12. RADIOLARIA

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CENOZOIC RADIOLARIAN ZONATION

On Leg 8 the entire Cenozoic section from the lowermost Oligocene to the Quaternary was sampled and contained Radiolaria at most of the sites cored. In addition, those parts of the Upper and Middle Eocene sampled usually contained Radiolaria. No sediments cored on Leg 8 were identified as being older than early Middle Eocene.

The generalized range chart of the species used in this study is presented in Figure 1. In composing this chart reliance was placed mainly on the long, unmixed sections which were continuously cored. The work of Riedel and Sanfilippo (1970) was followed in those parts of the Cenozoic section which either were not continuously cored (the Upper to Middle Eocene) or contained some mixed older or younger microfossils (particularly the Upper Miocene and Pliocene).

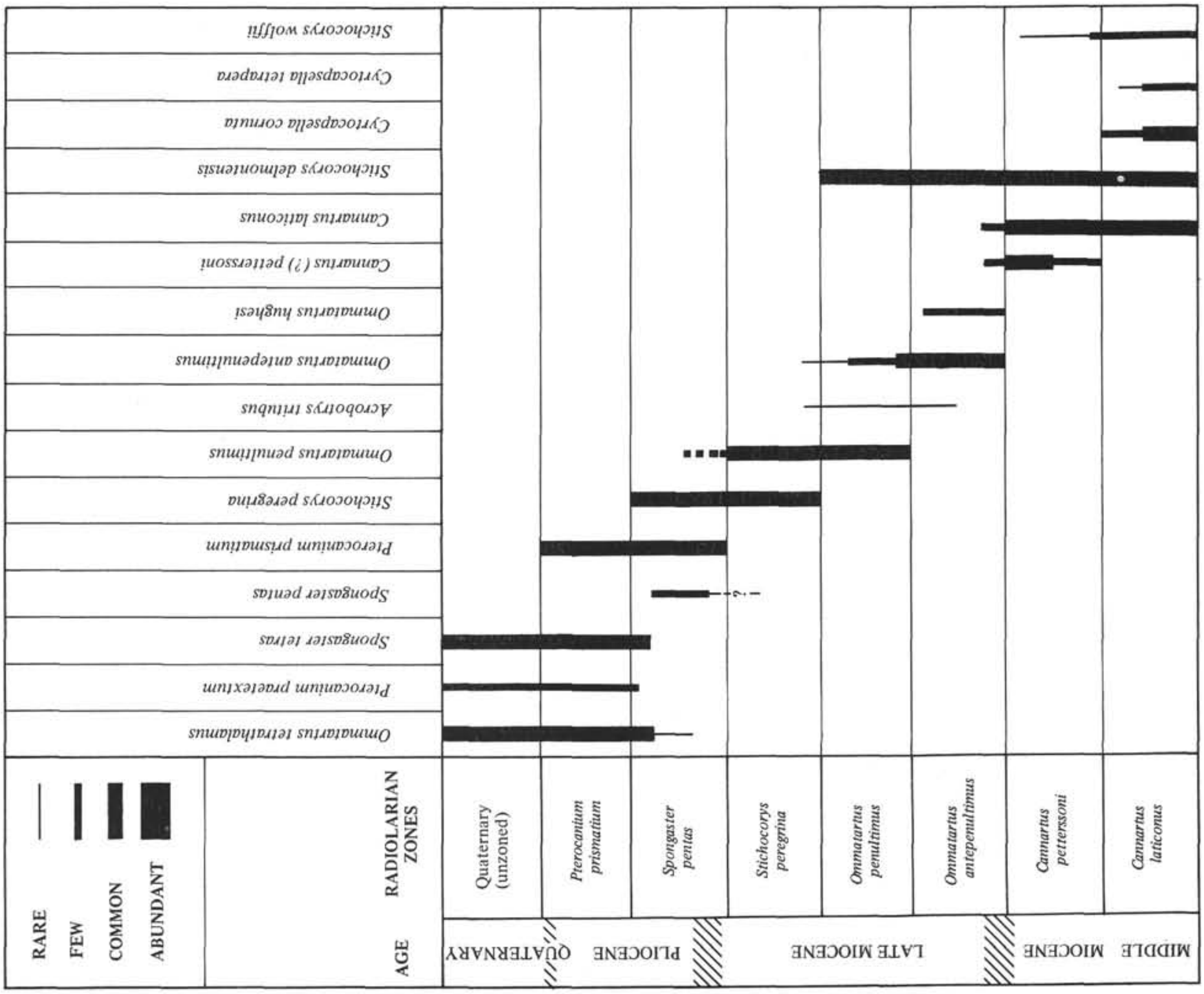

Figure 1. *Generalized radiolarian range chart and zonation for DSDP Leg 8. The zonation is based on that of Riedel and Sanfilippo (1970), with the addition of one new zone in the Eocene and two in the Oligocene.*

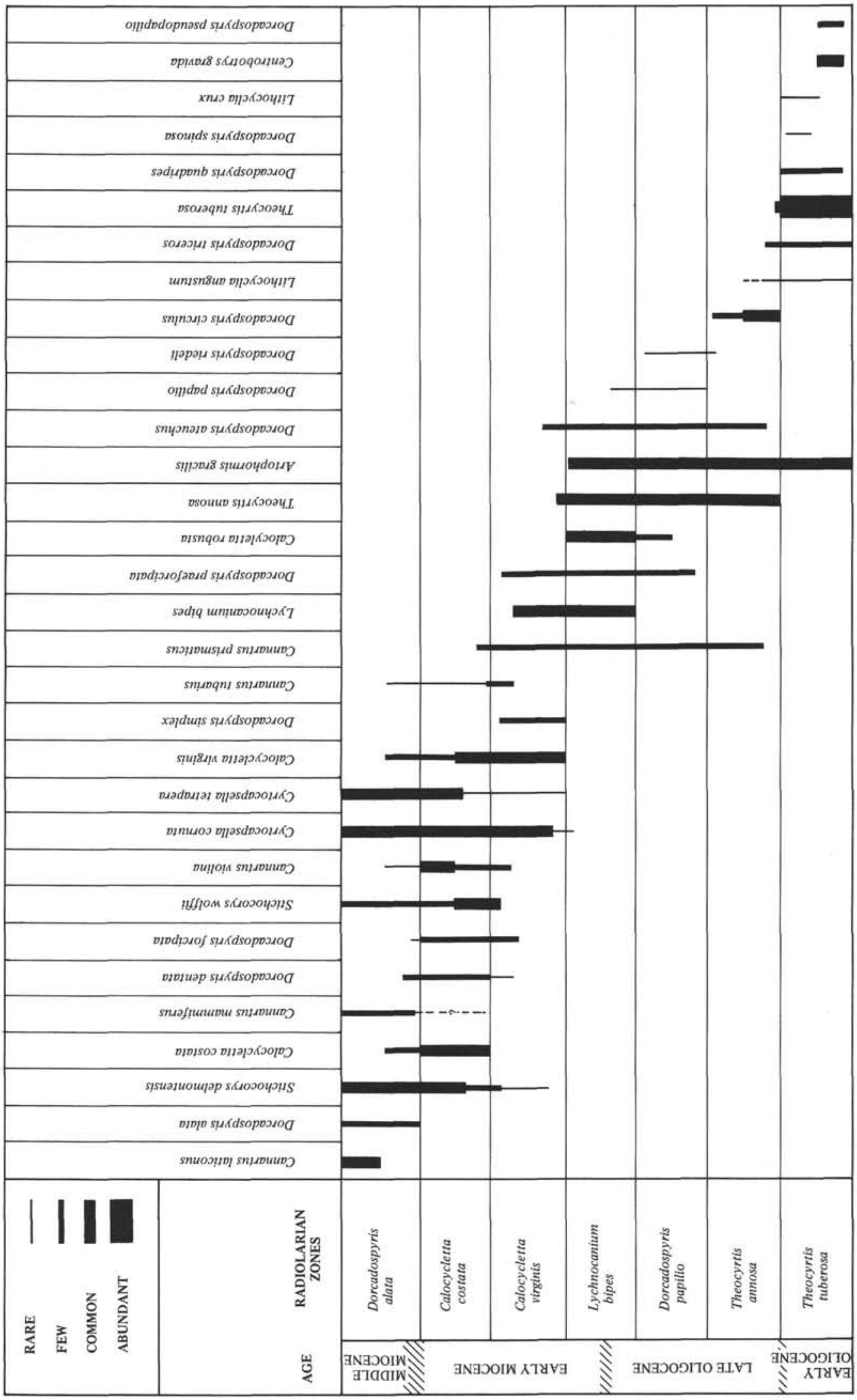

Figure 1. *Continued.*

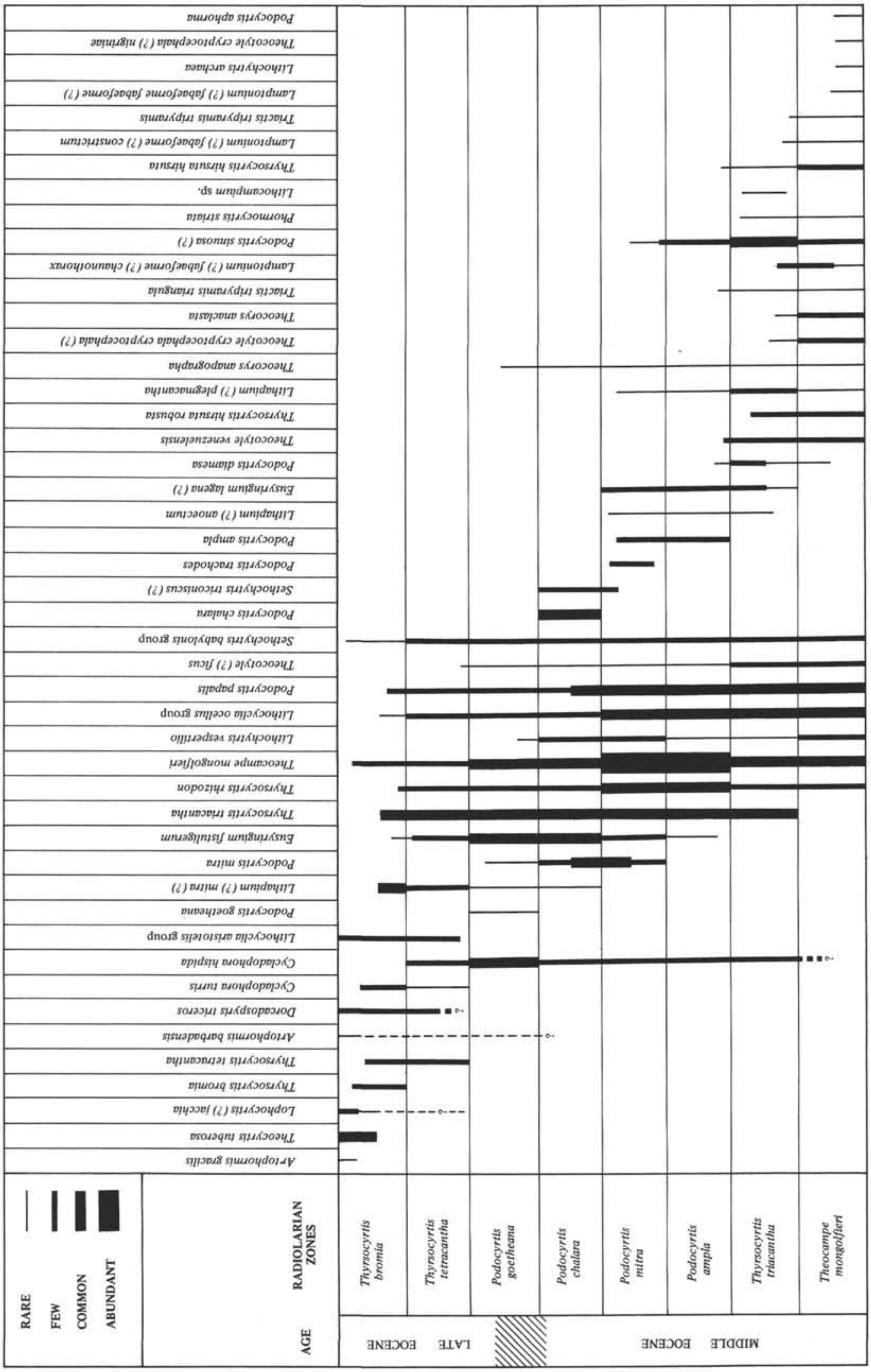

Figure 1. *Continued.*

The results of Leg 8 have allowed the addition of three new zones to those of Riedel and Sanfilippo (1970): one in the Eocene and two in the Oligocene. The new Oligocene zones are based on two continuously cored sections (Sites 69 and 70) and three partially cored sections (Sites 71, 72 and 73). Definitions of the Oligocene and Lower Miocene zones proposed by Riedel and Sanfilippo (1970) are modified to accommodate these new zones. The correlation of the radiolarian zones with those of other microfossil groups is given in the Biostratigraphy Summary.

Radiolarian Zone Definitions

Theocampe mongolfieri Zone (not sampled on Leg 8)

Base: First evolutionary appearance of *Theocampe mongolfieri.*

Top: Coincident with the base of *Thyrsocyrtis triacantha* Zone.

Last occurrences within this zone: *Podocyrtis aphorma, Theocotyle cryptocephala* (?) *nigriniae, Lithochytris archea* and *Lamptonium* (?) *fabaeforme fabaeforme.*

First appearance within this zone: *Podocyrtis diamesa.*

Thyrsocyrtis triacantha Zone

Base: First appearance of *Thyrsocyrtis triacantha*, which approximately coincides with the first appearance of *Eusyringium lagena* (?) and last occurrences of *Triactis tripyramis tripyramis* and *Lamptonium fabaeforme* (?) *chaunothorax.*

Top: Coincident with the base of *Podocyrtis ampla* Zone.

Last occurrences within this zone: *Lamptonium fabaeforme* (?) *constrictum, Thyrsocyrtis hirsuta hirsuta, Theocorys anaclasta, Theocotyle cryptochephala cryptocephala* (?), and *Thyrsocyrtis hirsuta robusta.*

First appearance within this zone: *Lithapium* (?) *anoectum.*

Podocyrtis ampla Zone (not sampled on Leg 8)

Base: First evolutionary appearance of *Podocyrtis ampla.*

Top: Coincident with the base of the *Podocyrtis mitra* Zone.

Last occurrences included: *Theocotyle venezuelensis* and *Podocyrtis diamesa.*

First appearance included: *Eusyrgingium fistuligerum.*

Podocyrtis mitra Zone (not sampled on Leg 8)

Base: First evolutionary appearance of *Podocyrtis mitra.*

Top: Coincident with the base of the *Podocyrtis mitra* Zone.

Last occurrences included: *Theocotyle venezuelensis* and *Podocyrtis diamesa.*

First appearance included: *Eusyringium fistuligerum.*

Podocyrtis mitra Zone (not sampled on Leg 8)

Base: First evolutionary appearance of *Podocyrtis mitra.*

Top: Coincident with the base of the *Podocyrtis chalara* Zone.

Last occurrences included: *Podocyrtis sinuosa* (?), *Lithapium* (?) *plegmacantha, Eusyringium lagena* (?), *Lithapium* (?) *anoectum* and *Podocyrtis ampla.*

First appearances included: *Sethochytris triconiscus* (?) and *Lithapium* (?) *mitra* (?).

Total range included: *Podocyrtis trachodes.*

Podocyrtis chalara Zone

Base: First evolutionary appearance of *Podocyrtis chalara.*

Top: Coincident with the base of the *Podocyrtis goetheana* Zone.

Podocyrtis goetheana Zone

Base: First evolutionary appearance of *Podocyrtis goetheana.*

Top: Coincident with the base of the *Thyrsocyrtis tetracantha* Zone.

First appearance included: *Lithocyclia aristotelis* group.

Thyrsocyrtis tetracantha Zone (not sampled on Leg 8)

Base: First evolutionary appearance of *Thyrsocyrtis tetracantha.*

Top: Coincident with the base of the *Thyrsocyrtis bromia* Zone.

Last occurrences included: *Podocyrtis papalis, Thyrsocyrtis tetracantha, Cycladophora turris, Thyrsocyrtis triacantha, Thyrsocyrtis rhizodon, Theocampe mongolfieri, Lithocyclia ocellus* group, and *Sethochytris babylonis* group.

First appearances included: *Artophormis gracilis* and *Theocyrtis tuberosa.*

Total range included: *Thyrsocyrtis bromia.*

Theocyrtis tuberosa Zone

Base: First appearance of *Lithocyclia angustum.*

Top: Coincident with the base of the *Theocyrtis annosa* Zone.

Total ranges included: *Dorcadospyris pseudopapilio, Centrobotrys gravida, Lithocyclia crux,* and *Dorcadospyris spinosa.*

Theocyrtis annosa Zone

Base: First appearance of *Theocyrtis annosa*, which approximately coincides with the last occurrence of *Theocyrtis tuberosa* and with the earliest appearance of *Dorcadospyris circulus.*

Top: Coincident with the base of the *Dorcadospyris papilio* Zone.

Last occurrences included: *Dorcadospyris triceros* and *Lithocyclia angustum.*

First appearances included: *Dorcadospyris ateuchus* and *Cannartus prismaticus.*

Total range included: *Dorcadospyris circulus.*

Dorcadospyris papilio Zone

Base: First appearance of *Dorcadospyris papilio*, which approximately coincides with the earliest appearance of *D. riedeli.*

Top: Coincident with the base of the *Lychnocanium bipes* Zone.

Last occurrence included: *Dorcadospyris riedeli.*

First appearances included: *Dorcadospyris praeforcipata* and *Calocycletta robusta.*

Lychnocanium bipes Zone

Base: First appearance of *Lychnocanium bipes.*

Top: Coincident with the base of the *Calocycletta virginis* Zone.

Last occurrences included: *Dorcadospyris papilio* and *Artophormis gracilis.*

Calocycletta virginis Zone

Base: First appearance of *Calocycletta virginis*, which approximately coincides with the last occurrence of *C. robusta* and the first appearances of *Cyrtocapsella cornuta* and *C. tetrapera.*

Top: Coincident with the base of the *Calocycletta costata* Zone.

Last occurrences included: *Theocyrtis annosa, Dorcadospyris ateuchus, D. praeforcipata,* and *Lychnocanium bipes.*

First appearances included: *Dorcadospyris forcipata, D. dentata, Stichocorys delmontense* and *S. wolffii.*

Total range included: *Dorcadospyris simplex.*

Calocycletta costata Zone

Base: First evolutionary appearance of *Calocycletta costata.*

Top: Coincident with the base of the *Dorcadospyris alata* Zone.

Last occurrence included: *Cannartus prismaticus.*

First appearance included: perhaps *Cannartus mammiferus.*

Dorcadospyris alata Zone

Base: First evolutionary appearance of *Dorcadospyris alata*, which approximately coincides with the last occurrence of *D. forcipata.*

Top: Coincident with the base of the *Cannartus laticonus* Zone.

