News of Osaka Micropaleontologists (NOM), Special Volume, no. 14, p. 91 – 108, Feb., 2009
ISSN 0287– 0436

Polycystine radiolarian assemblages from IODP Expedition 306 Site U1313 and Site U1314, a preliminary result

HATAKEDA Kentaro[1)] and Kjell R. BJØRKLUND[2)]

1) Institute of Geology and Paleontology, Graduate School of Science, Tohoku University, Sendai 980-8578, Japan
2) Natural History Museum, Department of geology, University of Oslo, PO Box 1172 Blindern, 0318 Oslo, Norway

(Recieved January 18, 2008; 1st review finished January 27, 2008; Accepted February 13, 2008)

Abstract

Late Pliocene-Pleistocene radiolarian faunal compositions showed significant differences between the middle latitude North Atlantic Site U1313 (41°N, 32°W) and U1314 (56°N, 27°W). At Site U1313, tropical-subtropical species were commonly observed throughout the studied interval, indicating that the radiolarian assemblages at this site generally had a warm water affinity, but species used for the low latitude radiolarian biostratigraphy were not recognized. On the other hand, radiolarian assemblages at Site U1314 (56°N, 27°W) were characterized by absence of typical warm water species and common-abundant occurrences of cold water species, showing more similar oceanographic conditions to the Norwegian Sea than Site U1313.

Introduction

The North Atlantic Ocean is one of the most climatically significant regions in the world as the source area of deep water formation. Reducing or increasing the North Atlantic Deep Water (NADW) flow has affected the global climate changes, including glacial-interglacial cycles. Therefore, many biostratigraphic and paleoceanographic studies have previously be done in the North Atlantic using faunal assemblages and/or chemical analysis of microfossils. One of these microfossil groups, polycystine radiolaria, has also been reported from recent materials and deep sea sediments in the North Atlantic. In the high latitude North Atlantic, Bjørklund (1976) illustrated the Quaternary radiolarians from the Iceland Plateau (DSDP Leg 38 Site 349; 69° 12'N, 8° 06'W), and 56 species obtained from Plankton samples in the Norwegian fjord (Jørgensen, 1905). The Holocene radiolarian assemblages were also obtained from the surface sediments in the Greenland-Iceland-Norwegian Sea and totally 114 species were was recognized in the Norwegian-Iceland-Greenland Seas (Bjørklund et al., 1998; Cortese et al., 2003). In the Tropical North Atlantic Takahashi (1991) indicated 208 radiolarian taxa including Phaeodaria from Station E (13° 30'N, 54° 00'W), and Boltovskoy et al. (1996) at station CB1 (22,55°N, 19,44°W) identified 145 polycystine taxa from plankton samples. However, detailed faunal compositions and their stratigraphic occurrences in the mid-latitude regions have not been well understood. Goll and Bjørklund (1971) exhibited geographic distributions of eight species from the recent sediments (11° S-63° N), and Petrushevskaya (1971) described several nassellarian species from plankton samples, but these studies could not provide a satisfactory explanation of modern geographic distribution of radiolaria in the North Atlantic. The late Neogene and Quaternary radiolarian assemblages have been obtained from DSDP and ODP materials in the North Atlantic (Benson, 1972; Petrushevskaya and Kozlova, 1972; Labrachrie, 1984; Westberg-Smith and Riedel, 1985; Westberg-Smith et al., 1986). However, these reports do not have enough illustrations and species descriptions to understand the detailed radiolarian faunal compositions.

The well preserved radiolarian assemblages were obtained from the middle latitude North Atlantic Site U1313 (41° 00'N, 32° 57'W) and Site U1314 (56° 22'N, 27° 53'W) drilled during IODP Expedition 306 (Shipboard Scientific Party, 2006).

To retrieve the significant radiolarian taxa for detailed paleoceanographic reconstruction and to provide a general data on radiolarian faunal province in the North Atlantic, species-level faunal compositions for Site U1313 and Site U1314 were examined based on Core Catcher (CC) samples (nine from Site U1313 and 28 from Site U1314). These data were compared with previously reported radiolarian assemblage from tropical North Atlantic (Takahashi, 1991; Boltovskoy et al., 1996) and Norwegian Sea (Bjørklund, 1976; Bjørklund et al., 1998; Cortese et al., 2003).

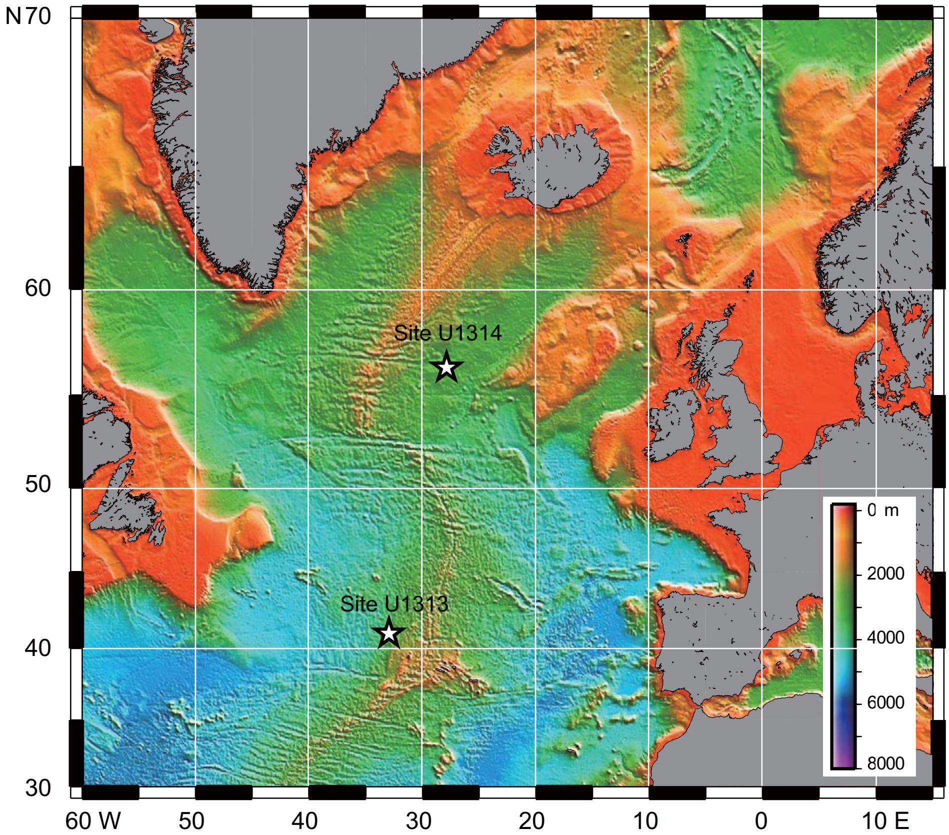


Fig. 1. Location map with the position of Site U1314 (56° 22'N, 27° 53'W) and surface water current.

Geologic setting

IODP Site U1313 (41°N, 32°W) is located at the base of the upper flank of the Mid-Atlantic Ridge in water depth of 3426 m (Fig. 1). Holocene to uppermost Miocene sediments were recovered from three holes (Hole U1313A, B and C) and Holocene to upper Pliocene sediments from Hole U1313D at this site (Fig. 2). Total cored intervals were 0-308.42 mbsf at Hole U1313A, 0-302.52 mbsf at Hole U1313B, 0-293.33 mbsf at Hole U1313C and 0-153.0 mbsf at Hole U1313D, respectively. Two major lithologic units were identified. Unit I (0–111.86 mbsf in Hole U1313A, 0–111.28 mbsf in Hole U1313B, 0–112.00 mbsf in Hole U1313C, and 0–113.14 mbsf in Hole U1313D) consists of Holocene to upper Pliocene alternating nannofossil ooze, silty clay nannofossil ooze, and nannofossil ooze with clay. This unit is further divided into two subunits, Subunit IA and IB. The former exhibits the large amplitude fluctuations of clay and biogenic carbonate, reflected in sediment color change (L*). The former is marked by less variability in these components. Unit II extends to the bottom of each hole and characterized by homogeneous high carbonate concentration, with a range if 89-96 %. Examined in this study was Holocene-upper Pliocene sedimentary sequence, ranging from top to 122.74 mbsf, corresponding to lithological Unit I and uppermost Unit II.

Site U1314 (56°N, 27°W) is located on the southern Gardar Drift in water depth of 2800 m (Fig. 1). Holocene to upper Pliocene sediments were recovered from two holes (Hole U1314A and B) and Holocene to around the boundary between Pliocene and Pleistocene sediments from Hole U1314C at this site (Fig. 2). Total cored intervals were 0-258.4 mbsf at Hole U1314A, 0-279.5 mbsf at Hole U1314B and 0-207.7 mbsf at Hole U1314C, respectively. The sedimentary sequence at Site U1314 mainly is composed of nannofossil- and clay-rich sediments with minor and varying proportions of biogenic opal and foraminifers. In this site, two sets of lithologies were identified and alternated each other. One is dominated by nannofossil oozes with enriched biogenic and terrigenous materials, reflected by light gray sediment color and the other is terrigenous silty clay with varying proportions of calcareous and siliceous organisms where the sediment color is very dark grey. Whole sedimentary sequence ranging from Holocene to upper Pliocene was examined in this study.

