12. CALCAREOUS NANNOPLANKTON BIOSTRATIGRAPHY OF THE SOUTHERN CORAL SEA, TASMAN SEA, AND SOUTHWESTERN PACIFIC OCEAN, DEEP SEA DRILLING PROJECT LEG 90: NEOGENE AND QUATERNARY[1]

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ABSTRACT

Leg 90 of the Deep Sea Drilling Project drilled 18 holes at eight sites (Sites 587–594) on several shallow-water platforms in the southern Coral Sea, Tasman Sea, and southwestern Pacific Ocean. The results from an additional hole (Hole 586B) drilled at Site 586 during Leg 89 are included in this report. Together, these sites form a latitudinal traverse which extends from the equator (Site 586) to 45°S (Site 594) and includes all the major water masses from tropical to subantarctic. Samples recovered at these sites range in age from middle Eocene to late Quaternary. The calcareous nannoplankton biostratigraphy for Leg 90 has divided into two parts: part 1, the Neogene and Quaternary of Sites 586-594. (this chapter); and part 2, the Paleogene of Sites 588, 592, and 593 (Martini, this volume). A slightly modified version of the Martini (1971) standard Tertiary and Quaternary zonation scheme was used to make age determinations on over 700 samples. All of the relevant Neogene and Quaternary zone-defining nannoplankton are present at Sites 586–591 (0°–30°S) but become increasingly rare or are absent at Sites 592–594 (35°–45°S). Species diversity increases southward from the equator (Site 586) and reaches a peak at 20°S (Site 587). A decrease at 25°S (Site 588) and 30°S (Sites 589–591) is followed by an increase in species diversity at 35°S (Site 592). South of 35°S, species diversity again decreases and reaches a low at 45°S (Site 594). Species diversity for all sites as a group generally increases through the early, middle, and late Miocene, reaches a peak in the early Pliocene, then gradually decreases through the late Pliocene and Quaternary.

INTRODUCTION

The southwest Pacific, unlike most other oceanic regions, contains numerous submarine topographic features. These bathymetric highs, or platforms, extend latitudinally over vast distances and are overlain by relatively uncomplicated middle to upper Cenozoic calcareous ooze and chalk, free of terrigenous content. One of the major platforms in the region, the Lord Howe Rise, is approximately 300 km wide and extends some 2000 km northward from central western New Zealand to about 20°S. The crest lies at water depths ranging from 750 to 1200 m.

Leg 90 of the Deep Sea Drilling Project (Noumea, New Caledonia, to Wellington, New Zealand) occupied eight sites (Fig. 1) in the southern Coral Sea, Tasman Sea, and southwestern Pacific east of New Zealand's South Island during December, 1982, and January, 1983. The sites are located on shallow-water platforms extending south from the southern slope of Lansdowne Bank (Site 587), northern to southern Lord Howe Rise (Sites 588–592), Challenger Plateau (Site 593), and the southern margin of the Chatham Rise (Site 594). Two methods of drilling, the hydraulic piston corer (HPC) and the extended core barrel (XCB), were used during Leg 90 to drill 18 holes in water depths ranging from 1068 m (from sea level) at Site 593 to 2131 m at Site 591. The XCB, first successfully used during Leg 90, is a core barrel that extends several centimeters ahead of the main rotary drill pipe bit and is used to core sediments after they have become too consolidated for coring with the HPC. The use of the HPC and XCB methods permitted greater core recovery with much less disturbance than with standard rotary coring and, as a result, a record 495 high-quality cores representing over 3700 m of sediment were recovered. An additional equatorial site (Site 586), located on the Ontong-Java Plateau at a water depth of 2207 m (from sea level), was drilled during Leg 89, and the 25 cores recovered from Hole 586B were set aside for study by Leg 90 scientists. The results from Hole 586B are included in the Leg 90 report. Samples recovered at these sites range in age from middle Eocene to late Quaternary. Only three sites (Sites 588, 592, and 593) penetrated pre-Miocene sediment.

The calcareous nannoplankton biostratigraphy for Leg 90 has been divided into two reports: part 1, the Neogene and Quaternary of Sites 586–594 (this chapter); and part 2, the Paleogene of Sites 588, 592, and 593 (Martini, this volume). Over 700 samples from the nine sites were examined for calcareous nannoplankton. All of the relevant Neogene and Quaternary zone-defining species used during Leg 90 are present at Sites 586–591 (0°–30°S) but become increasingly rare or are absent at Sites 592–594 (35°–45°S). The nannoplankton age determinations of Leg 90 samples made during this study agree very closely with those determined aboard the ship. Latitudinal effects on calcareous nannoplankton diversity are reflected in the changes in numbers of indigenous species observed from site to site along the traverse. Indigenous species range from a high of 48 in the early Pliocene at Site 587 (20°S) to a low of 13 in the late Pliocene at Site 594 (45°S).

[1] Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office).
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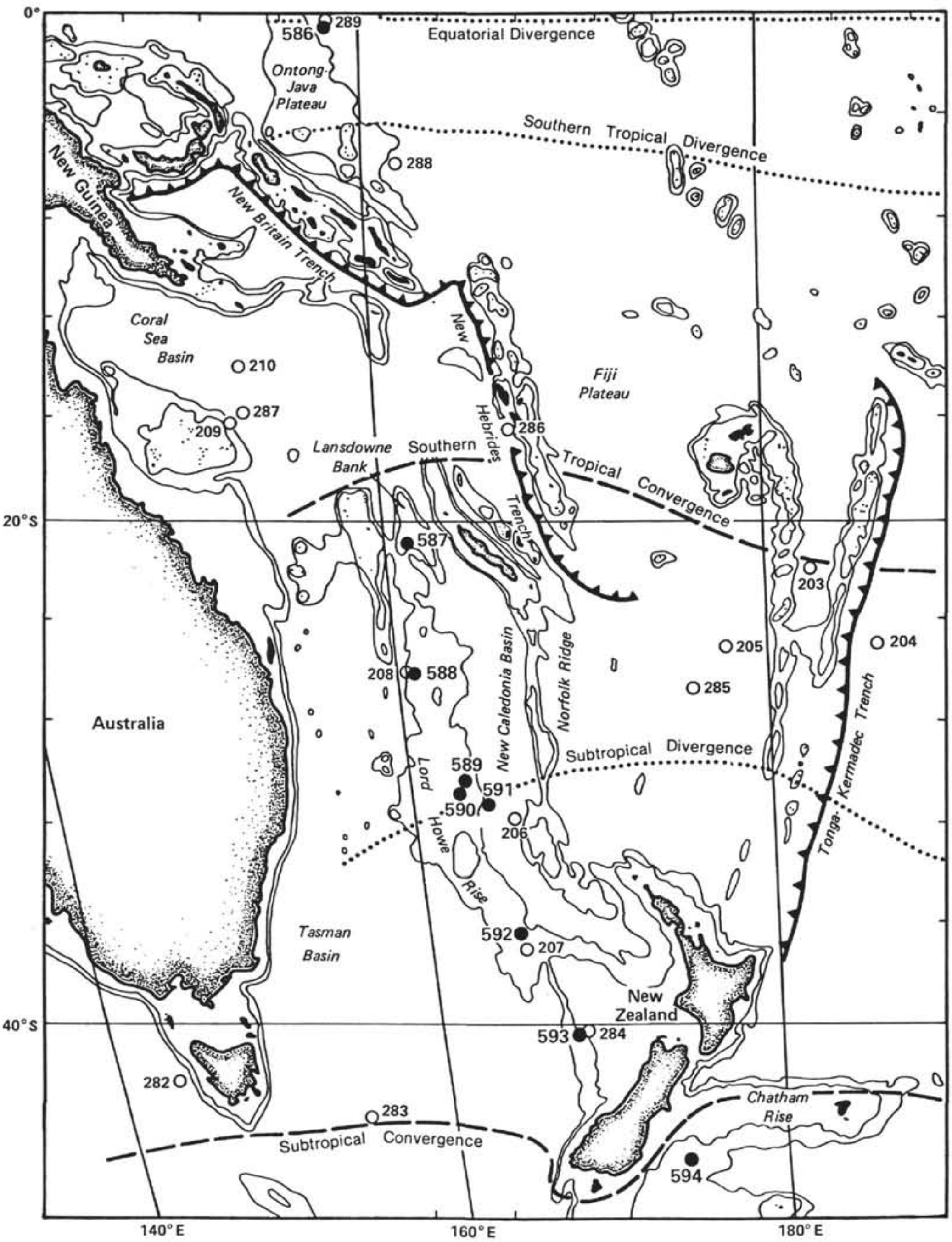

Figure 1. DSDP drill sites from Leg 90 and other DSDP legs in the southwest Pacific.

NANNOPLANKTON ZONATION

A slightly modified version of the Martini (1971) standard Tertiary and Quaternary zonation scheme (Fig. 2) was used to make the initial calcareous nannoplankton age determinations during Leg 90. For consistency, the zonation scheme used aboard ship is also used in this chapter.

The zonal modifications include the subdivision of Zones NN19 and NN11 and the use of an alternate species to define the upper boundary of Zone NN4. The last occurrence of *Calcidiscus macintyrei* occurs within the early Quaternary *Emiliania ovata* (= *Pseudoemiliania lacunosa*) Zone (NN19) and is used to subdivide Zone NN19 into Subzones NN19a and NN19b. Subzone NN19a is equivalent to the *Calcidiscus macintyrei* (= *Cyclococcolithina macintyrei*) Zone of Gartner (1977) and Subzone WPN-30a of Ellis (1982). Subzone NN19b is equivalent to Subzones WPN-31a and WPN-30b of Ellis (1982). The late Miocene *Discoaster quinqueramus* Zone (NN11) is subdivided into Subzones NN11a and NN11b by the first occurrence of *Amaurolithus primus* within Zone NN11. Subzone NN11b is equivalent to the *Amaurolithus primus* (= *Ceratolithus primus*) Subzone of Bukry (1973b), Subzone CN9b of Okada and Bukry (1980), and Subzone WPN-26b of Ellis (1982). Subzone

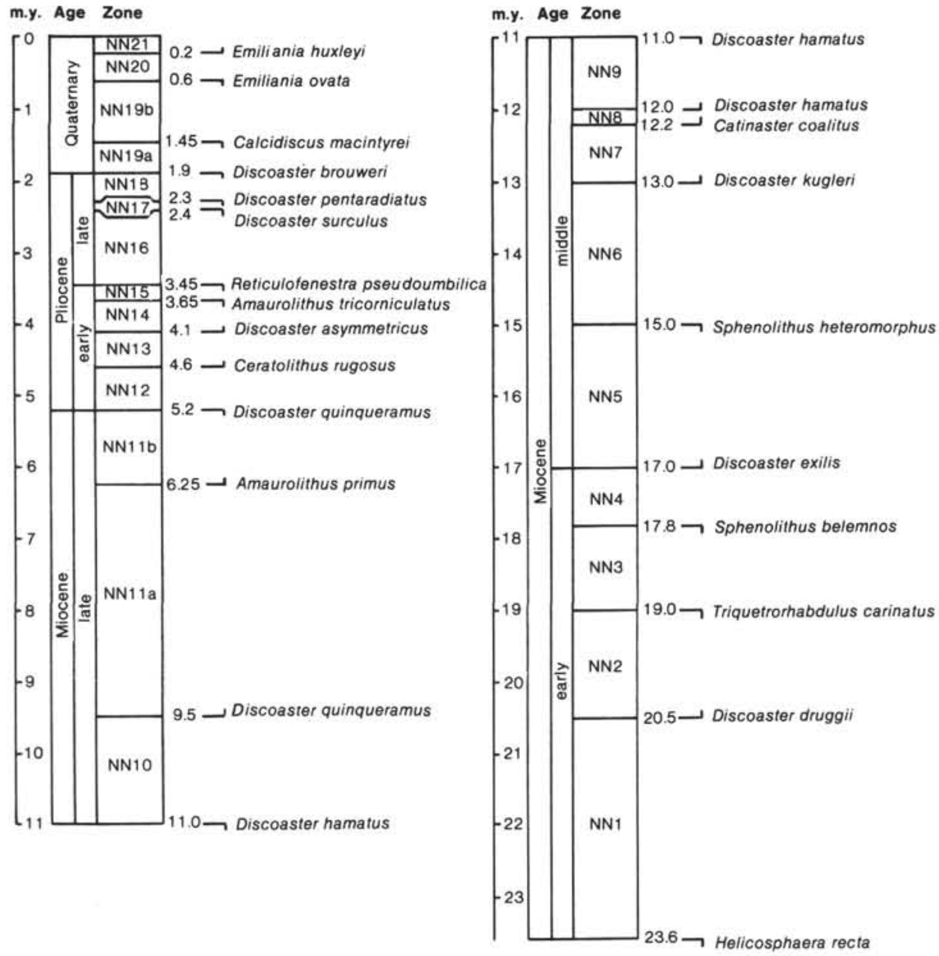

Figure 2. Calcareous nannoplankton zonation scheme used for the Quaternary and Neogene of Leg 90; modified after Martini (1971). Ages for zonal boundaries are standardized for Leg 90 (Martini, this volume).

NN11a is equivalent to Subzone WPN-26a of Ellis (1982). Because *Helicosphaera ampliaperta* is apparently absent in the western Pacific, the upper boundary of the early Miocene *Helicosphaera ampliaperta* Zone (NN4), normally placed at the last occurrence of the nominal species, is instead marked by the first occurrence of *Discoaster exilis*, which closely approximates this level (Martini and Worsley, 1971).

NANNOPLANKTON ABUNDANCE AND DIVERSITY

The locations of Sites 587–594 (Leg 90), together with Site 586 (Leg 89), form a latitudinal traverse which extends from the equator to 45°S and includes all the major surface-water masses between the tropics and the sub-Antarctic. The effects of higher latitudes and cooler waters are reflected in the changes in abundance and diversity of calcareous nannoplankton observed at sites along this traverse.

The average abundance of each of the Neogene and Quaternary zonal and subzonal indicators at various southern latitudes is shown in Figure 3. The vertical axis indicates abundance in terms of A = abundant, C = common, R = rare, and B = barren (for quantitative estimates of A, C, R, see below). The abundance values for each taxon were obtained by assigning a value of A = 3, C = 2, R = 1, or B = O for each occurrence on the nannoplankton range charts and calculating the numerical average for each taxon at each site. The horizontal axis includes each of the nine sites plotted to the nearest increment of 5°S latitude. Abundance values for taxa at 30°S are the average of those obtained at Sites 589, 590, and 591. For some taxa there are no data in some sections, because drilling operations ended at those sites before the sections were penetrated. In general, the abundance of zone-defining discoasters declines steadily at higher latitudes; they are extremely rare at 45°S. However, three discoasters (*Discoaster pentaradiatus, D. asymmetricus*, and *D. quinqueramus*) reach an abundance peak at 25°S before declining sharply. The abundances of other zone-defining species, including *Amaurolithus primus, A. tricorniculatus, Calcidiscus macintyrei, Helicosphaera recta, Reticulofenestra pseudoumbilica*, and *Triquetrorhabdulus carinatus* appear to change very little with latitude. The abundance of one species, *Emiliania huxleyi*, increases with latitude, reaching a peak at 40°S.

Changes in nannoplankton diversity for indigenous species at various southern latitudes are shown in Figure 4. The highest diversity of nannoplankton (33 species) in Quaternary sediments occurs at 20°S (Site 587).

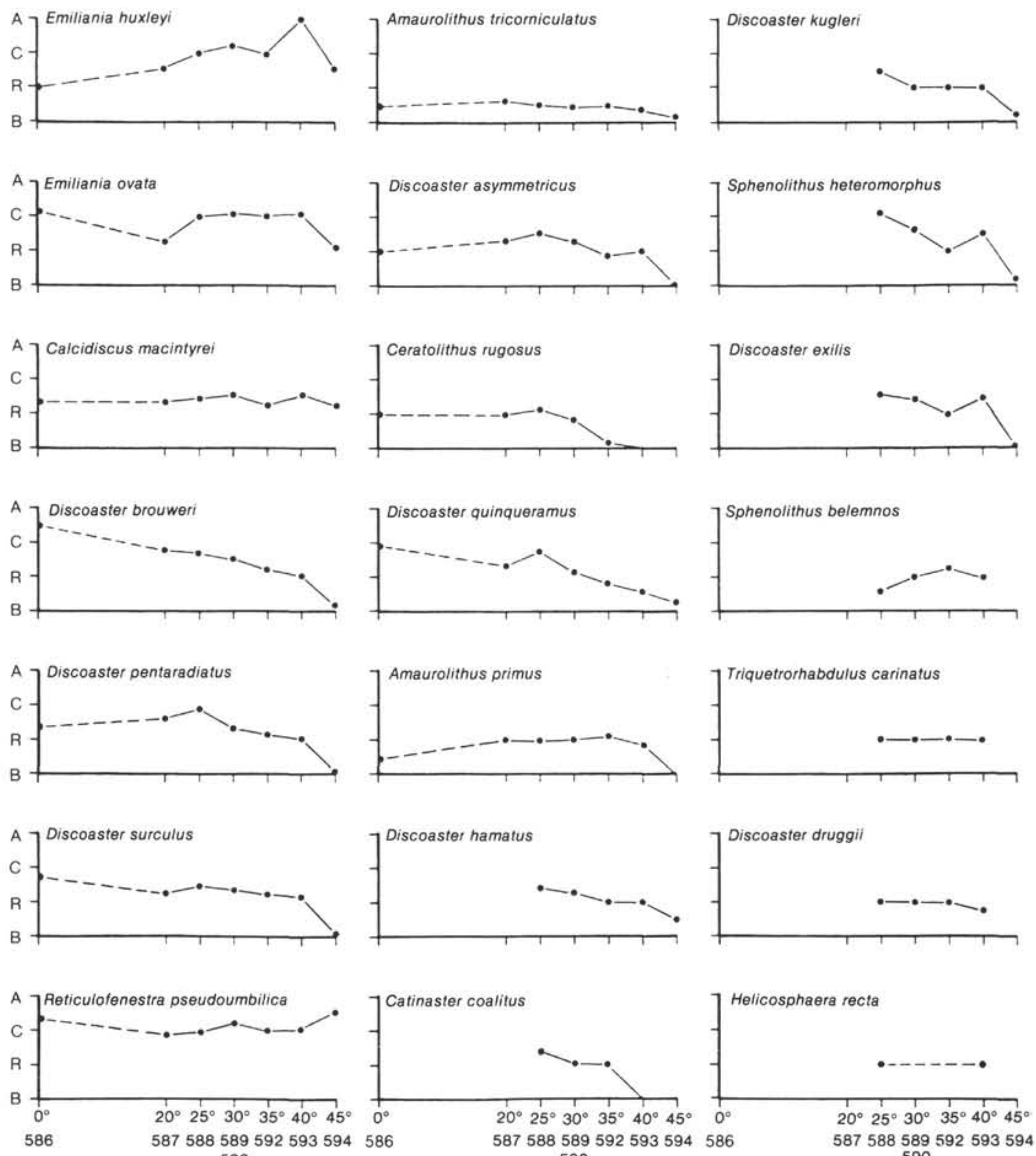

Figure 3. Relative abundances (●) of Quaternary and Neogene zonal and subzonal indicators encountered at various southern latitudes. Dashed lines indicate latitudes for which there are no data. Vertical axis: A = abundant, C = common, R = rare, and B = barren (fully defined in text). Horizontal axis: Approximate southern latitude of sites.

South of Site 587, there is a steady decline in diversity to a low of 20 species at 45°S (Site 594). In the late and early Pliocene and in the late Miocene, diversity peaks also occur at 20°S (Site 587), with a maximum of 48 species in the early Pliocene, South of Site 587, a decline in diversity at 25°S and 30°S (Sites 588–591) is followed by peaks of lesser diversity at 35°S (Site 592). The lowest diversity (13 species) occurs in the late Pliocene at 45°S (Site 594). The middle Miocene at Sites 588 and 590–594 and the early Miocene at Sites 588, 590, and 592–593 are marked by lower diversity.

The data presented in Figures 3 and 4 point out certain latitudinal abundance and diversity trends observed during Leg 90 and show the limitations of calcareous nannoplankton for zoning sediments south of 40°S.

SYSTEMATIC PALEONTOLOGY

Forty genera and 122 species of calcareous nannoplankton were recognized during the study of core samples from Sites 586–594 (Fig. 5). The genera are listed alphabetically for convenient reference and a brief synonomy of indigenous and reworked species is included.

Genus *AMAUROLITHUS* Gartner and Bukry, 1975

Amaurolithus amplificus (Bukry and Percival)

Ceratolithus amplificus Bukry and Percival, 1971, p. 125, pl. 1, figs. 9–11.
Amaurolithus amplificus (Bukry and Percival). Gartner and Bukry, 1975, pp. 455–456, figs. 6g–l.

Amaurolithus bizzarus (Bukry)

Ceratolithus bizzarus Bukry, 1973a, p. 676, pl. 1, figs. 6–10.
Amaurolithus bizzarus (Bukry). Gartner and Bukry, 1975, p. 456, figs. 8a–b.

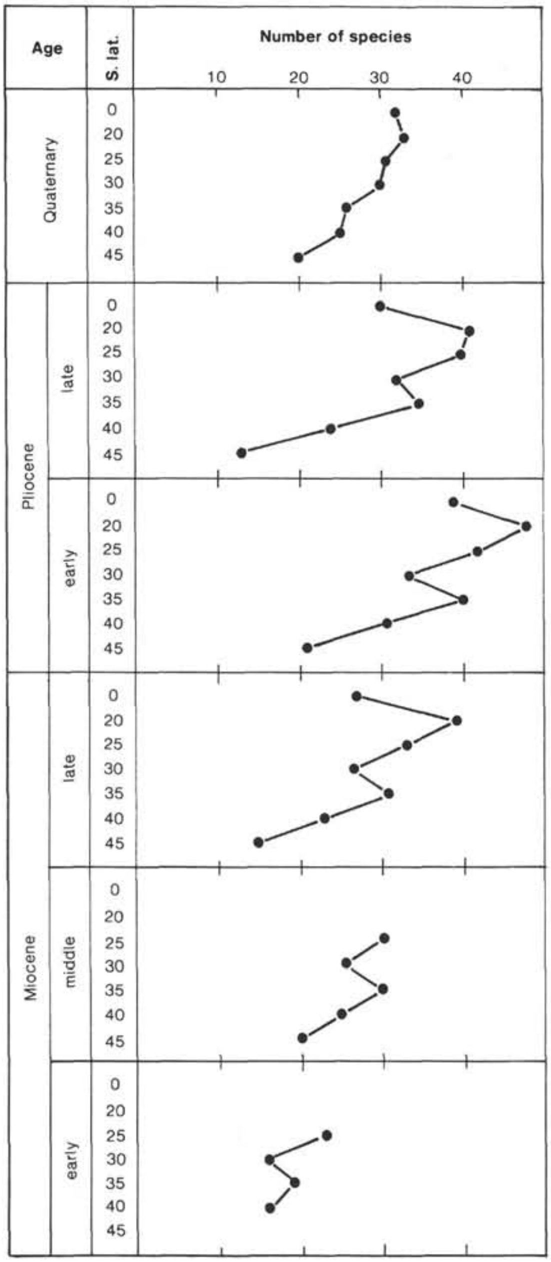

Figure 4. Total number of indigenous calcareous nannoplankton species observed in the Quaternary and Neogene at various southern latitudes.

Amaurolithus delicatus Gartner and Bukry

Amaurolithus delicatus Gartner and Bukry, 1975, p. 456, figs. 7a–f.

Amaurolithus primus (Bukry and Percival)

Ceratolithus primus Bukry and Percival, 1971, p. 126, pl. 1, figs. 12–14.
Amaurolithus primus (Bukry and Percival). Gartner and Bukry, 1975, p. 457, figs. 7g–1.

Amaurolithus tricorniculatus (Gartner)

Ceratolithus tricorniculatus Gartner, 1967, p. 5, pl. 10, figs. 4–6.
Amaurolithus tricorniculatus (Gartner). Gartner and Bukry, 1975, pp. 457–458, figs. 8c–h.

Genus *ANGULOLITHINA* Bukry, 1973

Angulolithina arca Bukry

Angulolithina arca Bukry, 1973a, p. 675, pl. 1, figs. 1–5.

Genus *BRAARUDOSPHAERA* Deflandre, 1947

Braarudosphaera bigelowii (Gran and Braarud)

Pontosphaera bigelowi Gran and Braarud, 1935, p. 389, fig. 67.
Braarudosphaera bigelowi (Gran and Braarud). Deflandre, 1947, p. 439, figs. 1–5.

Genus *CALCIDISCUS* Kamptner, 1950

Calcidiscus leptoporus (Murray and Blackman)

Coccosphaera leptopora Murray and Blackman, 1898, p. 430, pl. 15, figs. 1–7.
Calcidiscus leptoporus (Murray and Blackman). Loeblich and Tappan, 1978, p. 1391.

Calcidiscus macintyrei (Bukry and Bramlette)

Cyclococcolithus macintyrei Bukry and Bramlette, 1969, p. 132, pl. 1, figs. 1–3.
Calcidiscus macintyrei (Bukry and Bramlette). Loeblich and Tappan, 1978, p. 1392.

Genus *CATINASTER* Martini and Bramlette, 1963

Catinaster calyculus Martini and Bramlette

Catinaster calyculus Martini and Bramlette, 1963, p. 850, pl. 103, figs. 1–6.

Catinaster coalitus Martini and Bramlette

Catinaster coalitus Martini and Bramlette, 1963, p. 851, pl. 103, figs. 7–10.

Genus *CERATOLITHUS* Kamptner, 1950

Ceratolithus acutus Gartner and Bukry

Ceratolithus acutus Gartner and Bukry, 1974, pl. 115, pl. 1, figs. 1–4.

Ceratolithus armatus Müller

Ceratolithus armatus Müller, 1974, pl. 591, pl. 11, figs. 4–6; pl. 19, figs. 3–4.

Ceratolithus cristatus Kamptner

Ceratolithus cristatus Kamptner, 1954, p. 43, figs. 44–45.

Ceratolithus rugosus Bukry and Bramlette

Ceratolithus rugosus Bukry and Bramlette, 1968, p. 152, pl. 1, figs. 5–9.

Ceratolithus telesmus Norris

Ceratolithus telesmus Norris, 1965, p. 21, pl. 11, figs. 5–7; pl. 13, figs. 1–3.

Genus *CHIASMOLITHUS* Hay, Mohler, and Wade, 1966

Chiasmolithus altus Bukry and Percival

Chiasmolithus altus Bukry and Percival, 1971, p. 126, pl. 2, figs. 1–2.

Chiasmolithus bidens (Bramlette and Sullivan)

Coccolithus bidens Bramlette and Sullivan, 1961, p. 139, pl. 1, fig. 1.
Chiasmolithus bidens (Bramlette and Sullivan). Hay and Mohler, 1967, p. 1526, pl. 196, figs. 23–25.

