0	2H-2, 0	0.00	2.10	0.00	2.26
LO <i>Helotholus vema</i>	1H-1, 0	2H-2, 0	0.00	2.10	0.00	2.26
FO <i>Cycladophora davisiana</i>	1H-1, 0	2H-2, 0	0.00	2.10	0.00	2.26
LO <i>Actinocyclus ingens</i>	1H-1, 73-75	1H-2, 32-34	0.75	1.84	0.81	1.98
LO <i>Thalassiosira kolbei</i>	1H-2, 32-34	2H-1, 28-29	1.84	2.39	1.98	2.27
LO <i>Nitzschia interfrigidaria</i>	1H-2, 32-34	2H-1, 28-29	1.84	2.39	1.98	2.27
LO <i>Thalassiosira inura</i>	1H-2, 32-34	2H-1, 28-29	1.84	2.39	1.98	2.27
LO <i>Nitzschia barronii</i>	1H-2, 32-34	2H-1, 28-29	1.84	2.39	1.98	2.27
B C2r.1n			2.00	2.00	2.15	2.15
T C2An.1n			3.45	3.45	2.58	2.58
B C2An.1n			3.70	3.70	3.04	3.04
T C2An.2n			4.83	4.83	3.11	3.11
LO <i>Simonseniella barboi</i>	2H-3, 114-115	2H-4, 28-29	6.25	6.89	3.19	3.29
B C2An.2n			6.71	6.71	3.22	3.22
LO <i>Nitzschia praeinterfrigidaria</i>	2H-4, 28-29	2H-4, 114-115	6.89	7.75	3.29	3.68
T C2An.3n			6.98	6.98	3.33	3.33
B C2An.3n			7.23	7.23	3.58	3.58
FO <i>Thalassiosira lentiginosa</i>	2H-4, 114-115	2H-5, 28-29	7.75	8.39	3.68	3.81
FO <i>Nitzschia interfrigidaria</i>	2H-5, 28-29	2H-5, 114-115	8.39	9.25	3.81	3.98
LO <i>Prunopyle titan</i>	2H-6, 24	2H-CC	9.84	11.70	4.10	4.60
FO <i>Helotholus vema</i>	2H-6, 24	2H-CC	9.84	11.70	4.10	4.60
T C3n.1n			10.23	10.23	4.18	4.18
B C3n.1n			10.48	10.48	4.29	4.29
T C3n.2n			11.21	11.21	4.48	4.48
FO <i>Nitzschia barronii</i>	2H-7, 27-29	3H-1, 27-28	11.39	11.98	4.52	?
B C3n.2n			11.78	11.78	4.62	4.62
LO <i>Denticulopsis dimorpha</i>	3H-1, 27-28	3H-1, 115-116	11.98	12.86	4.63	4.68
FO <i>Thalassiosira inura</i>	3H-2, 114-115	3H-3, 73-75	14.36	15.21	?	?
FO <i>Nitzschia praeinterfrigidaria</i>	3H-3, 73-75	3H-3, 125-127	15.45	15.97	?	?
LO <i>Cycladophora spongothorax</i>	3H-4, 26	3H-6, 26	16.46	19.46	?	?
LO <i>Cycladophora humerus</i>	3H-CC	4H-2, 26-28	16.76	18.26	?	?
Unconformity			***	***	***	***
T C4Ar.1n			18.32	18.32	9.23	9.23
LO <i>Asteromphalus kennettii</i>	3H-5, 73-75	3H-5, 114-115	18.45	18.87	9.27	9.31
B C4Ar.1n			18.57	18.57	9.31	9.31
T C4Ar.2n			18.83	18.83	9.58	9.58
FO <i>Cosmiodiscus intersectus</i>	3H-5, 114-115	3H-6, 23-25	18.87	19.95	9.58	9.63
B C4Ar.2n			20.07	20.07	9.64	9.64
B C5n.1n			22.53	22.53	9.88	9.88
T C5n.2n			22.76	22.76	9.92	9.92
FO <i>Eucyrtidium pseudoinflatum</i>	4H-2, 26	4H-4, 26	23.16	26.16	10.00	10.58
LO <i>Actinomma golownini</i>	4H-2, 26	4H-4, 26	23.16	26.16	10.00	10.58
FO <i>Asteromphalus kennettii</i>	4H-1, 114-115	4H-3, 26-27	24.06	24.67	10.17	10.29
LO <i>Cycladophora humerus</i>	3H-CC	4H-2, 26-28	24.30	26.08	10.22	10.57
LO <i>Denticulopsis praedimorpha</i>	4H-5, 26-27	4H-5, 114-115	27.67	28.55	10.88	11.02
B C5n.2n			28.03	28.03	10.95	10.95
T C5r.2n			31.72	31.72	11.48	11.48
LO <i>Nitzschia denticuloides</i>	5H-1, 28-29	5H-1, 115-117	31.39	32.27	11.46	11.52
B C5r.2n			32.45	32.45	11.53	11.53
FO <i>Cycladophora spongothorax</i>	5H-2, 26	5H-4, 26	32.86	35.86	12.03	12.96
LO <i>Reticulofenestra gelida</i>	5H-1, 30-32	5H-2, 30-32	32.90	34.40	12.08	12.85
LO <i>Reticulofenestra hesslandii</i>	5H-1, 30-32	5H-2, 30-32	32.90	34.40	12.08	12.85
T C5Ar.2n			33.47	33.47	12.78	12.78
B C5Ar.2n			33.95	33.95	12.82	12.82
LO <i>Crucidentacula nicobarica</i>	5H-3, 27-29	5H-3, 115-117	34.39	35.25	12.85	12.91
FO <i>Denticulopsis dimorpha</i>	5H-3, 115-117	5H-4, 27-29	35.25	35.89	12.91	12.96
T C5AAn			36.35	36.35	12.99	12.99
FO <i>Denticulopsis praedimorpha</i>	5H-4, 115-117	5H-5, 27-29	36.75	37.39	13.09	13.35
B C5AAn			36.95	36.95	13.14	13.14
T C5ABn			37.20	37.20	13.30	13.30
FO <i>Actinomma golownini</i>	5H-5, 49-51	5H-6, 49-51	37.61	39.11	13.41	13.75
B C5ABn			37.97	37.97	13.51	13.51
FO <i>Nitzschia denticuloides</i>	5H-6, 27-29	5H-6, 115-117	38.89	39.75	13.68	14.02

(continued)

Table 11. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Nitzschia grossepunctata</i>	5H-6, 27-29	5H-6, 115-117	38.89	39.75	13.68	14.02
T C5ACn			38.97	38.97	13.70	13.70
FO <i>Cycladophora humerus</i>	5H-6, 49-51	6H-1, 51-52	39.11	41.32	13.75	14.51
FO <i>Antarctissa deflandrei</i>	5H-6, 49-51	6H-1, 51-52	39.11	41.32	13.75	14.51
B C5ACn			39.95	39.95	14.08	14.08
T C5ADn			40.20	40.20	14.18	14.18
LO <i>Denticulopsis maccollumnii</i>	5H-7, 27-29	6H-1, 27-29	40.39	41.08	14.24	14.44
FO <i>Denticulopsis hustedtii</i>	5H-7, 27-29	6H-1, 27-29	40.39	41.08	14.24	14.44
LO <i>Nitzschia maleinterpretaria</i>	6H-1, 50-52	6H-1, 115-117	41.32	42.00	14.51	?
LO <i>Synedra jouseana</i>	6H-1, 50-52	6H-1, 115-117	41.32	42.00	14.51	?
FO <i>Actinocyclus ingens v. nodus</i>	6H-1, 50-52	6H-1, 115-117	41.32	42.00	14.51	?
B C5ADn			41.68	41.68	14.61	14.61
Unconformity			***	***	***	***
T C5Cn.3n			42.16	42.16	16.56	16.56
B C5Cn.3n			42.41	42.41	16.73	16.73
LO <i>Crucidentacula kanayae</i>	6H-2, 49-51	6H-2, 115-117	42.81	43.45	16.91	17.19
FO <i>Nitzschia grossepunctata</i>	6H-2, 115-117	6H-3, 27-29	43.45	44.08	17.19	17.42
FO <i>Actinocyclus ingens</i>	6H-2, 115-117	6H-3, 27-29	43.45	44.08	17.19	17.42
FO <i>Nitzschia maleinterpretaria</i>	6H-2, 115-117	6H-3, 27-29	43.45	44.08	17.19	17.42
T C5Dn			43.66	43.66	17.28	17.28
FO <i>Denticulopsis maccollumnii</i>	6H-3, 27-29	6H-3, 49-51	44.08	44.31	17.42	17.50
FO <i>Crucidentacula kanayae</i>	6H-3, 27-29	6H-3, 49-51	44.08	44.31	17.42	17.50
B C5Dn			44.68	44.68	17.62	17.62
LO <i>Thalassiosira fraga</i>	6H-3, 115-117	6H-4, 27-29	44.95	45.58	17.86	18.59
T C5En			45.41	45.41	18.28	18.28
FO <i>Cycladophora golli regipileus</i>	6H-5, 49-51	6H-6, 49-51	45.41	47.31	18.28	19.20
B C5En			45.68	45.68	18.78	18.78
T C6n			46.68	46.68	19.05	19.05
FO <i>Cyrtocapsella longithorax</i>	6H-6, 49-51	6H-7, 49-51	47.31	48.81	19.20	19.55
FO <i>Crucidentacula nicobarica</i>	6H-5, 27-29	6H-5, 115-117	48.58	49.45	19.50	19.70
LO <i>Thalassiosira spumellaroides</i>	6H-6, 27-29	6H-6, 49-51	48.58	48.81	19.50	19.55
FO <i>Cyrtocapsella tetrapera</i>	6H-6, 49-51	7H-1, 49-51	48.81	50.89	19.55	20.04
FO <i>Thalassiosira fraga</i>	6H-7, 27-29	7H-1, 27-29	50.09	50.69	19.85	19.99
LO <i>Rocella gelida</i>	6H-7, 27-29	7H-1, 27-29	50.09	50.69	19.85	19.99
LO <i>Rocella vigilans</i>	7H-1, 27-29	7H-1, 49-51	50.68	50.91	19.99	20.04
FO <i>Thalassiosira aspinosa</i>	7H-1, 27-29	7H-1, 49-51	50.68	50.91	19.99	20.04
FO <i>Raphidodiscus marylandicus</i>	7H-1, 27-29	7H-1, 49-51	50.68	50.91	19.99	20.04
LO <i>Lisitzina ornata</i>	7H-1, 49-51	7H-1, 114-115	50.91	51.55	20.04	?
FO <i>Thalassiosira spumellaroides</i>	7H-1, 49-51	7H-1, 114-115	50.91	51.55	20.04	?
B C6n			51.28	51.28	20.13	20.13
Unconformity			***	***	***	***
LO <i>Chiasmolithus altus</i>			51.72	52.20	?	?
T C8n.2n			53.25	53.25	25.99	25.99
FO <i>Rocella gelida</i>	7H-3, 114-115	7H-4, 27-29	54.55	55.19	26.48	27.06
FO <i>Rocella vigilans</i>	7H-3, 114-115	7H-4, 27-29	54.55	55.19	26.48	27.06
B C8n.2n			54.75	54.75	26.55	26.55
T C9n			55.00	55.00	27.03	27.03
FO <i>Lisitzina ornata</i>	7H-6, 27-29	7H-6, 114-115	58.19	59.05	27.62	27.78
B C9n			60.11	60.11	27.97	27.97
T C10n.1n			60.99	60.99	28.28	28.28
B C10n.1n			67.98	67.98	28.51	28.51
T C10n.2n			68.23	68.23	28.58	28.58
B C10n.2n			68.48	68.48	28.75	28.75
LO <i>Reticulofenestra bisecta</i>	9H-2, 28-30	9H-3, 28-30	71.58	73.10	29.29	29.54
T C11n.1n			72.18	72.18	29.40	29.40
B C11n.1n			73.93	73.93	29.66	29.66
FO <i>Cyclicargolithus abisectus</i>	9H-6, 28-30	9H-7, 28-30	82.68	84.18	30.77	?
T C12n			80.76	80.76	30.48	30.48
B C12n			84.01	84.01	30.94	30.94
LO <i>Reticulofenestra umbilica</i>	10H-4, 26-28	10H-5, 26-28	84.18	85.68	?	?
LO <i>Isthmolithus recurvus</i>	11H-1, 29-31	11H-1, 130-132	89.39	90.09	?	?
Unconformity			***	***	***	***
B C16n.1n			91.95	91.95	35.53	35.53
T C16n.2n			92.21	92.21	35.69	35.69
FO <i>Isthmolithus recurvus</i>	11H-3, 29-31	11H-1, 130-132	92.41	93.42	35.73	35.92
LO <i>Reticulofenestra reticulata</i>	11H-3, 29-31	11H-1, 130-132	92.41	93.42	35.73	35.92
B C16n.2n			95.70	95.70	36.34	36.34

Data sets are integrated from the work of numerous authors (see Table 2).

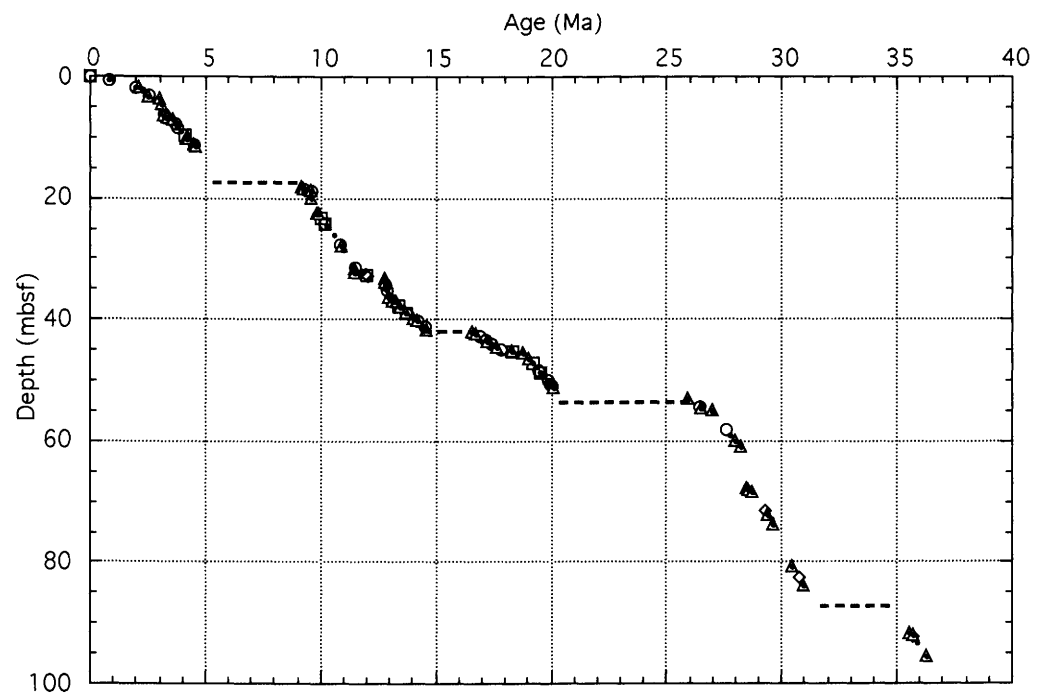


Fig. 14. A revised age–depth plot for DSDP Hole 690B utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols. Four stratigraphical breaks (dashed line) are based on the results of this study.

Hole 695A

Thirty-six cores were recovered from a total penetration of 341.1 mbsf representing a recovery of 75% of the cored interval. Sediments recovered consist of Quaternary to lower Pliocene diatom ooze with a variable terrigenous content and lower Pliocene to upper Miocene muds with diatoms (Barker *et al.* 1988). A good palaeomagnetic polarity reversal record was obtained using shipboard data (Barker *et al.* 1988). Diatoms and radiolarians are present throughout the sequence. Rare to abundant and poor to well preserved diatoms are recorded throughout the section (Gersonde & Burckle 1990). Calcareous nannofossils are absent from this site. Well-preserved radiolarians are common to abundant throughout the section with fewer radiolarians observed in the lowermost portion of the sequence (Barker *et al.* 1988). The previously used biostratigraphical and magnetostratigraphical data (palaeomagnetism: Barker *et al.* 1988; diatoms: Gersonde & Burckle 1990; calcareous nannofossils: none; radiolarians: none) integrated and calibrated to the GPTS of Berggren *et al.* (1985a, b) is presented in Table 12. An age–depth graph for Hole 113-695A using this data is shown in Fig. 15.

Figure 16 compares the polarity chronozones and diatom assigned by previous workers (Barker *et al.* 1988; Gersonde &

Burckle 1990) with the chronozone assignments in this study. The stratigraphical ranges reflect the placement of FO and LO of stratigraphically useful species as recognized by Gersonde & Burckle (1990). The revised chronozones illustrated are based on reassessing the data sets of these workers (Table 13). Comparison of the chronozone assignments recorded in Barker *et al.* (1988; Table 12) with those of this study (Table 13) indicates that only minimal reinterpretations occur resulting from differences in the specific GPTS used in each study.

An age–depth graph for Hole 113-695A using the stratigraphical markers determined in this study is shown in Fig. 17. Stratigraphical control is based predominantly on a continuous sequence of polarity reversals extending from the base of C2n at 5.5 mbsf to the base of C3n.2n at 191 mbsf. This sequence of reversals is correlated with the GPTS using the FO of *Nitzschia praeinterfrigidaria* (186.32–195.19 mbsf) and the FO of *Nitzschia barronii* (127.9–13.6 mbsf). The first occurrence of *Nitzschia barronii* at 4.02–4.18 Ma is approximately 0.25 million years younger than at other sites in this study. The results of this study are similar to those presented by Gersonde & Burckle (1990) and Barker *et al.* (1988).

Table 12. Composite dataset for ODP Hole 695A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande and Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Antarctissa cylindrica</i>	1H-1, 0	1H-CC	0.00	6.40	0.00	2.27
LO <i>Cycladophora pliocenica</i>	1H-1, 0	1H-CC	0.00	6.40	0.00	2.27
LO <i>Actinocyclus ingens</i>	1H1, 55-56	1H-2, 30-31	0.56	1.81	0.20	0.64
LO <i>Thalassiosira vulnifica</i>	1H4, 30-31	1H-4, 100-101	1.81	5.51	0.64	1.95
FO <i>Nitzschia kerguelensis</i>	1H3, 30-31	1H4, 30-31	3.31	4.80	1.17	1.70
B C2n			5.50	5.50	1.95	1.95
LO <i>Thalassiosira insigna</i>	1H-CC	2H-6, 70-71	6.40	11.11	2.11	2.77
LO <i>Desmospyris spongiosa</i>	1H-CC	2H-CC	6.40	12.40	2.11	2.89
LO <i>Helotholus vema</i>	1H-CC	2H-CC	6.40	12.40	2.11	2.89
FO <i>Cycladophora davisiana</i>	1H-CC	2H-CC	6.40	12.40	2.11	2.89
T C2An.1n			9.00	9.00	2.58	2.58
LO <i>Nitzschia praeinterfrigidaria</i>	2H-6, 70-71	2H-CC	11.11	12.40	2.77	2.92
FO <i>Thalassiosira vulnifica</i>	2H-CC	3H-4, 22-22	12.40	17.12	2.89	3.11
LO <i>Nitzschia interfrigidaria</i>	2H-CC	3H-4, 22-22	12.40	17.12	2.89	3.11
B C2An.1n			14.00	14.00	3.04	3.04
T C2An.2n			17.00	17.00	3.11	3.11
LO <i>Nitzschia barronii</i>	3H-4, 21-22	3H-5, 75-76	17.12	19.16	3.11	3.12
LO <i>Nitzschia weaveri</i>	3H-4, 21-22	3H-5, 75-76	17.12	19.60	3.11	3.12
FO <i>Thalassiosira insigna</i>	3H-CC	4H-CC	22.00	31.60	3.13	3.16
LO <i>Thalassiosira inura</i>	5HCC	6H-CC	41.20	50.80	3.20	3.30
B C2An.2n			48.00	48.00	3.22	3.22
FO <i>Nitzschia interfrigidaria</i>	6H-CC	7H-CC	50.80	60.40	3.30	3.71
T C2An.3n			52.00	52.00	3.33	3.33
B C2An.3n			53.00	53.00	3.58	3.58
T C3n.1n			87.00	87.00	4.18	4.18
B C3n.1n			103.50	103.50	4.29	4.29
T C3n.2n			137.00	137.00	4.48	4.48
FO <i>Nitzschia barronii</i>	15H-CC	16H-CC	127.90	137.60	4.42	4.48
FO <i>Nitzschia weaveri</i>	18X-CC	19X-CC	147.30	157.00	4.54	4.60
LO <i>Denticulopsis hustedtii</i>	19X-CC	20X-CC	157.00	166.80	4.60	4.68
LO <i>Prunopyle titan</i>	19X-CC	20X-CC	157.00	166.80	4.60	4.68
B C3n.2n			160.00	160.00	4.62	4.62
T C3n.3n			176.50	176.50	4.80	4.80
LO <i>Cosmiodiscus intersectus</i>	21X-CC	22X-CC	176.50	186.20	4.80	4.89
FO <i>Nitzschia praeinterfrigidaria</i>	22X-CC	23X-CC	186.20	195.90	4.83	4.86
B C3n.3n			205.60	205.60	4.89	4.89

Data sets are integrated from the work of numerous authors (see Table 2).

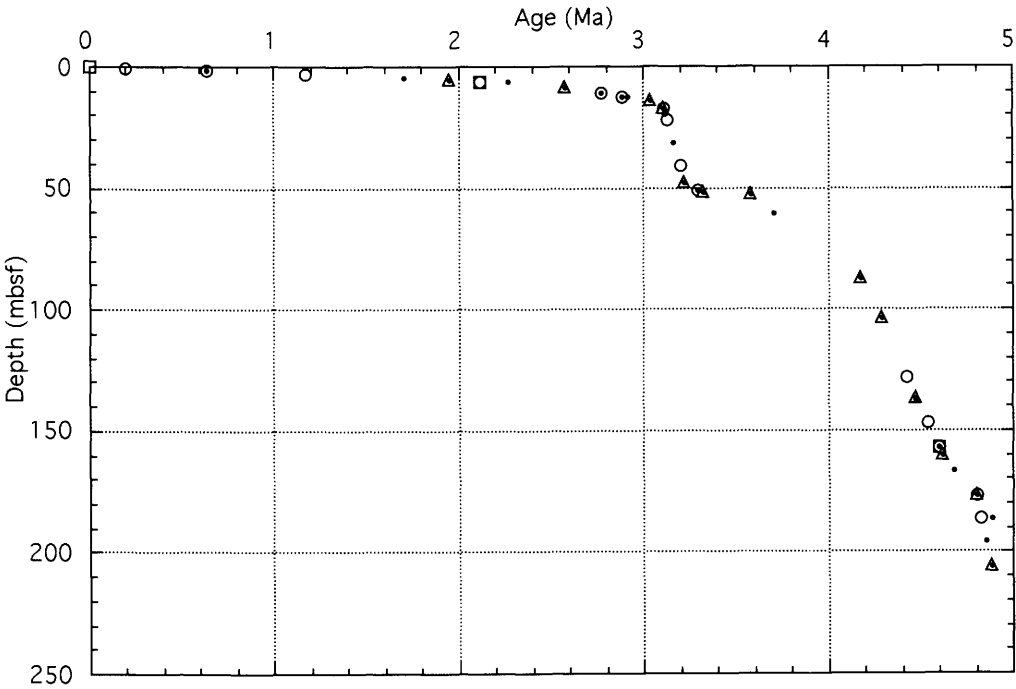


Fig. 15. An age-depth plot for DSDP Hole 695A utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

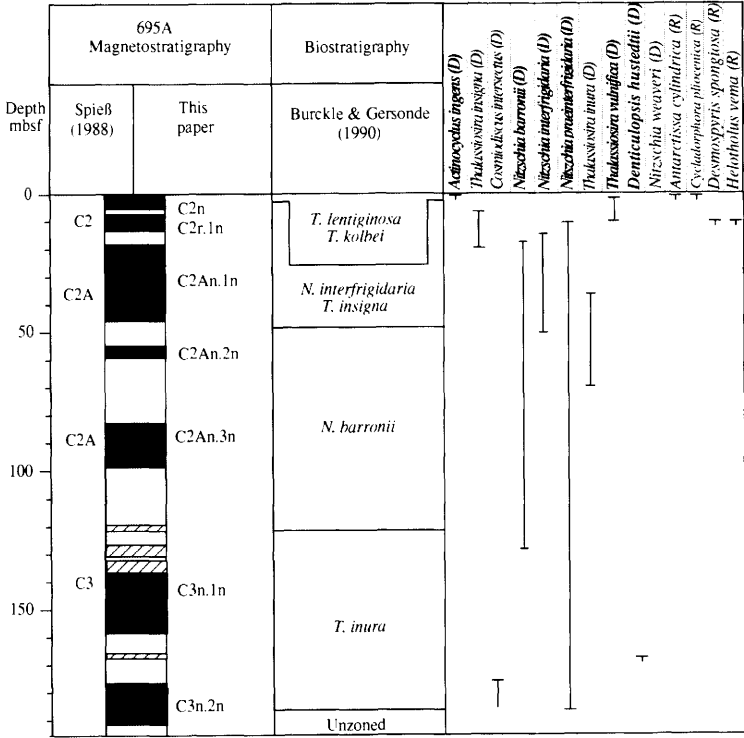


Fig. 16. Comparison of the ODP Hole 695A polarity chronozones and diatom zonal assignments by previous workers with the chronozoneal assignments of this study. The stratigraphical ranges of selected stratigraphical indicators are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995).

Table 13. Composite dataset for ODP Hole 695A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Antarctissa cylindrica</i>	1H-1, 0	1H-CC	0.00	6.40	0.00	2.27
LO <i>Cycladophora pliocenica</i>	1H-1, 0	1H-CC	0.00	6.40	0.00	2.27
LO <i>Actinocyclus ingens</i>	1H1, 55-56	1H-2, 30-31	0.56	1.81	0.20	0.64
LO <i>Thalassiosira vulnifica</i>	1H4, 30-31	1H-4, 100-101	1.81	5.51	0.64	1.95
FO <i>Nitzschia kerguelensis</i>	1H3, 30-31	1H4, 30-31	3.31	4.80	1.17	1.70
B C2n			5.50	5.50	1.95	1.95
LO <i>Thalassiosira insigna</i>	1H-CC	2H-6, 70-71	6.40	11.11	2.00	2.14
LO <i>Desmospyris spongiosa</i>	1H-CC	2H-CC	6.40	12.40	2.00	2.15
LO <i>Helotholus vema</i>	1H-CC	2H-CC	6.40	12.40	2.00	2.15
LO <i>Cycladophora davisiana</i>	1H-CC	2H-CC	6.40	12.40	2.00	2.15
T C2r.1n			9.00	9.00	2.14	2.14
LO <i>Nitzschia praeinterfrigidaria</i>	2H-6, 70-71	2H-CC	11.11	12.40	2.14	2.15
FO <i>Thalassiosira vulnifica</i>	2H-CC	3H-4, 22-22	12.40	17.12	2.15	2.61
LO <i>Nitzschia interfrigidaria</i>	2H-CC	3H-4, 22-22	12.40	17.12	2.15	2.61
B C2r.1n			14.00	14.00	2.15	2.15
T C2An.1n			17.00	17.00	2.58	2.58
LO <i>Nitzschia barronii</i>	3H-4, 21-22	3H-5, 75-76	17.12	19.16	2.58	2.61
LO <i>Nitzschia weaveri</i>	3H-4, 21-22	3H-5, 75-76	17.12	19.60	2.58	2.61
FO <i>Thalassiosira insigna</i>	3H-CC	4H-CC	22.00	31.60	2.65	2.80
LO <i>Thalassiosira inura</i>	5HCC	6H-CC	41.20	50.80	2.94	3.08
B C2An.1n			48.00	48.00	3.04	3.04
FO <i>Nitzschia interfrigidaria</i>	6H-CC	7H-CC	50.80	60.40	3.09	3.24
T C2An.2n			52.00	52.00	3.11	3.11
B C2An.2n			53.00	53.00	3.22	3.22
T C2An.3n			87.00	87.00	3.33	3.33
B C2An.3n			103.50	103.50	3.58	3.58
FO <i>Nitzschia barronii</i>	15H-CC	16H-CC	127.90	137.60	4.02	4.18
T C3n.1n			137.00	137.00	4.18	4.18
FO <i>Nitzschia weaveri</i>	18X-CC	19X-CC	147.30	157.00	4.23	4.27
LO <i>Denticulopsis hustedii</i>	19X-CC	20X-CC	157.00	166.80	4.28	4.37
LO <i>Prunopyle titan</i>	19X-CC	20X-CC	157.00	166.80	4.28	4.37
B C3n.1n			160.00	160.00	4.29	4.29
T C3n.2n			176.50	176.50	4.48	4.48
LO <i>Cosmiodiscus intersectus</i>	21X-CC	22X-CC	176.50	186.20	4.48	?
FO <i>Nitzschia praeinterfrigidaria</i>	22X-CC	23X-CC	186.20	195.90	4.57	?
B C3n.2n			191.00	191.00	4.62	4.62

Data sets are integrated from the work of numerous authors (see Table 2).

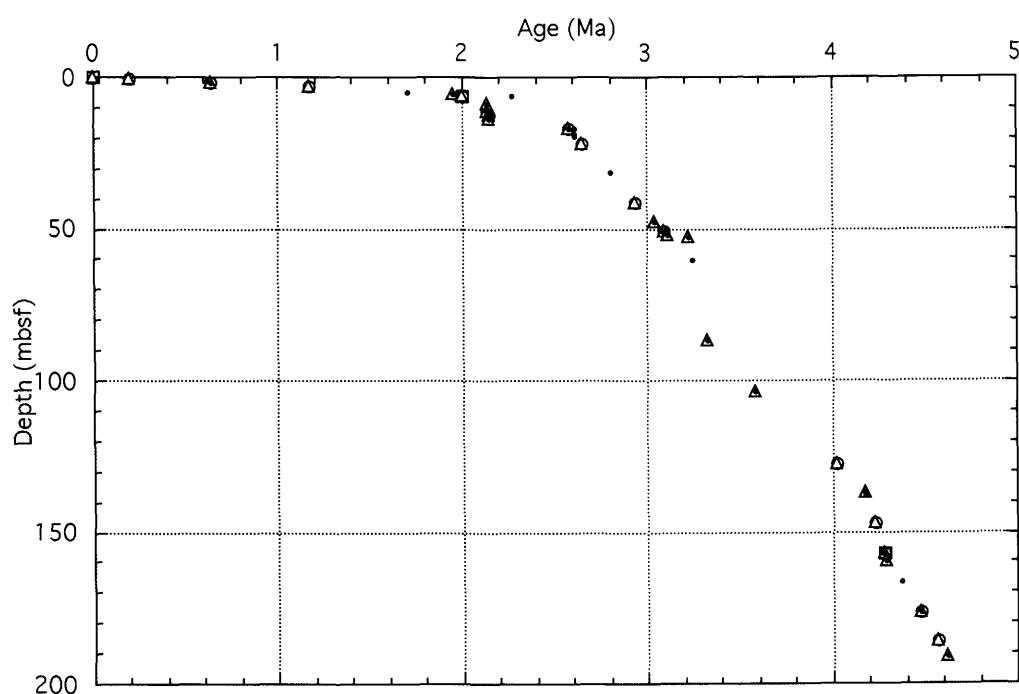


Fig. 17. A revised age–depth plot for DSDP Hole 695A utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Hole 696A

Twelve cores were recovered from a total penetration of 103 mbsf representing a recovery of 55% of the cored interval. Sediments recovered consist of Quaternary to lower Pliocene muds with a variable siliceous component (Barker, Kennett *et al.*, 1988). A good palaeomagnetic polarity reversal record was obtained using ship-board data (Barker *et al.* 1988). Diatoms and radiolarians are present throughout the sequence. Rare to common and moderately preserved diatoms are observed in the sequence. Radiolarians are common to abundant and well preserved throughout the section (Barker *et al.* 1988). Calcareous nannofossils are not recorded (Barker *et al.* 1988). The integrated biostratigraphical and magnetostratigraphical data previously used (palaeomagnetism: Barker *et al.* 1988; diatoms: Gersonde & Burckle 1990; calcareous nannofossils: none; radiolarians: none) and calibrated to the GPTS of Berggren *et al.* (1985a, b) is shown in Table 14. An age–depth graph for Hole 113-690B using this data is shown in Fig. 18.

Figure 19 compares the polarity chronozones and diatom zones assigned by previous workers (Barker *et al.* 1988; Gersonde & Burckle 1990) with the chronozone assignments in this study. The stratigraphical ranges reflect the placement of FO and LO of

stratigraphically useful diatom species as recognized by Gersonde & Burckle (1990). The revised chronozones and diatom zones illustrated are based on reassessing the data sets of these workers (Table 15). Comparison of the chronozone assignments stated in Barker *et al.* (1988; Table 14) with those in this study (Table 15) indicates that only minimal reinterpretations were completed and reflect differences in the GPTS used in each study.

Figure 20 shows an age–depth graph for Hole 113-696A using the stratigraphical markers determined in this study. The section is interpreted to be continuous based on both palaeomagnetic and biostratigraphical control. Palaeomagnetic control consists of a continuous polarity reversal sequence representing the base of C3n.1n at 6.0 mbsf to the base of C3Bn at 74.0 mbsf. Biostratigraphical markers used to calibrate this polarity sequence to the GPTS include the FO of *Nitzschia barronii* (11.21–12 mbsf), and the FO of *Nitzschia praeinterfrigidaria* (22.4–31.2 mbsf). The last occurrence of *Thalassiosira vulnifica* has an age of 1.64–1.95 Ma which is a minimum of 0.40 million years younger than its age at other sites. No primary biostratigraphical control points were recognized for the lower 30 m of the section.

Table 14. Composite dataset for ODP Hole 696A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande and Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Thalassiosira inura</i>	1H-2	1H-2, 55-56	0.00	3.56	?	?
LO <i>Actinocyclus ingens</i>	1H-2	1H-2, 55-56	0.00	3.56	?	?
LO <i>Denticulopsis hustedtii</i>	1H-2	1H-2, 55-56	0.00	3.56	?	?
LO <i>Nitzschia barronii</i>	1H-1, 0	1H-2, 55-56	0.00	3.56	?	?
B C3n.1n			6.00	6.00	4.29	4.29
T C3n.2n			9.00	9.00	4.48	4.48
LO <i>Thalassiosira vulnifica</i>	2H-6, 120-121	2H-CC	11.21	12.00	4.51	4.52
FO <i>Thalassiosira vulnifica</i>	2H-6, 120-121	2H-CC	11.21	12.00	4.51	4.52
LO <i>Thalassiosira insigna</i>	2H-6, 120-121	2H-CC	11.21	12.00	4.51	4.52
FO <i>Thalassiosira insigna</i>	2H-6, 120-121	2H-CC	11.21	12.00	4.51	4.52
FO <i>Nitzschia barronii</i>	2H-6, 120-121	2H-CC	11.21	12.00	4.51	4.52
LO <i>Thalassiosira complicata</i>	2H-CC	3H-1, 50-51	12.00	12.51	4.52	4.52
LO <i>Nitzschia praeinterfrigidaria</i>	3H-1, 50-51	3H-CC	12.51	21.60	4.52	4.64
FO <i>Nitzschia praeinterfrigidaria</i>	4H-1, 80-87	4H-CC	22.40	31.20	4.65	4.76
T C3n.3n			34.00	34.00	4.80	4.80
T C3n.4n			45.00	45.00	4.98	4.98
FO <i>Nitzschia kerguelensis</i>	6H-4, 120-121	6H-CC	46.51	50.40	5.13	5.65
B C3n.4n			47.50	47.50	5.23	5.23
T C3An.1n			52.00	52.00	5.89	5.89
B C3An.1n			63.50	63.50	6.14	6.14
FO <i>Rouxia heteropolara</i>	8H-4, 20-21	8H-CC	64.71	69.60	6.18	6.77
FO <i>Thalassiosira inura</i>	8H-4, 20-21	8H-CC	64.71	69.60	6.18	6.77
T C3An.2n			67.00	67.00	6.27	6.27
B C3An.2n			68.00	68.00	6.57	6.57
T C3Bn			71.00	71.00	6.94	6.94
B C3Bn			74.00	74.00	7.09	7.09
FO <i>Thalassiosira oestrupii</i>	9H-4, 120-121	9H-CC	75.31	79.30	?	?
FO <i>Nitzschia praecurta</i>	25R-CC	26R-CC	289.00	298.70	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

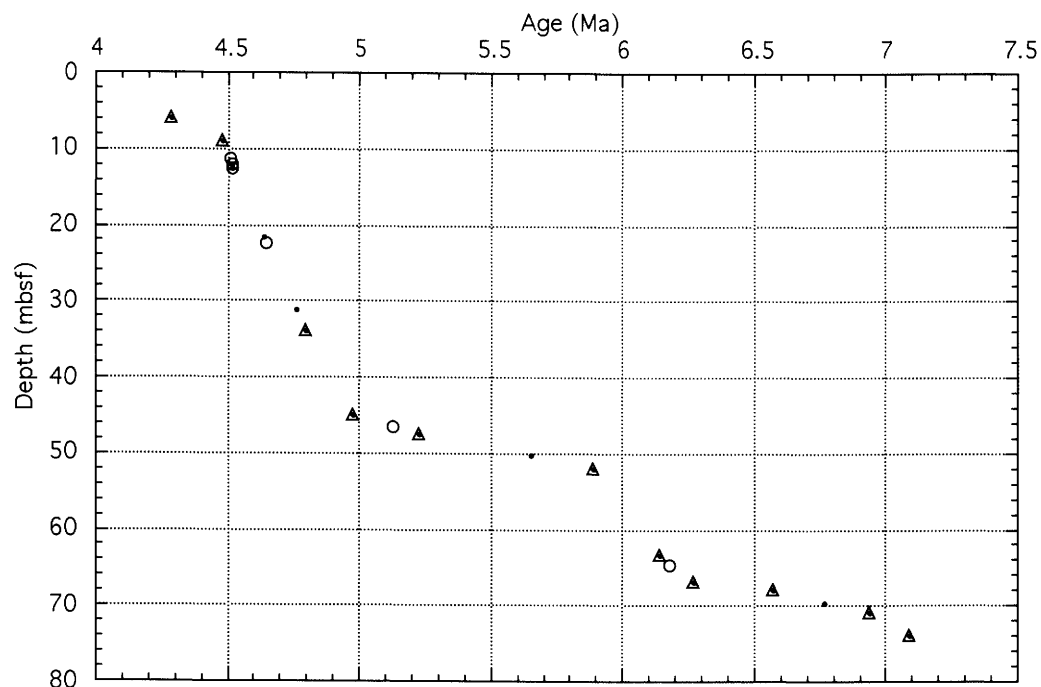


Fig. 18. An age–depth plot for DSDP Hole 696A utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

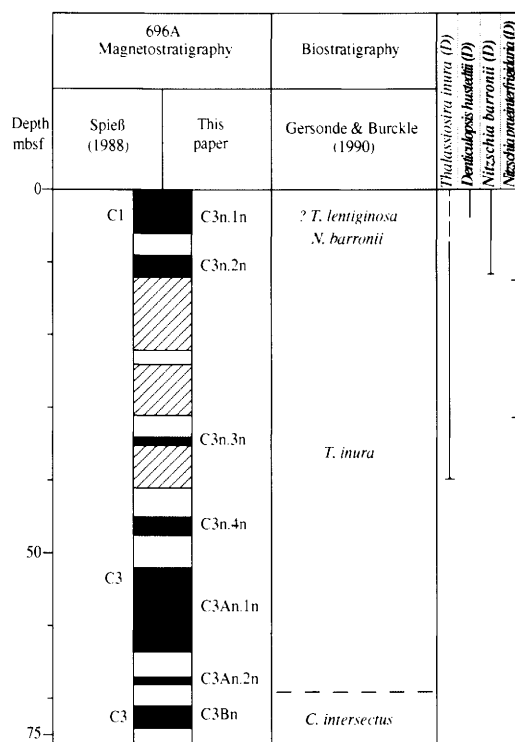


Fig. 19. Comparison of the ODP Hole 696A polarity chronozones and diatom zonal assignments by previous workers with the chronozone assignments of this study. The stratigraphical ranges of selected stratigraphical indicators are based on the original data sets (see text for references). D. diatoms; R. radiolaria; N. calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995). Diagonal lines indicate intervals of uncertainty.

Table 15. Composite dataset for ODP Hole 696A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Thalassiosira inura</i>	1H-2	1H-2, 55-56	0.00	3.56	?	?
LO <i>Actinocyclus ingens</i>	1H-2	1H-2, 55-56	0.00	3.56	?	?
LO <i>Denticulopsis hustedtii</i>	1H-2	1H-2, 55-56	0.00	3.56	?	?
LO <i>Nitzschia barronii</i>	1H-1, 0	1H-2, 55-56	0.00	3.56	?	?
B C3n.1n			6.00	6.00	4.29	4.29
T C3n.2n			9.00	9.00	4.48	4.48
LO <i>Thalassiosira vulnifica</i>	2H-6, 120-121	2H-CC	11.21	12.00	4.51	4.52
FO <i>Thalassiosira vulnifica</i>	2H-6, 120-121	2H-CC	11.21	12.00	4.51	4.52
LO <i>Thalassiosira insigna</i>	2H-6, 120-121	2H-CC	11.21	12.00	4.51	4.52
FO <i>Thalassiosira insigna</i>	2H-6, 120-121	2H-CC	11.21	12.00	4.51	4.52
FO <i>Nitzschia barronii</i>	2H-6, 120-121	2H-CC	11.21	12.00	4.51	4.52
LO <i>Thalassiosira complicata</i>	2H-CC	3H-1, 50-51	12.00	12.51	4.52	4.52
LO <i>Nitzschia praeinterfrigidaria</i>	3H-1, 50-51	3H-CC	12.51	21.60	4.52	4.64
FO <i>Nitzschia praeinterfrigidaria</i>	4H-1, 80-87	4H-CC	22.40	31.20	4.65	4.76
T C3n.3n			34.00	34.00	4.80	4.80
T C3n.4n			45.00	45.00	4.98	4.98
FO <i>Nitzschia kerguelensis</i>	6H-4, 120-121	6H-CC	46.51	50.40	5.13	5.65
B C3n.4n			47.50	47.50	5.23	5.23
T C3An.1n			52.00	52.00	5.89	5.89
B C3An.1n			63.50	63.50	6.14	6.14
FO <i>Rouxia heteropolara</i>	8H-4, 20-21	8H-CC	64.71	69.60	6.18	6.77
FO <i>Thalassiosira inura</i>	8H-4, 20-21	8H-CC	64.71	69.60	6.18	6.77
T C3An.2n			67.00	67.00	6.27	6.27
B C3An.2n			68.00	68.00	6.57	6.57
T C3Bn			71.00	71.00	6.94	6.94
B C3Bn			74.00	74.00	7.09	7.09
FO <i>Thalassiosira oestrupii</i>	9H-4, 120-121	9H-CC	75.31	79.30	?	?
FO <i>Nitzschia praecurta</i>	25R-CC	26R-CC	289.00	298.70	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

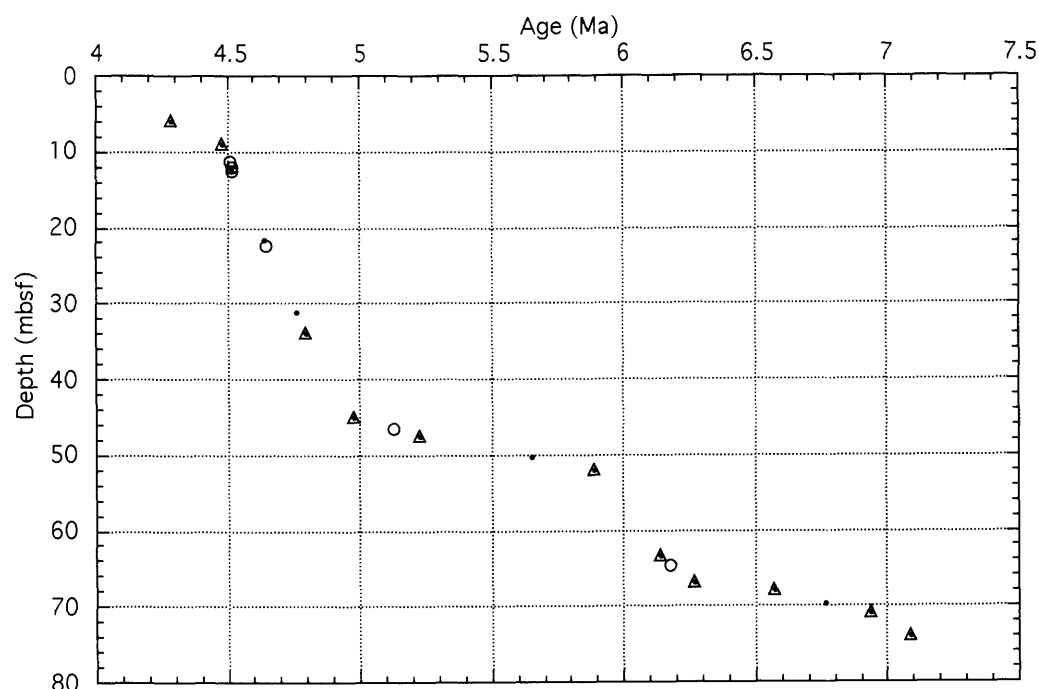


Fig. 20. A revised age-depth plot for DSDP Hole 696A utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Hole 697B

Thirty-two cores were recovered from a total penetration of 322.9 mbsf representing a recovery of 62% of the cored interval. Sediments recovered consist of Quaternary to lower Pliocene mud with a siliceous component. A good palaeomagnetic polarity reversal record was obtained through shipboard analysis (Barker *et al.* 1988). Variable core recovery occasionally limits the interpretation of the magnetostratigraphy. Diatoms and radiolarians are present throughout the section. Diatom abundance and preservation varies, ranging from rare to common and exhibiting poor to moderate preservation. Radiolarians are common in the Pliocene with moderate to poor preservation (Barker *et al.* 1988). The integrated biostratigraphical and magnetostratigraphical data previously used (palaeomagnetism: Barker *et al.* 1988; diatoms: Gersonde & Burckle 1990; calcareous nannofossils: none; radiolarians: Barker *et al.* 1988) and calibrated to the GPTS of Berggren *et al.* (1985a,b) are presented in Table 16. An age–depth graph for Hole 113-690B using this data is shown in Figure 21.

Figure 22 compares the polarity chronozones and diatom zones assigned by previous workers (Barker *et al.* 1988; Gersonde & Burckle 1990) with the chronozone assignments in this study. The

stratigraphical ranges of diatoms and radiolarians reflect the placement of the FO and LO of stratigraphically useful species as recognized by Gersonde & Burckle (1990), Abelmann (1990) and Lazarus (1990), respectively. The revised chronozones and diatom zones illustrated are based on reassessing the data sets of these workers (Table 17). Comparison of the chronozone assignments of Barker *et al.* (1988; Table 16) with those of this study (Table 17) indicates that only minimal reinterpretations were completed in this hole reflecting differences in the GPTS used in each study.

An age–depth graph for Hole 113-697B using the stratigraphical markers determined in this study is shown in Fig. 23. The section is interpreted to be continuous based on both palaeomagnetic and biostratigraphical control. Palaeomagnetic control consists of a continuous sequence of polarity reversals extending from the base of C1n at 37.0 mbsf to the base of C3n.2n at 200 mbsf. Biostratigraphical markers used to calibrate this polarity sequence include the LO of *Thalassiosira vulnifica* (104.7–114.3 mbsf) the FO of *Nitzschia interfrigidaria* (186.6–196.2 mbsf), and FO of *Nitzschia barronii* (207.56–215 mbsf) and the FO of *Denticulopsis hustedtii* (293–302.6 mbsf).

Table 16. Composite dataset for ODP Hole 697B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
B C1n			37.00	37.00	0.78	0.78
LO <i>Actinocyclus ingens</i>	2H-CC	3H-CC	37.10	46.80	0.79	1.10
T C1r.1n			40.05	40.05	0.99	0.99
B C1r.1n			46.00	46.00	1.07	1.07
LO <i>Nitzschia barronii</i>	3H-CC	4H-3, 145-146	46.80	51.26	1.10	1.25
LO <i>Thalassiosira kolbei</i>	5H-CC	6H-CC	66.20	76.00	1.74	1.95
T C2n			67.00	67.00	1.77	1.77
B C2n			76.00	76.00	1.95	1.95
LO <i>Thalassiosira vulnifica</i>	7H-CC	8H-CC	85.70	95.40	2.17	2.40
LO <i>Desmospyris spongiosa</i>	8H-CC	9H-CC	95.40	104.70	2.39	2.82
LO <i>Helotholus vema</i>	8H-CC	9H-CC	95.40	104.70	2.39	2.82
T C2An.1n			103.50	103.50	2.58	2.58
FO <i>Thalassiosira vulnifica</i>	9H-CC	10H-CC	104.70	114.30	2.61	2.82
LO <i>Denticulopsis hustedtii</i>	9H-CC	10H-CC	104.70	114.30	2.61	2.82
FO <i>Thalassiosira kolbei</i>	9H-CC	10H-CC	104.70	114.30	2.61	2.82
LO <i>Thalassiosira inura</i>	10H-CC	11H-CC	114.30	119.80	2.82	2.94
LO <i>Thalassiosira insigna</i>	11H-CC	12X-CC	119.80	128.60	2.94	3.08
B C2An.1n			124.00	124.00	3.04	3.04
FO <i>Cycladophora davisiana</i>	12X-CC	13X-CC	128.60	138.20	3.08	3.34
LO <i>Nitzschia interfrigidaria</i>	12X-CC	13X-3, 31-32	128.60	131.92	3.08	3.11
T C2An.2n			132.50	132.50	3.11	3.11
FO <i>Actinocyclus ingens</i>	13X-CC	14X-CC	138.20	147.90	3.21	3.34
B C2An.2n			139.00	139.00	3.22	3.22
T C2An.3n			147.00	147.00	3.33	3.33
FO <i>Thalassiosira lentiginosa</i>	15X-2, 48-49	15X-CC	151.39	157.50	3.40	3.49
LO <i>Thalassiosira complicata</i>	16X-2, 10-11	16X-2, 71-72	159.11	159.72	3.52	3.53
LO <i>Nitzschia praeinterfrigidaria</i>	16X-2, 71-72	16X-CC	157.72	167.20	3.50	3.65
B C2An.3n			163.00	163.00	3.58	3.58
LO <i>Simonseniella barboi</i>	17X-CC	18X-CC	176.90	186.60	3.86	4.05
FO <i>Nitzschia interfrigidaria</i>	18X-CC	19X-CC	186.60	196.20	4.05	4.35
T C3n.1n			193.00	193.00	4.18	4.18
FO <i>Nitzschia barronii</i>	21X-2, 15-16	21X-CC	207.56	215.50	?	?
FO <i>Thalassiosira oestrupii</i>	21X-2, 15-16	21X-CC	207.56	215.50	?	?
FO <i>Rouxia heteropolara</i>	21X-CC	22X-CC	215.50	225.20	?	?
FO <i>Cosmiodiscus intersectus</i>	24X-CC	25X-CC	244.50	254.20	?	?
FO <i>Nitzschia praecurta</i>	25X-CC	26X-CC	254.20	263.20	?	?
FO <i>Thalassiosira inura</i>	28X-3, 114-115	28X-CC	277.75	283.30	?	?
FO <i>Denticulopsis hustedtii</i>	29X-CC	30X-CC	293.00	302.60	?	?

Data sets are integrated from the work of numerous authors (see Table 2)

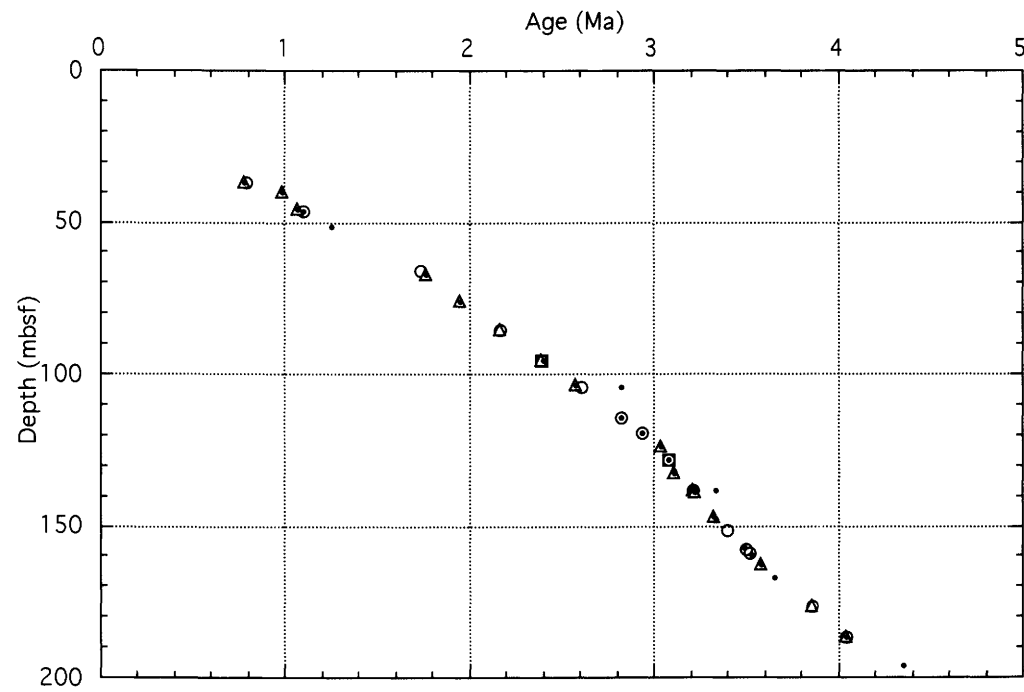


Fig. 21. An age-depth plot for DSDP Hole 697B utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

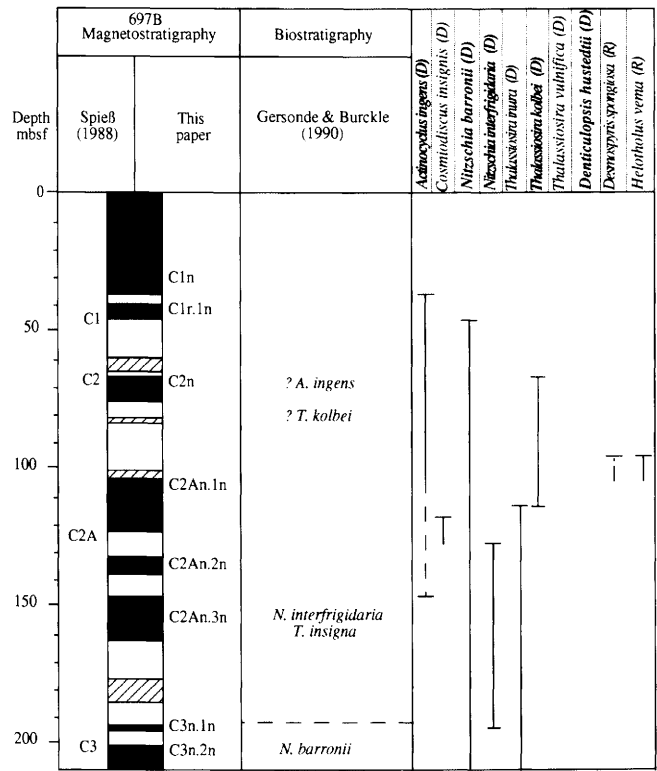


Fig. 22. Comparison of the ODP Hole 697B polarity chronozones and diatom zonal assignments by previous workers with the chronostratigraphical assignments of this study. The stratigraphical ranges of selected stratigraphical indicators are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995). Diagonal lines indicate intervals of uncertainty.

