

Middle to late Miocene radiolarians from ODP Site 1021 in the eastern North Pacific

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Abstract: The purpose of this study is to present microphotographs of all the encountered taxa of the middle to late Miocene age from Ocean Drilling Program (ODP) Site 1021 in the eastern North Pacific in order to analyze the species diversity of radiolarians. Totally 149 species or species groups of radiolarians were identified from Site 1021 in the eastern North Pacific. Micro-photographs have been illustrated in the 24 plates, and a new species, *Lychnocanoma californica*, is described.

Keywords: eastern North Pacific, Miocene, radiolaria, new species

1. Introduction

The California Current system is one of the most biologically productive ecosystems in the world's ocean because they benefit from nutrient-rich coastal upwelling. Ocean Drilling Program (ODP) Leg 167 was designed to study the evolution of the California Current system and associated upwelling systems from the middle Miocene to the Quaternary (Lyle *et al.*, 1997), and thirteen sites were drilled from about 30°N to 42°N along the California continental margin in the eastern North Pacific Ocean. Of these thirteen sites, Site 1021 was drilled for paleoceanographic reconstruction of the northern region of the area influenced by the California Current during the Neogene. LaRiviere *et al.* (2012) estimated quantitative geochemical sea surface temperature since the late middle Miocene from Site 1021 in the eastern North Pacific. Barron *et al.* (2002) presented weight percent opal records since the late middle Miocene from Site 1021, and indicated that a dramatic decline occurred at about 7.6 Ma.

Radiolarians, which is one of the siliceous microfossil group, were found in the sediment recovered from Site 1021, however its preservation of the fauna changed from age to age (Lyle *et al.*, 1997; Kamikuri, 2017). Sediments older than the latest Miocene was relatively abundant in radiolarians, of which preservation was good. The sediments from the middle to upper Miocene are suitable for studies of taxonomy, biostratigraphy and species diversity on radiolarians.

The most important taxonomic studies of the middle

to upper Miocene in the eastern North Pacific is that of Campbell and Clark (1944). The taxonomic studies were based on siliceous sediments of onshore California. After that, several biostratigraphic studies of radiolarians were conducted in the eastern North Pacific (Rowell, 1981; Poore *et al.*, 1981; Weaver *et al.*, 1981; Perez-Guzman, 1985; Perez-Guzman and Casey, 1986). Kamikuri (2017) studied biostratigraphic distribution of selected radiolarians from ODP Site 1021 in the eastern North Pacific. The purpose of this study is to present microphotographs of all the encountered taxa of the middle to late Miocene age from Site 1021 in the eastern North Pacific in order to analyze the species diversity of radiolarians.

2. Material and methods

Site 1021 was drilled at a water depth of 4211.5 m (39°5.248' N, 127°46.985' W) in the eastern North Pacific (Fig. 1). The lithology of the middle to upper Miocene of this site is characterized by clay and diatom ooze with well-preserved radiolarians (Lyle *et al.*, 1997). A total of 49 sediment samples from 1021B-22X-1, 20–22 cm to 33X-6, 20–22 cm (210.32 to 308.21 meters composite depth below seafloor; 7.50 to 12.83 Ma) were examined in this study (Plates 1 to 24). Sample preparation for microscopic examination followed the standard techniques (Sanfilippo *et al.*, 1985). Sediment samples were treated with H₂O₂ and HCl solution. The residues were sieved with 63 μm. An optical microscope was used for observation and photomicrographic work.

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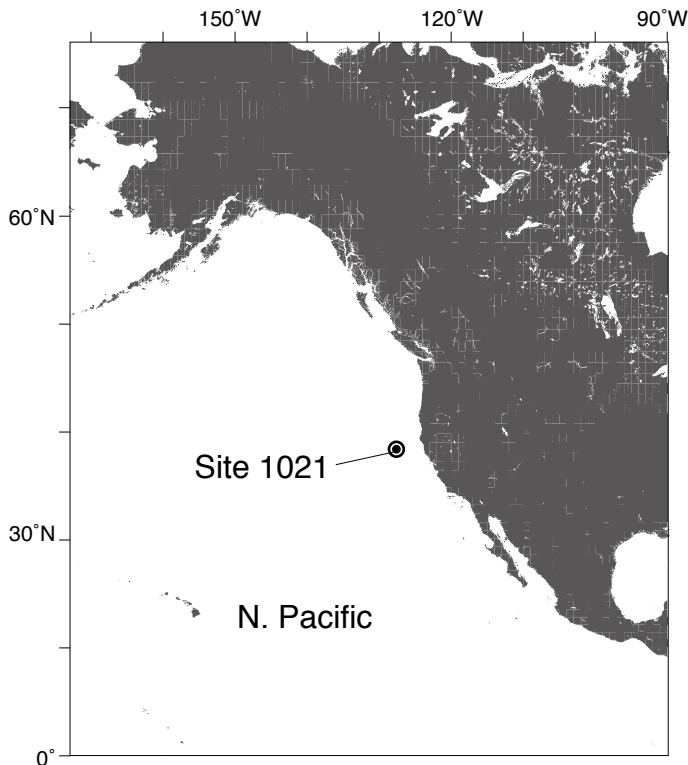


Fig. 1 Location map of ODP Site 1021 in the eastern North Pacific.

3. Radiolarian species diversity

Totally 149 species or species groups of radiolarians were identified from Site 1021 in the eastern North Pacific. Micro-photographs are illustrated in the 24 plates including a new species, *Lychnocanoma californica*.

4. Taxonomic Notes

Genus *Lychnocanoma* Haeckel 1887, emend.
Foreman 1973

Lychnocanoma californica Kamikuri n. sp.

Plate 1, figs. 6-11.

Lychnocanoma nipponica type B. Kamikuri 2017, figs. 2a, b.

Holotype: MPC-42136; ODP Hole 1021B-26X-4, 70-72 cm, D42/0. Plate 1, figs 8a, b. *Holotype* is on deposit in the micropaleontological reference collection of the Natural Science Museum, Tokyo, Japan.

Description: Cephalis moderate in size with a few small subcircular pores. Apical horn, simple unbladed and its length being 0.5 times to twice as long as cephalic diameter. Collar stricture distinct. Thorax hemispherical, usually thick-walled with a relatively smoothed surface and being subcircular pores aligned longitudinally. Thoracic pores, medium and regular in size, about 12-16 pores on a half circumference. Three feet, three-bladed, robust, straight or slightly curved with outward convexity. Feet have usually one or two proximal pores.

In some specimens, meshwork on the inner margin of the feet.

Dimensions (based on ten specimens): Length of apical horn: up to 40 μm ; cephalic diameter: 20-30 μm ; length of thorax: 50-70 μm ; width of thorax: 85-120 μm ; length of foot: up to 170 μm .

Distinguishing characters: *Lychnocanoma californica* is closely related to *Lychnocanoma parallelipes* Motoyama. *Lychnocanoma californica* differs from *L. parallelipes* by a relatively thin thorax with a smooth surface, and a shorter and thin apical horn. *Lychnocanoma californica* can be distinguished from *Lychnocanoma nipponica* Nakaseko and *Lychnocanoma magnacornuta* Sakai by its parallel or slightly convergent feet.

Occurrence: *Lychnocanoma californica* (= *Lychnocanoma nipponica* type B in original paper) occurred from 9.4 to 6.2 Ma in the late Miocene (Kamikuri, 2017).

Genus *Actinomma* Haeckel 1861a,
sensu Burridge *et al.* 2014

Actinomma hootsi (Campbell and Clark)

Plate 10, figs. 1a-4b, plate 16, figs. 8a, b.

Hexacantium hootsi Campbell and Clark 1944, p. 14, pl. 2, fig. 5.

Remarks: I changed the genus name to *Actinomma*, because this species characterized by three cortical shells with eight to ten unbranched spines.

Actinomma robusta (Kling)

Plate 12, figs. 4a-8b.

Sphaeropyle robusta Kling 1973, p. 634, pl. 1, figs. 11, 12, pl. 9, figs. 9-13, pl. 13, figs. 1-5; Morley and Nigrini 1995, p. 81, pl. 1, figs. 6, 7.

Remarks: I changed the genus name to *Actinomma*, because this species is similar to *Actinomma langii* (Dreyer) in Burridge *et al.* (2014).

Genus *Cinclopyramis* Haeckel 1879,
sensu Suzuki *et al.* 2009

Cinclopyramis circumtexta (Haeckel) group
Plate 6, figs. 13, 14, 17.

Peripyramis circumtexta Haeckel 1887, p. 1162, pl. 54, fig. 5.
Peripyramis circumtexta Haeckel group in Petrushevskaya 1975, p. 587, pl. 13, fig. 29, pl. 44, figs. 5, 6.

Remarks: I changed the genus name to *Cinclopyramis*, because *Peripyramis* is junior synonym of *Cinclopyramis* (Suzuki *et al.*, 2009).

Genus *Cycladophora* Ehrenberg 1872, emend.
Lombardi and Lazarus 1988

Cycladophora klingi Lombardi and Lazarus
Plate 1, figs. 3a, b.

Cycladophora bicornis klingi Lombardi and Lazarus 1988, p. 108, pl. 4, figs. 1-5.

Remarks: *Cycladophora klingi* was described originally as a subspecies of *Cycladophora bicornis* by Lombardi and Lazarus (1988). I have raised this taxon to species rank, because this species is distinguished from other cycladophorids by its small compact shape and lower thorax skirt.

Genus *Lamprotripus* Haeckel 1882
Lamprotripus splendens (Campbell and Clark)
Plate 2, fig. 6

Pterocorys (*Pterocyrtidium*) *splendens* Campbell and Clark 1944, p. 46, pl. 6, figs. 16, 19, 20.

Dictyophimus splendens (Campbell and Clark) in Morley and Nigrini 1995, p. 79, pl. 7, figs. 3, 4.

Remarks: I changed genus name to *Lamprotripus*, because this species is similar to *Lamprotripus cortina* (Haeckel) and *L. hirundo* (Haeckel) in Matsuzaki *et al.* (2015).

Genus *Rhizosphaera* Haeckel 1861b,
sensu Dumitrica 2017
Rhizosphaera churchi (Campbell and Clark) group
Plate 8, figs. 1-8.

Plegmosphaera churchi Campbell and Clark 1944, p. 10,

pl. 1, figs. 6-10.

Remarks: I changed genus name to *Rhizosphaera*, because this species is similar to *Rhizosphaera antarctica* (Haeckel) in Dumitrica (2017).

5. Species list

Amphistylus angelinus (Campbell and Clark) in Takemura 1992, p. 741, pl. 1, figs. 8, 9. [Plate 14, fig. 13.]

Amphymenium amphistylum Haeckel in Morley and Nigrini 1995, p. 78, pl. 1, figs. 8, 9. [Plate 19, fig. 4.]

Anthocyrtidium sp. A: This study. [Plate 3, figs. 9, 10.]

Anthocyrtidium sp. B: This study. [Plate 3, fig. 11.]

Axoprunum bispiculum (Popofsky) in Takemura 1992, p. 741, pl. 1, figs. 1, 2. [Plate 14, fig. 11.]

Botryostrobos bramlettei (Campbell and Clark) in Nigrini and Lombardi 1984, p. N175, pl. 31, figs. 2a-2c. [Plate 1, fig. 12.]

Calocyclella caepa Moore 1972, p. 150, pl. 2, figs. 4-7. [Plate 3, fig. 1.]

Calocyclella sp. A: This study. [Plate 3, fig. 5.]

Calocyclella sp. B: This study. [Plate 3, fig. 4.]

Calocyclella sp. C: This study. [Plate 3, figs. 2, 3.]

Carpocanium favosa (Haeckel): *Carpocanistrum favosum* (Haeckel) in Takahashi 1991, p. 131, pl. 45, fig. 8; *Carpocanium* spp. in O'Connor 1997, p. 111, pl. 3, figs. 18-20. [Plate 1, fig. 15.]

Cenosphaera jenkinsi Campbell and Clark group: *Cenosphaera jenkinsi* Campbell and Clark 1944, p. 9, pl. 1, figs. 2-4. [Plate 15, figs. 1-11; Plate 16, figs. 6, 7.]

Ceratocyrtis aff. *mashae* Bjørklund in Matsuzaki *et al.* 2015, p. 46, fig. 7.24. [Plate 5, figs. 10, 11.]

Ceratocyrtis sp. A: This study. [Plate 5, fig. 12.]

Ceratocyrtis sp. C: This study. [Plate 5, fig. 13.]

Cinclopyramis murrayana Haeckel in Matsuzaki *et al.* 2015, p. 58, figs. 9.19, 9.20; *Bathropyramis woodringi* Campbell and Clark 1944, p. 39, pl. 5, figs. 21, 22. [Plate 6, fig. 7.]

Circodiscus circularis (Clark and Campbell) in Jackett *et al.*, 2008, p. 50, pl. 4, figs. 10, 12; *Porodiscus circularis* Clark and Campbell 1942, p. 42, pl. 2, figs. 2, 6, 10. [Plate 20, figs. 1-4.]

Collosphaera glebulenta Bjørklund and Goll 1979, p. 1316, pl. 2, figs. 9-25. [Plate 17, figs. 1-6.]

Collosphaera reynoldsi Kamikuri 2010, p. 97, pl. 3, figs. 18-25. [Plate 17, fig. 7.]

Collosphaera sp. A: This study. [Plate 17, fig. 9.]

Collosphaera sp. B: This study. [Plate 17, fig. 8.]

Cornutella paloverdensis Campbell and Clark 1944, p. 40, pl. 5, figs. 17, 20, 24, 25. [Plate 6, fig. 3.]

Cornutella profunda Ehrenberg in Nigrini and Lombardi 1984, p. N93, pl. 22, fig. 1. [Plate 6, fig. 15.]

Cromydruppocarpus esterae Campbell and Clark 1944, p. 20, pl. 2, figs. 26-28. [Plate 14, figs. 4-6.]

