23. CENOZOIC RADIOLARIANS FROM DEEP SEA DRILLING PROJECT LEG 40

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BIOSTRATIGRAPHIC ZONATION

Only at Sites 360 and 362 are upper Miocene to Pleistocene radiolarians sufficiently abundant for detailed biostratigraphy. Because of the general absence of radiolarians at Leg 40 sites, it is difficult to define an adequate zonation for the southeastern Atlantic. However, the stratigraphic distribution of some radiolarian species at Site 362 seems to be similar to that in the North Pacific, and we therefore use the upper Miocene to Pliocene biostratigraphy of Kling (1973).

Miocene: The upper Miocene is represented by the *Stichocorys peregrina* Zone. The base of this zone (not identified at Site 362) is marked by the first occurrence of *Stichocorys peregrina*, and its top by the last occurrence of this species.

Pliocene: The base of the Pliocene *Lamprocyrtis heteroporos* Zone coincides with the top of the *S. peregrina* Zone. As discussed by Kling (1973), the Miocene-Pliocene boundary occurs within the *S. peregrina* Zone. In the Pacific Coast region, the boundary is tentatively taken as the lowest occurrence of *Lamprocyrtis heteroporos*. Thus, in the North Pacific, the ranges of *S. peregrina* and *L. heteroporos* overlap. The same is observed at Site 362. In the Antarctic, however, the base of the Pliocene is marked by the first appearance of *Cycladophora davisiana* (Chen, 1975). Based on calcareous nannoplankton and foraminifers, the Miocene-Pliocene boundary lies between Cores 362-13 and 15. At Site 362, as in the North Pacific, the first occurrences of *C. davisiana* and *L. heteroporos* are not synchronous. *C. davisiana* first appears in Section 362-14-4 and *L. heteroporos* in Section 362-18-4. Thus, the first appearance of *C. davisiana* more closely approximates the Miocene-Pliocene boundary, and at Site 362 *L. heteroporos* ranges down into the Miocene.

Pleistocene: The species used to identify the Pleistocene in other parts of the world were not found at Site 362 and thus the Pliocene/Pleistocene boundary cannot be identified.

SITE SUMMARIES

Site 360

Radiolarians are in general very scarce and poorly preserved. Species present in Cores 1 to 10 (*Stichocorys delmontensis*, *Ommatartus penultimus*, and *Ommatartus antepenultimus*) suggest that these sediments are upper Miocene.

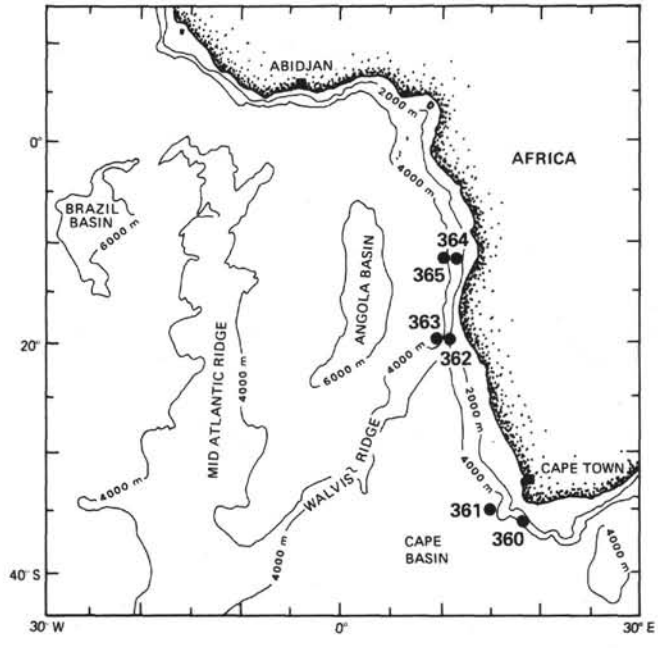

Figure 1. *Location of DSDP Leg 40 Sites 360 to 365.*

Site 361

No Cenozoic radiolarians were found at this site.

Site 362

Radiolarians were found in Cores 1 to 24 from Site 362, indicating that the sediments range from upper Miocene to possibly Pleistocene. Species tabulations and estimates of radiolarian abundances and preservation are shown in Table 1.

In general, the abundance of radiolarians is low through the upper Miocene and lower Pliocene, with preservation poor to moderately good. Samples from Cores 6 through 2 show increasing abundance of radiolarians with a marked increase in *Cycladophora davisiana*. The preservation in these samples is better than in samples above and below. The topmost sample examined, 362-1-4, 99-101 cm, has almost no radiolarians.

As previously discussed, the Miocene-Pliocene boundary is placed within Core 14 of Site 362. The identification of the Pliocene-Pleistocene boundary by means of radiolarians is not possible at this site, but the presence of *Axoprunum angelinum* in Sample 362-2-4, 99 cm, gives it a minimum age of 400,000 years.