Table 17. Composite dataset for ODP Hole 697B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
B C1n			37.00	37.00	0.78	0.78
LO <i>Actinocyclus ingens</i>	2H-CC	3H-CC	37.10	46.80	0.79	1.10
T C1r.1n			40.05	40.05	0.99	0.99
B C1r.1n			46.00	46.00	1.07	1.07
LO <i>Nitzschia barronii</i>	3H-CC	4H-3, 145-146	46.80	51.26	1.10	1.25
LO <i>Thalassiosira kolbei</i>	5H-CC	6H-CC	66.20	76.00	1.74	1.95
T C2n			67.00	67.00	1.77	1.77
B C2n			76.00	76.00	1.95	1.95
LO <i>Thalassiosira vulnifica</i>	7H-CC	8H-CC	85.70	95.40	2.17	2.39
LO <i>Desmospyris spongiosa</i>	8H-CC	9H-CC	95.40	104.70	2.39	2.82
LO <i>Helotholus vema</i>	8H-CC	9H-CC	95.40	104.70	2.39	2.82
T C2An.1n			103.50	103.50	2.58	2.58
FO <i>Thalassiosira vulnifica</i>	9H-CC	10H-CC	104.70	114.30	2.61	2.82
LO <i>Denticulopsis hustedtii</i>	9H-CC	10H-CC	104.70	114.30	2.61	2.82
FO <i>Thalassiosira kolbei</i>	9H-CC	10H-CC	104.70	114.30	2.61	2.82
LO <i>Thalassiosira inura</i>	10H-CC	11H-CC	114.30	119.80	2.82	2.94
LO <i>Thalassiosira insigna</i>	11H-CC	12X-CC	119.80	128.60	2.94	3.08
B C2An.1n			124.00	124.00	3.04	3.04
FO <i>Cycladophora davisiana</i>	12X-CC	13X-CC	128.60	138.20	3.08	3.34
LO <i>Nitzschia interfrigidaria</i>	12X-CC	13X-3, 31-32	128.60	131.92	3.08	3.11
T C2An.2n			132.50	132.50	3.11	3.11
FO <i>Actinocyclus ingens</i>	13X-CC	14X-CC	138.20	147.90	3.21	3.34
B C2An.2n			139.00	139.00	3.22	3.22
T C2An.3n			147.00	147.00	3.33	3.33
FO <i>Thalassiosira lentiginosa</i>	15X-2, 48-49	15X-CC	151.39	157.50	3.40	3.50
LO <i>Thalassiosira complicata</i>	16X-2, 10-11	16X-2, 71-72	159.11	159.72	3.52	3.53
LO <i>Nitzschia praeinterfrigidaria</i>	16X-2, 71-72	16X-CC	157.72	167.20	3.50	3.65
B C2An.3n			163.00	163.00	3.58	3.58
LO <i>Simonseniella barboi</i>	17X-CC	18X-CC	176.90	186.60	3.86	4.05
FO <i>Nitzschia interfrigidaria</i>	18X-CC	19X-CC	186.60	196.20	4.05	4.35
T C3n.1n			193.00	193.00	4.18	4.18
B C3n.1n			194.50	194.50	4.29	4.29
T C3n.2n			200.00	200.00	4.48	4.48
FO <i>Nitzschia barronii</i>	21X-2, 15-16	21X-CC	207.56	215.50	?	?
FO <i>Thalassiosira oestrupii</i>	21X-2, 15-16	21X-CC	207.56	215.50	?	?
FO <i>Rouxia heteropolara</i>	21X-CC	22X-CC	215.50	225.20	?	?
FO <i>Cosmodiscus intersectus</i>	24X-CC	25X-CC	244.50	254.20	?	?
FO <i>Nitzschia praecurta</i>	25X-CC	26X-CC	254.20	263.20	?	?
FO <i>Thalassiosira inura</i>	28X-3, 114-115	28X-CC	277.75	283.30	?	?
FO <i>Denticulopsis hustedtii</i>	29X-CC	30X-CC	293.00	302.60	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

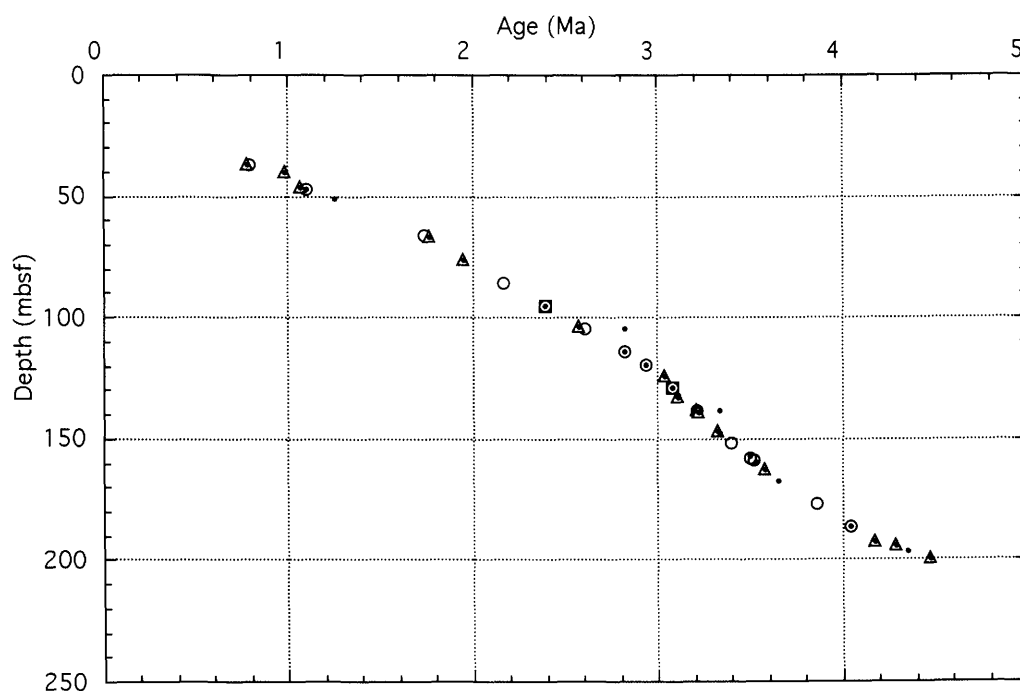


Fig. 23. A revised age-depth plot for DSDP Hole 697B utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Hole 699A

Fifty-six cores were recovered from a total penetration of 518.1 mbsf representing a recovery of 68% of the cored interval. Sediments recovered consist of Quaternary to lower Oligocene siliceous ooze with calcareous nannofossils and clay, lower Oligocene to middle/upper Eocene calcareous ooze with diatoms and radiolarians, and middle/upper Eocene to upper Palaeocene chalk (Ciesielski *et al.* 1988). A good palaeomagnetic polarity reversal record was obtained (Hailwood & Clement 1991a). Diatoms and radiolarians are present throughout the sequence. Diatoms are present in the Quaternary to upper Eocene sediments and typically exhibit moderate to good preservation. Diatom preservation is poor in the upper lower Oligocene interval (Ciesielski *et al.* 1988). Radiolarians are generally abundant and well preserved in the Quaternary to upper Eocene sediments. Radiolarians were not observed in sediments older than the late Eocene (Ciesielski *et al.* 1988). Calcareous nannofossils are absent from the Quaternary to lower Miocene sediments and abundant with poor preservation exhibited for the remaining sequence (Crux 1991). The integrated biostratigraphical and magnetostratigraphical data previously used (palaeomagnetism: Hailwood & Clement 1991a; diatoms: Ciesielski *et al.* 1988; Ciesielski 1991; calcareous nannofossils: Crux 1991; Wei 1991; radiolarians: Ciesielski *et al.* 1988) and calibrated to the GPTS of Berggren *et al.* (1985a, b) are presented in Table 18. An age-depth graph for Hole 113-699A using this data is shown in Fig. 24.

Figure 25 compares the polarity chronozones and diatom zones assigned by previous workers (Hailwood & Clement 1991a; Ciesielski 1991) with the chronozone assignments in this study. In addition, this figure illustrates the stratigraphical ranges of diatoms, radiolarians and calcareous nannofossils. The stratigraphical ranges reflect the placement of FO and LO of stratigraphically useful species as recognized by Ciesielski (1991), Ciesielski *et al.* (1988), Crux (1991) and Wei (1991), respectively. The revised chronozones and diatom zones illustrated are based on reassessing the data sets of these workers (Table 19). Comparison of the chronozone assignments of Hailwood & Clement (1991a; Table 18)

with those of this study (Table 19) indicates that minimal reinterpretations were completed.

An age-depth graph for Hole 114-699A using the stratigraphical markers determined in this study is presented in Fig. 26. Two hiatuses are placed in this section. The younger occurring between 62.39 and 62.56 mbsf and the older occurring between 70.29 and 87.57 mbsf. The upper boundary of the younger hiatus is constrained by a continuous sequence of polarity reversals from the base of C1n at 10.59 mbsf to the base of C3n.4n at 62.39 mbsf. This polarity sequence is calibrated to the GPTS with the LO of *Thalassiosira kolbei* (21.70–23.70 mbsf), the LO of *Thalassiosira vulnifica* (27.60–28.40 mbsf), the FO of *Nitzschia interfrigidaria* (31.00–32.00 mbsf) and the FO of *Nitzschia praeinterfrigidaria* (39.03–40.53 mbsf). The lower boundary of this hiatus is constrained by the base of C5ACn at 68.84 mbsf and the FO of *Nitzschia denticuloides* (67.5–69.20 mbsf). The upper boundary of the older hiatus is constrained by the base of C5ACn and the top of C5ADn at 70.29 mbsf. The lower boundary is constrained by a sequence of polarity reversals from C6Cn.1n (87.57 mbsf) to the top of C11n.1n (208.09 mbsf) calibrated to the GPTS. The continuity of this magnetic sequence is punctuated by uncertain intervals. There are also no primary biostratigraphical markers within this interval. The LO of *Reticulofenestra oamaruensis* (283.10–284.90 mbsf) provides a potentially useful event within this sequence.

This study suggests that the stratigraphy of the section is more continuous than previously recognized. Ciesielski *et al.* (1988) identified a possible hiatus at 31.0–32.2 mbsf and three unconformities at 39.03–43.07 mbsf, 54.52–62.15 mbsf and 67.2–69.20 mbsf. Recognition of these stratigraphical breaks are based on both palaeomagnetic and biostratigraphical markers. Hiatuses identified at 54.52–62.15 mbsf and 67.2–69.20 mbsf approximate those identified in this study. The potential hiatus at 31.0–32.2 mbsf and the hiatus at 39.03–40.37 mbsf are not recognized in this study and reflect differences in the polarity interpretations.

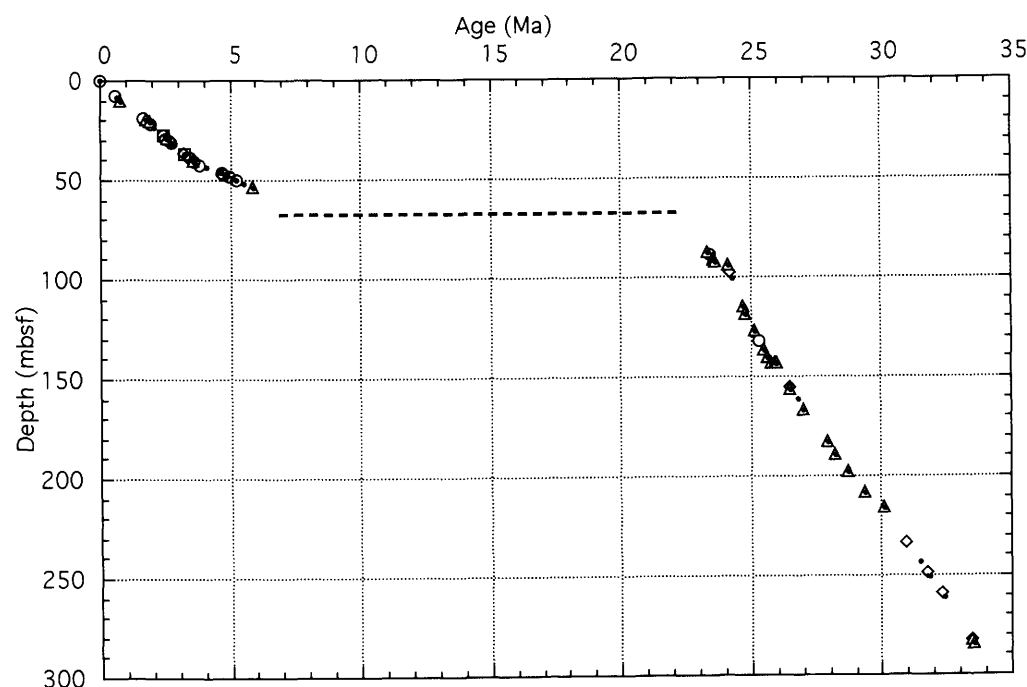


Fig. 24. An age-depth plot for DSDP Hole 699A utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols. One stratigraphical break (dashed line) is based on Hailwood & Clement (1991a).

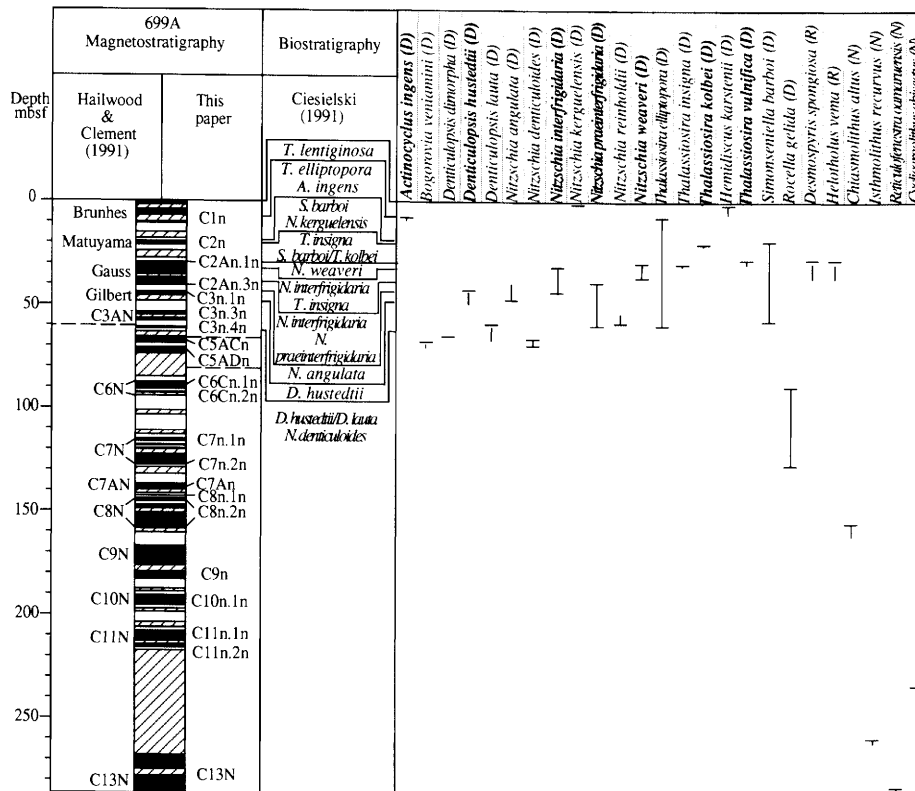


Fig. 25. Comparison of the ODP Hole 699A polarity chronozones and diatom zonal assignments by previous workers with the chronostratigraphic assignments of this study. The stratigraphical ranges of selected stratigraphical markers are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995).

Table 18. Composite dataset for ODP Hole 699A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande and Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Hemidiscus karstenii</i>	1H-1, 0	1H-1, 40-42	0.00	0.42	0.00	0.03
LO <i>Actinocyclus ingens</i>	1H-5, 140-142	1H-6, 140-142	7.42	8.92	0.55	0.66
LO <i>Thalassiosira elliptopora</i>	1H-5, 140-142	1H-6, 140-142	7.42	8.92	0.55	0.66
B C1n			10.59	10.59	0.78	0.78
LO <i>Simonseniella barboi</i>	3H-1, 67-70	3H-2, 67-69	18.80	20.90	1.68	1.92
T C2n			19.59	19.59	1.77	1.77
B C2n			21.19	21.19	1.95	1.95
LO <i>Thalassiosira kolbei</i>	3H-3, 60	3H-4, 110	21.70	23.70	1.93	2.10
LO <i>Thalassiosira vulnifica</i>	3H-CC	4H-1, 124	27.60	28.40	2.43	2.49
LO <i>Desmospyris spongiosa</i>	3H-CC	4H-CC	27.60	37.10	2.44	3.26
LO <i>Helotholus vema</i>	3H-CC	4H-CC	27.60	37.10	2.43	3.26
LO <i>Nitzschia reinholdii</i>	4H-1, 122-126	4H-2, 37-39	28.82	29.49	2.53	2.64
T C2An.1n			29.45	29.45	2.58	2.58
LO <i>Thalassiosira insigna</i>	4H-2, 143	4H-3, 40	30.53	31.00	2.68	2.72
LO <i>Nitzschia interfrigidaria</i>	4H-3, 30	4H-4, 9	31.00	32.20	2.72	2.82
LO <i>Nitzschia weaveri</i>	4H-3, 40	4H-4, 10	31.00	32.20	2.72	2.83
LO <i>Prunopyle titan</i>	4H-CC	5H-CC	37.10	46.60	3.26	4.64
FO <i>Nitzschia weaveri</i>	5H-2, 41	5H-3, 27	39.03	40.00	3.43	3.52
LO <i>Nitzschia praeinterfrigidaria</i>	5H-2, 41	5H-3, 27	39.03	40.53	3.43	3.57
FO <i>Nitzschia weaveri</i>	5H-3, 41-43	5H-4, 41-43	40.53	42.03	3.57	3.70
B C2An.3n			40.69	40.69	3.58	3.58
FO <i>Nitzschia interfrigidaria</i>	5H-4, 43	5H-5, 50	42.03	43.60	3.82	4.10
FO <i>Nitzschia angulata</i>	5H-CC	6H-1, 3	46.60	46.63	4.64	4.64
LO <i>Denticulopsis hustedtii</i>	6H-1, 42	6H-2, 6	47.02	48.16	4.71	4.92
LO <i>Hemidiscus cuneiformis</i>	6H-2, 40-42	6H-3, 40-42	48.52	50.02	4.98	5.25
FO <i>Nitzschia praeinterfrigidaria</i>	6H-3, 40-42	6H-4, 40-42	50.02	51.52	5.25	5.52
T C3An.1n			53.61	53.61	5.89	5.89
FO <i>Thalassiosira lentiginosa</i>	5H-5, 41-43	6H-1, 40-42	56.49	57.95	?	?
FO <i>Thalassiosira elliptopora</i>	7H-1, 39-43	7H-2, 44-47	56.53	58.60	?	?
LO <i>Denticulopsis lauta</i>	7H-3, 5	7H-5, 5	59.15	62.15	?	?
Unconformity			***	***	***	***
FO <i>Nitzschia reinholdii</i>	7H-5, 42-46	8H-1, 40-42	62.56	66.02	?	?
FO <i>Thalassiosira torokina</i>	7H-5, 42-46	8H-1, 40-42	62.56	66.02	?	?
FO <i>Hemidiscus cuneiformis</i>	7H-5, 42-46	8H-1, 40-42	62.56	66.02	?	?
FO <i>Hemidiscus karstenii</i>	7H-5, 42-46	8H-1, 40-42	62.56	66.02	?	?
LO <i>Denticulopsis dimorpha</i>	7H-CC	8H-1, 40	65.00	66.00	?	?
FO <i>Simonseniella barboi</i>	8H-1, 40-42	8H-2, 40-42	66.02	67.52	?	?

Table 18. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Denticulopsis lauta</i>	8H-1, 40-42	8H-2, 40-42	66.02	67.52	?	?
LO <i>Nitzschia denticuloides</i>	8H-1, 55	8H-1, 142	66.15	67.02	?	?
FO <i>Nitzschia denticuloides</i>	8H-2, 42	8H-3, 60	67.52	69.20	?	?
LO <i>Bogorovia veniamini</i>	8H-2, 42	8H-3, 60	67.52	69.20	?	?
T C6Cn.1n			87.57	87.57	23.35	23.35
LO <i>Rocella gelida</i>	10H-3, 143	10H-5, 4	89.02	90.64	23.43	23.51
B C6Cn.1n			91.17	91.17	23.54	23.54
T C6Cn.2n			92.49	92.49	23.68	23.68
B C6Cn.3n			94.47	94.47	24.12	24.12
LO <i>Reticulofenestra bisecta</i>	11H-3, 75	11H-5, 59	97.85	100.69	24.22	24.30
T C7n.1n			115.35	115.35	24.73	24.73
B C7n.1n			118.50	118.50	24.78	24.78
B C7n.2n			127.69	127.69	25.18	25.18
FO <i>Rocella gelida</i>	14H-CC	15H-CC	132.10	141.60	25.33	25.71
T C7An			137.09	137.09	25.50	25.50
B C7An			140.38	140.38	25.65	25.65
T C8n.1n			143.84	143.84	25.82	25.82
B C8n.1n			143.04	143.04	25.95	25.95
T C8n.2n			143.84	143.84	25.99	25.99
LO <i>Chiasmolithus altus</i>	17H-4, 30	18H-1, 110	155.90	161.70	26.54	26.80
B C8n.2n			156.14	156.14	26.55	26.55
T C9n			166.95	166.95	27.03	27.03
B C9n			182.69	182.69	27.97	27.97
T 10n.1n			189.34	189.34	28.28	28.28
B 10n.2n			198.35	198.35	28.75	28.75
T C11n.1n			208.09	208.09	29.40	29.40
B C11n.2n			216.05	216.05	30.10	30.10
FO <i>Cyclicargolithus abisectus</i>	26X-1, 4	27X-1, 56	233.64	243.66	30.98	31.49
LO <i>Reticulofenestra umbilica</i>	27X-4, 116	27X-6, 62	248.76	251.22	31.75	31.87
LO <i>Isthmolithus recurvus</i>	29X-1, 75	29X-2, 75	259.85	261.35	32.31	32.38
LO <i>Reticulofenestra oamaruensis</i>	31X-4, 50	31X-5, 80	283.10	284.90	33.48	?
B C13n			284.55	284.55	33.55	33.55

Data sets are integrated from the work of numerous authors (see Table 2).

Table 19. Composite dataset for ODP Hole 699A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Hemidiscus karstenii</i>	1H-1, 0	1H-1, 40-42	0.00	0.42	0.00	0.03
LO <i>Actinocyclus ingens</i>	1H-5, 140-142	1H-6, 140-142	7.42	8.92	0.54	0.55
LO <i>Thalassiosira elliptopora</i>	1H-5, 140-142	1H-6, 140-142	7.42	8.92	0.55	0.66
B C1n			10.59	10.59	0.78	0.78
LO <i>Simonseniella barboi</i>	3H-1, 67-70	3H-2, 67-69	18.80	20.90	1.68	1.92
T C2n			19.59	19.59	1.77	1.77
B C2n			21.19	21.19	1.95	1.95
LO <i>Thalassiosira kolbei</i>	3H-3, 60	3H-4, 110	21.70	23.70	1.99	2.14
LO <i>Thalassiosira vulnifica</i>	3H-CC	4H-1, 124	27.60	28.40	2.43	2.49
LO <i>Desmospyris spongiosa</i>	3H-CC	4H-CC	27.60	37.10	2.43	3.26
LO <i>Helotholus vema</i>	3H-CC	4H-CC	27.60	37.10	2.44	3.26
LO <i>Nitzschia reinholdii</i>	4H-1, 122-126	4H-2, 37-39	28.82	29.49	2.53	2.64
T C2An.1n			29.45	29.45	2.58	2.58
LO <i>Thalassiosira insignia</i>	4H-2, 143	4H-3, 40	30.53	31.00	2.68	2.72
LO <i>Nitzschia interfrigidaria</i>	4H-3, 30	4H-4, 9	31.00	32.00	2.72	2.81
LO <i>Nitzschia weaveri</i>	4H-3, 40	4H-4, 10	31.00	32.20	2.72	2.82
LO <i>Prunopyle titan</i>	4H-CC	5H-CC	37.10	46.60	3.26	4.64
FO <i>Nitzschia weaveri</i>	5H-2, 41	5H-3, 27	39.03	40.37	3.43	3.55
LO <i>Nitzschia praeinterfrigidaria</i>	5H-2, 41	5H-3, 27	39.03	40.53	3.43	3.56
FO <i>Nitzschia weaveri</i>	5H-3, 41-43	5H-4, 41-43	40.53	42.03	3.56	3.70
B C2An.3n			40.69	40.69	3.58	3.58
FO <i>Nitzschia interfrigidaria</i>	5H-4, 43	5H-5, 50	42.03	43.60	3.82	4.11
T C3n.1n			43.99	43.99	4.18	4.18
FO <i>Nitzschia angulata</i>	5H-CC	6H-1, 3	46.60	46.63	4.35	4.37
LO <i>Denticulopsis hustedtii</i>	6H-1, 42	6H-2, 6	47.02	48.16	4.38	4.49
LO <i>Hemidiscus cuneiformis</i>	6H-2, 40-42	6H-3, 40-42	48.52	50.02	4.47	4.63
FO <i>Nitzschia praeinterfrigidaria</i>	6H-3, 40-42	6H-4, 40-42	50.02	51.52	4.57	4.74

(continued)

Table 19. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
T C3n.3n			53.61	53.61	4.80	4.80
FO <i>Nitzschia reinholdii</i>	6H-6, 43	7H-2, 44	54.53	58.04	4.81	4.89
FO <i>Thalassiosira lentiginosa</i>	5H-5, 41-43	6H-1, 40-42	56.49	57.95	4.86	4.89
FO <i>Thalassiosira elliptopora</i>	7H-1, 39-43	7H-2, 44-47	56.53	58.60	4.86	4.91
B C3n.3n			58.00	58.00	4.89	4.89
LO <i>Denticulopsis lauta</i>	7H-3, 5	7H-5, 5	59.15	62.15	4.90	5.19
T C3n.4n			60.86	60.86	4.98	4.98
B C3n.4n			62.39	62.39	5.23	5.23
Unconformity			***	***	***	***
FO <i>Nitzschia reinholdii</i>	7H-5, 42-46	8H-1, 40-42	62.56	66.02	?	?
FO <i>Thalassiosira torokina</i>	7H-5, 42-46	8H-1, 40-42	62.56	66.02	?	?
FO <i>Hemidiscus cuneiformis</i>	7H-5, 42-46	8H-1, 40-42	62.56	66.02	?	?
FO <i>Hemidiscus karstenii</i>	7H-5, 42-46	8H-1, 40-42	62.56	66.02	?	?
LO <i>Denticulopsis dimorpha</i>	7H-CC	8H-1, 40	65.00	66.00	?	?
FO <i>Simonseniella barboi</i>	8H-1, 40-42	8H-2, 40-42	66.02	67.52	?	?
LO <i>Denticulopsis lauta</i>	8H-1, 40-42	8H-2, 40-42	66.02	67.52	?	?
LO <i>Nitzschia denticuloides</i>	8H-1, 55	8H-1, 142	66.15	67.02	?	?
FO <i>Nitzschia denticuloides</i>	8H-2, 42	8H-3, 60	67.52	69.20	?	?
LO <i>Bogorovia veniamini</i>	8H-2, 42	8H-3, 60	67.52	69.20	?	?
B C5ACn			68.84	68.84	14.08	14.08
T C5ADn			70.29	70.29	14.18	14.18
Unconformity			***	***	***	***
T C6Cn.1n			87.57	87.57	23.35	23.35
LO <i>Rocella gelida</i>	10H-3, 143	10H-5, 4	89.02	90.64	23.43	23.51
B C6Cn.1n			91.17	91.17	23.54	23.54
T C6Cn.2n			92.49	92.49	23.68	23.68
B C6Cn.2n			94.47	94.47	23.80	23.80
LO <i>Reticulofenestra bisecta</i>	11H-3, 75	11H-5, 59	97.85	100.69	23.83	23.86
T C6Cn.3n			115.35	115.35	24.00	24.00
B C6Cn.3n			116.22	116.22	24.12	24.12
T C7n.1n			118.09	118.09	24.73	24.73
B C7n.1n			118.50	118.50	24.78	24.78
T C7n.2n			119.22	119.22	24.84	24.84
B C7n.2n			127.69	127.69	25.18	25.18
FO <i>Rocella gelida</i>	14H-CC	15H-CC	132.10	141.60	25.33	25.76
T C7An			137.09	137.09	25.50	25.50
T C8n.1n			142.74	142.74	25.82	25.82
B C8n.1n			143.04	143.04	25.95	25.95
T C8n.2n			143.84	143.84	25.99	25.99
LO <i>Chiasmolithus altus</i>	17H-4, 30	18H-1, 110	155.90	161.70	26.53	26.80
B C8n.2n			156.14	156.14	26.55	26.55
T C9n			166.95	166.95	27.03	27.03
B C9n			182.69	182.69	27.97	27.97
T C10n.1n			189.34	189.34	28.28	28.28
B C10n.1n			198.35	198.35	28.51	28.51
T C11n.1n			208.09	208.09	29.40	29.40
B C11n.2n			216.05	216.05	30.10	30.10
LO <i>Cyclicargolithus abisectus</i>	26X-1, 4	27X-1, 56	233.64	243.66	30.99	31.49
LO <i>Reticulofenestra umbilica</i>	27X-4, 116	27X-6, 62	248.76	251.22	31.75	31.87
LO <i>Isthmolithus recurvus</i>	29X-1, 75	29X-2, 75	259.85	261.35	32.31	32.38
LO <i>Reticulofenestra oamaruensis</i>	31X-4, 50	31X-5, 80	283.10	284.90	33.48	?
B C13n			284.55	284.55	33.55	33.55

Data sets are integrated from the work of numerous authors (see Table 2).

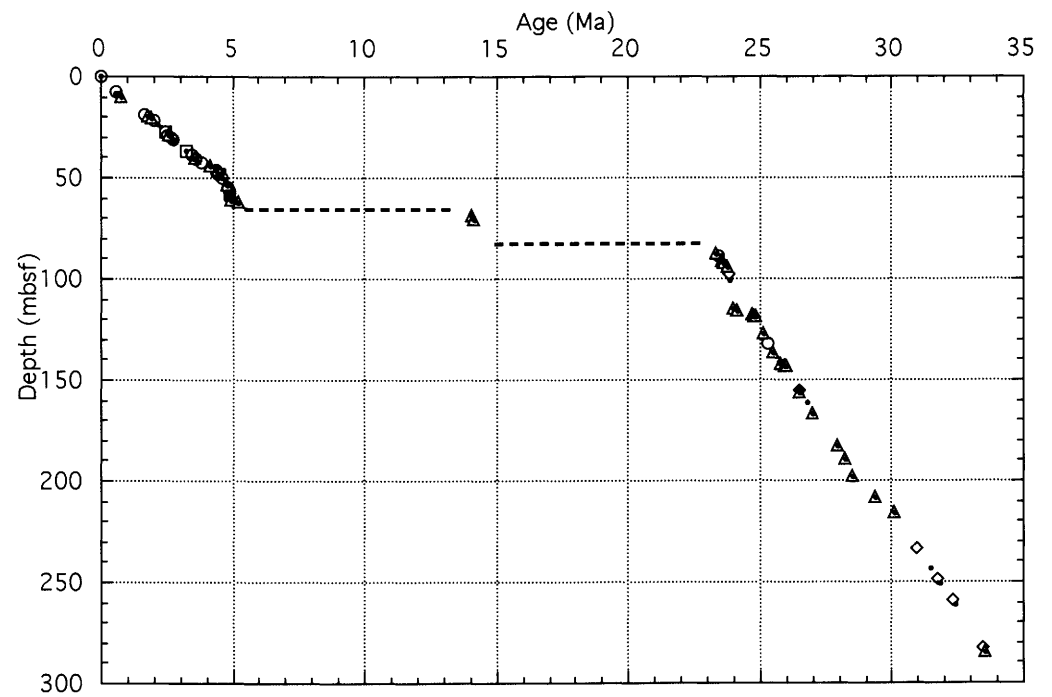


Fig. 26. A revised age–depth plot for DSDP Hole 699A utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols. Two stratigraphical breaks (dashed line) are based on the results of this study.

Hole 701A

Eight cores were recovered from a total penetration of 74.8 mbsf representing a recovery of 93% of the cored interval. Sediments recovered consist of Quaternary and upper Pliocene diatom ooze with ash and mud. A good palaeomagnetic polarity reversal record was obtained by both shipboard and shorebase analysis (Ciesielski *et al.* 1988; Clement & Hailwood 1991). Common to abundant diatoms and radiolarians occur throughout the sequence. Calcareous nannofossils are present in the sediments, but consist of long ranging species which are probably reworked (Ciesielski *et al.* 1988). The integrated biostratigraphical and magnetostratigraphical data previously used (palaeomagnetism: Clement & Hailwood 1991; diatoms: Ciesielski *et al.* 1988; Ciesielski 1991; calcareous nannofossils: none; radiolarians: Ciesielski *et al.* 1988) and calibrated to the GPTS of Berggren *et al.* (1985a, b) are shown in Table 20. An age-depth graph for Hole 114-701A using this data is shown in Fig. 27.

Figure 28 compares the polarity chronozones and diatom zones assigned by previous workers (Clement & Hailwood 1991; Ciesielski

et al. 1988) with the assignments in this study. The stratigraphical ranges for both diatoms and radiolarians reflect the placement of the FO and LO of stratigraphically useful species as recognized by Ciesielski *et al.* (1988). The revised chronozones and diatom zones illustrated are based on reassessing the data sets of these workers (Table 21). Comparison of the chronozone assignments of Clement & Hailwood (1991; Table 20) with those of this study (Table 21) indicates that only minimal reinterpretations were completed reflecting differences in the chronozone nomenclature and GPTS used in each study.

Figure 29 shows an age-depth graph for Hole 114-701A using the stratigraphical markers determined in this study. Seven biostratigraphical and palaeomagnetic control points are recognized in this sequence and provide evidence suggesting a continuous stratigraphical record. The results of this study are similar to those presented by Ciesielski *et al.* (1988).

Table 20. Composite dataset for ODP Hole 701A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande and Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Hemidiscus karstenii</i>	IH-4, 58	IH-4, 116	5.08	5.66	0.23	0.26
B C1n			17.02	17.02	0.78	0.78
LO <i>Actinocyclus ingens</i>	2H, CC	3H-1, 75	17.80	18.55	0.81	0.83
LO <i>Simonseniella barboi</i>	4H, CC	5H-2, 140	36.80	39.70	1.48	1.58
LO <i>Thalassiosira kolbei</i>	5H-5, 114	6H-4, 104	43.94	51.84	1.73	1.98
T C2n			44.93	44.93	1.77	1.77
B C2n			50.95	50.95	1.95	1.95
LO <i>Thalassiosira vulnifica</i>	6H, CC	7H-3, 77	55.80	59.57	2.12	2.26
LO <i>Helotholus vema</i>			55.80	65.30	2.12	2.46
LO <i>Desmospyris spongiosa</i>			55.80	65.30	2.12	2.46
FO <i>Cycladophora davisiana</i>			55.80	65.30	2.12	2.46
LO <i>Nitzschia interfrigidaria</i>	8H-1, 19	8H-3, 60	65.49	68.90	2.47	?
LO <i>Thalassiosira insigna</i>	8H-1, 19	8H-3, 60	65.49	68.90	2.47	?
T C2An.1n			68.73	68.73	2.58	2.58
LO <i>Nitzschia weaveri</i>	8H-3, 60	8H-4, 46	68.90	70.26	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

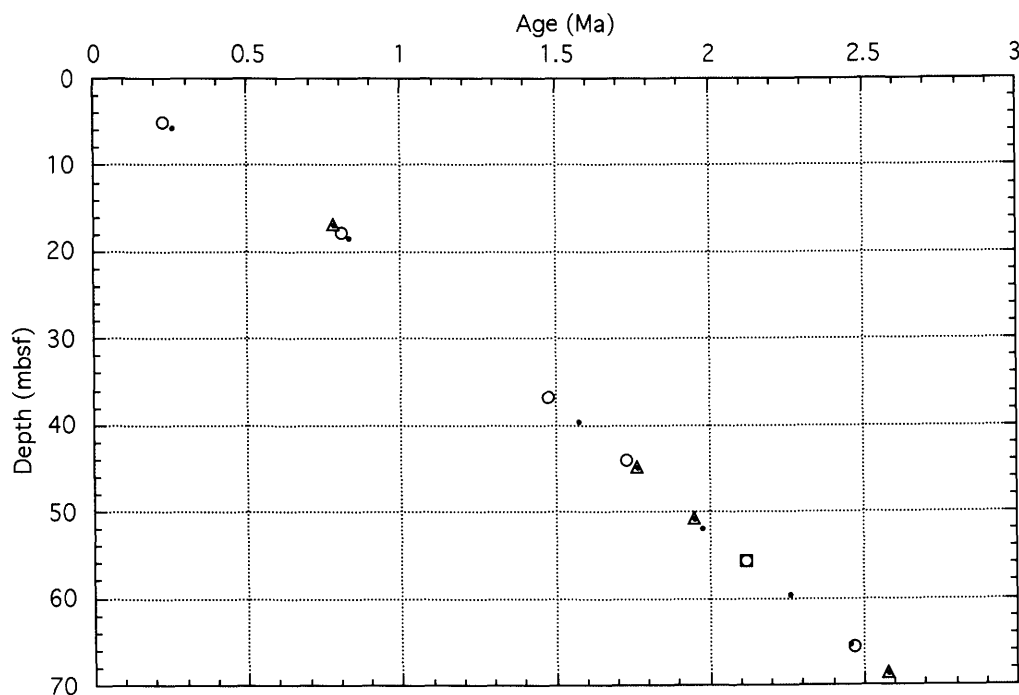


Fig. 27. An age-depth plot for DSDP Hole 701A utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

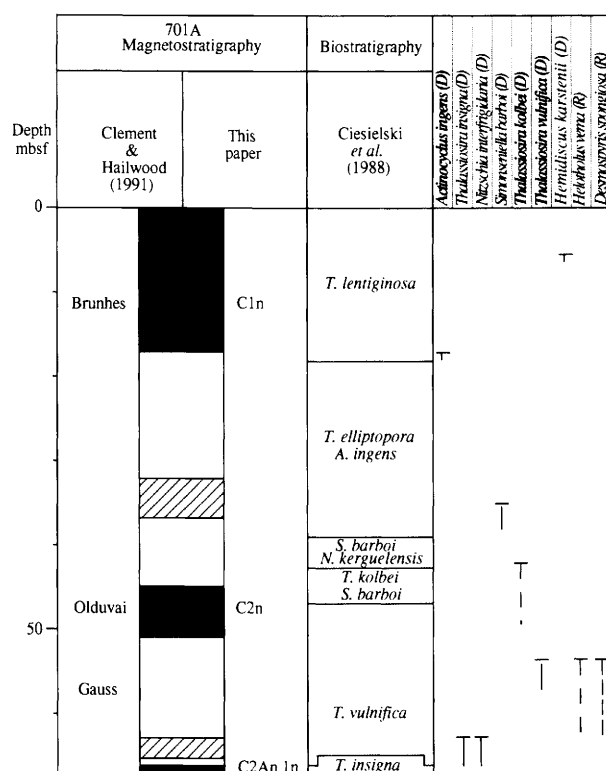


Fig. 28. Comparison of the ODP Hole 701A polarity chronozones and diatom zonal assignments by previous workers with the chronostratigraphical assignments of this study. The stratigraphical ranges of selected stratigraphical markers are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995). Diagonal lines indicate intervals of uncertainty.

Table 21. Composite dataset for ODP Hole 701A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Hemidiscus karstenii</i>	1H-4, 58	1H-4, 116	5.08	5.66	0.23	0.26
B C1n			17.02	17.02	0.78	0.78
LO <i>Actinocyclus ingens</i>	2H-CC	3H-1, 75	17.80	18.55	0.81	0.83
LO <i>Simonseniella barboi</i>	4H-CC	5H-2, 140	36.80	39.70	1.48	1.58
LO <i>Thalassiosira kolbei</i>	5H-5, 114	6H-4, 104	43.94	51.84	1.73	1.98
T C2n			44.93	44.93	1.77	1.77
B C2n			50.95	50.95	1.95	1.95
LO <i>Thalassiosira vulnifica</i>	6H-CC	7H-3, 77	55.80	59.57	2.12	2.26
LO <i>Helotholus vema</i>			55.80	65.30	2.12	2.46
LO <i>Desmospyris spongiosa</i>			55.80	65.30	2.12	2.46
FO <i>Cycladophora davisiana</i>			55.80	65.30	2.12	2.46
LO <i>Nitzschia interfrigidaria</i>	8H-1, 19	8H-3, 60	65.49	68.90	2.47	?
LO <i>Thalassiosira insigna</i>	8H-1, 19	8H-3, 60	65.49	68.90	2.47	?
T C2An.1n			68.73	68.73	2.58	2.58
LO <i>Nitzschia weaveri</i>	8H-3, 60	8H-4, 46	68.90	70.26	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

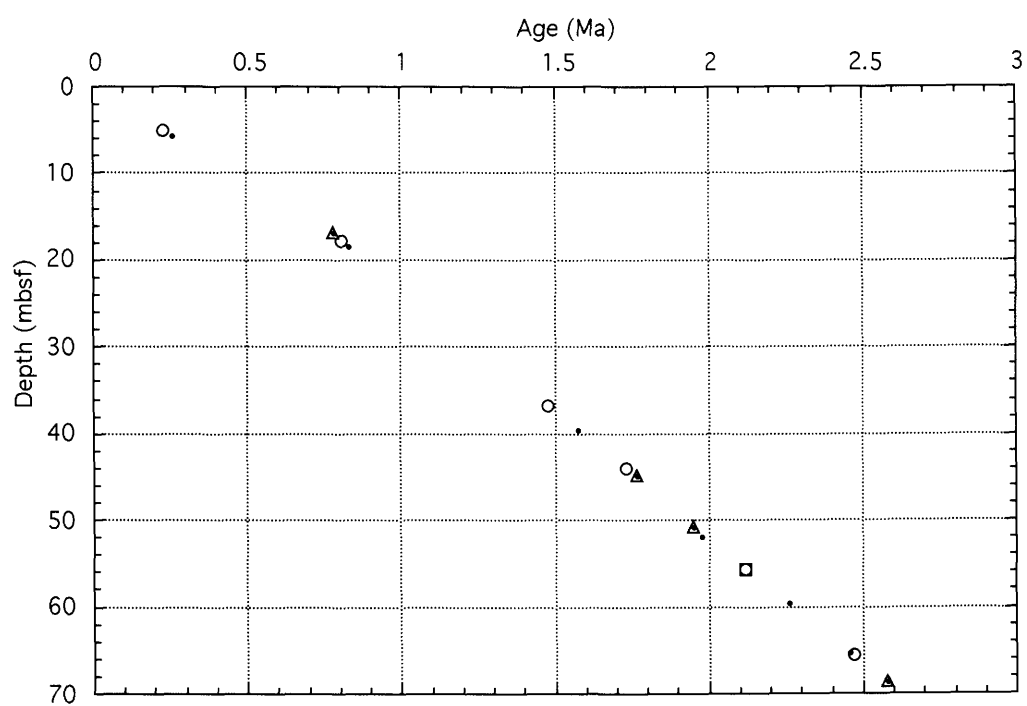


Fig. 29. A revised age-depth plot for DSDP Hole 701A utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Hole 704B

Seventy-two cores were recovered from a total penetration of 671.7 mbsf representing a recovery of 74% of the cored interval. Sediments recovered consist of Quaternary to upper Pliocene calcareous siliceous ooze and upper Pliocene to upper Miocene siliceous calcareous ooze, upper Miocene to middle Miocene calcareous nannofossil ooze, and middle Miocene to lower Oligocene chalk (Ciesielski *et al.* 1988). A good palaeomagnetic polarity reversal record was obtained by both shipboard and shorebase analysis (Ciesielski *et al.* 1988; Hailwood & Clement 1991b). Diatoms, calcareous nannofossils and radiolarians are present throughout the sequence. Diatoms are abundant and well preserved throughout the sequence with a decrease in abundance and preservation in the upper and lower Miocene. Calcareous nannofossils are present through the section. Radiolarians are generally abundant and well preserved through the section. The integrated biostratigraphical and magnetostratigraphical data previously used (palaeomagnetism: Hailwood & Clement 1991b; diatoms: Ciesielski *et al.* 1988; Ciesielski 1991; calcareous nannofossils: none; radiolarians: none) and calibrated to the GPTS of Berggren *et al.* (1985a, b) are shown in Table 22. An age–depth graph for Hole 114-704B using this data is shown in Fig. 30.

Figure 31 compares the polarity chronozones and diatom zones assigned by previous workers. Hailwood & Clement (1991b), Ciesielski *et al.* (1988) and Ciesielski (1991) with the assignments in this study. In addition, this figure illustrates the stratigraphical ranges of diatoms and calcareous nannofossils. The stratigraphical

ranges reflect the placement of FO and LO of stratigraphically useful species as recognized by Ciesielski *et al.* (1988) and Ciesielski (1991). The revised chronozones and diatom zones illustrated are based on reassessing the data sets of these workers (Table 23). Comparison of the chronozone assignments of Hailwood & Clement (1991b; Table 22) with those of this study (Table 23) indicate that the minimal reinterpretations reflect in part differences in the GPTS used in each study.

Figure 32 shows an age–depth graph for Hole 114-704B using the stratigraphical markers determined in this study. The LO of *Thalassiosira kolbei* (111.20–113.50 mbsf) and the last occurrence of *Thalassiosira vulnifica* (149.70–156.70 mbsf) have ages approximately 0.50 million years older than the ages of these events at other sites. These differences reflect the paucity of the polarity reversal record in the upper 200 mbsf. One hiatus is placed in the section at 452.15–453.60 mbsf. The upper boundary of this break is constrained by the First occurrence of *Nitzschia denticuloides* (439.00–442.49 mbsf), the FO of *Denticulopsis hustedtii* (445.51–451.67 mbsf) and the base of C5Bn.2n (443.00 mbsf). The lower boundary is constrained by the base of C5Cn.3n at 453.60 mbsf. Ciesielski *et al.* (1988) recognize two hiatuses within the sequence between 287 and 308 mbsf and between 425 and 432 mbsf. Hailwood & Clement (1991b) recognize one hiatus at approximately 440 mbsf. With the current data set, we interpret a hiatus at approximately 452 mbsf which is contemporaneous with that identified by Hailwood & Clement (1991b).