Chiasmolithus californicus (Sullivan)

Coccolithus californicus Sullivan, 1964, p. 180, pl. 2, figs. 3a–b, 4a–b.
Chiasmolithus californicus (Sullivan). Hay and Mohler, 1967, p. 1527, pl. 196, figs. 18–20; pl. 198, fig. 5.

Genus	Species	586	587	588	589	590	591	592	593	594
Amaurolithus	*amplificus*	●	●	●				●		
	bizzarus		●							
	delicatus		●	●		●	●	●	●	
	primus	●	●	●		●	●	●	●	
	tricorniculatus	●	●	●		●	●	●	●	●
Angulolithina	*arca*		●							
Braarudosphaera	*bigelowii*		●							
Calcidiscus	*leptoporus*	●	●	●	●	●	●	●	●	●
	macintyrei	●	●	●	●	●	●	●	●	●
Catinaster	*calyculus*			●		●				●
	coalitus			●		●	●	●		
Ceratolithus	*acutus*	●		●					●	
	armatus		●							
	cristatus	●	●	●	●	●	●	●		
	rugosus	●	●	●	●	●	●	●		
	telesmus	●	●	●	●	●	●	●		
Chiasmolithus	*altus*							x	●	x
	bidens									x
	californicus									x
	grandis									x
	oamaruensis									x
Coccolithus	*carteri*	●	●	●	●	●	●	●	●	●
	miopelagicus			●		●	●	●	●	●
	pelagicus	●	●	●	●	●	●	●	●	●
Coronocyclus	*nitiscens*			●		●	●	●	●	●
Crenalithus	*doronicoides*	●	●	●	●	●	●	●	●	●
Cricolithus	*jonesii*			●	●					●
Cyclicargolithus	*abisectus*			●		●	●	●	●	●
	floridanus			●		●	●	●	●	●
Dictyococcites	*bisectus*			●				●	●	x
	scrippsae			●					●	x
Discoaster	*asymmetricus*	●	●	●	x	●	●	●	●	
	barbadiensis									x
	bellus			●		●	●	●	●	
	berggrenii	●	●	●		●	●	●	●	
	blackstockae		●	●						
	bollii			●						
	brouweri	●	●	●	●	●	●	●	●	●
	calcaris			●						
	challengeri		●	●				●		
	decorus	●						●	●	

Genus	Species	586	587	588	589	590	591	592	593	594
Discoaster	*deflandrei*			●		●	●	●	●	●
	druggii			●		●		●	●	
	exilis		x	●		●	●	●	●	●
	hamatus			●		●	●	●	●	●
	intercalaris									x
	kugleri			●		●	●	●	●	●
	lodoensis									x
	loeblichii		x							
	moorei	x		●			●		●	
	neohamatus		●	●		●	●	●	●	●
	pentaradiatus	●	●	●	x	●	●	●	●	●
	perclarus							●		
	quinqueramus	●	●	●		●	●	●	●	●
	stellulus						●			●
	surculus	●	●	●	x	●	●	●	●	●
	tamalis	●	●	●	x	●	●	●	●	
	tridenus	●	●	●		●	●	●	●	
	triradiatus	●	●	●	●	●	●	●	●	●
	variabilis	●	●	●	x	●	●	●	●	●
Discolithina	*japonica*	●	●	●	●	●	●	●	●	●
	multipora	●							●	●
Discosphaera	*tubifera*		●	●	●	●				
Emiliania	*annula*	●	●	●	●	●	●	●	●	
	huxleyi	●	●	●	●	●	●	●	●	●
	ovata	●	●	●	●	●	●	●	●	●
Fasciculithus	*tympaniformis*									x
Gephyrocapsa	*caribbeanica*	●	●	●	●	●	●	●	●	●
	oceanica	●	●	●	●	●	●	●	●	●
	protohuxleyi									●
Hayaster	*perplexus*	●	●	●	●	●	●	●		
Helicosphaera	*ampliaperta*					●				
	carteri	●	●	●	●	●	●	●	●	●
	euphratis		●	●		●	●	●	●	
	hyalina	●	●	●	●	●	●	●	●	●
	intermedia					●	●	●	●	●
	recta			●					●	
	sellii	●	●	●	●	●	●	●	●	●
	wallichii	●				●				
Heliolithus	*kleinpellii*									x
Isthmolithus	*recurvus*							●		x
Lithostromation	*perdurum*					●		●		

Genus	Species	586	587	588	589	590	591	592	593	594
Lophodolithus	*nascens*									x
Oolithotus	*fragilis*	●	●	●	●	●	●	●	●	
Orthorhabdus	*serratus*			●						
Pontosphaera	*discopora*	●	●	●	●	●	●	●	●	●
Reticulofenestra	*hillae*									x
	pseudoumbilica	●	●	●	x	●	●	●	●	●
	umbilica			x				x		x
Rhabdosphaera	*clavigera*	●	●	●	●	●	●	●	●	
	procera	●	●	●	●	●	●	●	●	●
Scapholithus	*fossilis*	●	●	●	●	●	●	●	●	
Scyphosphaera	*amphora*	●					●			
	apsteinii	●	●			●				
	campanula		●							
	conica		●			●				
	cylindrica		●				●			
	globulata	●	●	●		●	●	●		
	intermedia	●	●	●		●	●	●	●	
	magna		●	●	●	●	●	●		
	pulcherrima	●	●	●	●	●	●	●	●	
	recurvata	●	●	●	●	●	●	●	●	●
Sphenolithus	*abies*	●	●	●		●	●	●	●	●
	belemnos			●		●		●	●	
	capricornutus			●						
	conicus			●						
	delphix			●						
	dissimilis			●					●	
	heteromorphus			●		●	●	●	●	●
	moriformis	x		●		●	●	●	●	●
	neoabies	●	●	●	x	●	●	●	●	●
Syracosphaera	*pulchra*	●	●	●	●	●	●	●	●	●
Thoracosphaera	*heimii*	●	●	●	●	●				
	saxea	●	●	●	●	●	●	●	●	●
Triquetro-rhabdulus	*carinatus*			●		●		●	●	●
	milowii			●						
	rugosus	●	●	●		●	●	●	●	●
Umbellosphaera	*irregularis*	●	●	●	●	●	●	●	●	●
Umbilicosphaera	*cricota*	●	●	●		●	●	●	●	●
	sibogae	●	●	●	●	●	●	●	●	
Watznaueria	*barnesae*	x								
Zygrhablithus	*bijugatus*			●					●	x

Figure 5. Occurrence plot of all species observed in Quaternary and Neogene sediments at Site 586 (Leg 89) and Sites 587-594 (Leg 90). Indigenous species (●) together with reworked species (×) are listed alphabetically for convenient reference.

Chiasmolithus grandis (Bramlette and Riedel)

Coccolithus grandis Bramlette and Riedel, 1954, p. 391, pl. 38, figs. 1a–b.
Chiasmolithus grandis (Bramlette and Riedel). Gartner, 1969b, p. 944, figs. 11-3, 14.

Chiasmolithus oamaruensis (Deflandre)

Tremalithus oamaruensis Deflandre *in* Deflandre and Fert, 1954, p. 154, pl. 11, fig. 22, text-figs. 72–74.
Chiasmolithus oamaruensis (Deflandre). Hay et al., 1966, p. 388, pl. 7, fig. 1.

Genus *COCCOLITHUS* Schwarz, 1894

Coccolithus carteri (Wallich)

Coccosphaera carteri Wallich, 1877, p. 348, pl. 17, figs. 3, 4, 6, 7, 17.
Coccolithus carteri (Wallich). Kamptner, 1941, p. 93.

Coccolithus miopelagicus Bukry

Coccolithus miopelagicus Bukry, 1971a, p. 310, pl. 2, figs. 6–9.

Coccolithus pelagicus (Wallich)

Coccosphaera pelagica Wallich, 1877, p. 348, pl. 17, figs. 1, 2, 5, 11, 12.
Coccolithus pelagicus (Wallich). Schiller, 1930, p. 246, figs. 123–124.

Genus *CORONOCYCLUS* Hay, Mohler, and Wade, 1966

Coronocyclus nitescens (Kamptner)

Umbilicosphaera nitescens Kamptner, 1963, pp. 187–188, pl. 1, fig. 5.
Coronocyclus nitescens (Kamptner). Bramlette and Wilcoxon, 1967, p. 103, pl. 1, fig. 4; pl. 5, figs. 7–8.

Genus *CRENALITHUS* Roth, 1973

Crenalithus doronicoides (Black and Barnes)

Coccolithus doronicoides Black and Barnes, 1961, p. 142, pl. 25, fig. 3.
Crenalithus doronicoides (Black and Barnes). Roth, 1973, p. 731, pl. 3, fig. 3.

Genus *CRICOLITHUS* Kamptner, 1958

Cricolithus jonesii Cohen

Cricolithus jonesi Cohen, 1965, p. 16, pl. 2, figs. j, k; pl. 16, figs. a–c.

Genus *CYCLICARGOLITHUS* Bukry, 1971

Cyclicargolithus abisectus (Müller)

Coccolithus? abisectus Müller, 1970, p. 92, pl. 9, figs. 9, 10; pl. 12, fig. 1.
Cyclicargolithus abisectus (Müller). Bukry, 1973b, p. 703.

Cyclicargolithus floridanus (Roth and Hay)

Coccolithus floridanus Roth and Hay *in* Hay et al., 1967, p. 445, pl. 6, figs. 1–4.
Cyclicargolithus floridanus (Roth and Hay). Bukry, 1971a, pp. 312–313.

Genus *DICTYOCOCCITES* Black, 1967

Dictyococcites bisectus (Hay, Mohler, and Wade)

Syracosphaera bisecta Hay, Mohler, and Wade, 1966, p. 393, pl. 10, figs. 1–6.
Dictyococcites bisectus (Hay, Mohler, and Wade). Bukry and Percival, 1971, p. 127, pl. 2, figs. 12, 13.

Dictyococcites scrippsae Bukry and Percival

Dictyococcites scrippsae Bukry and Percival, 1971, p. 128, pl. 2, figs. 7, 8.

Genus _DISCOASTER_ Tan, 1927

Discoaster asymmetricus Gartner

Discoaster asymmetricus Gartner, 1969a, p. 598, pl. 1, figs. 1-3.

Discoaster barbadiensis Tan

Discoaster barbadiensis Tan, 1927, p. 119.

Discoaster bellus Bukry and Percival

Discoaster bellus Bukry and Percival, 1971, p. 128, pl. 3, figs. 1, 2.

Discoaster berggrenii Bukry

Discoaster berggrenii Bukry, 1971b, p. 45, pl. 2, figs. 4-6.

Discoaster blackstockae Bukry

Discoaster blackstockae Bukry, 1973c, p. 307, pl. 1, figs. 1-4.

Discoaster bollii Martini and Bramlette

Discoaster bollii Martini and Bramlette, 1963, p. 851, pl. 105, figs. 1-4, 7.

Discoaster brouweri Tan

Discoaster brouweri Tan, 1927, p. 120, figs. 8a-b.

Discoaster calcaris Gartner

Discoaster calcaris Gartner, 1967, p. 2, pl. 2, figs. 1-3.

Discoaster challengeri Bramlette and Riedel

Discoaster challengeri Bramlette and Riedel, 1954, p. 401, pl. 39, fig. 10.

Discoaster decorus (Bukry)

Discoaster variabilis decorus Bukry, 1971b, p. 48, pl. 3, figs. 5, 6.
Discoaster decorus (Bukry). Bukry, 1973a, p. 677, pl. 2, figs. 8, 9; pl. 4, fig. 11.

Discoaster deflandrei Bramlette and Riedel

Discoaster deflandrei Bramlette and Riedel, 1954, p. 399, pl. 39, fig. 6; text-figs. 1a-c.

Discoaster druggii Bramlette and Wilcoxon

Discoaster druggii Bramlette and Wilcoxon, 1967, p. 220 (nom. subst. pro *D. extensus* Bramlette and Wilcoxon, 1967, *non* Hay, 1967).

Discoaster exilis Martini and Bramlette

Discoaster exilis Martini and Bramlette, 1963, p. 852, pl. 104, figs. 1-3.

Discoaster hamatus Martini and Bramlette

Discoaster hamatus Martini and Bramlette, 1963, p. 852, pl. 105, figs. 8, 10, 11.

Discoaster intercalaris Bukry

Discoaster intercalaris Bukry, 1971a, p. 315, pl. 3, fig. 12; pl. 4, figs. 1, 2.

Discoaster kugleri Martini and Bramlette

Discoaster kugleri Martini and Bramlette, 1963, p. 853, pl. 102, figs. 11-13.

Discoaster lodoensis Bramlette and Riedel

Discoaster lodoensis Bramlette and Riedel, 1954, p. 398, pl. 39, figs. 3a-b.

Discoaster loeblichii Bukry

Discoaster loeblichii Bukry, 1971a, pp. 315-316, pl. 4, figs. 3-5.

Discoaster moorei Bukry

Discoaster moorei Bukry, 1971b, p. 46, pl. 2, figs. 11, 12; pl. 3, figs. 1, 2.

Discoaster neohamatus Bukry and Bramlette

Discoaster neohamatus Bukry and Bramlette, 1969, p. 133, pl. 1, figs. 4-6.

Discoaster pentaradiatus Tan

Discoaster pentaradiatus Tan, 1927, p. 120, fig. 2.

Discoaster perclarus Hay

Discoaster perclarus Hay *in* Hay et al., 1967, p. 452, pl. 4, figs. 11, 12.

Discoaster quinqueramus Gartner

Discoaster quinqueramus Gartner, 1969a, p. 598, pl. 1, figs. 6, 7.

Discoaster stellulus Gartner

Discoaster stellulus Gartner, 1967, p. 3, pl. 4, figs. 1-3.

Discoaster surculus Martini and Bramlette

Discoaster surculus Martini and Bramlette, 1963, p. 854, pl. 104, figs. 10-12.

Discoaster tamalis Kamptner

Discoaster tamalis Kamptner, 1967, p. 166, pl. 24, fig. 131; text-fig. 28.

Discoaster tridenus Kamptner

Discoaster tridenus Kamptner, 1967, p. 166, text-fig. 30.

Discoaster triradiatus Tan

Discoaster triradiatus Tan, 1927, p. 417.

Discoaster variabilis Martini and Bramlette

Discoaster variabilis Martini and Bramlette, 1963, p. 854, pl. 104, figs. 4-8.

Genus _DISCOLITHINA_ Loeblich and Tappan, 1963

Discolithina japonica Takayama

Discolithina japonica Takayama, 1967, p. 177, 181, 189, pl. 2, fig. 11; pl. 9; pl. 10, text-figs. 6, 7.

Discolithina multipora (Kamptner)

Discolithus multiporus Kamptner, 1948, p. 5, pl. 1, fig. 9.
Discolithina multipora (Kamptner). Martini, 1965, p. 400.

Genus _DISCOSPHAERA_ Haeckel, 1894

Discosphaera tubifera (Murray and Blackman)

Rhabdosphaera tubifer Murray and Blackman, 1898, p. 438, pl. 15, figs. 8-11.
Discosphaera tubifera (Murray and Blackman). Ostenfeld, 1900, p. 200.

Genus _EMILIANIA_ Hay and Mohler, 1967

Emiliania annula (Cohen)

Coccolithites annulus Cohen, 1964, p. 237, pl. 3, figs. 1a-c.
Emiliania annula (Cohen). Bukry, 1973a, p. 678.

Emiliania huxleyi (Lohmann)

Pontosphaera huxleyi Lohmann, 1902, p. 130, pl. 4, figs. 1-6; pl. 6, fig. 69.
Emiliania huxleyi (Lohmann). Hay and Mohler *in* Hay et al., 1967, p. 447, pl. 10, 11, figs. 1, 2.

Emiliania ovata Bukry

Emiliania ovata Bukry, 1973a, p. 678, pl. 2, figs. 10–12.

Genus _FASCICULITHUS_ Bramlette and Sullivan, 1961

Fasciculithus tympaniformis Hay and Mohler

Fasciculithus tympaniformis Hay and Mohler *in* Hay et al., 1967, p. 447, pl. 8, figs. 1–5; pl. 9, figs. 1–5.

Genus _GEPHYROCAPSA_ Kamptner, 1943

Gephyrocapsa caribbeanica Boudreaux and Hay

Gephyrocapsa caribbeanica Boudreaux and Hay *in* Hay et al., 1967, p. 447, pl. 12, 13, figs. 1–4.

Gephyrocapsa oceanica Kamptner

Gephyrocapsa oceanica Kamptner, 1943, pp. 43–49.

Gephyrocapsa protohuxleyi McIntyre

Gephyrocapsa protohuxley McIntyre, 1970, pp. 187–189, fig. 1a–g.

Genus _HAYASTER_ Bukry, 1973

Hayaster perplexus (Bramlette and Riedel)

Discoaster perplexus Bramlette and Riedel, 1954, p. 400, pl. 39, fig. 9.
Hayaster perplexus (Bramlette and Riedel). Bukry, 1973c, p. 308.

Genus _HELICOSPHAERA_ Kamptner, 1954

Helicosphaera ampliaperta (Bramlette and Wilcoxon)

Helicopontosphaera ampliaperta Bramlette and Wilcoxon, 1967, p. 105, pl. 6, figs. 1–4.
Helicosphaera ampliaperta (Bramlette and Wilcoxon). Jafar and Martini, 1975, p. 390.

Helicosphaera carteri (Wallich)

Helicosphaera carteri (Wallich). Kamptner, 1954, pp. 21–23, 73–74, text-figs. 17a–c, 18, 19. Jafar and Martini, 1975, pp. 381–397, pl. 1, figs. 1, 4, 5.
Helicopontosphaera kamptneri Hay and Mohler *in* Hay et al., 1967, p. 448, pl. 10, fig. 5; pl. 11, fig. 5.

Helicosphaera euphratis Haq

Helicosphaera euphratis Haq, 1966, p. 33, pl. 2, figs. 1, 3.
Helicopontosphaera euphratis (Haq). Martini, 1969, p. 136.

Helicosphaera hyalina Gaarder

Helicosphaera hyalina Gaarder, 1970, pp. 113–114, text-figs. 1–3.
Helicopontosphaera hyalina (Gaarder). Haq, 1973, p. 37.

Helicosphaera intermedia Martini

Helicosphaera intermedia Martini, 1965, p. 404, pl. 35, figs. 1, 2.
Helicopontosphaera intermedia (Martini). Hay and Mohler *in* Hay et al., 1967, p. 448.

Helicosphaera recta (Haq)

Helicosphaera seminulum recta Haq, 1966, p. 34, pl. 2, fig. 6; pl. 3, fig. 4.
Helicopontosphaera recta (Haq). Martini, 1969, p. 136.
Helicosphaera recta (Haq). Jafar and Martini, 1975, p. 391.

Helicosphaera sellii (Bukry and Bramlette)

Helicopontosphaera sellii Bukry and Bramlette, 1969, p. 134, pl. 2, figs. 3–7.
Helicosphaera sellii (Bukry and Bramlette). Jafar and Martini, 1975, p. 391; Ellis and Lohman, 1979, p. 76.
Helicosphaera inversa Gartner, 1977, p. 23, pl. 1, figs. 4a–b, 5a–c.

Helicosphaera wallichii (Lohmann)

Coccosphaera wallichi Lohmann, 1902, p. 138, pl. 5, figs. 58–60.
Helicopontosphaera wallichi (Lohmann). Boudreaux and Hay, 1969, pp. 272–273, pl. 6, fig. 9.
Helicosphaera wallichii (Lohmann). Okada and McIntyre, 1977, pp. 14–15, pl. 4, fig. 8.

Genus _HELIOLITHUS_ Bramlette and Sullivan, 1961

Heliolithus kleinpellii Sullivan

Heliolithus kleinpellii Sullivan, 1964, p. 193, pl. 12, fig. 5.

Genus _ISTHMOLITHUS_ Deflandre, 1954

Isthmolithus recurvus Deflandre

Isthmolithus recurvus Deflandre *in* Deflandre and Fert, 1954, p. 169, pl. 12, figs. 9–13, text-figs. 119–122.

Genus _LITHOSTROMATION_ Deflandre, 1942

Lithostromation perdurum Deflandre

Lithostromation perdurum Deflandre, 1942b, p. 918, figs. 1–9.

Genus _LOPHODOLITHUS_ Deflandre, 1954

Lophodolithus nascens Bramlette and Sullivan

Lophodolithus nascens Bramlette and Sullivan, 1961, p. 145, pl. 4, figs. 7a–c, 8a–c.

Genus _OOLITHOTUS_ Reinhardt, _in_ Cohen and Reinhardt, 1968

Oolithotus fragilis (Lohmann)

Coccolithophora fragilis Lohmann, 1912, pp. 49, 54, text-fig. 11.
Discolithus antillarum Cohen, 1964, p. 236, pl. 1, figs. 3a–e.
Oolithotus fragilis (Lohmann). Okada and McIntyre, 1977, p. 11, pl. 4, fig. 3.

Genus _ORTHORHABDUS_ Bramlette and Wilcoxon, 1967

Orthorhabdus serratus Bramlette and Wilcoxon

Orthorhabdus serratus Bramlette and Wilcoxon, 1967, pp. 114–116, pl. 9, figs. 5–10.

Genus _PONTOSPHAERA_ Lohmann, 1902

Pontosphaera discopora Schiller

Pontosphaera discopora Schiller, 1925, p. 11, pl. 1, fig. 4.

Genus _RETICULOFENESTRA_ Hay, Mohler, and Wade, 1966

Reticulofenestra hillae Bukry and Percival

Reticulofenestra hillae Bukry and Percival, 1971, p. 136, pl. 6, figs. 1–3.

Reticulofenestra pseudoumbilica (Gartner)

Coccolithus pseudoumbilicus Gartner, 1967, p. 4, pl. 6, fig. 3.
Reticulofenestra pseudoumbilica (Gartner). Gartner, 1969a, pp. 587–589.

Reticulofenestra umbilica (Levin)

Coccolithus umbilicus Levin, 1965, p. 265, pl. 41, fig. 2.
Reticulofenestra umbilica (Levin). Martini and Ritzkowski, 1968, p. 245, pl. 1, figs. 11, 12.

Genus _RHABDOSPHAERA_ Haeckel, 1894

Rhabdosphaera clavigera Murray and Blackman

Rhabdosphaera clavigera Murray and Blackman, 1898, p. 438, pl. 15, figs. 13–15.

Rhabdosphaera procera Martini

Rhabdosphaera procera Martini, 1969, p. 289, pl. 26, figs. 10, 11.

Genus _SCAPHOLITHUS_ Deflandre, 1954

Scapholithus fossilis Deflandre

Scapholithus fossilis Deflandre *in* Deflandre and Fert, 1954, p. 165, pl. 8, figs. 12, 16, 17.

Genus *SCYPHOSPHAERA* Lohmann, 1902

***Scyphosphaera amphora* Deflandre**

Scyphosphaera amphora Deflandre, 1942a, p. 132, figs. 21, 22.

***Scyphosphaera apsteinii* Lohmann**

Scyphosphaera apsteinii Lohmann, 1902, p. 132, pl. 4, figs. 26–30.

***Scyphosphaera campanula* Deflandre**

Scyphosphaera campanula Deflandre, 1942a, pl. 134, figs. 23–27.

***Scyphosphaera conica* Kamptner**

Scyphosphaera conica Kamptner, 1955, p. 26, figs. 130, 131.

***Scyphosphaera cylindrica* Kamptner**

Scyphosphaera cylindrica Kamptner, 1955, p. 24, fig. 119.

***Scyphosphaera globulata* Bukry and Percival**

Scyphosphaera globulata Bukry and Percival, 1971, pp. 138–140, pl. 7, figs. 1–6.

***Scyphosphaera intermedia* Deflandre**

Scyphosphaera intermedia Deflandre, 1942a, p. 134, figs. 32–36.

***Scyphosphaera magna* Kamptner**

Scyphosphaera magna Kamptner, 1967, p. 150, text-figs. 20.

***Scyphosphaera pulcherrima* Deflandre**

Scyphosphaera pulcherrima Deflandre, 1942a, p. 133, figs. 28–31.

***Scyphosphaera recurvata* Deflandre**

Scyphosphaera recurvata Deflandre, 1942a, p. 132, figs. 17–20.

Genus *SPHENOLITHUS* Deflandre, 1952

***Sphenolithus abies* Deflandre**

Sphenolithus abies Deflandre *in* Deflandre and Fert, 1954, p. 164, pl. 10, figs. 1–4.

***Sphenolithus belemnos* Bramlette and Wilcoxon**

Sphenolithus belemnos Bramlette and Wilcoxon, 1967, p. 118, pl. 2, figs. 1–3.

***Sphenolithus capricornutus* Bukry and Percival**

Sphenolithus capricornutus Bukry and Percival, 1971, p. 140, pl. 6, figs. 4–6.

***Sphenolithus conicus* Bukry**

Sphenolithus conicus Bukry, 1971a, p. 320, pl. 5, figs. 10–12.

***Sphenolithus delphix* Bukry**

Sphenolithus delphix Bukry, 1973a, p. 679, pl. 3, figs. 19–22.

***Sphenolithus dissimilis* Bukry and Percival**

Sphenolithus dissimilis Bukry and Percival, 1971, p. 140, pl. 6, figs. 7–9.

***Sphenolithus heteromorphus* Deflandre**

Sphenolithus heteromorphus Deflandre, 1953, pp. 1785–1786, figs. 1, 2.

***Sphenolithus moriformis* (Brönnimann and Stradner)**

Nannoturbella moriformis Brönnimann and Stradner, 1960, p. 368, figs. 11–16.
Sphenolithus moriformis (Brönniman and Stradner). Bramlette and Wilcoxon, 1967, pp. 124–126, pl. 3, figs. 1–6.

***Sphenolithus neoabies* Bukry and Bramlette**

Sphenolithus neoabies Bukry and Bramlette, 1969, p. 140, pl. 3, figs. 9–11.

Genus *SYRACOSPHAERA* Lohmann, 1902

***Syracosphaera pulchra* Lohmann**

Syracosphaera pulchra Lohmann, 1902, p. 134, pl. 4, figs. 33, 36, 37.

Genus *THORACOSPHAERA* Kamptner, 1927

***Thoracosphaera heimii* (Lohmann)**

Syracosphaera heimii Lohmann, 1919, p. 117, fig. 29.
Thoracosphaera heimii (Lohmann). Kamptner, 1954, pp. 40–42, figs. 41, 42.

***Thoracosphaera saxea* Stradner**

Thoracosphaera saxea Stradner, 1961, p. 84, fig. 71.

Genus *TRIQUETRORHABDULUS* Martini, 1965

***Triquetrorhabdulus carinatus* Martini**

Triquetrorhabdulus carinatus Martini, 1965, p. 408, pl. 36, figs. 1–3.

***Triquetrorhabdulus milowii* Bukry**

Triquetrorhabdulus milowii Bukry, 1971a, p. 325, pl. 7, figs. 9–12.

