Micropaleontology of a Miocene Core from the Western Tropical Pacific[1]

JOHANNA M. RESIG,[2] HSIN-YI LING,[3] AND CAROL J. STADUM[3]

IN JANUARY 1968, members of the Hawaii Institute of Geophysics recovered a sediment core (S67-31) 110 cm long from the western tropical Pacific at 05°03.5'N, 166°56.2'E (Fig. 1). The sediment was cored by free-fall device in a water depth of 4,795 meters. This corer caused relatively little disturbance to the sedimentary layers of the core, which consist of thin Quaternary deposits overlying Miocene with well-preserved radiolarian assemblages. The microfaunal sequence is documented herein.

Reports on several other Miocene cores from the vicinity (Riedel, 1967) suggest rather extensive areal exposure of sediments of that age. At the sampled site, a northeast-southwest reflection profile reveals the older strata to be uplifted along what is probably a normal fault (Fig. 2).

CORE DESCRIPTION

Lithology

Figure 1 illustrates the lithologies of core S67-31. An upper calcareous-siliceous layer, 14 cm thick, rests upon brown siliceous clay that is cut discordantly by a band of lighter colored manganiferous clay between 30 and 35 cm. These relationships might be expected to result from interruption and change in the sedimentary regimen.

Micropaleontology

FORAMINIFERIDA: Foraminiferal tests occur only in the upper 14 cm of the core. The planktonic foraminiferal tests show strong evidence of solution, as might be anticipated at water depths below 4,000 meters in the area. The accompanying benthic specimens are more resistant to solution and are represented by numerous species of generally small size. The species identified are listed in Table 1.

The figures in Table 2 emphasize the small contribution of entire foraminiferal tests to the sediment at these water depths. Fortunately, some of the preserved species are of stratigraphic importance. These include the planktonics, *Pulleniatina obliquiloculata finalis* and *Globigerina digitata,* indicating a Quaternary age (Banner and Blow, 1965, 1967).

The benthic foraminifera are cosmopolitan species common in Recent abyssal sediments and extending back into Tertiary time. Most of the species were recovered during the "Challenger" voyage of 1873–1876, and many were named by H. B. Brady (1884) in his classic description of the foraminiferal collections of that expedition.

RADIOLARIA: Microfossils of the core below 14 cm consist exclusively of Radiolaria, and above this level radiolarians outnumber foraminifera. The radiolarians are grouped into three assemblages dominated by the following: a diversity of polycystine species in the upper 40 cm, and especially in the top 14 cm; orosphaerids in the interval between 40 and 90 cm; and trissocyclids from 100 cm downward.

Most of the polycystine Radiolaria found in the core, and particularly those of Tertiary age, have been adequately described recently. In the faunal distribution chart (Table 3), only those forms are listed that are abundant in the area and adequately discussed, or that seem to show potentiality for stratigraphic use. However, practically all of the species present below 15 cm are tabulated. Some of the taxa used for the age determination are illustrated (Figs. 3 and 4).

[1] Contribution No. 350 from the Hawaii Institute of Geophysics, University of Hawaii, and Contribution No. 541 from the Department of Oceanography, University of Washington. Manuscript received January 23, 1970.

[2] Hawaii Institute of Geophysics, University of Hawaii, Honolulu, Hawaii 96822.

[3] Department of Oceanography, University of Washington, Seattle, Washington 98105.

