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14. Late Cenozoic Radiolarians from South Atlantic Hole 1082A, Leg 175[1]

Isao Motoyama[2]

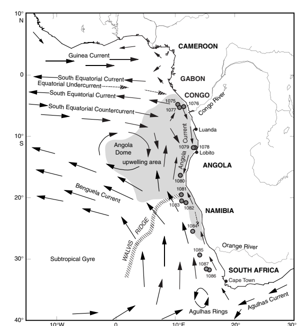
ABSTRACT

Latest Miocene to Pleistocene poorly to well-preserved radiolarians were recovered from Hole 1082A in the Walvis Basin by Ocean Drilling Program Leg 175. Having moderate sedimentation rates and a good magnetostratigraphic record, this hole provides an excellent reference section for biochronology of the eastern South Atlantic Ocean. A set of radiolarian census data is given, and distinctive bioevents are identified and tied to the geomagnetic polarity time scale. This is the first attempt at a direct correlation of Neogene radiolarian bioevents with the geomagnetic polarity time scale in the South Atlantic off southwest Africa. Any one of the previously proposed zonal frameworks alone is hard to fully apply to radiolarian assemblages in Hole 1082A because of the rarity of the diagnostic species.

INTRODUCTION

The Benguela Current is a northward-flowing cool current of the South Atlantic (Fig. F1). It is largely driven by the southeast trade winds and associated with strong coastal upwelling along the continental margin of Namibia, Africa. Ocean Drilling Program (ODP) Leg 175 was conducted to reconstruct the paleoceanography of the Angola-Benguela Current system and the paleoclimates of its nearby African continent (Wefer, Berger, Richter, et al., 1998). During this cruise, Site 1082 was drilled on the continental slope in the Walvis Bay area because it plays a large role in the reconstruction of the history of the Benguela Current

F1. Oceanographic settings in the southeastern Atlantic Ocean and location of Site 1082, p. 23.



[1] Motoyama, I., 2001. Late Cenozoic radiolarians from South Atlantic Hole 1082A, Leg 175. *In* Wefer, G., Berger, W.H., and Richter, C. (Eds.), *Proc. ODP, Sci. Results,* 175, 1–26 [Online]. Available from World Wide Web: <http://www-odp.tamu.edu/publications/175_SR/VOLUME/CHAPTERS/SR175_14.PDF>. [Cited YYYY-MM-DD]

[2] Institute of Geoscience, University of Tsukuba, Tennodai 1-1-1, Tsukuba, 305-8571, Japan.
Motoyama@arsia.geo.tsukuba.ac.jp

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as well as the history of the related upwelling. This paper is designed to present census data of the radiolarian assemblages from Hole 1082A, which are expected to record changes and timing of the ocean climate, structures, and productivity over the last 6 m.y. in the region of the Benguela Current off Namibia. Detailed radiolarian faunal analyses and paleoceanographic interpretations will appear elsewhere.

Neogene radiolarian stratigraphy for the South Atlantic off southwest Africa was first published by Pisias and Moore (1978) on the basis of the material collected on Deep Sea Drilling Project (DSDP) Leg 40, but no absolute age estimates have been attempted. DSDP Leg 75 was later conducted to the neighboring area, but no radiolarian report was proposed for it. Of the 13 sites drilled by ODP Leg 175, Site 1082 seems to be the most hopeful site for estimation of absolute ages of radiolarian events because this site produces a record of magnetic polarity reversals that covers the longest time interval down to the latest Miocene. Some of the other sites (Sites 1075–1081, 1083, and 1084) cover the reversal records of shorter time intervals, and in the rest of the Sites (1085, 1086, and 1087,) most of the stratigraphic section below the upper Pliocene does not contain any radiolarians (Wefer, Berger, Richter, et al., 1998). The present study provides correlation between the radiolarian stratigraphy of Hole 1082A and the geomagnetic time scale. Some biostratigraphic comments are also mentioned below.

MATERIAL AND METHODS

Hole 1082A is on the African continental slopes off Namibia (21°5.6373′S, 11°49.2361′E, 1279.3 m water depth). The lithologic composition is quite uniform throughout the 600.6 meters below seafloor (mbsf) hole, consisting largely of nannofossil-rich clay and nannofossil ooze (Shipboard Scientific Party, 1998). The middle part of the sequence (112–368 mbsf) is rather rich in diatoms. One sample per core was examined for a census of radiolarian assemblages.

Sample preparation for microscopic examination followed the standard techniques described by Sanfilippo et al. (1985). All samples were treated with hydrogen peroxide and hydrochloric acid and sieved at 63 µm and then briefly immersed in an ultrasonic bath and resieved. The cleaned residues were pipetted onto glass slides, dried without boiling, and mounted with Entellan-New alkylacrylate and coverslips. A minimum of 500 specimens of polycystine radiolarians were counted in each sample under a transmitted light microscope.

For each sample examined, qualitative estimates of radiolarian assemblage abundance and preservation were made (Table T1). Radiolarian assemblage abundance was assessed as follows:

T1. Census counts of radiolarian taxa, p. 25.

A = abundant; >10,000 specimens on a slide.
C = common; 1001–10,000 specimens on a slide.
F = few; 501–1000 specimens on a slide.
R = rare; 11–500 specimens on a slide.
T = trace; 1–10 specimens on a slide.
B = barren; 0 specimens.

Preservation of the radiolarian assemblage was based on the following categories:

G = good; radiolarians show no signs of dissolution with only minor fragmentation.
M = moderate; radiolarians show evidence of moderate dissolution with obvious fragmentation.
P = poor; radiolarians show signs of a high degree of dissolution with very few intact specimens.

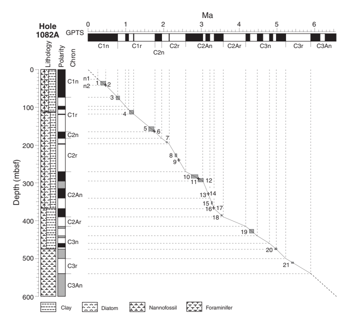
The following abbreviations are used in this study to express bioevents:

FO = first occurrence.
RI = rapid increase.
LCO = last common occurrence.
LO = last occurrence.
SA = short acme.

AGE-DEPTH MODEL

Figure F2 shows an age-depth curve of Hole 1082A. Magnetic properties of this hole were measured on board (Shipboard Scientific Party, 1998), and their “model 1” of the two interpretations for polarity-chron assignment is herein employed. Two calcareous nannofossil datums, FO of *Emiliania huxleyi* and LO of *Pseudoemiliania lacunosa* (Shipboard Scientific Party, 1998; Giraudeau et al., 1998), are employed to construct a part of the age-depth curve of the uppermost sequence that belongs to the polarity chron C1n. Cande and Kent (1995) and Berggren et al. (1995) are herein employed for the geomagnetic polarity time scale. Absolute ages between control points were estimated using linear interpolation.

F2. Age-depth curve for Hole 1082A, p. 24.



