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 conductive 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.
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.

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 Burr ridge et al. 2014
Actinomma hootsi (Campbell and Clark)
Plate 10, figs. 1a-4b, plate 16, figs. 8a, b.

Hexacanthium 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)
Peripyramis circumtexta Haeckel 1887, p. 1162, pl. 54, fig. 5.

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. Lombari and Lazarus 1988

Cycladophora klingi Lombari and Lazarus 1988
Plate 1, figs. 3a, b.

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

Remarks: Cycladophora klingi was described originally as a subspecies of Cycladophora bicornis by Lombari 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 (Pterocorytidium) 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 Rhizospaera Haeckel 1861b, sensu Dumitrica 2017

Rhizospaera churchi (Campbell and Clark) group
Plate 8, figs. 1-8.

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

Botryostrobus branlettei (Campbell and Clark) in Nigrini and Lombari 1984, p. N175, pl. 31, figs. 2a–2c. [Plate 1, fig. 12.]

Calocycletta caesa Moore 1972, p. 150, pl. 2, figs. 4–7. [Plate 3, fig. 1.]

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

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

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

Carpocanium favosum (Haeckel): Carpocanistrum favosum (Haeckel) in Takahashi 1991, p. 131, pl. 45, fig. 8: Carpocanistrum 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.]

Cirrhopdicus circularis (Clark and Campbell) in Jckett 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 gibulenta 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 Lombari 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. 1984, p. 46, pl. 5, figs. 18–20. [Plate 14, fig. 12.]

Cycladophora bicornis (Popofsky) in Takemura et al. 2009. [Plate 3, fig. 1.]
Didymocyrtis sp. C: This study.

Eucyrtidium hexagonatum (Popofsky) in Sakai 1980, p. 709, pl. 6, figs. 5–7.

Eucyrtidium inflatum Kling 1973, p. 636, pl. 11, figs. 7, 8, 15, figs. 7–10.

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.]

Haliothemma miocenica (Campbell and Clark) group in Petrushedevskaya and Kozlova 1972, p. 517, pl. 9, figs. 8, 9. [Plate 9, figs. 1–9.]

Heliodiscus sp. A: This study. [Plate 24, fig. 9.]

Hexacontium aff. arachnoidale Hollande and Enjumet: This study. [Plate 11, figs. 4, 5.]

Hexacontium minerva Kamikuri 2010, p. 97, pl. 3, figs. 12a–14b, 16a–17b. [Plate 11, figs. 6–9.]

Hexacontium sp. A: This study. [Plate 11, fig. 1.]

Hexacontium sp. B: This study. [Plate 11, figs. 2, 3.]

Hexacontium sp. E: This study. [Plate 12, fig. 1.]

Hexastylus aculeato (Campbell and Clark): Staurolonche aculeate 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): Calocyclus 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.]

Lamprotritus cortina (Haeckel) in Matsu zaki et al. 2015, p. 64, fig. 8.5. [Plate 2, fig. 4.]

Larcypyle aff. pylonaticus (Riedel): This study. [Plate 18, fig. 5.]

Larcypyle huetschlii Dreyer in Matsu zaki et al. 2015, p. 33, fig. 6.21–6.28. [Plate 18, figs. 18–22.]

Larcypyle polyacantha (Campbell and Clark): Larnacantha polyacantha Campbell and Clark 1944, p. 30, pl. 5, figs. 4–7. [Plate 18, figs. 7–17.]

Larcypyle sp. A: This study. [Plate 18, fig. 6.]

Larccysira moschkovskii Kruglikova in Nigrini and Lombari 1984, p. S91, pl. 13, figs. 2a, 2b. [Plate 20, fig. 17; Plate 22, fig. 8.]

Larccysira 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 (Petrushedevskaya) 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.]

Cycladophora cosma (Kruglikova in Nigrini and Lombari 1984, p. N115, pl. 23, fig. 8. [Plate 4, fig. 7.]

Diartus hughesi (Campbell and Clark) in Sanfilippo et al. 1985, p. 655. Fig. 8.11. [Plate 19, figs. 20, 21.]

Dictyoxyrene malagaenae Campbell and Clark group: Rhopalodictyum malagaenae Campbell and Clark 1944, p. 29, pl. 4, figs. 4, 5. [Plate 19, figs. 1, 2.]

Dictyoxyrene sp. A: This study. [Plate 19, fig. 19.]

Dictyophimus sp. A: This study. [Plate 5, fig. 16.]

Didymocyrts antepenultima Riedel and Sanfilippo in Sanfilippo et al. 1985, p. 657, fig. 8.6. [Plate 19, figs. 18, 19.]