Cycladophora bicornis (Popofsky) in Matsuzaki *et al.*

- 2015, p. 63, figs. 8.19–8. 22; Not *Cycladophora bicornis bicornis* (Popofsky) in Lombari and Lazarus 1988, p. 106, pl. 5, figs. 9–12. [Plate 1, fig. 4.]
- Cycladophora cabrilloensis* (Campbell and Clark): *Clathrocyclas cabrilloensis* Campbell and Clark 1944, p. 48, pl. 7, fig. 1 (only); *Cycladophora cabrilloensis cabrilloensis* (Campbell and Clark) in Lombari and Lazarus 1988, p. 118, pl. 7, figs. 1–12. [Plate 1, fig. 1.]
- Cycladophora cosma* Lombari and Lazarus: *Cycladophora cosma cosma* Lombari and Lazarus 1988, p. 104, pl. 1, figs. 1–6; *Cycladophora cosma irregularis* Lombari and Lazarus 1988, p. 105, pl. 1, figs. 7–12. [Plate 1, fig. 2.]
- Cycladophora sphaeris* (Popova): *Spuroclathrocylas sphaeris* Popova 1989, p. 73, pl. 11, fig. 17, pl. 12, fig. 3; *Cycladophora sakaii* Motoyama 1996, p. 246, pl. 4, figs. 4a–6b; *Cycladophora sphaeris* (Popova) in Kamikuri 2017, fig. 8.5. [Plate 1, fig. 5.]
- Cyrtocapsella cornuta* Haeckel in Sakai 1980, p. 709, pl. 8, figs. 8a, 8b. [Plate 5, fig. 4.]
- Cyrtocapsella japonica* (Nakaseko) in Sakai 1980, p. 709, pl. 8, figs. 7a, 7b. [Plate 5, figs. 8, 9.]
- Cyrtocapsella tetrapera* Haeckel in Sakai 1980, p. 709, pl. 8, figs. 5, 6. [Plate 5, fig. 5.]
- Cyrtolagena* sp. A: This study. [Plate 6, fig. 16.]
- Dendrospyris* aff. *bursa* (Sanfilippo and Riedel): This study. [Plate 7, figs. 12, 13.]
- Dendrospyris* sp. A: This study. [Plate 7, figs. 3–5.]
- Dendrospyris* sp. B: This study. [Plate 7, fig. 6.]
- Dendrospyris* sp. C: This study. [Plate 7, fig. 8.]
- Dendrospyris* sp. D: This study. [Plate 7, fig. 9.]
- Dendrospyris* sp. E: This study. [Plate 7, fig. 11.]
- Dendrospyris* sp. F: This study. [Plate 7, fig. 14.]
- Diartus hughesi* (Campbell and Clark) in Sanfilippo *et al.* 1985, p. 655, fig. 8.11. [Plate 19, figs. 20, 21.]
- Dictyocoryne malagaense* (Campbell and Clark) group: *Rhopalodictyum malagaense* Campbell and Clark 1944, p. 29, pl. 4, figs. 4, 5. [Plate 19, figs. 1, 2.]
- Dictyocoryne* sp. A: This study. [Plate 19, fig. 3.]
- Dictyophimus* sp. A: This study. [Plate 5, fig. 16.]
- Didymocyrtis antepenultima* (Riede and Sanfilippo) in Sanfilippo *et al.* 1985, p. 657, fig. 8.6. [Plate 19, figs. 18, 19.]
- Didymocyrtis laticonus* (Riedel) in Sanfilippo *et al.* 1985, p. 658, figs. 8.5a, 8.5b. [Plate 19, figs. 16, 17.]
- Didymocyrtis penultima* (Riede and Sanfilippo) in Sanfilippo *et al.* 1985, p. 658, figs. 8.7a, 8.7b. [Plate 19, figs. 14, 15.]
- Didymocyrtis* sp. C: This study. [Plate 19, figs. 22, 23.]
- Didymocyrtis* sp. D: This study. [Plate 19, figs. 24, 25.]
- Drupptractus hastatus* Blueford 1982, p. 206, pl. 6, figs. 3, 4. [Plate 14, fig. 7.]
- Eucyrtidium calvertense* Martin in Morley and Nigrini 1995, p. 82, pl. 4, fig. 8. [Plate 4, fig. 8.]
- Eucyrtidium cienkowskii* Haeckel group in Sakai 1980, p. 710, pl. 7, figs. 8a–10. [Plate 4, figs. 9–11.]
- Eucyrtidium hexagonatum* Haeckel in Nigrini and Lombari 1984, p. N115, pl. 23, fig. 8. [Plate 4, fig. 7.]
- Eucyrtidium inflatum* Kling 1973, p. 636, pl. 11, figs. 7, 8, pl. 15, figs. 7–10. [Plate 4, fig. 13; Plate 5, fig. 15.]
- Eucyrtidium* sp. D: This study. [Plate 5, fig. 14.]
- Eucyrtidium* sp. E: This study. [Plate 4, fig. 12.]
- Eucyrtidium* sp. G: This study. [Plate 4, fig. 14.]
- Excentrodiscus japonicus* (Nakaseko and Nishimura) in Kamikuri 2010, p. 86, pl. 2, figs. 2a–3b, 5a–6b, 8a–9b, 11a, 11b, 13a–14b, pl. 4, figs. 19a–19c. [Plate 10, figs. 5–7.]
- Gondwanaria campanulaeformis* (Campbell and Clark), Funakawa 2000, p. 100, pl. 1, figs. 1a–1d, pl. 7, figs. 1a, 1b, text-fig. 4. [Plate 6, fig. 2.]
- Haliometta miocenica* (Campbell and Clark) group in Petrushevskaya and Kozlova 1972, p. 517, pl. 9, figs. 8, 9. [Plate 9, figs. 1–9.]
- Heliodiscus* sp. A: This study. [Plate 24, fig. 9.]
- Hexacantium* aff. *arachnoidale* Hollande and Enjumet: This study. [Plate 11, figs. 4, 5.]
- Hexacantium minerva* Kamikuri 2010, p. 97, pl. 3, figs. 12a–14b, 16a–17b. [Plate 11, figs. 6–9.]
- Hexacantium* sp. A: This study. [Plate 11, fig. 1.]
- Hexacantium* sp. B: This study. [Plate 11, figs. 2, 3.]
- Hexacantium* sp. E: This study. [Plate 12, fig. 1.]
- Hexastylus aculeata* (Campbell and Clark): *Staurolonche aculeata* Campbell and Clark 1944, p. 13, pl. 2, figs. 2, 3. [Plate 12, fig. 3.]
- Hexastylus* sp. A: This study. [Plate 12, fig. 2.]
- Lamprocyclas hannai* (Campbell and Clark): *Calocyclas hannai* Campbell and Clark 1944, p. 48, pl. 6, figs. 21, 22; *Lamprocyclas hannai* (Campbell and Clark) in Sanfilippo *et al.* 1985, fig. 29.8. [Plate 4, figs. 1–6.]
- Lamprocyclas* sp. C: This study. [Plate 3, figs. 12, 13.]
- Lamprotripus cortina* (Haeckel) in Matsuzaki *et al.* 2015, p. 64, fig. 8.5. [Plate 2, fig. 4.]
- Larcopyle* aff. *pylomaticus* (Riedel): This study. [Plate 18, fig. 5.]
- Larcopyle buetschlii* Dreyer in Matsuzaki *et al.* 2015, p. 33, fig. 6.21–6.28. [Plate 18, figs. 18–22.]
- Larcopyle polyacantha* (Campbell and Clark): *Larnacantha polyacantha* Campbell and Clark 1944, p. 30, pl. 5, figs. 4–7. [Plate 18, figs. 7–17.]
- Larcopyle* sp. A: This study. [Plate 18, fig. 6.]
- Larcospira moschkovskii* Kruglikova in Nigrini and Lombari 1984, p. S91, pl. 13, figs. 2a, 2b. [Plate 20, fig. 17; Plate 22, fig. 8.]
- Larcospira quadrangula* Haeckel group in Nigrini and Lombari 1984, p. S93, pl. 13, figs. 3a–3c. [Plate 18, fig. 3; Plate 22, figs. 9, 10.]
- Liosphaera hexagonia* Haeckel in Takahashi and Honjo 1981, p. 146, pl. 1, fig. 23. [Plate 13, fig. 16.]
- Lipmanella hister* (Petrushevskaya) in Sugiyama and Furutani 1992, p. 209, pl. 13, figs. 7, 8. [Plate 6, fig. 11.]
- Lipmanella redondoensis* (Campbell and Clark) in Funakawa 2000, p. 108, pl. 4, figs. 2a–3c, pl. 7, figs. 6a–6c, text-fig. 8. [Plate 6, figs. 8–10.]

- Lithelius* aff. *elliptica* (Ehrenberg): This study. [Plate 18, fig. 4.]
- Lithelius klingi* Kamikuri 2010, p. 95, pl. 4, figs. 9-14. [Plate 18, fig. 1.]
- Lithelius minor* Jørgensen group: *Lithelius minor* Jørgensen in Nigrini and Moore 1979, p. S135, pl. 17, figs. 3-4b. [Plate 18, fig. 2.]
- Lithomelissa* cf. *ultima* Caulet: *Lithomelissa ultima* Caulet 1979, p. 129, pl. 1, figs. 2, 3. [Plate 6, fig. 4.]
- Lithomelissa* sp. A: This study. [Plate 6, fig. 5.]
- Lithomelissa* sp. B: This study. [Plate 6, fig. 6.]
- Lithopera neotera* Sanfilippo and Riedel in Sanfilippo *et al.* 1985, p. 675, figs. 16.5a-16.4c. [Plate 5, fig. 3.]
- Lithopera renzae* Sanfilippo and Riedel in Sanfilippo *et al.* 1985, p. 675, figs. 16.4a, 16.5b. [Plate 5, figs. 1, 2.]
- Lophoconus bihastatus* Clark and Campbell 1945, p. 47, pl. 6, fig. 15. [Plate 3, fig. 6.]
- Lophocyrtis aspera* (Ehrenberg) in Sanfilippo and Caulet 1998, p. 14, pl. 3A, figs. 5-10, pl. 3B, figs. 1, 2, 5-9, pl. 6, figs. 6-8. [Plate 6, fig. 1.]
- Lophospyris laventaensis* (Campbell and Clark): *Ceratospyrus* (*Lophospyris*) *laventaensis* Campbell and Clark 1944, p. 36, pl. 5, fig. 15. [Plate 7, figs. 1, 2.]
- Lychnocanoma magnacornuta* Sakai in Motoyama 1996, p. 248, pl. 5, figs. 10a-11. [Plate 2, fig. 5.]
- Lychnocanoma nipponica* (Nakaseko): *Lychnocanium nipponicum* Nakaseko in Shilov 1995, p. 109, pl. 3, figs. 4a, 4b; *Lychnocanoma nipponica nipponica* (Nakaseko) in Morley and Nigrini 1995, p. 81, pl. 5, figs. 4, 5; *Lychnocanoma nipponica* (Nakaseko) type A in Kamikuri 2017, pl. 6, figs. 1a, 1b. [Plate 2, figs. 1, 2.]
- Lychnodictyum* aff. *audax* Riedel: This study. [Plate 2, fig. 3.]
- Perichlamyidium scutaeforme* Campbell and Clark 1944, p. 24, pl. 3, figs. 14-16. [Plate, 20 figs. 10-15; Plate 23, figs. 9-12.]
- Perichlamyidium* sp. K: This study. [Plate 24, figs. 7, 8.]
- Perichlamyidium* sp. P: This study. [Plate 20, fig. 16.]
- Phormospyris stabilis* (Goll): *Phormospyris stabilis stabilis* (Goll) in Nigrini and Lombardi 1984, p. N59, pl. 19, fig. 7. [Plate 7, fig. 7.]
- Phormostichoartus fistula* Nigrini in Nigrini and Lombardi 1984, p. N183, pl. 31, figs. 6a-6c. [Plate 1, fig. 13.]
- Phorticium clevei* (Jørgensen) in Matsuzaki *et al.* 2015, p. 32, figs. 6.9, 6.10. [Plate 19, figs. 11-13.]
- Phorticium* sp. A: This study. [Plate 19, figs. 8-10.]
- Polysolenia murrayana* (Haeckel) in Nigrini and Moore 1979, p. S17, pl. 2, figs. 4a, 4b. [Plate 17, fig. 11.]
- Polysolenia pseudarktioides* (Caulet): *Acrosphaera pseudarktioides* Caulet 1986, p. 226, pl. 1, fig. 8. [Plate 17, fig. 10.]
- Saturnalis circularis* Haeckel in Takahashi 1991, p. 78, pl. 15, figs. 15-18. [Plate 13, fig. 11.]
- Spirocyrtis subscalaris* Nigrini in Nigrini and Lombardi 1984, p. N199, pl. 32, figs. 7a, 7b. [Plate 1, fig. 14.]
- Spongaster* sp. A: This study. [Plate 21, fig. 13.]
- Spongodiscus cauleti* Kamikuri 2010, p. 94, pl. 4, figs. 1-4. [Plate 24, figs. 5, 6.]
- Spongodiscus resurgens* Ehrenberg in Petrushevskaya and Kozlova 1972, p. 528, pl. 21, fig. 5. [Plate 21, figs. 1-12.]
- Spongodiscus* sp. D: This study. [Plate 21, fig. 14.]
- Spongopyle osculosa* Dreyer in Nigrini and Moore 1979, p. S115, pl. 15, fig. 1. [Plate 22, figs. 5-7.]
- Spongotrochus sol* Campbell and Clark 1944, p. 28, pl. 4, figs. 7, 9-11. [Plate 24, figs. 1, 2.]
- Spongotrochus* sp. B: This study. [Plate 22, fig. 1.]
- Spongotrochus* sp. C: This study. [Plate 22, figs. 2-4.]
- Spongotrochus* sp. Z: This study. [Plate 24, figs. 3, 4.]
- Spongurus cylindricus* Haeckel in Takahashi 1991, p. 85, pl. 17, figs. 6-9. [Plate 19, fig. 5.]
- Stichocorys delmontensis* (Campbell and Clark) in Kamikuri 2012, p. 24, pl. 1, figs. 1-9, pl. 3, figs. 1-6. [Plate 5, fig. 7.]
- Stichocorys peregrina* (Riedel) in Kamikuri 2012, p. 25, pl. 2, figs. 1-9, pl. 3, figs. 7-12. [Plate 5, fig. 6.]
- Stylatractus neptunus* Haeckel in Petrushevskaya and Kozlova 1972, p. 520, pl. 11, fig. 11. [Plate 16, figs. 3-5.]
- Stylatractus santaeannae* (Campbell and Clark) in Petrushevskaya and Kozlova 1972, p. 520, pl. 11, fig. 10. [Plate 16, fig. 9.]
- Stylatractus universus* Hays in Morley and Nigrini 1995, p. 82, pl. 2, fig. 3. [Plate 14, fig. 12.]
- Stylodictya ornata* Campbell and Clark 1944, p. 26, pl. 3, fig. 20. [Plate 23, figs. 1-6.]
- Stylodictya tenuispina* Jørgensen 1905, p. 118, pl. 10, fig. 39. [Plate 23, figs. 7, 8.]
- Stylodictya* sp. A: This study. [Plate 20, figs. 5-9.]
- Stylosphaera radiosa* Ehrenberg in Petrushevskaya and Kozlova 1972, p. 520; *Amphisphaera radiosa* (Ehrenberg) group in Petrushevskaya 1975, p. 570, pl. 2, figs. 18-20; *Lithatractus santaeannae pusillus* Campbell and Clark 1944, p. 19, pl. 2, figs. 23-25. [Plate 14, figs. 1-3.]
- Stylosphaera timmsi* (Campbell and Clark): *Stylosphaera* (?) *timmsi* (Campbell and Clark) in Sugiyama and Furutani 1992, p. 203, pl. 12, figs. 3, 4, pl. 15, figs. 1, 2. [Plate 14, figs. 8-10.]
- Styptosphaera spumacea* Haeckel in Vitukhin 1993, pl. 27, fig. 6, pl. 28, fig. 5. [Plate 16, figs. 1, 2.]
- Tetrapyle circularis/fruticosa* group: *Tetrapyle circularis* Haeckel in Zhang and Suzuki, 2017, p. 15, figs. 8.1-8.15, 9.1-9.9; *Tetrapyle fruticosa* (Tan and Chen) in Zhang and Suzuki 2017, p. 18, figs. 10.1-10.4; *Tetrapyle* spp. (juvenile form) in Zhang and Suzuki 2017, p. 19, figs. 11.1-11.18. [Plate 19, figs. 6, 7.]
- Thecosphaera dedoensis* Nakaseko in Motoyama 1996, pl. 2, fig. 2. [Plate 13, figs. 1-8.]
- Thecosphaera* sp. A: This study. [Plate 13, figs. 9, 10.]
- Thecosphaera* sp. B: This study. [Plate 13, figs. 12-15.]
- Thecorys perforalvus* O'Connor 1997, p. 86, pl. 4, figs. 9-12, pl. 10, figs. 9-14, pl. 11, fig. 6. [Plate 6, fig. 12.]
- Thecorythium* sp. A: This study. [Plate 3, fig. 7.]

Tholospyris kantiana (Haeckel) in Nigrini and Lombari 1984, p. N71, pl. 20, figs. 2a–2c. [Plate 7, fig. 10.]

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北東太平洋における国際深海掘削計画 (ODP) 1021 地点の
中部および上部中新統から産出した放散虫化石

上栗伸一

要 旨

北東太平洋における国際深海掘削計画 (ODP) 1021地点の中部および上部中新統から、合計149種の放散虫化石が産出した。その写真を24枚のプレートに示した。これらの分類群にはActinommoidea科, Eurcyrtidioidea科, Hexastylloidea科, Litheliidae科, Lychnocanoidea科およびSpongodiscidae科を含む40の未同定種が含まれている。本論文において *Lychnocanoma californica* を新種として記載した。

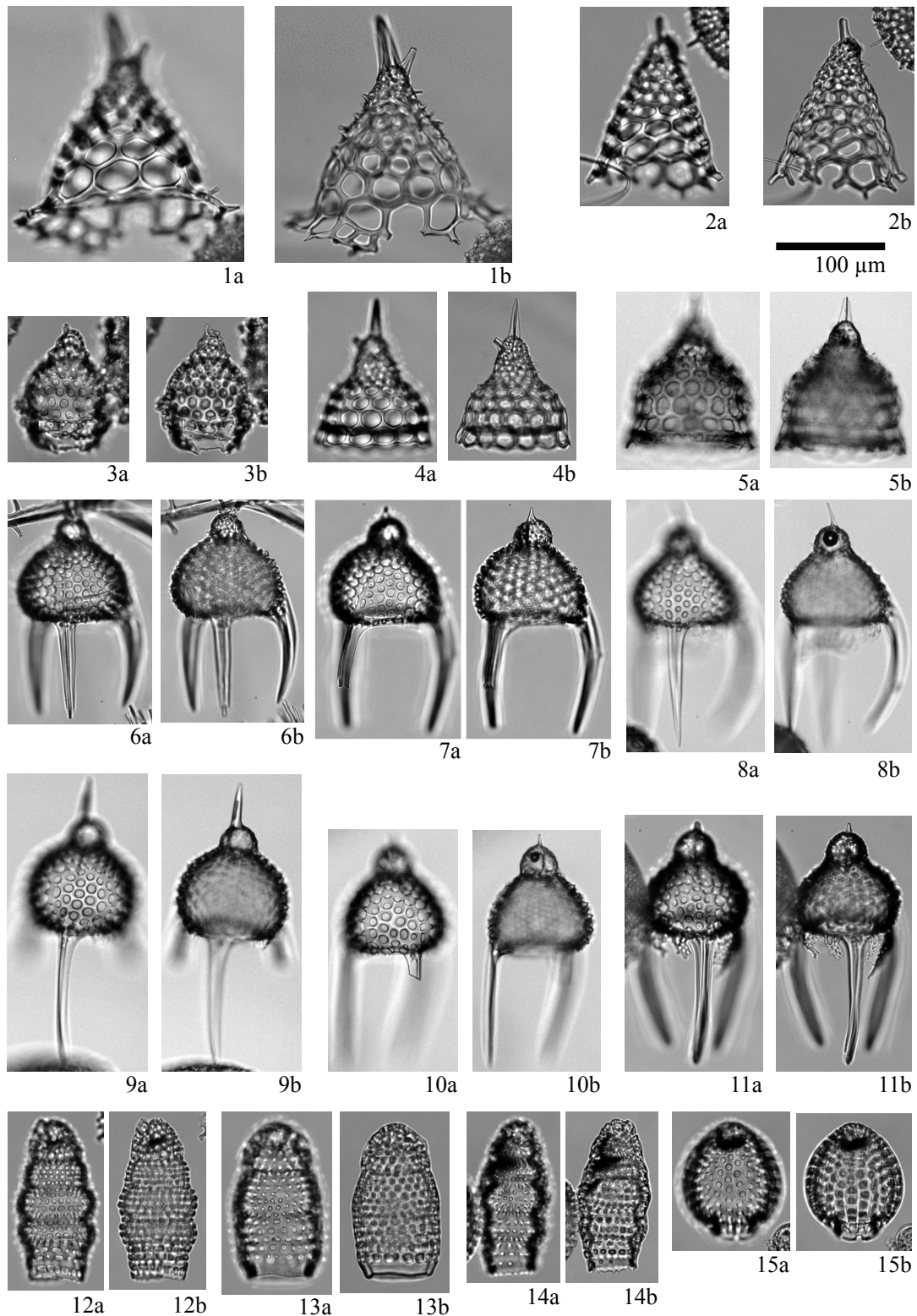


Plate 1 Illustrations of the encountered radiolarians. 1: *Cycladophora cabrilloensis* (Campbell and Clark) (Sample 1021B-26X-4, 70-72 cm, 9.0 Ma); 2: *Cycladophora cosma* Lombardi and Lazarus (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 3: *Cycladophora klingi* Lombardi and Lazarus (Sample 1021B-26X-6, 20-22 cm, 9.0 Ma); 4: *Cycladophora bicornis* (Popofsky) (Sample 1021B-26X-4, 70-72 cm, 9.0 Ma); 5: *Cycladophora sphaeris* (Popova) (Sample 1021B-22X-6, 20-22 cm, 7.8 Ma); 6-11: *Lychnocanoma californica* n. sp. (6-8, 11: Sample 1021B-26X-4, 70-72 cm, 9.0 Ma; 9, 10: Sample 1021B-26X-2, 120-122 cm, 8.9 Ma); 12: *Botryostrobus bramlettei* (Campbell and Clark) (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 13: *Phormostichoartus fistula* Nigrini (Sample 1021B-32X-6, 20-22 cm, 12.2 Ma); 14: *Spirocyrtis subscalaris* Nigrini (Sample 1021B-26X-6, 20-22 cm, 9.0 Ma); 15: *Carpocanium favosa* (Haeckel) (Sample 1021B-32X-6, 20-22 cm, 12.2 Ma).