SHORT NOTE ON RADIOLARIAN ASSEMBLAGES

About 150 radiolarian taxa were encountered during this study (Table T1). These taxa include some undescribed or unfamiliar forms, particularly within the families Actinommidae, Spongodiscidae, Pyloniidae, Litheliidae, and Plagoniidae. Many of these are not differentiated below the level of family or subfamily.

Generally, radiolarians are common to abundant and moderate to well preserved in the upper to middle portion (0 to ~380 mbsf) of Hole 1082A. Abundance and preservation of radiolarians decline in Sample 175-1082A–5H-4, 46–48 cm (41.26 mbsf). Similar reductions occur in short intervals at 20.05–29.93 mbsf in Hole 1081A, at 41.68 mbsf in Hole 1084A, and at 18.17 mbsf in Hole 1087A, where many species disappear temporarily (Wefer, Berger, Richter, et al, 1998). These changes may reflect a short-spanned oceanic event extending over the Benguela Current region, that possibly resulted in decline of productivity of radiolarians.

In the lower portion (below ~380 mbsf) of Hole 1082A, radiolarians are rare to abundant and absent in some horizons, and their preservation is poor to moderate. Radiolarian specimens from this interval often show dissolution signals because they were corroded and sometimes highly fragmented. Sample 175-1082A-63X-4, 46–48 cm (586.26 mbsf), is very poor in radiolarian abundance and preservation, so counting was not done for this sample.

Radiolarian assemblages are dominated by temperate- to cool-water species represented by the *Actinomma boreale* group, *Larcopyle buetschlii, Lithelius minor*, and *Cycladophora davisiana* through the upper to middle portion of Hole 1082A (above ~380 mbsf). This indicates the predominance of a temperate to cool oceanic climate through the equivalent time interval, similar to today's conditions under the cool Benguela Current. Temperate species *L. minor* is one of the dominant radiolarian elements in the lower middle to lower portion (below ~390 mbsf). Some Antarctic forms, *Cycladophora pliocenica* and *Antarctissa* species, occur in low abundance in the middle part of the sequence (193.47–364.86 mbsf), suggesting minor invasions of antarctic/subantarctic waters. Warm-water species, including collosphaerid species, *Didymocyrtis tetrathalamus,* and *Octopyle stenozona*/*Tetrapyle octacantha,* occur in low abundance consistently through the hole, indicating less influence of warm-water currents into the Walvis Basin.

RADIOLARIAN EVENTS AND POTENTIAL DATUM LEVELS

Because of the occurrence of radiolarians throughout the upper Miocene to Pleistocene and good records of magnetic polarity sequences, Site 1082 would be a key station for constructing upper Cenozoic radiolarian biozonations and dating their bioevents. Table **T2** summarizes radiolarian events that seem to be of potential stratigraphic significance in the vicinity of Site 1082, probably in the Benguela Current region. Table **T1** and the previously published occurrence chart (Shipboard Scientific Party, 1998, table 5), which was produced by shipboard investigations on the basis of the core-catcher samples, are both used for identification of the bioevents listed in Table **T2.** Numerical ages of the samples and these bioevents estimated based on the age-depth model (Fig. **F2**) are also shown in Tables **T1** and **T2.**

T2. Radiolarian event chart, p. 26.

The number of specimens searched in an assemblage is an important factor in stratigraphic interpretations (Sanfilippo et al., 1985). It must be noted that the number of specimens searched in a sample is about 500 in the case of the present study and several thousand in the case of most of the core-catcher samples that were searched on board. Based on the present census assessment of radiolarian assemblages, abundance change of taxa can be seen, and such bioevents as LCOs, RIs, and SAs characterized by abundance changes can be defined. An absence recorded after searching through thousands of specimens has more meaning than one recorded after searching through only a few hundred. Thus, the higher the number of specimens searched, the higher the accuracy of absence and the reliability of definition of first and last occurrences of a taxon.

As seen in descriptions of radiolarian biostratigraphy by Wefer, Berger, Richter, et al. (1998), any one of the previously proposed zonal frameworks alone (e.g., Johnson et al., 1989; Caulet, 1991; Lazarus, 1992; Moore, 1995; Motoyama, 1996) is hard to fully apply to radiolarian assemblages at Leg 175 sites because of the absence or scarcity of known zonal marker species. Pisias and Moore (1978) applied the North Pacific biozones of Kling (1973) to the upper Miocene and Pliocene at DSDP Leg 40 Site 362, which is near Site 1082. Although occurrences of *Axoprunum angelinum, Stichocorys peregrina, Lamprocyrtis heteroporos,* and *Spongurus pylomaticus* are recognized in Hole 1082A, the other key species, including *Eucyrtidium matuyamai, Sphaeropyle langii,* or *Dictyophimus robustus* are absent from Hole 1082A, demonstrating that part of the North Pacific radiolarian zonation could not be used for the biostratigraphic study at Hole 1082A. In this study, radiolarian zones are given in the tropical zonation of Moore (1995) wherever possible, and the North Pacific zonation of Motoyama (1996) is adopted in part (Table **T1**). Comments are made below on radiolarian events, some of which are expected to be useful for future biostratigraphic studies in the southeastern Atlantic Ocean.

The LO of *A. angelinum* (= *Stylatractus universus*) is known to be a globally synchronous event (Hays and Shackleton, 1976). This event is one of the widely traceable datum levels in the southeastern Atlantic Ocean, as it is recognized in the cores RC13–205 and RC13-229 (Morley and Shackleton, 1978) and Holes 1075A, 1076A, 1077A, 1080A, 1081A, 1083A, 1084A, 1085A, and 1087A (Wefer, Berger, Richter, et al., 1998) as well as in Hole 1082A; thus, it extends across the Angola-Benguela Current System.

The LO of *C. pliocenica* is a noticeable bioevent because this species is an important marker species in the Miocene to Pleistocene of the Antarctic Ocean. *C. pliocenica* is known to be common in Miocene–Pliocene sediments of subantarctic and antarctic cores between 45°S and 70°S (DSDP/ODP Sites 265–269, 274, 278, 281, 513, 514, 594, 689–696, 736, 737, and 744–746) (Chen, 1975; Petrushevskaya, 1975; Keany and Kennett, 1975; Weaver, 1983; Caulet, 1986, 1991; Lazarus, 1990). The species has not been reported from sediments of the Northern Hemisphere, so it is endemic to the southern oceans. *C. pliocenica* has been recognized in Holes 1081A, 1082A, 1083A, 1084A, and 1085A of Leg 175 (Wefer, Berger, Richter, et al., 1998), giving its record from the lowest latitude (20°S) so far. The LO of *C. pliocenica* of Hole 1082A is calculated to 2.08–2.11 Ma in age, suggesting that this species disappeared slightly earlier in the southeastern Atlantic than in the southern oceans where the species became extinct at 1.7–1.8 Ma (Lazarus, 1990; Caulet, 1991).

