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6. Oligocene and Earliest Miocene Diatom Biostratigraphy of ODP Leg 199 Site 1220, Equatorial Pacific[1]

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ABSTRACT

Completion of studies on material collected during Ocean Drilling Program Leg 199 at Site 1220 in the equatorial Pacific allows calibration of the ranges of >35 stratigraphically important diatoms to paleomagnetic stratigraphy for the Oligocene and earliest Miocene (~33.5–21.5 Ma). The taxonomy of these taxa is reviewed, and age estimates of their first and last occurrences are compiled. The diatom zonation for the Oligocene and earliest Miocene of the equatorial Pacific is revised and correlated with paleomagnetic stratigraphy. This biostratigraphy is likely to be applicable throughout the low-latitude regions of the world's oceans.

INTRODUCTION

Jousé (1973) was the first researcher to document the ranges of key diatom taxa in Oligocene and Miocene deep-sea sediments from the tropical oceans and to name a series of diatom assemblage zones based on distinctive species. Ten years later, Fenner (1984a) combined the results of diatom biostratigraphy from nine low-latitude Atlantic and Pacific Deep Sea Drilling Project (DSDP) sites and proposed a much more refined late middle Eocene through Oligocene low-latitude diatom zonation, emphasizing stratigraphic markers that were easily identifiable, somewhat resistant to dissolution, and generally consistent in their oc-

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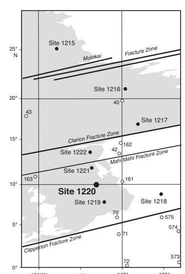
currences. Subsequent studies (Fenner, 1984b, 1985; Barron, 1985a; Fenner and Mikkelsen, 1990; Fourtanier, 1991) have shown that Fenner's (1984a) diatom zonation is widely applicable in low-latitude regions of the world's oceans. Studies of Oligocene and lower Miocene biosiliceous sediments in middle- to high-latitude regions of the North Pacific Ocean, Norwegian Sea, and Southern Ocean (Schrader and Fenner, 1976; Fenner, 1985; Harwood and Maruyama, 1992; Gladenkov and Barron, 1995) suggest that low-latitude diatom datum levels are widely applicable. To date, the primary correlation of low-latitude diatom biostratigraphy with the geological timescale for the Oligocene and earliest Miocene has been through correlation with calcareous nannofossil zones (Fenner, 1984a, 1984b; Fenner and Mikkelsen, 1990), with secondary calibration of calcareous nannofossil zones with magnetostratigraphy (Barron and Baldauf, 1995).

Whereas calibration of Southern Ocean diatom events with magnetostratigraphy has been established for much of the Oligocene (Baldauf and Barron, 1991; Harwood and Maruyama, 1992; Ramsay and Baldauf, 1999; Roberts et al., 2003), no direct correlation of low-latitude diatom biostratigraphies for the Oligocene and earliest Miocene has been made. Refinement of Oligocene and earliest Miocene diatom biostratigraphy in the North Pacific is even more severely limited by the lack of complete stratigraphic sequences (Gladenkov and Barron, 1995).

This paper documents the ranges of biostratigraphically useful diatoms in the Oligocene and lowermost Miocene sediments (~33.5–21.5 Ma) recovered at Ocean Drilling Program (ODP) Site 1220 (10°10.601′N, 142°45.491′W; water depth 5217.9 m) in the equatorial Pacific (Fig. **F1**). Precise identification of Oligocene and earliest Miocene paleomagnetic chrons by the Shipboard Scientific Party (2002) in sediments recovered from Site 1220 allows accurate ages to be assigned to numerous diatom datum levels. Compilations by Fenner (1984a, 1985) and Barron (1983) of Oligocene and early Miocene diatom biostratigraphy provide a framework for regional applications.

F1. Site 1220 location, p. 14.



MATERIALS AND METHODS

In general, Hole 1220A was sampled at 1.00-m intervals, with occasional samples taken at 50-cm intervals. Approximately 1 g of material was placed in a 250 mL beaker, disaggregated with a wooden stirring rod, and covered with distilled water. Dilute (~3%) hydrochloric acid was then added to remove the calcium carbonate. After the reaction ceased, a series of washing steps was performed to bring the solution to a neutral pH. Distilled water was added to the beaker, the solution was allowed to settle for at least 6 hr, and excess liquid was carefully decanted off. After completion of the washing process, strewn slides were prepared by transferring the suspended material with a disposable pipette to a 22 mm × 40 mm coverslip, which was then dried on a hot plate and mounted with Naphrax on a 22 mm × 75 mm glass slide.

These slides were examined in their entirety under a light microscope (Leitz Ortholux) at a magnification of 500×, with identifications checked at 1250×. Assessment of the overall abundance of diatoms was semi-quantitative; recorded as the coverage of diatom valves on the slide surface relative to other particles (in percent). The abundance of diatoms was listed as

A = abundant (>60%),

C = common (30%–60%),
F = few (5%–30%), and
R = rare (<5%).

The relative abundance of diatom species in an assemblage was estimated at 500× as follows:

A = abundant (more than one specimen seen in each field of view).
C = common (one specimen observed in two fields of view).
F = few (one specimen present in each horizontal traverse of the coverslip).
R = rare (sparser occurrences).

Diatom preservation was noted as

G = good (fine structures of the valves were preserved, and weakly silicified forms were present in the assemblage),
M = moderate (the assemblage showed moderate breakage and light dissolution), and
P = poor (>30% of all valves were broken, and the assemblage was affected by partial dissolution).

RESULTS

The occurrence of common and stratigraphically important diatom taxa in the Oligocene and lowermost Miocene sediments of Hole 1220A is documented in Table **T1.** Selected samples from Hole 1220B are included according to their composite depths (Shipboard Scientific Party, 2002) in order to fill missing intervals that were not recovered in Hole 1220A. Although the various diatom taxa were not counted for this report, it is clear from Table **T1** that taxa such as *Azpeitia, Cavitatus, Cestodiscus*, and *Rocella* vary considerably in their relative abundances, suggesting their utility for paleoceanographic studies. The taxonomy used for the diatoms is detailed in the **"Appendix,"** p. 10, and selected taxa are illustrated in Plates **P1, P2**, and **P3.**

Detailed paleomagnetic stratigraphy for the upper Eocene, Oligocene, and lowermost Miocene at Site 1220 (Shipboard Scientific Party, 2002) allows the ages of biostratigraphically important diatom datum levels to be estimated (Table **T2**).

Diatom Zonation

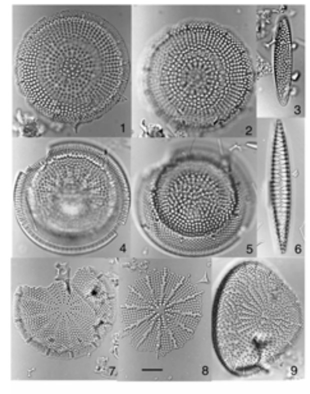
The diatom zonation applied for the latest Eocene, Oligocene, and earliest Miocene is reviewed below. Ranges of stratigraphically important diatoms and this diatom zonation are correlated with the paleomagnetic stratigraphy of Site 1220 in Figure **F2.**

Baxteriopsis brunii Partial Range Zone

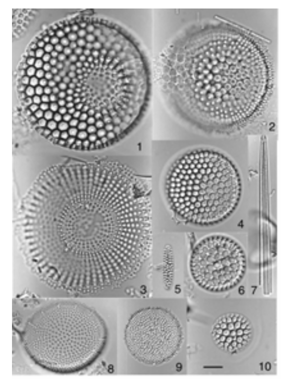
Author: Fenner (1984a)
Base: first continuous occurrence of specimens of *Baxteriopsis brunii* (van Heurck) Karsten that contain 4–7 areolae in 10 µm
Top: first occurrence of *Coscinodiscus excavatus* Greville ex Ralfs in Pritchard

T1. Common and stratigraphically important diatoms in the Oligocene and lowermost Miocene, p. 16.

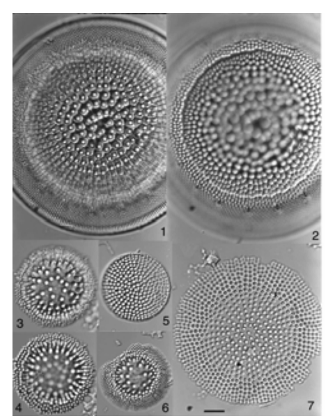
P1. Specimens in Cores 199-1220A-4H through 8H, p. 23.



P2. Specimens in Cores 199-1220A-5H through 8H, p. 24.



P3. Specimens in Sample 199-1220A-7H-5, 60–61 cm, p. 25.



T2. Stratigraphic constraints, paleomagnetic chron assignment, and age estimate, p. 22.

Remarks: This zone was not documented at Site 1220. *B. brunii* is not present in the uppermost Eocene–lower Oligocene section of Hole 1220B.

Coscinodiscus excavatus Range Zone

Author: Barron (1985a)
Base: first occurrence of *C. excavatus*
Top: last occurrence of *C. excavatus* (33.6–33.5 Ma)
Remarks: Jousé (1973) proposed a *C. excavatus* var. *quadriocellata* Assemblage Zone, which is essentially equivalent to this zone. Fenner (1984a) chose to separate this early Oligocene interval into two zones: the *C. excavatus* Partial Range Zone and the *Cestodiscus reticulatus* Interval Zone (incorrectly termed a range zone). This separation was based on the recognition of *C. reticulatus* Fenner. Barron (1985a) remarked that it was very difficult to distinguish *C. reticulatus* from *Cestodiscus robustus* Jousé and chose not to recognize the *C. reticulatus* zone of Fenner (1984a).

