15. CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY, DEEP SEA DRILLING PROJECT LEG 85, EASTERN EQUATORIAL PACIFIC[1]

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ABSTRACT

Pelagic sediments recovered during Leg 85 span the uppermost Eocene to Pleistocene interval in a series of fairly continuous sections. The calcareous nannofossils are normally not very well preserved in the cores from this leg; coccoliths, discoasters, and other morphologic types have been corroded and overgrown by secondary calcite. Poor preservation in some cases precludes a sharp and precise biostratigraphy at the subzonal level, although remarkably, most zones can be clearly identified. Middle Miocene markers are the most consistently troublesome, and it is suggested that *Coronocyclus nitescens* be introduced as an additional useful marker in this interval.

INTRODUCTION

During Leg 85, tropical deep-water pelagic sediments were cored in the equatorial Pacific. Four sites (572 to 575) in particular were cored extensively, and multiple holes were drilled at each site (Fig. 1). The sediment at each of these sites consists principally of pelagic, biogenic constituents, both calcareous and siliceous. In total, 217 samples from the four sites (two holes from each site) were used in biostratigraphic analysis. This chapter presents the results of these analyses. The scope of this study is to provide a concise biostratigraphic framework that is developed from the calcareous nannofossils and based on a limited number of samples. It is not intended to be a comprehensive regional study.

Age assignments are mostly made according to the zonation scheme of Bukry (Bukry, 1975; Okada and Bukry, 1980), with minor modifications where a given zonation proved inadequate or unsuitable. One such case is Pleistocene, but it was not sampled in sufficient detail to present serious problems. A second instance is the Miocene/Pliocene boundary, which, according to the best data available, should probably be placed at the extinction of *Discoaster quinqueramus* (Gartner et al., 1983). A third area of difficulty introduced by Bukry's zonation is his use of the beginning or end of an acme to delimit zones. The beginning or end of an acme can be rendered meaningless by differential dissolution because the abundance of a species can be decreased or enhanced greatly depending on its susceptibility to dissolution. Finally, the first appearance of *Sphenolithus distentus* cannot be used as a marker where indicated by Bukry because the species occurs consistently at a much lower level.

One recommendation for improving existing zonations of the middle Miocene where several of the designated markers are notably sporadic and unreliable is to use the highest occurrence of *Coronocyclus nitescens* as a marker. This species is distinctive and hence easy to recognize and identify. It is consistent in its occurrence in pelagic and hemipelagic sediments and relatively resistant to dissolution. Although the species is rarely a major constituent of the assemblage, it is in all other respects a nearly ideal marker species. The bio-horizon marked by the last or highest occurrence of this species is above the highest occurrence of *Sphenolithus heteromorphus* and below the first appearance of *Catinaster coalitus*. It probably occurs within the lower part of magnetic polarity epoch 13 and has an age of about 13 Ma. In Hole 572D *C. nitescens* last occurs somewhat below the CN5a/CN5b zonal boundary; in Holes 573B and 574 its last occurrence is imprecisely known because the accepted marker species are not present. In Hole 574C the highest occurrence of the species may not have been recovered, and in Hole 575 *C. nitescens* disappears just below the CN5a/CN5b zonal boundary. It should be noted that the apparent inconsistencies in the highest occurrence of *C. nitescens* can partly be explained by inconsistent occurrences of designated markers but could also reflect the relatively wide sample spacing of this study.

A summary overview of the zonal and age assignments of the cores from Leg 85 is given on Table 1.

METHODS

Smear slides were prepared for each sample from unprocessed material. The slides were examined with a light microscope at approximately ×1600 magnification using cross-polarized light, differential interference constrast, and phase contrast optics. Abundance estimates were made on optimum density areas of the slides, that is, areas where most of the field was covered with sample material without appreciable piling of specimens or sample material. The abundance code translates as follows: A (abundant), usually more than 10 specimens occurring per field; C (common), 1 to 10 specimens per field; F (few), 1 specimen per 1 to 10 fields; R (rare), 1 specimen per more than 10 fields.

SITE 572

Holes 572A and 572C

Forty-nine samples were examined from Site 572. Seventeen samples are from Holes 572A and 572C; four of

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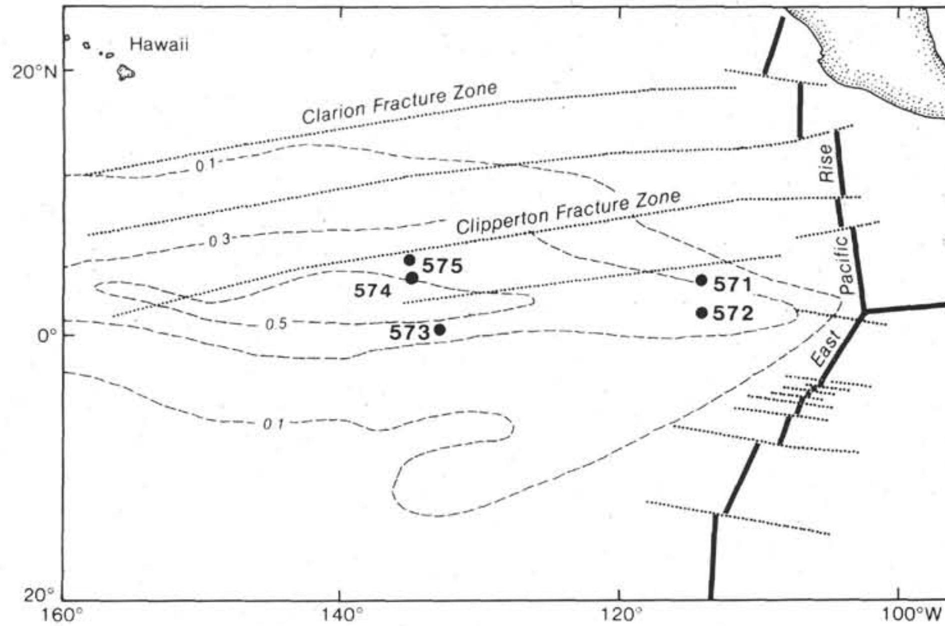

Figure 1. Location of DSDP Leg 85 sites in the eastern equatorial Pacific. Contours show sediment thickness in seconds (two-way traveltime).

these are core-catcher samples. The two samples from Hole 572C (Cores 1 and 2) are combined on one chart with fifteen samples from Hole 572A (Cores 3 through 17). The calcareous nannofossil checklist for these samples is given in Table 2. Preservation of nannofossils is fair to poor throughout the interval, and the biostratigraphy lacks sharp definition because marker species are usually present only sporadically. Nevertheless, the age determinations given are considered accurate and reliable.