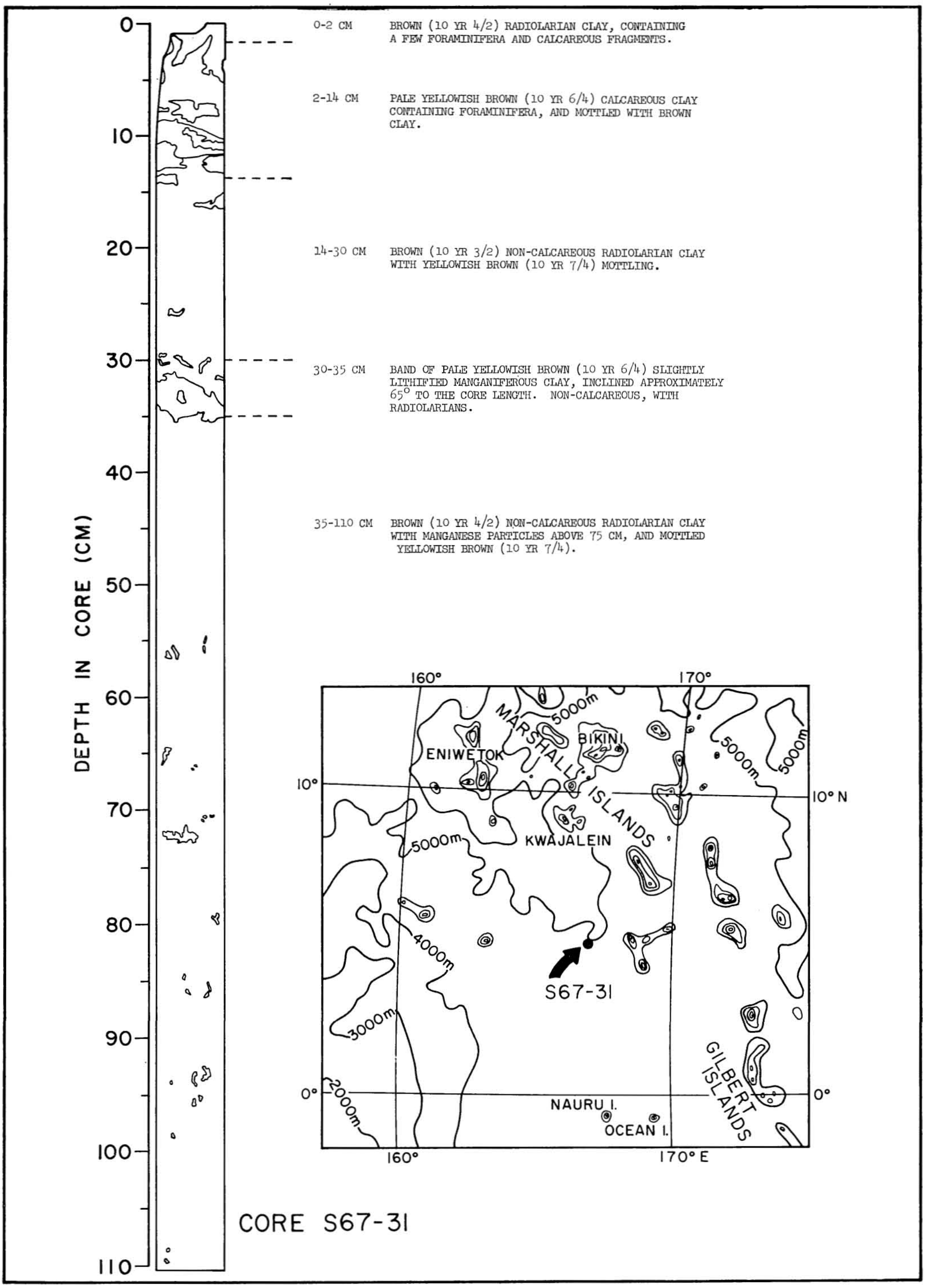


FIG. 1. Core description and location. Numerical color designation is that of the Munsell system. Generalized bathymetry after Menard (1964).

TABLE 1

FORAMINIFERA IN CORE S67-31

(Expressed as percent of entire foraminifera; + = less than 1%)

SPECIES OF FORAMINIFERA	DEPTH IN CORE (cm)					
	0	2.5	5	7.5	10	12.5
Planktonic Species:						
Globigerina digitata Brady	7	+				
Globigerinella siphonifera (d'Orbigny)	7	+	+	+	+	
Globigerinoides conglobatus (Brady)	+	+	+	2	5	
G. trilobus (Reuss)			+			
Globoquadrina conglomerata (Schwager)		+	+		2	
G. dutertrei (d'Orbigny)	+	14	14	5	7	5
Globorotalia crassaformis (Galloway and Wissler)			+			
G. tumida (Brady)	30	21	41	37	28	71
Orbulina universa d'Orbigny			+			
Pulleniatina obliquiloculata (Parker and Jones) and *P. obliquiloculata* (P. and J.) *finalis* Banner and Blow	30	24	29	37	14	2
Sphaeroidinella dehiscens (Parker and Jones)	+	+	+	+	2	+
Benthic Species:						
Ammobaculites agglutinans (d'Orbigny) var. *filiformis* Earland	+					
Bolivina sp.			+			
Cassidella pacifica Hofker		+	+		2	+
Cassidulina minuta Cushman		2		2	2	
C. subglobosa Brady		+	+			
Cibicides cicatricosus (Schwager)			+		+	
C. robertsonianus (Brady)	+	2	+	+		2
Eggerella bradyi (Cushman)	+	+	+	2	2	+
Ehrenbergina hystrix Brady			+		+	
Epistominella exigua (Brady)	7	14	7	2	7	5
Epistominella sp.		14		2	2	2
Favocassidulina favus (Brady)		+	+	+	2	2
Fissurina radiata Seguenza	+	2				
Fissurina spp.		+	+	2	2	+
Glommospira gordialis (Parker and Jones)	+		+	2		
Gyroidina neosoldanii Brotzen	+		2			+
Gyroidina sp.	7	2	+			
Lagena desmophora Rhymer Jones			+			
L. gracillima (Seguenza)	+					2
L. hispida Reuss	+		+			
L. sulcata (Walker and Jacob)	+					
Lagena spp.	+				+	
Lenticulina convergens (Bornemann)	+		+			
Melonis pompilioides (Fichtel and Moll)	+	+	+	+	12	+
Nuttallides umboniferus (Cushman)	7	+	5	2	5	2
Pullenia quinqueloba (Reuss)	+	2		2	2	2
Pyrgo murrhyna (Schwager)	+	+	+	+		+
Recurvoides turbinatus (Brady)			+		2	
Reophax scorpiurus Montfort	+					
Siphotextularia sp.			+			