Cestodiscus trochus Interval Zone

Author: New zone, this study
Base: last occurrence of *C. excavatus* (33.6–33.5 Ma)
Top: first occurrence of *Rocella vigilans* Fenner (29.9 Ma)
Remarks: The *C. reticulatus* Interval Zone of Fenner (1984a) extends above the last occurrence of *C. excavatus* to the first occurrence of *R. vigilans* Fenner. Although Barron (1985a) chose to include this interval in his *R. vigilans* Zone, it seems more appropriate to recognize the first occurrence of *R. vigilans* as the base of a *R. vigilans* Partial Range Zone, in the manner used by Fenner (1984a). Because *Cestodiscus trochus* Castracane (= *Cestodiscus muhinae* Jousé, 1973) is consistently present in this interval, it is appropriate to name this the *C. trochus* Interval Zone.

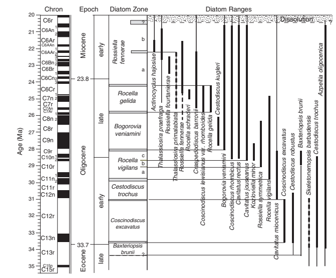
The first occurrence of *Cavitatus miocenicus* (Schrader) Akiba & Yanagisawa appears to coincide with the last occurrence of *C. excavatus* and the base of the *C. trochus* Interval Zone at ODP Site 1220, a relationship that is seemingly supported at DSDP Site 77 by Fenner's (1984b) occurrence chart. However, relatively poor preservation in these sections makes this relationship uncertain. *Skeletonemopsis barbadensis* (Greville) Sims and *Cestodiscus robustus* Jousé have their last occurrences in the lower part of the *C. trochus* Zone.

Rocella vigilans Partial Range Zone

Author: Fenner (1984a)
Base: first occurrence of *R. vigilans* Fenner (29.9 Ma)
Top: first occurrence of *Bogorovia veniamini* Jousé (28.2 Ma)
Remarks: As proposed by Fenner (1984a), the top of Subzone A (base of Subzone B) is recognized by the first occurrence of *Rossiella symmetrica* Fenner.

At Site 1220, *Cavitatus jouseanus* (Sheshukova-Poretzkaya) Williams, *Cavitatus rectus* Akiba & Hiramatsu, *Coscinodiscus rhombicus* Castracane, and *Kozloviella minor* Jousé all have their first

F2. Diatom zones and ranges correlated to paleomagnetic stratigraphy, p. 15.



occurrences in the upper part of Subzone B of Fenner (1984a). It is therefore appropriate to split Subzone B into an additional subzone. The base of a newly proposed Subzone C (top of a modified Subzone B) is hereby placed at the first occurrence of *C. jouseanus*. *C. trochus* (= *C. muhinae* of Jousé, 1974) has its last occurrence in Subzone C.

Bogorovia veniamini Partial Range Zone

Author: Fenner (1984a)
Base: first occurrence of *B. veniamini* Jousé (28.2 Ma)
Top: first occurrence of *Rocella gelida* (Mann) Bukry (~25.8 Ma)
Remarks: *Cestodiscus kugleri* Lohman is restricted to the *B. veniamini* Partial Range Zone at Site 1220. *K. minor* has its last occurrence in the lower part of the zone, and *R. symmetrica* has its last occurrence in the upper part of the zone.

Rocella gelida Range Zone

Author: sense used by Gombos (1983), essentially equivalent to the *R. gelida* Partial Range Zone of Barron (1983)
Base: first occurrence of *R. gelida* (Mann) Bukry (~25.8 Ma)
Top: last occurrence of *R. gelida* (Mann) Bukry (24.2 Ma)
Remarks: *Coscinodiscus lewisianus* var. *rhomboides* Barron, which has been mistakenly called *C. lewisianus* var. *similis* Rattray (see Barron, 1985a), has basically the same range as *R. gelida* and is a convenient secondary marker for the *R. gelida* Zone. *Rocella schraderi* Bukry is restricted to the middle part of the zone. *Craspedodiscus barronii* Bukry (= *Craspedodiscus coscinodiscus* of Jousé, 1973, and Gombos, 1983) has its first occurrence in the lowermost part of the *R. gelida* Partial Range Zone. *R. vigilans* last occurs in the upper part of the zone.

Rossiella fennerae Interval Zone

Author: This study, essentially equivalent to the *Rossiella paleacea* Zone of Barron (1983)
Base: last occurrence of *Rocella gelida* (Mann) Bukry (24.2 Ma)
Top: last occurrence of *Bogorovia veniamini* Jousé (~19.7 Ma) (Barron and Baldauf, 1995)
Remarks: Yanagisawa (1995a) proposed that the base of the *R. paleacea* Concurrent Zone of Barron (1983) should be redefined at the first abundant occurrence of *Rossiella fennerae* Yanagisawa, arguing that Barron's (1983) identification of *R. paleacea* (Grunow) Desikachary & Maheshwari actually included *R. fennerae* Yanagisawa. Previously, Barron (1983, 1985a) had remarked that the last occurrence of *R. gelida* coincided with the base of his *R. paleacea* Zone at DSDP Sites 71 and 574. Here we propose to redefine the base of Barron's (1983) *R. paleacea* Zone at the last occurrence of *R. gelida*. Taxonomic changes by Yanagisawa (1995a) to Barron's (1983) concept of *R. paleacea*, however, require that such a modified *R. paleacea* Zone of Barron (1983) should be renamed the *R. fennerae* Interval Zone.

The last occurrence of *Thalassiosira primalabiata* Gombos was used by Barron (1983) as the marker for the top of Subzone A and base of Subzone B of his *R. paleacea* Zone. Barron (1985a) argued that the first occurrence of *Actinocyclus hajosiae* was isochronous between DSDP Sites 574 and 575 and suggested that it would be a more consistent marker for the Subzone A/Subzone B boundary. At ODP Site 1220, the first occurrence of *A. hajosiae* Barron also coincides with the last sporadic occurrence of *T. primalabiata*; therefore, the first occurrence of *A. hajosiae* is proposed here to define the top of Subzone A and the base of Subzone B of the *R. fennerae* Interval Zone.

The first occurrences of *Rossiella fourtanierae* Yanagisawa, *Thalassiosira praefraga* Gladenkov & Barron, and *Thalassiosira spumellaroides* Schrader lie within Subzone A at Site 1220. However, Barron (1983) reports that *T. praefraga* (identified as *T. spinosa* Schrader) ranges into the lower part of the *R. gelida* Zone at DSDP Site 71.

The top of Subzone B and the base of Subzone C of the *Rossiella paleacea* Zone of Barron (1983) (= the *R. fennerae* Interval Zone of this study) is defined by the last occurrence of *Azpeitia oligocenica* (Jousé) Sims. At Site 1220, however, the last occurrence of *A. oligocenica* falls within an interval of dissolution (Fig. **F2**).

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APPENDIX

Diatom Taxonomy

The taxonomy of Oligocene and earliest Miocene diatoms can be confusing, as new taxonomic studies such as those of Yanagisawa (1995a, 1995b) and Strelnikova et al. (2001) must be considered along with an increasing number of papers by various authors on sediments collected by ODP. Consequently, an important part of this study will be to refer to updated diatom taxonomy, reference good illustrations of species concepts, and suggest synonyms of various taxa. The following section lists important Oligocene and earliest Miocene diatoms and references to illustrations and their taxonomy. Selected diatom taxa are illustrated on Plates **P1, P2,** and **P3.**

Actinocyclus hajosiae Barron, 1983, p. 504, pl. I, figs. 3, 4; pl. V, fig. 13; pl. VI, fig. 3.

Actinocyclus sp. aff. *A. octonarius* Ehrenberg; Hajós, 1976, p. 827, pl. 10, fig. 7.
Synonym: *A. ehrenbergii* Ralfs in Pritchard; Schrader and Fenner, 1976, p. 963, pl. 14, fig. 17.

Actinocyclus sp. aff. *A. radionovae* Barron, 1983, p. 504, pl. 3, figs. 1–3; pl. 4, figs. 4–6.

Asteromphalus oligocenicus Schrader & Fenner, 1976, p. 965, pl. 21, figs. 8, 13, 14; pl. 28, fig. 1.

Azpeitia oligocenica (Jousé) Sims in Sims et al., 1989, p. 302, pl. 2, figs. 1–3; pl. 3, figs. 8, 9.
Synonym: *Coscinodiscus oligocenicus* Jousé; Barron, 1983, p. 512, pl. 3, figs. 8, 11. (Pl. **P3,** fig. 5)

Azpeitia praenodulifera (Barron) Sims & Fryxell in Sims et al., 1989, p. 298, pl. 1, figs. 8–13; pl. 3, fig. 11.
Synonym: *Coscinodiscus praenodulifer* Barron, 1983, p. 511, pl. III, figs. 9, 10; pl. I, fig. 8.

Baxteriopsis brunii (van Heurck) Karsten; Fenner, 1985, p. 727, pl. 10, figs. 7, 8.

Bogorovia barronii Yanagisawa 1995b, p. 31, pl. 4, figs. 11–14; pl. 5, figs. 3–5.

Bogorovia veniamini Jousé, 1973, emend. Yanagisawa, 1995b, p. 25, pl. 4, figs. 4–10; pl. 8, figs. 1–9. (Pl. **P1,** fig. 6)

Bogorovia sp. cf. *B. puncticulata* Yanagisawa, 1995b, p. 32, pl. 4, figs. 15–20, 33, 34; pl. 12, figs. 1–5; pl. 13, figs. 1–11.

Cavitatus jouseanus (Sheshukova-Poretzkaya) Williams; Akiba et al., 1993, p. 20, figs. 6, 19, 20; Gladenkov and Barron, 1995, p. 31, pl. 5, figs. 3, 15, 18, 19, 22, 23.
Remarks: See remarks for *Cavitatus miocenicus.*

Cavitatus miocenicus (Schrader) Akiba & Yanagisawa; Gladenkov and Barron (1995), pl. 5, figs. 1, 2, 27.
Synonym: *Synedra miocenica* Schrader, 1976, p. 636, pl. 1, fig. 1; Schrader and Fenner, 1976, p. 999, pl. 5, fig. 2; pl. 45, figs. 19–21; *Cavitatus jouseanus* (Sheshukova-Poretzkaya) Williams sensu Harwood and Bohaty, 2001, p. 324, pl. 1, fig. 1, 2?; *Synedra* sp. of Jousé, 1973, pl. 4, fig. 23.
Remarks: Harwood and Bohaty (2001) state, "Specimens of *Cavitatus jouseanus* present in CRP-3 differ from *C. jouseanus* s.s. in that they are smaller and more lightly silicified with narrow, tapered ends, rather than broadly rounded ends. This morphology appears to be characteristic of 'early forms' of *C. jouseanus*." Schrader (1976) shows *S. miocenica* ranges below *Synedra jouseana* at Southern Ocean Site 278. Gladenkov and Barron (1995) show a similar relation-

ship between *C. miocenicus* and *C. jouseanus* at ODP Site 884 in the North Pacific.

