Winterer, E.L., Sager, W.W., Firth, J.V., and Sinton, J.M. (Eds.), 1995
Proceedings of the Ocean Drilling Program, Scientific Results, Vol. 143

34. *DATA REPORT:* CENOZOIC RADIOLARIANS FROM LEG 143, HOLE 869A, EQUATORIAL PACIFIC OCEAN[1]

Jonathan C. Aitchison[2] and Peter G. Flood[3]

ABSTRACT

Cenozoic (lower Eocene to lower Miocene) radiolarians are abundant and exceptionally well-preserved in cores from Leg 143 Hole 869A. The Eocene/Oligocene boundary sequence appears conformable, whereas erosional hiatuses are present between the early Oligocene and early Miocene and between the middle and late Eocene. These hiatuses may represent periods of emergence.

INTRODUCTION

Hole 869A (Leg 143), located at 11°0.009′N, 164°44.696′W, is situated 45 nmi (83 km) southwest of the atoll-guyot pair of Pikini (formerly Bikini) Atoll and Wodejebatao (formerly Sylvania) Guyot in the equatorial Pacific Ocean. Hole 869A was an APC/XCB-cored hole that had 100% recovery in the APC-cored section. The hole was drilled in a water depth of 4826.7 m and penetrated 166.5 m of radiolarian ooze.

The area examined has long been known as one in which well-preserved radiolarian faunas are present. Riedel and Sanfilippo (1971) presented an extensive report on Cenozoic tropical radiolarians from the western Pacific Ocean in the *Initial Reports* volume of Deep Sea Drilling Project (DSDP) Leg 7. Abundant and exceptionally well-preserved radiolarians were recovered from cores throughout Hole 869A (Table 1). The primary purpose of this paper is to provide radiolarian age constraints on sediments recovered from this section.

METHODS

Samples were taken at least one per core, and most core-catcher samples were examined. More detailed examinations were conducted in the vicinity of particular sedimentological or radiolarian events. To obtain clean radiolarian concentrates for microscopic examination, sediments were disaggregated and sieved to remove the clay-silt fraction. A 5-cm^3 sample was placed in a 400-cm^3 beaker that contained 150 mL of a 10% solution of hydrogen peroxide and a small amount of Calgon (to aid in disaggregating the sediment). If calcareous components were evident, they were dissolved by adding hydrochloric acid. The residue was sieved through a 63-µm sieve, and the remaining siliceous microfossils were pipetted evenly onto labeled glass slides. The accompanying water then was evaporated under a heat lamp, after which the remaining residue was mounted using Norland Optical Adhesive and covered with a 22 × 50 mm cover slip. Two slides were prepared and examined for each sample. Qualitative assessments of the radiolarians in each slide were not recorded for abundance and preservation as, in all cases, radiolarians were abundant and well preserved. Radiolarians were profusely abundant in some samples, and complete faunal lists are not presented herein but are the topic of ongoing study to be presented later (Aitchison and Flood, unpubl. data).

BIOSTRATIGRAPHIC FRAMEWORK

The Cenozoic radiolarian zonation of Sanfilippo et al. (1985), derived for the tropical equatorial Pacific, was used at all sites. Sanfilippo et al. (1985) summarized the taxonomy and evolutionary lineages of all stratigraphically important radiolarian taxa commonly found in low-latitude regions of this zonation. When suggesting tentative "absolute" ages for radiolarian datum levels and zonal boundaries, the schemes of Nigrini (1985) and Barron et al. (1985), established on the basis of DSDP Leg 85 sites in the equatorial Pacific, were followed. Although much of the material obtained during Leg 85 could not be directly dated paleomagnetically, sufficient duplicate sites were available in which all major microfossil events could be identified, some of which had been correlated to the polarity time scale in nearby piston cores. Thus, the ages of Pacific radiolarian events, estimated by Foreman (1981), Nigrini (1985), and Barron et al. (1985), are considered to provide a satisfactory working model. Tentative correlation with calcareous nannofossil stratigraphy has been based on correlation charts of Haq et al. (1987).