Table 22. Composite dataset for ODP Hole 704B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Hemidiscus karstenii</i>	1H-1, 0	1H2, 150	0.00	3.00	0.00	0.07
LO <i>Pseudoemiliana lacunosa</i>	1H-1, 0	1H-CC	0.00	6.70	0.00	0.15
LO <i>Actinocyclus ingens</i>	3H-CC	4H-2, 95	25.70	28.15	0.58	0.64
B C1n			34.51	34.51	0.78	0.78
B C1r.1n			44.27	44.27	1.07	1.07
LO <i>Simonseniella barboi</i>	11H-CC	12H-CC	101.70	111.20	2.12	2.30
LO <i>Thalassiosira kolbei</i>	12H-CC	13H-2, 125	111.20	113.50	2.30	2.34
LO <i>Helicosphaera sellii</i>	13H-CC	14H-CC	120.70	130.20	2.47	2.65
LO <i>Calcidiscus macintyreii</i>	16H-CC	17H-CC	147.20	156.70	2.96	3.13
LO <i>Discoaster browerii</i>	16H-CC	17H-CC	147.20	156.70	2.96	3.13
LO <i>Thalassiosira vulnifica</i>	17X-2, 100	17X-CC	149.70	156.70	3.00	3.13
FO <i>Thalassiosira vulnifica</i>	19X-1, 21	19X-1, 75	166.41	166.95	3.31	3.32
FO <i>Nitzschia weaveri</i>	19X-CC	20X-CC	175.70	185.20	3.48	3.66
LO <i>Reticulofenestra pseudumbilica</i>	21X-CC	22X-CC	194.70	204.20	3.83	4.01
FO <i>Nitzschia angulata</i>	23X-2, 70	23X-CC	206.40	213.70	4.05	4.18
T C3n.1n			213.70	213.70	4.18	4.18
LO <i>Hemidiscus cuneiformis</i>	23X-3, CC	24X-1, 80-82	213.70	214.52	4.18	4.25
LO <i>Simonseniella barboi</i>	23X-3, CC	24X-1, 80-82	213.70	214.52	4.18	4.25
LO <i>Thalassiosira miocenica</i>	23X-3, CC	24X-1, 80-82	213.70	214.52	4.18	4.25
LO <i>Denticulopsis hustedtii</i>	23X-CC	24X-CC	213.70	223.20	4.18	5.42
B C3n.1n			215.00	215.00	4.29	4.29
LO <i>Thalassiosira insignia</i>	24X-2, 80-82	24X-3, 80-82	216.02	217.52	4.42	4.57
LO <i>Nitzschia reinholdii</i>	24X-2, 80-82	24X-3, 80-82	216.02	217.52	4.42	4.57
T C3n.2n			216.50	216.50	4.48	4.48
LO <i>Cosmiodiscus intersectus</i>	24X-3, 80-82	24X-4, 80-82	217.52	219.02	4.52	4.57
LO <i>Nitzschia fossilis</i>	24X-4, 80-82	24X-5, 80-82	219.02	220.52	4.57	4.63
LO <i>Nitzschia marina</i>	24X-4, 80-82	24X-5, 80-82	219.02	220.52	4.57	4.63
B C3n.2n			220.50	220.50	4.62	4.62
LO <i>Stichocorys peregrina</i>	24X-CC	25X-CC	223.20	232.70	5.42	6.22
LO <i>Amphymenium challengerae</i>	24X-CC	25X-CC	223.20	232.70	5.42	6.22
LO <i>Thalassiosira praeconvexa</i>	25X-1, 80-82	25X-2, 80-82	224.02	225.52	5.67	5.92
T C3An.1n			224.76	224.76	5.89	5.89
FO <i>Thalassiosira oestrupii</i>	25X-2, 80-82	25X-3, 80-82	227.02	228.52	5.99	6.04
B C3An.1n			231.05	231.05	6.14	6.14
T C3An.2n			233.85	233.85	6.27	6.27
LO <i>Thalassiosira convexa</i> v. <i>aspinosa</i>	26X-4, 82	27X-2, 110	238.02	244.80	6.43	6.69

(continued)

Table 22. (continued)

	Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
B	C3An.2n			241.62	241.62	6.57	6.57
FO	<i>Amphymenium challengerae</i>	27X-2, 180	27X-4, 50	244.97	247.20	6.70	6.78
LO	<i>Lamprocyclas aegles</i>	27X-2, 180	27X-4, 50	244.97	247.20	6.70	6.78
T	C3Bn			251.25	251.25	6.94	6.94
FO	<i>Thalassiosira praeconvexa</i>	28X-1, 81	28X-2, 79	252.51	253.99	6.97	7.01
B	C3Bn			256.75	256.75	7.09	7.09
LO	<i>Denticulopsis lauta</i>	28X-4, 79-81	28X-6, 79-81	257.01	258.60	7.12	7.31
T	C4n.1n			259.50	259.50	7.43	7.43
LO	<i>Nitzschia porteri</i>	30X-1, 82	30X-2, 80	271.52	273.00	8.04	8.12
FO	<i>Lamprocyclas aegles</i>	30X-2, 45	30X-4, 45	272.65	275.65	8.10	8.25
B	C4r.1n			275.85	275.85	8.26	8.26
LO	<i>Diartus hughesi</i>	30X-CC	31X-2, 45	280.20	282.15	8.39	8.46
FO	<i>Stichocorys peregrina</i>	30X-CC	31X-2, 45	280.20	282.15	8.39	8.46
T	C4An			290.06	290.06	8.70	8.70
FO	<i>Thalassiosira insigna</i>	32X-6, 80-82	33X-1, 80-82	298.02	300.02	8.79	8.81
FO	<i>Nitzschia marina</i>	32X-6, 82	33X-1, 80	298.02	300.00	8.79	8.81
FO	<i>Nitzschia reinholdii</i>	32X-6, 80-82	33X-1, 80-82	298.02	300.02	8.79	8.81
FO	<i>Cosmiodiscus intersectus</i>	32X-6, 80-82	33X-1, 80-82	298.02	300.02	8.79	8.81
B	C4An			318.55	318.55	9.03	9.03
LO	<i>Denticulopsis dimorpha</i>	35X-1, 80-82	35X-3, 80-82	319.02	322.02	9.05	9.37
FO	<i>Nitzschia fossilis</i>	35X-2, 82	35X-5, 80	322.02	325.00	9.16	9.25
T	C4Ar.1n			324.10	324.10	9.23	9.23
B	C4Ar.1n			327.05	327.05	9.31	9.31
T	C4Ar.2n			338.55	338.55	9.58	9.58
FO	<i>Diartus hughesi</i>	39X-1, 1	39X-2, 80	356.20	358.10	9.92	9.96
FO	<i>Hemidiscus cuneiformis</i>	39X-5, 82	40X-2, 80	363.02	368.00	10.05	10.15
FO	<i>Thalassiosira miocenica</i>	40X-2, 82	41X-2, 80	368.02	376.02	10.15	10.30
FO	<i>Asteromphalus kenettii</i>	42X-2, 80-82	42X-6, 80-82	387.02	391.52	10.51	10.60
LO	<i>Cyrtocapsella japonica</i>	42X-4,56	42X-6, 13	389.76	392.33	10.57	10.62
B	C5n.2n			409.64	409.64	10.95	10.95
FO	<i>Simonsenella barboi</i>	46X-2, 80-82	46X-3, 80-82	425.00	426.50	11.90	11.99
FO	<i>Cyrtocapsella japonica</i>	45X-2, 61	45X-CC	415.31	422.70	11.30	11.76
FO	<i>Cyrtocapsella tetrapera</i>	45X-2, 59	45X-4, 70	424.79	427.29	11.89	12.04
LO	<i>Actinocyclus ingens v. nodus</i>	46X-2, 82	46X-5, 80	425.00	429.50	11.90	12.18
FO	<i>Denticulopsis dimorpha</i>	46X-2, 82	46X-5, 80	425.02	429.50	11.90	12.17
LO	<i>Crucidentacula nicobarica</i>	46X-5, 82	47X-2, 81	429.52	434.51	12.18	?
LO	<i>Crucidentacula kanayae</i>	46X-5, 80	47X-2, 81	429.50	434.51	12.18	?
T	C5An.2n			429.55	429.55	12.18	?
	Unconformity			***	***	***	***
LO	<i>Denticulopsis maccollumnii</i>	47X-2, 81	47X-5, 79	434.50	438.99	?	15.05
FO	<i>Actinocyclus ingens v. nodus</i>	47X-5, 79	47X-2, 81	434.51	438.99	?	15.05
LO	<i>Coscinodiscus lewisianus</i>	47X-2, 81	47X-5, 79	434.51	438.99	?	15.05
LO	<i>Nitzschia grossepunctata</i>	47X-2, 81	47X-5, 79	434.51	438.99	?	15.05
B	C5ADn			435.65	435.65	14.61	14.61
T	C5Bn.1n			436.60	436.60	14.80	14.80
B	C5Bn.1n			437.40	437.40	14.89	14.89
FO	<i>Nitzschia denticuloides</i>	47X-5, 81	48X-1, 79	439.00	442.49	15.06	15.13
T	C5Bn.2n			439.72	439.72	15.03	15.03
LO	<i>Nitzschia maleinterpretaria</i>	48X-1, 79	48X-3, 81	442.59	445.51	15.14	?
B	C5Bn.2n			443.00	443.00	15.16	15.16
FO	<i>Denticulopsis hustedtii</i>	48X-3, 81	49X-1, 47	445.51	451.67	?	?
FO	<i>Cestodiscus peplum</i>	48X-3, 81	49X-1, 47	445.51	451.67	?	?
LO	<i>Thalassiosira fraga</i>	48X-3, 81	49X-1, 47	445.51	451.67	?	?
FO	<i>Denticulopsis lauta</i>	48X-3, 79-81	49X-1, 47-49	445.51	451.69	?	?
FO	<i>Actinocyclus ingens</i>	48X-3, 79-81	49X-1, 47-49	445.51	451.69	?	?
FO	<i>Calcidiscus macintyreii</i>	48X-CC	49X-CC	451.20	460.70	?	16.84
FO	<i>Simonsensiella barboi</i>	49X-1, 47	49X-4, 49	451.69	456.19	?	?
	Unconformity			***	***	***	***
B	C5Cn.3n			453.60	453.60	16.73	16.73
LO	<i>Crucidentacula kanayae</i>	49X-4,49	50X-1, 41	456.19	461.15	16.77	16.85
FO	<i>Denticulopsis maccollumnii</i>	49X-4, 49	50X-1, 45	456.19	461.15	16.77	16.85
FO	<i>Nitzschia grossepunctata</i>	50X-1, 45	51X-1, 45	461.15	463.15	16.85	16.88
FO	<i>Raphidodiscus marylandicus</i>	50X-1, 45	51X-1, 45	461.15	463.15	16.85	16.88
FO	<i>Crucidentacula kanayae</i>	52X-1, 80-82	52X-4, 42	473.02	477.12	17.03	17.09
LO	<i>Coscinodiscus rhombicus</i>	52X-4, 42	52X-CC	477.12	481.70	17.09	17.16
LO	<i>Thalassiosira aspinosa</i>	53X-1, 42	53X-3, 42	482.12	485.12	17.17	17.21
FO	<i>Coscinodiscus lewisianus</i>	53X-3, 42	54X-2, 40	485.12	493.10	17.21	17.51
T	C5Dn			489.50	489.50	17.28	17.28
FO	<i>Crucidentacula nicobarica</i>	54X-2, 42	54X-5, 40	493.10	494.40	17.51	17.60
FO	<i>Nitzschia maleinterpretaria</i>	56X-1, 87	57X-2, 82	511.07	522.02	18.68	19.28
LO	<i>Rocella schraderi</i>	56X-1, 87	57X-2, 82	511.07	522.02	18.68	19.28

Table 22. (continued)

Event		Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO	<i>Rocella vigilans</i>	56X-1, 87	57X-2, 82	511.07	522.02	18.68	19.28
LO	<i>Rocella gelida</i>	56X-1, 87	57X-2, 82	511.07	522.02	18.68	19.28
B	C5En			512.59	512.59	18.78	18.78
T	C6n			513.94	513.94	19.05	19.05
FO	<i>Thalassiosira aspinosa</i>	58X-2, 70-72	58X-5, 70-72	531.42	534.45	19.86	20.05
LO	<i>Thalassiosira spumellaroides</i>	58X-5, 70-72	59X-2, 80-82	534.45	541.02	20.05	20.45
B	C6n			535.79	535.79	20.13	20.13
T	C6An.1n			538.29	538.29	20.52	20.52
FO	<i>Thalassiosira fraga</i>	59X-2, 82	60X-2, 80	541.02	550.50	20.75	21.54
LO	<i>Bogorovia veniamini</i>	59X-2, 82	60X-2, 80	541.02	550.50	20.75	21.54
B	C6AAr.1n			558.99	558.99	22.25	22.25
FO	<i>Rocella gelida</i>	65X-CC	66X-CC	605.20	614.70	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

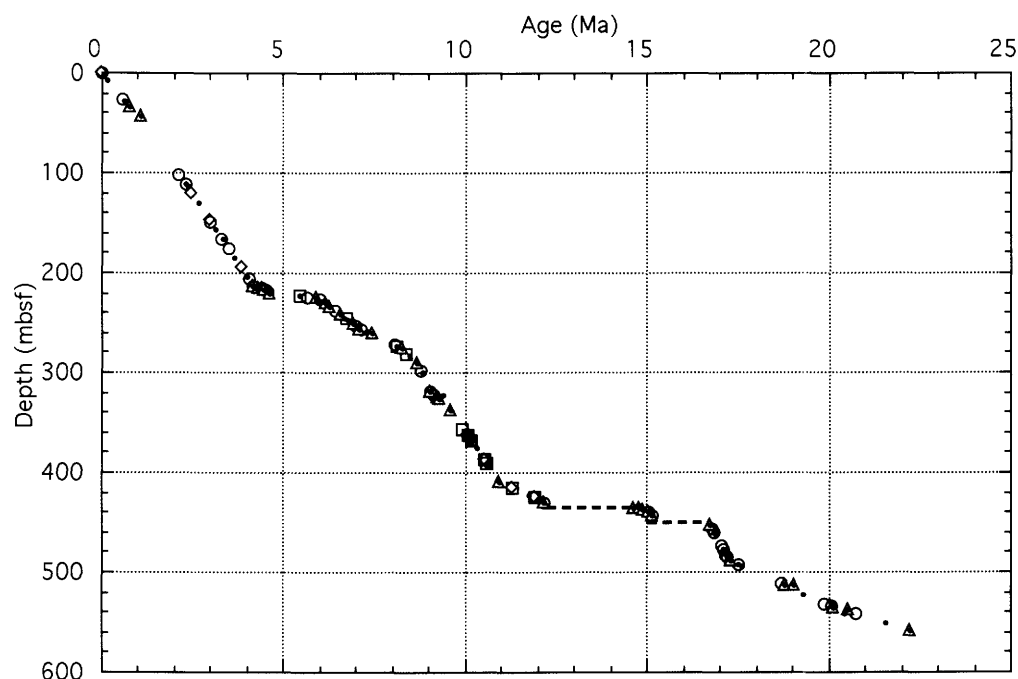


Fig. 30. An age-depth plot for DSDP Hole 704B utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols. One stratigraphical break (dashed line) is based on Hailwood & Clement (1991b).

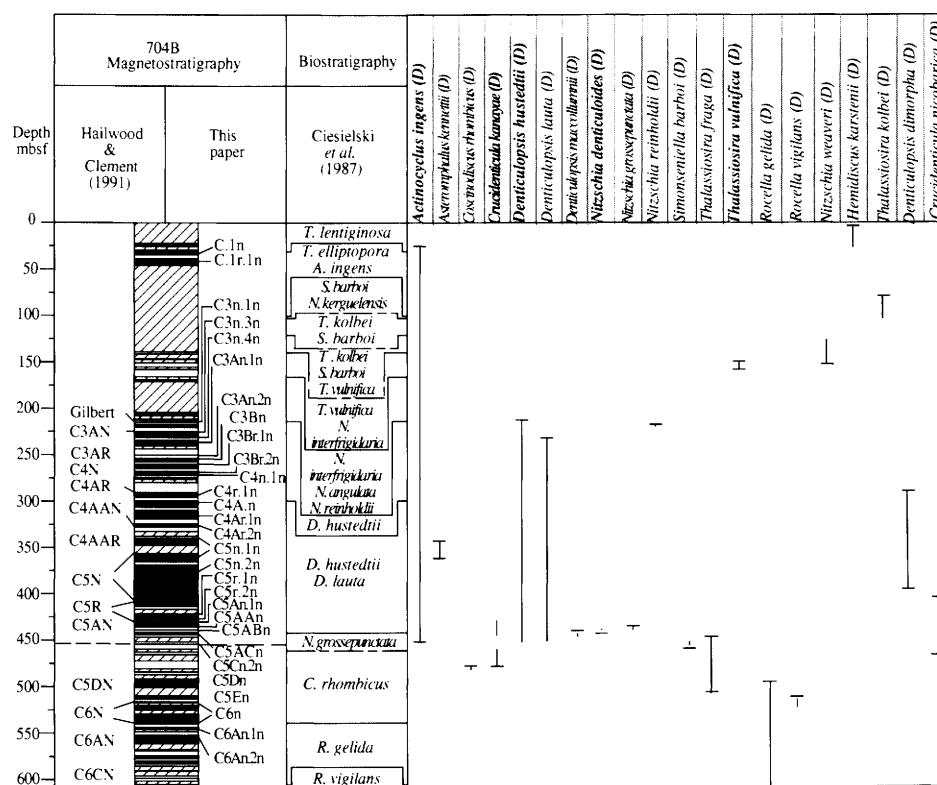


Fig. 31. Comparison of the ODP Hole 704B polarity chronozones and diatom zonal assignments by previous workers with the chronozone assignments of this study. The stratigraphical ranges of selected stratigraphical markers are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995). Diagonal lines indicate intervals of uncertainty.

Table 23. Composite dataset for ODP Hole 704B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Hemidiscus karstenii</i>	1H-1, 0	1H-2, 150	0.00	3.00	0.00	0.07
LO <i>Pseudoemiliana lacunosa</i>	1H-1, 0	1H-CC	0.00	6.70	0.00	0.15
LO <i>Actinocyclus ingens</i>	3H-CC	4H-2, 95	25.70	28.15	0.58	0.64
B C1n			34.51	34.51	0.78	0.78
B C1r.1n			44.27	44.27	1.07	1.07
LO <i>Simonseniella barboi</i>	11H-CC	12H-CC	101.70	111.20	2.12	2.30
LO <i>Thalassiosira kolbei</i>	12H-CC	13H-2, 125	111.20	113.50	2.30	2.34
LO <i>Helicosphaera sellii</i>	13H-CC	14H-CC	120.70	130.20	2.47	2.65
LO <i>Calcidiscus macintyreii</i>	16H-CC	17H-CC	147.20	156.70	2.96	3.13
LO <i>Discoaster browerii</i>	16X-CC	17X-CC	147.20	156.70	2.96	3.13
LO <i>Thalassiosira vulnifica</i>	17X-2, 100	17X-CC	149.70	156.70	3.00	3.13
FO <i>Thalassiosira vulnifica</i>	19X-1, 21	19X-1, 75	166.41	166.95	3.31	3.32
FO <i>Nitzschia weaveri</i>	19X-CC	20X-CC	175.70	185.20	3.48	3.66
LO <i>Reticulofenestra pseudumbilica</i>	21X-CC	22X-CC	194.70	204.20	3.83	4.01
FO <i>Nitzschia angulata</i>	23X-2, 70	23X-CC	206.40	213.70	4.05	4.18
T C3n.1n			213.70	213.70	4.18	4.18
LO <i>Hemidiscus cuneiformis</i>	23X-CC	24X-1, 80-82	213.70	214.52	4.18	4.25
LO <i>Simonseniella barboi</i>	23X-CC	24X-1, 80-82	213.70	214.52	4.18	4.25
LO <i>Thalassiosira miocenica</i>	23X-CC	24X-1, 80-82	213.70	214.52	4.18	4.25
LO <i>Denticulopsis hustedtii</i>	23X-CC	24X-CC	213.70	223.20	4.18	5.42
B C3n.1n			215.00	215.00	4.29	4.29
LO <i>Thalassiosira insigna</i>	24X-2, 80-82	24X-3, 80-82	216.02	217.52	4.42	4.57
LO <i>Nitzschia reinholdii</i>	24X-2, 80-82	24X-3, 80-82	216.02	217.52	4.42	4.57
T C3n.2n			216.50	216.50	4.48	4.48
LO <i>Cosmiodiscus intersectus</i>	24X-3, 80-82	24X-4, 80-82	217.52	219.02	4.52	4.57
LO <i>Nitzschia fossilis</i>	24X-4, 80-82	24X-5, 80-82	219.02	220.52	4.57	4.62
LO <i>Nitzschia marina</i>	24X-4, 80-82	24X-5.80-82	219.02	220.52	4.57	4.62
B C3n.2n			220.50	220.50	4.62	4.62
LO <i>Stichocorys peregrina</i>	24X-CC	25X-CC	223.20	232.70	4.73	5.75
LO <i>Amphymenium challengerai</i>	24X-CC	25X-CC	223.20	232.70	4.73	5.75
LO <i>Thalassiosira praeconvexa</i>	25X-1, 80-82	25X-2.80-82	224.02	225.52	4.77	4.89
T C3n.3n			224.76	224.76	4.80	4.80
FO <i>Thalassiosira oestrupii</i>	25X-2, 80-82	25X-3, 80-82	227.02	228.52	4.95	5.06
B C3n.4n			231.05	231.05	5.23	5.23
T C3An.1n			233.85	233.85	5.89	5.89
LO <i>Thalassiosira convexa</i> v. <i>aspinosa</i>	26X-4, 82	27X-2, 110	238.02	244.80	6.02	6.19
B C3An.1n			241.62	241.62	6.14	6.14
FO <i>Amphymenium challengerai</i>	27X-2, 180	27X-4, 50	244.97	247.20	6.20	6.24
LO <i>Lamprocyclus aegles</i>	27X-2, 180	27X-4, 50	244.97	247.20	6.20	6.24
T C3An.2n			248.80	248.80	6.27	6.27
B C3An.2n			249.45	249.45	6.57	6.57
T C3Bn			251.25	251.25	6.94	6.94
FO <i>Thalassiosira praeconvexa</i>	28X-1, 81	28X-2, 79	252.51	253.99	6.97	7.01
B C3Bn			256.75	256.75	7.09	7.09
LO <i>Denticulopsis lauta</i>	28X-4, 79-81	28X-6, 79-81	257.01	258.60	7.09	7.12
T C3Br.1n			259.50	259.50	7.14	7.14
B C3Br.1n			264.29	264.29	7.17	7.17
T C3Br.2n			265.79	265.79	7.34	7.34
B C3Br.2n			267.79	295.60	7.38	7.38
T C4n.1n			269.55	269.55	7.43	7.43
B C4n.1n			270.10	270.10	7.56	7.56
T C4n.2n			270.82	270.82	7.65	7.65
LO <i>Nitzschia porteri</i>	30X-1, 82	30X-2, 80	271.52	273.00	7.71	7.83
FO <i>Lamprocyclus aegles</i>	30X-2, 45	30X-4, 45	272.65	275.65	7.80	8.05
B C4n.2n			275.85	275.85	8.07	8.07
LO <i>Diartus hughesi</i>	30X-CC	31X-2, 45	280.20	282.15	8.12	8.14
FO <i>Stichocorys peregrina</i>	30X-CC	31X-2, 45	280.20	282.15	8.12	8.14
T C4r.1n			290.06	290.06	8.23	8.23
B C4r.1n			295.60	295.60	8.26	8.26
FO <i>Thalassiosira insigna</i>	32X-6, 80-82	33X-1, 80-82	298.02	300.02	8.54	8.73
FO <i>Nitzschia marina</i>	32X-6, 82	33X-1, 80	298.02	300.02	8.54	8.73
FO <i>Nitzschia reinholdii</i>	32X-6, 80-82	33X-1, 80-82	298.02	300.02	8.54	8.73
FO <i>Cosmiodiscus intersectus</i>	32X-6, 80-82	33X-1, 80-82	298.02	300.02	8.54	8.73
T C4An			299.37	299.37	8.70	8.70
B C4An			306.00	306.00	9.03	9.03
T C4Ar.1n			309.10	309.10	9.23	9.23
B C4Ar.1n			318.55	318.55	9.31	9.31
LO <i>Denticulopsis dimorpha</i>	35X-1, 80-82	35X-3, 80-82	319.02	322.02	9.33	9.48
FO <i>Nitzschia fossilis</i>	35X-2, 82	35X-5, 80	322.02	325.00	9.48	9.59
T C4Ar.2n			324.10	324.10	9.58	9.58

Table 23. (continued)

	Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
B	C4Ar.2n			331.00	331.00	9.64	9.64
T	C5n.1n			338.55	338.55	9.74	9.74
FO	<i>Diartus hughesi</i>	39X-1, 1	39X-2, 80	356.20	358.10	9.83	9.84
FO	<i>Hemidiscus cuneiformis</i>	39X-5, 82	40X-2, 80	363.02	368.00	9.87	9.90
B	C5n.1n			365.00	365.00	9.88	9.88
T	C5n.2n			366.00	366.00	9.92	9.92
FO	<i>Thalassiosira miocenica</i>	40X-2, 82	41X-2, 80	368.02	376.02	9.97	10.16
LO	<i>Denticulopsis dimorpha</i>	40X-5, 82	41X-5, 80	375.52	382.00	10.15	10.30
FO	<i>Asteromphalus kenettii</i>	42X-2, 80-82	42X-6, 80-82	387.02	391.52	10.42	10.52
LO	<i>Cyrtocapsella japonica</i>	42X-4, 56	42X-6, 13	389.76	392.33	10.48	10.54
B	C5n.2n			409.64	409.64	10.95	10.95
FO	<i>Cyrtocapsella japonica</i>	45X-2, 61	45X-CC	415.31	422.70	10.99	11.05
T	C5r.1n			423.10	423.10	11.05	11.05
FO	<i>Simonsenella barboi</i>	46X-2, 80-82	46X-3, 80-82	425.00	426.50	11.39	11.66
FO	<i>Cyrtocapsella tetrapera</i>	45X-2, 59	45X-4, 70	424.79	427.29	11.35	11.83
LO	<i>Actinocyclus ingens v. nodus</i>	46X-2, 82	46X-5, 80	425.00	429.50	11.06	12.95
FO	<i>Denticulopsis dimorpha</i>	46X-2, 82	46X-5, 80	425.02	429.50	11.06	12.95
T	C5r.2n			425.50	425.50	11.48	11.48
B	C5r.2n			426.20	426.20	11.53	11.53
T	C5An.1n			427.70	427.70	11.94	11.94
B	C5An.1n			428.50	428.50	12.08	12.08
LO	<i>Crucidentacula kanayae</i>	46X-5, 82	47X-2, 81	429.50	434.51	12.95	13.11
LO	<i>Crucidentacula nicobarica</i>	46X-5, 82	47X-2, 81	429.50	434.51	12.95	13.11
T	C5AAn			429.55	429.55	12.99	12.99
LO	<i>Denticulopsis maccollumnii</i>	47X-2, 81	47X-5, 79	434.50	438.99	13.11	13.22
FO	<i>Actinocyclus ingens v. nodus</i>	47X-5, 79	47X-2, 81	434.51	438.99	13.11	13.64
LO	<i>Coscinodiscus lewisianus</i>	47X-2, 81	47X-5, 79	434.51	438.99	13.11	13.64
LO	<i>Nitzschia grossepunctata</i>	47X-2, 81	47X-5, 79	434.51	438.99	13.11	13.64
B	C5AAn			435.65	435.65	13.14	13.14
T	C5ABn			436.60	436.60	13.30	13.30
B	C5ABn			437.40	437.40	13.51	13.51
FO	<i>Nitzschia denticuloides</i>	47X-5, 81	48X-1, 79	439.00	442.49	13.64	14.02
T	C5ACn			439.72	439.72	13.70	13.70
LO	<i>Nitzschia maleinterpretaria</i>	48X-1, 79	48X-3, 81	442.59	445.51	14.03	?
B	C5ACn			443.00	443.00	14.08	14.08
FO	<i>Denticulopsis hustedtii</i>	48X-3, 81	49X-1, 47	445.51	451.67	?	?
FO	<i>Cestodiscus peplum</i>	48X-3, 81	49X-1, 47	445.51	451.67	?	?
LO	<i>Thalassiosira fraga</i>	48X-3, 81	49X-1, 47	445.51	451.67	?	?
LO	<i>Denticulopsis lauta</i>	48X-3, 79-81	49X-1, 47-49	445.51	451.69	?	?
FO	<i>Actinocyclus ingens</i>	48X-3, 79-81	49X-1, 47-49	445.51	451.69	?	?
FO	<i>Calcidiscus macintyreii</i>	48X-CC	49X-CC	451.20	460.70	?	16.52
FO	<i>Simonsenella barboi</i>	49X-1, 47	49X-4, 49	451.69	456.19	?	16.50
	Unconformity			***	***	***	***
T	C5Cn.2n			452.15	452.15	16.33	16.33
B	C5Cn.2n			453.60	453.60	16.49	16.49
FO	<i>Denticulopsis maccollumnii</i>	49X-4, 49	50X-1, 45	456.19	461.15	16.50	16.52
FO	<i>Nitzschia grossepunctata</i>	50X-1, 45	51X-1, 45	461.15	463.15	16.52	16.52
FO	<i>Raphidodiscus marylandicus</i>	50X-1, 45	51X-1, 45	461.15	463.15	16.64	16.68
FO	<i>Crucidentacula kanayae</i>	52X-1, 80-82	52X-4, 42	473.02	477.12	16.56	16.81
T	C5Cn.3n			473.80	473.80	16.56	16.56
B	C5Cn.3n			475.05	475.05	16.73	16.73
LO	<i>Coscinodiscus rhombicus</i>	52X-4, 42	52X-CC	477.12	481.70	16.81	16.99
LO	<i>Thalassiosira aspinosa</i>	53X-1, 42	53X-3, 42	482.12	485.12	17.00	17.12
FO	<i>Coscinodiscus lewisianus</i>	53X-3, 42	54X-2, 40	485.12	493.10	17.12	17.42
FO	<i>Crucidentacula nicobarica</i>	54X-2, 42	54X-5, 40	493.10	494.40	17.42	17.47
LO	<i>Rocella gelida</i>	54X-5, 40	55X-1, 40	494.40	501.10	17.47	17.85
B	C5Dn			498.20	498.20	17.62	17.62
FO	<i>Nitzschia maleinterpretaria</i>	56X-1, 87	57X-2, 82	511.07	522.02	18.66	19.37
LO	<i>Rocella schraderi</i>	56X-1, 87	57X-2, 82	511.07	522.02	18.66	19.37
LO	<i>Rocella vigilans</i>	56X-1, 87	57X-2, 82	511.07	522.02	18.66	19.37
LO	<i>Rocella gelida</i>	56X-1, 87	57X-2, 82	511.07	522.02	18.66	19.37
B	C5En			512.59	512.59	18.78	18.78
T	C6n			513.94	513.94	19.05	19.05
FO	<i>Thalassiosira aspinosa</i>	58X-2, 70-72	58X-5, 70-72	531.42	534.45	19.74	19.86
LO	<i>Thalassiosira spumellaroides</i>	58X-5, 70-72	59X-2, 80-82	534.45	541.02	19.86	20.12
FO	<i>Thalassiosira fraga</i>	59X-2, 82	60X-2, 80	541.02	550.50	20.12	21.07
LO	<i>Bogorovia veniamini</i>	59X-2, 82	60X-2, 80	541.02	550.50	20.12	21.07
B	C6n			541.24	541.24	20.13	20.13
T	C6An.2n			548.34	548.34	21.00	21.00
B	C6An.2n			558.99	558.99	21.32	21.32
FO	<i>Rocella gelida</i>	65X-CC	66X-CC	605.20	614.70	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

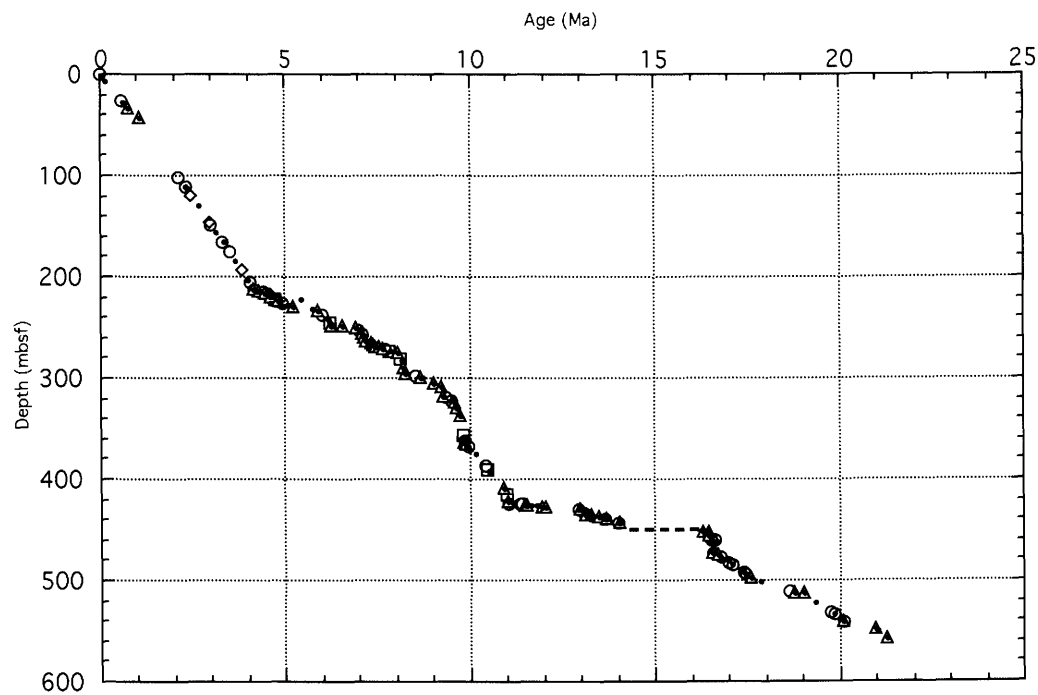


Fig. 32. An age–depth plot for DSDP Hole 704B utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Hole 737A

Twenty-nine cores were recovered from a total penetration of 273.2 mbsf representing a recovery of 66% of the cored interval. Sediments recovered consist of Quaternary to upper Miocene diatom ooze, upper Miocene to middle Miocene calcareous nannofossil ooze with a variable terrigenous and volcanic component, upper Oligocene middle Eocene claystone and limestone (Barron *et al.* 1989).

A partial palaeomagnetic polarity reversal record was interpreted by Barron *et al.* (1991) based on shipboard and shorebase analysis. Diatoms and radiolarians are generally present in the Quaternary to upper Oligocene section and absent from the lower Oligocene to middle Eocene interval. Calcareous nannofossils are generally present throughout the sequence except for a barren Pliocene/Miocene interval. Well-preserved and abundant diatoms are present in the Quaternary to middle Miocene interval. Both abundance and preservation declines with rare, poorly to moderately preserved specimens present in upper to lower upper Oligocene sediments. Diatoms are absent from the lower Oligocene to middle Eocene interval. Calcareous nannofossils are common to abundant with moderate preservation for the Quaternary to lower Pliocene, absent from the lower Pliocene to upper Miocene and abundant with variable preservation in the upper Miocene to middle Eocene. Radiolarians are rare to abundant with poor to good preservation for the Quaternary to upper Oligocene section. Radiolarians are absent from lower upper Oligocene to middle Eocene (Barron *et al.* 1989). The integrated biostratigraphical and magnetostratigraphical data previously used (palaeomagnetism: Barron *et al.* 1991; diatoms: Baldauf & Barron 1991; calcareous nannofossils: none; radiolarians: Caulet (1991) and calibrated to the GPTS of Berggren *et al.* (1985a, b) is presented in Table 24. An age–depth graph for Hole 119-737A using this data is shown in Fig. 33.

Figure 34 compares the polarity chronozones and diatom zones assigned by previous workers (Barron *et al.* 1991; Baldauf & Barron 1991) with the chronozone assignments in this study. The stratigraphical ranges of diatoms and radiolarians reflect the placement of FO and LO of stratigraphically useful species as recognized by Baldauf & Barron (1991), Barron *et al.* (1991) and Caulet (1991), respectively. The revised chronozones and diatom zones illustrated are based on reassessing the data sets of these workers (Table 25). Comparison of the chronozone assignments of Barron *et al.* (1991; Table 24) with those of this study (Table 25) indicates no changes to the polarity assignments.

Figure 35 shows an age–depth graph for Hole 119-737A using the stratigraphical markers determined in this study. The stratigraphical sequence is continuous for the interval examined (3.0 to about 7.5 Ma). Stratigraphical control is based on both biostratigraphical and palaeomagnetic markers. The stratigraphical markers used include only those markers proven to be useful based on this study. These include the FO of *Nitzschia interfrigidaria* (43.60–46.90 mbsf), FO of *Nitzschia barronii* (62.00–65.6 mbsf), the FO of *Helotholus vema* (62.00–71.50 mbsf) the FO of *Nitzschia praeinterfrigidaria* (78.10–81.00 mbsf) and the FO of *Denticulopsis hustedtii* (254.04–263.50 mbsf). Barron *et al.* (1991) recognize the occurrence of a hiatus at 1.5 mbsf and of a possible hiatus between 62 and 71 mbsf. The younger hiatus, which coincides with a boundary between glauconitic sand and diatom ooze, is inferred on the basis of diatom biostratigraphy and is adhered to in this study. The possible existence of an older hiatus is based on radiolarian biostratigraphy, but Barron *et al.* (1991) also indicate that the reduced sedimentation rate within the 62–71 mbsf interval may represent a condensed sequence. This study also records the occurrence of reduced sedimentation rates within this interval.

Table 24. Composite dataset for ODP Hole 737A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Nitzschia interfrigidaria</i>	1H-1, 57-59	1H-2, 57-59	0.59	2.10	?	?
LO <i>Nitzschia praeinterfrigidaria</i>	1H-1, 57-59	1H-2, 57-59	0.59	2.10	?	?
LO <i>Nitzschia weaveri</i>	1H-1, 57-59	1H-2, 57-59	0.59	2.10	?	?
Unconformity			***	***	***	***
FO <i>Nitzschia kerguelensis</i>	1H-2, 57-59	1H-CC	2.10	5.00	?	?
T C2An.2n			11.42	11.42	3.11	3.11
FO <i>Thalassiosira kolbei</i>	2H-5, 57-59	2H-CC	11.60	14.50	3.12	3.23
B C2An.2n			13.75	13.75	3.22	3.22
LO <i>Desmospyris spongiosa</i>			14.50	15.05	3.24	3.25
LO <i>Thalassiosira insigna</i>	3H-2, 57-59	3H-5, 57-59	16.59	21.10	3.28	3.60
FO <i>Nitzschia weaveri</i>	3H-2, 57-59	3H-5, 57-59	16.59	21.10	3.28	3.60
T C2An.3n			19.00	19.00	3.33	3.33
B C2An.3n			19.95	19.95	3.58	3.58
LO <i>Simonseniella barboi</i>	4H-2, 57-59	4H-5, 57-59	26.10	30.60	3.68	3.76
LO <i>Hemidiscus karstenii</i>	4H-CC	5H-2, 57-59	33.50	35.60	3.81	3.84
FO <i>Nitzschia interfrigidaria</i>	6H-1, 57-59	6H-5, 57-59	43.60	46.90	3.98	4.03
FO <i>Thalassiosira lentiginosa</i>	6H-5, 57-59	6H-CC	49.60	52.50	4.08	4.13
T C3n.1n			55.41	55.41	4.18	4.18
B C3n.1n			61.32	61.32	4.29	4.29
FO <i>Nitzschia barronii</i>	7H-CC	8H-3, 57-59	62.00	65.60	4.32	4.57
FO <i>Helotholus vema</i>			62.00	71.50	4.32	4.66
T C3n.2n			65.08	65.08	4.48	4.48
B C3n.2n			65.88	65.88	4.62	4.62
FO <i>Nitzschia praeinterfrigidaria</i>	9H-5, 57-59	9H-CC	78.10	81.00	4.70	4.72
FO <i>Thalassiosira inura</i>	9H-CC	10H-4, 57-59	81.00	87.60	4.72	4.77
FO <i>Thalassiosira torokina</i>	10H-5, 57-59	10H-6, 57-59	87.60	89.10	4.77	4.77
T C3n.3n			92.22	92.22	4.80	4.80
B C3n.3n			97.90	97.90	4.89	4.89
T C3n.4n			98.90	98.90	4.98	4.98
FO <i>Thalassiosira oestrupii</i>	11H-CC	12H-2, 57-59	100.00	102.00	5.01	5.08

(continued)

Table 24. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Stichocorys peregrina</i>			101.90	103.40	5.07	5.12
B C3n.4n			106.81	106.81	5.23	5.23
LO <i>Thalassiosira miocenica</i>	13H-2, 57-59	13H-CC	111.60	119.00	5.41	5.70
T C3An.1n			123.91	123.91	5.89	5.89
FO <i>Rouxia heteropolara</i>	17H-5, 57-59	17H-CC	154.10	157.00	6.36	6.41
B C3An.2n			167.21	167.21	6.57	6.57
FO <i>Thalassiosira miocenica</i>	19-1, 57-59	19X-CC	167.10	176.20	6.57	6.68
LO <i>Thalassiosira burckliana</i>	21X-CC	23X-2, 57-59	195.60	207.40	6.93	7.08
LO <i>Actinocyclus ingens</i>	23X-CC	25X-2, 57-59	215.00	228.90	7.17	7.35
T C4n.1n			235.28	235.28	7.43	7.43
FO <i>Actinocyclus fryxellae</i>	27X-3, 57-59	27X-CC	247.70	253.80	?	?
FO <i>Nitzschia reinholdii</i>	27X-3, 57-59	27X-CC	247.70	253.80	?	?
FO <i>Cosmiodiscus intersectus</i>			247.70	253.80	?	?
FO <i>Denticulopsis hustedtii</i>	28X-1, 57-59	28X-CC	254.40	263.50	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

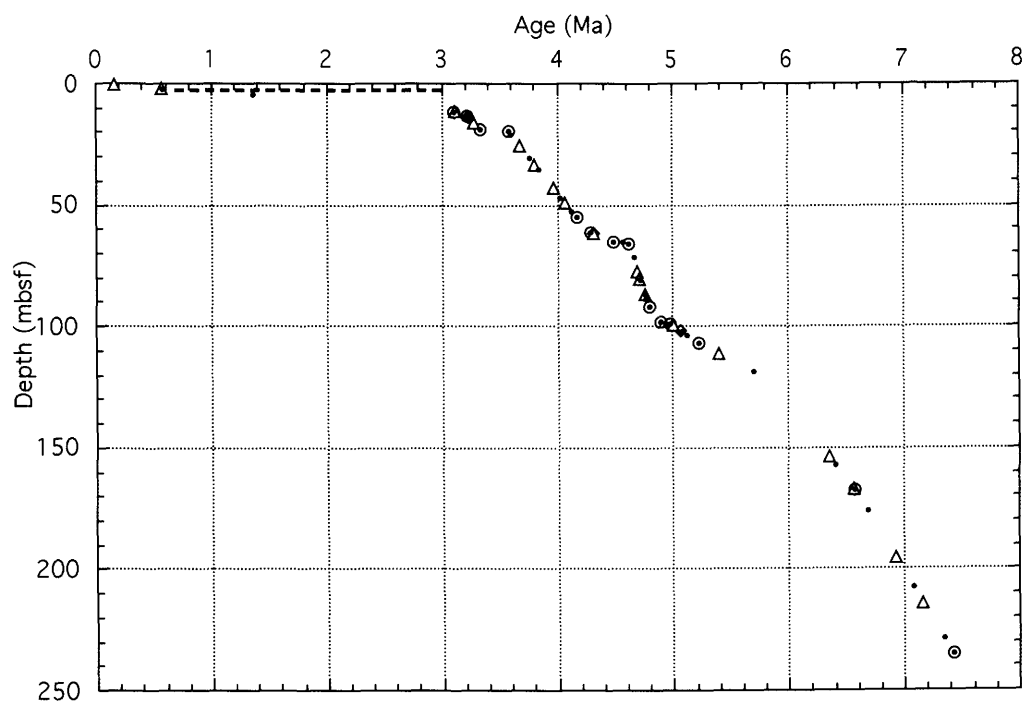


Fig. 33. An age–depth plot for DSDP Hole 737A utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

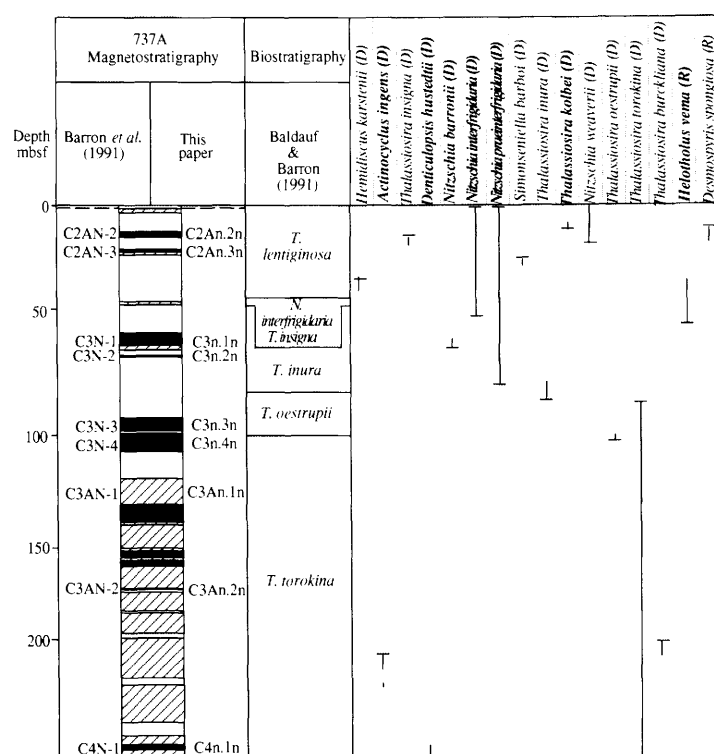


Fig. 34. Comparison of the ODP Hole 737A polarity chronozones and diatom zonal assignments by previous workers with the chronozone assignments of this study. The stratigraphical ranges of selected stratigraphical markers is based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995). Diagonal lines indicate intervals of no core recovery, dashed lines indicate intervals of uncertainty.

Table 25. Composite dataset for ODP Hole 737A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Nitzschia interfrigidaria</i>	1H-1, 57-59	1H-2, 57-59	0.59	2.10	?	?
LO <i>Nitzschia praeinterfrigidaria</i>	1H-1, 57-59	1H-2, 57-59	0.59	2.10	?	?
LO <i>Nitzschia weaveri</i>	1H-1, 57-59	1H-2, 57-59	0.59	2.10	?	?
Unconformity			***	***	***	***
FO <i>Nitzschia kerguelensis</i>	1H-2, 57-59	1H-CC	2.10	5.00	?	?
T C2An.2n			11.42	11.42	3.11	3.11
FO <i>Thalassiosira kolbei</i>	2H-5, 57-59	2H-CC	11.60	14.50	3.12	3.23
B C2An.2n			13.91	13.91	3.22	3.22
LO <i>Desmospyris spongiosa</i>			14.50	15.05	3.23	3.22
LO <i>Thalassiosira insigna</i>	3H-2, 57-59	3H-5, 57-59	16.59	21.10	3.28	3.60
FO <i>Nitzschia weaveri</i>	3H-2, 57-59	3H-5, 57-59	16.59	21.10	3.28	3.60
T C2An.3n			19.00	19.00	3.33	3.33
B C2An.3n			19.95	19.95	3.58	3.58
LO <i>Simonseniella barboi</i>	4H-2, 57-59	4H-5, 57-59	26.10	30.60	3.68	3.76
LO <i>Hemidiscus karstenii</i>	4H-CC	5H-2, 57-59	33.50	35.60	3.81	3.84
FO <i>Nitzschia interfrigidaria</i>	6H-1, 57-59	6H-5, 57-59	43.60	46.90	3.98	4.03
FO <i>Thalassiosira lentiginosa</i>	6H-5, 57-59	6H-CC	49.60	52.50	4.08	4.13
T C3n.1n			55.41	55.41	4.18	4.18
B C3n.1n			61.32	61.32	4.29	4.29
FO <i>Nitzschia barronii</i>	7H-CC	8H-3, 57-59	62.00	65.60	4.32	4.62
FO <i>Heliotholus vema</i>			62.00	71.50	4.32	4.66
T C3n.2n			65.08	65.08	4.48	4.48
B C3n.2n			65.88	65.88	4.62	4.62
FO <i>Nitzschia praeinterfrigidaria</i>	9H-5, 57-59	9H-CC	78.10	81.00	4.70	4.72
FO <i>Thalassiosira inura</i>	9H-CC	10H-4, 57-59	81.00	87.60	4.72	4.77
LO <i>Thalassiosira torokina</i>	10H-5, 57-59	10H-6, 57-59	87.60	89.10	4.77	4.78
T C3n.3n			92.22	92.22	4.80	4.80
B C3n.3n			97.90	97.90	4.89	4.89

(continued)

Table 25. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
T C3n.4n			98.90	98.90	4.98	4.98
FO <i>Thalassiosira oestrupii</i>	11H-CC	12H-2, 57-59	100.00	102.00	5.01	5.08
LO <i>Stichocorys peregrina</i>			101.90	103.40	5.07	5.12
B C3n.4n			106.81	106.81	5.23	5.23
LO <i>Thalassiosira miocenica</i>	13H-2, 57-59	13H-CC	111.60	119.00	5.41	5.70
T C3An.1n			123.91	123.91	5.89	5.89
FO <i>Rouxia heteropolara</i>	17H-5, 57-59	17H-CC	154.10	157.00	6.36	6.40
B C3An.2n			167.21	167.21	6.56	6.56
FO <i>Thalassiosira miocenica</i>	19-1, 57-59	19X-CC	167.10	176.20	6.56	6.67
LO <i>Thalassiosira burckliana</i>	21X-CC	23X-2, 57-59	195.60	207.40	6.92	7.07
LO <i>Actinocyclus ingens</i>	23X-CC	25X-2, 57-59	215.00	228.90	7.17	7.35
T C4n.1n			235.28	235.28	7.43	7.43
FO <i>Actinocyclus fryxellae</i>	27X-3, 57-59	27X-CC	247.70	253.80	?	?
FO <i>Nitzschia reinholdii</i>	27X-3, 57-59	27X-CC	247.70	253.80	?	?
FO <i>Cosmiodiscus intersectus</i>			247.70	253.80	?	?
FO <i>Denticulopsis hustedtii</i>	28X-1, 57-59	28X-CC	254.40	263.50	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

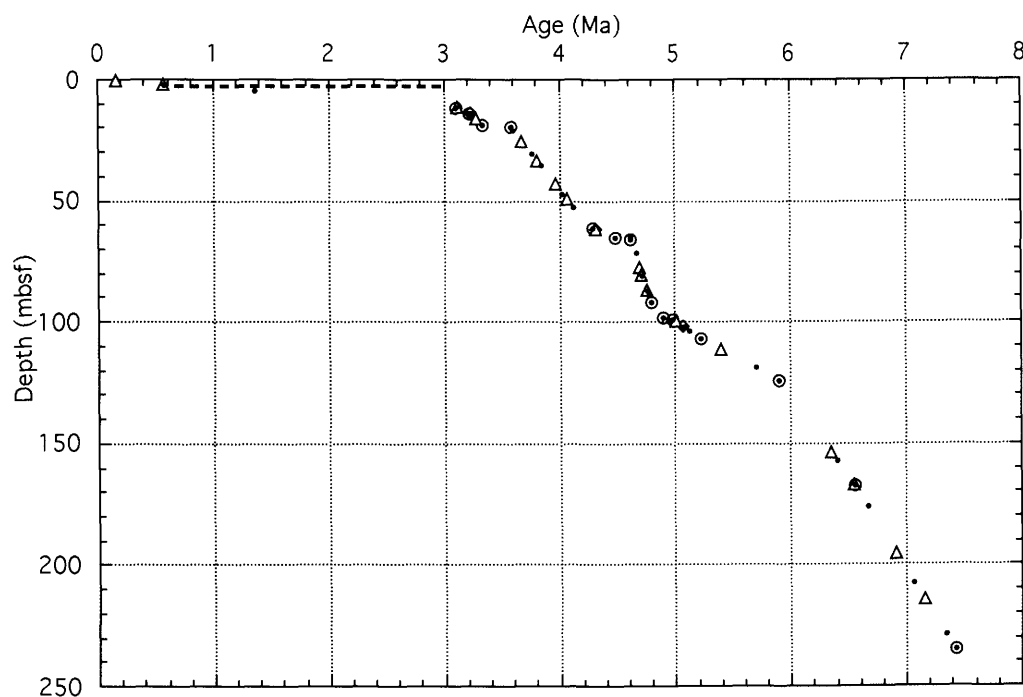


Fig. 35. An age-depth plot for DSDP Hole 737A utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Hole 744A

Twenty cores were recovered from a total penetration of 176.1 mbsf representing a recovery of 82% of the cored interval. Sediments recovered consist of Quaternary to lower Pliocene diatom ooze and upper Miocene to upper Eocene calcareous nannofossil ooze (Barron *et al.* 1989). A good palaeomagnetic polarity reversal record was interpreted by Barron *et al.* (1991) for the lowermost portion of the section. All three microfossil groups are recorded from the sediments examined (Barron *et al.* 1989). Diatoms are well preserved and abundant in the Quaternary to lower Oligocene interval. Abundance and preservation deteriorates in the lowermost Oligocene and diatoms are absent in upper Eocene sediments. Calcareous nannofossils are sporadic in the Quaternary to Pliocene and abundant in the upper Miocene to upper Eocene with moderate to good preservation. Radiolarians are common to abundant with moderate to good preservation for the Quaternary to lower Oligocene interval and are absent from upper Eocene sediments. The integrated biostratigraphical and magnetostratigraphical data previously used (palaeomagnetism: Barron *et al.* 1991; diatoms: Baldauf & Barron 1991; calcareous nannofossils: Wei & Thierstein 1991; radiolarians: none) and calibrated to the GPTS of Berggren *et al.* (1985a, b) is shown in Table 26. An age–depth plot for Hole 119-744A using this data is shown in Fig. 36.

Figure 37 compares the polarity chronozones and diatom zones assigned by previous workers. Barron *et al.* (1991) and Baldauf & Barron (1991) with the chronozone assignments in this study for the interval containing polarity reversals from 80 to 170 mbsf. In addition, this figure illustrates the stratigraphical ranges of diatoms, radiolarians and calcareous nannofossils. The stratigraphical ranges reflect the placement of FO and LO of stratigraphically useful species as recognized by Baldauf & Barron (1991) and Wei & Thierstein (1991) respectively. The revised chronozones and diatom zones illustrated are based on reassessing the data sets of these

workers (Table 27). Comparison of the chronozone assignments of Barron *et al.* (1991; Table 26) with those of this study (Table 27) indicates minimal reinterpretation which affects the placement of one hiatus. Nomenclature changes also reflect in part differences in the GPTS used in these studies.

Figure 38 shows an age–depth graph for Hole 119-744A using the stratigraphical markers determined in this study. Two hiatuses are recognized, the younger between 98.9 and 99.20 mbsf and the older between 115.29 and 118.37 mbsf. The upper boundary of the younger hiatus is constrained by the top of C6An at 98.9 mbsf. The lower boundary of this break is constrained by a sequence of polarity events from the base of C7An at 100.24 mbsf to the top of C9n at 115.29 mbsf. This interval lacks primary biostratigraphical events. The LO of *Chiasmolithus altus* (106.92–107.62 mbsf) provides a potentially useful marker within this sequence. The upper boundary of the older hiatus is constrained by the base of C9n mbsf. The lower boundary is constrained by the base of C11n.2n at 118.37 mbsf. Placement of the boundaries for the older hiatus is tenuous and is based on the polarity reversal succession directly above and below the break. This break is constrained by the FO of *Isthmolithus recurvus* (168.85–170.35 mbsf) and the LO of *Reticulofenestra reticulata* (168.86–170.36 mbsf) and the polarity reversals identified.

Barron *et al.* (1991) identified three hiatuses in this sequence. The younger two breaks occur at 97 and 99 mbsf. The placement of these unconformities is based on the basis of strontium isotope studies, diatom biostratigraphy and/or the interpretation of magnetostratigraphy. We combine these two unconformities into a single unconformity at 99 mbsf based on our interpretation of the magnetostratigraphy. The older hiatus identified by Barron *et al.* (1991) approximates a depth of 117 mbsf and corresponds in depth and age to the placement of the older hiatus in this study.

Table 26. Composite dataset for ODP Hole 744A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
B C5En			81.70	81.70	18.78	18.78
T C6n			83.18	83.18	19.05	19.05
LO <i>Thalassiosira spumellaroides</i>	10HCC	11H-1, 63-65	88.16	89.70	19.61	19.78
FO <i>Cyrtocapsella longithorax</i>	10HCC	11H-1, 63-65	88.25	90.30	19.61	19.85
FO <i>Thalassiosira fraga</i>	11H-1, 63-65	11H-2, 63-65	90.30	91.80	19.85	20.02
LO <i>Rocella schraderi</i>	11H-2, 63-65	11H-3, 63-65	91.80	93.30	20.01	20.24
B C6n			92.80	92.80	20.13	20.13
T C6An.1n			94.63	94.63	20.52	20.52
LO <i>Rocella gelida</i>	11H-4, 63-65	11H-5, 63-65	94.80	96.33	20.55	20.70
FO <i>Thalassiosira spumellaroides</i>	11H-4, 63-65	11H-5, 63-65	94.90	96.33	20.55	20.70
LO <i>Bogorovia veniamini</i>	11H-5, 63-65	11H-6, 63-65	96.33	97.83	20.69	?
FO <i>Raphidodiscus marylandicus</i>	11H-5, 63-65	11H-6, 63-65	96.40	97.83	20.69	?
B C6An.1n			96.68	96.68	20.73	20.73
Unconformity			***	***	***	***
B C6Cn.3n			97.77	97.77	24.12	24.12
Unconformity			***	***	***	***
T C7An			98.90	98.90	25.50	25.50
LO <i>Thalassiosira primalabiata</i>	11H-CC	12H-1, 60-62	99.20	99.80	25.53	25.60
LO <i>Reticulofenestra bisecta</i>	11H-CC	12H-1, 92.93	99.20	101.22	25.53	25.76
B C7An			100.24	100.24	25.65	25.65
LO <i>Lisitzina ornata</i>	12H-4, 60-62	12H-5, 60-62	104.30	106.00	25.80	25.86
T C8n.1n			104.79	104.79	25.82	25.82
LO <i>Chiasmolithus altus</i>	13H-1, 60-62	13H-2, 60-62	106.92	107.62	26.04	26.11
FO <i>Nitzschia maleinterpretaria</i>	12H-6, 60-62	12H-7, 61-63	106.30	108.70	25.98	26.22
FO <i>Rocella gelida</i>	13H-1, 60-62	13H-2, 60-62	108.70	110.20	26.23	26.38
FO <i>Lisitzina ornata</i>	13H-1, 60-62	13H-2, 60-62	109.32	110.80	26.29	26.44
B C8n.2n			111.81	111.81	26.55	26.55
T C9n			115.29	115.29	27.03	27.03
Unconformity			***	***	***	***
B C11n.2n			118.37	118.37	30.10	30.10

(continued)

Table 26. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO <i>Synedra jouseana</i>	14H-2, 60-62	14H-4, 60-62	118.82	120.32	30.27	30.56
T C12n			119.36	119.36	30.48	30.48
FO <i>Rocella vigilans</i>	14H-2, 60-62	14H-4, 60-62	121.80	123.30	30.69	30.83
B C12n			124.59	124.59	30.94	30.94
LO <i>Reticulofenestra umbilica</i>	14H-6, 75-76	14H-CC	126.45	127.70	31.21	31.38
FO <i>Cyclicargolithus abisectus</i>			127.70	128.46	31.39	31.50
LO <i>Isthmolithus recurvus</i>	14H-2, 75-76	14H-3, 75-76	129.95	131.45	31.72	31.93
T C13n			139.25	139.25	33.06	33.06
B C13n			146.64	146.64	33.55	33.55
FO <i>Rhizosolenia oligocenica</i>	17H-1, 0	17H-1, 68	146.70	147.53	33.56	33.66
LO <i>Reticulofenestra oamaruensis</i>	17H-1, 75-76	17H-2, 75-76	147.60	148.30	33.67	33.75
T C15n			155.65	155.65	34.66	34.66
B C15n			158.10	158.10	34.94	34.94
T C16n.1n			161.30	161.30	35.34	35.34
B C16n.1n			162.90	162.90	35.53	35.53
T C16n.2n			164.60	164.60	35.69	35.69
FO <i>Reticulofenestra oamaruensis</i>	19H-CC	20H-1, 75-76	166.60	167.35	35.86	35.92
FO <i>Isthmolithus recurvus</i>	20H-2, 75-76	20H-3, 75-76	168.85	170.35	36.03	36.15
LO <i>Reticulofenestra reticulata</i>	20H-2, 75-76	20H-3, 75-76	168.86	170.36	36.03	36.15
B C16n.2n			172.85	172.85	36.34	36.34

Data sets are integrated from the work of numerous authors (see Table 2).

