

Data report: early to middle Eocene radiolarian biostratigraphy, IODP Expedition 320 Site U1331, eastern equatorial Pacific¹

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Abstract

Quantitative analysis of radiolarian assemblages was used to establish the radiolarian biostratigraphy from Zone RP8 (lower Eocene) to RP16 (middle Eocene) in pelagic sequences recovered at Integrated Ocean Drilling Program Expedition 320 Site U1331 in the eastern equatorial Pacific Ocean.

Introduction

During Integrated Ocean Drilling Program (IODP) Expedition 320, six sites (U1331–U1336) were cored in the eastern equatorial Pacific Ocean (see the “[Expedition 320/321 summary](#)” chapter [Expedition 320/321 Scientists, 2010]). Early and middle Eocene thick radiolarian-rich biogenic sediments were collected at Site U1331 from Cores 320-U1331C-17X to 320-U1331A-6H. A total of 232 species and species groups were encountered in this study. We report the results of the quantitative data of radiolarian assemblage variation from the early to middle Eocene.

Materials and methods

Three holes were cored at Site U1331 (12°04.088'N, 142°09.708'W; 5116 meters below sea level [mbsl]) (Fig. [F1](#)). Early–middle Eocene sedimentary sequences from Site U1331 are composed mainly of radiolarian ooze with chert from Cores 320-U1331C-17X to 320-U1331A-11H and alternations of nannofossil ooze and radiolarian ooze from Cores 320-U1331A-11H to 320-U1331A-6H. In this study, depths reported as meters below seafloor (mbsf) indicate the revised composite core depth below seafloor, method A (CCSF-A), depth scale for the sediments as described in [Westerhold et al. \(2012\)](#).

Samples were prepared following the procedures outlined in [Sanfilippo et al. \(1985\)](#). Dried and weighed core sediment sample was placed into a beaker with 10% H₂O₂ to remove organic material and HCl solution to remove the calcareous fine fraction from radiolarian shells. After boiling for a few minutes, the sample was sieved and washed through a 63 µm mesh. The dried materials were divided equally into subsamples by a simple splitter to obtain ~2000 radiolarians. One sample split was moved to a slide, mounted with Canada balsam, and covered with a 24 mm × 40 mm cover glass. All radiolarian skeletons on the slides were

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observed and counted under light in order to reveal the faunal compositions (Table T1). For Site U1331, a total of 65 samples was examined.

Results

The zonal scheme of Sanfilippo and Nigrini (1998) was adopted for this study. The interval studied at Site U1331 was divided into nine radiolarian zones from Zone RP8 to RP16 (Sanfilippo and Nigrini, 1998). Terms used in this study to express events include evolutionary transition (ET), first occurrence (FO), and last occurrence (LO). The concept of evolutionary transition follows that of Sanfilippo and Nigrini (1998).

Zone RP16

Podocyrtes (Lampterium) goetheana interval zone (Moore, 1971, emend. Riedel and Sanfilippo, 1978)

The base of this zone is defined by the FO of *P. goetheana*. The interval from Samples 320-U1331A-6H-2, 105–107 cm (52.90 mbsf), to 7H-4, 95–97 cm (67.95 mbsf), was assigned to this zone. This zone contains the following species: *Anthocyrtes* spp., *Calocycloma ampulla*, *Dorcadospyrtes anastasis*, and the *Lithocyclia aristotelis* group.

Zone RP15

Podocyrtes (Lampterium) chalara lineage zone (Riedel and Sanfilippo, 1970, emend. Riedel and Sanfilippo, 1978)

The base of this zone is defined by the ET of *P. chalara*. The interval from Samples 320-U1331A-7H-CC (72.41 mbsf) to 9H-4, 105–107 cm (88.6 mbsf), was assigned to this zone. This zone includes the following species: *Lithochytris vespertilio*, *Lophocyrtes biaurita*, *Podocyrtes sinuosa*, and *Sethochytris triconiscus*.

Zone RP14

Podocyrtes (Lampterium) mitra lineage zone (Riedel and Sanfilippo, 1970, emend. Riedel and Sanfilippo, 1978)

The base of this zone is defined by the ET of *P. mitra*. Samples 320-U1331A-9H-CC (92.97 mbsf) through 13H-2, 104–106 cm (130.21 mbsf), were assigned to this zone. In this zone, *Eusyringium lagena*, *Podocyrtes fasciolata*, *Podocyrtes helenae*, *Podocyrtes trachodes*, and *Zealithapium anoectum* were recognized at Site U1331.

Zone RP13

Podocyrtes (Podocyrtes) ampla lineage zone (Riedel and Sanfilippo, 1970, emend. Riedel and Sanfilippo, 1978)

The base of this zone is defined by the ET of *P. ampla*. The interval spans from Samples 320-U1331A-13H-4, 104–106 cm (133.21 mbsf), to 14H-2, 104–106 cm (140.80 mbsf). This zone contains the following species: *Calocyclas trichopa*, *Dendrospyrtes didiceros*, *Eusyringium fistuligerum*, *Thyrsoyrtes triacantha*, and the *Lithocyclia ocellus* group.

