

41. MIDDLE MIOCENE TO RECENT RADIOLARIANS FROM THE WEDDELL SEA, ANTARCTICA, ODP LEG 113¹

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ABSTRACT

Well preserved middle Miocene to Recent radiolarians were recovered from several sites in the Weddell Sea by ODP (Ocean Drilling Program) Leg 113. Low rates of sedimentation, hiatuses, and poor core recovery in some sites are offset by the nearly complete recovery of a late middle Miocene to late Pliocene section at Site 689 on the Maud Rise. Although a hiatus within the latest Miocene exists, this site still provides an excellent reference section for Antarctic biostratigraphy. A detailed radiolarian stratigraphy for the middle Miocene to late Pliocene of Site 689 is given, together with supplemental stratigraphic data from ODP Leg 113 Sites 690, 693, 695, 696, and 697. A refined Antarctic zonation for the middle Miocene to Recent is presented, based on the previous zonations of Hays (1965), Chen (1975), Weaver (1976b), and Keany (1979). The late Miocene radiolarian *Acrosphaera australis* n. sp. is described and used to define the *A. australis* zone, ranging from the first appearance of the nominate species to the last appearance of *Cycladophora spongothorax* (Chen) Lombardi and Lazarus 1988. The species *Botryopera deflandrei* Petrushevskaya 1975 is transferred to *Antarctissa deflandrei* (Petrushevskaya) n. comb.

INTRODUCTION

Radiolarians are the most diverse, and often the best preserved, group of microfossils in Antarctic Neogene sediments, and thus important for stratigraphy, paleoceanography, and evolutionary studies. While Pliocene-Pleistocene radiolarian taxonomy and stratigraphy are relatively well known (Hays, 1965; Lozano and Hays, 1976; Petrushevskaya, 1968), prior to ODP Leg 113, knowledge of Antarctic Miocene radiolarians was much less complete, being restricted to studies of isolated piston cores and generally highly incomplete sections drilled by DSDP Legs 28, 29, 35, 36, and 71 (Chen, 1975a; Petrushevskaya, 1975; Weaver, 1976a; 1983).

ODP Leg 113 is one of four recent Antarctic legs which have collectively recovered a high quality, nearly complete Neogene record of Antarctic radiolarians. ODP Leg 113 drilled several holes at eight sites in the Weddell Sea region of the Southern Ocean between 61° and 72°S latitude. Radiolarians were recovered at all sites, although abundance and preservation differed considerably. Well preserved radiolarians were recovered from three distinct stratigraphic intervals: Early Cretaceous, early Oligocene, and late middle Miocene to Recent. Moderately preserved radiolarians were recovered from Late Cretaceous and late Oligocene to early middle Miocene intervals. The late middle Miocene to Recent radiolarians are described in this report, the Cretaceous radiolarians in Ling and Lazarus (this volume), and the late Oligocene to early middle Miocene radiolarians in Abelman (also this volume). Early Oligocene radiolarians are not the subject of a special report, since they were recovered only from a short interval in one hole (Cores 113-689B-12H to -14H), while similar, but much more extensive, early Oligocene assemblages were recovered by ODP Leg 114, and are the subject of a detailed Leg 114 report by Ling (pers. comm., 1988).

The primary purpose of this paper is to provide an improved radiolarian zonation for the late middle Miocene to Recent. The

calibration of this zonation is given in Gersonde et al. (this volume). Although some taxonomic discussion is given for stratigraphic forms, more detailed taxonomic studies of Leg 113 middle Miocene to Recent radiolarians will be the subject of a later report.

Five of the eight sites drilled during ODP Leg 113 recovered well preserved middle Miocene to Recent radiolarians (Table 1). The stratigraphic age distribution of recovered materials, quality and completeness of core recovery, and sedimentation rates, however, differ dramatically between these sites. The two Maud Rise sites, 689 and 690, have the best preserved assemblages, particularly in the Miocene, very complete core recovery, and high quality paleomagnetic data. The other ODP Leg 113 sites in Table 1, by contrast, recovered only relatively short stratigraphic intervals, have only moderate core recovery, and/or lack high quality paleomagnetic data. Given the goals of this report, it was decided to concentrate on the radiolarian stratigraphy of Sites 689, 690, and 693, and in particular, Site 689, which appears to have the most complete section. Stratigraphic data for other sites are given only in summary form in this paper, and Barker, Kennett, et al. (1988) should be consulted for additional information on these sites.

MATERIALS AND METHODS

Samples of sediment between 5 and 10 cm³ in size were disaggregated using either 35 vol% H₂O₂ followed by boiling in a 1 vol% solution of Calgon, or, if very clay rich, by addition of 35% H₂O₂, drying, addition of kerosene to the warm sample, decanting of excess kerosene, and boiling in Calgon solution. 10 vol% acetic acid or 10 vol% HCl was used to remove CaCO₃, when present. The disaggregated sediment was washed through a 63 μm stainless steel sieve, and a microscope slide prepared from the coarse fraction, using gum tragacanth to hold the specimens, and Canada balsam as the mounting medium. Shipboard samples were made into strewn slides using an eyedropper, while samples prepared on shore were made using the settling method described by Moore (1973). Qualitative abundances of radiolarians and other important components of the coarse fraction were recorded, together with information on the occurrences of stratigraphic indicator species.

¹ Barker, P. F., Kennett, J. P., et al., 1990. *Proc. ODP, Sci. Results*, 113: College Station, TX (Ocean Drilling Program).

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Table 1. Middle Miocene to recent radiolarians in Leg 113 sites. Age column gives ages of recovered sediments with radiolarians: M = Miocene; Pl = Pliocene; Ps = Pleistocene.

Site	Latitude	Longitude	Water depth (m)	Age	Recovery	Radiolarian abundance	Radiolarian preservation
689	64°31'S	3°6'E	2080	M-Pl	Excellent	Abundant	Good
690	65°10'S	1°12'E	2914	M-Pl	Excellent	Abundant	Good
693	70°50'S	14°35'W	2359	M-Pl	Moderate	Common	Moderate-Good
694	66°51'S	33°27'W	4653	M-Ps	Poor	Rare	Poor-Moderate
695	62°24'S	43°27'W	1305	Pl	Good	Common-Abundant	Good
696	61°51'S	42°56'W	650	M-Pl	Poor	Common	Good
697	61°49'S	40°17'W	3482	Pl-Ps	Moderate-Good	Few-Common	Poor-Moderate

NEOGENE RADIOLARIAN ZONATION OF ANTARCTIC SEDIMENTS AND PREVIOUS ANTARCTIC DRILLING

Radiolarian zonation of Antarctic Neogene sediments has been attempted by several workers, but no universally agreed upon zonation currently exists. Most studies have presented zonal schemes that are modifications of two basic zonations. The basis for most Pliocene-Pleistocene Antarctic radiolarian zonations is that of Hays (1965), and Hays and Opdyke (1967), while the most commonly used basis for Miocene zonation is that of Chen (1975a). A partial summary of earlier zonations is given by Keany (1979). An updated history of Antarctic radiolarian zonations is given below, followed by the zonation used in this report, and comments on various datum levels used. Figure 1 summarizes some of the more important zonal schemes referred to below.

Hays' (1965) zonation is based on the sequential disappearance of several species, and covers the interval from ~4.0 Ma (middle Gilbert magnetochron) to the Recent (Hays and Opdyke, 1967). This zonation has, for the most part, proved reliable in the Leg 113 material, and has been primarily modified by subdivision of zones using secondary markers. Chen's (1975a) zonation covered the entire Neogene, and was based on the first DSDP cores from the Antarctic, obtained by DSDP Leg 28. In the middle Pliocene to Pleistocene interval, Chen used Hays' zones, but renamed them from the Greek letter system of Hays to a more typical nomenclature based on species names. Chen also modified the early Pliocene part of Hays' zonation, combining Hays' Upsilon and Tau Zones into a single *Helotholus vema* Zone. Subsequent work (and this report) however has continued to employ Hays' original nomenclature, and his distinction between an Upsilon and a Tau Zone. In the Miocene, Chen defined a series of new zones, based primarily on the sequence seen in DSDP Site 266 (Leg 28) south of Australia, as this was the most complete Miocene section then available. Many of these zones have unfortunately subsequently proved to be of little use, chiefly due to the rarity of the defining species, together with the consequent difficulties in accurately identifying the range of these species in the Leg 28 material. Only one of Chen's (1975a) late middle Miocene to latest Miocene zones is used in this report, although it has been redefined and subdivided. Abelmann (this volume) presents a new zonal scheme for the earliest Miocene through lower middle Miocene interval. Petrushevskaya (1975) developed an independent zonation for the Neogene, based on DSDP Leg 29 material. This zonation however has not been employed by any subsequent workers. Chen's zonation was employed for Leg 35 (Weaver, 1976a), and no radiolarian report was produced for Leg 36. Weaver (1976b), using both piston cores and DSDP cores, provided a detailed zonation for the early Pliocene and late Miocene. In addition to defining new zones, and modifying several previous zones, Weaver (1976b) revised the taxonomy of some of the zonal marker species, and

identified several additional secondary marker events. Some of these primary and secondary marker events are incorporated into the present zonation. Keany (1979) also provided a revised zonation for the early Pliocene, based primarily on piston cores, and in part on Weaver's (1976b) study. Keany's (1979) early Pliocene zones, while similar to Weaver's, are based on different marker species and are differently named. Some of Keany's stratigraphy has been incorporated into the present zonation. Finally, Weaver (1983), in the Initial Reports from Leg 71, used a slightly modified form of the zonation first presented in Weaver (1976b).

Radiolarian Taxonomic Nomenclature and Zonations

One additional complexity must be considered in any discussion of Antarctic radiolarian zonations. Although Chen's (1975a) zonation has been largely modified by subsequent work, the species reported in Chen (1975a) as being of stratigraphic use are still widely employed in Miocene zonation schemes (e.g., Abelmann, this volume). Unfortunately, many of these species names are junior synonyms, with the correct names being given instead in Petrushevskaya (1975). Petrushevskaya's publication, dated January, 1975, has priority according to the Rules of Zoological Nomenclature, despite the publication in *Micropaleontology* of Chen's nomenclature for these forms (Chen, 1974). This is because this latter publication, although dated 1974, was in fact not mailed until after the mailing of DSDP Initial Reports Volume 29, which contains Petrushevskaya's paper. The Leg 28 volume, containing Chen (1975a) was also mailed after the Leg 29 volume. Thus, although Chen described as "new" several species, not once, but twice, neither set of descriptions are valid. Many previous works (including the author's own work for Leg 113 in Barker, Kennett, et al., 1988) did not recognize this fact, and thus used the incorrect names. Even Petrushevskaya (1986) apparently was unaware of the actual mailing dates of these papers, as she incorrectly synonymizes some of her own senior synonyms with the junior synonyms of Chen (1974, 1975a). The correct names are used in this report. Weaver (1976a) has provided a partial list of equivalences between Petrushevskaya's and Chen's nomenclature, and Chen has also noted equivalences between the two systems (Chen, unpubl. corrections to his Ph.D. thesis, 1975b).

DEFINITION OF ZONES

In the following zonation, datum levels which are believed to be most reliable are used to mark zonal boundaries, while other, less reliable datum levels are used to mark subzonal boundaries. The ages of all datum levels are from Gersonde et al. (this volume).

Cycladophora spongothorax Zone (11.3-9.0 Ma)

Base. First appearance of *Cycladophora spongothorax* (Chen) Lombardi and Lazarus, 1988.

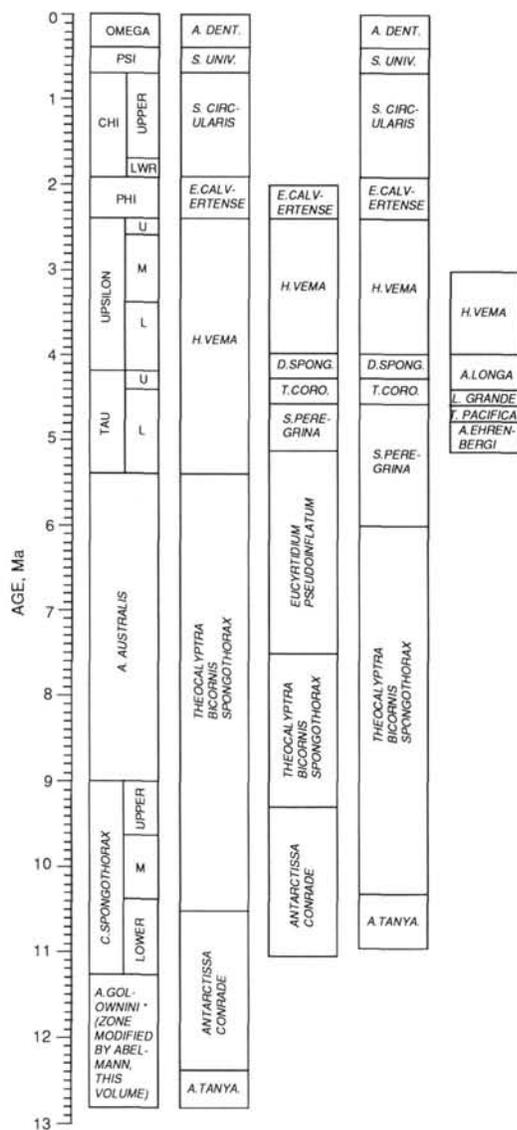


Figure 1. Radiolarian zonation of middle Miocene to Recent Antarctic sediments. The zonation used in this report is identical to that used in Barker, Kennett, et al. (1988), except for the conversion of the upper part of the upper *C. spongothorax* Subzone into the newly defined *A. australis* Zone. Chen's zonation is identical (except for nomenclature) in the Pliocene-Recent to Hays (1965) and Hays and Opdyke (1967). In the Miocene portion of his zonation no precise calibration was possible, and the age shown for his boundaries are approximate. Weaver's (1976b, 1983) and Keany's age estimates are as given by the authors, except for the Pliocene-Recent interval, where zonal boundaries have been corrected to align with the age estimates for the same biostratigraphic markers used in this report. In the Miocene however, different estimates exist for the same biostratigraphic markers. For example, the first appearance of *Cycladophora spongothorax* (= *Theocalyptra bicornis spongothorax*), used by all authors to mark the base of the *C.* (or *T. b.*) *spongothorax* Zone, varies between ~9.2 and 12.4 Ma. The age scale and calibration of the zonation as used in this report are discussed in Gersonde et al. (this volume). *A. australis* = *Acrosphaera australis*, *A. dent.* = *Antarctissa denticulata*, *A. ehrenbergi* = *Anthocyrtidium ehrenbergi*, *A. long.* = *Antarctissa longa*, *A. tanya.* = *Actinomma tanyacantha*, *D. spong.* = *Desmospyris spongiosa*, *E. calvertense* = *Eucyrtidium calvertense*, *H. vema* = *Helotholus vema*, *L. grande* = *Lychnocanium grande*, *S. circularis* = *Saturnalis circularis*, *S. peregrina* = *Stichocorys peregrina*, *S. univ.* = *Stylatractus univerversus*, *T. coro.* = *Tricerasypris coronata*, *T. pacifica* = *Tricerasypris pacifica*.

