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14. Quaternary Radiolarians in the Western Woodlark Basin, Southwest Pacific (ODP Leg 180)[1]

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ABSTRACT

Cores from the 11 sites drilled during Leg 180 showed radiolarian assemblages that appear only in the Quaternary sediments. The most diverse and well-preserved assemblages were found in hemipelagic sediments from Holes 1108A, 1110A, and 1115B.

INTRODUCTION

During Ocean Drilling Program (ODP) Leg 180, a transect of 11 sites was drilled in the Western Woodlark Basin (Table T1). The age of the recovered sediments ranges from Miocene to Pleistocene, and radiolarians were found only in a few samples of Pleistocene age. The assemblage consists of 121 taxa. Often the preservation is not very good, as evidenced by thinner tests. Although the data obtained during this study do not allow high stratigraphic resolution, they are nonetheless sufficient to assign the studied sediments to the Pleistocene.

MATERIALS AND METHODS

A preliminary study was carried out on more than 100 sediment samples to verify the presence of radiolarian assemblages and to give a stratigraphic interpretation of the cored sediments.

T1. Geographic location and water depths of Leg 180 holes, p. 13.

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Material from all sites, with the exception of Sites 1113 and 1117, and from all the encountered nonmarine sedimentary facies has been sampled. Sites 1113 and 1117 were not analyzed because they were lacking in sediments.

The result of a pilot study showed that radiolarians were confined exclusively to sediments of Quaternary age. A more detailed study was then carried out on the Quaternary sediments recovered from Holes 1108B, 1109C, 1110A, 1111A, 1112A, 1114A, 1115A, and 1115B. We typically analyzed two samples per core, with a total of 78 studied samples (Table T2).

Radiolarian assemblages, generally poorly preserved, were recovered in only 19 of these samples (Table T3). The general morphology of the specimens and their taxonomic identification were determined using a transmitted light microscope, whereas finer details of the test surface were analyzed by means of a scanning electron microscope.

Samples were prepared from core material according to the following procedure:

1. The sediment was dried in an oven for 5 hr at 100°C.
2. 10 g of dried sediment was placed in a beaker and boiled for 12 hr in diluted (5 parts water to 1 part peroxide) hydrogen peroxide.
3. Diluted (15%) hydrochloric acid (HCl) was added to the sample after it had cooled to room temperature.
4. The residue was sieved (45-µm mesh size).
5. The remaining residue was mixed in a beaker with 100 mL of distilled water and put into suspension. A fixed split (100 mL) of this suspension was taken by a pipette and strewn on a 27 mm × 46 mm coverslip.
6. The coverslip was dried on an hot plate at moderate temperature (30°–40°C) and then fixed to a slide with glycerine.

Because many of the studied samples showed a relevant clay component, the hydrogen peroxide boiling was repeated several times until the radiolarian tests were clean and free of any clay coating.

In some of the most clay-rich samples, dry sodium hexametaphosphate was added to the hydrogen peroxide solution to increase the effectiveness of clay mineral breakdown.

T2. Full designation of studied samples, p. 14.

T3. Distribution of radiolarian taxa, p. 15.

RADIOLARIAN PRESERVATION

Dissolution phenomena resulting in thinning of the radiolarian tests are linked to the various sediments containing them and sometimes to the presence of ash-rich layers.

In particular, the assemblages found in hemipelagic sediments mainly made up of clay or silty clay-bearing nannofossil ooze at the top of Holes 1108B, 1110A (Sample 180-1110A-1H-2, 77–79 cm), and 1115B (Sample 180-1115B-1H-1, 5–7 cm) appear to be the best preserved and the richest in specimens. In some sediments consisting of volcanic ash layers (Sample 180-1109C-3H-1, 49–50 cm), silty clay with volcanic ash (Sample 180-1109C-4H-1, 58–60 cm), and silty clay (Sample 180-1109C-6H-5, 24–26 cm), very few and poorly preserved specimens were found.

In samples made up mainly of silty clay in Holes 1111A and 1112A, the assemblages show an intermediate state of preservation compared to those described above.

In conclusion, we observed that usually under the same textural conditions in samples where ash layers are present (i.e., Sample 180-1115B-2H-4, 145–147 cm), test preservation is poor.

QUATERNARY RADIOLARIAN ZONATION

The radiolarian zonal scheme and code numbers adopted in this study (Sanfilippo and Nigrini, 1998) have been integrated with other published radiolarian zonations and their chronological interpretation (Nigrini, 1971; Caulet et al., 1993; Shackleton et al., 1995).

The Pleistocene epoch has been subdivided into five radiolarian biozones (Sanfilippo and Nigrini, 1998):

RN17: *Buccinosphaera invaginata* Taxon-Range Zone (Nigrini, 1971), defined by the range of *B. invaginata*.

RN16: *Collosphaera tuberosa* Interval Zone (Nigrini, 1971; emend. Caulet, 1979). The top is defined by the first morphotypic occurrence (FO) of *B. invaginata* and the base by the last morphotypic occurrence (LO) of *Stylatractus universus*.

RN15: *S. universus* Concurrent Range Zone (Caulet,1979; renamed by Johnson et al., 1989). The top is defined by the LO of *S. universus* and the base by the FO of *C. tuberosa*.

RN14: *Amphirhopalum ypsilon* Interval Zone (Nigrini, 1971). The top is defined by the FO of *C. tuberosa* and the base by the LO of *Anthocyrtidium angulare*.