Zone RP12

Thyrsoyrtes (Pentalacorys) triacantha interval zone (Riedel and Sanfilippo, 1970, emend. Riedel and Sanfilippo, 1978)

The base of this zone is defined by the FO of *E. lagena*. This zone was recognized from Samples 320-U1331A-14H-4, 104–106 cm (143.80 mbsf), to 16H-CC (159.38 mbsf). In Zone RP12 at Site U1331, *Calocycloma ampulla*, *Lychnocanoma bajunensis*, *Periphaena tripyramis triangula*, and *Rhopalocanium ornatum* were included in deep-sea sediments.

Zone RP11

Dictyoprora mongolfieri interval zone (Riedel and Sanfilippo, 1970, emend. Riedel and Sanfilippo, 1978)

The base of this zone is defined by the FO of *D. mongolfieri*. Samples 320-U1331A-17X-2, 104–106 cm (170.53 mbsf), through 19X-2, 25–27 cm (182.64 mbsf), were assigned to this zone. This zone includes the following species: *Buryella clinata*, *Calocycloma castum*, *Lithochytris archaea*, and *Zealithapium plegmancantha*.

Zone RP10

Theocotyle cryptocephala interval zone (Foreman, 1973)

The base of Zone RP10 is defined by the ET of *T. cryptocephala*. This zone was found in Sample 320-U1331A-19X-CC (182.76 mbsf) and contains the following species: *Lithochytris vespertilio*, the *L. ocellus* group, *Phormocyrtes embolum*, *Phormocyrtes striata striata*, and *Stylosphaera coronata coronata*.

Zone RP9

P. striata striata interval zone (Foreman, 1973, emend. Riedel and Sanfilippo, 1978)

The base of this zone is defined by the FO of *Theocorys anaclasta*. Zone RP9 was located in Sample 320-U1331A-20X-CC (187.40 mbsf) and includes the following species: *Dictyophimus craticula*, *P. tripyramis triangula*, *P. embolum*, and *S. coronata coronata*.

Zone RP8

Buryella clinata interval zone (Foreman, 1973, emend. Riedel and Sanfilippo, 1978)

The base of this zone is defined by the ET of *B. clinata*. The interval from Samples 320-U1331C-16H-2, 52–59 cm (200.27 mbsf), to 17H-2, 49–56 cm (lowermost sample in this study), was assigned to Zone RP8. This zone contains the following species: *Giraffospyris lata*, *Lamptonium sanfilippoae*, *Lophocyrtis biaurita*, *Lychnocanoma auxilla*, and *Thyrsochyrtis rhizodon*.