Top. First appearance of *Acrosphaera australis* n. sp.

This zone is subdivided into three subzones (lower, middle, and upper) by the last appearance of *Actinomma golownini* Petrushevskaya, 1975 (lower/middle-10.3 Ma) and the first appearance of *Eucyrtidium pseudoinflatum* Weaver, 1983 (9.6 Ma).

Comments. The top of this zone is now substantially older than in the definition of the *C. spongothorax* Zone used in Barker, Kennett, et al. (1988). The first appearance of *E. pseudoinflatum* was first used by Weaver to mark the base of his *E. pseudoinflatum* Zone. This species however is often quite rare when it first appears, and thus is not thought to be reliable enough (at least without further analysis) to serve as a primary zonal marker. The last appearance of *A. golownini* is also difficult to consistently identify, as it too becomes quite rare near the top of its range, and may also be shifted upward by reworking. In DSDP Site 278 in fact these two events appear to be coincident, and no middle *C. spongothorax* Zone is recognized (Lazarus, unpubl. observations). In Site 690 the two events are also quite close to each other, if not actually coincident.

Acrosphaera australis Zone (9.0-8.0 Ma)

Base. First appearance of *Acrosphaera australis* n. sp.

Top. Last consistent appearance of *Cycladophora spongothorax*.

Comments. This zone represents the upper part of the upper *C. spongothorax* zone as used in Barker, Kennett, et al. (1988). This zone is also recognizable in Leg 120 material from the Kerguelen Plateau (Lazarus, in prep.). The last appearance of *C. spongothorax* appears to be fairly reliable, although some reworking may be common (e.g., Site 689). The last consistent appearance is therefore used to mark the zonal boundary. Note however that in this report the age estimate for the LAD of *C. spongothorax* is significantly older than the 5.4 Ma estimate used in Barker, Kennett, et al. (1988). This datum could not be calibrated previously, as it generally occurs at, or very close to, a major latest Miocene hiatus in most Antarctic sediments. ODP Leg 119 however, has recovered a nearly complete late Miocene section at Site 746, which allows the LAD of *C. spongothorax* to be calibrated at ~8.0 Ma (J. P. Caulet, pers. comm., 1989).

Tau Zone (8.0-4.2 Ma)

Base. Last consistent occurrence of *C. spongothorax*.

Top. First occurrence of *Helotholus vema* Hays, 1965.

This zone is subdivided into two subzones (lower and upper) by the last common occurrence of *Lychnocanium grande* Campbell and Clark, 1944 (4.4 Ma).

Comments. The base of this zone is as first defined by Chen (1975a), while the top of the zone is the first appearance of *H. vema* as this species is defined by Weaver (1976b, 1983), and not the range of *H. vema* as shown by Hays (1965) and Kellogg (1975). In Barker, Kennett, et al. (1988), it was noted that the first appearance of *H. vema* was unreliable. This appears to have been due to the misidentification as *H. vema* of a previously unreported species similar to, but not conspecific with, *H. vema*. A description of this species will be included in a future report. The last common occurrence of *L. grande* as is used in this report appears to be chronologically equivalent to the last occurrence of this species as shown in Keany (1979). It should be noted however that in the present usage the two events are distinctly different, with the last occurrence of this species being well above its last common occurrence. Given the difficulty in reproducibly defining acme type datums, this event is only used as a subzonal marker. As noted above, the base of this zone is significantly older than the 5.4 Ma age used in Barker, Kennett, et al. (1988).

Upsilon Zone (4.2-2.4 Ma)

Base. First appearance of *H. vema*.

Top. Last appearance of *H. vema*.

This zone is subdivided into three subzones (lower, middle, upper) by the last appearance of *Prunopyle titan* Campbell and Clark, 1944 (lower/middle-~3.4 Ma) and the first consistent appearance of *Cycladophora davisiana* Ehrenberg, 1872a, b (middle/upper-~2.7 Ma).

Comments. Weaver (1976b) noted the subzonal markers as secondary biostratigraphic datum levels, but also specifically commented on the diachrony of the last occurrence of *P. titan*. Weaver's definition of this event however appears to be the last common occurrence, which is indeed unreliable, since the species is often, but not always, rare in the upper part of its range. Given Weaver's observations however, and the possibility for reworking, this event is only used as a subzonal marker.

The first appearance of *C. davisiana* appears to be globally isochronous (Hays, pers. comm., 1988), but is only distinguishable from the top of the Upsilon Zone itself in cores with better than average sedimentation rates and/or sampling density. It is therefore only used as a subzonal marker.

Phi Zone (2.4–1.9 Ma)

Base. Last appearance of *H. vema*.

Top. Last appearance of *Eucyrtidium calvertense* Martin, 1904.

Comments. As defined by Hays (1965). Note the species *E. calvertense* still exists in the modern ocean in warmer regions, thus its disappearance in the Antarctic is only a local one.

Chi Zone (1.9–~0.8 Ma)

Base. Last appearance of *Eucyrtidium calvertense*.

Top. Last appearance of *Pterocanium charybdeum trilobum* (Müller) Lazarus et al., 1985.

This zone is subdivided into two subzones by the last appearance of *Cycladophora pliocenica* (Hays) Lombardi and Lazarus, 1988 (~1.6 Ma).

Comments. The last appearance of *P. c. trilobum* (= Hays' *Pterocanium* sp.) is not easy to identify in many cores, as it is often quite rare (Hays and Opdyke, 1967), and in fact was generally not seen in Leg 113 material. Chen's suggested use of the last appearance of *Saturnalis circularis* Haeckel, 1887 instead is equally unsatisfactory, as this species is also quite rare. The last appearance of *Clathrocylcas bicornis* (Hays) (renamed to *Cycladophora pliocenica* by Lombardi and Lazarus, 1988) was noted by Hays and Opdyke to be a reliable event within the Chi Zone, and is here defined as a subzonal marker.

Psi Zone (~0.8–0.43 Ma)

Base. Last appearance of *P. c. trilobum*

Top. Last appearance of *Stylatractus universus* Hays 1970

Comments. As defined by Hays (1965). In Leg 113 material, no continuous, well preserved radiolarian sequences were recovered from the Pleistocene, so it is not possible to study the boundaries of this, and other Pleistocene zones. However, *S. universus* does not appear to be present in latest Pliocene–earliest Pleistocene sediments recovered during Leg 113 (a similar situation was noted by Weaver (1976a) for Leg 35). In the range charts given in Hays and Opdyke (1967), this species is consistently present only in Pleistocene sediments. The last appearance of *Antarctissa cylindrica* Petrushevskaya 1975 may prove to be a better marker within this stratigraphic interval, as it is generally abundant. This event could not be calibrated in Leg 113 material, as little Pleistocene material was recovered. Chen (1975b), using the same paleomagnetically dated cores as Hays and Opdyke (1967), has identified this event within the lower Brunhes, between the last appearance of *P. c. trilobum* and the last appearance of *S. universus*.

Omega Zone (~0.43 Ma–Recent)

Base. Last appearance of *S. universus*.

Top. Holocene.

Comments. As defined by Hays (1965).

RADIOLARIAN STRATIGRAPHY OF SITES 689, 690, AND 693

Tabular range charts showing the occurrence of all stratigraphic indicator species, and selected other species, are given for Holes 689B, 690B, and 693A as Tables 2–4. Only the late middle Miocene and younger interval is shown, as the earlier interval is described in Abelmann (this volume). Also, only one hole has so far been studied in detail at each site (Holes 689B and 690B). Shipboard analysis indicates that the sections in other holes are very similar. Only core-catcher samples were examined in Site 693. This is acceptable as incomplete core recovery and high sedimentation rates do not justify a more detailed sampling for biostratigraphic analysis.

In Hole 689B, the top of the section is middle Pliocene in age (middle Upsilon). Younger sediments are missing, either due to hiatus or incomplete core recovery. Most late Pliocene and Pleistocene sediment appears to be missing at this locality, as is also indicated by diatom stratigraphy of the surficial sediments in Holes 689A and 689B (Gersonde, this volume). All remaining

Pliocene to late middle Miocene zones and subzones are present. Paleomagnetic data and sedimentation rate estimates however indicate the existence of a significant hiatus between the late Miocene and early Pliocene at ~21.7 mbsf. In Hole 689B radiolarian stratigraphy the hiatus is apparent in the upper part of Core 3, Section 5. Sample 113-689B-3H-5, 47–49 cm, contains a mixture of late Miocene and early Pliocene forms, making zonal assignment questionable. The mixture of specimens of different ages also makes taxonomic assignment of populations belonging to gradually evolving lineages (such as *Antarctissa*) difficult. Samples immediately above and below this level are assigned to different zones—the late Miocene to early Pliocene lower Tau Subzone above, and the late Miocene *A. australis* zone below. The middle *C. spongothorax* Subzone is very long in Site 689. This is due, in part at least, to a high rate of sedimentation in this interval (Gersonde et al., this volume). The extent of this subzone may be exaggerated however, for the lower boundary of this subzone is hard to pick, the upper range of *A. golownini* being rare and discontinuous.

At Site 690, the top of the section is also in the middle Upsilon Subzone. While the main earlier Pliocene and Miocene zones are present, several subzones appear to be missing, and the *A. australis* Zone is very short. Several hiatuses are probably present at this site, and rates of sedimentation are also low (cf., Gersonde et al., this volume, for discussion).

At Site 693, some Pleistocene sediment is apparent in the top two or three cores, but the absence or rarity of zonal markers, and, in Core 113-693A-3H, the near absence of radiolarians, prevents more precise age assignment to this interval. The rare occurrence of *S. universus* in Sample 113-693A-2R, CC, suggests an age older than 400 k.y. It should be noted that if Chen's (1975b) calibration of the last appearance of *A. cylindrica* is correct, the upper two cores in Hole 693A are late Pleistocene in age (< ~550 k.y.). Cores 113-693A-4R to -7R are in the middle Upsilon Subzone (not, as indicated in Barker, Kennett, et al. (1988), the upper Upsilon Subzone). All other zones and subzones are present, down to the *A. australis* Zone. The *C. spongothorax* Zone is present only in a condensed interval, while a hiatus at ~262 mbsf separates this interval from underlying lower Miocene sediments.

Summary of Datum Levels at Leg 113 Sites

Table 5 gives the location of zonal and subzonal markers for all middle Miocene to Recent material recovered by Leg 113, with the exception of Site 694, where datable radiolarians were too scarce to identify zonal positions with any reliability. The age of the events are explained in Gersonde et al. (this volume). For information on the radiolarians at each of these sites, see Tables 2–4, and site chapters in Barker, Kennett, et al. (1988).

TAXONOMY

The following list gives, in alphabetical order, comments on selected species of stratigraphic importance, but is not comprehensive. Weaver (1983) gives references to many of those species not discussed here. In addition, one new species—*Acrosphaera australis*—is described, and *Antarctissa deflandrei* n. comb. is created.

Acrosphaera australis, n. sp.

(Pl. 1, Figs. 1–2 (Holotype), 3–4 (Paratypes), 5–6; Pl. 2, Fig. 6)

Description. Smooth, hyaline sphere with large, irregularly spaced and shaped pores extended outward radially into tubes; tube tips flared and in many of the pores joined to adjacent tube tips to form outer layer of hyaline bands or bridges between tube tips.

Comments. Distinguished from other collosphaerids by the presence of an outer layer of elevated bands joining tube tips. Evolves from *Acrosphaera murrayana* (Haeckel) Strelkov and Reshetnyak, 1971 by the joining together of the flared tips of the tubes. This evolutionary transition is clearly seen in Leg 113 material, with transitional specimens being quite common in populations at the base of *A. australis*' range. The

ANTARCTISSA

first appearance is defined by the first occurrence of specimens with more than one pair of pores joined by well developed bands. Specimens of *A. murrayana* still occur in these early, transitional populations. The generic assignment follows the revisions of Strelkov and Reshetnyak (1971) and Björklund and Goll (1979), which divide the collosphaerids into genera based on the presence or absence of tubes or spines. As noted by Björklund and Goll, even the current generic divisions in the collosphaerids are artificial, as evolutionary transitions between spinose, tubular, and unornamented forms are seen in fossil lineages. This is true in particular of the *Acrosphaera murrayana*-*A. australis* lineage, since *A. murrayana* is a spinose form, while *A. australis* is a tubular one. *Acrosphaera* is retained however until a better generic taxonomy for the collosphaerids becomes available.