RN13: *A. angulare* Interval Zone (Nigrini, 1971). The top is defined by the LO of *A. angulare* and the base by the LO of *Pterocanium prismatium*.

LEG 180 RADIOLARIAN BIOSTRATIGRAPHY

Zonal assignments for each of the studied samples is reported in Table **T4**.

T4. Radiolarian biozone assignments, p. 18.

Below, we discuss the occurrence and/or the absence of radiolarian species that can be used as stratigraphic markers in each of the studied samples. However, our sampling spacing is too broad to carry out a detailed stratigraphic study. Moreover, the paucity of radiolarian specimens in some of the samples could lead to the wrong inferences when interpreting the absence of a certain stratigraphically relevant taxon, as many of these taxa are rare even in well-preserved material.

Hole 1108B

Sample 180-1108B-1R-1, 10–12 cm, contains *C. tuberosa,* which constrains the age of this sample to the late Quaternary (*S. universus* Zone and younger).

The occurrence of *C. tuberosa* and the absence of both *B. invaginata* and *S. universus* would place this sample in the *C. tuberosa* Zone RN16 itself, spanning from 0.42 to 0.18 Ma (Johnson et al., 1989). However, because of the sparseness of the assemblage, a broader, late Quaternary age determination is suggested.

The scant assemblage contained in the lower sample of this core (Sample 180-1108B-1R-2, 50–52 cm) and the absence of any stratigraphic markers hindered the possibility to assign it to any radiolarian zone.

Hole 1109C

The only three samples containing radiolarians have abundances that are too scarce to allow for any zonal assignment.

Hole 1110A

The presence of *C. tuberosa* in Sample 180-1110A-2H-1, 58–62 cm, and the absence of *B. invaginata* and *S. universus* from Samples 1H-2, 77–79 cm, and 2H-1, 58–62 cm, leads us to assign these samples to Zone RN16 (see also **"Hole 1108B,"** p. 3). As for Sample 180-1110A-2H-1, 81–85 cm, there are no data available for any zonal assignment.

Hole 1111A

The presence of *Theocorythium trachelium* in all but one of the studied samples indicates a Quaternary age for all of them. In fact, this taxon is found in variable abundances at the base of the Quaternary in the tropical Pacific, whereas it is essentially absent at the top of the Pliocene (Nigrini, 1971).

More recently, Shackleton et al. (1995) assigned a 1.55-Ma age to the first appearance of *T. trachelium*.

The tests of *A. ypsilon* present in Samples 180-1111A-14R-1, 60–62 cm, and 14R-3, 62–64 cm, are characterized by the presence of four to five chambers before the branching of the arms. These morphotypes have been considered by Nigrini (1971) as being typical for the late Quaternary.

Based on this consideration, we assign a late Quaternary age to the latter two samples.

Hole 1112A

The only stratigraphically significant species recognized at this site is *Lamprocyrtis nigriniae*.

As Shackleton et al. (1995) date the first appearance of *L. nigriniae* at 1.23 Ma, the presence of this taxon indicates a Quaternary age for the only sample in which radiolarians were present (Sample 180-1112A-1R-1, 100–101 cm).

Hole 1115A

No radiolarian tests were observed in any of the studied samples.

Hole 1115B

T. trachelium was found in the two upper samples (Samples 180-1115B-1H-1, 5–7 cm, and 2H-4, 145–147 cm), therefore indicating a Pliocene or a Quaternary age.

A. ypsilon was also found in Sample 180-1115B-1H-1, 5–7 cm, narrowing its age to the late Quaternary (see **"Hole 1111A,"** p. 4). This conclusion is also supported by the presence of *Pterocorys hertwigii* in the same sample, as the FO of this taxon takes place in the *A. ypsilon* Zone (Sanfilippo and Nigrini, 1998).

The presence of *A. ypsilon* in Sample 180-1115B-3H-2, 58–60 cm, indicates an age ranging from early Pliocene to present, as this species has its first occurrence within the *Phormostichoartus doliolum* Zone (Sanfilippo and Nigrini, 1998) and is still extant.

No stratigraphically significant taxa have been observed in Samples 180-1115B-4H-6, 66–68 cm, and 5H-1, 19–21 cm.

RADIOLARIAN FAUNAL LIST

An alphabetically sorted list of the radiolarian taxa recognized in this study follows.

Additional pictures and synonymies for most of the taxa in the following list are reported in Nigrini (1967, 1968, 1970, 1977), Goll (1968, 1969, 1976), Riedel and Sanfilippo (1971, 1978), Nigrini and Moore (1979), and Boltovskoy and Riedel (1980).

Given the less-than-optimal preservation of the studied material, some of the observed taxa were classified only at genus or family level.

Acanthosphaera actinota (Haeckel, 1860b)

Acrosphaera spinosa (Haeckel, 1860a) (Pl. **P1,** fig. 1)

Actinomma spp.

Actinomma boreale (Cleve, 1899)

Actinomma haysi Bjøklund, 1976

Actinomma leptoderma (Jørgensen, 1900)
Remarks: Synonyms and additional taxonomic information in Cortese and Bjørklund (1998b)

Actinomma sol Cleve, 1899
Remarks: See also Boltovskoy and Riedel (1980).

Amphirhopalum ypsilon Haeckel, 1887 (Pl. **P1,** fig. 2)

Amphisphaera spp.