Last occurrence included: *Dorcadospyris dentata, Cannartus mammiferus, Calocycletta virginis* and *C. costata.*

First occurrence included: *Cannartus laticonus.*

Total range included: *Dorcadospyris alata.*

Cannartus laticonus Zone

Base: Last occurrence of *Dorcadospyris alata.*

Top: Coincident with the base of the *Cannartus* (?) *petterssoni* Zone.

Cannartus (?) *petterssoni* Zone

Base: First evolutionary appearance of *Cannartus petterssoni.*

Top: Coincident with the base of the *Ommatartus antepenultimus* Zone.

Ommatartus antepenultimus Zone

Base: First evolutionary appearance of *Ommatartus antepenultimus*, which approximately coincides with the last occurrence of *Cannartus laticonus.*

Top: Coincident with the base of the *Ommatartus penultimus* Zone.

Last occurrence included: *Cannartus petterssoni* and *C. hughesi.*

First appearance included: *Acrobotrys tritubus.*

Ommatartus penultimus Zone

Base: First evolutionary appearance of *Ommatartus penultimus.*

Top: Coincident with the base of the *Stichocorys peregrina* Zone.

Stichocorys peregrina Zone

Base: First evolutionary appearance of *Stichocorys peregrina*, which approximately coincides with the last occurrences of *S. delmontensis* and *Acrobotrys tritubus.*

Top: Coincident with the base of the *Spongaster pentas* Zone.

Spongaster pentas **Zone**

Base: First appearance of *Pterocanium prismatium.*

Top: Coincident with the base of the *Pterocanium prismatium* Zone.

Last occurrences included: *Spongaster pentas* and *Ommatartus penultimus.*

First appearances included: *Spongaster tetras, Pterocanium praetextum* and *Ommatartus tetrathalamus.*

Pterocanium prismatium **Zone**

Base: Last occurrence of *Stichocorys peregrina.*

Top: Last occurrence of *Pterocanium prismatium.*

PRESERVATION

Radiolaria were generally present and moderately well preserved at all sites except Site 75. Based on a subjective estimate of the degree of preservation of samples from each stratigraphic age, the radiolarian faunas from each site can be ranked according to their preservation (Table 1). The presence or absence of Radiolaria and their relative degrees of preservation can be tied to one or more of the following, interrelated factors: (a) rate of sediment accumulation, (b) spatial location, (c) age, and (d) diagenetic processes.

TABLE 1

Relative degrees of preservation of radiolarian faunas ranked for each stratigraphic age. Highest rank equivalent to best preservation. Rank equals zero when section missing or nonfossiliferous. Ranks based on a subjective estimate of the degree of solution of the best preserved assemblages from each site.

	Site No.							
	68	69	70	71	72	73	74	75
Quaternary	1	0	2	5	6	4		0
Pliocene	0	0	1	3	5	4	2	0
Upper Miocene	0	0	2	5	4	3	1	0
Middle Miocene	0	3.5	1	6	5	3.5	2	0
Lower Miocene	0	3	5	6	4	2	1	0
Upper Oligocene	0	5	3	4	1	2	0	0
Lower Oligocene	0	4	5	3	1	2	0	0
Upper Eocene	0	5	4	1	2	3	0	0
Middle Eocene	1	3	2	0	0	0	0	0

Rate of Sediment Accumulation

As a first approximation, the preservation of biogenous silica is expected to be related to the rate of total sediment accumulation. A comparison of the ranked rates of sediment accumulation for each stratigraphic grouping (from table in the Summary section) and the ranked degrees of preservation (Table 1) shows that although there is such a general trend, the match of the ranks is far from perfect (Figure 2). The highly subjective nature of the preservation ranking probably accounts for some of the scatter in this plot. A second cause for the lack of a direct correspondence may be the presence of erosional hiatuses. Breaks in the stratigraphic record that are due to the removal of a portion of the sedimentary column might leave a section with a very well-preserved radiolarian assemblage and a very low net rate of accumulation. Other explanations must be found for cases in which accumulation rates are reasonably high and yet no siliceous microfossils are found (for example, the lower part of Site 74 and all of Site 75).

Spatial Location

In the Middle and Upper Miocene, Pliocene, and Quaternary the best preserved radiolarian assemblages are found at the sites nearest the equator (Sites 71, 72 and 73, Table 4). This is in general agreement with the latitudinal pattern of productivity and the distribution of sediment accumulation rates discussed in this volume. Below the Middle Miocene the radiolarian faunas at Site 70 (north of the Clipperton Fracture Zone) are well preserved; however, radiolarian faunas in sections drilled at and south of the equator becomes less well preserved with increasing age. In particular, Site 74 (6° 14.2′S) has a very poorly preserved assemblage in the Lower Miocene; and in older parts of the cored section, radiolarian tests are almost totally dissolved. The sediments at the southernmost site (Site 75) are rich in calcareous microfossils, but siliceous microfossils are virtually absent. For the radiolarian faunas there appears to be a general north to south progression with time of a latitudinal band of good preservation similar to the progression of the "axis" of sediment accumulation discussed earlier in this report. The southern extremity of the equatorial zone of sediments containing opaline silica now lies between Sites 74 and 75, at about 10°S; and, the latitudinal extent of the equatorial band of siliceous sediments is greater than that of the calcareous sediments. Prior to the Early Miocene the reverse was true. Siliceous sediments did not reach as far south as Site 74 (6° 14′S), yet carbonate sediments extended south of Site 75 (12° 31′S).

A discussion of the east-west variation in the preservation of siliceous microfossils is best left till the faunas from Leg 9 are studied. However, from the scant evidence provided by a comparison of assemblages at Sites 69 and 70, the preservation of the Middle Miocene to Middle Eocene radiolarians appears to be slightly better at the western site (69).

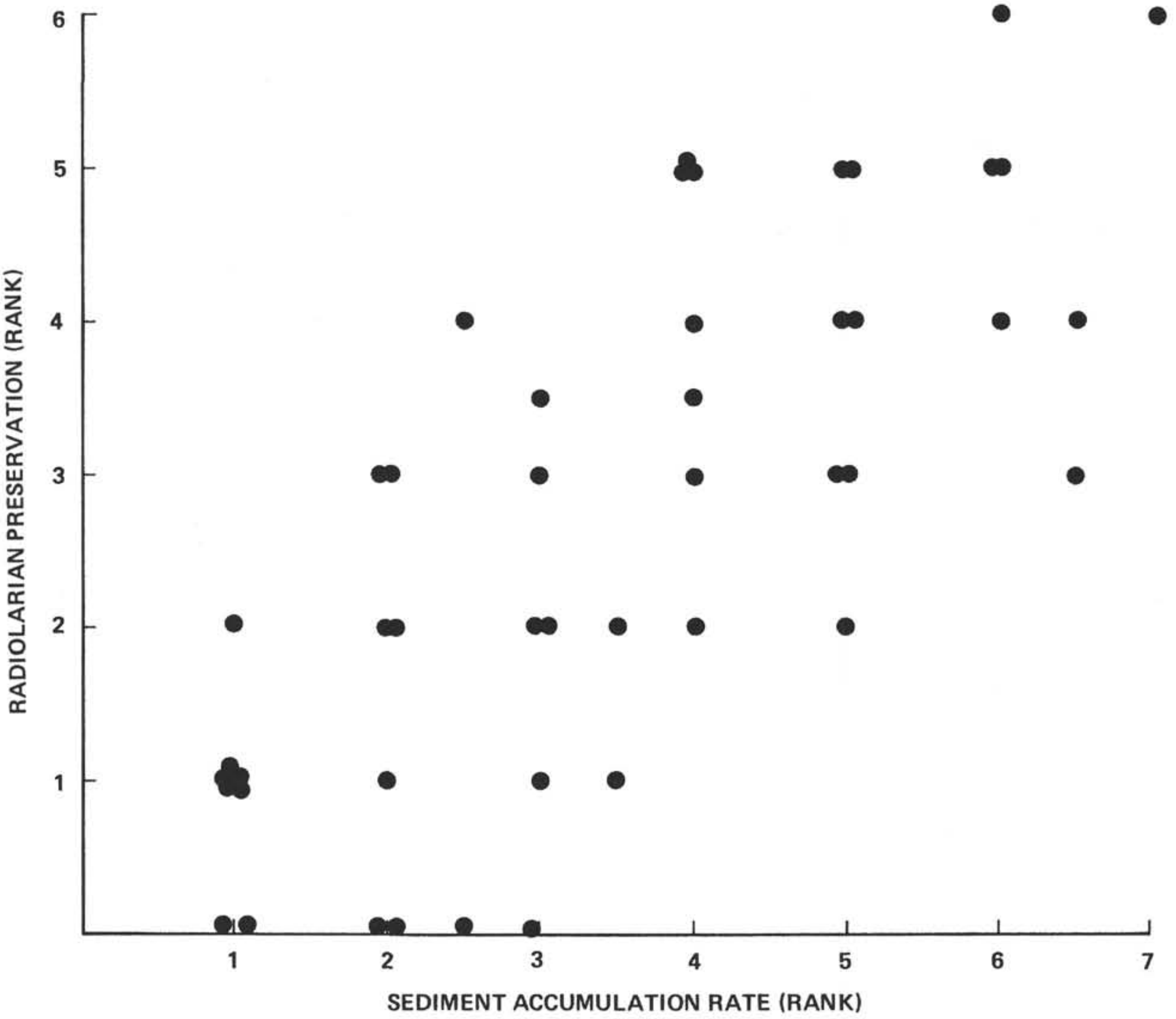

Figure 2. *Ranked preservation of radiolarian faunas for each stratigraphic age (from Table 1) plotted as a function of the ranked sediment accumulation rates for the same age groupings.*

Age

It is difficult to judge the relative degrees of preservation in radiolarian samples of different ages. It has been shown that the radiolarians of the equatorial Pacific have gradually developed a lower average test weight (Moore, 1969). The average test weight of Eocene Radiolaria is approximately four times that of Quaternary Radiolaria. The heavy tests of the Eocene fauna may show few signs of corrosion even though they have undergone solution that would lead to the mechanical disintegration of a large portion of the tests in younger faunas. Therefore, comparisons are generally made to a standard "best preserved fauna" within each stratigraphic age grouping (for example, as in Table 1). When comparing faunas of different ages only gross changes in the degree of preservation can be pointed out with certainty. Such changes occur in those parts of the cored sections in which hiatuses and the reworking of older microfossils are common (that is, near the Eocene-Oligocene boundary and in the Middle Miocene to Pliocene, Figure 3). The total fauna of the mixed assemblages appears less well preserved. Many of the tests are broken; spongy specimens and the delicate meshwork found on some species are destroyed. To some extent the degree of solution in such a mixed assemblage may be indicated by the proportion of the older, more robust forms.

In addition to those assemblages in which the degree of preservation seems tied to sedimentation processes, radiolarians in the middle part of the Oligocene are frequently found to be very poorly preserved. It is not known whether this general absence of well-preserved middle Oligocene faunas is the result of a period of change in oceanographic conditions or a diagenetic change related to age as well as depth of burial, sediment type, and the chemistry of interstitial solutions.

There are two parts of the stratigraphic section in which biogenic silica preservation appears particularly good: a part of the Lower Oligocene, and those Pliocene-Quaternary cores which do not contain numerous reworked microfossils. In addition to well-preserved Radiolaria, samples from these sections usually contain abundant diatom frustules.

Diagenesis

Silica derived from the tests of microfossils is found as nodular chert within the time-equivalent faunal zones of the foraminifera (Zone P. 21), calcareous nannoplankton (*Sphenolithus distentus*), and Radiolaria (*Theocyrtis annosa*) in the Upper Oligocene part of the section. Bedded chert is found in the Middle to Upper Eocene. Radiolarian skeletal debris is preserved in these cherts; however, above and below the nodules and beds the sediment is devoid of siliceous tests. Severe corrosion may extend a few centimeters to several meters above and below the cherts. In the case of the Oligocene cherts, the solution effects in the vicinity of nodules are difficult to separate from the general deterioration in preservation of siliceous tests throughout the middle part of the Oligocene section.

In addition to these obvious results of the diagenesis of opaline silica, there are other subtle but more pervasive indications of silica solution and local reprecipitation. Many samples from the lower and middle Tertiary contain small clods of cemented clay particles and bits of siliceous tests. Often these clods are found within the spherical cavity of a radiolarian test. The clods are not broken up by treatment with concentrated hydrochloric acid (HCl) and ultrasonic agitation; only a strong base will disaggregate them. It seems that the clods are cemented by, and predominantly formed of opaline silica that has dissolved from the siliceous tests and reprecipitated in the nearby sediment.

BREAKS IN THE STRATIGRAPHIC RECORD

Much of the sedimentary section sampled on Leg 8 was continuously cored; therefore, breaks in the stratigraphic record and reworking of older microfossils are more clearly evidenced than in sections that have only been spot cored. As shown by the Radiolaria, there are two parts of the stratigraphic column in which hiatuses and mixed assemblages commonly appear: the Middle Miocene to Pliocene and the Upper Eocene to Lower Oligocene (Figure 3). Mixing appears most intense in the Upper Tertiary part of the section. The gradual nature of the progression from mostly unmixed faunas in the Upper Oligocene to the highly mixed assemblages of the Pliocene (Figure 3) is dependent on location as well as time. At Site 68 (16° 43.3′N) a hiatus separates the Middle Eocene from the highly mixed fauna found in the top sample. Further south, at Site 69 (6°N) a hiatus represents Late Miocene to Holocene time; and at Site 70, near the same latitude but to the east of Site 69, breaks in the stratigraphic record are found within the Pliocene and Upper Miocene. South of the equator at Site 75 (12° 31′S), a hiatus extends from the Lower Miocene to the Holocene, and at Sites 74 (6° 14′S) and 73 (1° 54.6′S) breaks are found in the Upper and Middle Miocene. Only the near-equatorial Sites 71 and 72 contain thick, unmixed Tertiary sections.

The common occurrence of older microfossils, particularly from the Eocene, in Miocene to Quaternary sections, and the existence of Tertiary material cropping out on the sea floor of the central equatorial Pacific has been previously described from material collected by conventional gravity and piston cores (Riedel, 1957; Riedel and Funnell, 1964; Moore, 1970). This mixing and the outcropping of Tertiary sediments has been attributed to small-scale faulting or slumping which began sometime during or after the

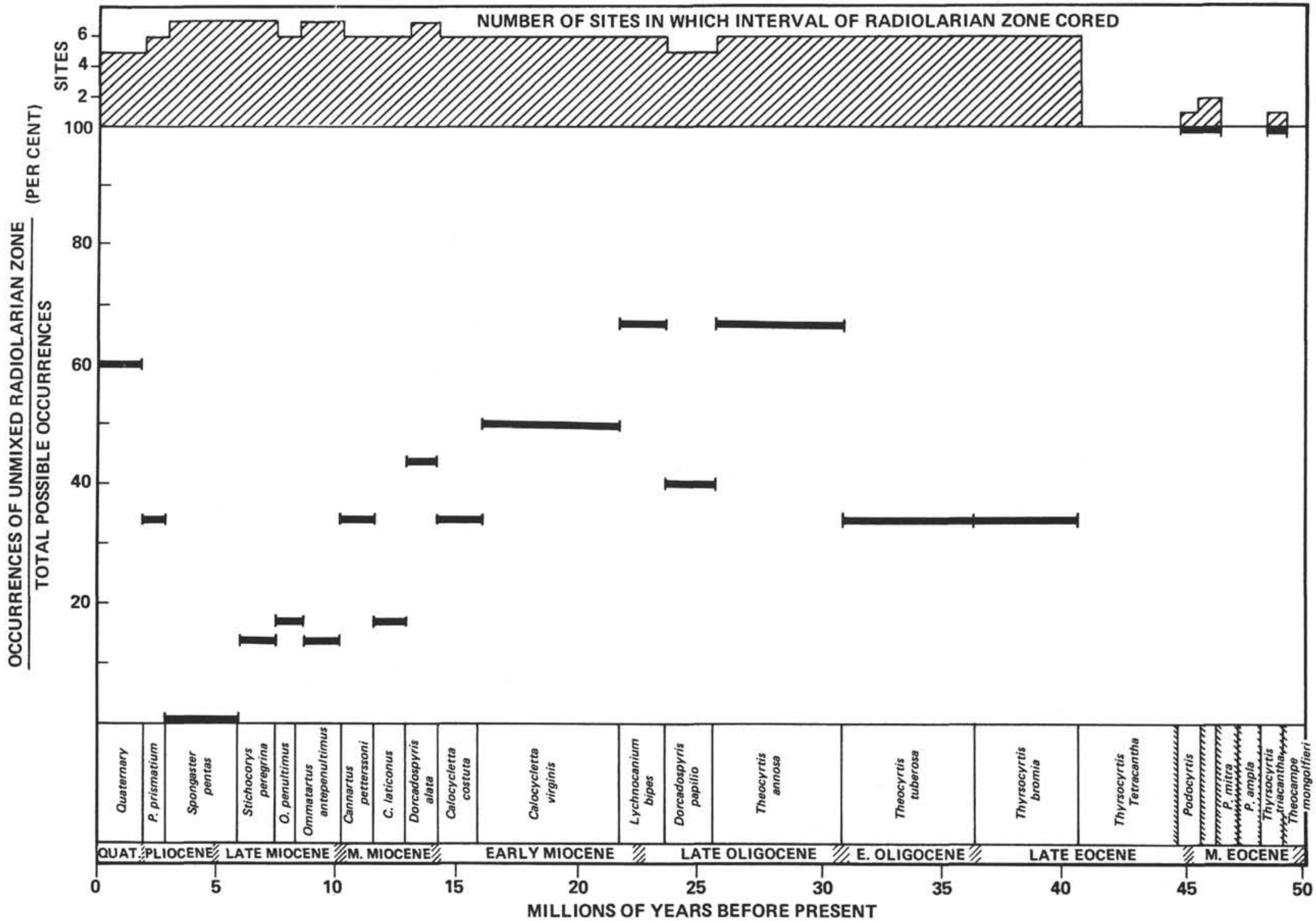

Figure 3. *Occurrence of pure (unmixed) radiolarian faunas for each radiolarian zone. Number of sites in which interval of each zone was cored is given in top bar graph. Zones were considered missing when, based on the zone definition, they could not be found in a continuously cored interval and partially missing when the range of one or more species indicated a short break in the stratigraphic record. Zones were considered mixed when more than 25 per cent of the samples studied from each zone contained admixed older radiolarians.*

Middle Miocene (Moore, 1970). It has been fairly well established that the admixed older microfossils must be transported laterally from outcrops of older sediments and redeposited with younger assemblages. Upward mixing by burrowing organisms is ruled out in most cases by the thickness of the stratigraphic section over which mixing must occur and by the abundance and age of the admixed faunas (for example, this report, Site 68 discussion on Radiolaria; Berger and Heath, 1969).