Etymology. "australis" = southern.

Known range. middle late Miocene to latest Miocene, circum-Antarctic, Southern Ocean.

Type material. From Sample 113-689B-3H-6, 56-58 cm. Type specimens deposited in the paleontological collections of the Geologisches Institut, ETH-Zürich.

Acrosphaera murrayana (Haeckel) Strelkov and Reshetnyak, 1971 (p. 347, fig. 25)
(Pl. 2, Figs. 3, 4)

The antarctic specimens referred to under this name differ somewhat from those illustrated from lower latitudes (e.g., Strelkov and Reshetnyak, 1971; Goll, 1980), with larger pores and spines in relation to shell diameter than is typical for the lower latitude populations. The forms illustrated by Goll (1980) as *Acrosphaera trepanata* (Haeckel) Goll, 1980 are also similar to the antarctic material. Without a more detailed comparative analysis however, creation of a new species is unjustified.

Acrosphaera sp.-"ringed" collosphaerid
(Pl. 2, Fig. 5)

Collosphaerid sp., Keany, 1979, (pl. 1, fig. 5.).

Large, spherical collosphaerid with raised, thickened rims around the pores. In transmitted light the pores appear to be surrounded by a halo or ring. In some specimens the rims between adjacent pores touch, giving a superficial similarity to *Acrosphaera australis*. These rims however are thickened areas of the main shell, not elevated bands, as in *A. australis*.

Range. late Miocene to earliest Pliocene (Tau Zone). Keany (1979) shows "Collosphaerids" in piston core E14-08 ranging up to C3N3 ("c" subchron of the Gilbert). Although he does not discuss the taxonomy, it is assumed that his stratigraphic data refers to the illustrated specimens—the "ringed" and "conical pore" types of this report.

Acrosphaera sp.-"conical pore" collosphaerid
(Pl. 2, Figs. 1, 2).

Collosphaerid sp., Keany, 1979, (pl. 1, fig. 4.).

Large, spherical collosphaerid with pores at ends of short conical tubular projections of the shell surface.

Range. late Miocene to earliest Pliocene. See also comments for previous taxon.

Actinomma golownini Petrushevskaya, 1975 (p. 569, pl. 2, fig. 16)
(Pl. 7, Figs. 6-8)

Actinomma tanyacantha Chen, 1974 (p. 481-482, pl. 1, figs. 1, 2); 1975a (p. 450, pl. 11, figs. 5, 6)

Actinomma golownini virtually always has 14 primary spines arranged at the corners and faces of a cube, and the cortical shell is slightly flattened in most specimens into a subcubical shape. The species is also recognizable by the relatively large cortical pores. Although Petrushevskaya's verbal description is not very accurate (she refers to only 10 primary external 3-blade spines) and the photograph is poor, her species is still identifiable as being equal to Chen's (1974, 1975a) species, and it thus takes priority. There is to my knowledge no other species in the stratigraphic interval in DSDP Site 278 (Leg 29) from which Petrushevskaya based her species description (Cores 12-15) which is similar to *A. golownini*, and therefore the identification of her species is unambiguous. *Actinomma golownini* evolves from a form with a spherical (unflattened) cortical shell in the middle Miocene. This ancestral form has more primary spines, smaller cortical pores, and a less regular arrangement of the primary spines.

The species taxonomy of this important genus is at the present time not well understood. Many species that have been described by previous authors appear to be only subspecies level variants. Species concepts also appear to differ dramatically between different authors. Thus Petrushevskaya (1986) identifies more than ten species in the late Miocene to Recent of the Antarctic, while Chen (1975b), based on extensive biometric measurements and character analyses, concluded that there were only five species in the same time interval. This study has followed Chen's (1975a, b) species and genus concepts throughout, although, as noted above, Petrushevskaya's (1975) species names are used.

Antarctissa cylindrica Petrushevskaya, 1975 (p. 591,
pl. 11, figs. 19, 20)
(Pl. 3, Figs. 8-12)

Antarctissa ewingi Chen, 1974, (p. 486, pl. 3, figs. 4-6), 1975a (p. 457,
pl. 16, figures 5-9)

Distinguished by the presence of an internal ring with more than 6 (typically 8 or more) radial connecting bars to the thorax lattice-wall, and by the short, cylindrical thorax. Because the internal structure is difficult to see, identification usually is based on overall shell shape. Specimens with short thoraxes (Pl. 3, Figs. 9, 11) dominate later Pliocene populations and are easy to identify, but earlier Pliocene populations contain many individuals with longer thoraxes. These specimens are difficult to reliably distinguish from coeval specimens of *Antarctissa denticulata* (Ehrenberg) Petrushevskaya 1968, which, in the early part of its range, has a similar shell shape. Weaver (1976a) incorrectly gives *A. denticulata* sensu Chen (1975a) as the equivalent to *A. cylindrica*. As Chen noted in his thesis (1975b), the correct equivalence is between *A. cylindrica* Petrushevskaya, 1975 and *A. ewingi* Chen, 1975a, since the holotype specimen of *A. cylindrica* (Petrushevskaya, 1975, pl. 11, fig. 19) is clearly equal to Chen's *A. ewingi*. Petrushevskaya's description of *A. cylindrica* however does not make any mention of the distinctive internal structure of this species.

Antarctissa strelkovi Petrushevskaya, 1968 (p. 89, pl. 51, figs. 3-6)
(Pl. 3, Figs. 13-15)

Some authors have provided separate stratigraphic data for *A. strelkovi* and *A. longa* (Popofsky) Petrushevskaya, 1968 (Petrushevskaya, 1975; Keany, 1979), while others have not (Chen, 1975a, 1975b; Weaver, 1976b, 1983). In this study no distinction was made between these forms.

Antarctissa deflandrei n. comb.
(Pl. 3, Figs. 18, 19)

Botryopera deflandrei Petrushevskaya, 1975 (p. 592, pl. 11, figs. 30-32)
Antarctissa conradae Chen, 1974 (p. 484, pl. 3, figs. 1-3); 1975a (p. 457, pl. 17, figs. 1-5)

Botryopera conradae (Chen) Petrushevskaya 1986, (p. 193, fig. 2, no. 6)

Chen placed this species within the genus *Antarctissa*, and postulated an evolutionary lineage leading from *A. conradae* to *A. longa*. I agree with Chen's lineage, and thus also with his generic assignment. Petrushevskaya's generic classification to *Botryopera* is based on relatively slight indentations of the cephalis wall in some specimens. This does not appear to be a valid criterion for generic definition in these particular radiolarians, as transitions between indented and non-indented individuals are seen within single lineages and also within single populations. This transition between *A. conradae* (*A. deflandrei*) was placed by Chen as occurring in the early Pliocene. In the definition of this species used here, *A. deflandrei* sensu stricto is confined to the Miocene, while latest Miocene and basal Pliocene specimens such as those of Plate 3, Figures 16 and 17 are simply referred to as "transitional" specimens.

Antarctissa denticulata (Ehrenberg) Petrushevskaya, 1968 (p. 84-86,
fig. 49, I-IV)
(Pl. 3, Figs. 1-4)

Antarctissa denticulata is distinguished by the triangular outline of the shell, formed by the flared thorax, and relatively smooth cephalic-thorax suture. It is the most common species of *Antarctissa* in late Pliocene-Pleistocene sediments, and common, though usually less abundant than *A. strelkovi*, in earlier Pliocene sediments. In the earliest Pliocene many individuals transitional between *A. denticulata* and *A. robusta* are

Table 2. Abundance of radiolarians and other siliceous microfossils in the acidified >63 µm coarse fraction of Hole 113-689B.

Hole, core, section, interval (cm)	Zone/Subzone	Diatoms			Radiolarian abundance		Radiolarian preservation					Other microfossils		
		Centric diatoms	Pennate diatoms	Silicoflagellates	Radiolarian abundance	Radiolarian preservation	<i>Eucyrtidium calvertense</i>	<i>Prunopyge titan</i>	<i>Stylatractus universus</i>	<i>Helotholus vema</i>	<i>Desmospyris spongiosa</i>	<i>Lychoanium grande</i>	<i>Antarctissa denticulata</i>	<i>Dendrospyris rhodospyroides</i>
689B-1H-1, 26-28	mid Upsilon	A	C	R	A	G	F			F	C			
689B-1H-2, 50-52	mid Upsilon	A	A	R-F	C	G	R			F	F-C			C
689B-1H-3, 56-58	mid Upsilon	A	A	-	A	G	•	-		•	•			A
689B-1H-3, 118-120	mid Upsilon	A	VA	C	A	G	F	-		R	C			C
689B-1H-4, 103-105	lwr Upsilon	A	A	A	A	G	F	F-C	R	R	•			C
689B-1H, CC	lwr Upsilon				A	G	•	•		•	•			C
689B-2H-1, 52-54	lwr Upsilon	C	C	-	A	G	R	C	+	F	C			C
689B-2H-2, 62-64	lwr Upsilon	C-A	C-A	F	A	G	R	C	R	F	C-A	R		A
689B-2H-2, 118-120	lwr Upsilon	VA	A	C	A	VG	F	R-F	?F	R-F	?C	F		C
689B-2H-3, 62-64	upper Tau	C	A	F	A	M	F	F-C	(R)	R	C	F		A
689B-2H-3, 130-132	upper Tau	C	F	C	A	G	F	F	R	R	C			R
689B-2H-4, 56-58	upper Tau	A	C	C	A	G	F	F			R	R		•
689B-2H-5, 55-57	upper Tau	A	A	VA	C	G	R-F	F	+			+		•
689B-2H-6, 56-68	upper Tau	VA	A	C	A	G	?R					-		C
689B-2H-6, 116-118	upper Tau	VA	C	A	C	M						R		C-A
689B-2H, CC	lower Tau				A	G	•			-	-	C		•
689B-3H-1, 56-58	lower Tau	A	A	F	A	G	R					C		C-A
689B-3H-2, 56-58	lower Tau	C-A	C-A	-	A	G	+					C		C
689B-3H-3, 56-58	lower Tau	A	C-A	-	A	G						C		F-C
689B-3H-3, 116-118	lower Tau	A	A	F	A	G		F	F		?C	F		C
689B-3H-4, 56-58	lower Tau	A	C	R	A	G		R-F	F-C			C		C
689B-3H-4, 94-96	lower Tau	A	A	C	A	G						C		C
689B-3H-5, 47-49	? <i>A. australis</i>	A	A	-	A	G		+	C		?C	R		C-A
689B-3H-5, 136-138	<i>A. australis</i>	C	R	F	A	M		R	C		?C-A			?C-A
689B-3H-6, 55-57	<i>A. australis</i>	A	A	R	A	VG			C		?C			?C
689B-3H-6, 116-118	<i>A. australis</i>	A	C	F	A	M			F-C		?C	F		?C
689B-3H, CC	<i>A. australis</i>	A	A	-	A	G			•			•		•
689B-4H-1, 56-58	<i>A. australis</i>	VA	VA	R-F	F	G		?R	C					C
689B-4H-2, 55-57	<i>A. australis</i>	VA	A	-	C	G		F	C					C-A
689B-4H-2, 117-119	<i>A. australis</i>	VA	A	R-F	C	G		F	C					C-A
689B-4H-3, 56-58	upr <i>C. spongothorax</i>	VA	A	R	C	G			F					A
689B-4H-4, 56-58	upr <i>C. spongothorax</i>	A	A	F	A	G			R-F					•
689B-4H-4, 116-118	mid <i>C. spongothorax</i>	VA	A	R	A	M-G			+			+		F
689B-4H-5, 55-57	mid <i>C. spongothorax</i>	A	A	R	A	G								F-C
689B-4H, CC	mid <i>C. spongothorax</i>				A	G			•					•
689B-5H-3, 56-58	mid <i>C. spongothorax</i>	A	A	-	A	VG						+		F
689B-5H-4, 56-58	mid <i>C. spongothorax</i>	A	A	-	C	M			R-F					F
689B-5H-5, 56-58	mid <i>C. spongothorax</i>	C-A	C-A	F	F-C	M			?C					F
689B-5H-5, 117-118	lwr <i>C. spongothorax</i>	A	A	F	C	M			?F-C					C
689B-5H-6, 118-120	lwr <i>C. spongothorax</i>	A	A	-	C	M-G								F
689B-5H, CC	lwr <i>C. spongothorax</i>				A	G								•
689B-6H-1, 59-61	<i>D. megalcephalis</i>	A	A	F	C	M								F-C
689B-6H-2, 56-58	<i>D. megalcephalis</i>	VA	A	F-C	C	P-M								C

Note: Estimates are subjective, but reproducible to nearest major category and based on examination of several thousand to several tens of thousands of radiolarians/sample. Diatoms, radiolarian, and silicoflagellate abundance as % total coarse fraction. Radiolarian species as % of radiolarian assemblage. VA = very abundant, >90% of total; A = abundant, 20%-50%; C = common, 5%-20%; F = few, 0.5%-5%; R = rare, >1 specimen but <0.5%; + = single specimen; • = present, but relative abundance not determined; - = specially searched for but not seen. For preservation column only: VG = very good; G = good; M = moderate; P = poor. ? = specimens with uncertain taxonomic assignment. Tops and bottoms of stratigraphic species ranges indicated by boxes.

seen. These specimens (e.g., Pl. 3, Fig. 5) have nearly cylindrical thoraxes and more pronounced cephalic-thorax sutures. In outline, they are similar to coeval *A. cylindrica*, but lack the internal ring of the latter form.