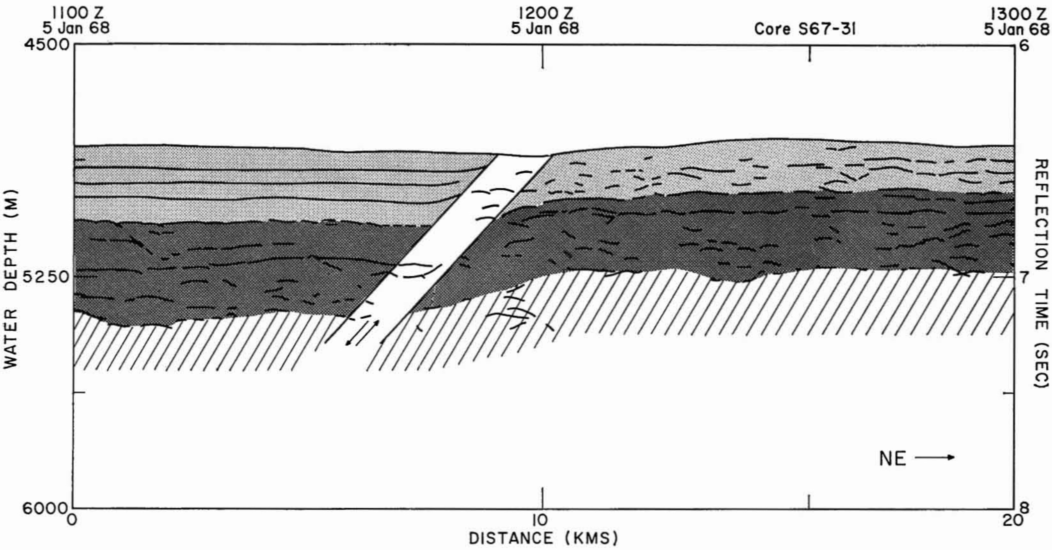


FIG. 2. Tracing of a reflection profile obtained with a 7000-joule sparker across the site of core S67-31.

TABLE 2

COMPONENTS OF CORE S67-31

(Expressed as percent of sand fraction)

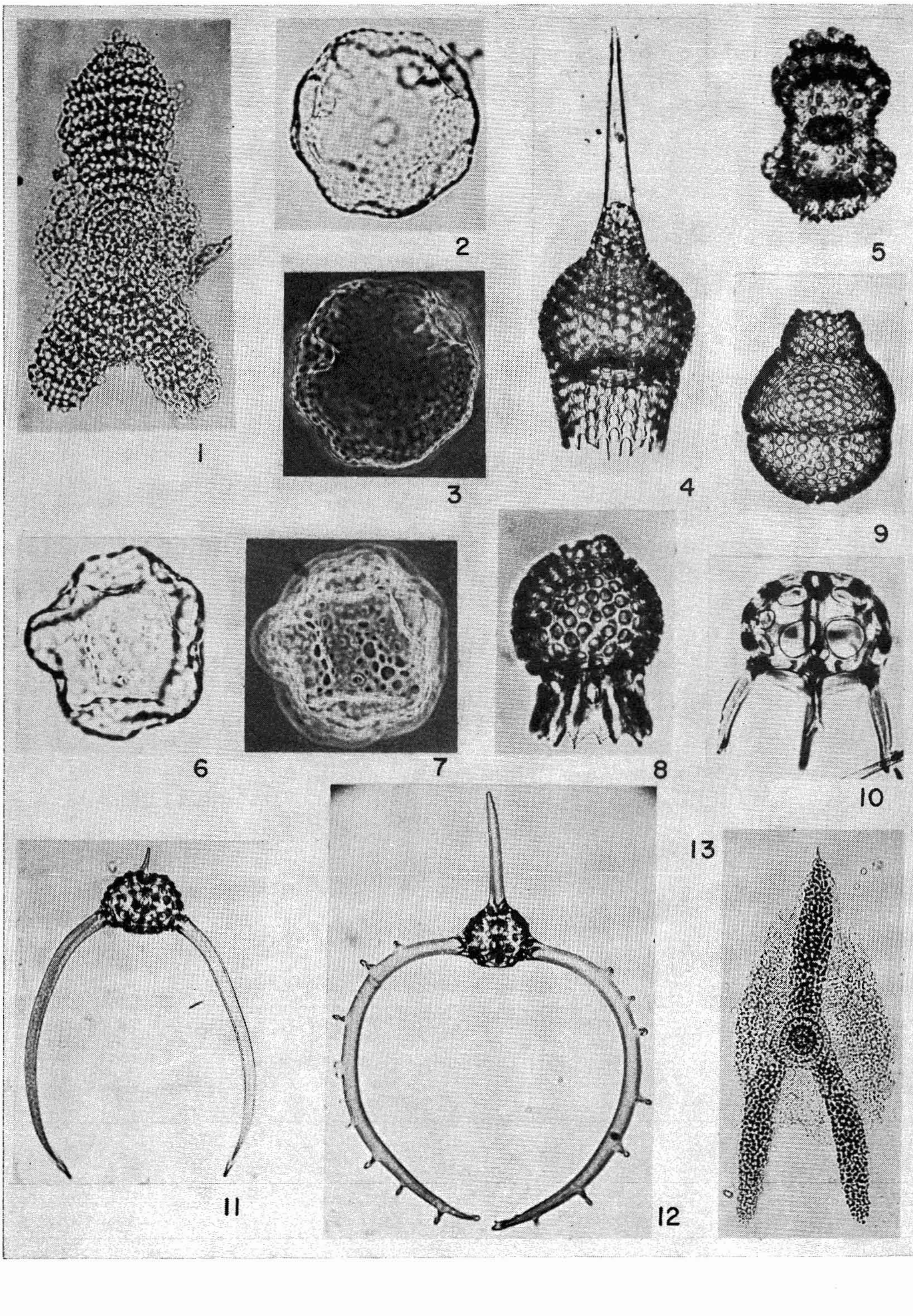
COMPONENT	DEPTH IN CORE (cm)					
	0	2.5	5	7.5	10	12.5
Entire foraminifera	2	2	2	+	1	1
Fragments of foraminifera	26	45	41	14	25	10
Radiolarians	71	51	56	82	72	88
Diatoms	+	+	+	1	+	+
Echinoid spines, sponge spicules, denticles	+	+	+	+	+	+
Mineral fragments	+	+	1	+	1	+

AGE OF THE SEDIMENT

Recently Riedel and Funnell (1964), Funnell (1967), and Riedel (1967) summarized the heretofore known deep-sea occurrences of pre-Quaternary sediments from the world ocean. Age determinations on siliceous sediments have been facilitated considerably through monographic works on orosphaerid (Friend and Riedel, 1967), trissocyclid (Goll, 1968, 1969), and "closed" theoperid (Sanfilippo and Riedel, manuscript: see faunal reference below) Radiolaria from tropical Pacific sediments.