Where sediment accumulation rates are high, the age span represented by the admixed older microfossils and the amount of admixed material is minimal. If both the section from which the older microfossils are derived and the younger section in which they are deposited are rich in carbonate, the foraminifera, Radiolaria and the calcareous nannofossils show the effects of the reworking. However, additional solution of the microfossils, particularly the calcareous forms, takes place during reworking and the more fragile forms may be destroyed. For example, in the Eocene sediments recovered on Leg 8 the calcareous microfossils are comparatively sparse, and the rather robust Eocene Radiolaria are quite common. Thus, upon re-exposure, reworking and redeposition, calcareous microfossils—if at all present in the Eocene sediments—are usually destroyed by solution, while the heavy, siliceous tests of the Radiolaria remain intact. Eocene Radiolaria are found in Oligocene, Miocene, Pliocene and even Quaternary sediments where calcareous microfossils give no evidence of the reworking.

SYSTEMATIC SECTION

The classification of Radiolaria is based on the recent revisions proposed by Riedel (1967, 1970), and, for the Trissocyclidae by Goll (1969). The systematics follow closely the work of Riedel and Sanfilippo (1970) and Sanfilippo and Riedel (1970) which contain more extensive synonomies than are presented here.

Type specimens will be deposited in the U. S. National Museum, Washington D. C.

Order POLYCYSTINA Ehrenberg

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

Suborder SPUMELLARIA Ehrenberg 1875

Family ACTINOMMIDAE Haeckel

Actinommidae Haeckel, 1862, emend. Riedel, 1 67b p. 294.

Genus *Lithapium* Haeckel

Lithapium Haeckel, 1887, p. 303. Type species (designated by Campbell, 1954, p. 69) *Lithapium pyriforme* Haeckel (1887, p. 303, Plate 14, Figure 9).

The following species are tentatively assigned to this genus by Riedel and Sanfilippo (1970):

Lithapium (?) *plegmacantha* Riedel and Sanfilippo
(Plate 1, Figure 1)

Lithapium (?) *plegmacantha* Riedel and Sanfilippo, 1970, Plate 4, Figures 2, 3.

Lithapium (?) *anoectum* Riedel and Sanfilippo

Lithapium (?) *anoectum* Riedel and Sanfilippo, 1970, Plate 4, Figures 4, 5.

Lithapium (?) *mitra* (Ehrenberg) (?)
(Plate 3, Figure 1)

(?) *Cornutella mitra* Ehrenberg, 1873, p. 221: 1875 Plate 2, Figure 8.
(?) *Cornutella circularis* Ehrenberg, 1873, p. 221; 1875, Plate 2, Figure 4.
Lithapium (?) *mitra* (Ehrenberg); Riedel and Sanfilippo, 1970, Plate 4, Figures 6, 7.

Genus *Cannartus* (Haeckel)

Cannartus Haeckel, 1881, p. 462. Type species (indicated by Campbell, 1954, p. 74). *Cannartus violina* Haeckel (1887, p. 358, Plate 39, Figure 10).
Cannartus Haeckel, emend.; Riedel, *in press a.*

Cannartus prismaticus (Haeckel)
(Plate 12, Figures 1, 2)

Pipetella prismatica Haeckel, 1887, p. 305.
Cannartus prismaticus (Haeckel); Riedel and Sanfilippo, 1970a, Plate 15, Figure 1.

Cannartus tubarius (Haeckel)
(Plate 12, Figure 3)

Pipettaria tubaria Haeckel, 1887, p. 339, Plate 39, Figure 15; Riedel, 1959, p. 289, Plate 1, Figure 2.
Cannartus tubarius (Haeckel); Riedel and Sanfilippo, 1970, Plate 15, Figure 2.

Cannartus violina Haeckel
(Plate 12, Figure 4)

Cannartus violina Haeckel, 1887, p. 358, Plate 39, Figure 10; Riedel, 1959, p. 290, Plate 1, Figure 3.

Cannartus mammiferus (Haeckel)
(Plate 12, Figure 5)

Cannartidium mammiferum Haeckel, 1887, p. 375, Plate 39, Figure 16.
Cannartus mammiferus (Haeckel); Riedel, 1959, p. 291, Plate 1, Figure 4.

Cannartus laticonus Riedel
(Plate 12, Figure 6)

Cannartus laticonus Riedel, 1959, p. 291, Plate 1, Figure 5.

Cannartus petterssoni Riedel and Sanfilippo
(Plate 12, Figure 7)

Cannartus petterssoni conditional manuscript name proposed in Riedel and Funnell, 1964, p. 310; Riedel and Sanfilippo, 1970a, Plate 14, Figure 3.

Genus *Ommatartus* Haeckel

Ommatartus Haeckel, 1881, p. 463. Type species indicated by Campbell, 1954, p. 76. *Ommatartus amphicanna* Haeckel (1887, p. 396).
Ommatartus Haeckel, emend.; Riedel (in press, a).

Ommatartus antepenultimus Riedel and Sanfilippo
(Plate 12, Figures 9 and 10)

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

Ommatartus hughesi (Campbell and Clark)
(Plate 12, Figure 8)

Ommatocampe hughesi Campbell and Clark, 1944a, p. 23, Plate 3, Figure 12.
Ommatartus hughesi (Clark and Campbell); Riedel and Sanfilippo, 1970, p. 521.

Ommatartus penultimus (Riedel)
(Plate 12, Figure 11)

Panarium penultimum Riedel, 1957a, p. 76, Plate 1, Figure 1.
Ommatartus penultimus (Riedel); Riedel and Sanfilippo (sensu. stricto), p. 521.

Ommatartus tetrathalamus (Haeckel)
(Plate 12, Figure 12)

Panartus tetrathalamus Haeckel, 1887, p. 378, Plate 40, Figure 3; Nigrini, 1967, p. 30-32, Plate 2, Figures 4a-4d.

Family PHACODISCIDAE Haeckel, 1881

Genus *Triactis* Haeckel

Triactis Haeckel, 1881, p. 457; as used by Riedel and Sanfilippo, 1970, p. 521.

Triactis tripyramis tripyramis Haeckel
(Plate 1, Figure 8)

Triactis tripyramis Haeckel, 1887, p. 432, Plate 33, Figure 6.
Triactis tripyramis tripyramis, Haeckel; Riedel and Sanfilippo, 1970, p. 521, Plate 4, Figure 8.

Triactis tripyramis triangula (Sutton)
(Plate 1, Figure 9)

Phacotriactis triangula Sutton, 1896a, p. 61.
Triactis trypyramis triangula (Sutton); Riedel and Sanfilippo, 1970, p. 521, Plate 4, Figures 9, 10.

Family COCCODISCADAE Haeckel, 1862

Genus *Lithocyclia* Ehrenberg

Lithocyclia Ehrenberg 1847a, chart to p. 385. Type species (by monotypy) *Lithocyclia ocellus* Ehrenberg (1854, p. 136, Figure 30; 1873, p. 240; 1875, Plate 29, Figure 3) and as used by Riedel and Sanfilippo, 1970, p. 522.

Lithocyclia crux, new species
(Plate 6, Figure 4)

Description: Phacoid cortical shell approximately two to three times as broad as medullary shell with subcircular to irregular pores. Cortical shell may be filled with spongy meshwork. Four arms, approximately perpendicular and in the same plane, are very irregularly pored to form spongy, subcylindrical columns. In rare specimens a spongy patagium is preserved. It connects the base of the arms and is formed parallel to the cortical shell. This species resembles *Lithocyclia angustum* (Riedel) in all respects except the number of arms.
Dimensions (based on 30 specimens): Diameter of cortical shell 113-132μ; of medullary shell (shadowy outline seen through cortical shell) 37-66μ; Length of arms 75-168μ; median breadth 22-47μ.
Localities and stratigraphic range: Deep Sea Drilling Project, Leg 8. Site 69: 69-5, 69A-7-1. Site 70: 70-17cc, 70-18, 70-20cc, 70-21cc, 70-22cc, 70-23cc, 70-24, 70-25cc. Site 73, 73-15-5 through 73-16-3. This species is found within the upper part of the *Theocyrtis tuberosa* Zone, Lower Oligocene to lowermost Upper Oligocene.
Remarks: This species is closely related to *L. angustum,* but has a much more restricted stratigraphic range. Within its range it is not a common species (rare to few in abundance), but is sometimes more abundant than *L. angustum.* There is no evidence that it is in the direct line of the *Lithocyclia-Cannartus* lineage. It may be possible that the three armed form of the *L. aristotelis* group gave rise to *L. angustum*, while the four armed *L. aristotelis* gave rise to the *L. crux.*

Lithocyclia angustum (Riedel)
(Plate 6, Figures 5 and 6)

Trigonactura angusta Riedel, 1959, p. 292, Plate 1, Figure 6.
Lithocyclia angustum (Riedel); Riedel and Sanfilippo, 1970, p. 13, Figures 1, 2.
Remarks: A very late form of this species is shown in Figure 6 of Plate 5.

Lithocyclia ocellus group
(Plate 4, Figure 1)

Lithocyclia ocellus group as used by Riedel and Sanfilippo, 1970, p. 522, Plate 5, Figures 1, 2.

Lithocyclia aristotelis group
(Plate 6, Figures 4 and 5)

Lithocyclia aristotelis group as used by Riedel and Sanfilippo, 1970, p. 522.

Family SPONGODISCIDAE Haeckel

Spongodiscidae Haeckel, 1862, emend. Riedel, 1967b, p. 295.

Genus *Spongaster* Ehrenberg

Spongaster Ehrenberg, 1860, p. 833. Type species (by monotypy)
Spongaster tetras Ehrenberg (1860; p. 833; 1861, p. 301; 1872b, Plate 6[3], Figure 8).

Spongaster tetras Ehrenberg
(Plate 13, Figure 4)

Spongaster tetras Ehrenberg, 1860, p. 833.

Spongaster pentas, Riedel and Sanfilippo
(Plate 13, Figures 5 and 6)

Spongaster pentas Riedel and Sanfilippo, 1970, p. 523, Plate 15, Figure 3.

Suborder NASSALLARIA Ehrenberg, 1875

Family ACANTHODESMIIDAE, Haeckel, 1862

Acanthodesmiidae Haeckel; Riedel 1967b, p. 296.

Genus *Dorcadospyris* Haeckel

Dorcadospyris Haeckel, 1881, p. 441. Type species (indicated by Campbell 1954, p. 112).
Dorcadospyris dentata Haeckel (1887, p. 1040, Plate 85, Figure 6).
Dorcadospyris Haeckel; emend. Goll 1969, p. 335.

Dorcadospyris praeforcipata new species
(Plate 9, Figures 4, 5, 6 and 7)

Dipodospyris forcipata (var.) Haeckel, Moore, 1968. Plate 4, Figures 2a, 2b, 2c.
Description: Shell nut-shaped, tuberculate with circular to subcircular pores irregularly to hexagonally arranged. A stout, long and tapering apical horn is found on all well-preserved specimens. Two primary feet, long, thick, circular in cross section, converge distally but may have slightly recurved ends, particularly in the early forms. Primary feet usually separated, but may be crossed. Four to six secondary feet, cylindrical (early forms) to tabular (late forms). Both primary and secondary feet tend to be shorter in the early forms.
Dimensions (based on 30 specimens): Length of apical horn 62-331μ; of shell 66-89μ; of primary feet 264-643μ; of secondary feet 19-302μ. Breadth of shell 85-125μ.
Localities and stratigraphic range: Deep Sea Drilling Project, Leg 8. Site 69: 69-4, 69A-1, 2-1, 2-5, 3-1. Site 70: 70-6cc, 7, 8, 9, 10, 11, 12, 70A-1, 2, 3-1. Site 71: 71-30cc, 31, 32, 34cc, 35, 36, 37, 38, 39, 40, 41, 42, 43. Site 72: 72-6-2, 6 cc. Site 73: 73-12. Site 74: 74-4-1, 4-2, 4-3, 4cc, 5, 6-1, 6-3. Scripps Institution of Oceanography, WAH 15G, WAH 12G, WAH 11P, WAH 24F-3. This species ranges from *Dorcadospyris papilio* Zone to the *Calocycletta virginis* Zone, from the Upper Oligocene to Lower Miocene.
Remarks: This species directly precedes *Dorcadospyris forcipata* and is distinguished from the latter by the presence of secondary feet. In early forms, these feet are delicate and are seen only in well-preserved specimens; however, a ragged edge on the basal ring may indicate their former existence on specimens which have been subjected to solution or mechanical damage. In later (Lower Miocene) forms the secondary feet are usually longer, tabular in shape and more robust, and their basal stubs can usually be seen even in broken specimens.

Dorcadospyris pseudopapilio new species
(Plate 6, Figures 7 and 8)

Description: Shell nut-shaped, tuberculate, thick-walled with a slight external indication of a sagittal stricture. A conical apical horn is present in most specimens. Two primary feet, circular in section and divergent at approximately 180°. These feet curve semicircularly and in some specimens cross or join. Two secondary feet, tabular in section, located at joint of the sagittal and basal rings. Along the lateral edges of these secondary feet, remnants of an irregular lamillar meshwork can usually be detected. This species is distinguished from *Dorcadospyris papilio* by the difference in their secondary feet.
Dimensions (based on 30 specimens): Length of apical horn; 19-134μ of shell 56-95μ; of primary feet 416-1002μ; of secondary feet 19-77μ. Breadth of shell 19-117μ.
Localities and stratigraphic range: Deep Sea Drilling Project Leg 8. Site 69: 69A-7-3; 69A-7cc, 69A-8-3, 69A-8-5. Site 70: 70A-19-2, 70A-20cc. Site 71: 71A-1. Site 73: 73-17-3, 17-5, 17cc, 18-4; This species is found within the lower part of the *Theocyrtis tuberosa* Zone of the Lower Oligocene.
Remarks: The consistent and unique nature of the secondary feet distinguish this species. Although the primary feet are usually strongly divergent (equal to or greater than 180°) as in *Dorcadospyris papilio*, some specimens have primary feet which diverge at an angle somewhat less than 180°.

Dorcadospyris quadripes new species
(Plate 7, Figures 3, 4 and 5)

Description: Shell nut-shaped, tuberculate, thick walled with slight external sagittal stricture and with circular to subcircular pores, irregularly, or hexagonally arranged. Apical horn conical and highly variable in length, often broken. Usually four (rarely six to eight) primary feet, circular in section. The front two arch up from the base of the shell (diverge at an angle greater than 180°) and then curve downward. The back pair of primary feet diverge at an angle less than 180° and extend downward. In six- and eight-footed specimens, the third and fourth pairs of primary feet may either arch up or curve down from the basal ring. In some specimens the arching feet are the thinner and more delicate of the primary feet. Primary feet may either slightly converge or diverge distally. Two secondary (sagittal) feet, tabular in shape.

Dimensions (based on 30 specimens): Length of apical horn 38-114μ; of shell 62-80μ; of primary feet 378-907μ; of secondary feet 22-264μ. Breadth of shell 79-95μ.

Localities and stratigraphic range: Deep Sea Drilling Project, Leg 8. Site 69: 69-5, 69A-7. Site 70: 70A-17cc, 18, 19, 20, 21-1, 23, 24, 25. Site 71: 71A-1. Site 73: 73-14, 15, 16, 17, 18-4, 18-6. This species is found within the upper part of the *Theocyrtis tuberosa* Zone of the Lower Oligocene and lowermost Upper Oligocene.

Remarks: This species is similar to *Dorcadospyris riedeli* but differs in that the arching legs arise from the basal ring and have an arch that is less pronounced than that found in *D. riedeli.* In addition, the lateral (non-arching) feet do not cross or join. *D. quadripes* is stratigraphically separated from *D. riedeli* by the section represented in the *Theocyrtis annosa* Zone.

Dorcadospyris riedeli new species
(Plate 9, Figures 1, 2 and 3)

Hexaspyris sp., Moore, 1968, Plate 3, Figures 3a, 3b.

Description: Shell nut-shaped, tuberculate, thick walled, with an external indication of a sagittal stricture and with subcircular to circular pores, irregularly or hexagonally arranged. A conical apical horn is found in some specimens. This horn is longer and more commonly present in early specimens. Four paired primary legs, laterally arranged, one pair extend from the basal ring, curve semicircularly and usually cross or join to form an irregular ellipse or circle. The second pair arch up from the shell, curve downward and may be slightly convergent distally but do not cross. Two to four secondary feet, cylindrical to tabular in shape.

Dimensions (based on 30 specimens): Length of apical horn 37-208μ; of shell 62-85μ; of primary feet 529-926μ; of secondary feet 19-321μ. Breadth of shell 77-100μ.

Localities and stratigraphic range: Deep Sea Drilling Project, Leg 8. Site 69: 69A-1-cc, 2. Site 70: 70A-3cc, 4-2, 4-3, 4-5. Site 71: 71-42-1, 42cc, 43-3, 44cc, 45cc. Site 74: 74-6-3, 6-5. Scripps Institution of Oceanography Core WAH 5G. This species is found within the Upper Oligocene in the uppermost part of the *Theocyrtis annosa* Zone and in the *Dorcadospyris papilio* Zone.

Remarks: The differences that exist between this species and *Dorcadospyris quadripes* are presented under the description of the latter species. In some specimens the arching feet are smaller in cross section than the basal primary feet. This species is named for William R. Riedel who is well known for his work on the taxonomy and stratigraphy of Radiolaria.

Dorcadospyris spinosa new species
(Plate 7, Figures 1 and 2)

Description: Shell nut-shaped, tuberculate, thick-walled with slight external sagittal stricture and with circular to subcircular pores hexagonally or irregularly arranged. A very small, conical apical horn is present in a few specimens. Four paired primary feet, cylindrical in section, extend laterally from the basal ring. Both pairs curve semicircularly. The front pair unite to form a ring; the back pair usually cross but do not join. Four to fifteen simple conical spines are found on the convex side of each primary foot. Rarely these spines are absent or barely discernible on the back (unjoined) feet. Two lamellar secondary feet are located sagitally.

Dimensions (based on 20 specimens): Length of apical horn 6-21μ; of shell 60-72μ; of primary feet (half circumference of ring) 472-1002μ; of secondary feet 22-227μ. Breadth of shell 75-98μ.

Localities and stratigraphic range: Deep Sea Drilling Project, Leg 8. Site 69: 69-5-3, 5-5, 5cc, 69A-7-1, 7-2. Site 70: 70A-20cc, 21-1. Site 73: 73-14, 15-3, 15-5, 15cc, 16. This species is found within the upper part of the *Theocyrtis tuberosa* Zone in the Lower Oligocene.

Remarks: There are rarely more than two or three specimens of this species found per slide; however, its distinctive appearance and short range make it very useful in stratigraphic studies.

Dorcadospyris ateuchus (Ehrenberg)
(Plate 8, Figures 1 and 2)

Ceratospyris ateuchus Ehrenberg, 1873, p. 218.