TABLE 1
Radiolarians at Site 362

Zone		Core	Section	Abundance	Preservation	Contamination	*Cycladophora davisiana*	*Axoprunum angelinum*	*Dictyophimus crisii*	*Spongocore puella*	*Ommatartus tetrathalamus*	*Anthocyrtidium angulare*	*Eucyrtidium calvertens*	*Lamprocyrtis heteroporos*	*Lamprocyrtis hannai*	*Stichocorys peregrina*	*Stichocorys delmontensis*	*Ommatartus penultimus*	*Ommatartus antepenultimus*	*Eucyrtidium acuminata*	*Anthocyrtidium ophirense*	*Cornutella profunda*	*Lipmanella dictyoceras*
Pliocene	*L. Heteroporos*	1	4	R	M		R																
		2	4	C	M		C	R	F	F	F	R	R	R									
		3	1	C	M		C			F													F
		3	2	C	G		C	R	F	F			C	F								F	F
		3	4	C	M		C			F				F									
		4	4	C	M		C			F	F			F							R		F
		5	4	A	M		C			F	F			F						R	R		
		6	4	C	M		C	R	F	F	R			F	R					R		R	F
		7	4	C	M		R	R			R			F									
		8	4	R	M	?									R	R				R			
		9	5	R	M				F	R			R	F	R							R	
		10	4	R	M		R							F	R								
		11	4	R	P		R	R	R					R	R								
		12	3	C	P		R	R					F		F								
		12	4	R	P					R			R	F	F								
		12	6	C	P		R		F	R			F		F	R							
		13	2	R	P								F		F								
		13	4	R	P																		
		13	6	R	M			R					C										
	S. peregina	14	1	A	M			R					C	F	F	C						R	
		14	2	C	M			F	R				F	R	F	R						R	
		14	3	C	P		R	R	F				F	R	F	R						R	
		14	4	R	P																		
		14	6	C	P					F			F	R	F	F						R	
		15	1	R	P									R	F	F							
		15	2	R	P								R	R	F								
		15	3	A	M					F			R	F	F	F							
		15	4	R	P										F								
		15	6	A	M				F					F		F						F	
Miocene		16	4	R	P	?		R					R	R	F	R							
		17	4	C	M				F		F		C	F	F	F	F	F				R	
		18	4	R	M			F					R			R							
		19	4	R	P						R		R										
		20	4																				
		21	4	R	P																		
		22	4	R	P																		
		23	4	R	P										F	F	F						
		24	4	R	M								R			F	F						
		25	4																				
		26	4																				
		27	4																				

Note: A = abundant, C = common, F = few, R = rare, G = good preservation, M = moderate, P = poor.

Site 364

Radiolarians were found only in the core-catcher sample of Core 6. Specimens in this sample are sparse and highly fragmented. Identifiable specimens of *Artophormis gracillis*, *Lithocyclia crux*, and an unnamed forerunner of this latter species (as in Plate 5, Figure 1), suggest that this sample is similar in age to Section 365-7-1 and belongs to the *Theocyrtis tuberosa* Zone.

Site 365

Radiolarians were found only in Sample 7-1, 32-35 cm from Site 365. This sample contains several radiolarian and diatom species that have been replaced by pyrite. Radiolarians present include:

Artophormis gracilis Riedel (Plate 4, Figure 3)
Lithocyclia angustum (Riedel) (Plate 4, Figure 4)
Lithocyclia crux Moore (Plate 5, Figures 2, 3)
Dorcadospyris spp. (Plate 4, Figures 1, 2)

On this basis, the sample is assigned to the *Theocyrtis tuberosa* Zone (Riedel and Sanfilippo, 1970a; Moore, 1971). Preservation is poor, and specimens of *Dorcadospyris* cannot be easily identified to the species level. Surprisingly, this assemblage does not appear to include *T. tuberosa*, a relatively abundant species in the tropical Pacific; however, the base of *T. tuberosa* Zone is defined by the first appearance of *L. angustum*, and the range of *L. crux* is contained within the upper part of this zone. The presence of these species together with others listed above and figured in Plates 4 and 5 allow the assignment of the sample to the middle to upper part of this basal Oligocene zone.

SYSTEMATICS

Order POLYCYSTINA Ehrenberg

POLYCYSTINA Ehrenberg, 1838, emend. Riedel, 1967b, p. 291

Suborder SPUMELLARIA Ehrenberg, 1875

Family ACTINOMMIDAE Haeckel, 1862, emend. Riedel 1967b

Genus AXOPRUNUM Haeckel

Axoprunum Haeckel, 1887, p. 298. Type species (by monotype) *Axoprunum stauraxonium* Haeckel (1887, p. 298, pl. 48, fig. 4)

Axoprunum angelinum (Campbell and Clark)
(Plate 1, Figure 4)

Stylosphaera angelina Campbell and Clark, 1944, p. 12, pl. 1, fig. 14-20.
Stylatractus sp. Hays, 1965, p. 167, pl. 1, fig. 6.
Stylatractus universus Hayes, 1970, p. 215, pl. 1, fig. 1, 2; Kling, 1971, p. 1086, pl. 1, fig. 7.
Axoprunum angelinum Kling, 1973, p. 634, pl. 12, fig. 13-16, pl. 6, fig. 14-18.

Genus OMMATARTUS Haeckel 1881

Ommatartus Haeckel, 1881, p. 463, Type species indicated by Riedel and Funnel, 1964, p. 311.