The base of the Quaternary portion of the core, at 10 to 15 cm, is indicated by the disap-

FIG. 3. *1, Amphirhopalum ypsilon* Haeckel, 5 cm, R-1, B12/4, ×200. *2* and *3, Buccinosphaera invaginata* Haeckel, 110 cm, R-1, D19/0, ×240. *9, Cyrtocapsa cornuta* Haeckel, 109 cm, R-2, M14/2, ×200. *10, Den-* 110 cm, R-2, F32/3, ×180. *5, Cannartus petterssoni* Riedel, 40 cm, R-1, O26/3, ×180. *6* and *7, Collosphaera tuberosa* Haeckel, 10 cm, R-1, F13/2, ×200: *6,* transmitted light; *7,* phase contrast. *8, Cycladophora favosa* Haeckel, 110 cm, R-1, D19/0, ×240. *9, Cyrtocapsa cornuta* Haeckel, 109 cm, R-2, M14/2, ×200. *10, Dendrospyris pododendros* (Carnevale), 109 cm, R-1, V21/1, ×240. *11, Dipodospyris forcipata* Haeckel, 109 cm, R-2, M14/4, ×130. *12, Dorcadospyris dentata* Haeckel, TT34-6 (single specimen slide), 410–413 cm, ×130. *13, Euchitonia elegans* (Ehrenberg), 0 cm, R-2, V31/2, ×120.