***Triquetrorhabdulus rugosus* Bramlette and Wilcoxon**

Triquetrorhabdulus rugosus Bramlette and Wilcoxon, 1967, pp. 128–129, pl. 9, figs. 17, 18.

Genus *UMBELLOSPHAERA* Paasche, 1955

***Umbellosphaera irregularis* Paasche**

Umbellosphaera irregularis Paasche *in* Markali and Paasche, 1955, p. 97, pl. 3–6.

Genus *UMBILICOSPHAERA* Lohmann, 1902

***Umbilicosphaera cricota* (Gartner)**

Cyclococcolithus cricotus Gartner, 1967, p. 5, pl. 7, figs. 5–7.
Umbilicosphaera cricota (Gartner). Cohen and Reinhardt, 1968, p. 296, pl. 19, figs. 1, 5; pl. 21, fig. 3; text-fig. 6.

***Umbilicosphaera sibogae* (Weber-van Bosse)**

Coccosphaera sibogae Weber-van Bosse, 1901, p. 137, 140, pl. 17, figs. 1, 2.
Umbilicosphaera mirabilis Lohmann, 1902, p. 139, pl. 5, figs. 66, 66a.
Umbilicosphaera sibogae (Weber-van Bosse). Gaarder, 1970, p. 126.

Genus *WATZNAUERIA* Reinhardt, 1964

***Watznaueria barnesae* (Black)**

Tremalithus barnesae Black *in* Black and Barnes, 1959, p. 325, pl. 9, figs. 1, 2.
Watznaueria barnesae (Black). Perch-Nielsen, 1968, p. 69, pl. 22, figs. 1–7; pl. 23, figs. 1, 4, 5, 16; text-fig. 32.

Genus *ZYGRHABLITHUS* Deflandre, 1959

***Zygrhablithus bijugatus* (Deflandre)**

Zygolithus bijugatus Deflandre *in* Deflandre and Fert, 1954, p. 148, pl. 11, figs. 20, 21.
Zygrhablithus bijugatus (Deflandre). Deflandre, 1959, p. 135.

SUMMARY OF NANNOPLANKTON BIOSTRATIGRAPHY

The nannoplankton biostratigraphy is summarized for each of the nine sites, together with brief site descriptions. The geologic age and nannoplankton zone or subzone assignment of the Quaternary and Neogene cores from Hole 586B (Leg 89) and the holes from Sites 587–594 (Leg 90) are shown in Table 1. In addition, a table of nannoplankton occurrences for each site has been prepared (Tables 2–10, later). For some sites where multiple holes were drilled, sets of samples from more than one

Table 1. Geologic age and nannoplankton zone assignment of Quaternary and Neogene cores from Site 586 (Leg 89) and Sites 587–594 (Leg 90).

Age		Zone or subzone	Leg 89	Leg 90 sites							
			Hole 586B	587	588	589	590	591	592	593	594
					Hole 588		**Hole 590**	**Hole 591**			**Hole 594**
Quaternary		NN21	1-Top	1-1	1-1	1-1/1-2	1-1/1-3	1-1/1-3	1-1/1-3	1-1/1-3	1-1/6-1
		NN20	1-3/1-4	3-3	1-2	1-3	1-4/1-5	1,CC/2-3	1,CC	1,CC/2-3	6-3/7-1
		NN19b	1-5/4-2	3-4/4-4	1-3/1,CC	1-5/3-5	1,CC/3-2	2-5/5-3	2-1/3-1	2-5/3-1	7,CC/11-3
							Hole 590A				
		NN19a	4-3/5-2	4-5	2-1/3-4	3-6/4-6	3-3/1,CC	5-5/6-5	3-2/3-5	3-3/5,CC	11-5
Pliocene	late	NN18	5-3/6-4	4-6	3-5/4-1	4,CC	2-1/2,CC	6,CC/8-1	3-6/4-1	6-1	
		NN17	6-5/6-6	4,CC	4-2		3-1	8-3	4-2	6-2	
		NN16	6-7/8,CC	5-1/5-5	4-3/6-5		3-2/7-3	8-5/12-3	4-3/6-3	6-3/8,CC	18-1
	early	NN15	9,CC/13-7	5-6/6-4	6-6/9-2		7-4/11-7	12-5/16,CC	6,CC/8-5	9-1/9,CC	18-3/20-5
		NN14	13,CC/15-1	6-5/7-1	9-3/11-1		11,CC/14-1	17-1/20,CC	8,CC/13,CC	11-1/13,CC	20,CC
		NN13	15-2/15,CC	7-2/7-3	11-2/11-3		14-2/16-2	21-1/21-5	14-1	14-1	
		NN12	16-1/17,CC	7-4	11-4/12-1		16-3/18-5	21,CC/24-1	14,CC	17-3	23-5
Miocene	late						**Hole 590B**				
		NN11b	18-1/21-4	7-5/10-1	12-2/18-3		18-6/30-3	24-3/28-3	15-1/17,CC	17-5/22-3	23,CC
								Hole 591B			
		NN11a	21-5/25,CC	10-3/11,CC	18-4/20-7		30-4/35-5	28-5/4,CC	18-1/19-1	22,CC/25-1	26-5
		NN10			20,CC/23-4		35,CC/38-5	5-1/8,CC	19-3/20,CC	25-3/26-5	26,CC/28-3
	middle	NN9			23-5/25-3		38,CC/40,CC	9-2/11-1	21-1/22,CC	26,CC/27,CC	28-5/29,CC
		NN8			25-4/25-6		41-5/41,CC	11,CC	23-1	28-1	30-1
					Hole 588A						
		NN7			25,CC/2-4		42-1/45-1	12-1/12,CC	23-3/24,CC	37-1	42-3
											Hole 594A
		NN6			2,CC/8,CC		45-3/47-3	13-1/18-3	25-1/28-1	37-3/42-4	42,CC/15-3
					Hole 588C						
		NN5			9-1/1,CC		47-5/49,CC	18-5/23,CC	28-3/29-3	42-4/43,CC	15,CC/26,CC
	early	NN4			2-1/2-5		50-1/50,CC	24-1/24,CC	29-5/31-3	44-1/44-5	
		NN3			2-6/3-6		51-1/52-5		31-5/32-3	44,CC/46-5	
		NN2			3,CC/5-1		52,CC/53-1		32-5/33-3	46,CC	
		NN1			5-2/10-3		53-3/53,CC			47-1/50-3	

Note: Slash separates first section of zonal interval from last section of interval.

hole were examined in order to provide complete stratigraphic coverage. For convenient reference, the index species are grouped together in the tables and the additional species are then listed alphabetically. The state of preservation is designated as G = good, little or no etching or overgrowth; F = fair, some etching or overgrowth which has damaged or obscured ornamentation; P = poor, considerable etching or overgrowth which has made many species difficult to recognize. Abundance values of each taxon were obtained by scanning an area measuring approximately 45 mm^2 and assigning the following values: A = abundant (>50 specimens), C = common (25–49 specimens), and R = rare (<25 specimens). Over 700 samples from the nine sites were examined with a light microscope to determine the Neogene and Quaternary nannoplankton biostratigraphy. In addition, 61 samples were further examined with a scanning electron microscope (SEM) to determine the range of *Emiliania huxleyi*. Time did not permit further SEM examination to determine the presence of other small Quaternary species.

All relevant zonal and subzonal indicators are present at Sites 586–591. However, at sites south of Site 591, some indicators become increasingly rare and consequently unusable, or they are absent. The paucity of *Ceratolithus rugosus* at Site 592 and its absence at Sites 593 and 594 prevents recognition of the NN13/NN12 boundary at these sites and the absence of *Catinaster coalitus* at Sites 593 and 594 prevents recognition of the NN8/NN7 boundary. At Site 594, 40% of the zonal and subzonal indicators are either missing or occur too sparsely to use. In addition to the absence of *Ceratolithus rugosus* and *Catinaster coalitus*, the absence of *Amaurolithus primus* and the sparse occurrences of *Discoaster brouweri, D. pentaradiatus, D. surculus,* and *D. asymmetricus* prevent recognition of the NN19/NN18, NN18/NN17, NN17/NN16, NN14/NN13, and NN11b/NN11a zonal and subzonal boundaries.

Site 586

Hole 586B

Site 586 is located on the northeastern upper slope of the Ontong-Java Plateau (00°29.84′S, 158°29.89′E) in tropical waters at a depth of 2207 m below sea level. Four holes were drilled at this site during DSDP Leg 89.

The 25 cores obtained from Hole 586B were set aside for study by DSDP Leg 90 scientists in order to complete the latitudinal traverse. Hole 586B was terminated at a depth of 240.3 m because equipment failed.

All of the zonal and subzonal indicators for Zones NN21 through NN11 are present and species diversity is good throughout Hole 586B (Table 2). Preservation changes from good to fair below Sample 586B-6-2, 30-31 cm, and only minor reworking was encountered.

Quaternary

The Quaternary includes Cores 1-4 and the upper part of Core 5 above the last occurrence of *Discoaster brouweri* in Sample 586B-5-3, 30-31 cm. Two rare occurrences of *D. brouweri* above this sample are reworked. The rare occurrence of *Emiliania huxleyi* in Sample 586B-1, top, places the uppermost part of Core 1 in Zone NN21. The two underlying samples (586B-1-3, 30-31 cm and 586B-1-4, 30-31 cm) belong in Zone NN20. The last occurrences of *E. ovata* in Sample 586B-1-5, 30-31 cm and *Calcidiscus macintyrei* in Sample 586B-4-3, 30-31 cm place Samples 586B-1-5, 30-31 cm through 586B-4-2, 30-31 cm in Subzone NN19b and Samples 586B-4-3, 30-31 cm through 586B-5-2, 30-31 cm in Subzone NN19a.

Pliocene

The Pliocene includes the lower part of Core 5 and Cores 6-17. The last occurrence of *Reticulofenestra pseudoumbilica* in Sample 586-9,CC marks the lower/upper Pliocene boundary. The last occurrences of *Discoaster pentaradiatus* in Sample 586B-6-5, 30-31 cm and *D. surculus* in Sample 586B-6-7, 30-31 cm place Samples 586B-5-3, 30-31 cm through 586B-6-4, 30-31 cm in Zone NN18, Samples 586B-6-5, 30-31 cm and 586B-6-6, 30-31 cm in Zone NN17, and Sample 586B-6-7, 30-31 cm through Core 8 in Zone NN16. The last occurrence of *Amaurolithus tricorniculatus* in Sample 586B-13,CC places Samples 586B-9,CC through 586B-13-7, 30-31 cm in Zone NN15. Zone NN14 includes Sample 586B-13,CC to the first consistent occurrence of *D. asymmetricus* in Sample 586B-15-1, 30-31 cm. The numerous occurrences of *D. asymmetricus* below this sample are probably due to contamination. The first occurrence of *Ceratolithus rugosus* in Sample 586B-15,CC places Samples 586B-15-2, 30-31 cm through 586B-15,CC in Zone NN13 and Samples 586B-16-1, 30-31 cm through 586B-17,CC in Zone NN12.

Miocene

The occurrence of *Discoaster quinqueramus* in Sample 586B-18-1, 30-31 cm through Core 25 determined that Hole 586B terminated within the late Miocene Zone NN11. This zone is subdivided into Subzones NN11b and NN11a by the first occurrence of *Amaurolithus primus* in Sample 586B-21-4, 30-31 cm.

Site 587

Hole 587

Site 587 is located on the southern slope of Lansdowne Bank (21°11.87'S, 161°19.99'E) in subtropical waters at a depth of 1101 m below sea level. One hole was cored to a depth of 147.0 m and 11 cores were obtained with good recovery. A sudden change in lithology at a depth of 99.1 m prevented further core recovery.

With the exception of the NN21/NN20 boundary, all of the nannoplankton zones and subzones through Subzone NN11a are recognized (Table 3). Species diversity is good throughout the hole. Preservation is good through Core 4, fair in Cores 5-10, and poor in Core 11. Rare reworked discoasters were observed in three of the Quaternary samples.

Quaternary

The Quaternary includes Cores 1-3 and most of Core 4. Rare to common occurrences of *Emiliania huxleyi* in all of the samples above the last occurrence of *E. ovata* in Sample 587-3-4, 20-21 cm prevent recognition of the boundary between Zones NN21 and NN20. Samples 587-1-1, 4-5 cm through 587-3-3, 20-21 cm are therefore placed in the combined Zone NN21/NN20. A thin Zone NN20 may, however, occur between Samples 587-3-3, 20-21 cm and 587-3-4, 20-21 cm. The last occurrence of *Discoaster brouweri* in Sample 587-4-6, 4-5 cm places Samples 587-3-4, 20-21 cm through 587-4-5, 4-5 cm in Zone NN19. The last occurrence of *Calcidiscus macintyrei* in Sample 587-4-5, 4-5 cm subdivides Zone NN19 into Subzones NN19b and NN19a.

Pliocene

The Pliocene includes the lower part of Core 4 through the upper part of Core 7. The last occurrence of *Reticulofenestra pseudoumbilica* in Sample 587-5-6, 4-5 cm marks the lower/upper Pliocene boundary. The presence of *Discoaster brouweri* and the absence of *D. pentaradiatus* in Sample 587-4-6, 4-5 cm places this sample in Zone NN18. The presence of *D. pentaradiatus* and the absence of *D. surculus* in Sample 587-4,CC places this sample in Zone NN17. The interval from the last occurrence of *D. surculus* down to Sample 587-5-5, 4-5 cm, above the last occurrence of *Reticulofenestra pseudoumbilica* in Sample 587-5-6, 4-5 cm, belongs in Zone NN16. Zone NN15 includes Samples 587-5-6, 4-5 cm through 587-6-4, 4-5 cm. The last occurrence of *Amaurolithus tricorniculatus* in Sample 587-6-5, 4-5 cm and the first occurrence of *D. asymmetricus* in Sample 587-7-1, 4-5 cm place this interval in Zone NN14. The first consistent occurrence of *Ceratolithus rugosus* in Sample 587-7-3, 4-5 cm places this sample and the overlying Sample 587-7-2, 4-5 cm in Zone NN13. Sample 587-7-4, 4-5 cm belongs in Zone NN12.

Miocene

The last occurrence of *Discoaster quinqueramus* in Sample 587-7-5, 4-5 cm and the first occurrence of *Amaurolithus primus* in Sample 587-10-1, 12-13 cm place this interval in Subzone NN11b. Sample 587-10-3, 12-13 cm through 587-11-1, 20-21 cm contain *D. quinqueramus* without *A. primus* and therefore belong in Subzone NN11a. Because preservation is poor and zonal indicators are missing below Sample 587-11-1, 20-21 cm, it can only be assumed that the remaining Core 11 samples also belong in Subzone NN11a.

Table 2. Nannoplankton occurrences, Hole 586B.

Index species:

Age	Zone	Core	Section	Interval (cm)	Depth below seafloor (m)	Preservation	Emiliania huxleyi	Emiliania ovata	Ceratolithus rugosus	Calcidiscus macintyrei	Discoaster brouweri	Discoaster asymmetricus	Discoaster pentaradiatus	Discoaster surculus	Reticulofenestra pseudoumbilica	Amaurolithus tricorniculatus	Amaurolithus primus	Discoaster quinqueramus
Quaternary	NN21	1		TOP	0.01	G	R											
	NN20		3	30-31	4.71	G												
			4	30-31	6.21	G					R							
	NN19b		5	30-31	7.71	G		R										
			6	30-31	9.21	G		A										
				CC	11.00	G		C	R									
		2		CC	20.60	G		A										
		3		CC	30.20	G		C	R									
		4	2	30-31	32.01	G		A	R		R							
	NN19a		3	30-31	33.51	G		A	R	R								
			5	30-31	36.51	G		A	R	R					R			
				CC	39.80	G		A	R	C								
		5	1	30-31	40.11	G		A	R	R								
			2	30-31	41.61	G		A	R	C								
Pliocene late	NN18		3	30-31	43.11	G		A	R	R	R							
			5	30-31	46.11	G		C	R	R	R							
				CC	49.40	G		A	R	R	C							
		6	1	30-31	49.71	G		C	R	R	A	R		R				
			2	30-31	51.21	G		A	R	R	A	R						
			3	30-31	52.71	F		C	R	R	A	R						
			4	30-31	54.21	F		C	R	R	A							
	NN17		5	30-31	55.71	F		C	R	R	A	R	R					
			6	30-31	57.21	F		C	R	R	A	R	C					
	NN16		7	30-31	58.71	F		C	R	R	A	R	A	R				
				CC	59.00	F		C	R	C	A	R	C	R				
		7	3	30-31	62.31	F		C	R	C	A	R	C	R				
			5	30-31	65.31	F		C	R	C	A	R	C	R				
			6	30-31	66.81	F		R	R	C	A	R	R	R				
				CC	68.60	F		R	R	C	A	R	R	R				
		8		CC	78.20	F		R	R	C	C	R	C	R				
Pliocene early	NN15	9		CC	87.80	F		R	R	C	C	R	C	R	R			
		10		CC	96.30	F		C	C	C	C	C	C	R	C			
		11		CC	105.90	F		R	R	C	A	R	C	R	A			
		12		CC	115.50	F			R	C	C	R	C	R	A			
		13	6	30-31	123.31	F			R	R	C	R	C	A	C			
			7	30-31	124.81	F			R	R	C	R	R	R	C			
	NN14			CC	125.10	F			R	R	A	R	A	C	C	R		
		14		CC	134.70	F			R	R	C	R	R	C	A	R		
		15	1	30-31	135.01	F			R	R	C	R	R	C	A			
	NN13		2	30-31	136.51	F			R	R	C		R	A	A			
			5	30-31	141.01	F			R	R	C		R	R	A		R	
				CC	144.30	F			R	R	A	R	R	A	C	R	R	
	NN12	16	1	30-31	144.60	F				R	A	R	R	C	C			
			3	30-31	147.60	F				R	A	R	R	A	A		R	
				CC	153.90	F				R	C		R	A	A			
		17		CC	163.50	F				R	C		R	C	C			
Miocene late	NN11b	18	1	30-31	163.81	F				R	C	R	R	C	C			R
			2	30-31	165.31	F				R	C		R	C	C			C
			4	30-31	168.31	F			R	R	A	R	R	A	C			R
				CC	173.10	F				R	A	R	R	C	A			C
		19		CC	182.70	F				R	A	R	R	R	C		R	A
		20		CC	192.30	F				C	A	R	R	A	A		R	C
		21	4	30-31	197.10	F				R	A	R	R	C	C		R	A
	NN11a		5	30-31	198.60	F				R	A	R	R	C	C			A
			6	30-31	200.10	F				R	A	R	R	R	C			C
				CC	201.90	F				R	A	R	R	C	A			R
		22		CC	211.50	F				R	C		R	R	C			R
		23		CC	221.10	F				C	C	R	R	C	C			C
		24		CC	230.70	F				C	C		R	R	C			A
		25		CC	240.30	F				C	C	R	R	R				R

Additional species (continued):

Depth below seafloor (m)	Amaurolithus amplificus	Calcidiscus leptoporus	Ceratolithus acutus	Ceratolithus cristatus	Ceratolithus telesmus	Coccolithus carteri	Coccolithus pelagicus	Crenalithus doronicoides	Discoaster berggrenii	Discoaster decorus	Discoaster moorei	Discoaster tamalis	Discoaster tridenus	Discoaster triradiatus	Discoaster variabilis	Discolithina japonica	Emiliania annula	Gephyrocapsa caribbeanica	Gephyrocapsa oceanica	Hayaster perplexus
0.01		C		R	R			A								R		A	A	
4.71		C		R	R			A								R		A	A	
6.21		C			R		R	A										A	A	
7.71		C		R	R			A										A	A	
9.21		C			R			A									C	A	A	
11.00		C			R			A									R	A	A	
20.60		C		R				A									R	C	C	
30.20		A		R	R			A									R	R	R	
32.01		C		R				A									R	R	R	
33.51		C		R	R			A									C	R	R	
36.51		C		R	R	R	C	A									R	R	R	
39.80		C		R	R	R	C	A									C	R	R	
40.11		C		R	R	R	R	A									C	R	R	
41.61		C		R		R	C	A									C	R	R	
43.11		C		R		R	C	A						R		R	R			
46.11		C		R		R	C	A									R			
49.40		C				R	C	A									R			
49.71		C				R	C	A						R			R			
51.21		C				R	C	A						R			C			
52.71		R					C	C									R			
54.21		R					C	C									R			
55.71		C					C	C						R			C			
57.21		C					C	C									R			R
58.71		R					C	C									R			
59.00		C		R	R	R	C	A						R			R			
62.31		C						C									R			R
65.31		C						C									R			R
66.81		C						A									R			R
68.60		C					C	A				R	R				R			
78.20		C					R	A		R		R				R	R			R
87.80		C		R				A		C				R	R		R			R
96.30		C						A		R		R		R	R	R	R			
105.90		C						A				R	R		R					
115.50		C						A				R	R		R					
123.31		C						C					R	R						
124.81		C						C					R	R						
125.10		C						C					R	R						
134.70		C	R					C					R	R						R
135.01		C	R					C					R	R	R					
136.51		C	R				R	C					R			R				
141.01		C	R				R	C			R		R		R	R				
144.30		C	C				C	C					R	R	R	R				
144.60		R	C				R	A					R	R	R	R				
147.60		C	R				R	C				R	R	R	R					
153.90		C	R				R	A					R	R	R					
163.50		R						C					R	R	R					
163.81		R					C	C	R				R	R	R					
165.31		R					R	C	R				R	R	R					
168.31		R					R	C	R				R	R	R					R
173.10		R					R	A	R				R	R	R	R				
182.70		R						A	C				R	R	R	R				
192.30	R	C					C	C	C				R	R						
197.10	R	R					R	C	A					R						
198.60	R	R					R	C	C					R						
200.10	R	R					R	C	R				R	R	R					
201.90		C					A	C	R				R	R	R					
211.50		R					C	C	R				R	R						
221.10		C					C	A	R				R	R	R					
230.70		R					C	A	R				R		R					
240.30		R					C	A	R				R		R					

Additional species (continued):

Depth below seafloor (m)	Helicosphaera carteri	Helicosphaera hyalina	Helicosphaera sellii	Helicosphaera wallichii	Oolithotus fragilis	Pontosphaera discopora	Rhabdosphaera clavigera	Rhabdosphaera procera	Scapholithus fossilis	Scyphosphaera amphora	Scyphosphaera apsteinii	Scyphosphaera globulata	Scyphosphaera intermedia	Scyphosphaera pulcherrima	Scyphosphaera recurvata	Sphenolithus abies	Sphenolithus moriformis	Sphenolithus neoabies	Syracosphaera pulchra	Thoracosphaera heimii	Thoracosphaera saxea	Triquetrorhabdulus rugosus	Umbellosphaera irregularis	Umbilicosphaera cricota	Umbilicosphaera sibogae	Watznauria barnesae
0.01	R	R	R	R		R	R	R	C									R		R	R				C	
4.71	R	R	R	R	R	R			R							R		R	C	R	R				C	
6.21	R	R	C	R	R				R							R			R	R	R				C	
7.71	R	R	C	R	R	R	R	R	R		R							R	C	R	R				C	
9.21	R	R	R	R	R	R			R										R	R	R		R		R	
11.00	R	R	R	R	R	R			R								R		R	R	R		R	R	R	
20.60	R	R	R		R	R													R	R	R		R			
30.20	C		R			R			R						R			R	R	R	R					R
32.01	C		R															R	R	R	R					
33.51	C		C			R								R	R					R	R					
36.51	C		C		R				R										R	R	R					
39.80	C		C											R					R	R	R					
40.11	C		C			R												R	R	R	R					
41.61	R		C		R	R								R					R	R	R					
43.11	C		C		R									R					R	R	R					
46.11	C		R			R			R					R	R			R	R	R	R					
49.40	C		R					R	R										R	R	R					
49.71	C		R		R	R								R					R	R	R					
51.21	C		R		R	R								R					R	R	R					
52.71	R		R																R							
54.21	R		R																R							
55.71	R		R			R								R					R							
57.21	R		R			R														R	R					
58.71	R		R			R								R	R					R	R					
59.00	C		R		R	R		R											R	R	R			R		
62.31	C		R		R	R								R	R				R	R	R					
65.31	C		R		R	R													R	R	R					
66.81	C		R			R								R						R	R					
68.60	C		R			R								R					R	R	R			R		
78.20	C		R		R	R				R		R			R					R	R					
87.80	R		R		R	R							R	R	R	R		R	R	R	R			R		
96.30	C		R		R	R							R	R	R	C		A		R	R			R		
105.90	C		R					R				R		R	R	C		A		R				C		
115.50	C		R			R						R		R	R	C		A		R	R			R		
123.31	C		R			R						R		R	R	C		A						R		
124.81	C		R											R	R	C		A		R	R					
125.10	C		R			R						R		R	R	R		A						C		
134.70	C		R									R			R	A		A						R		
135.01	C		R									R		R	C	A		A								
136.51	C		R							R		R		R	C	A		A								
141.01	R		R									R		R	R	C		A								
144.30	C		R			R						R		R	C	A		A								
144.60	C		R			R						R	R	R	C	C		A						R		
147.60	R		R									R	R	R	C	C		A								
153.90	C		R			R						R	R	R	R	A		A								
163.50	R		R											R	R	C		A						R		
163.81	R		R									R		R	R	C		A								
165.31	R		R									R		R	R	A		A								
168.31	R		R									R		R	R	A		A								
173.10	C		R										R	R	R	A		A						R		
182.70	R		R											C	C	A		A				R				
192.30	R											R		C	R	A		A						R		
197.10	R		R											R	R	A		A				R		R		
198.60	R													R		A		A				R				
200.10	R													R	R	A		A				R		R		
201.90	R		R									R		R	R	A		A								
211.50	R													R		C		A				R				
221.10	C		R											R		A		A						R		
230.70	C		R											R		A		A						R		
240.30	C		R											R		C		A								

Site 588

Holes 588, 588A, 588C

Site 588 is located on the northern Lord Howe Rise (26°06.70′S, 161°13.60′E) in subtropical waters at a depth of 1533 m below sea level. Four holes were drilled at this site. Hole 588 was cored to a depth of 236.0 m and 25 cores were obtained. Hole 588A was washed down to a depth of 236.0 m and then cored to a depth of 344.4 m. Eighteen cores were taken. Hole 588B, which duplicates Hole 588, was cored to a depth of 277.4 m and 31 cores were taken. Hole 588C was washed down to a depth of 305.7 m and then cored to a depth of 488.1 m. Nineteen cores were obtained. Core recovery was generally good throughout the four holes, but recovery was poor in the lowest sections of Holes 588A and 588C.

In order to obtain a complete stratigraphic section, cores from three holes (588, 588A, and 588C) were examined for calcareous nannoplankton (Table 4). Species diversity is good throughout the holes. Preservation changes from good to fair below Core 7 of Hole 588 and only minor reworking was encountered. The major regional unconformity of the southwest Pacific was encountered within Core 18 in the lower part of Hole 588C. It separates middle Eocene sediments (NP15/

Table 3. Nannoplankton occurrences, Site 587.