Samples 572C-1,CC through 572A-3,CC are of Pleistocene age (Zones CN14 and CN13) and extend from the middle to the upper Pleistocene in the topmost sample and down to the lower Pleistocene in the lowermost sample. Conspicuous markers include *Pseudoemiliania lacunosa* and *Calcidiscus tropicus* (= *C. macintyrei*).[3]

Sample 572A-4-5, 139–140 cm is uppermost Pliocene; it contains the lone asterolith species *Discoaster brouweri* characteristic of this level (Zone CN12d). The Pliocene extends through Core 10 (Sample 572A-10-7, 40–41 cm), the Miocene/Pliocene boundary being in the next lower core. The Pliocene succession is complete, although poor preservation prevents recognition of all subzones. Zones 12, 11, and 10 are, however, recognizable as distinct units.

Sample 572A-11-6, 140–141 cm contains *D. quinqueramus* and thus is assigned to the uppermost Miocene *D. quinqueramus* Zone (Zone CN9). This zone continues to the bottom of the section (Sample 572A-17-6, 8–9 cm) where the presence of *Amaurolithus amplificus* indicates an age probably not older than Zone CN9b, which corresponds to the upper part of the *D. quinqueramus* Zone.

[3] The name *Calcidiscus tropicus* (Kamptner) is used in preference to *C. macintyrei* (Bramlette and Bukry). The latter is considered a junior synonym (Gartner et al., 1983).

Hole 572D

The 32 samples from Hole 572D extended from the lower Pliocene (Zone CN10) to the lower middle Miocene (Zone CN4) (Table 3). Poor preservation makes accurate biostratigraphic subdivision of this hole difficult, although most of the zones and several subzones can be recognized. The Pliocene/Miocene boundary is tentatively placed within Core 5 because the sample immediately above it (Sample 4,CC) contains the birefringent *Ceratolithus armatus*, whereas the base of the next lower core (Sample 5,CC) lacks birefringent ceratoliths. *Discoaster quinqueramus*, the extinction of which marks the top of the Miocene, was encountered only lower (Sample 8, CC) where it co-occurs with *D. loeblichii*, a species that does not occur above the middle part of the upper Miocene.

Within the upper Miocene Subzones 9b, 9a, and 8b are recognizable, but below that zones and subzones are less clearly distinguishable. The marker species *D. hamatus* and *Catinaster coalitus* (for Zones CN7 and CN6, respectively) are very rare and both occur in only one (and the same) sample (15,CC). Immediately below Zone CN6, markers are lacking until *D. kugleri* is encountered in Samples 19,CC and 21,CC. This marks Zone CN5b, the *D. kugleri* Subzone. The next lower zone (CN5a) has no distinctive marker of its own, but its lower limit is recognizable by the last occurrence of *Sphenolithus heteromorphus* (Sample 28,CC), which continues to the bottom of the section (Sample 32,CC).

SITE 573

Hole 573

Nineteen core-catcher samples were examined from Hole 573 (Table 4). Calcareous nannofossils are common to abundant in all samples, but preservation is most-

Table 1. Summary of zonal and age assignments of Leg 85 cores based on calcareous nannofossils from Holes 572 through 575. Nannofossil zonal numbers are those of Okada and Bukry (1980). For more detailed age assignments see Tables 2 through 9.

Age		Nannofossil zones	572A	572C	572D	573	573B	574C	575	575A
Pleistocene		CN15 to CN13	3,CC	1,CC 2,CC		1,CC/ 3,CC				
Pliocene		CN12	4,CC 5,CC			4,CC 6,CC			1,CC	
Pliocene		CN11 to CN10	6,CC 10-7		1,CC/4,CC	7,CC 9,CC			2,CC	
Miocene	late	CN9	11-6 17-6		5,CC 7,CC	10,CC 18,CC			3,CC	
Miocene	late	CN8			8,CC	19,CC	1,CC/4,CC			
Miocene	middle	CN7					5,CC			
Miocene	middle	CN6								
Miocene	middle	CN5			27,CC		8,CC	1,CC	7,CC	
Miocene	middle	CN4			28,CC 32,CC		9,CC	2,CC	8,CC 11,CC	1,CC
Miocene	middle	CN3					13,CC	3,CC		5,CC
Miocene	middle/early	CN2					14,CC	4,CC		6,CC 9,CC
Miocene	early	CN1					15,CC 20,CC	5,CC 17,CC		10,CC 33,CC
Oligocene	late	CP19					21,CC 30,CC	18,CC 20,CC		
Oligocene	early	CP18					31,CC	21,CC		
Oligocene	early	CP17					37,CC	28,CC		
Oligocene	early	CP16					38,CC 40,CC	29,CC 34,CC		
Eocene	late	CP15						35,CC		

ly fair to poor. Only in the uppermost three core-catcher samples is nannofossil preservation fair to good. Both dissolution and overgrowth are noticeable, and the low species diversity of some samples suggests that some species have probably been removed by corrosion.