C. pliocenica first occurs in the upper Pliocene in Hole 1082A (3.3 Ma in age), whereas this species appears in Miocene time in the southern oceans (Chen, 1975; Petrushevskaya, 1975; Weaver, 1983; Caulet, 1991; Lazarus, 1992). Therefore, the FO of *C. pliocenica* is apparently diachronous between the southeastern Atlantic Ocean and the southern oceans.

Some bioevents characterized by abundance changes, such as the SA of *Heliosoma*? sp., SA of *Corocalyptra kruegeri,* RI of *Actinomma boreale* group, RI of *C. davisiana*, RI of *Cycladophora sakaii,* SA of *Antarctissa* group, and LCO of *Stichocorys* group, probably reflect changes in the ocean circulation.

Rare occurrences of *C. davisiana* in the lower sequence below 420 mbsf (~4.2 Ma) are probably downworked or contaminated specimens, judging from their better preservation than the other specimens in each sample. Consequently, the FO of this species in Hole 1082A was placed at the same level with the RI of the species (2.91–2.93 Ma).

Spongurus pylomaticus and *Spirema* sp. have been recorded in the Miocene to Pliocene submarine sequences of the North Pacific (Kling, 1973; Motoyama, 1996). The FO of *S. pylomaticus,* which defines the base of *S. pylomaticus* Zone, is given quite similar numerical ages in the North Pacific (5.2 Ma) (Motoyama and Maruyama, 1998) and in Hole 1082A (5.38–5.46 Ma). The Lower Pliocene LO of *Spirema* sp. may also be applicable in correlations between the North Pacific and the southeastern Atlantic.

SYSTEMATICS

Species List

Order SPUMELLARIA
Family COLLOSPHAERIDAE

Acrosphaera spinosa (Haeckel)

Collosphaera spinosa Haeckel, 1860, p. 845; 1862, p. 536, pl. 34, figs. 12, 13.

Acrosphaera spinosa (Haeckel) n. comb.: Haeckel, 1887, p. 100.

Collosphaera spp.

Remarks: Included in this category are individuals that can be assigned to the genus *Collosphaera* Müller emend. Bjørklund and Goll (1979).

Disolenia collina (Haeckel)

Disolenia collina (Haeckel) n. comb.: Takahashi, 1991, p. 57, pl. 3, figs. 1, 5–7.

Otosphaera auriculata Haeckel

Otosphaera auriculata Haeckel: Nigrini and Moore, 1979, p. S7, pl. 1, fig. 4.

Otosphaera polymorpha Haeckel

Otosphaera polymorpha Haeckel: Nigrini and Moore, 1979, p. S9, pl. 1, fig. 5.

Polysolenia murrayana (Haeckel)

Polysolenia murrayana (Haeckel): Nigrini and Moore, 1979, p. S17, pl. 2, figs. 4a, 4b.

Family ACTINOMMIDAE

Acanthosphaera circopora Popofsky

Acanthosphaera circopora Popofsky, 1912, p. 97, text–fig. 9.

Actinomma boreale Cleve group

Actinomma boreale Cleve, 1899, p. 26, pl. 1, fig. 5a, 5b, 5c.

Remarks: This category may involve individuals of *Prunopyle antarctica* Dreyer (1889, p. 24, pl. 5, fig. 75) and *Actinomma leptodermum* (Jorgensen) in Nigrini and Moore (1979, p. S35, pl. 3, fig. 7).

Actinomma haysi Bjørklund

Actinomma haysi Bjørklund, 1977, p. 117, pl. 1, figs. A–C, G, H, M, N.

Actinomma medianum Nigrini

Actinomma medianum Nigrini: Nigrini and Moore, 1979, p. S31, pl. 3, figs. 5, 6.

Actinomma popofskii (Petrushevskaya) group

Actinomma popofskii (Petrushevskaya): Morley and Nigrini, 1995, p. 81, pl. 1, figs. 4, 5.

Remarks: This category includes some specimens that have more rounded cortical shell, whereas *A. popofskii* show somewhat polygonal shapes.

Actinomma spp.

Remarks: This category contains any member of the genus which does not fall into one of the above species.

Axoprunum angelinum (Campbell and Clark)

Stylatractus universus Hays, 1970, p. 215, pl. 1, figs. 1, 2.

Axoprunum angelinum (Campbell and Clark): Kling, 1973, p. 634, pl. 1, figs. 13–16; pl. 6, figs. 14–18.

Axoprunum stauraxonium Haeckel

Axoprunum stauraxonium Haeckel: Nigrini and Moore, 1979, p. S57, pl. 6, figs. 2, 3.

Cenosphaera spp.

Remarks: Included in this category are all specimens that are composed of single latticed sphere without spines. Shell size is highly variable (several tens to 200 µm).

Cladococcus pinetum Haeckel

Cladococcus pinetum Haeckel, 1887, p. 226, pl. 27, fig. 1.

Cladococcus scoparius Haeckel

Cladococcus scoparius Haeckel: Dreyer, 1913, p. 58, pl. 1, figs. 2–4.

Cladococcus sp.

Remarks: Included in this category are all specimens, but those previously categorized, that are constructed with single latticed shell and many radial, robust spines that branch.

Druppatractus irregularis Popofsky

Druppotractus [!] *irregularis* Popofsky, 1912, p. 114, text–figs. 24–26.

Druppatractus irregularis Popofsky: Boltovskoy and Riedel, 1987, p. 97, pl. 1, fig. 21.

Heliosoma? sp.

Description: Two concentric latticed spheres with 7–15 radial spines. Inner spherical shell very thin walled, with 16 hexagonal pores on its circumference. Outer cortical shell moderately thick walled, with 16–20 pores on its circumference, connected with the former by several thin radial beams. Pores on the outer shell subcircular to irregular in shape. Radial spines simple in shape, of unequal length, irregularly spaced, projecting from the outer surface of the outer shell. Diameter of the inner shell 30 µm, of pores of the inner shell 4–5 µm, of the outer shell 100–110 µm, of pores of the outer shell 7–20 µm; width of bars of the outer shell 2–5 µm; thickness of the outer shell 5–10 µm; length of the radial spines up to 60 µm; thickness of basal part of the radial spines up to 11 µm. In a specimen, two to five radial spines long (25–60 µm), the other radial spines short (<25 µm).

Remarks: Inner shells and connecting beams are absent in most of encountered specimens, possibly as a result of dissolution in sediments.

Hexacontium spp.

Remarks: Included in this category are all specimens that consist of three concentric latticed spheres, two of which are medullary shell, and six radial three-bladed spines in three mutually perpendicular axes.

Hexalonche spp.

Remarks: Included in this category are all specimens that are constructed with two concentric latticed spheres, one cortical and one medullary, and six radial three-bladed spines in three mutually perpendicular axes.

Hexastylus spp.

Hexastylus spp. Nigrini and Lombari, 1984, p. S17, pl. 3, figs. 1a–1c.

Liosphaera sp.

Remarks: Specimens of this form have double large cortical shells. Pores on the shells are irregular in shape and small in size (5–20 µm in diameter). Diameter of outer and inner cortical shells is 400 and 320 µm, respectively.