Cantharospyris ateuchus (Ehrenberg); Riedel, 1959, p. 294, Plate 22, Figures 3 and 4.

Dorcadospyris ateuchus (Ehrenberg); Riedel and Sanfilippo, 1970, Plate 15, Figure 4.

Dorcadospyris circulus (Haeckel)
(Plate 8, Figures 3, 4 and 5)

Gamospyris circulus Haeckel, 1887, p. 1042, Plate 83, Figure 19.

Remarks: In this work *Dorcadospyris circulus* is used in the broad sense and includes all specimens having two, semicircularly curved, primary feet which unite to form a ring. This ring is generally smooth, but may be irregular in shape and may show a single spine where the feet join (Figure 5). Although not mentioned in the original description, two to six secondary feet, circular in section, are commonly found in well-preserved specimens.

Dorcadospyris triceros (Ehrenberg)
(Plate 6, Figures 1, 2 and 3)

Ceratospyris triceros Ehrenberg (1874, p. 220; 1876, Plate 21, Figure 5).

Tristylospyris triceros (Ehrenberg); Haeckel, 1887, p. 1033. Riedel, 1959, p. 292, Plate 1, Figures 7, 8.

Dorcadospyris papilio (Riedel)
(Plate 8, Figures 6 and 7)

Hexaspyris papilio Riedel, 1959, p. 294, Plate 2, Figures 1, 2.

Dorcadospyris papilio (Riedel); Riedel and Sanfilippo, 1970, p. 15, Figure 5.

Remarks: The more typical *Dorcadospyris papilio* is shown in Plate 8, Figure 6. In Figure 7 a broken varient form is shown. This rather rare varient is distinguished by its very small shell, its arching primary feet, and its two tabular secondary feet which branch distally.

Dorcadospyris simplex (Riedel)
(Plate 10, Figures 3 and 4)

Brachiospyris simplex Riedel, 1959, p. 293, Plate 1, Figure 10.
Dorcadospyris simplex (Riedel); Riedel and Sanfilippo, 1970, Plate 15, Figure 6.

Dorcadospyris forcipata (Haeckel)
(Plate 10, Figures 1 and 2)

Dipospyris forcipata Haeckel, 1887, p. 1037, Plate 85, Figure 1.

Dorcadospyris dentata Haeckel
(Plate 11, Figures 1 and 2)

Dorcadospyris dentata Haeckel, 1887, p. 1040, Plate 85, Figure 6; Riedel 1957a, p. 79, Plate 1, Figure 4.

Dorcadospyris alata (Riedel)
(Plate 11, Figures 3 and 4)

Brachiospyris alata Riedel, 1959, p. 293, Plate 1, Figures 5, 11 and 12.
Dorcadospyris alata (Riedel); Riedel and Sanfilippo, 1970, Plate 14, Figure 5.

Family THEOPERIDAE Haeckel

Theoperidae Haeckel, 1881, emend. Riedel, 1967b, p. 296.

Genus *Lamptonium* Haeckel

Lamptonium Haeckel, 1887, p. 1378, Type species (designated by Campbell, 1954, p. 132) *Cycladophora enneapleura* Haeckel (1887, p. 1378).

Lamptonium (?) *fabaeforme fabaeforme*
(Krasheninnikov) (?)
(Plate 1, Figure 5)

[?] *Cyrtocalpis fabaeformis* Krasheninnikov, 1960, p. 296, Plate 3, Figure 11.
Lamptonium (?) *fabaeforme fabaeforme* (Krasheninnikov) (?); Riedel and Sanfilippo, Plate 5, Figure 6.

Lamptonium (?) *fabaeforme* (?) *constrictum*
Riedel and Sanfilippo
(Plate 1, Figure 7)

Lamptonium (?) *fabaeforme* (?) *constrictum* Riedel and Sanfilippo, 1970, Plate 5, Figure 7.

Lamptonium (?) *fabaeforme* (?) *chaunothorax*
Riedel and Sanfilippo
(Plate 1, Figure 6)

Lamptonium (?) *fabaeforme* (?) *chaunothorax* Riedel and Sanfilippo, 1970, Plate 5, Figures 8, 9.

Genus *Theocotyle* Riedel and Sanfilippo

Theocotyle Riedel and Sanfilippo, 1970, p. 524. Type species *Theocotyle venezuelensis* Riedel and Sanfilippo.

Theocotyle cryptocephala cryptocephala
(Ehrenberg) (?)

Eucyrtidium cryptocephalum Ehrenberg, 1873, p. 227; 1875, Plate 11, Figure 11.
Theocotyle cryptocephalum (Ehrenberg) (?) Riedel and Sanfilippo, 1970, Plate 6, Figures 7, 8.

Theocotyle cryptocephala (?) *nigrinae*
Riedel and Sanfilippo
(Plate 1, Figure 10)

Theocotyle cryptocephala (?) *nigrinae* Riedel and Sanfilippo, 1970, Plate 6, Figures 5, 6.

Theocotyle venezuelensis Riedel and Sanfilippo
(Plate 1, Figure 11)

Theocotyle venezuelensis Riedel and Sanfilippo, 1970, Plate 6, Figures 9, 10; Plate 7, Figures 1, 2.

Theocotyle (?) *ficus* (Ehrenberg)
(Plate 1, Figure 12)

Eucyrtidium ficus Ehrenberg, 1873, p. 228; 1875, Plate 11, Figure 19.

Genus *Thyrsocyrtis* Ehrenberg

Thyrsocyrtis Ehrenberg, 1847b, chart to p. 54. Type species (indicated by Campbell, 1954, p. 130) *Thyrsocyrtis rhizodon* Ehrenberg (1873, p. 262; 1875, Plate 12, Figure 1).
Podocyrtidium Haeckel, 1887, p. 1337. Type species (designated by Campbell, 1954, p. 130) *Podocyrtis tripodiscus* Haeckel (1887), p. 1338, Plate 72, Figure 4.
Thyrsocyrtis Ehrenberg as used by Riedel and Sanfilippo, 1970, p. 525.

Thyrsocyrtis rhizodon Ehrenberg
(Plate 2, Figures 8 and 9)

Thyrsocyrtis rhizodon Ehrenberg, 1873, p. 262; 1875, Plate 12, Figure 1; Riedel and Sanfilippo, 1970, Plate 7, Figures 6, 7.

Thyrsocyrtis bromia Ehrenberg
(Plate 5, Figures 1, 2 and 3)

Thyrsocyrtis bromia Ehrenberg, 1873, p. 260; 1875, Plate 12, Figure 2.
Remarks: Figure 1 in Plate 5 shows a typical *Thyrsocyrtis bromia.* Transitional forms tending toward a heavier and more inflated abdomen are shown in Figures 2 and 3. In this study these inflated forms are included in *T. bromia* although they are distinctive and extend slightly higher in the section than does the more typical *T. bromia.*

Thyrsocyrtis hirsuta hirsuta (Krasheninnikov)

Podocyrtis hirsutus Krasheninnikov, 1960, p. 300, Plate 3, Figure 16.
Thyrsocyrtis hirsuta hirsuta Riedel and Sanfilippo, 1970, Plate 7, Figures 8, 9.

Thyrsocyrtis hirsuta robusta Riedel and Sanfilippo
(Plate 2, Figure 7)

Thyrsocyrtis hirsuta robusta Riedel and Sanfilippo, 1970, Plate 8, Figure 1.

Thyrsocyrtis triacantha (Ehrenberg)
(Plate 4, Figure 2)

[?] *Podocyrtis cothurnata* Ehrenberg, 1854, Plate 36, Figure 21; 1873, p. 250; 1875, Plate 14, Figure 1.

Podocyrtis triacantha Ehrenberg, 1873, p. 254; 1875, Plate 13, Figure 4.
Thyrsocyrtis triacantha (Ehrenberg); Riedel and Sanfilippo, 1970, Plate 8, Figures 2, 3.

Thyrsocyrtis tetracantha (Ehrenberg)
(Plate 4, Figure 3)

Podocyrtis tetracantha Ehrenberg, 1873, p. 254; 1875, Plate 13, Figure 2.
Thyrsocyrtis tetracantha (Ehrenberg); Riedel and Sanfilippo, 1970, p. 526.

Genus *Eusyringium* Haeckel

Eusyringium Haeckel (1881, p. 437). Type species (designated by Frezzell and Middour, 1951, p. 35) *Eusyringium conosiphon* Haeckel (1887, p. 1496, Plate 78, Figure 10).

Eusyringium lagena (Ehrenberg) (?)
(Plate 4, Figure 9)

[?] *Lithopera lagena* Ehrenberg, 1873, p. 241; 1875, Plate 3, Figure 4.
Eusyringium lagena (Ehrenberg) (?); Riedel and Sanfilippo, 1970, p. 527.

Eusyringium fistuligerum (Ehrenberg)
(Plate 4, Figures 10 and 11)

[?] *Eucyrtidium tubulus* Ehrenberg, 1854, Plate 36, Figure 19; 1873, p. 233; 1875, Plate 9, Figure 6.
Eucyrtidium fistuligerum Ehrenberg
Eusyringium fistuligerum (Ehrenberg) Haeckel, 1887, p. 1497; Riedel and Sanfilippo, 1970, p. 527, Plate 8, Figures 8, 9.
Remarks: Figures 10 and 11 in Plate 4 show two of the several possible morphologic extremes found in this species.

Genus *Sethochytris* Haeckel

Sethochytris Haeckel (1881, p. 433). Type species (indicated by Campbell, 1954, p. 124) *Sethochytris triconiscus* Haeckel (1887, p. 1239, Plate 57, Figure 13).

Sethochytris babylonis (Clark and Campbell) group
(Plate 3, Figures 9 and 10)

Dictyophimus babylonis Clark and Campbell, 1942, p. 67, Plate 9, Figures 32, 36.
Lychnocanium lucerna Ehrenberg, 1847b, Figure 5; 1854, Plate 36, Figure 6; 1873, p. 244.
Sethochytris babylonis (Clark and Campbell) group as used by Riedel and Sanfilippo, 1970, Plate 9, Figures 1-3.

Sethochytris triconiscus Haeckel (?)
(Plate 3, Figure 11)

Sethochytris triconiscus Haeckel, 1887, p. 1239, Plate 57, Figure 13; Riedel and Sanfilippo, 1970, Plate 9, Figure 6.

Genus *Lithochytris* Ehrenberg

Lithochytris Ehrenberg, 1847a chart to p. 385. Type species (indicated by Campbell, 1954, p. 132) *Lithochytris vespertilio* Ehrenberg (1873, p. 239; 1875, Plate 4, Figure 10).

Lithochytris archae, Riedel and Sanfilippo
(Plate 1, Figure 3)

Lithochytris archea Riedel and Sanfilippo; 1970, p. 528, Plate 9, Figure 7.

Lithochytris vespertilio Ehrenberg
(Plate 1, Figure 4)

Lithochytris vespertilio Ehrenberg, 1873, p. 239; 1875, Plate 4, Figure 10.
Lithochytris cheopsis Clark and Campbell, 1942, p. 81, Plate 9, Figure 37.
Lithochytris vespertilio Ehrenberg; Riedel and Sanfilippo, 1970, Plate 9, Figures 8, 9.

Genus *Lychnocanium* Ehrenberg

Lychnocanium Ehrenberg, 1847a, chart to p. 385. Type species (designated by Campbell, 1954, p. 124) *Lychnocanium falciferum* Ehrenberg (1854, Plate 36, Figure 7; 1875, p. 160, Plate 8, Figure 4). Genus as used by Riedel and Sanfilippo, 1970, p. 529.

Genus *Cycladophora* Ehrenberg

Cycladophora Ehrenberg, 1847a, chart to p. 385 (indicated by Campbell, 1954, p. 132) *Cycladophora stiligera* Ehrenberg (1873, p. 223; 1875, Plate 18, Figure 3).
Calocyclas Ehrenberg, 1847b, chart to p. 54. Type species (indicated by Campbell, 1954, p. 132) *Calocyclas turris* Ehrenberg (1873, p. 218; 1875, Plate 18, Figure 7).

Cycladophora hispida (Ehrenberg)
(Plate 4, Figures 6 and 7)

Anthocyrtis hispida Ehrenberg, 1873, p. 216; 1875, Plate 8, Figure 2.
Cycladophora hispida (Ehrenberg); Riedel and Sanfilippo, 1970, Plate 10, Figure 9.
Remarks: Figure 6 in Plate 4 shows the Middle Eocene form; Figure 7 shows the larger, late Middle Eocene to Late Eocene form.

Cycladophora turris Ehrenberg
(Plate 4, Figure 8)

Calocyclas turris Ehrenberg, 1873, p. 218; 1875, Plate 18, Figure 7.
Cycladophora stiligera Ehrenberg; 1873.
Cycladophora turris Ehrenberg; Riedel and Sanfilippo, 1970, p. 529, Plate 13, Figures 3, 4.

Genus *Lophocyrtis* Haeckel

Lophocyrtis Haeckel, 1887, p. 1410. Type species (designated by Campbell, 1954, p. 134).
Ecyrtidium stephanophorum Ehrenberg (1873, p. 233; 1875, Plate 8, Figure 14).

Lophocyrtis (?) *jacchia* (Ehrenberg)
(Plate 5, Figures 4 and 7)

Thyrsocyrtis jacchia, Ehrenberg, 1873, p. 261; 1875, Plate 12, Figure 7.

Lophocyrtis (?) *jacchia* (Ehrenberg); Riedel and Sanfilippo, 1970, p. 530.

Remarks: Riedel and Sanfilippo (1970) tentatively assigned this species to the genus *Lophocyrtis.* In this study early forms closely resemble the original illustration (Figure 4) while later forms appear more robust and have a closed abdomen (Figure 7). These later forms do show the structure of the cephalis and apical horn identical to the earlier forms of *L.* (?) *jacchia* and, therefore, are included in this species.

Genus *Theocorys* Haeckel

Theocorys Haeckel, 1881, p. 434. Type species (indicated by Campbell, 1954, p. 134). *Theocorys morchellula* Rust (1885, p. 308, Plate 37, Figure 6). Genus as used by Riedel and Sanfilippo, 1970, p. 530.

Theocorys anaclasta Riedel and Sanfilippo
(Plate 2, Figure 1)

Theocorys anaclasta Riedel and Sanfilippo, 1970, p. 530, Plate 10, Figures 2, 3.

Theocorys anapographa Riedel and Sanfilippo
(Plate 2, Figure 2)

Clathrocyclas sp. Nigrini, 1970, p. 403, Plate 2, Figure 3.

Theocorys anapographa Riedel and Sanfilippo, 1970, p. 530, Plate 10, Figure 4.

Genus *Stichocorys* Haeckel

Stichocorys Haeckel, 1881, p. 438. Type species (indicated by Campbell, 1954, p. 140). *Stichocorys wolffii* Haeckel (1887, p. 1479, Plate 80, Figure 10).

Stichocorys wolffii Haeckel
(Plate 13, Figure 8)

Stichocorys wolffii Haeckel, 1887, p. 1479, Plate 80, Figure 10; Riedel, 1957a, p. 92, Plate 4, Figures 6, 7.

Stichocorys delmontensis (Campbell and Clark)
(Plate 13, Figure 7)

Eucyrtidium delmontense, Campbell and Clark, 1944a, p. 56, Plate 7, Figures 19, 20; Riedel, 1952, p. 8, Plate 1, Figure 3; Riedel 1957a, p. 93.

Stichocorys delmontensis (Campbell and Clark); Riedel and Sanfilippo, 1970, p. 530, Plate 14, Figure 6.

Stichocorys peregrina (Riedel)
(Plate 13, Figures 9 and 10)

Eucyrtidium elongatum peregrinum Riedel, 1953, p. 812, Plate 85, Figure 2.

Stichocorys peregrina (Riedel); Riedel and Sanfilippo, 1970, p. 530.

Genus *Cyrtocapsella* Haeckel

Cyrtocapsella Haeckel, 1887, p. 1512. Type species (designated by Campbell, 1954, p. 143) *Cyrtocapsa tetrapera* Haeckel (1887, p. 1512, Plate 78, Figure 5). Genus as used by Riedel and Sanfilippo, 1970, p. 530.

Cyrtocapsella tetrapera Haeckel
(Plate 11, Figures 6 and 7)

Cyrtocapsa tetrapera Haeckel, 1887, p. 1512, Plate 78, Figure 5.

Cyrtocapsella tetrapera, Riedel and Sanfilippo, 1970, p. 530, Plate 14, Figure 7.

Cyrtocapsella cornuta Haeckel
(Plate 11, Figure 5)

Cyrtocapsa cornuta Haeckel, 1887, p. 1513, Plate 78, Figure 9.

Cyrtocapsella cornuta Riedel and Sanfilippo, 1970, p. 531, Plate 14, Figure 8.

Genus *Artophormis* Haeckel

Artophormis Haeckel, 1881, p. 438. Type species (indicated by Campbell, 1954, p. 139). *Artophormis horrida* Haeckel (1887, p. 1458, Plate 75, Figure 2).

Artophormis barbadensis (Ehrenberg)
(Plate 5, Figure 9)

Calocyclas barbadensis Ehrenberg, 1873, p. 217; 1875, Plate 18, Figure 8.

Artophormis barbadensis (Ehrenberg) Riedel and Sanfilippo, 1970, p. 532, Plate 13, Figure 5.

Artophormis gracilis Riedel
(Plate 5, Figures 10 and 11)

Artophormis gracilis Riedel, 1959, p. 300, Plate 2, Figures 12, 13.

Artophormis cf. *A. gracilis* Riedel
(Plate 5, Figure 12)

Remarks: This form resembles *A. gracilis* but has a series of regular large pores on the third segment adjacent to the lumbar stricture and thus may be distinctly separated from the otherwise rather variable *A. gracilis.* The range of this form is within the range of *A. gracilis* and may give rise to an undescribed species of the genus *Stichocorys* which has an identical arrangement of pores.

Genus *Phormocyrtis* Haeckel

Phormocyrtis Haeckel, 1887, p. 1368. Type species (designated by Campbell, 1954, p. 134) *Phormocyrtis longicornis* Haeckel (1887, p. 1370, Plate 69, Figure 15).

Phormocyrtis striata Brandt
(Plate 1, Figure 2)

Phormocyrtis striata Brandt, 1935, *in* Wetzel, 1935, p. 55, Plate 9, Figure 12.

Genus *Lithocampium* Haeckel

Lithocampium Haeckel, 1881, p. 437. Type species (indicated by Campbell, 1954, p. 141) *Lithocampium stabile* Rust (1885, p. 311, Plate 38, Figure 6).

Lithocampium sp.
(Plate 1, Figure 13)

Lithocampium sp., Riedel and Sanfilippo, 1970, p. 530, Plate 10, Figure 8.