Cavitatus rectus Akiba & Hiramatsu in Akiba et al., 1993, p. 28, pl. 6, figs. 7–15; Gladenkov and Barron, 1995, p. 31, pl. 5, figs. 7–10.

Synonym: *Thalassionema hirosakiensis* (Kanaya) Schrader sensu Schrader, 1976, p. 636, pl. 1, figs. 14–16.

Cestodiscus convexus Castracane, 1886, p. 128, pl. 7, fig. 6; Strelnikova et al., 2001, pl. VII, fig. 43; pl. X, figs. 49, 50; pl. XI, figs. 56–59. (Pl. **P1,** figs. 4, 5)

Cestodiscus robustus Jousé, 1973, p. 345, pl. 1, figs. 14, 15; Barron, 1985b, pl. 1, fig. 1.

Synonyms: *Coscinodiscus superbus* Hardman sensu Fenner, 1978, p. 516, pl. 13, figs. 1–5, pl. 14, figs. 1–4; sensu Gombos and Ciesielski, 1983, p. 601, pl. 4, figs. 1–8.

Cestodiscus gemmifer Castracane sensu Fenner and Mikkelsen, 1990, p. 441, pl. 1, fig. 3.

Cestodiscus trochus Castracane sensu Strelnikova et al., 2001, p. 79, figs. 51–54, 60–63; *Cestodiscus parmula* Castracane sensu Radionova, 1987, p. 149, pl. 2, figs. 6–8. (Pl. **P3,** figs. 3, 4)

Remarks: The marginal spines are often not preserved.

Cestodiscus kugleri Lohman, 1974, p. 340, pl. 4, figs. 4, 5, 8; Fourtanier, 1991, pl. 1, fig. 6; Gladenkov and Barron, 1995, p. 31, pl. 3, Figs. 2–6, 7?.

Synonym: *Cestodiscus* aff. *trochus* Castracane sensu Fenner, 1984b, p. 1270, pl. 1, fig. 4; *Cestodiscus* sp. 6 of Schrader, 1976, pl. 12, fig. 4. (Pl. **P1,** figs. 7, 8)

Cestodiscus ovalis Greville?; Lohman, 1974, p. 341, pl. 3, fig. 5. (Pl. **P2,** fig. 8)

Cestodiscus reticulatus Fenner 1984a, p. 331, pl. 1, fig. 10.

Remarks: These forms closely resemble *C. robustus* except for the reticulate pattern in the valve's center, and it is not clear that they should be separated. (Pl. **P3,** fig. 6)

Cestodiscus trochus Castracane, 1886, p. 123, pl. 7, figs. 1, 3.

Synonym: *Cestodiscus muhinae* Jousé, 1973, p. 344–345, pl. 1, figs. 1, 2, 3–5? Both Fenner (1985) and Harwood and Maruyama (1992) suggested this synonymy.

Remarks: Taxa figured as *Cestodiscus muhinae* by Jousé (1973) possess considerable variability, including the form illustrated in figure 7 of Plate **P3** of this report; however, it is not clear whether all of these forms should be included in *C. trochus* Castracane. The flat valve forms tabulated as *Cestodiscus antarcticus* Fenner by Strelnikova et al. (2001), p. 79, figs. 64–67 (not 55) are included here as *C. trochus* Castracane. *C. antarcticus* Fenner s.s. is a distinctive form that was not identified in the Oligocene at Site 1220. (Pl. **P2,** fig. 2; Pl. **P3,** fig. 7?)

Cestodiscus trochus (form with marginal labiate processes)

Synonym: *Cestodiscus pulchellus* Greville sensu Schrader, 1976, pl. 13, fig. 5. (Pl. **P3,** figs. 1, 2)

Cestodiscus sp. cf. *C. demergitus* (Fenner) Fenner & Mikkelsen, 1990.

Basionym: *Coscinodiscus demergitus* Fenner, 1978, p. 514, pl. 4, figs. 1–3.

Cestodiscus sp. aff. *C. pulchellus* Greville, 1866, p. 123, pl. 11, fig. 5.

Cestodiscus sp. 2 sensu Fenner, 1981, p. 89, pl. 14, figs. 3, 4; Strelnikova et al., 2001, pl. VI, fig. 34; pl. VIII, figs. 39–42; pl. IX, figs. 44–48.

Synonym: *Cestodiscus pulchellus* var. *novazealandica* Grove sensu Harwood and Maruyama, 1992, p. 701, pl. 1, fig. 4. (Pl. **P1,** figs. 1, 2; Pl. **P2,** fig. 3)

Remarks: Strelnikova et al. (2001) state that *C. pulchellus* var. *novazealandica* (Grove ex Rattray) Fenner possesses a "large concave center whose diameter is approximately half of the valve diameter," and that a hyaline field is present in the valve center with two to three or more isolated areolae. The specimen illustrated as *C.* sp. 2 (var.) meets these criteria and might be included in *C. pulchellus* var. *novazealandica*.

Coscinodiscus excavatus Greville ex Ralfs in Pritchard; Fenner, 1985, p. 728, pl. 7, figs. 26, 28; Barron, 1985a, pl. 1, fig. 8; Strelnikova et al., 2001, pl. XVII, figs. 92–97.

Coscinodiscus excavatus var. *semilunaris* Grunow; Fenner, 1978, p. 514, pl. 10, figs. 13, 14. (Pl. **P2,** fig. 1)

Coscinodiscus hajosiae Fenner 1984a, p. 331, pl. 2, fig. 1.
Synonym: *Coscinodiscus spiralis* sensu Hajós, 1976, p. 826, pl. 7, figs. 1–3.

Coscinodiscus lewisianus Greville; Barron, 1985b, p. 781, pl. 9, fig. 10.

Coscinodiscus lewisanus f. *concavus* Gombos, 1983, p. 796, pl. 3, fig. 8.

Coscinodiscus lewisanus var. *levis* (Jousé) Harwood & Maruyama, 1992, p. 702, pl. 3, figs. 12–15; Gladenkov and Barron, 1995, pl. 1, fig. 14.
Synonym: *Actinocyclus levis* Jousé, 1973, p. 353, pl. 5, fig. 2.

Coscinodiscus lewisianus var. *rhomboides* Barron, 1985b, p. 443, pl. 7, figs. 2, 3.
Synonym: *Coscinodiscus lewisianus* var. *similis* Rattray sensu Jousé 1973, pl. 3, figs. 6, 7; sensu Barron, 1983, p. 512, pl. 1, fig. 8; sensu Gombos, 1983, pl. 3, figs. 3–6.
Remarks: Barron (1985a) noted that *C. lewisianus* var. *similis* Rattray is restricted to the later part of the early Miocene and is distinguished from the late Oligocene diatom *C. lewisianus* var. *rhomboides* by it being less rhombic in shape and its possession of a broader, finely areolated margin.

Coscinodiscus marginatus Ehrenberg; Fenner, 1978, p. 515, pl. 8, figs. 3, 7.

Coscinodiscus radiatus Ehrenberg; Fenner, 1978, p. 516, pl. 7, fig. 6.

Coscinodiscus rhombicus Castracane; Schrader and Fenner, 1976, p. 972, pl. 21, figs. 1–3, 5; Gombos, 1983, pl. 3, fig. 1; Fenner, 1985, p. 729, pl. 7, figs. 1–4.

Coscinodiscus? sp. aff. *C. capensis* Grunow; Schrader and Fenner, 1976, p. 969, pl. 36, figs. 4, 8.
Remarks: The forms tabulated may belong to *Thalassiosira.*

Craspedodiscus barronii Bukry, 1984, p. 464, pl. 2, figs. 13–15; pl. 3, figs. 1–5; Fourtanier, 1991, pl. 3, fig. 7.
Remarks: Oligocene and early Miocene forms have been recorded as *C. coscinodiscus;* see Gombos, 1983, pl. 4, figs. 1–3.

Craspedodiscus elegans Ehrenberg; Schmidt et al., 1874–1959, pl. 66, fig. 1; Fenner, 1978, p. 518, pl. 9, fig. 3; pl. 37, fig. 6; Barron, 1983, p. 512, pl. 2, fig. 2; Barron, 1985a, pl. 2, fig. 2.

Distephanosira architecturalis (Brun) Gleser in Gleser et al., 1992, p. 68, table 56, figs. 1–9.
Synonym: *Melosira architecturalis* Brun; Fenner, 1978, p. 524, pl. 16, figs. 7–12; Hajós, 1976, p. 824, pl. 1, figs. 5, 6.

Kozloviella minor Jousé, 1973, p. 352, pl. 4, fig. 18; Gladenkov and Barron, 1995, pl. 1, figs. 13, 20.

Kozloviella sp. cf. *K. pacifica* Jousé, 1973, p. 352, pl. 4, fig. 17. (Pl. **P1,** fig. 9)

Lisitzinia ornata Jousé; Fenner, 1985, p. 734, pl. 10, fig. 11; Gladenkov and Barron, 1995, pl. 1, figs. 15–18.

Raphidodiscus marylandicus Christian; Schrader and Fenner, 1976, pl. 7, fig. 16; Barron, 1983, p. 512, pl. 5, fig. 4.