Species list

- Albatrossidium minzok* Sanfilippo and Riedel, 1992, p. 18, pl. 1, figs. 18, 19, pl. 2, fig. 7.
- Amphicraspedum murrayanum* Haeckel—Sanfilippo and Riedel, 1973, p. 524, pl. 10, figs. 3–6, pl. 28, fig. 1.
- Amphicraspedum prolixum* Sanfilippo and Riedel group—Sanfilippo and Riedel, 1973, p. 524, pl. 11, figs. 1–5, pl. 28, fig. 5: *Amphicraspedum prolixum* Sanfilippo and Riedel, 1973, p. 524, pl. 10, figs. 7–11, pl. 28, figs. 3, 4; Kozlova, 1999, p. 100, pl. 20, fig. 4, pl. 22, fig. 16, pl. 42, fig. 5.
- Amphymenium splendarmatum* Clark and Campbell—Popova et al., 2002, p. 21, fig. 7M.
- Anthocyrtis mespilus* Ehrenberg—Ogane et al., 2009, pl. 50, fig. 2a, 2b, pl. 80, fig. 5a–5e, pl. 81, figs. 1a–2d (not pl. 50, figs. 1a–1f).
- Anthocyrtoma* spp. Riedel and Sanfilippo, 1970, p. 524, pl. 6, figs. 2–4.
- Aphetocyrtis gnomabax* Sanfilippo and Caulet, 1998, pl. 2, figs. 6, 7, 10, 11, 14–17, pl. 7, figs. 10–13.
- Artophormis barbadensis* (Ehrenberg)—Nigrini et al., 2006, p. 25, pl. P3, figs. 17–19: *Calocyclus barbadensis* Ehrenberg—Ogane et al., 2009, pl. 96, fig. 3a–3c.
- Axoprunum pierinae* (Clark and Campbell)—Takemura, 1992, p. 742, pl. 6, figs. 3–6.
- Bathropyramis woodringi* Campbell and Clark, 1944, p. 39, pl. 5, figs. 21, 22.
- Buryella clinata* Foreman—Kozlova, 1999, p. 135, pl. 24, fig. 11, pl. 44, fig. 20.
- Calocyclus hispida* (Ehrenberg)—Moore, 1971, p. 741, pl. 4, figs. 6, 7: *Anthocyrtis hispida* Ehrenberg—Ogane et al., 2009, pl. 2, figs. 7a–9b, pl. 50, fig. 4a, 4b (Pl. P1, fig. 8).
- Calocyclus trichopa* (Ehrenberg): *Lychnocanum trichopus* Ehrenberg—Ogane et al., 2009, pl. 42, fig. 2 (not pl. 42, fig. 1).
- Calocyclus turris* Ehrenberg—Ogane et al., 2009, pl. 94, figs. 1a–7d.
- Calocyclus ampulla* (Ehrenberg)—Foreman 1973, p. 434, pl. 1, figs. 1–5, pl. 9, fig. 20.
- Calocyclus castum* (Haeckel)—Foreman, 1973, p. 434, pl. 1, figs. 7, 9, 10.
- Clathrocyclus (Clathrocyclus) universa* Clark and Campbell, 1942, p. 86, pl. 7, figs. 8–12, 14–21, 25.
- Cornutella profunda* Ehrenberg—Kling, 1973, p. 635, pl. 3, figs. 1–4, pl. 9, figs. 8–17.
- Cryptocarpium ornatum* (Ehrenberg)—Sanfilippo and Riedel, 1992, p. 6, pl. 2, figs. 18–20.
- Dendrospyris acuta* Goll, 1968, p. 1419, pl. 173, figs. 7–9, 12.
- Dendrospyris didiceros* (Ehrenberg): *Giraffospyris didiceros* (Ehrenberg)—Goll, 1969, p. 332, pl. 60, figs. 5–7, 9.
- Dendrospyris stylophora* (Ehrenberg)—Goll, 1968, pl. 173, figs. 21–24, text-fig. 8.
- Dictyophimus craticula* Ehrenberg—Ogane et al., 2009, pl. 21, fig. 5, pl. 36, fig. 1, pl. 37, figs. 2–4 (Pl. P2, fig. 7).
- Dictyoprora mongolfieri* (Ehrenberg)—Nigrini, 1977, p. 250, pl. 4, fig. 7 (Pl. P1, fig. 9).
- Dictyospyris melissium* Sanfilippo and Riedel, 1973, p. 527, pl. 17, figs. 1, 2, pl. 32, fig. 13.
- Dorcadospiris anastasis* Sanfilippo—Nigrini et al., 2006, p. 33, pl. P1, figs. 11, 12.
- Dorcadospiris argisca* (Ehrenberg)—Chen, 1975, p. 456, pl. 3, fig. 9: *Petalospyris argiscus* Ehrenberg—Ogane et al., 2009, pl. 2, fig. 11, pl. 18, fig. 7a–7e, pl. 39, fig. 8a–8c.
- Dorcadospiris ombros* Sanfilippo—Nigrini et al., 2006, p. 36, pl. P2, figs. 5, 6.
- Entapium regulare* Sanfilippo and Riedel, 1973, p. 491, pl. 1, figs. 10–19, pl. 24, figs. 1–3.
- Eucoronis hertwigii* (Bütschli) group—Petrushevskaya and Kozlova, 1972, p. 533, pl. 41, figs. 15–17.
- Eucyrtidium ? hillaby* Ehrenberg group—Funakawa et al., 2006, p. 22, pl. 5, figs. 6a–8b.
- Eucyrtidium* aff. *montiparum* Ehrenberg—Petrushevskaya and Kozlova, 1972, p. 548, pl. 26, figs. 2–4.
- Eucyrtidium argus* Ehrenberg—Ogane et al., 2009, pl. 48, fig. 8a–8f.
- Eucyrtidium scolopax* Ehrenberg—Ogane et al., 2009, pl. 58, fig. 3a–3f.
- Eucyrtidium ventriosum* O'Connor, 1999, p. 21, pl. 3, figs. 17–21b, pl. 6, figs. 28a–31.
- Eusyringium fistuligerum* (Ehrenberg)—Sanfilippo and Blome, 2001, p. 212, fig. 9a–9d: *Eucyrtidium fistuligerum* Ehrenberg—Ogane et al., 2009, pl. 47, fig. 3a–3f (Pl. P1, fig. 4).
- Eusyringium lagena* (Ehrenberg)—Kozlova, 1999, p. 155, pl. 27, figs. 17, 18, pl. 32, fig. 16 (Pl. P1, fig. 5).
- Flustrella concentrica* Ehrenberg—Ogane et al., 2009, pl. 66, fig. 3.
- Giraffospyris lata* Goll, 1969, p. 334, pl. 58, figs. 22, 24–26.
- Haliomma echinatum* Ehrenberg—Ogane et al., 2009, pl. 30, figs. 1a–3b.
- Heliodiscus pentasteriscus* Clark and Campbell—Petrushevskaya and Kozlova, 1972, p. 523, pl. 13, figs. 6, 7.
- Heliodiscus saturnalis* Clark and Campbell—Petrushevskaya and Kozlova, 1972, p. 523, pl. 13, fig. 8.
- Hexacantium palaeocenicum* Sanfilippo and Riedel, 1973, pl. 4, fig. 2, pl. 24, fig. 4.
- Lamptonium fabaeforme chaunothorax* Riedel and Sanfilippo—Nigrini et al., 2006, p. 41, pl. P4, fig. 5.
- Lamptonium fabaeforme constrictum* Riedel and Sanfilippo—Nigrini et al., 2006, p. 41: *Lamptonium (?) fabaeforme (?) constrictum* Riedel and Sanfilippo, 1970, p. 523, pl. 5, fig. 7.
- Lamptonium fabaeforme fabaeforme* (Krashennikov)—Nigrini et al., 2006, p. 41: *Lamptonium (?) fabaeforme fabaeforme* (Krashennikov)—Foreman, 1973, p. 436, pl. 6, figs. 6–9.
- Lamptonium pennatum* Foreman, 1973, p. 436, pl. 6, figs. 3–5, pl. 11, fig. 13.
- Lamptonium sanfilippoae* Foreman, 1973, p. 436, pl. 6, figs. 15, 16, pl. 11, figs. 16, 17.