Antarctissa robusta Petrushevskaya 1975, (p. 591, pl. 11, figs. 21, 22) (Pl. 3, Figs. 6, 7)

Antarctissa antedenticulata Chen, 1974, (p. 484, pl. 2, figs. 8, 9); 1975, (p. 456, pl. 18, figs. 1, 2)

?*Antarctissa equiceps* (Campbell and Clark) sensu Petrushevskaya 1975, (p. 591, pl. 11, figs. 23, 25)

?*Dictyocephalus equiceps* Campbell and Clark, 1944, (p. 46, pl. 6, fig. 15)

?*Botryopera equiceps* (Campbell and Clark) Petrushevskaya 1986, (p. 193)

This species, originally described by Petrushevskaya as *Antarctissa robusta*, and subsequently by Chen as *Antarctissa antedenticulata*, is probably con-specific with Campbell and Clark's species from the Miocene of California, although formal synonymy will require a comparative analysis of the Californian material. Chen postulated a lineage running from *A. robusta* to *A. denticulata*. If these species do form a lineage, and if *A. robusta* is conspecific with *B. equiceps*, this calls into question the assignment of *B. equiceps* to the genus *Botryopera* by Petrushevskaya (1986). It is not clear if Petrushevskaya (1975) actually transferred *D. equiceps* from *Dictyocephalus* to *Antarctissa*, since she

Table 2 (continued).

'ringed' collosphaeid	<i>Antarctissa cylindrica</i>	<i>Antarctissa deflandrei</i>	<i>Antarctissa strelkovi</i>	<i>Cycladophora pliocenica</i>	<i>Cycladophora spongothorax</i>	<i>Prunopylae hayesi</i>	<i>Eucyrtidium cienkowski</i>	<i>Acrosphaera murrayana</i>	<i>Acrosphaera australis</i>	<i>Cycladophora humerus</i>	<i>Druppactractus hastatus</i>	<i>Eucyrtidium pseudoinflatum</i>	<i>Actinomma golowini</i>	<i>Dendrosyrus megaloccephalis</i>
	C • A C •		C • A •	C • C • C •										
R	C A A • A • C C •		C-A A C A A A A A •	F-C C F F-C F C C C •								+ F-C +		
F F F-C R	• • • C • R		C-A A A A A •	F-C R F F-C •	+ R F-C R F-C			R C C-A C C •			+	R R F F R C C •		
	R	?A C-A F F •	?A •	?C •	+ F-C C C •	R F-C •								
	R R-F ?R R R •				+ F C C F F •	F F R F F •	+ R •	C ?F ?F-C C C C •		R R F-C C C •		+ R R +		?•
	C C F R A •				F R-F F C F-C •	R-F F F-C •		C F C-A C F •		C C C C-A F •	R F R R-F		?+ R F •	
	A C				?+ -	C-A C-A	F-C F	R C		C F-C	R R		R-F R	R-F C

refers to the species both with and without question marks after the generic name at several points within the text.

CYCLADOPHORA

Cycladophora spongothorax (Chen) Lombardi and Lazarus 1988 (p. 122, pl. 9, figs. 7-12)
(Pl. 4, Figs. 1-3)

Cycladophora humerus (Petrushevskaya) Lombardi and Lazarus 1988 (p. 123, pl. 9, figs. 1-6)
(Pl. 4, Figs. 4, 5)

Cycladophora pliocenica (Hays) Lombardi and Lazarus 1988, (p. 104)
(Pl. 4, Figs. 6, 7)

Cycladophora davisiana Ehrenberg 1872a, b. (pl. II, fig. 11)

Cycladophora golli golli (Chen) Lombardi and Lazarus 1988, (p. 124, pl. 11, figs. 1-12)
(Pl. 4, Fig. 8)

Species concepts in this genus follow the recent revision of Lombardi and Lazarus (1988), in which several zonal marker species were re-named: in the middle Miocene to Recent interval, *Clathrocyclas bicornis* Hays, 1965 was renamed to *Cycladophora pliocenica*, while *Theocalyptra bicornis spongothorax* Chen, 1975a was renamed to *Cycladophora spongothorax*. In the earlier Miocene, *Lophocyrtis golli* Chen 1975 was renamed to *Cycladophora golli golli*, and *L. regipileus* was renamed to *C. golli regileus*. Some individual specimens of *Cycladophora golli golli* (e.g., Pl. 4, Fig. 8) can be confused with *C. pliocenica* (Pl. 4, Figs. 6, 7), as the two species are rather similar. However, *C. g. golli* has smaller, more numerous, more rounded pores, a more cylindrical thorax, a sharper upper thoracic shoulder, and a wider upper thorax than does *C. pliocenica*. The illustrated specimens of *C. humerus* (Pl. 4, Figs. 4, 5) are smaller

Table 3. Abundance of radiolarians and other siliceous microfossils in the acidified >63 µm coarse fraction of Hole 113-690B.

Hole, core, section, interval (cm)	Zone/Subzone	Diatoms			Radiolarian abundance		Radiolarian preservation		Other microfossils					
		Centric diatoms	Pennate diatoms	Silicoflagellates	Radiolarian abundance	Radiolarian preservation	<i>Eucyrtidium calvertense</i>	<i>Prunopylites</i>	<i>Stylactis univertus</i>	<i>Helioholus vema</i>	<i>Desmospyris spongiosa</i>	<i>Lychocanium grande</i>	<i>Antarctissa denticulata</i>	<i>Dendrospyris rhodospyroides</i>
690B-1H, CC	mid Upsilon	R	R	-	A	G	•	•	•	•	•	+	•	
690B-2H-2, 25-27	mid Upsilon	C	A	F	A	G	F			F-C	F-C		•	
690B-2H-4, 25-27	mid Upsilon	A	VA	F	A	G	F			C	C		A	
690B-2H-6, 24-26	mid Upsilon	VA	C-A	R-F	F	G	R			F	C		C	
690B-2H, CC	upper Tau	A	A	A	A	G	•	•			•		•	
690B-3H-2, 26-28	upper Tau	A	F	VA	A	G	R	F		?R-F			F	
690B-3H-4, 26-28	upper Tau	A	C	C	A	G	+			?F				
690B-3H-6, 26-28	<i>A. australis</i>	A	-	R	A	P-M		R				R		?F-C
690B-3H, CC	upr <i>C. spongothorax</i>	A	C	R	A	G		R		C				F
690B-4H-2, 26-28	upr <i>C. spongothorax</i>	A	A	F-C	A	G								C
690B-4H-4, 26-28	lwr <i>C. spongothorax</i>	A	C	R	A	M								C
690B-4H, CC	lwr <i>C. spongothorax</i>	A	A	-	A	G				C				C
690B-5H-2, 22-24	lwr <i>C. spongothorax</i>	A	A	-	C	M								
690B-5H-4, 22-24	<i>D. megalcephalis/A. golownini</i>	A	C	-	A	M								

Note: Estimates are subjective, but reproducible to nearest major category and based on examination of several thousand to several tens of thousands of radiolarians/sample. Diatoms, radiolarian, and silicoflagellate abundance as % total coarse fraction. Radiolarian species as % of radiolarian assemblage. VA = very abundant, >90% of total; A = abundant, 20%-50%; C = common, 5%-20%; F = few, 0.5%-5%; R = rare, >1 specimen but <0.5%; + = single specimen; • = present, but relative abundance not determined; - = specially searched for but not seen. For preservation column only: VG = very good; G = good; M = moderate; P = poor. ? = specimens with uncertain taxonomic assignment.

than those shown in Lombardi and Lazarus (1988). These small individuals appear to be restricted to late Miocene sediments.

DESMOSPYRIS and DENDROSPYRIS

Desmospyris rhodospyroides Petrushevskaya 1975 (p. 593, pl. 10, figs. 27-29, 31, 32)
(Pl. 5, Figs. 11, 12)

Desmospyris ?haysi Petrushevskaya 1975 (p. 593, pl. 8, figs. 3, 4; pl. 27, Figs. 4-6)

Dendrospyris haysi Chen, 1974 (p. 482-3, pl. 2, figs. 3-5); 1975 (p. 455, pl. 15, figs. 3-5)
(Pl. 5, Fig. 9)

Dendrospyris megalcephalis Chen, 1974 (p. 484, pl. 2, figs. 6, 7); 1975 (p. 455, pl. 14, figs. 3-5)

Desmospyris spongiosa Hays 1965 (p. 173, pl. 2, fig. 1)
(Pl. 4, Figs. 9-11)

The Miocene species *D. rhodospyroides* appears to be one end member of a morphologic continuum running through *Dendrospyris haysi* and into *Dendrospyris megalcephalis* (a transitional specimen between *D. rhodospyroides* and *D. haysi* Chen is shown in Pl. 5, Fig. 10). *Desmospyris haysi* may be conspecific (in part—Petrushevskaya, 1975, pl. 8, figs. 3 and 4 only) with *Dendrospyris haysi*, although the specimens drawn by Petrushevskaya in her plate 27 appear not to belong to the same species—in fact, they look more like *Tricerasypris antarctica*, which is also present in the same sample. In the earliest Pliocene, *D. rhodospyroides* evolves into an unnamed form similar to *D. spongiosa* Hays, 1965. Species similar to this latter form, and described from the same stratigraphic interval, include *Tricerasypris* sp. (Hays and Opdyke, 1967); *Tricerasypris coronatus* Weaver, 1976a; 1983; and *Tricerasypris pacifica* Campbell and Clark, 1944 (Keany, 1979). The specimens illustrated by Weaver (1976a) and Keany (1979) however have stout feet and only traces of an abdomen, while most specimens seen in Leg 113 material have well developed abdomens and the feet only moderately developed, or absent. The Leg 113 specimens are listed as ?*D. spongiosa* in Tables 2-4. Goll (1968, 1969, 1976) made major revisions to the species and genera of the Trissocyclidae, and in his 1976 paper, formally synon-

ymized both *D. rhodospyroides* and *D. haysi* Chen into a single subspecies of his cosmopolitan taxon *Phormospyris stabilis stabilis*. Given the possible significance of these forms in antarctic stratigraphic and biogeographic studies, Goll's synonymy is not adopted at present, although the intergradation seen between these forms supports his one-species concept.

Druppactractus hastatus Blueford, 1982 (pl. 6, figs. 3, 4)

Druppactractus sp., Chen, 1975a, 1975b.

A ubiquitous, though rarely abundant, Oligocene and Miocene species, also seen in tropical Pacific sediments (Blueford, 1982) and in the North Atlantic (Lazarus and Pallant, 1989). Additional taxonomic discussion and measurements are given in the latter publication.

EUCYRTIDIUM

Eucyrtidium cienkowski Haeckel, 1887 (p. 1493, pl. 80, fig. 9)
(Pl. 6, Figs. 1-3)

Eucyrtidium calvertense Martin, 1904 (p. 450, pl. 130, fig. 5)
(Pl. 6, Figs. 4-6)

Eucyrtidium pseudoinflatum Weaver, 1983 (p. 675-676, pl. 5, figs. 8-9)
(Pl. 6, Figs. 12-14)

Several species of *Eucyrtidium* are found in Antarctic sediments, but only these three are common in the late Miocene to Recent. *Eucyrtidium calvertense* is distinguished from *E. pseudoinflatum* by the relatively uniform size of the abdomen and post-abdominal segments, fusiform shape, with the maximum shell diameter typically occurring in the fourth segment. *E. calvertense* gives rise in the late Miocene to *E. pseudoinflatum*. *E. calvertense* is present throughout the range of *E. pseudoinflatum*, and transitional specimens (e.g., Pl. 6, Fig. 3) are occasionally seen throughout this stratigraphic interval. The first appearance of *E. pseudoinflatum* is placed at the first consistent appearance of specimens with a maximum diameter in the third segment, due to an enlarged, inflated abdomen. *Eucyrtidium cienkowski* is distinguished by its inflated thorax, indented thorax-abdomen suture, thin, generally cylindrical post-thoracic shell, and strongly developed longitudinal pore rows.

Table 3 (continued).

<i>Antarctissa cylindrica</i>	<i>Antarctissa deflandrei</i>	<i>Antarctissa strelkovi</i>	<i>Cycladophora pliocenica</i>	<i>Cycladophora spongothorax</i>	<i>Prunopyle hayesi</i>	<i>Acrosphaera murrayana</i>	<i>Acrosphaera australis</i>	<i>Cycladophora humerus</i>	<i>Eucyrtidium pseudoinflatum</i>	<i>Actinomma golownini</i>
•	+		•							
C C C •			F-C C C •							
F	C C	A A	F-C F R	F C	F C		F-C		R C	
	F C R			C R-F F	R-F F C	C C	-	F C	R	R R-F
	C			R -				C F-C		R R-F

Helotholus vema Hays, 1965 (p. 176, pl. 2, fig. 3, text-fig. A)
(Pl. 7, Figs. 1-5)

Pseudocubus vema sensu Petrushevskaya, 1971 (p. 46); Keany and Kennett, (1972); Kellogg (1975)

Distinguished by an internal ring within the thorax, connected to the thorax lattice-wall by six (rarely seven) radial beams, by the short thorax, and the relatively small, large-pored cephalis. Kellogg (1975) has this species evolving from an ancestral population which she included within the same species, and which Weaver (1983) subsequently defined as *Helotholus praeveva*. This ancestral species was not identified in Leg 113 material. Chen (1975a) questionably identifies the ancestor of *H. vema* to be *Antarctissa cylindrica* Petrushevskaya, 1975. Another possible ancestral species is the undescribed form which was confused with *H. vema* in the initial shipboard work. This undescribed form possesses the same distinctive internal ring structure of *H. vema* and *A. cylindrica*, however it is much larger than early specimens of *H. vema*, and has a less regular, large pored outer lattice shell with only an indistinct cephalis.