LITHOSTRATIGRAPHY

Two lithostratigraphic units were identified in Hole 869A: (Unit I) cyclically bedded very pale brown to yellow-brown to dark reddish brown nannofossil ooze, radiolarian nannofossil ooze, and clayey nannofossil ooze; and (Unit II) cyclically bedded white to very pale brown to dark yellowish-brown clayey nannofossil ooze to nannofossil radiolarian ooze containing porcellanite and chert.

Unit I (0–88.20 mbsf, lower Miocene to upper Eocene)

The dominant sedimentary theme of Unit I is one of cycles, on various scales, which are characterized by regular changes in color and composition. The principal sedimentary components are nannofossils, radiolarians, sponge spicules, and clay; the colors vary from very pale brown to yellow-brown to dark reddish-brown, and the compositions range from nannofossils ooze through radiolarian nannofossil ooze to clayey nannofossil ooze. Thicknesses of different lithologies are on the scale of tens of centimeters, although some thinner bands do exist. Subunit IA is separated from Subunit IB by a stratigraphic hiatus. There is some reworking of Subunit IB into the basal bed of Subunit IA.

Unit II (88.2–166.5 mbsf, upper Eocene to middle Eocene)

As in Unit I, the dominant sedimentary theme of Unit II is one of cycles on various scales, characterized by regular changes in color and composition. In Core 143-869A-10X, the first porcellanite appears that is associated with clayey nannofossil ooze. Porcellanites and cherts appear intermittently at first, but increase in percentage

[1] Winterer, E.L., Sager, W.W., Firth, J.V., and Sinton, J.M. (Eds.), 1995. *Proc. ODP, Sci. Results,* 143: College Station, TX (Ocean Drilling Program).
[2] Department of Geology and Geophysics, University of Sydney, Sydney, New South Wales, 2006, Australia.
[3] Department of Geology and Geophysics, University of New England, Armidale, New South Wales, 2351, Australia.

Table 1. Age-diagnostic radiolarians present in samples from Hole 869A.

Epoch	Radiolarian zone	Core, section, interval (cm)	*Calocycletta virginis*	*Liriospyrus mutuaria*	*Stichocorys delmontensis*	*Didymocyrtis prismatica*	*Dorcadospyris ateuchus*	*Centrobotrys thermophila*	*Lychnocanoma elongata*	*Lithocyclia angusta*	*Tristylospyris triceros*	*Lychnodictyum audax*	*Artophormis gracilis*	*Centrobotrys petrushevskayae*	*Theocyrtis tuberosa*	*Thyrsocyrtis tetracantha*	*Thyrsocyrtis triacantha*	*Podocyrtis helenae*	*Podocyrtis fasciolata*	*Podocyrtis chalara*	*Calocyclas bandyca*	*Eusyringium fistuligerum*	*Calocyclas turris*	*Lithochytris vespertilio*	*Sethochytris triconiscus*	*Podocyrtis mitra*	*Podocyrtis trachodes*	*Spongatractus pachystylus*	*Lithocyclia ocellus*	*Thyrsocyrtis rhizodon*	*Dictyoprora mongolfieri*	*Podocyrtis sinuosa*	*Eusyringium lagena*	*Phormocyrtis striata*	*Podocyrtis ampla*	*Thyrsocyrtis tensa*	*Theocotyle venezuelensis*	*Thyrsocyrtis robusta*	*Thyrsocyrtis hirsuta*	*Podocyrtis diamesa*
early Miocene	*Stichocorys delmontensis*	1H-CC	X	X	X																																			
		2H-CC	X	X	X	X	X																																	
		3H-CC	X	X	X	X	X					X																												
		4H-1, 90-92	X		X		X	X	X																															
Oligocene	*Theocyrtis tuberosa*	5H-1, 90-92									X	X		X	X																									
		5H-CC				X				X	X	X	X	X																										
		6H-CC								X		X	X	X	X	X																								
		7H-CC									X	X		X	X																									
		8H,-CC									X	X		X	X																									
		9H-1, 100-102									X	X			X																									
late Eocene	*T. bromia*	9H-CC									X					X	X			X	X	X	X	X																
		10X-1, 55-56														X	X				X		X																	
		10X-1, 100-102															X	X	X	X	X	X	X	X		X	X			X	X									
middle Eocene	*Podocyrtis mitra*	11X-1, 100-102															X					X			X	X	X		X		X									
		11X-CC																				X			X	X	X	X												
		12X-CC															X					X		X		X	X		X	X	X									
		13X-4, 73-75															X							X		X	X		X	X	X		X	X						
	P. ampla	13X-CC															X							X					X	X	X	X	X		X					
	Thyrsocyrtis triacantha	14X-1, 112-114															X					X		X					X	X	X	X								
		14X-2, 95-97															X							X							X	X	X							
		14X-3, 148-150															X							X				X	X	X	X	X	X							
		14X-4, 129-131															X													X	X	X								
		14X-5, 69-71															X														X	X							X	
		14X-CC															X							X						X	X	X								
	Dictyoprora mongolfieri	15X-2, 114-116																						X				X	X	X	X	X					X	X	X	
		15X-3, 82-84																						X					X		X	X				X			X	
		15X-CC																						X					X		X	X				X	X		X	X