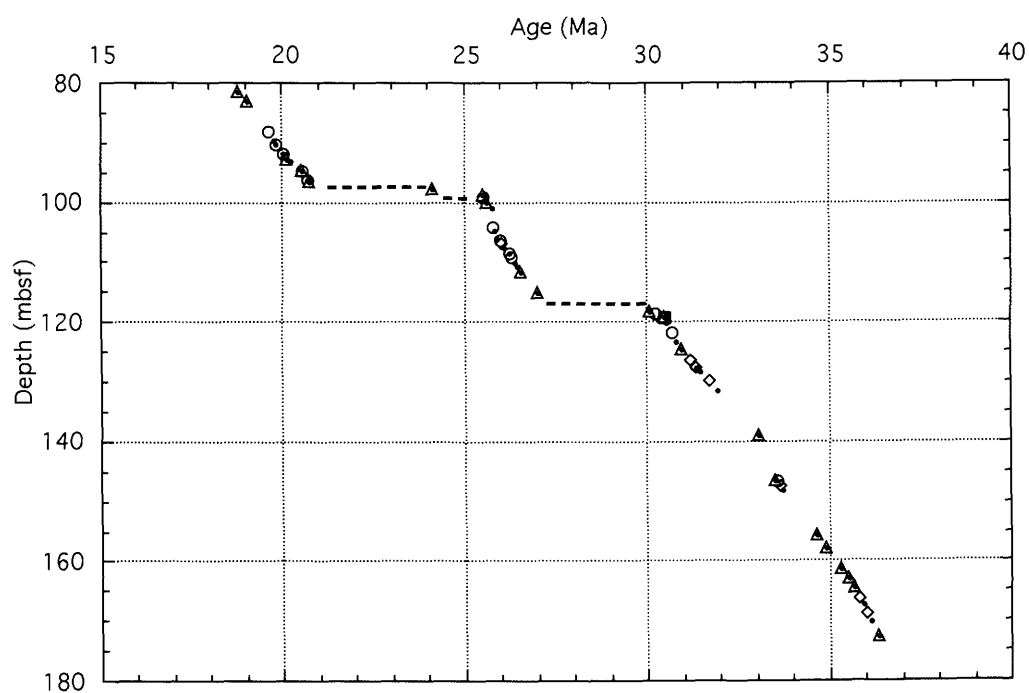


Fig. 36. An age-depth plot for DSDP Hole 744A utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

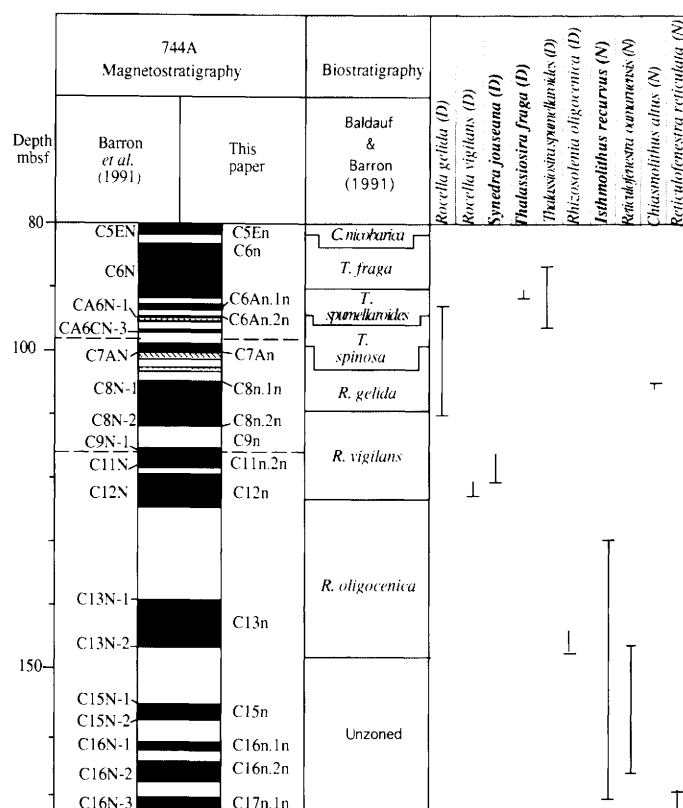


Fig. 37. Comparison of the ODP Hole 744A polarity chronozones and diatom zonal assignments by previous workers with the chronozoneal assignments of this study. The stratigraphical ranges of selected species are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995). Diagonal lines indicate intervals of uncertainty.

Table 27. Composite dataset for ODP Hole 744A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
B C5En			81.70	81.70	18.78	18.78
T C6n			83.18	83.18	19.05	19.05
LO <i>Thalassiosira spumellaroides</i>	10HCC	11H-1, 63-65	88.16	89.70	19.61	19.85
FO <i>Cyrtocapsella longithorax</i>	10HCC	11H-1, 63-65	88.25	89.40	19.61	19.85
FO <i>Thalassiosira fraga</i>	11H-1, 63-65	11H-2, 63-65	90.30	91.80	19.85	20.02
LO <i>Rocella schraderi</i>	11H-2, 63-65	11H-3, 63-65	91.80	93.30	20.01	20.24
B C6n			92.80	92.80	20.13	20.13
T C6An.1n			94.63	94.63	20.52	20.52
LO <i>Rocella gelida</i>	11H-4, 63-65	11H-5, 63-65	94.80	96.40	20.54	20.70
FO <i>Thalassiosira spumellaroides</i>	11H-4, 63-65	11H-5, 63-65	94.90	96.33	20.55	20.70
LO <i>Bogorovia veniamini</i>	11H-5, 63-65	11H-6, 63-65	96.33	97.83	20.69	21.34
FO <i>Raphidodiscus marylandicus</i>	11H-5, 63-65	11H-6, 63-65	96.33	97.83	20.69	21.34
B C6An.1n			96.68	96.68	20.73	20.73
B C6An.2n			97.77	97.77	21.32	21.32
B C6 AAn			98.90	98.90	21.86	21.86
Unconformity			***	***	***	***
LO <i>Thalassiosira primalabiata</i>	11H-CC	12H-1, 60-62	99.20	99.80	?	?
LO <i>Reticulofenestra bisecta</i>	11H-CC	12H-1, 92.93	99.20	99.80	?	?
B C7An			100.24	100.24	25.65	25.65
LO <i>Lisitzina ornata</i>	12H-4, 60-62	12H-5, 60-62	104.30	106.00	24.94	25.80
T C8n.1n			104.79	104.79	25.82	25.82
LO <i>Chiasmolithus altus</i>	13H-1, 60-62	13H-2, 60-62	106.92	107.62	26.04	26.11
FO <i>Nitzschia maleinterpretaria</i>	12H-6, 60-62	12H-7, 61-63	106.30	108.70	25.98	26.23
FO <i>Rocella gelida</i>	13H-1, 60-62	13H-2, 60-62	108.70	110.20	26.23	26.38
FO <i>Lisitzina ornata</i>	13H-1, 60-62	13H-2, 60-62	109.32	110.80	26.29	26.45
B C8n.2n			111.81	111.81	26.55	26.55
T C9n			115.29	115.29	27.03	27.03

(continued)

Table 26. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
Unconformity			***	***	***	***
B C11n.2n			118.37	118.37	30.10	30.10
FO <i>Synedra jouseana</i>	14H-2, 60-62	14H-4, 60-62	118.82	120.32	30.27	30.85
T C12n			119.36	119.36	30.48	30.48
FO <i>Rocella vigilans</i>	14H-2, 60-62	14H-4, 60-62	121.80	123.30	30.69	30.83
B C12n			124.59	124.59	30.94	30.94
LO <i>Reticulofenestra umbilica</i>			126.45	127.70	31.21	31.39
FO <i>Cyclicargolithus abisectus</i>			127.70	128.46	31.39	31.50
LO <i>Isthmolithus recurvus</i>			129.95	131.45	31.72	31.93
T C13n			139.25	139.25	33.06	33.06
B C13n			146.64	146.64	33.55	33.55
FO <i>Rhizosolenia oligocenica</i>	17H-1, 0	17H-1, 68	146.70	147.53	33.56	33.66
LO <i>Reticulofenestra oamaruensis</i>	17H-1, 75-76	17H-2, 75-76	147.60	148.30	33.67	33.75
T C15n			155.65	155.65	34.66	34.66
B C15n			158.10	158.10	34.94	34.94
T C16n.1n			161.30	161.30	35.34	35.34
B C16n.1n			162.90	162.90	35.53	35.53
T C16n.2n			164.60	164.60	35.69	35.69
FO <i>Reticulofenestra oamaruensis</i>	19H-CC	20H-1, 75-76	166.60	167.35	35.85	35.91
FO <i>Isthmolithus recurvus</i>	20H-2, 75-76	20H-3, 75-76	168.85	170.35	36.02	36.14
LO <i>Reticulofenestra reticulata</i>	20H-2, 75-76	20H-3, 75-76	168.86	170.36	36.03	36.14
B C16n.2n			172.85	172.85	36.34	36.34

Data sets are integrated from the work of numerous authors (see Table 2).

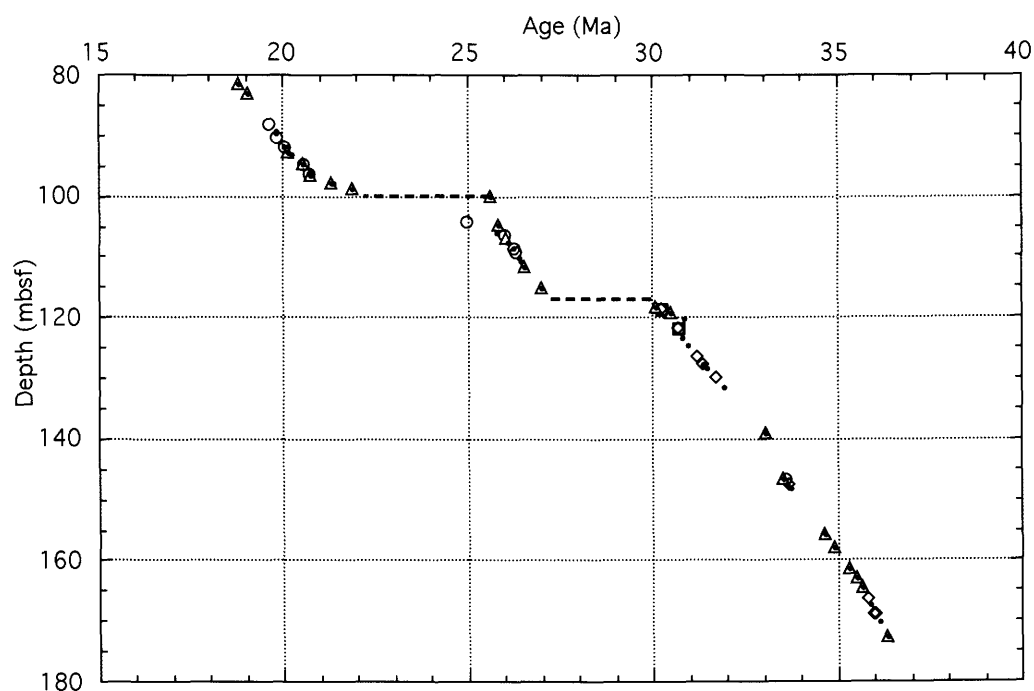


Fig. 38. An age-depth plot for DSDP Hole 744A utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Hole 744B

Nine cores were recovered from a total penetration of 78.5 mbsf representing a recovery of 101% of the cored interval. Sediments recovered consist of Quaternary to lower Pliocene diatom ooze and upper Miocene to lower Miocene calcareous nannofossil ooze (Barron *et al.* 1989). A good palaeomagnetic polarity reversal record was interpreted by Barron *et al.* (1991) for the entire section. Both diatoms and radiolarians are recorded from the sediments examined (Barron *et al.* 1989). Diatoms are well preserved and abundant in the Quaternary to lower Miocene interval. Calcareous nannofossils are sporadic in the Quaternary to Pliocene and abundant in the Miocene with moderate to good preservation. Radiolarians are common to abundant with moderate to good preservation for the Quaternary to lower Miocene section (Barron *et al.* 1989). The integrated biostratigraphical and magnetostratigraphical data previously used (palaeomagnetism: Barron *et al.* 1991; diatoms: Baldauf & Barron 1991; calcareous nannofossils: none; radiolarians: Caulet 1991; Lazarus 1992) is presented in Table 28. An age–depth graph for Hole 119-744B using this data is shown in Fig. 39.

Figure 40 compares the polarity chronozones and diatom zones assigned by previous workers (Barron *et al.* 1991; Baldauf & Barron 1991) with the chronozonal assignments in this study. In addition, this figure illustrates the stratigraphical ranges of diatoms and radiolarians. The stratigraphical ranges reflect the placement of FO and LO of stratigraphically useful species as recognized by Baldauf & Barron (1991) and Caulet (1991), respectively. The revised chronozones and diatom zones illustrated are based on reassessing the data sets of these workers (Table 29). Comparison of the chronozonal assignments of Barron *et al.* (1991; Table 28) with those of this study (Table 29) indicates that nomenclature changes reflect in part different GPTS used in these studies.

An age–depth graph for Hole 119-744B using the stratigraphical markers determined in this study is shown in Fig. 41. Three hiatuses are recognized in the section. The younger hiatus is placed at 21.5 mbsf, the intermediate break occurs between 23.90 and 24.55 mbsf, and the older hiatus is recognized between 52.20

and 53.70 mbsf. The upper boundary of the younger hiatus is constrained by the base of C3n.1n at 20.6 mbsf and the co-occurrence of the FO of *Nitzschia interfrigidaria*, *Nitzschia barronii* and *Nitzschia praeinterfrigidaria* at 21.5 mbsf. The lower boundary is constrained by a truncated C3An.1n at 23.55 mbsf. The occurrence of upper Miocene diatoms in the interval 21.5–23.9 mbsf indicates the occurrence of an upper Miocene section between these two younger hiatuses. The upper boundary of the intermediate hiatus is constrained by the base of C3An.1n at 23.55 mbsf. The lower boundary is constrained the top of C5n.2n at 24.55 mbsf. The upper boundary of the older hiatus is constrained by the base of C5r.2n at 51.72 mbsf and the lower boundary is constrained by the top C5ADn at 54.14 mbsf and the FO of *Denticulopsis praedimorpha* (53.7–55.2 mbsf), LO of *Synedra jouseana* (53.7–55.2 mbsf). Three additional primary events occur within the lower sequence, the FO of *Denticulopsis hustedtii* (56.70–58.20 mbsf), the FO of *Nitzschia denticuloides* (61.60–63.10 mbsf) and the FO of *Crucidentacula kanayae* (74.10–75.60 mbsf).

Barron *et al.* (1991) identify three hiatuses and discuss the probability of a fourth. The presence of the youngest hiatus, at approximately 22 mbsf, is based on the biostratigraphy of diatoms, radiolarians and benthic foraminifera and the interpretation of the magnetostratigraphy. This hiatus corresponds to the break recorded at 21.5 mbsf in this study. The recognition of the hiatus at approximately 24 mbsf, which corresponds to the intermediate hiatus of this study, is based on biostratigraphy (diatoms, radiolarians and benthic foraminifera) and the occurrence of an erosional contact between diatom ooze and calcareous ooze. The hiatus at 53 mbsf is inferred from the interpretation of the magnetostratigraphy and the presence of a colour change within the sequence. The occurrence of the earliest hiatus between 54.5 and 55.2 mbsf is based on integrating biostratigraphy with carbon isotope and magnetostratigraphy. The older hiatus of this study incorporates the lower two hiatuses of Barron *et al.* (1991).

Table 28. Composite dataset for ODP Hole 744B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO <i>Actinocyclus actinochilus</i>	1H-1, 8	1H-CC	0.80	9.50	0.11	1.76
LO <i>Actinocyclus ingens</i>	1H-1, 8	1H-CC	0.80	9.50	0.11	1.76
LO <i>Thalassiosira elliptopora</i>	1H-1, 8	1H-CC	0.80	9.50	0.11	1.76
B C1n			5.50	5.50	0.78	0.78
LO <i>Cycladophora plicenica</i>	1H-5, 123	1H-7, 23	7.73	9.23	1.33	1.69
LO <i>Coscinodiscus lewisianus</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
LO <i>Thalassiosira vulnifica</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
LO <i>Thalassiosira insigna</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
LO <i>Denticulopsis dimorpha</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
LO <i>Hemidiscus karstenii</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
LO <i>Nitzschia interfrigidaria</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
FO <i>Nitzschia kerguelensis</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
LO <i>Thalassiosira kolbei</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
FO <i>Thalassiosira lentiginosa</i>	1H-CC	2H-3, 50	9.50	13.00	1.75	2.32
LO <i>Prunopyle titan</i>	1H-CC	2H-CC	9.50	13.00	1.76	3.46
LO <i>Eucyrtidium calvertense</i>	1H-CC	2H-CC	9.50	13.00	1.76	3.46
LO <i>Desmospyris spongiosa</i>	1H-CC	2H-CC	9.50	13.00	1.76	3.46
LO <i>Helotholus vema</i>	1H-CC	2H-CC	9.50	13.00	1.76	3.46
T C2n			9.55	9.55	1.77	1.77
B C2n			10.05	10.05	1.95	1.95
LO <i>Denticulopsis dimorpha</i>	2H-3, 50	2H-CC	13.00	19.00	2.32	3.46
FO <i>Thalassiosira elliptopora</i>	2H-3, 50	2H-CC	13.00	19.00	2.32	3.46
FO <i>Thalassiosira vulnifica</i>	2H-3, 50	2H-CC	13.00	19.00	2.32	3.46
LO <i>Nitzschia praeinterfrigidaria</i>	2H-3, 50	2H-CC	13.00	19.00	2.32	3.46
LO <i>Simonseniella barboi</i>	2H-3, 50	2H-CC	13.00	19.00	2.32	3.46
FO <i>Thalassiosira inura</i>	2H-3, 50	2H-CC	13.00	19.00	2.32	3.46

(continued)

Table 28. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO <i>Thalassiosira kolbei</i>	2H-3, 50	2H-CC	13.00	19.00	2.32	3.46
T C2An.1n			15.05	15.05	2.58	2.58
LO <i>Nitzschia weaveri</i>	2H-CC	3H-2, 33	19.00	20.80	3.46	?
FO <i>Thalassiosira oestrupii</i>	2H-CC	3H-2, 33	19.00	20.80	3.46	?
B C2An.3n			19.55	19.55	3.58	3.58
T C3n.1n			20.40	20.40	4.18	4.18
B C3n.1n			20.60	20.60	4.29	4.29
FO <i>Nitzschia interfrigidaria</i>			20.80	21.50	?	?
Unconformity			***	***	***	***
FO <i>Nitzschia weaveri</i>	3H-2, 38	3H-CC	20.80	21.50	?	?
FO <i>Nitzschia praeinterfrigidaria</i>	3H-CC	4H-1, 70	21.50	22.20	?	?
FO <i>Nitzschia barronii</i>	3H-CC	4H-1, 70	21.50	22.20	?	?
LO <i>Thalassiosira miocenica</i>	3H-CC	4H-1, 70	21.50	22.20	?	?
FO <i>Nitzschia reinholdii</i>	4H-1, 70	4H-2, 24	22.20	23.24	?	?
LO <i>Thalassiosira praeconvexa</i>	4H-1, 70	4H-2, 24	22.20	23.24	?	?
FO <i>Thalassiosira miocenica</i>	4H-2, 37	4H-2, 90	23.37	23.90	?	?
FO <i>Thalassiosira torokina</i>	4H-2, 37	4H-2, 90	23.37	23.90	?	?
Unconformity			***	***	***	***
B C3An.1n			23.55	23.55	6.14	6.14
Unconformity			***	***	***	***
LO <i>Asteromphalus kennettii</i>	4H-2, 90	4H-3, 27	23.90	24.77	?	?
T C5n.1n			24.55	24.55	9.74	9.74
FO <i>Asteromphalus kennettii</i>	4H-6, 60	4H-CC	29.60	31.00	10.13	10.24
LO <i>Reticulofenestra pseudumbilica</i>	5H-1, 110-111	5H-2, 110-111	32.10	33.60	10.33	10.45
LO <i>Acrosphaera australis</i>	5H-3, 23	5H-5, 23	33.23	36.23	10.41	10.65
LO <i>Calcidiscus macintyreii</i>	5H-2, 110-111	5H-3, 110-111	33.60	35.10	10.45	10.56
FO <i>Hemidiscus cuneiformis</i>			34.50	36.10	10.52	10.64
LO <i>Denticulopsis lauta</i>	5H-5, 60	5H-6, 60	37.60	39.10	10.76	10.88
LO <i>Actinomma golownini</i>	5H-6, 10	6H-2, 123	37.60	42.73	10.76	11.12
B C5n.2n			40.05	40.05	10.95	10.95
FO <i>Actinocyclus fryxellae</i>	5H-CC	6H-1, 60	40.50	41.10	10.99	11.05
T C5r.1n			41.12	41.12	11.05	11.05
B C5r.1n			42.25	42.25	11.10	11.10
FO <i>Cycladophora spongothorax</i>	6H-5, 123	7H-2, 125	47.23	52.65	11.32	?
LO <i>Denticulopsis praedimorpha</i>	6H-6, 60	6H-CC	48.60	50.00	11.38	11.44
T C5r.2n			50.90	50.90	11.48	11.48
B C5r.2n			51.72	51.72	11.53	11.53
Unconformity			***	***	***	***
FO <i>Denticulopsis dimorpha</i>	7H-2, 60	7H-3, 70	52.20	53.70	?	?
LO <i>Denticulopsis maccollumnii</i>	7H-2, 60	7H-3, 70	52.20	53.70	?	?
LO <i>Nitzschia denticuloides</i>	7H-2, 60	7H-3, 70	52.20	53.70	?	?
LO <i>Nitzschia grossepunctata</i>	7H-2, 60	7H-3, 70	52.20	53.70	?	?
FO <i>Actinomma golownini</i>	7H-2, 125	7H-4, 123	52.65	55.23	?	?
FO <i>Dendrospyrus megalcephalis</i>	7H-2, 125	7H-4, 123	52.65	55.23	?	?
FO <i>Denticulopsis praedimorpha</i>	7H-3, 70	7H-4, 70	53.70	55.20	?	?
LO <i>Synedra jouseana</i>			53.70	55.20	?	?
T C5ACn			54.14	54.14	13.70	13.70
LO <i>Actinocyclus ingens v. nodus</i>	5H-3, 60	5H-4, 60	55.20	58.20	13.91	14.51
FO <i>Cycladophora humerus</i>	7H-4, 123	7H-5, 73	55.23	56.73	13.92	14.22
FO <i>Denticulopsis hustedtii</i>	7H-5, 70	7H-6, 50	56.70	58.20	14.21	14.51
B C5ADn			58.68	58.68	14.61	14.61
T C5Bn.2n			60.07	60.07	15.03	15.03
B C5Bn.2n			61.36	61.36	15.16	15.16
FO <i>Nitzschia denticuloides</i>	8H-1, 60	8H-2, 60	61.60	63.10	15.21	15.55
FO <i>Actinocyclus ingens v. nodus</i>	8H-3, 60	8H-4, 60	63.10	64.60	15.55	15.89
FO <i>Actinocyclus ingens</i>	8H-4, 60	8H-5, 60	64.60	66.10	15.89	16.40
T C5Cn.1n			65.11	65.11	16.01	16.01
LO <i>Crucidenticula kanayae</i>	8H-5, 60	8H-6, 60	66.10	67.60	16.40	16.80
LO <i>Nitzschia maleinterpretaria</i>	8H-5, 60	8H-6, 60	66.10	67.60	16.40	16.80
FO <i>Eucyrtidium pseudoinflatum</i>	8H-5, 73	9H-2, 53	66.23	71.30	16.45	17.20
B C5Cn.3n			66.95	66.95	16.73	16.73
LO <i>Thalassiosira fraga</i>	8H-6, 60	8H-CC	67.60	69.00	16.80	16.95
FO <i>Denticulopsis lauta</i>	8H-CC	9H-1, 58	69.00	69.60	16.95	17.02
FO <i>Denticulopsis maccollumnii</i>	8H-CC	9H-1, 58	69.00	69.60	16.95	17.02
FO <i>Nitzschia grossepunctata</i>	8H-CC	9H-1, 58	69.00	69.60	16.95	17.02
FO <i>Raphidodiscus marylandicus</i>	9H-1, 58	9H-2, 70	69.60	71.10	17.01	17.18
FO <i>Cycladophora golli regipileus</i>	9H-2, 90	9H-6, CC	71.30	80.73	17.20	?
T C5Dn			72.00	72.00	17.28	17.28
FO <i>Crucidenticula kanayae</i>	9H-4, 58	9H-5, 58	74.10	75.60	17.49	17.69

Table 28. (continued)

Event		Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO	<i>Crucidenticula nicobarica</i>	9H-4, 58	9H-5, 58	74.10	75.60	17.49	17.69
LO	<i>Reticulofenestra hesslandii</i>	9H-4, 118-119	9H-5, 118-119	74.70	76.20	17.55	17.92
B	C5Dn			75.43	75.43	17.62	17.62
T	C5En			77.10	77.10	18.28	18.28
B	C5En			77.50	77.50	18.78	18.78
FO	<i>Calcidiscus leptoporus</i>	9H-6, 118-119	9H-CC	77.70	78.50	?	?
FO	<i>Calcidiscus macintyreii</i>	9H-6, 118-119	9H-CC	77.70	78.50	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

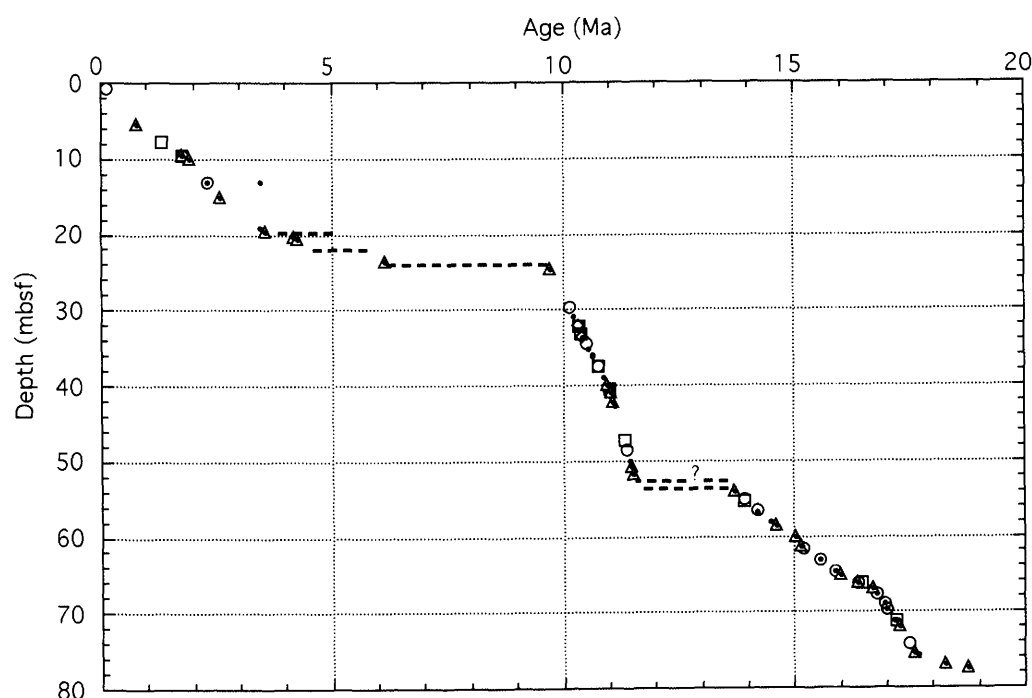


Fig. 39. An age-depth plot for DSDP Hole 744B utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

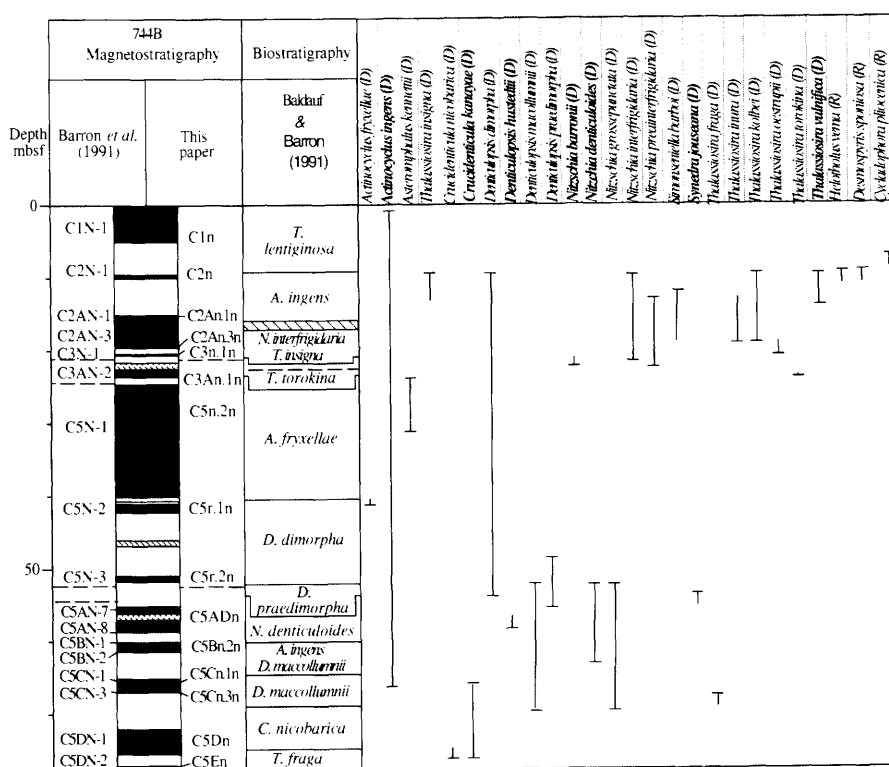


Fig. 40. Comparison of the ODP Hole 744B polarity chronozones and diatom zonal assignments by previous workers with the chronostratigraphical assignments of this study. The stratigraphical ranges of selected species are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995). Diagonal lines indicate intervals of uncertainty.

Table 29. Composite dataset for ODP Hole 744B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

	Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO	<i>Actinocyclus actinochilus</i>	1H-1, 8	1H-CC	0.80	9.50	0.89	1.76
LO	<i>Actinocyclus ingens</i>	1H-1, 8	1H-CC	0.80	9.50	0.89	1.76
LO	<i>Thalassiosira elliptopora</i>	1H-1, 8	1H-CC	0.80	9.50	0.89	1.76
B	C1n			5.50	5.50	0.78	0.78
LO	<i>Cycladophora pliocenica</i>	1H-5, 123	1H-7, 23	7.73	9.23	1.32	1.69
LO	<i>Coscinodiscus lewisianus</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
LO	<i>Thalassiosira vulnifica</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
LO	<i>Thalassiosira insigna</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
LO	<i>Denticulopsis dimorpha</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
LO	<i>Hemidiscus karstenii</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
LO	<i>Nitzschia interfrigidaria</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
FO	<i>Nitzschia kerguelensis</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
LO	<i>Thalassiosira kolbei</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
FO	<i>Thalassiosira lentiginosa</i>	1H-CC	2H-3, 50	9.50	13.00	1.76	2.32
LO	<i>Prunopyle titan</i>	1H-CC	2H-CC	9.50	13.00	1.76	3.46
LO	<i>Eucyrtidium calvertense</i>	1H-CC	2H-CC	9.50	13.00	1.76	3.46
LO	<i>Desmospyris spongiosa</i>	1H-CC	2H-CC	9.50	13.00	1.76	3.46
LO	<i>Helotholus vema</i>	1H-CC	2H-CC	9.50	13.00	1.76	3.46
T	C2n			9.55	9.55	1.77	1.77
B	C2n			10.05	10.05	1.95	1.95
LO	<i>Denticulopsis dimorpha</i>	2H-3, 50	2H-CC	13.00	19.00	2.32	3.46
FO	<i>Thalassiosira elliptopora</i>	2H-3, 50	2H-CC	13.00	19.00	2.32	3.46
FO	<i>Thalassiosira vulnifica</i>	2H-3, 50	2H-CC	13.00	19.00	2.32	3.46
LO	<i>Nitzschia praeinterfrigidaria</i>	2H-3, 50	2H-CC	13.00	19.00	2.32	3.46
LO	<i>Simonseniella barboi</i>	2H-3, 50	2H-CC	13.00	19.00	2.32	3.46
FO	<i>Thalassiosira inura</i>	2H-3, 50	2H-CC	13.00	19.00	2.32	3.46
FO	<i>Thalassiosira kolbei</i>	2H-3, 50	2H-CC	13.00	19.00	2.32	3.46
T	C2An.1n			15.05	15.05	2.58	2.58
LO	<i>Nitzschia weaveri</i>	2H-CC	3H-2, 33	19.00	20.80	3.46	?
FO	<i>Thalassiosira oestrupii</i>	2H-CC	3H-2, 33	19.00	20.80	3.46	?
B	C2An.3n			19.55	19.55	3.58	3.58
T	C3n.1n			20.40	20.40	4.18	4.18
B	C3n.1n			20.60	20.60	4.29	4.29
FO	<i>Nitzschia interfrigidaria</i>	3H-2, 38	3H-CC	20.80	21.50	?	?
FO	<i>Nitzschia weaveri</i>	3H-2, 38	3H-CC	20.80	21.50	?	?
FO	<i>Nitzschia praeinterfrigidaria</i>	3H-CC	4H-1, 70	21.50	22.20	?	?
FO	<i>Nitzschia barronii</i>	3H-CC	4H-1, 70	21.50	22.20	?	?
	Unconformity			***	***	***	***
LO	<i>Thalassiosira miocenica</i>	3H-CC	4H-1, 70	21.50	22.20	?	?
FO	<i>Nitzschia reinholdii</i>	4H-1, 70	4H-2, 24	22.20	23.24	?	?
LO	<i>Thalassiosira praeconvexa</i>	4H-1, 70	4H-2, 24	22.20	23.24	?	?
FO	<i>Thalassiosira miocenica</i>	4H-2, 37	4H-2, 90	23.37	23.90	?	?
FO	<i>Thalassiosira torokina</i>	4H-2, 37	4H-2, 90	23.37	23.90	?	?
B	C3An.1n			23.55	23.55	6.14	6.14
LO	<i>Asteromphalus kennettii</i>	4H-2, 90	4H-3, 27	23.90	24.77	?	?
	Unconformity			***	***	***	***
T	C5n.2n			24.55	24.55	9.92	9.92
FO	<i>Asteromphalus kennettii</i>	4H-6, 60	4H-CC	29.60	31.00	10.25	10.35
LO	<i>Reticulofenestra pseudumbilica</i>	5H-1, 110-111	5H-2, 110-111	32.10	33.60	10.42	10.52
LO	<i>Acrosphaera australis</i>	5H-3, 23	5H-5, 23	33.23	36.23	10.50	10.70
LO	<i>Calcidiscus macintyreii</i>	5H-2, 110-111	5H-3, 110-111	33.60	35.10	10.52	10.62
FO	<i>Hemidiscus cuneiformis</i>			34.50	36.10	10.58	10.69
LO	<i>Denticulopsis lauta</i>	5H-5, 60	5H-6, 60	37.60	39.10	10.79	10.89
LO	<i>Actinomma golownini</i>	5H-6, 10	6H-2, 123	37.60	42.73	10.79	11.12
B	C5n.2n			40.05	40.05	10.95	10.95
FO	<i>Actinocyclus fryxellae</i>	5H-CC	6H-1, 60	40.50	41.10	10.99	11.05
T	C5r.1n			41.12	41.12	11.05	11.05
B	C5r.1n			42.25	42.25	11.10	11.10
FO	<i>Cycladophora spongothorax</i>	6H-5, 123	7H-2, 125	47.23	52.65	11.32	?
LO	<i>Denticulopsis praedimorpha</i>	6H-6, 60	6H-CC	48.60	50.00	11.38	11.44
T	C5r.2n			50.90	50.90	11.48	11.48
B	C5r.2n			51.72	51.72	11.53	11.53
FO	<i>Denticulopsis dimorpha</i>	7H-2, 60	7H-3, 70	52.20	53.70	?	?
	Unconformity			***	***	***	***
LO	<i>Denticulopsis maccollumnii</i>	7H-2, 60	7H-3, 70	52.20	53.70	?	?
LO	<i>Nitzschia denticuloides</i>	7H-2, 60	7H-3, 70	52.20	53.70	?	?
LO	<i>Nitzschia grossepunctata</i>	7H-2, 60	7H-3, 70	52.20	53.70	?	?
FO	<i>Actinomma golownini</i>	7H-2, 125	7H-4, 123	52.65	55.23	?	?

Table 29. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO <i>Dendrospyrus megalcephalis</i>	7H-2, 125	7H-4, 123	52.65	55.23	?	?
FO <i>Denticulopsis praedimorpha</i>	7H-3, 70	7H-4, 70	53.70	55.20	?	?
LO <i>Synedra jouseana</i>			53.70	55.20	?	?
T C5ADn			54.14	54.14	14.18	14.18
LO <i>Actinocyclus ingens</i> v. <i>nodus</i>	7H-3, 60	5H-4, 60	55.20	58.20	14.28	14.56
FO <i>Cycladophora humerus</i>	7H-4, 123	7H-5, 73	55.23	56.73	14.28	14.42
FO <i>Denticulopsis hustedii</i>	7H-5, 70	7H-6, 50	56.70	58.20	14.42	14.56
B C5ADn			58.68	58.68	14.61	14.61
T C5Bn.2n			60.07	60.07	15.03	15.03
B C5Bn.2n			61.36	61.36	15.16	15.16
FO <i>Nitzschia denticuloides</i>	8H-1, 60	8H-2, 60	61.60	63.10	15.21	15.55
FO <i>Actinocyclus ingens</i> v. <i>nodus</i>	8H-3, 60	8H-4, 60	63.10	64.60	15.55	15.89
FO <i>Actinocyclus ingens</i>	8H-4, 60	8H-5, 60	64.60	66.10	15.89	16.40
T C5Cn.1n			65.11	65.11	16.01	16.01
LO <i>Crucidentacula kanayae</i>	8H-5, 60	8H-6, 60	66.10	67.60	16.40	16.80
LO <i>Nitzschia maleinterpretaria</i>	8H-5, 60	8H-6, 60	66.10	67.60	16.40	16.80
FO <i>Eucyrtidium pseudoinflatum</i>	8H-5, 73	9H-2, 53	66.23	71.30	16.45	17.20
B C5Cn.3n			66.95	66.95	16.73	16.73
LO <i>Thalassiosira fraga</i>	8H-6, 60	8H-CC	67.60	69.00	16.80	16.95
FO <i>Denticulopsis lauta</i>	8H-CC	9H-1, 58	69.00	69.60	16.95	17.02
FO <i>Denticulopsis maccollumii</i>	8H-CC	9H-1, 58	69.00	69.60	16.95	17.02
FO <i>Nitzschia grossepunctata</i>	8H-CC	9H-1, 58	69.00	69.60	16.95	17.02
FO <i>Raphidodiscus marylandicus</i>	9H-1, 58	9H-2, 70	69.60	71.10	17.01	17.18
FO <i>Cycladophora golli regipileus</i>	9H-2, 90	9H-6, CC	71.30	80.73	17.20	?
T C5Dn			72.00	72.00	17.28	17.28
FO <i>Crucidentacula kanayae</i>	9H-4, 58	9H-5, 58	74.10	75.60	17.49	17.69
FO <i>Crucidentacula nicobarica</i>	9H-4, 58	9H-5, 58	74.10	75.60	17.49	17.69
LO <i>Reticulofenestra hesslandii</i>	9H-4, 118-119	9H-5, 118-119	74.70	76.20	17.55	17.92
B C5Dn			75.43	75.43	17.62	17.62
T C5En			77.10	77.10	18.28	18.28
B C5En			77.50	77.50	18.78	18.78
FO <i>Calcidiscus leptoporus</i>	9H-6, 118-119	9H-CC	77.70	78.50	?	?
FO <i>Calcidiscus macintyreii</i>	9H-6, 118-119	9H-CC	77.70	78.50	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

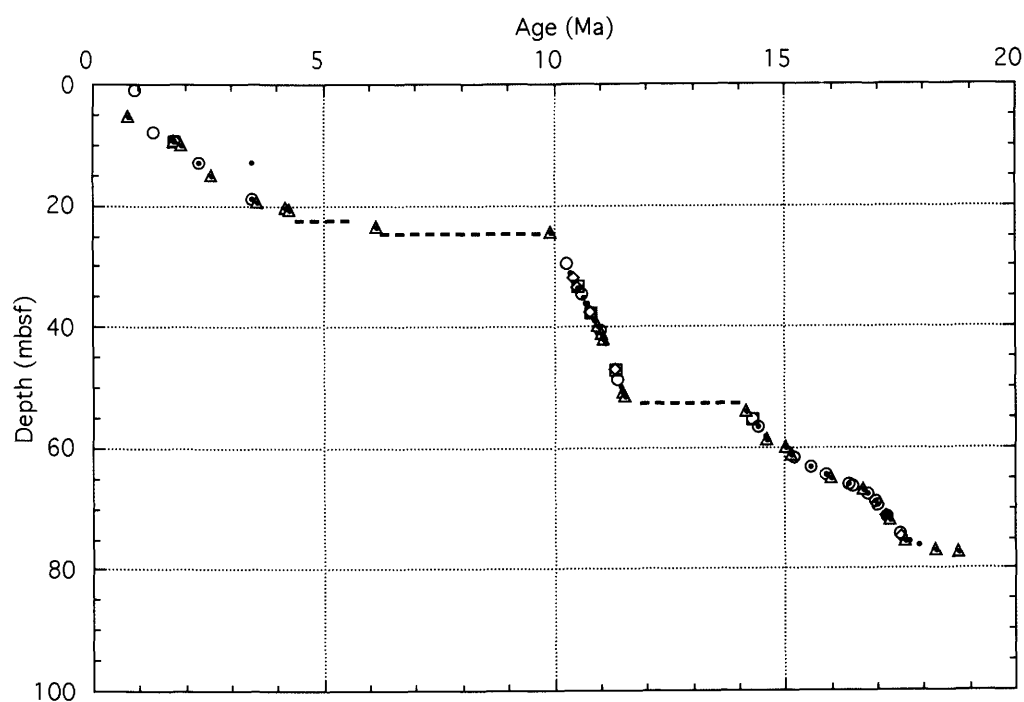


Fig. 41. An age-depth plot for DSDP Hole 744B utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Hole 745B

Twenty-four cores were recovered from a total penetration of 215 mbsf representing a recovery of 102% of the cored interval. Sediments recovered consist of Quaternary to upper Miocene diatom ooze with various amounts of clay (Barron *et al.* 1989). A palaeomagnetic polarity reversal record was interpreted by Barron *et al.* (1991) for the entire section. Diatoms and radiolarians are generally abundant and well preserved throughout the entire stratigraphical section. Calcareous nannofossils are generally absent, but have a sporadic occurrence in the Quaternary and upper Pliocene (Barron *et al.* 1989). The integrated biostratigraphical and magnetostratigraphical data previously used (palaeomagnetism: Barron *et al.* 1991; diatoms: Baldauf & Barron 1991; calcareous nannofossils: none; radiolarians: Caulet 1991; Lazarus 1992) and calibrated to the GPTS of Berggren *et al.* (1985a, b) is shown in Table 30. An age–depth graph for Hole 119-745B using this data is shown in Fig. 42.

Figure 43 compares the polarity chronozones and diatom zones assigned by previous workers (Barron *et al.* 1991; Baldauf & Barron 1991) with the chronozone assignments in this study. In addition, this figure illustrates the stratigraphical ranges of diatoms and radiolarians. The stratigraphical ranges reflect the

placement of FO and LO of stratigraphically useful species as recognized by Baldauf & Barron (1991); Caulet (1991), and Lazarus (1992), respectively. The revised chronozones and diatom zones illustrated are based on reassessing the data sets of these workers (Table 31). Comparison of the chronozone assignments of Barron *et al.* (1991; Table 30) with those of this study (Table 31) indicates that only minor changes, associated with differences in the GPTS were required.

Figure 44 shows an age–depth graph for Hole 119-745B using the stratigraphical markers determined in this study. The hole represents a continuous stratigraphical sequence to 205.66 mbsf as indicated by the continuous nature of the polarity record from the base of C1n.1n at 42.80 mbsf to the top of C3An.2n at 205.66 mbsf. Six primary biostratigraphical datums are recognized in this site, the LO of *Thalassiosira kolbei* (90.5–94.10 mbsf), the LO of *Thalassiosira vulnifica* (102.10–105.10 mbsf), the FO of *Nitzschia interfrigidaria* (135.10–136.60 mbsf), the FO of *Nitzschia barronii* (144.10–145.60 mbsf), the FO of *Helotholus vema* (153.50–155.00 mbsf) and the FO of *Nitzschia praeinterfrigidaria* (158.60–166.10 mbsf). These events are used to calibrate the polarity reversals and the results correspond with those of Barron *et al.* (1991).

Table 30. Composite dataset for ODP Hole 745B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Triceraporys antarctica</i>	1H-1, 0	1H-CC	0.00	5.00	0.00	0.09
LO <i>Hemidiscus karstenii</i>	2H-CC	3H-CC	14.50	24.00	0.26	0.44
LO <i>Actinocyclus ingens</i>	3H-CC	4H-CC	24.00	33.50	0.44	0.61
LO <i>Denticulopsis dimorpha</i>	4H-CC	5H-CC	33.50	43.00	0.61	0.79
LO <i>Eucyrtidium calvertense</i>	4H-CC	5H-1, 53-55	33.50	34.00	0.61	0.62
LO <i>Antarctissa cylindrica</i>			34.00	35.50	0.61	0.65
B C1n			42.80	42.80	0.78	0.78
LO <i>Thalassiosira elliptopora</i>	5H-CC	6H-CC	43.00	52.30	0.79	1.27
FO <i>Denticulopsis dimorpha</i>	5H-CC	6H-CC	43.00	52.30	0.79	1.27
T C1r.1n			50.30	50.30	0.99	0.99
B C1r.1n			54.64	54.64	1.07	1.07
FO <i>Thalassiosira elliptopora</i>	9H-CC	10H-CC	81.00	90.50	1.57	1.75
LO <i>Hemidiscus cuneiformis</i>	9H-CC	10H-CC	81.00	90.50	1.57	1.75
LO <i>Simonseniella barboi</i>	9H-CC	10H-CC	81.00	90.50	1.57	1.75
LO <i>Cycladophora pliocenica</i>	9H-CC	10H-1, 53-55	81.00	81.50	1.57	1.58
LO <i>Nitzschia weaveri</i>	10H-CC	11H-3, 60-62	90.50	94.10	1.75	1.97
LO <i>Thalassiosira kolbei</i>	10H-CC	11H-3, 60-62	90.50	94.10	1.75	1.97
T C2n			91.55	91.55	1.77	1.77
B C2n			93.55	93.55	1.95	1.95
LO <i>Nitzschia interfrigidaria</i>	11H-3, 60-62	11H-6, 60-62	94.10	98.60	1.97	2.12
LO <i>Thalassiosira torokina</i>	11H-6, 60-62	12H-1, 60-62	98.60	100.60	2.12	2.18
FO <i>Nitzschia kerguelensis</i>	11H-6, 60-62	12H-1, 60-62	98.60	100.60	2.12	2.18
LO <i>Thalassiosira insigna</i>	12H-1, 60-62	12H-2, 60-62	100.60	102.10	2.18	2.23
LO <i>Rouxia heteropolara</i>	12H-1, 60-62	12H-2, 60-62	100.60	102.10	2.18	2.23
FO <i>Actinocyclus ingens</i>	12H-2, 60-62	12H-4, 60-62	102.10	105.10	2.23	2.33
LO <i>Thalassiosira vulnifica</i>	12H-2, 60-62	12H-4, 60-62	102.10	105.10	2.23	2.33
FO <i>Nitzschia cylindrica</i>	12H-2, 60-62	12H-4, 60-62	102.10	105.10	2.23	2.33
LO <i>Rouxia californica</i>	12H-4, 60-62	12H-6, 60-62	105.10	108.10	2.33	2.43
LO <i>Helotholus vema</i>	12H-CC	13H-1, 53-55	109.50	110.00	2.48	2.50
LO <i>Desmospyris spongiosa</i>	13H-1, 53-55	13H-2, 53-55	110.00	111.00	2.50	2.53
T C2An.1n			112.55	112.55	2.58	2.58
FO <i>Cycladophora davisiana</i>	13H-4, 53-55	13H-5, 53-55	114.50	116.00	2.66	2.72
FO <i>Thalassiosira vulnifica</i>	13H-4, 60-62	13H-7, 60-62	115.60	118.60	2.71	2.83
LO <i>Nitzschia praeinterfrigidaria</i>	13H-4, 60-62	13H-7, 60-62	115.60	118.60	2.71	2.83
LO <i>Nitzschia reinholdii</i>	13H-4, 60-62	13H-7, 60-62	115.60	118.60	2.71	2.83
LO <i>Stephanopyxis grunowii</i>	13H-4, 60-62	13H-7, 60-62	115.60	118.60	2.71	2.83
FO <i>Thalassiosira insigna</i>	14H-1, 64-66	14H-2, 60-62	120.20	121.70	2.90	2.96
FO <i>Thalassiosira kolbei</i>	14H-1, 64-66	14H-2, 60-62	120.20	121.70	2.90	2.96
B C2An.1n			123.55	123.55	3.04	3.04
FO <i>Nitzschia weaveri</i>	14H-4, 64-66	14H-5, 64-66	124.20	125.70	3.06	3.13
T C2An.2n			125.55	125.55	3.11	3.11
B C2An.2n			126.55	126.55	3.22	3.22

Table 30. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
T C2An.3n			128.55	128.55	3.33	3.33
LO <i>Prunopyle titan</i>	15H-1, 53-55	15H-2, 53-55	130.50	132.00	3.44	3.52
B C2An.3n			133.05	133.05	3.58	3.58
FO <i>Nitzschia interfrigidaria</i>	15H-5, 60-62	15H-6, 60-62	135.10	136.60	3.71	3.80
LO <i>Nitzschia fossilis</i>	16H-CC	17H-2, 60-62	139.00	141.10	3.95	4.08
FO <i>Rouxia heteropolara</i>	17H-2, 60-62	17H-3, 60-62	139.00	141.10	3.95	4.08
LO <i>Rhizosolenia miocenica</i>	17H-2, 60-62	17H-3, 60-62	139.00	141.10	3.95	4.08
T C3n.1n			142.73	142.73	4.18	4.18
FO <i>Nitzschia barronii</i>	17H-4, 60-62	17H-5, 60-62	144.10	145.60	4.22	4.27
B C3n.1n			146.28	146.28	4.29	4.29
T C3n.2n			149.30	149.30	4.48	4.48
FO <i>Helotholus vema</i>	18H-4, 53-55	18H-5, 53-55	153.50	155.00	4.57	4.60
B C3n.2n			155.93	155.93	4.62	4.62
FO <i>Nitzschia praeinterfrigidaria</i>	19H-1, 60-62	19H-6, 60-62	158.60	166.10	4.72	4.87
T C3n.3n			160.82	160.82	4.80	4.80
B C3n.3n			167.90	167.90	4.89	4.89
FO <i>Thalassiosira inura</i>	20H-1, 60-62	20H-4, 60-62	168.10	172.60	4.80	4.89
T C3n.4n			177.95	177.95	4.98	4.98
B C3n.4n			180.85	180.85	5.23	5.23
LO <i>Rocella vigilans</i>	21H-2, 60-62	21H-5, 60-62	182.10	183.60	5.38	5.56
FO <i>Thalassiosira oestrupii</i>	21H-2, 60-62	21H-5, 60-62	182.10	183.60	5.38	5.56
T C3An.1n			186.37	186.37	5.89	5.89
LO <i>Thalassiosira convexa</i>	22H-3, 60-62	22H-6, 60-62	190.10	194.60	5.98	6.09
FO <i>Thalassiosira convexa</i> v. <i>aspinosa</i>	22H-6, 60-62	23H-3, 60-62	194.60	199.60	6.09	6.18
LO <i>Trinacria excavata</i>	21H-5, 60-62	22H-3, 60-62	194.60	199.60	6.09	6.18
B C3An.1n			196.63	196.63	6.14	6.14
T C3An.2n			205.66	205.66	6.27	6.27
FO <i>Rocella vigilans</i>	24H-2, 60-62	24H-6, 60-62	207.60	213.60	?	?
LO <i>Thalassiosira miocenica</i>	24H-3, 60-62	24H-6, 60	209.10	213.60	?	?
FO <i>Thalassiosira inura</i>	24H-1, 60-62	24H-2, 60-62	210.60	212.10	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

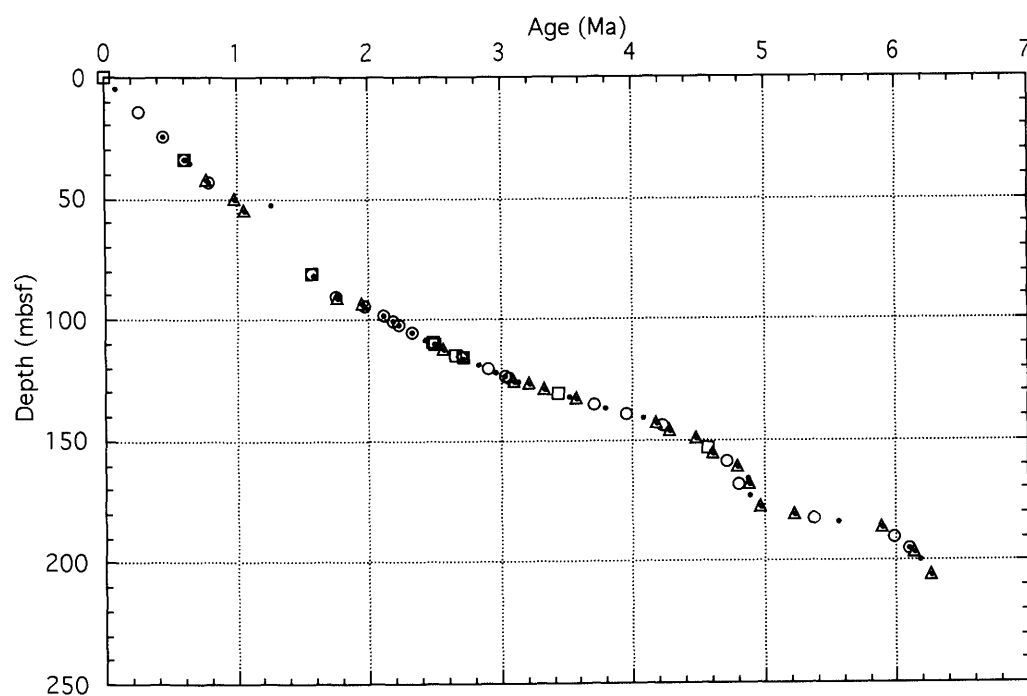


Fig. 42. An age-depth plot for DSDP Hole 745B utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

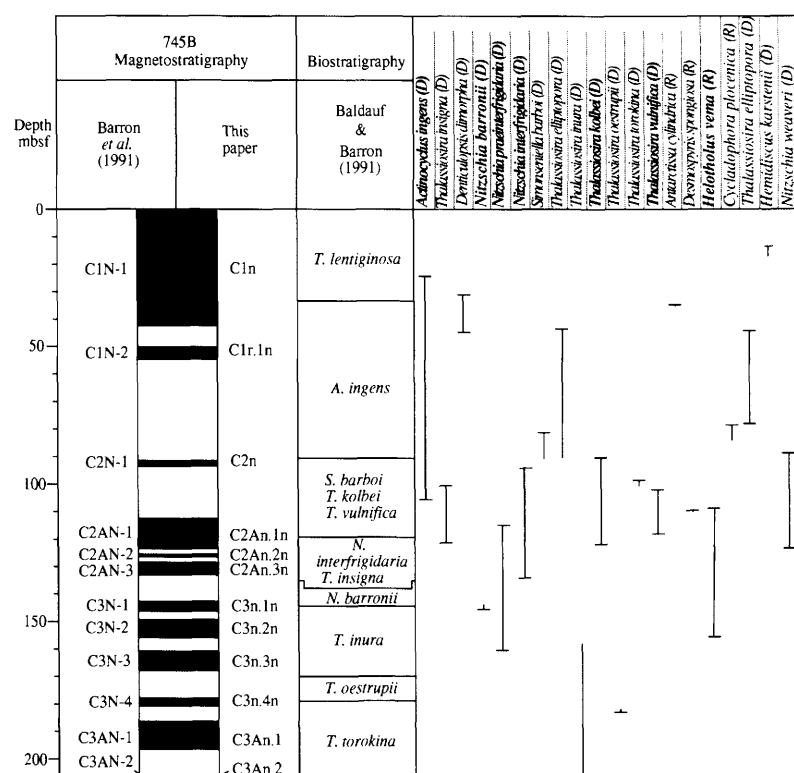


Fig. 43. Comparison of the ODP Hole 745B polarity chronozones and diatom zonal assignments by previous workers with the chronostratigraphic assignments of this study. The stratigraphical ranges of selected stratigraphical markers are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995).

