

10. CENOZOIC RADIOLARIANS FROM DEEP SEA DRILLING PROJECT SITES 612 AND 613 (LEG 95, NEW JERSEY TRANSECT) AND ATLANTIC SLOPE PROJECT SITE ASP 15¹

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ABSTRACT

A major objective of DSDP Leg 95 (New Jersey Transect) was to investigate the effects of eustatic sea-level fluctuation and crustal subsidence on the depositional and erosional patterns of the Atlantic continental margin in the Baltimore Canyon trough area. Deep Sea Drilling Project Sites 612 and 613 were drilled on the New Jersey continental slope and rise during this leg.

A more specific goal of Leg 95 was to investigate calcareous and siliceous microfossil biostratigraphy in order to identify biostratigraphic gaps and to intercorrelate the various microfossil zonations for the New Jersey margin. This study of radiolarians from Sites 612 and 613, and from Atlantic Slope Project (ASP) Site ASP 15, demonstrates that although radiolarians occur throughout the Cenozoic section in this region, they are most useful for biostratigraphic control in the upper Paleogene part of the stratigraphic record. Results of this investigation indicate that several biostratigraphic gaps occur in the Cenozoic sedimentary sequence penetrated by the three drill holes.

Upper Paleogene radiolarians are well preserved, abundant, and diverse. Although some tropical taxa are rare or absent, sufficient age-diagnostic species are present for biostratigraphic determinations. In comparison, lower Paleogene radiolarians are poorly preserved because pronounced silica diagenesis formed porcellanites in some stratigraphic intervals. The Neogene radiolarians faunas are rare and moderately well preserved at all the sites investigated here. Neogene assemblages are dominated by spongodiscids and porodiscids (similar to faunas of modern cold/temperate shelf waters), and contain few taxa useful for biostratigraphic determinations.

INTRODUCTION

Deep Sea Drilling Project Leg 95 contributes to ongoing studies of the depositional, erosional, and subsidence history of the Atlantic continental margin along the New Jersey Transect in the Baltimore Canyon trough area. Although numerous exploratory boreholes and other deep stratigraphic test wells were drilled on this margin to complement extensive regional seismic surveys (Schlee, 1981; Poag, 1985), none involved continuous coring beyond approximately 300 m sub-bottom. One of the primary goals of Leg 95, a study of the unconformity record of this passive margin, required long, continuously cored stratigraphic sequences. Site 612, on the middle part of the continental slope, and Site 613, on the toe of the upper continental rise, provide this material. Other objectives of the leg were characterization of depositional environments through the stratigraphic section, and intercorrelation of calcareous and siliceous microfossil biostratigraphic zonations.

The abundance, preservation, and diversity of radiolarians and other siliceous microfossils in the New Jersey margin deposits vary a great deal, but often demonstrate inverse relationships to the biogenic calcite component. The siliceous microfossils are important for biostratigraphic and paleoenvironmental information in some stratigraphic intervals where calcareous microfossils are sparse.

Previous studies have noted radiolarians in certain Cenozoic Atlantic margin deposits, both on shore in coastal plain deposits and in offshore sections (Palmer, 1984, 1986; Poag, 1980, 1984; R. N. Benson, personal communication, 1981), but relatively little has been done to evaluate their biostratigraphic and paleoenvironmental significance. In this study, two chief aspects of radiolarians from the New Jersey continental margin are discussed: (1) radiolarian biostratigraphy in this mid-latitude region with respect to previous radiolarian studies in lower and higher latitudes, and (2) general faunal characteristics with possible paleoenvironmental significance.

PROCEDURES

Samples were obtained during DSDP Leg 95 (New Jersey Transect) from Sites 612 and 613. Samples were also taken from Atlantic Slope Project Site ASP 15, a well drilled in 1967 by a consortium of petroleum companies at a location 6.4 km southwest of Site 612 (Poag, 1978; 1985). Locations of these sites are indicated in Figure 1.

In general, two samples were examined from each core from Holes 612 and 613, although four samples per core were examined from the upper Paleogene section of Hole 612 (Cores 612-16 through 612-36). Only one or two samples per core were available from Site ASP 15. Cores from ASP 15 are generally separated by a drilled interval because the hole was not continuously cored.

Conventional radiolarian preparation procedures (as outlined by Riedel and Sanfilippo, 1977) were followed, including disaggregation of the sample, acidification to remove calcium carbonate, and washing through a 63-μm mesh sieve. The high clay content of most samples made the disaggregation process difficult, as did the silicified nature of some of the lower Paleogene sediments. In samples with a high content of detrital quartz sand (from the Neogene section), radiolarians were concentrated by swirling the sand fraction in a beaker.

At least two strew slides of the resulting residue were made for each sample. To aid in the search for zonal indicators, large radiolarians were concentrated by sieving selected samples through a 150-μm mesh sieve. Slides were scanned at 250× for age-diagnostic taxa.

¹ Poag, C. W., Watts, A. B., et al., *Init. Repts. DSDP*, 95: Washington (U.S. Govt. Printing Office).

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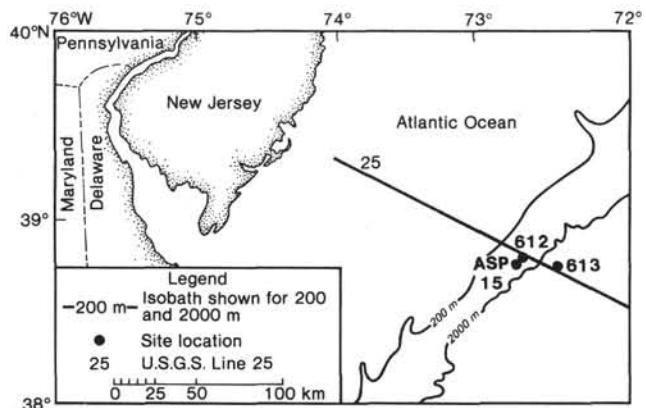


Figure 1. Map of the New Jersey Transect region showing the locations of Leg 95 Sites 612 and 613 and Atlantic Slope Project site ASP 15.

GENERAL OBSERVATIONS ABOUT ATLANTIC MARGIN RADIOLARIANS

The most diverse, well-preserved radiolarian assemblages in the New Jersey margin occur in upper Paleogene silica-rich nannofossil oozes and nannofossil chalks (Figs. 2–4). Lower Paleogene assemblages may have once been similar, but silica diagenesis caused varying degrees of dissolution and recrystallization of radiolarians in the silica-rich chalks and porcellanites. Age determinations based on radiolarians are difficult to make in the lower Paleogene section, because poor preservation hinders identification of taxa.

The best-preserved, most abundant Neogene radiolarian faunas in the on-shore coastal plain, shelf, and upper rise occur in lower and lower middle Miocene diatomaceous muds (Palmer, 1984, 1986; Poag, 1980; 1985). These units occur at some sites on the New Jersey outer shelf and slope (i.e., the COST B-3 well; Palmer, unpublished data), but were not recovered on Leg 95 (see Poag and Mountain, this volume, for discussion). Neogene radiolarians from New Jersey margin sites are more abundant, in finer-grained sediments relative to the sandier lithologies, but all the Leg 95 Neogene faunas are of low diversity, are poorly preserved, and are dominated by non-age-diagnostic taxa. Upper Pliocene to Pleistocene sediments contain few radiolarians; better preservation and greater abundance occur in muddier lithologies, compared with glauconitic sands. These late Neogene assemblages are of low diversity and contain few to no age-diagnostic taxa.

RESULTS FROM EACH SITE

Results presented here are based on studies conducted on shore, and in some cases significantly revise preliminary shipboard radiolarian results (site chapters, this volume).

The presence of low-latitude taxa in the Atlantic margin assemblage makes it possible to recognize the standard radiolarian zones of Riedel and Sanfilippo (1978; and subsequent modifications in Saunders et al., 1985), but some uncertainties remain. Many of the nominate and indicator species in the standard radiolarian zonation are absent, or occur so sporadically that they do

not provide reliable datums. Further, as discussed later, the sequence of first and last appearances and evolutionary transition events observed in low latitudes (Riedel and Sanfilippo, 1978 and in Saunders et al., 1985) appears to be slightly different in the New Jersey margin section. The use of tropical zones and datums at this mid-latitude location does not allow the stratigraphic resolution possible in lower latitudes. It may be desirable in the future to establish a middle-latitude Atlantic zonation (as suggested by Sanfilippo et al., 1973, with regard to Mediterranean Neogene radiolarians). Such a zonation would be particularly valuable if correlations were made with both Riedel and Sanfilippo's (1978) low-latitude zonation and Bjorklund's (1976) Norwegian Sea zones.

Correlation of Riedel and Sanfilippo's radiolarian zones (1978; and modifications in Saunders, et al., 1985) with other planktonic microfossil zones and with the absolute time scale is based on the Berggren et al. (1985b) time scale. The Leg 95 shipboard scientific party agreed upon the use of this time scale in reporting all cruise results; this created some difficulty in reporting the age of the Eocene/Oligocene boundary interval, because different ages are assigned to radiolarian zones in this interval by Berggren et al. (1985a, b) and Riedel and Sanfilippo (1978; in Saunders et al., 1985), as discussed below.

Figure 5 indicates the Paleogene radiolarian zones that have been identified at Sites 612 and 613, and their absolute age correlation based on the Berggren et al. (1985a, b) time scale. The correlations used by Berggren et al. (1985a, b) change the traditional age assignments of certain zones, such as the *Thrysocyrtis bromia* Zone (now subdivided, as explained below). The top of this zone (placed at the evolutionary transition of *Lithocyclia aristotelis* to *L. angusta*, and the last morphological appearances of *Lophocyrtis jacchia*, *Lychnocanoma amphitrite*, and *Dictyoprora pirum*) was equivalent to the Eocene/Oligocene boundary, according to Riedel and Sanfilippo (1978). In Saunders et al. (1985), Riedel and Sanfilippo divided the *T. bromia* Zone (from oldest to youngest) into the *Carpocanistrum azyx*, *Calocyclus bandycia*, and *Cryptoprora ornata* zones; the top of the *C. ornata* Zone (placed at the evolutionary transition of *Lithocyclia aristotelis* to *L. angusta* and the last morphological appearance of *Lophocyrtis jacchia*) marks the Eocene/Oligocene boundary. Berggren et al. (1985a), however, review evidence that places the *Cryptoprora ornata/Theocyrtis tuberosa* zonal boundary near the NP21/22 boundary, within the early Oligocene.

Other significant differences involve the placement of the early/middle Eocene and middle/late Eocene boundaries. According to Riedel and Sanfilippo (1978), these fall within the *Thrysocyrtis triacantha* and *Podocyrtis mitra* zones, respectively. In the new time scale the same boundaries occur within the *Theocotyle cryptocephala* and *Carpocanistrum azyx* zones (Fig. 5).

Site 612

Figure 2 indicates the abundance and preservation of radiolarians and the ranges of age-diagnostic species in Hole 612. Table 1 shows the abundance of selected spe-

cies at a more detailed sampling interval through the upper Paleogene section of Hole 612; this interval contains well-preserved radiolarians, and important biostratigraphic events are recognized. Figure 6 correlates this sequence of events with the tropical sequence observed by Riedel and Sanfilippo (1978 and in Saunders et al., 1985).