downhole until they constitute the dominant recovered lithology. Also included in this section are Cores 143-869B-2R to -9R whose recovered lithology is dominated by porcellanite and chert, colored various shades of brown, locally containing radiolarians, and accompanied in some places by nannofossil limestone.

Some sections also contain several millimeter- to centimeter-thick levels of graded radiolarian sands that exhibit sharp contacts with the enveloping clayey radiolarian ooze. Radiolarian ooze, colored in various shades of yellowish-brown, becomes a progressively more important sediment type in Cores 143-869A-12X through -15X, where it contains subsidiary and variable amounts of clay and nannofossils. Those levels that contain abundant nannofossils are chalky in texture.

RESULTS

Abundant, well-preserved radiolarians were found in all samples from Hole 869A. A diverse assemblage that includes the age-diagnostic species *Calocycletta virginis, Liriospyris mutuaria, Stichocorys delmontensis, Didymocyrtis prismatica, Dorcadospyris ateuchus, Centrobotrys thermophila*, and *Lychnocanoma elongata* was recovered in Samples 143-869A-1H-CC through -4H-1, 90–92 cm. The presence of these radiolarians indicates an early Miocene age, and the co-occurrence of *Stichocorys delmontensis* and *Dorcadospyris ateuchus* permits assignment to the *Stichocorys delmontensis* Zone of Sanfilippo et al. (1985). Samples 143-869A-5H-1, 90–92 cm, through -9H-1, 100–102 cm, can be assigned an early Oligocene age, based on the occurrence of *Lithocyclia angusta, Tristylospyris triceros, Lychnodictyum audax, Artophormis gracilis, Centrobotrys petrushevskayae, Theocotylissa auctor,* and *Theocyrtis tuberosa.* The presence of species such as *Centrobotrys petrushevskayae* and *Theocyrtis tuberosa* permits an age assignment to the *Theocyrtis tuberosa* Zone of Sanfilippo et al. (1985). The boundary between the *Stichocorys delmontensis* and *Theocyrtis tuberosa* zones was not precisely defined because Sample 143-869A-4H-3, 100–102 cm, was one of the few samples that did not contain well-preserved, abundant radiolarians.

No hiatus was detected at the Oligocene/Eocene boundary, which lies between Samples 143-869A-9H-1, 100–102 cm, and -9H-CC, with the latter containing a latest Eocene assemblage that includes *Thyrsocyrtis tetracantha, Thyrsocyrtis triacantha, Podocyrtis chalara, Lychnocanoma bandyca, Eusyringium fistuligerum, Calocyclas turris,* and *Lithochytris vespertilio.* This assemblage was assigned to the *Thyrsocyrtis bromia* Zone of Sanfilippo et al. (1985). Reworking of middle Eocene radiolarians is evident in Samples 143-869A-10X-1, 55–56 cm, and -10X-1, 100–102 cm. These samples are latest Eocene in age, but contain elements of a middle Eocene fauna that includes *Podocyrtis mitra* and *Podocyrtis trachodes,* which are characteristic of the *Podocyrtis mitra* Zone of Sanfilippo et al. (1985), together with a latest Eocene fauna identical to that found in Sample 143-869A-9H-CC.