Table 31. Composite dataset for ODP Hole 745B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Tricerapys antarctica</i>	1H-1, 0	1H-CC	0.00	5.00	0.00	0.09
LO <i>Hemidiscus karstenii</i>	2H-CC	3H-CC	14.50	24.00	0.26	0.44
LO <i>Actinocyclus ingens</i>	3H-CC	4H-CC	24.00	33.50	0.44	0.61
LO <i>Denticulopsis dimorpha</i>	4H-CC	5H-CC	33.50	43.00	0.61	0.79
LO <i>Eucyrtidium calvertense</i>	4H-CC	5H-CC	33.50	34.00	0.61	0.62
LO <i>Antarctissa cylindrica</i>	4H-CC	5H-1, 53-55	34.00	35.50	0.61	0.65
B C1n			42.80	42.80	0.78	0.78
LO <i>Thalassiosira elliptopora</i>	5H-CC	6H-CC	43.00	52.30	0.79	1.27
FO <i>Denticulopsis dimorpha</i>	5H-CC	6H-CC	43.00	52.30	0.79	1.27
T C1r.1n			50.30	50.30	0.99	0.99
B C1r.1n			54.64	54.64	1.07	1.07
FO <i>Thalassiosira elliptopora</i>	9H-CC	10H-CC	81.00	90.50	1.57	1.75
LO <i>Hemidiscus cuneiformis</i>	9H-CC	10H-CC	81.00	90.50	1.57	1.75
LO <i>Simonseniella barboi</i>	9H-CC	10H-CC	81.00	90.50	1.57	1.75
LO <i>Cycladophora plicocena</i>	9H-CC	10H-1, 53-55	81.00	81.50	1.57	1.58
LO <i>Nitzschia weaveri</i>	10H-CC	11H-3, 60-62	90.50	94.10	1.75	1.97
LO <i>Thalassiosira kolbei</i>	10H-CC	11H-3, 60-62	90.50	94.10	1.75	1.97
T C2n			91.55	91.55	1.77	1.77
B C2n			93.55	93.55	1.95	1.95
LO <i>Nitzschia interfrigidaria</i>	11H-3, 60-62	11H-6, 60-62	94.10	98.60	1.97	2.12
LO <i>Thalassiosira torokina</i>	11H-6, 60-62	12H-1, 60-62	98.60	100.60	2.12	2.18
FO <i>Nitzschia kerguelensis</i>	11H-6, 60-62	12H-1, 60-62	98.60	100.60	2.12	2.18
LO <i>Thalassiosira insigna</i>	12H-1, 60-62	12H-2, 60-62	100.60	102.10	2.18	2.23
LO <i>Rouxia heteropolara</i>	12H-1, 60-62	12H-2, 60-62	100.60	102.10	2.18	2.23
FO <i>Actinocyclus ingens</i>	12H-2, 60-62	12H-4, 60-62	102.10	105.10	2.23	2.33
LO <i>Thalassiosira vulnifica</i>	12H-2, 60-62	12H-4, 60-62	102.10	105.10	2.23	2.33
FO <i>Nitzschia cylindrica</i>	12H-2, 60-62	12H-4, 60-62	102.10	105.10	2.23	2.33
LO <i>Rouxia californica</i>	12H-4, 60-62	12H-6, 60-62	105.10	108.10	2.33	2.43
LO <i>Helotholus vema</i>	12H-CC	13H-1, 53-55	109.50	110.00	2.48	2.50
LO <i>Desmospyris spongiosa</i>	13H-1, 53-55	13H-2, 53-55	110.00	111.00	2.50	2.53
T C2An.1n			112.55	112.55	2.58	2.58
FO <i>Cycladophora davisiana</i>	13H-4, 53-55	13H-5, 53-55	114.50	116.00	2.66	2.72
FO <i>Thalassiosira vulnifica</i>	13H-4, 60-62	13H-7, 60-62	115.60	118.60	2.71	2.83
LO <i>Nitzschia praeinterfrigidaria</i>	13H-4, 60-62	13H-7, 60-62	115.60	118.60	2.71	2.83
LO <i>Nitzschia reinholdii</i>	13H-4, 60-62	13H-7, 60-62	115.60	118.60	2.71	2.83
LO <i>Stephanopyxis grunowii</i>	13H-4, 60-62	13H-7, 60-62	115.60	118.60	2.71	2.83
FO <i>Thalassiosira insigna</i>	14H-1, 64-66	14H-2, 60-62	120.20	121.70	2.90	2.96

Table 31. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO <i>Thalassiosira kolbei</i>	14H-1, 64-66	14H-2, 60-62	120.20	121.70	2.90	2.96
B C2An.1n			123.55	123.55	3.04	3.04
FO <i>Nitzschia weaveri</i>	14H-4, 64-66	14H-5, 64-66	124.20	125.70	3.06	3.13
T C2An.2n			125.55	125.55	2.99	3.11
B C2An.2n			126.55	126.55	3.22	3.22
T C2An.3n			128.55	128.55	3.33	3.33
LO <i>Prunopyle titan</i>	15H-1, 53-55	15H-2, 53-55	130.50	132.00	3.44	3.52
B C2An.3n			133.05	133.05	3.58	3.58
FO <i>Nitzschia interfrigidaria</i>	15H-5, 60-62	15H-6, 60-62	135.10	136.60	3.71	3.80
LO <i>Nitzschia fossilis</i>	16H-CC	17H-2, 60-62	139.00	141.10	3.95	4.08
FO <i>Rouxia heteropolara</i>	17H-2, 60-62	17H-3, 60-62	139.00	141.10	3.95	4.08
LO <i>Rhizosolenia miocenica</i>	17H-2, 60-62	17H-3, 60-62	139.00	141.10	3.95	4.08
T C3n.1n			142.73	142.73	4.18	4.18
FO <i>Nitzschia barronii</i>	17H-4, 60-62	17H-5, 60-62	144.10	145.60	4.22	4.27
B C3n.1n			146.28	146.28	4.29	4.29
T C3n.2n			149.30	149.30	4.48	4.48
FO <i>Helotholus vema</i>	18H-4, 53-55	18H-5, 53-55	153.50	155.00	4.57	4.60
B C3n.2n			155.93	155.93	4.62	4.62
FO <i>Nitzschia praeinterfrigidaria</i>	19H-1, 60-62	19H-6, 60-62	158.60	166.10	4.72	4.87
T C3n.3n			160.82	160.82	4.80	4.80
B C3n.3n			167.90	167.90	4.89	4.89
FO <i>Thalassiosira inura</i>	20H-1, 60-62	20H-4, 60-62	168.10	172.60	4.80	4.89
T C3n.4n			177.95	177.95	4.98	4.98
B C3n.4n			180.85	180.85	5.23	5.23
LO <i>Rocella vigilans</i>	21H-2, 60-62	21H-5, 60-62	182.10	183.60	5.38	5.56
FO <i>Thalassiosira oestrupii</i>	21H-2, 60-62	21H-5, 60-62	182.10	183.60	5.38	5.56
T C3An.1n			186.37	186.37	5.89	5.89
LO <i>Thalassiosira convexa</i>	22H-3, 60-62	22H-6, 60-62	190.10	194.60	5.98	6.09
FO <i>Thalassiosira convexa</i> v. <i>aspinosa</i>	22H-6, 60-62	23H-3, 60-62	194.60	199.60	6.09	6.18
LO <i>Trinacria excavata</i>	21H-5, 60-62	22H-3, 60-62	194.60	199.60	6.09	6.18
B C3An.1n			196.63	196.63	6.14	6.14
T C3An.2n			205.66	205.66	6.27	6.27
FO <i>Rocella vigilans</i>	24H-2, 60-62	24H-6, 60-62	207.60	13.60	?	?
LO <i>Thalassiosira miocenica</i>	24H-3, 60-62	24H-6, 60	209.10	213.60	?	?
FO <i>Thalassiosira inura</i>	24H-1, 60-62	24H-2, 60-62	210.60	212.10	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

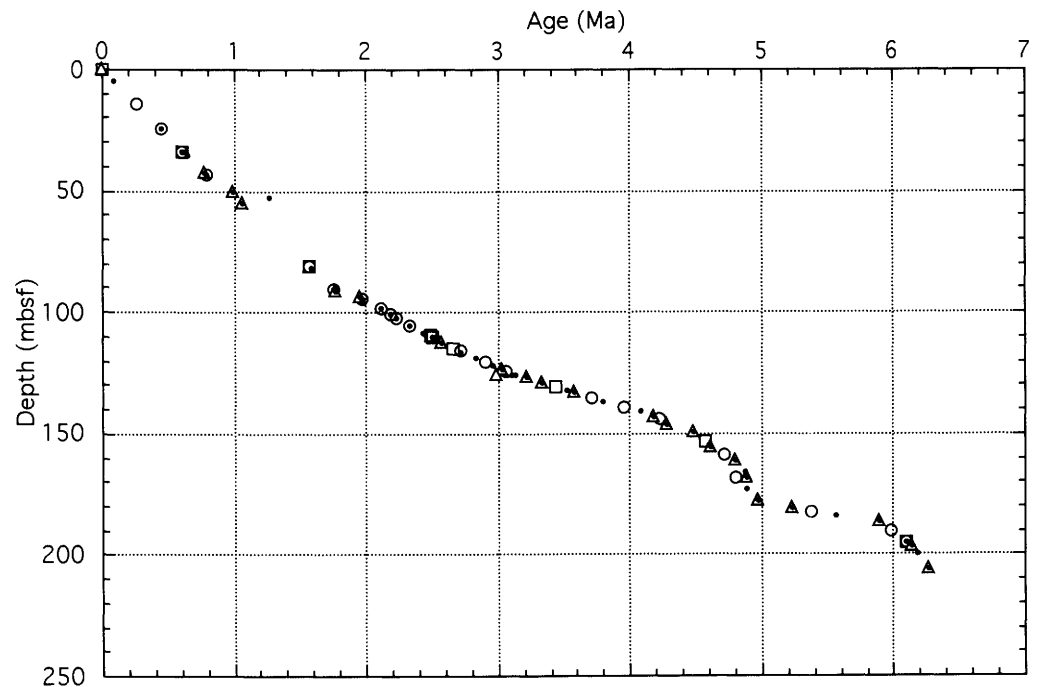


Fig. 44. An age-depth plot for DSDP Hole 745B utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Hole 746A

Sixteen cores were recovered from a total penetration of 280.8 mbsf representing a recovery of 33% of the cored interval. Sediments recovered consist of lower Pliocene and upper Miocene diatom ooze (Barron *et al.* 1989). A palaeomagnetic polarity reversal record was interpreted by Barron *et al.* (1991) for the upper Miocene section. Diatoms and radiolarians are generally abundant and well preserved throughout the entire stratigraphical section. Calcareous nannofossils are recorded in a single sample from the upper Miocene. (Barron *et al.* 1989). The integrated biostratigraphical and magnetostratigraphical data previously used (palaeomagnetism: Barron *et al.* 1991; diatoms: Baldauf & Barron 1991; calcareous nannofossils: none; radiolarians: Caulet 1991; Lazarus 1992) and calibrated to the GPTS of Berggren *et al.* (1985a, b) is shown in Table 32. An age-depth graph for Hole 119-46A using this data is shown in Fig. 45.

Figure 46 compares the polarity chronozones and diatom zones assigned by previous workers (Barron *et al.* 1991) with the

chronozonal assignments in this study. In addition, this figure illustrates the stratigraphical ranges of diatoms and radiolarians. The stratigraphical ranges reflect the placement of FO and LO of stratigraphically useful species as recognized by Baldauf & Barron (1991), Caulet (1991) and Lazarus (1992). The revised chronozones and diatom zones illustrated are based on reassessing the data sets of these workers (Table 33). Comparison of the chronozonal assignments of Barron *et al.* (1991) with those of this study indicate only nomenclatural changes.

Figure 47 shows an age-depth graph for Hole 119-746A for the interval 180–250 mbsf, which contains a record of polarity reversals. The interval from 168 to 236 mbsf contains a continuous sequence of polarity reversals from the base of C3An.2n to the top of C4Ar.2n. These findings compare with those of Barron *et al.* (1991). There are no primary biostratigraphical events within this sequence.

Table 32. Composite dataset for ODP Hole 746A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO <i>Thalassiosira miocenica</i>	4H-1, 60	4H-2, 60	165.40	166.90	?	?
B C3An.2n			168.86	168.86	6.57	6.57
FO <i>Thalassiosira praeconvexa</i>	4H-4, 60	4H-5, 60	169.90	171.40	6.60	6.65
LO <i>Actinocyclus ingens v. nodus</i>	4H-4, 60	4H-5, 60	169.90	171.40	6.60	6.65
LO <i>Denticulopsis dimorpha</i>	4H-4, 60	4H-5, 60	169.90	171.40	6.60	6.65
FO <i>Nitzschia miocenica</i>	4H-6, 60	4H-CC	172.90	174.30	6.70	6.74
LO <i>Thalassiosira burckliana</i>	5H-2, 60	5H-3, 60	176.40	177.90	6.81	6.86
T C3Bn			180.37	180.37	6.94	6.94
T C4n.1n			189.26	189.26	7.43	7.43
T C4n.2n			193.47	193.47	7.65	7.65
LO <i>Hemidiscus karstenii</i>	7H-CC	8H-1, 60	202.80	203.40	7.99	8.01
FO <i>Actinocyclus ingens v. nodus</i>	8H-2, 60	8H-3, 60	204.90	206.40	8.07	8.12
B C4n.2n			204.97	204.97	8.07	8.07
FO <i>Nitzschia marina</i>	8H-1, 60	8H-2, 60	206.40	208.00	8.12	8.18
LO <i>Cycladophora humerus</i>	8H-CC	9H-4, 48-50	209.30	214.30	8.23	8.27
T C4r.1n			209.30	209.30	8.23	8.23
B C4r.1n			213.80	213.80	8.26	8.26
LO <i>Actinocyclus ingens</i>	9H-4, 45	9H-5, 45	214.30	215.80	8.27	8.32
FO <i>Thalassiosira torokina</i>	9H-CC	10H-1, 60	217.80	218.40	8.38	8.39
FO <i>Cosmiodiscus intersectus</i>	10H-2, 60	10H-3, 60	219.90	221.40	8.44	8.48
T C4An			228.85	228.85	8.70	8.70
B C4An			231.35	231.35	9.03	9.03
LO <i>Cycladophora spongothorax</i>	11X-4, 53-55	11X-5, 53-55	233.30	233.80	9.11	9.13
LO <i>Asteromphalus kennettii</i>	11X-CC	13X-1, 60	234.80	242.80	9.17	?
FO <i>Thalassiosira burckliana</i>	13X-6, 60	13X-CC	234.80	242.80	9.17	?
T C4Ar.1n			236.30	236.30	9.23	9.23
FO <i>Hemidiscus karstenii</i>	13H-5, 60	13H-6, 60	249.00	250.30	?	?
FO <i>Cycladophora humerus</i>	13X-6, 53-55	13X-CC	250.20	251.80	?	?
FO <i>Asteromphalus kennettii</i>	13H-CC	14H-1, 60	251.80	252.40	?	?
FO <i>Eucyrtidium pseudoinflatum</i>	14X-CC	15X-CC	261.50	271.00	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

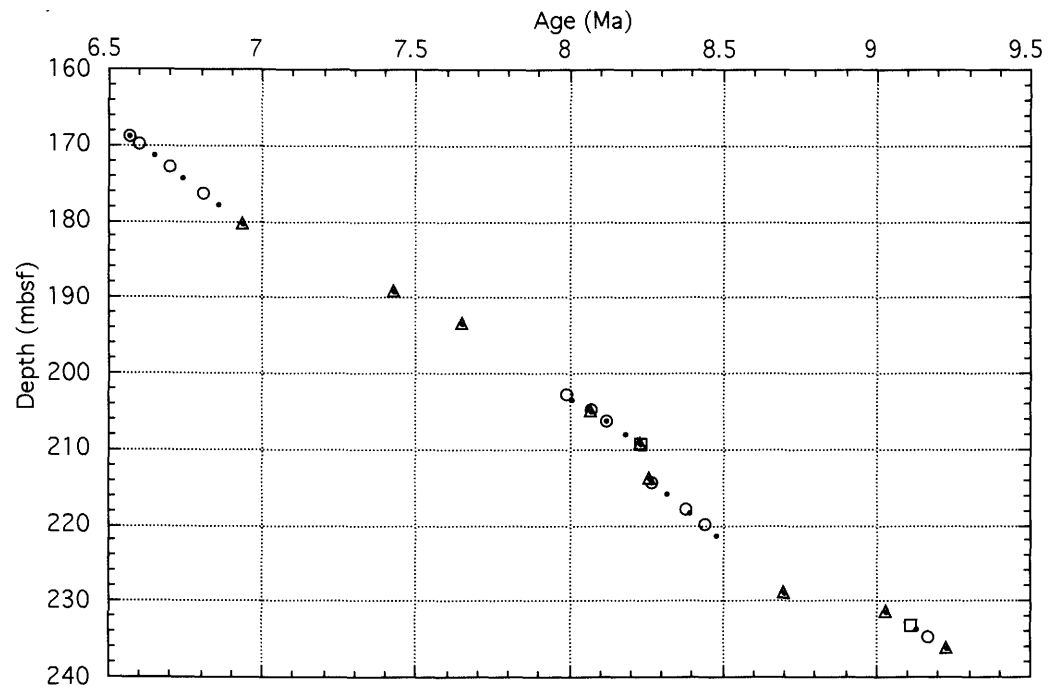


Fig. 45. An age–depth plot for DSDP Hole 746A utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

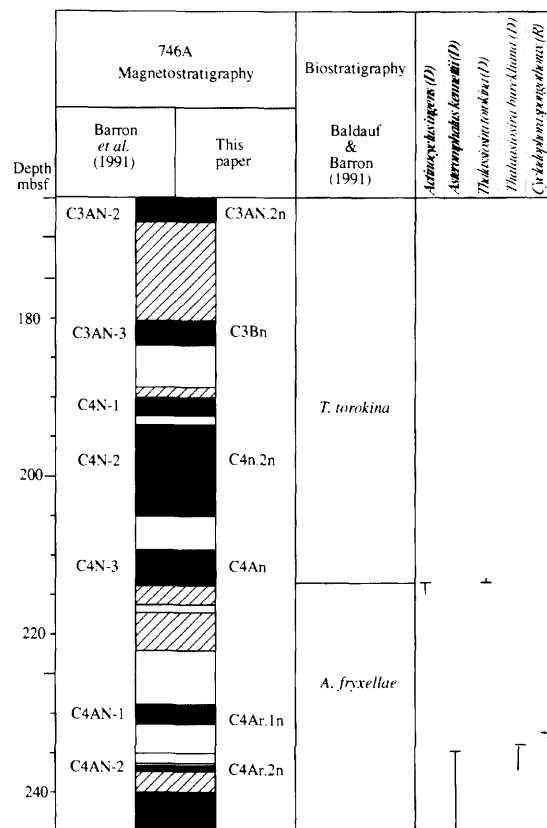


Fig. 46. Comparison of the ODP Hole 746A polarity chronozones and diatom zonal assignments by previous workers with the chronozoneal assignments of this study. The stratigraphical ranges of selected stratigraphical markers are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995). Diagonal lines indicate intervals of uncertainty.

Table 33. Composite dataset for ODP Hole 746A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event		Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO	<i>Thalassiosira miocenica</i>	4H-1, 60	24H-2, 60	165.40	166.90	?	?
B	C3An.2n			168.86	168.86	6.57	6.57
FO	<i>Thalassiosira praeconvexa</i>	4H-4, 60	24H-5, 60	169.90	171.40	6.60	6.65
LO	<i>Actinocyclus ingens v. nodus</i>	4H-4, 60	24H-5, 60	169.90	171.40	6.60	6.65
LO	<i>Denticulopsis dimorpha</i>	4H-4, 60	24H-5, 60	169.90	171.40	6.60	6.65
FO	<i>Nitzschia miocenica</i>	4H-6, 60	4H-CC	172.90	174.30	6.70	6.74
LO	<i>Thalassiosira burckliana</i>	5H-2, 60	25H-3, 60	176.40	177.90	6.81	6.86
T	C3Bn			180.37	180.37	6.94	6.94
B	C3Bn			183.31	183.31	7.09	7.09
T	C4n.1n			189.26	189.26	7.43	7.43
B	C4n.1n			192.29	192.29	7.56	7.56
T	C4n.2n			193.47	193.47	7.65	7.65
LO	<i>Hemidiscus karstenii</i>	7H-CC	8H-1, 60	202.80	203.40	7.99	8.01
FO	<i>Actinocyclus ingens v. nodus</i>	8H-2, 60	28H-3, 60	204.90	206.40	8.07	8.12
B	C4n.2n			204.97	204.97	8.07	8.07
FO	<i>Nitzschia marina</i>	8H-1, 60	28H-2, 60	206.40	208.00	8.12	8.18
LO	<i>Cycladophora humerus</i>	8H-CC	9H-4, 48-50	209.30	214.30	8.23	8.29
T	C4r.1n			209.30	209.30	8.23	8.23
B	C4r.1n			213.80	213.80	8.26	8.26
LO	<i>Actinocyclus ingens</i>	9H-4, 45	29H-5, 45	214.30	215.80	8.29	8.39
FO	<i>Thalassiosira torokina</i>	9H-CC	10H-1, 60	217.80	218.40	8.52	8.56
FO	<i>Cosmiodiscus intersectus</i>	10H-2, 60	210H-3, 60	219.90	221.40	8.65	8.75
T	C4Ar.1n			228.85	228.85	9.23	9.23
B	C4Ar.1n			231.35	231.35	9.31	9.31
LO	<i>Cycladophora spongothorax</i>	11X-4, 53-55	211X-5, 53-55	233.30	233.80	9.41	9.44
LO	<i>Asteromphalus kennettii</i>	11X-CC	13X-1, 60	234.80	242.80	9.50	?
FO	<i>Thalassiosira burckliana</i>	13X-6, 60	13X-CC	234.80	242.80	9.50	?
T	C4Ar.2n			236.30	236.30	9.58	9.58
FO	<i>Hemidiscus karstenii</i>	13H-5, 60	213H-6, 60	249.00	250.30	?	?
FO	<i>Cycladophora humerus</i>	13X-6, 53-55	13X-CC	250.20	251.80	?	?
FO	<i>Asteromphalus kennettii</i>	13H-CC	14H-1, 60	251.80	252.40	?	?
FO	<i>Eucyrtidium pseudoinflatum</i>	14X-CC	15X-CC	261.50	271.00	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

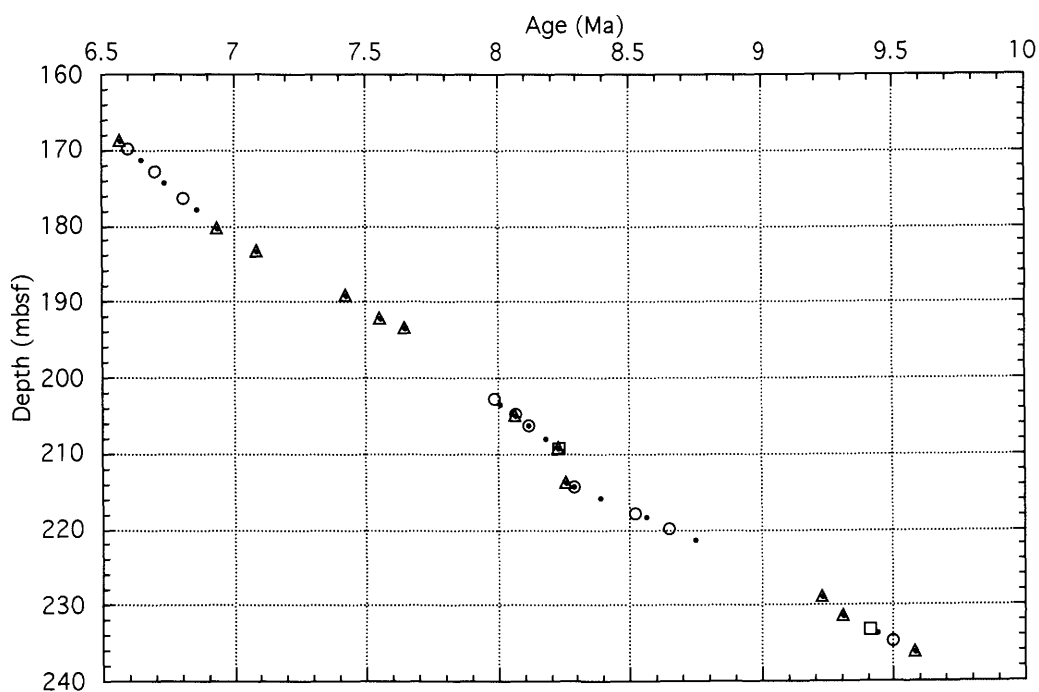


Fig. 47. An age-depth plot for DSDP Hole 746A utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Hole 747A

Twenty-seven cores were recovered from a total penetration of 256 mbsf representing a recovery of 88% of the cored interval. Sediments recovered consist of Quaternary to lower Pliocene diatom ooze with calcareous nannofossils and planktonic foraminifers, upper Pliocene to upper Oligocene calcareous nannofossil ooze, upper Oligocene to upper Cretaceous chalk with calcareous nannofossils. Basaltic pebbles and chert occur in the Cretaceous portion of the section (Wise *et al.* 1989).

A palaeomagnetic polarity record was obtained for the Quaternary to Cretaceous sequence. Shipboard workers resolved their inability to recognize short polarity reversals, by shorebase measurements of discrete samples (Wise *et al.* 1989; Heider *et al.* 1992a). Diatoms calcareous nannofossils and radiolarians are observed in the sequence recovered. Diatoms are abundant and well preserved in the Quaternary and Pliocene with few moderately well-preserved valves recorded in the Miocene and upper Oligocene. Calcareous nannofossils are few to abundant and well preserved throughout the sedimentary sequence (Aubry 1992; Wei & Wise 1992a). Radiolarians are common to abundant and generally well preserved in the Quaternary to middle Miocene sediments. Abundance and preservation declines in the lower Miocene and Oligocene. Radiolarians were not observed in sediments older than Oligocene (Wise *et al.* 1989). The integrated biostratigraphical and magnetostratigraphical data previously used (palaeomagnetism: Heider *et al.* 1992; Harwood *et al.* 1992; diatoms: Harwood & Maruyama 1992; calcareous nannofossils: Wei & Wise 1992; radiolarians: Abelmann 1992; Lazarus 1992) and calibrated to the GPTS of Berggren *et al.* (1985a,b) are presented in Table 34. An age–depth graph for Hole 120-747A using these data is presented in Fig. 48.

Figure 49 compares the polarity chronozones and diatom zones assigned by previous workers (Heider *et al.* 1992; Harwood *et al.* 1992; Harwood & Maruyama 1992) with the chronozoneal assignments in this study. In addition, this figure illustrates the stratigraphical ranges of diatoms, radiolarians and calcareous nannofossils. The stratigraphical ranges reflect the placement of FO and LO of stratigraphically useful species as recognized by Harwood & Maruyama (1992), Abelmann (1992), Lazarus (1992), and Wei & Wise (1992). The revised chronozones and diatom zones illustrated are based on reassessing the data sets of these workers (Table 34). Comparison of the chronozoneal assignments of Harwood *et al.* (1992; Table 34) with those of this study (Table 35) indicates that whereas the chronozoneal placements are somewhat similar, the interpretation of hiatuses and the continuity of the section differs significantly.

An age–depth graph for Hole 120-747A using the stratigraphical markers determined in this study is presented in Fig. 50. Two hiatuses are placed in the section. The younger break is placed at approximately 24 mbsf and the older unconformity occurs between 30.26 and 33.0 mbsf. The upper boundary of the younger break is constrained by the continuous sequence of polarity reversals from the top of C1r.1n (14 mbsf) to the top of C2An.3n at 22.30 mbsf. The last occurrence of *Thalassiosira kolbei* (18.50–19.00 mbsf) and the LO of *Thalassiosira vulnifica* (21.50–22.00 mbsf). The lower boundary is constrained by the base of C3n.1n (25.90 mbsf), the FO of *Nitzschia barronii* (28.00–28.50 mbsf), the FO of *Helotholus vema* (28.00–29.50 mbsf) and the FO of *Nitzschia praeinterfrigidaria* (28.50–30.00 mbsf). The upper boundary of the older hiatus is constrained by the top of C3n.3n (30.26 mbsf) and the biostratigraphical events identified above. The lower boundary is constrained by the top of C4An (33.0 mbsf) and the top C4Ar.1n (34.41 mbsf). This study suggests that the stratigraphical section is significantly more continuous than previously recognized. Harwood & Maruyama (1992) and Harwood *et al.* (1992) identified ten hiatuses for the interval representing the last 25 million years based on both biostratigraphical and palaeomagnetic data. The two unconformities identified in this study approximate the placement of two of the unconformities previously recognized.

Harwood & Maruyama (1992) and Harwood *et al.* (1992) identified the youngest hiatus between 18 and 20 mbsf. The placement of this break is based on the co-occurrence of the LO of *Thalassiosira insigna*, LO of *Nitzschia weaveri* and the occurrence of *Thalassiosira vulnifica*. In addition, the previously used markers, such as the LO of *Thalassiosira inura*, FO of *Nitzschia kerguelensis* and the LO of *Nitzschia interfrigidaria* have shortened ranges. The stratigraphical relationship between the LO of *Thalassiosira insigna*, LO of *Nitzschia weaveri* and the FO of *Thalassiosira vulnifica* differs in holes where they have been identified for Legs 113, 119 and 120. The stratigraphical occurrence of *Nitzschia weaveri* is sporadic and therefore is not stratigraphically reliable. *Thalassiosira vulnifica* and *Thalassiosira insigna* co-occur in several holes with the FO of *Thalassiosira insigna* generally placed beneath the FO of *Thalassiosira vulnifica*. The LO of *Thalassiosira vulnifica* generally supersedes the LO of *Thalassiosira insigna*. These datums have a sporadic record in the Southern Ocean and we question their reliability as stratigraphical markers based on the currently available data discussed above.

Harwood & Maruyama (1992) and Harwood *et al.* (1992) place a second hiatus between 28.0 and 28.47 mbsf based on the LO of *Rhizosolenia costata* at 28 mbsf, below the FO of *Nitzschia barronii* (28.00–28.50 mbsf). The LO of *Nitzschia praeinterfrigidaria* is restricted based on previous stratigraphical interpretations. The recognition of a hiatus suggests a premature FO of *Nitzschia barronii* which is based on non overlapping ranges of *Nitzschia barronii* and *Rhizosolenia costata*. We, however, incorporate the FO of *Nitzschia barronii* into our biostratigraphical model based on the consistent chronostratigraphical occurrence of this datum at sites throughout the Southern Ocean, including Hole 747A. The FO of *Helotholus vema* in Hole 747A at 28.0 mbsf approximates the FO of *Nitzschia barronii* in this hole. A similar relationship is observed throughout the Southern Ocean and supports our interpretation. This interpretation suggests that the LO of *Rhizosolenia costata* is an unreliable stratigraphical marker.

A third hiatus was identified by Harwood & Maruyama (1992) and Harwood *et al.* (1992) between 28.47 and 29.98 mbsf based on the co-occurrence of the LO of *Lychocanium grande*, the FO of *Thalassiosira inura*, the FO of *Nitzschia praeinterfrigidaria*, the LO of *Thalassiosira compacta* and the absence of *Thalassiosira oestrupii* in this interval. Based on this study, the most reliable stratigraphical marker from this interval is the FO of *Nitzschia praeinterfrigidaria* at 28.0–30.00 mbsf. This event has an estimated age range of 4.46–4.76 Ma at Hole 747A which is within the ranges estimated for this event at other Southern Ocean sites.

Harwood & Maruyama (1992) and Harwood *et al.* (1992) identify an additional hiatus between 34.5 and c. 36 mbsf based on the premature FO of *Acrosphaera labrata* at 33.6 mbsf and the LO of *Nitzschia reinholdii* without the occurrence of *Thalassiosira miocenica* from this interval. The FO of *Acrosphaera labrata* at 33.6 mbsf and the LO of *Cycladophora spongothorax* at 35.95 mbsf are potential stratigraphical indicators based on then results of this study. The presence of these events within this interval suggests that the sequence is continuous.

Harwood & Maruyama (1992) and Harwood *et al.* (1992) place another hiatus between 47.47 and 48.97 mbsf based on an interpreted premature FO of *Asteromphalus kennettii* at 49.0 mbsf. This interpretation was based on the absence of a gap between the placement of the FO of *Asteromphalus kennettii* and the last common occurrence (LCO) of *Denticulopsis dimorpha* in this hole. This relationship was previously recognized by Baldauf & Barron (1991) at Site 744. In addition, Baldauf & Barron (1991) questioned the stratigraphical integrity of *Asteromphalus kennettii* because its finely silicified skeleton may have been prone to dissolution and relied on *Denticulopsis dimorpha* as a stratigraphical marker. The usefulness of *Asteromphalus kennettii* as a stratigraphical indicator requires additional analysis.

Harwood & Maruyama (1992) and Harwood *et al.* (1992) interpret the occurrence of an additional hiatus at 59.97 and

Table 34. Composite dataset for ODP Hole 747A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO <i>Emiliana huxleyi</i>	1H-2, 10-11	1H-3, 58-62	1.60	3.58	1.70	0.38
LO <i>Actinocyclus ingens</i>	1H-3, 47-48	1H-4, 47-48	3.50	5.00	0.37	0.53
LO <i>Thalassiosira inura</i>	1H-5, 47-48	1H-6, 47-48	6.50	8.00	0.69	0.85
LO <i>Antarctissa cylindrica</i>	1H-6, 45	1H-CC	7.95	9.00	0.84	0.95
LO <i>Pterocanium trilobium</i>	1H-6, 45	1H-CC	7.95	9.00	0.84	0.95
LO <i>Thalassiosira elliptopora</i>	1H-6, 47-48	1H-CC	8.00	9.00	0.85	0.95
LO <i>Nitzschia barronii</i>	2H-2, 47-50	2H-3, 47-50	11.00	12.50	1.17	1.32
FO <i>Thalassiosira elliptopora</i>	2H-3, 47-48	2H-4, 47-50	12.50	14.00	1.32	1.48
LO <i>Cycladophora plicenica</i>	2H-5, 45	2H-6, 45	15.45	16.95	1.64	1.80
LO <i>Simonseniella barboi</i>	2H-6, 47-48	2H-CC	17.00	18.50	1.80	?
B 2n			18.40	18.40	1.95	1.95
LO <i>Tricerapys antarctica</i>	2H-7, 45	2H-CC	18.45	18.50	?	?
LO <i>Eucyrtidium calvertense</i>	2H-7, 45	2H-CC	18.45	18.50	?	?
LO <i>Thalassiosira kolbei</i>	2H-CC	3H-1, 47-48	18.50	19.00	?	?
Unconformity			***	***	***	***
LO <i>Desmospyris spongiosa</i>	3H-1, 45	3H-2, 45	18.95	20.45	?	?
LO <i>Helotholus vema</i>	3H-1, 45	3H-2, 45	18.95	20.45	?	?
FO <i>Actinocyclus actinochilus</i>	3H-1, 47-48	3H-2, 47-48	19.00	20.50	?	?
LO <i>Nitzschia interfrigidaria</i>	3H-1, 47-48	3H-2, 47-48	19.00	20.50	?	?
FO <i>Nitzschia kerguelensis</i>	3H-1, 47-48	3H-2, 47-48	19.00	20.50	?	?
LO <i>Nitzschia weaveri</i>	3H-1, 47-48	3H-2, 47-48	19.00	20.50	?	?
LO <i>Thalassiosira insigna</i>	3H-1, 47-48	3H-2, 47-48	19.00	21.50	?	?
LO <i>Thalassiosira vulnifica</i>	3H-1, 47-48	3H-2, 47-48	19.00	21.50	?	?
LO <i>Reticulofenestra hesslandii</i>	3H-2, 58-62	3H-3, 34-36	20.58	22.58	?	?
T C2An.1n			21.30	21.30	2.58	2.58
FO <i>Thalassiosira vulnifica</i>	3H-2, 47-48	3H-3, 47-48	21.50	22.00	?	?
FO <i>Cycladophora davisiana</i>	3H-3, 45	3H-4, 45	21.95	23.45	?	?
LO <i>Prunopyle titan</i>	3H-3, 45	3H-4, 45	21.95	23.45	?	?
FO <i>Nitzschia weaveri</i>	3H-4, 47-48	3H-5, 47-48	23.50	25.00	?	?
LO <i>Thalassiosira complicata</i>	3H-4, 47-48	3H-5, 47-48	23.50	25.00	?	?
LO <i>Lampromitra coronata</i>	3H-5, 45	3H-6, 45	24.95	26.45	?	?
FO <i>Nitzschia interfrigidaria</i>	3H-5, 47-48	3H-6, 47-48	25.00	26.50	?	?
LO <i>Nitzschia praeinterfrigidaria</i>	3H-5, 47-48	3H-6, 47-48	25.00	26.50	?	?
LO <i>Rouxia diploneides</i>	3H-5, 47-48	3H-6, 47-48	25.00	26.50	?	?
FO <i>Thalassiosira kolbei</i>	3H-6, 47-48	3H-CC	26.50	28.00	?	?
FO <i>Thalassiosira oestrupii</i>	3H-6, 47-48	3H-CC	26.50	28.00	?	?
Unconformity			***	***	***	***
FO <i>Nitzschia barronii</i>	3H-CC	4H-1, 47-50	28.00	28.50	?	?
FO <i>Thalassiosira lentiginosa</i>	3H-CC	4H-1, 47-50	28.00	28.50	?	?
FO <i>Helotholus vema</i>	3H-CC	4H-2, 45	28.00	29.50	?	?
LO <i>Denticulopsis dimorpha</i>	4H-1, 47-50	4H-2, 47-50	28.50	30.00	?	?
FO <i>Nitzschia praeinterfrigidaria</i>	4H-1, 47-50	4H-2, 47-50	28.50	30.00	?	?
FO <i>Rouxia heteropolara</i>	4H-1, 47-50	4H-2 47-50	28.50	30.00	?	?
FO <i>Thalassiosira complicata</i>	4H-1, 47-50	4H-2 47-50	28.50	30.00	?	?
B C3n.2n			29.00	29.00	4.62	4.62
Unconformity			***	***	***	***
LO <i>Asteromphalus kennettii</i>	4H-2, 47-50	4H-3, 47-50	30.00	31.50	?	?
LO <i>Hemidiscus triangularis</i>	4H-2 47-50	4H-3, 47-50	30.00	31.50	?	?
LO <i>Neobrunia mirabilis</i>	4H-2 47-50	4H-3, 47-50	30.00	31.50	?	?
FO <i>Nitzschia praecurta</i>	4H-2 47-50	4H-3, 47-50	30.00	31.50	?	?
T C3n.3n			31.00	31.00	4.80	4.80
T C3An.1n			31.50	31.50	5.89	5.89
FO <i>Thalassiosira inura</i>	4H-3, 47-48	4H-4, 47-50	31.50	33.00	5.89	6.14
B C3An.1n			33.00	33.00	6.14	6.14
FO <i>Thalassiosira torokina</i>	4H-4, 47-50	4H-5, 47-50	33.00	34.50	6.14	?
FO <i>Acrosphaera labrata</i>	4H-4, 110	4H-5, 45	33.60	34.45	6.20	?
T C3An.2n			34.41	34.41	6.27	6.27
LO <i>Cycladophora spongothorax</i>	4H-5, 45	4H-6, 45	34.45	35.95	?	?
Unconformity			***	***	***	***
FO <i>Hemidiscus ovalis</i>	4H-6, 47-50	4H-7, 48-50	36.00	37.50	?	?
B C4An			40.97	40.97	9.00	9.00
LO <i>Calcidiscus macintyreii</i>	5H-6, 10-11	5H-7, 58-62	45.10	47.08	9.68	9.85
T C5n.1n			45.47	45.47	9.74	9.74
B C5n.1n			47.56	47.56	9.88	9.88
Unconformity			***	***	***	***
FO <i>Eucyrtidium pseudoinflatum</i>	6H-3, 45	6H-4, 45	50.45	51.95	10.20	10.37
LO <i>Actinomma golownini</i>	6H-4, 45	6H-6, 45	51.95	54.95	10.37	10.71
FO <i>Hemidiscus cuneiformis</i>	6H-4, 47-48	6H-5, 47-48	52.00	53.50	10.38	10.55

Table 34. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
B C5n.2n			57.10	57.10	10.95	10.95
FO <i>Cycladophora spongothorax</i>	7H-2, 45	7H-3, 45	58.45	59.45	?	?
LO <i>Denticulopsis praedimorpha</i>	7H-2, 47-49	7H-3, 47-49	58.50	60.00	?	?
Unconformity			***	***	***	***
LO <i>Nitzschia denticuloides</i>	7H-3, 47-49	7H-4, 47-49	60.00	61.50	?	?
FO <i>Reticulofenestra hesslandii</i>	7H-4, 10-11	7H-5, 62-63	61.15	63.08	?	16.73
T C5An.1n			61.30	61.30	11.94	11.94
B C5An.1n			62.10	62.10	12.08	12.08
B C5An.2n			65.10	65.10	12.40	12.40
FO <i>Denticulopsis dimorpha</i>	7H-CC	8H-1, 47-49	66.00	66.50	?	?
LO <i>Actinocyclus ingens</i> v. <i>nodus</i>	7H-CC	8H-1, 47-49	66.00	66.50	?	?
FO <i>Denticulopsis praedimorpha</i>	7H-CC	8H-1, 47-49	66.00	66.50	?	?
Unconformity			***	***	***	***
FO <i>Actinomma golownini</i>	7H-CC	8H-1.45	66.00	66.50	?	?
LO <i>Nitzschia grosssepunctata</i>	8H-1, 47-49	8H-2, 47-49	66.50	68.00	?	?
LO <i>Coscinodiscus lewistanus</i>	8H-1, 47-49	8H-2, 47-49	66.50	68.00	?	?
T C5ABn			66.80	66.80	13.30	13.30
FO <i>Nitzschia denticuloides</i>	9H-6, 47-49	9H-7, 47-49	67.97	69.47	13.41	13.60
B C5ABn			68.90	68.90	13.51	13.51
T C5ACn			70.10	70.10	13.70	13.70
FO <i>Denticulopsis hustedtii</i>	8H-5, 47-49	8H-6, 47-49	72.50	74.00	14.13	14.31
T C5ADn			72.80	72.80	14.18	14.18
LO <i>Denticulopsis maccolumnii</i>	8H-6, 47-49	8H-CC	74.00	75.50	14.31	14.49
FO <i>Actinocyclus ingens</i>	v. <i>nodus</i> 8H-CC	9H-2, 47-49	75.50	77.49	14.49	14.68
LO <i>Synedra jouseana</i>	8H-CC	9H-2, 47-49	75.50	79.10	14.49	14.80
LO <i>Crucidentacula kanayae</i>	9H-2, 47-49	9H-4, 47-49	76.06	79.06	14.56	14.80
B C5ADn			76.50	76.50	14.61	14.61
T C5Bn.1n			79.10	79.10	14.80	14.80
B C5Bn.1n			80.00	80.00	14.89	14.89
B C5Bn.2n			81.30	81.30	15.16	15.16
FO <i>Actinocyclus ingens</i>	9H-CC	10H-1, 47-48	85.00	85.50	?	?
FO <i>Nitzschia grosssepunctata</i>	9H-CC	10H-1, 47-49	85.00	85.50	?	?
FO <i>Denticulopsis lauta</i>	9H-CC	10H-1, 47-49	85.00	85.60	?	?
Unconformity			***	***	***	***
T C5Cn.1n			85.47	85.47	16.01	16.01
LO <i>Reticulofenestra pseudumbilica</i>	10H-4, 10-11	10H5-58-62	89.60	91.58	16.51	16.75
B C5Cn.3n			91.47	91.47	16.73	16.75
FO <i>Denticulopsis maccolumnii</i>	10H-5, 47-49	10H-6, 47-49	91.50	93.00	16.74	17.14
FO <i>Calcidiscus macintyreii</i>	10H-6, 58-62	10H-7, 20-24	93.08	94.20	17.17	17.38
T C5Dn			93.50	93.50	17.28	17.28
FO <i>Crucidentacula kanayae</i>	10H-7, 47-49	11H-1, 47-49	94.50	95.00	17.43	17.51
FO <i>Calcidiscus leptoporus</i>	11H-1, 58-62	11H-2, 10-11	95.08	96.10	17.52	17.68
LO <i>Thalassiosira fraga</i>	11H-3, 47-49	11H-5, 47-49	98.00	101.00	17.97	18.38
T C5En			100.00	100.00	18.28	18.28
T C6n			107.50	107.50	19.05	19.05
B C6n			112.90	112.90	20.13	20.13
FO <i>Thalassiosira fraga</i>	13H-1, 47-49	13H-2, 47-49	114.00	115.50	20.33	20.57
T C6An.1n			115.07	115.07	20.52	20.52
B C6An.1n			116.80	116.80	20.73	20.73
LO <i>Bogorovia veniamini</i>	13H-3, 47-49	13H-4, 47-49	116.99	118.49	20.79	21.26
B C6An.2n			118.68	118.68	21.32	21.32
FO <i>Raphidodiscus marylandicus</i>	13H-5, 47-49	13H-6, 47-49	119.97	121.47	21.68	22.19
T C6AAn			120.30	120.30	21.77	21.77
B C6AAr.1n			121.65	121.65	22.25	22.25
T C6Bn.1n			123.10	123.10	22.59	22.59
LO <i>Rocella gelida</i>	13H-CC	14H-1, 47-49	123.47	126.47	22.68	23.50
B C6Bn.2n			125.05	125.05	23.07	23.07
T C6Cn.1n			125.70	125.70	23.35	23.35
LO <i>Lisitzina ornata</i>	14H-3, 47-49	14H-4, 47-49	126.00	128.00	23.41	23.78
B C6Cn.1n			126.70	126.70	23.54	23.54
T C6n.2n			127.60	127.60	23.68	23.68
LO <i>Thalassiosira primalabiata</i>	14H-4, 47-49	14H-5, 47-49	128.00	129.50	23.78	24.14
LO <i>Reticulofenestra bisecta</i>	14H-4, 58-62	14H-4, 10-12	128.08	129.10	23.80	?
B C6n.2n			128.10	128.10	23.80	23.80
T C6n.3n			128.90	128.90	24.00	24.00
Unconformity			***	***	***	***
B C7n.2n			133.60	133.60	25.20	25.20
LO <i>Rocella vigilans</i>	15H-3, 47-49	15H-4, 47-49	135.97	137.47	?	?

(continued)

Table 34. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
Unconformity			***	***	***	***
T C7An			137.50	137.50	25.50	25.50
B C7An			138.30	138.30	25.65	25.65
T C8n.1n			138.70	138.70	25.82	25.82
FO <i>Rocella gelida</i>	15H-5, 47-49	15H-6, 47-49	140.00	140.50	25.89	25.92
B C8n.1n			141.05	141.05	25.95	25.95
LO <i>Chiasmolithus altus</i>	15H-7, 10-12	16H-1, 10-12	141.60	142.10	25.96	25.97
T C8n.2n			143.17	143.17	25.99	25.99
FO <i>Lisitzina ornata</i>	16H-CC	17H-1, 47-49	151.50	151.97	26.53	?
FO <i>Rocella vigilans</i>	16H-CC	17H-1, 47-49	151.50	151.97	26.53	?
B C8n.2n			151.84	151.84	26.55	26.55

Data sets are integrated from the work of numerous authors (see Table 2).

61.47 mbsf based on the assumption that the LO of *Nitzschia denticuloides* is premature relatively to the LO of *Denticulopsis praedimorpha*. The LO of *Nitzschia denticuloides* is assigned to sample 7H-4, 47–48 cm and the LO of *Denticulopsis praedimorpha* is assigned either to sample 7H-5, 47–48 cm or to sample 7H-3, 47–48 cm. Barron & Baldauf (1991) have shown that these events are approximately coeval. Harwood & Maruyama (1992) suggest that the LO of *Denticulopsis praedimorpha* is approximately 0.1 million years younger than the LO of *Nitzschia denticuloides*; however we question the stratigraphical usefulness of the LO of *Nitzschia denticuloides* (Table 3).