Anthocyrtidium ophirense (Ehrenberg, 1872)

Anthocyrtidium zanguebaricum (Ehrenberg, 1872)

Arachnocorys umbellifera (Haeckel, 1887)

Artostrobus annulatus (Bailey, 1856)

Artostrobus joergenseni Petrushevskaya, 1971

Botryocyrtis scutum (Harting, 1863) (Pl. **P1,** fig. 3)

Botryopyle cribrosa (Popofsky, 1913)

Botryostrobus aquilonaris (Bailey, 1856)

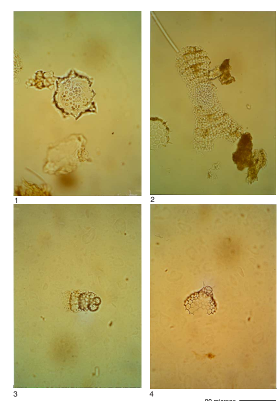
Botryostrobus auritus/australis (Ehrenberg, 1844)

Callimitra spp.

Carpocanarium papillosum (Ehrenberg, 1872)

Carpocanistrum spp.
Remarks: For a definition of this morphotype see Riedel and Sanfilippo (1971); Nigrini and Moore (1979).

Cladoscenium spp.



P1. Radiolarians from Leg 180, p. 19.

Clathrocanium coarctatum Ehrenberg, 1860

Clathrocanium reginae Haeckel, 1887

Collosphaera spp.

Collosphaera macropora Popofsky, 1917

Collosphaera tuberosa Haeckel, 1887

Cornutella profunda Ehrenberg, 1858 (Pl. **P1,** fig. 5)

Cycladophora bicornis (Popofsky, 1908) (Pl. **P1,** fig. 4)

Cycladophora davisiana (Ehrenberg) *cornutoides* (Petrushevskaya, 1967)

Cycladophora davisiana (Ehrenberg) *davisiana* (Petrushevskaya, 1967).

Cyrtolagena laguncula Haeckel, 1887

Dictyocoryne profunda Ehrenberg, 1860

Dictyocoryne truncatum (Ehrenberg, 1861)
Remarks: Transitional forms between *Dictyocoryne truncatum* and *Euchitonia* spp. have been observed and counted as *Dictyocoryne truncatum*. Further details in Van de Paverd (1995).

Dictyophimus spp.

Dictyophimuscrisiae Ehrenberg, 1854
Remarks: *Dictyophimus hirundo* (Haeckel, 1887) has also been included.

Didymocyrtis tetrathalamus (Haeckel, 1887)

Dorydruppa bensoni Takahashi, 1991

Druppatractus irregularis (Bailey, 1856)

Eucecryphalus gegenbauri Haeckel, 1860a

Euchitonia spp.
Remarks: This taxon includes those specimens lacking complete arms, which were therefore not possible to identify at a species level.

Euchitonia elegans (Ehrenberg, 1872)

Euchitonia furcata Ehrenberg, 1872 (Pl. **P1,** fig. 6)

Eucyrtidium spp.

Eucyrtidium acuminatum (Ehrenberg, 1844)

Eucyrtidium anomalum (Haeckel, 1860a) (Pl. **P1,** fig. 7)

Eucyrtidium hexagonatum Haeckel, 1887

Eucyrtidium teuscheri Haeckel *teuscheri* Caulet, 1986

Giraffospyris angulata (Haeckel, 1887)

Heliodiscus asteriscus Haeckel, 1887

Hexacontium spp.

Hexacontium enthacanthum Jørgensen, 1900

Hexacontium laevigatum Haeckel, 1887

Hexacontium pachydermum Jørgensen, 1900
Remarks: This genus was emended by Cortese and Bjørklund (1998a). In Sample 180-1112A-1R-1, 100–101 cm, the three specimens assigned to this species had a cortical shell diameter >130 µm, therefore bigger than the typical *H. pachydermum* as defined by Jørgensen. They could therefore represent a different low-latitude morphotype. We, however, include them in this taxon, as all the other taxonomic characters coincide.

Hexacontium pythagoraea (Haeckel, 1887)

Hexapyle dodecantha Haeckel, 1887

Hexastylus spp.

Hymeniastrum euclidis (Haeckel, 1887)

Lamprocyclas maritalis maritalis Haeckel, 1887 (Pl. **P1,** fig. 8)

Lamprocyrtis nigriniae (Caulet, 1971)

Larcoidea spp.

Larcopyle bütschlii Dreyer, 1889

Larcospira quadrangula Haeckel, 1887

Liriospyris reticulata (Ehrenberg, 1872)

Litharachnium tentorium Haeckel, 1860a

Lithelius minor Jørgensen, 1899

Lithobotrys inflatum Bailey, 1856

Lithocampe furcaspiculata Popofsky, 1908

Lithocampe platycephala (Ehrenberg, 1872)

Lithomelissa setosa Jørgensen, 1900

Lithomelissa thoracites Haeckel, 1862

Lophophaena bütschlii (Haeckel, 1887)

Lophophaena hispida (Ehrenberg, 1872)

Lophospyris pentagona pentagona (Ehrenberg, 1872)

Otosphaera polymorpha Haeckel, 1887

Peridium longispinum Jørgensen, 1900

Peripyramis circumtexta Haeckel, 1887

Peromelissa phalacra Haeckel, 1887

Phormospyris stabilis scaphipes (Haeckel, 1887)

Phormospyris stabilis stabilis (Goll, 1968)

Phormostichoartus corbula (Harting, 1863)

Porodiscus sp.
Remarks: similar to *Porodiscus* sp. A in Nigrini and Moore (1979).