1
2
3
4
5
6
7
8
9
10
11
12
13

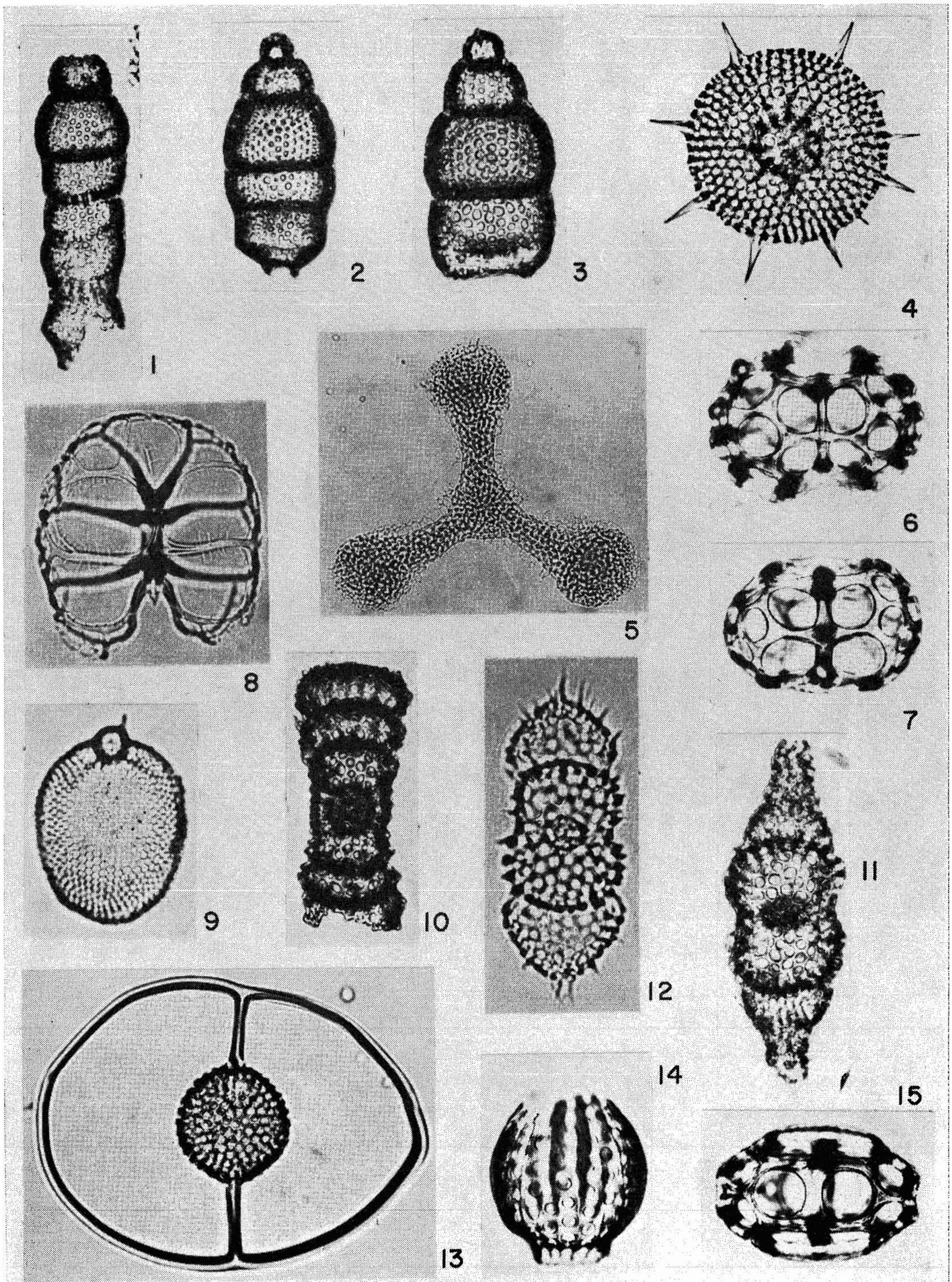

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

FIG. 4. *1–3, Eucyrtidium delmontense* Campbell and Clark, *1,* 15 cm, R-1, Q32/0, ×190: *2,* 15 cm, R-1, X46/1, ×190; *3,* 40 cm, R-1, N33/2, ×250. *4, Heliodiscus astericus* Haeckel, 15 cm, R-2, N39/0, ×200. *5, Hymeniastrum euclidis* Haeckel, 10 cm, R-1, J22/0, ×120. *6, Liriospyris geniculosa* Goll, 109 cm, R02, T40/1, ×300. *7, Liriospyris mutuaria* Goll, 100 cm, R-1, S34/3, ×230. *8, Liriospyris reticulata* (Ehrenberg), 0 cm, R-2, R10/3, ×200. *9, Lithopera bacca* Ehrenberg, 0 cm, R-2, S10/1, ×200. *10, Ommatocampe hughesi* Campbell and Clark, 15 cm, R-2, O23/3, ×200. *11, Panarium antepenultimum* Riedel, 30 cm, R-2, Q26/0, ×200. *12, Panartus tetrathalamus* Haeckel, 0 cm, R-1, V34/3, ×200. *13, Saturnalis circularis* Haeckel, 15 cm, R-1, J28/0, ×200. *14, Sethamphora* sp., 110 cm, R-2, N40/2, ×250. *15, Tympanidium binoctonum* Haeckel, 110 cm, R-2, H11/0, ×250.

pearance of *Amphirhopalum ypsilon, Buccinosphaera invaginata, Collosphaera tuberosa, Euchitonia elegans,* and other modern forms typical of the area. This faunal break corresponds with the lithological change to noncalcareous sediment.

The next faunal break occurs between 40 and 60 cm. Radiolarians at 50 cm are too few and too fragmentary to delineate the change sharply. Although there is no associated change in the lithology, *Cannartus petterssoni, Eucyrtidium delmontense,* and *Tholospyris cortinisca* have their lower limit at this break. This Miocene assemblage spans the time of slow sedimentation evidenced by the manganiferous clay band at 30 to 35 cm. Since the upper Miocene-Pliocene indices, *Pterocanium prismatium* and *Spongaster pentas,* are absent, there is evidently a stratigraphic hiatus encompassing late Miocene, Pliocene, and probably part of Quaternary time at about 14 cm.

The interval between 60 cm and 90 to 100 cm is characterized by an abundance of orosphaerids. This group of radiolarians is generally common in tropical radiolarian assemblages of late Oligocene and early Miocene age and invariably rare in the Eocene, lower Oligocene, upper Miocene, and Pliocene. From 100 cm downward, the orosphaerids are accompanied by a variety of polycystine Radiolaria, among which *Calocyclas virginis, Stichocorys wolffii, Cyrtocapsa cornuta, Dipodospyris forcipata,* and *Dorcadospyris dentata* indicate an age of late early Miocene to early middle Miocene.

Occurrences of *Sethamphora* sp. (see faunal reference below) were noted below 100 cm in the core. A similar association of this species with typical Miocene radiolarian forms was also found in some eastern tropical Pacific deep-sea deposits (e.g., University of Washington core TT34-6 from 09°50.5′N, 128°14.3′W at 4,654 meters water depth).

SUMMARY

A large stratigraphic hiatus apparently associated with faulting has permitted the sampling of lower to middle Miocene radiolarian faunas by a western tropical Pacific core.

ACKNOWLEDGMENTS

The writers are indebted to Loren W. Kroenke of the Hawaii Institute of Geophysics for interpretation of the seismic profile. Financial support was contributed by National Science Foundation grants GA-1443 and GA-11308 (HYL), and Office of Naval Research Contract Nonr 477(37), Project NR 083 012 to the Department of Oceanography, University of Washington. The collection of the core and the reflection profiling were made under Office of Naval Research Contract Nonr 3748(05), Project NR 083 603, to the Hawaii Institute of Geophysics, University of Hawaii.

RADIOLARIAN FAUNAL REFERENCE

The radiolarian species shown in Table 3 are listed alphabetically below. Recently, Sanfilippo and Riedel (manuscript) revised the Neogene "closed" theoperid radiolarians and suggested their phylogenetic relationships. Discussed among them are the Miocene forms reported from Japan by Nakaseko (1955, 1963). Because we feel that closer examination is needed for us to evaluate the Japanese forms, the latest taxonomy of Sanfilippo and Riedel is not followed in this paper, but is indicated wherever it is appropriate.