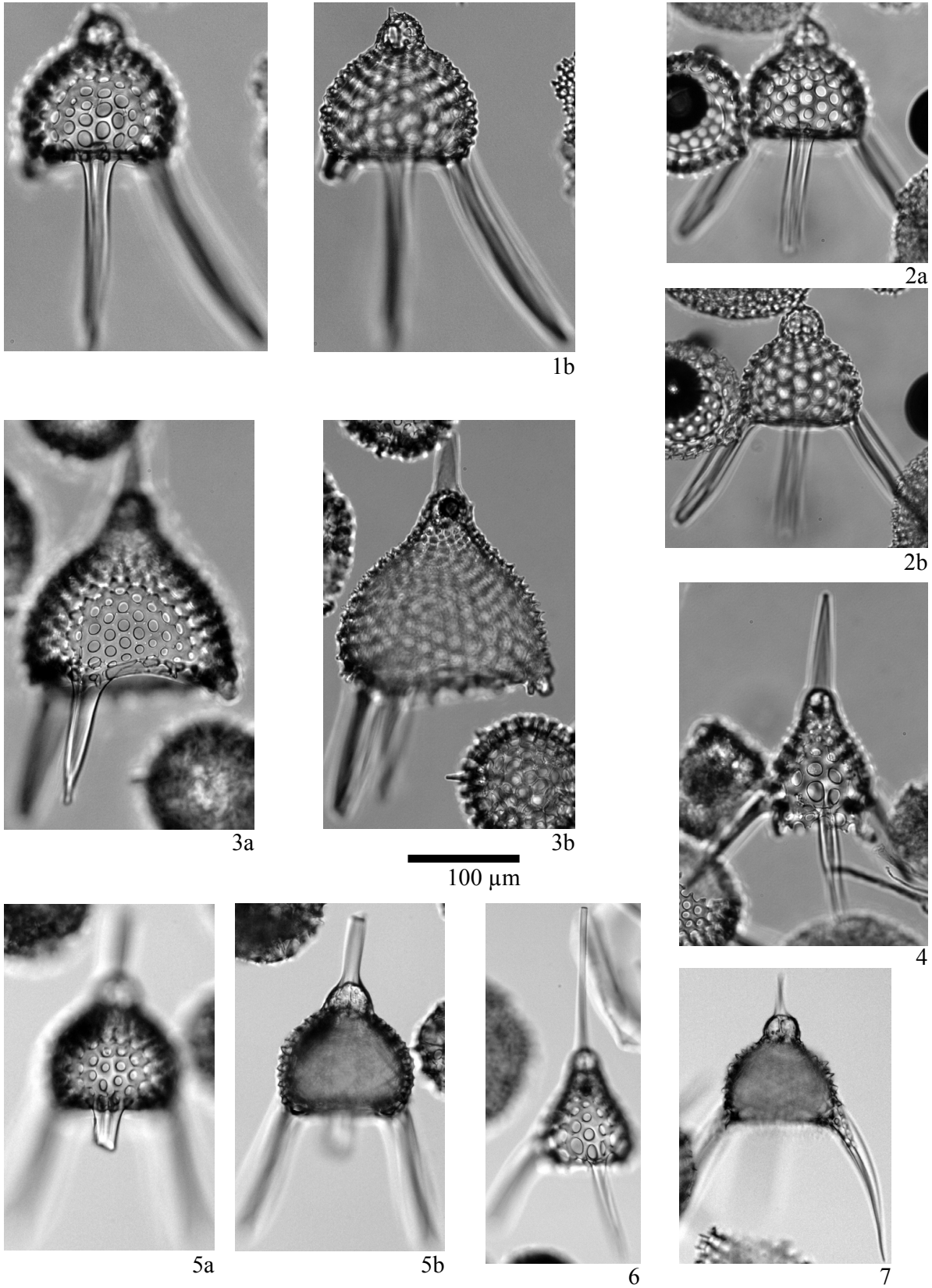


Plate 2 Illustrations of the encountered radiolarians. 1, 2: *Lychnocanoma nipponica* (Nakaseko) (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 3: *Lychnodictyum* aff. *audax* Riedel (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 4: *Lamprotripus cortina* (Haeckel) (Sample 1021B-28X-6, 20-22 cm, 9.8 Ma); 5: *Lychnocanoma magnacornuta* Sakai (Sample 1021B-29X-4, 70-72 cm, 10.2 Ma); 6: *Lamprotripus splendens* (Campbell and Clark) (Sample 1021B-29X-2, 120-122 cm, 10.1 Ma); 7: *Pterocanium* sp. A (Sample 1021B-32X-4, 70-72 cm, 12.1 Ma).

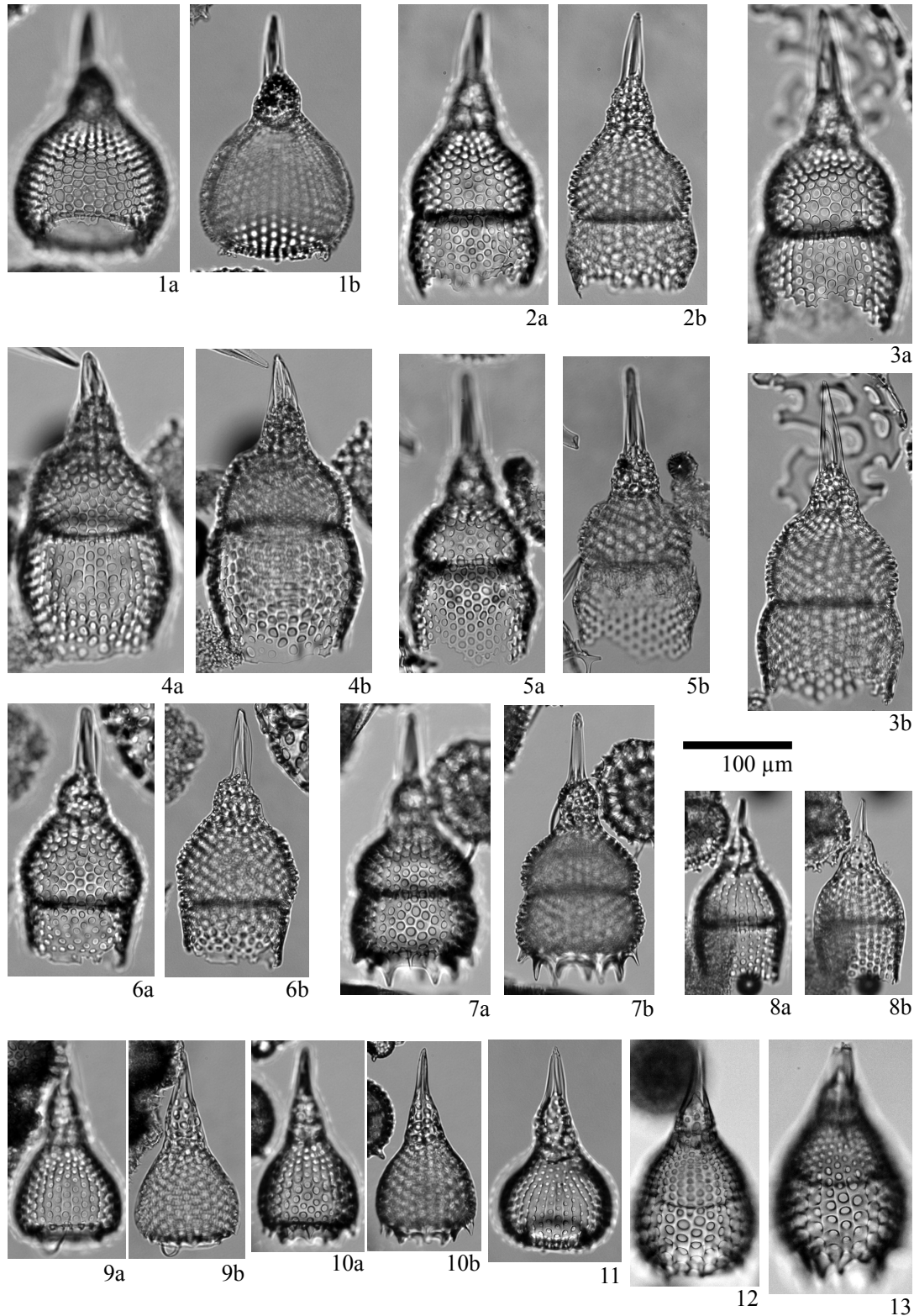


Plate 3 Illustrations of the encountered radiolarians. 1: *Calocyclus caepa* Moore (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 2, 3: *Calocyclus* sp. C (2: Sample 1021B-32X-6, 20-22 cm, 12.8 Ma; 3: Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 4: *Calocyclus* sp. B (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 5: *Calocyclus* sp. A (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 6: *Lophoconus biastatus* Clark and Campbell (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 7: *Theocorythium* sp. A (Sample 1021B-26X-4, 70-72 cm, 9.0 Ma); 8: *Albatrossidium* sp. C (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 9, 10: *Anthocyrtdium* sp. A (9: Sample 1021B-33X-2, 120-122 cm, 12.5 Ma; 10: Sample 1021B-26X-4, 70-72 cm, 9.0 Ma); 11: *Anthocyrtdium* sp. B (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 12, 13: *Lamprocyclus* sp. C (Sample 1021B-29X-4, 70-72 cm, 10.2 Ma).

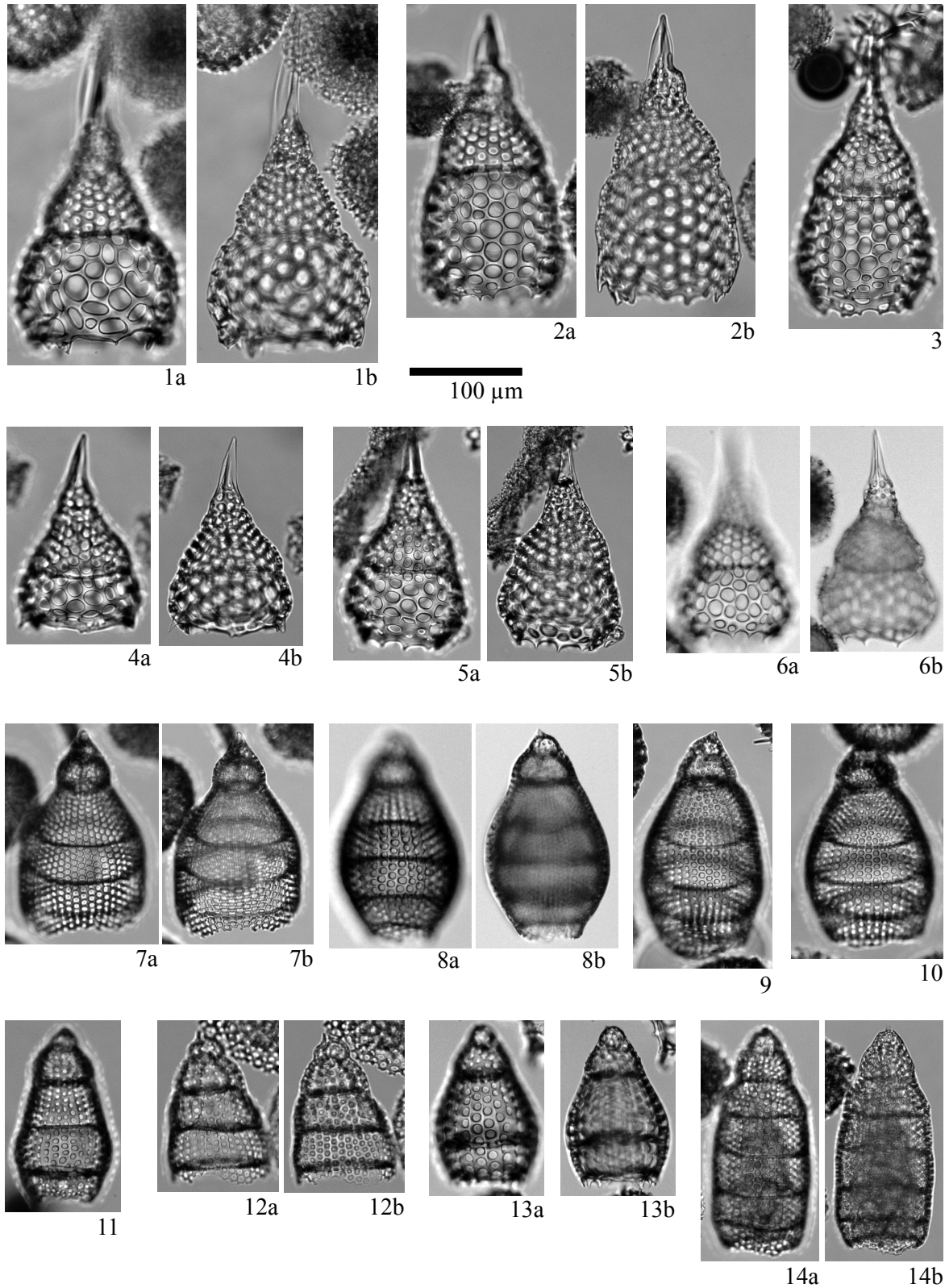


Plate 4 Illustrations of the encountered radiolarians. 1–3: *Lamprocyclas hannai* (Campbell and Clark) type A (1, 3: Sample 1021B-33X-2, 120–122 cm, 12.5 Ma; 2: Sample 1021B-32X-6, 20–22 cm, 12.2 Ma); 4–6: *Lamprocyclas hannai* (Campbell and Clark) type B (4, 5: Sample 1021B-32X-6, 20–22 cm, 12.2 Ma; 6: 1021B-32X-4, 70–72 cm, 12.1 Ma); 7: *Eucyrtidium hexagonatum* Haeckel (Sample 1021B-26X-4, 70–72 cm, 9.0 Ma); 8: *Eucyrtidium calvertense* Martin (Sample 1021B-31X-6, 20–22 cm, 11.6 Ma); 9–11: *Eucyrtidium cienkowskii* Haeckel group (9, 10: Sample 1021B-26X-4, 70–72 cm, 9.0 Ma; 11: Sample 1021B-28X-6, 20–22 cm, 9.8 Ma); 12: *Eucyrtidium* sp. E (Sample 1021B-33X-2, 120–122 cm, 12.5 Ma); 13: *Eucyrtidium inflatum* Kling (Sample 1021B-33X-2, 120–122 cm, 12.5 Ma); 14: *Eucyrtidium* sp. G (Sample 1021B-33X-2, 120–122 cm, 12.5 Ma).