Age	Zone	Core	Section	Interval (cm)	Depth below seafloor (m)	Preservation	Index Species												Additional species																																																										
							Emiliania huxleyi	*Ceratolithus rugosus*	*Emiliania ovata*	*Calcidiscus macintyrei*	*Discoaster brouweri*	*Discoaster asymmetricus*	*Discoaster pentaradiatus*	*Discoaster surculus*	*Reticulofenestra pseudoumbilica*	*Amaurolithus primus*	*Amaurolithus tricorniculatus*	*Discoaster quinqueramus*	*Amaurolithus amplificus*	*Amaurolithus bizzarus*	*Amaurolithus delicatus*	*Angulolithina arca*	*Braarudosphaera bigelowii*	*Calcidiscus leptoporus*	*Ceratolithus armatus*	*Ceratolithus cristatus*	*Ceratolithus telesmus*	*Coccolithus carteri*	*Coccolithus pelagicus*	*Crenalithus doronicoides*	*Discoaster berggrenii*	*Discoaster blackstockae*	*Discoaster challengeri*	*Discoaster exilis*	*Discoaster loeblichii*	*Discoaster neohamatus*	*Discoaster tamalis*	*Discoaster tridenus*	*Discoaster triradiatus*	*Discoaster variabilis*	*Discolithina japonica*	*Discolithina multipora*	*Discosphaera tubifera*	*Emiliania annula*	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Hayaster perplexus*	*Helicosphaera carteri*	*Helicosphaera euphratis*	*Helicosphaera hyalina*	*Helicosphaera sellii*	*Oolithotus fragilis*	*Pontosphaera discopora*	*Rhabdosphaera clavigera*	*Rhabdosphaera procera*	*Scapholithus fossilis*	*Scyphosphaera apsteinii*	*Scyphosphaera campanula*	*Scyphosphaera conica*	*Scyphosphaera cylindrica*	*Scyphosphaera globulata*	*Scyphosphaera intermedia*	*Scyphosphaera magna*	*Scyphosphaera pulcherrima*	*Scyphosphaera recurvata*	*Sphenolithus abies*	*Sphenolithus neoabies*	*Syracosphaera pulchra*	*Thoracosphaera heimii*	*Thoracosphaera saxea*	*Triquetrorhabdulus rugosus*	*Umbellosphaera irregularis*	*Umbilicosphaera cricota*	*Umbilicosphaera sibogae*
Quaternary	NN21 — NN20	1	1	4-5	0.05	G	C																R	C		C	R			R											C		R		R	R	R	C		R	R	R	R	C	R	R									R			R	R	R				R
			2	5-6	1.55	G	C	R															R	R		R	R		R	R											R		R		R	R	R	R		R	R	C	R	R	R	R									R			R	R	R		R	R	R
			CC		3.10	G	C	R						R										R		R	R		R	R								R			R		R		R	R	R	R		R	R	C	R	R	R	R									R			R	R	R		R	R	R
		2	1	12-13	3.23	G	C	R															R	R		R	R			R											R		R		R	R	R	R		R	R	C	R	R	R	R									R			R	R	R		R	R	R
			2	12-13	4.73	G	R	R																R		R	R			R											R		R		R	R	R	R		R	R	R	R	R	R	R									R			R	R	R		R	R	R
			3	2-3	6.13	G	R	R																R		R	R		R	R											R		R		R	R	R	R		R	R	C	R	R	R	R									R			R	R	R		R	R	R
			4	2-3	7.63	G	R	R																R		R	R			R											R		R		R	R	R	R		R	R	A	R	R	R	R									R			R	R	R		R	R	R
			5	2-3	9.13	G	R	R			R												R	C		R	R			R											R		R		R	R	R	R		R	R	C	R	R	R	R									R			R	R	R		R	R	C
			6	2-3	10.63	G	C	R															R	C		R	R			C											R		R		R	C	R	C		R	R	C	R	R	R	R									R			R	R	R		R	R	R
			CC		12.70	G	C	R			R												R	C		R	R			A											R		R		C	C	R	R		R	R	C	R	R	R	R									R			R	R	R		R	R	R
		3	1	20-21	12.90	G	C	R																R		R				A											R		R		C	R	R	R		R	R	R	R	R	R	R									R			R	R	R		R	R	R
			2	20-21	14.40	G	C	R																C		R				A											R		R		C	R	R	R		R	R	R	R	R	R	R									R			R	R	R		R	R	R
			3	20-21	15.90	G	C	R																C		R			R	A											R		R		C	C	R	R		R	R	R	R	R	R	R									R			C	R	R		R	R	R
	NN19b		4	20-21	17.40	G		R	R															C		R				A											R		R		R	R	R	R		R	R	R	R	R	C	R									R			C	R	R		R	R	R
			5	50-51	19.20	G		R	R															C						A											R		R		C	R	R	R		R	R	R	R	R	R	R									R			C	R	R		R	R	R
			6	26-27	20.47	G		R	C															C						A											R		R	R	C	C	R	R		R	R	R	R	R	R	R									R			R	R	C		R	R	R
			CC		22.30	G		R	R															C						A											R		R	R	C	C	R	R		R	R	R	R	R	R	R									R			R	R	R		R	R	R
		4	2	4-5	23.85	G		R	R															C					R	A											R		R	R	C	R	R	C		R	R	R	R	R	R	R	R						R	R	R			C	R	R		R	R	R
			3	4-5	25.35	G		R	C															C						A											R		R	R	C	R	R	C		R	R	R	R	R	R	R	R						R	R	R			C	R	R			R	R
			4	4-5	26.85	G		R	R															C						A											R		R	R	R	R	R	R		R	R	R	R	R	R	R	R						R	R	R			R	R	R			R	
	NN19a		5	4-5	28.35	G		R	R	R													R	C						A											R		R	R	R	R	R	C		R	R	R	R	R	C	R	R						R	R	R			C	R	R			R	
Pliocene late	NN18		6	4-5	29.85	G		R	R	R	R													C					R	A											R			R	R	R	R	C		R	R	R	R	R	R	R	R						R	R	R			C	R	R			R	
	NN17		CC		31.90	G		R	C	C	C	R	R										R	C				R	R	A										R		R			R	R	R	R	C		R	R	R	R	R	R	R	R						R	R	R			C	R	R			R	
	NN16	5	1	106-107	32.97	F		R	R	C	C	R	R	R										C				R	C	A							R		R		R			R			R	R				R	R	R	R	R	R	R						R	R	R			R	R	R			R	
			2	4-5	33.45	F		R	R	C	C	R	R	R										R					C	A							R		R		R			R			R	C			R	R	R	R	R	R	R		R				R	R	R		R	C	R	R			R	
			3	4-5	34.95	F		R	R	C	C	R	C	R										C					R	A		R	R				C	R	R	R	R			R			R	R			R	R	R	R	R	R	R		R			R	R	R	R			C	R	R			C	
			4	4-5	36.45	F		R	C	C	C	C	C	C										C					R	A		R					C	R	R	R	R			R			R	R			R	R	R	R	R	R	R		R			R	R	R	R			C	R	R			R	
			5	4-5	37.95	F		R	R	C	C	R	C	C										C					R	A		R					R	R	R	R	R			R			R	C			R	R	R	R	R	R	C		R			R	R	R	C			R	R	R			C	
Pliocene early	NN15		6	4-5	39.45	F		R	C	C	C	C	C	C	R									C						A							C	R	R	R	R			R			R	C			R	R	R		R	R	R		R	R		R	R	R	R	R	R	R	R	R			C	
			CC		41.50	F		R	R	R	C	R	R	R	R									C						A							R	R	R	R	R			R			R	R			R	R	R		R	R	R		R	R		R		R	R	C	C	R	R	R			R	
		6	1	2-3	41.53	F		R	R	C	C	C	R	C	R									C						A							R	R	R	R	R			R			R	C			R	R	R		R	R	R		R	R		R		R	R	C	C	R	R	R			R	
			2	4-5	43.05	F		R	R	C	C	C	C	C	C									C						A							R	R	R	R	R			R			R	C			R	R	R		R	R	R		R	R		R		R	R	C	C	R	R	R			R	
			3	4-5	44.55	F		R	C	C	C	C	C	C	C									C						A							R	R	R	R	R			R			R	C			R	R	R		R	R	R		R	R		R		R	R	C	C	R	R	R			C	
			4	4-5	46.05	F		R		C	C	C	C	C	C									C						C			R				R	R	R	C	R						R	C			R	R	R		R	R	R		R	R	R	R		R	R	C	C	R	R	R			R	
	NN14		5	4-5	47.55	F		R		C	C	R	C	C	C	R	R							C					C	C		R	R				R	R	R	R	R						R	C			R		R		R	R	R		R	R	R	R		R	R	C	C	R	R	R			C	
			6	4-5	49.05	F		R		C	C	R	C	C	C	R	R			R				C					R	C		R						R	R	R	R	R					R	C	R		R		R		R	R	R		R	R	R	R		R	R	C	C	R	R	R			R	
			7	4-5	50.55	F		R		C	C	R	C	C	C	R	R				R			C					C	R								R	R	R	R						R	C	R		R		R		R	R	R				R	R		R	R	C	C	R	R	R			R	
			CC		51.10	F		R		R	C	R	C	R	C	R	R		R		R			C	R				C	C			R					R	R	R	R						R	C	R		R		R		R	R	R				R	R		R	R	C	C	R	R	R			R	
		7	1	4-5	51.15	F		R		C	C	R	C	R	C	R	R		R		R			C					C	C			R						R	R	R						R	C	R		R		R		R	R	R	R			R	R		R	R	C	C	R	R	R			R	
	NN13		2	4-5	52.65	F		R		R	C		R	R	C	R			R		R			R					R	C								C	R	R	R						R	R	R		R		R		R	R	R				R	R		R		C	C		R	R			R	
			3	4-5	54.15	F		R		R	C		C	R	C	R			R		R			R					C	C								C	R	R	R						R	C	R		R		R		R	R	R				R	R		R		C	C		R	R			R	
	NN12		4	4-5	55.65	F				R	C		C	R	C	R			R		R			R					C	C								C	R	C	R						R	C	R		R		R		R	R	R				R	R		R		C	C		R	R			R	
Miocene late	NN11b		5	4-5	57.15	F				R	C		C	R	C	R		R	R		R			R					R	C								C	R	R	R						R	C	R				R		R	R	R			R	R	R		R		C	C		R	R			R	
			6	4-5	58.65	F				R	R		R	R	C	R		R	R		R			R					C	C								C	R	C	R						R	R	R				R		R	R	R				R	R		R		C	C		R	R			R	
			CC		60.70	F				R	R		R	R	C	R	R	R	R		R			R					C	R								C	R	R	R						R	R	R				R		R	R	R				R	R		R		C	C		R				R	
		8	1	115-116	61.86	F				R	C		R	R	C	R		C	R		R			R					C	C								R	R	R	R						R	C	R				R		R	R	R					R		R		C	C		R				R	
			2	115-116	63.36	F		R		R	R		R	R	C	R		C	R		R			R					C	C				R				R	R	R	R						R	C					R		R	R	R					R		R		C	A		R				R	
			3	115-116	64.86	F				R	R		C	R	C	R		R	R		R	R		R					C	C				R				C	R	R	R						R	C							R	R	R					R		R		C	C						R	
			4	115-116	66.36	F				R	C	R	C	R	C	R		R	R		R			R					C	C				R				C	R	C	R						R	R	R						R		R							R		C	C			R			C	
			5	115-116	67.86	F				R	C		C	R	C	R		C	R		R			R					C	C				R	R	R		R	R	C	R								R						R		R							R		C	C						R	
			6	115-116	69.36	F				R	R		C	R	C	R		C	R		R			R					C	A	R			R		R		R	R	C									C	R								R							R		C	A						R	
			CC		70.30	F				R	R		C	R	C	R		C	R		R			R					C	C	R			R		R		R	R	C									C	R						R		R					R		R		C	A						R	
		9	1	70-71	71.01	F				R	C		C	R	C	R		C	R		R			R					C	C	R			R		R		R	R	C	R							C					R				R					R		R		C	C						R	
			2	30-31	72.10	F				R	C		C	R	C	R		R			R			R					C	C	R			R		R			R	C									C									R							R		C	C						R	
			CC		79.90	F				R	C		C	R	C	R		R			R			C					C	C	R			R		R		C	R	R	R															R		R					R		R		C	C		R		R		R	
		10	1	12-13	80.03	F				R	C		R	R	C	R		R			R			R					C	C	R					R		C	R	R								R	R	R							R									C	C		R				R	
	NN11a		3	12-13	83.03	F				R	C		R	R	C			R						C					C	C	R					R		R		R								R	R					R			R							R		C	C			R	R		C	
			5	12-13	86.03	F				R	C		R	R	C			R						R					R	R	R					R		R		R	R								R	R							R									R	R		R		R		R	
		11	1	20-21	89.71	P				R	R		R	R	R			R						R					R	R						R																				R									R	R							
			3	20-21	92.71	P									R															R																																			R								
			5	20-21	95.71	P									R																									R							R																			R								
			CC		99.10	P																		R					R	R																																										

Table 4. Nannoplankton occurrences, Holes 588, 588A, and 588C.

Index species

Age	Zone	Core	Section	Interval (cm)	Depth below seafloor (m)	Preservation	Emiliania huxleyi	Emiliania ovata	Calcidiscus macintyrei	Discoaster brouweri	Ceratolithus rugosus	Discoaster asymmetricus	Discoaster pentaradiatus	Discoaster surculus	Reticulofenestra pseudoumbilica	Amaurolithus tricorniculatus	Amaurolithus primus	Discoaster quinqueramus	Discoaster hamatus	Catinaster coalitus	Discoaster exilis	Discoaster kugleri	Sphenolithus heteromorphus	Sphenolithus belemnos	Discoaster druggii	Triquetrorhabdulus carinatus	Helicosphaera recta
Quaternary	NN21	1	1	85-86	0.86	G	C																				
	NN20		2	85-86	2.36	G																					
	NN19b		3	85-86	3.86	G		R																			
				CC	5.60	G		A																			
	NN19a	2	1	85-86	6.46	G		C	R																		
			3	85-86	9.45	G		C	R																		
				CC	15.20	G		A	R																		
		3	4	0-1	19.70	G		A	C																		
Pliocene, late	NN18		5	0-1	21.20	G		A	C	C																	
				CC	24.80	G		C	C	A																	
		4	1	0-1	24.80	G		C	C	A	R																
	NN17		2	0-1	26.31	G		C	C	A	R	R	R														
	NN16		3	0-1	27.81	G		A	C	C	R	R	A	R													
		5		CC	44.00	G		C	C	C	R	C	A	C													
		6	5	0-1	50.01	G		R	C	C	R	C	C	C													
Pliocene, early	NN15		6	0-1	51.51	G		R	C	C	R	C	C	C	R												
		7	2	0-1	55.11	G		R	C	C	R	A	A	C	C												
			3	0-1	56.61	G		R	C	C	R	A	A	C	A		R										
				CC	63.20	G			C	C	C	C	C	C	A		R										
		8		CC	72.80	F			R	C	C	R	A	R	A		R										
		9	2	0-1	74.31	F			R	C	R	R	A	R	A		R										
	NN14		3	0-1	75.81	F			R	C	R	R	A	R	A	R	R										
				CC	82.40	F			R	C	R	R	A	C	A	R	R										
		10	5	0-1	88.41	F			R	C	R	R	C	C	A	R	R										
			6	0-1	89.91	F			R	C	R	R	C	C	A	R	R										
		11	1	0-1	92.01	F			C	C	R	R	C	C	A	R	R										
	NN13		2	0-1	93.51	F			C	C			C	C	A		R										
			3	0-1	95.01	F			C	C			C	C	A		R										
	NN12		4	0-1	96.51	F			C	C			C	C	A		R										
		12	1	0-1	101.60	F			C	C			C	C	A		R										
late	NN11b		2	0-1	103.10	F			C	C			C	C	A		R	R									
			3	0-1	104.60	F			C	C			A	C	A	R	C	C									
				CC	111.20	F			C	C			C	R	A		R	C									
		13		CC	120.80	F			R	R			C	R	A		C	C									
		14		CC	130.40	F			R	R			C	R	A		C	C									
		15		CC	140.00	F			R	C			C	R	A		R	C									
		16		CC	149.60	F			C	R			C	R	A		R	C									
		17		CC	159.20	F			R	R			C	R	C		R	C									
		18	3	0-1	162.21	F			R	R			C	R	C		R	C									
	NN11a		4	0-1	163.71	F			R	R			C	R	C			C									
				CC	168.80	F			R	R			R	R	C			C									
		19		CC	178.40	F			R	R			R	R	R			C									
		20	3	0-1	181.41	F			C	C			R	R	R			C									
			4	0-1	182.91	F			C	C			R	R	R			R									
			6	0-1	185.91	F			C	C			R	R	R			R									
			7	0-1	187.41	F			C	C			R	R	R			R									
				CC	188.00	F			C	C			R	R	R												

Additional species

Depth below seafloor (m)	Amaurolithus amplificus	Amaurolithus delicatus	Calcidiscus leptoporus	Catinaster calyculus	Ceratolithus acutus	Ceratolithus cristatus	Ceratolithus telesmus	Coccolithus carteri	Coccolithus miopelagicus	Coccolithus pelagicus	Coronocyclus nitescens	Crenalithus doronicoides	Cricolithus jonesi	Cyclicargolithus abisectus	Cyclicargolithus floridanus	Dictyococcites bisectus	Dictyococcites scrippsae	Discoaster bellus	Discoaster berggrenii	Discoaster blackstockae	Discoaster bollii	Discoaster calcaris	Discoaster challengeri	Discoaster deflandrei	Discoaster moorei	Discoaster neohamatus	Discoaster tamalis	Discoaster tridenus	Discoaster triradiatus	Discoaster variabilis	Discolithina japonica	Discosphaera tubifera	Emiliania annula	Gephyrocapsa caribbeanica
0.86			A			R	R			R		A	R																		R	R		C
2.36			A			R				R		A	R																		R			A
3.86			C			R				R		A	R																		R		R	A
5.60			A			R						A	R																		R		A	C
6.46			C			R	R					A	R																		R		C	C
9.45			C			R						A	R																		R		R	C
15.20			C			R				R		A	R																		R		R	C
19.70			C			R	R	R		R		A																			R		R	
21.20			C			R				C		A																	R		R		R	
24.80			C			R	R			C		A																	R		R		R	
24.80			C			R				R		A																	R		R		R	
26.31			C			R				R		A																	R		C		R	
27.81			C				R	R		C		A															R		R		R		C	
44.00			C					R		R		A								R							C	R	R		R		R	
50.01			A							R		A											R				C	R	R	R	R		R	
51.51			A					R		R		A											R				C	R	R	R	R		R	
55.11		R	C							R		A											R				R	R	R	R	R		R	
56.61		R	C							R		A											R				R	R	R	R	R		R	
63.20		R	C					R		R		A											R				R	R	R	C	C			
72.80		R	C							R		A											R					C	R	R	C			
74.31		R	C							R		A											R					C	R	R	R			
75.81		R	C							R		C											R					R	R	R	R			
82.40		R	C							R		C											R					R	R	R	R			
88.41		R	C							C		C											R					R	R	R	R			
89.91	R	R	C		R					C		C											R					R	R	R	R			
92.01		R	C		R					A		C											R					C	R	R	R			
93.51		R	C		R					C		C											R					R	R	R	R			
95.01		R	C							C		C											R					R	R	R	R			
96.51		R	C							C		C											R					R	R	R	R			
101.60		R	C							C		C											R					R	R	C	R			
103.10		R	C							C		C											R					R	R	C	R			
104.60		R	C							A		A											R					R	R	C	R			
111.20		R	C							A		C											R					R	R	R	R			
120.80		R	C							C		C																R	R	R	R			
130.40		R	C							C		A																R	R	C	R			
140.00		R	C							C		C							R									R	R	R	R			
149.60		R	C							C		C							R									R	R	R	R			
159.20		R	R							C		C							R										R	R	R			
162.21		R	R							C		C							R										R	C	R			
163.71			R							C		C							R										R	R	R			
168.80			R							C		R							R										R	R				
178.40			C							A		C							C							R				C				
181.41			R							A		R							C							R				C				
182.91			R							A		R							R							R				R				
185.91			R							C		R							R							R				R				
187.41			R						R	C		R						R	R							C				R				
188.00			C						R	C		R						R						R		C	R			R				

Depth below seafloor (m)	Gephyrocapsa oceanica	Hayaster perplexus	Helicosphaera carteri	Helicosphaera euphratis	Helicosphaera hyalina	Helicosphaera sellii	Oolithotus fragilis	Orthorhabdus serratus	Pontosphaera discopora	Reticulofenestra umbilica	Rhabdosphaera clavigera	Rhabdosphaera procera	Scapholithus fossilis	Scyphosphaera globulata	Scyphosphaera intermedia	Scyphosphaera magna	Scyphosphaera pulcherrima	Scyphosphaera recurvata	Sphenolithus abies	Sphenolithus capricornutus	Sphenolithus conicus	Sphenolithus delphix	Sphenolithus dissimilis	Sphenolithus moriformis	Sphenolithus neoabies	Syracosphaera pulchra	Thoracosphaera heimii	Thoracosphaera saxea	Triquetrorhabdulus milowii	Triquetrorhabdulus rugosus	Umbellosphaera irregularis	Umbilicosphaera cricota	Umbilicosphaera sibogae	Zygrhablithus bijugatus
0.86	C	R	C		R	R	A		C		C	C	A													C	R	C			R		R	
2.36	A	R	C		R	C	C		R		C	R	A					R								C	R	C			R	R	R	
3.86	C	R	C		R	R	R		R		R	C	C													C	R	R			R	R	R	
5.60	C	R	C		C	R	R		C		C	C	C					C								C	C	C			R	R	C	
6.46			C			R	R		R		R	C	R					R								C	R	R			R	R	R	
9.45			C			R	C		R		R	R	R					R								C	R	R			R	R	R	
15.20			C			R	R		R		R	R	R					R								C	R	R			R	R	R	
19.70			C			R	R		R		R	R	R					R								C	R	R			R	R	R	
21.20			C			R	R		R		C	C	R				R	R								C	R	R				R	R	
24.80		R	C			R	R		R		C	C	R	R	R	R	R	C								C		R						
24.80			C			R	R		C		C	C	R	R			R	R								C		R						
26.31		R	C			C	R		R		C	C	R	R	R		R	R								C		R						
27.81		R	C			C	C		R		R	C	R	R	R		R	C								R		R				R		
44.00		R	C			C	C		R		R	C	R	R	R		R	R								R		R				C		
50.01		R	C			C	C		R			R	R	R	R		R	R	R							R		R			R	R		
51.51		R	C			C	C					C	R	R	R	R	R	R	R						R	R		R			R	C		
55.11		R	C			C	C					R	R	R	R	R	R	R	C						C	R						C		
56.61		R	C			R	R					R	R	R	C	R	R	C	C						A	R						C		
63.20		R	C			R						R	R	R	R		R	C	A						A							C		
72.80		R	C			R						R		R	R		R	R	C						A							C		
74.31		R	C			R						R		R	R		R	R	C						A							C		
75.81		R	C			R						R		R	R		R	R	A						A							C		
82.40		R	C			R						R		R	R		R	R	A						A							C		
88.41		R	C	R		R						R		R	R		R	R	A						A							R		
89.91		R	C			R						R		R	R		R	R	A						A							R		
92.01		R	C			R						R		R	R		R	R	A						A							C		
93.51		R	C			R						R		R	R		R	R	A						A							R		
95.01		R	C			R						R		R	R		R	R	A						A							R		
96.51		R	C			R						R		R	R		R	R	A						A							R		
101.60		R	C			R						R		R	R		R	R	A						A							R		
103.10		R	C			R						R		R	R		R	R	A						A							R		
104.60		R	C									R		R	R		R	R	A						A							C		
111.20		R	C										R	R	R		R	R	A						A							R		
120.80			C												R		R	R	A						A							R		
130.40			R												R		R	R	A						A							R		
140.00			R												R		R	R	A						A							R		
149.60			C												R		R	R	A						A							C		
159.20			C												R		R	R	A						A							R		
162.21			C												R		R	R	A						A							R		
163.71			C												R		R	R	A						A							R		
168.80			C												R		R	R	C						C					R		R		
178.40			R														R	R	A						A					R		R		
181.41			C														R		C						C					R		R		
182.91			C														R		C						C					R		R		
185.91			C														R		C						C					R		R		
187.41			C														R		C						C					R		R		
188.00			C	R									R				R		C						C					R		R		