Ommatartus antepenultimus Riedel and Sanfilippo
(Plate 1, Figure 3)

Panarium antepenultimus conditional manuscript name proposed by Riedel and Funnell, 1964, p. 311.
Ommatartus antepenultimus Riedel and Sanfilippo, 1970, pl. 14, fig. 4.

Ommatartus penultimus (Riedel)
(Plate 1, Figure 2)

Panarium penultimus Riedel, 1957, p. 76, pl. 1, fig. 1.
Ommatartus penultimus (Riedel) Riedel and Sanfilippo (senu. stricto), 1970, p. 521.

Ommatartus tetrathalamus (Haeckel)
(Plate 1, Figure 1)

Panartus tetrathalamus Haeckel, 1887, p. 378, pl. 40, fig. 3, Nigrini, 1967, p. 30-32, pl. 2, fig. 4a-4d.
Ommatartus tetrathalamus (Haeckel), Renz, 1973, p. 158, pl. 1, fig. 6.

Family COCCODISCADAE Haeckel, 1862

Genus LITHOCYCLIA Ehrenberg

Lithocyclia Ehrenberg 1847 chart to p. 385. Type species (by monotype) *Lithocyclia ocellus* Ehrenberg (1854, p. 136, fig. 30; 1873, p. 240; 1875, pl. 29, fig. 3)

Lithocyclia crux Moore
(Plate 5, Figures 2, 3)

Lithocyclia crux Moore 1971, p. 737, pl. 6, fig. 4.

Lithocyclia angustum (Riedel)
(Plate 4, Figure 4)

Trigonactura angusta Riedel, 1959, p. 292, pl. 1, fig. 6.
Lithocyclia angustum (Riedel) Riedel and Sanfilippo, 1970, pl. 13, fig. 1, 2.

Family SPONGODISCIDAE Haeckel, 1862, emend. Riedel, 1967b

Genus SPONGOCORE Haeckel

Sponcore velata Haeckel (1887, p. 346)

Spongocore puella Haeckel
(Plate 1, Figure 5)

Spongocore puella Haeckel, 1887, p. 347, pl. 48, fig. 6; Benson, 1964, pl. 1, fig. 21; Nigrini, 1970, p. 168, pl. 2, fig. 3.
Spongocore lata Campbell and Clark, 1944, p. 22, pl. 3, fig. 5, 6.
Spongocore puer Campbell and Clark, 1944, p. 22, pl. 3, fig. 7-9.

Suborder NASSALARIA Ehrenberg, 1875

Family ACANTHODESMIIDAE, Haeckel, 1862

Acanthodemiidae Haeckel: Riedel 1967b, p. 296.

Genus DORCADOSPYRIS Haeckel, 1862
(Plate 4, Figures 1, 2)

Dorcadospyris Haeckel, 1881, p. 141. Type species (indicated by Campbell 1954, p. 112.
Dorcadospyris dentata Haeckel (1887, p. 1040, pl. 85, fig. 6).
Dorcadospyris Haeckel; emend. Goll, 1969, p. 335.

Family THEORPERIDA Haeckel, 1881, emend. Riedel, 1967b

Genus ARTOPHORMIS Haeckel

Arthophormis Haeckel 1881, p. 438. Type species (indicated by Campbell, 1954, p. 139), *Artophormis horrida* Haeckel (1887, p. 1458, pl. 74, fig. 2)

Artophormis gracilis Riedel
(Plate 4, Figure 3)

Artophormis gracilis Riedel, 1959, p. 300, pl. 2, fig. 12, 13.

Genus CORNUTELLA Ehrenberg

Cornutella Ehrenberg, 1838, p. 138. Type species (indicated by Campbell, 1954), *Cornutella clathrata* Ehrenberg (1838, p. 129; 1844, pl. 77; 1856, pl. 22, fig. 39).

Cornutella profunda Ehrenberg
(Plate 1, Figure 5)

Cornutella profunda Ehrenberg, 1858, p. 31; Riedel, 1958, p. 232, pl. 3, fig. 1, 2; Nigrini, 1967, p. 60, pl. 6, fig. 5a-5c.
Cornutella palverdensis Campbell and Clark, 1944, p. 40, pl. 5, fig. 7, 20, 23, 24, 25.
Cornutella clathrata β profunda Ehrenberg, 1956, pl. 35B, fig. 21; Bailey, 1856, p. 2, pl. 1, fig. 23.

Genus DICTYOPHIMUS Ehrenberg

Dictyophimus Ehrenberg, 1847, p. 54. Type species (by monotype), *Dictyophimus crisiae*.
Nigrini (1967, p. 68) discusses the correct type species for this genus.

Dictyophimus crisiae Ehrenberg
(Plate 2, Figure 5)

Dictyophimus crisiae Ehrenberg, 1854, p. 241, Nigrini, 1967, p. 66, pl. 6, fig. 7a, 7b.

Pterocorys hirundo Haeckel, Casey, 1971, pl. 23.1, fig. 6, 7.; Petrushevskaya, 1967 (Partim), p. 115, fig. 4, 5).
Pterocorys hirundo Haeckel, Riedel, 1958, p. 238, pl. 3, fig. 11, pl. 4, fig. 1; Petrushevskaya, 1967 (Partim), p. 115, fig. 1-3.