The 19 samples extend from the upper Pleistocene at the top (Zone CN14b) to the upper Miocene *Discoaster neohamatus* Zone (Zone CN8) at the bottom. All of the intervening zones can be recognized, and in several cases subzones can be distinguished as well. The Pliocene/Pleistocene boundary is placed within Core 4; the base of that core contains the upper Pliocene marker *D. brouweri*. The next higher sample (3,CC) lacks discoasters. The Pliocene zones appear to be of uneven spans (e.g., CN11 and CN12), which could be the result of poor preservation of some marker species or notably different sediment accumulation rates, possibly stemming from differential dissolution of biogenic carbonate. However, it may be entirely an artifact introduced by the wide spacing between adjacent samples.

The Miocene/Pliocene boundary is placed at the highest occurrence of *D. quinqueramus*, which is within Core 10. The upper Miocene *D. quinqueramus* Zone (Zone CN9) is more expanded than the Pliocene zones, although nannofossil preservation is not notably better.

Hole 573B

Forty samples, all but one of them core-catcher samples, were examined from Hole 573B (Table 5), and these extend from the upper Miocene at the top to upper Oli-

Table 2. Occurrence of calcareous nannofossils in core-catcher samples, DSDP Holes 572A and 572C, Leg 85.

Age	Sample (interval in cm)	Preservation	Nannofossil zones	*Gephyrocapsa oceanica*	*Pseudoemiliania lacunosa*	*Crenalithus productellus*	*Gephyrocapsa caribbeanica*	*Calcidiscus leptoporus*	*Ceratolithus cristatus*	*Helicosphaera carteri*	*Umbilicosphaera sibogae*	*Reticulofenestra minutulus*	*Ceratolithus rugosus*	*Ceratolithus telesmus*	*Calcidiscus tropicus*	*Helicosphaera sellii*	*Coccolithus pelagicus*
Pleist.	572C-1,CC	F	CN14	C	C	A	C	C		C	F						
	2,CC	F-P	to	F	A	C	C	C	F	F	C	C	F	F	C		
	572A-3,CC	F-P	CN13		A		F	C	R	C	C	A	F		C	C	F
Pliocene	4-5, 139–140	F-P	CN12d		C			F		F		A	R		A	A	
	5,CC, 14–15	F-P	CN12a						F	F		F	F		A	F	A
	6-6, 140–141	F-P			F				F			A			A		
	7-6, 100–101	P	CN11									C	F		C		C
	8-6, 59–60	P							R			A	R		C		F
	9-6, 140–144	P-F	CN10			C				C		A			C		
	10-7, 40–41	F-P				F		F		C		A			C		R
Miocene	11-6, 140–141	P-F						F		R		A			R		
	12-6, 140–141	P-F						F		C		A			C		
	13-6, 140–141	P-F						C		F		A			C		C
	14-6, 140–141	P-F	CN9					F		C		A					F
	15-6, 100–101	P-F						C		R		A			C		
	16-6, 40–41	P-F								R		C				R	F
	17-6, 8–9	F-P						R		F		C					A

Note: A = abundant; C = common; F = few; R = rare. See text for further explanation. Preservation: F = fair; P = poor.

gocene at the bottom of this hole. Not all intervening zones are identifiable, again resulting from poor preservation and the absence of certain key marker species. The youngest zone represented is the upper Miocene *Discoaster neohamatus* Zone (Zone CN8). The middle Miocene Zones CN7, CN6, and CN5 cannot be differentiated, although all three may be represented in the interval of Cores 5 through 8. The two critical markers for this interval, *Catinaster coalitus* and *D. hamatus*, were not found in the samples. Zones CN4 and CN3, which are the *Sphenolithus heteromorphus* and *Helicosphaera ampliaperta* Zones, together cover the interval of Cores 9 through 13. The marker species for differentiating these two zones, however, were not considered reliable over this interval.

The Oligocene/Miocene boundary cannot be placed precisely (it does not correspond to a nannofossil biohorizon used in Bukry's zonation), although the interval in which it is contained, the *Triquetrorhabdulus carinatus* Zone (Zone CN1), is well developed from Cores 15 through 20. The Oligocene Zones CP19 through CP16, which are the *Sphenolithus ciperoensis* through *Helicosphaera reticulata* Zones, are represented from Cores 21 through 40. Zones CP18 and CP17 cannot be separated because the marker species *Sphenolithus distentus* extends well below the next lower marker, an apparent internal inconsistency in Bukry's zonation. There is a break in the range of *S. distentus* (Cores 33 and 34), and it is tempting to place the zonal boundary at this level; however, that interpretation of the data would be incorrect.

SITE 574

Two suites of samples were examined from Site 574: one from Hole 574 consists of 30 core-catcher samples, and the second from Hole 574C consists of 35 core-catcher samples. The two sections combined extend from the Pleistocene at the top of Hole 574 to the uppermost Eocene at the bottom (Core 35) of Hole 574C. The section appears to be continuous over the entire interval to the extent that it can be resolved given the sample spacing and the poor preservation of much of the section.

Hole 574

The 30 samples from Hole 574 are from the core catchers of each of the 31 successive cores, except for Core 23 from which no sample was available (Table 6). The upper Neogene (upper Miocene, Pliocene, and Pleistocene) is represented in only the uppermost 7 cores (Zones CN8 through CN14), whereas the middle Miocene is represented in Cores 8 through 31 (Zones CN4 through CN7). This great difference in thickness probably indicates a pronounced change in sedimentation rates; however, the preservation of the nannofossils is poor throughout and thus does not reflect the different sedimentation rates perfectly. Preservation is rendered poor by both dissolution of some species and overgrowth of others, often within the same sample.