The generic assignment of this species is uncertain. The distinctive internal structures led Petrushevskaya to refer to this species as *Pseudocubus vema*, although she did not formally reassign the species to the genus *Pseudocubus*. Dumitrica refers to a species similar to *H. vema* as *Pseudocubus cf. vema* (Hays). It is not clear whether Dumitrica meant to transfer *H. vema* into *Pseudocubus*. Keany and Kennett (1972) refer to this species as *Pseudocubus vema*, without formally transferring the species, or citing an author for this implied revision. Keany (1979) specifically rejects the assignment of *H. vema* to *Pseudocubus*. Kellogg (1975) also referred to this species as *P. vema*, again without formally transferring the species.

Lychnocanium grande Campbell and Clark, 1944 (p. 42, pl. 6, figs. 3-6)
(Pl. 7, Fig. 9)

Lychnocanium grande rugosum Riedel, 1952; Hays, 1965; Keany, 1979. *Lychnocanoma grande rugosum* (Riedel), Weaver, 1976a, 1976b, 1983.

This taxon is simply referred to as *Lychnocanium grande* in this report, as no attempt was made to distinguish between subspecies. Weaver did not explain his reasons for transferring this species to a different genus. The relationship of the Antarctic species to similar Pacific and North Pacific forms is not known. As noted in Lazarus et al. (1985), this form may be closely related to *Pterocanium korotnevi* Dogiel.

PRUNOPYLE

Prunopyle titan Campbell and Clark, 1944 (p. 20, pl. 3, figs. 1-3)
(Pl. 5, Figs. 1-4)

Prunopyle hayesi Chen, 1975a (p. 454, pl. 9, figs. 3-5)
(Pl. 5, Figs. 5-8)

The origins and evolutionary relationships of these two species are not known. *Prunopyle hayesi* is a very characteristic member of the Miocene assemblage, and can be distinguished by the radially arranged light and dark bands caused by the alignment of the relatively large, hexagonally framed pores. Similar species exist in high latitude Tertiary sediments, but have smaller, more irregular, unframed pores, more closely spaced spirals, and only faint radial banding. *Prunopyle titan* is identified by the densely spongy shell interior, with spirals only weakly developed, by the small, circular pores, and particularly by the outline of the shell, which in most specimens has slightly flattened sides.

Stylatractus universus Hays, 1970 (p. 215, pl. 1, fig. 1)
(Pl. 6, Figs. 9-11)

Stylatractus sp. Hays, 1965 (p. 167, pl. 1, fig. 6)

Axoprimum angelinum (Campbell and Clark) Kling, 1973 (p. 634, pl. 1, figs. 13-16, pl. 6, figs. 14-18)

Late Miocene and early Pliocene populations of this species tend to be less robust than in the Pleistocene. In the late Miocene, a very lightly silicified variant is seen (Pl. 6, Fig. 11). *Stylatractus universus* appears to evolve in the Antarctic from the species referred to by Chen (1975a) as *Amphistylus angelinus* (Pl. 6, Figs. 7, 8). The transition involves the development of an ellipsoidal cortical shell, increasing colinearity of the polar spines, and loss of secondary external spines. Chen (1975a) noted the presence of transitional specimens in late Miocene and Pliocene sediments, although I would place the transition somewhat earlier, in the early middle Miocene. Kling (1973) synonymized *S. universus* with *A. angelinus*. The specimens figured by Campbell and Clark (1944) and by Kling (1973) appear to be morphologically intermediate between these two Antarctic forms. Because of the different stratigraphic range of these two forms, I do not at present accept Kling's proposed synonymy, although the similarities between all of these forms suggests that taxonomic revision of some type is needed.

Table 4. Abundance of radiolarians and other siliceous microfossils in the acidified >63 µm coarse fraction of Hole 113-693A.

Hole, core, section, interval (cm)	Zone/Subzone	Centric diatoms	Pennate diatoms	Silicoflagellates	Radiolarian abundance	Radiolarian preservation	Cycladophora davisiana	Eucyrtidium calvertense	Prunopyle titan	Sylatractus universus	Heloholus vema	Desmospyris spongiosa	Lychocanium grande	Antarctissa denitculata	Dendrospyris rhodospyroides
693A-1R, CC	?Omega	-	-	-	C	M-G	R								C
693A-2R, CC	?Psi	F	-	-	F-C	M				•					•
693A-3R, CC	?Pleistocene	-	-	-	R	P									
693A-4R, CC	mid Upsilon	F	-	-	F	M	?+	R	-		F	C	-		C
693A-5R, CC	mid Upsilon	-	A	-	A	G		F	-		F	C			F
693A-6R, CC	mid Upsilon	C	A	-	A	G		C		F	C	C			C
693A-7R, CC	mid Upsilon	F	F	-	A	M		•			•	•			
693A-8R, CC	lower Upsilon				A			F	R	F	R-F	C			
693A-9R, CC	lower Upsilon	C	C	-	A	G		•	•		•	•			•
693A-10R, CC	upper Tau	C	-	-	A	M-G		F	F		-	C	F		F
693A-11R, CC	upper Tau	C	-	-	A	G		?C	F	F	-	-			
693A-12R, CC	upper Tau	C-A	C	-	A	G		F-C	•				R-F		R
693A-13R, CC	lower Tau	A	A	-	A	G		C		F			C		
693A-14R, CC	lower Tau	A	C	-	A	M-G			F				C		
693A-15R, CC	lower Tau	A	C	-	A	M-G							VA		
693A-16R, CC	lower Tau	A	F	-	A	M			F				C-A		
693A-17R, CC	lower Tau	C	-	-	A	M			F	A		?F	C		
693A-18R, CC	lower Tau	C-A	-	-	C	P		+	•	C			C		
693A-19R, CC	lower Tau	C	-	-	C-A	P-M			R						
693A-20R, CC	lower Tau	C	-	-	C	M			R				?A		
693A-21R, CC	<i>A. australis</i>	A	-	-	C-A	M		R		C			?C		
693A-22R, CC	<i>A. australis</i>	A	-	-	A	G		F	F				?C		
693A-24R, CC	<i>A. australis</i>	F	-	-	A	G				A					A
693A-25R, CC	<i>A. australis</i>	A	-	-	A	G			?F-C	C					
693A-26R, CC	mid <i>C. spongothorax</i>	C	F	-	A	G									A
693A-27R, CC	lower <i>C. spongothorax</i>	A	-	-	C	P-M				?C					F

Note: Estimates are subjective, but reproducible to nearest major category and based on examination of several thousand to several tens of thousands of radiolarians/sample. Diatoms, radiolarian, and silicoflagellate abundance as % total coarse fraction. Radiolarian species as % of radiolarian assemblage. VA = very abundant, >90% of total; A = abundant, 20%-50%; C = common, 5%-20%; F = few, 0.5%-5%; R = rare, >1 specimen but <0.5%; + = single specimen; • = present, but relative abundance not determined; - = specially searched for but not seen. For preservation column only: VG = very good; G = good; M = moderate; P = poor. ? = specimens with uncertain taxonomic assignment.

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REFERENCES

- Barker, P. F., Kennett, J. P., et al., 1988. *Proc. ODP, Init. Repts.*, 113: College Station, TX (Ocean Drilling Program).
- Björklund, K., and Goll, R. M., 1979. Internal skeletal structures of *Collosphaera* and *Trisolenia*: a case of repetitive evolution in the Collosphaeridae (Radiolaria). *J. Paleontol.*, 53:1293-1326.
- Blueford, J., 1982. Miocene actinomid Radiolaria from the equatorial Pacific. *Micropaleontology*, 28:189-213.
- Campbell, A. S., and Clark, B. L., 1944. Miocene Radiolarian Faunas from Southern California. *Geol. Soc. Am. Spec. Pap.*, 51:1-76.
- Chen, P. H., 1974. Some new Tertiary radiolaria from Antarctic deep-sea sediments. *Micropaleontology*, 20(4):480-492.
- _____, 1975a. Antarctic radiolaria. In Hayes, D. E., Frakes, L. A., et al., *Init. Repts. DSDP*, 28: Washington (U.S. Govt. Printing Office), 437-513.
- _____, 1975b. Post Paleocene Antarctic radiolaria: their taxonomy, biostratigraphy and phylogeny, and the development of Late Neogene cold-water faunas. [Ph.D. Dissert.]: Columbia Univ., New York.
- Dumitrica, P., 1973. Cretaceous and Quaternary Radiolaria in deep-sea sediment from the northwest Atlantic Ocean and Mediterranean Sea. In Ryan, W.B.F., Hsu, K. J., et al., *Init. Repts. DSDP*, 13: Washington (U.S. Govt. Printing Office), 829-901.
- Ehrenberg, C. G., 1872a. Mikrogeologischen Studien als Zusammenfassung seiner Beobachtungen des kleinsten Lebens der Meeres-Tiefgrunde aller Zonen und dessen geologischen Einfluss. *Kgl. Preuss. Akad. Wiss. Berlin, Monats.* 1872, 265-322.
- _____, 1872b. Mikrogeologischen Studien über des kleinsten Lebens der Meeres-Tiefgrunde aller Zonen und dessen geologischen Einfluss. *Kgl. Preuss. Akad. Wiss. Berlin, Abh.*, 1872, 131-399.
- Goll, R. M., 1968. Classification and phylogeny of the Cenozoic Trissocyclidae (Radiolaria) in the Pacific and Caribbean basins, part I. *J. Paleontol.* 42:1409-1432.
- _____, 1969. Classification and phylogeny of the Cenozoic Trissocyclidae (Radiolaria) in the Pacific and Caribbean basins, part II. *J. Paleontol.* 43:322-339.
- _____, 1976. Morphological intergradation between modern populations of *Lophospyris* and *Phormospyris* (Trissocyclidae, Radiolaria). *Micropaleontology*, 22(4):379-418.
- _____, 1980. Pliocene-Pleistocene radiolarians from the East Pacific Rise and the Galapagos spreading center, Deep Sea Drilling Project Leg 54. In Rosendahl, B. R., Hekinian, R., et al., *Init. Repts. DSDP*, 54: Washington (U.S. Govt. Printing Office), 425-453.

Table 4 (continued).

<i>Antarctissa cylindrica</i>	<i>Antarctissa deflandrei</i>	<i>Antarctissa strelkovi</i>	<i>Cycladophora pliocenica</i>	<i>Cycladophora spongothorax</i>	<i>Prunopyle hayesi</i>	'conical pore' Collosphaerid	<i>Acrosphaera murrayana</i>	<i>Acrosphaera australis</i>	<i>Eucyrtidium pseudoinflatum</i>	<i>Actinomma golownini</i>
-										
F		F								
C		C	C							
C		C	C							
•		•	•							
•		•	•							
•		•	•							
•		•	•							
R-F		C	C						R	
C		C	C						?C	
		C	C						F-C	
		C	C						R-F	
		A	C						R	
F		A	•							
		A	C						C	
		A	F						F	
C	R-F	A	C		?F				F	
		A	F		F				+	
		A	C		F				F	
	?A	A	F		F				C	
	C	A	?C	F	F				C	
	C			F	F				C	
	C			F	C				C	
	F			F	A				C	
	F			C	A				C	
	+			F-C	F				?+	
										R-F

Haeckel, E., 1887. *Report on the Scientific Results of the Voyage of H.M.S. Challenger during the Years 1873-1876. Zoology, Vol. 18. Report on the Radiolaria.* London (Eyre and Spottiswoode).

Hays, J. D., 1965. Radiolaria and late Tertiary and Quaternary history of Antarctic seas. In Llano, G. A. (Ed.), *Biology of the Antarctic Seas II*, Am. Geophys. Union, Antarct. Res. Ser., 5:125-184.

_____, 1970. Stratigraphy and evolutionary trends of Radiolaria in North Pacific deep sea sediments. In Hays, J. D. (Ed.), *Geological Investigations of the North Pacific*. Geol. Soc. Am. Mem. 126:185-218.

Hays, J. D., and Opdyke, N. D., 1967. Antarctic radiolaria, magnetic reversals, and climate change. *Science*, 158:1001-1011.

Keany, J., 1979. Early Pliocene radiolarian taxonomy and biostratigraphy in the Antarctic region. *Micropaleontology*, 25(1):50-74.

Keany, J., and Kennett, J. P., 1972. Pliocene-early Pleistocene paleoclimatic history recorded in Antarctic-Subantarctic deep-sea cores. *Deep-Sea Res.*, 19:529-548.

Kellogg, D. E., 1975. The role of phyletic change in the evolution of *Pseudocubus vema* (Radiolaria). *Paleobiology*, 1:359-370.

Lazarus, D. B., and Pallant, A., 1989. Oligocene and Neogene radiolarians from the Labrador Sea, ODP Leg 105. In Arthur, M. A., Srivastava, S. P., et al., *Proc. ODP, Sci. Results*, 105: College Station, TX (Ocean Drilling Program), 349-380.