Genus EUCYRTIDIUM Ehrenberg, 1847

Eucyrtidium calvertense Martin
(Plate 1, Figure 7)

Eucyrtidium calvertense Martin, 1904, p. 450, pl. 130, fig. 5; Hays, 1965, p. 181, pl. 3, fig. 4; 1970, p. 213, pl. 1, fig. 6.

Eucyrtidium acuminatum (Ehrenberg)

Lithocampe acuminatum Ehrenberg, 1844, p. 84.
Eucyrtidium acuminatum (Ehrenberg), 1847, p. 43; Nigrini, 1967, p. 81, pl. 8, fig. 3a, 3b.

Genus LIPMANELLA Loeblich and Tappan, 1961

Lipmanella Loeblich and Tappan, 1961, p. 229 (=*Dictyoceras* Haeckel, 1862). Species *Lithornithium dictyoceres* Haeckel (=*Dictyoceras virchowii* Haeckel).

Lipmanella dictyoceras (Haeckel)
(Plate 3, Figure 4)

Lithornithium dictyoceras Haeckel, 1860, p. 840.
Dictyoceras virchowii Haeckel, 1862, p. 333, pl. 8, fig. 1-5.
Lipmanella virchowii (Haeckel) Petrushevskaya, 1971, p. 220, fig. 198.
Lipmanella dictyoceras (Haeckel) Kling, (1973), p. 636.

Genus STICHOCORYS Haeckel, 1881

Stichocorys delmontensis (Campbell and Clark)

Eucyrtidium delmontensis Campbell and Clark, 1944, p. 56, pl. 7, fig. 19, 20.
Stichocorys delmontensis (Campbell and Clark), Sanfilippo and Riedel, 1970, p. 451, pl. 1, fig. 9.

Stichocorys peregrina (Riedel)
(Plate 3, Figures 1-3)

Eucyrtidium elongatum peregrinum Riedel, 1953, p. 812, p. 1.85, fig. 2.
Stichocorys peregrina (Riedel) Sanfilippo and Riedel, 1970, p. 451, pl. 1, fig. 10.
Remarks: As was observed in the north Pacific (Kling, 1973), the specimens of *S. peregrina* found at Sites 360 and 362 have a less markedly conical third segment than in equatorial regions, with many not conical at all. The same criterion used by Kling (1973) to separate *S. peregrina* and *S. delmontensis* is used here, namely, specimens with the fourth segment as wide as the third, and thicker walled than the fifth and subsequent segments distinguish *S. peregrina*.

Genus CYCLADOPHORA Ehrenberg, 1847

Cycladophora davisiana Ehrenberg
(Plate 4, Figure 5)

Cycladophora davisiana Ehrenberg, 1862, p. 297; 1873, pl. 2, fig. 11; Petrushevskaya, 1967, p. 122, fig. 69, 70.
Theocalyptra davisiana (Ehrenberg) Riedel, 1958, p. 239, pl. 4, fig. 2, 3, text-fig. 10.

Family PTEROCORYIDAE Haeckel, 1881, emend. Riedel, 1967b

Genus LAMPROCYRTIS Kling

Lamprocyrtis hannai (Campbell and Clark)
(Plate 2, Figure 4)

Calocyclas hannai Campbell and Clark, 1944, p. 69, fig. 21, 22; Casey et al., 1972, pl. 3, fig. 10-22.
Calocyclas margatensis Campbell and Clark, 1944, p. 47, pl. 6, fig. 17, 18; Casey et al., 1972, pl. 3, fig. 10-22.

Lamprocyrtis hannai Kling, 1973, p. 638, pl. 5, fig. 12-14, pl. 12, fig. 10-14.

Lamprocyrtis heteroporos (Hays)
(Plate 2, Figures 1, 2)

Lamprocyclas heteroporos Hays, 1965, p. 179, pl. 3, fig. 1; Hays, 1970, p. 214, pl. 1, fig. 3; Kling, 1971, p. 1088, pl. 1, fig. 1.
Lamprocyrtis heteroporos (Hays) Kling, 1973, p. 639, pl. 5, fig. 19-21, pl. 15, fig. 6.

Genus ANTHOCYRTIDIUM Haeckel, 1881

Anthocyrtidium angulare Nigrini

Anthocyrtidium angulare Nigrini, 1971, p. 445, pl. 34.1, fig. 3a, 3b.
Anthocyrtidium ophirense (Ehrenberg).
Anthocyrtidium cineraria Haeckel, 1887, p. 1278, pl. 62, fig. 16.
Anthocyrtidium ophirense (Ehrenberg) Nigrini, 1967, p. 56, pl. 6, fig. 3.

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PLATE 1
(Scale = 100 μm)

Figure 1 *Ommatartus tetrathalamus.*
Sample 360-4-3, 99-101 cm.

Figure 2 *Ommatartus penultimus.*
Sample 362-4-4, 99-101 cm.

Figure 3 *Ommatartus antepenultimus* (broken).
Sample 360-10-2, 99-101 cm.