Didymocyrts laticanus Riedel in Sanfilippo et al. 1985, p. 658, figs. 8.5a, 8.5b. [Plate 19, figs. 16, 17.]

Didymocyrts penultima Riedel and Sanfilippo in Sanfilippo et al. 1985, p. 658, figs. 8.7a, 8.7b. [Plate 19, figs. 14, 15.]

Didymocyrts sp. C: This study. [Plate 19, figs. 22, 23.]

Didymocyrts sp. D: This study. [Plate 19, figs. 24, 25.]

Drupatracectus 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
Lychnocanoma magnacornuta (Ehrenberg): This study. [Plate 18, fig. 4.]
Lychnocanoma klingi Kamikuri 2010, p. 95, pl. 4, figs. 9-14. [Plate 18, fig. 1.]
Lychnocanoma minor Jørgensen group: Lychnocanoma 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.]
Lithohera neoterus Sanfilippo and Riedel in Sanfilippo et
al. 1985, p. 675, figs. 16.5a-16.4c. [Plate 5, fig. 3.]
Lithohera renzeae 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): Ceratospyris (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): Lychnocanum nipponicum Nakaseko in Shilov 1995, p. 109, pl. 3, figs. 4a, 4b; Lychnocanum 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.]
Perichlamydium scutiforme Campbell and Clark 1944, p. 24, pl. 3, figs. 14-16. [Plate 20, figs. 10-15; Plate 23, figs. 9-12.]
Perichlamydium sp. K: This study. [Plate 24, figs. 7, 8.]
Perichlamydium sp. P: This study. [Plate 20, fig. 16.]
Phorospyris stablis (Goll?): Phorospyris stablis stablis (Goll) in Nigrini and Lombari 1984, p. N59, pl. 19, fig. 7. [Plate 7, fig. 7.]
Phormostichoartus fistula Nigrini in Nigrini and Lombari 1984, p. N183, pl. 31, figs. 6a-6c. [Plate 1, fig. 13.]
Phorticum clevei (Jørgensen) in Matsuzaki et al. 2015, p. 32, figs. 6.9, 6.10. [Plate 19, figs. 11-13.]
Phorticum sp. A: This study. [Plate 19, figs. 8-10.]
Polysoenia murrayana (Haeckel) in Nigrini and Moore 1979, p. S17, pl. 2, figs. 4a, 4b. [Plate 17, fig. 11.]
Polysoenia pseudarcticis (Caulet): Acrosphaera pseudarcticis 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.]
Sporocyrtis subscalaris Nigrini in Nigrini and Lombari
1984, p. N199, pl. 32, figs. 7a, 7b. [Plate 1, fig. 14.]
Spongaster sp. A: This study. [Plate 21, fig. 13.]
Spongidosculus 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.]
Spongotrecha sol Campbell and Clark 1944, p. 28, pl. 4, figs. 7, 9-11. [Plate 24, figs. 1, 2.]
Spongotrecha sp. B: This study. [Plate 22, fig. 1.]
Spongotrecha sp. C: This study. [Plate 22, figs. 2-4.]
Spongotrecha 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.]
Stylosphaera radiosa Ehrenberg in Petrushevskaya and Kozlova 1972, p. 520; Amphipsphaera radiosa (Ehrenberg) group in Petrushevskaya 1975, p. 570, pl. 2, figs. 18-20; Lithatractus santaeannae pusillus Campbell and Clark 1944, p. 19, pl. 23, 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.]
Stytopsphaera spinacea Haeckel in Vitukhin 1993, p. 27, fig. 6, pl. 28, fig. 5. [Plate 16, figs. 1, 2.]
Tetrapyle circularis/fracotosa group: Tetrapyle circularis
Haeckel in Zhang and Suzuki, 2017, p. 15, figs. 8.1-8.15, 9.1-9.9; Tetrapyle fraticosa (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, p. 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.]
Theocorys perforalvus O’Connor 1997, p. 86, pl. 4, figs. 9-12, pl. 10, figs. 9-14, pl. 11, fig. 6. [Plate 6, fig. 12.]
Theocorythium sp. A: This study. [Plate 3, fig. 7.]
References

Barron, J. A., Lyle, M. and Koizumi, I. (2002) Late Miocene and early Pliocene biosiliceous sedimentation along the California margin. Revista Mexicana de Ciencias Geológicas, 19, 161–169.

Bjørklund, K. R. and Goll, R. M. (2014) Inter- and intraspecific morphological variation of four shelled Actinomma taxa (Radiolaria) in polar and subpolar regions. Marine Micropaleontology, 110, p. 50–71.