Pseudodictyophimus gracilipes (Bailey, 1856)

Pterocanium praetextum (Ehrenberg, 1872) *eucolpum* (Haeckel, 1887)

Pterocanium praetextum praetextum Ehrenberg (1872) (Pl. **P1,** fig. 9)

Pterocanium spp.

Pterocanium trilobum (Haeckel, 1860a)

Pterocorys clausus (Popofsky, 1913)
Remarks: *Pterocorys zancleus* (Müller) has also been included.

Pterocorys hertwigii (Haeckel, 1887)

Pterocorys minythorax (Nigrini, 1968)

Pylospira octopyle (Haeckel, 1887

Rhizoplegma boreale (Cleve, 1899)

Siphocampe arachnea (Ehrenberg, 1838)

Siphocampe lineata (Ehrenberg, 1838)

Siphocampe nodosaria (Haeckel, 1887)

Siphonosphaera polysiphonia Haeckel, 1887

Spongaster tetras tetras Ehrenberg, 1860 (Pl. **P1,** fig. 10)

Spongocore puella Haeckel, 1887 (Pl. **P1,** fig. 11)

Spongodiscus resurgens Ehrenberg, 1854

Spongopyle osculosa Dreyer, 1889 (Pl. **P1,** fig. 12)

Spongotrochus glacialis Popofsky, 1908

Spongurus(?) sp. Petrushevskaya, 1967
Remarks: For descriptions and pictures see Petrushevskaya (1967) and Ling et al. (1971).

Songurus ellipticus (Ehrenberg, 1872)

Spongurus pylomaticus Riedel, 1958

Spirocyrtis scalaris Haeckel, 1887

Stylatractus spp.
Remarks: Described by Nigrini and Moore (1979) as *Stylatractus* sp. and by Boltovskoy (1998) as *Stylatractus* spp. group.

Stylochlamydium asteriscus Haeckel, 1887

Stylochlamydium venustum (Bailey, 1856)

Stylodictya aculeata Jørgensen, 1905

Stylodictya validispina Jørgensen, 1905

Tessarastrum straussi Haeckel, 1862

Tetrapyle octacantha Müller, 1858
Remarks: *Octopyle stenozona* Haeckel has also been included.

Theocorys veneris Haeckel, 1887

Theocorythium trachelium (Ehrenberg, 1872)

Theopylium tricostatum Haeckel, 1887

Tholospyris tripodiscus Haeckel, 1887

Trissocyclidae spp.
Remarks: This taxon includes all nassellarians having a sagittal ring and not included in any other species-level taxon.

Zygocircus productus (Hertwig, 1879)
Remarks: *Tholospyris* sp. Takahashi and Honjo (1981) has also been included.

CONCLUSIONS

Radiolarian assemblages are mainly localized in the Quaternary upper portions of the recovered cores at Sites 1108, 1109, 1110, 1111, 1112, and 1115.

Considering the less-than-optimal preservation for many of the samples studied, we cannot perform a detailed stratigraphic zonation. With regard to the poor test preservation, even if we believe that it is due to secondary dissolution processes considering the uniformity of the phenomenon on the entire test surface, we could even suppose that the test thinness is original and due to silica scarcity in the living environment, as we observe at present in tropical areas.

We also point out that the best-preserved specimens were recovered in hemipelagic sediments rich in calcareous nannoplankton; this could lead one to suppose a preserving action linked to sedimentation velocity and to "proofing" induced by these sediments.

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Table T1. Geographic location and water depth of ODP Leg 180 drilled holes.

Hole	Latitude (S)	Longitude (E)	Water depth (m)
180-			
1108A	9°44.708′	151°37.514′	3162.7
1108B	9°44.724′	151°37.543′	3177.2
1109A	9°30.390′	151°34.388′	2210.9
1109B	9°30.396′	151°34.391′	2211.0
1109C	9°30.392′	151°34.390′	2211.0
1109D	9°30.380′	151°34.355′	2211.0
1110A	9°43.599′	151°34.511′	3246.4
1110B	9°43.609′	151°34.509′	3246.3
1110C	9°43.599′	151°34.498′	3245.8
1110D	9°43.588′	151°34.526′	3245.8
1111A	9°43.059′	151°34.533′	3200.7
1112A	9°44.749′	151°36.721′	3046.7
1112B	9°44.746′	151°36.714′	3046.6
1113A	9°45.449′	151°36.737′	2915.6
1114A	9°47.613′	151°34.504′	406.5
1115A	9°11.389′	151°34.450′	1149.6
1115B	9°11.382′	151°34.437′	1148.8
1115C	9°11.383′	151°34.422′	1148.7
1116A	9°51.934′	151°34.508′	1851.3
1117A	9°46.526′	151°32.945′	1663.2
1117B	9°46.527′	151°32.951′	1663.2
1117C	9°46.520′	151°32.943′	1663.2
1118A	9°35.110′	151°34.421′	2303.6

Table T2. Full designation of the studied samples.