Harwood & Maruyama (1992) and Harwood *et al.* (1992) use the concurrent FO's of *Denticulopsis praedimorpha* and *Denticulopsis dimorpha* at 66 mbsf and the FO of *Nitzschia denticuloides* at 67.97 mbsf to interpret the occurrence of a hiatus between 66.0 and 66.47 mbsf. This interpretation was based on results from Baldauf & Barron (1991), Hole 744B, which placed the FO of *D. praedimorpha* between the FO of *Nitzschia denticuloides* and the FO of *Denticulopsis dimorpha*. The FO of *Denticulopsis praedimorpha* is identified in this study as a primary marker. The potential

usefulness of *Denticulopsis dimorpha* as a stratigraphical indicator needs to be re-examined.

Harwood & Maruyama (1992) and Harwood *et al.* (1992) identify the occurrence of a hiatus between 85 and 85.47 mbsf based on the FO of *Nitzschia grossepunctata*, the FO of *Denticulopsis lauta* and the FO of *Actinocyclus ingens* at 85 mbsf. The succession of these datums is inconsistent within the Southern Ocean (see Gersonde & Burckle 1990, Hole 689B; Baldauf & Barron 1991, Hole 744B), and they are therefore unreliable as stratigraphical markers. The FO of *Nitzschia denticuloides* (67.97–69.47 mbsf), the FO of *Denticulopsis hustedtii* (72.50–74.00 mbsf) and the LO of *Synedra jouseana* (76.10–79.10) are primary markers as they have consistent ranges throughout the Southern Ocean. The occurrence of these events within this interval suggests that the sequence is complete.

Harwood *et al.* (1992) record a hiatus between 129.47 and 130.97 and a possible second break from 135.97 to 137.47 mbsf but do not indicate the rationale for the placement of these breaks. In this study we infer a continuous polarity sequence throughout this interval which is devoid of primary markers.

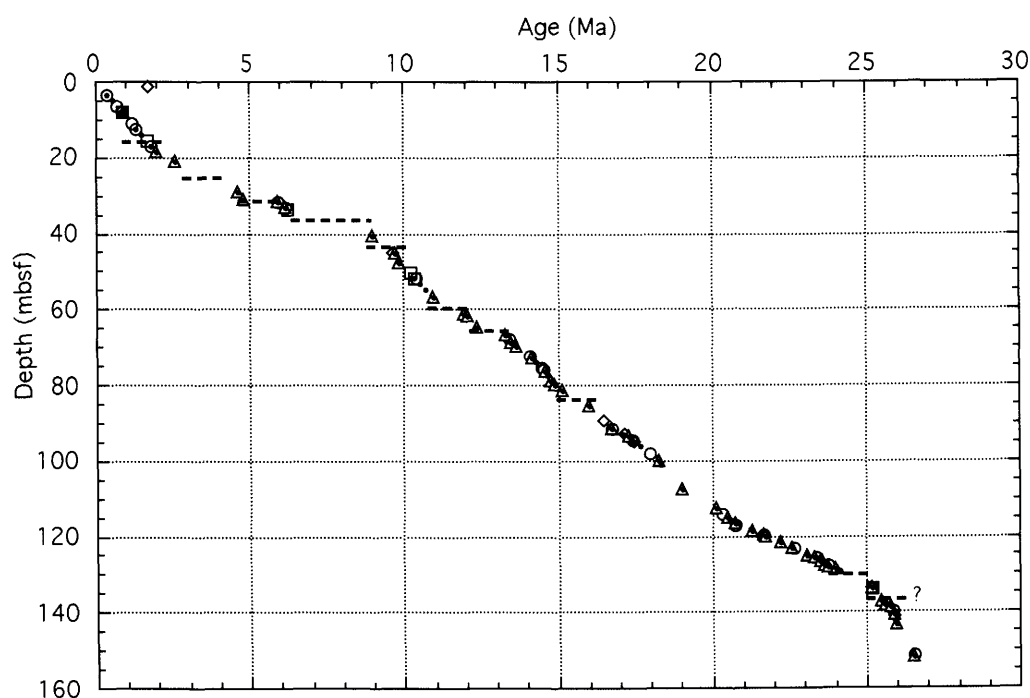


Fig. 48. An age–depth plot for DSDP Hole 747A utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

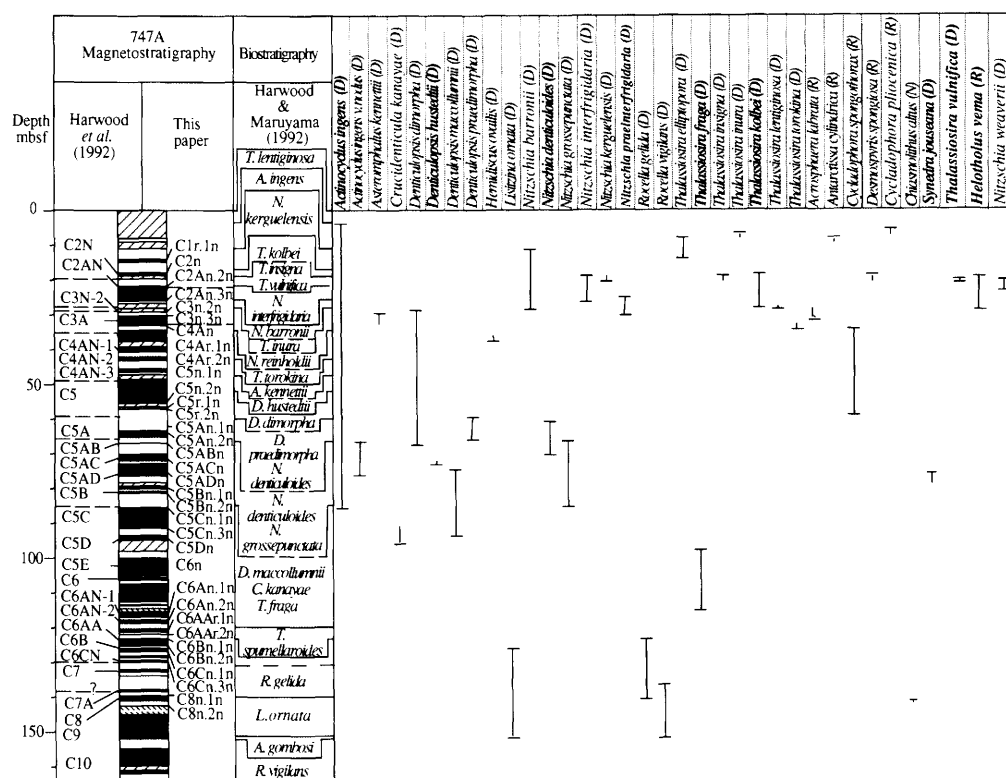


Fig. 49. Comparison of the ODP Hole 747A polarity chronozones and diatom zonal assignments by previous workers with the chronozoneal assignments of this study. The stratigraphical ranges of selected stratigraphical markers are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995). Diagonal lines indicate intervals of uncertainty.

Table 35. Composite dataset for ODP Hole 747A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO <i>Emiliania huxleyii</i>	1H-2, 10-11	1H-3, 58-62	1.60	3.58	0.11	0.25
LO <i>Actinocyclus ingens</i>	1H-3, 47-48	1H-4, 47-48	3.50	5.00	0.25	0.35
LO <i>Thalassiosira inura</i>	1H-5, 47-48	1H-6, 47-48	6.50	8.00	0.46	0.57
LO <i>Antarctissa cylindrica</i>	1H-6, 45	1H-CC	7.95	9.00	0.56	0.64
LO <i>Pterocanium trilobium</i>	1H-6, 45	1H-CC	7.95	9.00	0.56	0.64
LO <i>Thalassiosira elliptopora</i>	1H-6, 47-48	1H-CC	8.00	9.00	0.57	0.64
LO <i>Nitzschia barronii</i>	2H-2, 47-50	2H-3, 47-50	11.00	12.50	0.78	0.88
FO <i>Thalassiosira elliptopora</i>	2H-3, 47-48	2H-4, 47-50	12.50	14.00	0.88	0.99
T C1r.1n			14.00	14.00	0.99	0.99
B C1r.1n			14.65	14.65	1.07	1.07
LO <i>Cycladophora pliocenica</i>	2H-5, 45	2H-6, 45	15.45	16.95	1.27	1.63
LO <i>Simonseniella barboi</i>	2H-6, 47-48	2H-CC	17.00	18.50	1.65	1.99
T C2n			17.50	17.50	1.77	1.77
B C2n			18.40	18.40	1.95	1.95
LO <i>Tricerapys antarctica</i>	2H-7, 45	2H-CC	18.45	18.50	1.97	1.99
LO <i>Eucyrtidium calvertense</i>	2H-7, 45	2H-CC	18.45	18.50	1.97	1.99
LO <i>Thalassiosira kolbei</i>	2H-CC	3H-1, 47-48	18.50	19.00	1.99	2.19
LO <i>Desmospyris spongiosa</i>	3H-1, 45	3H-2, 45	18.95	20.45	2.17	2.77
LO <i>Helotholus vema</i>	3H-1, 45	3H-2, 45	18.95	20.45	2.17	2.77
FO <i>Actinocyclus actinochilus</i>	3H-1, 47-48	3H-2, 47-48	19.00	20.50	2.19	2.79
LO <i>Nitzschia interfrigidaria</i>	3H-1, 47-48	3H-2, 47-48	19.00	20.50	2.19	2.79
FO <i>Nitzschia kerguelensis</i>	3H-1, 47-48	3H-2, 47-48	19.00	20.50	2.19	2.79
LO <i>Nitzschia weaveri</i>	3H-1, 47-48	3H-2, 47-48	19.00	20.50	2.19	2.79
LO <i>Thalassiosira insigna</i>	3H-1, 47-48	3H-2, 47-48	19.00	21.50	2.19	3.22
LO <i>Thalassiosira vulnifica</i>	3H-1, 47-48	3H-2, 47-48	19.00	21.50	2.19	3.22
LO <i>Reticulofenestra hesslandii</i>	3H-2, 58-62	3H-3, 34-36	20.58	22.58	2.82	3.56
T C2An.2n			21.30	21.30	3.11	3.11
B C2An.2n			21.50	21.50	3.22	3.22
FO <i>Thalassiosira vulnifica</i>	3H-2, 47-48	3H-3, 47-48	21.50	22.00	3.22	3.29
FO <i>Cycladophora davisiana</i>	3H-3, 45	3H-4, 45	21.95	23.45	3.28	?
LO <i>Prunopyle titan</i>	3H-3, 45	3H-4, 45	21.95	23.45	3.28	?
T C2An.3n			22.30	22.30	3.33	3.33
FO <i>Nitzschia weaveri</i>	3H-4, 47-48	3H-5, 47-48	23.50	25.00	?	?
LO <i>Thalassiosira complicata</i>	3H-4, 47-48	3H-5, 47-48	23.50	25.00	?	?
Unconformity			***	***	***	***
LO <i>Lampromitra coronata</i>	3H-5, 45	3H-6, 45	24.95	26.45	?	?

(continued)

Table 35. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO <i>Nitzschia interfrigidaria</i>	3H-5, 47-48	3H-6, 47-48	25.00	26.50	?	?
LO <i>Nitzschia praeinterfrigidaria</i>	3H-5, 47-48	3H-6, 47-48	25.00	26.50	?	?
LO <i>Rouxia diploneides</i>	3H-5, 47-48	3H-6, 47-48	25.00	26.50	?	?
B C3n.1n			25.90	25.90	4.29	4.29
FO <i>Thalassiosira kolbei</i>	3H-6, 47-48	3H-CC	26.50	28.00	4.33	4.43
FO <i>Thalassiosira oestrupii</i>	3H-6, 47-48	3H-CC	26.50	28.00	4.33	4.43
FO <i>Nitzschia barronii</i>	3H-CC	4H-1, 47-50	28.00	28.50	4.43	4.43
FO <i>Thalassiosira lentiginosa</i>	3H-CC	4H-1, 47-50	28.00	28.50	4.43	4.43
FO <i>Helotholus vema</i>	3H-CC	4H-2, 45	28.00	29.50	4.43	4.69
LO <i>Denticulopsis dimorpha</i>	4H-1, 47-50	4H-2, 47-50	28.50	30.00	4.46	4.76
FO <i>Nitzschia praeinterfrigidaria</i>	4H-1, 47-50	4H-2, 47-50	28.50	30.00	4.46	4.76
FO <i>Rouxia heteropolara</i>	4H-1, 47-50	4H-2, 47-50	28.50	30.00	4.46	4.76
FO <i>Thalassiosira complicata</i>	4H-1, 47-50	4H-2, 47-50	28.50	30.00	4.46	4.76
T C3n.2n			28.73	28.73	4.48	4.48
B C3n.2n			29.00	29.00	4.62	4.62
LO <i>Asteromphalus kennettii</i>	4H-2, 47-50	4H-3, 47-50	30.00	31.50	4.76	?
LO <i>Hemidiscus triangularis</i>	4H-2, 47-50	4H-3, 47-50	30.00	31.50	4.76	?
LO <i>Neobrunia mirabilis</i>	4H-2, 47-50	4H-3, 47-50	30.00	31.50	4.76	?
FO <i>Nitzschia praecurta</i>	4H-2, 47-50	4H-3, 47-50	30.00	31.50	4.76	?
T C3n.3n			30.26	30.26	4.80	4.80
Unconformity			***	***	***	***
T C4An			30.33	30.33	8.70	8.70
FO <i>Acrosphaera labrata</i>	4H-4, 110	4H-5, 45	31.30	31.62	8.82	8.86
FO <i>Thalassiosira inura</i>	4H-3, 47-48	4H-4, 47-50	31.50	33.00	8.84	9.03
B C4An			33.00	33.00	9.03	9.03
FO <i>Thalassiosira torokina</i>	4H-4, 47-50	4H-5, 47-50	33.00	34.50	9.03	9.24
FO <i>Acrosphaera labrata</i>	4H-4, 110	4H-5, 45	33.60	34.45	9.12	9.24
T C4Ar.1n			34.41	34.41	9.23	9.23
LO <i>Cycladophora spongothorax</i>	4H-5, 45	4H-6, 45	34.45	35.95	9.23	9.25
FO <i>Hemidiscus ovalis</i>	4H-6, 47-50	4H-7, 48-50	36.00	37.50	9.25	9.27
B C4Ar.1n			41.20	41.20	9.31	9.31
T C4Ar.2n			42.10	42.10	9.58	9.58
B C4Ar.2n			43.02	43.02	9.64	9.64
LO <i>Calcidiscus macintyreii</i>	5H-6, 10-11	5H-7, 58-62	45.10	47.08	9.72	9.80
T C5n.1n			45.47	45.47	9.74	9.74
B C5n.1n			47.56	47.56	9.88	9.88
T C5n.2n			49.61	49.61	9.92	9.92
FO <i>Eucyrtidium pseudoinflatum</i>	6H-3, 45	6H-4, 45	50.45	51.95	10.08	10.37
LO <i>Actinomma golownini</i>	6H-4, 45	6H-6, 45	51.95	54.95	10.37	10.94
FO <i>Hemidiscus cuneiformis</i>	6H-4, 47-48	6H-5, 47-48	52.00	53.50	10.38	10.66
B C5n.2n			55.00	55.00	10.95	10.95
B C5r.1n			56.45	56.45	?	?
T C5r.2n			56.80	56.80	?	?
B C5r.2n			57.10	57.10	11.53	11.53
FO <i>Cycladophora spongothorax</i>	7H-2, 45	7H-3, 45	58.45	59.45	11.66	11.76
LO <i>Denticulopsis praedimorpha</i>	7H-2, 47-49	7H-3, 47-49	58.50	60.00	11.67	11.81
LO <i>Nitzschia denticuloides</i>	7H-3, 47-49	7H-4, 47-49	60.00	61.50	11.81	11.98
FO <i>Reticulofenestra hesslandii</i>	7H-4, 10-11	7H-5, 62-63	61.15	63.08	11.93	12.18
T C5An.1n			61.30	61.30	11.94	11.94
B C5An.1n			62.10	62.10	12.08	12.08
B C5An.2n			65.10	65.10	12.40	12.40
FO <i>Actinomma golownini</i>	7H-CC	8H-1.45	66.00	66.50	12.88	13.11
FO <i>Denticulopsis dimorpha</i>	7H-CC	8H-1, 47-49	66.00	66.50	12.88	13.14
LO <i>Actinocyclus ingens v. nodus</i>	7H-CC	8H-1, 47-49	66.00	66.50	12.88	13.14
FO <i>Denticulopsis praedimorpha</i>	7H-CC	8H-1, 47-49	66.00	66.50	12.88	13.14
LO <i>Nitzschia grossepunctata</i>	8H-1, 47-49	8H-2, 47-49	66.50	68.00	13.14	13.57
LO <i>Coscinodiscus lewisianus</i>	8H-1, 47-49	8H-2, 47-49	66.50	68.00	13.14	13.57
T C5ABn			66.80	66.80	13.30	13.30
B C5ABn			66.95	66.95	13.51	13.51
FO <i>Nitzschia denticuloides</i>	9H-6, 47-49	9H-7, 47-49	67.97	69.47	13.57	13.66
T C5ACn			70.10	70.10	13.70	13.70
B C5ACn			72.00	72.00	14.08	14.08
FO <i>Denticulopsis hustedtii</i>	8H-5, 47-49	8H-6, 47-49	72.50	74.00	14.14	14.32
T C5ADn			72.80	72.80	14.18	14.18
LO <i>Denticulopsis maccolumnii</i>	8H-6, 47-49	8H-CC	74.00	75.50	14.32	14.49
FO <i>Actinocyclus ingens v. nodus</i>	8H-CC	9H-2, 47-49	75.50	77.49	14.49	14.68
LO <i>Synedra jouseana</i>	8H-CC	9H-2, 47-49	75.50	79.10	14.49	14.80
LO <i>Crucidenticula kanayae</i>	9H-2, 47-49	9H-4, 47-49	76.06	79.06	14.56	14.80
B C5ADn			76.50	76.50	14.61	14.61

Table 35. (continued)

	Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
T	C5Bn.1n			79.10	79.10	14.80	14.80
B	C5Bn.1n			80.00	80.00	14.89	14.89
B	C5Bn.2n			81.30	81.30	15.16	15.16
FO	<i>Actinocyclus ingens</i>	9H-CC	10H-1, 47-48	85.00	85.50	15.91	16.01
FO	<i>Nitzschia grossepunctata</i>	9H-CC	10H-1, 47-49	85.00	85.50	15.91	16.01
FO	<i>Denticulopsis lauta</i>	9H-CC	10H-1, 47-49	85.00	85.60	15.91	16.02
T	C5Cn.1n			85.47	85.47	16.01	16.01
LO	<i>Reticulofenestra pseudumbilica</i>	10H-4, 10-11	10H-5, 58-62	89.60	91.58	16.51	16.75
B	C5Cn.3n			91.47	91.47	16.73	16.73
FO	<i>Denticulopsis maccollumii</i>	10H-5, 47-49	10H-6, 47-49	91.50	93.00	16.74	17.28
FO	<i>Calcidiscus macintyre</i>	10H-6, 58-62	10H-7, 20-24	93.08	94.20	17.17	17.45
T	C5Dn			93.50	93.50	17.28	17.28
FO	<i>Crucidentacula kanayae</i>	10H-7, 47-49	11H-1, 47-49	94.50	95.00	17.52	17.65
B	C5Dn			94.90	94.90	17.62	17.62
FO	<i>Calcidiscus leptoporus</i>	11H-1, 58-62	11H-2, 10-11	95.08	96.10	17.67	17.96
LO	<i>Thalassiosira fraga</i>	11H-3, 47-49	11H-5, 47-49	98.00	101.00	18.49	19.13
T	C6n			100.00	100.00	19.05	19.05
B	C6n			113.83	113.83	20.13	20.13
FO	<i>Thalassiosira fraga</i>	13H-1, 47-49	13H-2, 47-49	114.00	115.50	20.18	20.57
T	C6An.1n			115.07	115.07	20.52	20.52
B	C6An.1n			116.80	116.80	20.73	20.73
B	C6An.2n			118.68	118.68	21.32	21.32
LO	<i>Bogorovia veniamini</i>	13H-3, 47-49	13H-4, 47-49	119.00	120.00	21.48	22.00
FO	<i>Raphidodiscus marylandicus</i>	13H-5, 47-49	13H-6, 47-49	119.97	121.47	21.98	22.42
T	C6AAr.1n			120.30	120.30	22.15	22.15
T	C6AAr.2n			121.65	121.65	22.46	22.46
T	C6Bn.1n			123.10	123.10	22.59	22.59
LO	<i>Rocella gelida</i>	13H-CC	14H-1, 47-49	123.47	126.47	22.68	23.50
B	C6Bn.2n			125.05	125.05	23.07	23.07
T	C6Cn.1n			125.70	125.70	23.35	23.35
LO	<i>Lisitzina ornata</i>	14H-3, 47-49	14H-4, 47-49	126.00	128.00	23.34	23.80
B	C6Cn.1n			126.70	126.70	23.54	23.54
T	C6Cn.2n			127.60	127.60	23.68	23.68
LO	<i>Thalassiosira primalabiata</i>	14H-4, 47-49	14H-5, 47-49	128.00	129.50	23.78	24.11
LO	<i>Reticulofenestra bisecta</i>	14H-4, 58-62	14H-4, 10-12	128.08	129.10	23.80	24.03
B	C6Cn.2n			128.10	128.10	23.80	23.80
T	C6Cn.3n			128.90	128.90	24.00	24.00
B	C6Cn.3n			129.70	129.70	24.12	24.12
T	C7n.1n			132.10	132.10	24.73	24.73
B	C7n.1n			132.60	132.60	24.78	24.78
T	C7n.2n			133.10	133.10	24.84	24.84
B	C7n.2n			133.60	133.60	25.18	25.18
LO	<i>Rocella vigilans</i>	15H-3, 47-49	15H-4, 47-49	135.97	137.47	25.37	25.50
T	C7An			137.50	137.50	25.50	25.50
B	C7An			138.30	138.30	25.65	25.65
T	C8n.1n			138.70	138.70	25.82	25.82
FO	<i>Rocella gelida</i>	15H-5, 47-49	15H-6, 47-49	140.00	140.50	25.89	25.92
B	C8n.1n			141.05	141.05	25.95	25.95
LO	<i>Chiasmolithus altus</i>	15H-7, 10-12	16H-1, 10-12	141.60	142.10	25.96	25.97
T	C8n.2n			143.17	143.17	25.99	25.99
FO	<i>Lisitzina ornata</i>	16H-CC	17H-1, 47-49	151.50	151.50	26.53	?
FO	<i>Rocella vigilans</i>	16H-CC	17H-1, 47-49	151.50	151.97	26.53	?
B	C8n.2n			151.84	151.84	26.55	26.55

Data sets are integrated from the work of numerous authors (see Table 2).

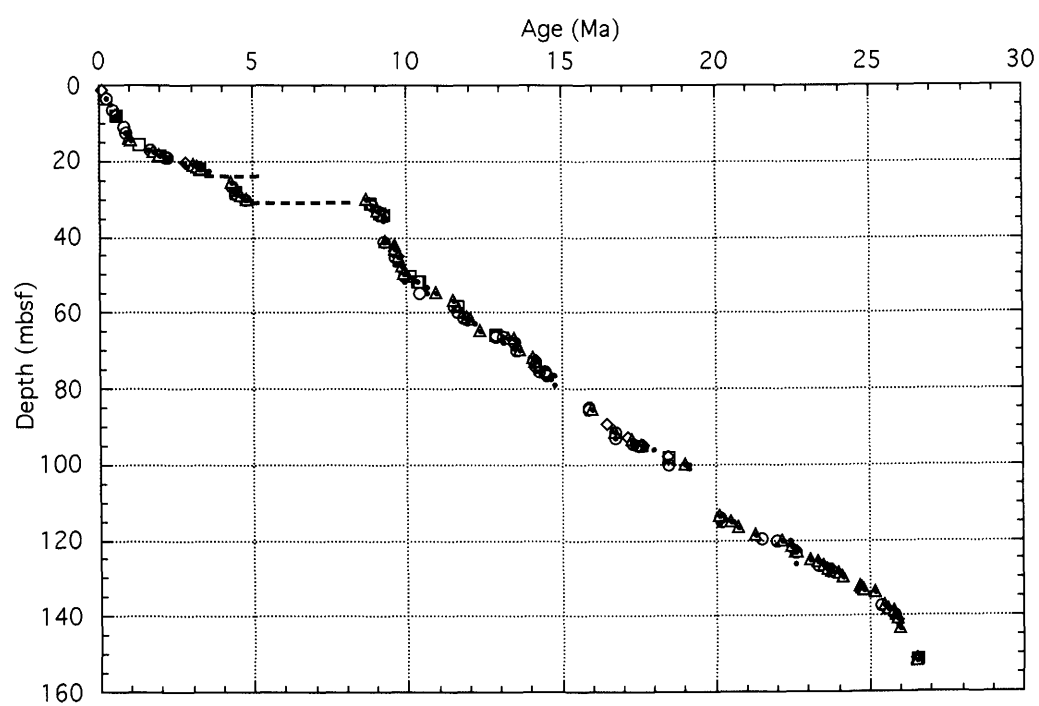


Fig. 50. An age–depth plot for DSDP Hole 747A utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Hole 747B

Six cores were recovered from a total penetration of 53.3 mbsf representing a recovery of 97% of the cored interval. Sediments recovered consist of Quaternary to upper Miocene diatom and nannofossil ooze (Wise *et al.* 1989). A palaeomagnetic polarity record was obtained for the Quaternary to upper Miocene sequence. Shipboard workers resolved their inability to recognize short polarity reversal by shorebase measurements of discrete samples (Wise *et al.* 1989; Heider *et al.* 1992). Diatoms, calcareous nannofossils and radiolarians are observed in the sequence recovered. Diatoms are abundant and well preserved in the Quaternary and Pliocene and are few and moderately preserved in the Miocene. Calcareous nannofossils are recorded from the sedimentary section. Radiolarians are common to abundant and generally well preserved in the Quaternary to Miocene sediments (Wise *et al.* 1989). The integrated biostratigraphical and magnetostratigraphical data previously used (palaeomagnetism: Heider *et al.* 1992; diatoms: Harwood & Maruyama 1992; calcareous nannofossils: none; radiolarians: Lazarus 1992) and calibrated to the GPTS of Berggren *et al.* (1985a, b) is shown in Table 36. An age–depth graph for Hole 120-747B using these data is shown in Fig. 51.

Figure 52 compares the polarity chronozones (Heider *et al.* 1992) and diatom zones assigned by previous workers (Harwood & Maruyama 1992) with the chronozoneal and diatom zonal assignments in this study. The stratigraphical ranges reflect the placement of FO and LO of stratigraphically useful species as recognized by Harwood & Maruyama (1992) and Lazarus (1990), respectively. The revised chronozones and diatom zones illustrated are based on reassessing the data sets of these workers (Table 37). Comparison of the chronozoneal assignments of Heider *et al.* (1992; Table 36) to

those of this study (Table 37) indicates that the chronozoneal placements are similar.

Figure 53 shows an age–depth graph for Hole 120-747B using the stratigraphical markers determined in this study. The polarity sequence in this hole has intervals of uncertainty (Fig. 52). One hiatus is identified at approximately 28.5 mbsf. The upper boundary of this break is constrained by the FO of *Nitzschia interfrigidaria* (21.80–23.80 mbsf), the FO of *Helotholus vema* (24.4–25.1 mbsf), the FO of *Nitzschia barronii* (26.80–28.10) and the FO of *Nitzschia praeinterfrigidaria* (28.1–28.3 mbsf). The lower boundary is constrained by the top of C4An (29.54 mbsf) and the base of C4An (30.33 mbsf).

Harwood & Maruyama (1992) recognize three hiatuses. The stratigraphical break between 12.30 and 12.8 mbsf is based on the absence of *Thalassiosira vulnifica* in this hole and a single occurrence of this species in Hole 747A. The LO of *Thalassiosira kolbei* (12.80–14.30 mbsf) in conjunction with the base of C1n (7.63 mbsf) and the top of C2An.1n (13.6 mbsf) suggest a possibly continuous record. The LO of *Thalassiosira vulnifica* is considered a primary marker and the absence of this species/event in this hole may support placement of a stratigraphical break. The intermediate hiatus between 26.8 and 28.06 mbsf is based on a single occurrence of *Nitzschia barronii* in this hole compared with a more continuous occurrence of this species in Hole 747A. The placement of this break approximates the hiatus identified in this study. In the absence of primary stratigraphical markers we are unable to evaluate the placement of the hiatus recorded between 31.81 and 36.31 mbsf which Harwood & Maruyama (1992) base on the absence of *Hemidiscus ovalis*.

Table 36. Composite dataset for ODP Hole 747B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Actinocyclus ingens</i>	1H-2, 144-145	1H-CC	2.50	2.80	0.67	0.75
FO <i>Nitzschia weaveri</i>	1H-CC	2H-1, 20-21	2.80	3.00	0.75	0.80
LO <i>Thalassiosira elliptopora</i>	1H-CC	2H-1, 20-21	2.80	3.00	0.75	0.80
B C1n			2.90	2.90	0.78	0.78
B C2n			7.63	7.63	1.95	1.95
FO <i>Thalassiosira oestrupii</i>	2H-CC	3H-1, 50-51	12.30	12.80	?	?
Unconformity			***	***	***	***
LO <i>Thalassiosira inura</i>	3H-1, 50-51	3H-2, 50-51	12.80	14.30	?	?
LO <i>Thalassiosira kolbei</i>	3H-1, 50-51	3H-2, 50-51	12.80	14.30	?	?
FO <i>Actinocyclus actinochilus</i>	3H-2, 50-51	3H-5, 147-148	14.30	19.80	?	?
LO <i>Hemidiscus karstenii</i>	3H-2, 50-51	3H-5, 147-148	14.30	19.80	?	?
LO <i>Nitzschia interfrigidaria</i>	3H-2, 50-51	3H-5, 147-148	14.30	19.80	?	?
FO <i>Nitzschia kerguelensis</i>	3H-2, 50-51	3H-5, 147-148	14.30	19.80	?	?
FO <i>Thalassiosira elliptopora</i>	3H-2, 50-51	3H-5, 147-148	14.30	19.80	?	?
LO <i>Thalassiosira insigna</i>	3H-2, 50-51	3H-5, 147-148	14.30	19.80	?	?
FO <i>Thalassiosira lentiginosa</i>	3H-2, 50-51	3H-5, 147-148	14.30	19.80	?	?
T C2An.1n			17.92	17.92	2.58	2.58
B C2An.2n			21.32	21.32	3.22	3.22
FO <i>Nitzschia interfrigidaria</i>	3H-CC	4H-2, 50-51	21.80	23.80	3.30	?
LO <i>Nitzschia praeinterfrigidaria</i>	3H-CC	4H-2, 50-51	21.80	23.80	3.30	?
FO <i>Thalassiosira insigna</i>	3H-CC	4H-2, 50-51	21.80	23.80	3.30	?
FO <i>Thalassiosira kolbei</i>	3H-CC	4H-2, 50-51	21.80	23.80	3.30	?
LO <i>Lampromitra coronata</i>	3H-CC	4H-2, 32	21.80	23.62	3.30	?
LO <i>Nitzschia barronii</i>	4H-2, 50-51	4H-4, 50-51	23.80	26.80	3.60	?
FO <i>Helotholus vema</i>			24.42	25.12	3.75	?
FO <i>Nitzschia barronii</i>	4H-4, 50-51	4H-5, 50-51	26.80	28.10	4.17	?
FO <i>Thalassiosira inura</i>	4H-4, 50-51	4H-5, 26-27	26.80	28.10	4.17	?
T C3n.1n			26.84	26.84	4.18	4.18
Unconformity			***	***	***	***
FO <i>Nitzschia praeinterfrigidaria</i>	4H-5, 26-27	4H-5, 50-51	28.10	28.30	?	?
LO <i>Denticulopsis dimorpha</i>	4H-5, 50-51	4H-CC	28.30	31.30	?	?
LO <i>Thalassiosira miocenica</i>	4H-5, 50-51	4H-CC	28.30	31.30	?	?

(continued)

Table 36. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
T C3n.2n			29.54	29.54	4.48	4.48
B C3n.2n			30.33	30.33	4.62	4.62
FO <i>Nitzschia reinholdii</i>	4H-CC	5H-1, 50-51	31.30	31.80	5.19	5.49
FO <i>Thalassiosira miocenica</i>	4H-CC	5H-1, 50-51	31.30	31.80	5.19	5.49
FO <i>Acrosphaera labrata</i>	4H-CC	5H-1, 32	31.30	31.62	5.19	5.38
LO <i>Cycladophora spongothorax</i>	5H-1, 32	5H-1, 112	31.62	34.42	5.38	6.45
LO <i>Asteromphalus kennettii</i>	5H-1, 50-51	5H-4, 50-51	31.80	36.30	5.49	?
B C3An.1n			32.90	32.90	6.14	6.14
B C3An.2n			35.00	35.00	6.57	6.57
Unconformity			***	***	***	***
T C4An			36.32	36.32	8.70	8.70
FO <i>Asteromphalus kennettii</i>	5H-5, 50-51	5H-CC	37.80	40.80	8.88	9.77
B C4An			39.10	39.10	9.03	9.03
T C5n.1n			40.53	40.53	9.74	9.74
FO <i>Thalassiosira torokina</i>	5H-CC	6H-1, 67-68	40.80	41.50	9.77	9.87
LO <i>Actinomma golownini</i>	6H-4, 113	6H-5, 32	46.43	47.12	10.53	10.62
FO <i>Acrosphaera australis</i>	6H-7, 16	6H-CC	47.93	49.43	10.73	10.93
FO <i>Eucyrtidium pseudoinflatum</i>	6H-6, 32	6H-6, 113	48.62	49.43	10.82	10.93
B C5n.2n			49.61	49.61	10.95	10.95
FO <i>Cycladophora spongothorax</i>	6H-7, 16	6H-CC	49.96	50.30	10.99	?
LO <i>Denticulopsis praedimorpha</i>	6H-7, 20-23	6H-CC	50.00	50.30	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

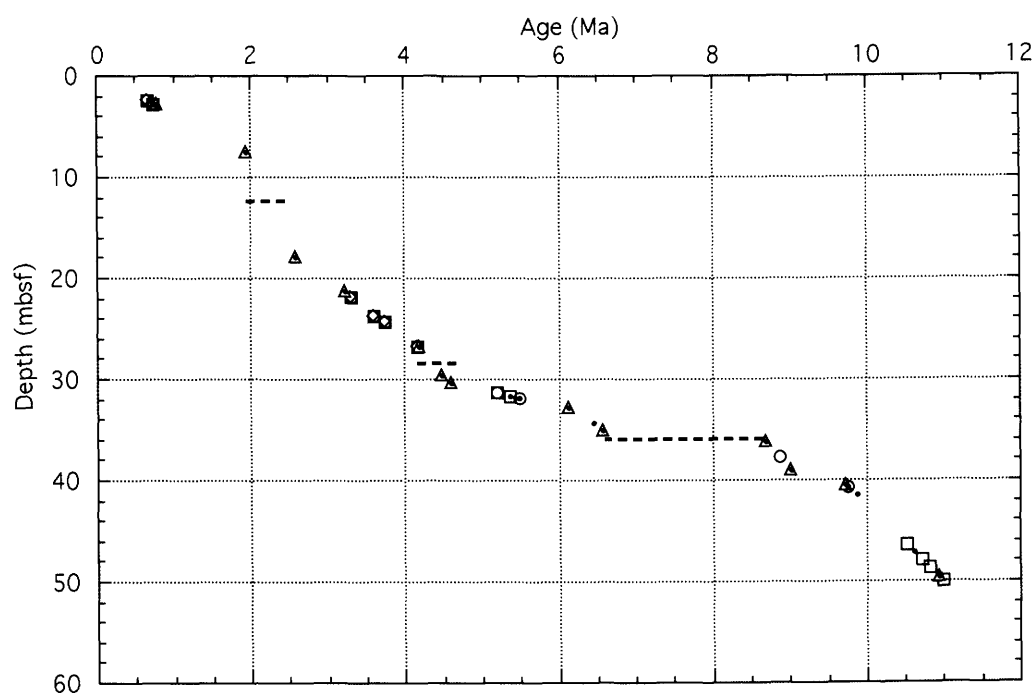


Fig. 51. An age-depth plot for DSDP Hole 747B utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Fig. 52. Comparison of the ODP Hole 747B polarity chronozones and diatom zonal assignments by previous workers with the chronozone assignments of this study. The stratigraphical ranges of selected stratigraphical markers are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995). Diagonal lines indicate intervals of uncertainty.

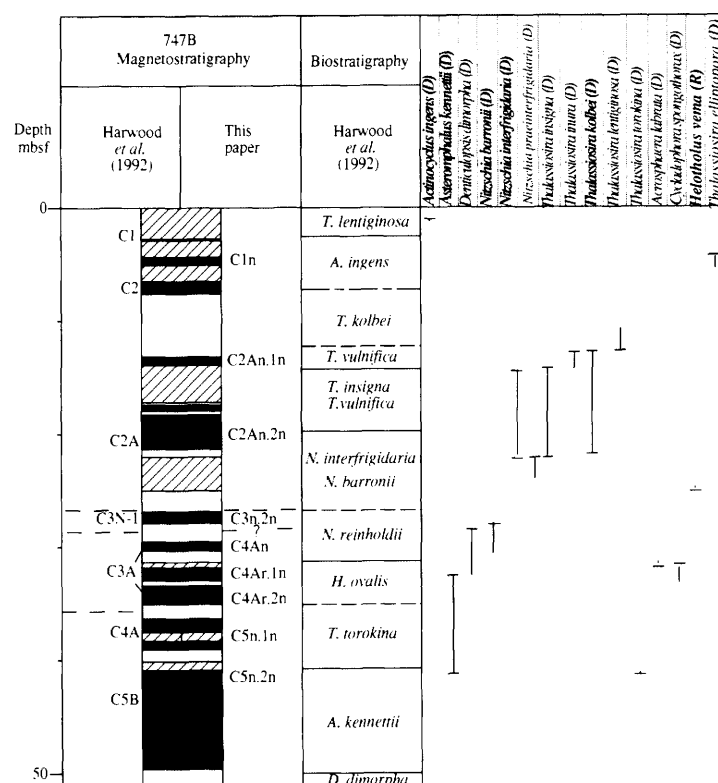


Table 37. Composite dataset for ODP Hole 747B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Actinocyclus ingens</i>	1H-2, 144-145	1H-CC	2.50	2.80	0.26	0.29
FO <i>Nitzschia weaveri</i>	1H-CC	2H-1, 20-21	2.80	3.00	0.29	0.31
LO <i>Thalassiosira elliptopora</i>	1H-CC	2H-1, 20-21	2.80	3.00	0.29	0.31
B C1n			7.63	7.63	0.78	0.78
FO <i>Thalassiosira oestrupii</i>	2H-CC	3H-1, 50-51	12.30	12.80	2.30	2.46
LO <i>Thalassiosira inura</i>	3H-1, 50-51	3H-2, 50-51	12.80	14.30	2.46	2.70
LO <i>Thalassiosira kolbei</i>	3H-1, 50-51	3H-2, 50-51	12.80	14.30	2.46	2.70
T C2An.1n			13.16	13.16	2.58	2.58
FO <i>Actinocyclus actinochilus</i>	3H-2, 50-51	3H-5, 147-148	14.30	19.80	2.70	3.17
LO <i>Hemidiscus karstenii</i>	3H-2, 50-51	3H-5, 147-148	14.30	19.80	2.70	3.17
LO <i>Nitzschia interfrigidaria</i>	3H-2, 50-51	3H-5, 147-148	14.30	19.80	2.70	3.17
FO <i>Nitzschia kerguelensis</i>	3H-2, 50-51	3H-5, 147-148	14.30	19.80	2.70	3.17
FO <i>Thalassiosira elliptopora</i>	3H-2, 50-51	3H-5, 147-148	14.30	19.80	2.70	3.17
LO <i>Thalassiosira insigna</i>	3H-2, 50-51	3H-5, 147-148	14.30	19.80	2.70	3.17
FO <i>Thalassiosira lentiginosa</i>	3H-2, 50-51	3H-5, 147-148	14.30	19.80	2.70	3.17
B C2An.1n			17.40	17.40	3.04	3.04
T C2An.2n			17.92	17.92	3.11	3.11
B C2An.2n			21.32	21.32	3.22	3.22
LO <i>Lampromitra coronata</i>	3H-CC	4H-2, 32	21.80	23.62	?	?
FO <i>Nitzschia interfrigidaria</i>	3H-CC	4H-2, 50-51	21.80	23.80	?	?
LO <i>Nitzschia praeinterfrigidaria</i>	3H-CC	4H-2, 50-51	21.80	23.80	?	?
FO <i>Thalassiosira insigna</i>	3H-CC	4H-2, 50-51	21.80	23.80	?	?
FO <i>Thalassiosira kolbei</i>	3H-CC	4H-2, 50-51	21.80	23.80	?	?
LO <i>Nitzschia barronii</i>	4H-2, 50-51	4H-4, 50-51	23.80	26.80	?	?
FO <i>Helotholus vema</i>	4H-2, 112	4H-3, 32	24.42	25.12	?	?
Unconformity (?)			***	***	***	***
FO <i>Nitzschia barronii</i>	4H-4, 50-51	4H-5, 50-51	26.80	28.10	4.47	?
FO <i>Thalassiosira inura</i>	4H-4, 50-51	4H-5, 26-27	26.80	28.10	4.47	?
T C3n.2n			26.84	26.84	4.48	4.48
FO <i>Nitzschia praeinterfrigidaria</i>	4H-5, 26-27	4H-5, 50-51	28.10	28.30	?	?
Unconformity			***	***	***	***
LO <i>Denticulopsis dimorpha</i>	4H-5, 50-51	4H-CC	28.30	31.30	?	?
LO <i>Thalassiosira miocenica</i>	4H-5, 50-51	4H-CC	28.30	31.30	?	?
T C4An			29.54	29.54	8.70	8.70
B C4An			30.33	30.33	9.03	9.03
FO <i>Nitzschia reinholdii</i>	4H-CC	5H-1, 50-51	31.30	31.80	9.14	9.14

(continued)

Table 37. (continued)

Event		Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO	<i>Thalassiosira miocenica</i>	4H-CC	5H-1, 50-51	31.30	31.80	9.14	9.14
FO	<i>Acrosphaera labrata</i>	4H-CC	5H-1, 32	31.30	31.62	9.14	9.17
LO	<i>Cycladophora spongothorax</i>	5H-1, 32	5H-1, 112	31.62	34.42	9.17	9.62
LO	<i>Asteromphalus kennettii</i>	5H-1, 50-51	5H-4, 50-51	31.80	36.30	9.19	9.74
B	C4Ar.1n			32.90	32.90	9.31	9.31
T	C4Ar.2n			33.40	33.40	9.58	9.58
B	C4Ar.2n			35.00	35.00	9.64	9.64
T	C5n.1n			36.32	36.32	9.74	9.74
FO	<i>Asteromphalus kennettii</i>	5H-5, 50-51	5H-CC	37.80	40.80	9.81	9.95
B	C5n.1n			39.10	39.10	9.88	9.88
T	C5n.2n			40.53	40.53	9.92	9.92
FO	<i>Thalassiosira torokina</i>	5H-CC	6H-1, 67-68	40.80	41.50	9.95	10.03
LO	<i>Actinomma golownini</i>	6H-4, 113	6H-5, 32	46.43	47.12	10.59	10.67
FO	<i>Acrosphaera australis</i>	6H-7, 16	6H-CC	47.93	49.43	10.76	10.93
FO	<i>Eucyrtidium pseudoinflatum</i>	6H-6, 32	6H-6, 113	48.62	49.43	10.84	10.93
B	C5n.2n			49.61	49.61	10.95	10.95
FO	<i>Cycladophora spongothorax</i>	6H-7, 16	6H-CC	49.96	50.30	10.99	?
LO	<i>Denticulopsis praedimorpha</i>	6H-7, 20-23	6H-CC	50.00	50.30	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

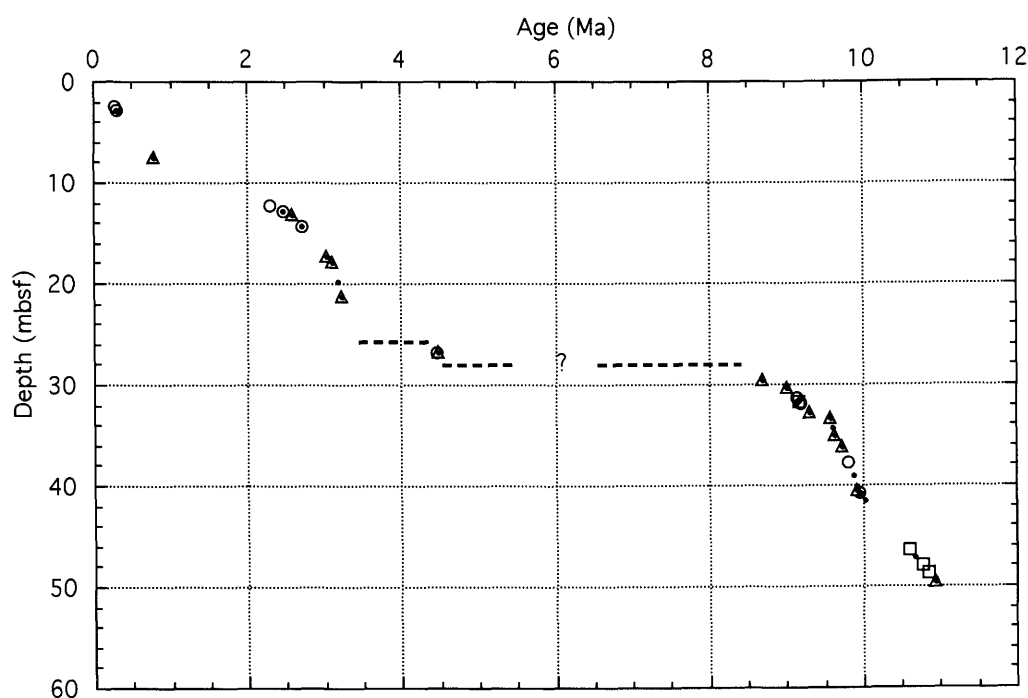


Fig. 53. An age-depth plot for DSDP Hole 747B utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Hole 748B

Twenty-five cores were recovered from a total penetration of 225.1 mbsf representing a recovery of 84% of the cored interval. Sediments recovered consist of Quaternary to Pliocene diatom ooze, upper Miocene to middle Eocene calcareous nannofossils ooze, and middle Eocene chalk with chert. A palaeomagnetic polarity record was obtained for the Quaternary to middle Eocene portion of the section (Wise *et al.* 1989; Inokuchi & Heider 1992). Abundant and well-preserved diatoms occur in Quaternary to lower Oligocene sediments. Eocene diatoms are poorly preserved. Calcareous nannofossils are generally absent in Quaternary and Pliocene sediments (Wei & Wise 1992a). Miocene and upper Eocene calcareous nannofossils are abundant and moderately preserved (Wei & Wise 1992a; Aubry 1992). Radiolarians were observed in samples examined throughout the Quaternary to middle Miocene sediments and significant reworking is recorded in upper Pliocene sediments (Wise *et al.* 1989). The integrated biostratigraphical and magnetostratigraphical data previously used (palaeomagnetism: Inokuchi & Heider 1992; Harwood *et al.* 1992; diatoms: Harwood & Maruyama 1992; calcareous nannofossils: Wei & Wise 1992; Wei 1992; radiolarians: Abelman 1992; Lazarus 1992) and calibrated to the GPTS of Berggren *et al.* (1985a, b) is shown in Table 38. An age–depth graph for Hole 120-748B using this data is shown in Fig. 54.

Figure 55 compares the polarity chronozones and diatom zones assigned by previous workers (Inokuchi & Heider 1992; Harwood & Maruyama 1992) with the chronozone and diatom zonal assignments used in this study. In addition, this figure illustrates the stratigraphical ranges of diatoms, radiolarians and calcareous nannofossils. The stratigraphical ranges reflect the placement of FO and LO of stratigraphically useful species as recognized by Harwood & Maruyama (1992), Abelman (1992), Lazarus (1992) and Wei & Wise (1992), respectively. The revised chronozones and diatom zones illustrated are based on reassessing the data sets of these workers (Table 38). Comparison of the chronozone assignments of Wise *et al.* (1989) and Inokuchi & Heider (1992) with those of this study (Table 39) indicate only minimal modifications based either on differences in GPTS or in the species selected for biostratigraphical control. There are significant modifications concerning the continuity of the sequence.

Figure 56 shows an age–depth graph for Hole 120-748B using the stratigraphical markers determined in this study. Four hiatuses are identified. The youngest occurs between 2.8 and 3.0 mbsf based on then joint LO of *Thalassiosira kolbei* and *Thalassiosira vulnifica*. The intermediate hiatus occurs between 10.10 and

11.60 mbsf and is constrained by the FO of *Nitzschia barronii* and *Nitzschia praeinterfrigidaria* at a depth of 10.00–10.30, the FO of *Nitzschia interfrigidaria* (8.00–8.40 mbsf) and the base of C3n.1n (6.95 mbsf). The two oldest unconformities occur at approximately 38 and 40 mbsf respectively. Placement of these two breaks is constrained by a continuous succession of magnetic reversals to C5r.2n (37.6 mbsf), above the interval, and the FO of *Crucidentula kanayae* (41.6–43.10 mbsf) below the interval. The primary markers, the FO of *Denticulopsis hustedtii* the FO of *Nitzschia denticuloides* and the FO of *Denticulopsis praedimorpha* between 38.10 and 38.6 mbsf separate these two unconformities.

This study suggests that the stratigraphical section may be more continuous than previously recognized. Harwood & Maruyama (1992) identified 13 hiatuses. The youngest occurs at 0–0.10 mbsf. A second hiatus 2.80 and 3.00 mbsf is based on the co-occurrence of the LO of *Thalassiosira kolbei*, *Thalassiosira vulnifica* and *Thalassiosira insigna*. We concur with the placement of a hiatus at 2.80 mbsf. An additional hiatus is placed between 10.03 and 10.28 mbsf. This coincides with the placement of the second hiatus identified in this study. Harwood & Maruyama (1992) place a hiatus at 19.57–21.07 mbsf using a criterion similar to that at Hole 747A, namely the absence of a gap between the last common occurrence of *Denticulopsis dimorpha* and the FO of *Asteromphalus kennettii*. The two hiatuses recognized by Harwood & Maruyama (1992) between 38.10 and 38.57 mbsf, and 38.57 and 40.07 mbsf approximate the two older hiatuses recognized in this study. These workers define a hiatus at 57.1–57.50 mbsf based on the stratigraphical relationship between *Rosella symmetrica*, *Azpeitia gombosi* and *Thalassiosira fraga*. In this study the chronostratigraphy of the FO of *Thalassiosira fraga* is shown to be a potentially useful marker, and there is minimal data available to assess the chronostratigraphical reliability of the other two species. Harwood & Maruyama (1992) place four additional hiatuses at 60.57–63.57, 68.57–70.07, 70.07–71.57 and 79.57–81.07 mbsf. This series of hiatuses occur within a polarity sequence which is interpreted to be continuous from the base C6Bn.2n (62.20) to the base of C15n at 119.07. Although no primary events are identified in this interval the LO of *Reticulofenestra oamaruensis* (115.84–115.94) is used to constrain the base of the hole. Harwood & Maruyama (1992) recognize two additional hiatuses at 89.07–90.57 and 107.26–108.08 mbsf based on the stratigraphical ranges of *Rocella vigilans* var. A and *Triceratium polymorphus*. The succession of diatom markers as used by these workers is complete throughout this entire stratigraphical interval and we question the placement of these hiatuses.

Table 38. Composite dataset for ODP Hole 748B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
Unconformity			***	***	***	***
B C1n			1.30	1.30	0.78	0.78
LO <i>Triceratium antarctica</i>	2H-2, 45	2H-3, 0	2.05	3.10	?	?
LO <i>Prunopyles titan</i>	2H-2, 45	2H-3, 0	2.05	3.10	?	?
LO <i>Thalassiosira vulnifica</i>	2H-2, 120	2H-2, 140	2.07	2.80	?	?
LO <i>Nitzschia barronii</i>	2H-2, 47-48	2H-2, 100	2.10	2.80	?	?
LO <i>Nitzschia interfrigidaria</i>	2H-2, 120	2H-2, 140	2.80	3.00	?	?
FO <i>Thalassiosira elliptopora</i>	2H-2, 120	2H-2, 140	2.80	3.00	?	?
LO <i>Thalassiosira insigna</i>	2H-2, 120	2H-2, 140	2.80	3.00	?	?
LO <i>Thalassiosira inura</i>	2H-2, 120	2H-2, 140	2.80	3.00	?	?
LO <i>Thalassiosira kolbei</i>	2H-2, 120	2H-2, 140	2.80	3.00	?	?
Unconformity			***	***	***	***
LO <i>Cycladophora pliocenica</i>	2H-3, 0	2H-3, 150	3.10	4.60	?	?
LO <i>Eucyrtidium calvertense</i>	2H-3, 0	2H-3, 0	3.10	4.60	?	?
LO <i>Desmospyris spongiosa</i>	2H-3, 0	2H-3, 0	3.10	4.60	?	?
LO <i>Helotholus vema</i>	2H-3, 0	2H-3, 0	3.10	4.60	?	?
FO <i>Cycladophora davisiana</i>	2H-3, 0	2H-3, 0	3.10	4.60	?	?