Family PTEROCORYIDAE Haeckel

Genus *Podocyrtis* Ehrenberg

Podocyrtis Ehrenberg, 1847a chart to p. 385. Type species (indicated by Campbell, 1954, p. 130) *Podocyrtis papalis* Ehrenberg (1847b, Figure 2; 1854, Plate 36, Figure 23; 1873, p. 251).

Subgenus *Podocyrtis* Ehrenberg

Podocyrtis (Podocyrtidium) Haeckel, 1887, p. 1344, *Podocyrtis (Podocyrtis)* in Campbell, 1954, p. 130.

Podocyrtis (Podocyrtis) papalis Ehrenberg
(Plate 2, Figure 4)

Podocyrtis papilis, Ehrenberg, 1847b, Figure 2; 1854, Plate 36, Figure 23; 1873, p. 251.
Podocyrtis fasciata Clark and Campbell, 1942, p. 80, Plate 7, Figures 29, 33.
Podocyrtis (Podocyrtis) papalis Riedel and Sanfilippo, 1970, p. 533, Plate 11, Figure 1.

Podocyrtis (Podocyrtis) diamesa Riedel and Sanfilippo
(Plate 2, Figure 5)

Podocyrtis (Podocyrtis) diamesa Riedel and Sanfilippo, 1970, p. 533, Plate 12, Figures 4-6.

Podocyrtis (Podocyrtis) ampla Ehrenberg
(Plate 2, Figure 6)

Podocyrtis (?) *ampla* Ehrenberg, 1873, p. 248; 1875, Plate 16, Figure 7.
Podocyrtis (Podocyrtis) ampla Ehrenberg; Riedel and Sanfilippo, 1970, p. 533, Plate 12, Figure 7, 8.

Subgenus *Lampterium* Haeckel

Lampterium Haeckel, 1881, p. 434. Type species (indicated by Campbell, 1954, p. 132) *Cycladophora goetheana* Haeckel (1887, p. 1376, Plate 65, Figure 5).
Lampterium Haeckel; Riedel and Sanfilippo, 1970, p. 534.

Podocyrtis (Lampterium) aphorma
Riedel and Sanfilippo
(Plate 3, Figure 2)

Podocyrtis (Lampterium) aphorma Riedel and Sanfilippo, 1970, p. 534, Plate 11, Figure 2.

Podocyrtis (Lampterium) sinuosa Ehrenberg (?)
(Plate 3, Figure 3)

[?] *Podocyrtis sinuosa* Ehrenberg, 1873, p. 253; 1875, Plate 15, Figure 5.
Podocyrtis sinuosa Ehrenberg (?); Riedel and Sanfilippo, 1970, p. 534, Plate 11, Figures 3, 4.

Podocyrtis (Lampterium) mitra Ehrenberg
(Plate 3, Figure 4)

Podocyrtis mitra Ehrenberg, 1854, Plate 36, Figure 1320; 1873, p. 251; [*non* Ehrenberg, 1875, Plate 15, Figure 4].
Podocyrtis (Lamptonium) mitra Ehrenberg; Riedel and Sanfilippo, 1970, p. 534, Plate 11, Figures 5, 6.

Podocyrtis (Lampterium) trachodes
Riedel and Sanfilippo

Podocyrtis (Lampterium) trachodes Riedel and Sanfilippo, 1970, p. 535, Plate 11, Figure 7; Plate 12, Figure 1.

Podocyrtis (Lampterium) chalara
Riedel and Sanfilippo
(Plate 3, Figures 5 and 6)

[?] *Podocyrtis* (?) sp. Bury, 1862, Plate 12, Figure 2.
Podocyrtis (Lampterium) chalara Riedel and Sanfilippo, 1970, p. 535, Plate 12, Figures 2 and 3.

Podocyrtis (Lampterium) goetheana (Haeckel)
(Plate 3, Figures 7 and 8)

Cycladophora goetheana Haeckel, 1887, p. 1376, Plate 65, Figure 5.
Podocyrtis (Lampterium) goetheana (Haeckel); Riedel and Sanfilippo, 1970, p. 535, Plate 65, Figure 5.

Genus *Theocyrtis* Haeckel

Theocyrtis Haeckel, 1887, p. 1405. Type species (designated by Campbell, 1954, p. 134) *Eucyrtidium barbadense* Ehrenberg (1873, p. 226, 1885, Plate 9, Figure 7).

Theocyrtis tuberosa Riedel
(Plate 5, Figures 5 and 6)

Theocyrtis tuberosa Riedel, 1959, p. 298, Plate 2, Figures 10, 11.
Remarks: The Eocene *Theocyrtis tuberosa* has a fairly smooth thorax (Figure 5) and a slender apical horn. The more typical form (Figure 6) is found in the Lower Oligocene.

Theocyrtis annosa (Riedel)
(Plate 7, Figures 6 and 7)

Phormacyrtis annosa Riedel, 1959, p. 295, Plate 2, Figure 7.
Theocyrtis annosa (Riedel); Riedel and Sanfilippo, 1970, p. 535, Plate 15, Figure 9.

Genus *Calocycletta* Haeckel

Calocycletta Haeckel, 1887, p. 1381. Type species (designated by Campbell, 1954, p. 132) *Calocyclas veneris* Haeckel (1887, p. 1381, Plate 74, Figure 5).

Calocycletta robusta, new species
(Plate 10, Figures 5 and 6)

Calocyclas cf. *C. virginis,* Moore, 1968, p. 104, Plate 7, Figure 4a, 4b.
Description: Stout conical apical horn which envelopes or nearly envelopes an ovate, lobed cephalis.

Cephalis has very sparce subcircular pores. Thorax robust and hemispherical to subspherical in shape. Rough surface of the thorax contains circular, hexagonally arranged pores with a tendency toward longitudinal alignment. Lumbar stricture usually not marked externally (except in early forms). Abdomen tapers distally and contains subcircular pores which are strongly longitudinally aligned. Abdominal termination usually ragged, but may end in irregular lamellar and tapering feet in the later forms. Early forms of *C. robusta* (Moore, 1968, Plate 7, Figure 4a) have a nearly hemispherical thorax, a cylindrical shape in the region of the lumbar stricture, and an abdomen that tapers distally. Later forms (Figure 6; Moore, 1968, Plate 7, Figure 4b) have a subspherical thorax that gives rise smoothly to the uniform taper of the abdomen at or slightly above the lumbar stricture.

Dimensions (based on 30 specimens): Length of apical horn 80-185μ; of cephalis 34-48μ; of thorax 73-144μ; of abdomen 64-120μ; of feet (when present) 16-48μ. Breadth of cephalis 40-56μ; of thorax 120-178μ; of abdomen (distal) 64-96μ.

Localities and stratigraphic range: Deep Sea Drilling Project, Leg 8. Site 69: 69-4, 69A-1, 69A-2-1. Site 70: 70-11-5, 70-11cc, 70-12, 70A-1 through 70A-3cc. Site 71: 71-35-4 through 71-42cc. Site 72: 72-6. Site 73: 73-12. Site 74: 74-4-3, 74-4-5. Core WAH 5G of the Scripps Institution of Oceanography. This species ranges from the middle part of the *Dorcadospyris papilio* Zone to the lower part of the *Calocycletta virginis* Zone (Upper Oligocene to Lower Miocene).

Remarks: C. robusta appears to give rise to *Calocycletta virginis* as well as another (unnamed) species of *Calocycletta* (Kling, 1970, Plate 5, Figure C). The later forms of *C. robusta* are distinguished from *C. virginis* by the presence in the latter species of regular terminal feet as described by Riedel (1959): "Terminal feet eleven to sixteen, lamillar, usually truncate, parallel, broader than spaces between them, usually situated opposite alternate rows of pores".

Calocycletta virginis (Haeckel)
(Plate 10, Figure 7)

Calocyclas virginis Haeckel, 1887, p. 1381, Plate 74, Figure 4; Riedel, 1959, p. 295, Plate 2, Figure 8.
Calocycletta virginis (Haeckel); Riedel and Sanfilippo, 1970, p. 535, Plate 14, Figure 10.

Calocycletta costata (Riedel)
(Plate 10, Figure 8)

Calocyclas costata Riedel, 1959, p. 296, Plate 2, Figure 9.
Calocycletta costata (Riedel), Riedel and Sanfilippo, 1970, p. 535, Plate 14, Figure 12.

Family ARTOSTROBIIDAE Riedel

Artostrobiidae, Riedel, 1967a, p. 148-149.

Genus *Theocampe* Haeckel

Theocampe Haeckel, 1887, p. 1422. Type species (designated by Campbell, 1954, p. 134). *Dictyomitra ehrenbergi* Zittel (1876, p. 82, Plate 2, Figure 5).

Theocampe mongolfieri (Ehrenberg)
(Plate 2, Figure 3)

Eucyrtidium mongolfieri Ehrenberg, 1854, Plate 36, Figure 18B; 1873, p. 230; 1873, Plate 10, Figure 3.
Sethamphora mongolfieri (Ehrenberg), Haeckel, 1887, p. 1251.
Theocampe mongolfieri (Ehrenberg), Burma, 1959, p. 329.

Family CANNOBOTRYIDAE

Cannobotryidae Haeckel, 1881, emend. Riedel, 1967b, p. 296.

Genus *Acrobotrys* Haeckel

Acrobotrys Haeckel, 1881, p. 440. Type species (indicated by Campbell, 1954, p. 144) *Acrobotrys monosolenia* Haeckel (1887, p. 1114).

Acrobotrys tritubus Riedel
(Plate 11, Figure 8)

Acrobotrys tritubus Riedel, 1957a, p. 80, Plate 1, Figure 5.

Genus *Centrobotrys* Petrushevskaya

Centrobotrys Petrushevskaya, 1965, p. 113.

Centrobotrys gravida, new species
(Plate 5, Figure 8)

Description: Internal cephalic lobe heavy, spherical with no observable pores. The arrangement of the internal spines and axial rod appears to be as illustrated by Nigrini (1967, p. 50) for *C. thermophila.* However, only the ventral spine forms a pronounced opening in the outer cephalic wall. Outer shell, heavy and rough with irregularly arranged subcircular pores. Pores vary in size but are generally largest in the equatorial region of the spherical to subspherical thorax. Lumbar stricture marked; thorax closed.

Dimensions: Maximum length 128-166μ. Maximum breadth 75-113μ.

Localities and stratigraphic range: Deep Sea Drilling Project, Leg 8. Site 69: 69A-7-3 through 69A-8-5. Site 70: 70A-19-2. Site 71: 71A-1. Site 73: 73-17-3 through 73-18-4. Found within the lower part of the *Theocyrtis tuberosa* (Lower Oligocene).

Remarks: Although there are similar forms with a lighter, more elongate thorax in the Upper Eocene and Oligocene, the heavy shell and nearly spherical thorax of this species make it distinctive. Its heavy shell, short stratigraphic range and general abundance in samples make it particularly useful in stratigraphic studies.

EVOLUTIONARY LINEAGES

Through the efforts of mainly W. R. Riedel and co-workers (Riedel, 1959; Riedel and Sanfilippo, 1970; Sanfilippo and Riedel, 1970) several evolutionary lineages have been proposed. Not only do these lineages provide a firmer basis for taxonomic classification, but they also furnish a strong framework for radiolarian zonation, species distribution studies and stratigraphic correlations. The material being provided by the Deep Sea Drilling Project continues to increase our understanding of these lineages and improve our knowledge of radiolarian stratigraphy. The lineages presented below were originally based on the work of Riedel and Sanfilippo (1970) and have been useful in the stratigraphic studies of this report. In some cases lineages have been combined or expanded to include new species presented in the taxonomic section of this report.

Lithapium (?) *anoectum-L.* (?) *mitra*

Species: Two.
Origin: Unknown.
Termination: Apparently ends with *L.* (?) *mitra.*

Lithocyclia ocellus-Ommatartus tetrathalamus

Species: Fourteen. It is thought that during the Late Eocene the *Lithocyclia ocellus* group gave rise to the *L. aristotelis* group which in turn gave rise to *L. angustum* and *L. crux* in the Early Oligocene. Near the Early to Late Oligocene boundary one of these two Early Oligocene species, probably *L. angustum*, gave rise to *Cannartus prismaticus* which in turn started a long series of closely related forms: *Cannartus tubarius, C. violina, C. mammiferus, C. laticonus, Ommatartus antepenultimus, O. penultimus* and *O. tetrathalamus. Cannartus* (?) *petterssoni* (which gave rise to *Ommatartus hughesi*) branched off from *Cannartus laticonus.* This series is the longest and best known of all the radiolarian evolutionary lineages studied; however, several off shoots of the direct lineage remain to be investigated. In addition, it is thought that perhaps one or two species, as yet unnamed, belong in the direct lineage between *Cannartus prismaticus* and *C. tubarius* or *C. violina.*
Origin: At present this lineage is known only as far back as *Lithocyclia ocellus*; however, the immediate predecessor may be *Spongatraetus pachystylus* (Ehrenberg) (Sanfilippo, personal communication).
Termination: *Ommatartus tetrathalamus*, an extant species.

Triactis tripyramis tripyramis-T. tripyramis triangula

Species: Two subspecies.
Origin: Probably from a phacodiscid with more than three marginal spines.
Termination: There are no known descendants of *T. tripyramis triangula* which disappeared in the Middle Eocene.

Dorcadospyris triceros-D. alata

Species: Thirteen named, but probably several more that remain unnamed. The lines of evolutionary lineage appear to be highly branching and remain somewhat uncertain. *D. triceros* gave rise to *D. quadripes* and possibly *D. pseudopapilio* in the Early Oligocene and *D. ateuchus* near the Early to Late Oligocene boundary. *D. quadripes* gave rise in turn to *D. spinosa*, a very rare and short lived species of the Early Oligocene. Either *D. quadripes* or *D. spinosa* (through an unnamed spiny *Dorcadospyris* species with only two feet) gave rise to *D. circulus* near the Early to Late Oligocene boundary. From this point in the record there are probably two distinct lineages: 1) *D. ateuchus* which gave rise to and terminated with *D. simplex*, and 2) *D. circulus* which gave rise to *D. riedeli, D. papilio, D. praeforcipata, D. forcipata, D. dentata,* and *D. alata.* It is interesting to note that short conical spines on the convex side of the primary feet is a feature which recurs in three named species and possibly three more unnamed species in the genus *Dorcadospyris.*
Origin: It is thought that a five to six legged species gave rise to *D. triceros* sometime in the Middle to Late Eocene.
Termination: The *D. ateuchus* branch terminated in the Early Miocene with *D. simplex* and the *D. quadripes* branch terminated in the Middle Miocene with *D. alata.*

Lamptonium (?) *fabaeforme fabaeforme* (?)-
L. (?) *fabaeforme* (?) *constrictum*

Species: Two subspecies with a third, *L. fabaeforme* (?) *chaunothorax*, as a possible side branch.
Origin: Uncertain.
Termination: *L. fabaeforme* (?) *chaunothorax* appears to be the longest ranging (to the upper Middle Eocene) and most abundant of the three taxa.

Theocotyle cryptocephala (?) *nigriniae-*
T. venezuelensis

Species: Three, *T. cryptocephala cryptocephala* being the intermediate form.
Origin: Uncertain.
Termination: *T. venezuelensis* disappeared in the Middle Eocene and apparently had no descendants.

Thyrocyrtis rhizodon-T. bromia

Species: Two, but both species are defined broadly and may include other forms.
Origin: The origins and the relationship (if any) between *T. rhizodon* and *T. hirsuta* remain uncertain.

Termination: An inflated form of *T. bromia* disappeared just below the Eocene-Oligocene boundary and apparently left no descendants.

Thyrocyrtis hirsuta-T. tetracantha

Species: Three species, two subspecies, *T. hirsuta* and *T. hirsuta robusta*, one of which (probably *T. hirsuta robusta*) gave rise to *T. triacantha. T. tetracantha* arose from the latter species in the Late Eocene.
Origin: Uncertain.
Termination: *T. tetracantha* disappeared in the late Eocene and apparently left no descendants.

Eusyringium lagena (?)-*E. fistuligerum*

Species: Two.
Origin: Uncertain.
Termination: *E. fistuligerum* disappeared in the Late Eocene and apparently left no descendants.

Sethochyrtis babylonis **group**-*S. triconiscus* (?)

Species: Two, with several transitional forms which may later be defined as separate species.
Origin: Uncertain.
Termination: *S. triconiscus* disappears in the upper Middle Eocene, but members of the *S. babylonis* group continue into the Late Eocene.

Lithochytris archaea-L. vespertilio

Species: Two, with several similar forms which are now included in these species, but which may later be separated into separate taxa.
Origin: Uncertain.
Termination: *L. vespertilio* disappeared near the Middle to Late Eocene boundary and left no descendants.

Cycladophora hispida-C. turris

Species: Two.
Origin: Uncertain.
Termination: *C. turris* disappeared at just below the Eocene-Oligocene boundary and apparently left no descendants.

Stichocorys delmontense-S. peregrina (?)

Species: Two, with a third, *S. wolffii* as a possible offshoot from the long ranging *S. delmontensis.*
Origin: Uncertain.
Termination: *S. peregrina* disappeared in the Late Pliocene and apparently left no descendants.

Artophormis barbadensis-A. gracilis

Species: Two included here but a possible third species may represent a branch from this lineage (*Artophormis* cf. *A. gracilis* Plate 5, Figure 12).
Origin: The delicate nature of *A. barbadensis* make it difficult to trace; however, in this study specimens were found in the *Podocyrtis chalara* Zone of the Middle Eocene. Antecedents are uncertain.

Termination: *A. gracilis* disappeared in the *Lychnocanium bipes* Zone (Late Oligocene to Early Miocene).

Podocyrtis papalis-P. ampla

Species: Three, with *P. diamesa* being the intermediate species.
Origin: Uncertain.
Termination: *P. ampla* disappeared in the Middle Eocene and apparently left no descendants.

Podocyrtis aphorma-P. goetheana

Species: Seven, including *P. papalis* and *P. trachodes* which apparently arose from *P. mitra.* The direct lineage starts with *P. papalis* and continues with *P. aphorma, P. sinuosa* (?), *P. mitra, P. chalara* and *P. goetheana.*
Origin: *P. papalis.*
Termination: *P. goetheana* disappeared near the Middle to Late Eocene boundary and apparently left no descendants.

Calocycletta robusta-C. costata

Species: Three, *C. robusta* gives rise to *C. virginis* which in turn gives rise to *C. costata.* Another, as yet unnamed, species (Kling, 1970, Plate 5, Figure C) probably branches off from the direct lineage near the *C. robusta-C. virginis* transition.
Origin: Uncertain.
Termination: *C. virginis* disappeared in the Middle Miocene and probably left at least one (unnamed) descendant species that continued to the Late Miocene.