Material and Methods

Totally 37 core catcher samples where common to abundant and well preserved radiolarians were recovered, nine from the site 1313 and 28 from the site 1314, were examined in this study. In the disaggregation process hydrochloric acid was added to eliminate the calcareous components and boiled with hydrogen peroxide and calgon. Then, they were washed with 45 µm

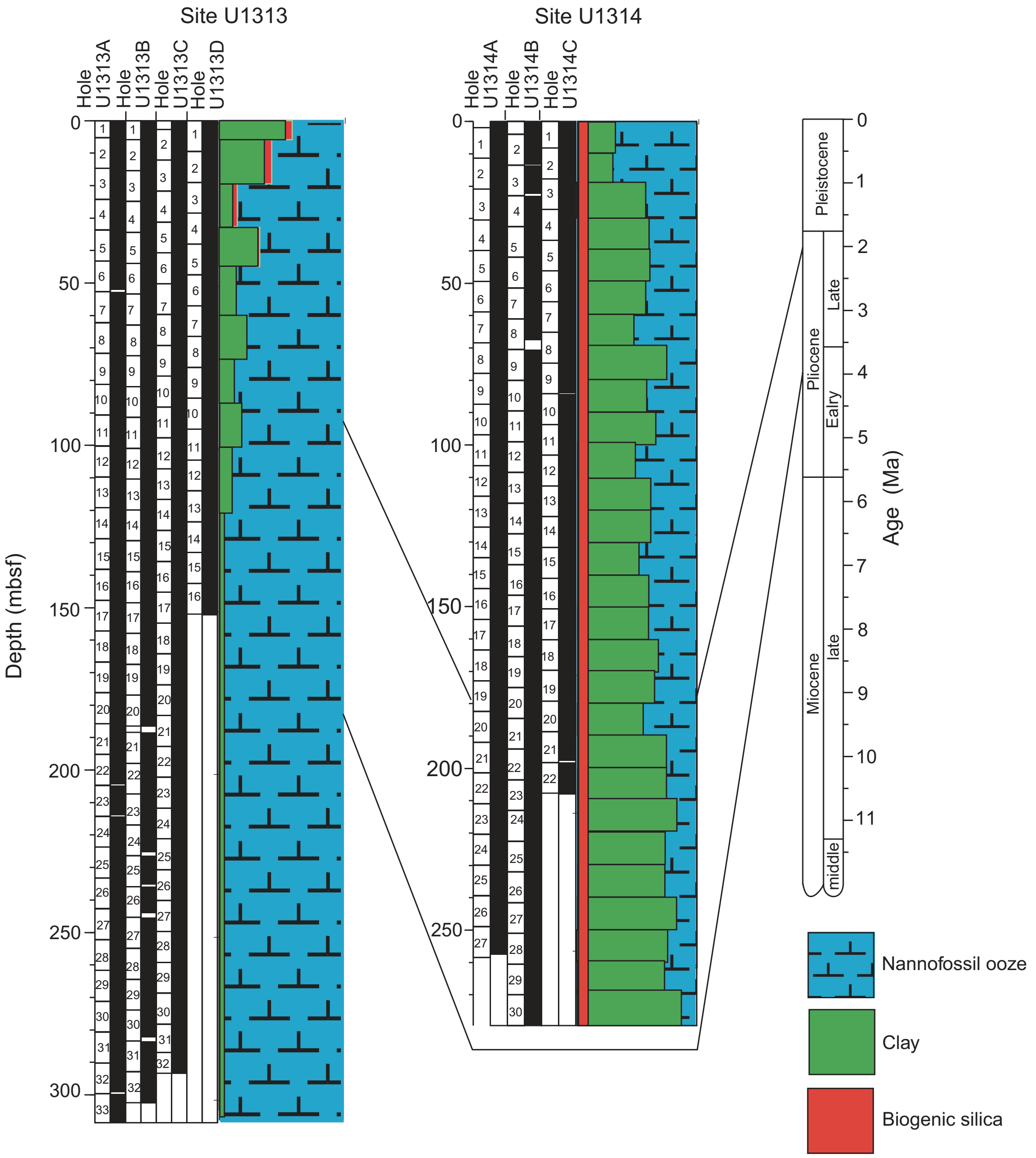


Fig. 2. The lithology of the four holes at Site U1313 and three holes at Site U1314.

sieve. The residues were extracted with pipette and transferred to microscope slides. A few drops of optical adhesive dropped and coverslips mounted on the slides. Relative abundances of species were calculated using the slides.

Results

In total, about 140 species were recognized at Site U1313. *Acrosphaera spinosa* (Haeckel), *Actinomma boreale* Cleve, *Botryostrobus auritus/australis* (Ehrenberg) group, *Cornutella profunda* Ehrenberg, *Cycladophora davisiana* Ehrenberg, *Druppatractus* sp. A, *Druppatractus irregularis* (Popofsky), *Porodiscus* sp., *Larcopyle buetschlii* Dreyer, *Larcospira minor* (Jørgensen), *Pseudodictyophimus gracilipes* (Bailey) group, *Spongocore puella* Haeckel, *Spongopyle osculosa* Dreyer, *Stylochlamydium* cf. *venustum* Bailey and *Tetrapyle octacantha* Müller were commonly observed at this site (Table 1). Of these species, *A. spinosa* and *T. octacantha* is known as warm surface water dwellers based on the data from surface sediments (e.g. Lombari and Borden, 1985) and plankton and/or sediment trap samples (e.g. Renz, 1976; Kling, 1979; Takahashi, 1991; Boltovskoy et al., 1996). In addition, *Botryocyrtis scutum* (Harting), *Collosphaera tuberosa* Haeckel, *Didymocyrtis tetrathalamus* (Haeckel), *Lamprocyrtis nigrinae* (Caulet), *Lithopera bacca* Ehrenberg and *Spongaster tetras tetras* (Ehrenberg) whose geographic distributions were mainly restricted to warm

Tropical-Subtropical region (e.g. Lombari and Borden, 1985) were generally rare but occurred in several samples.

At Site U1314, a total of about 100 species were recognized. Many of the major constituents of radiolarian assemblages at Site U1313 (*A. boreale*, *B. auritus/australis* group, *C. profunda*, *C. davisiana*, *D.* sp. A, *D. irregularis*, *L. buetschlii*, *L. minor* and *S.* aff. *venustum*) were also commonly observed at Site U1314 (Table 2). In addition to these species, *Artostrobus annulatus* (Bailey), *Artostrobus joergenseni* Petrushevskaya, *Lithomelissa setosa* Jørgensen, *Lithomitra lineata/arachnea* Ehrenberg group, *Lithocampe platycephala* (Ehrenberg), *Pseudodictyophimus gracilipes* (Bailey) and *Spongotrochus glacialis* Popofsky showed common occurrences at this site. The major difference of radiolarian faunal compositions between Site U1313 and U1314 is lack of the warm water species and more abundant occurrences of cold water species at Site U1314. Most of the warm water species occurred at Site U1313 (*B. scutum*, *C. tuberosa*, *L. nigrinae*, *L. bacca* and *Spongaster tetras tetras*) were absent and only *A. spinosa*, *D. tetrathalamus* and *T. octacantha* exhibit rare and sporadic occurrences at Site U1314. *Artobotrys borealis* (Cleve) and *Phorticium pylonium* Haeckel, the cold-water species mainly reported from Greenland-Norwegian Sea and Southern Ocean (Swanberg and Eide, 1992; Abelmann and Gowing, 1997; Bjørklund et al., 1998), are only recognized in the Site U1314, and the "cold-water form" of *S. glacialis* (Abelmann and Gowing, 1997) and *S.* aff. *venustum*, previously reported from the Subarctic North Pacific region (Itaki and Takahashi, 1995; Okazaki et al., 2004) and Southern Ocean (Abelmann and Gowing, 1997), are more abundant than in Site U1313.

Discussion

The radiolarian faunal compositions in the North Atlantic exhibited major difference between the middle latitude Site U1313 (41° 00'N, 32° 57'W) and Site U1314 (56° 22'N, 27° 53'W). The radiolarian assemblages at Site U1313 are characterized by continuous occurrences of warm water species, such as *Acrosphaera spinosa*, *Botryocyrtis scutum*, *Didymocyrtis tetrathalamus*, *Lithopera bacca*, *Spongaster tetras*, *Tetrapyle octacantha*, with a total of about 140 species, showing similarity to those in the low latitude regions reported by Takahashi (1991) and Boltovskoy et al. (1996), who found 208 radiolarian taxa, including Phaeodaria, from Station E (13°N, 54°W), and 145 polycystine taxa at station CB1 (22. 55°N, 19.44°W), respectively. However, the species used in the low latitude Neogene-Quaternary radiolarian biostratigraphy, such as *Anthocyrtidium angurae* Nigrini and *Pterocanium prismatium* Riedel (Sanfilippo and Nigrini, 1998), are not recognized at Site U1313. This indicates that these low latitude biostratigraphic markers are more restricted to the equatorial region in the North Atlantic. On the other hand, at Site U1314, tropical-subtropical species recognized at Site U1313 are generally absent and instead the radiolarian assemblages are characterized by more abundant occurrences of cold water species, such as *Amphimelissa setosa*, *Artobotrys borealis*, *Spongotrochus glacialis* and *Stylochlamydium* aff. *venustum* when compared to Site U1313, showing that the faunal compositions at this site are more similar to the Norwegian Sea reported by Bjørklund (1976), Bjørklund et al. (1998) and Cortese et al. (2003) than those at Site U1313.

Summery

We examined the detailed radiolarian species compositions of the two deep-sea drilling cores recovered from the mid-latitude North Atlantic (IODP Exp. 306 Site U1313 and U1314), and revealed that the radiolarian assemblages at Site U1313 (41°N, 32°W) were characterize by common and continuous occurrences of warm water species, but species used for the low latitude radiolarian biostratigraphy were not recognized at this site. On the other hand, radiolarian assemblages at Site U1314 (56°N, 27°W) showed relatively cold water affinity and more similarity to the Norwegian Sea than Site U1313.

Acknowledgements

We thank to the Co-Chief Scientists and all colleagues of the Shipboard Scientific Party for their cooperation during the cruise. We are also grateful to Dr. T. Itaki (Pusan National University) for reviewing this manuscript. This study was supported by the Japan Drilling Science Consortium (J-DESC).

References

Abelmann, A. and Gowing, M.M., 1997, Spatial distribution pattern of living polycystine radiolarian taxa— baseline study for paleoenvironmental reconstructions in the Southern Ocean (Atlantic sector). *Marine Micropaleontology*, **30**, 3-28.