Cretaceous

Cretaceous radiolarians were observed in Sample 612-61,CC (569.0 m sub-bottom). Specimens observed included few badly corroded spongodiscids and *Dictyomitra* sp. cf. *D. multicostata*. Shipboard nannofossil biostratigraphy assigns a middle Maestrichtian age to this sample.

Lower Eocene

Radiolarians occur in lower Eocene siliceous chalks and porcellanites from Sample 612-60,CC through Sample 612-46,CC (559.4–424.6 m sub-bottom). Preservation tends to be poor at best, with radiolarians completely dissolved and recrystallized in some samples. Sample 612-59,CC (549.8 m sub-bottom) contains *Buryella tetradica* and *Phormocyrtis striata exquisita*, which indicate the *Buryella clinata* Zone or the *Bekoma bidartensis* Zone. The *Bekoma bidartensis* Zone is partly of Paleocene age, but this assignment does not conclusively demonstrate the presence of Paleocene strata at Site 612.

Samples 612-56,CC through 612-46,CC (521.0–424.6 m sub-bottom) contain poorly preserved specimens of *Phormocyrtis striata striata*, *Peripheraena delta*, *Theocotylissa fucus*, *Ceratospyris articulata*, *Buryella clinata*, *Podocyrtis diamesa*, and *Lophocyrtis biaurita*. The occurrence of these species and the absence of *Dictyophimus craticula*, *Theocotyle cryptocephala*, and *Dictyoprora mongolfieri* suggest placement of this interval into the *Phormocyrtis striata striata* Zone.

Middle Eocene

No age-diagnostic radiolarians could be identified from the diagenetically altered interval between Samples 612-45,CC and 612-36-5, 110–112 cm (414.9–325.6 m sub-bottom). The *Theocotyle cryptocephala* and *Dictyoprora mongolfieri* zones (and thus the lower/middle Eocene boundary) evidently occur in Hole 612 within the zone of poor silica preservation, and cannot be recognized using radiolarians. Shipboard nannofossil and planktonic foraminiferal data and Poag and Low (this volume) place the unconformable lower/middle Eocene contact within Core 612-39 (347.3–357.0 m sub-bottom).

Well-preserved middle Eocene radiolarians first occur in a siliceous nannofossil ooze in Sample 612-36-3, 110–112 cm (322.6 m sub-bottom), and are found through Sample 612-21,CC (183.8 m sub-bottom). Three zones are recognized in this interval: the *Thrysocyrtis triacantha*, *Podocyrtis ampla*, and *Podocyrtis mitra* zones.

Sample 612-36-3, 110–112 cm (322.6 m sub-bottom) is the first sample above the porcellanite interval with well-preserved radiolarians. This sample is assigned to the *Thrysocyrtis triacantha* Zone on the basis of the presence of *Eusyringium lagena*, *Podocyrtis dorus*, and *Podocyrtis diamesa*. Species restricted to this zone in Hole 612 include *Lamptonium fabaeforme chaunothorax*, *The-*

ocotyle cryptocephala, and very rare *Theocotyle nigriniae*.

The *Podocyrtis phyxis*-to-*P. ampla* transition, which marks the boundary between the *Thrysocyrtis triacantha* and *Podocyrtis ampla* zones of Riedel and Sanfilippo (1978), was not recognized. The boundary between the *Thrysocyrtis triacantha* Zone and the overlying *Podocyrtis ampla* Zone is therefore placed stratigraphically below Sample 612-27,CC (241.4 m sub-bottom), above the first appearance of *Eusyringium fistuligerum*, and below both the first appearance of *Podocyrtis fasciolata* and the last appearances of *Podocyrtis dorus* and *Podocyrtis diamesa*. In Hole 612 the interval between Samples 612-27,CC and 612-23,CC (241.4–203.0 m sub-bottom) contains the last appearances of *Theocotyle conica* and *Thrysocyrtis tensa* and the evolutionary transition of *Eusyringium lagena* to *E. fistuligerum*.

The boundary between the *Podocyrtis ampla* Zone and the overlying *Podocyrtis mitra* Zone occurs stratigraphically below Sample 612-23,CC (203.0 m sub-bottom), at the *Podocyrtis sinuosa*-to-*P. mitra* evolutionary transition. The interval between Samples 612-23,CC and 612-21,CC (203.0–183.8 m sub-bottom) contains the last appearances of *Podocyrtis fasciolata* and *Thrysocyrtis hirsuta*. However, biostratigraphic events which Riedel and Sanfilippo (1978) observe near the top of the *Podocyrtis mitra* Zone, such as the *Lithapium anoectum*-to-*L. mitra* transition and the last appearance of *Lophocyrtis biaurita*, are not observed in the middle Eocene of Hole 612. Because *Lithapium mitra* is subordinate in abundance to its ancestor *L. anoectum*, and *Lophocyrtis biaurita* is abundant through Sample 612-21,CC (183.0 m sub-bottom), it appears that only the lower portion of the *Podocyrtis mitra* Zone is present through Sample 612-21,CC (183.8 m sub-bottom).

Upper Eocene (to lower Oligocene?)

No sample was available from Section 612-21-5, but Poag and Low (this volume) identify a disconformity in this section, marked by a glauconite layer. Sample 612-21-3, 110–112 cm (178.3 m sub-bottom) contains specimens of *Lithocyclia aristotelis*, *Theocytis tuberosa*, *Cryptopora ornata*, *Dictyoprora armadillo*, *Lychnocanoma amphitrite*, *Lophocyrtis jacchia*, *Cyclampterium longiventer*, *Thrysocyrtis bromia*, *Thrysocyrtis tetricantha*, *Lithapium mitra*, *Artophormis barbadensis*, *Dictyoprora pirum*, *Tristylospyris triceros*, and *Dictyoprora ovata*, which together indicate the *Calocyclas bandycya* Zone.

The abrupt appearance of upper Eocene radiolarians agrees with Poag and Low's placement of an unconformity between the middle and upper Eocene sediments in Core 612-21. Neither the middle Eocene *Podocyrtis chalara* and *Podocyrtis goetheana* zones nor the late Eocene *Carpocanistrum azyx* Zone (corresponding to the lower part of the *Thrysocyrtis bromia* Zone of Riedel and Sanfilippo, 1978) are present, indicating that a biostratigraphic gap of 5 m.y. (from 42.2 to 37.2 Ma) exists between the middle and upper Eocene sediments at this site.

The last appearance of *Thrysocyrtis tetricantha* in Sample 612-19,CC (164.7 m sub-bottom) marks the top of the *Calocyclas bandycya* Zone. Samples 612-19-5, 110–

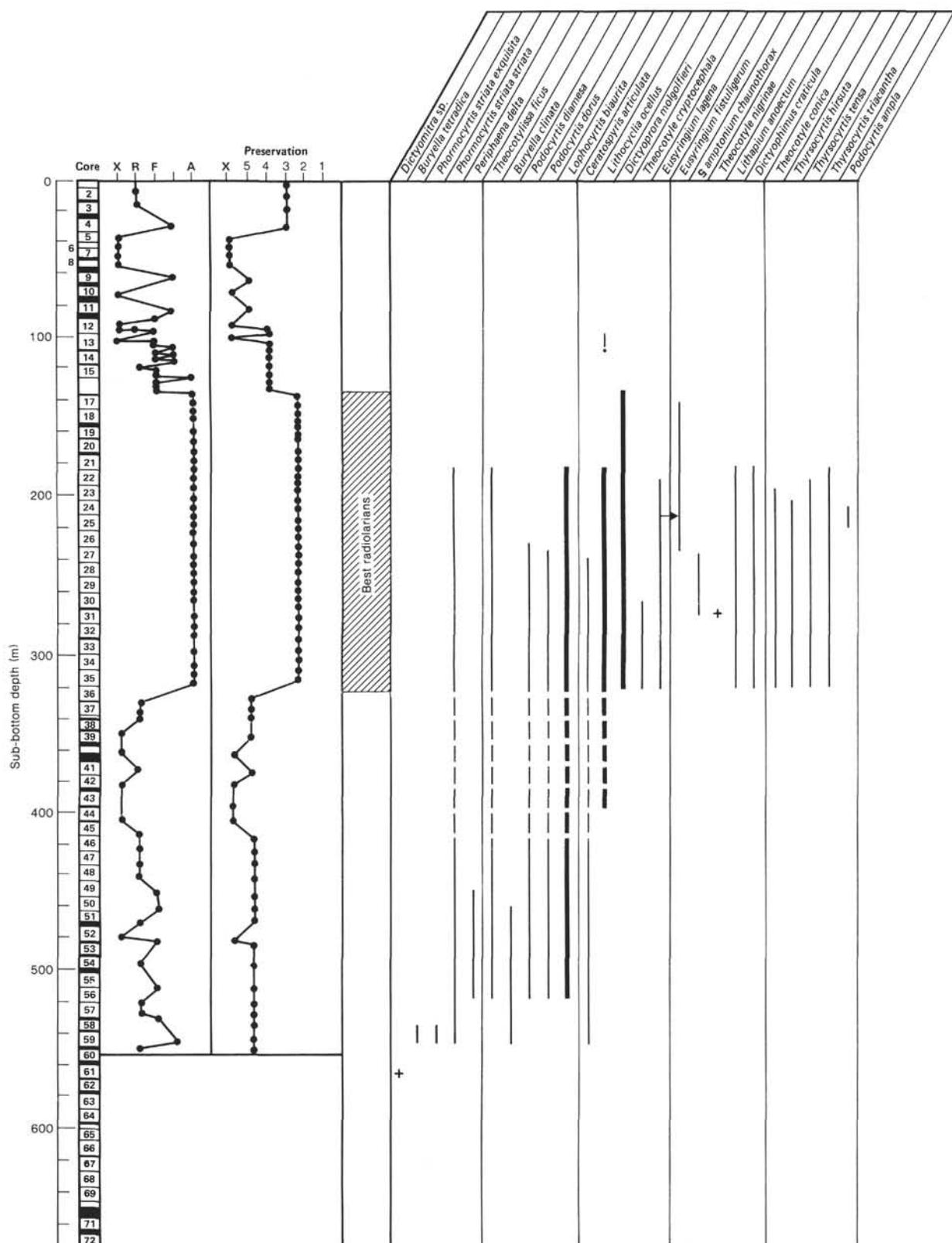


Figure 2. Radiolarian abundance and preservation, ranges of important species, zones, and geologic ages, Hole 612. Overall abundance is indicated by A = abundant (10^4 radiolarians per slide), C = common (10^3 radiolarians per slide), F = frequent (10^2 radiolarians per slide), R = rare (10 radiolarians per slide), X = barren (no radiolarians per slide). Preservation is shown according to the preservation grades of Westberg and Riedel (1978), with 1 = best preservation and 5 = worst preservation. More abundant species are indicated by heavier range bars (dashed where radiolarian preservation is poor and/or abundance is low). Isolated specimens of a species are indicated by a plus sign (+). Reworked older specimens are recorded with an exclamation point (!). In recovery column, black indicates unrecovered interval.