Saturnalis circularis Haeckel

Saturnalis circularis Haeckel, 1887, p. 131.

Saturnalis circularis Haeckel: Nigrini, 1967, p. 25, pl. 1, fig. 9.

Stylacontarium bispiculum Popofsky

Stylacontarium bispiculum Popofsky: Kling, 1973, pl. 15, figs. 11–14.

Stylacontarium sp. aff. *S. bispiculum* Popofsky: Kling, 1973, p. 634, pl. 6, figs. 19–23, pl. 14, figs. 5–8.

Stylatractus sp. A

Stylatractus spp. Nigrini and Lombari, 1984, p. S25, pl. 4, figs. 2a, 2b.

Stylatractus sp. B

Stylatractus sp. Sanfilippo et al., 1985, Fig. 5(4).

?*Styptosphaera spumacea* Haeckel

Styptosphaera (?) *spumacea* Haeckel: Nigrini and Moore, 1979, p. S71, pl. 8, figs. 6a, 6b.

Thecosphaera dedoensis Nakaseko

Thecosphaera dedoensis Nakaseko: Motoyama, 1996, p. 252, pl. 2, figs. 2a, 2b.

Thecosphaera inermis (Haeckel)

Actinomma inerme Haeckel, 1862, p. 440, pl. 24, fig. 5.

Thecosphaera inermis, Haeckel: Haeckel, 1887, p. 80.

Thecosphaera japonica Nakaseko

Thecosphaera japonica Nakaseko: Motoyama, 1996, p. 252, pl. 2, figs. 3a, 3b.

Thecosphaera miocenica Nakaseko

Thecosphaera miocenica Nakaseko: Motoyama, 1996, p. 252, pl. 2, figs. 4a, 4b.

Thecosphaera pseudojaponica Nakaseko

Thecosphaera pseudojaponica Nakaseko: Motoyama, 1996, p. 252, pl. 2, figs. 5a, 5b.

Thecosphaera aff. *pseudojaponica* Nakaseko

Thecosphaera aff. *pseudojaponica* Nakaseko: Motoyama, 1996, p. 242, pl. 2, figs. 6, 7a, 7b.

Thecosphaera spp.

Remarks: Included in this category are any thecosphaerid specimens that are not previously categorized. These have three concentric spheres, two of which are medullary shells, and no external spines.

Family PHACODISCIDAE

Heliodiscus asteriscus Haeckel

Heliodiscus asteriscus Haeckel: Nigrini and Moore, 1979, p. S73, pl. 9, figs. 1, 2(?).

Heliodiscus echiniscus Haeckel

Heliodiscus echiniscus Haeckel: Nigrini, 1967, p. 34, pl. 3, figs, 2a, 2b.

Family COCCODISCIDAE

Didymocyrtis avita (Riedel)

Didymocyrtis avita: Sanfilippo et al., 1985, p. 657, figs. 8.8a, 8b.

Didymocyrtis tetrathalamus (Haeckel), s. lat.

Ommatartus tetrathalamus tetrathalamus (Haeckel): Nigrini and Moore, 1979, p. S49, pl. 6, figs. 1a–1d.

Ommatartus tetrathalamus coronatus (Haeckel): Nigrini and Moore, 1979, p. S53, pl. 6, figs. 2a, 2b.

Didymocyrtis tetrathalamus (Haeckel): Sanfilippo and Riedel, 1980, p. 1010, text-fig. 4(g).

Family PORODISCIDAE

Amphirhopalum ypsilon Haeckel

Amphirhopalum ypsilon Haeckel: Nigrini and Moore, 1979, p. S75, pl. 10, figs. 1a–1e.

Circodiscus microporus (Stöhr) group

Circodiscus microporus (Stöhr) group: Nigrini and Lombari, 1984, p. S73, pl. 10, fig. 3.

Euchitonia spp.

Euchitonia sp. Molina-Cruz, 1977, pl. 4, figs. 1, 2.

"Euchitonia" spp.: Boltovskoy and Riedel, 1987, p. 98, pl. 2, fig. 20.

Euchitonia cf. *furcata* Ehrenberg: Takahashi, 1991, p. 80, pl. 16, fig. 8.

Remarks: This category may involve immature forms of *Euchitonia furcata* Ehrenberg (1872a, p. 308; 1872b, pl. 6.3, fig. 6).

Stylochlamydium asteriscus Haeckel

Stylochlamydium asteriscus Haeckel: Nigrini and Moore, 1979, p. S113, pl. 14, fig. 5.

Stylodictya camerina Campbell and Clark

Stylodictya camerina Campbell and Clark: Motoyama, 1996, p. 254, pl. 2, fig. 9.

Stylodictya multispina Haeckel

Stylodictya multispina Haeckel, 1860, p. 842; 1862, p. 496, pl. 29, fig. 5.

Porodiscus sp. A Nigrini and Moore, 1979, p. S107, pl. 14, fig. 1. (partim)

Stylodictya multispina/*Porodiscus* spp. Boltovskoy and Vrba, 1988, pl. 1, figs. 1a, 1b only.

Stylodictya validispina Jörgensen

Stylodictya validispina Jörgensen, 1905, p. 119, pl. 10, figs. 40a, 40b.

Family SPONGODISCIDAE

Dictyocoryne spp.

Remarks: This category may involve immature forms of *Dictyocoryne profunda* Ehrenberg (1872a, p. 307; 1872b, p. 289, pl. 7, fig. 23) and *Dictyocoryne truncatum* (Ehrenberg) in Nigrini and Moore (1979, p. S89, pl. 12, fig. 2a, 2b).

Perichlamydium venustum Bailey?

?*Perichlamidium* [!] *venustum* Bailey: Motoyama, 1996, p. 254, pl. 2, fig. 8.

Spongocore puella Haeckel

Spongocore puella Haeckel: Nigrini and Moore, 1979, p. S69, pl. 8, figs. 5a–5c.

Spongodiscus communis Clark and Campbell

Spongodiscus (*Spongocyclia*) *communis* Clark and Campbell, 1942, p. 47, pl. 2, figs. 1, 11, 13, 14, pl. 3, figs. 1, 4.

Spongodiscus spp.

Spongodiscus group Mullineaux and Westberg-Smith, 1986, p. 65, pl. 1, fig. 12.

Spongopyle osculosa Dreyer

Spongopyle osculosa Dreyer: Motoyama, 1996, p. 254, pl. 2, fig. 11.

Spongotrochus glacialis Popofsky

Spongotrochus glacialis Popofsky, 1908, p. 228, pl. 26, fig. 8; pl. 27, fig. 1, pl. 28, fig. 2.

Spongotrochus glacialis Popofsky: Petrushevskaya, 1967, p. 43, fig. 21(1–7); fig. 22(1–7); fig. 26(2).

Family PYLONIIDAE

Octopyle stenozona Haeckel/*Tetrapyle octacantha* Müller

Octopyle stenozona Haeckel: Nigrini and Moore, 1979, p. S123, pl. 16, figs. 2a, 2b.