The Pleistocene is represented in Core 1 and possibly the upper part of Core 2, although the base of Core 2 is Pliocene as are Cores 3 through 5. The three zones of

Discoaster brouweri	Discoaster pentaradiatus	Discoaster tamalis	Discoaster surculus	Discoaster asymmetricus	Discoaster variabilis	Ceratolithus armatus	Reticulofenestra pseudoumbilica	Sphenolithus abies	Ceratolithus acutus	cf. Catinaster sp.	Discoaster intercalaris	Amaurolithus primus	Amaurolithus delicatus	Amaurolithus tricorniculatus	Discoaster quinqueramus	Discoaster berggrenii	Discoaster sanmiguelensis	Triquetrorhabdulus rugosus	Discoaster neohamatus	Amaurolithus amplificus	Helicosphaera parallela
F																					
A	A	R	F	R	F																
F				R	F	R	R	F	cf.	F											
C					C		C	C													
C	F		F		C		C														
C	C	R	F		F	R	A	C	R		F	R									
F	F		F		F		C	C	R		R		R	R							
C	R		C		F		C	C			R				R						
R	F		R				C	C				R			R						
F			F				C	A				R				F					
							A	A				F			R	R	C	R			
C			R		R		C	A					R		C	R					
C			C		C		C	C				R			F	F			R		
F	R		R		R		A	C				cf.			R	R				R	R

the Pliocene (CN12 through CN10b) are represented but subzones cannot be identified consistently. The upper Miocene zones can only be identified imperfectly. Subzone CN10a was not identified, although it may be present within an unsampled interval of Core 6. The bottom of Core 6 (Sample 6,CC) belongs to Zone CN9. The interval from the *Discoaster neohamatus* Zone through the *D. exilis* Zone (Zones CN8, CN7, CN6, and CN5) is reasonably complete, but the boundary between the lower two zones is unclear because of the absence in the samples of the marker species *Catinaster coalitus*.

The boundary between Zone CN5 and CN4 is also unclear because of the rare but unambiguous occurrence of *Sphenolithus heteromorphus* in Core 16. This species is not found in the three immediately subjacent cores but does occur in much greater abundance from Cores 20 through 31. Thus the occurrence of the species in Core 16 is suspect. If the occurrence of *Sphenolithus heteromorphus* in Core 16 is spurious, as assumed here, then the sedimentation rate change in the section implied by the spacing of nannofossil bio-horizons occurred somewhat later and was less intense than indicated by the actually documented last occurrence of *Sphenolithus heteromorphus*.

Hole 574C

The 35 core-catcher samples from Hole 574C (Table 7) extend from the middle Miocene *Sphenolithus heteromorphus* Zone (CN5) to the upper Eocene *Discoaster barbadiensis* Zone (CP15). Although not all zones and subzones can be clearly identified, primarily resulting from poor preservation of marker species, the section appears to be continuous. The lower to middle Miocene *Helicosphaera ampliaperta* Zone (CN3) cannot be clearly identified. Similarly the Miocene/Oligocene boundary remains somewhat ambiguous because it is not possible to clearly identify the marker horizon, the acme of *Cyclicargolithus abisectus*. The boundary is placed within Core 17; however, it could be somewhat higher because specimens intermediate between *C. abisectus* and the smaller *C. floridanus* are common.

The Paleogene interval from *Sphenolithus ciperoensis* Zone through the *D. barbadiensis* Zone (Zones CP19 through CP15) are well represented. The boundary between the *S. distentus* Zone (CP18) and the *S. predistentus* Zone (CP17), however, cannot be determined because the marker species *S. distentus* ranges well below the level implied by the zonation scheme. Clearly the Oligocene zonal succession merits further study, including identification of some additional nannofossil marker species.

The Eocene/Oligocene boundary is within Core 35 because the base of that core contains the distinctive *D. barbadiensis* and *D. saipanensis*, both characteristic of the upper Eocene, along with several other upper Eocene species.

SITE 575

Two suites of sample were examined from Site 575: one from Hole 575 consists of 11 samples, and the second from Hole 575A consists of 33 samples. All of the samples are from core-catcher material. The total interval represented by the two sections includes part of the Pliocene and nearly all of the Miocene. Pleistocene nannofossil assemblages were not identified; the youngest sample, although nearly barren, appears to be Pliocene

Table 3. Occurrence of calcareous nannofossils in core-catcher samples, DSDP Hole 572D, Leg 85.

Age	Sample	Preservation	Nannofossil zones	*Sphenolithus abies*	*Reticulofenestra pseudoumbilica*	*Coccolithus pelagicus*	*Calcidiscus leptoporus*	*Discoaster variabilis*	*Discoaster brouweri*	*Discoaster pentaradiatus*	*Helicosphaera carteri*	*Discoaster surculus*	*Amaurolithus primus*	*Calcidiscus tropicus*	*Ceratolithus armatus*	*Amaurolithus tricorniculatus*	*Helicosphaera sellii*	*Discoaster challengeri*	*Discoaster loeblichii*	*Discoaster quinqueramus*	*Helicosphaera granulata*	*Discoaster bellus*	*Discoaster neohamatus*	*Helicosphaera parallela*	*Catinaster coalitus*	*Discoaster hamatus*	*Discoaster bollii*	*Discoaster kugleri*	*Discoaster deflandrei*	*Discoaster exilis*	*Triquetrorhabdulus rugosus*	*Coronocyclus nitescens*	*Cyclicargolithus floridanus*	*Sphenolithus heteromorphus*
	572D-1,CC	F-P		C	A	C	C	C	F	R	R	R	R	R																				
Pliocene	2,CC	F-P	CN10	A	A	A	C	C	F		R	R																						
	3,CC	P		C	A	A	C	C				R		R																				
	4,CC	F-P		A	A	A	C				F		R	R	R	R																		
	5,CC	P	CN9 b	A	A	C	A	C	F		F	C		R																				
	6,CC	F-P		A	A	C	C	C			F	F	R	F			F																	
	7,CC	P	a	C	F	C	C	R	R	R	F	R		R				R																
	8,CC	P	CN8 b	A		C	C	C	F										F	R														
	9,CC	P-F		C	C	C	C	C	F		F								R	R	F													
	10,CC	F	a	A		F	C				C			R							F	C												
	11,CC	F		A	C	C	R	F	C		F			R								C	R											
	12,CC	F	?	A	VA	F	R	C	C		R																							
	13,CC	P		C	C	R	R	F	R					R								R												
	14,CC	F	CN7	C	A	C	R	R	R		R			R			cf.					C												
	15,CC	F		C	A	C	C	F			F			R			cf.					R		R	R	R								
	16,CC	F-P		C	A	C	F	F			F																							
	17,CC	F-P		C	A	C	C	F			F			R										R			cf.							
	18,CC	F-P		A	A	C	F	F			F			R							R													
Miocene	19,CC	F-P	?	F	A	C	C	F			R										R							F	R					
	20,CC	F-P		C	A	C	C				R																R		R	F	F			
	21,CC	F-P	CN5 b	C	A	C	C	R			R																C	F	R	R				
	22,CC	F-P		C	C	C	C	F	F		R																							
	23,CC	F-P		C	A	C	R	F			R										F			R					R					
	24,CC	F-P		C	A	C	F														R								F	R				
	25,CC	F-P	a	A	A	C	R														R									R		R		
	26,CC	F-P		A	A	C	C														F								F	R		R		
	27,CC	F-P		C	C	C	R				F										R						R			R		R	R	
	28,CC	F		C	C	F	R				R										R									F				C
	29,CC	F-P		F	C	C					R																			R				C
	30,CC	P-F	CN4	R	A	C															R									F			C	A
	31,CC	F-P		C		C					F										R								R				C	C
	32,CC	F-P		F	F	C	R				F										R								R	R			C	F