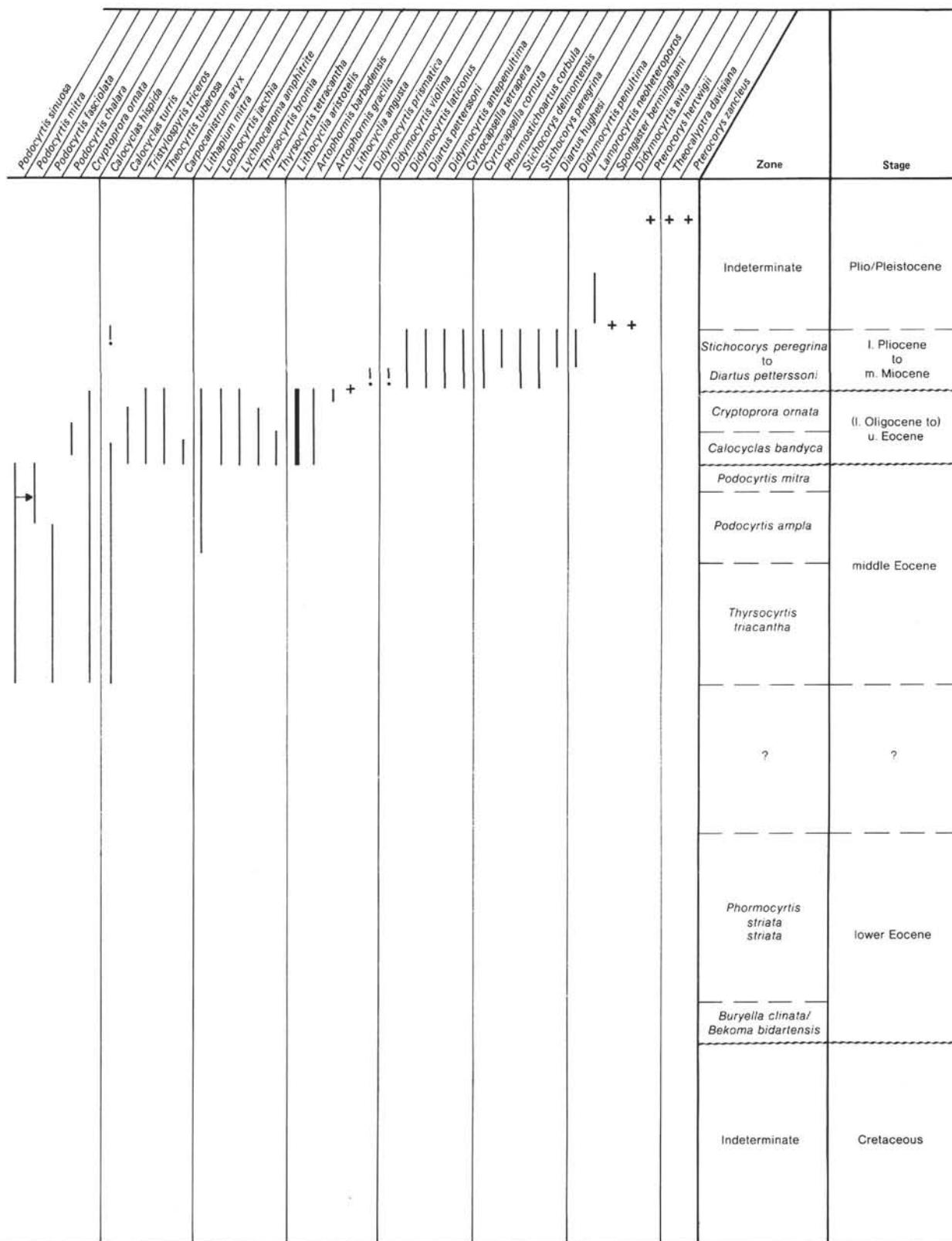


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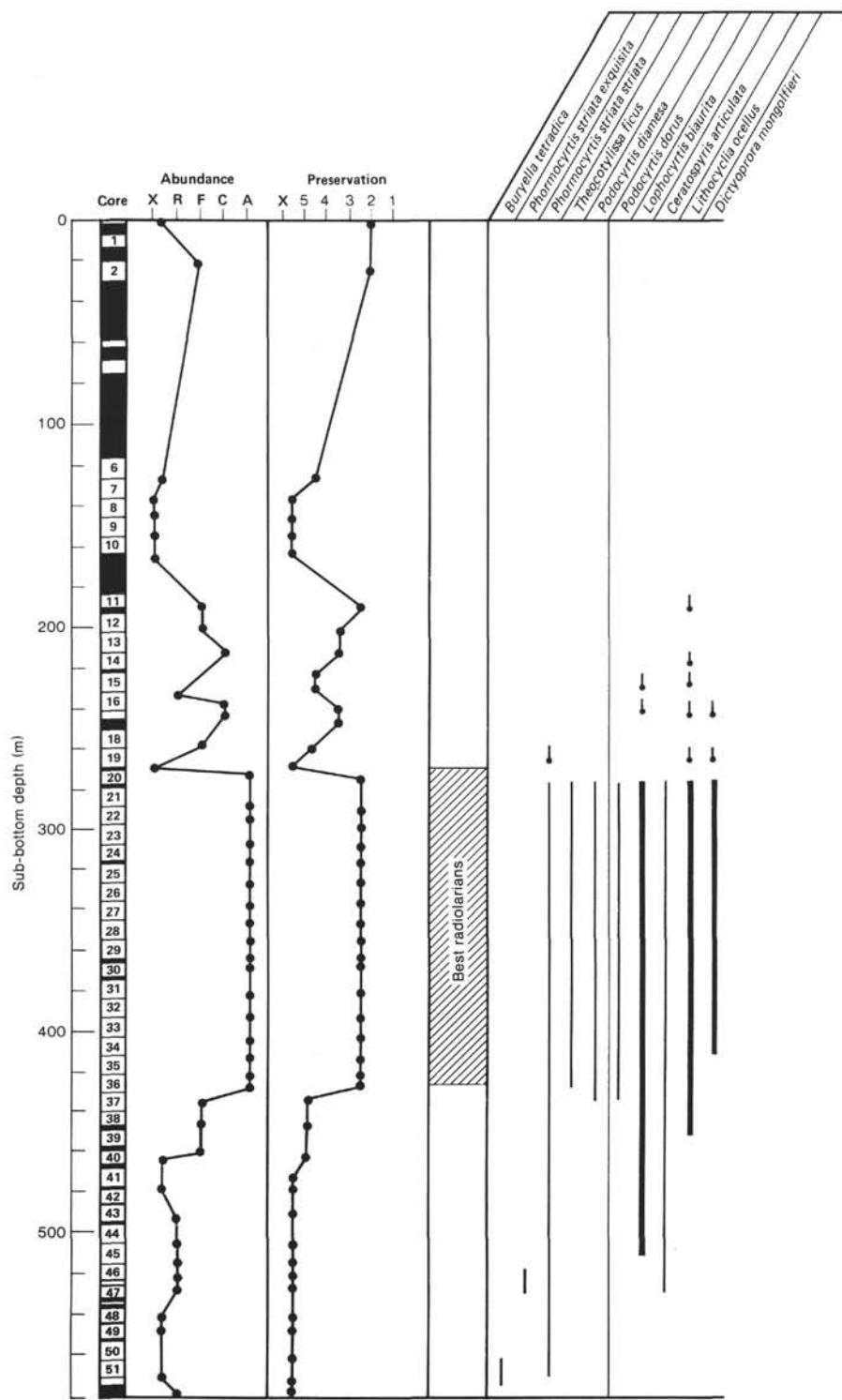


Figure 3. Radiolarian abundance and preservation, stratigraphic ranges of important species, zones, and geologic ages, Hole 613. Symbols the same as for Figure 2.

112 through 612-16,CC (162.3-136.2 m sub-bottom) represent the *Cryptopora ornata* Zone, which overlies the *Calocyclus bandyea* Zone.

The appearance of Oligocene species such as *Artophoromis gracilis* in Sample 612-17,CC (145.7 m sub-bottom) and *Lithocyctis angusta* in Sample 612-17-3, 110-112 cm (140.3 m sub-bottom) in subordinate abundance to

their respective ancestors, *A. barbadensis* and *L. aristotelis*, suggests that Sample 612-16,CC (136.2 m sub-bottom) can be placed in the upper portion of the *Cryptopora ornata* Zone. The Eocene/Oligocene boundary is placed by Berggren et al. (1985a, b) within the *Cryptopora ornata* Zone. Therefore, radiolarian biostratigraphic results suggest that the stratigraphic interval from 612-

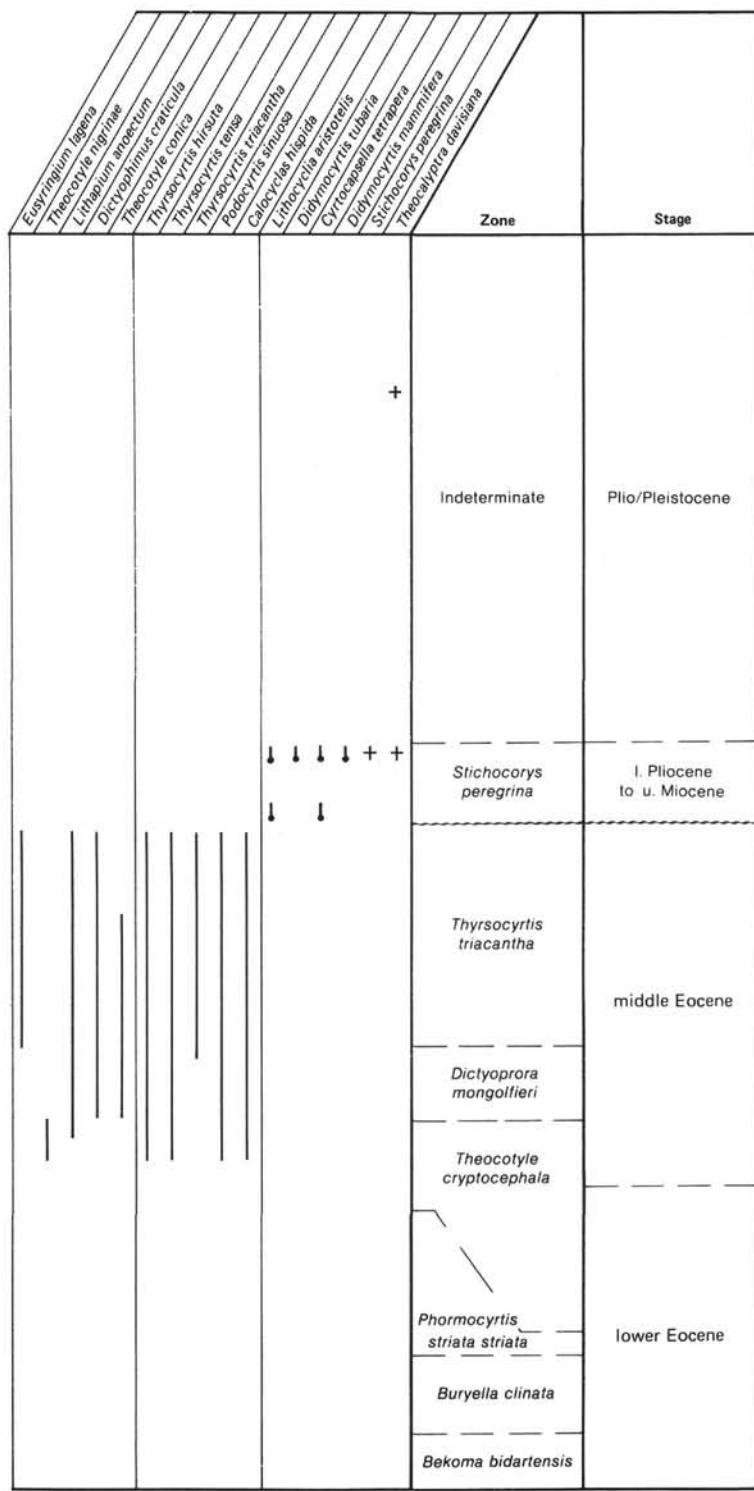


Figure 3 (continued).