- Lithelius hexaxyphophorus* (Clark and Campbell)—Sanfilippo and Riedel, 1973, p. 522, pl. 7, figs. 7–9, pl. 26, figs. 6, 7.
- Lithochytris archaea* Riedel and Sanfilippo—Foreman, 1973, p. 436, pl. 2, figs. 4, 5.
- Lithochytris vespertilio* Ehrenberg—Ogane et al., 2009, pl. 45, figs. 1–3.
- Lithocyelia aristotelis* (Ehrenberg) group—Riedel and Sanfilippo, 1971, p. 1588, pl. 3A, figs. 4, 5.
- Lithocyelia ocellus* Ehrenberg group—Riedel and Sanfilippo, 1971, p. 1588, pl. 3A, fig. 6 (Pl. P2, fig. 6).
- Lithomelissa lautouri* O'Connor, 1999, p. 16, pl. 2, figs. 23–27, pl. 6, figs. 11a–15.
- Lophocyrtis (Apoplanius) aspera* (Ehrenberg) group: *Lophocyrtis (Apoplanius) aspera* (Ehrenberg)—Sanfilippo and Caulet, 1998, p. 14, pl. 3A, figs. 5–10, pl. 3B, figs. 1, 2, 5–9, pl. 6, figs. 6–8.
- Lophocyrtis (Apoplanius) nomas* Sanfilippo and Caulet, 1998, p. 15, pl. 3A, figs. 1–4; pl. 3B, figs. 3, 4; pl. 6, figs. 1a–5b.
- Lophocyrtis biaurita* (Ehrenberg)—Cita et al., 1970, p. 404, pl. 2, figs. I–K: *Eucyrtidium biauratum* Ehrenberg—Ogane et al., 2009, pl. 18, fig. 8, pl. 20, figs. 1a–2b, 6.
- Lychnocanoma auxilla* Foreman, 1973, p. 437, pl. 2, fig. 6, pl. 11, figs. 1, 2.
- Lychnocanoma babylonis* (Clark and Campbell) group—Foreman, 1973, p. 437, pl. 2, fig. 1.
- Lychnocanoma bajunensis* Renz, 1984, p. 459, pl. 1, figs. 4–6.
- Lychnocanoma tetrapodium* (Ehrenberg): *Lychnocanium tetrapodium* Ehrenberg—Ogane et al., 2009, pl. 7, fig. 9a–9c.
- Lychnocanoma turgidum* (Ehrenberg)—Nigrini et al., 2006, p. 44, pl. P4, fig. 6.
- Periphaena decora* Ehrenberg—Popova et al., 2002, p. 41, fig. 17H.
- Periphaena delta* Sanfilippo and Riedel, 1973, p. 523, pl. 8, figs. 11, 12, pl. 27, figs. 6, 7.
- Periphaena tripyramis triangula* (Sutton)—Sanfilippo and Riedel, 1973, p. 523, pl. 9, figs. 10, 11 (Pl. P2, fig. 5).
- Petalospyris carinata* Ehrenberg—Ogane et al., 2009, pl. 40, fig. 5a–5d.
- Petalospyris foveolata* Ehrenberg—Ogane et al., 2009, pl. 38, fig. 9a–9c.
- Phormocyrtis* cf. *proxima* Clark and Campbell: cf. *Phormocyrtis proxima* Clark and Campbell, 1942, p. 82, pl. 7, figs. 24, 26.
- Phormocyrtis embolum* (Ehrenberg)—Kozlova, 1999, p. 148, pl. 31, fig. 14.
- Phormocyrtis striata exquisita* (Kozlova)—Foreman, 1973, p. 438, pl. 7, figs. 1–4, 7, 8, pl. 12, fig. 5: *Eusyringium striata exquisita* (Kozlova)—Kozlova, 1999, p. 157, pl. 7, fig. 3, pl. 8, fig. 17, pl. 10, figs. 10, 12, pl. 12, fig. 11, pl. 18, fig. 5, pl. 44, fig. 3.
- Phormocyrtis striata striata* Brandt—Foreman, 1973, p. 438, pl. 7, figs. 5, 6, 9: *Eusyringium striata striata* (Brandt)—Kozlova, 1999, p. 156, pl. 15, fig. 10, pl. 8, fig. 6.
- Phormospyris stabilis stabilis* (Goll)—Goll, 1976, p. 390, pl. 1, figs. 1–13.
- Podocyrtis (Lampterium) aphorma* Riedel and Sanfilippo, 1970, p. 534, pl. 11, fig. 2.
- Podocyrtis (Lampterium) chalara* Riedel and Sanfilippo, 1970, p. 535, pl. 12, figs. 2, 3 (Pl. P1, fig. 2).