	NN10		21		CC	197.60	F	C	C	R	C										C			C						R					C	R	R					C						C		R	R	
			22		CC	207.20	F	C	C	R	A										R			C						R					C	C	R					C						C		R	R	
			23	4	0-1	211.71	F	C	R	R	A										R			C						R					C	C	R					C						C		R	R	
Miocene middle	NN9			5	0-1	213.21	F	C	R	R	A	R									C			C						R					C	C	R					R						R		R	R	
				6	0-1	214.71	F	C	C		A	R	R								C	C		C						R					C	C	R				R	R						R		R	R	
					CC	216.80	F	C	R		C	C	R								C	A		C						R	R	R			C	C	R					C						C		R	R	
			24		CC	226.40	F	C	C		C	C	C								R	R		C						R					C	C	R					R						C		R	R	
			25	2	0-1	227.91	F	R	C		A	R	R								R	C		C						R					R	C	R					R						R		R	R	
				3	0-1	229.41	F	R	C		A	R	R								R	R		C						R					R	C	R					R						R		R	R	
	NN8			4	0-1	230.91	F	R	C		C		C	R							R			C											R	C	R					R						R		R	R	
				5	0-1	232.41	F	R	C		C		C	R							R			C										R	R	C	R					R						R		R	R	
				6	0-1	233.91	F	R	C		C		R	R							R			C										R		C	R					R						R		R	R	
	NN7				CC	236.00	F	R	R		A			R							R			C										R		C	R					R						R		R	R	
		A	1	2	0-1	237.51	F	R	R		A			C							C		R	C												C	R					R						R		R	R	
				4	0-1	240.51	F	R	R		C			C							R		R	C												R	R					R						R		R	R	
				5	0-1	242.01	F	R	R		C			C	R						R		R	C												R	R					R						R		R	R	
					CC	245.60	F	C	R		A			C	C						C		R	A												C	R					C						C		R	R	
			2	2	0-1	247.10	F	C	R		C			C	C						C		R	C												C	R					R						R		R	R	
				4	0-1	250.10	F	C	R		C			C	R						C		R	C									R			C	R					R					R	R		R	R	
	NN6				CC	250.62	F	R	R		C			C							R		R	C									C			R	R					R					R	R		R	R	
			3		CC	255.60	F	R	R		C			C							R		R	C		C	R						C			R	C					R					R	R		R	R	
			4		CC	260.60	F	R	R		C			R							R		R	R		R	R						C			R	R					R					R	R		R	R	
			5		CC	265.60	F	R	R		R			R							R		R	R		R	R						R			R	R					R					R			R	R	
			6		CC	270.60	F	R	R		R			R							R		R	R		C	R						R			R	C					R					R			R	R	
			7		CC	275.60	F	R			C			C							R		R	C		C	R						R			R	C										R				R	
			8		CC	280.60	F	R	R		C			C							R		R	C		C	R						R			R	C	R									R				R	
	NN5		9	1	0-1	280.60	F	R			R			C		R					R		R	C		C	R						R			R	R										R				R	
				3	0-1	283.60	F	R			R			C		R					R		R	C		C	C						R			R	R										R				R	
					CC	285.60	F	R			R			C		C					R		R	C		C	C						R			R	R										R				R	
			10		CC	290.60	F	R			R			R		C					R		R	C		C	C						R			R	R										R				R	
			11		CC	295.60	F	R			R			R		C					R		R	R		C	C						R			R	R										R				R	
			12		CC	300.60	F	C			R			R		C					R		C	C		A	C						C			C	R										R				R	
		C	1		CC	315.30	F	C			n			R		C							C	A		A	C						C			C	R	R									C					
early	NN4		2	1	0-1	315.31	F	C			R					C							C	A		A	C						C			R	R										C					
				2	0-1	316.81	F	R			R					C							R	C		A	R						C				R										C					
				3	0-1	318.31	F	R			R					A							R	C		A	R						C				R										C					
				4	0-1	319.81	F	R			R					A							R	C		A	R						A				R										C					
				5	0-1	321.31	F	R			R					A							R	C		A	C						A				R										C					
	NN3			6	0-1	322.81	F	R			R					A	R						R	C		A	C						A				R	R									C					
					CC	324.90	F	R			R						C						C	C	R	A	C						A				R	R									A		R			
			3	1	0-1	324.91	F	R			R						A						R	C		A	C						A				R										C					
				2	0-1	326.41	F	R			R						A						R	C		A	C						A				R										C					
				3	0-1	327.91	F	R			R						C						R	C		A	C						A				R										C		R			
				4	0-1	329.41	F	R			R						C						R	C		A	C						A				R									R	C					
				5	0-1	330.91	F	R			R						C						R	C		A	C						A				R										C					
				6	0-1	332.41	F	R			R						A						R	C	R	A	C						A				R									R	C		R			
	NN2				CC	334.50	F	R			R						C	R	R				R	C		A	C						A				R									R	A					
			4		CC	344.10	F										R	R	R				R	C	R	C	R						C													R	C					
			5	1	21-22	344.32	F										R	R	R				R	C		C	R						C													R	C					
	NN1			2	0-1	345.61	F										R		R				C	C	R	C	C						C													R	C		R			
					CC	353.70	F										R		R				C	C	R	A	C	R	R				C													R	C					
			6	1	0-1	353.71	F												R				C	C	R	A	C	R	R				A					R								C	C					
Oligocene late	NP25			2	0-1	355.21	F												R	R			C	C	R	A	C	R	R				A					R								C	C					R
				3	0-1	356.23	F												R	R			C	C	R	C	C	R	R				C					R								R	C					
					CC	363.23	F												R	R			C	C	R	C	C	R	R				A					R								C	C		R			
			7		CC	372.90	F												R	R			R	C	R	C	C	R	R				C					R								R	C		R			
			8		CC	382.50	F												R	R			C	C	R	C	C	R	R				C					R								R	C		R			
			9		CC	382.10	F												R	R			R	C	R	A	C	R	R				C										R	R	R	R	C		R			R
			10	3	0-1	399.43	F												C	R			C	C		A	C	R	R				C					R		R			R	R		R	C		R			
					CC	401.70	F												R	R			C	A		C	C	R	R				A											R		C	C					C
			11	1	0-1	401.71	F												R	R			C	C		C	C	R	R				A					R	R					R			C		R			C

NP16) from immediately overlying upper Oligocene sediments (NP24). A complete Quaternary, Neogene, and upper Oligocene section overlies the unconformity.

Quaternary

The Quaternary includes Cores 1-2 and the upper part of Core 3. The presence of *Emiliania huxleyi* in Sample 588-1-1, 85-86 cm places this sample in Zone NN21. The last occurrence of *E. ovata* in Sample 588-1-3, 85-86 cm places the intervening Sample 588-1-2, 85-86 cm in Zone NN20. The last occurrence of *Discoaster brouweri* in Sample 588-3-5, 0-1 cm places Samples 588-1-3, 85-86 cm through 588-3-4, 0-1 cm in Zone NN19. The last occurrence of *Calcidiscus macintyrei* in Sample 588-2-1, 85-86 cm subdivides Zone NN19 into Subzones NN19b and NN19a.

Pliocene

The Pliocene section includes the lower part of Core 588-3 through the upper part of Core 588-12. The last occurrence of *Reticulofenestra pseudoumbilica* in Sample 588-6-6, 0-1 cm marks the lower/upper Pliocene boundary. The presence of *Discoaster brouweri* and the absence of *D. pentaradiatus* in Samples 588-3-5, 0-1 cm through 588-4-1, 0-1 cm place these samples in Zone NN18. Sample 588-4-2, 0-1 cm contains *D. pentaradiatus* without *D. surculus* and belongs in Zone NN17. The interval from the last occurrence of *D. surculus* in Sample 588-4-3, 0-1 cm through Sample 588-6-5, 0-1 cm is placed in Zone NN16. The last occurrences of *R. pseudoumbilica* in Sample 588-6-6, 0-1 cm and *Amaurolithus tricorniculatus* in Sample 588-9-3, 0-1 cm place Samples 588-6-6, 0-1 cm through 588-9-2, 0-1 cm in Zone NN15. The first occurrences of *D. asymmetricus* in Sample 588-11-1, 0-1 cm and *Ceratolithus rugosus* in Sample 588-11-3, 0-1 cm place Samples 588-9-3, 0-1 cm through 588-11-1, 0-1 cm in Zone NN14 and Samples 588-11-2, 0-1 cm and 588-11-3, 0-1 cm in Zone NN13. Samples 588-11-4, 0-1 cm and 588-12-1, 0-1 cm, between the first occurrence of *C. rugosus* and the last occurrence of *D. quinqueramus,* belong in Zone NN12.

Miocene

The Miocene includes the upper part of Core 12, Hole 588, through the upper part of Core 10, Hole 588C. The middle/upper Miocene boundary lies between Samples 588-23-4, 0-1 cm and 588-23-5, 0-1 cm and the lower/middle Miocene boundary lies between Core 588C-1 and Sample 588C-2-1, 0-1 cm. The range of *Discoaster quinqueramus,* Samples 588-12-2, 0-1 cm through 588-20-7, 0-1 cm, defines Zone NN11. The first occurrence of *Amaurolithus primus* in Sample 588-18-3, 0-1 cm subdivides Zone NN11 into Subzones NN11b and NN11a. The range of *D. hamatus,* from Samples 588-23-5, 0-1 cm through 588-25-3, 0-1 cm, places these samples in Zone NN9 and the overlying interval, Samples 588-20,CC through 588-23-4, 0-1 cm, in Zone NN10. The successive first occurrences of *Catinaster coalitus* in Sample 588-25-6, 0-1 cm and *D. kugleri* in Sample 588A-2-4, 0-1 cm place Samples 588-25-4, 0-1 cm through 588-25-6, 0-1 cm in Zone NN8 and Samples 588-25,CC through 588A-2-4, 0-1 cm in Zone NN7. The last occurrence of *Sphenolithus heteromorphus* in Sample 588A-9-1, 0-1 cm places Sample 588A-2,CC and Cores 3-8 of Hole 588A in Zone NN6. The first occurrence of *D. exilis* in Sample 588C-1,CC places Samples 588A-9-1, 0-1 cm through 588C-1,CC in Zone NN5. Zone NN4 includes Samples 588C-2-1, 0-1 cm through 588C-2-5, 0-1 cm. The last occurrences of *S. belemnos* in Sample 588C-2-6, 0-1 cm and *Triquetrorhabdulus carinatus* in Sample 588C-3,CC place Samples 588C-2-6, 0-1 cm through 588C-3-6, 0-1 cm in Zone NN3. Zone NN2 includes Sample 588C-3,CC down to the first occurrence of *D. druggii* in Sample 588C-5-1, 21-22 cm. The last occurrence of *Helicosphaera recta* in Sample 588C-6-2, 0-1 cm marks the Oligocene/Miocene boundary and places Samples 588C-5-2, 0-1 cm through 588C-6-1, 0-1 cm in Zone NN1.

Site 589

Hole 589

Site 589, at a water depth of 1391 m below sea level, is located east of the crest of Lord Howe Rise (30°42.72′S, 163°38.39′E) in waters transitional between subtropical and temperate water masses. One hole was drilled and four cores were obtained before the onboard positioning computer failed and drilling operations ended at a depth of 36.1 m. Hole 589 penetrated a complete Quaternary sequence and terminated in the latest Pliocene Zone NN18 (Table 5).

Species diversity and preservation are good throughout Hole 589. However, there was considerable reworking of some species, particularly several discoaster species in Cores 3 and 4.

Quaternary

Emiliania huxleyi occurs abundantly in Samples 589-1-1, 0-1 cm and 589-1-2, 0-1 cm. Therefore, these samples are placed in Zone NN21. The last common occurrence of *E. ovata* in Sample 589-1-5, 0-1 cm is taken as the top of Subzone NN19b, which places Sample 589-1-3, 0-1 cm in Zone NN20. Rare occurrences of *E. ovata* above Sample 589-1-5, 0-1 cm are interpreted as reworking. The last consistently common occurrence of *Calcidiscus macintyrei* in Sample 589-3-6, 0-1 cm marks the top of Subzone NN19a, placing Samples 589-1-5, 0-1 cm through 589-3-5, 0-1 cm in Subzone NN19b and Samples 589-3-6, 0-1 cm through 589-4-6, 0-1 cm in Subzone NN19a. Rare to common occurrences of *C. macintyrei* above Sample 589-3-6, 0-1 cm are interpreted as reworking.

Pliocene

The common occurrence of *Discoaster brouweri* in Sample 589-4,CC places this sample in the latest Pliocene Zone NN18. Rare occurrences of *D. brouweri* above this sample are interpreted as reworking.

Site 590

Holes 590, 590A, 590B

Site 590 is located on the crest of Lord Howe Rise (31°10.02′S, 163°21.51′E) immediately north of the sub-

Table 5. Nannoplankton occurrences, Hole 589.

Age	Zone	Core	Section	Interval in cm	Depth below seafloor (m)	Preservation	Index species				Additional species																																					
							Emiliania huxleyi	*Emiliania ovata*	*Calcidiscus macintyrei*	*Discoaster brouweri*	*Calcidiscus leptoporus*	*Ceratolithus cristatus*	*Ceratolithus rugosus*	*Ceratolithus telesmus*	*Coccolithus carteri*	*Coccolithus pelagicus*	*Crenalithus doronicoides*	*Cricolithus jonesi*	*Discoaster asymmetricus*	*Discoaster pentaradiatus*	*Discoaster surculus*	*Discoaster tamalis*	*Discoaster triradiatus*	*Discoaster variabilis*	*Discolithina japonica*	*Discosphaera tubifera*	*Emiliania annula*	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Hayaster perplexus*	*Helicosphaera carteri*	*Helicosphaera hyalina*	*Helicosphaera sellii*	*Oolithotus fragilis*	*Pontosphaera discopora*	*Reticulofenestra pseudoumbilica*	*Rhabdosphaera clavigera*	*Rhabdosphaera procera*	*Scapholithus fossilis*	*Scyphosphaera magna*	*Scyphosphaera pulcherrima*	*Scyphosphaera recurvata*	*Sphenolithus neoabies*	*Syracosphaera pulchra*	*Thoracosphaera heimii*	*Thoracosphaera saxea*	*Umbellosphaera irregularis*	*Umbilicosphaera sibogae*
Quaternary	NN21	1	1	0-1	0.01	G	A	R	C		A			R	R	R	C								R	R		C	C		R	C	R		R		C	C	C					C	R	R	R	C
			2	0-1	1.51	G	A	R	C		A	R		R	R	C	C	R							C	R		C	C		C	R	R		R	R	C	C	C	R		R		C	R	C	R	C
	NN20		3	0-1	3.01	G		R	C		C	R		R	R	R	C	R							R	R		C	C		C	R	R		R		R	C	R	R		R		R	R	C	R	R
	NN19b		5	0-1	6.01	G		C	C		R	R		R	R	R	A	R							R		R	A	C		C	R	R		R		R	R	R	R		R		R	R	R	R	R
			CC		7.30	G		C	R		R	R		R	R	R	A	R							R		R	C	C		C	R	R		R		R	R	R	R		R		R	R	R	R	R
		2	3	0-1	10.31	G		C	R		C	R	R	R	R	R	A	R							R		R	R	R		C	R	C	R	C		R	R	R	R		C		R	R	R	R	R
			4	0-1	11.81	G		C	R		R	R	R	R	R	R	A	R	R						R		R	R	R		C	R	C	R	R		R	R	R	R		R		R	R	R	R	R
			5	0-1	13.31	G		C	R		C	R	R	R		R	A	R			R				R		R	R	R		C	R	R	R	R		R	R	R	R		R		R	R	R	R	R
			6	0-1	14.81	G		C	R		C	R	R	R		R	A								R		R	R	R		C	R	R	R	R		R	R	R	R		R		R	R	R	R	R
			7	0-1	16.31	G		C	R		C	R	R		R	R	A								R		R	R	R		C	R	R	R	R		R	R	R	R	R	R		R	R	R	R	R
			CC		16.90	G		A	R		C	R	R	R		R	A			R				R	R		R	R	R		C	R	R	R	R		R	R	R		R	R		R	R	R	R	R
		3	1	0-1	16.91	G		A	R	R	C	R	R			R	A			R					R		R	R	R		C	R	R	R	R		R	R	R			R		R	R	R	R	R
			2	0-1	18.41	G		A	R	R	C	R	R		R	R	A		R						R		C	R	R		C	R	R	R	R		R	R	R			R		R	R	R	R	R
			3	0-1	19.91	G		A	R	R	C	R	R	R	R	R	A						R		R		C	R	R		C	R	R	R	R		R	R	R		R	R		R	R	R	R	R
			4	0-1	21.41	G		A	R	R	R	R	R	R		R	A			R					R		C	R	R		C		R	R	R		R	R	R			R		R	R	R	R	R
			5	0-1	22.91	G		C	R	R	R	R	R			R	A			R					R		C	R	R		C		R	R	R		R	R	R			R		R	R	R	R	R
	NN19a		6	0-1	24.41	G		A	C	R	R	R	R		R	R	A			R					R		C	R	R		C		R	R	R		R	R	R			R		R	R	R	R	R
			CC		26.17	G		A	C	R	R	R	R	R		R	A		R	R					R		C	R	R		C		R	R	R		R	R	R			R		R	R	R	R	R
		4	1	0-1	26.51	G		A	C	R	R	R	R		R	R	A			R	R				R		C	C	C		C		C	R	R		R	R	R			R	R	R	R	R	R	R
			2	0-1	28.01	G		A	C	R	R	R	R	R	R	R	A			R	R				R		R	C	R	R	C		C	R	R		R	R	C		R	R		C	R		R	
			3	0-1	29.51	G		A	C	R	R	R	R	R	R	R	A			R	R	R	R		R		R	R			C		R	R			R	R	R			R		R	R		R	
			4	0-1	31.01	G		A	C	R	R	R	R	R	R	C	A			R	R				R		C	R			C		C	R			R	R	R			R		R	R		R	
			5	0-1	32.51	G		C	C	R	R	R	R	R	R	C	A			R	R		R	R	R		R				C		C	R			R	R	R			R		R	R		R	
			6	0-1	34.01	G		A	C	R	R	R		R		C	A			R	R			R	R		C				C		C	R			R	R	R			R		C	R		R	
Plio. late	NN18			CC	36.10	G		A	C	C	R	R	R	R	R	C	A			R	R		C	R	R		C				C		C	R			R	R	R		R			C	R		R	

tropical divergence at a water depth of 1299 m below sea level. Site 590 consists of three holes: Hole 590 was cored to a depth of 26.2 m and three cores were taken; Hole 590A was washed down to the depth of Hole 590, then cored to a depth of 280.8 m, and 27 cores were obtained; and Hole 590B was cored to a depth of 499.1 m and 53 cores were taken. Core recovery was good throughout the three holes.

In order to obtain a complete stratigraphic section, the three cores from Hole 590 together with 18 cores from Hole 590A and 31 cores from Hole 590B were examined for calcareous nannoplankton. All of the Neogene and Quaternary nannoplankton zones are present at Site 590 (Table 6). Species diversity is good throughout Site 590 and little reworking was encountered. Preservation is good down through Sample 590A-14-1, 0-1 cm and fair below this level.

Quaternary

The Quaternary includes Cores 1-3 of Hole 590 and Core 1 of Hole 590A. The presence of *Emiliania huxleyi* in Samples 590-1-1, 5-6 cm through 590-1-3, 5-6 cm places these samples in Zone NN21. The last occurrence of *E. ovata* in Sample 590-1,CC places Samples 590-1-4, 5-6 cm and 590-1-5, 5-6 cm in Zone NN20. The last occurrence of *Discoaster brouweri* in Sample 590A-2-1, 5-6 cm places Samples 590-1,CC through 590A-1,CC in Zone NN19. The last occurrence of *Calcidiscus macintyrei* in Sample 590-3-3, 5-6 cm subdivides Zone NN19 into Subzones NN19b and NN19a. A rare occurrence of *C. macintyrei* is reworked in Sample 590-1-1, 5-6 cm. Rare occurrences of several discoaster species are reworked into Subzone NN19a and Zone NN18.

Pliocene

The interval from Core 2 of Hole 590A through Sample 590A-18-5, 5-6 cm belongs in the Pliocene. The lower/upper Pliocene boundary is placed between Samples 590A-7-3, 0-1 cm and 590A-7-4, 0-1 cm. The last consistent occurrences of *Discoaster brouweri* in Sample 590A-2-1, 5-6 cm, *D. pentaradiatus* in Sample 590A-3-1, 5-6 cm, *D. surculus* in Sample 590A-3-2, 5-6 cm, and *Reticulofenestra pseudoumbilica* in Sample 590A-7-4, 0-1 cm place Samples 590A-2-1, 5-6 cm through 590A-2,CC in Zone NN18, Sample 590A-3-1, 5-6 cm in Zone NN17, and Samples 590A-3-2, 5-6 cm through 590A-7-3, 0-1 cm in Zone NN16. The interval between the last occurrence of *R. pseudoumbilica* in Sample 590A-7-4, 0-1 cm and the last occurrence of *Amaurolithus tricorniculatus* in Sample 590A-11-7, 0-1 cm belongs in Zone NN15. Zone NN14 includes Samples 590A-11,CC through 590A-14-1, 0-1 cm, the first occurrence of *D. asymmetricus. Ceratolithus rugosus* has its first occurrence in Sample 590A-16-2, 5-6 cm, thus placing Samples 590A-14-2, 0-1 cm through 590A-16-2, 5-6 cm in Zone NN13. Zone NN12 includes samples from 590A-16-3, 5-6 cm down to Sample 590A-18-5, 5-6 cm.

Miocene

The Miocene includes the interval from Sample 590A-18-6, 5-6 cm through 590B-53,CC. The middle/upper Miocene boundary lies between Sample 590B-38-5, 5-

Table 6. Nannoplankton occurrences, Holes 589, 590A, and 590B.

							Index species																				Additional species																																																												
Age	Zone	Core	Section	Interval (cm)	Depth below seafloor (m)	Preservation	*Emiliania huxleyi*	*Emiliania ovata*	*Calcidiscus macintyrei*	*Discoaster brouweri*	*Discoaster pentaradiatus*	*Discoaster asymmetricus*	*Discoaster surculus*	*Reticulofenestra pseudoumbilica*	*Amaurolithus tricorniculatus*	*Ceratolithus rugosus*	*Discoaster quinqueramus*	*Amaurolithus primus*	*Discoaster hamatus*	*Catinaster coalitus*	*Discoaster kugleri*	*Discoaster exilis*	*Sphenolithus heteromorphus*	*Sphenolithus belemnos*	*Discoaster druggii*	*Triquetrorhabdulus carinatus*	*Amaurolithus delicatus*	*Calcidiscus leptoporus*	*Catinaster calyculus*	*Ceratolithus cristatus*	*Ceratolithus telesmus*	*Coccolithus carteri*	*Coccolithus miopelagicus*	*Coccolithus pelagicus*	*Coronocyclus nitescens*	*Crenalithus doronicoides*	*Cyclicargolithus abisectus*	*Cyclicargolithus floridanus*	*Discoaster bellus*	*Discoaster berggrenii*	*Discoaster deflandrei*	*Discoaster neohamatus*	*Discoaster tamalis*	*Discoaster tridenus*	*Discoaster triradiatus*	*Discoaster variabilis*	*Discolithina japonica*	*Discosphaera tubifera*	*Emiliania annula*	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Hayaster perplexus*	*Helicosphaera ampliaperta*	*Helicosphaera carteri*	*Helicosphaera euphratis*	*Helicosphaera hyalina*	*Helicosphaera intermedia*	*Helicosphaera sellii*	*Helicosphaera wallichii*	*Lithostromation perdurum*	*Oolithotus fragilis*	*Pontosphaera discopora*	*Rhabdosphaera clavigera*	*Rhabdosphaera procera*	*Scapholithus fossilis*	*Scyphosphaera apsteinii*	*Scyphosphaera conica*	*Scyphosphaera globulata*	*Scyphosphaera intermedia*	*Scyphosphaera magna*	*Scyphosphaera pulcherrima*	*Scyphosphaera recurvata*	*Sphenolithus abies*	*Sphenolithus moriformis*	*Sphenolithus neoabies*	*Syracosphaera pulchra*	*Thoracosphaera heimii*	*Thoracosphaera saxea*	*Triquetrorhabdulus rugosus*	*Umbellosphaera irregularis*	*Umbilicosphaera cricola*	*Umbilicosphaera sibogae*
Quaternary	NN21	1	1	5-6	0.06	G	A		R																			A			R			R		A											R	R		C	C			C		C		R				R	R	C	C							R				R	R	R		C	R	R
			2	5-6	1.55	G	R																					C			R	R		R		C											R			C	C			R		R		R				R	R	R	R							R				R	R	R		R	R	R
			3	5-6	3.05	G	R																					C				R		R		C											R			C	C			R		R		R				R	R	R	R							R				R	R	R		R	R	R
	NN20		4	5-6	4.55	G																						C			R	R		R		A											R			C	C			R		R		R			R	R	R	R	R							R				R	R	R		R	R	R
			5	5-6	6.06	G																						C				R		R		A											R			A	C			R		R		R	R		R	R	R	R	R							R				R	R	R		R	R	R
	NN19b			CC	7.00	G		R																				C			R			R		A											R			A	C			R		R		R			R	R	R	R	R							R				R	R	R		R	R	
		2	3	5-6	10.06	G		C																				C						R		A											C		R	C	C			C		C		R			R	C	R	R	R							R				R	R	R		R	R	
				CC	16.60	G		C																				C						R		A											R		R	C	R			C		C		R			R	R	R	R	C	R						R				R	R	R		R	R	
		3	2	5-6	18.16	G		C																				C			R	R		R		A											C		R	C	C			C		C		R			R	R	R	R	R	R						R				R	R	R		R	R	
			3	5-6	19.66	G		C	R																			C			R			R		A											C		R	C	C			C		C		R			R	R	R	R	R	R				R		R				R	R	R		R	R	
	NN19a			CC	26.20	G		A	R							R												C			R			R		A											R		R	C	R			C		R		R			R	R	R	R	R	R						R				R	R	R		R	R	R
	A	1		CC	35.80	G		A	C			R				R												C				R		C		C											R	R	R	R				R		R		R				R	R	R	R						R	R			R	R	R	R			R	
Pliocene, late	NN18	2	1	5-6	35.86	G		C	C	R	R		R															C						C		A									R	R	R		R	R				C				R				R	R	R	R						R	R				R	R	R			R	
			3	5-6	38.86	G		R	C	C																		C						C		A									R		R		R					C				R				R	R	R	R						R	R				R		R			R	
			5	5-6	41.86	G		R	C	C				R														C		R		R		A		A									R		R		R					C				R				R	R	R	R						R	R				R		R			R	
				CC	45.40	G		R	C	C						R												C						A		A									R		R		R					C				R				R		R	R						R	R				R		R			R	
	NN17	3	1	5-6	45.46	G		R	R	C	R																	C				R		A		A											R		R			R		C				C				R		R	R						R	R				R		R			R	
	NN16		2	5-6	46.96	G		R	R	C	C	R	R															R						C		A											R		R					R				R				R		R	R						R	R				R					R	
			3	5-6	48.46	G		R	C	C	C	R	R															C						C		A											R		R					C				R				R		R	R						R	R				R					R	
			4	5-6	49.96	G		R	C	C	C	R	R															C						C		A							R				R		R					C				R				R		R	R			R			R	R				R					R	
			5	5-6	51.46	G		C	C	C	C	R	R															C						A		A							R				R		R					C				R				R		C	R						R	R				R					R	
		4		CC	64.60	G		C	C	C	C	R	C			R												C						C		A							C				R		R					C				R				R		C	R		R		R		R	R				R					R	
		5		CC	74.20	G		C	C	R	C	R	R															C						R		A							R				R		R					C				R				R		R	R		R		R		R	R				R					R	
		6		CC	83.80	G		C	C	R	R	R	R															C				R		R		A							C			R	R		R					C				R				R		R	R				R			R			R	R					R	
		7	3	0-1	86.81	G		R	C	R	R	R	R			R												R						R		C							R			R	R		R			R		R				R				R		R	R				R			R	R		R	R					R	
Pliocene, early	NN15		4	0-1	88.31	G			C	R	R	C	R	R		R												R						R		A							R			R	R							C				C		R		R		R				R	R			R	R		R	R					R	
			5	0-1	89.81	G			C	R	R	C	R	R		R												R						R		C							R			R	R							C				R				R		R					R				R		R	R					R	
			6	0-1	91.31	G			R	R	R	C	R	C		R												R						R		C							R			R	R							R				R				R		R					R				R		C	R					R	
				CC	93.40	G			R	C	R	C	R	C		R												R						R		C							R			R	R					R		R				R				R		R					R		R		R		C	R					R	
		8		CC	103.00	G			R	C	R	C	R	C		R												C						R		C							R			R	R							C				R				R		R					R				R		C						R	
		10		CC	122.20	G			R	R	R	R	C	C		R												C						R		C								R		R	R							R				R				R		R					R				C		A						R	
		11	7	0-1	131.21	G			R	R	R	R	R	C		R											R	C						R		C								R		R								R				R				R		R					R				C		A						R	
	NN14			CC	131.80	G			R	R	R	R	R	C	R	R		R									R	C						R		C								R		R								R				R				R		R	R			R	R		R		C		A						R	
		12		CC	141.40	G			R	C	R	R	C	C	R	R		R									R	C						R		C								R		R								R								R		R				R	R				C		A						R	
		13		CC	151.00	G			R	C	C	R	C	C	R	R		R									R	C						C		C								R		R								C								R		R				R	R		R		C		A						R	
		14	1	0-1	151.01	G			R	C	R	R	C	A	R	R		R									R	C						C		C								R		R								R								R						R	R		R		C		A						R	
	NN13		2	0-1	152.51	F			R	C	R		C	A	R	R		R									R	C						R		R								R		R								R								R						R	R		R		C		A						R	
				CC	160.60	F			R	C	R		R	A	R	R		R									R	C						R		R								R		R								R								R			R			R	R				C		A						R	
		15		CC	170.20	F			R	R	R		R	A		R		R									R	C						C		R								R		R								R								R						R	R				A		A						R	
		16	2	5-6	171.76	F			R	R	R		R	A		R		R									R	C						C		R								R		R								R														R	R				A		A						R	
	NN12		3	5-6	173.26	F			R	R	R		C	A				R									R	C						A		R								R		R								R										R				R	R		R		A		A						R	
				CC	179.80	F			R	R	C		C	A				R									R	C						C		R								R		R								R															R		R		A		A						R	
		17		CC	189.40	F			R	C	C		C	A				R									R	C						C		R								C		R								R															R		R		C		A						R	
		18	5	5-6	195.46	F			R	C	C		C	A				R									R	C						C		R								C		R								R															R		R		C		A						R	