(continued)

Table 38. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
FO <i>Thalassiosira insigna</i>	2H-3, 100	2H-3, 140	4.10	4.50	?	?
FO <i>Thalassiosira vulnifica</i>	2H-3, 100	2H-3, 140	4.10	4.50	?	?
LO <i>Hemidiscus karstenii</i>	2H-4, 140	2H-5, 20	6.00	6.30	?	?
LO <i>Simonseniella barboi</i>	2H-4, 140	2H-5, 20	6.30	6.60	?	?
LO <i>Nitzschia praeinterfrigidria</i>	2H-5, 20	2H-5, 80	6.30	6.90	?	?
FO <i>Helotholus vema</i>	2H-5, 45	2H-6, 45	6.55	8.55	?	?
FO <i>Thalassiosira torokina</i>	2H-5, 80	2H-5, 140	6.90	7.50	?	?
B C2An3n			6.95	6.95	3.58	3.58
FO <i>Nitzschia interfrigidaria</i>	2H-6, 40	2H-6, 80	8.00	8.40	?	?
LO <i>Lampromitra coronata</i>	2H-6, 45	2H-6, 45	8.05	10.60	?	?
LO <i>Navicula wisei</i>	2H-5, 140	2H-6, 140	8.40	8.80	?	?
FO <i>Navicula wisei</i>	2H-6, 120	2H-7, 40	8.80	9.60	?	?
FO <i>Rouxia heteropolara</i>	3H-1, 3	3H-1, 25	9.60	9.90	?	?
FO <i>Thalassiosira kolbei</i>	3H-1, 3	3H-1, 25	9.60	9.90	?	?
FO <i>Nitzschia barronii</i>	3H-1, 43	3H-1, 68	10.00	10.30	?	?
FO <i>Nitzschia praeinterfrigidria</i>	3H-1, 43	3H-1, 68	10.00	10.30	?	?
FO <i>Nitzschia reinholdii</i>	3H-1, 43	3H-1, 68	10.00	10.30	?	?
FO <i>Thalassiosira complicata</i>	3H-1, 43	3H-1, 68	10.00	10.30	?	?
FO <i>Thalassiosira inura</i>	3H-1, 43	3H-1, 68	10.00	10.30	?	?
FO <i>Thalassiosira oestrupii</i>	3H-1, 43	3H-1, 68	10.00	10.30	?	?
LO <i>Asteromphalus kennettii</i>	3H-1, 43	3H-1, 68	10.03	10.30	?	?
LO <i>Denticulopsis dimorpha</i>	3H-1, 68	3H-1, 110	10.10	10.30	?	?
Unconformity			***	***	***	***
LO <i>Neobrunia mirabilis</i>	3H-2, 47-48	3H-3, 47-48	11.60	13.10	?	?
T C4Ar.2n			13.80	13.80	9.23	9.23
T C5n.1n			17.25	17.25	9.74	9.74
FO <i>Asteromphalus kennettii</i>	3H-CC	4H-1, 47-48	19.10	19.60	?	?
LO <i>Cycladophora humerus</i>	3H-CC	4H-1, 45	19.10	19.55	?	?
FO <i>Acrosphaera australis</i>	4H-1, 45	4H-2, 45	19.55	21.05	?	?
FO <i>Eucyrtidium pseudoinflatum</i>	4H-1, 45	4H-2, 45	19.55	21.05	?	?
FO <i>Cycladophora spongothorax</i>	4H-1, 45	4H-2, 45	19.55	21.05	?	?
LO <i>Nitzschia denticuloides</i>	4H-1, 47-48	4H-2, 47-48	19.60	20.10	?	?
Unconformity			***	***	***	***
LO <i>Calcidiscus macintyreii</i>			21.18	22.68	?	?
B C5n.2n			25.10	25.10	10.95	10.95
B C5r.1n			26.90	26.90	11.10	11.10
LO <i>Denticulopsis praedimorpha</i>	5H-3, 47-48	5H-4, 47-48	32.10	33.60	11.33	11.40
T C5r.2n			35.40	35.40	11.48	11.48
FO <i>Denticulopsis lauta</i>	5H-6, 47-48	5H-7, 47-48	36.60	38.10	11.51	11.54
FO <i>Hemidiscus ovalis</i>	5H-6, 47-48	5H-7, 47-48	36.60	38.10	11.51	11.54
LO <i>Crucidenticula kanayae</i>	5H-6, 47-48	5H-7, 47-48	36.60	38.10	11.51	11.54
FO <i>Calcidiscus macintyreii</i>	5H-6, 58-62	5H-7, 10-11	36.70	37.62	11.51	11.54
B C5r.2n			37.60	37.60	11.53	11.53
LO <i>Coscinodiscus lewisianus</i>	5H-CC	6H-1, 47-48	38.10	38.60	?	?
Unconformity			***	***	***	***
FO <i>Actinocyclus ingens</i>	5H-CC	6H-1, 47-48	38.10	38.60	?	?
FO <i>Denticulopsis dimorpha</i>	5H-CC	6H-1, 47-48	38.10	38.60	?	?
FO <i>Denticulopsis hustedtii</i>	5H-CC	6H-1, 47-48	38.10	38.60	?	?
FO <i>Denticulopsis praedimorpha</i>	5H-CC	6H-1, 47-49	38.10	38.60	?	?
FO <i>Nitzschia denticuloides</i>	5H-CC	6H-1, 47-49	38.10	38.60	?	?
LO <i>Nitzschia grossepunctata</i>	5H-CC	6H-1, 47-49	38.10	38.60	?	?
FO <i>Dendrospyrus megaloccephalis</i>	5H-CC	6H-1, 65	38.10	38.75	?	?
FO <i>Actinomma golownini</i>	5H-CC	6H-1, 65	38.10	38.75	?	?
Unconformity			***	***	***	***
FO <i>Denticulopsis maccolumnii</i>	6H-1, 47-48	6H-2, 47-48	38.60	40.10	?	?
FO <i>Nitzschia grossepunctata</i>	6H-1, 47-48	6H-2, 47-48	38.60	40.10	?	?
LO <i>Nitzschia maleinterpretaria</i>	6H-1, 47-48	6H-2, 47-48	38.60	40.10	?	?
Unconformity			***	***	***	***
T C5Bn.2n			39.80	39.80	15.03	15.03
Unconformity			***	***	***	***
LO <i>Denticulopsis maccolumnii</i>	5H-CC	6H-1, 47-49	40.07	41.57	?	?
LO <i>Thalassiosira fraga</i>	6H-2, 47-48	6H-3, 47-48	40.10	41.60	?	?
FO <i>Crucidenticula kanayae</i>	6H-3, 47-48	6H-4, 47-48	41.60	43.10	?	?
FO <i>Calcidiscus leptoporus</i>	6H-3, 58-62	6H-4, 58-62	41.68	43.68	?	?
B C5Dn			42.00	42.00	17.62	17.62
LO <i>Reticulofenestra pseudoumbilica</i>	6H-5, 58-62	6H-6, 58-62	44.70	46.70	18.02	18.29
T C5En			46.50	46.50	18.28	18.28
B C5En			53.69	53.69	18.78	18.78
LO <i>Thalassiosira spumellaroides</i>	7H-5, 47-48	7H-6, 47-48	54.07	55.57	18.85	?

Table 38. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
T C6n			55.20	55.20	19.05	19.05
Unconformity			***	***	***	***
FO <i>Nitzschia maleinterpretaria</i>	7H-CC	8H-1, 47-49	57.10	57.60	?	?
T C6A.2n			58.90	58.90	21.00	21.00
FO <i>Thalassiosira fraga</i>	8H-2, 47-48	8H-3, 47-48	59.10	60.60	?	?
FO <i>Thalassiosira spumellaroides</i>	8H-7, 47-48	8H-CC	60.57	63.57	?	?
LO <i>Bogorovia veniamini</i>	8H-3, 47-48	8H-5, 47-48	60.57	63.57	?	?
LO <i>Thalassiosira primalabiata</i>	8H-3, 47-48	8H-5, 47-48	60.57	63.57	?	?
Unconformity			***	***	***	***
B C6Bn.1n			62.20	62.20	22.75	22.75
B C6Cn.1n			64.00	64.00	23.54	23.54
LO <i>Reticulofenestra bisecta</i>	8H-7, 55-59	9H-1, 10-11	66.65	66.70	?	?
LO <i>Rocella vigilans</i>	9H-2, 47-48	9H-3, 47-48	68.60	70.10	?	?
LO <i>Lisitzina ornata</i>	9H-2, 47-48	9H-3, 47-48	68.60	70.10	?	?
T C7n.1n			69.60	69.60	24.73	24.73
Unconformity			***	***	***	***
FO <i>Rocella gelida</i>	9H-3, 47-48	9H-6, 47-48	70.10	71.60	?	?
Unconformity			***	***	***	***
T C8n.1n			71.10	71.10	25.82	25.82
LO <i>Chiasmolithus altus</i>	9H-5, 10-11	9H-6, 10-11	72.20	72.70	25.93	?
B C8n.1n			72.40	72.40	25.95	25.95
Unconformity			***	***	***	***
B C11n.2n			98.80	98.80	30.10	30.10
FO <i>Rocella vigilans</i>	12H-4, 47-49	12H-5, 47-49	100.07	101.57	30.29	30.52
T C12n			101.29	101.29	30.48	30.48
B C12n			104.90	104.90	30.94	30.94
FO <i>Cyclicargolithus abisectus</i>	13H-1, 10-11	13H-2, 10-11	104.70	106.20	30.89	31.25
LO <i>Isthmolithus recurvus</i>	13H-4, 10-11	13H-5, 10-11	109.80	113.30	32.11	32.94
T C13n			113.80	113.80	33.06	33.06
B C13n			114.70	114.70	33.55	33.55
LO <i>Reticulofenestra oamaruensis</i>	14H-2, 24-26	14H-3, 24-26	115.84	115.95	33.74	33.76
T C16n.1n			125.25	125.25	35.34	35.34

Data sets are integrated from the work of numerous authors (see Table 2).

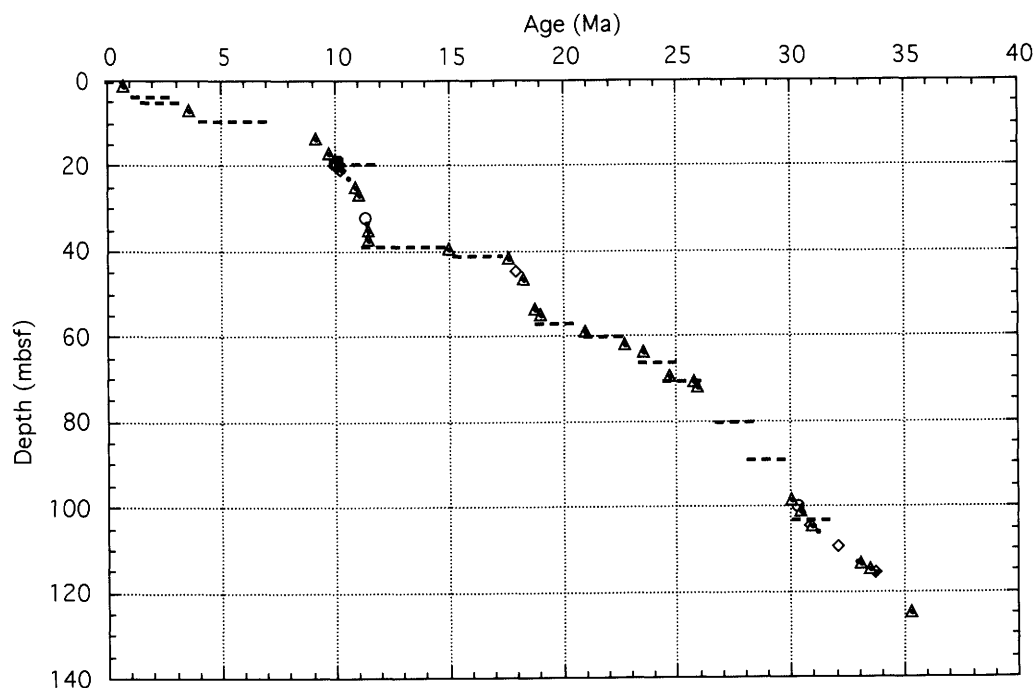


Fig. 54. An age-depth plot for DSDP Hole 748B utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

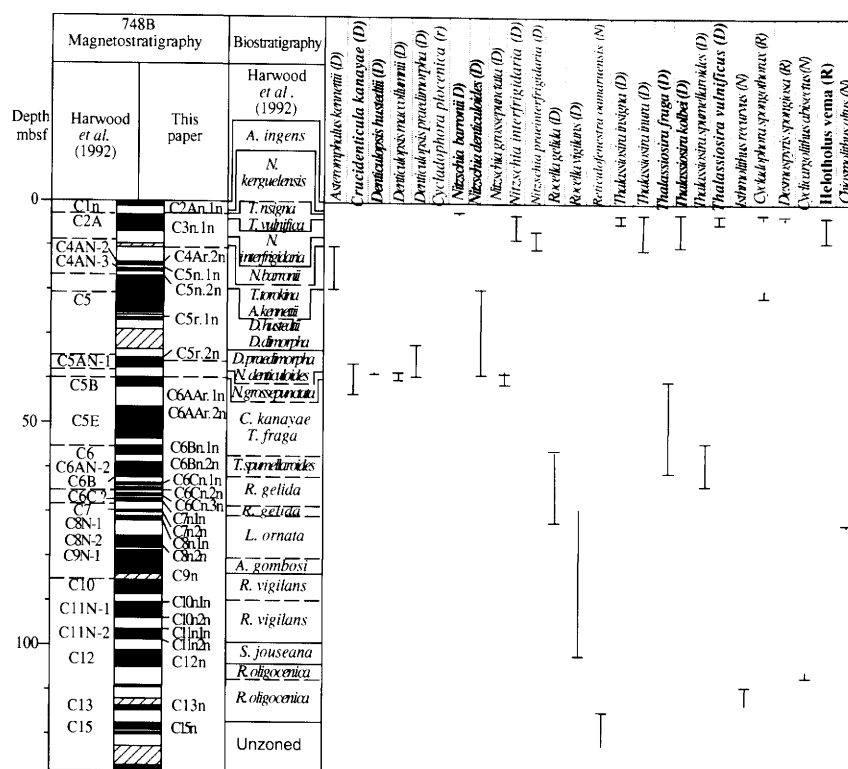


Fig. 55. Comparison of the ODP Hole 748B polarity chronozones and diatom zonal assignments by previous workers with the chronozone assignments of this study. The stratigraphical ranges of selected stratigraphical markers are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995). Diagonal lines indicate intervals of uncertainty.

Table 39. Composite dataset for ODP Hole 748B containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
Unconformity			***	***	***	***
B C1n			1.30	1.30	0.78	0.78
LO <i>Tricerapys antarctica</i>	2H-2, 45	2H-3, 0	2.05	3.10	1.62	2.81
LO <i>Prunopyle titan</i>	2H-2, 45	2H-3, 0	2.05	3.10	1.62	2.81
LO <i>Nitzschia barronii</i>	2H-2, 47-48	2H-2, 100	2.10	2.80	1.68	2.47
LO <i>Nitzschia interfrigidaria</i>	2H-2, 120	2H-2, 140	2.80	3.00	2.47	2.69
LO <i>Thalassiosira kolbei</i>	2H-2, 120	2H-2, 140	2.80	3.00	2.47	2.69
LO <i>Thalassiosira inura</i>	2H-2, 120	2H-2, 140	2.80	3.00	2.47	2.69
LO <i>Thalassiosira insigna</i>	2H-2, 120	2H-2, 140	2.80	3.00	2.47	2.69
LO <i>Thalassiosira vulnifica</i>	2H-2, 120	2H-2, 140	2.80	3.00	2.47	2.69
T C2An.1n			2.90	2.90	2.58	2.58
FO <i>Thalassiosira insigna</i>	2H-2, 120	2H-2, 140	4.10	4.50	3.09	3.26
FO <i>Thalassiosira vulnifica</i>	2H-2, 120	2H-2, 140	4.10	4.50	3.09	3.26
LO <i>Cycladophora plicocenic</i>	2H-3, 0	2H-3, 150	3.10	4.60	2.66	3.30
LO <i>Eucyrtidium calvertense</i>	2H-3, 0	2H-3, 0	3.10	4.60	2.66	3.30
LO <i>Desmospyris spongiosa</i>	2H-3, 0	2H-3, 0	3.10	4.60	2.66	3.30
LO <i>Helotholus vema</i>	2H-3, 0	2H-3, 0	3.10	4.60	2.66	3.30
FO <i>Cycladophora davisiana</i>	2H-3, 0	2H-3, 0	3.10	4.60	2.66	3.30
LO <i>Hemidiscus karstenii</i>	2H-4, 140	2H-5, 20	6.00	6.30	3.89	4.02
LO <i>Simonseniella barboi</i>	2H-4, 140	2H-5, 20	6.30	6.60	4.02	4.15
LO <i>Nitzschia praeinterfrigidaria</i>	2H-5, 20	2H-5, 80	6.30	6.90	4.02	4.27
FO <i>Helotholus vema</i>	2H-5, 45	2H-6, 45	6.55	8.05	4.12	4.75
FO <i>Thalassiosira torokina</i>	2H-5, 80	2H-5, 140	6.90	7.50	4.27	?
B C3n.1n			6.95	6.95	4.29	4.29
FO <i>Nitzschia interfrigidaria</i>	2H-6, 40	2H-6, 80	8.00	8.40	?	?
LO <i>Lampromitra coronata</i>	2H-6, 45	2H-6, 45	8.05	9.60	?	?
LO <i>Navicula wisei</i>	2H-5, 140	2H-6, 140	8.40	8.80	?	?
FO <i>Navicula wisei</i>	2H-6, 120	2H-7, 40	8.80	9.60	?	?
FO <i>Rouxia heteropolara</i>	3H-1, 3	3H-1, 25	9.60	9.90	?	?
FO <i>Thalassiosira kolbei</i>	3H-1, 3	3H-1, 25	9.60	9.90	?	?
FO <i>Nitzschia barronii</i>	3H-1, 43	3H-1, 68	10.00	10.30	?	?
FO <i>Nitzschia praeinterfrigidaria</i>	3H-1, 43	3H-1, 68	10.00	10.30	?	?
FO <i>Thalassiosira complicata</i>	3H-1, 43	3H-1, 68	10.00	10.30	?	?
FO <i>Thalassiosira inura</i>	3H-1, 43	3H-1, 68	10.00	10.30	?	?
FO <i>Thalassiosira oestrupii</i>	3H-1, 43	3H-1, 68	10.00	10.30	?	?
LO <i>Asteromphalus kennettii</i>	3H-1, 43	3H-1, 67	10.03	10.30	?	?
LO <i>Denticulopsis dimorpha</i>	3H-1, 68	3H-1, 110	10.10	10.30	?	?

Table 39. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
Unconformity			***	***	***	***
LO <i>Neobrunia mirabilis</i>	3H-2, 47-48	3H-3, 47-48	11.60	13.10	?	?
T C4Ar.2n			13.80	13.80	9.58	9.58
B C4Ar.2n			14.57	14.57	9.64	9.64
T C5n.1n			14.80	14.80	9.74	9.74
B C5n.1n			16.10	16.10	9.88	9.88
T C5n.2n			16.98	16.98	9.92	9.92
FO <i>Asteromphalus kennettii</i>	3H-CC	4H-1, 47-48	19.10	19.60	10.19	10.25
LO <i>Cycladophora humerus</i>	3H-CC	4H-1, 45	19.10	19.55	10.19	10.25
FO <i>Acrosphaera australis</i>	4H-1, 45	4H-2, 45	19.55	21.05	10.25	10.44
FO <i>Eucyrtidium pseudoinflatum</i>	4H-1, 45	4H-2, 45	19.55	21.05	10.25	10.44
FO <i>Cycladophora spongothorax</i>	4H-1, 45	4H-2, 45	19.55	21.05	10.25	10.44
LO <i>Nitzschia denticuloides</i>	4H-1, 47-48	4H-2, 47-48	19.60	20.10	10.25	10.32
FO <i>Eucyrtidium pseudoinflatum</i>	4H-2, 45	4H-3, 45	21.05	22.55	10.44	10.63
LO <i>Calcidiscus macintyreii</i>			21.18	22.68	10.45	10.64
B C5n.2n			25.10	25.10	10.95	10.95
T C5r.1n			25.60	25.60	11.05	11.05
B C5r.1n			26.90	26.90	11.10	11.10
LO <i>Denticulopsis praedimorpha</i>	5H-3, 47-48	5H-4, 47-48	32.10	33.60	11.33	11.40
T C5r.2n			35.40	35.40	11.48	11.48
FO <i>Denticulopsis lauta</i>	5H-6, 47-48	5H-7, 47-48	36.60	38.10	11.48	?
FO <i>Hemidiscus ovalis</i>	5H-6, 47-48	5H-7, 47-48	36.60	38.10	11.48	?
LO <i>Crucidentacula kanayae</i>	5H-6, 47-48	5H-7, 47-48	36.60	38.10	11.48	?
FO <i>Calcidiscus macintyreii</i>	5-H6, 58-62	5-H7, 10-11	36.70	37.62	11.49	11.51
B C5r.2n			37.60	37.60	11.53	11.53
Unconformity			***	***	***	***
LO <i>Coscinodiscus lewisianus</i>	5H-CC	6H-1, 47-48	38.10	38.57	?	?
FO <i>Actinocyclus ingens</i>	5H-CC	6H-1, 47-48	38.10	38.60	?	?
FO <i>Denticulopsis dimorpha</i>	5H-CC	6H-1, 47-48	38.10	38.60	?	?
FO <i>Denticulopsis hustedtii</i>	5H-CC	6H-1, 47-48	38.10	38.60	?	?
LO <i>Denticulopsis maccollumii</i>	5H-CC	6H-1, 47-49	38.10	38.60	?	?
FO <i>Denticulopsis praedimorpha</i>	5H-CC	6H-1, 47-49	38.10	38.60	?	?
FO <i>Nitzschia denticuloides</i>	5H-CC	6H-1, 47-49	38.10	38.60	?	?
LO <i>Nitzschia grossepunctata</i>	5H-CC	6H-1, 47-49	38.10	38.60	?	?
FO <i>Dendrospyrus megalcephalis</i>	5H-CC	6H-1, 65	38.10	38.75	?	?
FO <i>Actinomma golownini</i>	5H-CC	6H-1, 65	38.10	38.75	?	?
LO <i>Nitzschia maleinterpretaria</i>	6H-1, 47-48	6H-2, 47-48	38.60	40.10	?	?
FO <i>Nitzschia grossepunctata</i>	6H-1, 47-48	6H-2, 47-48	38.60	40.10	?	?
B Magnetic reversal :- unidentified			39.80	39.80	?	?
FO <i>Denticulopsis maccollumii</i>	6H-1, 47-48	6H-2, 47-48	40.07	41.57	?	?
Unconformity			***	***	***	***
LO <i>Thalassiosira fraga</i>			40.10	41.60	?	?
FO <i>Crucidentacula kanayae</i>	6H-3, 47-48	6H-4, 47-48	41.60	43.10	?	?
FO <i>Calcidiscus leptoporus</i>	6H-3, 58-62	6H-4, 58-62	41.68	43.68	?	?
B C6AAr.1n			42.00	42.00	22.25	22.25
LO <i>Reticulofenestra pseudumbilica</i>	6H-5, 58-62	6H-6, 58-62	44.70	46.70	22.50	22.46
T C6AAr.2n			46.50	46.50	22.46	22.46
B C6AAr.2n			53.69	53.69	22.49	22.49
LO <i>Thalassiosira spumellaroides</i>	7H-5, 47-48	7H-6, 47-48	54.07	55.57	22.52	22.62
T C6Bn.1n			55.20	55.20	22.59	22.59
LO <i>Rocella gelida</i>	7H-6, 47-48	7H-CC	55.70	57.10	22.63	22.73
FO <i>Nitzschia maleinterpretaria</i>	8H-1, 47-48	8H-2, 47-48	57.10	57.60	22.73	22.76
B C6Bn.1n			57.40	57.40	22.75	22.75
T C6Bn.2n			58.90	58.90	22.80	22.80
FO <i>Thalassiosira fraga</i>	8H-2, 47-48	8H-3, 47-48	59.10	60.60	22.82	22.93
FO <i>Thalassiosira spumellaroides</i>	8H-7, 47-48	8H-CC	60.57	63.57	22.94	23.38
LO <i>Bogorovia veniamini</i>	8H-7, 47-48	8H-CC	60.57	63.57	22.94	23.38
LO <i>Thalassiosira primalabiata</i>	8H-7, 47-48	8H-CC	60.57	63.57	22.94	23.38
B C6Bn.2n			62.20	62.20	23.07	23.07
T C6Cn.1n			63.48	63.48	23.35	23.35
B C6Cn.1n			64.00	64.00	23.54	23.54
T C6Cn.2n			64.50	64.50	23.68	23.68
B C6Cn.2n			65.20	65.20	23.80	23.80
T C6Cn.3n			65.70	65.70	24.00	24.00
B C6Cn.3n			66.35	66.35	24.12	24.12
LO <i>Reticulofenestra bisecta</i>	8H-7, 55-59	9H-1, 10-11	66.65	66.70	24.53	24.59
T C7n.1n			66.80	66.80	24.73	24.73
B C7n.1n			67.70	67.70	24.78	24.78

(continued)

Table 39. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
T C7n.2n			69.60	69.60	24.84	24.84
B C7n.2n			70.07	70.07	25.18	25.18
FO <i>Rocella gelida</i>	9H-3, 47-48	9H-4, 47-48	70.10	71.60	25.20	25.87
T C8n.1n			71.10	71.10	25.82	25.82
LO <i>Chiasmolithus altus</i>	9H-5, 10-11	9H-6, 10-11	72.20	72.70	25.93	25.95
B C8n.1n			72.40	72.40	25.95	25.95
T C8n.2n			75.44	75.44	25.99	25.99
B C8n.2n			78.06	78.06	26.55	26.55
T C9n			78.71	78.71	27.03	27.03
B C9n			88.50	88.50	27.97	27.97
T C10n.1n			90.40	90.40	28.28	28.28
B C10n.2n			93.90	93.90	28.75	28.75
T C11n.1n			96.40	96.40	29.40	29.40
B C11n.2n			98.80	98.80	30.10	30.10
FO <i>Rocella vigilans</i>	12H-4, 47-49	12H-5, 47-49	100.07	101.57	30.29	30.52
T C12n			101.29	101.29	30.48	30.48
B C12n			104.90	104.90	30.94	30.94
FO <i>Cyclicargolithus abisectus</i>	13H-1, 10-11	13H-2, 10-11	104.70	106.20	30.89	31.25
LO <i>Isthmolithus recurvus</i>	13H-4, 10-11	13H-5, 10-11	109.80	113.30	32.11	32.94
T C13n			113.80	113.80	33.06	33.06
B C13n			114.70	114.70	33.55	33.55
LO <i>Reticulofenestra oamaruensis</i>	14H-2, 24-26	14H-3, 24-26	115.84	115.95	33.99	34.03
T C15n			117.60	117.60	34.66	34.66
B C15n			119.07	119.07	34.94	34.94

Data sets are integrated from the work of numerous authors (see Table 2).

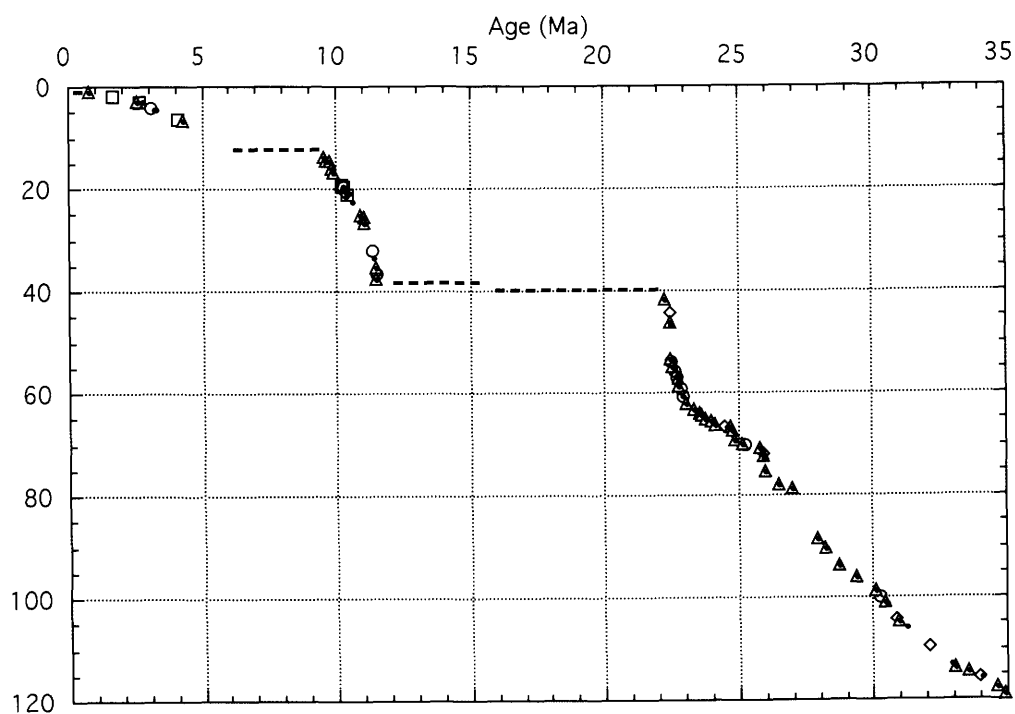


Fig. 56. An age-depth plot for DSDP Hole 748B utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Hole 751A

Eighteen cores were recovered from a total penetration of 166.2 mbsf representing a recovery of 98% of the cored interval. Sediments recovered consist of Quaternary and lower Pliocene diatom ooze with chert and Miocene calcareous nannofossil ooze (Wise *et al.* 1989). A partial palaeomagnetic polarity record was obtained from the sequence. The interval from 2–25 and 70–98 mbsf is difficult to interpret as a result of the lack of data and scatter (Wise *et al.* 1989; Heider *et al.* 1992). All three microfossil groups were recorded from this hole. Diatoms are generally common and well preserved. Two intervals, one in the upper middle Miocene and the other in the lower Miocene contain specimens exhibiting poor preservation (Wise *et al.* 1989). Calcareous nannofossils are absent or rare in the Quaternary and Pliocene and are abundant with moderate preservation for the Miocene (Wei & Wise 1992a). Radiolarians are abundant and well preserved for the Quaternary to middle Miocene and abundant and poorly preserved in the lower Miocene (Wise *et al.* 1989). The integrated biostratigraphical and magnetostratigraphical data previously used (palaeomagnetism: Heider *et al.* 1992; Harwood *et al.* 1992; diatoms: Harwood & Maruyama, 1992; calcareous nannofossils: none; radiolarians: Abelmann 1992; Lazarus 1992) calibrated to the GPTS of Berggren *et al.* (1985a,b) are shown in Table 40. An age–depth graph for Hole 120-751A using this data is shown in Fig. 57.

Figure 58 compares the polarity chronozones and diatom zones assigned by previous workers (Heider *et al.* 1992; Harwood *et al.* 1992; diatoms: Harwood & Maruyama 1992) with the chronozoneal and diatom zonal assignments used in this study. In addition, this figure illustrates the stratigraphical ranges of diatoms and radiolarians. The stratigraphical ranges reflect the placement of FO and LO of stratigraphically useful species as recognized by Abelmann (1992) and Lazarus (1992), respectively. The revised chronozones and diatom zones illustrated are based on reassessing the data sets

of these workers (Table 41). Comparison of the chronozoneal assignments of Harwood *et al.* (1992) show minimal differences reflecting the GPTS used in each study.

Figure 59 shows an age–depth graph for Hole 120-51A using the stratigraphical markers determined in this study. One hiatus is placed in the section between approximately 39 and 42 mbsf. The upper boundary of this break is constrained by the FO of *Nitzschia praeinterfrigidaria* at 34.80–35.80 mbsf and the top of C3n.3n at 36.5 mbsf. The lower boundary is constrained by a continuous polarity sequence from the base of C4An at 41 mbsf to the base of C5Cn.2n at 134.35 mbsf. Two primary events the FO of *Nitzschia denticuloides* and *Denticulopsis hustedtii* occur within this sequence.

Harwood & Maruyama (1992) recognize seven hiatuses within the sequence. The youngest is placed between 0 and 0.1 mbsf. The second hiatus is placed between 1.05 and 1.47 mbsf. A third hiatus between 5.71 and 6.30 mbsf is based on the ranges of *Thalassiosira vulnifica*, *Thalassiosira insigna* and *Thalassiosira kolbei*. We cannot assess the placement of this hiatus given the current data set. A fourth hiatus occurs between 34.8 and 35.75 mbsf based on the ranges of *Nitzschia barronii*, *Thalassiosira oestrupii* and *Asteromphalus kennettii*. Based on our interpretation of the data we use the FO of *Nitzschia barronii* as a primary stratigraphical marker and question the placement of this hiatus. The fourth hiatus of Harwood & Maruyama (1992) between 42.7 and 43.75 mbsf approximates the placement of our hiatus at 40 mbsf. The hiatus between 103.75 and 105.25 mbsf is based on the range of *Nitzschia grossepunctata*. This hiatus is placed at a depth interval well constrained by our study with both biostratigraphical and palaeomagnetic data. The oldest unconformity between 129.25 and 130.75 mbsf corresponds to an interval with a continuous polarity sequence constrained by the first occurrence of *Crucidentacula kanayae* (137.70–138.80 mbsf)

Table 40. Composite dataset for ODP Hole 751A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
Unconformity			***	***	***	***
LO <i>Nitzschia barronii</i>	1H-1, 105-106	1H-1, 145-146	1.10	1.50	?	?
Unconformity			***	***	***	***
LO <i>Thalassiosira elliptopora</i>	1H-1, 145-146	1H-3, 10-11	1.50	3.30	?	?
LO <i>Antarctissa cylindrica</i>	1H-1, 150	1H-2, 106	1.50	2.56	?	?
LO <i>Tricerapys antarctica</i>	1H-2, 106	1H-3, 45	2.56	3.45	?	?
LO <i>Cycladophora pliocenica</i>	2H-1, 98	2H-2, 98	5.68	7.18	?	?
LO <i>Eucyrtidium calvertense</i>	2H-1, 98	2H-2, 98	5.68	7.18	?	?
LO <i>Helotholus vema</i>	2H-1, 98	2H-2, 98	5.68	7.18	?	?
LO <i>Thalassiosira insigna</i>	2H-1, 105-107	2H-2, 10-11	5.70	6.30	?	?
LO <i>Thalassiosira vulnifica</i>	2H-1, 105-107	2H-2, 10-11	5.70	6.30	?	?
Unconformity			***	***	***	***
FO <i>Actinocyclus actinochilus</i>	2H-2, 10-12	2H-2, 105-106	6.30	7.30	?	?
LO <i>Nitzschia interfrigidaria</i>	2H-3, 10-12	2H-3, 105-106	6.30	7.30	?	?
FO <i>Nitzschia kerguelensis</i>	2H-2, 10-11	2H-2, 105-106	6.30	7.30	?	?
LO <i>Nitzschia weaveri</i>	2H-2, 10-11	2H-2, 105-106	6.30	7.30	?	?
LO <i>Simonseniella barboi</i>	2H-2, 10-11	2H-2, 105-106	6.30	7.30	?	?
LO <i>Thalassiosira inura</i>	2H-2, 10-11	2H-2, 105-106	6.30	7.30	?	?
LO <i>Thalassiosira kolbei</i>	2H-2, 10-11	2H-2, 105-106	6.30	7.30	?	?
LO <i>Desmospyris spongiosa</i>	2H-2, 98	2H-3, 98	7.18	8.68	?	?
FO <i>Cycladophora davisiana</i>	2H-2, 98	2H-3, 98	7.18	8.68	?	?
LO <i>Thalassiosira complicata</i>	2H-3, 10-11	2H-3, 105-106	7.80	8.80	?	?
FO <i>Thalassiosira vulnifica</i>	2H-3, 10-11	2H-3, 105-106	7.80	8.80	?	?
LO <i>Nitzschia praeinterfrigidaria</i>	2H-3, 10-12	2H-3, 105-106	7.81	8.76	?	?
FO <i>Nitzschia weaveri</i>	2H-3, 105-106	2H-4, 10-11	8.80	9.30	?	?
FO <i>Thalassiosira elliptopora</i>	2H-4, 145-146	2H-CC	9.30	14.20	?	?
FO <i>Thalassiosira insigna</i>	2H-CC	3H-1, 47-48	14.20	15.30	?	?
LO <i>Navicula wisei</i>	3H-1, 47-48	3H-1, 105-106	14.70	15.30	?	?
LO <i>Lampromitra coronata</i>	2H-CC	3H-1, 98	14.80	15.80	?	?
FO <i>Thalassiosira torokina</i>	3H-2, 10-11	3H-2, 105-106	15.80	16.80	?	?

(continued)

Table 40. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO <i>Prunopyle titan</i>	3H-3, 98	3H-4, 98	18.18	19.68	?	?
FO <i>Nitzschia interfrigidaria</i>	3H-4, 105-106	3H-5, 10-11	19.80	20.30	?	?
LO <i>Denticulopsis dimorpha</i>	3H-6, 10-11	3H-CC	21.80	23.70	?	?
FO <i>Nitzschia barronii</i>	3H-CC	4H-2, 105-106	23.70	26.30	?	?
FO <i>Thalassiosira kolbei</i>	4H-2, 105-106	4H-3, 10-11	26.30	26.80	?	?
FO <i>Navicula wisei</i>	4H-4, 10-11	4H-4, 105-106	28.30	29.30	?	?
FO <i>Actinocyclus ingens</i>	4H-CC	5H-1, 10-11	33.20	33.30	?	?
FO <i>Rouxia heteropolara</i>	5H-1, 10-11	5H-1, 105-106	3.30	34.30	?	?
T C3n.3n			34.50	34.50	4.89	4.89
			***	***	***	***
FO <i>Thalassiosira oestrupii</i>	5H-2, 10-11	5H-2, 105-106	34.80	35.80	?	?
FO <i>Thalassiosira inura</i>	5H-2, 105-106	5H-3, 10-11	34.80	35.80	?	?
FO <i>Nitzschia praeinterfrigidaria</i>			34.80	35.80	?	?
T C3An.2n			36.50	36.50	6.27	6.27
LO <i>Asteromphalus kennettii</i>	5H-4, 10-11	5H-4, 105-106	37.80	38.75	6.42	6.47
LO <i>Thalassiosira miocenica</i>	5H-4, 105-106	5H-5, 10-11	38.80	39.30	6.47	6.50
LO <i>Reticulofenestra hesslandii</i>	5H-5, 5-7	5H-6, 5-7	39.25	40.75	6.49	6.55
FO <i>Hemidiscus ovalis</i>	5H-5, 10-11	5H-CC	39.30	42.70	6.49	6.65
FO <i>Nitzschia praecurta</i>	5H-5, 10-11	5H-CC	39.30	42.70	6.49	6.65
FO <i>Nitzschia reinholdii</i>	5H-5, 10-11	5H-CC	39.30	42.70	6.49	6.65
FO <i>Thalassiosira miocenica</i>	5H-5, 10-11	5H-CC	39.30	42.70	6.49	6.65
B C3An.2n			41.00	41.00	6.57	6.57
			***	***	***	***
FO <i>Acrosphaera labrata</i>	5H-5, 10-11	6H-1, 53	42.70	43.23	?	?
T C4Ar.1n			43.60	43.60	9.23	9.23
LO <i>Cycladophora spongothorax</i>	6H-1, 98	6H-2, 50	43.68	44.70	9.23	9.30
B C4Ar.1n			44.90	44.90	9.31	9.31
T C4Ar.2n			45.20	45.20	9.58	9.58
FO <i>Asteromphalus kennettii</i>	6H-4, 105-106	6H-5, 105-106	48.30	49.60	9.63	9.69
B C4Ar.2n			48.60	48.60	9.64	9.64
T C5n.1n			50.50	50.50	9.74	9.74
T C5n.2n			51.88	51.88	9.92	9.92
LO <i>Reticulofenestra pseudumbilica</i>	7H-4, 5-7	7H-5, 5-7	56.80	58.30	10.14	10.21
FO <i>Acrosphaera australis</i>	8H-3, 98	8H-4, 98	65.68	67.18	10.54	10.61
LO <i>Cycladophora humerus</i>	8H-CC	9H-1, 98	71.20	72.28	10.79	10.84
FO <i>Eucyrtidium pseudoinflatum</i>	8H-CC	9H-1, 98	71.20	72.28	10.79	10.84
LO <i>Actinomma golownini</i>	9H-2, 98	9H-3, 98	73.68	75.18	10.90	10.97
LO <i>Denticulopsis praedimorpha</i>	11H-2, 105-107	11H3, 105-107	92.80	94.30	11.77	11.84
LO <i>Nitzschia denticuloides</i>	11H-2, 105-107	11H3, 105-107	94.25	95.75	11.83	11.90
FO <i>Cycladophora spongothorax</i>	11H-6, 98	11H-CC	98.68	99.70	12.03	12.08
B C5An.1n			99.70	99.70	12.08	12.08
FO <i>Denticulopsis dimorpha</i>	12H-1, 105-107	12H-2, 105-107	100.80	102.30	12.15	?
LO <i>Actinocyclus ingens v. nodus</i>	12H-1, 105-107	12H-2, 105-107	101.00	102.30	12.17	?
T C5An.2n			101.20	101.20	12.18	12.18
B C5An.2n			102.26	102.26	12.40	12.40
LO <i>Denticulopsis maccollumii</i>	12H-2, 105-107	12H-3, 105-107	102.30	103.80	?	?
T C5Ar.2n			103.75	103.75	12.78	12.78
FO <i>Denticulopsis praedimorpha</i>	12H-3, 105-107	12H-4, 105-107	103.75	105.25	?	?
LO <i>Nitzschia grossepunctata</i>	12H-3, 105-107	12H-4, 105-107	103.75	105.25	?	?
			***	***	***	***
T C5AAn			104.22	104.22	12.99	12.99
B C5ABn			108.20	108.20	13.51	13.51
FO <i>Actinomma golownini</i>	12H-CC 13H-CC	109.20	118.70	13.66	14.40	FO
<i>Nitzschia denticuloides</i>	12H-CC	13H-1, 105-107	109.30	110.30	13.67	13.84
T C5ACn			109.48	109.48	13.70	13.70
B C5ACn			111.75	111.75	14.08	14.08
FO <i>Denticulopsis hustedtii</i>	13H-2, 105-107	13H-2, 105-107	111.80	113.30	14.08	14.15
T C5ADn			113.84	113.84	14.18	14.18
FO <i>Actinocyclus ingens v. nodus</i>	13H-5, 105-107	13H-6, 105-107	116.30	117.80	14.29	14.36
FO <i>Crucidenticula nicobarica</i>	13H-CC	14H-1, 105-107	118.80	119.80	14.41	14.45
LO <i>Synedra jouseana</i>			121.25	122.75	14.52	14.59
B C5ADn			123.30	123.30	14.61	14.61
T C5Bn.1n			127.20	127.20	14.80	14.80
FO <i>Denticulopsis lauta</i>	14H-CC	15H-1, 105-107	128.20	129.30	?	?
			***	***	***	***
FO <i>Nitzschia grossepunctata</i>	15H-1, 105-107	15H-2, 105-107	129.30	130.80	?	?
B C5Bn.2n			129.51	129.51	15.16	15.16
T C5Cn.1n			132.56	132.56	16.01	16.01
FO <i>Calcidiscus macintyreii</i>	15H-2, 5-6	15H-3, 55-56	132.75	137.72	16.03	16.53

Table 40. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
B C5Cn.1n			134.35	134.35	16.29	16.29
T C5Cn.2n			136.02	136.02	16.33	16.33
LO <i>Nitzschia maleinterpretaria</i>	15H-6, 105-107	15H-CC	136.80	137.70	16.42	16.53
FO <i>Denticulopsis maccollumii</i>	15H-CC	16H-1, 105-107	137.70	138.80	16.53	16.66
LO <i>Crucidenticula kanayae</i>	15H-CC	16H-1, 105-107	137.70	138.80	16.53	16.66
FO <i>Calcidiscus leptoporus</i>	16H-7, 2-4	17H-1, 22-25	146.70	147.40	17.58	17.67
B C5Dn			147.00	147.00	17.62	17.62
FO <i>Crucidenticula kanayae</i>	16H-CC	17H-2, 105-107	147.20	149.80	17.64	17.94
FO <i>Nitzschia maleinterpretaria</i>	16H-CC	17H-2, 105-107	147.20	149.80	17.64	17.94
T C5En			152.75	152.75	18.28	18.28
LO <i>Thalassiosira fraga</i>	17H-6, 105-107	17H-CC	165.30	166.20	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

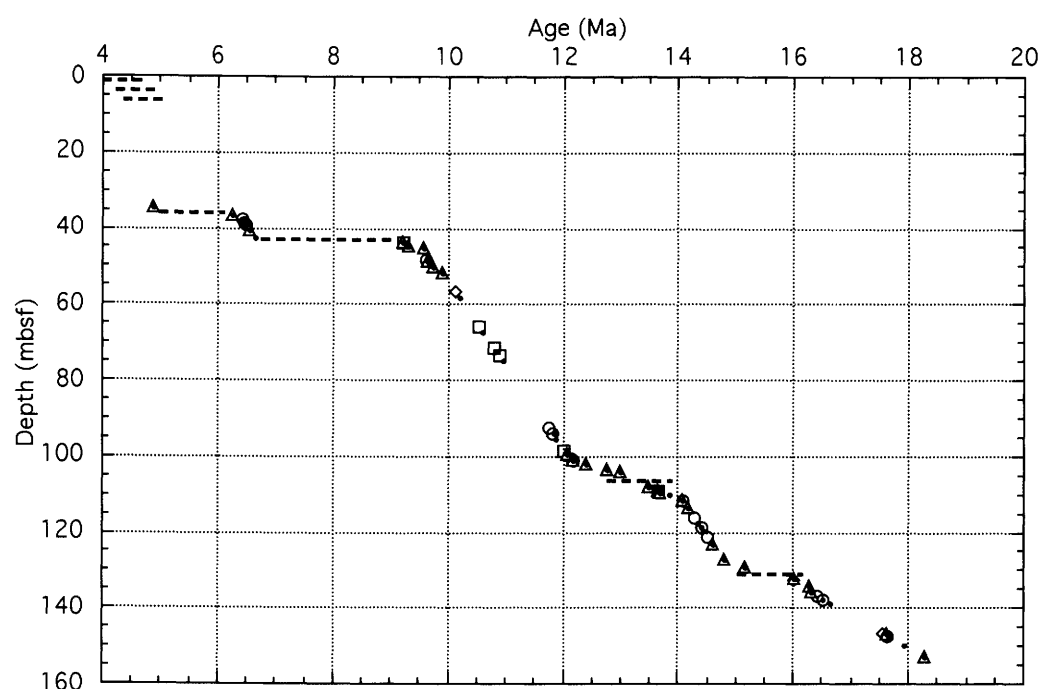


Fig. 57. An age-depth plot for DSDP Hole 751A utilizing the previously used biostratigraphical datums and polarity reversal interpretation calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

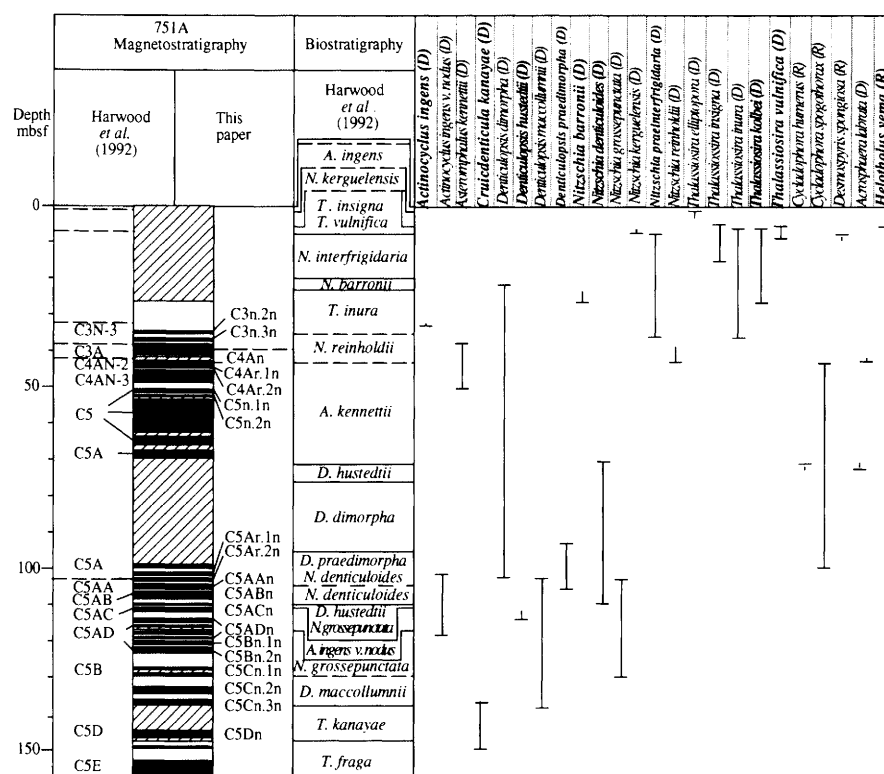


Fig. 58. Comparison of the ODP Hole 751A polarity chronozones and diatom zonal assignments by previous workers with the chronozone assignments of this study. The stratigraphical ranges of selected stratigraphical marker are based on the original data sets (see text for references). D, diatoms; R, radiolaria; N, calcareous nannofossils. Emboldened events indicate primary biostratigraphical events recognized in this study. The polarity record shown represents the original interpretation calibrated to the GPTS of Cande & Kent (1995) and the interpretation from this study correlated with the GPTS of Cande & Kent (1995). Diagonal lines indicate intervals of no core recovery, dashed lines indicate intervals of uncertainty.