Benson, R.N., 1972, Radiolaria, Leg 12, Deep Sea Drilling Project. *In* Laughton, A.S., Berggren, W.A. et al. eds., *Initial Reports of the Deep Sea Drilling Project*, **12**, 1085-1113.

Bjørklund, K.R., 1976, Radiolaria from the Norwegian Sea, Leg 38 of the Deep Sea Drilling Project. *In* Talwani, M., Udintsev, G., et al. eds., *Initial Reports of the Deep Sea Drilling Project*, **38**, 1101-1168.

Bjørklund, K.R., Cortese, G., Swanberg, N. and Schrader, H.J., 1998, Radiolarian faunal provinces in surface sediments of the Greenland, Iceland and Norwegian (GIN) Seas. *Marine Micropaleontology*, **35**, 105-140.

Boltovskoy, D., Oberhänsli, H. and Wefer, G., 1996, Radiolarian assemblages in the eastern tropical Atlantic: patterns in the plankton and in sediment trap samples. *Journal of Marine Systems*, **8**, 31-51.

Cortese, G., Bjørklund, K.R. and Dolven, J.K., 2003, Polycystine radiolarians in the Greenland-Iceland-Norwegian Seas: species and assemblage distribution. *Sarsia*, **88**, 65-88.

Goll, R.B. and Bjørklund, K.R., 1971, Radiolaria in surface sediments of the North Atlantic Ocean. *Micropaleontology*, **17**, 434-454.

Itaki, T. and Takahashi, K., 1995, Preliminary results on radiolarian fluxes in the central subarctic Pacific and Bering Sea. *Proceedings of Hokkaido Tokai University Science and Engineering*, **7**, 37-47. (in Japanese with English Abstract)

Jørgensen, E., 1905, The protist plankton and the diatoms in bottom samples. *In* Nordgaard, O. ed., *Hydrographical and biological investigations in Norwegian fiords*. Bergens Museum Skrifter, **1**, 59-151.

Kling, S.A., 1979, Vertical distribution of polycystine radiolarians in the central North Pacific. *Marine Micropaleontology*, **4**, 295-318.

Labracherie, M., 1985, Pleistocene radiolarians from Goban Spur, Deep Sea Drilling Project Hole 548, Leg 80. *In* de Graciansky, P.C., Poag, C.W. et al. eds. *Initial Reports of the Deep Sea Drilling Project*, **80**, 757-760.

Lombari, G. and Boden, G., 1985, Modern radiolarian global distributions. *Cushman Foundation for Foraminiferal Research, Special Publication*, no. 16A, 125pp.

Okazaki, Y., Takahashi, K., Itaki, T. and Kawasaki, Y., 2004, Comparison of radiolarian vertical distributions in the Okhotsk Sea near the Kuril Islands and in the northwestern North Pacific off Hokkaido Island. *Marine Micropaleontology*, **51**, 257-284.

Petrushevskaya, M.G., 1971, Radiolyarii Nassellaria v planktone Mirovogo Okeana. *Issledovaniya Fauny Morei, Nauka, Leningrad*, no. 9, 294pp. (In Russian)

Petrushevskaya, M.G. and Koslova, G.E., 1972, Radiolaria: Leg 14, Deep Sea Drilling Project. *In* Hayes, D.E., Pimm, A.C. et al. eds., *Initial Reports of the Deep Sea Drilling Project*, **14**, 495-648.

Renz, G.W., 1976, The distribution and ecology of Radiolaria in the Central Pacific: plankton and surface sediments. *Bulletin of the Scripps Institution of Oceanography (San Diego)*, University of California Press, no. 22, 267pp.

Sanfilippo, A. and Nigrini, C., 1998, Code numbers for Cenozoic low latitude radiolarian biostratigraphic zones and GPTS conversion tables. *Marine Micropaleontology*, **33**, 109-156.

Shipboard Scientific Party, 2005, North Atlantic Climate. *Proceedings of the Integrated Ocean Drilling Program, 303/306* [http://publications.iodp.org/proceedings/303_306/30306title.htm]

Swanberg, N.R. and Eide, L.K., 1992, The radiolarian fauna at the ice edge in the Greenland Sea during summer, 1988. *Journal of Marine Research*, **50**, 297-320.

Takahashi, K., 1991, Radiolaria: flux, ecology, and taxonomy in the Pacific and Atlantic. *Ocean Biocoenosis*, Series 3, 303pp.

Westberg-Smith, M.J. and Riedel, W.R., 1985, Radiolarians from the western margin of the Rockall Plateau: Deep Sea Drilling Project Leg 81. *In* Roberts, D.G., Schnitker, D. et al. eds., *Initial Reports of the Deep Sea Drilling Project*, **81**, 479-501.

Westberg-Smith, M.J., Tway, L.E. and Riedel, W.R., 1986, Radiolarians from the North Atlantic Ocean, Deep Sea Drilling Project Leg 94. *In* Ruddiman, W.F., Kidd, R.B., Thomas, E. et al. eds., *Initial Reports of the Deep Sea Drilling Project*, **94**, 763-777.

Table 1. Stratigraphic occurrences of radiolarian taxa at Site U1313.

Samples	1313A 1H–CC	1313A 2H–CC	1313A 3H–CC	1313A 4H–CC	1313A 5H–CC	1313C 6H–CC	1313B 7H–CC	1313D 8H–CC	1313A 12H–CC
mbsf	5	15.52	26.01	37.61	48.31	55.12	70.79	83.82	122.74
Acrosphaera spinosa	+	+	+	+	+	+			+
Acrosphaera lappacea	+	+							
Actinomma boreale	+	+	+	+	+	+	+	+	+
Actinomma delicatulum	+	+		+					
Actinomma haysi	+	+	+	+	+	+			?
Actinomma leptoderma	+	+	+	+	+	+	+		
Actinomma medianum	+	+	+	+	+	+			
Actinomma popofsky	+	+	+	+	+	+	+	+	+
Actinomma sol	+	+							
Amphimelissa setosa	+	+							
Amphiplecta acrostoma	+			+					
Amphirhopalum ypsilon	+		+		+	+		+	
Androcyclas ganphonycha	+	+	+	+	+	+	+	+	+
Anomalacantha dentata	+	+	+	+	+	+	+	+	
Anthocyrtidium ophirense	+	+	+	+	+	+	+	+	
Anthocyrtidium zanguebaricum	+	+	+	+	+	+	+		+
Anthocyrtium anthemis	+	+	+	+	+	+	+		
Artostrobus annulatus	+	+				+		+	
Artostrobus jorgenseni	+	+	+	+	+	+	+	+	+
Botryocampe inflata	+	+	+	+	+	+	+	+	
Botryocyrtis scutum	+	+			+	+			
Botryopyle cribrosa	+	+			+	+	+	+	+
Botryostrobus aquilonaris	+	+	+	+	+			+	+
Botryostrobus auritus/australi	+	+	+	+	+	+	+	+	+
Carpocanarium papillosum	+	+	+	+	+	+	+	+	+
Carpocanistrum spp.	+	+	+	+	+	+	+	+	+
Ceratocyrtis galeus		+		+	+				
Ceratocyrtis historicosus	+	+	+	+	+	+	+	+	+
Collosphaera tuberosa	+	+							
Cornutella profunda	+	+	+	+	+	+	+	+	+
Corocalyptra craspedota	+	+	+	+			+	+	
Colocalyptra elizabethae	+	+		+					
Cycladophora bicornis	+	+	+	+	+	+	+		
Cycladophora cornutoides	+	+	+	+		+		+	+
Cycladophora davisiana	+	+	+	+	+	+	+	+	+
Dictyocoryne profunda	+	+	+	+					
Dictyophimus crisiae	+	+		+					
Dictyophimus hirundo	+	+	+	+	+	+	+	+	+
Druppatractus variabilis	+	+	+	+	+	+	+	+	+
Druppatractus irregularis	+	+	+	+	+	+	+	+	+
Dictyophimus infabricatus		+							
Didymocyrtis tetrathalamus	+	+	+	+	+	+	+		
Eucecryphalus gegenbauri	+	+		+					
Eucecryphalus schltzei	+		+						
Eucyrtidium acuminatum	+	+	+	+	+	+	+	+	
Eucyrtidium anomalum		+		+	+	+			
Eucyrtidium calvertense	+		+	+	+	+	+	+	+
Eucyrtidium hexagonatum	+	+	+	+	+	+	+	+	
Eucyrtidium hexastichum	+	+	+	+	+	+	+		
Eucyrtidium teuscheri	+	+	+	+	+	+	+	+	+