Miocene	late	NN11b		6	5-6	196 96	F	R	C	C	C	A	R	R									R	C			C		R							C	R		R			R	R	C		C			R
		B	22		CC	203 80	F	R	R	R	R	A	R	R									R	C			C		C							R	R	R	R					C		A			R
			24		CC	223 00	F	R	R	R	R	C	R	R									R	C			C		R				R			R	C		R					C		C			R
			26		CC	242 20	F	R	R	R	R	A	R	R									R	C			A		R							R	C		R				R	A		A			R
			28		CC	259 10	F	R	R	R	R	A	R	R									R	R			C		R								R		R					A		A			R
			30	3	5-6	271 76	F	R	R	R	R	A	R	R										R			C		R				R				R		R				R	A		A			R
		NN11a		4	5-6	273 26	F	R	R	R	R	A	R											R			A		R								C		R			R	R	A		A			R
				5	5-6	274 76	F	R	R	R	R	A	C											R			A		R								C		R			R		A		A	R		R
			32		CC	297 50	F	R	C	R		A	C											R			A		R				R				R		C				R	A		A	R		R
			34		CC	316 70	F	R	C	R		C	C											R			A		R			R	R	R	R		R		R	R				C		C			R
			35	5	5-6	322 76	F	R	C	R		R	R											R			C		R			R		R	R		R		C					C		C	R		R
		NN10			CC	326 30	F	C	C	R		R												R			C					R			R		R		R	R				R		R		R	R
			36		CC	335 90	F	R	C	R		C												R			R					R		R	R		R		R					R		R	R		R
			37		CC	345 50	F	R	C	R		A												R			R					R			R		R		R	R				R		R	R		R
			38	5	5-6	351 56	F	R	C			C												R			R					R			R		R		R					R		R	R		R
	middle	NN9			CC	355 10	F	R	C			A			R									R	R		C					R			R		R		R					R		R	R		R
			39		CC	364 70	F	C	R			A			C	R								C	R		C					R			R		R		R					R		R	R		R
			40		CC	374 30	F	C	R			A			R	R								R	R		C					R			R		R		R					R		R	R		R
		NN8	41	5	5-6	380 36	F	R	R			C				R								R			C					R			R		R		R					R		R	R		R
					CC	383 90	F	C	R			C				R		R						R			C										R		R					R		R	R		R
		NN7	42	1	5-6	383 96	F	R	R			A						R						R		R	C							R			R		R					R		R	R		R
					CC	393 50	F	C	R			A					R	C						C		C	A							R			R		R					R	R	C	R		R
			43		CC	403 10	F	R	R			A					R	C						C		C	C			R	C			R			R		R					R	R	R	R		R
			44		CC	412 70	F	R	R			C					R	R						R		C	C			R	C			R			R		R					R	R	R	R		R
			45	1	5-6	412 76	F	R				C					R	R						R		C	C			R	C			R			R		R					R	R	R	R		R
		NN6		3	5-6	415 76	F	R				C						C						R		C	C			R	R			R			R		R					R	R	R	R		R
					CC	422 30	F	C				A						C						R		C	C			R	R			R			R		R					R	R	R	R		R
			46		CC	431 90	F	R				C						C						R		R	A			C	C			R			C		R						C	R			R
			47	3	5-6	434 96	F	R				C						C						R		R	C			C	C			R			R		R						R	R			R
		NN5		5	5-6	437 96	F	R				C						C	R					R		R	C			R	C			R			R		R						C	R			R
			48		CC	451 10	F	R				R						C	R					R		R	C			R	C			C			R		R						C				
			49		CC	460 70	F	R				R						R	R					R		R	C			R	C			C			R		R						R				
	early	NN4	50	1	5-6	460 76	F	R				R							R							R	A			R	C			C					R		R				C				
				3	5-6	463 76	F	R				R							C							R	C			R	C			A					R							A				
					CC	470 30	F	R				R							C					R		R	C	R		R	C			A					R							C				
		NN3	51	1	5-6	470 36	F	R				R								R						R	C	R		R	C			A				R	R	R					A				
					CC	479 90	F	R				C								R	R					R	C	R		C	C			C					R							C				
			52	5	5-6	485 96	F	R				R								R	R					R	C	R		R	R			C					R	R	R				A				
		NN2			CC	489 50	F	R				R								R	R	R				R	C	R		R	C			C					R	R					C				
			53	1	5-6	489 56	F					R									R	R				R	C	R		R	C			C					R							C				
		NN1		3	5-6	492 56	F					R										R				R	C	R		R	C			C					R							C				
				5	5-6	495 56	F					R										R				C	A	R		R	C			A					R							C				
					CC	499 10	F					R										R				C	A	R		R	C			A					R							C				

6 cm and 590B-38,CC and the lower/middle Miocene boundary is placed between Samples 590B-49,CC and 590B-50-1, 5-6 cm. The range of *Discoaster quinqueramus* from Samples 590A-18-6, 5-6 cm through 590B-35-5, 5-6 cm defines Zone NN11. The first occurrence of *Amaurolithus primus* in Sample 590B-30-3, 5-6 cm subdivides this zone into Subzones NN11b and NN11a. The range of *D. hamatus* from Samples 590B-38,CC through 590B-40,CC places these samples in Zone NN9 and Samples 590B-35,CC through 590B-38-5, 5-6 cm in Zone NN10. The first occurrences of *Catinaster coalitus* in Sample 590B-41,CC and *D. kugleri* in Sample 590B-45-1, 5-6 cm place Samples 590B-41-5, 5-6 cm and 590B-41,CC in Zone NN8 and Samples 590B-42-1, 5-6 cm through 590B-45-1, 5-6 cm in Zone NN7. The interval from Sample 590B-45-3, 5-6 cm to Sample 590B-47-3, 5-6 cm, above the last occurrence of *Sphenolithus heteromorphus* in Sample 590B-47-5, 5-6 cm, belongs in Zone NN6. The interval from Sample 590B-47-5, 5-6 cm to 590B-49,CC, the first occurrence of *D. exilis,* is placed in Zone NN5. Although *Helicosphaera ampliaperta* is normally absent in samples from the western Pacific, a single specimen was observed in Sample 590B-51-1, 5-6 cm. The last occurrence of *S. belemnos* in Sample 590B-51-1, 5-6 cm places Core 50 in Zone NN4. The last occurrence of *Triquetrorhabdulus carinatus* in Sample 590B-52,CC and the first occurrence of *Discoaster druggii* in Sample 590B-53-1, 5-6 cm place Samples 590B-51-1, 5-6 cm through 590B-52-5, 5-6 cm in Zone NN3, Samples 590B-52,CC and 590B-53-1, 5-6 cm in Zone NN2, and Sample 590B-53-3, 5-6 cm through 590B-53,CC in Zone NN1.

Site 591

Holes 591, 591B

Site 591 is located on a spur of Lord Howe Rise (31°35.06′S, 164°26.92′E) and lies on the subtropical divergence at a water depth of 2131 m below sea level. Three holes were drilled at Site 591. Hole 591 was cored to a depth of 283.1 m and 31 cores were taken. Hole 591A, a duplication of Hole 591, was cored to a depth of 284.6 m and 30 cores were taken. Hole 591B was washed down to a depth of 270.6 m and then cored to a depth of 500.4 m. Twenty-four cores were taken. Core recovery was good throughout Hole 591 and most of Hole 591A and fair throughout Hole 591B.

In order to obtain a complete stratigraphic section, 31 cores from Hole 591 and 22 cores from Hole 591B were examined for calcareous nannoplankton. Species diversity is good throughout Site 591 and reworking is minimal. Preservation of calcareous nannoplankton is good throughout Cores 1-16 of Hole 591 and fair below this level. Hole 591B terminated in the early Miocene Zone NN4 and all of the overlying Neogene and Quaternary nannoplankton zones are recognized (Table 7).

Quaternary

The Quaternary includes Samples 591-1-1, 4-5 cm through 591-6-5, 3-4 cm. The occurrence of *Emiliania huxleyi* in Samples 591-1-1, 4-5 cm and 591-1-3, 4-5 cm places these samples in Zone NN21. The last common occurrence of *E. ovata* in Sample 591-2-5, 3-4 cm marks the top of Subzone NN19b. A rare occurrence of *E. ovata* above this level is interpreted as reworking. The intervening samples belong in Zone NN20. The last consistent occurrence of *Calcidiscus macintyrei* in Sample 591-5-5, 3-4 cm marks the top of Subzone NN19a. A single occurrence of *C. macintyrei* in Sample 591-1,CC is interpreted as reworking.

Pliocene

The Pliocene includes Samples 591-6,CC through 591-24-1, 3-4 cm. The lower/upper Pliocene boundary is located between Samples 591-12-3, 3-4 cm and 591-12-5, 3-4 cm. The top of Zone NN18 is marked by the last occurrence of *Discoaster brouweri* in Sample 591-6,CC. Zone NN18 extends down to the last occurrence of *D. pentaradiatus* in Sample 591-8-3, 3-4 cm. This sample is placed in Zone NN17. The last occurrence of *D. surculus* in Sample 591-8-5, 3-4 cm down to the last consistent occurrence of *Reticulofenestra pseudoumbilica* in Sample 591-12-5, 3-4 cm places Sample 591-8-5, 3-4 cm through 591-12-3, 3-4 cm in Zone NN16. Two occurrences of *R. pseudoumbilica* above this level are interpreted as reworking. The interval from the last occurrence of *Amaurolithus tricorniculatus* in Sample 591-17-1, 21-22 cm through Sample 591-20,CC, the first occurrence of *Discoaster asymmetricus*, is placed in Zone NN14. The next two samples, down to the first occurrence of *Ceratolithus rugosus* in Sample 591-21-5, 3-4 cm, belong in Zone NN13. The interval from Sample 591-21,CC to Sample 591-24-1, 3-4 cm, above the last occurrence of *D. quinqueramus* in Sample 591-24-3, 3-4 cm, is placed in Zone NN12.

Miocene

The Miocene ranges from Sample 591-24-3, 3-4 cm through Sample 591B-24,CC. Hole 591B penetrated just into the early Miocene Zone NN4. The middle/upper Miocene boundary lies between Samples 591B-8,CC and 591B-9-2, 4-5 cm and the lower/middle Miocene boundary lies between Samples 591B-23,CC and 591B-24-1, 3-4 cm. The range of *Discoaster quinqueramus*, down through Sample 591B-4,CC, defines Zone NN11. The first consistent occurrence of *Amaurolithus primus* in Sample 591-28-3, 3-4 cm marks the boundary between Subzones NN11b and NN11a. The interval from Sample 591B-5-1, 3-4 cm through Sample 591B-8,CC is placed in Zone NN10. The range of *D. hamatus*, from Sample 591B-9-2, 4-5 cm through Sample 591B-11-1, 4-5 cm, places these samples in Zone NN9. The occurrence of *Catinaster coalitus* in Sample 591B-11,CC places this sample in Zone NN8. The next two samples belong in Zone NN7, based on the first occurrence of *D. kugleri* in Sample 591B-12,CC. Zone NN6 includes Samples 591B-13-1, 3-4 cm through 591B-18-3, 3-4 cm. The interval from the last occurrence of *Sphenolithus heteromorphus* in Sample 591B-18-5, 3-4 cm down to the first occurrence of *D. exilis* in Sample 591B-23,CC is placed in Zone NN5. Core 24 belongs in Zone NN4.

Table 7. Nannoplankton occurrences, Holes 591 and 591B.

Index species

Age	Zone	Core	Section	Interval (cm)	Depth below seafloor (m)	Preservation	Emiliania huxleyi	Emiliania ovata	Calcidiscus macintyrei	Discoaster brouweri	Ceratolithus rugosus	Discoaster pentaradiatus	Discoaster asymmetricus	Discoaster surculus	Reticulofenestra pseudoumbilica	Amaurolithus primus	Amaurolithus tricorniculatus	Discoaster quinqueramus	Discoaster hamatus	Discoaster exilis	Catinaster coalitus	Discoaster kugleri	Sphenolithus heteromorphus
Quaternary	NN21	1	1	4-5	0.05	G	C																
			3	4-5	3.05	G	R	R																
	NN20			CC	3.40	G			R						R							
		2	3	3-4	6.44	G																	
	NN19b		5	3-4	9.44	G		C																
		3		CC	22.60	G		C							C							
		4		CC	32.20	G		C																
		5	3	3-4	35.24	G		C																
	NN19a		5	3-4	38.24	G		C	R															
		6	5	3-4	47.84	G		C	C															
Pliocene, late	NN18			CC	51.40	G		C	C	R														
		7		CC	61.00	G		C	R	C	R													
		8	1	3-4	61.04	G		C	C	C	R													
	NN17		3	3-4	64.04	G		C	C	C	R	R	R											
	NN16		5	3-4	67.04	G		C	C	C	R	C	R	R										
		9		CC	80.20	G		C	C	C	R	C	C	C										
		10		CC	89.80	G		R	C	C	R	C	C	C										
		11		CC	99.40	G			C	C	R	C	C	C										
		12	3	3-4	102.44	G			C	C	R	C	C	C										
Pliocene, early	NN15		5	3-4	105.44	G			C	C	R	C	C	C	R									
		13		CC	118.30	G			C	C	R	C	C	R	A									
		14		CC	127.60	G			C	C	R	C	R	C	A									
		15		CC	136.90	G			C	C	R	C	R	C	A									
		16		CC	146.20	G			C	C	R	C	R	R	A	R								
	NN14	17	1	21-22	146.24	G			C	C	R	C	R	C	C	R	R							
				CC	155.50	G			R	C	R	C	R	C	A	R	R							
		18		CC	164.80	G			R	C	R	C	R	C	A	R	R							
		19		CC	174.30	F			R	C	R	C	R	C	C	R	R							
		20		CC	183.80	F			R	C	R	C	R	C	C	R	R							
	NN13	21	1	3-4	188.84	F			R	C	R	C		C	C	R								
			5	3-4	189.84	F			R	C	R	C		C	C	R								
	NN12			CC	193.30	F			R	R		R		R	C	R								
		22		CC	202.70	F			R	R		R		C	C	R								
		23		CC	212.10	F			R	C		R		C	C	R								
		24	1	3-4	212.14	F			C	R		R		R	C	R								
Miocene, late	NN11b		3	3-4	215.14	F			C	R		R		R	C	R		R						
		25		CC	231.10	F			R	C		R		R	C	R		R						
		26		CC	240.70	F			R	R		R		R	C	C		R						
		27		CC	250.30	F			R	R		R		R	C	R		R						
		28	3	3-4	253.34	F			R	R		R		R	C	R		R						
	NN11a		5	3-4	256.34	F			R	R		R			C			R						
		29		CC	269.30	F			R	R		R		R	C	R		R						
		30		CC	274.30	F			R	R		R			C			R						
		31		CC	283.10	F			R	R		R			C			R						
		B 3		CC	299.40	F			R	R		R		R	C			R						
		4		CC	308.80	F			R	C		R			C			R						
	NN10	5	1	3-4	308.85	F			R	C		R			C									
				CC	318.20	F			R	C		R			C									
		6		CC	327.60	F			R	C		R			A									
		7		CC	337.20	F			R	C		R			A									
		8		CC	346.80	F			R	R					A									
Miocene, middle	NN9	9	2	4-5	348.35	F			R	R					A				R				
				CC	356.40	F			R	R					A				R				
		10		CC	366.00	F			C	R					A				R				
		11	1	4-5	366.05	F			C	R					A				C				
	NN8			CC	375.60	F			C	R					A					R	R		
	NN7	12	1	3-4	375.64	F			C	R					A					R		R	
				CC	385.20	F			C	R					A					R		R	
	NN6	13	1	3-4	385.24	F			C	R					A					R			
				CC	394.80	F			C	R					A					C			
		14		CC	404.40	F			R	R					A					C			
		15		CC	414.00	F			R						C					C			
		16		CC	423.60	F			R						C					C			
		17		CC	433.20	F			R						C					R			
		18	3	3-4	436.24	F			R						C					R			
	NN5		5	3-4	439.24	F			C						C					R			R
				CC	442.80	F			C						C					R			C
		19		CC	452.40	F			C						C					R			C
		20		CC	462.00	F			C						C					R			C
		21		CC	471.60	F			C						C					R			C
		22		CC	481.20	F			C						C					R			C
		23		CC	490.80	F			R						C					R			C
Miocene, e.	NN4	24	1	3-4	490.84	F									C								C
				CC	500.50	F									C								C

Additional species

Depth below seafloor (m)	Amaurolithus delicatus	Calcidiscus leptoporus	Ceratolithus cristatus	Ceratolithus telesmus	Coccolithus carteri	Coccolithus miopelagicus	Coccolithus pelagicus	Coronocyclus nitescens	Crenalithus doronicoides	Cyclicargolithus abisectus	Cyclicargolithus floridanus	Discoaster bellus	Discoaster berggrenii	Discoaster deflandrei	Discoaster moorei	Discoaster neohamatus	Discoaster stellulus	Discoaster tamalis	Discoaster tridenus	Discoaster triradiatus	Discoaster variabilis	Discolithina japonica	Emiliania annula	Gephyrocapsa caribbeanica	Gephyrocapsa oceanica	Hayaster perplexus
0.05		A		R	R		R		A														R		C	C	
3.05		C		R	R		R		C	R													R		C	C	
3.40		C		R	R		R		C													R		R	R	
6.44		C	R		R		R		A													R		R	R	
9.44		R			R		R		A													R	R	R		
22.60		C	R		R		R		A													R		R		
32.20		C			R		R		C													R	C	C		
35.24		C			R		R		C													R	C	C		
38.24		C			R		R		C													R	C			
47.84		C			R		C		A													R	C			
51.40		C			R		C		A												R	R	R	C			
61.00		C			C		C		A													R	C			
61.04		C			R		C		A													R	R			
64.04		C			R		C		C													R	R			R
67.04		C			R		C		C													R	R			
80.20		C			R		C		C										R			R	R	R			
89.80		C			R		C		C										R			R	R	R			
99.40		C			R		C		C										R			R	R				
102.44		C			R		C		C										C			R	R				
105.44		C			R		R		C										C			R	R				
118.30	R	C					C		C												R	R				R
127.60		C					C		C												R					
136.90		C					C		C												R					
146.20	R	C					R		C												R					
146.24	R	C					R		C												R					
155.50	R	C					R		C												R					
164.80	R	C					R		C												R					R
174.30	R	C					C		A												R					
183.80	R	C					C		A												R					
188.84	R	R					C		C											R		R					
189.84		C					C		C											R		R					
193.30		C					C		C											R		R					
202.70		R					C		A											R		R					
212.10		R					C		C											R		R					
212.14		C					C		C											C		R					
215.14		C					C		C											R		R					
231.10	R	C					C		A											R		R					
240.70		C					C		C											R		R					
250.30		C					C		C											R		R					
253.34		R					C		C											R		R					
256.34		R					C		C													R					
269.30		R					C		A													R					
274.30		R					C		C					R									R					
283.10		R					C		R					R									R					
299.40		R					C		R				R	R									R					
308.80		R					A		R				R	R		R							R					
308.85		R					C		R			R		R		R							R					
318.20		R					C		R			R		R		R	R						R					
327.60		R					R		R			R		R		C	R						R					
337.20		R					R						R		R		C							R					
346.80		R					C						R		R	R	C							R					
348.35		R					C						R		R		C							R					
356.40		R					C						R		R	R	R	R						R					
366.00		R					C						R		R	R	R	R						R					
366.05		R					C									R		R	R						R					
375.60		R					C									R									C					
375.64		R					C									R	R								C					
385.20		R					C									R									C					
385.24		R				R	C									R									R					
394.80		R				R	C									C									R					
404.40		R				R	C									C									R					
414.00		R				R	C			R	R			C									R					
423.60		R				R	C			C	C			R	R								R					
433.20		R				R	C	R		C	C			R									R					
436.24		R				R	C	R		C	C			R									R					
439.24		R				R	C	R		C	C			R									R					
442.80		R				R	C	R		C	C			R									R					
452.40		R				R	C	R		C	C			R									R					
462.00		R				R	C	R		C	C			R									R					
471.60		R				R	C	R		C	C			C									R					
481.20		R				R	C	R		C	C			C														
490.80						R	R	R		C	C			C														
490.84						R	R	R		C	C			C														
500.50						R	R	R		C	C			C														

Additional species (continued)

Depth below seafloor (m)	Helicosphaera carteri	Helicosphaera euphratis	Helicosphaera hyalina	Helicosphaera intermedia	Helicosphaera sellii	Oolithotus fragilis	Pontosphaera discopora	Rhabdosphaera clavigera	Rhabdosphaera procera	Scapholithus fossilis	Scyphosphaera amphora	Scyphosphaera cylindrica	Scyphosphaera globulata	Scyphosphaera intermedia	Scyphosphaera magna	Scyphosphaera pulcherrima	Scyphosphaera recurvata	Sphenolithus abies	Sphenolithus moriformis	Sphenolithus neoabies	Syracosphaera pulchra	Thoracosphaera saxea	Triquetrorhabdulus rugosus	Umbilicosphaera irregularis	Umbilicosphaera cricota	Umbilicosphaera sibogae
0.05	C		R		R	R	R	C	C	C											C	R		R	C	C
3.05	C		R		R	R	R	C	R	C											C	R		R	C	R
3.40	C		R		R		R	R	R	R										R	C	R		R	R	R
6.44	C		R		R		R	R	R	R											C			R	R	R
9.44	R		R		R		R	R	R	R											C			R	R	
22.60	C		R		R		R	R	R	R											R				R	
32.20	C		R		R		C	R	R	R											R				R	
35.24	C		R		R		C	R	R	R							R				R				R	
38.24	C		R		R		C	R	R	R							R				R	R			R	
47.84	C		R		R		R	R	R	R											C				R	
51.40	C		R		R		R	R	R	R											C				R	
61.00	C				R		R	R	R	R						R					C	R			R	
61.04	C				R		R	R	R	R						R	R				R	R			R	
64.04	C				R		R		R	R						R	R				R	R			R	
67.04	C				R		R		R	R						R					R				R	
80.20	C				R		R		R												C				R	
89.80	C				R		R		R												C				R	
99.40	C				R		R		R												C				R	
102.44	C				R		R		R					R		R	R				C	R			R	
105.44	C				C		C		R					R		R					R				R	
118.30	C				C		C		R		R			R	R	R	R	C		C	R				R	
127.60	C				R		R		R		R	R		R			R	C		C					R	
136.90	C				R		R		R		R	R	R	R		R		C		C					R	
146.20	C				R		R		R				R	R			C		C					R	
146.24	C				R		R		R	R				R			R	C		C					R	
155.50	C				R		R											R	C		C					R	
164.80	C				R		R											R	C		C					R	
174.30	R				R												R	C		C					R	
183.80	R				R												R	C		C			R		R	
188.84	R				R					R				R				C		C			R		R	
189.84	R				R													C		C			R		R	
193.30	R				R												R		C		C			R		R	
202.70	R				R										R			R	A		A			R		R	
212.10	R				R										R		R	R	A		A			R		R	
212.14	R	R			R													C		C			R		R	
215.14	R				R													C		C			R		R	
231.10	R				R										R			R	C		C			R		R	
240.70	R																	R	C		A			R		R	
250.30	R															R			R	C		C			R		R	
253.34	R																		C		C			R		R	
256.34	R																	R	C		C			R		R	
269.30	R			R															C		C			R		R	
274.30	R																	R	C		C			R		R	
283.10	R																		C		C			R		R	
299.40	R																		C		C			R		R	
308.80	C	R																	C		C			R		R	
308.85	R																		C		C			R		R	
318.20	R																		C		C			R		R	
327.60	R																		R		C			R		R	
337.20	R																		R		R			R		R	
346.80	R																		R		R			R		R	
348.35	R																		R		R			R		R	
356.40	R																		R		R			R		R	
366.00	R																		R		R			C		R	
366.05	R																		C		C			R		R	
375.60	R																		C		C			R		R	
375.64	R																		C		C			R		R	
385.20	R																		R		R			R			
385.24	C	R																	R		R			R			
394.80	C																		C		C			R			
404.40	R																		R	R	R			R			
414.00	R																		R	R	R			R			
423.60	R																		R	R	R			R			
433.20	R	R																	R	R	R			R			
436.24	R																		R	R	R					
439.24	R																			C	R					
442.80	R																			C	R					
452.40	R																			C	R					
462.00	R																			C						
471.60	R	R																		C						
481.20	R	R																		C						
490.80	R																			C						
490.84	R																			C						
500.50	R																			C						

Site 592

Hole 592

Site 592 is located on the southern Lord Howe Rise (36°28.40′S, 165°26.53′E) at a water depth of 1098 m below sea level. Hole 592, which lies in the temperate water mass, was cored to a depth of 388.5 m (late Eocene Zone NP18). Forty-one cores were taken and recovery was good throughout the hole.

The major regional unconformity of the southwest Pacific was encountered within Core 33 at a depth of 306 m. It separates lower Oligocene sediment (Zone NP22) from immediately overlying lower Miocene sediment (Zone NN2). Except for the boundary between the early Pliocene Zones NN13 and NN12, the Neogene and Quaternary nannoplankton zonation is complete down to the unconformity (Table 8). The preservation of calcareous nannoplankton in Hole 592 is good in Cores 1–4

Table 8. Nannoplankton occurrences, Hole 592.