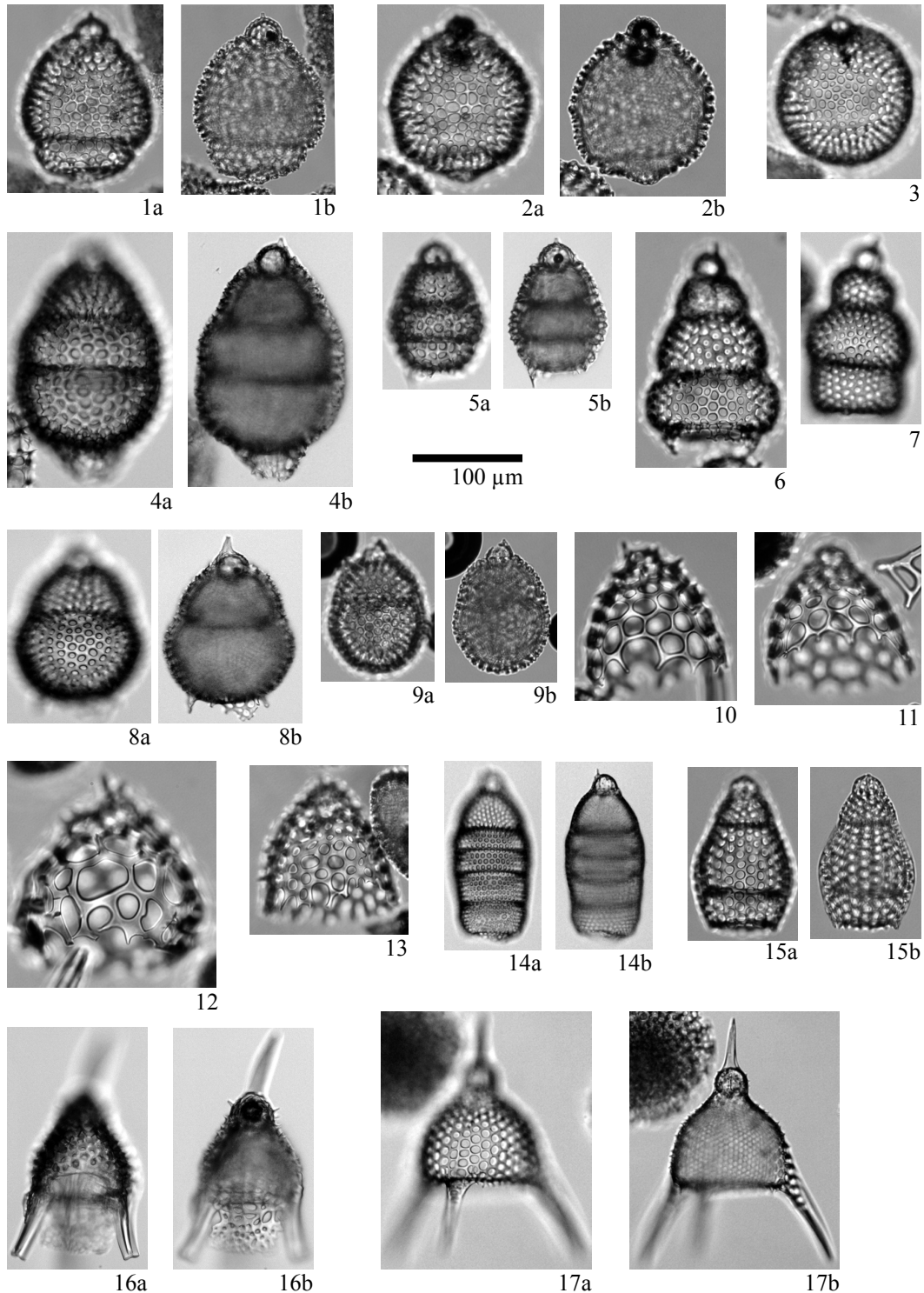


Plate 5 Illustrations of the encountered radiolarians. 1, 2: *Lithopera renzae* Sanfilippo and Riedel (1: Sample 1021B-32X-6, 20-22 cm, 12.2 Ma; 2: Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 3: *Lithopera neotera* Sanfilippo and Riedel (Sample 1021B-32X-6, 20-22 cm, 12.2 Ma); 4: *Cyrtocapsella cornuta* Haeckel (Sample 1021B-33X-4, 70-72 cm, 12.7 Ma); 5: *Cyrtocapsella tetrapera* Haeckel (Sample 1021B-33X-4, 70-72 cm, 12.7 Ma); 6: *Stichocorys peregrina* (Riedel) (Sample 1021B-28X-6, 20-22 cm, 9.8 Ma); 7: *Stichocorys delmontensis* (Campbell and Clark) (Sample 1021B-31X-6, 20-22 cm, 11.6 Ma); 8, 9: *Cyrtocapsella japonica* (Nakaseko) (8: Sample 1021B-33X-4, 70-72 cm, 12.7 Ma; 9: Sample 1021B-32X-4, 70-72 cm, 12.1 Ma); 10, 11: *Ceratocyrtis* aff. *mashae* Bjørklund (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 12: *Ceratocyrtis* sp. A (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 13: *Ceratocyrtis* sp. C (Sample 1021B-32X-6, 20-22 cm, 12.2 Ma); 14: *Eucyrtidium* sp. D (Sample 1021B-32X-4, 70-72 cm, 12.1 Ma); 15: *Eucyrtidium inflatum* Kling (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 16: *Dictyophimus* sp. A (Sample 1021B-32X-4, 70-72 cm, 12.1 Ma); 17: *Pterocanium* sp. A (Sample 1021B-32X-4, 70-72 cm, 12.1 Ma).

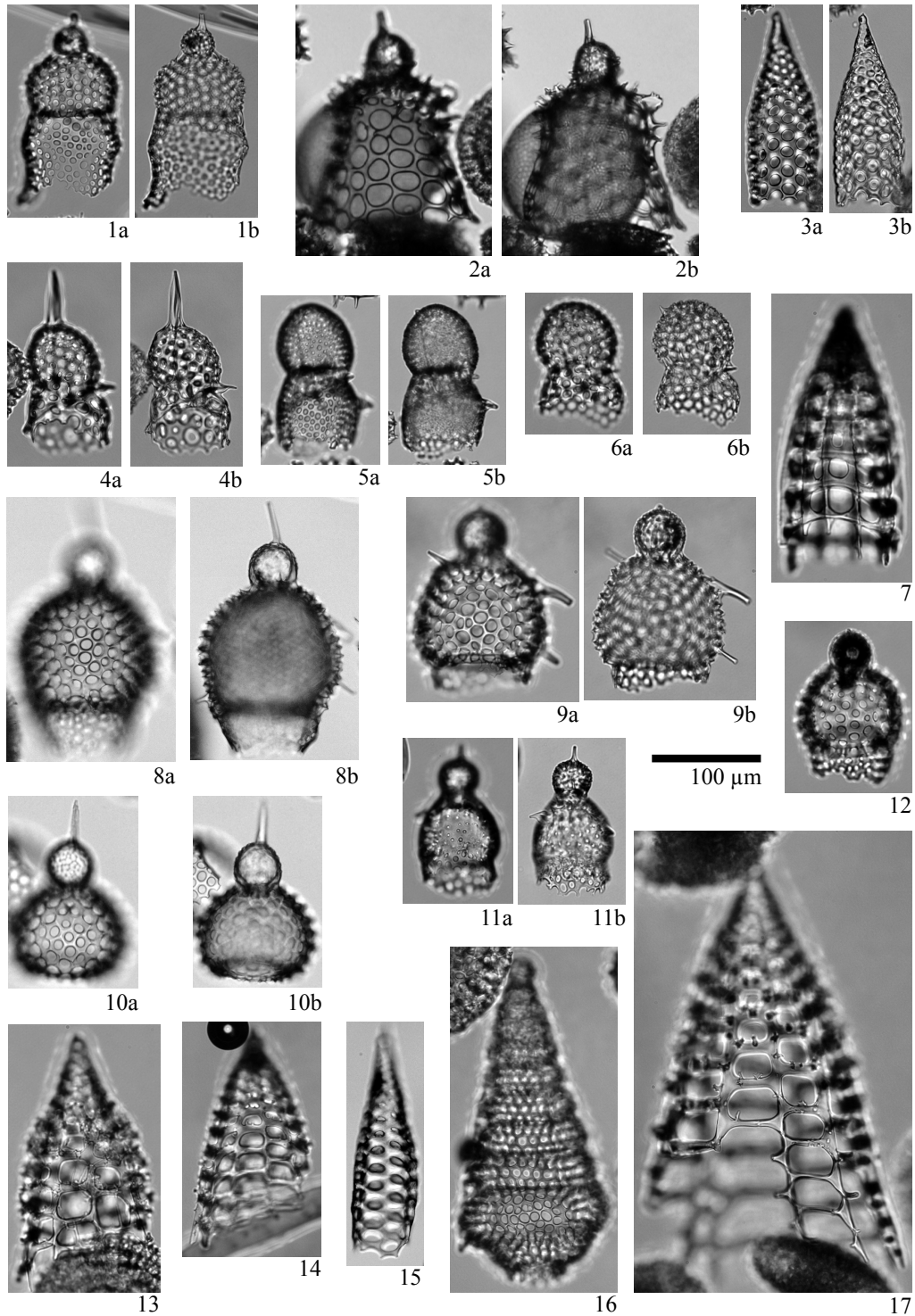


Plate 6 Illustrations of the encountered radiolarians. 1: *Lophocyrtis aspera* (Ehrenberg) (Sample 1021B-28X-6, 20-22 cm, 9.8 Ma); 2: *Gondwanaria campanulaeformis* (Campbell and Clark) (Sample 1021B-26X-4, 70-72 cm, 9.0 Ma); 3: *Cornutella paloverdensis* Campbell and Clark (Sample 1021B-28X-6, 20-22 cm, 9.8 Ma); 4: *Lithomelissa* cf. *ultima* Caulet (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 5: *Lithomelissa* sp. A (Sample 1021B-26X-4, 70-72 cm, 9.0 Ma); 6: *Lithomelissa* sp. B (Sample 1021B-28X-6, 20-22 cm, 9.8 Ma); 7: *Cincolopyramis murrayana* Haeckel (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 8-10: *Lipmanella redondoensis* (Campbell and Clark) (8: Sample 1021B-26X-2, 120-122 cm, 8.9 Ma; 9: Sample 1021B-26X-4, 70-72 cm, 9.0 Ma; 10: 1021B-33X-4, 70-72 cm, 12.7 Ma); 11: *Lipmanella hister* (Petrushevskaya) (Sample 1021B-26X-4, 70-72 cm, 9.0 Ma); 12: *Theocorys perforalvus* O'Connor (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 13, 14, 17: *Cincolopyramis circumtexta* (Haeckel) group (13, Sample 1021B-28X-6, 20-22 cm, 9.8 Ma; 14: Sample 1021B-33X-2, 120-122 cm, 12.5 Ma; 17: Sample 1021B-24X-1, 120-122 cm, 8.1 Ma); 15: *Cornutella profunda* Ehrenberg (Sample 1021B-26X-4, 70-72 cm, 9.0 Ma); 16: *Cyrtolagena* sp. A (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma).

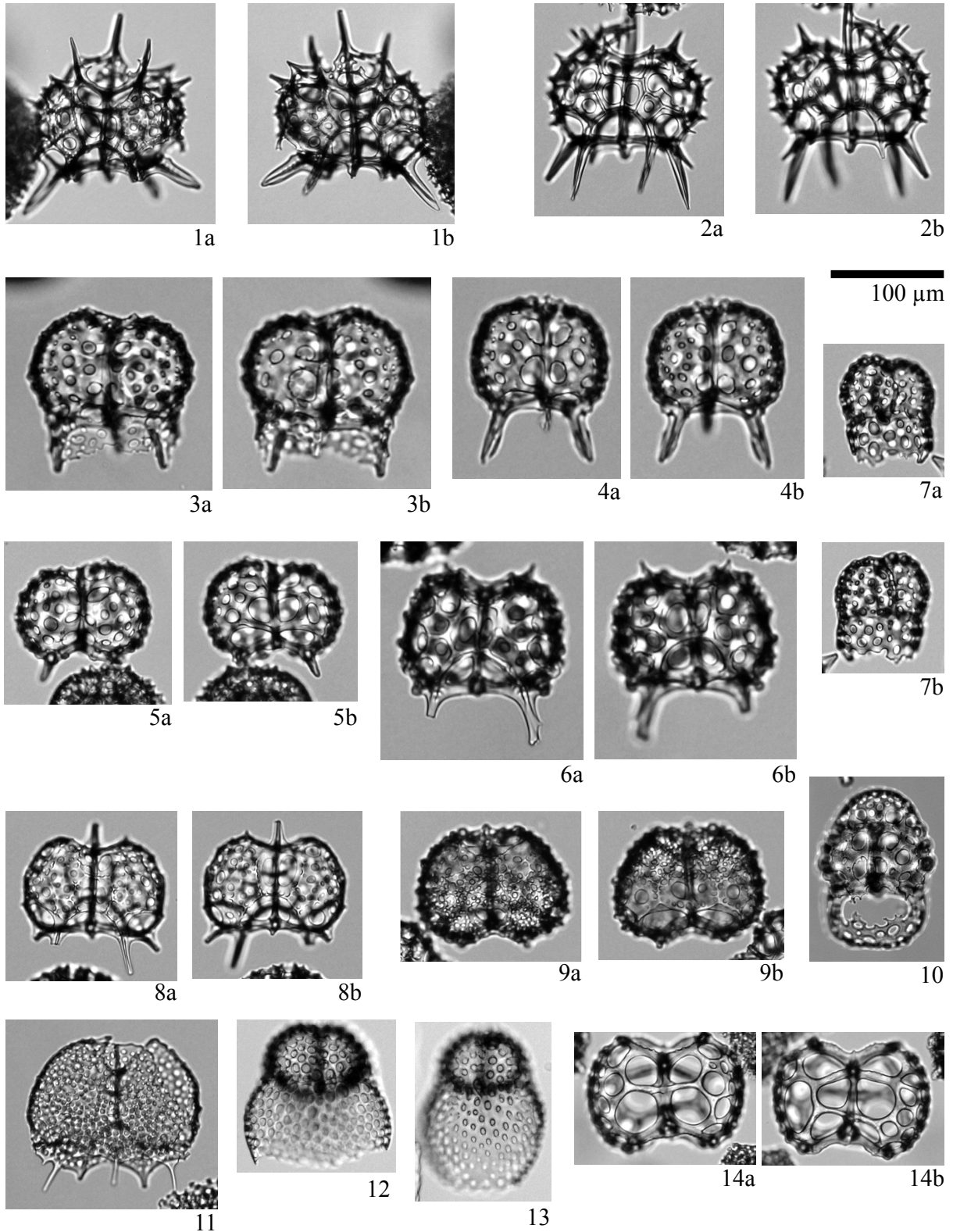


Plate 7 Illustrations of the encountered radiolarians. 1, 2: *Lophospyris laventaensis* (Campbell and Clark) (Sample 1021B-26X-4, 70-72 cm, 9.0 Ma); 3-5: *Dendrospyris* sp. A (3, 4: Sample 1021B-33X-2, 120-122 cm, 12.5 Ma; 5: Sample 1021B-32X-6, 20-22 cm, 12.2 Ma); 6: *Dendrospyris* sp. B (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 7: *Phormospyris stabilis* (Goll) (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 8: *Dendrospyris* sp. C (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 9: *Dendrospyris* sp. D (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 10: *Tholospyris kantiana* (Haeckel) (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 11: *Dendrospyris* sp. E (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 12, 13: *Dendrospyris* aff. *bursa* (Sanfilippo and Riedel) (Sample 1021B-29X-2, 120-122 cm, 10.1 Ma); 14: *Dendrospyris* sp. F (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma).

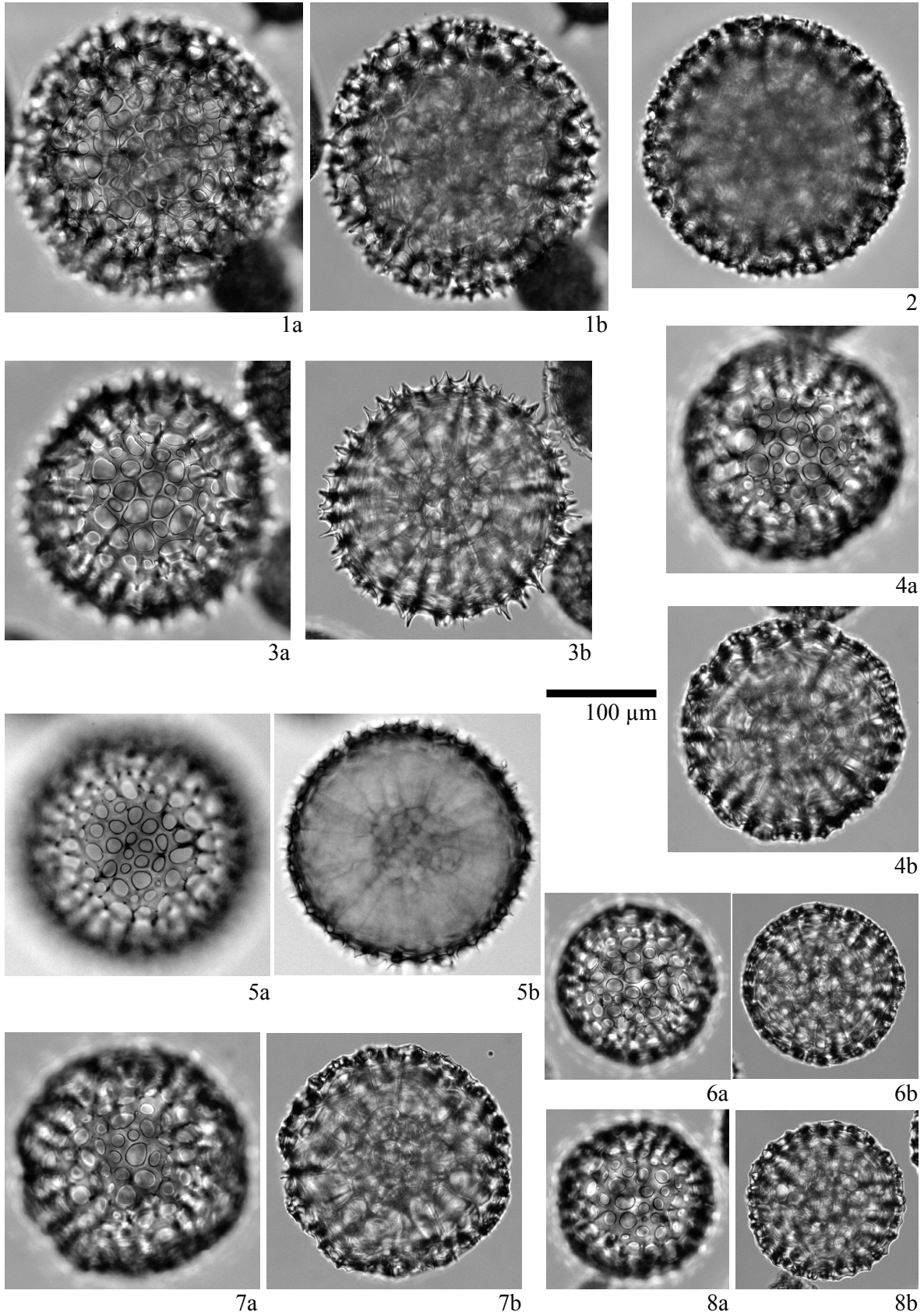


Plate 8 Illustrations of the encountered radiolarians. 1–8: *Rhizosphaera churchi* (Campbell and Clark) group (1–4, 7: Sample 1021B-26X-4, 70–72 cm, 9.0 Ma; 5: Sample 1021B-27X-1, 20–22 cm, 9.1 Ma; 6: Sample 1021B-33X-2, 120–122 cm, 12.5 Ma; 8: Sample 1021B-32X-6, 20–22 cm, 12.2 Ma).