Samples	1313A 1H–CC	1313A 2H–CC	1313A 3H–CC	1313A 4H–CC	1313A 5H–CC	1313C 6H–CC	1313B 7H–CC	1313D 8H–CC	1313A 12H–CC
mbsf	5	15.52	26.01	37.61	48.31	55.12	70.79	83.82	122.74
Flustrella spp.	+	+	+	+	+	+	+	+	+
Heliodiscus asteriscus	+	+	+	+	+	+	+	+	+
Hexacontium enthacanthum	+	+	+	+	+	+	+	+	
Hexacontium hostile	+	+	+	+					
Hexacontium pachydermum	+	+	+	+	+	+	+	+	+
Lamprocyrtis nigrinae	+								
Lamprocyclas maritalis	+	+	+	+	+	+	+	+	+
Larcopyle buetschlii	+	+	+	+	+	+	+	+	+
Larcopyle weddellium	+		+		+	+	+		
Larcospyra quadrangula	+			+					
Litharachnium tentorium	+	+	+	+	+	+	+	+	+
Larcospira minor	+	+	+	+	+	+	+	+	+
Lithocampe platycephala	+	+	+	+	+	+	+	+	+
Lithocampe sp.	+	+	+	+	+	+	+	+	+
Lithomelissa laticeps		+		+					
Lithomelissa setosa	+	+	+		+	+	+	+	
Lithomelissa thoracites	+	+	+	+	+	+	+	+	+
Lithomitra arachnea/lineata	+	+	+	+	+	+	+	+	+
Lithopera bacca				+		+			
Lithostrobus cuspidatus	+	+		+	+	+			
Peripyramis circumtexta	+	+	+	+	+	+	+	+	+
Phormostichoartus corbula	+	+		+					
Pseudodictyophymus gracilipes	+	+	+	+	+	+	+	+	+
Pterocanium korotveni		+			+		+	+	+
Pterocanium praetextum	+	+		+			+		
Pterocanium trilobum	+	+	+	+	+	+	+	+	+
Pterocorys clausus	+	+		+					+
Pterocorys zancleus	+	+	+	+					
Saturnalis circularis		+		+					
Sethoconus dogieli	+	+	+	+	+	+	+		
Sethoconus tabulatus	+	+					+		
Siphonosphaera polysiphonia	+	+	+	+	+	+			
Spongaster tetras irregularis				+		+			
Spongaster tetras tetras	+				+	+	+		
Spongocore puella	+	+	+	+	+	+	+	+	+
Spngoplegma spp.	+	+		+	+		+	+	
Spongopyle osculosa	+	+	+	+	+	+	+	+	+
Spongotrochus glacialis	+	+		+		+	+		+
Stichocorys seriata	+	+	+	+		+		+	
Stichopilium bicorne	+	+							
Stylacontarium bispiculum	+	+	+	+	+	+	+		+
Stylatractus spp.	+	+	+	+	+	+	+	+	+
Stylochlamydium aff. venustum	+	+	+	+	+	+	+		+
Stylodictya sp.	+	+	+		+	+	+	+	
Tetrapyle octacantha	+	+	+	+	+	+	+		+
Thecosphaera spp.	+	+	+	+	+	+	+	+	+
Theocorys veneris	+	+	+	+	+	+	+	+	+
Theocorythium trachelium/vetulu	+	+	+	+	+	+	+	+	+
Trislucus triacanthus								+	

Table 2. Stratigraphic occurrences of radiolarian taxa at Site U1314.

Samples	1314C 1H–CC	1314B 2H–CC	1314B 3H–CC	1314B 4H–CC	1314C 5H–CC	1314B 7H–CC	1314C 8H–CC	1314B 9H–CC	1314C 10H–CC	1314C 11H–CC	1314A 12H–CC	1314B 13H–CC	1314B 14H–CC	1314B 15H–CC	1314C 16H–CC	1314B 17H–CC	1314B 18H–CC	1314C 19H–CC	1314B 21H–CC	1314B 22H–CC	1314B 23H–CC	1314B 24H–CC	1314A 25H–CC	1314A 26H–CC	1314B 27H–CC	1314A 28H–CC	1314B 29H–CC	1314B 30H–CC
mbsf	8.07	14.55	23.89	33.95	46.64	63.66	76.81	84.82	98.81	109.69	113.42	128.83	138.64	149.07	162.16	169.39	179.83	189.65	209.31	219.83	229.55	239.96	246.11	256.35	270.93	277.27	290.29	300.13
Acrosphaera spinosa				+																								
Acrosphaera lappacea									+																			
Actinomma boreale	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Actinomma delicatulum					+	+																						
Actinomma haysi	+			+	+												+									+	+	+
Actinomma leptoderma	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+							
Actinomma medianum				+	+	+	+	+	+	+	+	+			+	+	+					+		+	+	+	+	+
Actinomma popofsky					+	+			+									+										
Actinomma sol		+		+					+																			
Amphimelissa setosa	+		+		+																							
Amphiplecta acrostoma				+		+	+							+	+													
Amphirhopalum ypsilon								?			+														+			
Androcyclas gamphonycha	+	+			+	+		+	+	+							+				+	+			+	+	+	+
Anomalacantha dentata	+	+	+	+	+	+	+	+	+	+	+	+			+			+	+			+						
Antarctissa sp.															+													
Anthocyrtidium ophirense				+		+			+								+	+		+	+						+	
Anthocyrtidium zanguebaricum				+		+			+					+	?	+			+						+			
Anthocyrtium anthemis	+		+	+	+	+	+	+	+	+		+		+	+	+		+				+						
Stichocorys seriata	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+				+	+		+	
Artostrobus annulatus	+	+	+	+	+	+	+		+	+		+			+	+	+		+	+	+	+	+	+	+		+	+
Artostrobus jorgenseni	+	+	+	+	+	+	+	+	+	+			+		+	+	+	+	+	+	+			+	+		+	+
Botryocampe inflata	+	+	+	+	+	+	+	+	+	+		+	+		+	+		+	+	+	+		+	+	+			+
Botryopyle cribrosa				+	+								+								+						+	
Botryostrobus aquilonaris	+	+	+	+	+		+	+	+	+	+		+	+		+	+						+	+		+		+
Botryostrobus auritus/australis	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Carpocanarium papillosum	+		+	+	+			+			+	+	+	+	+	+		+			+		+			+		+
Carpocanistrum spp.					+									+	+								+			+		
Ceratocyrtis galeus	+	+	+	+		+	+	+	+					+								+						
Ceratocyrtis historicosus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cornutella profunda	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Corocalyptra craspedota	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			+		+	+		+	+	+	
Cycladophora bicornis	+	+	+	+	+	+	+		+					+			+	+		+	+	+				+	+	
Cycladophora cornutoides		+	+				+								+	+		+					+		+	+		
Cycladophora davisiana	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	?	?	?	?
Cycladophora sakaii																							+	+				
Dictyocoryne profunda	+			+		?																						
Dictyophimus crisiae/hirundo	+		+	+	+	+		+	+	+	+	+				+		+								+		+
Druppatractus variabilis	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+		+	+	+		
Druppatractus irregularis									+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
Didymocyrtis tetrathalamus										+	+	+	+							+	+							
Eucecryphalus gegenbauri				+					+	+		+		+	+	+						+						
Eucecryphalus schltzei						+									+	+						+						
Eucyrtidium acuminatum/hexagonatum	+	+		+	+		+	+				+	+	+	+	+	+		+	+	+			+	+			
Eucyrtidium anomalum																												
Eucyrtidium calvertense				+	+	+	+	+		+	+			+	+	+					+		+		+	+	+	
Eucyrtidium hexastichum	+		+	+	+	+			+						+	+						+					+	
Eucyrtidium teuscheri	+		+	+	+	+	+	+	?	+	+		+		+	+		+	+	+	+			+	+	+	+	

Table 2 (Continued)

Samples	1314C 1H-CC	1314B 2H-CC	1314B 3H-CC	1314B 4H-CC	1314C 5H-CC	1314B 7H-CC	1314C 8H-CC	1314B 9H-CC	1314C 10H-CC	1314C 11H-CC	1314A 12H-CC	1314B 13H-CC	1314B 14H-CC	1314B 15H-CC	1314C 16H-CC	1314C 17H-CC	1314B 18H-CC	1314I9C H-CC	1314B 21H-CC	1314B 22H-CC	1314B 23H-CC	1314B 24H-CC	1314A 25H-CC	1314A 26H-CC	1314B 27H-CC	1314A 28H-CC	1314B 29H-CC	1314B 30H-CC
mbsf	8.07	14.55	23.89	33.95	46.64	63.66	76.81	84.82	98.81	109.69	113.42	128.83	138.64	149.07	162.16	169.39	179.83	189.65	209.31	219.83	229.55	239.96	246.11	256.35	270.93	277.27	290.29	300.13
Flustrella sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Heliodiscus asteriscus	+				+	+	+	+	+		+			+				+	+				+			+		+
Hexacontium enthacanthum	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+			+	+		+
Hexacontium hostile					+																							
Hexacontium laevigatum				+																								
Hexacontium pachydermum	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+			+	+		+
Lamprocyclas maritalis				+	+			+	+		+				+	+		+						+	+	+		
Larcopyle buetschlii	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Larcopyle weddellium	+	+		+		+							+		+		+		+									+
Larcospira minor	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+		+	+	+	+
Larcospyra quadrangula						+			+	+									+									
Lipmanella xiphophalum			+	+		+		+							+			+			+							
Litharachnium tentorium	+		+	+	+	+	+	+	+	+	+	+	+	+	+						+	+	+	+	+	+	+	+
Lithocampe platycephala	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Lithocampe sp.				+		+	+							?	+			+			+	+						
Lithomelissa laticeps				+		+			+																			
Lithomelissa setosa	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+		+	+	+	+	+	+	+	+	+	+	+
Lithomelissa thoracites	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Lithomitra arachnea/lineata	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Lithostrobus cuspidatus	+	+	+	+	+	+	+	+	+	+						+				+	+	+		+				
Lithostrobus hexagonalis							+							+														
Lophophaena buetschlii			+	+	+	?			+		+					+												
Peripyramis circumtexta	+	+	+				+	+			+		+	+	+				+		+	+	+					+
Phormostichoartus corbula				+											+										+			
Phorticium pylonium	+	+																										
Pseudodictyophymus gracilipes	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pterocanium korotnevi									+						+													+
Pterocanium trilobum		+	+	+	+	+	+	+	+	+	+	+		+	+	+		+	+	+	+	+	+		+	+	+	
Pterocorys clausus/zancleus	+	+	+	+	+	+		+																				
Saturnalis circularis		+	+				+																					
Sethoconus dogieli	+	+	+	+				+	+		+								+	+			+	+				
Sethoconus tabulatus	+	+	+	+		+	+	+	+	+	+	+		+	+	+		+	+	+	+	+			+		+	+
Spongasteriscus sp.																									+		+	+
Spongocore puella	+	+	+	+	+	+	+	+	+	+	+						+				+	+				+		
Spongoplegma sp.	+	+	+	+	+	+	+	+	+			+	+		+									+				+
Spongopyle osculosa	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Spongotrochus glacialis	+	+		+	+	+	+	+	+	+	+		+	+	+		+	+			+	+	+	+	+	+		+
Stichopilium bicorne	+		+						+						+													
Stylacontarium bispiculum							+		+												+							
Stylatractus spp.	+	+		+	+	+	+	+			+		+					+		+	+	+		+	+			
Stylochlamydium aff. venustum	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Stylodictya sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Tetrapyle octacantha				+						+											+			+	+			+
Theocosphaera spp.				+	+			+	+	+	+			+	+	+	+		+			+		+			+	
Theocorys veneris				+		+		+		+	+			+	+	+		+		+							+	
Theocorythium trachelium/vetulum	+	+						+		+		+			+							+	+	+	+	+		
Trisiucus triacanthus					+		+			+	+	+				+											+	

