31. COCCOLITH STRATIGRAPHY, OFFSHORE WESTERN AUSTRALIA, DEEP SEA DRILLING PROJECT LEG 27[1]

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INTRODUCTION

Leg 27 of the Deep Sea Drilling Project, through the eastern Indian Ocean (Figure 1), recovered 173 cores at five drilling sites, Sites 259-263. Light-microscope techniques were used to study the coccoliths of 100 samples from these cores. Mesozoic coccolith zonation, summarized in Figure 2, is based on Thierstein (1971), Roth and Thierstein (1972), and Roth (1973). Cenozoic zonation is based on Bukry (1973).

SITE SUMMARIES

SITE 259
(lat 29°37'S, long 112°42'E, depth 4712 m)

Coccoliths of Early Cretaceous (Albian), late Paleocene, early Eocene, and Pleistocene age occur at Site 259 at the base of the continental slope west of Fremantle, Australia. Most of the Mesozoic samples examined are barren, but samples from Cores 13 to 17 (113 to 160 m) contain excellent Albian assemblages (Figure 3). Assemblages of coccoliths in representative samples from this site are listed below from youngest to oldest.

Pleistocene
(*Gephyrocapsa oceanica* **Zone**)

Sample 259-1-2, 84-85 cm (1 m):

Coccolithus pelagicus (rare), *Cyclococcolithina leptopora, Emiliania annula* (abundant), *Gephyrocapsa oceanica, Helicopontosphaera kamptneri* (abundant), *H. sellii* (rare), *Rhabdosphaera clavigera, Syracosphaera* sp.

Lower Eocene
(*?Discoaster lodoensis* **Zone**)

Sample 259-4-2, 84-85 cm (29 m):

Discoaster barbadiensis, D. lodoensis, D. mirus, Discoasteroides kuepperi. All specimens are thin and centerless as a result of intense dissolution.

Lower Eocene
(*Tribrachiatus orthostylus* **Zone**)

Sample 259-4-3, 65-66 cm (31 m):

Chiasmolithus sp. cf. *C. grandis, Coccolithus pelagicus* s. ampl., *Discoaster barbadiensis, D. lodoensis, Discoasteroides, kuepperi, Sphenolithus radians, Tribrachiatus orthostylus.*

Sample 259-4-5, 70-71 cm (34 m):

Chiasmolithus sp. cf. *C. grandis, C.* sp. cf. *C. solitus, Coccolithus pelagicus* s. ampl., *Discoaster barbadiensis, D. lodoensis, Discoasteroides kuepperi, Micrantholithus* sp. (fragment), *Sphenolithus radians, ?Striatococcolithus pacificanus, Tribrachiatus orthostylus.*

Sample 259-5-2, 84-85 cm (39 m):

Chiasmolithus grandis, Coccolithus pelagicus s. ampl., *Discoaster barbadiensis, D. diastypus, D. lodoensis* (rare), *D.* sp. cf. *D. salisburgensis, Sphenolithus radians, Tribrachiatus orthostylus, Zygrhablithus bijugatus* (rare).

Upper Paleocene
(*Discoaster multiradiatus* **Zone**)

Sample 259-6-2, 66-67 cm (48 m):

Chiasmolithus bidens, Coccolithus pelagicus s. ampl., *Discoaster lenticularis, D. multiradiatus, D. nobilis.*

Sample 259-7-3, 21-22 cm (59 m):

Chiasmolithus bidens, Coccolithus pelagicus s. ampl., *Discoaster lenticularis, D. multiradiatus* (abundant), *D. nobilis, Fasciculithus involutus, F. schaubii, F. tympaniformis* (abundant).

Sample 259-8-5, 128-129 cm (72 m):

Chiasmolithus bidens (rare), *Discoaster multiradiatus* (abundant), *D. nobilis, Fasciculithus tympaniformis* (abundant), *Zygodiscus sigmoides.*

Lower Cretaceous, lower Albian
(*Prediscosphaera cretacea* **Zone**)

Sample 259-14-2, 107-108 cm (125 m):

Biscutum sp., *Chiastozygus* sp. cf. *C. litterarius, Cretarhabdus loriei, Cribrosphaera* sp. (two-piece diagonal crossbar in central area), *Lithastrinus floralis, Manivitella pemmatoidea, Parhabdolithus angustus, P. embergeri, Prediscosphaera cretacea, Tetralithus* sp. cf. *T. malticus, Watznaueria barnesae, W. biporta, W. britannica, Zygodiscus* spp.