Campbell, A. S. and Clark, B. L. (1944) Miocene radiolarian faunas from southern California. Geol. Soc. Amer., Spec. Pap., 51, 1–76.

Caulet, J.-P. (1979) Les Radiolaires des boues superficielles de la Méditerranée. Bulletin du Muséum National d’Histoire Naturelle, Série 3, 39, 217–287.

Caulet, J.-P. (1986) Radiolarians from the southwest Pacific. In Kennett, J. P., von der Borch, C. C. et al., eds., Init. Rep. Deep Sea Drilling Project, 90, Washington, D. C.: U.S. Government Printing Office, 835–861.

Clark, B. L. and Campbell, A. S. (1942) Eocene radiolarian faunas from the Mt. Diablo area, California. Geol. Soc. Amer., Spec. Pap., 39, 1–112.

Clark, B. L. and Campbell, A. S. (1945) Radiolaria from the Kreyhagen formation near Los Banos, California. Geol. Soc. Amer., Mem., 10, 1–66.

Dumitrice, P. (2017) Contribution to the knowledge of the Entactinaria radiolarian family Rhizosphaeridae Haeckel and description of some new genera and species. Revue de Micropaleontol., 60, 469–491.

Ehrenberg, C. G. (1872) Mikrogeologische Studien über das kleinste Leben der Meeres-Tiefe und dessen geologischen Einfluss. Abhandlungen der K. Akademie der Wissenschaften zu Berlin, Jahrg. 1872, 131–399.

Foreman, H. P. (1973) Radiolaria of Leg 10 with systematics and ranges for the families Amphipyndacidae, Artostrobiidae, and Theoperidae. In Worzel, J. L., Bryant, W., et al., eds., Init. Rep. Deep Sea Drilling Project, 10, Washington, D. C.: U.S. Government Printing Office, 407–474.

Funakawa, S. (2000) Internal skeletal structures of the Cenozoic genera Gondwanaria, Lipmanella and Lithomelissa (Plagiocanathidae, Nassellaria) and their taxonomy. Micropaleontology, 46, 97–121.

Haeckel, E. (1861a) Über neue, lebende Radiolarians des Mittelmeeres und legte die dazu gehörigen Abbildungen. Monatsberichte der Königlich Preußischen Akademie der Wissenschaften zu Berlin, 1860, 794–817.

Haeckel, E. (1861b) Abbildungen und Diagnosen neuer Gattungen und Arten von lebenden Radiolarien des Mittelmeeres, 1860. Monatsberichte der Königlich Preußischen Akademie der Wissenschaften zu Berlin, 1860, 835–845.

Haeckel, E. (1879) Natürliche Schöpfungsgeschichte. Reimer, Berlin, 1–718.

Haeckel, E. (1882) Entwurf eines Radiolarien-System auf Grund von Studien der Challenger Radiolarien. Jenaische Zeitschrift Naturwissenschaft, 15, 418–472.

Haeckel, E. (1887) Report on the Radiolaria collected by H. M. S. Challenger during the years 1873–76. Report Voyage Challenger, Zoology, 18, 1–140.

Jackett, S. J., Baumgartner, P. O. and Bandini, A. N. (2008) A new low-latitude late Paleocene–early Eocene radiolarian biozonation based on unitary associations: applications for accreted terranes. Stratigraphy, 54, 39–62.

Jørgensen, E. (1905) The protist plankton and the diatoms in bottom samples. Bergens Museum Skrifter, 7, 49–151.

Kamikuri, S. (2010) New late Neogene radiolarian species from the middle to high latitudes of the North Pacific. Revue de Micropaléontol., 53, 85–106.

Kamikuri, S. (2012) Evolutionary changes in the biometry of the fossil radiolarian Stichocorys peregrina lineage in the eastern equatorial and eastern North Pacific. Marine Micropaleontology, 90, 13–28.

Kamikuri, S. (2017) Late Neogene radiolarian biostratigraphy of the eastern North Pacific ODP Sites 1020/1021. Paleontol. Res., 21, 230–254.

Kling, S. A. (1973) Radiolaria from the eastern North Pacific, Deep Sea Drilling Project Leg 18. In Kulm, L. D., von Huene, R., et al., Init. Rep. Deep Sea Drilling Project, 18, Washington, D. C.: U.S. Government Printing Office, 617–671.

LaRiviere, J. P., Ravelo, A. C., Crimmins, A., Dekens, P. S., Ford, H. L., Lyle, M. and Wara, M. W. (2012) Late Miocene decoupling of oceanic warmth and atmospheric carbon dioxide forcing. Nature, 486, 97–100.