Explanation of plates

Plate 1

1. *Acrosphaera lappacea* (Haeckel)
(Hole 1313A 1H-CC)

2. *Acrosphaera spinosa* (Haeckel)
(Hole 1313A 1H-CC)

3-5. *Actinomma boreale* Cleve
(3: Hole 1314C 10H-CC, 4: Hole 1314C 1H-CC, 5: Hole 1314C 5H-CC)

6. *Actinomma delicatulum* Dogiel
(Hole 1313A 4H-CC)

7. *Actinomma haysi* Bjørklund
(Hole 1314C 1H-CC)

8-9. *Actinomma leptoderma leptoderma* (Jørgensen)
(8: Hole 1313A 1H-CC, 9: Hole 1314C 5H-CC)

10. *Actinomma leptoderma* (Jørgensen) *longispina* Cortese and Bjørklund
(Hole 1313A 1H-CC)

11-12. *Actinomma medianum* Nigrini
(Hole 1314C 5H-CC)

13. *Actinomma popofskii* (Petrushevskaya)
(Hole 1313A 2H-CC)

14. *Actinomma sol* Cleve
(Hole 1313A 1H-CC)

15-16. *Amphirhopalum ypsilon* Haeckel
(Hole 1313A 1H-CC)

Plate 2

1. *Anomalacantha dentata* (Mast)
(Hole 1314B 4H-CC)

2. *Collosphaera tuberosa* Haeckel
(Hole 1313A 2H-CC)

3. *Dictyocoryne profunda* Ehrenberg
(Hole 1314B 4H-CC)

4. *Didymocyrtis tetrathalamus* (Haeckel)

5-6. *Druppatractus variabilis* Dumitrica
(5: Hole 1314B 4H-CC, 6: Hole 1314C 1H-CC)

7-8. *Druppatractus irregularis* (Popofsky)
(Hole 1314B 14H-CC)

9-11. *Flustrella* sp.
(9: Hole 1314C 5H-CC, 10-11: Hole 1313A 1H-CC)

12-13. *Heliodiscus asteriscus* Haeckel
(Hole 1313C 1H-CC)

14. *Hexacontium enthacanthum* Jørgensen
(Hole 1313C 1H-CC)

15. *Hexacontium gigantheum* Cortese and Bjørklund
(Hole 1313C 1H-CC)

16-17. *Hexacontium hostile* Cleve
(16: Hole 1313A 4H-CC, 17: Hole 1314C 5H-CC)

18. *Hexacontium laevigatum* Haeckel
(Hole 1313C 1H-CC)

19-21. *Hexacontium pachydermum* Jørgensen
(Hole 1313C 1H-CC)

Plate 3

1-3. *Larcopyle buetschlii* Dreyer
(1: Hole 1313A 1H-CC, 2: Hole 1314C 10H-CC, 3: Hole 1314C 1H-CC)

4. *Larcospira quadrangula* Haeckel
(Hole 1313A 2H-CC)

5-6. *Larcopyle weddellium* Lazarus, Faust and Popova-Goll
(Hole 1314C 1H-CC)

7-8. *Larcospira minor* (Jørgensen)
(Hole 1314C 1H-CC)

9-11. *Phorticium pylonium* Haeckel
(Hole 1314A 1H-CC)

12. *Saturnalis circularis* Haeckel
(Hole 1313A 4H-CC)

13. *Spongaster tetras tetras* Ehrenberg
(Hole 1313A 2H-CC)

14. *Spongaster tetras* Ehrenberg *irregularis* Nigrini
(Hole 1313A 4H-CC)

15. ***Spongasteriscus*** **sp. (*Spongaster* (?) *tetras* of Goll and Bjørklund, 1989)**
(Hole 1314B 27H-CC)

16. ***Spongocore puella*** **Haeckel**
(Hole 1313A 1H-CC)

17-18. ***Styptosphaera*** **(?)** ***spumacea*** **Haeckel of Nigrini (1970)**
(17: Hole 1313A 1H-CC, 18: Hole 1314C 7H-CC)

19-20. ***Spongopyle osculosa*** **Dreyer**
(Hole 1313A 1H-CC)

21-22. ***Spongotrochus glacialis*** **Popofsky**
(Hole 1314C 1H-CC)

Plate 4

1-2. ***Stylacontarium bispiculum*** **(Popofsky)**
(1: Hole 1313A 2H-CC, 2: Hole 1313C 5H-CC)

3-4. ***Stylatractus*** **spp.**
(3: Hole 1313A 1H-CC, 4: Hole 1313A 2H-CC)

5-9. ***Stylochlamydium*** **aff.** ***venustum*** **(Bailey)**
(5-7: Hole 1313C 5H-CC, 8: Hole 1313B 14H-CC, 9: Hole 1313B 30H-CC)

10-11. ***Stylodictya*** **sp.**
(Hole 1313A 1H-CC)

12-14. ***Tetrapyle octacantha*** **Müller**
(12-13: Hole 1313A 1H-CC, 14: Hole 1313A 2H-CC)

Plate 5

1-2. ***Amphimelissa setosa*** **(Cleve)**
(Hole 1314C 1H-CC)

3. ***Amphiplecta acrostoma*** **Haeckel**
(Hole 1313A 1H-CC)

4. ***Androcyclas gamphonycha*** **(Jørgensen)**
(Hole 1313A 1H-CC)

5-6. ***Antarctissa*** **sp.**
(Hole 1313B 13H-CC)

7. ***Anthocyrtidium ophirense*** **(Ehrenberg)**
(Hole 1313B 4H-CC)

8. ***Anthocyrtidium zanguebaricum*** **(Ehrenberg)**
(Hole 1313A 1H-CC)

9. ***Anthocyrtium anthemis*** **Haeckel**
(Hole 1313A 1H-CC)

10. ***Artobotrys borealis*** **(Cleve)**
(Hole 1314C 1H-CC)

11. ***Artostrobus annulatus*** **(Bailey)**
(Hole 1314C 5H-CC)

12. ***Artostrobus joergenseni*** **Petrushevskaya**
(Hole 1313A 1H-CC)

13-15. ***Botryocampe inflata*** **(Bailey)**
(13: Hole 1314C 5H-CC, 14-15: Hole 1313A 2H-CC)

16. ***Botryocyrtis scutum*** **(Harting)**
(Hole 1313A 2H-CC)

17-18. ***Botryopyle cribrosa*** **(Popofsky)**
(17: Hole 1313C 6H-CC, 18: Hole 1313A 1H-CC)

19-20. ***Botryostrobus aquilonaris*** **(Bailey)**
(Hole 1313A 1H-CC)

21-22. ***Botryostrobus auritus/australis*** **(Ehrenberg) group**
(Hole 1313A 1H-CC)

23. ***Carpocanarium papillosum*** **(Ehrenberg)**
(Hole 1314B 7H-CC)

24. ***Carpocanistrum*** **spp.**
(Hole 1314B 4H-CC)

25-26. ***Ceratocyrtis histricosus*** **(Jørgensen)**
(25: Hole 1314C 1H-CC, 26: Hole 1314C 5H-CC)

27-28. ***Cornutella profunda*** **Ehrenberg**
(27: Hole 1314C 1H-CC, 28: Hole 1314C 5H-CC)

29-30. ***Corocalyptra craspedota*** **(Jørgensen)**
(Hole 1314C 1H-CC)

31-32. ***Cycladophora bicornis*** **(Popofsky)**
(Hole 1314C 1H-CC)

33-34. ***Cycladophora cornuta*** **(Bailey)**
33-34. Hole 1314C 1H-CC

35-36. ***Cycladophora davisiana*** **Ehrenberg**
35-36. Hole 1314C 1H-CC

37-38. ***Cycladophora sakaii*** **Motoyama**
(Hole 1314A 26H-CC)

39-40. ***Dictyophimus crisiae*** **Ehrenberg**
(Hole 1314C 10H-CC)

Plate 6

1-2. *Dictyophimus hirundo* (Haeckel)
(1: Hole 1313A 1H-CC, 2: Hole 1314C 10H-CC)

3. *Eucecryphalus gegenbauri* Haeckel
(Hole 1313A 1H-CC)

4-5. *Eucyrtidium acuminatum* (Ehrenberg)
(4: Hole 1313A 1H-CC, 5: Hole 1313A 2H-CC)

6-7. *Eucyrtidium anomalum* Haeckel
(6: Hole 1313A 1H-CC, 7: Hole 1313A 4H-CC)

8-9. *Eucyrtidium calvertense* Martin
(8: Hole 1313C 6H-CC, 9: Hole 1314B 4H-CC)

10-11. *Eucyrtidium hexagonatum* Haeckel
(Hole 1313A 1H-CC)

12-13. *Eucyrtidium hexastichum* (Haeckel)
(12: Hole 1313A 2H-CC, 13: Hole 1314B 4H-CC)

14-15. *Eucyrtidium teuscheri* Haeckel
(Hole 1313A 1H-CC)

16-17. *Lamprocyclas maritalis* Haeckel
(Hole 1313A 1H-CC)

18. *Lamprocyrtis nigrinae* (Caulet)
(Hole 1313A 1H-CC)

19. *Lipmanella xiphophalum* (Jørgensen)
(Hole 1314B 7H-CC)

20. *Litharachnium tentorium* Haeckel
(Hole 1314C 1H-CC)