21,CC through 612-16,CC (178.3–136.2 m sub-bottom) is entirely of late Eocene age, but cannot conclusively demonstrate the presence or absence of lowermost Oligocene deposits in Hole 612. Miller and Katz (this volume) and Poag and Low (this volume) agree that 612-16,CC is of late Eocene age, but recognize a thin overlying Oligocene section.

Table 1 shows the abundances of selected radiolarian taxa in the middle to upper Eocene section of Hole 612. The morphologic tops and bottoms of selected species' ranges, and important evolutionary transitions, are shown. In Figure 6 this sequence of events is compared with the sequence determined by Riedel and Sanfilippo in their biostratigraphic studies of tropical radiolarians (Riedel

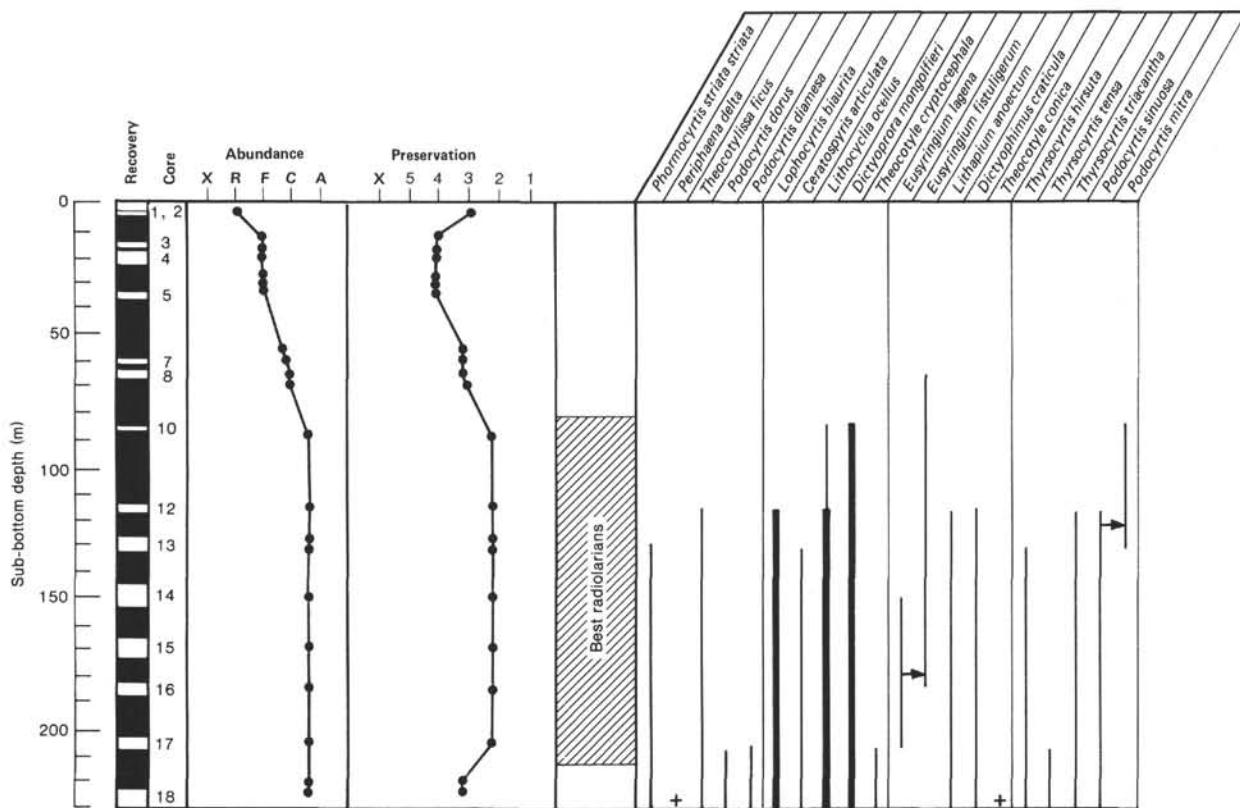


Figure 4. Radiolarian abundance and preservation, stratigraphic ranges of important species, zones, and geologic ages, ASP 15. Symbols the same as for Figure 2.

and Sanfilippo, 1978 and in Saunders et al., 1985). This comparison shows that many of the events known from the tropics were not recognized in the New Jersey margin sedimentary record. Some of the recognized events involve taxa that are rare or occur sporadically, and the reliability of the event as a biostratigraphic datum is consequently reduced. A large number of events are coincident in Hole 612 at the unconformity between the middle and upper Eocene sediments. In general, however, the biostratigraphic events recognized in the New Jersey margin occur in an overall sequence similar to that observed by Riedel and Sanfilippo (1978 and in Saunders et al., 1985) in the tropics.

Upper Miocene to Pliocene

A major unconformity between the Paleogene and Neogene sections in Hole 612 is marked by the occurrence of sandy, glauconitic sediments overlying siliceous nannofossil ooze in Section 612-16-6 (134.2–135.7 m sub-bottom) (see Poag and Low, this volume). Neogene radiolarians make an abrupt appearance in Sample 612-16-5, 110–112 cm (133.8 m). Although non-age-diagnostic radiolarians dominate the assemblage between Section 612-16-5 and Sample 612-13-5, 110–112 cm (133.8–104.9 m), *Diatrus petterssoni*, *Didymocyrtis antepenultima*, *Stichocorys delmontensis*, *Cyrtocapsella tetrapera*, *Phormostichoartus corbula*, and specimens of *Diatrus* sp. which appear to be intergradational between *D. petterssoni* and *D. hughesi* are present. A few specimens of *Stichocorys peregrina* were also observed, although this

occurrence is below the stratigraphic range attributed to *S. peregrina* by Riedel and Sanfilippo (1978). The majority of these taxa suggest the *Diatrus petterssoni* to *Didymocyrtis antepenultima* zones. Some poorly preserved and probably reworked lower to middle Miocene taxa, such as *Didymocyrtis prismatica* and *Didymocyrtis violina*, occur throughout this interval, although strata of this age were not recognized in Hole 612.

Radiolarians occur only sporadically in Samples 612-13-5, 110–112 cm through 612-13-1, 110–112 cm (104.9–98.9 m sub-bottom), and are absent from the glauconitic sand lithologies. The assemblage consists almost entirely of non-age-diagnostic taxa, including *Dictyocoryne* spp., *Eucyrtidium* spp., *Lynchnocanoma* spp., litheliids, pyloniids, actinommids, porodiscids, and other circular spongodiscs.

A few specimens of *Stichocorys peregrina*, *Didymocyrtis penultima*, *Spongaster berminghami*, *Didymocyrtis antepenultima*, and *Stichocorys delmontensis* suggest that the interval between Samples 612-13-5, 110–112 cm and 612-13-1, 110–112 cm (104.9–98.9 m sub-bottom) can be assigned to the *Stichocorys peregrina* Zone or the *Didymocyrtis penultima* Zone. *Diatrus hughesi* also occurs in this assemblage, although stratigraphically above its range as indicated by Riedel and Sanfilippo (1978). Some reworked middle Eocene radiolarians were noted, including *Lithocyrtia ocellata* and *Calocyclus hispida*.

Because biostratigraphic markers are rare throughout the interval from Sample 612-16-5, 110–112 through Sample 612-13-1, 110–112 cm (133.8–98.9 m sub-bottom),

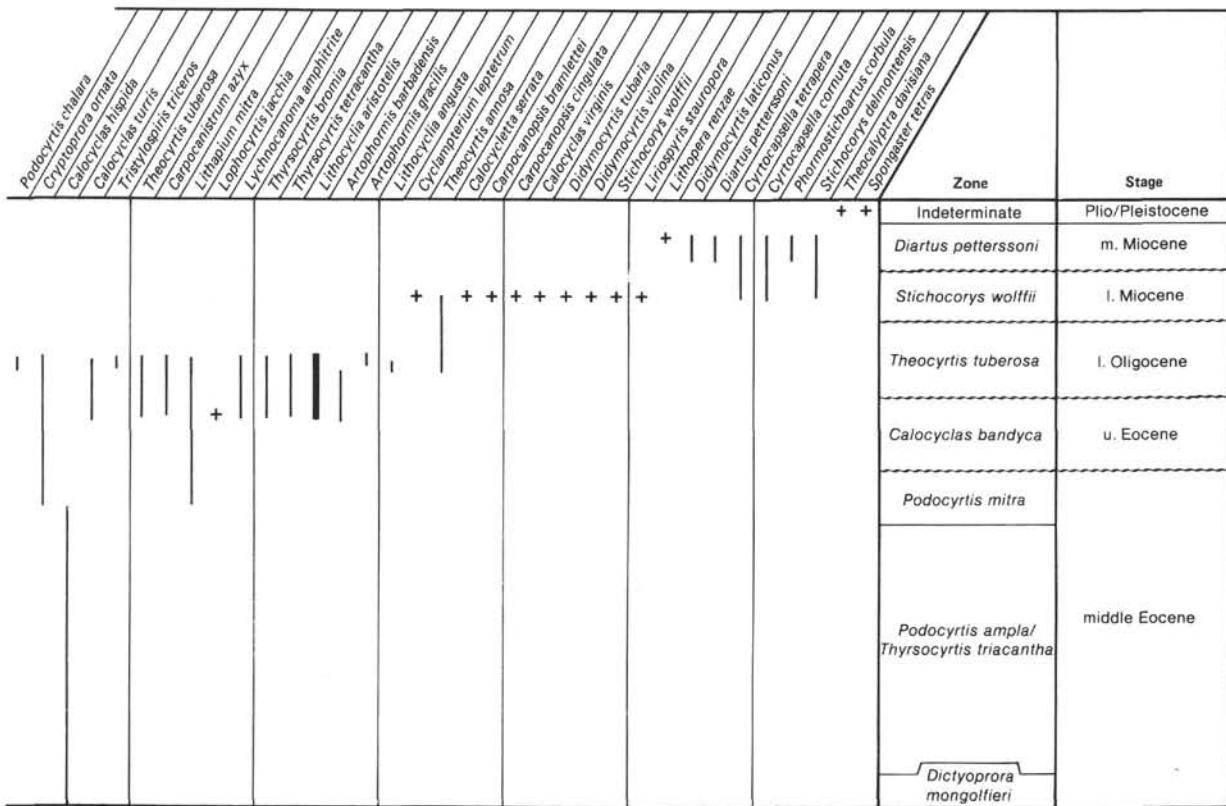


Figure 4 (continued).

the entire interval is assigned to the *Diarthus petterssoni* to *Stichocorys peregrina* zones.

Pliocene-Pleistocene

An undifferentiated Pliocene-Pleistocene interval is recognized in sandy, glauconitic muds in Samples 612-12,CC through 612-1,CC (97.8-4.8 m sub-bottom), on the basis of an extremely sparse radiolarian assemblage. Most taxa, such as *Dictyocoryne* spp., *Eucyrtidium* spp., porodiscids, pyloniids, and litheliids, are not age-diagnostic. The few somewhat age-informative taxa include *Pterocorys zanckleus*, *Pterocorys hertwigi*, *Theocalyptra davisianna*, and *Lamprocyrtis neoheteroporus*, which indicate a general Pliocene-Pleistocene age rather than a specific zone. No biostratigraphic gaps could be recognized in the upper Neogene of Site 612 on the basis of radiolarian age data.