Rocella gelida (Mann) Bukry; Gombos, 1983, pl. 1, figs. 1–6; Barron, 1985b, pl. 12, fig. 16; Gladenkov and Barron, 1995, pl. 1, figs. 3, 7.

Rocella princeps (Jousé) Fenner, 1984a, p. 335; Gombos, 1983, pl. 2, figs. 13–16.

Rocella semigelida Gombos, 1983, p. 796, pl. 2, figs. 1–12.

Remarks: Some early forms tabulated as *Rocella vigilans* Jousé may be transitional with *R. semigelida* (see Pl. **P2,** fig. 10).

Rocella schraderi Bukry; Gombos, 1983, pl. 1, figs. 13–16.
Synonym: *R. gelida* var. *schraderi* (Bukry) Barron; Barron, 1985b, pl. 12, fig. 15.

Rocella vigilans Fenner, 1984a, p. 333, pl. 1, fig. 11; Gombos, 1983, pl. 1, figs. 7–12; Fenner, 1985, pl. 7, figs. 14, 15. (Pl. **P2,** figs. 4, 6, 10)
Remarks: Although Harwood and Maruyama (1992) recognize small and large forms (varieties a and b) that are separated stratigraphically, specimens from Site 1220 display a range in size and morphology and no attempt was made to separate them.

Rocella vigilans var. 1
Remarks: Center of valve is raised in a domelike manner.

Rouxia spp.
Remarks: Undifferentiated fragments are tabulated here.

Rossiella fennerae Yanagisawa, 1995a, p. 8, pl. 4, figs. 7–10; pl. 7, figs. 1–8.
Synonyms: *Rossiella symmetrica* Fenner, 1984a, pl. 1, figs. 3, 4 (non fig. 2); *Rossiella paleacea* (Grunow) Desikachary & Maheswari sensu Barron, 1983, pl. 5, fig. 4. (Pl. **P1,** fig. 3)

Rossiella fourtanierae Yanagisawa, 1995a, p. 9, pl. 4, figs. 11–14; pl. 9, figs. 1–6.
Synonym: *Rossiella paleacea* (Grunow) Desikachary & Maheswari, robust form of Barron, 1983, p. 512, pl. 5, fig. 6.

Rossiella paleacea (Grunow) Desikachary & Maheshwari; Barron, 1985a, pl. 8, fig. 2; Barron, 1985b, p. 790, pl. 9, figs. 6, 7; Fourtanier, 1991, pl. 4, fig. 4; Yanagisawa, 1995a, p. 11, pl. 4, figs. 15–20; pl. 12, figs. 1–6.

Rossiella symmetrica Fenner, 1984a, p. 333, pl. 2, fig. 2 (non pl. 1, figs. 3, 4); Fenner, 1985, p. 737, pl. 7, figs. 5–7; Yanagisawa, 1995a, p. 5, pl. 4, figs. 1–6.

Skeletonemopsis barbadensis (Greville) Sims, 1994.
Synonym: *Skeletonema barbadense* Greville; Fenner, 1985, pl. 9, figs. 1, 2; Fenner and Mikkelsen, 1990, p. 447, pl. 1, fig. 5.

Stephanopyxis sp. aff. *S. turris* (Greville and Arnott) Ralfs; Fenner, 1978, p. 532, pl. 12, fig. 7; Schrader and Fenner, 1976, p. 1000, pl. 30, figs. 1–10; pl. 37, figs. 17–19.

Thalassionema sp. cf. *T. nitzschioides* (Grunow) Van Heurck; Schrader and Fenner, 1976, p. 1001, pl. 5, fig. 8.

Thalassiosira? *bukryi* Barron, 1983, p. 511, pl. 4, figs. 1–2; pl. 6, fig. 9; Fenner and Mikkelsen, 1990, p. 448, pl. 1, fig. 4. (Pl. **P2,** fig. 9)

Thalassiosira praefraga Gladenkov and Barron, 1995, p. 30, pl. 2, figs. 3–6, 9.
Synonym: *Thalassiosira spinosa* Schrader sensu Barron, 1983, p. 512, pl. IV, fig. 8; sensu Barron, 1985b, p. 793, pl. 11, fig. 15; sensu Fourtanier, 1991, pl. 2, figs. 9, 10.

Thalassiosira primalabiata Gombos in Gombos and Ciesielski, 1983, pl. 9, figs. 1–8; Barron, 1983, p. 512, pl. III, figs. 7, 12.

Thalassiosira spumellaroides Schrader, 1976, p. 636, pl. 6, figs. 1, 2; Barron, 1983, p. 513, pl. IV, fig. 7; Barron, 1985a, pl. 5, fig. 4; Fourtanier, 1991, pl. 2, fig. 12.

Thalassiothrix sp. cf. *T. primitiva* Schrader, 1976, p. 637, pl. 1, fig. 3. (Pl. **P2,** fig. 7)

Figure F1. Location of Site 1220 and other Leg 199 drill sites in the equatorial Pacific (solid circles). Open circles = locations of DSDP sites. Gray shading = seafloor depths >5000 mbsl.

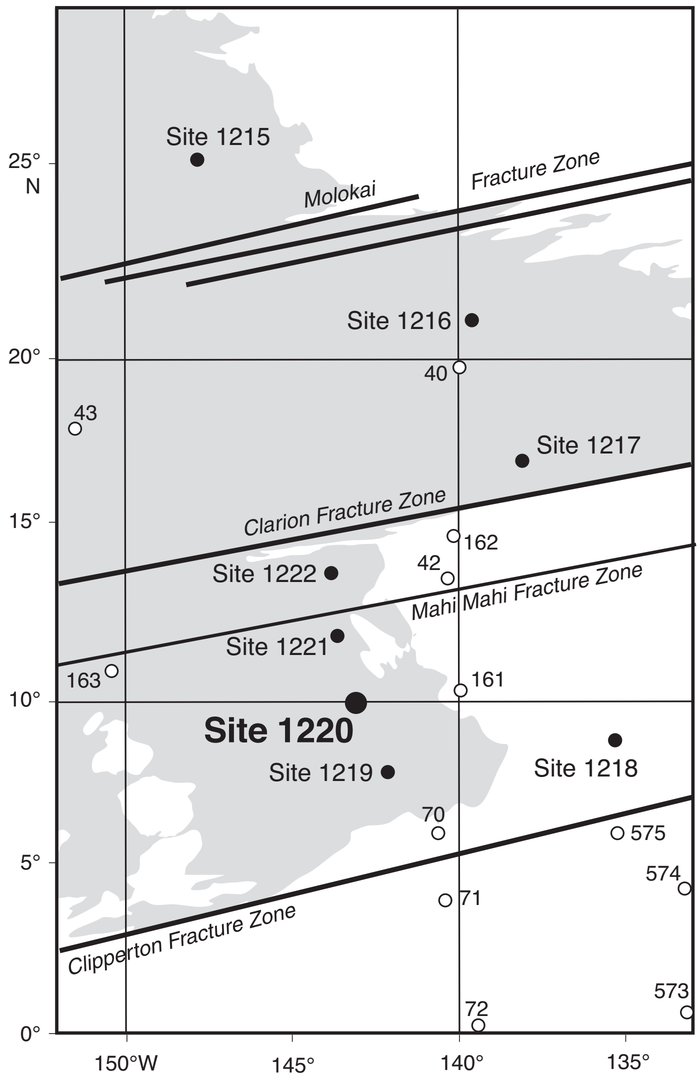

Figure F2. Diatom zones and ranges of selected diatoms in the Oligocene and earliest Miocene of the equatorial Pacific correlated to paleomagnetic stratigraphy. Thick range lines = ranges at ODP Site 1220, thick, dashed lines = sporadic occurrences, thin lines = extended ranges of these diatom taxa at other sites after Fenner (1984a), Barron (1983, 1985b), and Yanagisawa (1995a, 1995b). Paleomagnetic chrons and ages after Cande and Kent (1995); geologic timescale after Berggren et al. (1995).