Sample 259-16-2, 106-107 cm (143 m):

Biscutum sp. (common), *Bukryaster hayi, Chiastozygus* sp., *Cribrosphaera* sp. (two-piece diagonal crossbar in central area), *Cyclagelosphaera margerelii, Lithastrinus floralis, Manivitella pemmatoidea, Parhabdolithus angustus, P. embergeri, Prediscosphaera cretacea, Stephanolithion laffitei, Vagalapilla matalosa, Watznaueria barnesae, W. biporta, W. britannica, W. ovata, Zygodiscus bicrescenticus, Zygodiscus* spp.

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[1]Publication authorized by the Director, U.S. Geological Survey.

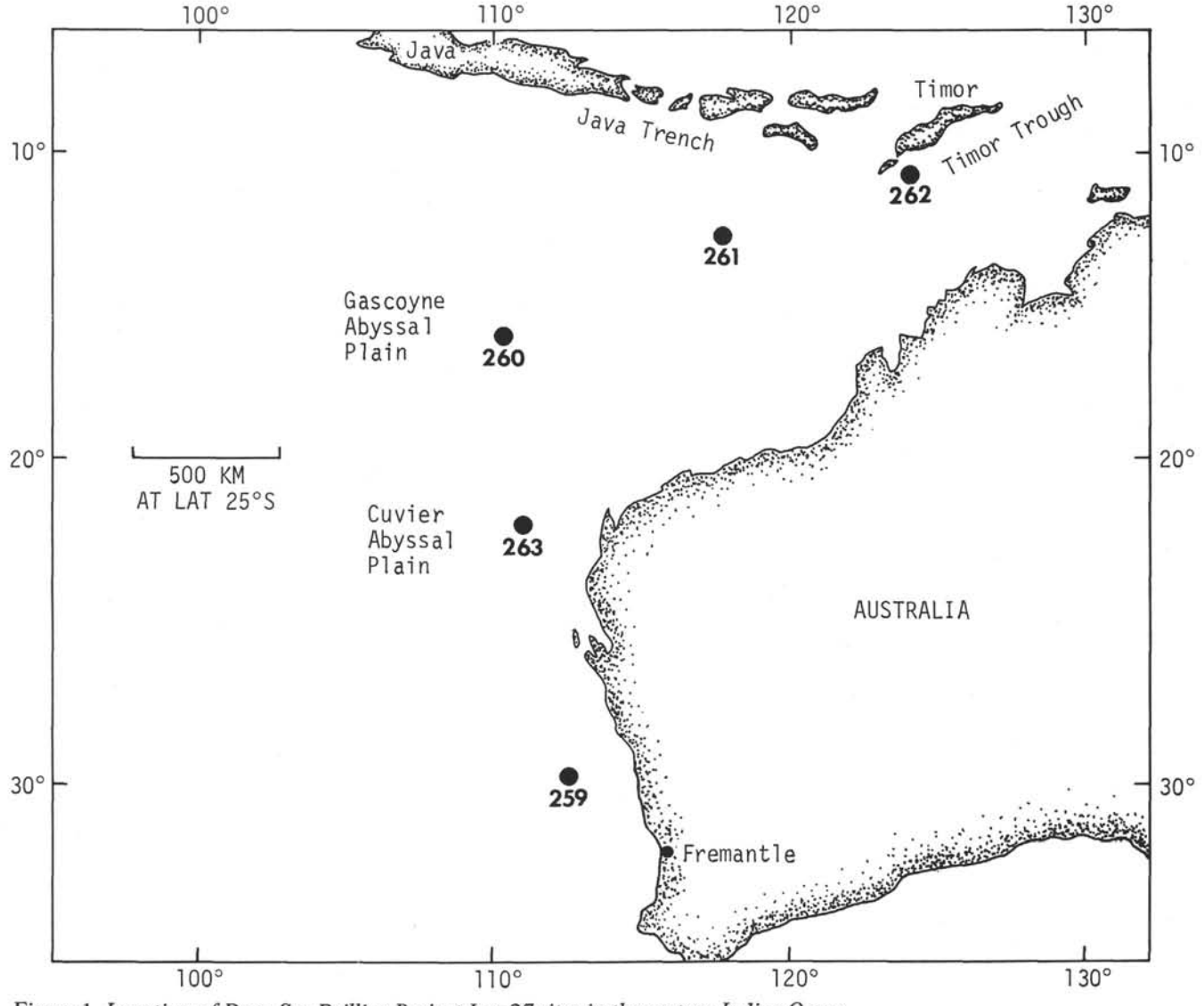

Figure 1. *Location of Deep Sea Drilling Project Leg 27 sites in the eastern Indian Ocean.*

Sample 259-17-2, 33-34 cm (152 m):

Biscutum sp., *Bukryaster hayi* (few), *Chiastozygus* sp., *Cribrosphaera* sp. (two-piece diagonal crossbar in central area), *Cyclagelosphaera margerelii, Lithastrinus floralis, Manivitella pemmatoidea, Parhabdolithus angustus, P. embergeri, Prediscosphaera cretacea, Stephanolithion laffitei, Vagalapilla matalosa* (common), *Watznaueria barnesae, W.* sp. cf. *W. bayackii, W.* sp. cf. *W. britannica, W. ovata, Zygodiscus* spp.

Cretaceous (?)

Sample 259-28-1, 74-76 cm (256 m):

Watznaueria barnesae, W. britannica.

SITE 260
(lat 16°09′S, long 110°18′E, depth 5709 m)

Coccoliths in samples examined from Site 260 in the Gascoyne Abyssal Plain range in age from Early Cretaceous (Berriasian?) to late Oligocene. Owing to the poor preservation and low diversity of the lowest samples from Cores 13 to 18, the stratigraphic assignment is questionable (Figure 4). The presence of *Cretarhabdus angustiforatus* and the absence of *?Watznaueria manivitae* suggest an Early Cretaceous age. The only Cenozoic sample examined, Sample 260-4-5, 63-64 cm (133 m), is Oligocene; reworked species of Cretaceous, Paleocene, and Eocene age are common. Some representative assemblages are listed below.

Upper Oligocene
(*Sphenolithus distentus* **Zone**)

Sample 260-4-5, 63-64 cm (133 m):

Upper Oligocene: *Cyclicargolithus abisectus, Sphenolithus capricornutus, S. distentus.*

Eocene or Oligocene: *Bramletteius serraculoides, Coccolithus eopelagicus, Cyclicargolithus floridanus,*