An unusual radiolarian fauna occurs in Sample 612-4,CC (33.6 m sub-bottom) which contains abundant specimens of *Theocalyptra davisianna* (75% of all radiolarians in the sample) and large centric diatoms. The high abundance of this species has been linked with increased productivity related to Pliocene-Pleistocene glaciation (Morley and Hays, 1979). Furthermore, Benson (1972) noted that this species was "ubiquitous and often dominant in Pleistocene (and glacial Pliocene?) assemblages cored in the North Atlantic on DSDP Leg 12." Its abundance in Sample 612-4,CC thus appears to record a period of increased productivity, possibly associated with a Pliocene-Pleistocene glacial event.

Site 613

Radiolarian abundance and preservation and stratigraphic ranges of important species in Hole 613 are indicated in Figure 3.

Lower Eocene

As at Site 612, radiolarians at Site 613 are poorly preserved in lower Eocene siliceous chalks and porcellanites, because of silica diagenesis. Age-diagnostic taxa occur only in certain stratigraphic intervals, and age determinations are tentative at best. *Buryella tetradica* occurs in Samples 613-52,CC through 613-50,CC (581.9-562.9 m sub-bottom), suggesting the *Bekoma bidartensis* Zone. *Phormocyrtis striata exquisita* is present in Samples 613-47,CC and 613-46,CC (534.4-524.9 m sub-bottom), suggesting the *Buryella clinata* Zone. In Samples 613-43,CC through 613-35,CC (496.4-421.0 m sub-bottom), *Phormocyrtis striata striata* without *Dictyoprora mongolfieri* indicates the *Phormocyrtis striata striata* Zone or the *Theocotyle cryptocephala* Zone.

Middle Eocene

Abundant, moderately well preserved radiolarians occur in Hole 613 in siliceous nannofossil oozes from Samples 613-36,CC through 613-20,CC (440.0-278.6 m sub-bottom). This middle Eocene interval includes the *Theocotyle cryptocephala*, *Dictyoprora mongolfieri*, and *Thysocyrtis triacantha* zones.

The *Theocotyle cryptocephala* Zone (which contains the lower/middle Eocene boundary, according to Berg-

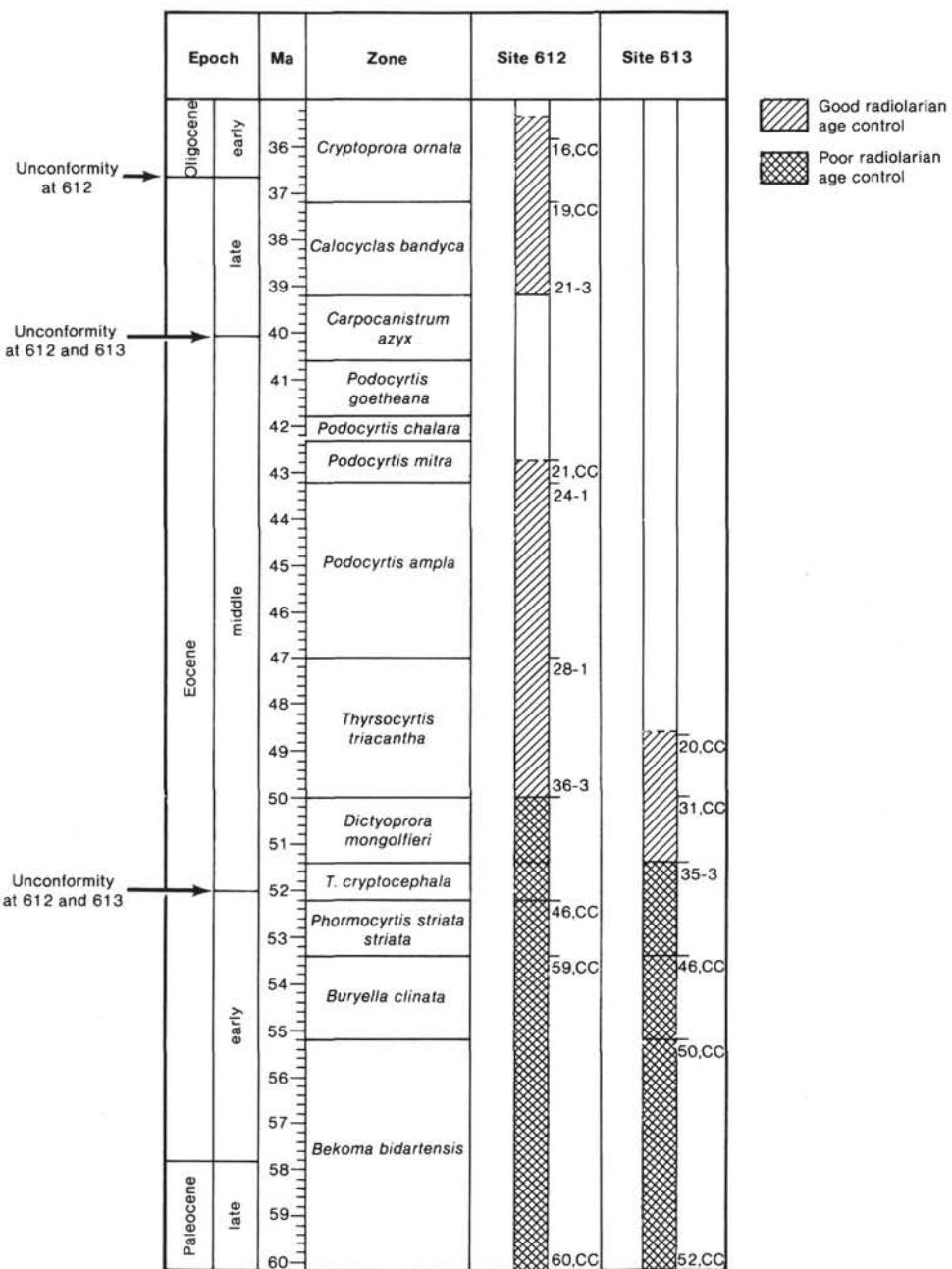


Figure 5. Absolute ages of Riedel and Sanfilippo's tropical Cenozoic radiolarian zones (Riedel and Sanfilippo, 1978; in Saunders, et al., 1985) for the late Paleogene, according to the Berggren et al. (1985) time scale. Intervals with relatively good and poor age control in Holes 612 and 613 are shown. Numbers indicate cores in which certain radiolarian zones were found in each hole. See Poag and Low (this volume) for discussion of unconformities.

gren et al., 1985a, b) occurs below the first occurrence of *Dictyoprora mongolfieri* in Sample 613-34,CC (411.5 m sub-bottom). The *Dictyoprora mongolfieri* Zone occurs above this datum, through Sample 613-31-3, 50-52 cm (379.0 m sub-bottom).

The base of the *Thrysocyrtis triacantha* Zone is placed at the first morphologic occurrence of *Eusyringium lagena* in Sample 613-30,CC (374.0 m sub-bottom). The upper part of the zone is apparently not present at the top of the middle Eocene section in Hole 613, because events which occur in the upper part of this zone and

the lower part of the *Podocyrtis ampla* Zone—that is, last appearances of *Podocyrtis dorus* and *Podocyrtis diamesa*, and the first morphologic appearance of *Eusyringium fistuligerum*—were not observed through Sample 613-20,CC (278.6 m sub-bottom).

Neogene

Radiolarians are sparse in the sandy, glauconitic Neogene sediments of Site 613. Sample 613-19,CC (269.0 m sub-bottom) is barren of radiolarians, and Sample 613-18,CC (259.5 m sub-bottom) contains only reworked Eo-

cene taxa. The presence of *Stichocorys peregrina* in Samples 613-17,CC and 613-16,CC (250.0-240.5 m sub-bottom) supports a tentative *Stichocorys peregrina* Zone assignment. This indicates the presence of a biostratigraphic gap of approximately 31 m.y. between the middle Eocene and the Neogene of Site 613, extending from below the top of the *Thrysocyrtis triacantha* Zone (about 48.6 Ma) to the base of the *Stichocorys peregrina* Zone (6.2 Ma).

Radiolarians are sparse or entirely absent in the interval from Sample 613-15,CC (231.0 m) to the top of the hole. The only age-diagnostic species present are *Pseudocubus* sp. in Sample 613-11,CC (193.6 m sub-bottom), and *Theocalyptra davisiiana* in Sample 613-5,CC (115.8 m sub-bottom), both indicating a Pliocene-Pleistocene age. The radiolarian fauna of Sample 613-5,CC is similar to the *Theocalyptra davisiiana*-dominated assemblage at Site 612 in Sample 612-4,CC. Further studies are required to determine whether one or more *Theocalyptra davisiiana* high-abundance horizons exist elsewhere in the New Jersey Transect region.

Atlantic Slope Project Site ASP 15

Radiolarian abundance and preservation and the stratigraphic ranges of important species are shown in Figure 4.

Middle Eocene

The middle Eocene interval of ASP 15 is similar to the sections encountered at DSDP Sites 612 and 613; it consists of siliceous nannofossil ooze with abundant and well-preserved radiolarians. Four middle Eocene zones are recognized, as follows:

1. The presence of *Peripheraena delta*, *Podocyrtis diamesa*, and *Podocyrtis dorus*, and the absence of *Eusyringium lagena* in Core 18, indicate the *Dictyoprora mongolfieri* Zone.
2. *Eusyringium lagena* appears in Core 17 with *Podocyrtis dorus*, indicating the *Thrysocyrtis triacantha* Zone to lower *Podocyrtis ampla* Zone.
3. *Podocyrtis diamesa* and *Podocyrtis dorus* are absent above Core 17, and the predominance of *Podocyrtis sinuosa* over *Podocyrtis mitra* in Cores 16 through 13 indicates the *Podocyrtis ampla* Zone. The *Eusyringium lagena*-to-*E. fistuligerum* evolutionary transition evidently occurs between Cores 16 and 15.
4. The base of the *Podocyrtis mitra* Zone, the evolutionary transition from *Podocyrtis sinuosa* to *P. mitra*, is placed between Cores 13 and 12.

Upper Eocene

Upper Eocene radiolarians appear in Core 10, including specimens of *Lithocyclia aristotelis*, *Thrysocyrtis bromia*, *Thrysocyrtis tuberosa*, *Thrysocyrtis tetricantha*, *Lychnocanoma amphitrite*, *Cryptopora ornata*, *Lithapium mitra*, *Lophocyrtis jacchia*, *Carpocanistrum azyx*, *Calocyclus turris*, *Artophormis barbadensis*, *Thrysocyrtis bromia*, and *Dictyoprora amphora*, which suggest the *Calocyclus bandycia* Zone. The *Podocyrtis chalara*, *Podocyrtis goetheana*, and *Carpocanistrum azyx* zones could be present in the unsampled interval between Cores

10 and 12, although it seems more likely that a disconformity exists between the middle and upper Eocene sediments at ASP 15, similar to that observed at Site 612.