The remainder of the section is an apparently conformable middle Eocene succession. Sample 143-869A-13X-CC contains *Podocyrtis ampla* and *Podocyrtis sinuosa* and was assigned to the *Podocyrtis ampla* Zone of Sanfilippo et al. (1985). Samples 143-869A-14X-1, 112–114 cm, through -14X-CC contain *Thyrsocyrtis triacantha,* but not *Podocyrtis ampla,* suggesting that they belong to the *Thyrsocyrtis triacantha* Zone of Sanfilippo et al. (1985). *Thyrsocyrtis triacantha* is absent from Samples 143-869A-15X-2, 114–116 cm through 143-869A-15X-CC, but *Dictyoprora mongolfieri* is present in great abundance together with *Thyrsocyrtis hirsuta,* indicating that these samples are from the middle Eocene *Dictyoprora mongolfieri* Zone of Sanfilippo et al. (1985).

CONCLUSIONS

Exceptionally well-preserved, abundant middle Eocene to lower Miocene radiolarians in cores from Leg 143 Hole 869A permit refinement of shipboard age assignments on the basis of calcareous nannofossils. Radiolarian data indicate that the Eocene/Oligocene boundary sequence appears conformable, whereas significant erosional hiatuses are present between the early Oligocene and early Miocene and between the middle and late Eocene.

SPECIES LIST

Detailed original descriptions of the biostratigraphically significant radiolarian species, identified in samples from Leg 143, have already been presented. Therefore, the following list simply provides a bibliographic reference for the species mentioned here. In most cases, only the reference containing the original description is presented, except where this description differs from present consensus or has been revised. These species are listed in alphabetical order.