Lazarus, D. B., Scherer, R., and Prothero, D. R., 1985. Evolution of the radiolarian species-complex *Pterocanium*: a preliminary survey. *J. Paleontol.*, 59:183-220.

Lombardi, G., and Lazarus, D. B., 1988. Neogene cycladophorid radiolarians from North Atlantic, Antarctic, and North Pacific Deep Sea Sediments. *Micropaleontology*, 34(2):97-135.

Lozano, J. A., and Hays, J. D., 1976. Relationship of radiolarian assemblages to sediment types and physical oceanography in the Atlantic and western Indian Ocean sectors of the Antarctic Ocean. In

Cline, R. M., and Hays, J. D. (Eds.), *Investigations of Late Quaternary Paleooceanography and Paleoclimatology*. Geol. Soc. Am. Mem., 145:303-336.

Martin, G. C., 1904. Radiolaria. *Maryland Geol. Surv. (Miocene), Gen. Ser.*, 447-459.

Moore, T. C., Jr., 1973. Method of randomly distributing grains for microscopic examination. *J. Sediment. Petrol.*, 43:904-906.

Petrushevskaya, M. G., 1968. Radiolarians of the orders Spumellaria and Nassellaria of the Antarctic region. In Andriyashev, A. P., and Ushako, P. V. (Eds.), *Biological Reports of the Soviet Antarctic Expedition 1955-1958* (Vol. 3): Jerusalem (Israel Program for Scientific Translations), 2-186.

_____, 1971. Radiolyarii Nassellaria v planktone Mirovogo okeana. In Bykhovshii, B. E. (Ed.), *Radiolyarii Mirovogo Okeana po materialam Sovetskikh ekspeditsii. Issled. Fauny Morey*: Leningrad (Nauka), 9(17):3-294.

_____, 1975. Cenozoic radiolarians of the Antarctic, Leg 29, DSDP. In Kennett, J. P., Houtz, R. E., et al., *Init. Repts. DSDP, 29*: Washington (U.S. Govt. Printing Office), 541-675.

_____, 1986. Evolution of the *Antarctissa* group. *Mar. Micropaleontol.*, 11:185-195.

Riedel, W. R., 1952. Tertiary radiolaria in western Pacific sediments. *Goeteborgs K. Vetensk. Ort. Vitterhets-Samh. Handl. Ser. B*, 3:1-22.

Strelkov, A. A., and Reshetnjak, V. V., 1971. Kolonialnie radiolyarii Spumellaria mirovogo okeana. In Bykhovshii, B. E. (Ed.), *Radiolyarii Mirovogo Okeana po materialam Sovetskikh ekspeditsii. Issled. Fauny Morey*: Leningrad (Nauka), 9(17):295-369.

Weaver, F. M., 1976a. Antarctic radiolaria from the southeast Pacific Basin, DSDP, Leg 35. In Hollister, C. D., Craddock, C., et al., *Init. Repts. DSDP, 35*: Washington (U.S. Govt. Printing Office), 569-603.

_____, 1976b. Late Miocene and Pliocene radiolarian paleobiogeography and biostratigraphy of the Southern Ocean. [Ph.D. Dissert.]. Florida State Univ., Tallahassee.

_____, 1983. Cenozoic radiolarians from the Southwest Atlantic, Falkland Plateau region, Deep Sea Drilling Project Leg 71. *In* Ludwig,

W. J., Krashennikov, V. A., et al., *Init. Repts. DSDP*, 71: Washington (U.S. Govt. Printing Office), 667-686.

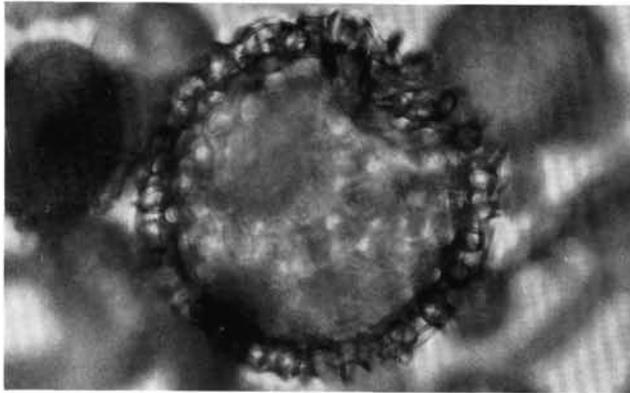
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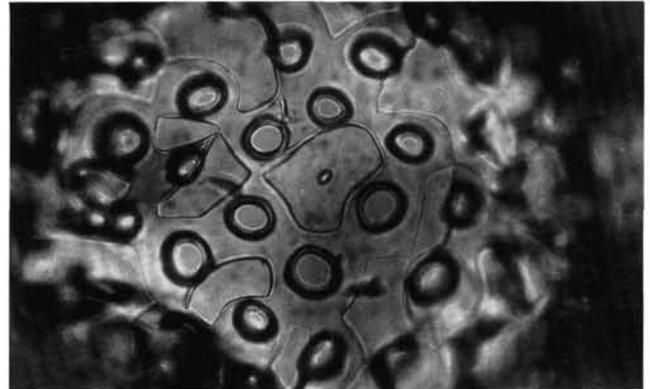
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Table 5. Middle Miocene to recent radiolarian datum levels in Leg 113 holes. Age for each event (in Ma) from Gersonde et al. (this volume). ? = location undeterminable or uncertain; — = acme event missing in hiatus.

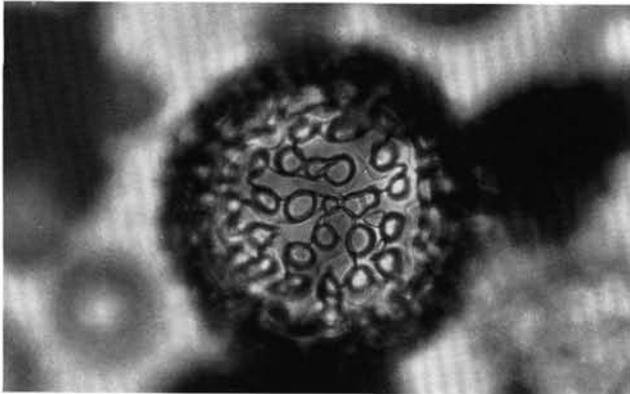
Event	Age (Ma)	Hole 689B	Hole 690B	Hole 693A	Hole 695A	Holes 696A, B	Hole 697B
<i>T. A. cylindrica</i>	0.55	above 1-1, 26	above 1, CC	2, CC to 4, CC	above 1, CC	A-1, CC to 2, CC	?
<i>T. C. pliocenica</i>	1.6	above 1-1, 26	above 1, CC	4, CC to 5, CC	above 1, CC	above A-1, CC	?
<i>T. E. calvertense</i>	1.9	above 1-1, 26	above 1, CC	3, CC to 5, CC	?	A-1, CC to 2, CC	?
<i>T. H. vema. D. spongiosa</i>	2.4	above 1-1, 26	above 1, CC	2, CC to 4, CC	1, CC to 2, CC	A-1, CC to 2, CC	8, CC to 9, CC
<i>B. C. davisiana</i>	2.7	above 1-1, 26	above 1, CC	?	1, CC to 2, CC	A-1, CC to 2, CC	12, CC to 13, CC
<i>T. P. titan</i>	3.4	1-3, 118 to 1-4, 103	2-6, 24 to 2, CC	7, CC to 8, CC	?19, CC to 20, CC	?	23, CC to 24, CC
<i>B. H. vema</i>	4.2	2-2, 118 to 2-3, 62	2-6, 24 to 2, CC	9, CC to 10, CC	?26, CC to 27, CC	?A-9, CC to 11, CC	23, CC to 24, CC
T common <i>L. grande</i>	4.4	2-6, 116 to 2, CC	—	12, CC to 13, CC	30, CC to 32, CC	B-3, CC to 5, CC	29, CC to 30, CC
<i>T. C. spongothorax</i>	8.0	3-4, 94 to 3-5, 136	3-4, 26 to 3-6, 26	20, CC to 21, CC	?39, CC to 40, CC	B-10, CC to 17, CC	
<i>B. A. australis</i>	9.0	4-2, 117 to 4-3, 56	3-6, 26 to 4-2, 26	25, CC to 26, CC		?	
<i>B. E. pseudoinflatum</i>	9.6	4-4, 56 to 4-4, 116	4-2, 26 to 4-4, 26	25, CC to 27, CC		?	
<i>T. A. golownini</i>	10.3	5-5, 56 to 5-5, 117	4-2, 26 to 4-4, 26	26, CC to 27, CC		?	
<i>B. C. spongothorax</i>	11.3	5, CC to 6-1, 59	5-2, 26 to 5-4, 26	27, CC to 29, CC		?	



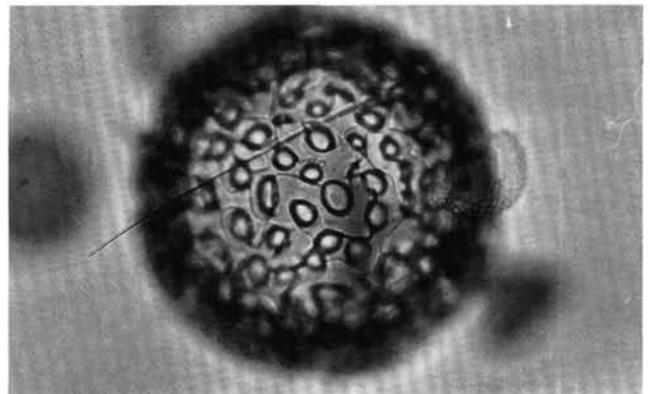
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100 μ m

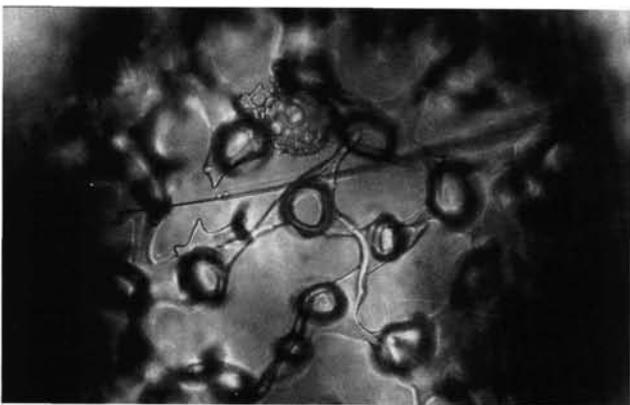
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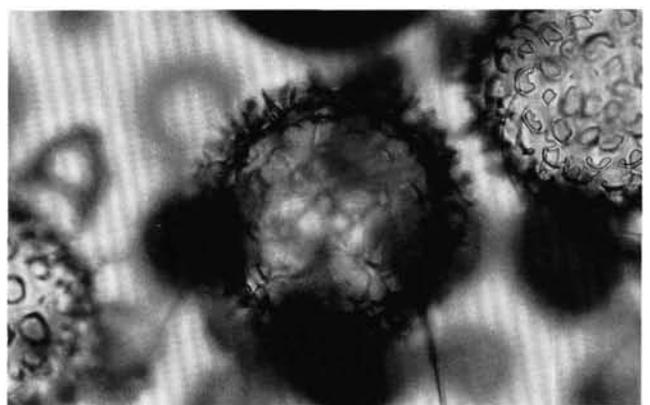
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4

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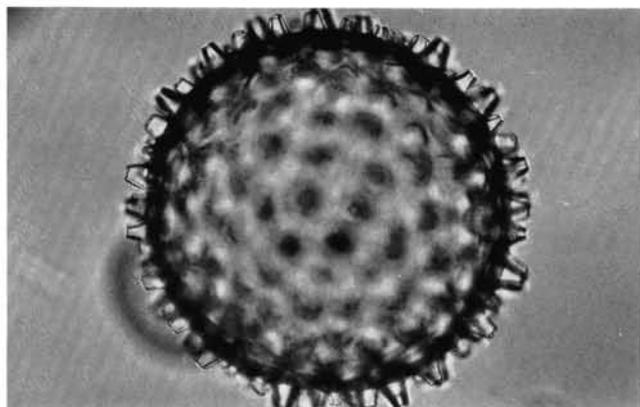
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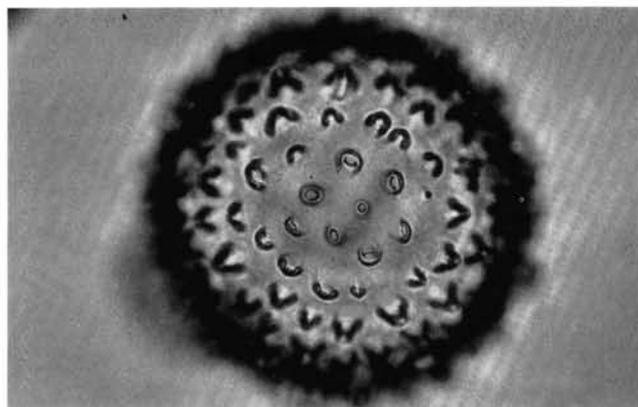
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100 μ m

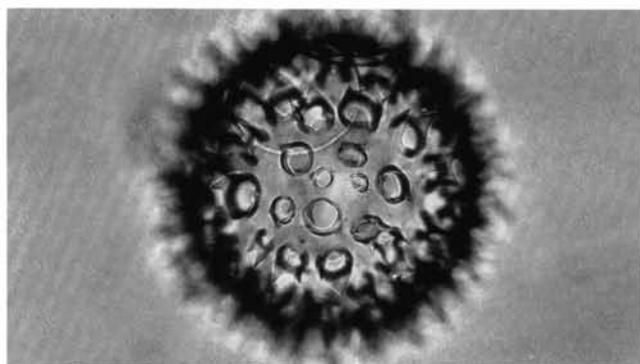
Plate 1. All specimens are of *Acrosphaera australis*, n. sp., from Sample 113-689B-3H-6, 56-58 cm. Scale bar = 100 μ m. 1, 2. Holotype (1) Focus showing shell shape and wall thickness; (2) Surface of shell showing pores and bridges. England Finder position W44. 3, 4. Paratypes (3) F37.4; (4) YZ40-41. 5, 6. Early morphotype showing thin bridges. Y41.2.