The specimens illustrated in Figures 3 and 4 are from strewn slides (with core serial number S67-31), except for Figure 3, *12* which is from a single specimen slide and from core TT34-6. The position on the strewn slides is recorded by the sample depth (in centimeters) in the

TABLE 3

DISTRIBUTION OF SELECTED RADIOLARIAN SPECIES IN CORE S67-31

RADIOLARIAN TAXA	DEPTH IN CORE (cm)														
	0	5	10	15	20	30	40	50	60	70	80	90	100	109	110
Amphirhopalum ypsilon Haeckel	R	R	R												
Lithopera bacca Ehrenberg	R	+	R												
Buccinosphaera invaginata Haeckel	R	R	R												
Collosphaera tuberosa Haeckel	R	R	R												
Euchitonia elegans (Ehrenberg)	F	R	R												
Euchitonia furcata Ehrenberg	C	C	C	R	R	R									
Hymeniastrum euclidis Haeckel	F	F	F	R	R	R									
Liriospyris reticulata (Ehrenberg)	R	R													
Ommatocampe hughesi Campbell and Clark				R	R										
Panarium antepenultimum Riedel				R	+	R	R								
Tholospyris cortinisca (Haeckel)		+		+	+	+									
Heliodiscus asteriscus Haeckel	F	R	+	R	R	R									
Cannartus petterssoni Riedel					R	R	R								
Panartus tetrathalamus Haeckel	C	F	C	R	R	R	R								

SYMBOLS: A = abundant (> 40%); C = common (25–40%); F = frequent (11–25%); R = rare (2–10%); + = 1% or individual specimen. For orosphaerid Radiolaria, F = 11–25 specimens; R = 2–10 specimens; + = individual specimen.

TABLE 3 (*continued*)

RADIOLARIAN TAXA	DEPTH IN CORE (cm)														
	0	5	10	15	20	30	40	50	60	70	80	90	100	109	110
Saturnalis circularis Haeckel	R		R	R	R	R									
Eucyrtidium delmontense Campbell and Clark				R	F	F	R								
Oroscena carolae Friend and Riedel					+	R	+	R	R	R	R	F	F	F	F
O. gegenbauri Haeckel									+	R	+	R	+	R	+
Oroscena spp.								+	R	R	R	R	+	+	+
Orodapis spongiosa Friend and Riedel									+	+	+		+		
Liriospyris geniculosa Goll										+	R	A	A	A	A
Tympanidium binoctonum Haeckel											R	F	R	R	R
Dipodospyris forcipata Haeckel											+	R	R	R	F
Cyrtocapsa cornuta Haeckel													R	R	F
Sethamphora sp.													R	R	R
Liriospyris mutuaria Goll													R	R	R
Tholospyris mammillaris (Haeckel)													+	F	F
Dendrospyris pododendros (Carnevale)													+	R	+
Calocyclas virginis Haeckel														+	R
Stichocorys wolffii Haeckel														+	+
Cycladophora favosa Haeckel														+	+
Dorcadospyris dentata (Haeckel)														R	R

core, followed by the slide number and the coordinate reading of an England Finder as previously discussed (Ling and Anikouchine, 1967). These slides are deposited in the Department of Oceanography, University of Washington.

Amphirhopalum ypsilon Haeckel, 1887, p. 522; Nigrini, 1967, pp. 35–37, pl. 3, figs. 3a–3d. Length of an unpaired arm from the distal end to the center of the central structure, 150μ. [Fig. 3, *1.*]

Buccinosphaera invaginata Haeckel, 1887, p. 99, pl. 5, fig. 11; Brandt, 1905, p. 332, pl. 10, fig. 20. Maximum diameter, 110μ. [Fig. 3, *2* and *3.*] Figure 3, *3* is the same specimen as Figure 3, *2* except with phase contrast showing the inwardly directed tubes.

Calocyclas virginis Haeckel, 1887, pp. 1381–1382, pl. 74, fig. 4; Riedel, 1959, pp. 295–296, pl. 2, fig. 9. Total length, including apical horn, 350μ. [Fig. 3, *4.*] The species is referred to as *Calocycletta virginis* (Haeckel) by Sanfilippo and Riedel (manuscript).

Cannartus petterssoni Riedel, 1968, p. 6g/5, pl. 1, fig. 9; Riedel and Funnell, 1964, p. 310. Total length of shell, 155μ. [Fig. 3, *5.*]

Collosphaera tuberosa Haeckel, 1887, p. 97; Brandt, 1905, pp. 330–331, pl. 9, fig. 16 = *Collosphaera huxleyi* var. Haeckel, 1862 (part), pp. 534–536, pl. 34, figs. 3, 9. Maximum diameter, 135μ. [Fig. 3, *6* and *7.*] Figure 3, *7* is the same specimen as Figure 3, *6* except with phase contrast showing numerous irregular pores on the surface.

Cycladophora favosa Haeckel, 1887, pp. 1381–1382, pl. 74, fig. 4; Riedel, 1959, pp. 295–296, pl. 2, fig. 8. Maximum width of thorax, 90μ. [Fig. 3, *8.*]

Cyrtocapsa cornuta Haeckel, 1887, p. 1513, pl. 78, fig. 8 = *Cyrtocapsa pyrum* Haeckel, Riedel, 1959 (part), pp. 300–301, pl. 2, fig. 15. Maximum width, 115μ. [Fig. 3, *9.*] The form is referred to as *Cyrtocapsella cornuta* (Haeckel) by Sanfilippo and Riedel (manuscript).

Dendrospyris pododendros (Carnevale) Goll, 1968, p. 1422, pl. 174, figs. 1–4; text-fig. 8 = *Tessarospyris pododendros* Carnevale, 1908, p. 28, pl. 3, fig. 18. Maximum width of lattice shell, 90μ. [Fig. 3, *10.*]

Dipodospyris forcipata Haeckel, 1887, p. 1037, pl. 85, fig. 1; Riedel, 1957, p. 79, pl. 1, fig. 3. Maximum height, including apical horn of lattice shell, 100μ. [Fig. 3, *11.*]

Dorcadospyris dentata Haeckel, 1887, p. 1040, pl. 85, fig. 6; Goll, 1969, p. 338, pl. 70, figs. 8, 10–13, text-fig. 2. Height of lattice shell including apical horn, 205μ. [Fig. 3, *12.*]

Euchitonia elegans (Ehrenberg) Haeckel, 1887, p. 535; Ling and Anikouchine, 1967, p. 1486, pls. 189–190, figs. 3, 4 = *Pteractis elegans* Ehrenberg, 1872, p. 319. Length of unpaired arm from the distal end to the center of the central structure, 300μ. [Fig. 3, *13.*]

Euchitonia furcata Ehrenberg, 1861, p. 767; Ling and Anikouchine, 1967, pp. 1484–1486, pl. 189, 190, figs. 1–2, 5–7.