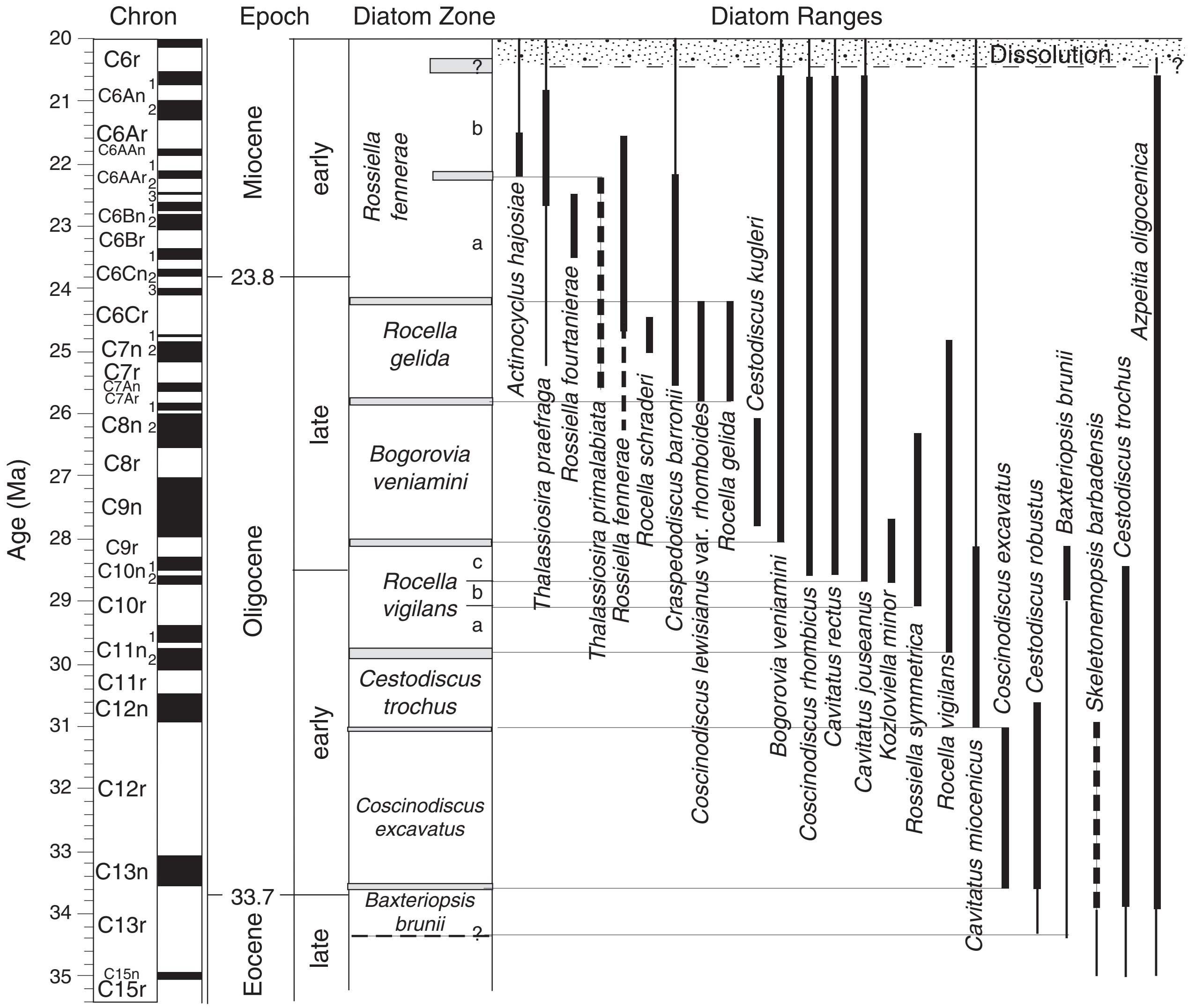

Table T1. Occurrence chart of common and stratigraphically important diatoms in the Oligocene and lowermost Miocene, Site 1220. (See table notes. Continued on next five pages.)

Zone	Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Age (Ma)	Abundance	Preservation	*Actinocyclus hajosiae*	*Actinocyclus* sp. aff. *A. octonarius*	*Actinocyclus* sp. aff. *A. radionovae*	*Asteromphalus oligocenica*	*Azpeitia oligocenica*	*Azpeitia praenodulifera*	*Baxteriopsis brunii*	*Bogorovia barronii*	*Bogorovia veniamini*	*Bogorovia* cf. *puncticulata*	*Cavitatus jouseanus*	*Cavitatus miocenicus*	*Cavitatus rectus*	*Cestodiscus convexus*	*Cestodiscus kugleri*	*Cestodiscus ovalis*	*Cestodiscus reticulatus*	*Cestodiscus robustus*	*Cestodiscus trochus*	*C. trochus* (marginal spines)	*Cestodiscus* sp. cf. *C. demergitus*	*Cestodiscus* sp. aff. *C. pulchellus*	*Cestodiscus* sp. 2 of Fenner, 1981	*Coscinodiscus excavatus*	*Coscinodiscus excavatus* var. *semilunaris*	*Coscinodiscus hajosiae*	*Coscinodiscus lewisianus*	*Coscinodiscus lewisianus* f. *concavus*	*Coscinodiscus lewisianus* var. *levis*	*Coscinodiscus lewisianus* var. *rhomboides*	*Coscinodiscus marginatus*	*Coscinodiscus radiatus*	*Coscinodiscus rhombicus*	*Coscinodiscus*? sp. cf. *C. capensis*	*Craspedodiscus barronii*
Rossiella fennerae	199-1220A-																																								
	3H-1, 27–28	19.27	19.27	20.19	B	B																																			
	3H-1, 102–103	20.02	20.02	20.47	R	P																																			
	3H-2, 27–28	20.72	20.72	20.72	F	P					R	R			R		R	R	R						r	r		R					R				R		R		
	3H-2, 102–103	21.47	21.47	21.12	F	M					R	R			R	R	F		F						r			R					R				F		R		R
	3H-3, 27–28	22.22	22.22	21.44	F	M			R		R			R	R		F	R	R									F					R						R		
	3H-3, 102–103	22.97	22.97	21.81	F	M	R				R			R	R		F		R						r			R					R						R		
	3H-4, 27–28	23.72	23.72	22.06	F	M	R		VR		R			R	R		F		R									cf					R				R		R		
	3H-4, 99–100	24.44	24.44	22.31	R	M					R			R	R		R		R									R									R		R		R
	3H-5, 27–28	24.72	24.72	22.40	F	M				R	R			R	R		F		R									R									R		R		
	3H-5, 102–103	25.47	25.47	22.67	F	M				cf	R				R		F		R																		R		R		
	3H-6, 27–28	26.22	26.22	22.94	F	M				R	R				R		F		R									R									R	F	R		R
	3H-6, 102–103	26.97	26.97	23.15	F	M				R	R				R		F		R			R						R									F	R	F		R
	3H-7, 32–33	27.77	27.77	23.40	F	M					R						F		R			R						R									R	F	F		R
	3H-7, 107–108	28.52	28.52	23.64	C	M				R	F				R		C		R			R						R									R		F		R
	199-1220C-																																								
	1H-5, 2–3	31.02	29.77	24.13	R	P					R				R		R		R					r				R									R		R		R
Rocella gelida	1H-5, 77–78	31.77	30.52	24.32	F	M		R			R				R		F		R			R						F					R			R	R		R		
	199-1220A-																																								
	4H-1, 10–11	28.60	30.85	24.62	F	M		R			F				R		F		R									F								R	R		R		R
	4H-1, 110–111	29.60	31.85	24.74	R	P									R		R		R																	R					R
	4H-2, 10–11	30.10	32.35	24.80	R	M					R				R		R		R					r												R					
	4H-2, 40–41	30.40	32.65	24.84	R	M					R				R		R																			R					R
	4H-2, 80–81	30.80	33.05	24.96	R	P											F		R									R											R		R
	4H-2, 110–11	31.10	33.35	25.05	R	M					R				R		R		R																	R			R		R
	4H-3, 10–11	31.60	33.85	25.20	F	P					R				R		R		F					r															R		
	4H-3, 110–111	32.60	34.85	25.53	F	M					R				R		R		F					r				R								R			R		R
	4H-4, 10–11	33.10	35.35	25.70	C	M					R				R		F		R					r				R								R					
Bogorovia veniamini	4H-4, 110–111	34.10	36.35	26.01	C	M					R				R		R		R			R		r													R		R		
	4H-5, 10–11	34.60	36.85	26.10	A	M					R				R		R		F		R	R		r			R	R						R					R		
	4H-5, 110–111	35.60	37.85	26.29	C	M				R					R		R		R		R			r				R									R		R		
	4H-6, 10–11	36.10	38.35	26.39	F	M					R				R		F		F		F						R	R									R		R		
	4H-6, 110–111	37.10	39.35	26.58	F	M					R				R		F		F		R						R	F											R		
	4H-7, 10–11	37.60	39.85	26.71	C	M				R	F				R		C		R		R			r				F					R				F		F		

Table T1 (continued).

Zone	Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Age (Ma)	Abundance	Preservation	*Craspedodiscus elegans*	*Distephanosira architecturalis*	*Kozloviella minor*	*Kozloviella* cf. *pacifica*	*Lisitzinia ornata*	*Raphidodiscus marylandicus*	*Rocella gelida*	*Rocella princeps*	*Rocella semigelida*	*Rocella schraderi*	*Rocella vigilans*	*Rocella vigilans* var. 1	*Rouxia* spp.	*Rossiella fennerae*	*Rossiella fourtanierae*	*Rossiella paleacea*	*Rossiella symmetrica*	*Skeletonemopsis barbadensis*	*Stephanopyxis* aff. *turris*	*Thalassionema* cf. *T. nitzschioides*	*Thalassiosira? bukryi*	*Thalassiosira praefraga*	*Thalassiosira primalabiata*	*Thalassiosira spumellaroides*	*Thalassiothrix* sp. cf. *T. primitiva*
Rossiella fennerae	199-1220A-																														
	3H-1, 27–28	19.27	19.27	20.19	B	B																									
	3H-1, 102–103	20.02	20.02	20.47	R	P		R																							
	3H-2, 27–28	20.72	20.72	20.72	F	P																									R
	3H-2, 102–103	21.47	21.47	21.12	F	M						R										R					R	R			R
	3H-3, 27–28	22.22	22.22	21.44	F	M																R				R		R		R	R
	3H-3, 102-103	22.97	22.97	21.81	F	M		R												R						R		R			R
	3H-4, 27–28	23.72	23.72	22.06	F	M		R												R						R					R
	3H-4, 99–100	24.44	24.44	22.31	R	M																					R		R		R
	3H-5, 27–28	24.72	24.72	22.40	F	M		R												R						R		R		R	R
	3H-5, 102–103	25.47	25.47	22.67	F	M		R												R	cf					R		R			F
	3H-6, 27–28	26.22	26.22	22.94	F	M		R												R	R										R
	3H-6, 102–103	26.97	26.97	23.15	F	M														F	R						R				F
	3H-7, 32–33	27.77	27.77	23.40	F	M														R	R										F
	3H-7, 107–108	28.52	28.52	23.64	C	M														F						R	R		R		R
	199-1220C-																														
	1H-5, 2–3	31.02	29.77	24.13	R	P														R											R
Rocella gelida	1H-5, 77–78	31.77	30.52	24.32	F	M							R							R							R		R		F
	199-1220A-																														
	4H-1, 10–11	28.60	30.85	24.62	F	M		R				R	R			R				R					R				R		F
	4H-1, 110–111	29.60	31.85	24.74	R	P							R			R									R						R
	4H-2, 10–11	30.10	32.35	24.80	R	M		R					R			R	R														R
	4H-2, 40–41	30.40	32.65	24.84	R	M								R		R	R														R
	4H-2, 80–81	30.80	33.05	24.96	R	P										R	R								R	R					R
	4H-2, 110–11	31.10	33.35	25.05	R	M		R						R			R			R					R				R		
	4H-3, 10–11	31.60	33.85	25.20	F	P		R					R				F								R						R
	4H-3, 110–111	32.60	34.85	25.53	F	M							F	R			R									R			R		R
	4H-4, 10–11	33.10	35.35	25.70	C	M					R		R	R			F									R					R
Bogorovia veniamini	4H-4, 110–111	34.10	36.35	26.01	C	M		R						R			C									R					R
	4H-5, 10–11	34.60	36.85	26.10	A	M					R						F														
	4H-5, 110–111	35.60	37.85	26.29	C	M											C			R						R	R				R
	4H-6, 10–11	36.10	38.35	26.39	F	M		R									C		R				R								
	4H-6, 110–111	37.10	39.35	26.58	F	M											R						R				R				R
	4H-7, 10–11	37.60	39.85	26.71	C	M											R						R			R					R

Table T1 (continued).