Tetrapyle octacantha Muller [!]: Nigrini and Moore, 1979, p. S125, pl. 16, figs. 3a, 3b.

Family LITHELIIDAE

Larcopyle buetschlii Dreyer

Larcopyle butschlii [!] Dreyer: Motoyama, 1996, p. 254, pl. 3, figs. 3a, 3b, 4.

Larcospira quadrangula Haeckel

Larcospira quadrangula Haeckel: Nigrini and Moore, 1979, p. S133, pl. 17, fig. 2.

Lithelius minor Jörgensen

Lithelius minor Jørgensen: Nigrini and Lombari, 1984, p. S95, pl. 14, figs. 1a, 1b.

Lithelius? sp.

Pylonid gen. et sp. indet. 1 Dumitrica, 1978, pl. 6, fig. 2.

Spirema sp.

Spirema sp. Kling, 1973, p. 635, pl. 7, figs. 23–25.

Lithelius sp. Nigrini and Lombari, 1984, p. S99, pl. 14, figs. 3a–3c.

Spongurus pylomaticus Riedel

Spongurus pylomaticus Riedel, 1958, p. 226, pl. 1, figs. 10, 11.

Spongurus? sp. A

Spongurus? sp. A Nigrini and Lombari, 1984, p. S33, pl. 5, fig. 1b.

Order NASSELLARIA

Family PLAGONIIDAE

Sethophormin group

Remarks: In this category are forms that can be assigned to the family Sethophormididae Haeckel, emend. Petrushevskaya (1971a).

Antarctissa aff. *denticulata* (Ehrenberg)

Remarks: This species resembles *Antarctissa denticulata* (Ehrenberg) of Petrushevskaya (1967, p. 87, fig. 50.1–4), but differs in its longer thorax.

Antarctissa longa (Popofsky)

Antarctissa longa (Popofsky): Petrushevskaya, 1975, p. 591, pl. 11, figs. 8–10.

Arachnocorallium group

Arachnocorallium group Motoyama, 1996, p. 256, pl. 3, figs. 17, 18.

Ceratocyrtis group

Ceratocyrtis galeus (Cleve): Bjørklund, 1976, p. 1124, pl. 11, figs. 1–3.

Ceratocyrtis histricosa (Jörgensen): Petrushevskaya, 1971b, p. 98, figs. 52(2–4).

Ceratocyrtis sinuosa (Popofsky): Petrushevskaya, 1971b, p. 101, figs. 53(2–4).

Ceratocyrtis group Motoyama, 1996, pl. 256, pl. 3, figs. 23, 24.

Lophophaena cf. *capito* Ehrenberg

Lophophaena cf. *capito* Ehrenberg: Takahashi, 1991, p. 96, pl. 25, figs. 6–9.

Pseudodictyophimus spp.

Pseudodictyophimus group Motoyama, 1996, p. 256, pl. 3, figs. 21, 22.

Lophophaenins genn. et spp. indet.

Remarks: This category includes forms that can be assigned to the subfamily Lophophaeninae Haeckel, emend. Petrushevskaya (1971a), except for those previously categorized.

Sethoperins genn. et spp. indet.

Remarks: This category includes forms that can be assigned to the subfamily Sethoperinae Haeckel, emend. Petrushevskaya (1971a).

Neosemantis distephanus (Haeckel)

Neosemantis distephanus (Haeckel): Goll, 1979, p. 384, pl. 4, figs. 1–15.

Family THEOPERIDAE

Bathropyramis sp.

Remarks: This category includes forms that can be assigned to the genus *Bathropyramis* Haeckel (1881).

Cinclopyramis sp.

Remarks: Forms included in this category usually have a very long, robust apical spine that bears many branching spines. A secondary apical spine rises from the cephalis in an oblique angle.

Cornutella profunda Ehrenberg

Cornutella profunda Ehrenberg: Nigrini and Lombari, 1984, p. N93, pl. 22, fig. 1.

Cornutella profunda Ehrenberg: Kling, 1973, p. 635, pl. 3, figs. 1–4; pl. 9, figs. 8–17.

Corocalyptra kruegeri Popofsky

Corocalyptra kruegeri Popofsky, 1908, p. 289, pl. 35, fig. 8.

Cycladophora bicornis (Popofsky) group

Pterocorys bicornis Popofsky, 1908, p. 288, pl. 34, figs. 7, 8.

Theocalyptra bicornis (Popofsky): Riedel, 1958, p. 240, pl. 4, fig. 4.

Theocalyptra (?) *bicornis* (Popofsky): Petrushevskaya, 1967, p. 126, fig. 71(1–7); fig. 72(1–4).

Theocalyptra bicornis (Popofsky): Nigrini and Moore, 1979, p. N53, pl. 24, fig. 1.

Cycladophora bicornis bicornis (Popofsky): Lombari and Lazarus, 1988, p. 106, pl. 5, figs. 9–12.

?*Cycladophora bicornis amphora* Lombari and Lazarus, 1988, p. 110, pl. 4, figs. 6–12.

?*Cycladophora bicornis helios* Lombari and Lazarus, 1988, p. 114, pl. 5, figs. 1–8.

Cycladophora bicornis klingi Lombari and Lazarus

Cycladophora bicornis klingi Lombari and Lazarus, 1988, p. 108, pl. 4, figs. 1–5.

Cycladophora cornutoides Kling

Cycladophora cornutoides Kling: Motoyama, 1997, p. 56, pl. 1, figs. 1–3.

Cycladophora davisiana Ehrenberg

Cycladophora davisiana Ehrenberg: Motoyama, 1997, p. 60, pl. 1, figs. 4–10.

Cycladophora pliocenica (Hays)

Clathroyclas [!] *bicornis* Hays, 1965, p. 179, pl. 3, fig. 3.

Cycladophora pliocenica (Hays): Lombari and Lazarus, 1988, p. 104.

not *Cycladophora pliocenica* (Hays): Morley and Nigrini, 1995, p. 79, pl. 4, fig. 1.

Cycladophora sakaii Motoyama

Cycladophora davisiana/sakaii intermediate forms: Motoyama, 1997, pl. 1, figs. 11–14.

Cycladophora sakaii Motoyama: Motoyama, 1997, p. 60, pl. 1, figs. 15–25.

Remarks: Intermediate forms between *C. davisiana* and *C. sakaii* are gathered into this species tentatively in this study.

Cycladophora spp.

Remarks: This category includes forms that can be assigned to the genus *Cycladophora* Ehrenberg, emend. Lombari and Lazarus (1988), except for those above categorized.

Dictyophimus hirundo (Haeckel) group

Dictyophimus hirundo (Haeckel) group: Motoyama, 1996, p. 256, pl. 6, figs. 6, 7.

Dictyophimus infabricatus Nigrini?

Dictyophimus infabricatus Nigrini: Nigrini and Moore, 1979, p. N37, pl. 22, fig. 5.

Dictyophimus spp.