Note: Symbols as in Table 2.

Table 4. Occurrence of calcareous nannofossils in core-catcher samples, DSDP Hole 573, Leg 85.

Age	Sample	Preservation	Nannofossil zones	*Gephyrocapsa oceanica*	*Gephyrocapsa caribbeanica*	*Calcidiscus leptoporus*	*Helicosphaera carteri*	*Umbilicosphaera sibogae*	*Ceratolithus cristatus*	*Thoracosphaera* sp.	*Pseudoemiliania lacunosa*	*Helicosphaera sellii*	*Discoaster brouweri*	*Discoaster brouweri* (3 rays)	*Coccolithus pelagicus*	*Calcidiscus tropicus*	*Discoaster pentaradiatus*	*Discoaster tamalis*	*Discoaster asymmetricus*	*Ceratolithus rugosus*	*Reticulofenestra minutula*	*Discoaster variabilis*	*Sphenolithus abies*	*Reticulofenestra pseudoumbilica*	*Discoaster surculus*	cf. *Discoaster sanmiguelensis*	*Amaurolithus primus*	*Amaurolithus tricorniculatus*	*Ceratolithus acutus*	*Amaurolithus delicatus*	*Discoaster quinqueramus*	*Amaurolithus amplificus*	*Discoaster berggrenii*	*Discoaster loeblichii*	*Discoaster bellus*	*Discoaster challengeri*
Pleist.	573-1,CC	F-G	CN14b	A	A	C	F	R	R																											
	2,CC	F-G	CN14a	A	A	C	F		R	C	A																									
	3,CC	F-G	CN13	C	A	C	F	R	R		A	F																								
Pliocene	4,CC	F	CN12			F	R		R		A		C	R	C	C																				
	5,CC	F	CN12			F	C			F			F		C	C	F	F	R																	
	6,CC	P	CN12			A	F		R		C		F	R			R		R	R	A	F														
	7,CC	F	CN11			C	R		F				A		C	F			R	R	A	R	A	A	R	R										
	8,CC	F	CN10						F				C		C	C	F		R	F	A	R	A	A	F	R	R									
	9,CC	F	CN10			C									A	C	R					R	C	A	C		R	R	R	R						
Miocene	10,CC	P-F	CN9b				R						F		C	C	C					C	A	A	C		R			R	C					
	11,CC	F	CN9b										C		C		R					R	C	C	C		R			R	R	R				
	12,CC	F-P	CN9b										F		A		R					C	A	C						R	R		F			
	13,CC	F-P	CN9b			F	R						F	R	C	C					C	F			F		F			R	R	R				
	14,CC	F-P	CN9 b/a				R						F		C	C					C	F			F					R	R					
	15,CC	F-P	CN9a			F	R						F		C	C					C	F	C		F											
	16,CC	F-P	CN9a			C							C	R	C	C					A	C	C	R	F									R		
	17,CC	F-P	CN9a			C	R						A	R	C	C					F	A	A	R	F						R			R		
	18,CC	F-P	CN9a			C									F	R	F					A	C	A											C	R
	19,CC	F-P	CN8			C							F		C	C						F	A	C											R	

Note: Symbols as in Table 2.

in age (see below). Preservation of nannofossils is rather poor throughout both sections, with notable evidence for corrosion and overgrowth.

Hole 575

Hole 575 (Table 8) extends possibly from Pliocene (the core-catcher sample of Core 1 yielded only very rare *Discoaster brouweri*) to the middle Miocene *Sphenolithus heteromorphus* Zone (CN4). From Cores 2 through 7 the *D. quinqueramus* through *D. exilis* Zones (Zones CN10c through CN5) are represented, but the assemblages are too poorly preserved to allow more refined zonal assignments. Marker species are not present, and even some of the most resistant species are notably sporadic in their occurrence. Samples from Cores 8 through 11 yielded abundant *Sphenolithus heteromorphus*, and these cores are thus assigned to the *S. heteromorphus* Zone (CN4).

Hole 575A

The samples from Hole 575A (Table 9) extend from the *Sphenolithus heteromorphus* Zone (CN4) through the *Triquetrorhabdulus carinatus* Zone (CN1). The *S. heteromorphus* Zone grades into the subjacent *Helicosphaera ampliaperta* Zone (CN3) from which, however, it cannot be separated because of inadequate preservation of marker species. The next lower zone, the *S. belemnos* Zone (CN2), extends from Cores 6 through 9. The remaining interval, Cores 10 through 33, is assigned to the *Triquetrorhabdulus carinatus* Zone (CN1). Further subdivision of the relatively long Zone CN1 is not practical in this section because the two critical marker species *Discoaster druggii* and *Cyclicargolithus abisectus* are unreliable. The first is a generalized asterolith species that is particularly susceptible to overgrowth and alteration; the second is a solution-resistant form whose abundance is enhanced in a residual assemblage, and hence, a true acme is not necessarily recognizable.