- Podocyrtis (Lampterium) fasciolata* (Nigrini)—Sanfilippo et al., 1985, p. 697, fig. 30.7.
- Podocyrtis (Lampterium) goetheana* (Haeckel)—Moore, 1971, p. 743, pl. 3, figs. 7, 8 (Pl. P1, fig. 3).
- Podocyrtis (Lampterium) helenae* Nigrini, 1974, p. 1070, pl. 1L, figs. 9–11, pl. 4, figs. 4, 5.
- Podocyrtis (Lampterium) sinuosa* Ehrenberg: *Podocyrtis sinuosa* Ehrenberg—Ogane et al., 2009, pl. 1, fig. 1a–1c, pl. 2, figs. 4a–5b, pl. 57, fig. 2a–2d.
- Podocyrtis (Lampterium) trachodes* Riedel and Sanfilippo, 1970, p. 535, pl. 11, fig. 7, pl. 12, fig. 1.
- Podocyrtis (Podocyrtis) papalis* Ehrenberg—Sanfilippo and Riedel, 1992, p. 9, pl. 3, figs. 1, 9, 10: *Podocyrtis papalis* Ehrenberg—Kozlova, 1999, p. 151, pl. 15, fig. 6, pl. 24, figs. 16, 17.
- Podocyrtis (Podocyrtoges) ampla* Ehrenberg—Sanfilippo and Riedel, 1992, p. 14, pl. 5, fig. 4: *Podocyrtis (?) ampla* Ehrenberg—Ogane et al., 2009, pl. 25, fig. 1a–1d, pl. 57, fig. 4a–4b, pl. 85, fig. 6a–6c.
- Podocyrtis (Podocyrtoges) diamesa* Sanfilippo and Riedel—Nigrini et al., 2006, p. 46, pl. P5, fig. 10 (Pl. P2, fig. 4).
- Podocyrtis (Podocyrtoges) physis* (Sanfilippo and Riedel)—Sanfilippo and Riedel, 1992, p. 14: *Podocyrtis (Podocyrtis) physis* Sanfilippo and Riedel—Sanfilippo et al., 1985, p. 695, fig. 30.3.
- Podocyrtis (Lampterium) mitra* Ehrenberg—Riedel and Sanfilippo, 1970, p. 534, pl. 11, figs. 5, 6 (Pl. P1, fig. 1).
- Porodiscus charlestonensis* Clark and Campbell—Popova et al., 2002, p. 46, fig. 17L.
- Porodiscus circularis* Clark and Campbell, 1942, p. 42, pl. 2, figs. 2, 6, 10: *Plectodiscus circularis* (Clark and Campbell)—Popova et al., 2002, p. 46, fig. 7P.
- Pterocodon campana* Ehrenberg—Ogane et al., 2009, pl. 8, fig. 2a–2c, pl. 87, figs. 1a–3b.
- Rhopalocanium ornatum* Ehrenberg—Ling, 1975, p. 729, pl. 11, figs. 1–3.
- Saturnaris circularis* Haeckel—Nigrini, 1967, p. 25, pl. 1, fig. 9.
- Sethochytris triconiscus* Haeckel—Ling, 1975, p. 729, pl. 11, figs. 4–6.
- Siphocampe quadrata* (Petrushevskaya and Kozlova)—Takemura, 1992, p. 743, pl. 7, fig. 7: *Lithamphora sacculifera quadrata* Petrushevskaya and Kozlova, 1972, p. 539, pl. 30, figs. 4–6.
- Spongatractus balbis* Sanfilippo and Riedel, 1973, p. 518, pl. 2, figs. 1–3, pl. 25, figs. 1, 2.
- Spongatractus pachystylus* (Ehrenberg)—Sanfilippo and Riedel, 1973, p. 519, pl. 2, figs. 4–6, pl. 25, fig. 3: *Spongosphaera pachystyla* Ehrenberg—Ogane et al., 2009, pl. 13, figs. 1a–1d, 3a–3b, pl. 27, fig. 2a–2d.
- Stichopilidium sphinx* (Ehrenberg)—Petrushevskaya and Kozlova, 1972, p. 552, pl. 27, fig. 1.
- Stylatractus neptunus* Haeckel—Petrushevskaya and Kozlova, 1972, p. 520, pl. 11, fig. 11.
- Stylosphaera coronata coronata* Ehrenberg—Sanfilippo and Riedel, 1973, p. 520, pl. 1, figs. 13–17, pl. 25, fig. 4: *Stylosphaera coronata* Ehrenberg—Ogane et al., 2009, pl. 12, fig. 1a–1d.
- Stylosphaera coronata laevis* Ehrenberg—Sanfilippo and Riedel, 1973, p. 520, pl. 1, fig. 19, pl. 25, figs. 5, 6.