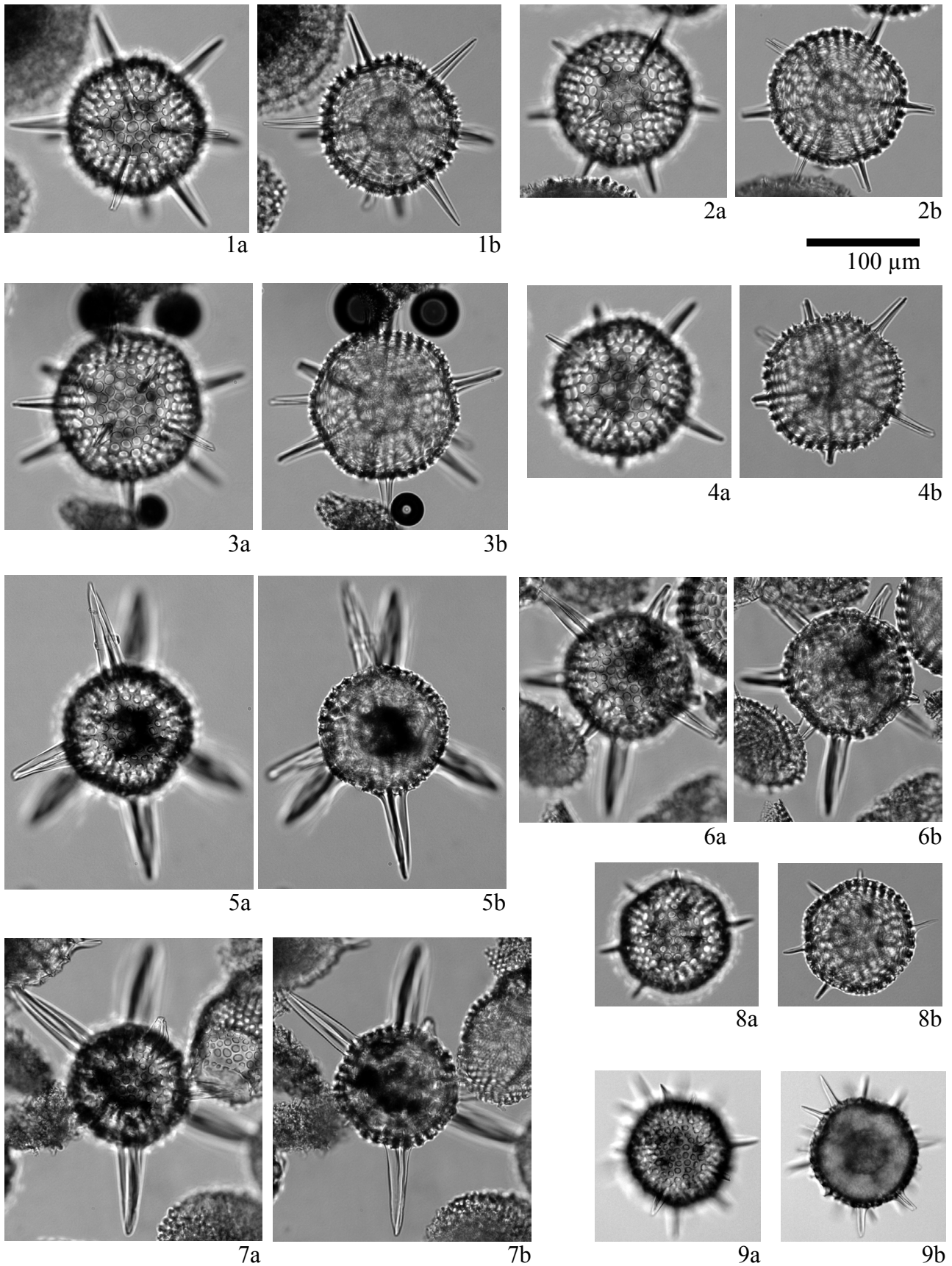


Plate 9 Illustrations of the encountered radiolarians. 1–9: *Haliometta miocenica* (Campbell and Clark) group (1, 2, 4: Sample 1021B-33X-2, 120–122 cm, 12.5 Ma; 3, 6–8: Sample 1021B-32X-6, 20–22 cm, 12.2 Ma; 5: 1021B-28X-6, 20–22 cm, 9.8 Ma).

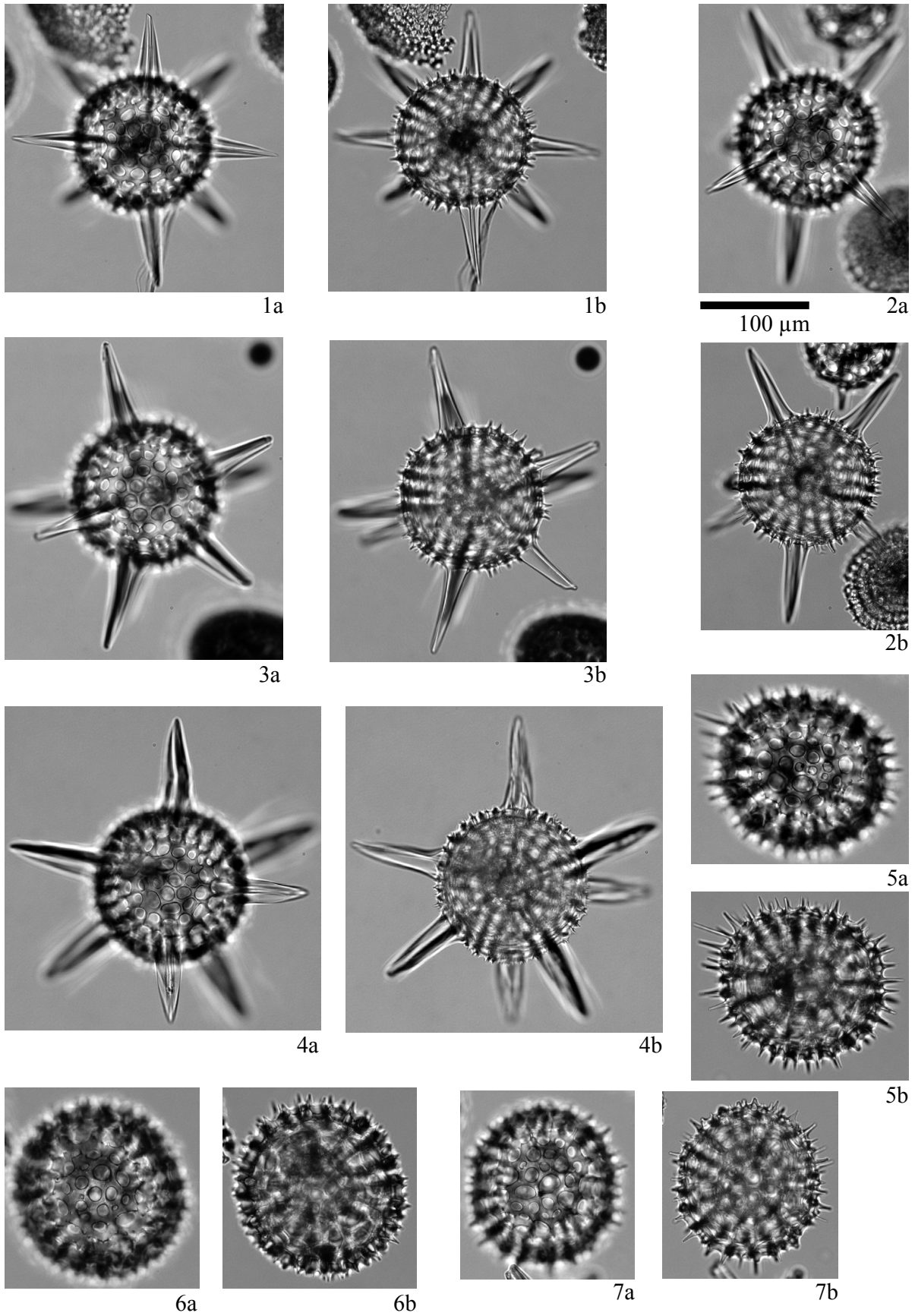


Plate 10 Illustrations of the encountered radiolarians. 1–4: *Actinomma hootsi* (Campbell and Clark) (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 5–7: *Excentrodiscus japonicus* (Nakaseko and Nishimura) (Sample 1021B-28X-6, 20-22 cm, 9.8 Ma).

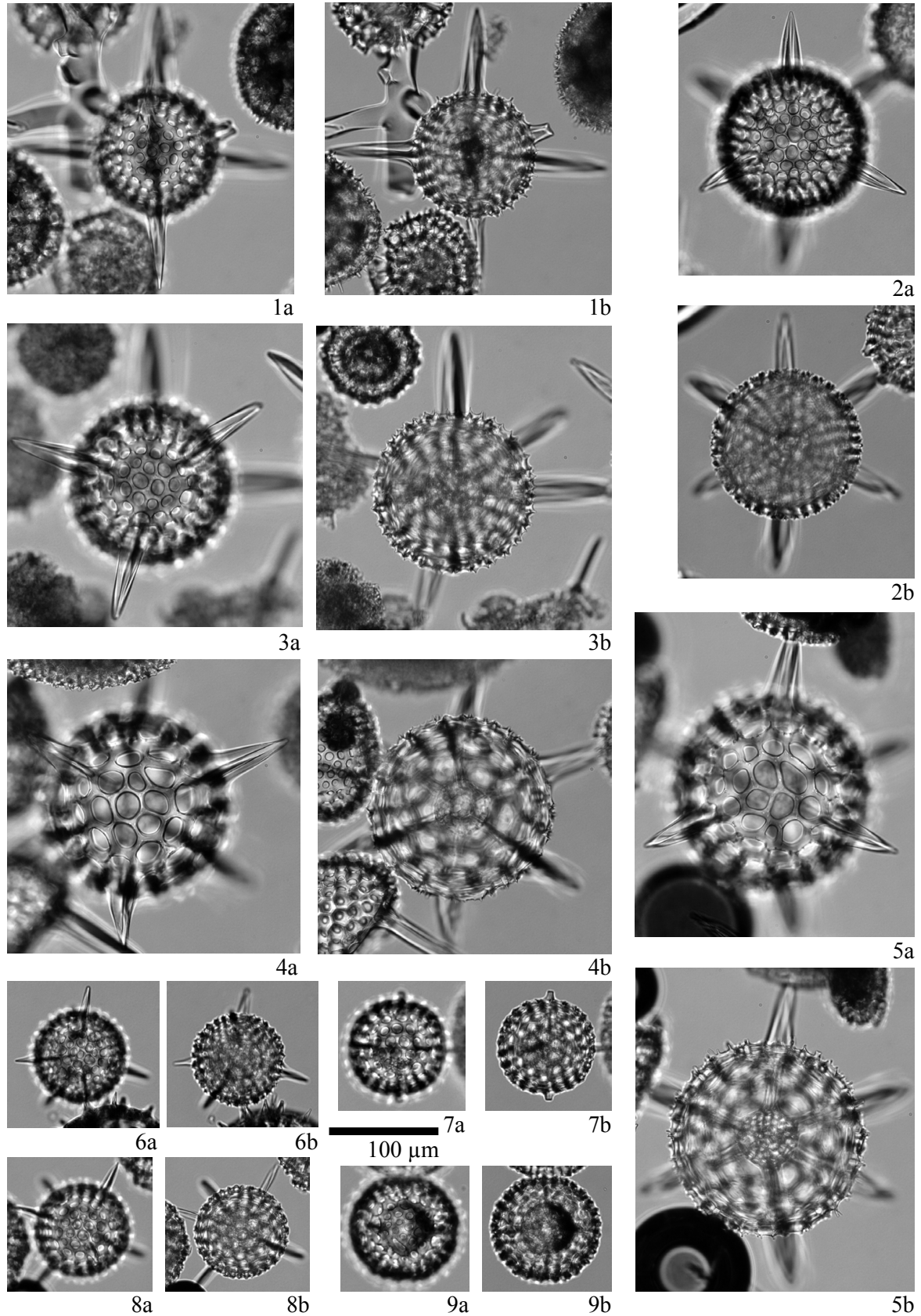


Plate 11 Illustrations of the encountered radiolarians. 1: *Hexacontium* sp. A (Sample 1021B-28X-6, 20-22 cm, 9.8 Ma); 2, 3: *Hexacontium* sp. B (2: Sample 1021B-33X-2, 120-122 cm, 12.5 Ma; 3: Sample 1021B-32X-6, 20-22 cm, 12.2 Ma); 4, 5: *Hexacontium* aff. *arachnoidale* Hollande and Enjumeat (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 6-9: *Hexacontium minerva* Kamikuri (6, 8: Sample 1021B-32X-6, 20-22 cm, 12.2 Ma; 7: Sample 1021B-28X-6, 20-22 cm, 9.8 Ma; 9: Sample 1021B-29X-4, 70-72 cm, 10.2 Ma).

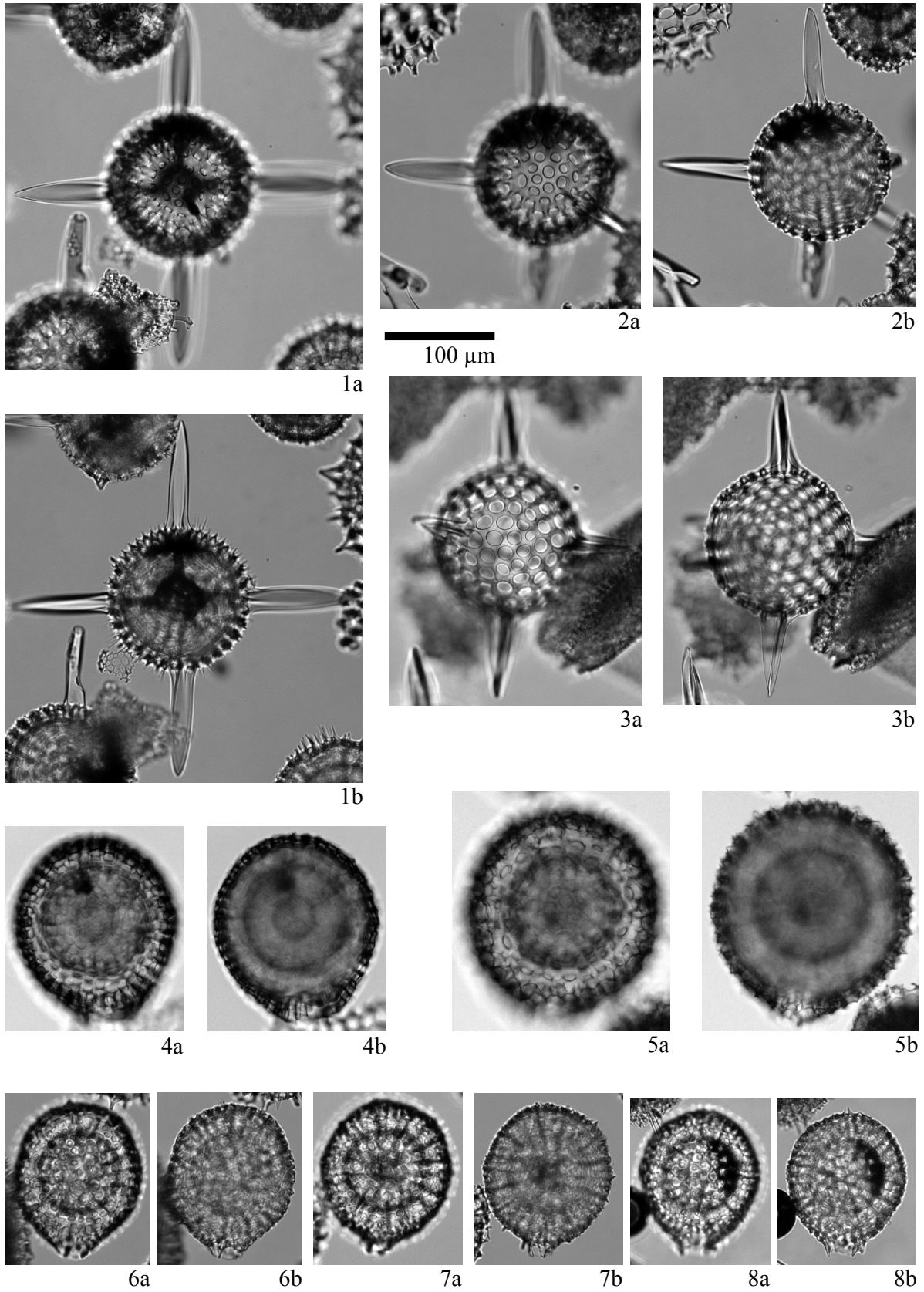


Plate 12 Illustrations of the encountered radiolarians. 1: *Hexacontium* sp. E (Sample 1021B-28X-6, 20-22 cm, 9.8 Ma); 2: *Hexastylus* sp. A (Sample 1021B-28X-6, 20-22 cm, 9.8 Ma); 3: *Hexastylus aculeata* (Campbell and Clark) (Sample 1021B-32X-6, 20-22 cm, 12.2 Ma); 4–8: *Actinomma robusta* (Kling) (4, 7: Sample 1021B-26X-4, 70-72 cm, 9.0 Ma; 5, 6: Sample 1021B-28X-6, 20-22 cm, 9.8 Ma; 8: Sample 1021B-32X-6, 20-22 cm, 12.2 Ma).