Lombardi, G. and Lazarus, D. B. (1988) Neogene cycladophorid radiolarians from North Atlantic, Antarctic, and North Pacific deep-sea sediments. Micropaleontology, 34, 97–135.
Middle to late Miocene radiolarians in the eastern North Pacific (Kamikuri)

Lyle, M., Koizumi, I., Richter, C., Behl, R. J., Bodén, P., Caulet, J.-P., Delaney, M. L., deMenocal, P., Desmet, M., Fornaciari, E., Hayashida, A., Heider, F., Hood, J., Hova, S. A., Janecek, T. R., Janik, A. G., Kennett, J., Lund, D., Castillo, M. L. M., Maruyama, T., Merril, R. B., Mossman, D. J., Pike, J., Ravelo, A. C., Vera, G. A. R., Stax, R., Tada, R., Thurow, J. and Yamamoto, M. (1997) Proc. Ocean Drilling Program, Init. Rep., 167, Ocean Drilling Program, College Station, TX, 1–1378.

Matsuzaki, K. M., Suzuki, N. and Nishi, H. (2015) Middle to Upper Pleistocene pycnocystine radiolarians from Hole 902-C9001C, northwestern Pacific. Paleontol. Res., 19, 1–77.

Moore, T. C. Jr. (1972) Mid-Tertiary evolution of the radiolarian genus Calocyathela. Micropaleontology, 18, 144–152.

Morley, J. J. and Nigrini, C. (1995) Miocene to Pleistocene radiolarian biostratigraphy of North Pacific Sites 881, 884, 885, 886 and 887. In Rea, D. K., Basov, I. A., Scholl, D. W. and Allan, J. F., eds., Proc. Ocean Drilling Program, Sci. Results, 145, College Station, TX (Ocean Drilling Program), 55–91.

Motoyama, I. (1996) Late Neogene radiolarian biostratigraphy in the subarctic Northwest Pacific. Micropaleontology, 42, 221–262.

Nigrini C. and Lombari, G. (1984) A guide to Miocene Radiolarians. Cushman Found. Foram. Res., Spec. Pub., 22, S1-S102, N1-N206.

Nigrini, C. and Moore, T. C., Jr. (1979) A guide to modern Radiolarians. Cushman Found. Foram. Res., Spec. Pub., 16, S1-S142, N1-N106.

O’Connor, B. (1997) New radiolarian from the Oligocene and early Miocene of Northland, New Zealand. Micropaleontology, 43, 63–100.

Perez-Guzman, A. M. (1985) Radiolarian biostratigraphy of the late Miocene in Baja California and the Tres Marias Islands, Mexico. Micropaleontology, 31, 320–334.

Perez-Guzman, A. M. and Casey, R. E. (1986) Paleocoenographic reconstructions from radiolarian-bearing Baja California and adjacent sections. In Casey, R. E. and Barron, J. A., eds., Siliceous Microfossil and Microplankton of the Monterey Formation and Modern Analogues, Society of Economic Paleontologists and Mineralogists, Pacific Section, 45, 55–68.

Petrusheskaya, M. G. (1975) Cenozoic radiolarians of the Antarctic, Leg 29, DSDP. In Kennett, J. P., Houtz, R. E., et al., Init. Rep. Deep Sea Drilling Project, 29, Washington (U.S. Govt. Printing Office), 541–675.

Petrusheskaya, M. G. and Kozlova, G. E. (1972) Radiolaria, Leg 14, Deep Sea Drilling Project. In Hayes, D. E., Pimm, A. C., et al., Init. Rep. Deep Sea Drilling Project, 14, Washington (U.S. Govt. Printing Office), 495–648.

Poore, R. Z., McDougall J. A., Barron, J. A., Brabb, E. E. and Kling, S. A. (1981) Microfossil biostratigraphy and biochronology of the type Relizian and Lusian stages of California. In Garrison, R. E. and Douglas, R. G., eds., The Monterey Formation and Related Siliceous Rocks of California, Society of Economic Paleontologists and Mineralogists, Pacific Section, 15, 15–41.

Popova, I. (1989) New insight on the systematics of some Theopiliinae (Radiolaria). In Anonymous ed., Paleontologo-Stratigraphicheskie Issledovaniya Fanerozoya. Dal’nego Vostoka, Dal’nevostochnyi Otdel Akademii Nauk SSSR, Vladivostok, 68–77, 131, and 143–145. (in Russian; original title translated).