Figure 4 *Axopunum angelinum.*
Sample 362-7-4, 99-101 cm.

Figure 5 *Cornutella profunda.*
Sample 362-6-4, 99-101 cm.

Figure 6 *Spongocore puella.*
Sample 362-14-4, 99-101 cm.

Figure 7 *Eucyrtidium calvertense.*
Sample 362-24-4, 99-101 cm.

PLATE 2
(Scale = 100 μm)

Figure 1 *Lamprocyrtis heteroporos.*
Sample 362-5-4, 99-101 cm.

Figure 2 *L. heteroporos.*
Sample 362-4-4, 99-101 cm.

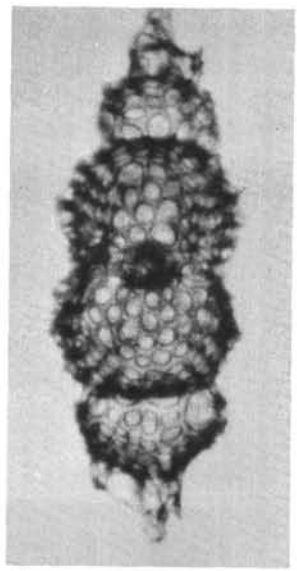
Figure 3 *L. heteroporos.*
Sample 362-15-3, 99-101 cm.

Figure 4 *Lamprocyrtis hannai.*
Sample 362-24-4, 99-101 cm.

Figure 5 *Dictyophimus crisiae.*
Sample 362-6-4, 99-101 cm.

(see p. 852)

PLATE 1



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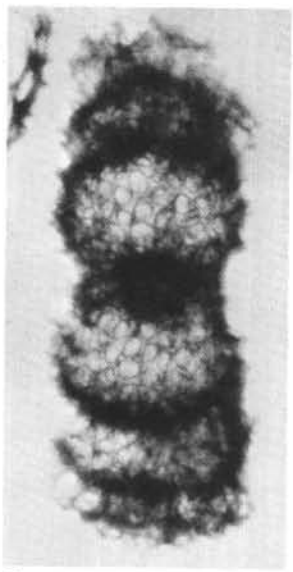

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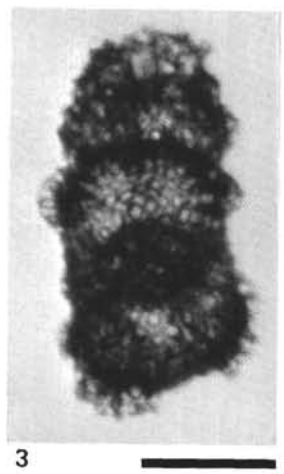

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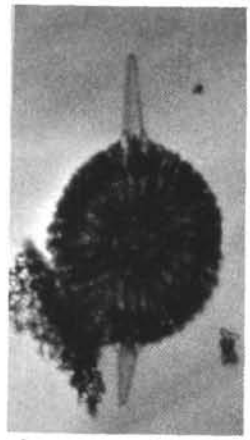

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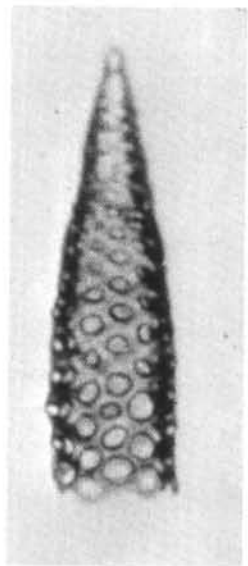

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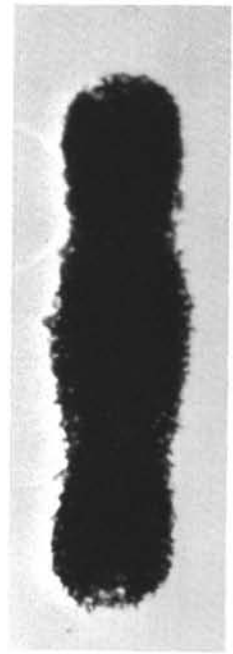

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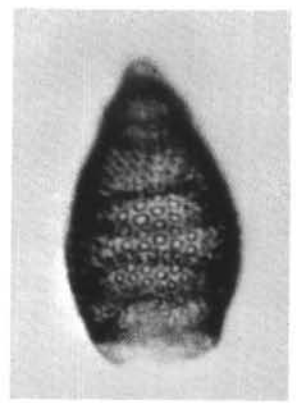

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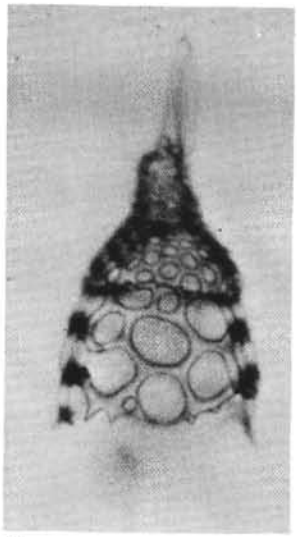
PLATE 2