21. *Lithocampe platycephala* (Ehrenberg)
(Hole 1314C 1H-CC)

22-23. *Lithocampe* sp. of Nigrini (1967)
(Hole 1313A 1H-CC)

24-25. *Lithomelissa laticeps* Jørgensen
(24: Hole 1313A 2H-CC, 25: Hole 1314B 7H-CC)

26-27. *Lithomelissa setosa* Jørgensen
(Hole 1313A 1H-CC)

28-29. *Lithomelissa thoracites* Haeckel
(28: Hole 1313A 1H-CC, 29: Hole 1313A 2H-CC)

30-31. *Lithomitra arachnea* (Ehrenberg)
(Hole 1313A 2H-CC)

32-33. *Lithomitra lineata* (Ehrenberg)
(Hole 1313A 2H-CC)

Plate 7

1. *Lithopera bacca* Ehrenberg
(Hole 1313C 6H-CC)

2. *Lithostrobus cuspidatus* (Bailey)
(Hole 1314C 1H-CC)

3. *Lithostrobus hexagonalis* Haeckel
(Hole 1314C 1H-CC)

4-5. *Lophophaena buetschlii* (Haeckel)
(4: Hole 1314C 5H-CC, 5: Hole 1314C 7H-CC)

6. *Peripyramis circumtexta* Haeckel
(Hole 1314C 1H-CC)

7-8. *Phormostichoartus corbula* (Harting)
(7: Hole 1314C 1H-CC, 8: Hole 1314C 2H-CC)

9-12. *Pseudodictyophimus gracilipes* (Bailey)
(Hole 1314C 1H-CC)

13. *Pterocanium korotnevi* (Dogiel)
(Hole 1313A 5H-CC)

14-15. *Pterocanium trilobum* (Haeckel)
(14: Hole 1313A 2H-CC, 15: Hole 1314B 4H-CC)

16-17. *Pterocorys clausus* (Popofsky)
(Hole 1313A 1H-CC)

18-19. *Pterocorys zancleus* (Müller)
(18: Hole 1313A 1H-CC, 19: Hole 1314C 5H-CC)

20-21. *Sethoconus dogieli* Petrushevskaya
(20: Hole 1314B 7H-CC, 21: Hole 1313A 2H-CC)

22. *Sethoconus tabulatus* (Ehrenberg)
(Hole 1313A 2H-CC)

23-24. *Stichocorys seriata* Jørgensen
(23: Hole 1314C 1H-CC, 24: Hole 1314C 5H-CC)

25. *Stichopilium bicorne* Haeckel
(Hole 1313A 1H-CC)

26-27. *Theocorys veneris* Haeckel
(Hole 1313A 1H-CC)

28-29. *Theocorythium trachelium* (Ehrenberg)
(27: Hole 1314C 1H-CC, 28: Hole 1313A 1H-CC)