Core, section, interval (cm)	Depth (mbsf)
180-1108B-	
1R-1, 10–12	0.1
1R-2, 50–52	1.5
8R-1, 18–20	62.88
8R-1, 55–57	63.25
9R-1, 20–22	72.5
9R-1, 101–103	73.31
9R-1, 115–117	73.45
10R-1, 80–82	82.7
14R-1, 73–75	120.93
14R-2, 67–69	122.03
15R-2, 35–37	130.98
15R-2, 85.5–87	131.49
16R-2, 30–32	141.2
16R-2, 104–105	141.94
180-1109C-	
2H-2, 43–45	9.33
2H-4, 37–39	12.27
3H-1, 40–42	17.30
3H-1, 49.5–50.5	17.40
3H-6, 104–106	25.44
4H-1, 58–60	26.98
4H-4, 83.5–86	31.74
5H-3, 85–86	39.75
5H-5, 29–31	42.19
6H-5, 24–26	51.64
7H-3, 23–25	58.13
7H-4, 118–120	60.58
8H-6, 126–126	73.16
9H-7, 50–52.5	83.4
10H-5, 13–15	89.53
11H-6, 81–83	101.21
12X-4, 80–82	107.70
12X-6, 74–76	110.64
13X-5, 38–40	118.38
14X-1, 7.5–10	121.68
16X-4, 59–60	145.89
20X-4, 43–45	184.23
23X-7, 60–62	216.35
180-1110A-	
1H-2, 77–79	2.27
1H-4, 94–96	5.44
2H-1, 58–62	7.58
2H-1, 81–85	7.81

Core, section, interval (cm)	Depth (mbsf)
180-1111A-	
8R-1, 77–81	68.47
8R-3, 29–31	70.99
11R-1, 44–46	97.14
13R-2, 21–23	117.37
14R-1, 60–62	126.4
14R-3, 62–64	129.42
15R-1, 38–40	135.78
16R-1, 5–7	145.05
180-1112A-	
1R-1, 100–101	1.00
180-1114A-	
1R-CC, 23–25	0.23
4R-1, 5–7	26.25
180-1115A-	
1H-2, 5–7	0.33
1H-4, 4.5–6.5	3.05
180-1115B-	
1H-1, 5–7	0.05
1H-1, 27–29	3.27
2H-4, 145–147	13.15
2H-6, 130–132	16.00
3H-2, 58–60	18.78
4H-4, 59–62	31.29
4H-6, 66–68	34.36
5H-1, 19–21	35.89
5H-4, 70–72	40.9
6H-2, 53–55	47.23
6H-5, 55–57	51.75
6H-7, 39–43	54.59
7H-4, 77–79	59.97
7H-6, 78–80	62.98
8H-3, 111–113	68.31
8H-6, 17–19	71.87
9H-1, 5–7	73.75
9H-3, 64–66	77.34
10H-7, 14–16.5	92.34
11H-3, 21–23	95.91
11H-5, 8–15	98.78
11H-7, 9–11	101.79
12H-1, 17–19	102.37
12H-4, 33–35	107.03

Table T3. Distribution of radiolarian taxa in Holes 1108B, 1109C, 1110A, 1111A, 1112A, and 1115B. (See table note. Continued on next two pages.)

Core, hole:	180-1108B-		180-1109C-			180-1110A-			180-1111A-					180-1112A-	180-1115B-				
Section, interval (cm):	1R-1, 10–12	1R-2, 50–52	3H-1, 49–50	4H-1, 58–60	6H-5, 24–26	1H-2, 77–79	2H-1, 58–62	2H-1, 81–85	11R-1, 44–46	14R-1, 60–62	14R-3, 62–64	15R-1, 38–40	16R-1, 5–7	1R-1, 100–101	1H-1, 5–7	2H-4, 145–147	3H-2, 58–60	4H-6, 66–68	5H-1, 19–21
Acanthosphaera actinota																			
Acrosphaera spinosa	R	R						R	R	R	R	R		R	R		R	R	
Actinomma spp.	+	R		+						R				R	R			R	+
Actinomma boreale						R													
Actinomma haysi						+													
Actinomma leptoderma	+																		
Actinomma sol	+					R			R		+	+						+	
Amphirhopalum ypsilon	R									R	R				+		R		
Amphisphaera sp.						+													
Anthocyrtidium ophirense	R																R		
Anthocyrtidium zanguebaricum	+								+										
Arachnocorys umbellifera													R		R				
Artostrobus annulatus													+						
Artostrobus joergenseni						+							+				+		
Botryocyrtis scutum	C	F	+			A		C	C	F	C	C	F	R	F	+	C	+	
Botryopyle cribrosa	+	+										R	R		+		+		
Botryostrobus spp.	+	+												R					
Botryostrobus aquilonaris	+										+	R	+						
Botryostrobus auritus/australis	F					F		R			R	+	R		+		F		
Callimitra spp.	+																		
Carpocanarium papillosum	R	+				R		R	+		R	R	R	R	R		R		
Carpocanistrum spp.	R	+				F		F	F	R	F	R	F	R	+		R		
Cladoscenium spp.						+			+		+				+		R		
Clathrocanium coarctatum															+				
Clathrocanium reginae	+																		
Collosphaera spp.	+	R	+					F	F	R	R	R	R	R		+		+	R
Collosphaera macropora	+																		
Collosphaera tuberosa	+						+												
Cornutella profunda	C	R				F		R	R		R		F	+	R		R	+	
Cycladophora bicornis	R	+				F		+	R	R		R	R		R		F		
Cycladophora davisiana cornutoides									R		+	R							
Cycladophora davisiana davisiana								+	+	R		F	R						
Cyrtolagena laguncula	+	+							+				+	+	+				
Dictyocoryne profunda	R	R				+		R	R	+	+			R	R		+		
Dictyocoryne truncatum	F	R	+			R		R	R	R	F	F	+	R	R		F		
Dictyophimus spp.	R	R				R		R	R	R	R		R	R	R	+	R		
Dictyophimus crisiae		+						+	+		R		+	R	R	+	R		
Didymocyrtis tetrathalamus	C	F	+			F		C	+	R	C	F	F	C	F		F	R	
Dorydruppa bensoni						+								+			R		
Druppatractus irregularis													+				R		
Eucecryphalus gegenbauri	R									+		+	R		R	+	+		
Euchitonia spp.	R	F	+			F		F	F	F	F	R	+	F	R	+	R		
Euchitonia elegans	+	R				R		R	R		+	+	+	+	R	R	R		
Euchitonia furcata	C	F				C		C	F	R	C	F	R	F	R	R	F		
Eucyrtidium spp.						R				R									
Eucyrtidium acuminatum	R	+									R		R		+		+		
Eucyrtidium anomalum								+											