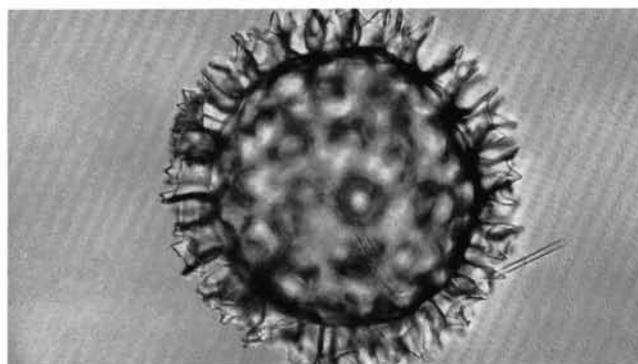
1 100μm



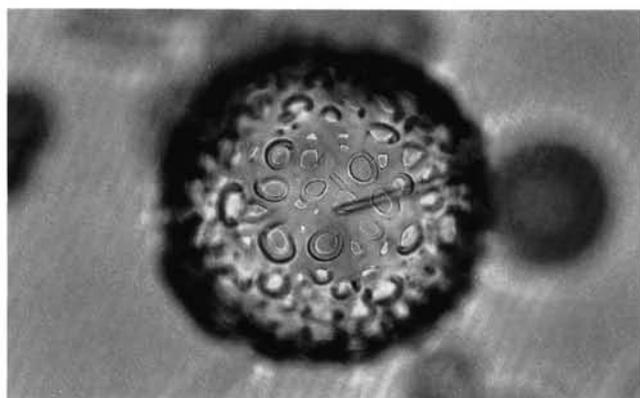
2 100μm



3 100μm



4 100μm



5 100μm



6 100μm

Plate 2. Scale bar = 100 μm. 1, 2. "Conical pore" collosphaerid. Sample 113-689B-3H-6, 56-58 cm. 3, 4. *Acrosphaera murrayana* (3) Sample 113-689B-5H-3, 56-58 cm, A35.1; (4) Sample 113-689B-3H-6, 56-58 cm; UT33-34. 5. "Ringed" collosphaerid. Sample 113-689B-3H-3, 56-58 cm; AB53. 6. Fragment of *A. australis* in side-view, showing flared tubular pores and connecting bridges. Sample 113-689B-3H-6, 56-58 cm.

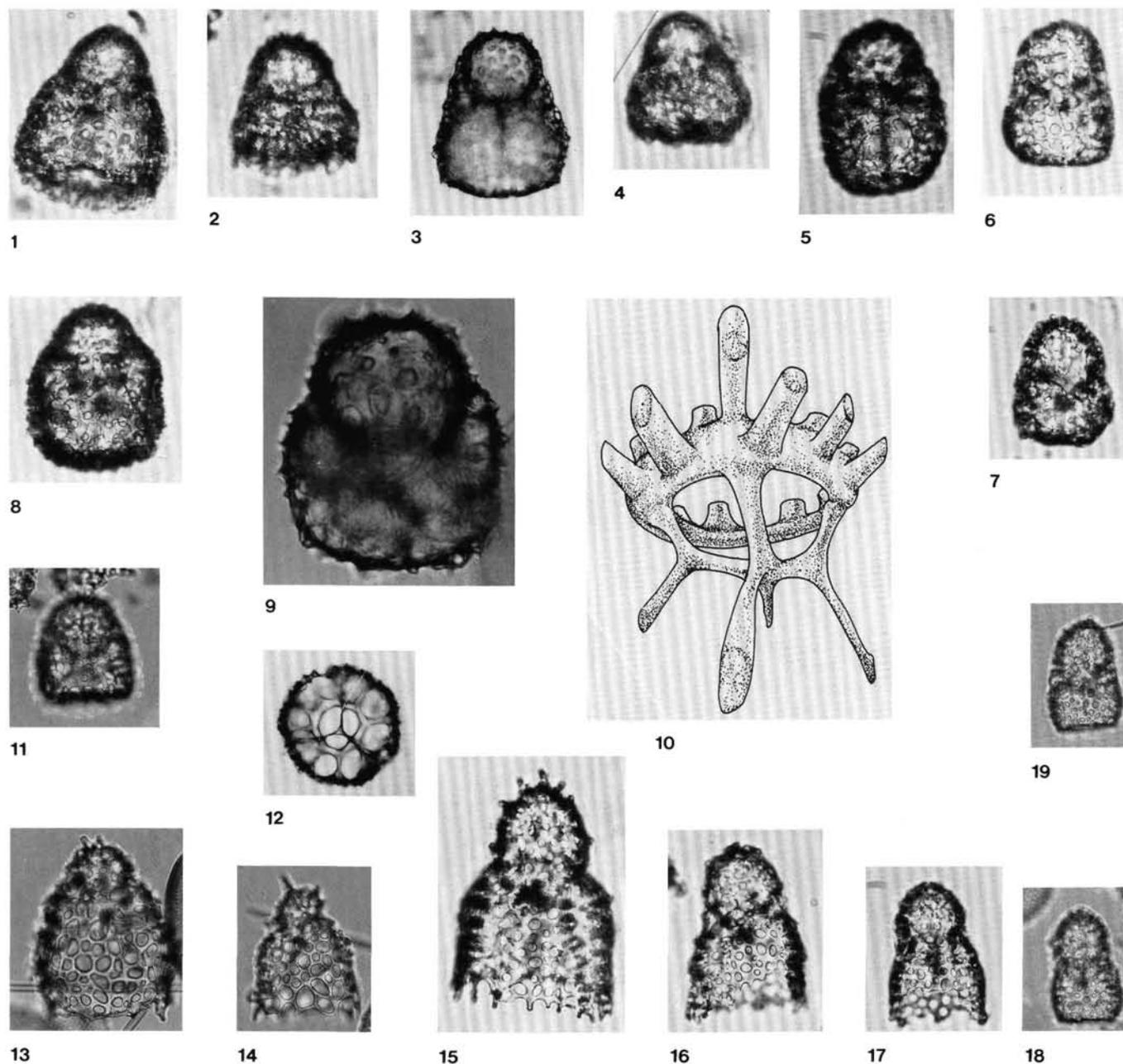


Plate 3. 1-4. *Antarctissa denticulata* (1, 2, 4) DSDP 28-266-1, CC; (3) DSDP 29-278-8-2, 10-12 cm. 5. Transitional specimen between *A. denticulata* and *A. robusta* DSDP 29-278-8-4, 0-2 cm. 6, 7. *Antarctissa robusta* DSDP 29-278-8-6, 0-2 cm. 8-12. *Antarctissa cylindrica* (8) DSDP 29-278-8-4, 0-2 cm; (9) DSDP 29-278-8-2, 10-12 cm; (10) Diagrammatic illustration of internal ring structure (lattice-wall not shown) in oblique view, looking upward; (11) Sample 113-689B-2H-1, 52-54 cm; (12) DSDP 29-278-8-2, 10-12 cm. View looking upward from base of thorax into shell. 13-15. *Antarctissa strelkovi* (13) Sample 113-689B-2H-1, 52-54 cm; (14) Sample 113-689B-5H-3, 56 cm; (15) Islas Orcadas Piston Core 1176-71, 0-1 cm. 16, 17. Transitional specimens between *A. strelkovi* and *Antarctissa deflandrei*, DSDP 29-278-8-4, 0-2 cm. 18, 19. *Antarctissa deflandrei* n. comb. Sample 113-689B-5H-3, 56 cm.

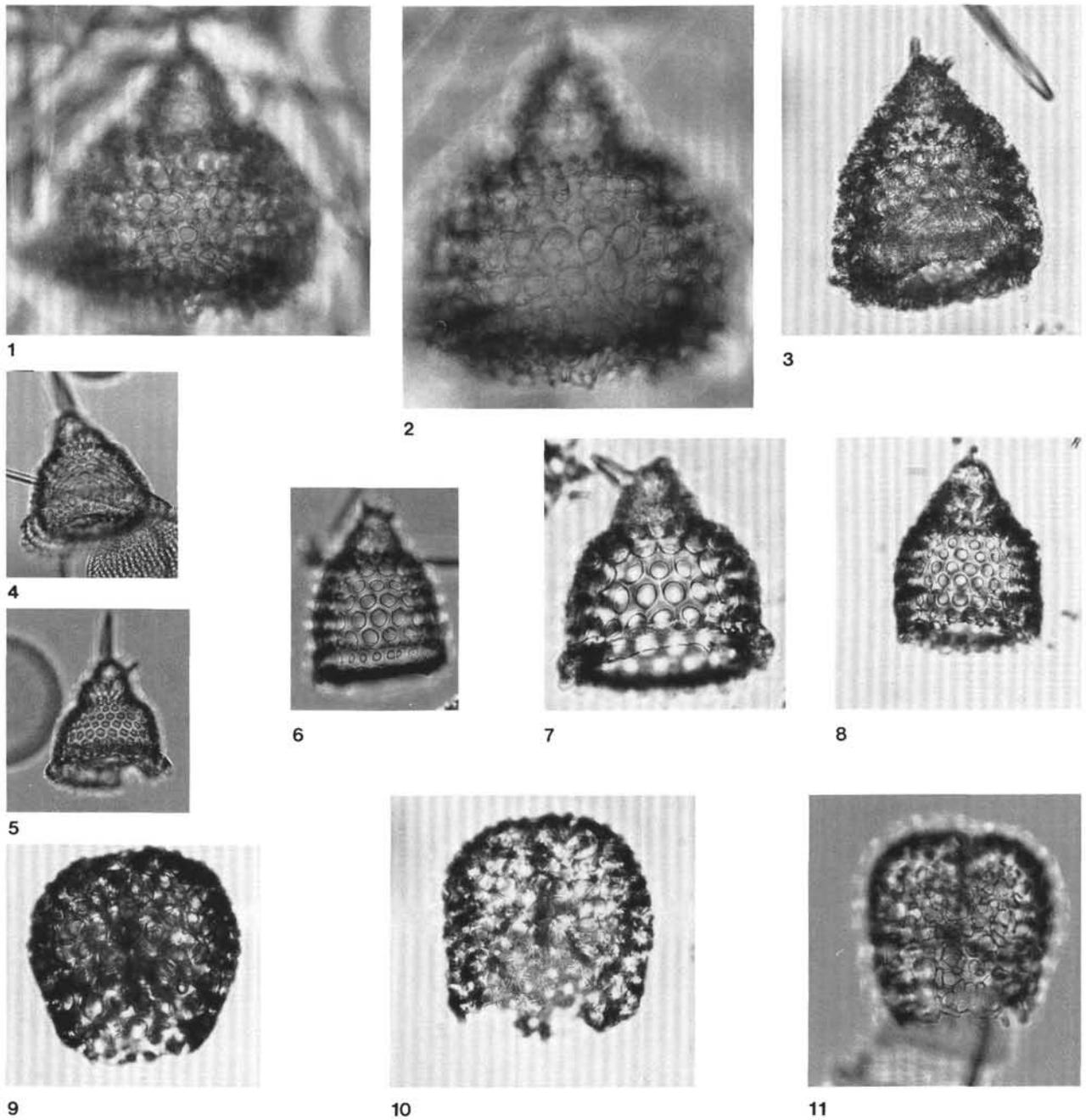


Plate 4. 1-3. *Cycladophora spongothorax* (1, 2) Two images of same specimen taken at different focal planes, Sample 113-689B-4H-2, 55 cm; (3) DSDP 29-278-9-3, 0-2 cm. 4, 5. *Cycladophora humerus*, Sample 113-689B-5H-3, 56 cm. 6, 7. *Cycladophora pliocenica* (6) Sample 113-689B-2H-1, 52-54 cm. (7) DSDP 29-278-8-4, 0-2 cm. 8. *Cycladophora golli golli*, DSDP 28-266-13, CC. 9-11. *Desmospyris spongiosa* (9, 10) DSDP 29-278-8-6, 0-2 cm; (11) Sample 113-689B-2H-1, 52-54 cm.