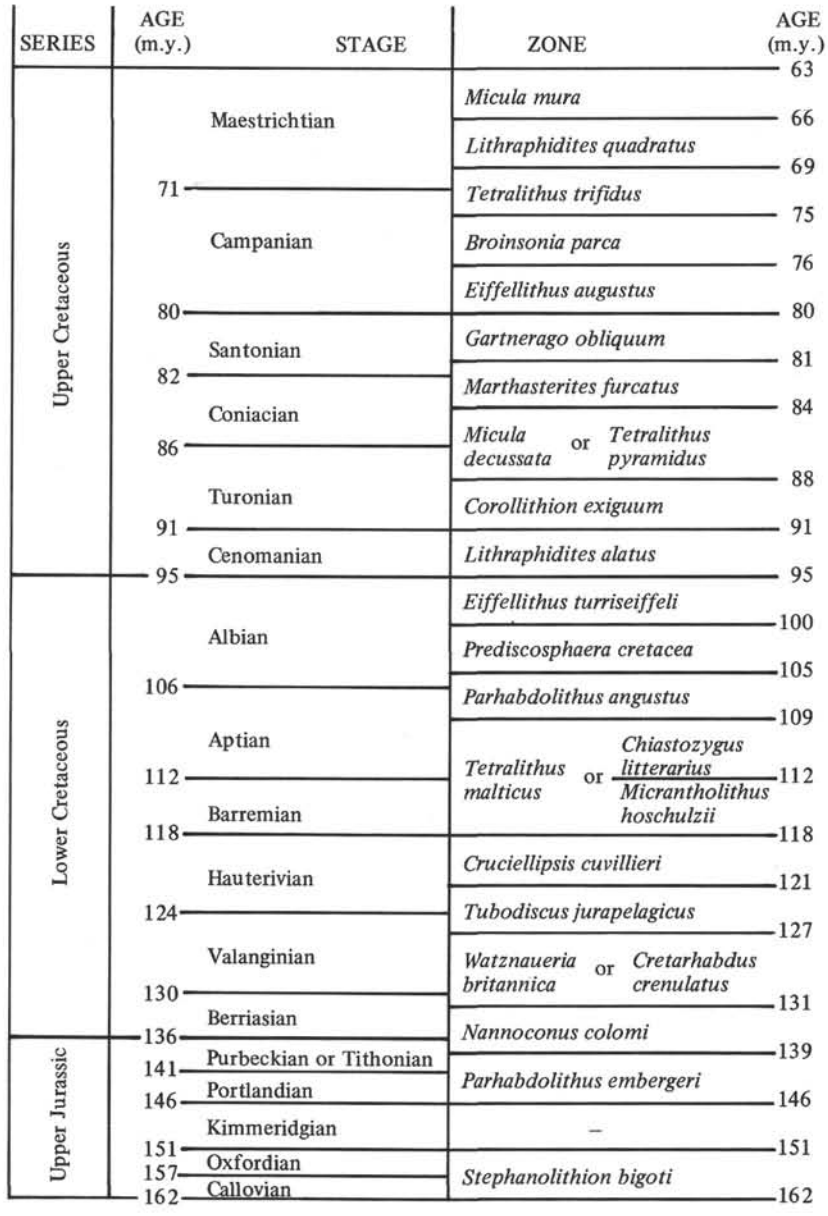

Figure 2. *Estimated ages in million years of Mesozoic universal-stage and coccolith-zone boundaries. Ages obtained from Harland et al. (1964), Lambert (1971), and Izett et al. (1971). Coccolith zonation based on Stradner (1964), Cepek and Hay (1969), Thierstein (1971), Bukry (1973), and Roth (1973).*

Cyclococcolithina formosa, C. kingii, Dictyococcites bisectus, Discoaster deflandrei, D. nodifer, D. tanii, Peritrachelina joidesa, Reticulofenestra hillae, Sphenolithus predistentus, S. pseudoradians.

Eocene: *Chiasmolithus grandis, Discoaster barbadiensis, D. saipanensis, Triquetrorhabdulus inversus.*

Paleocene: *Cruciplacolithus tenuis, Discoaster multiradiatus, Fasciculithus tympaniformis, Toweius eminens.*

Cretaceous: *Cribrosphaera ehrenbergii, Eiffellithus augustus, E. turriseiffeli, Gartnerago obliquum, Parhabdolithus embergeri, Zygodiscus spiralis.*

Aptian or Albian
(*Parhabdolithus angustus* **Zone**)

Sample 260-11-1, 85-86 cm (254 m):

Chiastozygus sp., *Cretarhabdus conicus, C. crenulatus, Cruciellipsis chiasta, Lithastrinus floralis, Lithraphidites carniolensis, Manivitella pemmatoidea, Parhabdolithus* sp. cf. *P. angustus, P. asper, P. embergeri, Rucinolithus wisei* s. str., *Stephanolithion laffitei, Vagalapilla stradneri, Watznaueria barnesae, W. bayackii, W.* sp. cf. *W. britannica.*