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PLATE 1

Figure 1	*Lithapium* (?) *plegmacantha*. 69A-12-CC. ×138.
Figure 2	*Phormocyrtis striata*. 68-1-1, 134-136 cm. ×138.
Figure 3	*Lithochytris archea*. 68-1-1, 134-136 cm. ×138.
Figure 4	*Lithochytris vespertilio*. 69A-11-CC. ×138.
Figure 5	*Lamptonium* (?) *fabaeforme fabaeforme* (?). 69A-11-1, 81-83 cm. ×138.
Figure 6	*Lamptonium* (?) *fabaeforme* (?) *chaunothorax*. 69A-12-CC. ×138.
Figure 7	*Lamptonium* (?) *fabaeforme* (?) *constrictum*. 69A-12-CC. ×138.
Figure 8	*Triactis tripyramis tripyramis*. 69A-10-3, 83-85 cm. ×138.
Figure 9	*Triactis tripyramis triangula*. 69A-11-1, 81-83 cm. ×138.
Figure 10	*Theocotyle cryptocephala* (?) *nigriniae*. 68-1-1, 134-136 cm. ×138.
Figure 11	*Theocotyle venezuelensis*. 69A-11-1, 81-83 cm. ×138.
Figure 12	*Theocotyle* (?) *ficus*. 69A-12-CC. ×138.
Figure 13	*Lithocampium* sp. 68-1-1, 134-136 cm. ×138.

PLATE 1

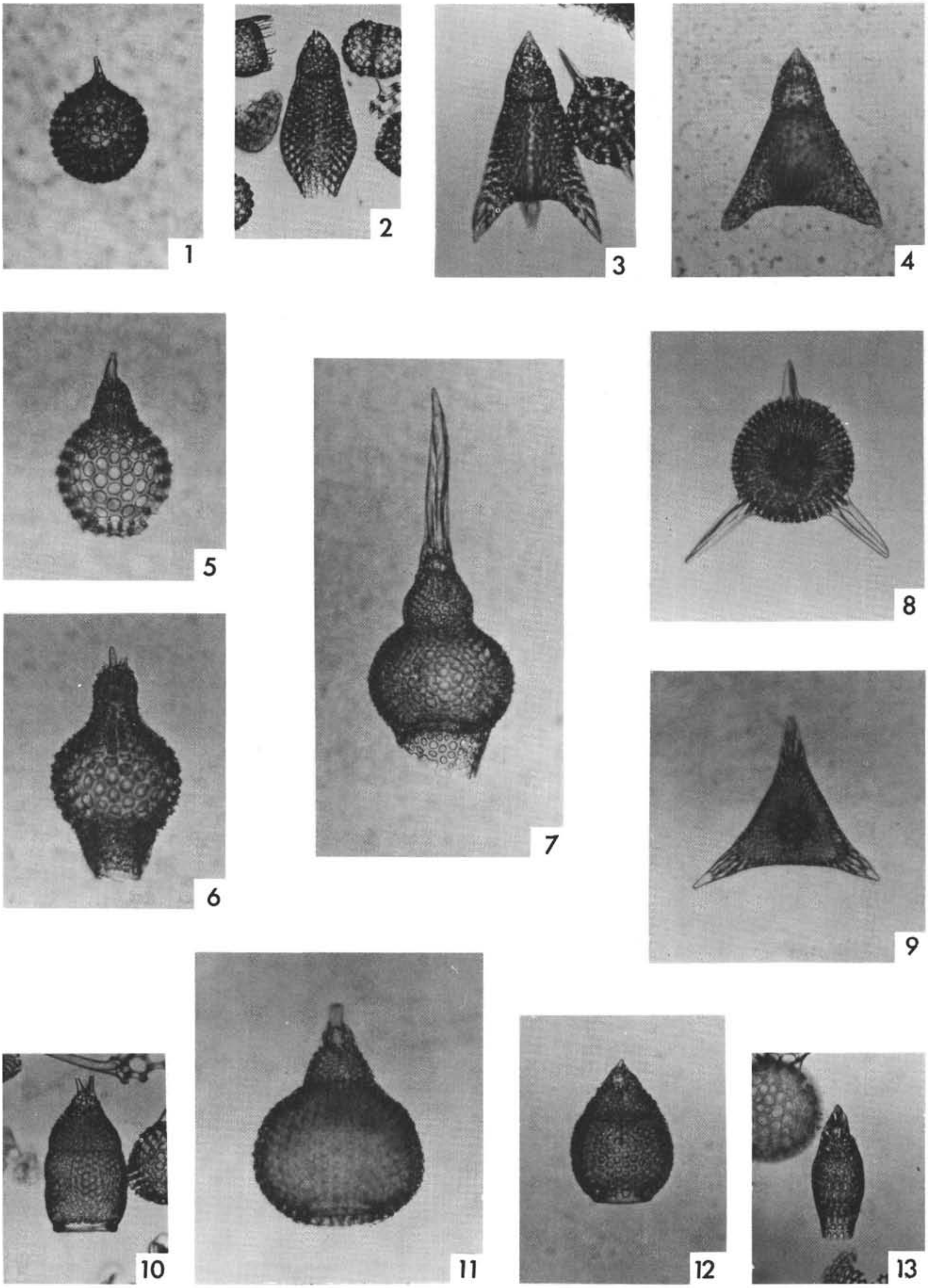

PLATE 2

Figure 1	*Theocorys anaclasta.* 69A-11-1, 81-83 cm. ×138.
Figure 2	*Theocorys anapographa.* 69-6-1, 81-83 cm. ×138.
Figure 3	*Theocampe mongolfieri.* 69A-11-CC. 81-83 cm. ×138.
Figure 4	*Podocyrtis papalis.* 70A-29-CC. ×138.
Figure 5	*Podocyrtis diamesa.* 69A-11-1, 81-83 cm.
Figure 6	*Podocyrtis ampla.* 69A-9-3, 143-145 cm. ×138.
Figure 7	*Thyrsocyrtis hirsuta robusta.* 69A-12-CC. ×138.
Figures 8, 9	*Thyrsocyrtis rhizodon.* (8) 69-11-CC. ×138. (9) 69-6-1, 81-83 cm. ×138.

PLATE 2

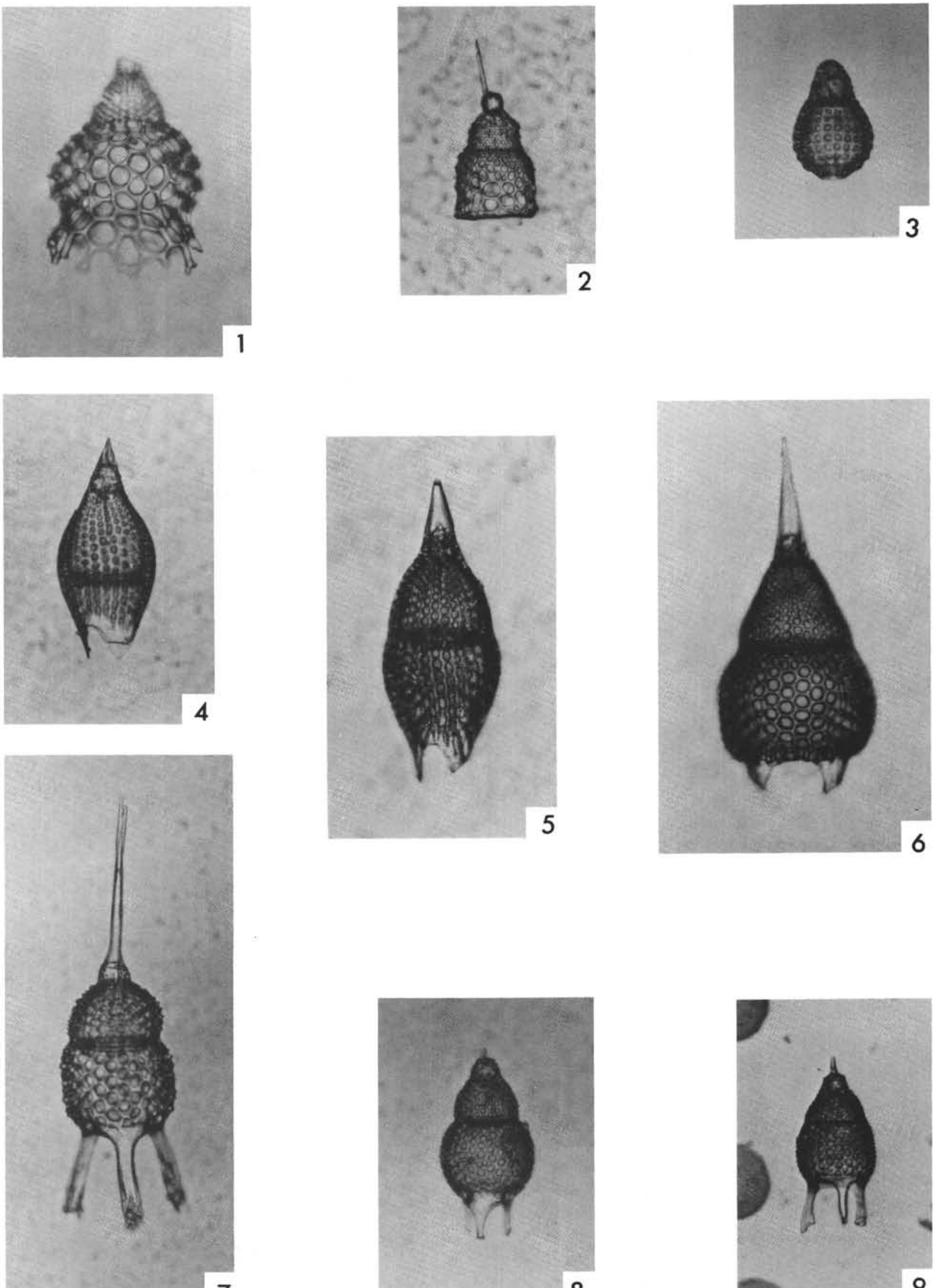

PLATE 3

Figure 1	*Lithapium mitra.* 69-6-3, 84-86 cm. ×138.
Figure 2	*Podocyrtis aphorma.* 68-1-1, 134-136 cm. ×138.
Figure 3	*Podocyrtis sinuosa.* 69A-11-CC. ×138.
Figure 4	*Podocyrtis mitra.* 69-6-3, 84-86 cm. ×138.
Figure 5	*Podocyrtis chalara.* 69A-7-1, 81-83 cm. ×138.
Figure 6	*Podocyrtis chalara.* Diminutive form, 69-6-3, 84-86 cm. ×138.
Figure 7	*Podocyrtis goetheana.* (Broken) 70A-29-CC. ×138.
Figure 8	*Podocyrtis goetheana.* Diminutive form, 70A-29-CC. ×138.
Figures 9, 10	*Sethochytris babylonis* group. (9) 69A-10-3, 83-85 cm. (10) 69A-12-CC. ×138.
Figure 11	*Sethochytris triconiscus* (?). 69-6-3, 84-86 cm.

PLATE 3

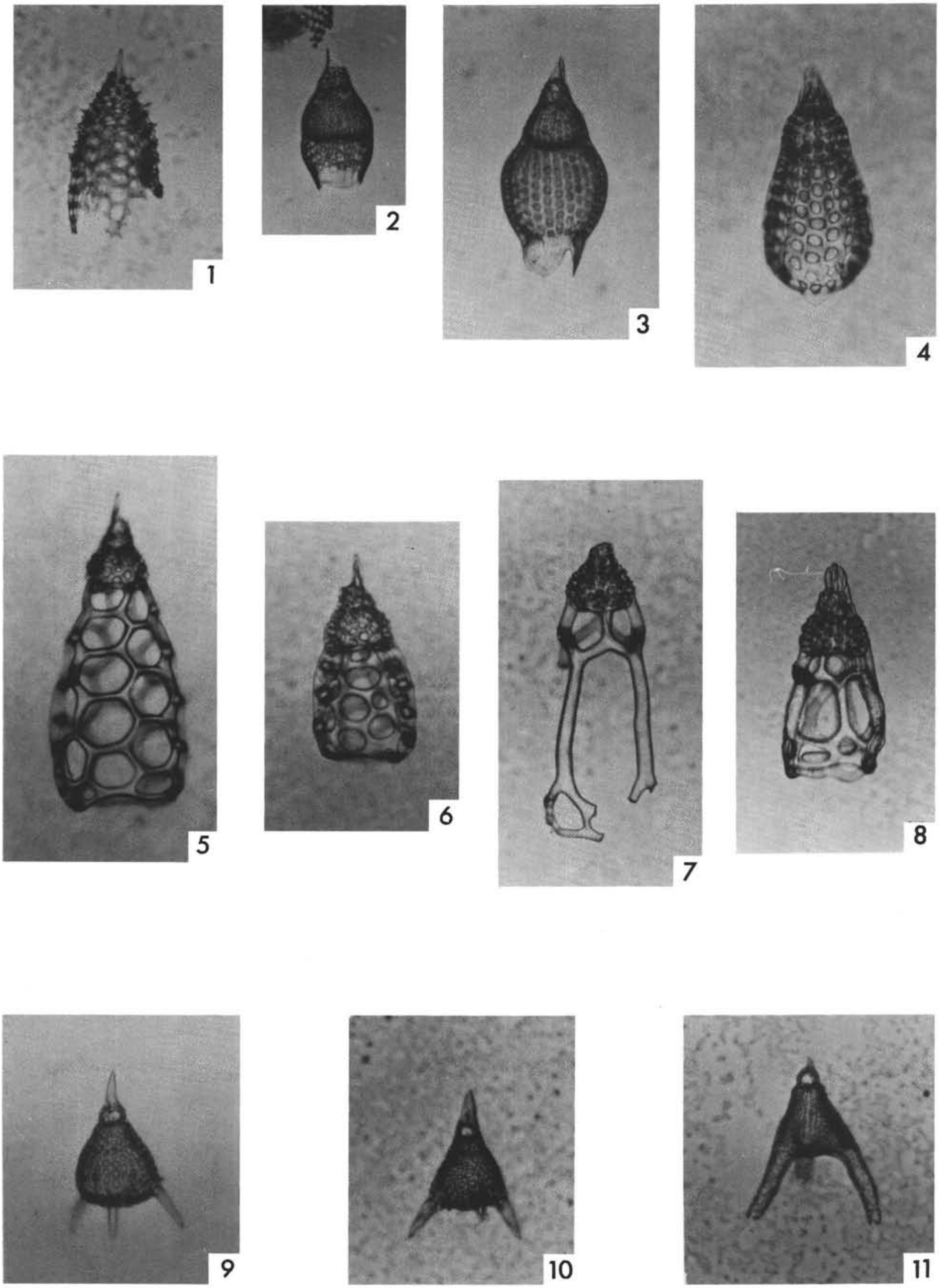

PLATE 4

Figure 1	*Lithocyclia ocellus* group. 69A-11-CC. X138.
Figure 2	*Thyrsocyrtis triacantha.* 69A-11-1, 81-83 cm. X138.
Figure 3	*Thyrsocyrtis tetracantha.* 69A-10-3, 83-85 cm. X138.
Figure 4, 5	*Lithocyclia aristotelis* group. 69A-10-3, 83-85 cm. X138.
Figure 6, 7	*Cycladophora hispida.* (6) 69A-12-CC, (7) 70A-29-CC. X138.
Figure 8	*Cycladophora turris.* 69A-9-5, 81-83 cm. X138.
Figure 9	*Eusyringium lagena* (?). 69A-11-1, 81-83 cm. X138.
Figure 10, 11	*Eusyringium fistuligerum.* 70A-29CC. X138.

PLATE 4

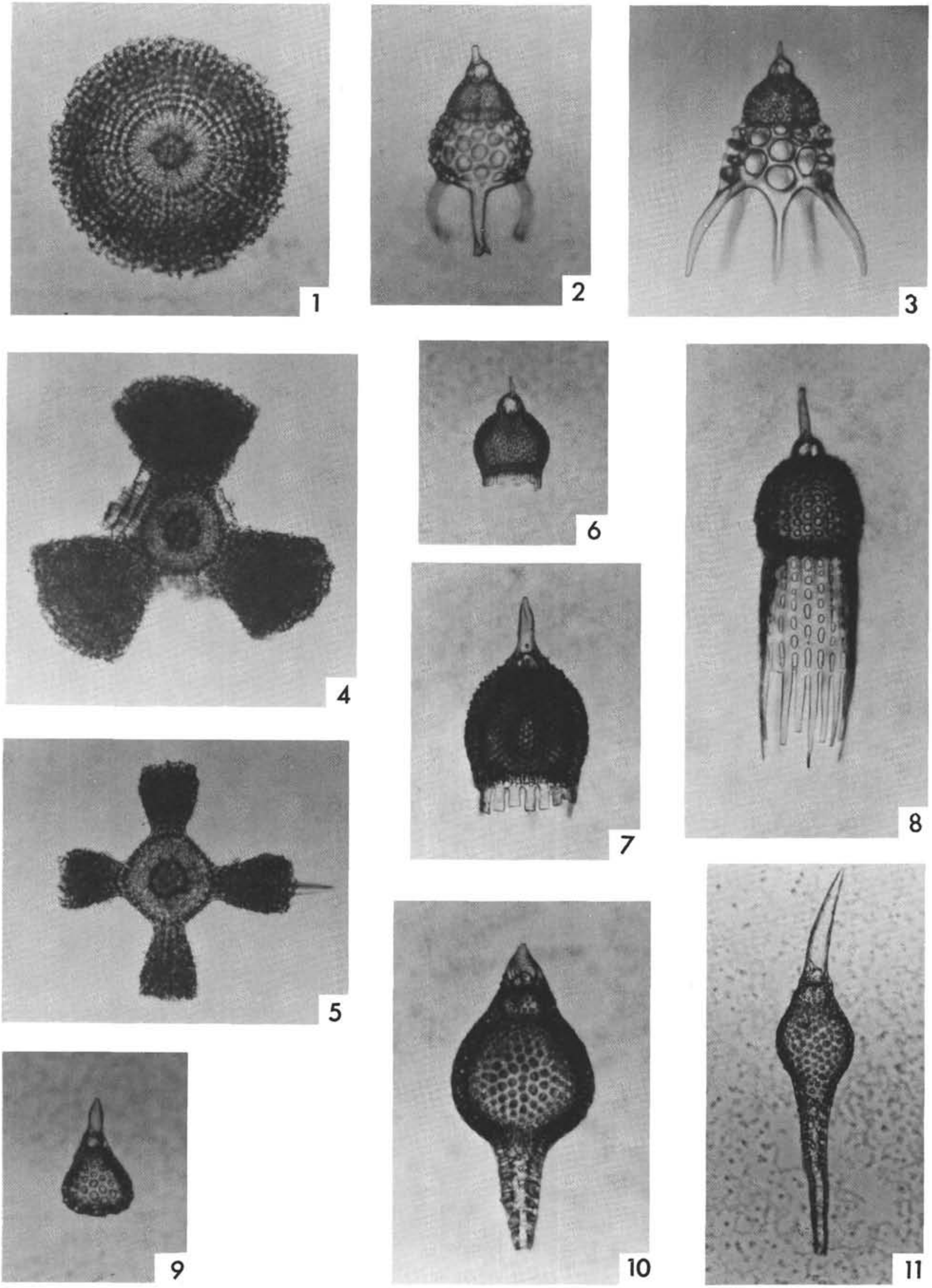

PLATE 5

Figure 1	*Thyrsocyrtis bromia.* 69A-10-3, 83-85 cm.
Figure 2, 3	*Thyrsocyrtis bromia.* (Variant) 69A-10-3, 83-85 cm.
Figure 4	*Lophochytris* (?) *jacchia.* 69A-10-3, 83-85 cm.
Figure 5, 6	*Theocyrtis tuberosa.* (5) 70A-27-2, 139-141 cm. ×138. (6) 69A-7-1, 81-83 cm. ×138.
Figure 7	*Lophochytris* (?) *jacchia.* (Variant) 70A-27-2, 139-141 cm. ×138.
Figure 8	*Centrobotrys gravida.* (Holotype 69A-8-3, 81-83 cm. ×138.
Figure 9	*Artophormis barbadensis.* 69-6-1, 82-84 cm. ×138.
Figure 10, 11	*Artophormis gracilis.* (10) 69A-7-1, 81-83 cm. (11) 69A-1-CC. ×138.
Figure 12	*Artophormis* cf. *A. gracilis.* 69A-5-CC. ×138.