Lower Oligocene

Lower Oligocene radiolarians occur in Cores 8 and 7 from ASP 15. Diagnostic taxa present include *Lithocyclia angusta*, *Cyclampterium longiventer*, *Tristylospyris tricerus*, *Thrysocyrtis tuberosa*, *Artophormis gracilis*, and *Lithocyclia crux*, indicating the lower Oligocene *Thrysocyrtis tuberosa* Zone. Some upper Eocene taxa occur in these cores, however, including *Lithocyclia aristotelis*, *Cryptopora ornata*, *Thrysocyrtis bromia*, *Thrysocyrtis tetricantha*, *Podocyrtis chalara*, *Lithapium mitra*, and *Calocyclus turris*, suggesting that the upper part of the *Cryptopora ornata* Zone may be present.

Lower Miocene

As at Sites 612 and 613, the Neogene sediments at ASP 15 are sandier than the Paleogene deposits. Lower Miocene radiolarians appear in Core 5 of ASP 15. The diagnostic species include *Carpocanopsis cingulata*, *Cryptocapsella tetrapera*, *Stichocorys wolffii*, *Cyclampterium leptetrum*, *Carpocanopsis bramlettei*, and *Eucyrtidium diaphanes*. These taxa indicate the *Stichocorys wolffii* Zone. There is no indication of the lower Miocene *Stichocorys delmontensis*, *Cryptocapsella tetrapera* zones, although they could possibly occur in the unsampled interval between Cores 5 and 7.

Middle Miocene

Cores 3 and 4 contain fewer, less well preserved taxa than the underlying lower Miocene or Paleogene units. Taxa indicating the middle Miocene *Diatrurus petterssoni* Zone include *Diatrurus petterssoni*, *Lithopera renzae*, *Cryptocapsella cornuta*, *Didymocystis antepenultima*, *Stichocorys delmontensis*, *Cryptocapsella tetrapera*, *Phormostichoartus corbula*, and *Didymocystis laticonus*. Many nondiagnostic taxa are also present in this assemblage; spongodiscids and actinomimids are particularly abundant.

Pliocene-Pleistocene(?)

As in the Pliocene-Pleistocene sections of Sites 612 and 613, radiolarians in Cores 1 and 2 from ASP 15 are predominantly nondiagnostic for biostratigraphic purposes. *Spongaster tetras* and *Theocalyptra davisiiana* indicate a general Pliocene-Pleistocene age for these cores.

PALEOENVIRONMENTAL INTERPRETATIONS

Paleogene

Radiolarians are abundant and diverse in the middle and upper Eocene and lower Oligocene sediments of Holes 612, 613, and ASP 15, suggesting that bathyal water depths and high rates of biological productivity prevailed on the margin during the late Paleogene. However, certain taxa (notably the genera *Podocyrtis*, *Lamptonium*, and *Thrysocyrtis*) are rare in the mid-latitude New Jersey margin, compared with lower latitude regions. In the New Jersey margin assemblage, the actinomimids,

Table 1. Abundance of selected species in the upper Paleogene section of Hole 612, where radiolarian abundance and preservation is optimal for making biostratigraphic determinations; morphologic first and last appearances and evolutionary transitions are also indicated.

Note: Species abundance is indicated by the following symbols (after Westberg and Riedel, 1978): C = common (>10% of all radiolarians on a slide); F = frequent (1-10%); R = rare (0.1-1%); r = very rare (0.01-0.1%).

B_m = morphologic bottom; T_m = morphologic top.

² B_{M(1)}(1) indicates morphologic bottom of *Lychnocanthurus amphitrite*, *Lophocyritis jacksoni*, *Carpocanistrum azyx*, *Thryscocyrtis tetrocantha*, *Thryscocyrtis bromia*, *Thryscocyrtis tuberosa*; T_{M(2)}(2) indicates morphologic top of *Lophocyritis biaurita*.

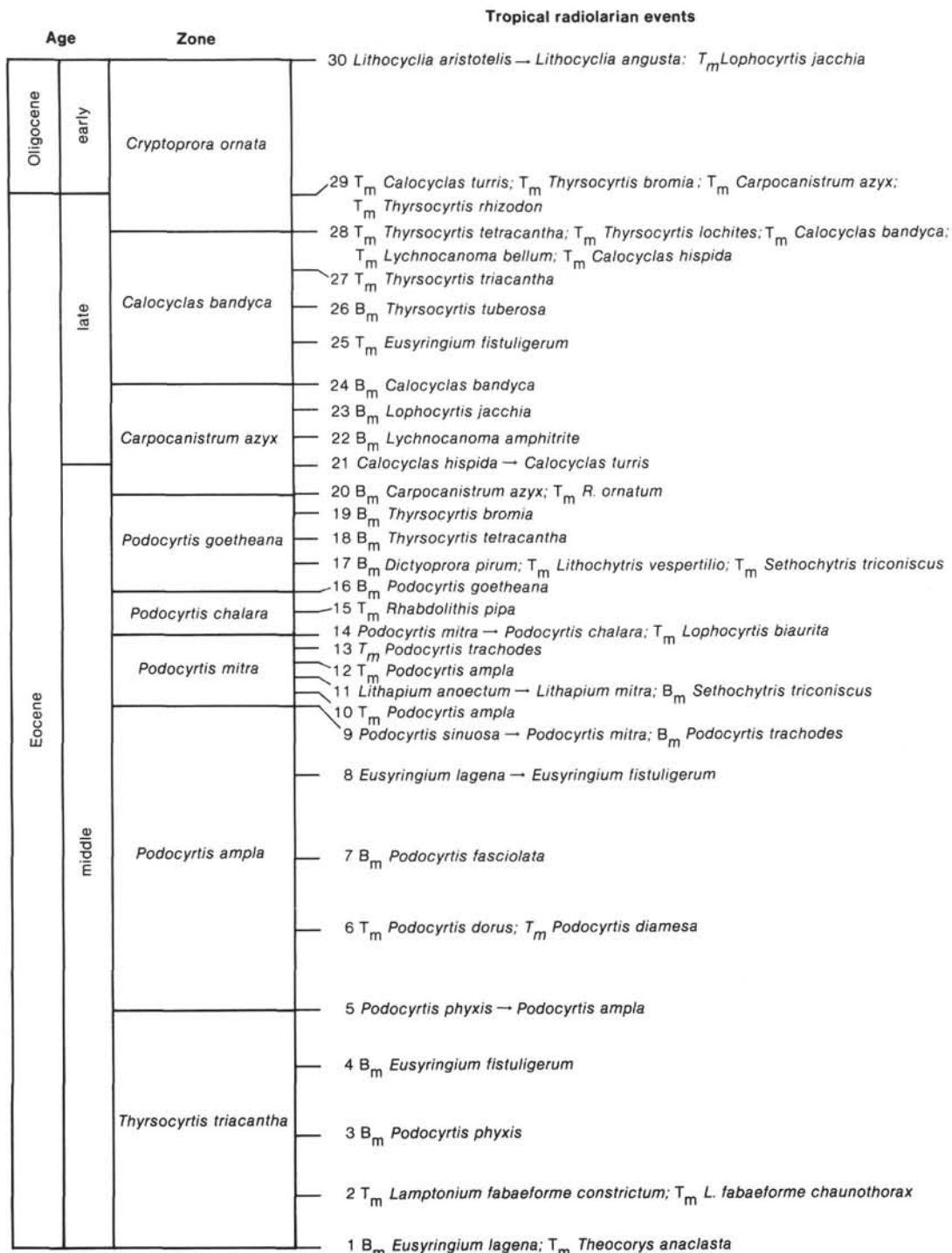


Figure 6. Upper Paleogene radiolarian events observed by Riedel and Sanfilippo (1978; in Saunders, et al., 1985) in tropical sections, and those observed in the upper Paleogene in Hole 612. Vertical scale for Zone column is proportional to absolute age (as in Fig. 2); the order of events within each zone is in the proper sequence, but no specific time value between events is implied. B_m = morphologic base of species; T_m = morphologic top; horizontal arrow = evolutionary transition.

spongodiscids, porodiscids, litheliids, and coccodiscids are the predominant taxa. The first four groups are major components of high-latitude Paleogene faunas (such as those encountered on DSDP Legs 38, 48, and 81 in the North Atlantic); the last is important in tropical faunas. This assemblage is significantly different from those previously described from low-latitude localities in the

Atlantic and Caribbean drilled on DSDP Leg 4 (Riedel and Sanfilippo, 1970), Leg 10 (Riedel and Sanfilippo, 1973; Foreman, 1973), Leg 15 (Riedel and Sanfilippo, 1973), and Leg 44 (Weaver and Dinkelman, 1978).

The co-occurrence of taxa typically found at high and low latitudes in the New Jersey margin assemblage suggests the existence of a Paleogene north-south faunal

Hole 612

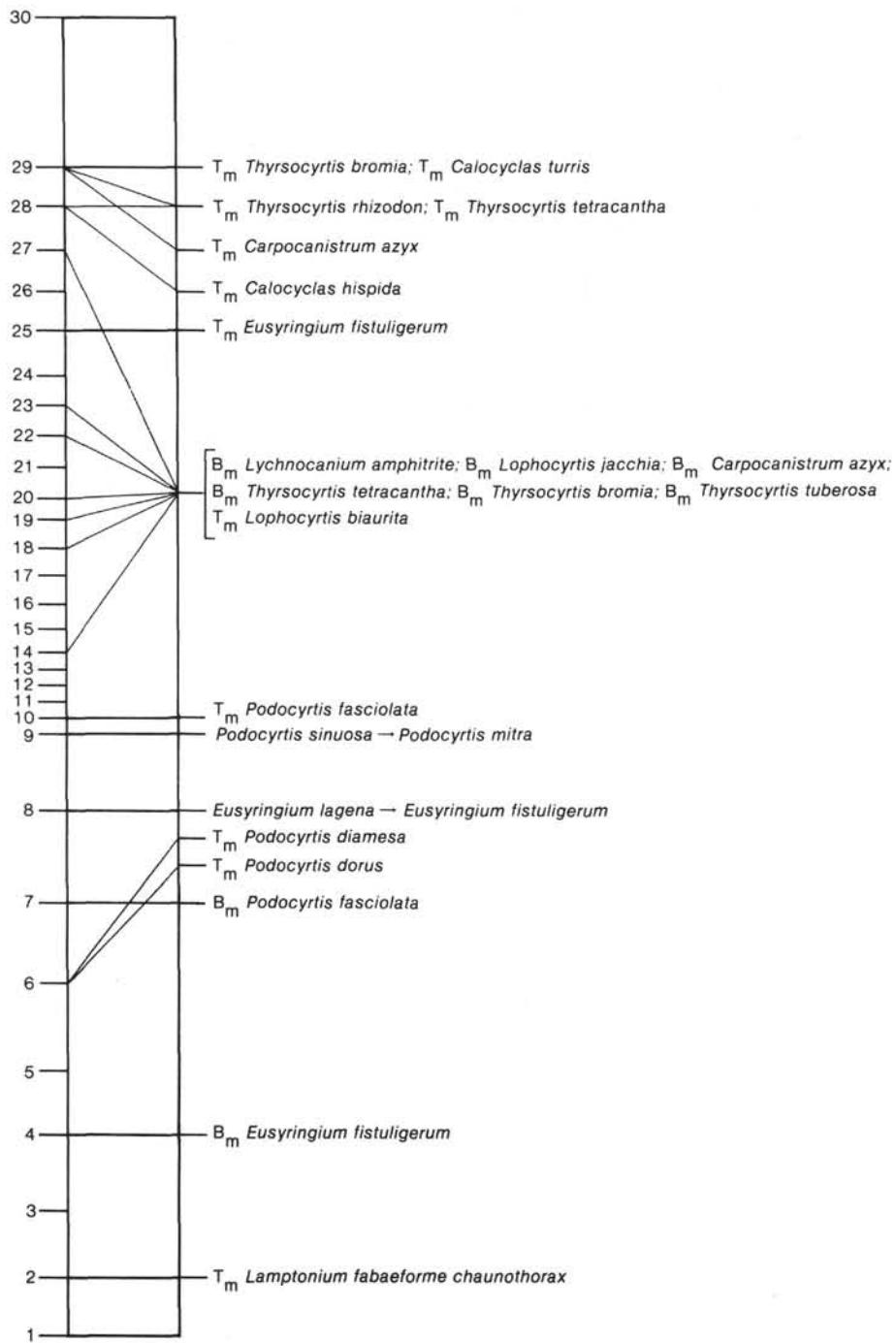


Figure 6 (continued).