One line of evidence that may indicate that Hole 575A penetrated into the uppermost Oligocene is the presence of *Helicosphaera recta* in Core 31; however, that is an isolated occurrence and may be spurious.

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Table 5. Occurrence of calcareous nannofossils in core-catcher samples, DSDP Hole 573B, Leg 85.

Age	Sample (interval in cm)	Preservation	Nannofossil zones	*Calcidiscus leptoporus*	*Sphenolithus abies*	*Coccolithus pelagicus*	*Discoaster variabilis*	*Reticulofenestra pseudoumbilica*	*Discoaster brouweri*	*Discoaster loeblichii*	*Discoaster bellus*	*Helicosphaera granulata*	*Discoaster neohamatus*	*Discoaster bollii*	*Coronocyclus nitescens*	*Helicosphaera parallela*	*Sphenolithus heteromorphus*	*Cyclicargolithus floridanus*	*Discoaster exilis*	*Discoaster deflandrei*	*Coccolithus miopelagicus*	*Discoaster calculosus*	*Sphenolithus belemnos*	*Triquetrorhabdulus carinatus*	*Sphenolithus conicus*	*Sphenolithus moriformis*	*Sphenolithus dissimilis*	*Cyclicargolithus abisectus*	*Sphenolithus ciperoensis*	*Helicosphaera intermedia*	*Sphenolithus distentus*	*Discoaster tani*	*Reticulofenestra bisecta*	*Sphenolithus pseudoradians*	*Helicosphaera compacta*	*Sphenolithus predistentus*	*Helicosphaera reticulata*	*Helicosphaera euphratis*	*Reticulofenestra umbilica*	*Leptodiscus larvalis*
	573B-1,CC	F-P	CN8	C	A	C	C	F	F	R	R	R																												
	2,CC	P		C	C	F	F	F	F	R	C	R																												
	3,CC	P		F	C	F	R	A	R																															
	4,CC	P		C	C	F	F	A					R																											
	5,CC	P	CN7 to CN5	C	C	F	F	A																																
	6,CC	P		R	C	C	F	A	F					F																										
	7,CC	P		C	A	C		C				R			R	R																								
	8,CC	P		C		C		A				R																												
Miocene	9,CC	P	CN4 to CN3	R	A	C		A				C			R		C	F	F																					
	10,CC	P		F	C	C		C				C			R		A	C		F																				
	11,CC	P		R	C	C		C				F			R		A	C	cf.	R																				
	12,CC	P		cf.	C	C		C				R					C	C	cf.	C	F																			
	13,CC	P		cf.	C	C		F									C	C	cf.	C		cf.																		
	14,CC	P	CN2		C	C		F							F			C			F	R	F																	
	15,CC	P	CN1		C	C		F							F			C		F	F	R		C																
	16,CC	P-F			C	C		F							F			C				F		C	F	C														
\\\\\\\\	17,CC	P-F			C	C									F			A		F		R		C		C														
	18,CC	P-F			C	C												A						C		C														
	19,CC	P-F			C	C												C		F				C	F		F													
	20,CC	P-F			C	C		F										A		C		F		C	F	C		R												
	21,CC	P-F			C	C		R										A		C		F				C		R	R	R										
	22,CC	P-F				C		R										A		C		F				F		R	R											
	23,CC	P-F	b			C		R							R			C		C		F				F		C	R											
	24,CC	P				C									F			C		C						F		C	R											
	25,CC	P	CP19 —			C												C		C						C	F	C	R											
	26,CC	P				C		F										C		C	R					C		C	R		F									
	27,CC	P				C												C		A						F			R	R	F									
	28,CC	P	a			C		F							R			A		F	R							F			R									
	29,CC	P				C									C			C		F						F			R		R	cf.								
Oligocene	30,CC	P				C												C		C						F			R		R									
	31,CC	P	CP18 to CP17			C		C										A		F	C					F					F	cf.								
	32,CC	P				C		C										A		F						A					C	cf.	R	F	R					
	33,CC	P				C		F										C								A							F	R						
	34,CC	P				C		C										C								A							F		R	F				
	35,CC	P				C		C										C								C					R		R		F	C				
	36,CC	P				C		C										C								C					R	R	C			F				
	37-2, 23-24	P				C												C								A				R	R	R	C		F	R	R	R		
	38,CC	P	CP16			C																				A					R	R	C		F	C	R	R	F	R
	39,CC	P				C		C										C								C					C		R		R	C		R		
	40,CC	P				C																									C		C		R	F	R	R	F	

Note: Symbols as in Table 2.

Table 6. Occurrence of calcareous nannofossils in core-catcher samples, DSDP Hole 574, Leg 85.