Sample (Interval in cm)	Depth (m)	Quantity and Preservation	Zone	Time-Stratigraphic Unit
1-2, 84-85	1	Ag	*Gephyrocapsa oceanica*	Upper Pleistocene
1-4, 79-80	4	Am		
1-6, 71-72	7	–	?	?
4-1, 74-75	28	–		
4-2, 84-85	29	Ap	*?Discoaster lodoensis*	Lower Eocene
4-3, 65-66	31	Ap	*Tribrachiatus orthostylus*	
4-4, 77-78	32	Rm		
4-5, 70-71	34	Am		
5-2, 84-85	39	Ap		
6-2, 66-67	48	Ap	*Discoaster multiradiatus*	Upper Paleocene
7-3, 21-22	59	Ap		
8-2, 108-109	68	–		
8-3, 47-48	68	Rp		
8-4, 42-43	70	–		
8-5, 128-129	72	Ap		
9-2, 80-81	77	–	?	?
10-2, 78-79	86	–		
11-2, 94-95	95	–		
12-2, 78-79	105	Rp	?	Cretaceous
13-2, 105-106	116	Am	*Prediscosphaera cretacea*	Lower Cretaceous, Albian
14-2, 107-108	125	Am		
15-2, 95-96	134	Am		
16-2, 106-107	143	Ag		
17-2, 33-34	152	Ag		
17-3, 94-95	154	–	?	?
18-2, 107-108	163	–		
19-2, 90-91	172	–		
20-2, 96-97	181	–		
21-2, 114-115	192	–		
22-2, 120-121	201	–		
23-2, 110-111	211	–		
24-2, 123-124	220	–		
25-2, 103-104	230	–		
26-2, 64-65	238	–		
27-2, 41-42	248	–		
28-1, 74-76	256	Cp	?	Cretaceous (?)
28-2, 91-92	257	–	?	?
29-2, 90-91	267	–		
30-2, 53-54	276	–		
31-2, 63-64	286	–		
32-2, 78-79	295	–		

Figure 3. *Quantity, preservation, zone, and time-stratigraphic designations of samples from Site 259 based on coccoliths. Quantity indicated as* A, *abundant;* C, *common;* R, *rare; or* –, *absent. Preservation indicated as* g, *good;* m, *moderate;* p, *poor.*

Valanginian or Hauterivian
(*Tubodiscus jurapelagicus* Zone)

Sample 260-12-2, 54-56 cm (265 m):

Chiastozygus sp., *Cretarhabdus angustiforatus, C. crenulatus, Cyclagelosphaera margerelii, Hayesites bulbus* [this species may be referrable to *Bukryaster*], *Markalius? circumradiatus, Parhabdolithus embergeri, Rucinolithus wisei, Stephanolithion laffitei, Tubodiscus jurapelagicus, Vagalapilla stradneri, Watznaueria barnesae, W. biporta, W. britannica, W. coronata, W. ovata, Zygodiscus* spp.

Berriasian or Valanginian

Sample 260-13-1, 115-116 cm (273 m):

Cretarhabdus angustiforatus, Parhabdolithus embergeri, Watznaueria barnesae, W. bayackii, W. biporta, W. britannica, W. ovata.

Sample 260-15-2, 111-112 cm (293 m):

Cyclagelosphaera margerelii, Parhabdolithus embergeri, Watznaueria barnesae, W. britannica.

Sample 260-18-2, 123-124 cm (322 m):

Cretarhabdus sp., *Parhabdolithus embergeri, Watznaueria barnesae, W. britannica.*

Sample (Interval in cm)	Depth (m)	Quantity and Preservation	Zone	Subseries or Stage
4-5, 63-64	133	Am	*Sphenolithus distentus*	Upper Oligocene
5-6, 71-72	160	–	?	?
10-1, 111-112	245	Am	*Parhabdolithus angustus*	Albian or Aptian
10-2, 60-61	245	Am		
11-1, 85-86	254	Am		
12-2, 54-56	265	Am	*Tubodiscus jurapelagicus*	Hauterivian or Valanginian
13-1, 115-116	273	Ap	?	Valanginian or Berriasian
14-1, 145-146	283	Rp		
15-2, 111-112	293	Cp		
15-4, 82-83	296	Cp		
16-2, 21-23	302	–		
17-1, 48-49	310	Am		
18-2, 123-124	322	Rp		