gradient that probably reflected an environmental gradient (including such factors as temperature, insolation, etc.). Furthermore, Blueford (1983, 1984) and Blueford and King (1983) observed that spongy radiolarians are typical of shelf-water faunas in cold/temperate regions, both modern and ancient. Blueford and White (1984) applied this argument to a paleoenvironmental analysis of the Eocene Kreyenhagen Formation of California, in which they found that "porodiscids and spongodiscids

dominate the radiolarian fauna, actinommids are common and nassellarians are of lesser importance." The presence of a large component of spongy radiolarians in the Atlantic margin deposits thus also suggests cool/temperate conditions along the Paleogene Atlantic margin.

Neogene

Compared with the Paleogene, radiolarians in the Neogene of the New Jersey margin are less abundant and

more poorly preserved. The sandy Neogene lithologies indicate considerable detrital influx and terrigenous influence. The delta-influenced paleoenvironmental conditions associated with these lithologies may have been responsible for the diminished radiolarian fauna. Many taxa in the Neogene assemblage, including *Dictyocoryne*, *Didymocystis*, porodiscids, litheliids, and circular spongodiscids, are typical of spongy cold/temperate shelf-water assemblages (Blueford, 1983; Blueford and King, 1983), and here appear to be delta-related. Deep-dwelling taxa such as *Cornutella*, *Bathropyramis*, and *Peripyramis* are consistently present, however, indicating bathyal depths. In contrast, these taxa are virtually absent from on-shore Neogene Coastal Plain deposits which represent neritic paleoenvironments (Palmer, 1984).

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Artophormis barbadensis (Ehrenberg), Riedel and Sanfilippo, 1970, p. 532, pl. 13, fig. 5.
Artophormis gracilis Riedel, 1959, p. 300, pl. 2, figs. 12, 13.
Buryella clinata Foreman, 1973, p. 433, pl. 8, figs. 1-3; pl. 9, fig. 19.
Buryella tetradica Foreman, 1973, pl. 8, figs. 4, 5; pl. 9, figs. 13, 14.
Calocyclus hispida (Ehrenberg)
Anthrocyclis hispida Ehrenberg, 1873, p. 216; 1875, pl. 8, fig. 2.
Calocyclus hispida (Ehrenberg), Foreman 1973, p. 434, pl. 1, figs. 12-15; pl. 9, fig. 18.
Calocyclus turris Ehrenberg, 1873, p. 218; 1875, pl. 18, fig. 7.
Calocycletta serrata Moore, 1972, p. 148, pl. 2, figs. 1-3.
Calocycletta virginis (Haeckel)
Calocyclus virginis Haeckel, 1887, p. 1381, pl. 74, fig. 4.
Calocycletta virginis (Haeckel), Moore, 1972, p. 147, pl. 1, fig. 4.
Carpocanistrum azyx Sanfilippo and Riedel, 1973, p. 530, pl. 35, fig. 9.
Carpocanopsis bramlettei Riedel and Sanfilippo, 1971, p. 1597, p. 2G, figs. 8-14, pl. 8, fig. 7.
Carpocanopsis cingulata Riedel and Sanfilippo, 1971, p. 1597, pl. 2G, figs. 17-21; pl. 8, fig. 8.
Ceratospyris articulata Ehrenberg, 1873, p. 218; Sanfilippo and Riedel, 1973, p. 526, pl. 15, figs. 1-3; pl. 31, figs. 8, 9.
Cryptopora ornata Ehrenberg, 1873, p. 222; 1875, pl. 5, fig. 8.
Cyclampterium leptetrum Sanfilippo and Riedel, 1970, p. 456, pl. 2, figs. 11, 12.
Cyclampterium longiventer Chen, 1975, p. 459, pl. 10, fig. 7.
Cyrtocapsella cornuta (Haeckel)
Cyrtocapsa cornuta Haeckel, 1887, p. 1513, pl. 78, fig. 9.
Cyrtocapsella cornuta (Haeckel), Sanfilippo and Riedel, 1970, p. 453, pl. 1, figs. 19, 20.
Cyrtocapsella tetrapera (Haeckel)
Cyrtocapsa tetrapera Haeckel, 1887, p. 1512, pl. 78, fig. 5.
Cyrtocapsella tetrapera (Haeckel), Sanfilippo and Riedel, 1970, p. 453, pl. 1, figs. 16-18.
Diarthus hughesi (Campbell and Clark)
Ommatocampe hughesi Campbell and Clark, 1944, p. 23, pl. 3, fig. 12.
Diarthus hughesi (Campbell and Clark), Sanfilippo and Riedel, 1980, p. 1010.
Diarthus petterssoni (Riedel and Sanfilippo)
Cannartus(?) petterssoni Riedel and Sanfilippo, 1970, p. 520, pl. 14, fig. 3.
Diarthus petterssoni (Riedel and Sanfilippo), Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1h.
Dictyophimus craticula Ehrenberg, 1873, p. 223; Sanfilippo and Riedel, 1973, p. 529, pl. 19, fig. 1; pl. 33, fig. 11.
Dictyoprora amphora (Haeckel) group
Dictyocephalus amphora Haeckel, 1887, p. 1305, pl. 62, fig. 4.
Dictyoprora amphora (Haeckel) group, Nigrini, 1977, p. 250, pl. 4, figs. 1, 2.
Dictyoprora sp. aff. *D. amphora* (Haeckel) group
Theocampe sp. aff. *T. amphora* (Haeckel) group, Foreman, 1973, p. 432, pl. 9, fig. 10.
Dictyoprora sp. aff. *D. amphora* (Haeckel) group, Nigrini, 1977, p. 250, pl. 4, fig. 3.
Dictyoprora armadillo (Ehrenberg)
Eucyrtidium armadillo Ehrenberg, 1873, p. 225; 1875, p. 70, pl. 9, fig. 10.
Dictyoprora armadillo (Ehrenberg), Nigrini, 1977, p. 250, pl. 4, fig. 4.
Dictyoprora mongolfieri (Ehrenberg)
Eucyrtidium mongolfieri Ehrenberg, 1854, pl. 36, fig. 18, B lower; 1873, p. 230.
Dictyoprora mongolfieri (Ehrenberg), Nigrini, 1977, p. 250, pl. 4, fig. 7.
Dictyoprora ovata (Haeckel)
Theocampe ovata Haeckel, 1887, p. 1416, pl. 69, fig. 16.
Dictyoprora ovata (Haeckel), Nigrini, 1977, p. 251, pl. 4, figs. 5, 6.
Dictyoprora pirum (Ehrenberg)
Eucyrtidium pirum Ehrenberg, 1873, p. 232; 1875, pl. 10, fig. 14.
Dictyoprora pirum (Ehrenberg), Nigrini, 1977, p. 251, pl. 4, fig. 8.

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APPENDIX Species List

The following is a list of Cenozoic radiolarian species identified in samples from the New Jersey Transect.