Index species

Age	Zone	Core	Section	Interval (cm)	Depth below seafloor (m)	Preservation	Emiliania huxleyi	Emiliania ovata	Calcidiscus macintyrei	Discoaster brouweri	Discoaster pentaradiatus	Discoaster surculus	Discoaster asymmetricus	Reticulofenestra pseudoumbilica	Amaurolithus tricorniculatus	Amaurolithus primus	Discoaster quinqueramus	Discoaster hamatus	Discoaster exilis	Catinaster coalitus	Catinaster kugleri	Sphenolithus heteromorphus	Sphenolithus belemnos	Sphenolithus druggii	Triquetrorhabdulus carinatus	Reticulofenestra umbilica
Quaternary	NN21	1	1	3-4	0.04	G	A																			
			3	3-4	3.04	G	R																			
	NN20			CC	4.50	G																				
	NN19b	2	1	3-4	4.54	G		R																		
			3	3-4	7.54	G		A																		
			5	3-4	10.54	G		A																		
		3	1	3-4	14.14	G		A																		
	NN19a		2	3-4	15.64	G		C	R																	
			5	3-4	20.14	G		A	C																	
Pliocene, late	NN18		6	3-4	21.92	G		A	A	R																
				CC	23.70	G		A	A	R																
		4	1	3-4	23.74	G		A	A	C																
	NN17		2	3-4	25.24	G		A	A	C	R															
	NN16		3	3-4	26.74	G		C	C	C	R	R														
			4	3-4	28.24	G		C	R	R	R	R	R													
			6	3-4	31.24	G		C	C	R	R	C	R													
			7	3-4	32.74	G		C	C	R	R	R	R	R												
				CC	33.30	G		C	C	C	C	C	R	R												
		5	3	3-4	36.34	F		R	C	C	R	C	R	R												
			6	3-4	40.84	F		R	C	R	R	C	R	R												
				CC	42.90	F		R	C	R	R	R	R	R												
		6	3	3-4	45.94	F		R	C	R	R	R	R	R												
Pliocene, early	NN15			CC	52.50	F		R	C	R	R	R	R	C												
		7	1	3-4	52.54	F		R	R	R	R	R	R	C												
				CC	62.10	F			R	R	R	R	R	C												
		8	3	3-4	65.14	F			R	R	C	C	R	C												
			5	3-4	68.14	F			R	R	R	R	R	C												
	NN14			CC	71.70	F			R	C	C	C	P	C	R	R										
		9	3	3-4	74.74	F			R	C	C	C	R	C	R	R										
				CC	81.30	F			C	C	C	C	R	C	R	C										
		10	1	3-4	81.34	F			C	R	R	R	R	C	R	R										
			3	3-4	84.34	F			R	R	R	C	R	C	R	R										
				CC	90.90	F			C	C	R	C	R	R		R										
		11		CC	100.50	F			R	C	C	R	R	A												
		12	5	3-4	106.54	F			R	R	C	R	R	A												
				CC	110.10	F			R	R	R	R	R	C		R										
		13		CC	119.70	F			R	R	R	R	R	C		R										
	NN13	14	1	3-4	119.74	F				R	R	R		C	R	R										
			3	3-4	122.74	F				R	R	R		C		R										
	NN12		5	3-4	125.74	F			R	R	R	R		C	R	R		R	R							
				CC	129.30	F			R	R	R	R		C		R			R							

Additional species

Depth below seafloor (m)	Amaurolithus amplificus	Amaurolithus delicatus	Calcidiscus leptoporus	Ceratolithus cristatus	Ceratolithus rugosus	Ceratolithus telesmus	Chiasmolithus altus	Chiasmolithus sp.	Coccolithus carteri	Coccolithus miopelagicus	Coccolithus pelagicus	Coronocyclus nitescens	Crenalithus doronicoides	Cyclicargolithus abisectus	Cyclicargolithus floridanus	Dictyococcites bisectus	Discoaster bellus	Discoaster berggrenii	Discoaster challengeri	Discoaster decorus	Discoaster deflandrei	Discoaster neohamatus	Discoaster perclarus	Discoaster sp.	Discoaster tamalis	Discoaster tridenus	Discoaster triradiatus	Discoaster variabilis	Discolithina japonica	Discolithina sp.
0.04			C	R		R			R		C		A																R	
3.04			C						R		C		A																R	
4.50			C						R		C		A																R	
4.54			C						R		C		A																R	
7.54			C						R		C		A																R	
10.54			C						R		R		A																R	
14.14			C	R					R		R		A																R	
15.64			C						R		A		C																R	
20.14			C						R		C		C																R	
21.92			C						R		A		C														R		R	
23.70			C						R		A		C														R		R	
23.74			C						R		A		C														R		R	
25.24			C	R					R		A		A														R		R	
26.74			C						R		C		A																R	
28.24			C						R		C		A																R	
31.24			C						R		A		A														R	R	R	
32.74			C						R		A		A															R	R	
33.30			C						R		A		A												R			R	R	
36.34			C						R		A		A												R		R	R	R	
40.84			C						R		A		A												R		R	R	R	
42.90			C		R		R		R		A		A												R			R	R	
45.94			C						R		C		A												R			R	R	
52.50			C						R		C		A												C	R		R	R	
52.54			C		R				R		C		A												R			R	R	
62.10			C						R		C		A															R	R	
65.14			C						R		C		A															R	R	
68.14			C								C		A														R	C	R	
71.70	R	R	C								C		A															R	R	
74.74	R	R	C								C		A															R	R	
81.30		R	C		R						C		A													R	R	R	R	
81.34		R	C		R						C		A						R						R		R	R	R	
84.34		R	C		R						C		A															R	R	
90.90			R								C		A															R	R	
100.50			C								C		A						R	R								C	R	
106.54			R								R		C							R								R	R	
110.10			R								R		C															R	R	
119.70			R								C		A													R		R		
119.74			R								C		C													R		R		
122.74			R								C		C													R		R		
125.74			R								R		C													R		R	R	
129.30			R								R		C												R	R		R		

Depth below seafloor (m)	Emiliania annula	Gephyrocapsa caribbeanica	Gephyrocapsa oceanica	Hayaster perplexus	Helicosphaera carteri	Helicosphaera euphratis	Helicosphaera hyalina	Helicosphaera intermedia	Helicosphaera sellii	Isthmolithus recurvus	Lithostromation perdurum	Oolithotus fragilis	Pontosphaera discopora	Rhabdosphaera clavigera	Rhabdosphaera procera	Scapholithus fossilis	Scyphosphaera globulata	Scyphosphaera intermedia	Scyphosphaera magna	Scyphosphaera pulcherrima	Scyphosphaera recurvata	Sphenolithus abies	Sphenolithus moriformis	Sphenolithus neoabies	Syracosphaera pulchra	Thoracosphaera saxea	Triquetrorhabdulus rugosus	Umbellosphaera irregularis	Umbilicosphaera cricota	Umbilicosphaera sibogae	Zygrhablithus bijugatus
0.04		C	C		C		R		R			R		R	R	C									C	R		R	R	R	
3.04		C	C		C		R		R			R	R	R	R	C									C	R		R	R	R	
4.50		A	C		C		R		R			R	R	R	R	C									R	R		R	R	R	
4.54		A	C		C		R		R			R	R	R	R	C									C	R		R	R		
7.54	C	C	C		C		R		R			R	R	R	R	C									R	R		R	R		
10.54	R	R	R		C		R		R			R	R	R	R	R					R				R	R		R	R		
14.14	C	R	R		C				R			R	R	R	R	R			R		R				R			R	R		
15.64	R	R	R		C				R			R	R	R	R	R					R				R			R	R		
20.14	C	R			C				C			R	R	R	R	R					R				R			R	R		
21.92	C	R			C				R			R	R	R	R	R					R				R			R	R		
23.70	C	R			C				R			R	R	R	R	R					R				C			R	R		
23.74	C				C				R			R	R	R	R	R					R				C			R	R		
25.24	R				C				R			R	R	R	R	R				R	R				C			R	R		
26.74	R				R				R				R		R	R				R	R				R			R	R		
28.24	R				R				C				R		R	R				R	R				R			R	R		
31.24	R				C				R				R		R	R					R				C				R		
32.74	R				C				R				R		R	R					R				R				R		
33.30	R				C				R				R		R	R		R		R	R				C				R		
36.34	R				R				R				R		R	R		R			R				R				R		
40.84	R				R				R				R		R	R		R		R	R				R				R		
42.90	R				C				R				R		R	R	R	R	R	R	R				R				R		
45.94					C				R				R		R	R		R			R				R				R		
52.50					C				R				R		R	R		R		R	R	R		R	R				R		
52.54					R				R				R		R	R		R			R	R		R	R				R		
62.10					R				R						R			R			R	C		C	R				R		
65.14					C				R						R			R		R	R	C		C	R				R		
68.14					C				R						R			R			R	C		C	R				R		
71.70					R				R						R			R			R	C		C	R				R		
74.74					R				R		R				R			R		R	R	C		C	R				R		
81.30				R	C				R						R		R	R		R	R	C		C	R				R		
81.34					C				R		R				R			R		R	R	C		C	R				R		
84.34					C				R						R			R		R	R	C		C	R				R		
90.90					C										R			R			R	C		C					R		
100.50					C										R			R		R	R	A		A					R		
106.54					R										R						R	A		A					R		
110.10					R										R					R	R	C		A					R		
119.70					R																R	C		A					R		
119.74					R																R	C		C					R		
122.74					R													R		R	R	C		C					R		
125.74					R													R		R	R	C		C					R		
129.30					R													R			R	C		C					R		

Miocene	late	NN11b	15	1	3-4	129.34	F		C	R	R	A	R	R	R												R			C		C														R			R					R		R	C		C		R	
				3	3-4	132.34	F	R	R	R	R	A	R	R	R												R			C		C												R		R			R					R		R	C		C		R	
				5	3-4	135.34	F	R	R	R	R	A	R	C												R	R			R		R												R		C			R					R	R	R	C		C		R	
					CC	138.90	F	R	R	R	R	C	R	C	R										R	R	R			C		R													R	C			C					R	R	R	C		C		R	
			16	1	3-4	138.94	F	R	R	R	R	C	R	C											R	R	R			C		R														R	R		C					R	R	R	C		A		R	
				3	3-4	141.94	F	R	R	R	R	A	C	C	R										R	R	R			C		R														C			C	R				R	R	R	C		A		R	
				5	3-4	144.94	F	R	R	R	R	C	R	R	R										R		R			C		C	R						R							R			C	R		R	R	R	R	R	C		A		R	
					CC	148.50	F	R	R	R	R	C	R	R	R												R			C		C					R		R							R			R					R	R	R	C		C		R	
			17		CC	158.10	F	R	R	R	R	A	R	C	R											R	R			A		R														R			R					R			C		C		R	
		NN11a	16	1	3-4	158.14	F	R	R	R	R	A			R												R			A		R														R			R					R		R	C		C	R	R	
					CC	167.70	F	R	R	R	R	A			R												R			A		R							R							R			R						R		C		C	R	R	
			19	1	3-4	167.74	F	R	R	R	R	A			R												R			A		R									R						R			R					R	R		C		C	C	R	
		NN10		3	3-4	170.74	F	R	R	R		A															R			A		R									R						R			R	R							C		C	R	R	
			20		CC	186.90	F	R	C	R		C															R			C		R								R	R						R			R								C		C	R	R	
	middle	NN9	21	1	3-4	186.94	F	C	R	R		R				R											C			C		R									R						C			C	R						R	C		C	R	R	
				3	3-4	189.94	F	R	C	R		R				R											R			C								R			R						C			R								C		C	R	R	
				5	3-4	192.94	F	R	R	R		R				R											R			C						R		R			C						C			R								R		C	R	R	
					CC	196.50	F	R	R			A				R											C			C						R					R						R			R								R		C	R	R	
			22		CC	206.10	F	C	R			A				R	R										C			A						R					R						C			C								C		C	R	R	
		NN8	23	1	3-4	206.14	F	C	R			A					R	R									C			C						R					R						R			R								R		R	R	R	
		NN7		3	3-4	209.14	F	R	R			A					R										C			C																R			R								R		R	R	R	
			24	3	3-4	218.74	F	R	R			A					R										C		R	C										R							R			C								R		R	R	R	
				5	3-4	221.74	F	R	R			A					R		R								C		R	C										R							R			R								R		R	R	R	
					CC	225.30	F	R	R			A					R		R								C		R	C										C							R			R								R		R	R	R	
		NN6	25	1	3-4	225.34	F	R	R			A					R										C		R	C										C							R			R								R		C	R	R	
					CC	234.90	F	R	R			A					R										C		R	C			C	R						C			R			R			R								R		C	R	R	
			26		CC	244.50	F	R	R			A					R										C		C	C			A	C						C			R			R			R								R		R	C	R	
			28	1	3-4	254.14	F	C				C					R										R		R	A			A	C						C			R			R			R									R	R		R	
		NN5		3	3-4	257.14	F	R				C					R			R							C		R	A			A	C						C			R			R		R	R									R			R	
					CC	263.70	F	R				C					R			R							R		R	C			A	C						C		R	R			R			R									R			R	
			29	3	3-4	266.74	F	R				R					R			C							R		R	C			A	C						C			R			R			R									R			R	
	early	NN4		5	3-4	269.74	F	R				R								R							R		R	C			A	C						C			R						C									C			R	
			30		CC	282.90	F	R				R								C							R		R	C			A	C						A									R									R				
			31	3	3-4	285.94	F					R								R							R		R	C	R		C	C						C									R									C				
		NN3		5	3-4	288.94	F	R				R									R						R		R	R	R		C	C	R					C									R									C				
					CC	292.50	F					R									C								R	C	R		C	C						A									R									C				
			32	3	3-4	295.54	F					R									R	R							R	R	R		C	R						A									R		R								C				
		NN2		5	3-4	298.54	F					R									R	R	R						C	R	R		C	R						A										R									C				
					CC	302.10	F					R										R	R						R	R			C	R						C																		C				
			33	3	5-6	305.14	F					R										R	R						C	C			C	R	R					C																		C				
Olig.	e.	NP22		4	5-6	306.64	F					R												C				C	R	C					A					R													R										C

and fair in Cores 5–33. Species diversity is good throughout these cores.

Quaternary

The Quaternary includes Samples 592-1-1, 3–4 cm through 592-3-5, 3–4 cm. Zone NN21, based on the range of *Emiliania huxleyi*, includes Samples 592-1-1, 3–4 cm and 592-1-3, 3–4 cm. Sample 592-1,CC, above the last occurrence of *E. ovata* in Sample 592-2-1, 3–4 cm, belongs in Zone NN20. The last occurrence of *Calcidiscus macintyrei* in Sample 592-3-2, 3–4 cm places Samples 592-2-1, 3–4 cm to 592-3-1, 3–4 cm in Subzone NN19b. Subzone NN19a includes Samples 592-3-2, 3–4 cm and 592-3-5, 3–4 cm, above the last occurrence of *Discoaster brouweri* in Sample 592-3-6, 3–4 cm.

Pliocene

The Pliocene includes Sample 592-3-6, 3–4 cm through Core 14. The lower/upper Pliocene boundary is between Samples 592-6-3, 3–4 cm and 592-6,CC. The last occurrence of *Discoaster pentaradiatus* in Sample 592-4-2, 3–4 cm places Samples 592-3-6, 3–4 cm to 592-4-1, 3–4 cm in Zone NN18. One sample, Sample 592-4-2, 3–4 cm, belongs in Zone NN17. The interval between the last occurrence of *D. surculus* in Sample 592-4-3, 3–4 cm and the last common occurrence of *Reticulofenestra pseudoumbilica* in Sample 592-6,CC is placed in Zone NN16. Rare occurrences of *R. pseudoumbilica* above Sample 592-6,CC are interpreted as reworking. The last occurrence of *Amaurolithus tricorniculatus* in Sample 592-8,CC places Samples 592-6,CC to 592-8-5, 3–4 cm in Zone NN15. Samples 592-8,CC through 592-13,CC, the first occurrence of *D. asymmetricus*, are placed in Zone NN14. The paucity of *Ceratolithus rugosus* at Site 592 prevents determination of the NN13/NN12 boundary.

Miocene

Samples 592-15-1, 3–4 cm through 592-33-3, 5–6 cm are in the Miocene. The middle/upper Miocene boundary is between Samples 592-20,CC and 592-21-1, 3–4 cm and the lower/middle Miocene boundary is between Samples 592-29-3, 3–4 cm and 592-29-5, 3–4 cm. The range of *Discoaster quinqueramus* from Sample 592-15-1, 3–4 cm to Sample 592-19-1, 3–4 cm determines Zone NN11. The first occurrence of *Amaurolithus primus* in Sample 592-17,CC subdivides Zone NN11 into Subzones NN11b and NN11a. The range of *D. hamatus* from Sample 592-21-1, 3–4 cm to Sample 592-22,CC places this interval in Zone NN9. The overlying interval belongs in Zone NN10. The first occurrence of *Catinaster coalitus* in Sample 592-23-1, 3–4 cm places this sample in Zone NN8. Zone NN7 includes Sample 592-23-3, 3–4 cm to the first occurrence of *D. kugleri* in Sample 592-24,CC. *Sphenolithus heteromorphus* last occurs in Sample 592-28-3, 3–4 cm, placing Samples 592-25-1, 3–4 cm through 592-28-1, 3–4 cm in Zone NN6. The interval from Sample 592-28-3, 3–4 cm to the first occurrence of *D. exilis* in Sample 592-29-3, 3–4 cm is placed in Zone NN5. Samples 592-29-5, 3–4 cm to 592-31-3, 3–4 cm, above the last occurrence of *S. belemnos* in Sample 592-31-5, 3–4 cm, belong in Zone NN4. The last occurrence of *Triquetrorhabdulus carinatus* in Sample 592-32-5, 3–4 cm places Samples 592-31-5, 3–4 cm through 592-32-3, 3–4 cm in Zone NN3. Based upon the occurrence of *D. druggii* in Sample 592-33-3, 5–6 cm and the common occurrence of *Reticulofenestra umbilica* in Sample 592-33-4, 5–6 cm, the major regional unconformity of the southwest Pacific occurs between these samples, with early Miocene Zone NN2 lying immediately above early Oligocene Zone NP22. The missing NN1 and NP25/NP23 zones represent a hiatus of at least 15.5 m.y.

Site 593

Hole 593

Site 593 is located on the Challenger Plateau west of the northern tip of the South Island of New Zealand (40°30.47′S, 167°40.47′E) at a water depth of 1068 m below sea level. Site 593, which lies in the temperate water mass, is a reoccupation of Site 284 (DSDP Leg 29).

Two holes were drilled at Site 593. Hole 593 was cored to a depth of 571.5 m (late Eocene Zone NP18) and 60 cores were taken. Core recovery was good throughout most intervals. Hole 593A was cored to a depth of 209.3 m; then washed down to a depth of 448.8 m, where coring was resumed to a depth of 496.9 m. Twenty-seven cores were taken.

Only Cores 1–50 from Hole 593 were examined in order to determine the Neogene and Quaternary nannoplankton zonation, because the Oligocene/Miocene boundary occurs within Core 50 (Table 9). Preservation of calcareous nannoplankton in Hole 593 is good in Cores 1–11 and fair in Cores 12–50. Species diversity is good throughout the hole. With the exception of the NN13/NN12 and the NN8/NN7 boundaries, all of the Neogene and Quaternary nannoplankton zones are recognized. Hole 284 (DSDP Leg 29) was cored to a depth of 208.0 m (late Miocene). The placement of the lower/upper Pliocene and the upper Pliocene/Quaternary boundaries in Hole 593 and in Hole 284, as determined by Edwards and Perch-Nielsen (1973), agrees very closely. The Miocene/Pliocene boundary in Hole 284 was not recognized. Species diversity in upper Miocene/Quaternary sediments in Hole 593 is somewhat greater than in Hole 284.

Quaternary

The Quaternary includes Sample 593-1-1, 3–4 cm through Core 5. Samples 593-1-1, 3–4 cm and 593-1-3, 3–4 cm contain common to abundant *Emiliania huxleyi* and are placed in Zone NN21. The last occurrence of *E. ovata* in Sample 593-2-5, 3–4 cm places Samples 593-1,CC through 593-2-3, 3–4 cm in Zone NN20. Subzone NN19b includes Samples 593-2-5, 3–4 cm through 593-3-1, 3–4 cm, above the last occurrence of *Calcidiscus macintyrei* in Sample 593-3-3, 3–4 cm. Subzone NN19a extends down through Core 5.

Pliocene

The Pliocene includes Samples 593-6-1, 39–40 cm through 593-17-3, 3–4 cm. The lower/upper Pliocene boundary lies between Samples 593-8,CC and 593-9-1, 3–4 cm. The last occurrence of *Discoaster brouweri* in Sample 593-6-1, 39–40 cm marks the top of Zone NN18.

The two samples below contain the last occurrences of *D. pentaradiatus* and *D. surculus*, respectively, placing Sample 593-6-2, 3-4 cm in Zone NN17. The last occurrence of *Reticulofenestra pseudoumbilica* in Sample 593-9-1, 3-4 cm places Samples 593-6-3, 3-4 cm through 593-8,CC in Zone NN16. Zone NN15 includes all of Core 9. The last occurrence of *Amaurolithus tricorniculatus* in Sample 593-11-1, 3-4 cm and the first occurrence of *D. asymmetricus* in Sample 593-13,CC place Cores 11-13 in Zone NN14. The NN13/NN12 boundary cannot be recognized because *Ceratolithus rugosus* is absent at Site 593.

Miocene

The Miocene includes Samples 593-17-5, 3-4 cm through 593-50-3, 3-4 cm. The middle/upper Miocene boundary is between Samples 593-26-5, 3-4 cm and 593-26,CC and the lower/middle Miocene boundary lies between Samples 593-43,CC and 593-44-1, 3-4 cm. The last occurrence of *Discoaster quinqueramus* in Sample 593-17-5, 3-4 cm and the first occurrence of *Amaurolithus primus* in Sample 593-22-3, 3-4 cm places this interval in Subzone NN11b. Subzone NN11a extends from Sample 593-22,CC down to 593-25-1, 3-4 cm, the first occurrence of *D. quinqueramus.* Samples 593-26,CC and 593-27,CC contain *D. hamatus,* which places this interval in Zone NN9. The intervening Samples 593-25-3, 3-4 cm through 593-26-5, 3-4 cm belong in Zone NN10. The absence of *Catinaster coalitus* at Site 593 prevents the determination of the NN8/NN7 boundary. The first occurrence of *D. kugleri* in Sample 593-37-1, 3-4 cm and the last occurrence of *Sphenolithus heteromorphus* in Sample 593-42-4, 99-100 cm place Samples 593-37-3, 3-4 cm through 593-42-4, 3-4 cm in Zone NN6. The interval from Sample 593-42-4, 99-100 cm through Sample 593-43,CC, the first occurrence of *D. exilis,* belongs in Zone NN5. The last occurrence of *S. belemnos* in Sample 593-44,CC places Samples 593-44-1, 3-4 cm and 593-44-5, 3-4 cm in Zone NN4. Zone NN3 includes samples above the last occurrence of *Triquetrorhabdulus carinatus* and the first occurrence of *D. druggii* in Sample 593-46,CC, which here constitutes Zone NN2. Zone NN1 extends down to the Oligocene/Miocene boundary between Samples 593-50-3, 3-4 cm and 593-50-5, 3-4 cm. The top of Zone NP25 is based on the last occurrence of *Helicosphaera recta* in Sample 593-50-5, 3-4 cm.

Site 594

Holes 594, 594A

Site 594 is located on the southern margin of Chatham Rise east of the South Island of New Zealand (45°31.41′S, 174°56.88′E) at a water depth of 1204 m below sea level. The site lies in the subantarctic water mass south of the Subtropical Convergence and is the southernmost site of Leg 90.

Three holes were drilled at Site 594. Hole 594 reached the middle Miocene NN5/NN6 zones at a depth of 505.1 m. Fifty-three cores were taken and core recovery through Core 31 (293.9 m) was generally good; however, below Core 31, core recovery was poor. Twenty-six cores were obtained from Hole 594A which duplicates portions of Hole 594 and extends the total depth down to 639.5 m (Zone NN5). Core recovery below 495.5 m (top of Core 12) was generally poor. Hole 594B was drilled to a depth of 42.9 m and 5 cores were obtained.

Cores 1-53 from Hole 594 and Cores 13-26 from Hole 594A were examined in order to determine the nannoplankton biostratigraphy at Site 594. Because Site 594 is near the South Island of New Zealand, numerous Paleogene as well as some Neogene taxa are reworked into indigenous assemblages. Preservation is fair throughout the site but discoasters are poorly preserved and their numbers are markedly reduced. Most of the nannoplankton zones are recognized; however, because of the paucity of zonal indicators, the Miocene and Pliocene zonal boundaries are shown with dashed lines (Table 10). Zones NN18, NN17, NN13, and the boundary between NN8 and NN7 cannot be determined.

Quaternary

The Quaternary includes Samples 594-1-1, 3-4 cm through at least 594-11-5, 3-4 cm. The base of the Quaternary cannot be determined. Samples 594-1-1, 3-4 cm through 594-6-1, 25-26 cm contain *Emiliania huxleyi* and are assigned to Zone NN21. The last occurrence of *E. ovata* in Sample 594-7,CC places Samples 594-6-3, 3-4 cm through 594-7-1, 3-4 cm in Zone NN20. Subzone NN19b includes Samples 594-7,CC through 594-11-3, 3-4 cm, above the last occurrence of *Calcidiscus macintyrei* in Sample 594-11-5, 3-4 cm.

Pliocene

The top of the Pliocene cannot be determined. The lower/upper Pliocene boundary lies between Samples 594-18-1, 3-4 cm and 594-18-3, 3-4 cm and the base of the Pliocene is between Samples 594-23-5, 3-4 cm and 594-23,CC. The last common occurrence of *Reticulofenestra pseudoumbilica* in Sample 594-18-3, 3-4 cm marks the top of Zone NN15. The presence of *R. pseudoumbilica* above this sample is interpreted as reworking. The intervening zones and subzones (NN19a-NN16) cannot be determined. A single rare occurrence of *Amaurolithus tricorniculatus* in Sample 594-20,CC places Samples 594-18-3, 3-4 cm through 594-20-5, 3-4 cm in Zone NN15. The boundaries between Zones NN14 and Zones NN13 and between Zones NN13 and NN12 cannot be recognized.