PLATE 5

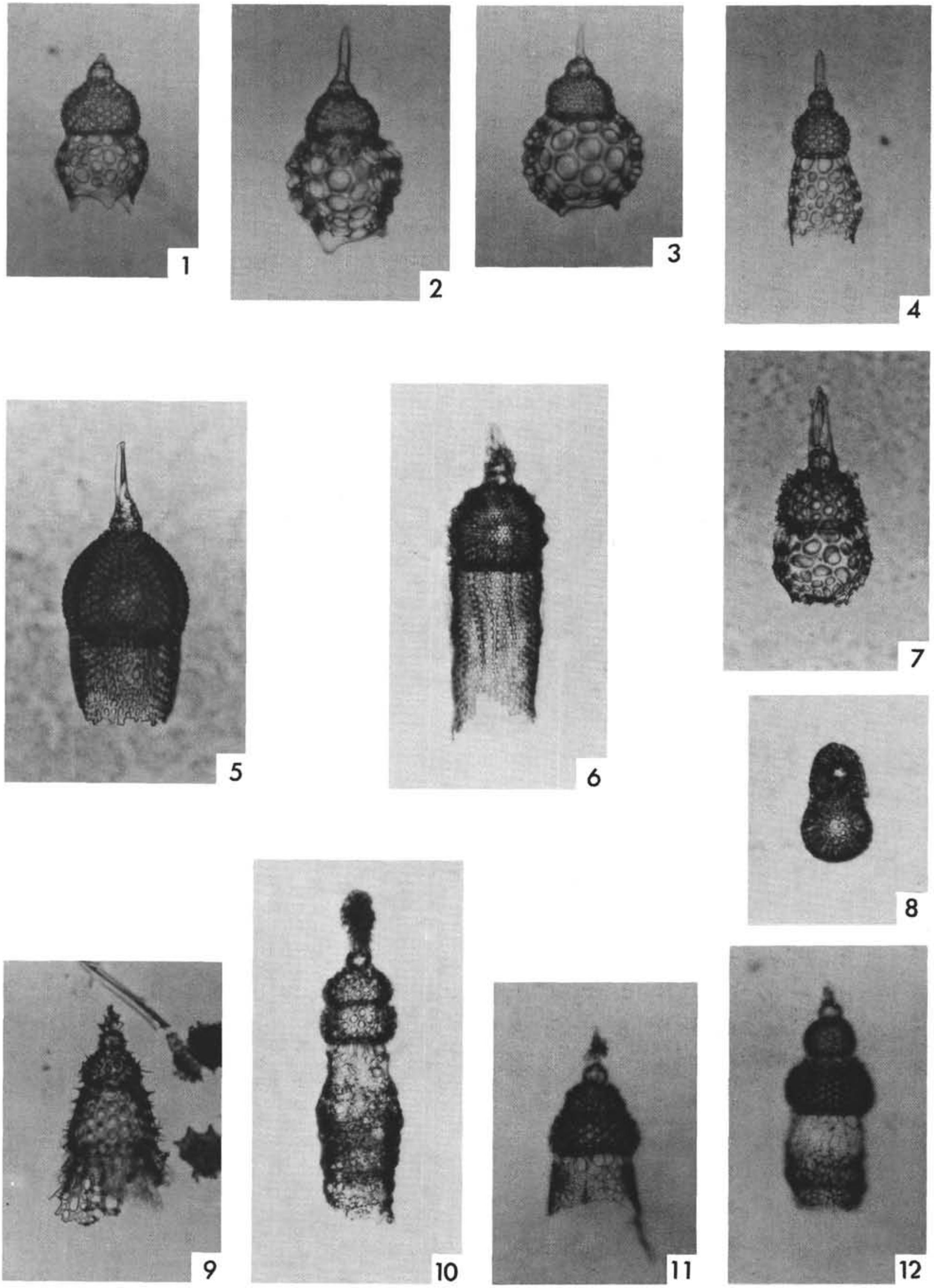

PLATE 6

Figure 1	*Dorcadospyris triceros.* 69A-6-3, 100-102 cm. X204.
Figure 2	*Dorcadospyris triceros.* Basal view, 70A-27-2, 139-131 cm. X138.
Figure 3	*Dorcadospyris triceros.* 69A 8-3, 81-83 cm. X138.
Figure 4	*Lithocyclia crux.* (Holotype) 69-5-5, 81-83 cm. X138.
Figure 5, 6	*Lithocyclia angustum.* (5) 69-5-5, 81-83 cm. (6) 69A-5-CC. X138.
Figure 7	*Dorcadospyris pseudopapilio.* (Holotype)69A-8-3, 81-83cm. X138.
Figure 8	*Dorcadospyris pseudopapilio.* 69A-8-3, 81-83 cm. X102.

PLATE 6

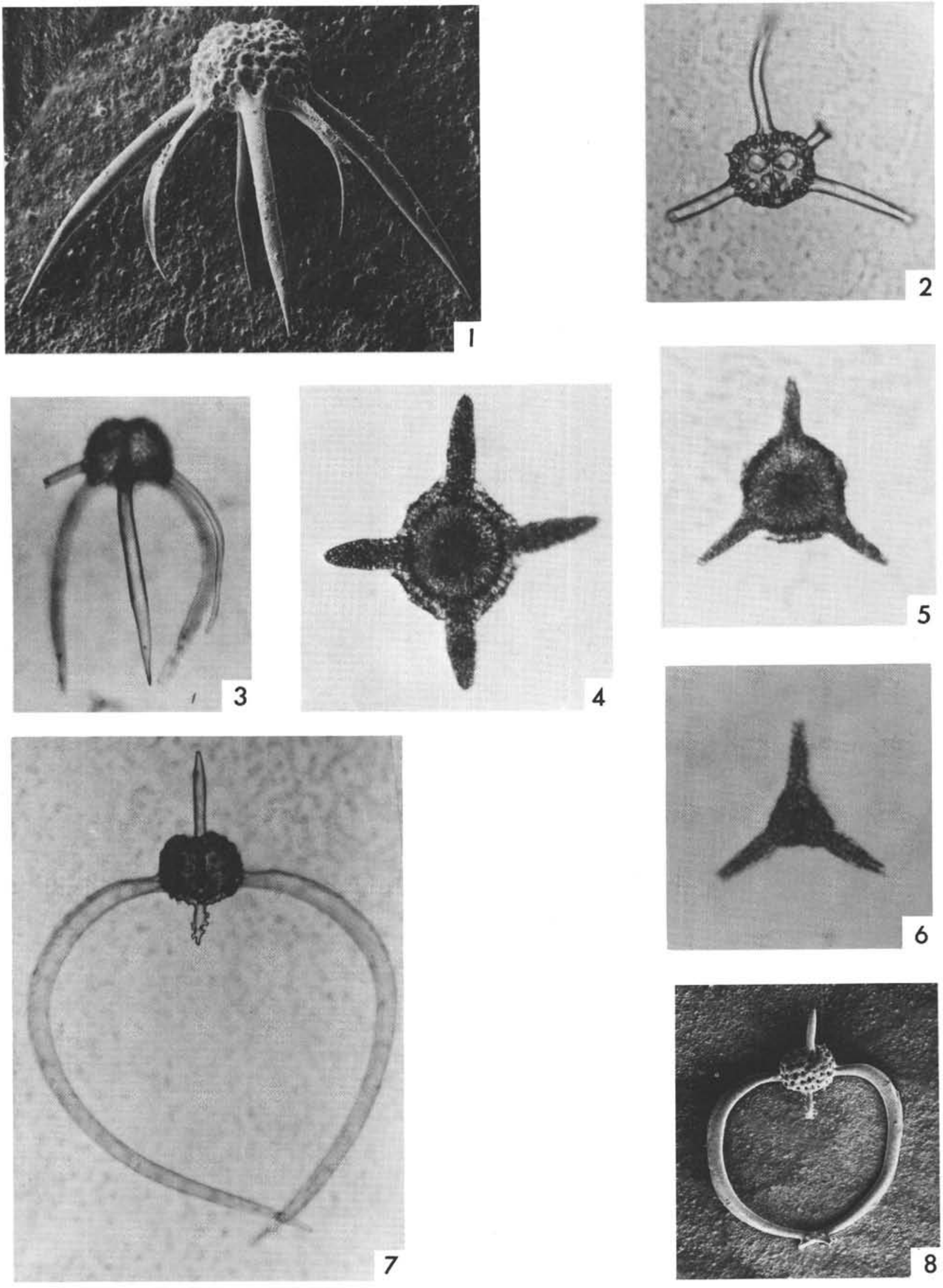

PLATE 7

Figure 1	*Dorcadospyris spinosa.* (Paratype) 69-5-5, 81-83 cm. ×138.
Figure 2	*Dorcadospyris spinosa.* (Holotype) 69A-7-1, 81-83 cm. ×200.
Figure 3, 4, 5	*Dorcadospyris quadripes.* (3) (Paratype) 69-5-5, 81-83 cm. ×138. U. S., (4) 69A-7-1, 81-83 cm. (5) (Holotype) 69-5-5, 81-83 cm. ×95.
Figure 6, 7	*Theocyrtis annosa.* (6) 69A-1-5, 81-83 cm. (7) 69A-5-CC. ×138.

PLATE 7

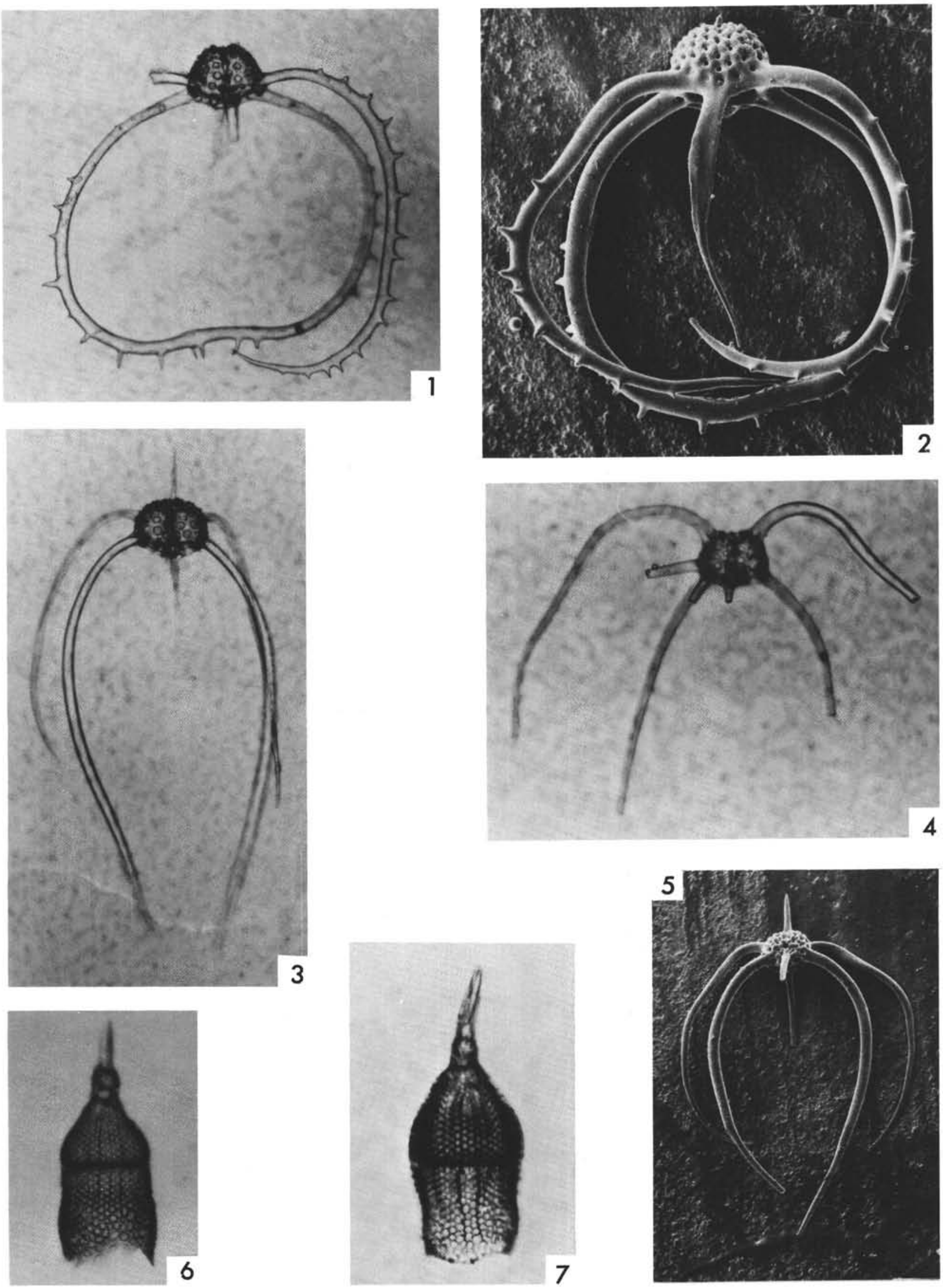

PLATE 8

Figures 1, 2	*Dorcadospyris ateuchus.* (1) 69A-2-5, 81-83 cm. (2) 69A-5-CC. X138.
Figure 3, 4, 5	*Dorcadospyris circulus.* (3) 69A-6-3, 100-102 cm. X200. (4) 69A-6-3, 100-102 cm. X138. (5) 69A-6-3, 100-102 cm. X138.
Figure 6	*Dorcadospyris papilio.* Apical horn broken, 69A-1-CC. X95.
Figure 7	*Dorcadospyris papilio.* (Variant) 69A-1-CC. X138.

PLATE 8

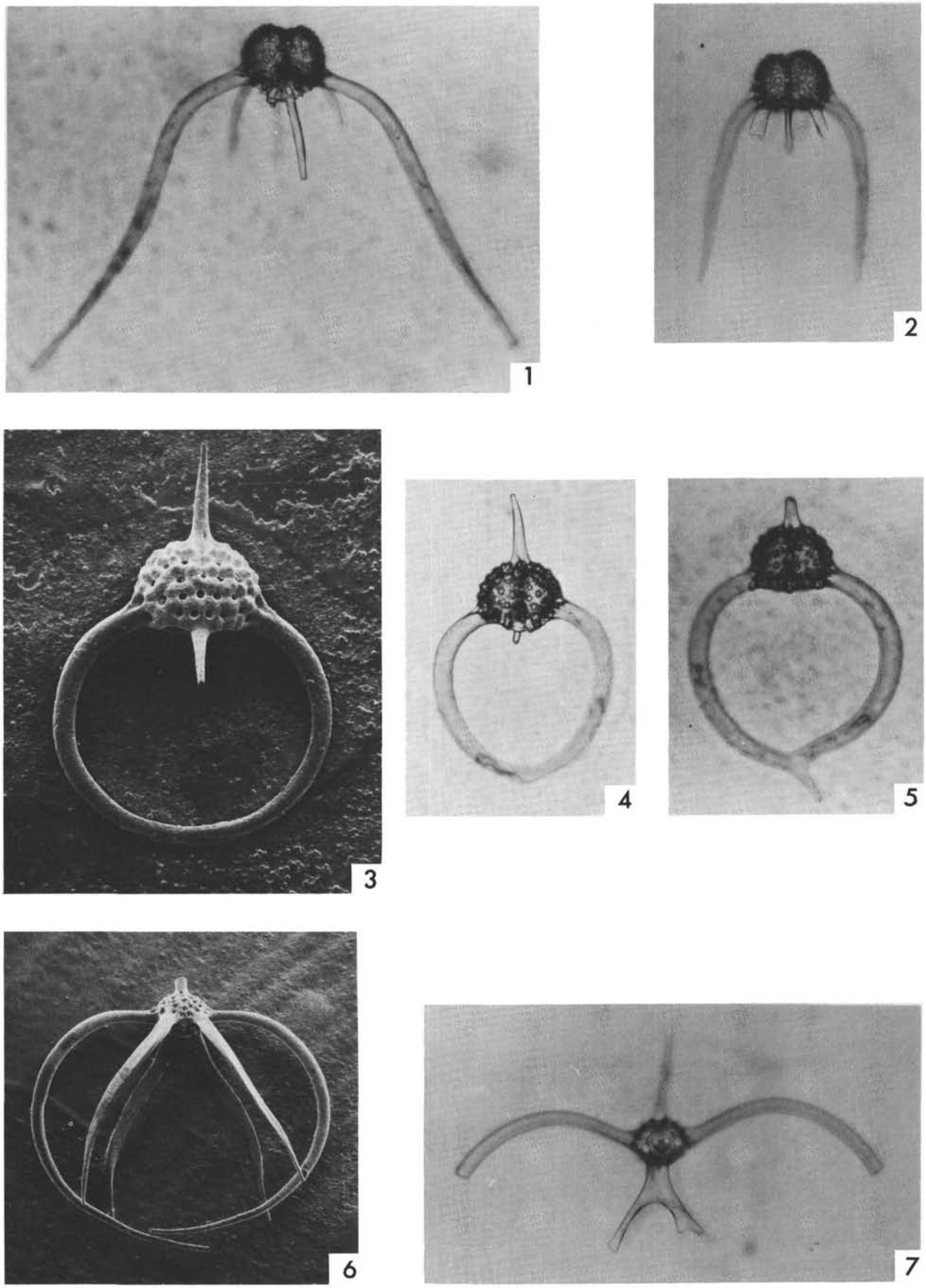

PLATE 9

Figure 1	*Dorcadospyris riedeli.* (Holotype) 70A-3-CC. ×100.
Figures 2, 3	*Dorcadospyris riedeli.* (2) (Paratype) 70A-3-CC. ×106. (3) 69A-2-3, 81-83 cm. ×138.
Figure 4, 5	*Dorcadospyris praeforcipata.* (4) (Holotype) 69-4-1, 45-47 cm. ×138. (5) (Paratype) 69-4-1, 45-47 cm. ×100.
Figure 6, 7	*Dorcadospyris praeforcipata.* (6) 69A-1-5, 81-83 cm. ×138 cm. (7) (Paratype) 69A-1-5, 81-83 cm. ×100.
Figure 8	*Lychnocanium bipes.* 69-4-1, 45-47 cm. ×138.