Eucyrtidium delmontense Campbell and Clark, 1944, p. 56, pl. 7, figs. 19, 20; Riedel, 1952, pp. 8–9, pl. 1, fig. 5. Total length for Figure 4, *1,* 240μ; Figure 4, *2,* 192μ; and Figure 4, *3,* 144μ. [Fig. 4, *1–3.*] Specimens with three and four segments are more common than those with more segments. This species is discussed under *Stichocorys delmontense* (Campbell and Clark) in Sanfilippo and Riedel (manuscript).

Heliodiscus astericus Haeckel, 1887, p. 445, pl. 33, fig. 8; Nigrini, 1967, pp. 32–33, pl. 3, figs. 1a, 1b. Diameter of shell, 150μ. [Fig. 4, *4.*]

Hymeniastrum euclidis Haeckel, 1887, p. 531, fig. 13; Ling and Anikouchine, 1967, p. 1488, pls. 191, 192, fig. 3. Length of arm from the distal end to the center of the central structure, 200μ. [Fig. 4, *5.*]

Liriospyris geniculosa Goll, 1968, p. 1427, pl. 175, figs. 21–24, text-fig. 9. Maximum width of lattice shell, 100μ. [Fig. 4, *6.*]

Liriospyris mutuaria Goll, 1968, pp. 1428–1429, pl. 175, figs. 6, 10, 11, 14, text-fig. 9. Maximum width of lattice shell, 128μ. [Fig. 4, *7.*]

Liriospyris reticulata (Ehrenberg) Goll, 1968, pp. 1429–1430, pl. 176, figs. 9, 11, 13, text-fig. 9 = *Dictyospyris reticulata* Ehrenberg, 1872, p. 307. Maximum width of lattice shell, 166μ. [Fig. 4, *8.*]

Lithopera bacca Ehrenberg, 1872, p. 314; Nigrini, 1967, pp. 54–56, pl. 6, fig. 2. Maximum width of shell, 110μ. [Fig. 4, *9.*] The form is referred to as *Lithopera* (*Lithopera*) *bacca* Ehrenberg by Sanfilippo and Riedel (manuscript).

Ommatocampe hughesi Campbell and Clark, 1944, pp. 23–24, pl. 3, fig. 12; Riedel, 1968, p. 6g/4, pl. 1, fig. 7. Total length, 192μ. [Fig. 4, *10.*] The generic assignment is changed to *Ommatartus* in Sanfilippo and Riedel (manuscript).

Orodapis spongiosa Friend and Riedel, 1967, pp. 222–223, pl. 1, figs. 7–10.

Oroscena carolae Friend and Riedel, 1967, p. 225, pl. 2, figs. 9–10, pl. 3, figs. 1–2.

Oroscena gegenbauri Haeckel, 1887, pp. 1597–1598, pl. 106, fig. 4; Friend and Riedel, 1967, p. 225, pl. 2, figs. 7, 8.

Panarium antepenultimum Riedel, 1968, p. 6g/4, pl. 1, fig. 8; Riedel and Funnell, 1964, p. 311. Total length including polar columns, 250μ. [Fig. 4, *11.*]

Panartus tetrathalamus Haeckel, 1887, p. 378, pl. 40, fig. 3; Nigrini, 1967, pp. 30–31, pl. 2, figs. 4a–4d. Total length including polar caps, 200μ. [Fig. 4, *12.*]

Saturnalis circularis Haeckel, 1887, p. 131; Nigrini, 1967, pp. 25–26, pl. 1, fig. 9. Maximum diameter of outside ring, 300μ. [Fig. 4, *13.*]

Sethamphora sp. Maximum width of abdomen, 90μ. [Fig. 4, *14.*] The species is similar to an Eocene form, *Sethamphora mongolfieri* (Ehrenberg) (Haeckel, 1887; Riedel, 1957), but differs from it in possessing a spherical rather than an ovate outline and irregularly arranged circular pores, particularly in transverse rows, in the abdomen.

Stichocorys wolffii Haeckel, 1887, p. 1479, pl. 80, fig. 10; Riedel, 1957, pp. 92–93, pl. 4, figs. 6, 7.

Tholospyris cortinisca (Haeckel) Goll, 1969, pp. 325–326, pl. 56, figs. 3, 5, 6, 8, text-fig. 1 = *Tripospyris cortiniscus* Haeckel, 1887, p. 1026, pl. 84, fig. 6.

Tholospyris mammillaris (Haeckel) Goll, 1969, pp. 327–328, pl. 55, figs. 5, 6, 8, 9, text-fig. 1 = *Dictyospyris mammillaris* Haeckel, 1887, p. 1076, pl. 89, figs. 9, 10.

Tympanidium binoctonum Haeckel, 1887, p. 1004, pl. 94, fig. 18; Riedel, 1957, pp. 78–79, pl. 1, fig. 2. Maximum width of lattice shell, 120μ. [Fig. 4, *15.*]

LITERATURE CITED

BANNER, F. T., and W. H. BLOW. 1965. Progress in the planktonic foraminiferal biostratigraphy of the Neogene. Nature, vol. 208, no. 5016, pp. 1164–1166.