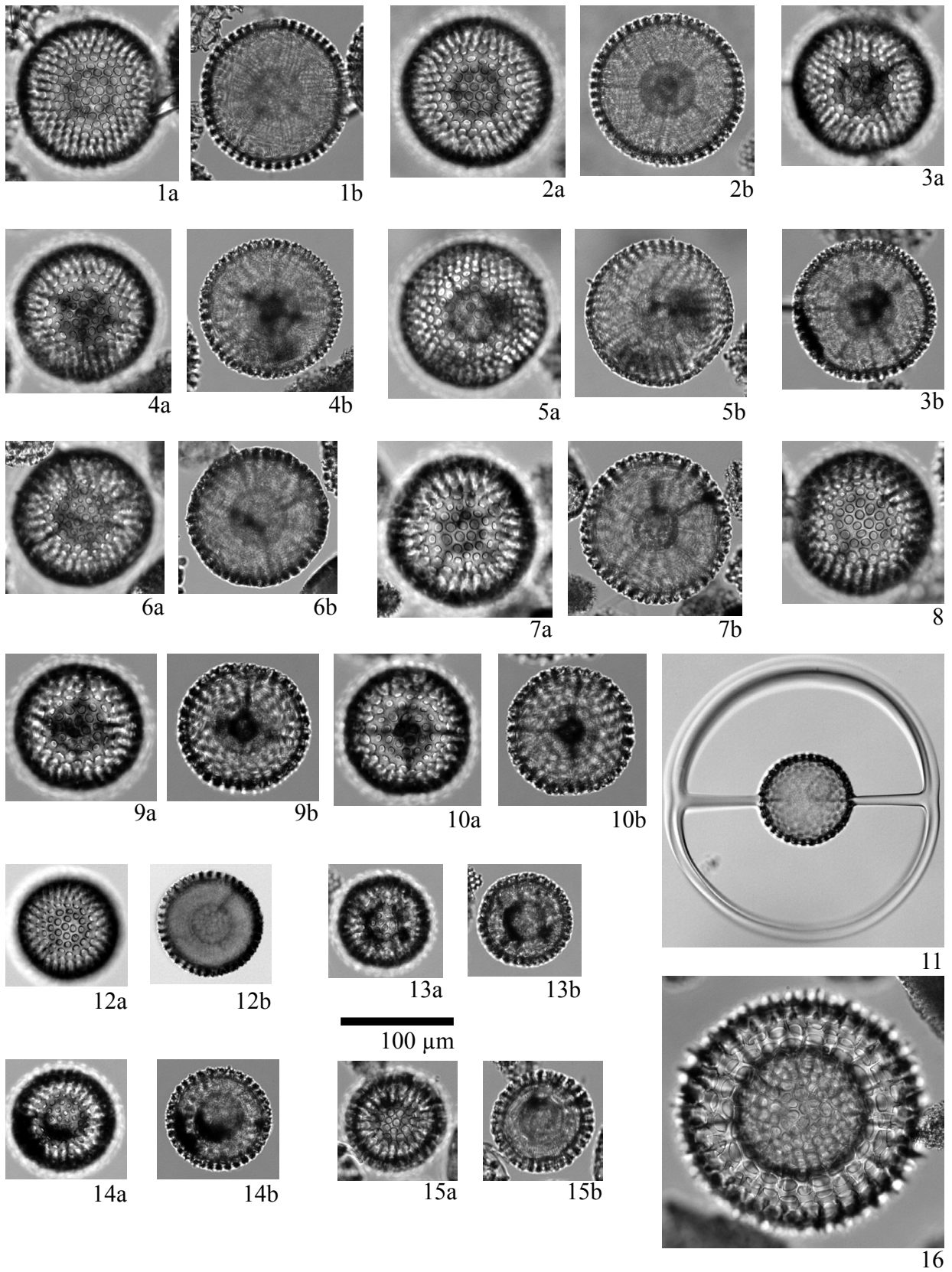


Plate 13 Illustrations of the encountered radiolarians. 1–8: *Thecosphaera dedoensis* Nakaseko (1–5: Sample 1021B-32X-6, 20–22 cm, 12.2 Ma; 6: 1021B-26X-4, 70–72 cm, 9.0 Ma; 7, 8: Sample 1021B-33X-2, 120–122 cm, 12.5 Ma); 9, 10: *Thecosphaera* sp. A (Sample 1021B-28X-6, 20–22 cm, 9.8 Ma); 11: *Saturnalis circularis* Haeckel (Sample 1021B-28X-6, 20–22 cm, 9.8 Ma); 12–15: *Thecosphaera* sp. B (12, 13, 15: Sample 1021B-32X-6, 20–22 cm, 12.2 Ma; 14: Sample 1021B-28X-6, 20–22 cm, 9.8 Ma); 16: *Liosphaera hexagonia* Haeckel (Sample 1021B-28X-6, 20–22 cm, 9.8 Ma).

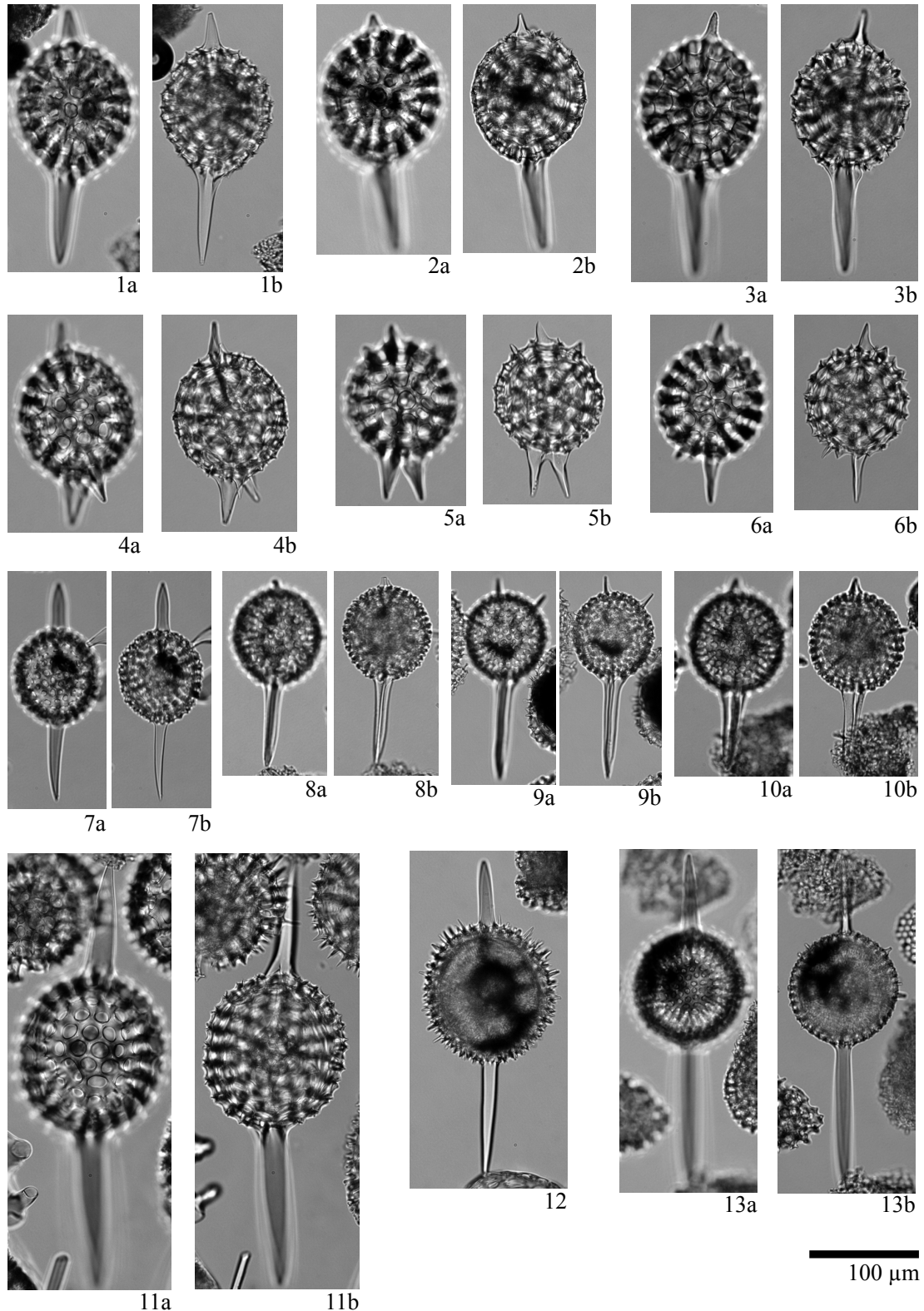


Plate 14 Illustrations of the encountered radiolarians. 1–3: *Stylosphaera radiosa* Ehrenberg (1: Sample 1021B-32X-6, 20–22 cm, 12.2 Ma; 2, 3: Sample 1021B-33X-2, 120–122 cm, 12.5 Ma); 4–6: *Cromydruppocarpus esterae* Campbell and Clark (Sample 1021B-33X-2, 120–122 cm, 12.5 Ma); 7: *Drupptractus hastatus* Blueford (Sample 1021B-33X-2, 120–122 cm, 12.5 Ma); 8–10: *Stylosphaera timmsi* (Campbell and Clark) (8, 10: Sample 1021B-32X-6, 20–22 cm, 12.2 Ma; 9: Sample 1021B-33X-2, 120–122 cm, 12.5 Ma); 11: *Axoprunum bispiculum* (Popofsky) (Sample 1021B-28X-6, 20–22 cm, 9.8 Ma); 12: *Stylatractus universus* Hays (Sample 1021B-33X-2, 120–122 cm, 12.5 Ma); 13: *Amphistylus angelinus* (Campbell and Clark) (Sample 1021B-32X-6, 20–22 cm, 12.2 Ma).

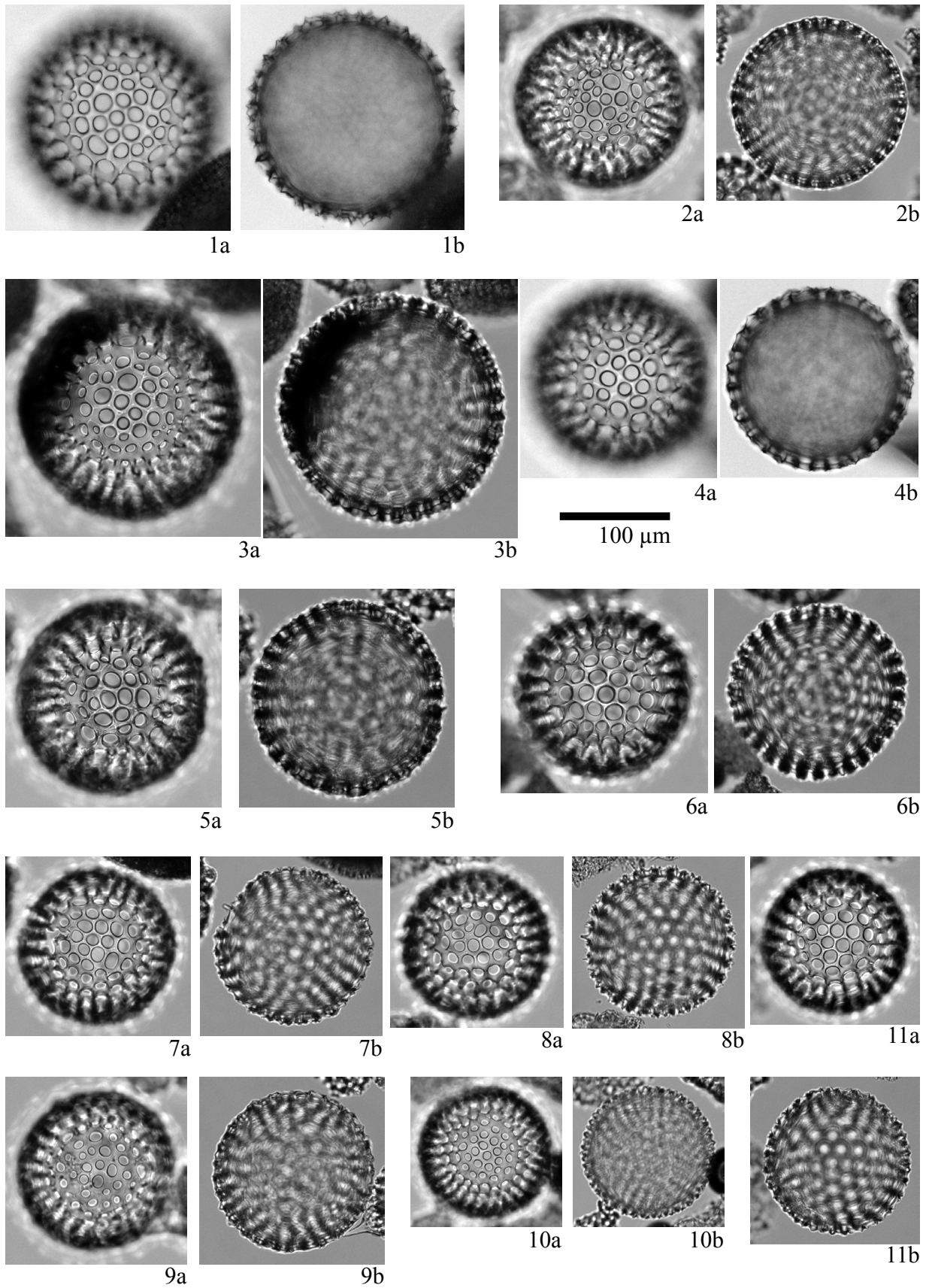


Plate 15 Illustrations of the encountered radiolarians. 1–11: *Cenosphaera jenkinsi* Campbell and Clark group (1, 3, 5: Sample 1021B-28X-6, 20–22 cm, 9.8 Ma; 2, 4, 6–11: Sample 1021B-32X-6, 20–22 cm, 12.2 Ma).

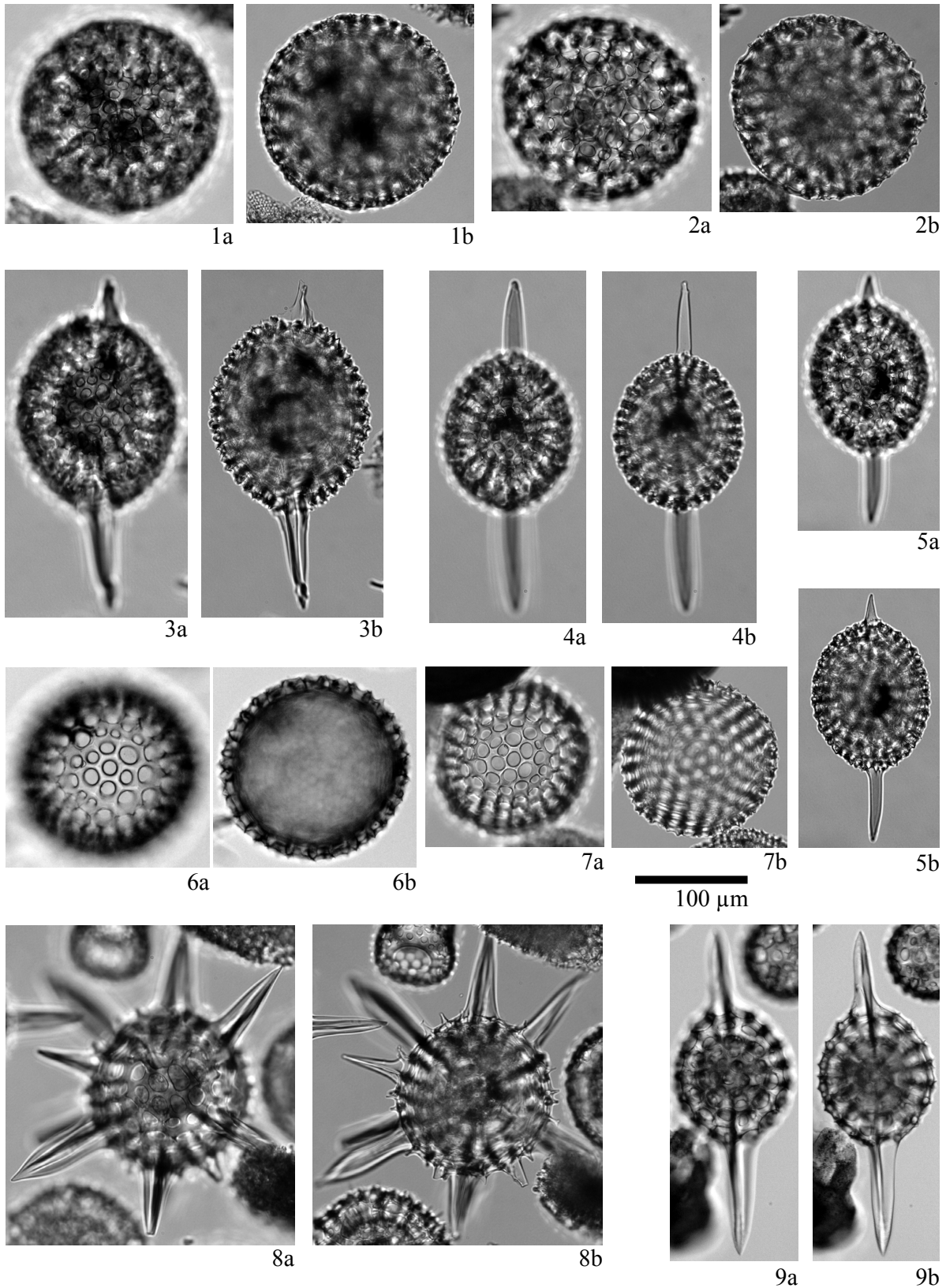


Plate 16 Illustrations of the encountered radiolarians. 1, 2: *Styptosphaera spumacea* Haeckel (Sample 1021B-32X-6, 20-22 cm, 12.2 Ma); 3-5: *Stylatractus neptunus* Haeckel (3: Sample 1021B-32X-6, 20-22 cm, 12.2 Ma; 4: Sample 1021B-26X-6, 20-22 cm, 9.0 Ma; 5: Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 6, 7: *Cenosphaera jenkinsi* Campbell and Clark group (Sample 1021B-32X-6, 20-22 cm, 12.2 Ma); 8: *Actinomma hootsi* (Campbell and Clark) (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 9: *Stylatractus santaeannae* (Campbell and Clark) (Sample 1021B-32X-6, 20-22 cm, 12.2 Ma).