Plate 1

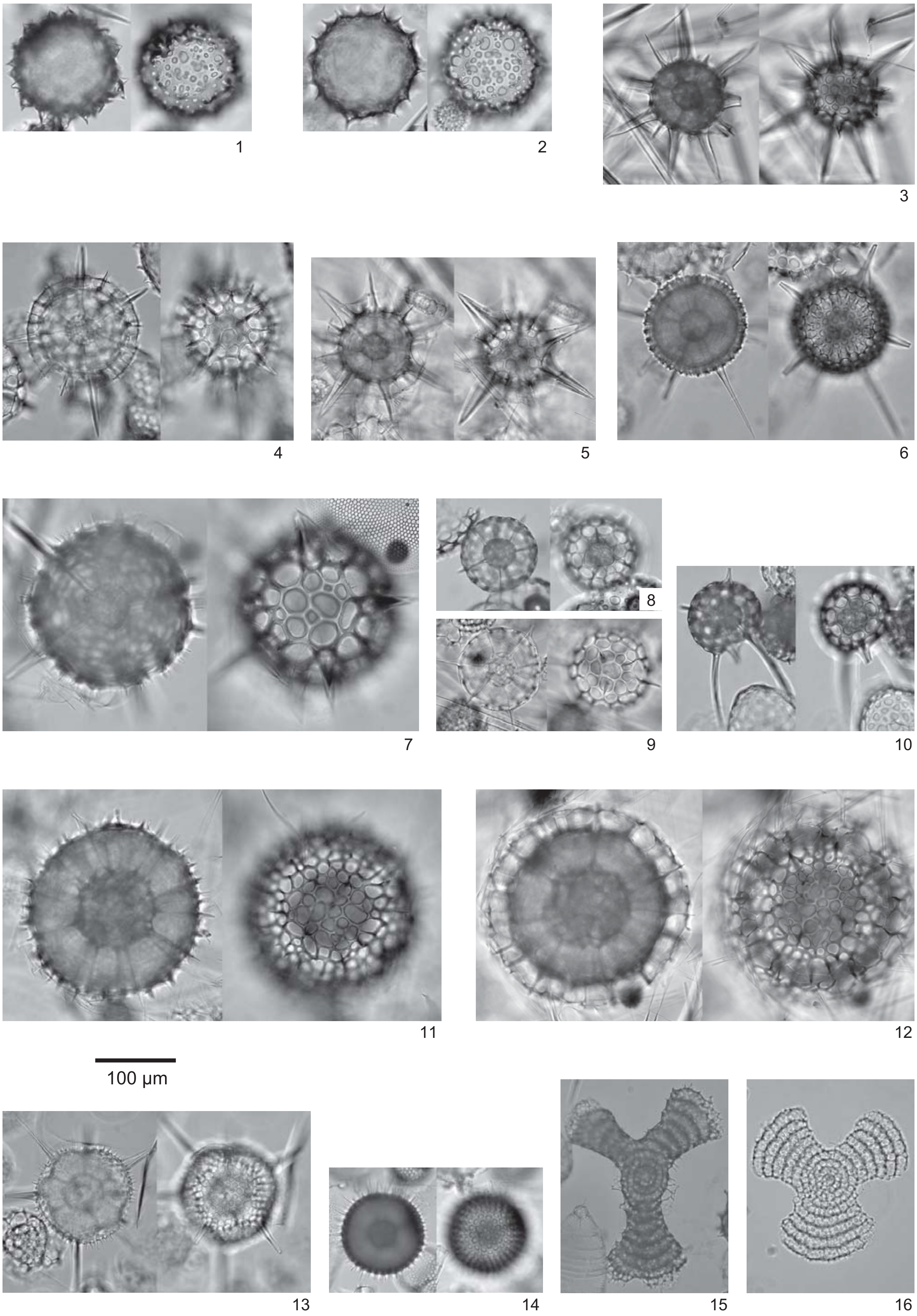


Plate 2

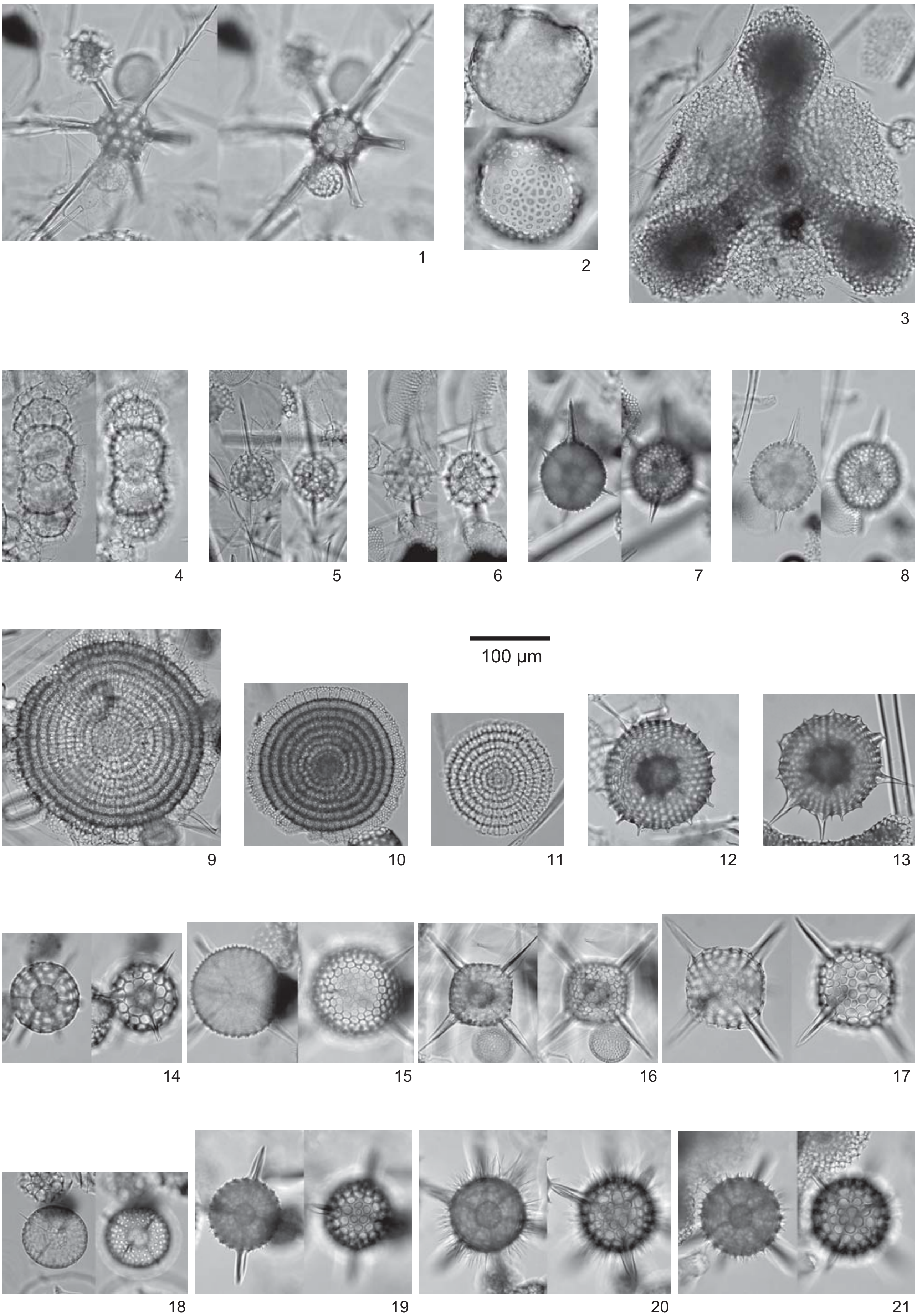


Plate 3

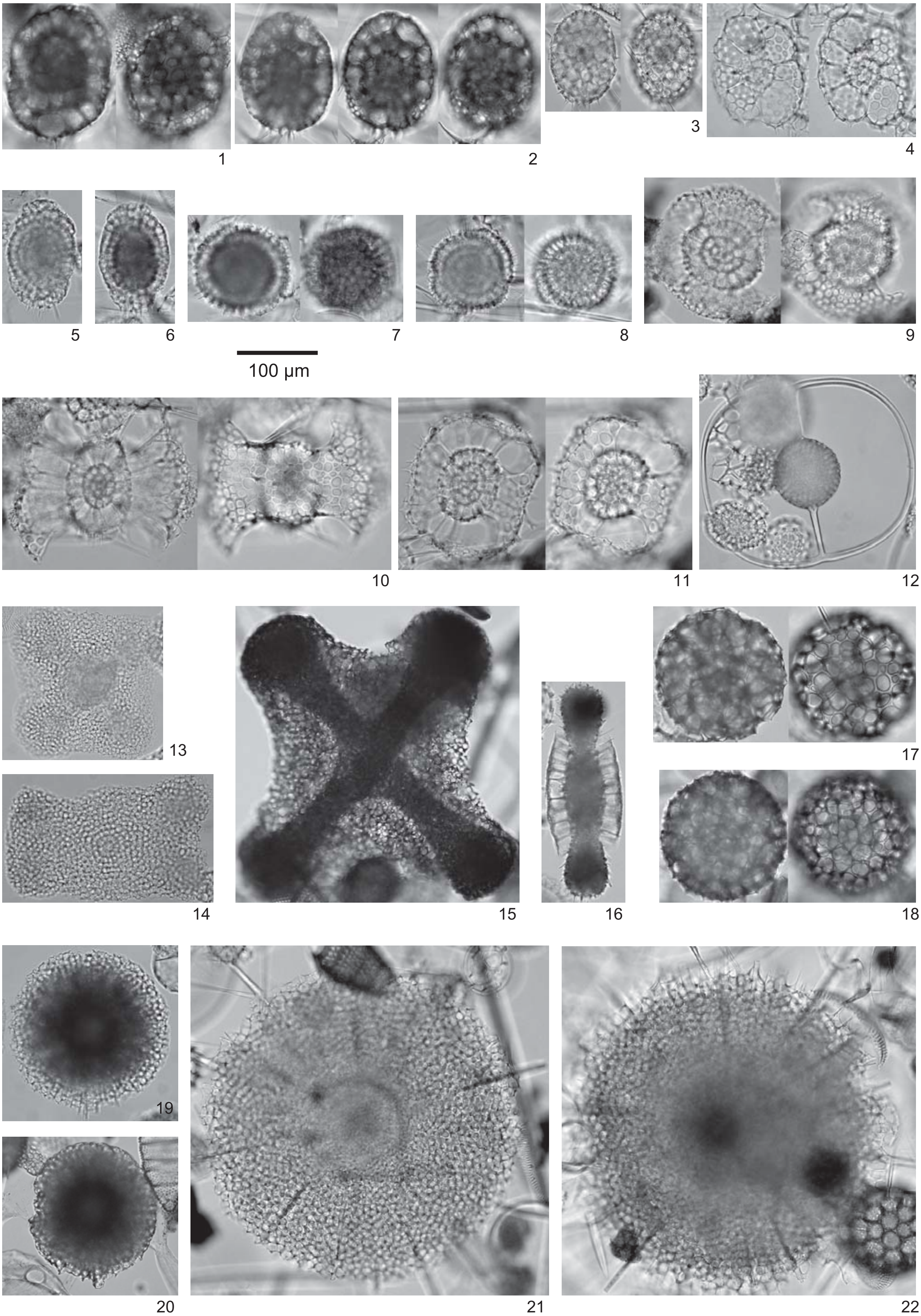


Plate 4

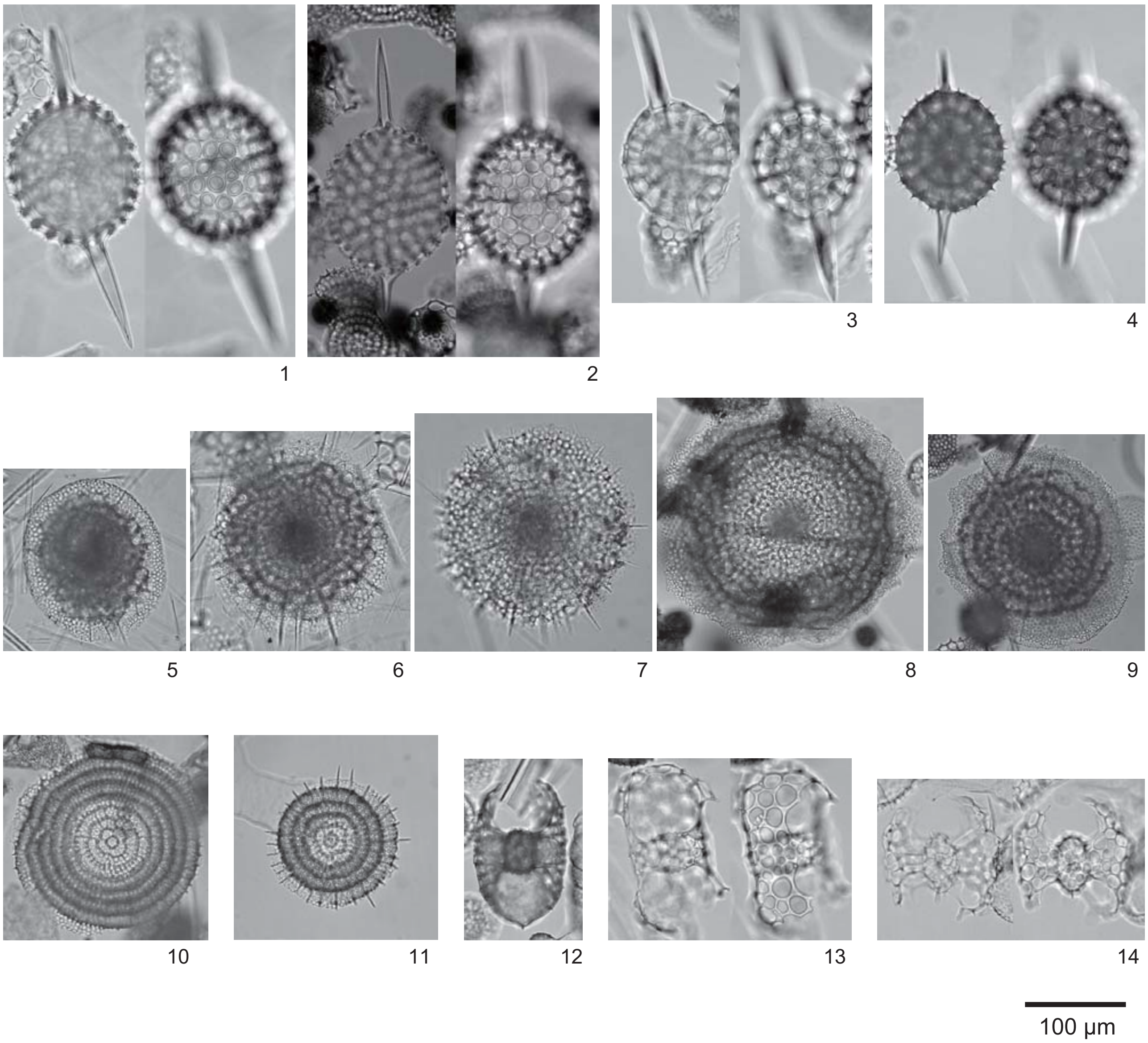


Plate 5

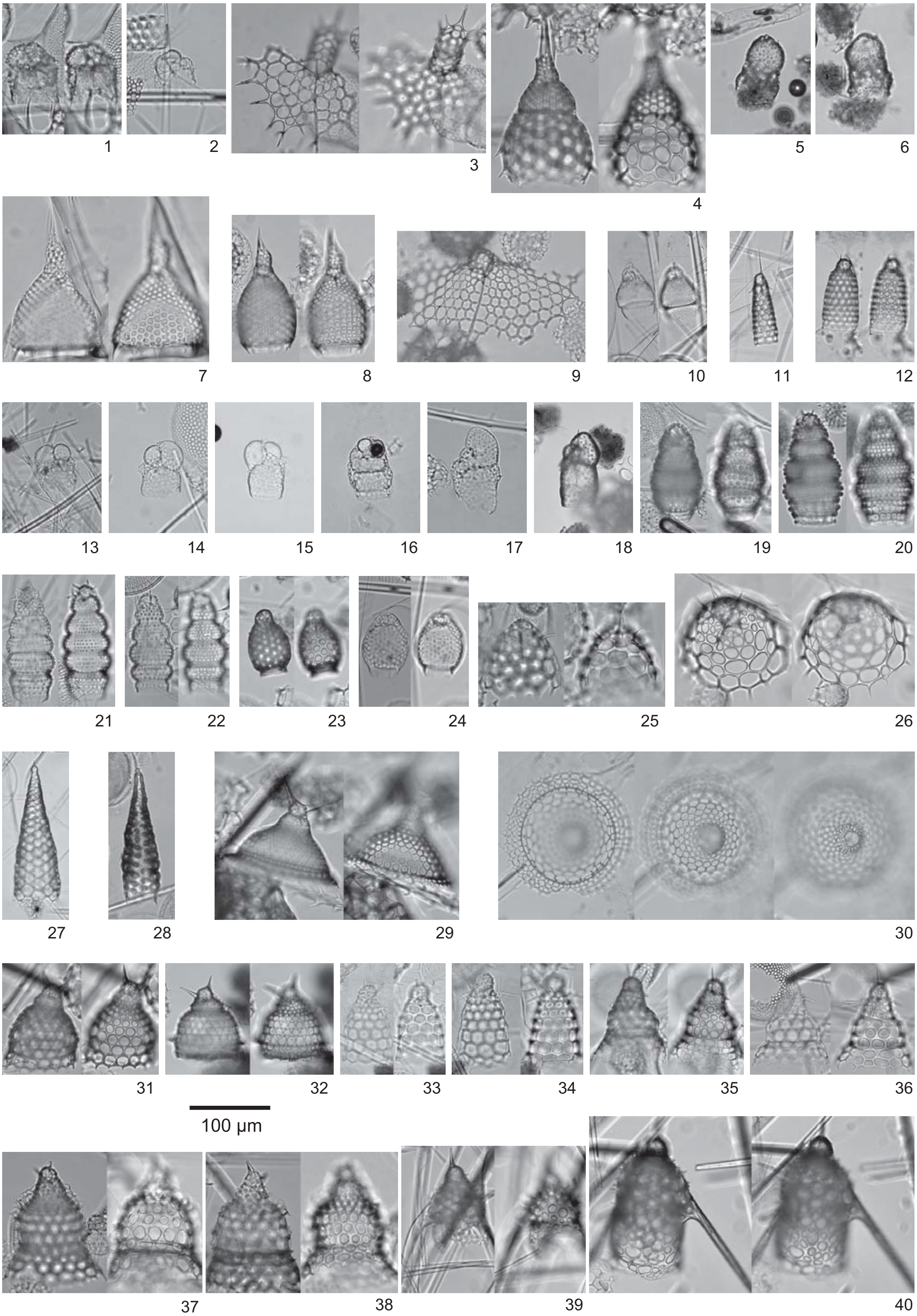

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