Zone	Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Age (Ma)	Abundance	Preservation	*Actinocyclus hajosiae*	*Actinocyclus* sp. aff. *A. octonarius*	*Actinocyclus* sp. aff. *A. radionovae*	*Asteromphalus oligocenica*	*Azpeitia oligocenica*	*Azpeitia praenodulifera*	*Baxteriopsis brunii*	*Bogorovia barronii*	*Bogorovia veniamini*	*Bogorovia* cf. *puncticulata*	*Cavitatus jouseanus*	*Cavitatus miocenicus*	*Cavitatus rectus*	*Cestodiscus convexus*	*Cestodiscus kugleri*	*Cestodiscus ovalis*	*Cestodiscus reticulatus*	*Cestodiscus robustus*	*Cestodiscus trochus*	*C. trochus (marginal spines)*	*Cestodiscus* sp. cf. *C. demergitus*	*Cestodiscus* sp. aff. *C. pulchellus*	*Cestodiscus* sp. 2 of Fenner, 1981	*Coscinodiscus excavatus*	*Coscinodiscus excavatus* var. *semilunaris*	*Coscinodiscus hajosiae*	*Coscinodiscus lewisianus*	*Coscinodiscus lewisianus* f. *concavus*	*Coscinodiscus lewisianus* var. *levis*	*Coscinodiscus lewisianus* var. *rhomboides*	*Coscinodiscus marginatus*	*Coscinodiscus radiatus*	*Coscinodiscus rhombicus*	*Coscinodiscus?* sp. cf. *C. capensis*	*Craspedodiscus barronii*
	199-1220A-																																								
Bogorovia veniamini	5H-1, 10–11	38.10	41.39	27.12	A	M				R	F				R		F		R		R							R					R				C		F		
	5H-1, 110–111	39.10	42.39	27.44	A	M		R			F				R		R		R		R	R													R		C		F		
	5H-2, 10–11	39.60	42.89	27.60	C	M					R				R		F		R		R	R					R	R							R		F		F		
	5H-2, 110–111	40.60	43.89	27.92	C	M				R	R						F	R	R			R			R		R	R							R		F		F		
	5H-3, 10–11	41.10	44.39	28.12	C	M				R	R				R		F		R			R					R	R							R		R		R		
Rocella vigilans	5H-3, 110–111	42.10	45.39	28.35	A	M				R	R		R				F		R			R					R	R									F		R	R	
	5H-4, 10–11	42.60	45.89	28.40	C	M					R		R				F		R								R	R									F		R	R	
	5H-4, 110–111	43.60	46.89	28.51	F	M				R	R						F		R			R			R												F		R		
	5H-5, 10–11	44.10	47.39	28.65	F	M				R	R		R				R								F		R	R									F				aff
	5H-5, 110–111	45.10	48.39	28.82	F	M				R	R		F												F												F				
	5H-6, 10–11	45.60	48.89	28.88	F	M				R			R												F												R				
	5H-6, 110–111	46.60	49.89	28.99	C	M				R	R		R												C			R									R				
	5H-7, 10–11	47.10	50.39	29.05	C	M		R			F														C			R									R			R	
	199-1220B-																																								
	2H-4, 60–61	48.60	50.99	29.11	F	P					R														R												R				
	2H-4, 135–136	49.35	51.74	29.20	F	P																			R			R									F				
	2H-5, 35–36	49.85	52.24	29.25	F	M					R							R							R												R				
	199-1220A-																																								
	6H-1, 10–11	47.60	52.94	29.33	F	M		R			R							R							F												F				
	6H-1, 110–111	48.60	53.94	29.44	F	M					R							R							F	R											F				
	6H-2, 10–11	49.10	54.44	29.50	F	P																			R	R											F				
	6H-2, 110–111	50.10	55.44	29.63	A	M				R	R							C							F	F											C	F			
	6H-3, 10–11	50.60	55.94	29.74	C	M				R	F							F						R	F	F											C				
Cestodiscus trochus	6H-3, 110–111	51.60	56.94	29.98	C	M					F							R							F	R	R										C	R			
	6H-4, 10–11	52.10	57.44	30.09	C	M				R	R							F							R		R										F	R			
	6H-4, 110–111	53.10	58.44	30.26	F	M					R							R							R	R											F				
	6H-5, 10–11	53.60	58.94	30.35	F	M		R		R	F							F							R												F				
	6H-5, 110–111	54.60	59.94	30.56	F	P		R			R							R							R												F				
	6H-6, 10–11	55.10	60.44	30.73	F	P					R							R						R	R												F				
	6H-6, 110–111	56.10	61.44	30.99	C	M					R							R		R				R	C	R											F				

Table T1 (continued).

Zone	Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Age (Ma)	Abundance	Preservation	*Craspedodiscus elegans*	*Distephanosira architecturalis*	*Kozloviella minor*	*Kozloviella* cf. *pacifica*	*Lisitzinia ornata*	*Raphidodiscus marylandicus*	*Rocella gelida*	*Rocella princeps*	*Rocella semigelida*	*Rocella schraderi*	*Rocella vigilans*	*Rocella vigilans* var. 1	*Rouxia* spp.	*Rossiella fennerae*	*Rossiella fourtanierae*	*Rossiella paleacea*	*Rossiella symmetrica*	*Skeletonemopsis barbadensis*	*Stephanopyxis* aff. *turris*	*Thalassionema* cf. *T. nitzschioides*	*Thalassiosira? bukryi*	*Thalassiosira praefraga*	*Thalassiosira primalabiata*	*Thalassiosira spumellaroides*	*Thalassiothrix* sp. cf. *T. primitiva*
	199-1220A-																														
Bogorovia veniamini	5H-1, 10–11	38.10	41.39	27.12	A	M											F		R				R								R
	5H-1, 110–111	39.10	42.39	27.44	A	M											F		R				R				R				R
	5H-2, 10–11	39.60	42.89	27.60	C	M		R									F						R				R				R
	5H-2, 110–111	40.60	43.89	27.92	C	M			R								F		R				R		R		R				R
	5H-3, 10–11	41.10	44.39	28.12	C	M		R	F								F		R				F		R						R
Rocella vigilans	5H-3, 110–111	42.10	45.39	28.35	A	M		R	F	R							R	R					F		F		R				
	5H-4, 10–11	42.60	45.89	28.40	C	M			R	R							R	R					F		R		R				
	5H-4, 110–111	43.60	46.89	28.51	F	M		R	R								R	R					R		R		R				
	5H-5, 10–11	44.10	47.39	28.65	F	M		R	R								R	R					F		R	F	R				
	5H-5, 110–111	45.10	48.39	28.82	F	M		R									VR	R					aff		R	F	R				R
	5H-6, 10–11	45.60	48.89	28.88	F	M											R						aff		R	R					R
	5H-6, 110–111	46.60	49.89	28.99	C	M											R						aff		R		R				
	5H-7, 10–11	47.10	50.39	29.05	C	M	R	R							R		F						aff			R	R				R
	199-1220B-																														
	2H-4, 60–61	48.60	50.99	29.11	F	P																			R						R
	2H-4, 135–136	49.35	51.74	29.20	F	P											R									R					R
	2H-5, 35–36	49.85	52.24	29.25	F	M		R									R									R	R				F
	199-1220A-																														
	6H-1, 10–11	47.60	52.94	29.33	F	M	R	R									R										R				
	6H-1, 110–111	48.60	53.94	29.44	F	M	R	R									R														
	6H-2, 10–11	49.10	54.44	29.50	F	P		R									R														
	6H-2, 110–111	50.10	55.44	29.63	A	M		R									F														
	6H-3, 10–11	50.60	55.94	29.74	C	M		R									F										R				
Cestodiscus trochus	6H-3, 110–111	51.60	56.94	29.98	C	M		R											R						R	R	R				R
	6H-4, 10–11	52.10	57.44	30.09	C	M		R																	R	F	R				
	6H-4, 110–111	53.10	58.44	30.26	F	M																			R	R	F				
	6H-5, 10–11	53.60	58.94	30.35	F	M		R																			R				R
	6H-5, 110–111	54.60	59.94	30.56	F	P		R																			R				R
	6H-6, 10–11	55.10	60.44	30.73	F	P		R																							R
	6H-6, 110–111	56.10	61.44	30.99	C	M		R																R		R					R

Table T1 (continued).