Miocene

The Miocene includes Samples 594-23,CC through 594A-26,CC. The middle/upper Miocene boundary lies between Samples 594-28-3, 3-4 cm and 594-20-5, 3-4 cm. The rare occurrences of *Discoaster quinqueramus* in Samples 594-23,CC and 594-26-5, 3-4 cm place this interval in Zone NN11, but the absence of *Amaurolithus primus* at Site 594 prevents the subdivision of this zone. The rare occurrences of *D. hamatus* in Samples 594-28-5, 3-4 cm and 594-29,CC place this interval in Zone NN9. Samples 594-26,CC through 594-28-3, 3-4 cm therefore belong in Zone NN10. The boundary between Zones NN8 and NN7 cannot be determined. The rare occurrences of *D. kugleri* in Sample 594-42, 3-4 cm

Table 9. Nannoplankton occurrences, Hole 593.

Index species

Age	Zone	Core	Section	Interval (cm)	Depth below seafloor (m)	Preservation	*Emiliania huxleyi*	*Emiliania ovata*	*Calcidiscus macintyrei*	*Discoaster brouweri*	*Discoaster pentaradiatus*	*Discoaster asymmetricus*	*Discoaster surculus*	*Reticulofenestra pseudoumbilica*	*Amaurolithus tricorniculatus*	*Amaurolithus primus*	*Discoaster quinqueramus*	*Discoaster hamatus*	*Discoaster exilis*	*Discoaster kugleri*	*Sphenolithus heteromorphus*	*Sphenolithus belemnos*	*Discoaster druggii*	*Triquetrorhabdulus carinatus*	*Helicosphaera recta*
Quaternary	NN21	1	1	3-4	0.04	G	A		R																
			3	3-4	3.04	G	C																		
				CC	5.10	G																			
	NN20	2	1	3-4	5.14	G																			
			3	3-4	8.14	G																			
			5	3-4	11.14	G		R																	
	NN19b			CC	14.70	G		A																	
		3	1	3-4	14.74	G		C																	
			3	3-4	17.74	G		C	R																
	NN19a	4		CC	33.90	G		A	R																
		5		CC	43.50	G		A	C																
Pliocene, late	NN18	6	1	39-40	43.90	G		C	R	R															
	NN17		2	3-4	45.04	G		C	R	R	R														
	NN16		3	3-4	46.54	G		C	C	R	R	R	R												
				CC	53.10	G		C	C	R	R	R	R												
		7		CC	62.70	G		R	C	R	R	R	R												
		8		CC	65.80	G			C	R	R	R	C												
Pliocene, early	NN15	9	1	3-4	70.54	G			C	R	R	R	R	R											
			3	3-4	73.54	G			C	R	R	R	C	C											
				CC	81.90	G			C	R	R	R	C	C											
	NN14	11	1	3-4	91.54	G			C	R	R	R	R	C	R	R									
			3	3-4	94.54	G			R	R	R	R	R	C	R	R									
			5	3-4	97.54	G			R	R	R	R	R	C	R	R									
				CC	101.10	G			R	R	R	R	R	C	R	R									
		12		CC	110.70	F			R	R	R	R	R	C		R									
		13		CC	120.30	F			C	R	C	R	R	C		R									
	NN13–NN12	14	1	3-4	120.34	F			C	R	R		R	C		R									
				CC	129.90	F			C	R	R		R	C		R									
		15		CC	139.50	F			R	R	R			C											
		16		CC	149.10	F			R	R	R			C		R									
		17	3	3-4	152.14	F			R	R	R			C		R									
late	NN11b		5	3-4	155.14	F			R	R	R			C			R								
				CC	158.70	F			R	R				C											
		18		CC	168.30	F			R	R				C		R	R								
		19		CC	177.90	F			R	R				C		R									
		20		CC	187.50	F			R	C				A		R									
		21		CC	197.10	F			R	R				C		R									
		22	3	3-4	200.14	F			R	R				C		R									

Additional species

Depth below seafloor (m)	*Amaurolithus delicatus*	*Calcidiscus leptoporus*	*Ceratolithus acutus*	*Chiasmolithus altus*	*Coccolithus carteri*	*Coccolithus miopelagicus*	*Coccolithus pelagicus*	*Coronocyclus nitescens*	*Crenalithus doronicoides*	*Cyclicargolithus abisectus*	*Cyclicargolithus floridanus*	*Dictyococcites bisectus*	*Dictyococcites scrippsae*	*Discoaster bellus*	*Discoaster berggrenii*	*Discoaster decorus*	*Discoaster deflandrei*	*Discoaster moorei*	*Discoaster neohamatus*	*Discoaster tamalis*	*Discoaster tridenus*	*Discoaster triradiatus*	*Discoaster variabilis*	*Discolithina japonica*	*Discosphaera tubifera*
0.04		A			R		A		C															R	R
3.04		C			R		A		A															R	
5.10		C			R		A		A															R	
5.14		C			R		C		A															R	
8.14		R			R		C		A															R	
11.14		C			R		R		A															R	
14.70		A			C		A		A															R	
14.74		C			C		A		A															R	
17.74		C			R		R		C															R	
33.90		C			R		C		A															R	
43.50		C			R		C		A															R	
43.90		C			R		C		A															R	
45.04		C			R		C		A															R	
46.54		C			R		C		C															R	
53.10		C			R		C		C											R		R		R	
62.70		C			R		C		A											R				R	
65.80		C			R		C		A											R				R	
70.54		C			R		C		A															R	
73.54		C			R		C		A															R	
81.90		C					C		A															R	
91.54	R	C					C		C														R	R	
94.54	R	C					C		C														R	R	
97.54	R	C					C		C														R	R	
101.10	R	C					C		C														R	R	
110.70	R	C					C		C														C	R	
120.30	R	C	R				C		A							R							R	R	
120.34	R	C					C		C												R		R	R	
129.90	R	C					C		C												R		R	R	
139.50		C					C		C														R		
149.10		C					C		C														R		
152.14	R	C					R		A														R		
155.14		R					R		A						R								C		
158.70		R					C		A						R								C		
168.30		C					C		C														R		
177.90		C					C		C														R		
187.50		C					C		A														C		
197.10		C					C		C														R		
200.14		C					C		C														R		

Depth below seafloor (m)	*Emiliania annula*	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Helicosphaera carteri*	*Helicosphaera euphratis*	*Helicosphaera hyalina*	*Helicosphaera intermedia*	*Helicosphaera sellii*	*Oolithotus fragilis*	*Pontosphaera discopora*	*Rhabdosphaera clavigera*	*Rhabdosphaera procera*	*Scapholithus fossilis*	*Scyphosphaera intermedia*	*Scyphosphaera pulcherrima*	*Scyphosphaera recurvata*	*Sphenolithus abies*	*Sphenolithus dissimilis*	*Sphenolithus moriformis*	*Sphenolithus neoabies*	*Syracosphaera pulchra*	*Thoracosphaera saxea*	*Triquetrorhabdulus rugosus*	*Umbellosphaera irregularis*	*Umbilicosphaera sibogae*	*Umbilicosphaera cricola*	*Zygrhablithus bijugatus*
0.04		C	C	R		R		R		R	R	R	R			R					C	R		R	R	R	
3.04		A	R	R		R		R		R	R	R	R								C			R	R	R	
5.10		C	R	C		R		R	R	R	R	R	R								C			R	R	R	
5.14		C	R	R		R			R	R	R	R	R								C			R	R	R	
8.14		C	R	R		R		R	R	R	R	R	R								C			R	R	R	
11.14		C	R	R		R			R	R	R	R	R								C				R	R	
14.70	R	R		R		R			R	R	R	R	R			R					R	R			R	R	
14.74	R	R		R		R			R	R	R	R	R			R					R					R	
17.74	R	R		C		R		R	R	R	R	R	R			R					R					R	
33.90	R			R				R	R	R	R	R	R			R					R					R	
43.50	R			R				R		R	R	R	R			R					R					R	
43.90	R			R				C		R	R	R	R			R					R					R	
45.04	R			R				C		R	R	R	R			R					R					R	
46.54	R			R				R		R	R	R	R			R					R					R	
53.10	R			R				R		R	R	R	R			R					R					R	
62.70				R				R		R	R	R	R	R		R					R					R	
65.80				C				R		R	R	R		R	R	R					R					R	
70.54				C				R		R	R	R	R	R		R					R					R	
73.54				C				R		R		C		R		C	R			R	R					R	
81.90				C				R		R		C		R	R	R	R			R	R					R	
91.54				C				R		R		C	R	R	R		R			R	R					R	
94.54				R				R		R		C				R	R			R	R					R	
97.54				R				R		R		C		R			R			R	R					R	
101.10				R				R		R		C	R				R			R	R					R	
110.70				R				R		R		R		R	R		R			R						R	
120.30				R				R		R		R	R	R	R	R	C			R						R	
120.34				R						R		R				R	R			R						R	
129.90				R						R		R		R		R	R			R						R	
139.50				R						R		R		R		R	R			R	R					R	
149.10				R													R			R						R	
152.14				R	R												R			R						R	
155.14				R										R		R	R			R						R	
158.70				R										R		R	R			R						R	
168.30				R											R	R	R			R						R	
177.90				R													R			R						R	
187.50				R									R				C			R						R	
197.10				R													C			R			R			R	
200.14				R													C			C			R			R	

Miocene	late	NN11a			CC	206.70	F	R	R			C	R									R			C		C											C	R					C			C	C	R	
			23		CC	216.30	F	R	R			C	R									R			C		C						R					R	R					C			C	C	R	
			24		CC	225.90	F	R	R			C	R									C			C		C								R			C	R					C			C	C	R	
			25	1	3-4	225.94	F	R	R			C	R									C			A		R											C	C	R		R	R	C			C	C	R	
		NN10		3	3-4	228.94	F	R	R			C										C			C		R									R	R	C	R					C			C	C	R	
					CC	235.50	F	R	C			C										C			C		R					R				R	R	C	R					C			C	C	R	
			26	5	3-4	241.54	F	R	R			C										C			C		R					R			R	R	R	C	R					C			C	C	R	
	middle	NN9			CC	245.10	F	C	C			C		R								C			C		R								R	R	R	C	C					C			C	C	R	
			27		CC	254.70	F	C	R			A		R								C			C		R					R				R	R	A	C					C			C	R	R	
		NN8/NN7	28	1	3-4	254.74	F	R	R			C			C							R			C		R									R		C	R					R			C	R	R	
					CC	264.30	F	C	R			A			C							C			C		R									R		C	C					C			C	R	R	
			29		CC	273.90	F	C	R			A			R							C			C		R					R						C	R					C			C	R	R	
			30		CC	283.50	F	C	R			A			R							A			C		R											R	R					C			C	R	R	
			31		CC	293.10	F	C	R			A			C							C			C		R					R						R	R					C			C	R	R	
			32		CC	302.70	F	C	R			A			C							C			C		R											R	R					C			C	R	R	
			33		CC	312.30	F	C				A			R							C			C		R											R	R	R				R			R	R	R	
			34		CC	321.90	F	C				A			R							C			C		R											R	R					R			R	R	R	
			35		CC	331.50	F	C				A			R							C		R	C		R											R	R					R			R	R	R	
			36		CC	341.10	F	C				A			R	R						C		C	C		R								R			R	R					R			R	R	R	
			37	1	3-4	341.14	F	C				A			R	R						C		C	C		R											R	R					R			R	R	R	
		NN6		3	3-4	344.14	F	C				A			R							C		C	C		R											R	R					R			R	R	R	
					CC	350.70	F	C	C	R	R	A			C							C		C	C		R		R					R	R			R	R					R			R	R	R	
			38		CC	360.30	F	C	R		R	A			C							C		R	C		R	R	C						C			R	R					R			R	C	R	
			39		CC	369.90	F	C				A			C							C		R	C		R	C	C						C	R		R	R					C			C	C	R	
			40		CC	379.50	F	C				C			C							C		R	C			C	C						C			R	R					R			R	R	R	
			41		CC	389.10	F	C				C			C							C		R	C			C	A						C			R	R	R				R		C	R		R	
			42	1	2-3	389.13	F	C				R			C							C		R	C			A	A						C			R	R					R		C	R		R	
				3	3-4	392.14	F	C				R			C							C		R	C	R		A	A						C			R	C							C	R		R	
				4	28-29	393.89	F	C				R			R							C		C	C	R		C	C						C				R	R						C	R			
		NN5		4	99-100	394.60	F	C				R			R		R					C		C	C	R		C	C						C				R	R						C				
				5	3-4	395.14	F	C				R			R		C					C		R	C	R		A	A						C				R							C				
			43		CC	408.30	F	R				R			R		R					R		R	C	R		C	A						C				R							C				
	early	NN4	44	1	3-4	408.34	F	R				C					C					R		R	C	R		C	C						A				R							C				
				5	3-4	414.34	F	R				C					C					R		R	C	R		C	C						A				R							C				
		NN3			CC	417.90	F	R				C					R	R	R			R		R	C	R		C	C						C											C				
			45		CC	427.50	F					C						R						R	R	R		C	C						C										R	C				
			46	5	3-4	433.54	F					C						R	R					R	R	R		C	C						C										R	C				
		NN2			CC	437.10	F					C							R	R				R	R	R		C	C	R					C										R	C				
		NN1	47	1	3-4	437.14	F					R								R				R	C	R		C	C						A											C				
					CC	446.70	F					R								R				C	C	R		C	C	R					A											C				
			48		CC	456.30	F					C								R				C	C	R		C	C						C											C				
			49		CC	465.90	F					R								R				C	C	R		C	C						C											C				
			50	1	3-4	465.94	F					R								R				R	C	R		C	C						C											C				
				3	3-4	468.94	F					R								R				R	C	R		C	C						C											C				
Olig	late	NP25		5	3-4	471.94	F					R								R	R			C	C	R		C	C	R					C											C				R
					CC	475.50	F					R								R	R		R	R	C			C	C	C	R				C						R					C				C

Table 10. Nannoplankton occurrences, Holes 594 and 594A.

Age	Zone	Core	Section	Interval (cm)	Depth below seafloor (m)	Preservation	Index species									Additional species																																																										
							Emiliania huxleyi	Emiliania ovata	Calcidiscus macintyrei	Reticulofenestra pseudoumbilica	Amaurolithus tricorniculatus	Discoaster quinqueramus	Discoaster hamatus	Discoaster kugleri	Sphenolithus heteromorphus	Calcidiscus leptoporus	Catinaster calyculus	Chiasmolithus altus	Chiasmolithus bidens	Chiasmolithus californicus	Chiasmolithus grandis	Chiasmolithus oamaruensis	Chiasmolithus sp.	Coccolithus carteri	Coccolithus miopelagicus	Coccolithus pelagicus	Coronocyclus nitescens	Crenalithus doronicoides	Cricolithus jonesi	Cyclicargolithus abisectus	Cyclicargolithus floridanus	Dictyococcites bisectus	Dictyococcites scrippsae	Discoaster barbadiensis	Discoaster brouweri	Discoaster deflandrei	Discoaster exilis	Discoaster intercalaris	Discoaster lodoensis	Discoaster neohamatus	Discoaster pentaradiatus	Discoaster stellulus	Discoaster surculus	Discoaster triradiatus	Discoaster variabilis	Discolithina japonica	Discolithina multipora	Fasciculithus tympaniformis	Gephyrocapsa caribbeanica	Gephyrocapsa oceanica	Gephyrocapsa protohuxleyi	Helicosphaera carteri	Helicosphaera hyalina	Helicosphaera intermedia	Helicosphaera sellii	Heliolithus kleinpellii	Isthmolithus recurvus	Lophodolithus nascens	Pontosphaera discopora	Reticulofenestra hillae	Reticulofenestra umbilica	Rhabdosphaera procera	Scyphosphaera recurvata	Sphenolithus abies	Sphenolithus moriformis	Sphenolithus neoabies	Syracosphaera pulchra	Thoracosphaera saxea	Triquetrorhabdulus carinatus	Triquetrorhabdulus rugosus	Umbellosphaera irregularis	Umbilicosphaera cricota	Zygrhablithus bijugatus
Quaternary	NN21	1	1	3-4	0.04	F	C			R						A								R		C		C																					R	R		C			R												R	R			R		
				CC	5.90	F	R			R						C						R		C		C		C	R		R					R													R	R		R			R														R				
		2	3	3-4	8.94	F	R			R						R								C		C		A			R					R													C	R		R			R																		
				CC	15.50	F	A									R								C		C		A																					A	R		R	R																				
		3	3	3-4	18.54	F	R			R						R			R					C	R	C		A	R							R		R								R		R	A	R		R			R	R		R			R												
				CC	25.10	F	A			R						A								C	R	A		C	R																			R	R	R		R			R			R				R											
		4	3	3-4	28.14	F	R			R						R								C	R	A		A	R		R		R															R	C	R		R						R		R	R												
				CC	34.70	F	R			R						C								C		A		A	R		R					R													A	R	C	R																R					
		5	3	3-4	37.74	F	C			R						R								C	R	A		A	R		R															R		R	C	C	C	R			R														R					
				CC	44.30	F	R			R						R								C		C		A	R																				C	R	R	R			R																			
		6	1	25-26	44.56	F	R			R						R								C		C		A	R																				C	R	R	R			R																			
	NN20		3	3-4	47.34	F				R						R								R		C		A		R	R	R	R			R													C	R		R						R			R								R					
				CC	53.90	F				R						R								R		C		C	R		R																		R	R		R			R																			
		7	1	3-4	53.94	F				R						R								R		C		A			R	R																	C	R		R																	R					
	NN19b			CC	63.50	F		R		R														R		C		A		R		R																R	C	R		R															R						
		8	1	3-4	63.54	F		R		R						R				R				C		A		A	R	R		R																	C	R		R						R	R															
				CC	73.10	F		C		R						A				R				C		A		A				R																	C	R		C															R	R					
		9	3	3-4	76.14	F		R		R						R								C		A		A			R	R	R			R										R			A	C		R			R						R												
				CC	82.70	F		R		R						A								R		R		A			R		R																A	C		R			R																		
		10		CC	92.30	F		R		R						R				R				R		C		C		R	R	R														R			C	R		R																R					
		11	3	3-4	95.34	F		R								C			R	R				R		A		C	R			R	R			R										R			C	R		R																					
	NN19a/NN16		5	3-4	98.34	F		C	R	R						C								R		A		C	R	R																R			R	R		A			R							R					R						
				CC	101.90	F		C	C	R						C				R				R		C		C					R													R			C	R		R			R						R							R					
		12	3	3-4	104.94	F		C	R	R						R			R			R		R		C		C			R															R			C	C		R			R												R	R		R			
				CC	111.50	F		C	R	R						R			R					R		A		C	R	R		R																	R			R			R											R	R						
		13	3	3-4	114.54	F		R	R	R						R								R		A		C	R			R	R																R			R			R						R							R					
				CC	121.10	F				R														C		A		C	R		R															R																					R					
Pliocene / late		14	3	3-4	124.14	F		R	R	R									R					R		A		R	R																				R						R			R									R					
				CC	130.70	F			R	R						R								R		A		C								R													R			R		R																			
		15	3	3-4	133.74	F			R	R						R								R		C		C																								R			R											R	R						
				CC	140.30	F		R	R	R						R								R		A		A	R			R	R													R									R													R					
		16	3	3-4	143.34	F				R						R								R		A		A	R		R	R																																								
				CC	149.90	F				R						R										A		A	R																										R											R							
		18	1	3-4	159.54	F			R	R						R			R					R		A		A																											R						R											
early	NN15		3	3-4	162.54	F				R						C				R				R		A		A	R																	R						R							R			R	R	R			R						
			5	3-4	165.54	F			R	C						R				R						A		A	R																	R						R			R							R						R					
				CC	169.10	F			R	C						R										A		A			R	R				R																R			R				R		R												
		19	3	3-4	172.14	F			R	C						R			R							C		A	R	R	R	R	R																			R			R				R														
				CC	173.70	F			C	C						R									R	A		C		R	R	R				R																R										R											
		20	3	3-4	181.74	F			C	A						R										C		R		R						R																R																					
			5	3-4	184.74	F			R	A						R			R						R	C		R		R		R																																								
	NN14/NN12			CC	188.30	F			R	A	R					R			R							C		R		R		R																				R																					
		21	1	3-4	188.34	F			R	A						R				R					R	C		R		R		R				R							R		R							R									R												
			3	3-4	191.34	F			C	A						R									R	C		C		R	R	R				R																R									R												
				CC	197.90	F			C	A															R	C		C		R		R				R																																						
		23	1	3-4	207.54	F			R	A						R										C		R							R	R									R																												
			3	3-4	210.54	F			R	A											R				R	C		R			R				R	R			R		R		R		R							R																		R			
			5	3-4	213.54	F			R	A						R							R		R	C		R																			R																						R			
late	NN11			CC	217.10	F			R	A		R								R						C		R							R	R							R		R																										R			
		24	1	3-4	217.47	F			R	A						R			R			R				R		R								R									R							R					R									R				R			
			3	3-4	220.14	F			R	A						R							R			C		R		R			R			R									R		R						R			R						R					R				R			
				CC	226.70	F			R	A						R			R	R					R	C		R		R		R	R		R	R									R							R									R												
		25	3	3-4	229.74	F			R	A										R			R			C		R		R			R	R		R									R							R							R	R			R		R							
				CC	236.30	F			R	A												R	R		R	C		R		R			R			R																									R					R							
		26	3	3-4	239.34	F			C	A						R				R		R	R		R	C		R				R	R			R									R																R					R				R			
			5	3-4	242.34	F			R	A		R				R			R				R		R	C		R		R		R	R		R	R									R																R					R				R			

Miocene		NN10			CC	245 90	F	R	A				R				R		R	R	C		R	R		R		R		R	R		R	R	R						R		
			27	3	3-4	248 94	F	R	A				R						R	R	R		R	R				R			R												
						CC	255 50	F	R	A				R						R	R	C		R	R				R			R				R						R				
			28	3	3-4	258 54	F	R	A				R	R						R	R	C		R		R	R		R											R		R		R		
		middle	NN9		5	3-4	261 54	F	C	A	R			R						R	R	C		R	R		R		R			R				R		R	R		R				
						CC	265 10	F	R	A											R		C		R	R				R								R			R		R				
			29	3	3-4	268 14	F	R	A				R			R			R	R	C		R	R		R		R								R			R	R	R				
						CC	274 70	F	R	A	R											R	C			R				R			R							R		C				
		NN8/NN7	30	1	3-4	274 74	F	R	A											R		C		R	R				R						R				R		R				
				3	3-4	277 74	F	R	A													C							R										R		R				
						CC	284 30	F	R	A											R	R	C							R										R	R		R				
			31	3	3-4	287 34	F	R	A													R			R				R							R			R		C				
						CC	293 90	F	C	A				R									C		R	R				R											R		R				
			33		CC	313 10	F	C	A				R						R	R	R							R								R		R		C				
			34	3	3-4	315 14	F	R	A				R							R	R																		R		C		R		
						CC	322 70	F	R	C											R	C			R																R	R			
			35	3	3-4	324 74	F	C	A				R							R	R				R										R		R		R				
						CC	332 30	F	C	A				R			R				C	R																			R				
			36	3	3-4	334 34	F	R	A		R		R			R				C	R			R													R		R				
						CC	341 90	F	C	A				R								R	C							R												R				
			37		CC	351 50	F	R	A													C	C					R		R												R				
			38	3	3-4	353 56	F	C	A				R						R	C	C					R		R												R				
						CC	361 10	F	R	A													R	C					R	R											R						
			39		CC	370 10	F	R	A													R	C						R											R						
			40	3	3-4	372 76	F	R	A				R								R	C			R															R				
						CC	380 30	F	R	A				R								R	R							R											R	R	R				
			41	3	3-4	383 36	F	R	A											R		R						R	R											R	R				
						CC	389 90	F	R	A											R		R						R												R	R				
			42	3	3-4	392 96	F	C	A		R									R	R																	R	R	R	R				
		NN6			CC	399 50	F	C	A													C	C			R	R										R										
			43		CC	409 10	F	R	A				R								R	C			R				R									R	R				
			44		CC	418 70	F	R	A				R						R	R	C																	R	R	R				
			45		CC	428 30	F	C	A				R								C	R																		R		R				
			46		CC	437 90	F	C	A				R								C	R																				R				
			47		CC	447 50	F	R	A				R								R	C			R				R									R		R				
			48	3	3-4	450 56	F	C	A				R						R	C	C	R		R		R		R								R	R	R	R				
						CC	457 10	F	C	A				R						R	R	C			R		R		R									R	R	R				
			49	3	3-4	460 16	F	C	A				R								R	A			R													R	R	C				
						CC	466 70	F	C	A				R								R	C			R													R	R	R				
			50		CC	476 30	F	R	A				R						R	R	C							R												R				
			51		CC	485 90	F	R	C													R	C			R				R											R	R				R
			52		CC	495 50	F	R	A				R								R	C			R															R			R	
			53		CC	505 10	F	C	A													C	C			R				R						R		R		R		C				
			A 13	3	3-4	508 14	F	R	A				R						R	C	A			R	R			R				R			R			R	R	R				
						CC	514 70	F	R	C				R						R		C			C	R	R		R												R				
			14	3	3-4	517 74	F	R	C				R					R		R	C			C				R							R		R	R	R	R				
						CC	524 30	F	C	C				R								R	C			C	R			R							R			R	R	R				
			15	3	3-4	527 33	F	R	C				R								R	C			C				R								R	R	R	R				
		NN5			CC	533 90	F	R	C			R	R						R	R	C			C	R			R	R								R	C	R				
			16	3	3-4	536 93	F	R	C				R								R	A			A	R			R						R		R	R	C	R				
						CC	543 50	F	R	R				R						R	C	A			A	R	R		R						R			R	C	R				
			17	3	3-4	546 53	F	R	R				R						R	C	A	R		A	R	R		R									R	C	R				R
						CC	553 10	F	R	R											R	A	A			A	C	R		R									R	C	R				
			18	3	3-4	556 14	F	C	R				R		R						A	A			A	C	R		C						R			C	R	C				
						CC	562 70	F	C	R				R		R				R	C	A			A	R	R		C						R		R	R	R	R				
			19		CC	572 30	F	R	R											R	R	A			A	R	R	R	R												C	R				
			20	3	3-4	575 30	F	C	R											R	R	A			A	R	R		R									R	C						
						CC	581 90	F	R	R													R	C			A	R			R								R		R	R				
			21		CC	591 50	F	R	R				R						R	R	A			C	R	R		C										R						
			22		CC	601 10	F	C	C				R		R				R	R	A			A	C		R	R								R		C						
			23		CC	610 70	F	R	C			R			R				R	R	A			A	C	R	R	C						R		R	R	A	R				
			24		CC	620 30	F	R	C				R						R	R	A			A	C	R	R	C						R		R	R	A	R				
			25		CC	629 90	F	R	C				R		R				R	R	C			A	C		R	C									R	R	A	R				R
			26		CC	639 50	F	R	C				R		R						R	C			A	C			R						R			R	C	R				

and *Sphenolithus heteromorphus* in Sample 594A-15,CC place Samples 594-42,CC through 594A-15-3, 3-4 cm in Zone NN6 and Samples 594A-15,CC through 594A-26,CC in Zone NN5.

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