Remarks: This category includes any members of the genus *Dictyophimus* Ehrenberg, emend. Nigrini (1968), except for the preceding groups.

Eucecryphalus group

Remarks: This category may include *Corocalyptra cervus* (Ehrenberg) of Renz (1974, p. 790, pl. 16, fig. 22), *Theocalyptra* sp. Renz (1974, p. 798, pl. 16, fig. 21) and *Eucecryphalus tricostatus* (Haeckel) of Takahashi (1991, p. 110, pl. 33, figs. 4, 6.)

Eucyrtidium acuminatum (Ehrenberg)

Eucyrtidium acuminatum (Ehrenberg): Nigrini and Moore, 1979, p. N61, pl. 24, figs. 3a, 3b.

Eucyrtidium anomalum (Haeckel)

Eucyrtidium anomalum (Haeckel): Petrushevskaya, 1971b, p. 219, fig. 98(1–4).

Eucyrtidium calvertense Martin

Eucyrtidium calvertense Martin, 1904, p. 450, pl. 130, fig. 5.

Eucyrtidium calvertense Martin: Hays, 1965, p. 181, pl. 3, fig. 4.

Eucyrtidium hexastichum (Haeckel)

Eucyrtidium hexastichum (Haeckel): Petrushevskaya, 1971b, p. 220, fig. 99(3–10).

Eucyrtidium punctatum (Ehrenberg)

Eucyrtidium punctatum (Ehrenberg) group: Riedel and Sanfilippo, 1978, p. 114, pl. 4, figs. 14–16.

Eucyrtidium teuscheri Haeckel group

Eucyrtidium teuscheri gr. (Haeckel) sensu emend. Caulet, 1986, p. 850, pl. 5, figs. 1–8.

Eucyrtidium spp.

Remarks: Included in this category are any specimens of the genus *Eucyrtidium* Ehrenberg, emend. Nigrini (1967) that do not fall into one of the above groups.

Gondwanaria dogieli (Petrushevskaya)

Gondwanaria dogieli (Petrushevskaya): Petrushevskaya, 1975, p. 585.

Lipmanella group

Remarks: This category may include *Lipmanella dictyoceras* (Haeckel) of Kling (1973, p. 636, pl. 4, figs. 24–26), *Lipmanella pyramidale* (Popofsky) of Takahashi (1991, p. 121, pl. 40, fig. 18) and *Lipmanella virchowii* (Haeckel) of Takahashi (1991, p. 122, pl. 40, figs. 19–21).

Litharachnium tentorium Haeckel

Litharachnium tentorium Haeckel: Takahashi, 1991, p. 114, pl. 35, figs. 14–18.

Lithostrobus hexagonalis Haeckel

Lithostrobus hexagonalis Haeckel: Takahashi, 1991, p. 122, pl. 41, figs. 1–3.

Peripyramis circumtexta Haeckel

Peripyramis circumtexta Haeckel: Nigrini and Moore, 1979, p. N29, pl. 21, figs. 4a, 4b.

Pterocanium auritum Nigrini and Caulet

Pterocanium auritum Nigrini and Caulet, 1992, p. 152, pl. 4, figs. 6–8.

Pterocanium korotnevi (Dogiel)

Pterocanium korotnevi (Dogiel): Nigrini and Moore, 1979, p. N39, pl. 23, figs. 1a, 1b.

Pterocanium praetextum (Ehrenberg) *eucolpum* Haeckel

Pterocanium praetextum (Ehrenberg) *eucolpum* Haeckel: Nigrini and Moore, 1979, p. N43, pl. 23, fig. 3.

Pterocanium trilobum (Haeckel)

Pterocanium trilobum (Haeckel): Nigrini and Moore, 1979, p. N45, pl. 23, figs. 4a, 4b.

Pterocanium spp.

Remarks: This category includes forms that can be assigned to the genus *Pterocanium* Ehrenberg (1847, p. 385), except for those categorized above.

Stichocorys delmontensis (Campbell and Clark)

Stichocorys delmontensis (Campbell and Clark): Motoyama, 1996, p. 258, pl. 5, fig. 3.

Stichocorys peregrina (Riedel)

Stichocorys peregrina (Riedel): Motoyama, 1996, p. 258, pl. 5, fig. 2.

Stichocorys spp.

Stichocorys spp. Motoyama, 1996, p. 250, pl. 5, fig. 4.

Stichopera pectinata Haeckel

Stichopera pectinata Haeckel group: Kling, 1973, p. 638, pl. 3, figs. 25–27; pl. 10, figs. 1–5.

Stichopilium anocor Renz

Stichopilium anocor Renz, 1976, p. 124, pl. 5, fig. 10.

Stichopilium bicorne Haeckel

Stichopilium bicorne Haeckel: Nigrini and Moore, 1979, p. N91, pl. 26, figs. 1a, b.

Family CARPOCANIIDAE

Carpocanarium papillosum (Ehrenberg)

Carpocanarium papillosum (Ehrenberg) group: Nigrini and Moore, 1979, p. N27, pl. 21, fig. 3.

Carpocanistrum spp.

Carpocanistrum spp. Nigrini and Moore, 1979, p. N23, pl. 21, figs. 1a–1c.

Family PTEROCORYTHIDAE

Anthocyrtidium nosicaae Caulet

Anthocyrtidium nosicaae Caulet: Nigrini and Caulet, 1988, p. 351, pl. 1, figs. 15–17.

Anthocyrtidium ophirense (Ehrenberg)

Anthocyrtidium ophirense (Ehrenberg): Nigrini and Moore, 1979, p. N67, pl. 25, fig. 1.

Anthocyrtidium zanguebaricum (Ehrenberg)

Anthocyrtidium zanguebaricum (Ehrenberg): Nigrini and Moore, 1979, p. N69, pl. 25, fig. 2.

Lamprocyclas maritalis Haeckel, s. lat.

Lamprocyclas maritalis maritalis Haeckel: Nigrini and Moore, 1979, p. N75, pl. 25, fig. 4.

Lamprocyclas maritalis Haeckel *polypora* Nigrini: Nigrini and Moore, 1979, p. N77, pl. 25, fig. 5.

Lamprocyrtis hannai (Campbell and Clark)

Lamprocyrtis hannai (Campbell and Clark): Motoyama, 1996, p. 258, pl. 7, fig. 3.

Lamprocyrtis heteroporos (Hays)

Lamprocyrtis heteroporos (Hays): Motoyama, 1996, p. 258, pl. 7, fig. 4.

Lamprocyrtis neoheteroporos Kling

Lamprocyrtis neoheteroporos Kling, 1973, p. 639, pl. 5, figs. 17, 18; pl. 15, figs. 4, 5.

Lamprocyrtis nigriniae (Caulet)

Lamprocyrtis nigriniae (Caulet): Nigrini and Moore, 1979, p. N81, pl. 25, fig. 7.

Lamprocyrtis spp.

Remarks: This category may involve immature specimens of the preceding four species.