- Dictyopora urceolus* (Haeckel)
Dictycephalus urceolus Haeckel, 1887, p. 1305.
Dictyopora urceolus (Haeckel), Nigrini, 1977, p. 251, pl. 4, figs. 9, 10.
- Didymocystis antepenultima* (Riedel and Sanfilippo)
Ommatartus antepenultimus Riedel and Sanfilippo, 1970, p. 521, pl. 14, fig. 4.
Didymocystis antepenultima (Riedel and Sanfilippo), Sanfilippo and Riedel, 1980, p. 1010.
- Didymocystis avita* (Riedel)
Panartus avitus Riedel, 1953, p. 808, fig. 7.
Didymocystis avita (Riedel), Sanfilippo and Riedel, 1980, p. 1010.
- Didymocystis laticonus* (Riedel)
Cannartus laticonus Riedel, 1959, p. 291, pl. 1, fig. 5.
Didymocystis laticonus (Riedel), Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1e.
- Didymocystis penultima* (Riedel)
Panarium penultimum Riedel, 1957, p. 76, pl. 1, fig. 1.
Didymocystis penultima (Riedel), Sanfilippo and Riedel, 1980, p. 1010.
- Didymocystis prismatica* (Haeckel)
Pipettella prismatica Haeckel, 1887, p. 305, pl. 39, fig. 6.
Didymocystis prismatica (Haeckel), Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1c.
- Didymocystis violina* (Haeckel)
Cannartus violina Haeckel, 1887, p. 358.
Didymocystis violina (Haeckel), Sanfilippo and Riedel, 1980, p. 1010.
- Eusyringium fistuligerum* (Ehrenberg)
Eusyringium fistuligerum Ehrenberg, 1873, p. 229; 1875, pl. 9, fig. 3.
Eusyringium fistuligerum (Ehrenberg), Riedel and Sanfilippo, 1970, p. 527, pl. 8, figs. 8, 9.
- Eusyringium lagena* (Ehrenberg)
Lithopera lagena Ehrenberg, 1873, p. 241.
Eusyringium lagena (Ehrenberg), Foreman, 1973, p. 435, pl. 11, figs. 4, 5.
- Lamprocystis neoheteroporos* Kling, 1973, p. 639, pl. 5, figs. 17, 18; pl. 15, figs. 4, 5.
- lamptonium fabaeforme chaunothorax* Riedel and Sanfilippo, 1970, p. 524, pl. 5, figs. 8, 9.
- Lamptonium obelix* Sanfilippo and Riedel, 1979, p. 503, pl. 1, figs. 1, 2.
- Liriospyris stauropora* (Haeckel)
Trissocyclus stauropora Haeckel, 1887, p. 987, pl. 83, fig. 5.
Liriospyris stauropora (Haeckel), Goll, 1968, p. 1431, pl. 75, figs. 1-3, 7, text-fig. 9.
- Lithapium anoectum* Riedel and Sanfilippo, 1970, p. 520, pl. 4, figs. 4, 5.
- Lithapium mitra* (Ehrenberg)
Cornutella mitra Ehrenberg, 1873, p. 221.
Lithapium mitra (Ehrenberg), Riedel and Sanfilippo, 1970, p. 520, pl. 4, figs. 6, 7.
- Lithapium plegmacantha* Riedel and Sanfilippo, 1970, p. 520, pl. 4, figs. 2, 3; Sanfilippo and Riedel, 1973, pp. 516-517, pl. 3, figs. 1, 2; pl. 24, figs. 8, 9.
- Lithochytris vespertilio* Ehrenberg, 1873, p. 239; Riedel and Sanfilippo, 1970, p. 528, pl. 9, figs. 8, 9.
- Lithocyclia angusta* (Riedel)
Trigonactura angusta Riedel, 1959, p. 292, pl. 1, fig. 6.
Lithocyclia angusta (Riedel), Riedel and Sanfilippo, 1970, p. 522, pl. 13, figs. 1, 2.
- Lithocyclia aristotelis* (Ehrenberg)
Astromma aristotelis Ehrenberg, 1847, p. 55, fig. 10.
Lithocyclia aristotelis (Ehrenberg) group, Riedel and Sanfilippo, 1970, p. 522.
- Lithocyclia ocellus* Ehrenberg group
Lithocyclia ocellus Ehrenberg, 1854, pl. 36, fig. 30; Riedel and Sanfilippo, 1970, p. 522, pl. 5, figs. 1, 2.
- Lithopera renzae* Sanfilippo and Riedel, 1970, p. 454, pl. 1, figs. 21-23, 27.
- Lophocystis biaurita* (Ehrenberg)
Eucyrtidium biauritum Ehrenberg, 1873, p. 226.
- Lophocystis biaurita* (Ehrenberg), Cita, Nigrini and Gartner, 1970, p. 404, pl. 2, figs. I-K.
- Lophocystis jacchia* (Ehrenberg)
Thysrocystis jacchia Ehrenberg, 1873, p. 261.
- Lophocystis jacchia* (Ehrenberg), Riedel and Sanfilippo, 1971, p. 1594, pl. 3C, figs. 4, 5; pl. 7, fig. 16.
- Lychnocanoma amphitrite* Foreman, 1973, p. 437, pl. 11, fig. 10.
- Peripaena decora* Ehrenberg, 1873, p. 246; 1875, pl. 28, fig. 6.
- Peripaena delta* Sanfilippo and Riedel, 1973, p. 523, pl. 8, figs. 11, 12; pl. 27, figs. 6, 7.
- Peripaena tripyramis tripyramis* (Haeckel)
Triactus tripyramis Haeckel, 1887, p. 432, pl. 33, fig. 6.
- Peripaena tripyramis tripyramis* (Haeckel), Sanfilippo and Riedel, 1973, p. 523, pl. 9, figs. 7-9.
- Peripaena tripyramis triangula* (Sutton)
Phacotriactis triangula Sutton, 1896, p. 61.
- Peripaena tripyramis triangula* (Sutton), Sanfilippo and Riedel, 1973, p. 523, pl. 9, figs. 10, 11.
- Phormocystis striata exquisita* (Kozlova)
Podocystis exquisita Kozlova In Kozlova and Gorbovets, 1966, p. 106, pl. 17, fig. 2.
- Phormocystis striata exquisita* (Kozlova), Foreman, 1973, p. 438, pl. 7, figs. 1-4, 7, 8; pl. 12, fig. 5.
- Phormocystis striata striata* Brandt
Phormocystis striata Brandt, 1935, p. 55, pl. 9, fig. 12.
- Phormocystis striata striata* Brandt—Foreman 1973, p. 438, pl. 7, figs. 5, 6, 9.
- Phormostichoartus corbula* (Harting)
Lithocampe corbula Harting, 1863, p. 12, pl. 1, fig. 21.
- Phormostichoartus corbula* (Harting), Nigrini, 1977, p. 252, pl. 1, fig. 10.
- Podocystis ampla* Ehrenberg
Podocystis ampla Ehrenberg, 1873, p. 248; 1875, pl. 16, fig. 7.
- Podocystis (Podocystis) ampla* Ehrenberg, Riedel and Sanfilippo, 1970, p. 533, pl. 12, figs. 7, 8.
- Podocystis chalara* Riedel and Sanfilippo
Podocystis (Lampterium) chalara Riedel and Sanfilippo, 1970, p. 535, pl. 12, figs. 2, 3.
- Podocystis diamesa* Riedel and Sanfilippo, emend. Sanfilippo and Riedel
Podocystis diamesa Riedel and Sanfilippo, 1970, p. 523, pl. 12, fig. 4.
- Podocystis dorus* Sanfilippo and Riedel, 1973, p. 531, pl. 35, figs. 12-14.
- Podocystis fasciolata* Nigrini
Podocystis ampla fasciolata Nigrini, 1974, p. 1069, pl. 1K, figs. 1, 2; pl. 4, figs. 2, 3.
- Podocystis fasciolata* Nigrini—Sanfilippo et al., 1985.
- Podocystis mitra* Ehrenberg, 1854, pl. 36, fig. B20; Riedel and Sanfilippo, 1970, p. 534, pl. 11, figs. 5, 6.
- Podocystis sinuosa* Ehrenberg
Podocystis sinuosa Ehrenberg, 1873, p. 253; 1875, pl. 15, fig. 5.
- Podocystis (Lampterium) sinuosa* Sanfilippo et al., 1985.
- Pterocorys hertwigi* (Haeckel)
Eucyrtidium hertwigi Haeckel, 1887, p. 1491, pl. 80, fig. 12.
- Pterocorys hertwigi* (Haeckel), Petrushevskaya, 1972, fig. 1 (10).
- Pterocorys zancleus* (Müller)
Eucyrtidium zancleum Müller, 1858, p. 41, pl. 6, figs. 1-3.
- Theoconus zancleus* (Müller), Benson, 1966, p. 482, pl. 33, fig. 4.
- Spongaster berminghami* (Campbell and Clark)
Spongasteriscus berminghami Campbell and Clark, 1944, p. 10, pl. 5, figs. 1, 2.
- Spongaster berminghami* (Campbell and Clark), Sanfilippo and Riedel, 1973, p. 524.
- Spongaster tetras* Ehrenberg, 1860, p. 833; Riedel and Sanfilippo, 1971, p. 1589, pl. 1D, figs. 2, 4.
- Spongatractis balbis* Sanfilippo and Riedel, 1973, p. 518, pl. 2, figs. 1-3; pl. 25, figs. 1, 2.
- Spongatractus pachystylus* (Ehrenberg)
Spongphaera pachystyla Ehrenberg, 1873, p. 256; 1875, pl. 26, fig. 3.
- Spongatractus pachystylus* (Ehrenberg), Sanfilippo and Riedel, 1973, p. 519, pl. 2, figs. 4-6; pl. 25, fig. 3.

- Stichocorys delmontensis* (Campbell and Clark)
Eucyrtidium delmontense Campbell and Clark, 1944, p. 56, pl. 7, figs. 19, 20.
Stichocorys delmontensis (Campbell and Clark), Sanfilippo and Riedel, 1970, p. 451, pl. 1, fig. 9.
- Stichocorys peregrina* (Riedel)
Eucyrtidium elongatum peregrinum Riedel, 1953, p. 812, pl. 85, fig. 2.
Stichocorys peregrina (Riedel), Sanfilippo and Riedel, 1970, p. 451, pl. 1, fig. 10.
- Stichocorys wolfii* Haeckel, 1887, p. 1479, pl. 80, fig. 10.
- Theocalyptra davisianna* (Ehrenberg)
Cycladophora? davisianna Ehrenberg, 1861, p. 297.
Theocalyptra davisianna (Ehrenberg), Riedel, 1958, p. 239, pl. 4, figs. 2, 3; text-fig. 10.
- Theocorys anapographa* Riedel and Sanfilippo, 1970, p. 530, pl. 10, fig. 4; Foreman, 1973, p. 440, pl. 5, figs. 9, 10.
- Theocotyle conica* Foreman
Theocotyle (Theocotyle) cryptocephala(?) conica Foreman, 1973, p. 440, pl. 4, fig. 11; pl. 12, figs. 19, 20.
Theocotyle conica Foreman—Sanfilippo and Riedel, 1982, pp. 177–178, pl. 2, fig. 13.
- Theocotyle cryptocephala* (Ehrenberg)
Eucyrtidium cryptocephalum Ehrenberg, 1873, p. 227; 1875, pl. 11, fig. 11.
Theocotyle cryptocephala (Ehrenberg), Sanfilippo and Riedel, 1982, p. 178, pl. 2, figs. 4–7.
- Theocotyle nigrinae* (Riedel and Sanfilippo)
Theocorys sp. Nigrini in Cita et al., 1970, pl. 2, fig. L.
Theocotyle nigrinae Sanfilippo and Riedel, 1982, p. 178, pl. 2, figs. 1–3.
- Theocotylissa ficus* (Foreman)
Eucyrtidium ficus Ehrenberg, 1873, p. 228; 1875, pl. 11, fig. 19.
Theocotylissa ficus Foreman—Sanfilippo and Riedel, 1982, pp. 180–181, pl. 2, figs. 19–20.
- Theocyrtis annosa* (Riedel)
Phormocyrtis annosa Riedel, 1959, p. 295, pl. 2, fig. 7.
Thrysocyrtis annosa (Riedel), Riedel and Sanfilippo, 1970, p. 535, pl. 15, fig. 9.
- Theocyrtis tuberosa* Riedel, 1959, p. 298, pl. 2, figs. 10, 11.
- Theocyrtis* sp. cf. *T. tuberosa*
Theocyrtis sp. ancestral to *T. tuberosa*, Riedel and Sanfilippo, 1978, p. 78, pl. 1, fig. 10.
- Thrysocyrtis bromia* Ehrenberg
Thrysocyrtis bromia Ehrenberg, 1873, p. 260; 1875, pl. 12, fig. 2.
Thrysocyrtis (Thrysocyrtis) bromia Ehrenberg—Sanfilippo and Riedel, 1982, p. 172, pl. 1, figs. 17–20.
- Thrysocyrtis hirsuta* (Krasheninnikov)
Podocyrtis hirsutus Krasheninnikov, 1960, p. 300, pl. 3, fig. 16.
Thrysocyrtis (Thrysocyrtis) hirsuta (Krasheninnikov), Sanfilippo and Riedel, 1982, p. 173, pl. 1, figs. 3–4.
- Thrysocyrtis rhizodon* Ehrenberg
Thrysocyrtis rhizodon Ehrenberg, 1873, p. 262; 1875, pl. 12, fig. 1.
Thrysocyrtis (Thrysocyrtis) rhizodon Ehrenberg—Sanfilippo and Riedel, 1982, pp. 173–174, pl. 1, figs. 14–16; pl. 3, figs. 12–17.
- Thrysocyrtis tensa* Foreman
Thrysocyrtis? sp. Foreman, 1973, pl. 3, figs. 18–19; pl. 13, fig. 2.
Thrysocyrtis (Pentalacorys) tensa Foreman—Sanfilippo and Riedel, 1982, p. 176, pl. 1, figs. 6–7; pl. 3, figs. 1, 2.
- Thrysocyrtis tetricantha* (Ehrenberg)
Podocyrtis tetricantha Ehrenberg, 1873, p. 254; 1875, pl. 13, fig. 2.
Thrysocyrtis (Pentalacorys) tetricantha (Ehrenberg), Sanfilippo and Riedel, 1982, p. 176, pl. 1, figs. 11–12; pl. 3, fig. 10.
- Tristylospyris triceros* (Ehrenberg)
Ceratospyris triceros Ehrenberg, 1873, p. 220.
Tristylospyris triceros (Ehrenberg), Haeckel, 1887, p. 1033.