Figure 4. *Quantity, preservation, zone, and stage designations of samples from Site 260 based on coccoliths. See Figure 3 for key to abbreviations.*

Sample (Interval in cm)	Depth (m)	Quantity and Preservation	Zone or Subzone	Time-Stratigraphic Unit
3-1, 143-144	48	Ag	*Sphenolithus neoabies*	Lower Pliocene
3-3, 10-11	50	Ag		
4-2, 49-50	97	Ag	*Ceratolithus primus*	Upper Miocene
27-2, 111-112	440	Rp	?	Cretaceous (?)
28-3, 77-78	449	Rp		Lower Cretaceous
29-2, 120-121	467	Rp		
30-1, 133-134	485	Rp		Berriasian or Tithonian
30-2, 114-115	487	Ap		
30-3, 132-133	489	Am		
31-2, 89-90	505	Rp		?
31-5, 82-83	509	Rp		
32-2, 79-80	524	Cp		Tithonian to Callovian
32-4, 90-91	527	Cp		

Figure 5. *Quantity, preservation, zone, and time-stratigraphic designations of samples from Site 261 based on coccoliths. See Figure 3 for key to abbreviations.*

SITE 261
(lat 12°57'S, long 117°54'E, depth 5687 m)

At Site 261, south of the southern end of the Java Trench between Australia and Java, basal sediment contains the oldest Mesozoic coccoliths yet cored in the Indian Ocean. Coccoliths from Core 30 (485 to 494 m) are near the Jurassic-Cretaceous boundary (Tithonian or Berriasian), those from Core 32 (523 to 532 m) Late Jurassic, possibly as old as Oxfordian or Callovian (151 to 162 m.y.).

Only three Cenozoic samples of Pliocene and Miocene age were examined from this site (Figure 5). The *Sphenolithus neoabies* Subzone of Sample 261-3-1, 243-244 cm (48 m) contains a distinctly tropical assemblage dominated by *Discoaster* and *Sphenolithus*. Reworking from lower Pliocene and upper Miocene strata is indicated by the co-occurrence of species such as *Ceratolithus acutus, C. primus, C. rugosus, C. tricorniculatus, Discoaster berggrenii, D. neohamatus, D. pentaradiatus, D. quinqueramus, Reticulofenestra pseudoumbilica*, and *Triquetrorhabdus rugosus*. Sample 261-3-3, 10-11 cm (50 m) contains a typical tropical assemblage of the subzone lacking reworked taxa. Species present include *Ceratolithus rugosus, Coccolithus pelagicus,*

Sample (Interval in cm)	Depth (m)	Quantity and Preservation	Zone or Subzone	Subseries
40-2, 70-71	368	Ag	*?Gephyrocapsa caribbeanica*	Lower Pleistocene
41-2, 85-86	377	Ap	*?Emiliania annula*	
42-2, 140-141	386	Am		
43-2, 86-87	397	Ap		
44-2, 18-19	406	Am		
45-1, 89-90	415	Am	*Cyclococcolithina macintyrei*	Upper Pliocene

Figure 6. *Quantity, preservation, zone, and subseries designations of samples from Site 262 based on coccoliths. See Figure 3 for key to abbreviations.*

Cyclococcolithina macintyrei, Discoaster assymmetricus (rare), *D. brouweri, D. challengeri, D. pentaradiatus, D. quadramus. D. surculus, D. variabilis, Discolithina multipora, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Scyphosphaera globulata, Sphenolithus abies* and *S. neoabies* [abundant].