Artophormis gracilis Riedel
Artophormis gracilis Riedel, 1959, p. 300, pl. 2, figs. 12, 13.
Calocyclas bandyca (Mato and Theyer)
Lychnocanoma bandyca Mato and Theyer, 1980, p. 225, pl. 1, figs. 1–6.
Calocyclas bandyca (Mato and Theyer), Sanfilippo and Riedel in Saunders et al., 1985, p. 411, pl. 5, figs. 1, 5–6.
Calocyclas turris Ehrenberg
Calocyclas turris Ehrenberg, 1873, p. 218; 1875, pl. 18, fig. 7.
Calocyclas turris (Ehrenberg) Foreman, 1973, p. 434.
Calocycletta virginis Haeckel
Calocyclas (Calocycletta) virginis Haeckel, 1887, p. 1381, pl. 74, fig. 4.
Calocycletta virginis (Haeckel) Riedel and Sanfilippo, 1970, p. 535, pl. 14, fig. 10.
Centrobotrys petrushevskayae Sanfilippo and Riedel
Centrobotrys petrushevskayae Sanfilippo and Riedel, 1973, p. 532, pl. 36, figs. 12, 13.
Centrobotrys thermophila Petrushevskaya
Centrobotrys thermophila Petrushevskaya, 1965, p. 115, text-fig. 20.
Centrobotrys thermophila (Petrushevskaya) Nigrini, 1967, p. 49, text-fig. 26, pl. 5, fig. 7.
Dictyoprora mongolfieri (Ehrenberg)
Eucyrtidium mongolfieri Ehrenberg, 1854, pl. 36, fig. 18, Blower, 1873, p. 230.
Dictyoprora mongolfieri (Ehrenberg) Nigrini, 1977, p. 250, pl. 4, fig. 10.
Didymocyrtis prismatica (Haeckel)
Pipettella prismatica Haeckel, 1887, p. 305, pl. 39, fig. 6.
Didymocyrtis prismatica (Haeckel), Sanfilippo and Riedel, 1980, p. 1010.
Dorcadospyris ateuchus (Ehrenberg)
Ceratospyris ateuchus Ehrenberg, 1873, p. 218; 1875, pl. 21, fig. 4D.
Dorcadospyris ateuchus (Ehrenberg), Riedel and Sanfilippo, 1970, p. 523, pl. 15, fig. 4.
Eusyringium fistuligerum (Ehrenberg)
Eucyrtidium 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; 1875, pl. 3, fig. 4.
Eusyringium lagena (Ehrenberg), Riedel and Sanfilippo, 1970, p. 527, pl. 8, figs. 5–7.
Liriospyris mutuaria Goll
Liriospyris mutuaria Goll, 1968, p. 1428, pl. 175, figs. 6, 10, 11 and 14, text-fig. 9.
Lithochytris vespertilio Ehrenberg
Lithochytris vespertilio Ehrenberg, 1873, p. 239.
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 ocellus Ehrenberg
Lithocyclia ocellus Ehrenberg, 1854, pl. 36, fig. 30; 1873, p. 240.
Lithocyclia ocellus (Ehrenberg) Riedel and Sanfilippo, 1970, p. 522, pl. 5, figs. 1, 2.
Lychnodictyum audax Riedel
Lychnodictyum audax Riedel, 1953, p. 810, pl. 85, fig. 9.
Lychnocanoma elongata (Vinassa de Regny)
Tetrahedrina elongata Vinassa de Regny, 1900, p. 243, pl. 2, fig. 31.
Lychnocanium bipes Riedel, 1959, p. 294, pl. 2, figs. 5-6.
Lychnocanoma elongata (Vinassa de Regny), Sanfilippo et al., 1973, p. 221, 222, pl. 5, figs. 19–20.
Phormocyrtis striata striata Brandt
Phormocyrtis striata Brandt in Wetzel, 1935, p. 55, pl. 9, fig. 12.
Phormocyrtis striata striata (Brandt) Foreman, 1973, p. 438, pl. 7, figs. 5, 6, 9.
Podocyrtis (Podocyrtoges) ampla Ehrenberg
Podocyrtis (?) *ampla* Ehrenberg 1873, p. 248, 1875, pl. 16, fig. 7.
Podocyrtis ampla (Ehrenberg) Riedel and Sanfilippo, 1970, p. 533, pl. 12, figs. 5, 7, 8.
Podocyrtis (Podocyrtoges) ampla (Ehrenberg) Sanfilippo and Riedel, 1992, p. 14, pl. 5, fig. 4.
Podocyrtis (Lampterium) chalara Riedel and Sanfilippo
Podocyrtis (Lampterium) chalara Riedel and Sanfilippo, 1970, p. 535, pl. 12, figs. 2, 3.
Podocyrtis (Lampterium) chalara Riedel and Sanfilippo, 1978, p. 71, pl. 8, fig. 3, text fig. 3.