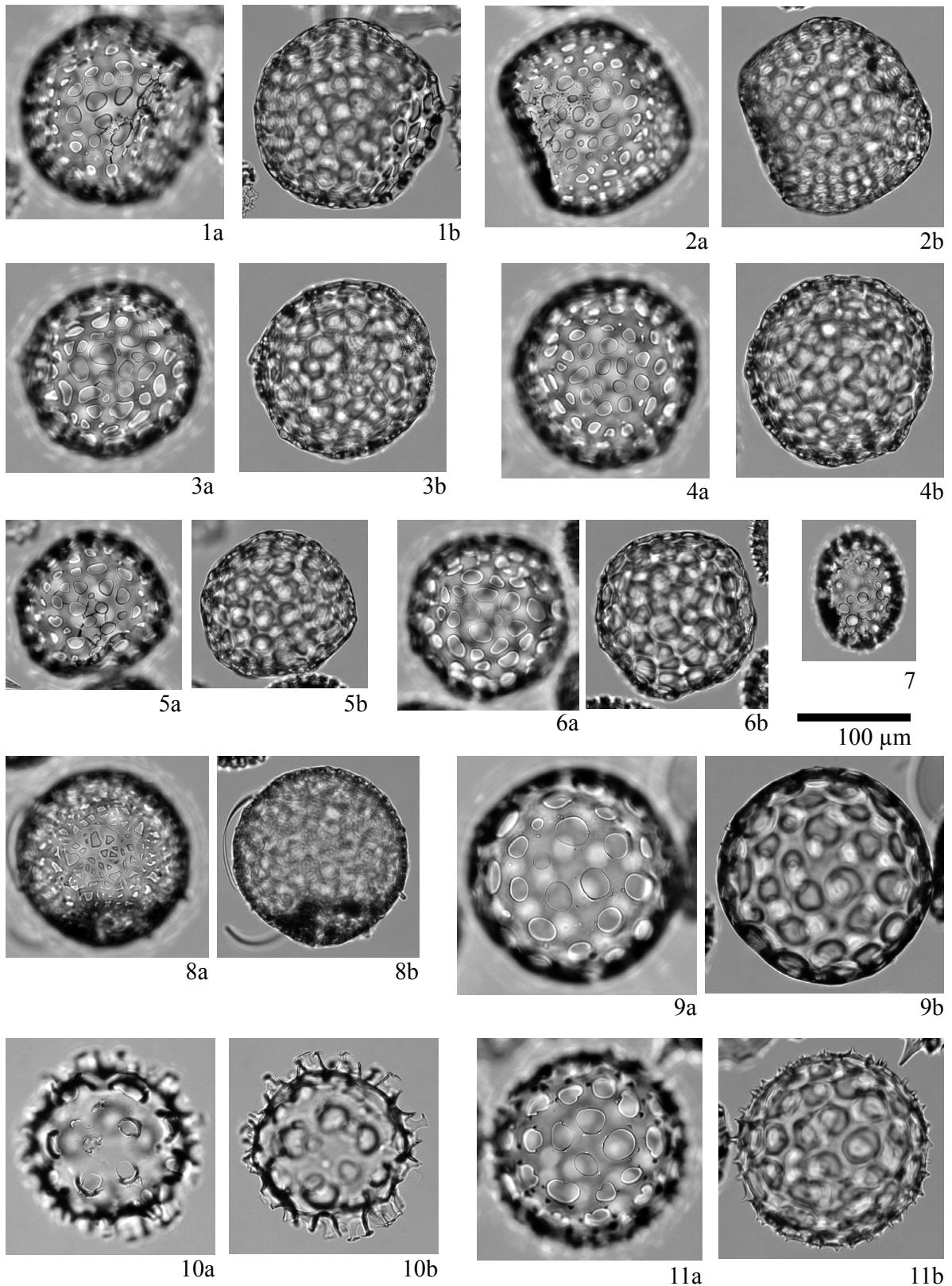


Plate 17 Illustrations of the encountered radiolarians. 1–6: *Collosphaera glebulenta* Bjørklund and Goll (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 7: *Collosphaera reynoldsi* Kamikuri (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 8: *Collosphaera* sp. B (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 9: *Collosphaera* sp. A (Sample 1021B-26X-4, 70-72 cm, 9.0 Ma); 10: *Polysolenia pseudarktiot* (Caulet) (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 11: *Polysolenia murrayana* (Haeckel) (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma).

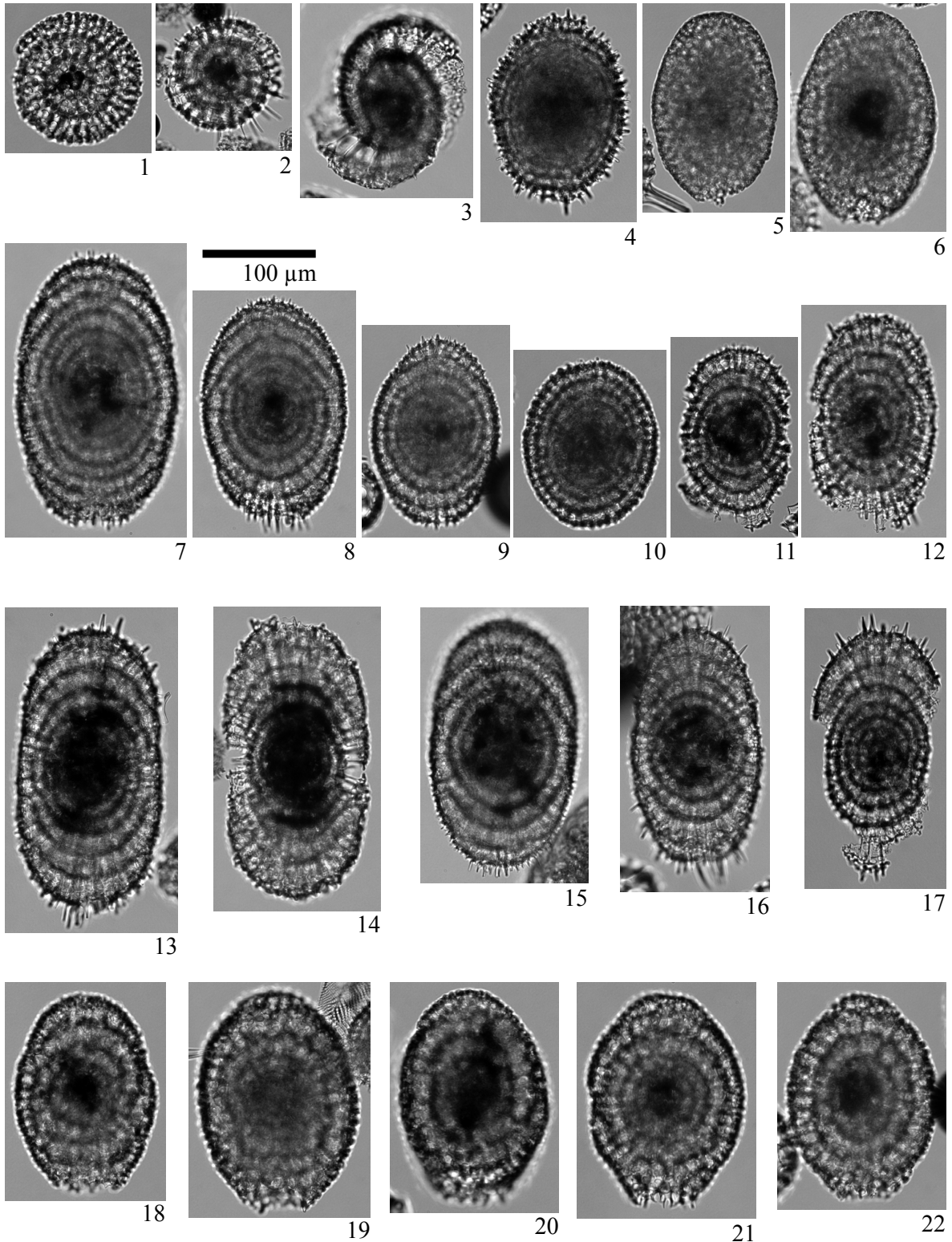


Plate 18 Illustrations of the encountered radiolarians. 1: *Lithelius klingi* Kamikuri (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 2: *Lithelius minor* Jørgensen group (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 3: *Larcospira quadrangula* Haeckel group (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 4: *Lithelius* aff. *elliptica* (Ehrenberg) (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 5: *Larcopyle* aff. *pylomaticus* (Riedel) (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 6: *Larcopyle* sp. A (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 7–11: *Larcopyle polyacantha* (Campbell and Clark) type A (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 12: *Larcopyle polyacantha* (Campbell and Clark) type B (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 13–17: *Larcopyle polyacantha* (Campbell and Clark) type C (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 18–22: *Larcopyle buetschlii* Dreyer (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma).

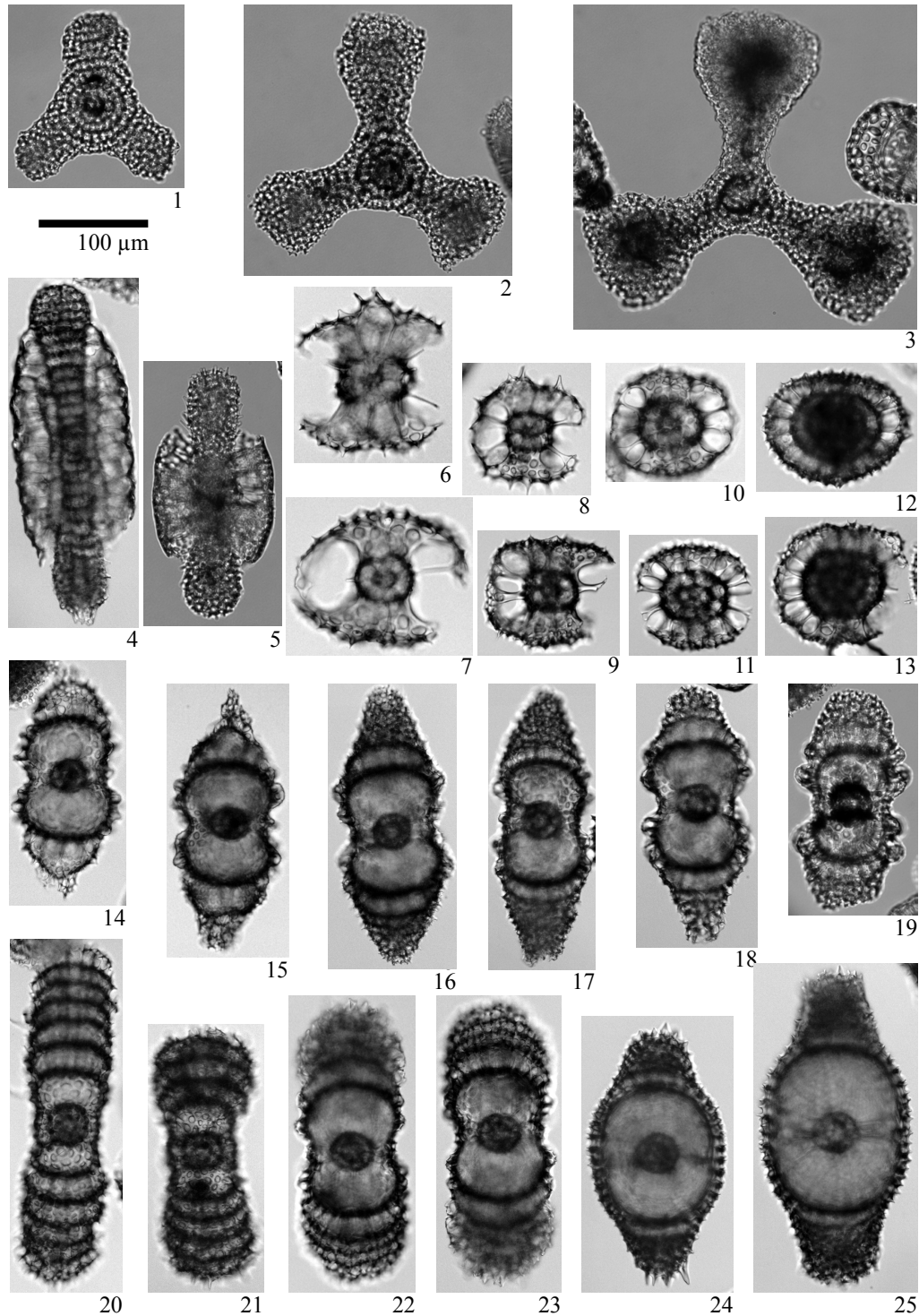


Plate 19 Illustrations of the encountered radiolarians. 1, 2: *Dictyocoryne malagaense* (Campbell and Clark) group (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 3: *Dictyocoryne* sp. A (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 4: *Amphymenium amphistylum* Haeckel (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 5: *Spongurus cylindricus* Haeckel (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 6, 7: *Tetrapyle circularis/fruticosa* group (Sample 1021B-26X-2, 120-122 cm, 8.9 Ma); 8–10: *Phorticium* sp. A (Sample 1021B-26X-2, 120-122 cm, 8.9 Ma); 11–13: *Phorticium clevei* (Jørgensen) (Sample 1021B-26X-2, 120-122 cm, 8.9 Ma); 14: 15: *Didymocyrtis penultima* (Riedel) (Sample 1021B-26X-2, 120-122 cm, 8.9 Ma); 16, 17: *Didymocyrtis laticonus* (Riedel) (Sample 1021B-33X-4, 70-72 cm, 12.7 Ma); 18, 19: *Didymocyrtis antepenultima* (Riedel and Sanfilippo) (Sample 1021B-32X-1, 20-22 cm, 11.7 Ma); 20, 21: *Diartus hughesi* (Campbell and Clark) (20: Sample 1021B-26X-2, 120-122 cm, 8.9 Ma; 21: Sample 1021B-28X-6, 20-22 cm, 9.8 Ma); 22, 23: *Didymocyrtis* sp. C (Sample 1021B-31X-6, 20-22 cm, 11.6 Ma); 24, 25: *Didymocyrtis* sp. D (24: Sample 1021B-26X-2, 120-122 cm, 8.9 Ma; 25: Sample 1021B-27X-1, 20-22 cm, 9.1 Ma).

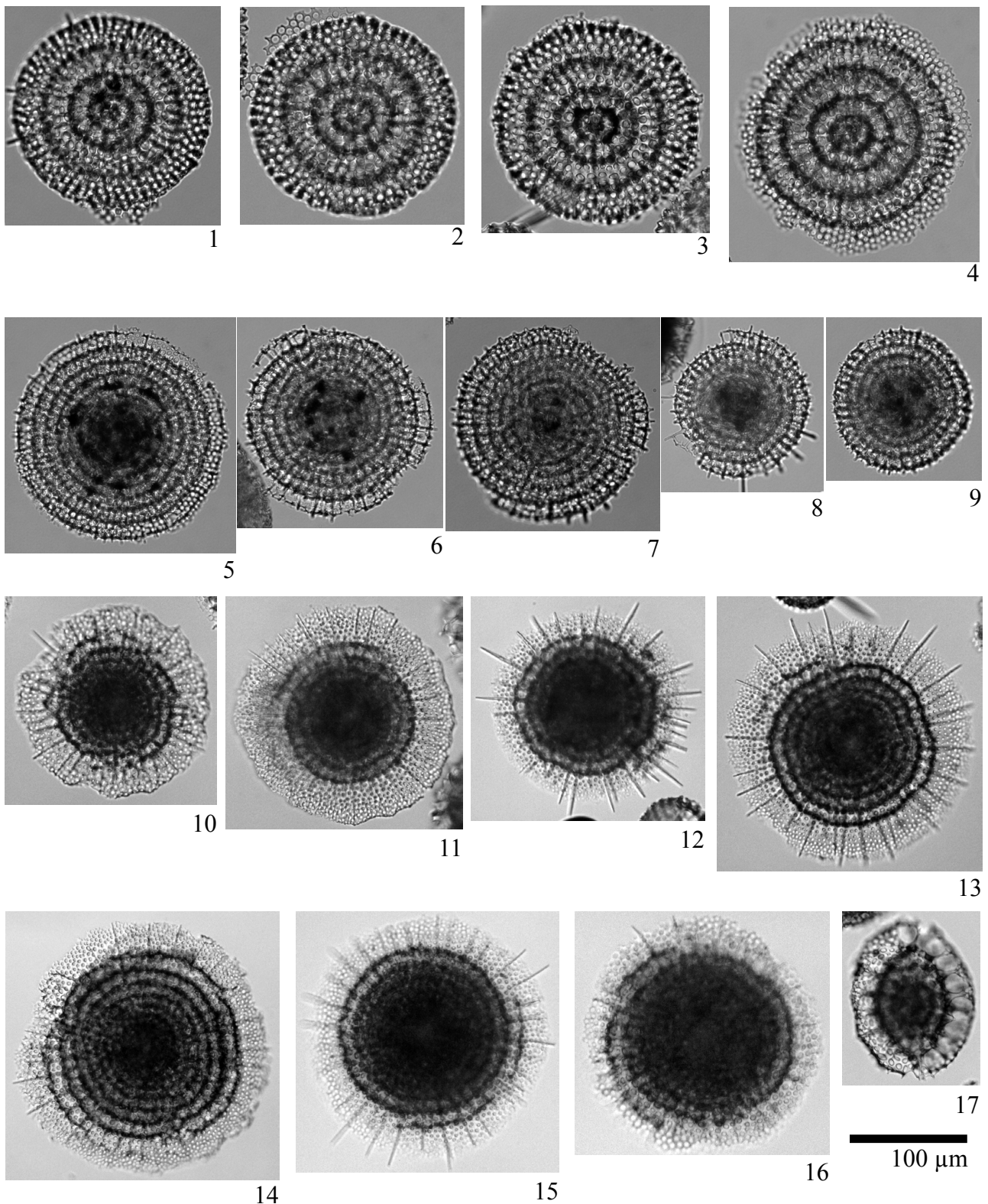


Plate 20 Illustrations of the encountered radiolarians. 1–4: *Circodiscus circularis* (Clark and Campbell) (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 5–9: *Stylodictya* sp. A (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 10–15: *Perichlamyidium scutaeforme* Campbell and Clark type A (10, 14, 15: Sample 1021B-26X-2, 120-122 cm, 8.9 Ma; 11–13: Sample 1021B-26X-4, 70-72 cm, 9.0 Ma); 16: *Perichlamyidium* sp. P (Sample 1021B-25X-4, 70-72 cm, 8.6 Ma); 17: *Larcospira moschkovskii* Kruglikova (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma).