The *Ceratolithus primus* Subzone of Sample 2614-2, 49-50 cm (97 m) contains reworked older Miocene species such as *Catinaster calyculus, C. coalitus, Cyclicargolithus,* and *Minylitha convallis.* Taxa present that probably represent the indigenous assemblage include *Ceratolithus primus, Cyclococcolithina cricota, C. macintyrei, Discoaster assymmetricus, D. berggrenii, D. brouweri, D. quinqueramus, D. surculus, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Scyphosphaera intermedia, S. pulcherrima, S. recurvata, Sphenolithus abies, S. neoabies,* and *Triquetrorhabdulus rugosus.*

As Mesozoic coccoliths of Cores 27 to 32 (437 to 532 m) are variously overgrown, recrystallized, solution welded, and fragmented, definite zonal assignment of the low-diversity assemblages is not possible. Samples from Cores 27 to 29 (437 to 475 m) contain only rare *Watznaueria barnesae* and *?W. britannica.* A pre-Late Cretaceous age is suggested by *?W. britannica.*

Preservation is slightly better in Core 30 (485 to 494 m), where the occurrence of *?Cretarhabdus* sp., *Cruciellipsis cuvillieri, Cyclagelosphaera margerelii, Parhabdolithus embergeri,* and *Watznaueria ovata,* in addition to *W. barnesae* and *W. britannica,* suggests a Late Jurassic or Early Cretaceous age. Many other species typical of that time are missing.

In Core 31 (504 to 513 m) only rare *Cyclagelosphaera margerelii, Watznaueria barnesae,* and *W. britannica* are present. These species are solution-welded into clumps in Sample 261-31-2, 89-90 cm (505 m).

The common occurrence of a large placolith, *Watznaueria manivitae* [=*Coccolithus? deflandrei* Manivit] or an undescribed species of *Watznaueria,* in Core 30 could suggest a Late Jurassic age. The only other species identified in this core are *Cyclagelosphaera margerelii, Watznaueria barnesae,* and *W. britannica.* In the deepest sample, Sample 261-32-4, 90-91 cm (527 m), *Watznaueria britannica* and *?W. manivitae* predominate over *W. barnesae.* This and the absence of *Parhabdolithus embergeri* could be used to suggest a Callovian or Oxfordian age, as presumed Oxfordian or Callovian sediment from Sicily and from Site 105 in the western Atlantic contain similar assemblages (Bukry, 1972). The presence of *Stephanolithion bigotii* at both of those localities, however, makes the absence of the more resistant *Parhabdolithus embergeri* stratigraphically diagnostic and permits more precise correlation. Because *P. embergeri* has only slightly less potential for preservation than *Watznaueria,* the assemblage at Site 261 could be as old as Callovian but is too limited to suggest an assignment more precise than probable Late Jurassic (Callovian to Tithonian).

SITE 262
(lat 10°52'S, long 123°51'E, depth 2315 m)

Site 262 is just south of Timor in the Timor Trough. Only a few samples near the Pliocene-Pleistocene boundary were examined from an interval in Cores 40 to 45 (366 to 423 m) characterized by abundant tiny placoliths (probably *Gephyrocapsa producta*) and common larger calcareous debris, including rhombs and ascidian spicules (Figure 6). Coccoliths of average size are relatively rare and include few species, principally *Coccolithus pelagicus, Crenalithus doronicoides, Cyclococcolithina leptopora, Discolithina japonica, Emiliania annula, Gephyrocapsa* sp. cf. *G. caribbeanica, Helicopontosphaera kamptneri, Pontosphaera scutellum, Rhabdosphaera stylifera,* and *Syracosphaera histrica.*

The distribution of *Discoaster* in this interval is used to indicate the Pliocene-Pleistocene boundary because other indicator species such as *Ceratolithus rugosus* or *Cyclococcolithina macintyrei* are missing. The ratio of *Discoaster* to other coccoliths is very small. Based on a population of 6000 specimens, *Discoaster* is 1.3% in Core 45, Section 1, 0.05% in Core 44, Section 2, 0.12% in Core 43, Section 2, and absent in Core 42, Section 2. To help avoid the need to differentiate allochthonous *Discoaster* specimens reworked from surrounding areas, a dramatic reduction in *Discoaster* to levels below 1% can be used to identify the top of the *Discoaster brouweri* Zone at low latitude (Bukry, 1973). On this basis, the Pliocene-Pleistocene boundary, based on coccoliths, is