Podocyrtis (Podocyrtoges) diamesa Riedel and Sanfilippo
Podocyrtis (Podocyrt) diamansa Riedel and Sanfilippo, 1970, p. 533 (*partim*), pl. 12, fig. 4, *non* figs. 5, 6.
Podocyrtis (Podocyrtis) diamesa Sanfilippo and Riedel 1973, p. 531, pl. 20, figs. 9, 10, pl. 35, figs. 10, 11.
Podocyrtis (Podocyrtoges) diamesa (Riedel and Sanfilippo) Sanfilippo and Riedel, 1992, p. 14.
Podocyrtis (Lampterium) fasciolata (Nigrini)
Podocyrtis (Podocyrtis) ampla fasciolata Nigrini, 1974, p. 1069, pl. 1K, figs. 1, 2, pl. 4, figs. 2, 3.
Podocyrtis (Lampterium) fasciolata (Nigrini) Sanfilippo et al., 1985, p. 697, fig. 30.7.
Podocyrtis (Lampterium) helenae Nigrini
Podocyrtis (Lampterium) helenae Nigrini, 1974, p. 1070, pl. 1L, figs. 9–11, pl. 4, figs. 4, 5.
Podocyrtis (Lampterium) mitra Ehrenberg
Podocyrtis (Lampterium) mitra Ehrenberg, 1854, pl. 36, fig. B20: 1873, p. 251; *non* Ehrenberg, 1875, pl. 15, fig. 4.
Podocyrtis (Lampterium) mitra (Ehrenberg) Riedel and Sanfilippo, 1970, p. 534; 1978, text-fig. 3.
Podocyrtis (Lampterium) sinuosa Ehrenberg
Podocyrtis (Lampterium) sinuosa Ehrenberg, 1873, p. 253; 1875, pl. 15, fig. 5; Riedel and Sanfilippo, 1970, p. 534, pl. 11, figs. 3, 4; 1978, text-fig. 3.
Podocyrtis (Lampterium) trachodes Riedel and Sanfilippo
Podocyrtis (Lampterium) trachodes Riedel and Sanfilippo 1970, p. 535, pl. 11, fig. 7, pl. 12, fig. 1.
Sethochytris triconiscus Haeckel
Sethochytris triconiscus Haeckel, 1887, p. 1239, pl. 57, fig. 13.
Spongatractus pachystylus (Ehrenberg)
Spongosphaera 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 delmontensis, 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.
Theocotyle venezuelensis Riedel and Sanfilippo
Theocotyle venezuelensis Riedel and Sanfilippo, 1970, 525, pl. 6, figs. 9, 10, pl. 7, figs. 1, 2.
Theocyrtis tuberosa Riedel emend. Sanfilippo et al.
Theocyrtis tuberosa Riedel, 1959, p. 298, pl. 2, figs. 10, 11; Sanfilippo et al., 1985, p. 701, figs. 32, 1a–1d.
Thyrsocyrtis (Thyrsocyrtis) hirsuta (Krasheninnikov)
Podocyrtis hirsutus Krasheninnikov, 1960, p. 300, pl. 3, fig. 16.
Thyrsocyrtis (Thyrsocyrtis) hirsuta (Krasheninnikov) Sanfilippo and Riedel, 1982, p. 173, pl. 1, figs. 3, 4.
Thyrsocyrtis (Thyrsocyrtis) rhizodon Ehrenberg
Thyrsocyrtis rhizodon Ehrenberg, 1873, p. 262; 1875, p. 94, pl. 12, fig. 1; Sanfilippo and Riedel, 1982, p. 173, pl. 1, figs. 14–16, pl. 3, figs. 12–17.
Thyrsocyrtis (Thyrsocyrtis) robusta Riedel and Sanfilippo
Thyrsocyrtis hirsuta robusta Riedel and Sanfilippo, 1970, p. 526, pl. 8, fig. 1.
Thyrsocyrtis (Thyrsocyrtis) robusta (Riedel and Sanfilippo) Sanfilippo and Riedel, 1982, p. 174, pl. 1, fig. 5.
Thyrsocyrtis (Pentalacorys) tensa Foreman
Thyrsocyrtis hirsuta tensa Foreman, 1973, p. 442, pl. 3, figs. 13–16, pl. 12, fig. 8.
Thyrsocyrtis (Pentalacorys) tetracantha (Ehrenberg)
Podocyrtis tetracantha Ehrenberg, 1873, p. 254; 1875, pl. 13, fig. 2.
Thyrsocyrtis (Pentalacorys) tetracantha (Ehrenberg) Sanfilippo and Riedel, 1982, p. 176, pl. 1. figs. 11, 12, pl. 3, fig. 10.
Thyrsocyrtis (Pentalacorys) triacantha (Ehrenberg)
Podocyrtis triacantha Ehrenberg, 1873, p. 254; 1875, pl. 13, fig. 4.
Thyrsocyrtis (Pentalacorys) triacantha (Ehrenberg) Sanfilippo and Riedel, 1982, p. 176, pl. 1. figs. 8–10, pl. 3, figs. 3, 4.