Age	Sample	Preservation	Nannofossil zones	*Gephyrocapsa oceanica*	*Pseudoemiliania lacunosa*	*Calcidiscus leptoporus*	*Calcidiscus tropicus*	*Discoaster brouweri*	*Discoaster tamalis*	*Ceratolithus cristatus*	*Discoaster pentaradiatus*	*Coccolithus pelagicus*	*Discoaster surculus*	*Discoaster variabilis*	*Sphenolithus abies*	*Reticulofenestra pseudoumbilica*	*Helicosphaera carteri*	*Discoaster asymmetricus*	*Discoaster brouweri* (3 rays)	*Ceratolithus acutus*	*Amaurolithus primus*	*Discoaster quinqueramus*	*Discoaster berggrenii*	*Triquetrorhabdulus rugosus*	*Amaurolithus delicatus*	*Discoaster bellus*	*Discoaster loeblichii*	*Helicosphaera granulata*	*Discoaster challengeri*	*Discoaster hamatus*	*Discoaster prepentaradiatus*	*Discoaster kugleri*	*Discoaster bollii*	*Discoaster exilis*	*Coronocyclus nitescens*	*Discoaster deflandrei*	*Sphenolithus heteromorphus*	*Coccolithus miopelagicus*	*Discoaster druggii*	*Cyclicargolithus floridanus*
Pleist.	574-1,CC	P	CN14a	R	C	F	C																																	
Plio.	2,CC	P	CN12		C		F	C	R	R	R	R	R	R																										
	3,CC	P	CN11				C	C		R	C	F		R	C	C	R																							
	4,CC	P					C	C							C	C		R	R	R																				
	5,CC	P	CN10 c/b				F	C			F	F		R	A	C	R				F																			
Miocene	6,CC	P	CN9				C	C				C			A							R	F	R	R															
	7,CC	P	CN8b				C	C				C		F	A	C	R					R				F	F	F												
	8,CC	P	CN7				C	C						C	R	C			R			A		F					R	cf.										
	9,CC	P					F	C				C		C	A	C						A							F	R	R									
	10,CC	P	CN6 to CN5b				F					C		C	F	C								cf.								cf.	R	F						
	11,CC	P					C					C		F	F	A																		R						
	12,CC	P						R				C		R	A	C	R							R				R												
	13,CC	P				F	F	R				C		R	A	C	F							R				F				R			R					
	14,CC	P				F	aff.					C			A	A	F																		R					
	15,CC	P				F		cf.				C			A	A	R															R		R	F	R				
	16,CC	P				F	aff.					C		R	A	C	R											R				R		R		R	R	F		
	17,CC	P	CN5a				F					C			C	A																		R				F	F	
	18,CC	P				F	R					C			C	C																		R	R			F	F	
	19,CC	P				C	F					A		R	A	A												R						R				R	R	R
	20,CC	P	CN4									A			A	A																		R	R		A	F		
	21,CC	P										C			A	A												R						R	R	C	A	F		F
	22,CC	P				F						C			C	C	F											R							R	C	C			F
	24,CC	P										C			C	C																			R		C	F		R
	25,CC	P					aff.					C			C	C	F																		R	R	A	R		R
	26,CC	P										C				C	F											R								F	A			F
	27,CC	P										C			F	C	F											R							R	F	A	R		C
	28,CC	P										A			F	C												F								F	C	F		C
	29,CC	P										C			cf.	C	R																	F	R		A			C
	30,CC	P										A			cf.	A																		cf.	R	C	A	R		A
	31,CC	P				F						C			C	C																					A	R	R	C

Note: Symbols as in Table 2.

Table 7. Occurrence of calcareous nannofossils in core-catcher samples, DSDP Hole 574C, Leg 85.

Age	Sample	Preservation	Nannofossil zones	*Discoaster exilis*	*Coccolithus miopelagicus*	*Coccolithus pelagicus*	*Discoaster deflandrei*	*Sphenolithus moriformis*	*Cyclicargolithus floridanus*	*Coronocyclus nitescens*	*Discoaster calculosus*	*Sphenolithus heteromorphus*	*Discoaster variabilis*	*Calcidiscus leptoporus*	*Sphenolithus belemnos*	*Sphenolithus abies*	*Reticulofenestra pseudoumbilica*	*Helicosphaera granulata*	*Triquetrorhabdulus carinatus*	*Sphenolithus conicus*	*Helicosphaera intermedia*	*Triquetrorhabdulus milowii*	*Cyclicargolithus abisectus*	*Sphenolithus ciperoensis*	*Helicosphaera wilcoxoni*	*Dictyococcites bisectus*	*Sphenolithus distentus*	*Leptodiscus larvalis*	*Chiasmolithus altus*	*Helicosphaera truncata*	*Helicosphaera parallela*	*Discoaster tani*	*Helicosphaera compacta*	*Sphenolithus predistentus*	*Sphenolithus pseudoradians*	*Reticulofenestra umbilica*	*Bramletteius serraculoides*	*Cyclococcolithus formosus*	*Isthmolithus recurvus*	*Helicosphaera euphratis*	*Discoaster barbadensis*	*Cribrocentrum reticulatum*	*Discoaster saipanensis*	*Helicosphaera reticulata*
	574C-1,CC	P	CN5	F	R	C	C	C	C	R	F																																	
	2,CC	P	CN4-CN3	R		C	C	C	C		F	C	C	R																														
	3,CC	P				C		C	C	F	F	R	C		C	F	R	R	C																									
	4,CC	P	CN2		R	A	C	C	C	F	F				C		F		C																									
	5,CC	P				C	F	C	F	R	F					C	C		R	F																								
Miocene	6,CC	P						C	C		F					C	C		F																									
	7,CC	P			C	C	F	C	C		F					C	C	R	F																									
	8,CC	P	c/b		R	C	F		C	R	R						C	R	R	F																								
	9,CC	F			R	C	F		VA	R	R						C		R		R																							
	10,CC	P				C	C	C	VA	R	R						R		C	F	R																							
	11,CC	P	CN11			F	C	C	VA	R	R								F	F	R	F																						
	12,CC	P						C	A	R							F		F			F																						
	13,CC	P				F	F	C	C								F		R				cf.																					
	14,CC	P	a?			C	F	C	A	F	F								F				cf.																					
	15,CC	P					F	C	A	R									C	F			cf.																					
	16,CC	P				C	C	C	C								cf.		C	C	R		cf.																					
	17,CC	P						A	A								cf.			C			C																					
	18,CC	F				C	C	A	A								cf.				R		F	R	R																			
	19,CC	P	CP19			A	R	C	C	R							cf.						F	F		R																		
	20,CC	P				C	R	C	C	F							cf.						C	F																				
	21,CC	P				C		C	A	F													R		R		F									cf.								
	22,CC	P				C	F	C	A														R				F	R								cf.								
	23,CC	P	CP18			C	C	C	A	R																	R		R	R	R					cf.								
	24,CC	F	to			C	C	A	A	R																		R			R					cf.								
Oligocene	25,CC	F	CP17			C	F	A	A	R											R										R	R				cf.								
	26,CC	P				C		A	F																	R	R			R		R	R			cf.								
	27,CC	P				F		A	C																		F		R	R			R	F		cf.								
	28,CC	F				C		C	A																	R	R			R		F		F	R	cf.								
	29,CC	P				C	R	C	C																	C				R		R	R	R		C								
	30,CC	P	c			C		C	F																	R		R	R	R	R		R	R		C								
	31,CC	P	CP16			C		C	C																	F	F	R		R	R	R	R	F		C								
	32,CC	P				C		C	F																	C			R	R			R	F		C	F	R						
	33,CC	P	b/a			C		F	F																	A						R			R	F	F	C	F					
	34,CC	P				C		F																		F										C		F	R					
Eoc.	35,CC	P	CP15			A		F																		F							R			C	R	C		R	F	R	R	R

Note: Symbols as in Table 2.