Sample (Interval in cm)	Depth (m)	Quantity and Preservation	Zone	Stage
4-2, 128-129	113	Ag	*Parhabdolithus angustus*	Aptian
5-1, 120-121	129	Am	?	Aptian to Valanginian
6-2, 20-21	149	Rp		
7-3, 69-70	178	Rp		
8-1, 126-127	206	–		
9-2, 92-93	226	–	?	?
10-2, 70-71	245	–		
11-2, 77-78	264	Rm		
12-2, 104-105	283	–		
13-2, 45-46	302	Cm	*?Parhabdolithus angustus*	Aptian
14-2, 100-101	322	–		
15-2, 121-122	341	–		
16-1, 69-70*	357	–		
17-2, 125-126	388	–		
18-2, 114-118	416	Rp		
19-2, 103-104	454	–	?	?
20-2, 66-67	482	–		
21-2, 81-82	519	Rp		
21-4, 10-11	522	–		
22-2, 71-72	558	Rp		
23-2, 80-81	596	Rp		
24-4, 48-49	637	Rp	?	Aptian (?)
25-3, 33-34	673	–	?	?
26-3, 75-76	703	Rp	*?Micrantholithus hoschulzii*	Barremian (?)
26-4, 98-99	704	–		
28-2, 95-96	729	Rp	?	?
29-3, 132-133	740	Rp		

Figure 7. *Quantity, preservation, zone, and stage designations of samples from Site 263 based on coccoliths. See Figure 3 for key to abbreviations.*

placed between Core 44, Section 2 and 45, 1. All discoasters identified are heavily overgrown *D. asymmetricus* and *D. brouweri.*

Site 263
(lat 23°20′S, long 110°58′E, depth 5065 m)

Coccoliths are rare and poorly preserved through most of the section cored at Site 263 on the Cuvier Abyssal Plain (Figure 7). Samples from Cores 4 to 29 (110 to 746 m) contain poorly diagnostic Lower Cretaceous assemblages. The occurrence of *Vagalapilla matalosa* in most of the upper coccolith-bearing samples down through Core 24 (637 m) suggests Aptian. No specimens of Albian indicators *Lithastrinus floralis* or *Prediscosphaera cretacea* occur. Several large specimens of *Micrantholithus hoschulzii* are present in Core 26 (703 m). This occurrence below the range of *V. matalosa* suggests a Barremian age (Thierstein, 1971). Some representative assemblages are listed below.

Aptian
(*Parhabdolithus angustus* Zone)

Sample 263-4-2, 128-129 cm (113 m):

Chiastozygus litterarius, Chiastozygus sp., *Cretarhabdus crenulatus, C. loriei, Lithraphidites carniolensis, Parhabdolithus asper* (common), *P.* sp. cf. *P. angustus, P. embergeri, Podorhabdus* sp., *Stephanolithion laffitei, Vagalapilla stradneri, V. matalosa, Watznaueria barnesae, W.* sp. cf. *W. bayackii, W. britannica, W. ovata, Zygodiscus* spp.

Aptian to Valanginian

Sample 263-5-1, 120-121 cm (129 m):

Cretarhabdus crenulatus, Manivitella pemmatoidea, Parhabdolithus asper, P. embergeri, Vagalapilla stradneri, Watznaueria barnesae (abundant), *W. britannica, W. ovata, Zygodiscus* spp.

Aptian
(*?Parhabdolithus angustus* Zone)

Sample 263-13-2, 45-46 cm (302 m):

Cretarhabdus crenulatus, Parhabdolithus sp. cf. *P. angustus, P. asper, P. embergeri, Vagalapilla stradneri, V. matalosa, Watznaueria barnesae, W. britannica.*

Aptian (?)

Sample 263-24-4, 48-49 cm (637 m):

Chiastozygus sp., *Vagalapilla stradneri, V. matalosa, Watznaueria barnesae, W. britannica.*

Barremain (?)
(*?Micrantholithus hoschulzii* **Zone**)

Sample 263-26-3, 75-76 cm (703 m):

Chiastozygus sp., *?Eiffellithus turriseiffeli, Micrantholithus hoschulzii, M. obtusus, Parhabdolithus embergeri, Watznaueria barnesae, W.* sp. cf. *W. britannica.*

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