Tristylospyris triceros (Ehrenberg)
Ceratospyris triceros Ehrenberg, 1873, p. 220; 1875, pl. 21, fig. 5.
Tristylospyris triceros (Ehrenberg) Haeckel, 1887, p. 1033.

REFERENCES*

Barron, J., Nigrini, C.A., Pujos, A., Saito, T., Theyer, F., Thomas, E., and Weinrich, N., 1985. Synthesis of biostratigraphy, central Equatorial Pacific, Deep Sea Drilling Project Leg 85: refinement of Oligocene to Quaternary biochronology. *In* Mayer, L., Theyer, F., Thomas, E., et al., *Init. Repts. DSDP,* 85: Washington (U.S. Govt. Printing Office), 905–934.

Campbell, A.S., and Clark, B.L., 1944. Miocene radiolarian faunas from Southern California. *Spec. Pap.—Geol. Soc. Am.,* 51:1–76.

Ehrenberg, C.G., 1854. Die systematiche Charakteristik der neuen mikroskopischen Organismen des tiefen Atlantischen Oceans. *K. Preuss. Akad. Wiss. Berlin,* Berichte, Jahre 1854:236–250.

————, 1873. Grössere Felsproben des Polycystinen-Mergels von Barbados mit weiteren Erläuterungen. *K. Preuss. Akad. Wiss. Berlin,* Monatsbericht, Jahre 1873:213–263.

————, 1875. Fortsetzung der mikrogeologischen Studien als Gesammt-Uebersicht der mikroskopischen Paläontologie gleichartig analysirter Gebirgsarten der Erde, mit specieller Rücksicht auf den Polycystinen-Mergel von Barbados. *Abh. K. Akad. Wiss. Berlin,* Jahre 1875:1–225.

Foreman, H.P., 1973. Radiolaria of Leg 10 with systematics and ranges for the families Amphipyndacidae, Artostrobiidae, and Theoperidae. *In* Worzel, J.L., Bryant, W., et al., *Init. Repts. DSDP,* 10: Washington (U.S. Govt. Printing Office), 407–474.

————, 1981. Radiolaria. *In* Emiliani, C. (Ed.), *The Sea* (Vol. 6): *The Oceanic Lithosphere:* New York (Wiley), 1121–1144.

Goll, R.M., 1968. Classification and phylogeny of Cenozoic Trissocyclidae (Radiolaria) in the Pacific and Caribbean basins. Part I. *J. Paleontol.,* 42:1409–1432.

Haeckel, E., 1887. Report on the Radiolaria collected by H.M.S. *Challenger* during the years 1873–1876. *Rep. Sci. Results Voy. H.M.S. Challenger, 1873–1876, Zool.,* 18:1–1803.

Haq, B.U., Hardenbol, J., and Vail, P.R., 1987. Chronology of fluctuating sea levels since the Triassic. *Science,* 235:1156–1167.

Krasheninnikov, V.A., 1960. Nekotorye Radiolyarii Nizhnego i Srednego Eotsena Zapadnogo Predkavkazya. *Min. Geol. Okhr. Nedr SSSR, Vses. Nauchno-Issled. Geol. Neft. Inst.,* 16:271–301.

Mato, C.Y., and Theyer, F., 1980. *Lychnocanoma bandyca* n. sp., a new stratigraphically important late Eocene radiolarian. *In* Sliter, W.V. (Ed.), *Studies in Marine Micropaleontology and Paleoecology: A Memorial Volume to Orville L. Bandy.* Spec. Publ. Cushman Found. Foram. Res., 19:225–229.

Nigrini, C., 1967. Radiolaria in pelagic sediments from the Indian and Atlantic Oceans. *Bull. Scripps Inst. Oceanogr.,* 11:1–125.

————, 1974. Cenozoic Radiolaria from the Arabian Sea, DSDP Leg 23. *In* Davies, T.A., Luyendyk, B.P., et al., *Init. Repts. DSDP,* 26: Washington (U.S. Govt. Printing Office), 1051–1121.