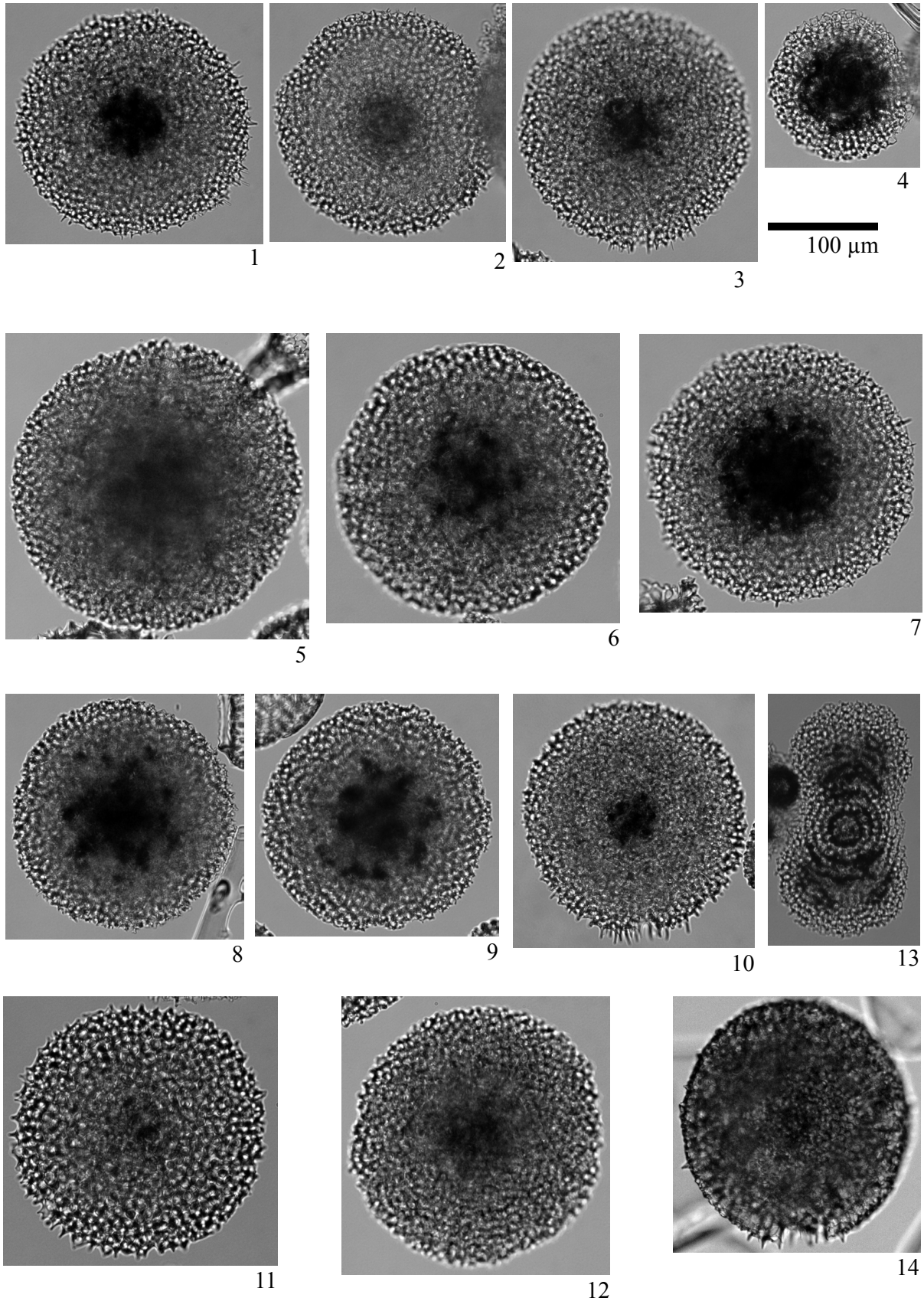


Plate 21 Illustrations of the encountered radiolarians. 1–12: *Spongodiscus resurgens* Ehrenberg (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 13: *Spongaster* sp. A (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 14: *Spongodiscus* sp. D (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma).

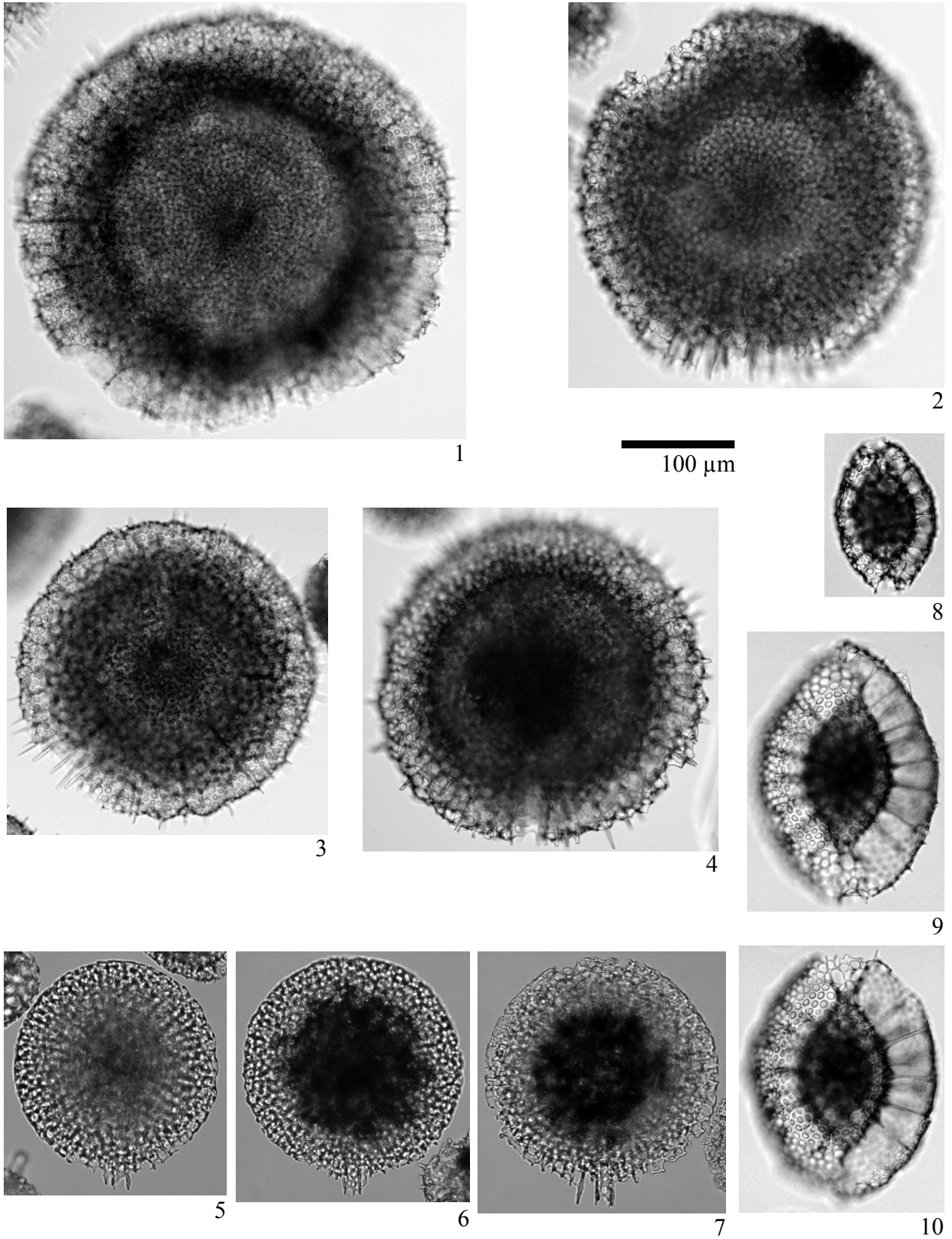


Plate 22 Illustrations of the encountered radiolarians. 1: *Spongotrochus* sp. B (Sample 1021B-24X-4, 70-72 cm, 8.3 Ma); 2-4: *Spongotrochus* sp. C (Sample 1021B-24X-4, 70-72 cm, 8.3 Ma); 5-7: *Spongopyle osculosa* Dreyer (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 8: *Larcospira moschkovskii* Kruglikova (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 9, 10: *Larcospira quadrangula* Haeckel group (9: Sample 1021B-26X-2, 120-122 cm, 8.9 Ma; 10: Sample 1021B-27X-1, 20-22 cm, 9.1 Ma).

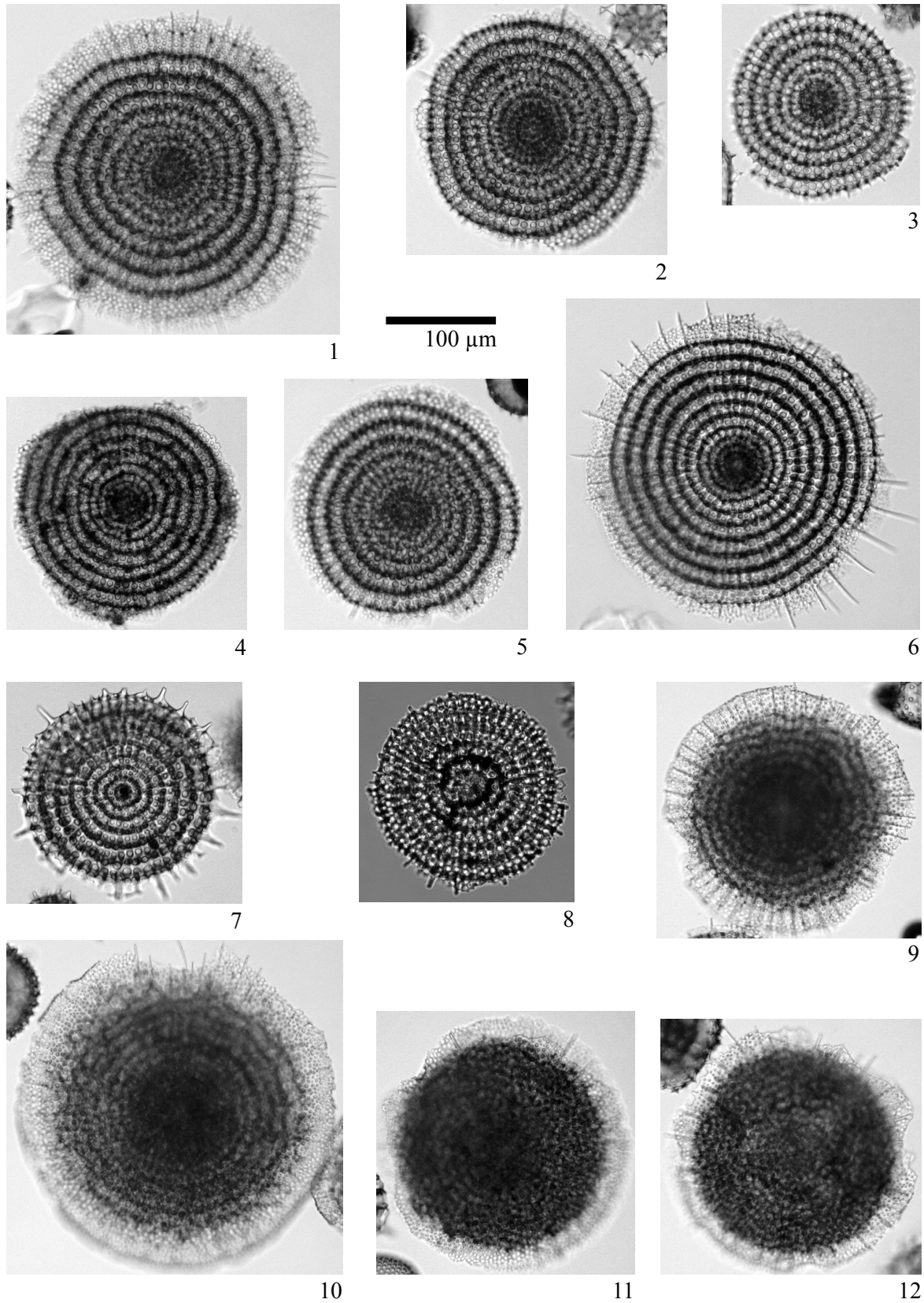


Plate 23 Illustrations of the encountered radiolarians. 1–6: *Stylocdictya ornata* Campbell and Clark (Sample 1021B-26X-2, 120-122 cm, 8.9 Ma); 7, 8: *Stylocdictya tenuispina* Jørgensen (Sample 1021B-25X-4, 70-72 cm, 8.6 Ma); 9, 10: *Perichlamydidium scutaeforme* Campbell and Clark type B (Sample 1021B-26X-4, 70-72 cm, 9.0 Ma); 11, 12: *Perichlamydidium scutaeforme* Campbell and Clark type C (Sample 1021B-26X-2, 120-122 cm, 8.9 Ma).

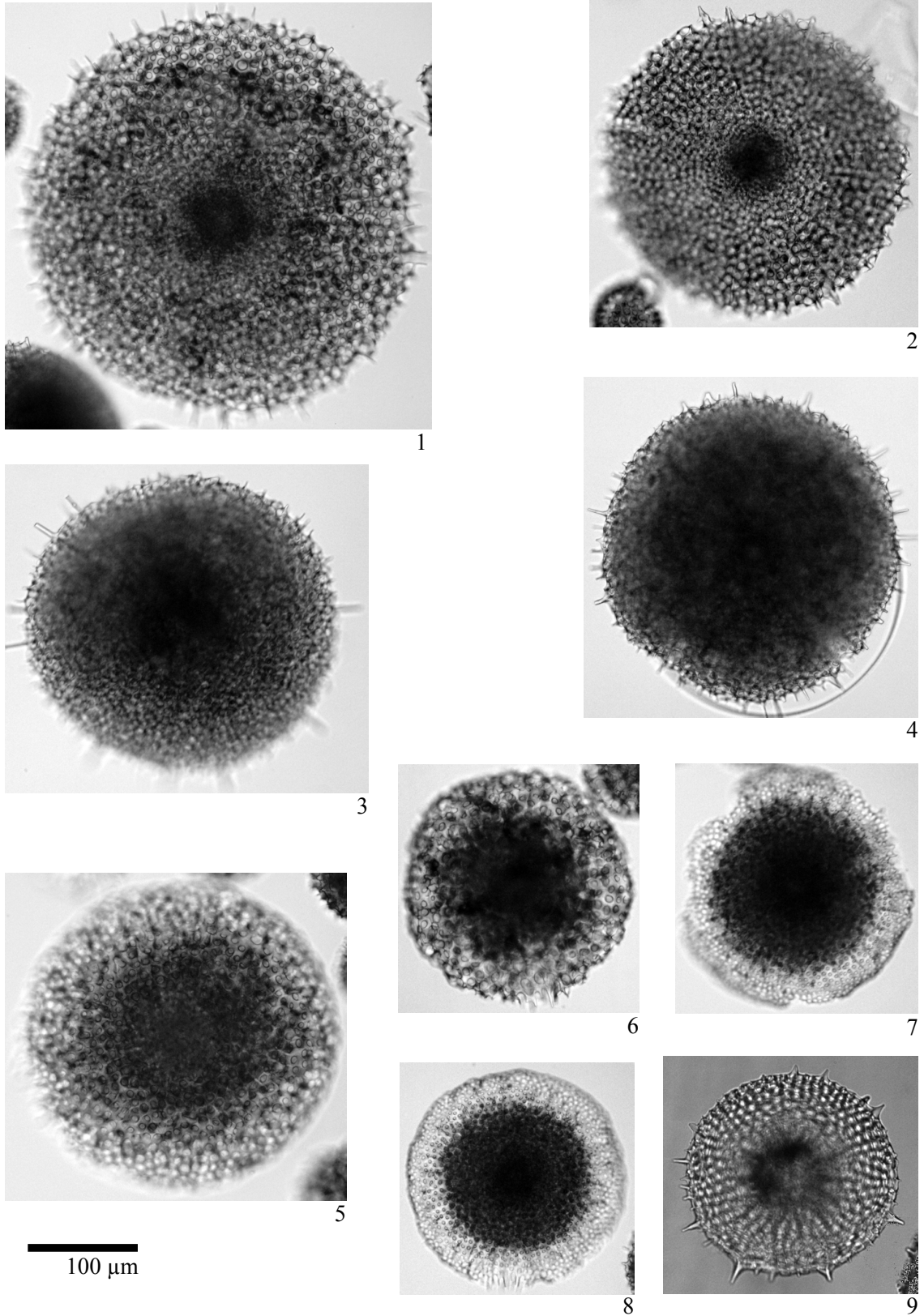


Plate 24 Illustrations of the encountered radiolarians. 1: *Spongotrochus sol* Campbell and Clark type A (Sample 1021B-26X-2, 120-122 cm, 8.9 Ma); 2: *Spongotrochus sol* Campbell and Clark type B (Sample 1021B-26X-2, 120-122 cm, 8.9 Ma); 3, 4: *Spongotrochus* sp. Z (Sample 1021B-26X-2, 120-122 cm, 8.9 Ma); 5, 6: *Spongodiscus cauleti* Kamikuri (5: Sample 1021B-31X-1, 20-22 cm, 11.1 Ma; 6: Sample 1021B-30X-4, 70-72 cm, 10.8 Ma); 7, 8: *Perichlamydidium* sp. K (7: Sample 1021B-26X-2, 120-122 cm, 8.9 Ma; 8: Sample 1021B-26X-4, 70-72 cm, 9.0 Ma); 9: *Heliodiscus* sp. A (Sample 1021B-26X-6, 20-22 cm, 9.0 Ma).