Table T3 (continued).

Core, hole:	180-1108B-		180-1109C-			180-1110A-			180-1111A-					180-1112A-	180-1115B-				
Section, interval (cm):	1R-1, 10–12	1R-2, 50–52	3H-1, 49–50	4H-1, 58–60	6H-5, 24–26	1H-2, 77–79	2H-1, 58–62	2H-1, 81–85	11R-1, 44–46	14R-1, 60–62	14R-3, 62–64	15R-1, 38–40	16R-1, 5–7	1R-1, 100–101	1H-1, 5–7	2H-4, 145–147	3H-2, 58–60	4H-6, 66–68	5H-1, 19–21
Eucyrtidium hexagonatum	R									+							R		
Eucyrtidium teuscheri teuscheri	R																		
Giraffospyris angulata	R	R		+		+		R	R						R	+	R	+	
Heliodiscus asteriscus	+									R	+	+					R		
Hexacontium spp.	R					R		+	R			R			R		R		
Hexacontium enthacanthum												+	R						
Hexacontium laevigatum	+																		
Hexacontium pachydermum								+						R			R		
Hexacontium pythagoraea						+													
Hexapyle dodecantha	R					R		+	+	R	R	R		R	R		R	+	
Hexastylus spp.	+																		
Hymeniastrum euclidis	R	+				+		R	+	R	R	+		+		+	F		
Lamprocyclas maritalis maritalis	+							+							+			+	
Lamprocyrtis nigriniae														+					
Larcoidea spp.	F	R				A		F	C	C	C	C	C	F	C		C		
Larcopyle bütschlii	R	+						R	R		+	+			R		F		
Larcospira quadrangula	R							+				+			R		+		
Liriospyris reticulata	+																		
Litharachnium tentorium	+	+						R				R	R		+		+		
Lithelius minor	+																		
Lithobotrys inflatum	R												R						
Lithocampe furcaspiculata									+								R		
Lithocampe platycephala	+					+		+			R								
Lithomelissa setosa						+						+					+		
Lithomelissa thoracites	C	R				F		F	R	R	F	F	C	R	R	+	F	+	
Lophophaena bütschlii	R							R		R		+	R				+		
Lophophaena hispida	F	R				R		R	R	R	R	R	F	+	R	R	+		
Lophospyris pentagona pentagona	+														+				
Otosphaera polymorpha	+																		
Peridium longispinum	+	+				+							R		+		R		
Peripyramis circumtexta	+																		
Peromelissa phalacra	F					R		R	R	R	R	+	C	R					
Phormospyris stabilis scaphipes	+																+		
Phormospyris stabilis stabilis															+				
Phormostichoartus corbula	+											+		+					
Porodiscus sp.		R				R		R	R	+	R	R		R	R	+	F		
Pseudodictyophimus gracilipes													R						
Pterocanium spp.		+									R		+		+	+			
Pterocanium praetextum praetextum	+					R		R							R		R		
Pterocanium praetextum eucolpum								R					R				+		
Pterocanium trilobum	R	+						+					+		+		R		
Pterocorys clausus/zancleus	C	R				F		F	R	R	F	F	C	R	C	R	F		
Pterocorys hertwigii															+				
Pterocorys minithorax									+								+		
Pylospira octopyle	+	R				+		R	R	R	R	R		R	R	+	R	+	
Rhizoplegma boreale						+													
Siphocampe arachnea								+					R						
Siphocampe lineata									R				+						

Table T3 (continued).