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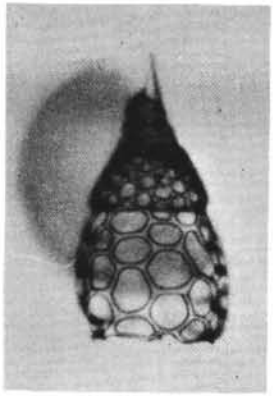

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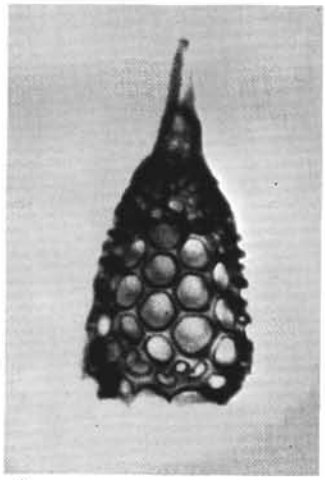

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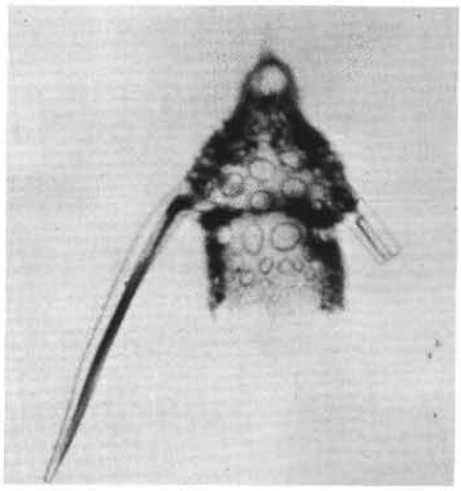


5

PLATE 3
(Scales = 100 μm)

Figure 1 *Stichocorys peregrina.*
Sample 362-24-4, 99-101 cm.

Figure 2 *Stichocorys peregrina.*
Sample 362-24-4, 99-101 cm.

Figure 3 *Stichocorys peregrina.*
Sample 362-18-4, 99-101 cm.

Figure 4 *Lipmanella dictyoceras.*
Sample 362-6-4, 99-101 cm.

Figure 5 *Cycladophora davisiana.*
Sample 362-4-4, 99-101 cm.

Figure 6 *Dictyophimus crisiae.*
Sample 362-2-4, 99-101 cm.

(see p. 854)

PLATE 4
(Sample 365-7-1, 32-35 cm)

Figure 1 *Dorcadospyris* sp. (648×).

Figure 2 *Dorcadospyris* sp. (658×).

Figure 3 *Artophormis gracilis* (624×).

Figure 4 *Lithocyclia angustum* (428×).

(see p. 855)

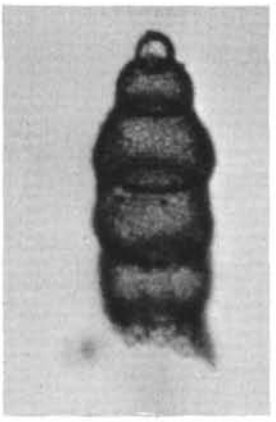
PLATE 5
(Sample 365-7-1, 32-35 cm)

Figure 1 *Lithocyclia* c.f. *La crux* (484×).

Figure 2 *Lithocyclia crux* (396×).

Figure 3 *Lithocyclia crux* (420×).

(see p. 856)



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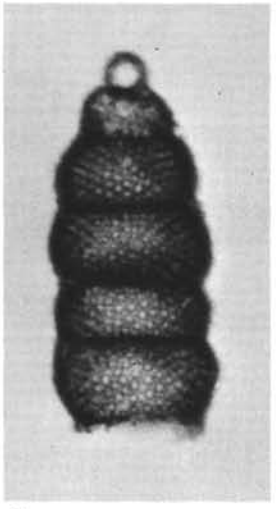

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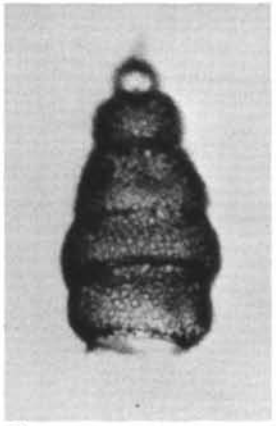

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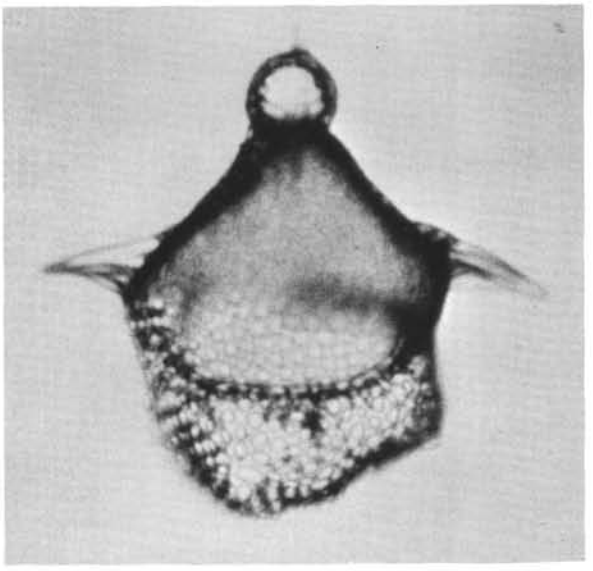