- Stylosphaera coronata sabaca* Sanfilippo and Riedel, 1973, p. 521, pl. 1, fig. 18, pl. 25, figs. 7, 8.
- Stylosphaera flexuosa* Ehrenberg—Ogane et al., 2009, pl. 11, fig. 4a–4f.
- Stylotrochus nitidus* Sanfilippo and Riedel, 1973, p. 525, pl. 13, figs. 9–14, pl. 30, figs. 7–10.
- Stylotrochus quadribrahiatus quadribrahiatus* Sanfilippo and Riedel, 1973, p. 526, pl. 14, figs. 1, 2, pl. 31, fig. 1.
- Thecosphaerella glebulenta* Sanfilippo and Riedel, 1973, p. 521, pl. 3, figs. 12, 13, pl. 26, fig. 1.
- Thecosphaerella rotunda* (Borisenko)—Kozlova, 1999, p. 80, pl. 7, figs. 1, 2, pl. 11, figs. 1, 2, pl. 27, figs. 1, 4.
- Theocorys acroria* Foreman, 1973, p. 439, pl. 5, figs. 11–13, pl. 12, fig. 2.
- Theocorys anaclasta* Riedel and Sanfilippo, 1970, p. 530, pl. 10, figs. 2, 3.
- Theocorys anapographa* Riedel and Sanfilippo var. A—Sanfilippo and Blome, 2001, p. 219, fig. 11m, 11n.
- Theocorys anapographa* Riedel and Sanfilippo—Moore, 1971, pl. 2, fig. 2.
- Theocorys bianulus* O'Connor, 1997, p. 84, pl. 4, figs. 1–4, pl. 10, figs. 1–4, pl. 11, fig. 5.
- Theocorys puriri* O'Connor, 1997, p. 88, pl. 4, figs. 5–8; pl. 10, figs. 5–8.
- Theocotyle conica* Foreman—Sanfilippo and Riedel, 1982, p. 177, pl. 2, fig. 13.
- Theocotyle cryptocephala* (Ehrenberg)—Sanfilippo and Riedel, 1982, p. 178, pl. 2, figs. 4–7; *Eucyrtidium cryptocephalum* Ehrenberg—Ogane et al., 2009, pl. 95, fig. 2a–2d.
- Theocotyle nigrinae* Riedel and Sanfilippo—Sanfilippo and Riedel, 1982, p. 178, pl. 2, figs. 1–3.
- Theocotyle venezuelensis* Riedel and Sanfilippo, 1970, p. 525, pl. 6, figs. 9, 10, pl. 7, figs. 1, 2.
- Theocotylissa ficus* (Ehrenberg)—Sanfilippo and Riedel, 1982, p. 180, pl. 2, figs. 19, 20; *Eucyrtidium ficus* Ehrenberg—Ogane et al., pl. 59, fig. 2a–2c.
- Thyrocorytis perpumila* Sanfilippo—Nigrini et al., 2006, p. 51, pl. P5, figs. 19–22 (Pl. P2, fig. 3).
- Tholodiscus splendens* (Ehrenberg)—Petrushevskaya and Kozlova, 1972, p. 525, pl. 18, figs. 3–5.
- Thyrocorytis (Pentalacorys) krooni* Sanfilippo and Blome, 2001, p. 207, fig. 7a–7e.
- Thyrocorytis (Pentalacorys) tensa* Foreman—Sanfilippo and Riedel, 1982, p. 176, pl. 1, figs. 6, 7, pl. 3, figs. 1, 2.
- Thyrocorytis (Pentalacorys) triacantha* (Ehrenberg)—Sanfilippo and Riedel, 1982, p. 176, pl. 1, figs. 8–10, pl. 3, figs. 3, 4 (Pl. P2, fig. 2).
- Thyrocorytis (Thyrocorytis ?) pinguisicoides* O'Connor, 1999, p. 29, pl. 4, figs. 28–32, pl. 1, figs. 17–20.
- Thyrocorytis (Thyrocorytis) bromia* Ehrenberg—Sanfilippo and Riedel, 1982, p. 172, pl. 1, figs. 14–16, pl. 3, figs. 12–17 (Pl. P2, fig. 8).
- Thyrocorytis (Thyrocorytis) hirsuta* (Krasheninnikov)—Sanfilippo and Riedel, 1982, p. 173, pl. 1, figs. 3, 4.
- Thyrocorytis (Thyrocorytis) rhizodon* Ehrenberg—Sanfilippo and Riedel, 1982, p. 173, pl. 1, figs. 14–16, pl. 3, figs. 12–17; *Thyrocorytis rhizodon* Ehrenberg—Ogane et al., 2009, pl. 56, fig. 1a–1c.
- Thyrocorytis (Thyrocorytis) robusta* Riedel and Sanfilippo—Sanfilippo and Riedel, 1982, p. 174, pl. 1, fig. 5 (Pl. P2, fig. 1).
- Thyrocorytis (Thyrocorytis) tarsipes* Foreman—Sanfilippo and Riedel, 1982, p. 174, pl. 1, figs. 1, 2.
- Tristylospyris tricerus* (Ehrenberg)—Sanfilippo et al., 1985, p. 665, fig. 10.3a, 10.3b; *Ceratospyris tricerus* Ehrenberg—Ogane et al., 2009, pl. 40, fig. 1a–1d, pl. 77, fig. 6, pl. 78, fig. 1a–1d.
- Zealithapium anoectum* (Riedel and Sanfilippo)—O'Connor, 1999, p. 5; *Lithapium anoectum* Riedel and Sanfilippo—Kozlova, 1999, p. 125, pl. 32, fig. 19 (Pl. P1, fig. 6).
- Zealithapium mitra* (Ehrenberg)—O'Connor, 1999, pp. 5, 6, pl. 9, fig. 47; *Cornutella mitra* Ehrenberg—Ogane et al., 2009, pl. 82, figs. 3a–3d, 5a–6.
- Zealithapium plegmacantha* (Riedel and Sanfilippo)—O'Connor, 1999, p. 5; *Lithapium (?) plegmacantha* Riedel and Sanfilippo, 1970, p. 520, pl. 4, figs. 2, 3 (Pl. P1, fig. 7).
- Zygocircus cimelium* Petrushevskaya—Petrushevskaya and Kozlova, 1972, p. 534, pl. 41, figs. 5, 6.