Core, hole:	180-1108B-		180-1109C-			180-1110A-			180-1111A-					180-1112A-	180-1115B-				
Section, interval (cm):	1R-1, 10–12	1R-2, 50–52	3H-1, 49–50	4H-1, 58–60	6H-5, 24–26	1H-2, 77–79	2H-1, 58–62	2H-1, 81–85	11R-1, 44–46	14R-1, 60–62	14R-3, 62–64	15R-1, 38–40	16R-1, 5–7	1R-1, 100–101	1H-1, 5–7	2H-4, 145–147	3H-2, 58–60	4H-6, 66–68	5H-1, 19–21
Siphocampe nodosaria						R			+				+						
Siphonosphaera polysiphonia	+					+		+			+								
Spongaster tetras tetras	+					+		R	R	R	R	+	R	R	R		F		
Spongocore puella	R							+		R	+	+		+	R		R		
Spongodiscus resurgens	R	F		+		F		F	F	F	F	F	R	F	F		C		
Spongopyle osculosa	R	+				R		R		R	R	+			R		+		
Spongotrochus glacialis	F	R				R			R	R	R	R		R			+		
Spongurus (?) sp.		+				+		+	R		R	+			+				
Spongurus ellipticus		+				+		R			R	+	+				+		
Spongurus pylomaticus												+					+		
Spirocyrtis scalaris	R														+				
Stylatractus spp.	R	R						R			R	R							
Stylochlamydium asteriscus	F	+		+		+		+	+	R	R	R	R		R		R		
Stylochlamydium venustum	+	+				F		+	+	R	R	R	R		F		F		
Stylodictya aculeata	F	+				F		R	F	F	F	R	R	R	R	R	C	+	
Stylodictya validispina	+	R	+			R		R	F	R	C	C	R	R	F	R	F	R	
Tessarastrum straussi											+						+		
Tetrapyle octacantha	A	A	R	R		A		A	A	A	A	A	A	A	A	R	A	R	
Theocorys veneris	+					R		+	R	+	+	+	R		R		R		
Theocorythium trachelium									R		+	R	R		+	+			
Theopylium tricostatum	+										+		+		R				
Tholospyris tripodiscus	+								+						+				
Trissocyclidae spp.	R	R				F		R	R	R	R	+	R	R	R		F	R	
Zygocircus productus	R	C	+	+	+	F		C	C	C	R	F	F	F	F	F	F	R	
Spumellaria indet.	F	A	R	R	+	C	R	C	A	A	A	A	C	C	C	F	A	R	+
Nassellaria indet.	R	C	+			F	+	C	C	C	C	F	C	C	C	F	C	R	

Note: + = single specimen, R = rare (2–5), F = few (6–10), C = common (11–25), A = abundant (>25) specimens per 27 mm × 46 mm slide.

Table T4. Radiolarian biozone assignments for the dated samples.

Biozones (Sanfilippo and Nigrini, 1998)		Basal Zone age (Johnson et al., 1989)	Basal Zone age (Caulet et al., 1993)	Basal Zone age (Shackleton et al., 1995b)	180-1108B-	180-1110A-	
					1R-1, 10–12 cm	1H-2, 77–79 cm	2H-1, 58–62 cm
RN17 - *Buccinosphaera invaginata*	Taxon-Range Zone	0.18			█		
RN16 - *Collosphaera tuberosa*	Interval Zone		0.42	0.42	█	█	█
RN15 - *Stylatractus universus*	Concurrent Range Zone		0.47	0.61	█		
RN14 - *Amphiropalum ypsilon*	Interval Zone		1.10	1.12			
RN13 - *Anthocyrtidium angulare*	Interval Zone		1.65	1.74			

Note: The biostratigraphic scheme (Sanfilippo and Nigrini, 1998) and the age assignments for the base of each biozone (Johnson et al., 1989; Caulet et al., 1993; Shackleton et al., 1995) are also shown.

Table T4 (continued).

Biozones (Sanfilippo and Nigrini, 1998)		180-1111A-					180-1112A-	180-1115B-		
		11R-1, 44–46 cm	14R-1, 60–62 cm	14R-3, 62–64 cm	15R-1, 38–40 cm	16R-1, 5–7 cm	1R-1, 100–101 cm	1H-1, 5–7 cm	2H-4, 145–147 cm	3H-2, 58–60 cm
RN17 - *Buccinosphaera invaginata*	Taxon-Range Zone	█	█	█	█	█	█	█	█	█
RN16 - *Collosphaera tuberosa*	Interval Zone	█	█	█	█	█	█	█	█	█
RN15 - *Stylatractus universus*	Concurrent Range Zone	█	█	█	█	█	█	█	█	█
RN14 - *Amphiropalum ypsilon*	Interval Zone				█	█	█		█	█
RN13 - *Anthocyrtidium angulare*	Interval Zone									

Plate P1. Radiolarians from Leg 180. All are at 315×. **1.** *Acrosphaera spinosa* (Sample 180-1108B-1R-1, 10–12 cm). **2.** *Amphirhopalum ypsilon* (Sample 180-111A-14R-1, 60–62 cm). **3.** *Botryocyrtis scutum* (Sample 180-1110A-1H-2, 77–79 cm). **4.** *Cycladophora bicornis* (Sample 180-1115B-3H-2, 58–60 cm). (Continued on next two pages.)