Pterocorys zanclaeus (Müller)

Eucyrtidium zanclaeum Müller, 1855, p. 672; 1856, p. 492; 1858, p. 41, pl. 6, figs. 1–3.

Pterocorys zancleus [!] (Müller): Petrushevskaya, 1971b, p. 233, fig. 119(1–7).

Theocorythium trachelium (Ehrenberg), s. lat.

Theocorythium trachelium trachelium (Ehrenberg): Nigrini and Moore, 1979, p. N93, pl. 26, fig. 2.

Family ARTOSTROBIIDAE

Botryostrobus aquilonaris (Bailey)

Botryostrobus aquilonaris (Bailey): Motoyama, 1996, p. 258, pl. 7, figs. 6, 7.

Botryostrobus auritus/australis (Ehrenberg) group

Botryostrobus auritus/australis (Ehrenberg) group: Nigrini and Moore, 1979, p. N101, pl. 27, figs. 2a–2d.

Phormostichoartus sp.

Remarks: This category includes specimens that can be assigned to the genus *Phormostichoartus* Campbell, emend. Nigrini (1977).

Siphocampe arachnea (Ehrenberg)

Siphocampe arachnea (Ehrenberg) group: Nigrini, 1977, p. 255, pl. 3, figs. 7, 8.

Spirocyrtis scalaris Haeckel

Spirocyrtis scalaris Haeckel: Nigrini, 1977, p. 259, pl. 2, figs. 12, 13.

Spirocyrtis subscalaris Nigrini

Spirocyrtis subscalaris Nigrini, 1977, p. 259, pl. 3, figs. 1, 2.

Suborder SPYRIDA

Giraffospyris angulata (Haeckel)

Giraffospyris angulata (Haeckel): Nigrini and Moore, 1979, p. N11, pl. 19, figs. 2a–3d.

Lophospyris cheni Goll

Lophospyris cheni Goll, 1976, p. 402, pl. 11, fig. 4; pl. 12, figs. 1–7.

Lophospyris pentagona (Ehrenberg), s. lat.

Lophospyris pentagona Ehrenberg: Petrushevskaya, 1971b, p. 254, fig. 132(1–9).

Phormospyris stabilis (Goll), s. lat.

Dendrospyris stabilis Goll, 1968, p. 1422, pl. 173, figs. 16–18, 20.

Phormospyris stabilis stabilis (Goll): Takahashi, 1991, p. 104, pl. 30, figs. 2–5.

Zygocircus spp.

Zygocircus group Riedel et al., 1985, p. 508, pl. 3, figs. 10a, 10b.

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Figure F1. Oceanographic settings in the southeastern Atlantic Ocean and locations of Site 1082 and the other Leg 175 sites.

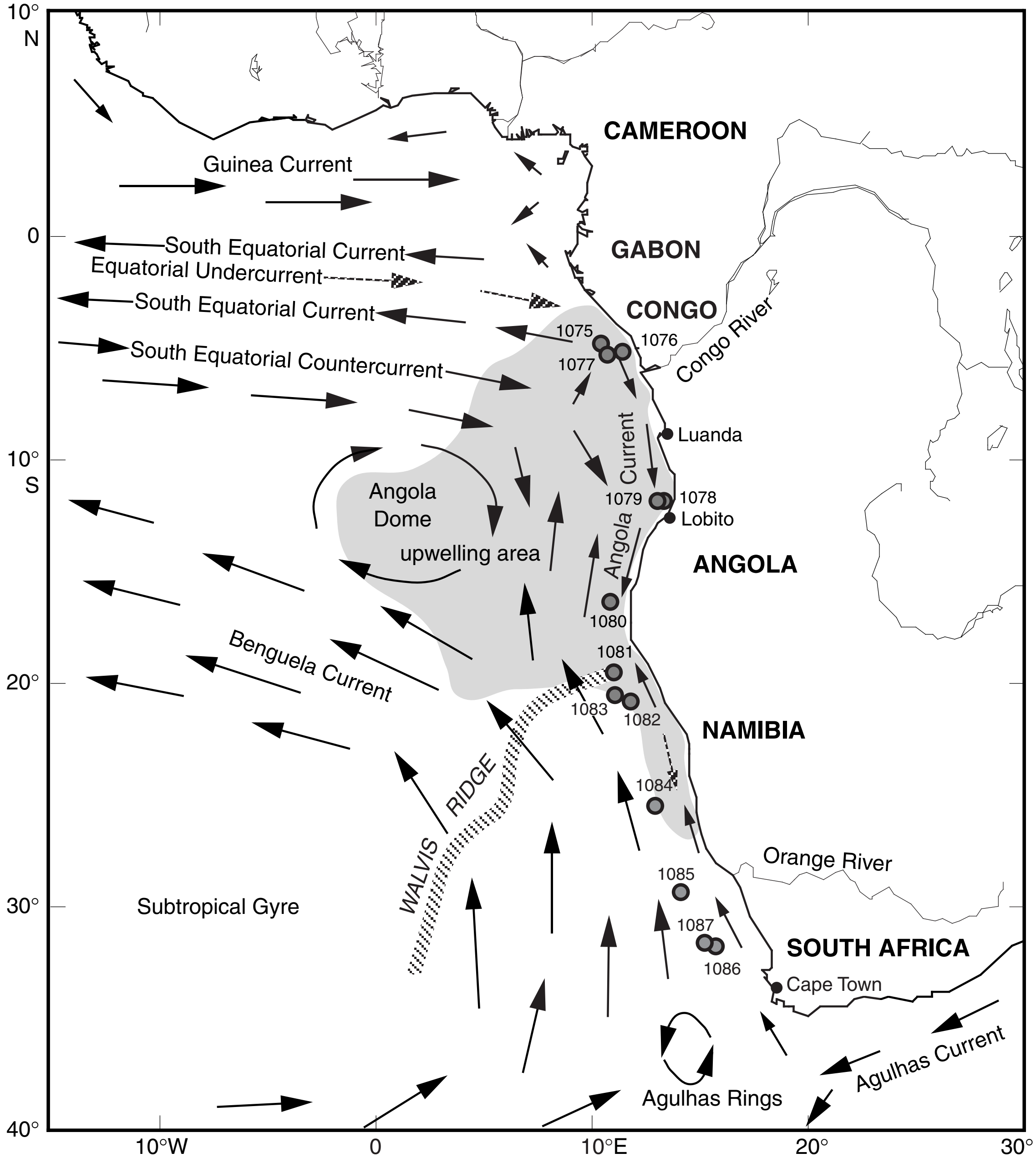

Figure F2. Age-depth curve for Hole 1082A. The paleomagnetic "model 1" (Shipboard Scientific Party, 1998) and two calcareous nannofossil datums (n1 = FO of *Emiliania huxleyi;* n2 = LO of *Pseudoemiliania lacunosa*) (Shipboard Scientific Party, 1998) are used. Geomagnetic polarity time scale (GPTS) after Cande and Kent (1995) and Berggren et al. (1995). Numbers (1–21) indicate radiolarian events (see Table T2, p. 26).