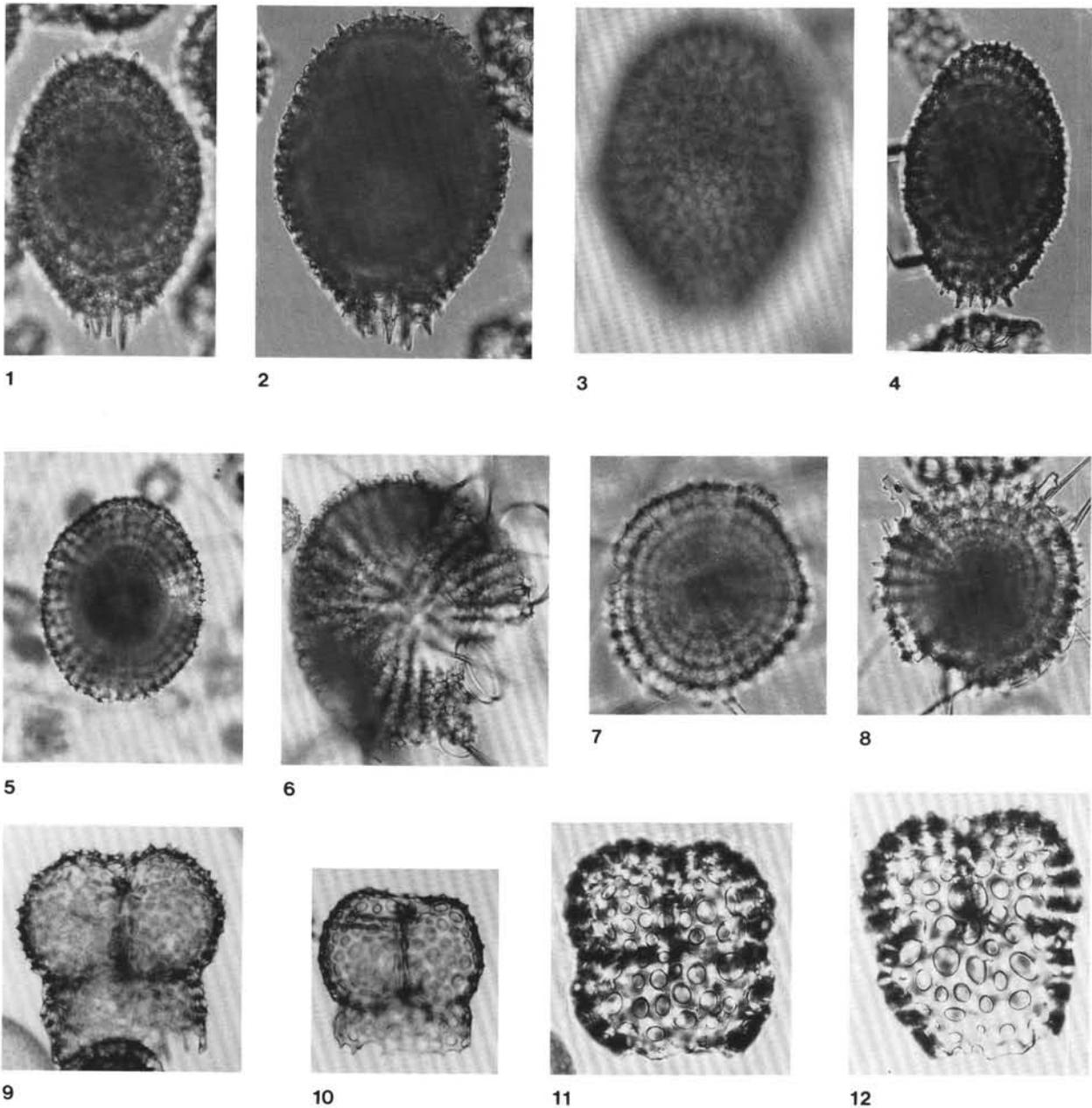


Plate 5. 1-4. *Prunopyle titan* (1) Sample 113-689B-2H-1, 52-54 cm; (2, 3) Two images of same specimen taken at different focal planes. Sample 113-689B-2H-1, 52-54 cm; (4) Sample 113-689B-3H-3, 56 cm. 5-8. *Prunopyle hayesi* (5, 7) Sample 120-747A-4, CC; (6, 8) Sample 113-689B-4H-2, 55 cm. 9. *Desmospyris haysi* DSDP 36-329-13, CC. 10. Transitional specimen between *D. haysi* and *D. rhodospyroides*; DSDP 36-329-13, CC. 11, 12. *Desmospyris rhodospyroides*; (11) DSDP 29-278-9-3, 0-2 cm; (12) Eltanin Piston Core 34-5, 291-293 cm.

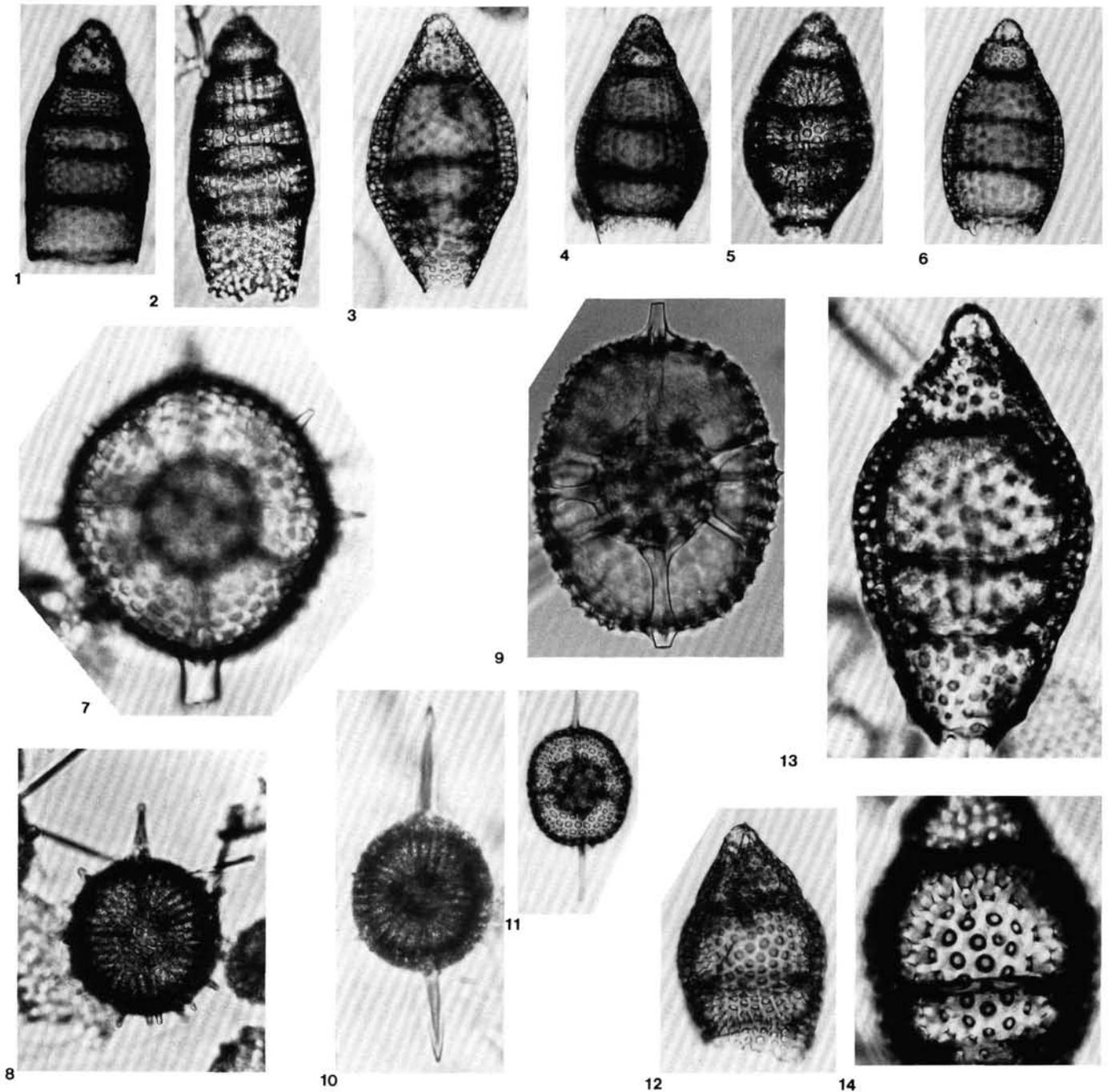


Plate 6. 1, 2. *Eucyrtidium cienkowski* (1) DSDP 28-266-11-1, 51-53 cm; (2) DSDP 28-266-13-1, 101-103 cm. 3. Transitional specimen between *Eucyrtidium calvertense* and *E. pseudoinflatum*. DSDP 36-329-13, CC. 4-6. *E. calvertense* (4, 5) DSDP 29-278-8-2, 10-12 cm; (6) DSDP 36-329-13, CC. 7, 8. *Amphistylus angelinus* (7) DSDP 29-278-26-1, 140-144 cm; (8) DSDP 28-266-13-1, 101-103 cm. 9-11. *Stylatractus universus* (9) DSDP 36-329-13, CC; (10) DSDP 28-266-10-3, 147-149 cm; (11) DSDP 36-329-13, CC. 12-14. *Eucyrtidium pseudoinflatum* (12) DSDP 36-329-13, CC; (13, 14) Two images of same specimen taken at different focal planes. DSDP 29-278-11-3, 53-57 cm.

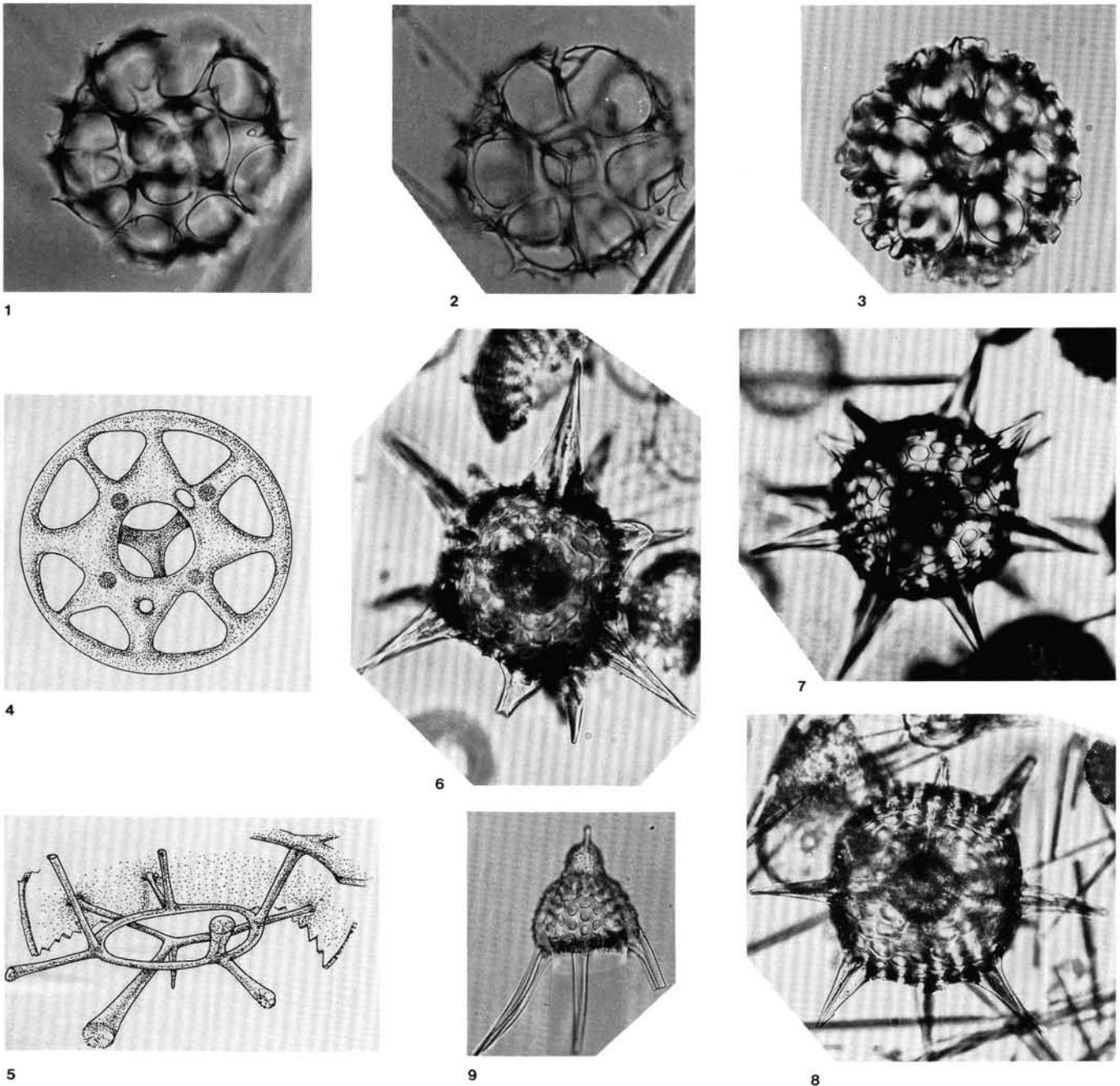


Plate 7. 1-5. *Helotholus vema* (1, 2) Two images of same specimen taken in apical view at different focal planes; (1) Focus on upper wall of thorax; (2) Focus on internal ring structure, DSDP 29-278-8-2, 10-12 cm; (3) View of specimen looking upward from base of thorax into shell. DSDP 29-278-8-6, 0-2 cm; (4) Diagrammatic illustration of upper lattice-wall of thorax, viewed from below and looking toward cephalis. The four shaded dots indicate where vertical bars from internal ring structure are attached; (5) Diagrammatic illustration of internal ring structure in cut-away view, looking obliquely downward toward open base of thorax. Lattice-wall pores of thorax not drawn in. 6-8. *Actinomma golownini* (6) DSDP 29-278-14, CC; (7) DSDP 29-278-13-5, 56-59 cm; (8) DSDP 28-266-10-3, 147-149 cm. 9. *Lychnocanium grande* Photo-composite of two images of same specimen taken at different focal planes, Sample 113-689B-3H-3, 56 cm.