Zone	Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Age (Ma)	Abundance	Preservation	*Actinocyclus hajosiae*	*Actinocyclus* sp. aff. *A. octonarius*	*Actinocyclus* sp. aff. *A. radionovae*	*Asteromphalus oligocenica*	*Azpeitia oligocenica*	*Azpeitia praenodulifera*	*Baxteriopsis brunii*	*Bogorovia barronii*	*Bogorovia veniaminii*	*Bogorovia* cf. *puncticulata*	*Cavitatus jouseanus*	*Cavitatus miocenicus*	*Cavitatus rectus*	*Cestodiscus convexus*	*Cestodiscus kugleri*	*Cestodiscus ovalis*	*Cestodiscus reticulatus*	*Cestodiscus robustus*	*Cestodiscus trochus*	*C. trochus* (marginal spines)	*Cestodiscus* sp. cf. *C. demergitus*	*Cestodiscus* sp. aff. *C. pulchellus*	*Cestodiscus* sp. 2 of Fenner, 1981	*Coscinodiscus excavatus*	*Coscinodiscus excavatus* var. *semilunaris*	*Coscinodiscus hajosiae*	*Coscinodiscus lewisianus*	*Coscinodiscus lewisianus* f. *concavus*	*Coscinodiscus lewisianus* var. *levis*	*Coscinodiscus lewisianus* var. *rhomboides*	*Coscinodiscus marginatus*	*Coscinodiscus radiatus*	*Coscinodiscus rhombicus*	*Coscinodiscus*? sp. cf. *C. capensis*	*Craspedodiscus barronii*
	199-1220A-																																								
Coscinodiscus excavatus	6H-7, 10–11	56.60	61.94	31.07	A	M		R			F									R				R	A	R				R								F			
	6H-CC, 10–11	57.23	62.57	31.17	A	M					F									R				R	A	R				R								F			
	7H-1, 10–11	57.10	63.41	31.30	A	M				R	F									F				C	A	R				R								R			
	7H-1, 110–111	58.10	64.41	31.45	A	M				R	C									F				C	A	R				F											
	7H-2, 10–11	58.60	64.91	31.53	A	M					R									R				F	A	R				R											
	7H-2, 110–111	59.60	65.91	31.69	A	M					R									F				C	A	R				R	R										
	7H-3, 10–11	60.06	66.37	31.76	C	M					F									R		R		C	C	R				R	R										
	7H-3, 110–111	61.06	67.37	31.91	A	M					F									R		R		A	C	F				R	R							R			
	7H-4, 10–11	61.56	67.87	31.99	A	M					F									R		R		A	C	F				R								F			
	7H-4, 60–61	62.06	68.37	32.07	A	M					R									R				C	A	R				R	R							R			
	7H-4, 110–111	62.56	68.87	32.14	A	M					R									R		R		F	A	R				R	R							R			
	7H-5, 10–11	63.06	69.37	32.22	A	G				R	C									F				C	A	R				F								R			
	7H-5, 60–61	63.56	69.87	32.30	A	G				R	F									F				C	A	R				F	R										
	7H-5, 110–111	64.06	70.37	32.37	A	G				R	C									F			F	F	A	F				R		R									
	7H-6, 10–11	64.56	70.87	32.45	A	G		R		R	F									R			F	C	A	F				F											
	7H-6, 60–61	65.06	71.37	32.53	A	M		R		R	F									R			F	C	A	F				R								R			
	7H-6, 110–111	65.56	71.87	32.61	A	M				R	F									F				C	A	F				R								F			
	7H-7, 10–11	66.06	72.37	32.68	A	M				R	F									F				A	A	F				F								F	R		
	7H-CC, 10–11	66.63	72.94	32.77	A	M				R	F									R			R	A	C	F				R								F	R		
	8H-1, 10–11	66.60	74.24	32.97	C	M				R	R									R			R	C	C	F				R		R						F	R		
	8H-1, 60–61	67.10	74.74	33.05	C	M				R	R									F				C	C	F				R		R						F			
	8H-1, 110–111	67.60	75.24	33.16	C	M					R									R				C	C	F			R	R		R						F	R		
	8H-2, 12–13	68.12	75.76	33.27	C	M					R									R				R	C	F			F	R								F	R		
	8H-2, 62–63	68.62	76.26	33.39	C	M				R														R	C	F	R		F	R								F			
	8H-2, 112–113	69.12	76.76	33.50	C	P					R													VR	F	R				R								F			
Baxteriopsis brunii	8H-3, 10–11	69.60	77.24	33.60	C	M				R															F	R			R			R						F			
	8H-3, 60–61	70.10	77.74	33.70	C	M					R														F	R	R		F			R						C			
	8H-3, 110–111	70.60	78.24	33.79	F	P					R														R													R			

Notes: A = abundant, C = common, F = few, P = present, B = barren, R = rare, VR = very rare. r = reworked (see **"Materials and Methods,"** p. 2, for explanation).

Table T1 (continued).

Zone	Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Age (Ma)	Abundance	Preservation	*Craspedodiscus elegans*	*Distephanosira architecturalis*	*Kozloviella minor*	*Kozloviella* cf. *pacifica*	*Lisitzinia ornata*	*Raphidodiscus marylandicus*	*Rocella gelida*	*Rocella princeps*	*Rocella semigelida*	*Rocella schraderi*	*Rocella vigilans*	*Rocella vigilans* var. 1	*Rouxia* spp.	*Rossiella fennerae*	*Rossiella fourtanierae*	*Rossiella paleacea*	*Rossiella symmetrica*	*Skeletonemopsis barbadensis*	*Stephanopyxis* aff. *turris*	*Thalassionema* cf. *T. nitzschioides*	*Thalassiosira? bukryi*	*Thalassiosira praefraga*	*Thalassiosira primalabiata*	*Thalassiosira spumellaroides*	*Thalassiothrix* sp. cf. *T. primitiva*
	199-1220A-																														
Coscinodiscus excavatus	6H-7, 10–11	56.60	61.94	31.07	A	M																			R		R				
	6H-CC, 10–11	57.23	62.57	31.17	A	M																			R		R				
	7H-1, 10–11	57.10	63.41	31.30	A	M																			R		R				
	7H-1, 110–111	58.10	64.41	31.45	A	M																									
	7H-2, 10–11	58.60	64.91	31.53	A	M																									
	7H-2, 110–111	59.60	65.91	31.69	A	M																									
	7H-3, 10–11	60.06	66.37	31.76	C	M																									
	7H-3, 110–111	61.06	67.37	31.91	A	M																						R			
	7H-4, 10–11	61.56	67.87	31.99	A	M			R																						
	7H-4, 60–61	62.06	68.37	32.07	A	M			R																			R			
	7H-4, 110–111	62.56	68.87	32.14	A	M			R																			R			
	7H-5, 10–11	63.06	69.37	32.22	A	G		R	R																R						
	7H-5, 60–61	63.56	69.87	32.30	A	G																			R						
	7H-5, 110–111	64.06	70.37	32.37	A	G																						R			
	7H-6, 10–11	64.56	70.87	32.45	A	G																			R			R			
	7H-6, 60–61	65.06	71.37	32.53	A	M																			R	R					
	7H-6, 110–111	65.56	71.87	32.61	A	M																									
	7H-7, 10–11	66.06	72.37	32.68	A	M																									
	7H-CC, 10–11	66.63	72.94	32.77	A	M																									
	8H-1, 10–11	66.60	74.24	32.97	C	M																						R			
	8H-1, 60–61	67.10	74.74	33.05	C	M																			R			R			
	8H-1, 110–111	67.60	75.24	33.16	C	M	R		R																						
	8H-2, 12–13	68.12	75.76	33.27	C	M																									
	8H-2, 62–63	68.62	76.26	33.39	C	M																									
	8H-2, 112–113	69.12	76.76	33.50	C	P																									
Baxteriopsis brunii	8H-3, 10–11	69.60	77.24	33.60	C	M			F																						
	8H-3, 60–61	70.10	77.74	33.70	C	M			R																R						
	8H-3, 110–111	70.60	78.24	33.79	F	P			R																R						

Table T2. Stratigraphic constraints, paleomagnetic chron assignment, and age estimate of selected diatom datum levels in the Oligocene and lowermost Miocene, Site 1220.