Rowell, H. C. (1981) Diatom biostratigraphy of the Monterey Formation, Palos Verdes Hills, California. In Garrison, R. E. and Douglas, R. G., eds., The Monterey Formation and Related Siliceous Rocks of California, Society of Economic Paleontologists and Mineralogists, Pacific Section, 15, 55–70.

Sakai, T. (1980) Radiolarians from Sites 434, 435, and 436, Northwest Pacific. Leg 56, Deep Sea Drilling Project. In Scientific Party, Init. Rep. Deep Sea Drilling Project, 56/57, Washington (U.S. Govt. Printing Office), 695–733.

Sanfilippo, A. and Caulet, J.-P. (1998) Taxonomy and evolution of Paleogene Antarctic and tropical Lophocystid radiolarians. Micropaleontology, 44, 1–43.

Sanfilippo, A., Westberg-Smith, M. J. and Riedel, W. R. (1985) Cenozoic radiolaria. In Bolli, H. M., Saunders, J. B. and Perch-Nielsen, K., eds., Plankton Stratigraphy, Cambridge Univ. Press, Cambridge, UK, 631–712.

Shilov, V. V. (1995) Miocene-Pleistocene radiolarians from Leg 145, North Pacific. In Rea, D. K., Basov, I. A., Scholl, D. W. and Allan, J. F., eds., Proc. Ocean Drilling Program, Sci. Results, 145, College Station, TX (Ocean Drilling Program), 93–116.

Sugiyama, K. and Furutani, H. (1992). Middle Miocene radiolarians from the Oidawara Formation, Mizunami Group, Gifu Prefecture, central Japan. Bull. Mizunami Fossil Mus., 19, 199-213.

Suzuki, N., Ogane, K. and Chiba, K. (2009) Middle Eocene pycnocystine radiolarians from the Site 1172, Leg 189, Southwest Pacific. News Osaka Micropaleontol. (NOM), Spec. Vol., no. 14, 239–296.

Takahashi, K. (1991) Radiolarians: flux, ecology, and taxonomy in the Pacific and Atlantic. Ocean Biocoenosis Series, no. 3, Woods Hole Oceanographic Institution, 1–303.

Takahashi, K. and Honjo, S. (1981) Vertical flux of Radiolaria: A taxon-quantitative sediment trap study from the western tropical Atlantic. Micropaleontology, 27, 140–190.

Takekura, A. (1992) Radiolarian Paleogene biostratigraphy in the Southern Indian Ocean, Leg 120. In Wise, S. W., Jr., Schlich, R., et al., Proc. ODP, Sci. Results,
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

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120, College Station, TX (Ocean Drilling Program), 735–756.

Vitukhin, D. I. (1993) Subdivision of the Russian Far East Cenozoic sediments based on Radiolaria. Transactions, Geol. Inst., Russian Academi Sci., 485, p. 1–105. (in Russian with English abstract).

Weaver, F. M., Casey, R. E. and Perez, A. M. (1981) Stratigraphic and paleoceanographic significance of early Pliocene to middle Miocene radiolarian assemblages from Northern to Baja California. In Garrison, R. E. and Douglas, R. G., eds., The Monterey Formation and Related Siliceous Rocks of California, Society of Economic Paleontologists and Mineralogists, Pacific Section, 15, 71–86.

Zhang, L. and Suzuki, N. (2017) Taxonomy and species diversity of Holocene pylonioid radiolarians from surface sediments of the northeastern Indian Ocean. Palaeontol. Electron., 20, 3, 48A, 1–68.

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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 bramblei (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: Carpocanum 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: *Calocycletta caepa* Moore (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 2, 3: *Calocycletta* 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: *Calocycletta* sp. B (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 5: *Calocycletta* sp. A (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 6: *Lophoconus bihastatus* 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: *Anthocyrtidium* 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: *Anthocyrtidium* sp. B (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 12, 13: *Lamprocyclas* sp. C (Sample 1021B-29X-4, 70-72 cm, 10.2 Ma).
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 pergrina* (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).
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: *Cinclopyramis 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: *Cinclopyramis 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).
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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).
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Plate 9  Illustrations of the encountered radiolarians. 1–9: *Haliommetta 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).
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 Enjumet (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: *Cromydrycoparcus esterae* Campbell and Clark (Sample 1021B-33X-2, 120-122 cm, 12.5 Ma); 7: *Drupatractus 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 glebula*enta Bjorklund 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 pseudarktios* (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: *Larco spir a 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 amphistylium* 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: *Perichlamydium 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: *Perichlamydium* 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).
Middle to late Miocene radiolarians in the eastern North Pacific (Kamikuri)

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