PLATE 9

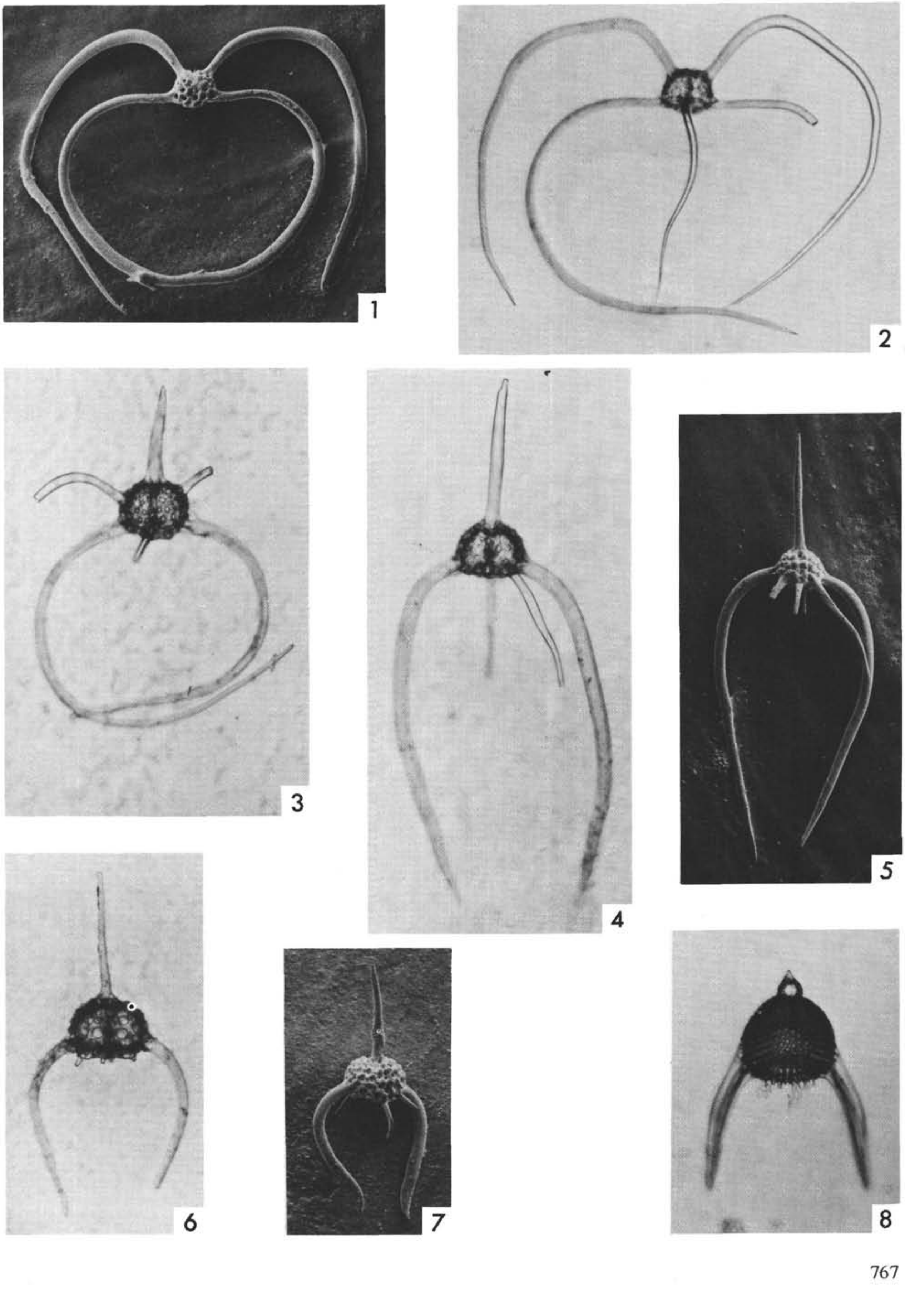

PLATE 10

Figure 1, 2	*Dorcadospyris forcipata.* (1) 69-3-1, 83-85 cm. ×138. (2) 71-26CC. ×100.
Figures 3, 4	*Dorcadospyris simplex.* (3) 71-30-CC. ×100. (4) 71-30-CC. ×138.
Figure 5, 6	*Calocycletta robusta.* (5) (Holotype) 70A-1-3, 81-83 cm. ×138. (6) (Paratype) 69-4-1, 45-47 cm. ×138.
Figure 7	*Calocycletta virginis.* 69-3-1, 83-85 cm. ×138.
Figure 8	*Calocycletta costata.* 69-3-1, 83-85 cm. ×138.

PLATE 10

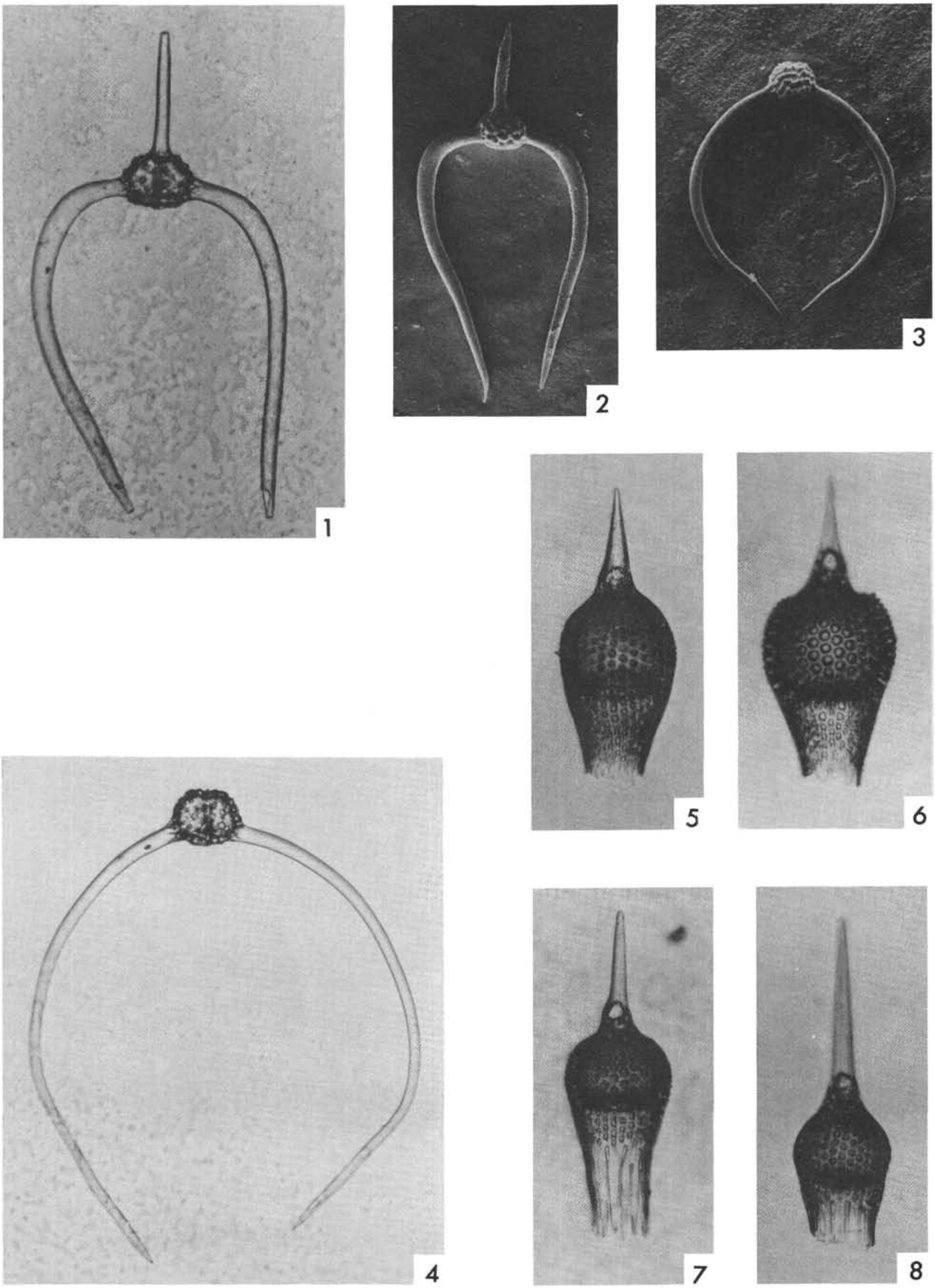

PLATE 11

Figure 1, 2	*Dorcadospyris dentata.* (1) 69-3-1, 83-85 cm. ×138. (2) 69-3-1, 83-85 cm. ×101.
Figure 3, 4	*Dorcadospyris alata.* (3) 71-17-3, 81-83 cm. ×100. (4) 70-4-3, 81-83 cm. ×138.
Figure 5	*Cyrtocapsella cornuta.* 69-3-3, 81-83 cm. ×138.
Figure 6, 7	*Cyrtocapsella tetrapera.* (6) 70-4-3, 81-83 cm. ×138. 71-30-CC. ×138.
Figure 8	*Acrobotrys tritubus.* 72-3-1, 81-83 cm. ×138.

PLATE 11

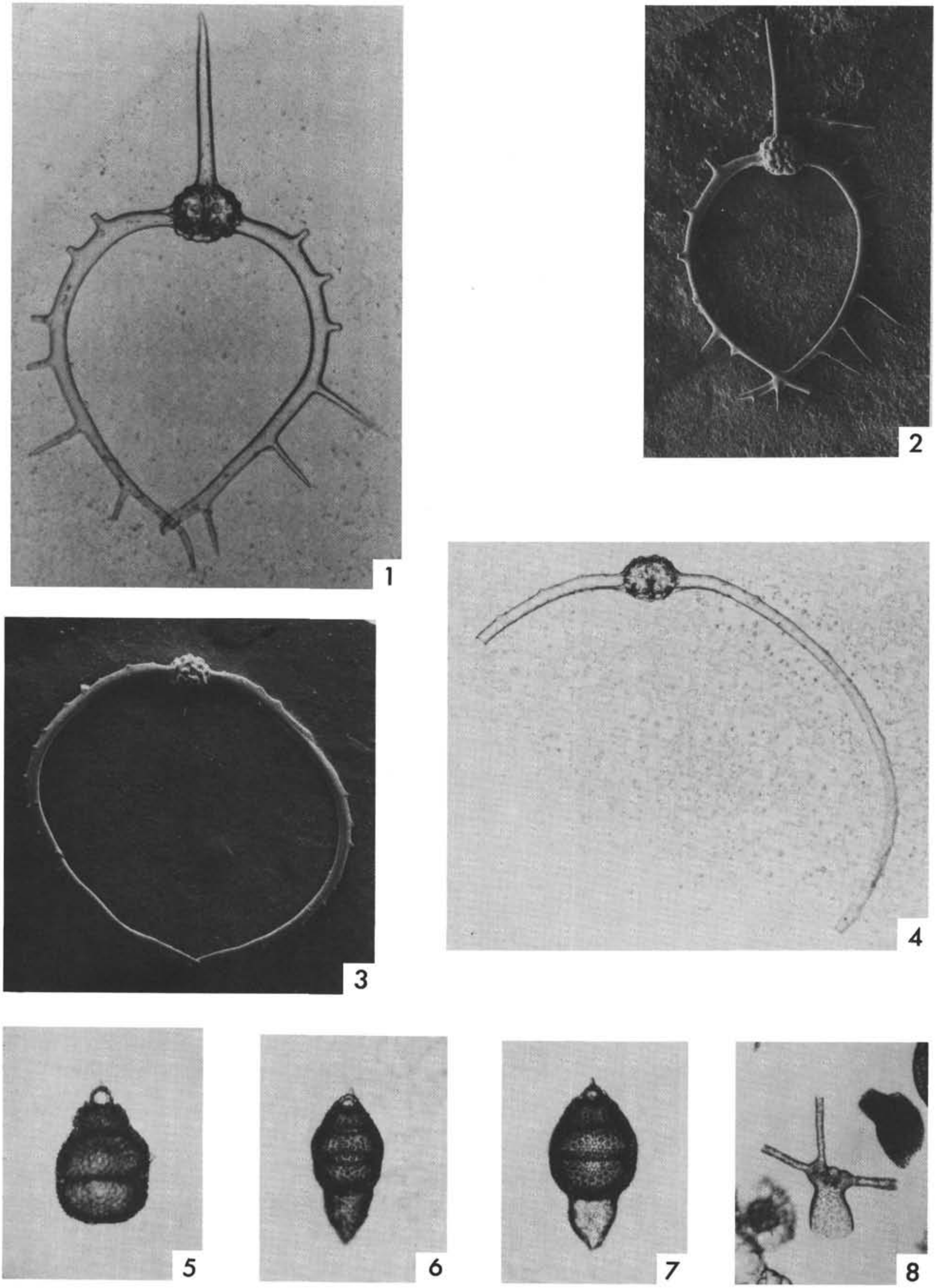

PLATE 12

Figure 1, 2	*Cannartus prismaticus.* (1) 69A-5-CC. ×138. (2) 69-3-1, 83-85 cm. ×138.
Figure 3	*Cannartus tubarius.* 69-3-1, 83-85 cm. ×138.
Figure 4	*Cannartus violina.* 69-3-1, 83-85 cm. ×138.
Figure 5	*Cannartus mammiferus.* 70-4-3, 81-83 cm. ×138.
Figure 6	*Cannartus laticonus.* 69-1-1, 55-57 cm. ×138.
Figure 7	*Cannartus petterssoni.* 69-1-1, 55-57 cm. ×138.
Figure 8	*Ommatartus hughesi.* 69-1-1, 55-75 cm. ×138.
Figure 9, 10	*Ommatartus antepenultimus.* 69-1-1, 55-57 cm. ×138.
Figure 11	*Ommatartus penultimus.* 69-1-1, 55-57 cm. ×138.
Figure 12	*Ommatartus tetrathalamus.* 73-1-CC. ×138.

PLATE 12

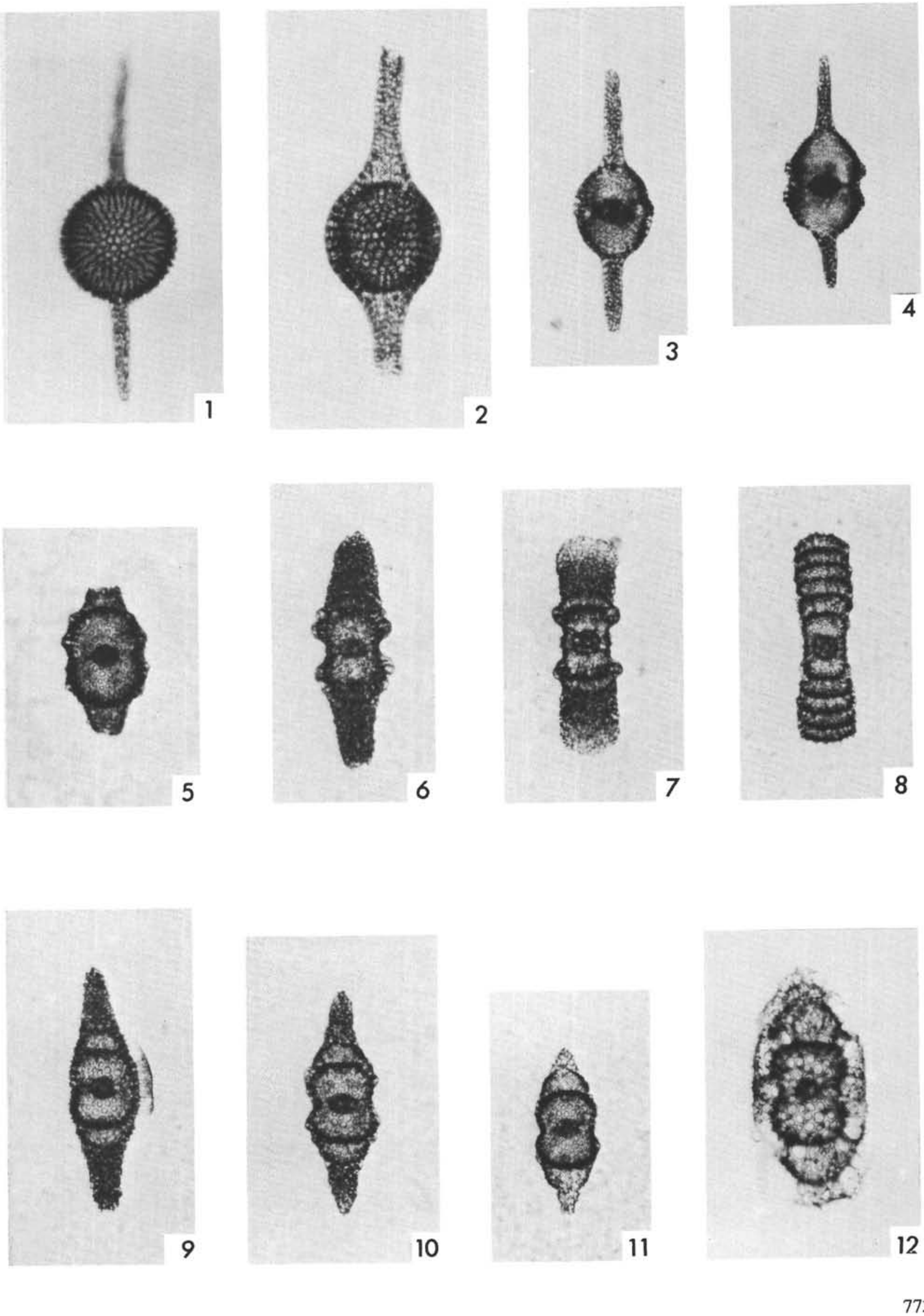

PLATE 13

Figure 1, 2	*Pterocanium prismatium.* 73-6-3, 81-83 cm. ×138.
Figure 3	*Pterocanium praetextum.* 73-1-CC. ×138.
Figure 4	*Spongaster tetras.* 73-1-CC. ×138.
Figure 5, 6	*Spongaster pentas.* 73-6-3, 81-83 cm. ×138.
Figure 7	*Stichocorys delmontensis.* 70-4-3, 81-83 cm. ×138.
Figure 8	*Stichocorys wolffii.* 69-3-1, 83-85 cm. ×138.
Figure 9, 10	*Stichocorys peregrina.* 73-6-3, 81-83 cm. ×138.

PLATE 13