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Figure F1. Location of Expedition 320 Site U1331 in the eastern equatorial Pacific Ocean.

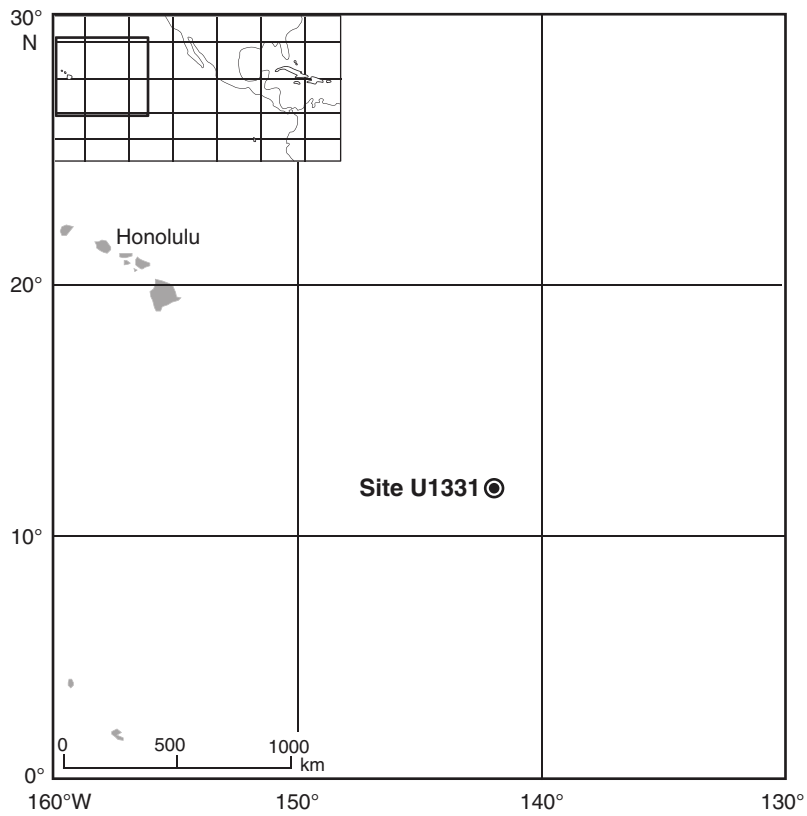


Table T1. Abundance of radiolarian species, species diversity, evenness, and radiolarian mass accumulation rate (MAR), Site U1331. This table is available in an [oversized format](#).

Plate P1. Photographs of selected radiolarian species. Scale bar = 100 μm . 1. *Podocyrts (Lampterium) mitra* Ehrenberg (Sample 320-U1331B-11H-CC), R40/2. 2. *Podocyrts (Lampterium) chalara* Riedel and Sanfilippo (Sample 320-U1331B-5H-CC), L24/0. 3. *Podocyrts (Lampterium) goetheana* (Haeckel) (Sample 320-U1331B-5H-CC), K23/0. 4. *Eusyringium fistuligerum* (Ehrenberg) (Sample 320-U1331B-6H-CC), C33/0. 5. *Eusyringium lagena* (Ehrenberg) (Sample 320-U1331B-14H-CC), C41/3. 6. *Zealithapium anoectum* (Riedel and Sanfilippo) (Sample 320-U1331B-13H-CC), T11/3. 7. *Zealithapium plegmacantha* (Riedel and Sanfilippo) (Sample 320-U1331C-12H-CC), H38/4. 8. *Calocyclas hispida* (Ehrenberg) (Sample 320-U1331B-8H-CC), K42/2. 9. *Dictyoprora mongolfieri* (Ehrenberg) (Sample 320-U1331C-6H-CC), G18/4.