100 µm
37
38
39
40

Plate 6

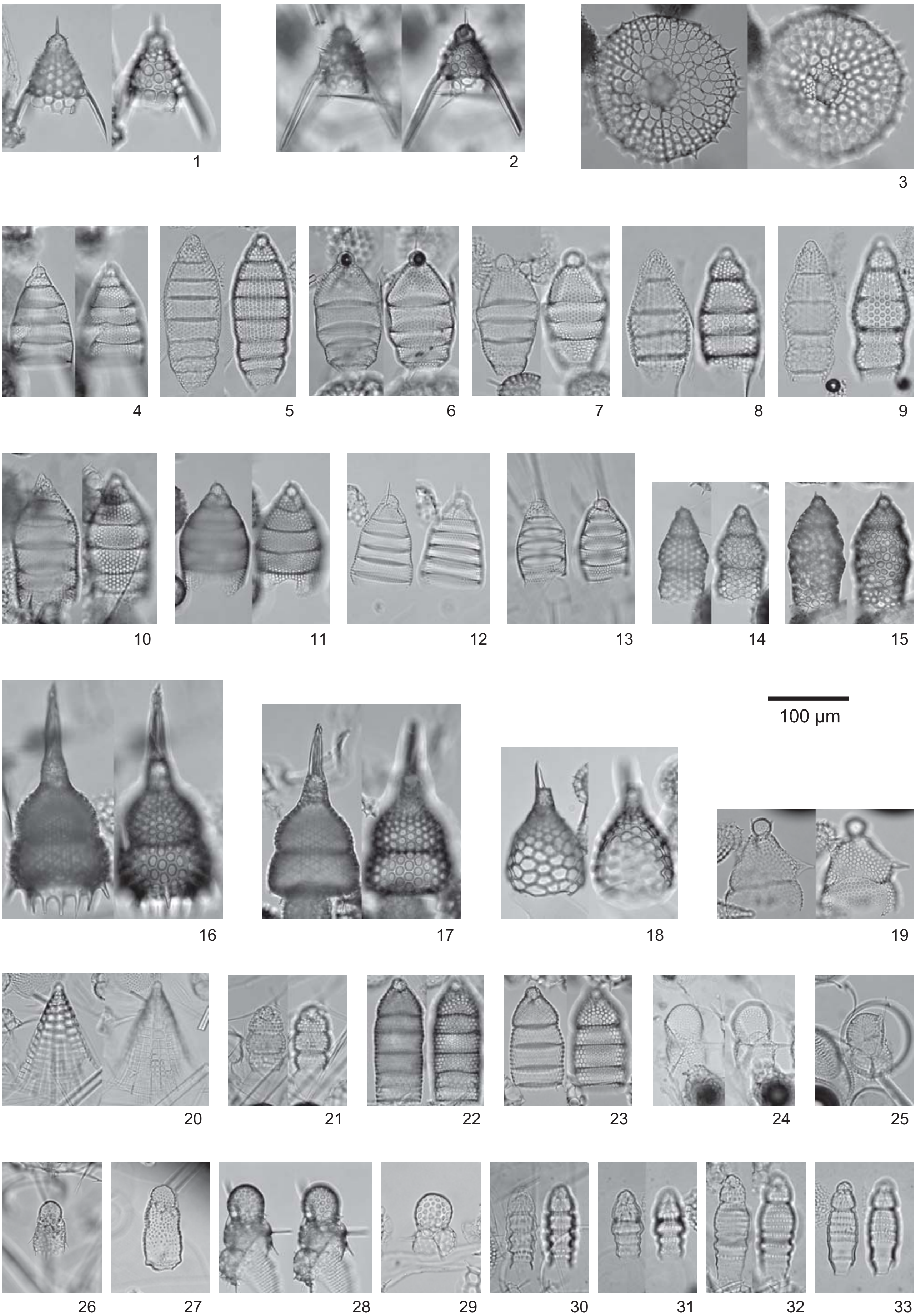
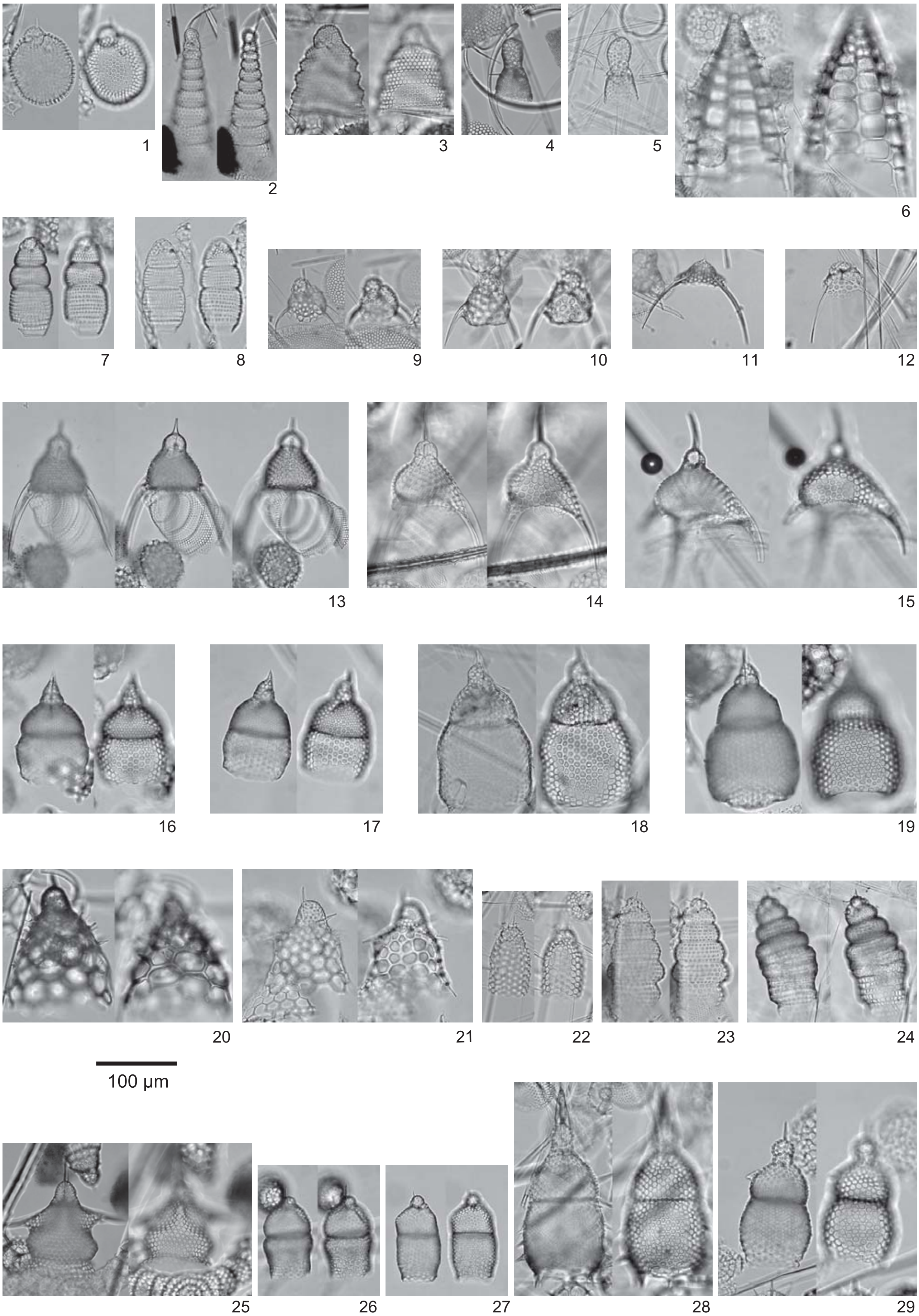

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
100 μm
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33

Plate 7


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
100 µm
25
26
27
28
29