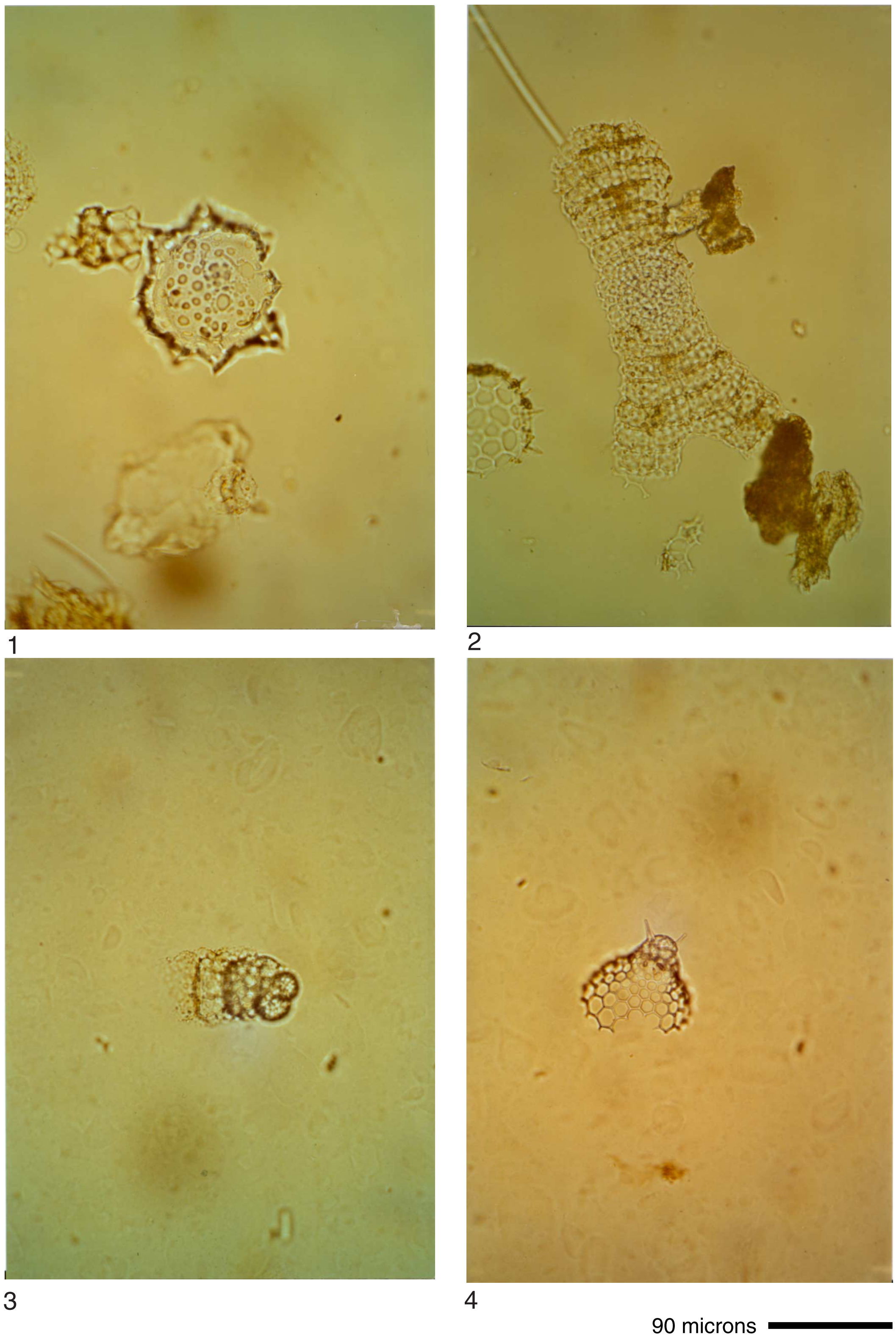


Plate P1 (continued). **5.** *Cornutella profunda* (Sample 180-1108B-1R-1, 10–12 cm). **6.** *Euchitonia furcata* (Sample 180-1108B-1R-2, 50–52 cm). **7.** *Eucyrtidium anomalum* (Sample 180-1110A-2H-1, 81–85 cm). **8.** *Lamprocyclas maritalis maritalis* (Sample 180-1108B-1R-1, 10–12 cm).

5

6

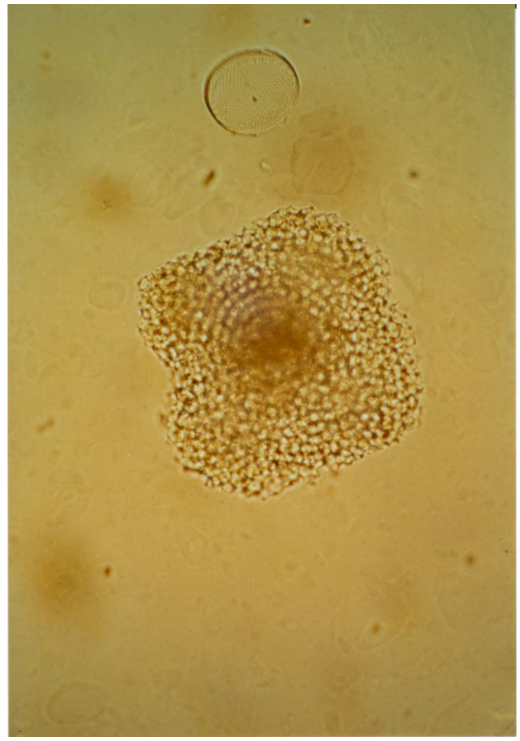
7

8

90 microns

Plate P1 (continued). **9.** *Pterocanium praetextum praetextum* (Sample 180-1115B-1H-1, 5–7 cm). **10.** *Spongaster tetras tetras* (Sample 180-1111A-1R-1, 44–46 cm). **11.** *Spongocore puella* (Sample 180-1108B-1R-1, 10–12 cm). **12.** *Spongopyle osculosa* (Sample 180-1110A-1H-2, 77–79 cm).


9


10


11


12

90 microns