————, 1977. Tropical Cenozoic *Artostrobiidae* (Radiolaria). *Micropaleontology,* 23:241–269.

Nigrini, C.A., 1985. Radiolarian biostratigraphy in the central equatorial Pacific, Deep Sea Drilling Project Leg 85. *In* Mayer, L., Theyer, F., Thomas, E., et al., *Init. Repts. DSDP,* 85: Washington (U.S. Govt. Printing Office), 511–551.

Petrushevskaya, M.G., 1965. Osobennosti i konstruktsii skeleta radiolyarii Botryoidae otr. (Nassellaria). (Peculiarities of the construction of the skeleton of radiolarians Botryoidae [Order Nassellaria]). *Tr. Zool. Inst., Akad. Nauk SSSR,* 35:79–118.

Riedel, W.R., 1953. Mesozoic and late Tertiary Radiolaria of Rotti. *J. Paleontol.,* 27:805–813.

————, 1959. Oligocene and Lower Miocene Radiolaria in tropical Pacific sediments. *Micropaleontology,* 5:285–302.

Riedel, W.R., and Sanfilippo, A., 1970. Radiolaria, Leg 4, Deep Sea Drilling Project. *In* Bader, R.G., Gerard, R.D., et al., *Init. Repts. DSDP,* 4: Washington (U.S. Govt. Printing Office), 503–575.

————, 1971. Cenozoic Radiolaria from the western tropical Pacific, Leg 7. *In* Winterer, E.L., Riedel, W.R., et al., *Init. Repts. DSDP,* 7 (Pt. 2): Washington (U.S. Govt. Printing Office), 1529–1672.

————, 1978. Stratigraphy and evolution of tropical Cenozoic radiolarians. *Micropaleontology,* 24:61–96.

Sanfilippo, A., Burckle, L.H., Martini, E., and Riedel, W.R., 1973. Radiolarians, diatoms, silicoflagellates and calcareous nannofossils in the Mediterranean Neogene. *Micropaleontology,* 19:209–234.

Sanfilippo, A., and Riedel, W.R., 1973. Cenozoic Radiolaria (exclusive of theoperids, artostrobiids and amphipyndacids) from the Gulf of Mexico, Deep Sea Drilling Project Leg 10. *In* Worzel, J.L., Bryant, W., et al., *Init. Repts. DSDP,* 10: Washington (U.S. Govt. Printing Office), 475–611.

————, 1980. A revised generic and suprageneric classification of the Artiscins (Radiolaria). *J. Paleontol.,* 54:1008–1011.

————, 1982. Revision of the radiolarian genera *Theocotyle, Theocotylissa,* and *Thyrsocyrtis. Micropaleontology,* 28:170–188.

————, 1992. The origin and evolution of Pterocorythidae (Radiolaria): a Cenozoic phylogenetic study. *Micropaleontology,* 38:1–36.

Sanfilippo, A., Westberg-Smith, M.J., and Riedel, W.R., 1985. Cenozoic radiolaria. *In* Bolli, H.M., Saunders, J.B., and Perch-Nielsen, K. (Eds.), *Plankton Stratigraphy:* Cambridge (Cambridge Univ. Press), 631–712.

Schlanger, S.O., and Premoli Silva, I., 1986. Oligocene sea-level falls recorded in mid-Pacific atoll and archipelagic apron settings. *Geology,* 14:392–395.

Vinassa de Regny, P.E., 1900. Radiolari Miocenici Italiani. *Mem. R. Acad. Sci. Inst. Bologna, Ser. 5,* 8:227–257.

Wetzel, O., 1935. Die Mikropalaeontologie des Heiligenhafener Kieseltones (Ober-Eözan). *Niedersaechs. Geol. Verein, Jahresbericht,* 27:41–75.

* Abbreviations for names of organizations and publication titles in ODP reference lists follow the style given in *Chemical Abstracts Service Source Index* (published by American Chemical Society).

Date of initial receipt: 8 November 1993
Date of acceptance: 3 February 1994
Ms 143SR-208