Table 8. Occurrence of calcareous nannofossils in core-catcher samples, DSDP Hole 575, Leg 85.

Age	Sample	Preservation	Nannofossil zones	*Discoaster brouweri*	*Coccolithus pelagicus*	*Reticulofenestra minutulus*	*Calcidiscus tropicus*	*Discoaster surculus*	*Calcidiscus leptoporus*	*Sphenolithus abies*	*Discoaster pentaradiatus*	*Ceratolithus rugosus*	*Discoaster variabilis*	*Reticulofenestra pseudoumbilica*	*Discoaster asymmetricus*	*Discoaster quinqueramus*	*Discoaster deflandrei*	*Helicosphaera granulata*	*Coccolithus miopelagicus*	*Helicosphaera carteri*	*Cyclicargolithus floridanus*	*Coronocyclus nitescens*	*Sphenolithus heteromorphus*	*Discoaster exilis*
Plio.	575-1,CC	VP	CN12-	VR																				
	2,CC	P	CN10c	P	C	A	C	F	R	F	R	R	R	C	R									
Miocene	3,CC	P		P	C				C	F	F		F	C		A								
	4,CC	P	CN9b	P	C		F		C	C			R	C										
	5,CC	P	to	P	C				C	C			cf	A			F	R	R					
	6,CC	P	CN5 b/a	P	C				C	A			cf	A			F	F						
	7,CC	P		P	A				R	A			cf	A			R			F	C	R		
	8,CC	P	CN4	P	A				R					A			R	F			C	R	A	R
	9,CC	P		P	A				R	A				C			R	F			C		A	R
	10,CC	P		P	C				R	C				C			R	C			C		A	R
	11,CC	P		P	C				F	C				C			F	F		R	C	F	A	

Note: Symbols as in Table 2; V = very.

Table 9. Occurrence of calcareous nannofossils in core-catcher samples, DSDP Hole 575A, Leg 85.

Age	Sample	Preservation	Nannofossil zones	*Discoaster exilis*	*Coccolithus pelagicus*	*Sphenolithus moriformis*	*Cyclicargolithus floridanus*	*Coronocyclus nitescens*	*Reticulofenestra pseudoumbilica*	*Sphenolithus heteromorphus*	*Discoaster deflandrei*	*Coccolithus miopelagicus*	*Helicosphaera intermedia*	*Sphenolithus belemnos*	*Triquetrorhabdulus carinatus*	*Sphenolithus abies*	*Cyclicargolithus abisectus*	*Orthorhabdus serratus*	*Sphenolithus dissimilis*	*Helicosphaera granulata*	*Helicosphaera parallela*	*Helicosphaera obliqua*	*Sphenolithus capricornutus*	*Sphenolithus conicus*	*Helicosphaera recta*
	575A-1,CC	P		R	C	C	A	R	C	A															
	2,CC	P	CN4	R	C	C	A	F	C	A	F														
	3,CC	P	to	R	C	C	A	F	C	C	C														
	4,CC	P	CN3	R	C	C	C	F	C	C		R·													
	5,CC	P			C	C	C	F	C	C		R	R												
	6,CC	P			C	C	C	F	C		C			F											
	7,CC	P	CN2		C		F	F	C					A	F	C									
	8,CC	P			C	C	C	F	C		F	R		C											
	9,CC	P			C	F	C	F	C		R			F		C	R								
	10,CC	P			C	C	C	F	C		R				R	R	F	C	F						
	11,CC	P			C	C	R	.F	A						R	R	F	F	F						
	12,CC	P			A	C	C	F	C		C	F				F	F	cf.	F						
	13,CC	P			C	C		F	A		F				F	A	F			F					
	14,CC	P			A	C	C	F	C		C					A	F								
Miocene	15,CC	P			C	C	C		A						C	A	F			R					
	16,CC	P			C	F	C		A		F				F	C	F								
	17,CC	P			C	C	C		A		C				C	C	C								
	18,CC	P			C	C	C		cf.								F								
	19,CC	P			C	C	C				C				F	F	C								
	20,CC	P			C	C	A	R	cf.		C	cf.					C								
	21,CC	P	CN1		C	C	A	R	F		F	C			R	R	C								
	22,CC	P			A	C	A	R	C		F	C			R	C	F								
	23,CC	P			F	C	A	F	C		F	C			F		F								
	24,CC	P			C	C	A	R	R		A	C			R	A	C								
	25,CC	P			F	C	A	R	F		C	C			F	A	C			R	R				
	26,CC	P			C	C	A	R	F		C	F			F	A	C			R					
	27,CC	P			F	R	A	R	R		C	C			F	A	C				R				
	28,CC	P			F	C	A	R	R						R	A	C			R					
	29,CC	P			F	C	A	R	R						R	F	C			R		R	R		
	30,CC	P			F	F	A	R			F				R	A	C			R					
	31,CC	P			C	C	A	R	F		C		R		R	C	C			R				R	R
	32,CC	P			C	F	A	R	F		F		R		F	C	C			R		R		R	
Oligo.?	33,CC	P			C	C	A	R	F				R		F		C		F	R				R	

Note: Symbols as in Table 2.