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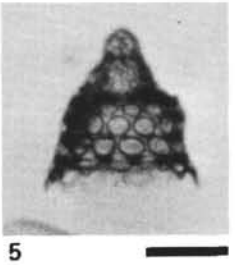

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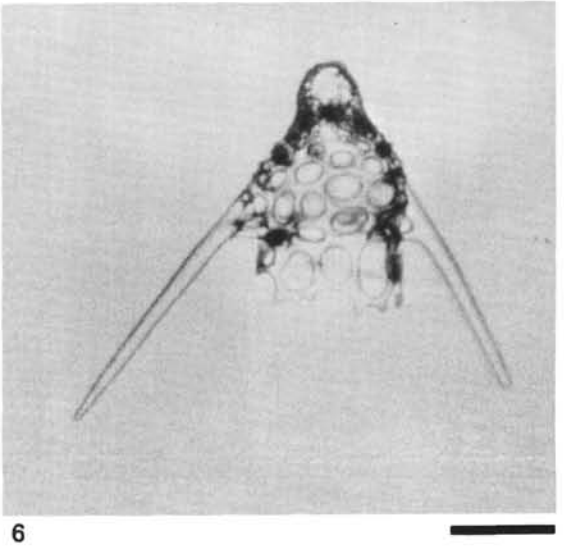

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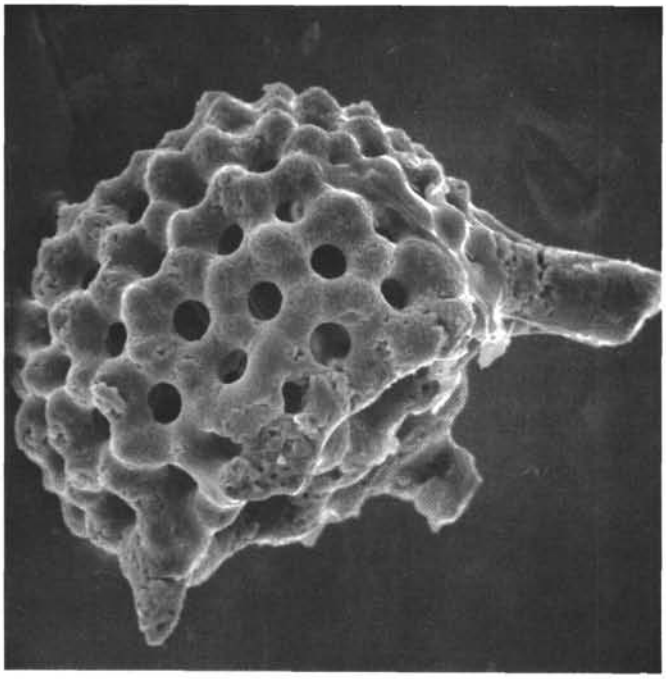
PLATE 4



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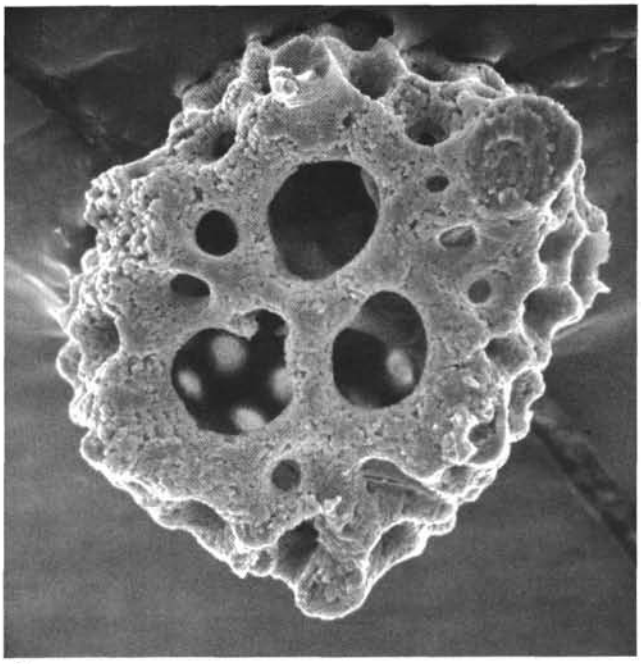