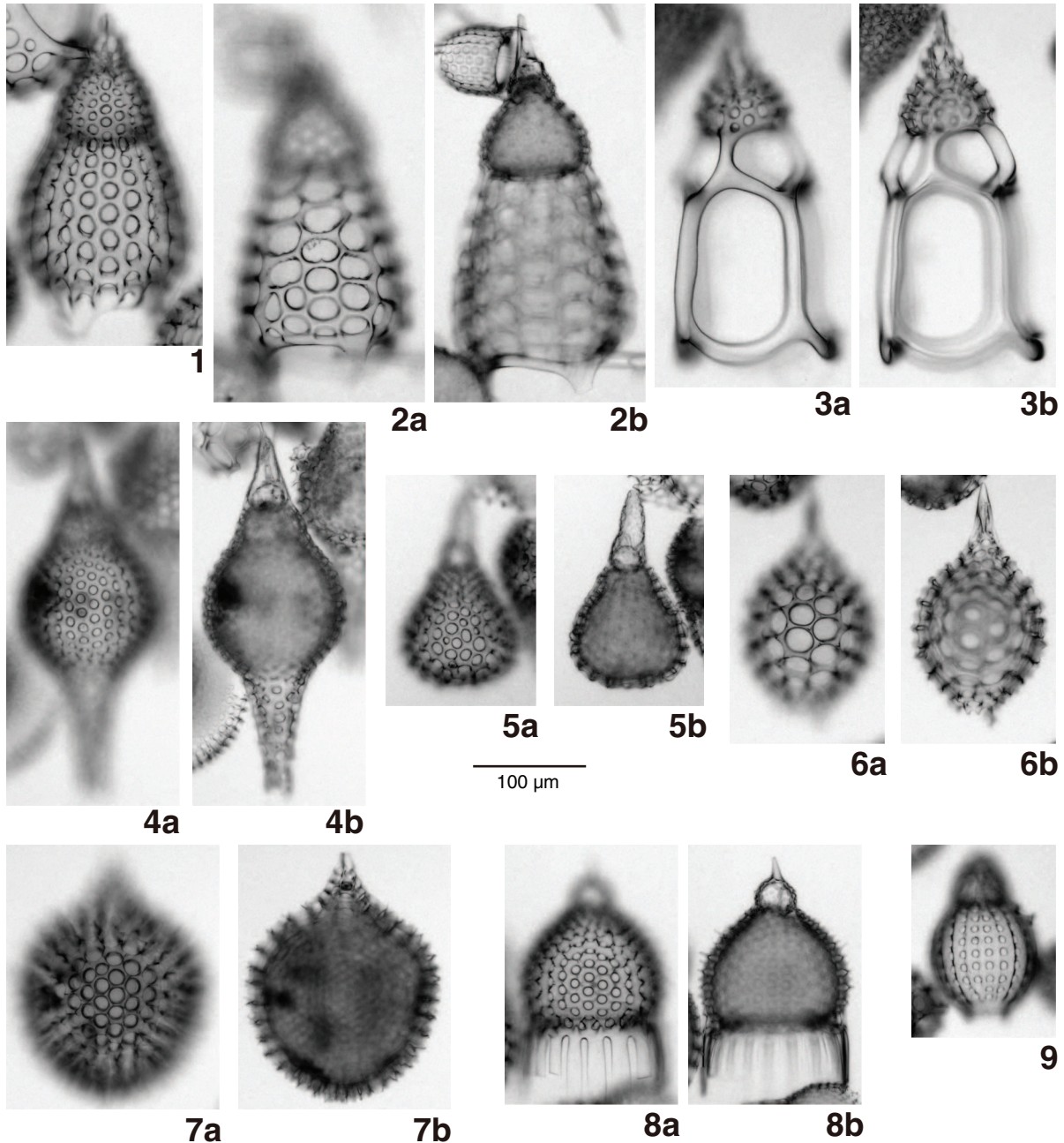


Plate P2. Photographs of selected radiolarian species. Scale bar = 100 μm . 1. *Thyrsocyrtis* (*Thyrsocyrtis*) *robusta* Riedel and Sanfilippo (Sample 320-U1331B-16H-CC), H28/0. 2. *Thyrsocyrtis* (*Pentalacorys*) *triacantha* (Ehrenberg) (Sample 320-U1331C-13H-CC), M32/0. 3. *Theocyrtis perpumila* Sanfilippo (Sample 320-U1331B-6H-CC), Y43/3. 4. *Podocyrtis* (*Podocyrtoges*) *diamesa* Sanfilippo and Riedel (Sample 320-U1331B-14H-CC), F51/1. 5. *Periphaena tripyramis triangula* (Sutton) (Sample 320-U1331B-16H-CC), H32/0. 6. *Lithocyclia ocellus* Ehrenberg group (Sample 320-U1331C-13H-CC), Q29/4. 7. *Dictyophimus craticula* Ehrenberg (Sample 320-U1331B-15H-CC), J33/3. 8. *Thyrsocyrtis* (*Thyrsocyrtis*) *bromia* Ehrenberg (Sample 320-U1331B-4H-CC), T39/0.