Table 41. Composite dataset for ODP Hole 751A containing the diatom, radiolarian, calcareous nannofossil and palaeomagnetic data calibrated to the GPTS of Cande & Kent (1995) using the biochronological interpretation based on this study

	Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
LO	<i>Nitzschia barronii</i>	1H-1, 105-106	1H-1, 145-146	1.10	1.50	?	?
LO	<i>Thalassiosira elliptopora</i>	1H-1, 145-146	1H-3, 10-11	1.50	3.30	?	?
LO	<i>Antarctissa cylindrica</i>	1H-1, 150	1H-2, 106	1.50	2.56	?	?
LO	<i>Tricerasypris antarctica</i>	1H-2, 106	1H-3, 45	2.56	3.45	?	?
LO	<i>Cycladophora pliocenica</i>	2H-1, 98	2H-2, 98	5.68	7.18	?	?
LO	<i>Eucyrtidium calvertense</i>	2H-1, 98	2H-2, 98	5.68	7.18	?	?
LO	<i>Helotholus vema</i>	2H-1, 98	2H-2, 98	5.68	7.18	?	?
LO	<i>Thalassiosira insigna</i>	2H-1, 105-107	2H-2, 10-11	5.70	6.30	?	?
LO	<i>Thalassiosira vulnifica</i>	2H-1, 105-107	2H-2, 10-11	5.70	6.30	?	?
FO	<i>Actinocyclus actinochilus</i>	2H-2, 10-12	2H-2, 105-106	6.30	7.30	?	?
LO	<i>Nitzschia interfrigidaria</i>	2H-3, 10-12	2H-3, 105-106	6.30	7.30	?	?
FO	<i>Nitzschia kerguelensis</i>	2H-2, 10-11	2H-2, 105-106	6.30	7.30	?	?
LO	<i>Nitzschia weaveri</i>	2H-2, 10-11	2H-2, 105-106	6.30	7.30	?	?
LO	<i>Simonseniella barboi</i>	2H-2, 10-11	2H-2, 105-106	6.30	7.30	?	?
LO	<i>Thalassiosira inura</i>	2H-2, 10-11	2H-2, 105-106	6.30	7.30	?	?
LO	<i>Thalassiosira kolbei</i>	2H-2, 10-11	2H-2, 105-106	6.30	7.30	?	?
LO	<i>Desmospyris spongiosa</i>	2H-2, 98	2H-3, 98	7.18	8.68	?	?
FO	<i>Cycladophora davisiana</i>	2H-2, 98	2H-3, 98	7.18	8.68	?	?
LO	<i>Thalassiosira complicata</i>	2H-3, 10-11	2H-3, 105-106	7.80	8.80	?	?
FO	<i>Thalassiosira vulnifica</i>	2H-3, 10-11	2H-3, 105-106	7.80	8.80	?	?
LO	<i>Nitzschia praeinterfrigidaria</i>	2H-3, 10-12	2H-3, 105-106	7.81	8.76	?	?
FO	<i>Nitzschia weaveri</i>	2H-3, 105-106	2H-4, 10-11	8.80	9.30	?	?
FO	<i>Thalassiosira elliptopora</i>	2H-4, 145-146	2H-CC	9.30	14.20	?	?
FO	<i>Thalassiosira insigna</i>	2H-CC	3H-1, 47-48	14.20	15.30	?	?
LO	<i>Navicula wisei</i>	3H-1, 47-48	3H-1, 105-106	14.70	15.30	?	?
LO	<i>Lampromitra coronata</i>	2H-CC	3H-1, 98	14.80	15.80	?	?
FO	<i>Thalassiosira torokina</i>	3H-2, 10-11	3H-2, 105-106	15.80	16.80	?	?
LO	<i>Prunopyle titan</i>	3H-3, 98	3H-4, 98	18.18	19.68	?	?
FO	<i>Nitzschia interfrigidaria</i>	3H-4, 105-106	3H-5, 10-11	19.80	20.30	?	?
LO	<i>Denticulopsis dimorpha</i>	3H-6, 10-11	3H-CC	21.80	23.70	?	?
FO	<i>Nitzschia barronii</i>	3H-CC	4H-2, 105-106	23.70	26.30	?	?
FO	<i>Thalassiosira kolbei</i>	4H-2, 105-106	4H-3, 10-11	26.30	26.80	?	?
FO	<i>Navicula wisei</i>	4H-4, 10-11	4H-4, 105-106	28.30	29.30	?	?
FO	<i>Actinocyclus ingens</i>	4H-CC	5H-1, 10-11	33.20	33.30	?	?
FO	<i>Rouxia heteropolara</i>	5H-1, 10-11	5H-1, 105-106	33.30	34.30	?	?
T	C3n.2n			34.50	34.50	?	?
FO	<i>Thalassiosira oestrupii</i>	5H-2, 10-11	5H-2, 105-106	34.80	35.80	?	?
FO	<i>Thalassiosira inura</i>	5H-2, 105-106	5H-3, 10-11	34.80	35.80	?	?
FO	<i>Nitzschia praeinterfrigidaria</i>	5H-2, 105-106	5H-3, 10-11	34.80	35.80	?	?
B	C3n.2n			35.20	35.20	4.62	4.62
T	C3n.3n			36.50	36.50	4.80	4.80
LO	<i>Asteromphalus kennettii</i>	5H-4, 10-11	5H-4, 105-106	37.80	38.75	?	?
LO	<i>Thalassiosira miocenica</i>	5H-4, 105-106	5H-5, 10-11	38.80	39.30	?	?
LO	<i>Reticulofenestra hesslandii</i>	5H-5, 5-7	5H-6, 5-7	39.25	40.75	?	?
	Unconformity			***	***	***	***
FO	<i>Hemidiscus ovalis</i>	5H-5, 10-11	5H-CC	39.30	42.70	?	?
FO	<i>Nitzschia praecurta</i>	5H-5, 10-11	5H-CC	39.30	42.70	?	?
FO	<i>Nitzschia reinholdii</i>	5H-5, 10-11	5H-CC	39.30	42.70	?	?
FO	<i>Thalassiosira miocenica</i>	5H-5, 10-11	5H-CC	39.30	42.70	?	?
B	C4An			41.00	41.00	9.03	9.03
FO	<i>Acrosphaera labrata</i>	5H-CC	6H-1, 53	42.70	43.23	9.21	9.27
B	C4Ar.1n			43.60	43.60	9.31	9.31
LO	<i>Cycladophora spongothorax</i>	6H-1, 98	6H-2, 50	43.68	44.70	9.32	9.57
T	C4Ar.2n			45.20	45.20	9.58	9.58
FO	<i>Asteromphalus kennettii</i>	6H-4, 105-106	6H-5, 105-106	48.30	49.60	9.63	9.69
B	C4Ar.2n			48.60	48.60	9.64	9.64
T	C5n.1n			50.50	50.50	9.74	9.74
B	C5n.1n			51.88	51.88	9.88	9.88
T	C5n.2n			51.88	51.88	9.92	9.92
LO	<i>Reticulofenestra pseudumbilica</i>	7H-4, 5-7	7H-5, 5-7	56.80	58.30	10.18	10.25
FO	<i>Acrosphaera australis</i>	8H-3, 98	8H-4, 98	65.68	67.18	10.64	10.71
LO	<i>Cycladophora humerus</i>	9H-1, 98	9H-CC	71.20	72.28	10.92	10.98
FO	<i>Eucyrtidium pseudoinflatum</i>	8H-CC	9H-1, 98	71.20	72.28	10.92	10.98
LO	<i>Actinomma golownini</i>	9H-2, 98	9H-3, 98	73.68	75.18	11.05	11.13
LO	<i>Denticulopsis praedimorpha</i>	11H-2, 105-107	11H3, 105-107	92.80	94.30	12.04	12.12
LO	<i>Nitzschia denticuloides</i>	11H-2, 105-107	11H3, 105-107	92.80	94.30	12.04	12.12
FO	<i>Cycladophora spongothorax</i>	11H-6, 98	11H-CC	98.68	99.70	12.35	12.40
B	C5An.2n			99.70	99.70	12.40	12.40
FO	<i>Denticulopsis dimorpha</i>	12H-1, 105-107	12H-2, 105-107	100.80	102.30	12.61	12.78
LO	<i>Actinocyclus ingens v. nodus</i>	12H-1, 105-107	12H-2, 105-107	101.00	102.30	12.64	12.78

Table 41. (continued)

Event	Sample (top)	Sample (bottom)	Depth (t)	Depth (b)	Age (t)	Age (b)
T C5Ar.1n			101.20	101.20	12.68	12.68
B C5Ar.1n			101.71	101.71	12.71	12.71
T C5Ar.2n			102.26	102.26	12.78	12.78
LO <i>Denticulopsis maccollumnii</i>	12H-2, 105-107	12H-3, 105-107	102.30	103.80	12.78	12.83
B C5Ar.2n			103.72	103.72	12.82	12.82
FO <i>Denticulopsis praedimorpha</i>	12H-3, 105-107	12H-4, 105-107	103.75	105.25	12.83	13.11
LO <i>Nitzschia grossepunctata</i>	12H-3, 105-107	12H-4, 105-107	103.75	105.25	12.83	13.11
T C5AAn			104.22	104.22	12.99	12.99
B C5AAn			105.50	105.50	13.14	13.14
T C5ABn			105.76	105.76	13.30	13.30
B C5ABn			108.20	108.20	13.51	13.51
FO <i>Actinomma golownini</i>	12H-CC	13H-CC	109.20	118.70	13.66	14.57
FO <i>Nitzschia denticuloides</i>	12H-CC	13H-1, 105-107	109.30	110.30	13.67	13.84
T C5ACn			109.48	109.48	13.70	13.70
B C5ACn			111.75	111.75	14.08	14.08
FO <i>Denticulopsis hustedtii</i>	13H-2, 105-107	13H-2, 105-107	111.80	113.30	14.08	14.15
T C5ADn			113.84	113.84	14.18	14.18
FO <i>Actinocyclus ingens v. nodus</i>	13H-5, 105-107	13H-6, 105-107	116.30	117.80	14.38	14.50
FO <i>Crucidentacula nicobarica</i>	13H-CC	14H-1, 105-107	118.80	119.80	14.58	14.67
B C5ADn			119.21	119.21	14.61	14.61
T C5Bn.1n			119.47	119.47	14.80	14.80
B C5Bn.1n			120.90	120.90	14.89	14.89
T C5Bn.2n			121.28	121.28	15.03	15.03
B C5Bn.2n			123.00	123.00	15.16	15.16
T C5Cn.1n			127.20	127.20	16.01	16.01
FO <i>Denticulopsis lauta</i>	14H-CC	15H-1, 105-107	128.20	129.30	16.13	16.26
FO <i>Nitzschia grossepunctata</i>	15H-1, 105-107	15H-2, 105-107	129.30	130.80	16.26	16.31
B C5Cn.1n			129.51	129.51	16.29	16.29
T C5Cn.2n			132.56	132.56	16.33	16.33
FO <i>Calcidiscus macintyreii</i>	15H-2, 5-6	15H-3, 55-56	132.75	137.72	16.35	16.72
B C5Cn.2n			134.35	134.35	16.49	16.49
T C5Cn.3n			136.02	136.02	16.56	16.56
LO <i>Nitzschia maleinterpretaria</i>	15H-6, 105-107	15H-CC	136.80	137.70	16.63	16.72
FO <i>Denticulopsis maccollumnii</i>	15H-CC	16H-1, 105-107	137.70	138.80	16.72	16.83
LO <i>Crucidentacula kanayae</i>	15H-CC	16H-1, 105-107	137.70	138.80	16.72	16.83
FO <i>Calcidiscus leptoporus</i>	16H-7, 2-4	17H-1, 22-25	146.70	147.40	17.58	17.65
B C5Dn			147.10	147.10	17.62	17.62
FO <i>Crucidentacula kanayae</i>	16H-CC	17H-2, 105-107	147.20	149.80	17.63	17.94
FO <i>Nitzschia maleinterpretaria</i>	16H-CC	17H-2, 105-107	147.20	149.80	17.63	17.94
T C5En			152.75	152.75	18.28	18.28
LO <i>Thalassiosira fraga</i>	17H-6, 105-107	17H-CC	165.30	166.20	?	?

Data sets are integrated from the work of numerous authors (see Table 2).

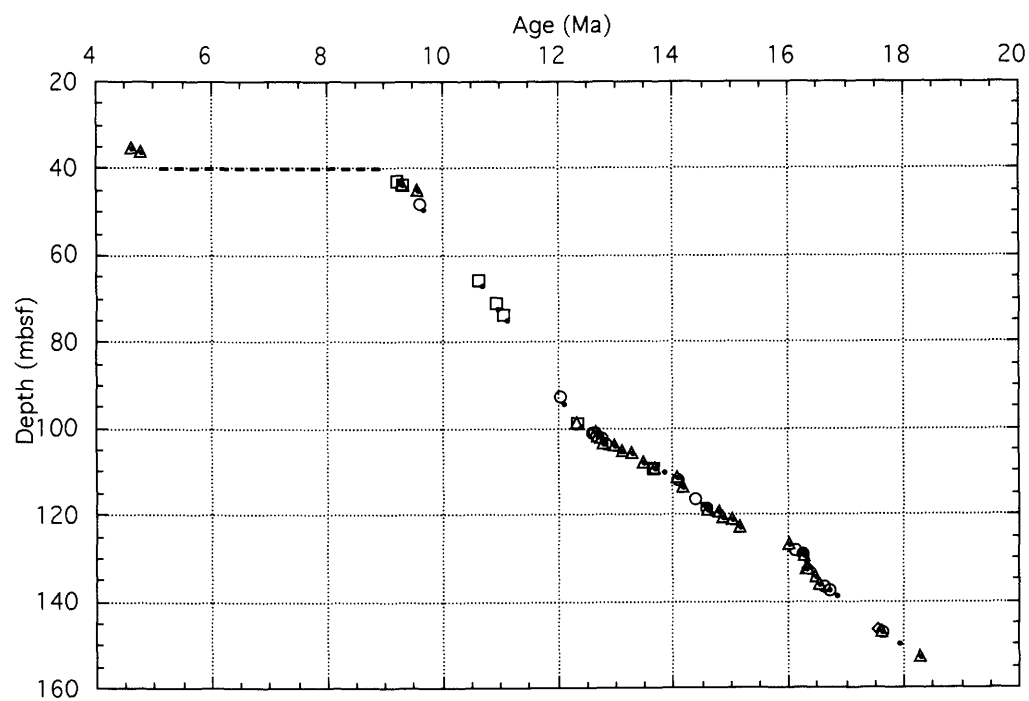


Fig. 59. An age-depth plot for DSDP Hole 751A utilizing the biostratigraphical and polarity reversal events identified in this study and calibrated to the GPTS of Cande & Kent (1995). See Fig. 5 for legend of symbols.

Discussion

Ages for the original 173 events calibrated to the Cande & Kent (1995) GPTS are presented in Table 3. These assigned ages have been revised based on the iterative process used in this study and the results are shown in Table 42. All events shown in Table 42 have been used previously as biostratigraphical markers in the Southern Ocean. It is impossible to evaluate the stratigraphical usefulness of the 37 datums that occur at only one site. Of the 136 datums that occur at more than one site, 15 are calcareous nannofossils, 27 are radiolarians, and 94 are diatoms. Of these events six are exclusive to the South Atlantic sector and nine to the Indian Ocean sector of the Southern Ocean. All 136 datums occur within intervals where a reliable polarity record was obtained and it is possible to evaluate their value as stratigraphical markers. Age constraints for each datum are influenced by the original sampling constraints in a given hole. Most datums are constrained within an age range of less than 0.3 million years. In several holes, however, age constraints exceeds 1.0 million years. This accuracy is largely an artefact of sampling and can only be reduced by additional sampling. The information provided by these less-constrained events is often still useful when compared to the age estimates of the same event in the remaining holes. Such a comparison often provides an indication to the datums reliability throughout the Southern Ocean.

The number of primary stratigraphical events exhibiting chronological consistency throughout the Southern Ocean is surprisingly few and suggests that the biochronological resolution which can be achieved for the Southern Ocean is coarser than previously believed using the currently available data. For example, more than forty datums previously defined are currently being used as biostratigraphical indicators for the Pliocene and Pleistocene. Results from this study suggest that, at most, six of these events have consistent stratigraphical ranges and can be used to correlate throughout the Southern Ocean. An additional eight events may prove biostratigraphically useful with a better understanding of their spatial and temporal distribution. The remaining biostratigraphical events are considered unreliable given the diachronous ages of each specific event. Similarly, 61 events are currently used as biostratigraphical indicators for the Miocene. This study suggests that only seven primary events are useful for the Miocene to Late Eocene interval.

Thirteen primary datums are defined as control points for the Southern Ocean biostratigraphy and an additional twenty datums are identified as potentially useful (Table 42; Table 43). Primary datums show a generally consistent occurrence in most holes. In cases where an estimated age for a datum in one hole is anomalous to its age in other holes we consider the event as useful until further studies are completed.

In compiling the primary events we have identified an additional 20 datums that have potential stratigraphical usefulness (Table 43). These events are not promoted as primary indicators for the following reasons: the paucity of data, the occurrence of events limited to two holes, poorly constrained events with age range distributions greater than 0.25 million years and the inconsistent cluster of age constraints for a specific event.

Pliocene–Quaternary

Six primary biostratigraphical markers consisting of five diatom events and one radiolarian event were identified within the Pliocene of the Southern Ocean (Table 42). Nine potentially useful events (five diatom and one radiolarian) are also identified within this interval. The paucity of primary events results from the inconsistent occurrence of the majority of marker species previously determined as stratigraphically useful or limited data. The calculation of age ranges for first occurrences and last occurrences is constrained by sampling intervals, the availability of magnetic data within critical intervals and by the occurrence of stratigraphical breaks which result in unreliable age determinations. The further recognition of

potential markers however, may provide local or regionally reliable datums. The limited number of events (diatoms and radiolarians) and the elimination of calcareous nannofossil datums raises doubts concerning the reliability of previous biostratigraphical interpretations for the Pliocene of the Southern Ocean. The primary and potential events defined for this time interval are discussed below.

LO *Thalassiosira kolbei* (diatom). This event is recorded by previous workers in twelve of the holes used in this study (Table 42). Age constraints, which are calculated for this event in eleven sites, vary in each hole and reflect differences in the sampling density. Given the sampling constraint this event is contemporaneous at eight of the 11 sites. In six holes this event is constrained by less than 0.3 million years and at one site by 0.15 million years. The LO of *Thalassiosira kolbei* approximates or occurs directly below the base of Chron C2n at eight of the 11 holes. In three holes (704B, 747B and 748B) this event is older. The similarity in age estimates for this event from holes in the Atlantic Ocean (Leg 113) and the Indian Ocean (Leg 119) sectors of the Southern Ocean suggest that this event is a useful primary biostratigraphical indicator.

LO *Thalassiosira vulnifica* (diatom). This event is recorded in ten holes (Table 42). In eight of these holes it falls within our constraint of 0.25 million years. This event is best constrained in two holes, Hole 514 (2.3–2.40 Ma) and Hole 699A (2.43–2.49 Ma). At five of the other holes the age of this event is younger e.g. at Hole 744B this event has an age between 1.76 and 2.32 Ma. We did not anticipate the usefulness of this species given its susceptibility to dissolution.

FO *Nitzschia praeinterfrigidaria* (diatom). This event is recorded in 11 holes (Table 42). In four of these holes the occurrence of an unconformity prevents the determination of age constraints. In Hole 747A this event is constrained to within 0.3 million years and in six of the remaining seven holes this event is constrained to less than 0.17 million years and to within 0.3 million years at Hole 747A. With the exception of an occurrence in Hole 514 (3.24–3.36 Ma) this event occurs between the base of C3n.2n and the top of C3n.3n and has an estimated age of 4.70 Ma. We consider this species as an excellent primary event.

FO *Nitzschia interfrigidaria* (diatom). This event is recorded in thirteen holes used in this study (Table 42). The occurrence of unconformities in seven holes prevents the calculation of age constraints for this event. In the six remaining holes its constraints are less than 0.3 million years. In two holes, 737A (3.98–4.03 Ma) and 745B (3.71–3.80 Ma) this species is constrained by less than 0.1 million years. In three of the four remaining holes the age ranges for this species fall within our constraint of 0.25 million years. At Hole 695A this event ranges from 3.09 to 3.26 Ma.

FO *Helotholus yema* (radiolarian). This event is recorded in eight holes considered in this study (Table 42). The presence of unconformities in three holes prevents the calculation of age constraints for this event. In five holes this event occurs within an interval of less than 0.3 million years. The event is best constrained at two holes 689B (4.40–4.50 Ma) and 745B (4.57–4.60 Ma) and occurs within Chron C3n.2n. There are no holes where a discrepancy in ages is recorded.

***Nitzschia barronii* (diatom).** This event is recorded in 12 holes used in this study (Table 42). The presence of unconformities at six holes

prevents the calculation of age constraints for this species. In four of the remaining six holes the age range of the species is less than 0.1 million years. The event is best constrained at Hole 696A (4.51–4.52 Ma) and coincides with the FO of *Helotholus vema*. In Hole 695A the event ranges from 4.12 to 4.18 Ma.

Miocene

The paucity of reliable stratigraphical markers identified in this study contrasts distinctly with the voluminous number of events previously identified. The results from this study suggest that five diatom events are useful primary markers (Table 42). An additional nine events (seven diatom and two radiolarian) are identified as potentially useful biostratigraphical indicators.

FO *Denticulopsis praedimorpha* (diatom). This event occurs in seven of the holes examined (Table 42). An unconformity in three holes prevents an age calculation for this event. In the remaining four holes this event is constrained by 0.28 million years and has an age range of 12.83–13.14 Ma in Holes 747A and 751A. In Hole 690B the age of this event ranges from 13.09–13.35 Ma and overlaps the age of this event at the other two holes. In Hole 689B this event has a younger age of 12.51–12.76 Ma.

FO *Nitzschia denticuloides* (diatom). This event is recorded in seven holes used in this study (Table 42). An unconformity prevents calculation of age constraints in Holes 699A. In the six remaining holes the age range of this event is constrained by 0.38 million years. The event is best constrained in Holes 689B (13.43–13.54 Ma) and Hole 747A (13.57–13.66 Ma). An older age range of 15.21–15.55 Ma is recorded in Hole 744B.

FO *Denticulopsis hustedtii* (diatom). This event is recorded in eight holes (Table 42). The occurrence of unconformities in three sites precludes the calculation of age ranges for this event. The age range of this event is best constrained in Hole 751A between 14.08 and 14.15 Ma. In two Holes 689B and 747A the age ranges for this event partially overlap the range recorded in Hole 751A. In Holes 690B and 744B the age ranges for the event fall within our constraint of 0.25 million years.

LO *Synedra jouseana* (diatom). This event occurs in five holes (Table 42). The occurrence of unconformities at three holes prevents determination of an age constraint for this event. In Hole 689B the age of this event ranges from 14.51 to 14.57 Ma and at Hole 747A from 14.49 to 14.80 Ma.

FO *Crucidenticula kanayae* (diatom). This event is recorded in seven holes used in this study (Table 42). An unconformity in Hole 748B prevents an age estimate for this event. The age range is less than 0.1 million years in three holes (689B, 690B and 751A). In five holes this event has an age range between 17.42 and 17.69 Ma and in Hole 704B the age range, between 16.56 and 16.81 Ma, is significantly younger.

Oligocene–late Eocene

The definition of events within this interval is hindered by limited core recovery and/or the paucity of palaeomagnetic data. Two primary events are recognized within this interval for the Southern Ocean (Table 42). These consist of the LO and FO of two calcareous nannofossil species respectively. This study confirms the

usefulness of calcareous nannofossil events recognized by Wei & Wise (1990, 1992a, b), Wei (1990; 1992) and Wei *et al.* (1992).

FO *Isthmolithus recurvus* (calcareous nannofossil). This event is recorded in three holes (Table 42) and the estimate of the total age range for this event occurs between 35.73 and 36.15 Ma. The age of this event approximates 36 Ma.

LO *Reticulofenestra reticulata* (calcareous nannofossil). This event is recorded in three holes (Table 42) and the estimate of the total age range for this event occurs between 35.73 and 36.15 Ma. The age of this event coincides with that of the LO of *Isthmolithus recurvus* at approximately 36 Ma.

Potential events:

In compiling the primary events we have identified an additional 20 datums that have potential stratigraphical usefulness (Table 43). These events are not promoted as primary indicators for the following reasons: the paucity of data, the occurrence of events limited to two holes, poorly constrained events with age range distributions greater than 0.25 million years and the inconsistent cluster of age constraints for a specific event. Five examples are given below.

LO *Chiasmolithus altus* has an age constraint, in Holes 744A, 747A, and 748B, between 25.93 and 26.11 Ma, suggesting that this event is chronostratigraphically useful for these holes. In Hole 699A this event ranges from 26.54 to 26.80 Ma and in Hole 689B this event has an age younger than 29.43 Ma. These age ranges indicate the questionable reliability of this event and confirm the results of Wei (1992).

LO *Coscinodiscus rhombicus* is constrained between 16.66 and 16.72 Ma in Hole 689B and has an age constraint between 16.81 and 16.99 Ma in Hole 704B. Age constraints are unavailable for other sites. We therefore elect not to use this event as a primary marker.

FO *Acrosphaera labrata* occurs in four holes. This event has an age constraint of 9.32–9.46 Ma (Hole 689B), 8.46–8.82 Ma (Hole 747A), 9.14–9.17 Ma (747B) and 9.21–9.27 Ma (Hole 751A). Although these data show that this event is useful for two holes and potentially for a third hole we cannot assess the usefulness of this event until further data become available.

LO *Denticulopsis hustedtii* occurs in four holes. This event has an age constraint of 4.28–4.37 Ma (695A), 4.38–4.49 Ma (699A) and 4.18–5.24 Ma (Hole 704B) suggesting that this event is potentially a primary event. The age constraint of this event in Hole 697B (2.61–2.82 Ma), raises questions concerning the reliability of this event as a primary marker.

LO *Antarctissa cylindrica* is well constrained at two holes (745B and 747A) with an age constraint between 0.56 and 0.65 Ma. In Holes 690B and 695A this event has an age range between 0.00 and 2.27 Ma.

A comparison between the Miocene diatom datum levels for the Southern Ocean (this study) and the North Pacific (Barron and Gladenkov, 1995) shows that the first occurrences of *Crucidenticula kanayae* and *Denticulopsis praedimorpha* provide useful datum in

Event	514t	514b	689Bt	689Bb	690Bt	690Bb	695At	695Ab	696At	696Ab	697Bt	697Bb	699At	699Ab	701At	701Ab
LO <i>Pterocanium trilobium</i>																
LO <i>Triceraspyris antarctica</i>																
LO <i>Pseudoemiliana lacunosa</i>																
FO <i>Emiliana huxleyi</i>																
LO <i>Thalassiosira elliptopora</i>	0.72	0.84											0.55	0.66		
LO <i>Hemidiscus karstenii</i>													0.00	0.03	0.23	0.26
LO <i>Simonseniella barboi</i>	1.82	1.83			3.19	3.32					3.86	4.05	1.68	1.92	1.48	1.58
FO <i>Nitzschia miocenica</i>																
FO <i>Nitzschia kerguelensis</i>	2.40	2.42	?	?	0.00	0.81	1.17	1.70	5.13	5.65						
LO <i>Actinocyclus ingens</i>	0.59	0.72	?	?	0.81	1.98	0.20	0.64	?	?	0.79	1.10	0.54	0.55	0.81	0.83
LO <i>Thalassiosira kolbei</i>	1.92	2.15	?	?	1.98	2.27					1.74	1.95	1.99	2.14	1.73	1.98
LO <i>Thalassiosira inura</i>			?	?	1.98	2.27	2.94	3.08	?	?	2.82	2.94				
LO <i>Thalassiosira vulnifica</i>	2.37	2.40					0.64	1.95			2.17	2.39	2.43	2.49	2.12	2.26
LO <i>Thalassiosira insigna</i>							2.00	2.14			2.94	3.08	2.68	2.72	2.47	?
LO <i>Nitzschia interfrigidaria</i>	2.91	2.93	?	?	1.98	2.27	2.15	2.61			3.08	3.11	2.72	2.72	2.47	?
LO <i>Denticulopsis dimorpha</i>													?	?		
LO <i>Nitzschia barronii</i>			?	?	1.98	2.27	2.58	2.61	?	?	1.10	1.25				
LO <i>Helicosphaera sellii</i>																
LO <i>Discoaster browerii</i>																
FO <i>Thalassiosira elliptopora</i>													4.86	4.89		
LO <i>Rouxia diploneides</i>																
LO <i>Nitzschia cylindrica</i>																
FO <i>Actinocyclus actinochilus</i>																
LO <i>Antarctissa cylindrica</i>			?	?	0.00	2.26	0.00	2.27								
LO <i>Cycladophora pliocenica</i>			?	?	0.00	2.26	0.00	2.27								
LO <i>Eucyrtidium calvertense</i>			?	?	0.00	2.26										
LO <i>Desmospyris spongiosa</i>	2.42	2.50	?	?	0.00	2.26	2.00	2.15			2.39	2.82	2.44	3.26	2.12	2.46
LO <i>Helotholus vema</i>	2.42	2.50	?	?	0.00	2.26	2.00	2.15			2.39	2.82	2.44	3.26	2.12	2.46
FO <i>Cycladophora davisiana</i>	2.59	2.63	?	?	0.00	2.26					3.08	3.34			2.12	2.46
LO <i>Nitzschia weaveri</i>	2.74	2.76					2.58	2.61					3.43	3.70	?	?
LO <i>Nitzschia reinholdii</i>	2.91	2.93											2.53	3.70		
LO <i>Cosmiodiscus intersectus</i>							4.48	?								
LO <i>Rouxia heteropolara</i>																
LO <i>Thalassiosira torokina</i>																
LO <i>Rouxia californica</i>																
LO <i>Stephanopyxis grunowii</i>																
LO <i>Nitzschia praeinterfrigidaria</i>			?	?	3.29											

704Bt	704Bb	737At	737Ab	744At	744Ab	744Bt	744Bb	745Bt	745Bb	746At	746Ab	747At	747Ab	747Bt	747Bb	748Bt	748Bb	751At	751Ab
								0.00	0.09			0.56	0.64			1.62	2.81	?	?
0.00	0.15											1.97	1.99						
						0.89	1.76	0.79	1.27			0.11	1.25					?	?
												0.57	0.64	0.29	0.31				
0.00	0.07	3.81	3.84			1.76	2.32	0.26	0.44	7.99	8.01			2.70	3.17	3.89	4.02		
2.12	2.13	3.68	3.76			2.32	3.46	1.57	1.75			1.65	1.99			4.02	4.15	?	?
		?	?			1.76	2.32	2.12	2.18	6.70	6.74								
0.58	0.64	7.17	7.35			0.89	1.76	0.44	0.61	8.29	8.79	2.19	2.79	2.70	3.17			?	?
												0.25	0.35	0.26	0.29				
2.30	2.34					1.76	2.32	1.75	1.97			1.99	2.19	2.46	2.70	2.47	2.69	?	?
												0.46	0.57	2.46	2.70	2.47	2.69	?	?
3.00	3.13					1.76	2.32	2.23	2.33			2.19	3.22			2.47	2.69	?	?
4.42	4.57	3.28	3.60			1.76	2.32	2.18	2.23			2.19	3.22	2.70	3.17	2.47	2.69	?	?
		?	?			1.76	2.32	1.97	2.12			2.19	2.79	2.70	3.27	2.47	2.69	?	?
9.33	9.48					1.76	2.32	0.61	0.79	6.60	6.65	4.46	4.76	?	?	?	?	?	?
												0.78	0.88	?	?	1.68	2.47	?	?
2.47	2.65																		
2.96	3.13																		
						2.32	3.46	1.57	1.75			0.88	0.99	2.70	3.17			?	?
												?	?						
								2.23	2.33										
												2.19	2.79	2.70	3.17			?	?
								0.61	0.65			0.56	0.64					?	?
						1.32	1.69	1.57	1.58			1.67	1.73			2.66	3.33	?	?
						1.76	3.46	0.61	0.62			1.97	1.99			2.66	3.33	?	?
		3.20	3.33			1.76	3.46	2.50	2.53			2.17	2.77			2.66	3.33	?	?
						1.76	3.46	2.48	2.50			2.17	2.77			2.66	3.33	?	?
								2.66	2.72			3.28	?			2.66	3.33	?	?
		?	?			3.46	?	1.75	1.97			2.19	2.79	0.29	0.31			?	?
4.42	4.57							2.71	2.83										
4.52	4.57																		
								2.18	2.23										
		4.77	4.78					2.12	2.18										
								2.23	2.43										
								2.71	2.83										
		?	?			2.32	3.46	2.71	2.83			?	?	?	?	4.02	4.27	?	?
		4.08	4.13			1.76	2.32					4.33	4.43	2.70	3.17				
		3.12	3.33			2.32	3.46	2.90	2.96			4.33	4.43	?	?	?	?	?	?
		4.72	4.77			2.32	3.46	4.80	4.89			8.84	9.03	?	?	?	?	4.54	4.70
3.31	3.32					2.32	3.46	2.71	2.83			3.22	3.29			3.09	3.26	?	?
		4.70	4.72			?	?	4.72	4.87			4.46	4.76	?	?	?	?	4.54	4.70
																?	?	?	?
3.48	3.66	?	?			?	?	3.06	3.13			?	?					?	?
												?	?	?	?	?	?	?	?
		3.98	4.03			?	?	3.71	3.80			?	?	?	?	?	?	?	?
						1.76	3.46	3.44	3.52			3.28	?			1.62	2.81	?	?
4.57	4.63							3.95	4.08										
								3.95	4.08										
		4.32	4.66					4.57	4.60			4.43	4.69	?	?	4.12			
		4.32	4.62			?	?	4.22	4.27			4.33	4.69	?	?	?	?	?	?
												?	?			?	?	?	?
4.18	5.42											4.46	4.76						
												4.76	?			?	?		
												4.76	?					?	?
4.05	4.18																		
4.95	5.06	5.01	5.08			3.46	?	5.38	5.56			4.33	4.33	2.30	2.60	?	?	4.54	4.70
		6.92	7.07							6.83	6.88								
4.18	4.25	5.41	5.70			?	?	?	?					?	?			?	?
4.18	4.25							1.57	1.75										
4.73	5.75																	?	?
4.73	5.75	5.07	5.12																
4.57	4.62																		

(continued)

Table 42. (continued)

Event	514t	514b	689Bt	689Bb	690Bt	690Bb	695At	695Ab	696At	696Ab	697Bt	697Bb	699At	699Ab	701At	701Ab
LO <i>Thalassiosira praeconvexa</i>																
LO <i>Thalassiosira convexa</i> v. <i>aspinosa</i>																
LO <i>Lamprocyclas aegles</i>																
FO <i>Thalassiosira praeconvexa</i>																
LO <i>Nitzschia porteri</i>																
FO <i>Lamprocyclas aegles</i>																
LO <i>Diartus hughesi</i>																
FO <i>Stichocorys peregrina</i>																
FO <i>Nitzschia reinholdii</i>			4.67	4.69								?	?			
FO <i>Thalassiosira insigna</i>	3.20	3.26					2.65	2.80								
FO <i>Nitzschia marina</i>																
LO <i>Denticulopsis lauta</i>													4.90	5.19		
FO <i>Navicula wisei</i>																
FO <i>Thalassiosira inura</i>																
FO <i>Rouxia heteropolara</i>									6.18	6.77	?	?				
LO <i>Cycladophora spongothorax</i>			8.28	8.31	?	?										
LO <i>Hemiaulus triangularis</i>																
FO <i>Simonseniella barboi</i>													?	?		
LO <i>Raphidodiscus marylandicus</i>																
FO <i>Cestodiscus peplum</i>																
LO <i>Thalassiosira convexa</i>																
FO <i>Thalassiosira convexa</i> v. <i>aspinosa</i>																
LO <i>Trinacria excavata</i>																
FO <i>Hemidiscus karstenii</i>													?	?		
LO <i>Asteromphalus kennettii</i>			8.55	9.25	9.27	9.31										
LO <i>Reticulofenestra pseudumbilica</i>																
FO <i>Amphymenium challengerae</i>																
FO <i>Thalassiosira burckliana</i>																
FO <i>Hemidiscus ovalis</i>																
LO <i>Actinocyclus ingens</i> v. <i>nodus</i>			9.25	9.29												
LO <i>Acrosphaera australis</i>																
FO <i>Cosmiodiscus intersectus</i>			9.31	9.35	9.58	9.63					?	?				
FO <i>Acrosphaera labrata</i>			9.32	9.46												
LO <i>Reticulofenestra gelida</i>			9.60	9.92	12.08	12.85										
FO <i>Acrosphaera australis</i>			10.16	10.25												
LO <i>Calcidiscus macintyreii</i>																
FO <i>Thalassiosira torokina</i>													?	?		
LO <i>Cycladophora humerus</i>			10.16	10.25	10.22	10.57										
FO <i>Eucyrtidium pseudoinflatum</i>			10.41	10.47	10.00	10.58										
FO <i>Nitzschia fossilis</i>																
FO <i>Diartus hughesi</i>																
FO <i>Hemidiscus cuneiformis</i>	2.60	2.62											?	?		
FO <i>Thalassiosira miocenica</i>																
LO <i>Denticulopsis dimorpha</i>			3.95	4.02	11.98	12.86										
LO <i>Actinomma golownini</i>			11.86	11.87	10.00	10.58							?	?		
FO <i>Asteromphalus kennettii</i>			10.23	10.31	10.17	10.29										
FO <i>Actinocyclus fryxellae</i>																
LO <i>Cyrtocapsella japonica</i>																
LO <i>Denticulopsis praedimorpha</i>					10.88	11.02										
LO <i>Nitzschia denticuloides</i>			11.80	11.92	11.46	11.52							?	?		
LO <i>Reticulofenestra hesslandii</i>			11.91	11.93	12.08	12.85										
FO <i>Reticulofenestra hesslandii</i>																
FO <i>Cyrtocapsella japonica</i>																
FO <i>Denticulopsis dimorpha</i>			11.91	11.92	12.91	12.96										
LO <i>Dendrospyris megalocephalis</i>			11.88	11.92												
FO <i>Cycladophora spongothorax</i>			11.90	11.91	12.03	12.96										
LO <i>Nitzschia grossepunctata</i>			12.15	12.51	13.68	14.02										
FO <i>Denticulopsis praedimorpha</i>			12.51	12.76	13.09	13.35										
LO <i>Crucidenticula nicobarica</i>			11.95	12.14	12.85	12.91										
FO <i>Actinomma golownini</i>			13.06	13.28	13.41	13.75										
FO <i>Nitzschia denticuloides</i>			13.43	13.54	13.68	14.02							?	?		
FO <i>Antarctissa deflandrei</i>			13.38	13.43	13.75	14.51										
LO <i>Denticulopsis maccollumnii</i>			13.99	14.24	14.24	14.44										
FO <i>Denticulopsis hustedtii</i>			13.99	14.24	14.24	14.44					?	?				
FO <i>Cycladophora humerus</i>			14.13	?	13.75	14.51										

704Bt	704Bb	737At	737Ab	744At	744Ab	744Bt	744Bb	745Bt	745Bb	746At	746Ab	747At	747Ab	747Bt	747Bb	748Bt	748Bb	751At	751Ab
4.77	4.89					?	?												
6.02	6.19																		
6.20	6.24																		
6.97	7.01									6.60	6.65								
7.71	7.83																		
7.80	8.05																		
8.12	8.14																		
8.12	8.14																		
8.54	8.73	?	?			?	?							9.11	5.14			?	?
8.54	8.73							2.90	2.96					?	?	3.09	3.26	?	?
8.54	8.73									8.12	8.18								
7.09	7.12					10.78	10.89												
																?	?	?	?
								?	?										
		6.36	6.40					3.95	4.08			4.46	4.76			?	?	?	?
										9.41	9.44	9.23	9.25	9.17	9.62			9.32	9.70
												4.76	?						
11.39	11.66																		
?	?			20.69	?														
								5.98	6.09										
								6.09	6.18										
								6.09	6.18										
										?	?								
						?	?			9.50	?	4.76	?	9.19	9.74	?	?	?	?
3.83	4.01					10.42	10.52					16.51	16.75			22.46	22.50	10.18	10.25
6.20	6.24																	?	?
										9.50	?								
												9.25	9.27			11.48	?	?	?
11.06	12.95					14.28	14.56			6.60	6.65	12.88	13.14					12.64	12.78
						10.50	10.70												
8.54	8.74	?	?							8.65	8.75							9.21	9.27
												8.46	8.82	9.14	9.17				
														10.76	10.93	10.25	10.44	10.64	10.71
2.96	3.13					10.52	10.62					9.72	9.80			10.45	10.64		
						?	?			8.52	8.56	9.03	9.24	9.95	10.03	4.27	?	?	?
				8.23	8.29					8.23	8.29					10.19	10.25	10.92	10.98
						16.45	17.20			?	?	10.08	10.37	10.84	10.93	10.44	10.63	10.92	10.98
9.48	9.59																		
9.83	9.84																		
9.87	9.90					10.58	10.69					10.38	10.66					?	?
9.97	10.16	6.56	6.67			?	?			?	?			9.11	9.14			?	?
10.15	10.30			4.46	4.76	2.32	3.46			6.60	6.65			?	?	?	?	?	?
						10.79	11.12					10.37	10.94	10.59	10.67			11.05	11.13
10.42	10.52					10.25	10.35			?	?			9.81	9.95	10.19	10.25	9.63	9.69
		?	?			10.99	11.05												
10.48	10.54																		
						11.38	11.44					11.67	11.81			11.33	11.40	12.04	12.12
						?	?					11.81	11.98			10.25	10.32	12.04	12.12
						17.55	17.92					2.82	3.56					?	?
												11.93	12.18						
10.99	11.05																		
11.06	12.95					?	?	0.79	1.27			12.88	13.14			?	?	12.61	12.78
						11.32	?					11.66	11.76	?	?	10.25	10.44	12.35	12.40
13.11	13.64					?	?					13.14	13.57			?	?	12.83	13.11
						?	?					12.88	13.14	?	?	?	?	12.83	13.11
12.95	13.11																		
						?	?					12.88	13.11			?	?	13.66	14.57
13.64	14.02					15.21	15.55					13.57	13.66			?	?	13.67	13.84
13.11	13.64					?	?					14.32	14.49			?	?	12.78	12.83
?	?	?	?			14.42	14.56					14.14	14.32			?	?	14.08	14.15
						14.28	14.42			?	?								

(continued)

Table 42. (continued)

Event	514t	514b	689Bt	689Bb	690Bt	690Bb	695At	695Ab	696At	696Ab	697Bt	697Bb	699At	699Ab	701At	701Ab
FO <i>Dendrospyrus megalcephalis</i>			14.13	?												
LO <i>Synedra jouseana</i>			14.51	14.57	14.51	?										
FO <i>Actinocyclus ingens</i> v. <i>nodus</i>			?	?	14.51	?										
LO <i>Coscinodiscus lewistanus</i>			16.61	16.66												
FO <i>Simonseniella barboi</i>																
LO <i>Coscinodiscus rhombicus</i>			16.66	16.72												
FO <i>Eucyrtidium punctatum</i>			16.72	17.33												
LO <i>Nitzschia maleinterpretaria</i>			16.85	17.07	14.51	?										
LO <i>Crucidenticula kanayae</i>			16.81	17.05	16.91	17.19										
FO <i>Denticulopsis lauta</i>																
FO <i>Nitzschia grossepunctata</i>			16.85	17.09	17.19	17.42										
FO <i>Nitzschia maleinterpretaria</i>					17.19	17.42										
LO <i>Thalassiosira fraga</i>			17.09	17.20	17.86	18.59										
FO <i>Calcidiscus macintyreii</i>																
FO <i>Actinocyclus ingens</i>	2.35	2.37	17.22	17.45	17.19	17.42					3.21	3.34				
FO <i>Denticulopsis maccollumii</i>			17.22	17.45	17.42	17.50										
FO <i>Calcidiscus leptoporus</i>																
FO <i>Crucidenticula kanayae</i>			17.45	17.55	17.42	17.50										
FO <i>Cycladophora golli regipileus</i>			18.94	19.00	18.28	19.20										
FO <i>Crucidenticula nicobarica</i>			19.01	19.14	19.50	19.70										
FO <i>Cyrtocapsella tetrapera</i>			18.94	?	19.55	20.04										
FO <i>Cyrtocapsella longithorax</i>			?	?	19.20	19.55										
LO <i>Thalassiosira aspinosa</i>																
FO <i>Coscinodiscus lewistanus</i>																
LO <i>Thalassiosira spumellaroides</i>			15.57	?	19.50	19.55										
FO <i>Raphidodiscus marylandicus</i>			?	?	19.99	20.04										
FO <i>Thalassiosira fraga</i>			?	?	19.85	19.99										
LO <i>Chiasmolithus altus</i>			?	24.93	?	?							26.54	26.80		
LO <i>Reticulofenestra bisecta</i>			?	24.93	29.29	29.54							23.83	23.86		
FO <i>Thalassiosira aspinosa</i>					19.99	20.04										
LO <i>Rocella gelida</i>			?	24.84	19.85	19.99							23.43	23.51		
LO <i>Rocella schraderi</i>																
LO <i>Rocella vigilans</i>			24.91	25.05	19.99	20.04										
LO <i>Bogorovia veniamini</i>												?	?			
LO <i>Lisitzina ornata</i>					20.04	?										
FO <i>Thalassiosira spumellaroides</i>			24.77	25.05	20.04	?										
FO <i>Rocella vigilans</i>			26.07	26.13	26.48	27.06										
FO <i>Rocella gelida</i>			26.07	26.13	26.48	27.06							25.33	25.76		
LO <i>Thalassiosira primalabiata</i>																
FO <i>Lisitzina ornata</i>					27.62	27.78										
LO <i>Reticulofenestra umbilica</i>			30.74	31.03	?	?							31.75	31.88		
LO <i>Isthmolitus recurvus</i>			31.83	32.35	?	?							32.31	32.39		
LO <i>Reticulofenestra oamaruensis</i>			33.60	34.01									33.48	?		
FO <i>Reticulofenestra oamaruensis</i>			35.24	35.26												
FO <i>Isthmolitus recurvus</i>			35.82	36.01	35.73	35.92										
FO <i>Cyclicargolithus abisectus</i>					30.77	?							30.99	31.49		
LO <i>Reticulofenestra reticulata</i>			35.82	36.01	35.73	35.92										
LO <i>Rhizosolenia oligocenica</i>																
LO <i>Synedra jouseana</i>																

Emboldened events are primary stratigraphical indicators based on this study. ? indicates the occurrence of undated specific biostratigraphical events. Dating these events was prohibited either by the absence of magnetic data and/or the presence of an unconformity.

both regions. The ages of the FO of *Denticulopsis praedimorpha* are nearly isochronous (12.8 Ma in the North Pacific and 12.96 Ma in the Southern Ocean). Thus, using the criteria adopted in this study, *Denticulopsis praedimorpha* would qualify as a primary datum level for correlating between the two regions. The FO of *Crucidenticula kanayae*, 16.9 Ma in the North Pacific, is younger than the age of this event, 17.55 Ma, in the Southern Ocean. We would not consider this event either as a primary or potentially useful event for correlation between the North Pacific and Southern Ocean. Some Miocene diatom datum levels which have been recorded as diachronous in the Southern Ocean, FO *Denticulopsis lauta*, FO *Denticulopsis dimorpha*, LO *Denticulopsis dimorpha*, and FO *Thalassiosira oestrupii*, appear to be approximately isochronous

and widely applicable in the North Pacific (Barron and Gladenkov, 1995). These observations confirm our reservations concerning the transfer and application of useful diatom datum levels between the high latitude regions of the northern and southern hemispheres.

Stratigraphical continuity

The occurrence of regionally consanguineous hiatuses is used by palaeoceanographers to infer temporal changes in the characteristics of major deep water masses (Ramsay *et al.* 1994). Burckle & Abrams (1987) reconsidered the diatom zonation which was used to identify and correlate hiatuses in Quaternary and Pliocene (0–5 Ma)

704Bt	704Bb	737At	737Ab	744At	744Ab	744Bt	744Bb	745Bt	745Bb	746At	746Ab	747At	747Ab	747Bt	747Bb	748Bt	748Bb	751At	751Ab
						?	?									?	?	?	?
						?	?					14.49	14.80					?	?
13.11	13.64					15.55	15.89			8.07	8.12	14.49	14.68					14.38	14.50
13.11	13.64					1.76	2.32					13.14	13.57			?	?		
?	?																		
16.81	16.99																		
14.03	?					16.40	16.80					14.46	14.58			?	?	16.63	16.72
12.95	13.11					16.40	16.80									11.48	?	16.72	16.83
						16.95	17.02					15.91	16.01			11.48	?	16.13	16.26
16.52	16.52					16.95	17.02					15.91	16.01			?	?	16.26	16.31
18.66	19.37			25.98	26.23											22.73	22.76	17.63	17.94
?	?					16.80	16.95					18.49	19.13			?	?	?	?
?	16.52					?	?					17.17	17.45			11.49	11.51	16.35	16.72
?	?					15.89	16.40	2.23	2.33			15.91	16.01			?	?	?	?
16.50	16.52					16.95	17.02					16.74	17.28			?	?	16.72	16.83
						?	?					17.67	17.96					17.58	17.65
16.56	16.81					17.49	17.69					17.52	17.65			?	?	17.63	17.67
						17.20	?												
17.42	17.47					17.49	17.69											14.58	14.67
11.35	11.83																		
				19.61	19.78														
17.00	17.12																		
17.12	17.42																		
19.86	20.12			19.61	19.78											22.52	22.62		
				20.69	21.34	17.01	17.18					21.98	22.42						
20.12	21.07			19.85	20.02							20.18	20.57			22.82	22.93		
				26.04	26.11							25.96	25.97			25.93	25.95		
				?	?							23.80	24.03			24.53	24.59		
19.74	19.76											?	?					?	?
18.66	19.37			20.54	20.70							22.68	23.50			22.63	22.73		
18.66	19.37			20.01	20.24														
18.66	19.37							5.38	5.56			25.37	25.50						
20.12	21.07			20.69	21.34							21.48	21.22			22.94	23.38		
				24.94	25.80							23.34	23.80						
				20.55	20.70											22.94	23.38		
				30.69	30.83			?	?			26.53	?			30.29	30.52		
?	?			26.23	26.38							25.89	25.92			25.28	26.12		
				?	?							23.78	24.11			22.94	23.38		
				26.29	26.45							26.53	?						
				31.21	31.39											22.46	22.50		
				31.72	31.93											32.11	32.94		
				33.67	33.75											33.99	34.03		
				35.86	35.92														
				36.03	36.15														
				31.39	31.50											30.89	31.25		
				36.03	36.15														
				33.56	33.66														
				30.27	30.56														

sequences from piston cores from the Southern Ocean. In this study, which also incorporated palaeomagnetic data, these workers recorded the occurrence of fewer hiatuses than had been previously identified and identified diachronous diatom events. Burckle & Abrams (1987) concluded that the recognition of regionally synchronous hiatuses in the Southern Ocean required both the reevaluation of the magnetostratigraphy and the development of locally and regionally applicable biozonations.

The choice of an age model used to interpret the stratigraphy of drill sites can have a profound influence on the placement and number of hiatuses within a drillsite. Figure 60 shows the distribution of breaks in the stratigraphical sections based on the age model used in this study. The current interpretation indicates

that, in general, the sequences are more continuous with fewer breaks than previously recognized (see Fig 3). Comparing Figs 3 and 60 illustrates the noticeable differences, especially the completeness of the records. In particular, the numerous hiatuses previously identified in Holes 690B, 747A, 748B and 751A are a consequence of the biostratigraphical markers and the age model used. Although the current study identifies more continuous sections, the age model used relies to a greater extent on the record of palaeomagnetic reversals with fewer biostratigraphical control points. Therefore this interpretation is based on a coarser stratigraphical resolution which was achieved by eliminating previously used datums that, according to our data sets are less reliable for stratigraphical control. Although the number of

Table 43. Primary and potentially useful Quaternary, Neogene and late Palaeogene stratigraphical indicators for the Southern ocean based on this study.

Primary events

LO *Thalassiosira kolbei*
 LO *Thalassiosira vulnifica*
 FO *Nitzschia praeinterfrigidaria*
 FO *Nitzschia interfrigidaria*
 FO *Helotholus vema*
 FO *Nitzschia barronii*
 FO *Denticulopsis praedimorpha*
 FO *Nitzschia denticuloides*
 FO *Denticulopsis hustedtii*
 LO *Synedra jouseana*
 FO *Crucidentacula kanayae*
 FO *Isthmolithus recurvus*
 LO *Reticulofenestra reticulata*

Potential events

LO *Thalassiosira elliptopora*
 LO *Hemidiscus karstenii*
 LO *Actinocyclus ingens*
 LO *Antarctissa cylindrica*
 LO *Cycladophora pliocenica*
 LO *Desmospyris spongiosa*
 LO *Helotholus vema*
 FO *Nitzschia weaveri*
 LO *Denticulopsis hustedtii*
 LO *Thalassiosira burckliana*
 LO *Cycladophora spongothorax*
 LO *Asteromphalus kennettii*
 FO *Acrosphaera labrata*
 FO *Asteromphalus kennettii*
 FO *Denticulopsis dimorpha*
 LO *Crucidentacula nicobarica*
 LO *Coscinodiscus rhombicus*
 LO *Thalassiosira fraga*
 LO *Chiasmolithus altus*
 LO *Reticulofenestra oamaurensis*

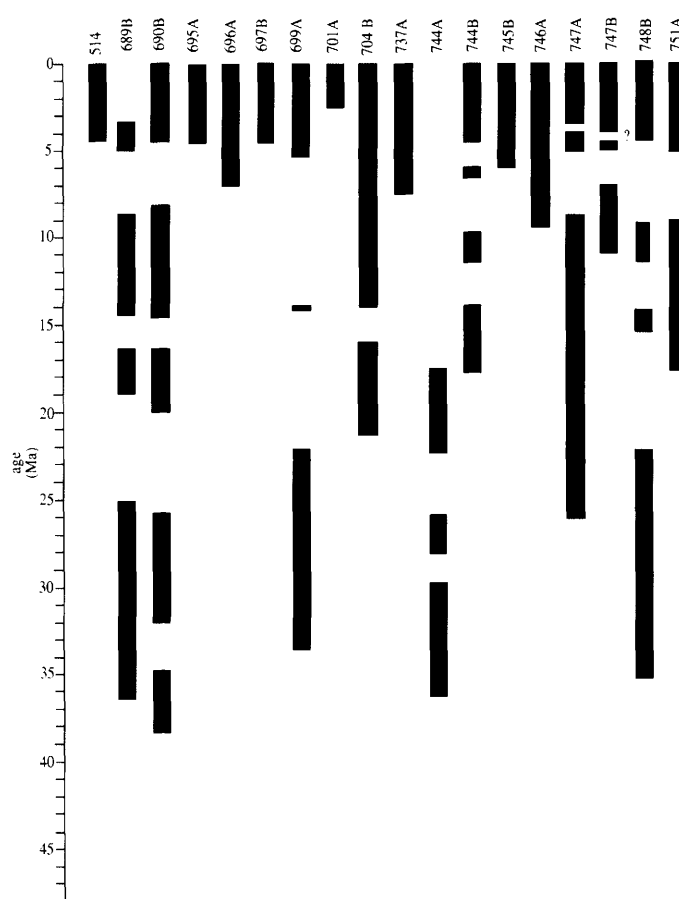


Fig. 60. Chronostratigraphical assignment of sediments recovered from the DSDP and ODP holes used in this study. Solid bars represent intervals containing diatoms, radiolarians or calcareous nannofossils and a polarity record.

biostratigraphical events in the Quaternary and Pliocene provide a reasonable framework the paucity of events in the older stratigraphical sequence limits the available chronostratigraphical resolution when the stratigraphy is constrained only by biostratigraphical events. The chronostratigraphical control is enhanced by using an integrated approach including polarity sequences. It was inevitable that the methodology employed in this study, which included the maintenance of stratigraphical continuity, resulted in

the recognition of fewer primary and secondary biostratigraphical markers and fewer unconformities. Thus in some sites e.g. 689B, 690B, 699A and 744A the chronostratigraphy of some intervals is based, in the absence of primary markers, on our reassessment of the polarity sequence. Determination of the polarity stratigraphy for intervals where primary biostratigraphical markers are lacking is based on a coarser stratigraphy that incorporates a broad age assignment of the flora and fauna.

Conclusion

Reinterpretation of the numerous biostratigraphical and palaeomagnetic data sets generated by previous workers for 18 holes in the Southern Ocean have provided the opportunity to reassess the reliability of the current Quaternary–Neogene and late Palaeogene biochronological models. Emphasis is placed however, on the younger record. This reassessment is focused on Southern Ocean sites that contain both biostratigraphical and polarity reversal records. All data sets were integrated and the polarity reversal records reinterpreted and calibrated to the Geopolarity Timescale of Cande & Kent (1995).

Earlier biochronological models have relied on the assumed isochroneity of specific primary biostratigraphical markers. These markers were used to calibrate the polarity reversal record. In these models 'reliable' primary markers were often identified on the basis of leg-specific results and from secondary and even tertiary correlations. In this study these models were extended by applying an ocean wide approach. The integration of data sets obtained throughout the Southern Ocean provided the first opportunity to assess the accuracy of specific events and determine the reliability of previously identified biochronological models.

The results from this study indicate the paucity of useful biostratigraphical markers and show that the majority of previously

used biostratigraphical events (diatoms, radiolarians and calcareous nannofossils) are diachronous throughout the Southern Ocean and less reliable than previously thought. These results suggest that previous palaeoceanographical interpretations will require significant modification.

The biochronology resulting from this study indicates that 13 biostratigraphical events meet the requirements established in this study (age constraint less than 0.25 million years) and are considered as primary biostratigraphical markers. Twenty biostratigraphical events are identified as potential biostratigraphical indicators and additional data are required to further assess their chronostratigraphical potential. The paucity of biostratigraphical events which include diatoms, radiolarians, and calcareous nannofossils has resulted in a much coarser stratigraphy than previously applied.

The results from this study provide an integrated biochronological framework for the Southern Ocean. This framework will continue to be refined as additional stratigraphical sequences are recovered that allow testing the current stratigraphical model and as samples from pre-existing sequences are re-examined to refine the stratigraphical placement of specific species.

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