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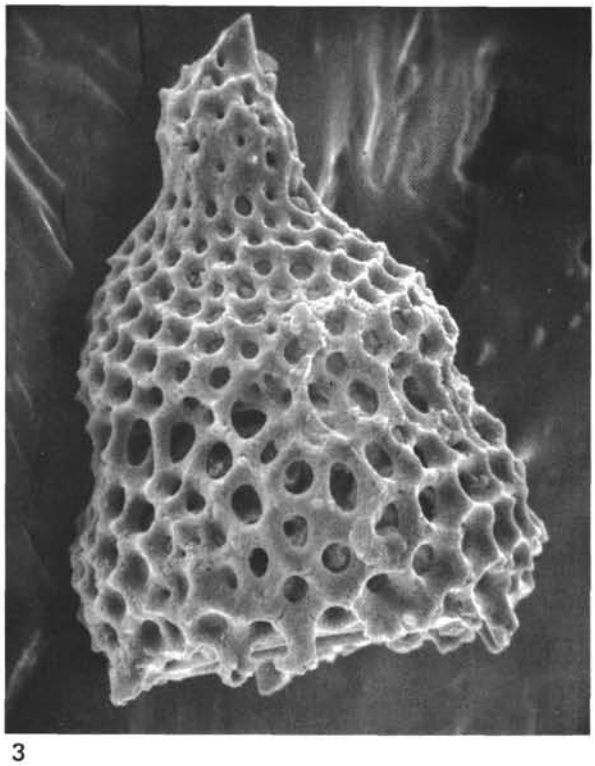

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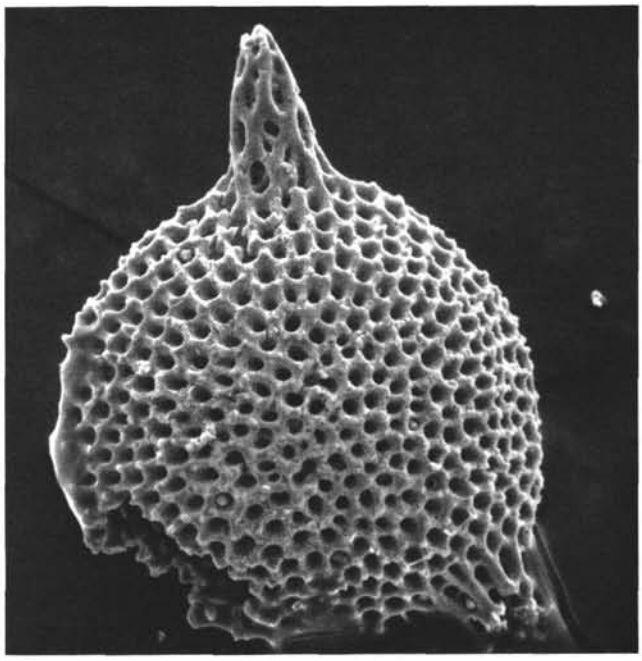

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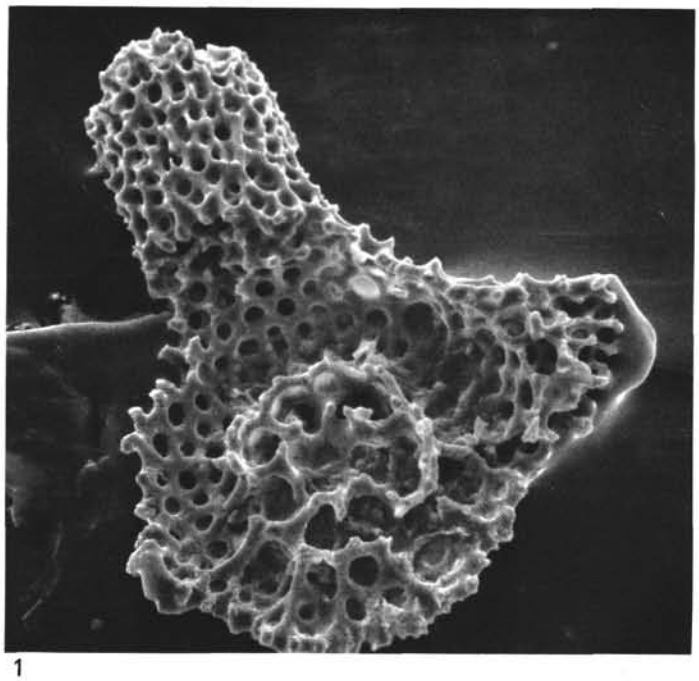
PLATE 5



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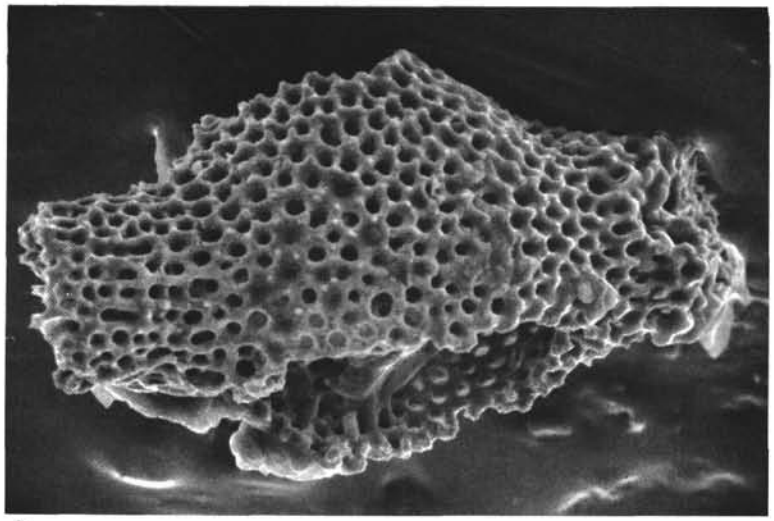

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