——— 1967. The origin, evolution and taxonomy of the foraminiferal genus *Pulleniatina* Cushman, 1927. Micropaleontology, vol. 13, no. 2, pp. 133–162.

BRADY, H. B. 1884. Report on the foraminifera dredged by H.M.S. "Challenger," during the years 1873–1876. "Challenger" Report, Zoology, vol. 9, pp. 1–814.

BRANDT, K. 1905. Zur Systematik der koloniebildenden Radiolarien. Zoologische Jahrbücher, suppl. vol. 8, no. 2, pp. 311–352, taf. 9–10.

CAMPBELL, A. S., and B. L. CLARK. 1944. Miocene radiolarian faunas from southern California. Geological Society of America, Special Paper 51, pp. 1–76, 7 pls., tables 1–2.

CARNEVALE, P. 1908. Radiolarie e silicoflagellati de Bergonzana (Reggio Emilia). Memorie del R. Istituto veneto di scienze, lettere ed arti, vol. 28, no. 3, pp. 1–46, pls. 1–4.

EHRENBERG, C. G. 1861. Über die organischen und unorganischen Mischungsverhältnisse des Meeresgrundes. Königlich Preussischen Akademie der Wissenschaften, Berlin, Monatsberichte. Jahrg. 1860, pp. 765–774.

——— 1872. Mikrogeologische Studien als Zusammenfassung seiner Beobachtungen des kleinsten Lebens der Meeres-Tiefgründe aller Zonen und dessen geologischen Einfluss. Königlich Preussischen Akademie der Wissenschaften, Berlin, Monatsberichte, Jahrg. 1872, pp. 265–322.

FRIEND, J. K., and W. R. RIEDEL. 1967. Cenozoic orosphaerid radiolarians from tropical Pacific sediments. Micropaleontology, vol. 13, no. 2, pp. 217–232, pls. 1–3.

FUNNELL, B. M. 1967. The occurrence of pre-Quaternary microfossils in the oceans. SCOR Symposium (1967), Cambridge, England. Manuscript.

GOLL, R. M. 1968. Classification and phylogeny of Cenozoic Trissocyclidae (Radiolaria) in the Pacific and Caribbean basins, pt. 1. Journal of Paleontology, vol. 42, no. 6, pp. 1409–1432, pls. 173–176.

——— 1969. Classification and phylogeny of Cenozoic Trissocyclidae (Radiolaria) in the Pacific and Caribbean basins, pt. 2. Journal of Paleontology, vol. 43, no. 2, pp. 322–339, pls. 55–60.

HAECKEL, E. 1862. Die Radiolarien (Rhizopoda Radiaria), Eine Monographie. Berlin, Georg Reimer. 572 pp, 35 pls.

——— 1887. Report on the Radiolaria collected by H.M.S. "Challenger" during the year 1873–1876. "Challenger" Report, Zoology, vol. 18. clxxxviii + 1803 pp., 140 pls., 1 chart.

LING, H. Y., and W. A. ANIKOUCHINE. 1967. Some spumellarian Radiolaria from the Java, Philippine, and Mariana trenches. Journal of Paleontology, vol. 41, no. 6, pp. 1481–1491, pls. 189–192.

MENARD, H. W. 1964. Marine geology of the Pacific. New York, McGraw-Hill. 271 pp., ref. p. 18, fig. 1.11.

NAKASEKO, K. 1955. Miocene radiolarian fossil assemblage from the southern Toyama Prefecture in Japan. Osaka University, Science Reports, no. 4, pp. 65–127, pls. 1–11.

——— 1963. Neogene Cyrtoidea (Radiolaria) from the Isozaki Formation in Ibaraki Prefecture, Japan. Osaka University, Science Reports, vol. 12, no. 2, pp. 165–198, pls. 1–4.

NIGRINI, C. 1967. Radiolaria in pelagic sediments from the Indian and Atlantic oceans. Bulletin, Scripps Institution of Oceanography, vol. 11, 106 pp., pls. 1–9.

RIEDEL, W. R. 1952. Tertiary Radiolaria in western Pacific sediments. Göteborgs Kungl. vetenskaps- och vitterhets-samhälles handlingar, följ. 6, ser. B., vol. 6, no. 3, pp. 1–21, pl. 1–2 (Medd. Oceanogr. Inst. Göteborg 19).

——— 1957. Radiolaria: a preliminary stratigraphy. Swedish Deep-Sea Expedition, Report 6, no. 3, pp. 61–96, 4 pls.

——— 1959. Oligocene and Lower Miocene Radiolaria in tropical Pacific sediments. Micropaleontology, vol. 5, no. 3, pp. 285–302.

——— 1967. Occurrence of pre-Quaternary Radiolaria in deep-sea sediments. SCOR Symposium (1967), Cambridge, England. Manuscript.

——— 1968. Radiolaria. In: Core description manual, pt. VII. Biostratigraphy. Chapter 6, Deep Sea Drilling Project, pp. 1–20, pls. 1–6.

RIEDEL, W. R., and B. M. FUNNELL. 1964. Tertiary sediment cores and microfossils from the Pacific Ocean floor. Quarterly Journal of the Geological Society of London, vol. 120, pp. 14–32, 305–368, pls. 14–32.

SANFILIPPO, A., and W. R. RIEDEL. Post-Eocene "closed" theoperid radiolarians. Manuscript.