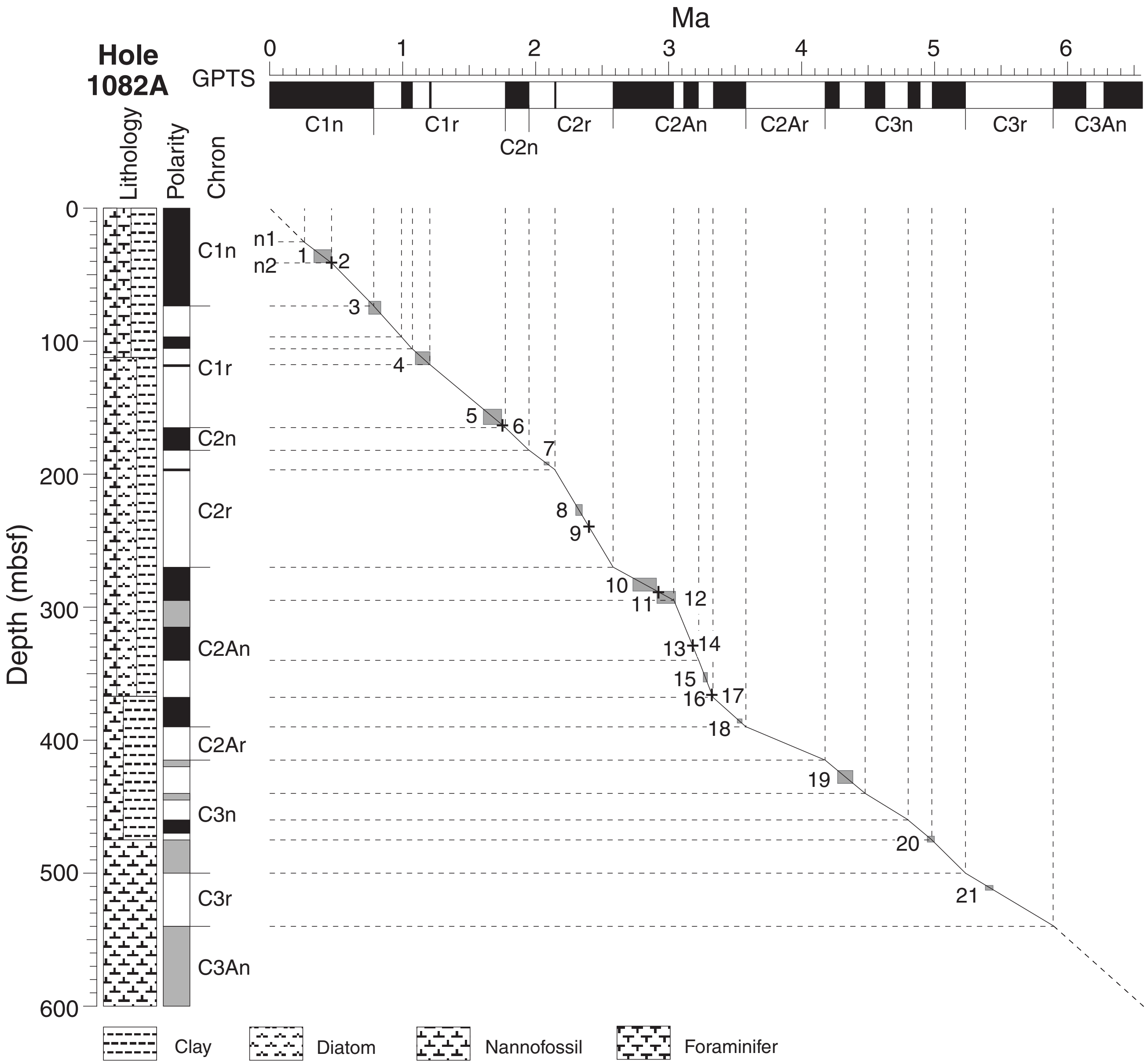

Table T1. Census counts of radiolarian taxa, Hole 1082A. (This table is available in an **oversized format.**)

Table T2. Radiolarian event chart for Hole 1082A.

	Event	Species	Core, section, interval (cm)	Depth (mbsf)	Age (Ma)
			175-1082A-		
1	LO	*Axoprunum angelinum*	4H-4, 46-48	31.76	0.34
			5H-4, 46-48	41.26	0.46
2	SA	*Heliosoma*? sp.	5H-4, 46-48	41.26	0.46
3	FO	*Lamprocyrtis nigriniae*	8H-4, 46-48	69.76	0.74
			9H-4, 46-48	79.26	0.83
4	FO	*Pterocanium trilobum*	12H-4, 45-47	107.75	1.10
			13H-4, 46-48	117.26	1.19
5	LO	*Lamprocyrtis heteroporos*	17X-3, 44-46	151.34	1.60
			18X-4, 83-85	162.93	1.74
6	LO	*Lamprocyrtis neoheteroporos*	18X-4, 83-85	162.93	1.74
			18X-CC	163.06	1.75
7	LO	*Cycladophora pliocenica*	21X-4, 46-48	191.46	2.08
			21X-CC	193.47	2.11
8	LO	*Cycladophora sakaii*	24X-CC	223.03	2.30
			25X-4, 46-48	230.16	2.34
9	SA	*Corocalyptra kruegeri*	26X-4, 46-48	239.76	2.40
10	RI	*Actinomma boreale* group	30X-4, 46-48	278.26	2.73
			31X-4, 46-48	287.86	2.91
11	FO/RI	*Cycladophora davisiana*	31X-4, 46-48	287.86	2.91
			31X-CC	289.10	2.93
12	RI	*Cycladophora sakaii*	31X-4, 46-48	287.86	2.91
			32X-4, 46-48	297.46	3.05
13	FO	*Cycladophora sakaii*	36X-CC	328.55	3.17
			35X-CC	328.60	3.17
14	FO	*Amphirhopalum ypsilon*	36X-CC	328.55	3.17
			35X-CC	328.60	3.17
15	LO	*Stichocorys peregrina*	38X-CC	349.23	3.26
			39X-CC	356.49	3.28
16	FO	*Cycladophora pliocenica*	40X-4, 46-48	364.86	3.32
			40X-CC	366.46	3.32
17	SA	*Antarctissa* group	40X-4, 46-48	364.86	3.32
18	LO	*Spirema* sp.	42X-4, 46-48	384.16	3.51
			43X-4, 46-48	393.76	3.67
19	LCO	*Stichocorys* group	46X-4, 30-32	422.50	4.27
			47X-4, 46-48	432.26	4.39
20	FO	*Lamprocyrtis neoheteroporos*	51X-CC	472.75	4.95
			52X-CC	482.40	5.05
21	FO	*Spongurus pylomaticus*	55X-4, 46-48	509.06	5.38
			55X-CC	513.60	5.46

Note: FO = first occurrence, RI = rapid increase, LCO = last common occurrence, LO = last occurrence, SA = short acme.