		Depth (mcd)		Subchron		Age (Ma)		
Datum		Top	Bottom	Top	Bottom	Top	Bottom	Midpoint
LO	*Bogorovia barronii*	21.47	22.22	C6An.2n	C6An.2r	21.12	21.44	21.28
FO	*Azpeitia praenodulifera*	21.47	22.22	C6An.2n	C6An.2r	21.12	21.44	21.28
FO	*Rossiella paleacea*	22.22	22.97	C6An.2r	C6AAn	21.44	21.81	21.62
LO	*Thalassiosira primalabiata*	23.72	24.44	C6AAn.1r	C6AAr.1r	22.06	22.31	22.19
FO	*Actinocyclus hajosiae*	23.72	24.44	C6AAn.1r	C6AAr.1r	22.06	22.31	22.19
FO	*Thalassiosira spumellaroides*	24.72	25.47	C6AAr.1r	C6Bn.1n	22.40	22.67	22.53
FO	*Bogorovia barronii*	24.72	25.47	C6AAr.1r	C6Bn.1n	22.40	22.67	22.53
FO	*Thalassiosira praefraga*	25.47	26.22	C6Bn.1n	C6Bn.2n	22.67	22.94	22.80
FO	*Rossiella fourtanierae*	27.77	28.52	C6Cn.1n	C6Cn.1r	23.40	23.64	23.52
LO	*Rocella gelida*	29.77	30.52	C6Cn.3r	C6Cn.3r	24.13	24.32	24.22
LO	*Coscinodiscus lewisianus* var. *rhomboides*	29.77	30.52	C6Cn.3r	C6Cn.3r	24.13	24.32	24.22
LO	*Rocella schraderi*	30.52	30.85	C6Cn.3r	C6Cn.3r	24.32	24.62	24.47
FcO	*Rossiella fennerae*	30.85	31.85	C6Cn.3r	C6Cn.3r	24.62	24.74	24.68
LO	*Rocella vigilans*	31.85	32.35	C6Cn.3r	C7n.1r	24.74	24.80	24.77
LO	*Rocella princeps*	32.35	32.65	C7n.1r	C7n.2n	24.80	24.84	24.82
FO	*Rocella schraderi*	33.05	33.35	C7n.2n	C7n.2n	24.96	25.05	25.00
FO	*Craspedodiscus barronii*	34.85	35.35	C7n.2r	C7n.2r	25.53	25.70	25.62
FO	*Rocella gelida*	35.35	36.35	C7n.2r	C8n.2n	25.70	26.01	25.85
FO	*Coscinodiscus lewisianus* var. *rhomboides*	35.35	36.35	C7n.2r	C8n.2n	25.70	26.01	25.85
FO	*Rocella princeps*	36.35	36.85	C8n.2n	C8n.2n	26.01	26.10	26.05
LO	*Cestodiscus kugleri*	36.35	36.85	C8n.2n	C8n.2n	26.01	26.10	26.05
LO	*Rossiella symmetrica*	37.85	38.35	C8n.2n	C8n.2n	26.29	26.39	26.34
LO	*Kozloviella minor*	42.89	43.89	C9n	C9n	27.60	27.92	27.76
FO	*Cestodiscus kugleri*	42.89	43.89	C9n	C9n	27.60	27.92	27.76
FO	*Coscinodiscus lewisianus* var. *levis*	44.39	45.39	C9r	C10n.1n	28.12	28.35	28.23
FO	*Bogorovia veniamini*	44.39	45.39	C9r	C10n.1n	28.12	28.35	28.23
LO	*Baxteriopsis brunii*	44.39	45.39	C9r	C10n.1n	28.12	28.35	28.23
LcO	*Cestodiscus trochus*	45.89	46.89	C10n.1n	C10n.1r	28.40	28.51	28.46
FO	*Coscinodiscus rhombicus*	46.89	47.39	C10n.1r	C10n.2n	28.51	28.65	28.58
FO	*Cavitatus rectus*	46.89	47.39	C10n.1r	C10n.2n	28.51	28.65	28.58
FO	*Kozloviella minor*	47.39	48.39	C10n.2n	C10n.1r	28.65	28.82	28.74
FO	*Cavitatus jouseanus*	47.39	48.39	C10n.2n	C10n.1r	28.65	28.82	28.74
FO	*Rossiella symmetrica*	50.39	50.99	C10n.2r	C10n.1r	29.05	29.11	29.08
FO	*Rocella vigilans*	55.94	56.94	C11n.1n	C11n.2n	29.74	29.98	29.86
LcO	*Cestodiscus robustus*	59.94	60.44	C12n	C12n	30.56	30.73	30.65
LO	*Skeletonemopsis barbadensis*	60.44	61.44	C12n	C12r	30.73	30.99	30.86
LO	*Cestodiscus trochus* (marginal labiate processes)	60.44	61.44	C12n	C12r	30.73	30.99	30.86
LO	*Cestodiscus convexus*	60.44	61.44	C12n	C12r	30.73	30.99	30.86
LO	*Coscinodiscus excavatus*	61.44	61.94	C12n	C12r	30.99	31.07	31.03
FO	*Cavitatus miocenicus*	61.44	61.94	C12n	C12r	30.99	31.07	31.03
FO	*Thalassionema* cf.*nitzschioides*	63.41	64.41	C12r	C12r	31.30	31.45	31.38
LO	*Coscinodiscus excavatus* var. *semilunaris*	64.91	65.91	C12r	C12r	31.53	31.69	31.61
FO	*Coscinodiscus excavatus* var. *semilunaris*	69.87	70.37	C12r	C12r	32.30	32.37	32.34
LO	*Cestodiscus reticulatus*	69.87	70.37	C12r	C12r	32.30	32.37	32.34
FO	*Thalassiothrix* cf. *primitiva*	74.24	74.74	C12r	C12r	32.97	33.05	33.01
FO	*Cestodiscus reticulatus*	74.24	74.74	C12r	C12r	32.97	33.05	33.01
LO	*Cestodiscus* sp. 2 of Fenner 1981	74.74	75.24	C12r	C13n	33.05	33.16	33.10
FO	*Cestodiscus convexus*	75.76	76.26	C13n	C13n	33.27	33.39	33.33
FO	*Coscinodiscus excavatus*	76.76	77.24	C13r	C13r	33.50	33.60	33.55
FO	*Cestodiscus robustus*	76.76	77.24	C13r	C13r	33.50	33.60	33.55

Notes: FO = first occurrence, LO = last occurrence, FcO = first consistent occurrence, LcO = last consistent occurrence. Paleomagnetic chrons and ages after Cande and Kent (1995); geologic time scale after Berggren et al. (1995).

Plate P1. Specimens from Cores 199-1220A-4H through 8H. Scale bar = 10 µm. **1, 2.** *Cestodiscus* sp. 2 sensu Fenner 1981, low and high focus of same specimen (Sample 199-1220A-8H-3, 10–11 cm). **3.** *Rossiella fennerae* Yanagisawa (Sample 199-1220A-4H-6, 10–11 cm). **4, 5.** *Cestodiscus convexus* Castracane, low and high focus of the same specimen (Sample 199-1220A-7H-5, 60–61 cm). **6.** *Bogorovia veniamini* Jousé (Sample 199-1220A-4H-6, 10–11 cm). **7, 8.** *Cestodiscus kugleri* Lohman (Sample 199-1220A-4H-6, 10–11 cm). **9.** *Kozloviella* sp. cf. *K. pacifica* Jousé (Sample 199-1220A-5H-3, 110–111 cm).

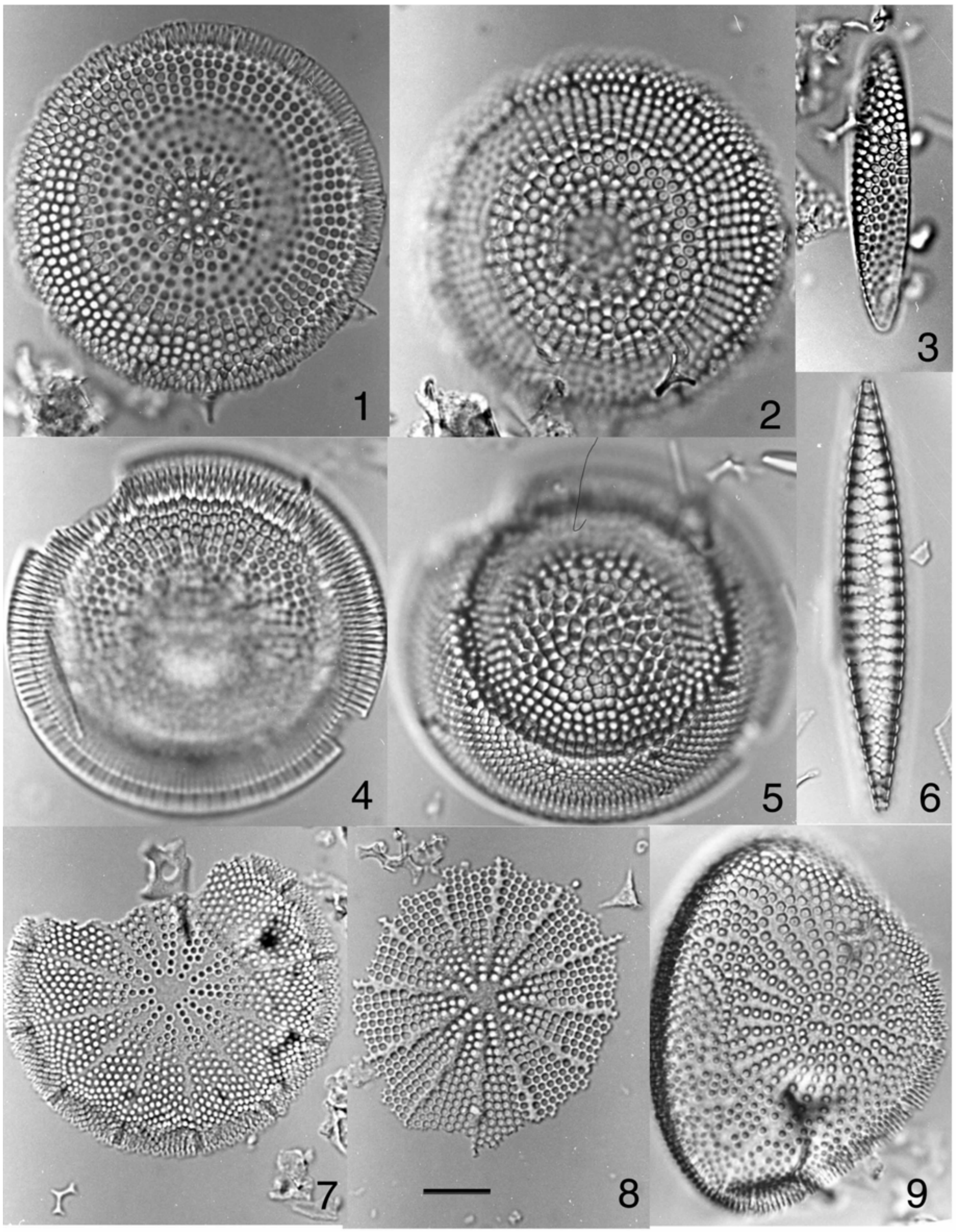

Plate P2. Specimens from Cores 199-1220A-5H through 8H. Scale bar = 10 µm. **1.** *Coscinodiscus excavatus* var. *semilunaris* Grunow (Sample 199-1220A-7H-5, 60–61 cm). **2.** *Cestodiscus trochus* Castracane (199-1220A-7H-5, 60–61 cm). **3.** *Cestodiscus* sp. 2 sensu Fenner 1981 (Sample 199-1220A-8H-3, 10–11 cm). **4.** *Rocella vigilans* Fenner, larger-sized form (Sample 199-1220A-5H-3, 110–111 cm). **5.** *Rossiella symmetrica* Fenner (Sample 199-1220A-5H-3, 110–111 cm). **6.** *Rocella vigilans* Fenner, intermediate in size (Sample 199-1220A-6H-2, 110–111 cm). **7.** *Thalassiothrix* sp. cf. *T. primitiva* Schrader (Sample 199-1220A-6H-2, 110–111 cm). **8.** *Cestodiscus ovalis* Greville? (Sample 199-1220A-5H-3, 110–111 cm). **9.** *Thalassiosira*? *bukryi* Barron (Sample 199-1220A-5H-3, 110–111 cm). **10.** *Rocella vigilans* Fenner, small-sized form that may be a transitional form to *Rocella semigelida* Gombos (Sample 199-1220A-6H-2, 110–111 cm).

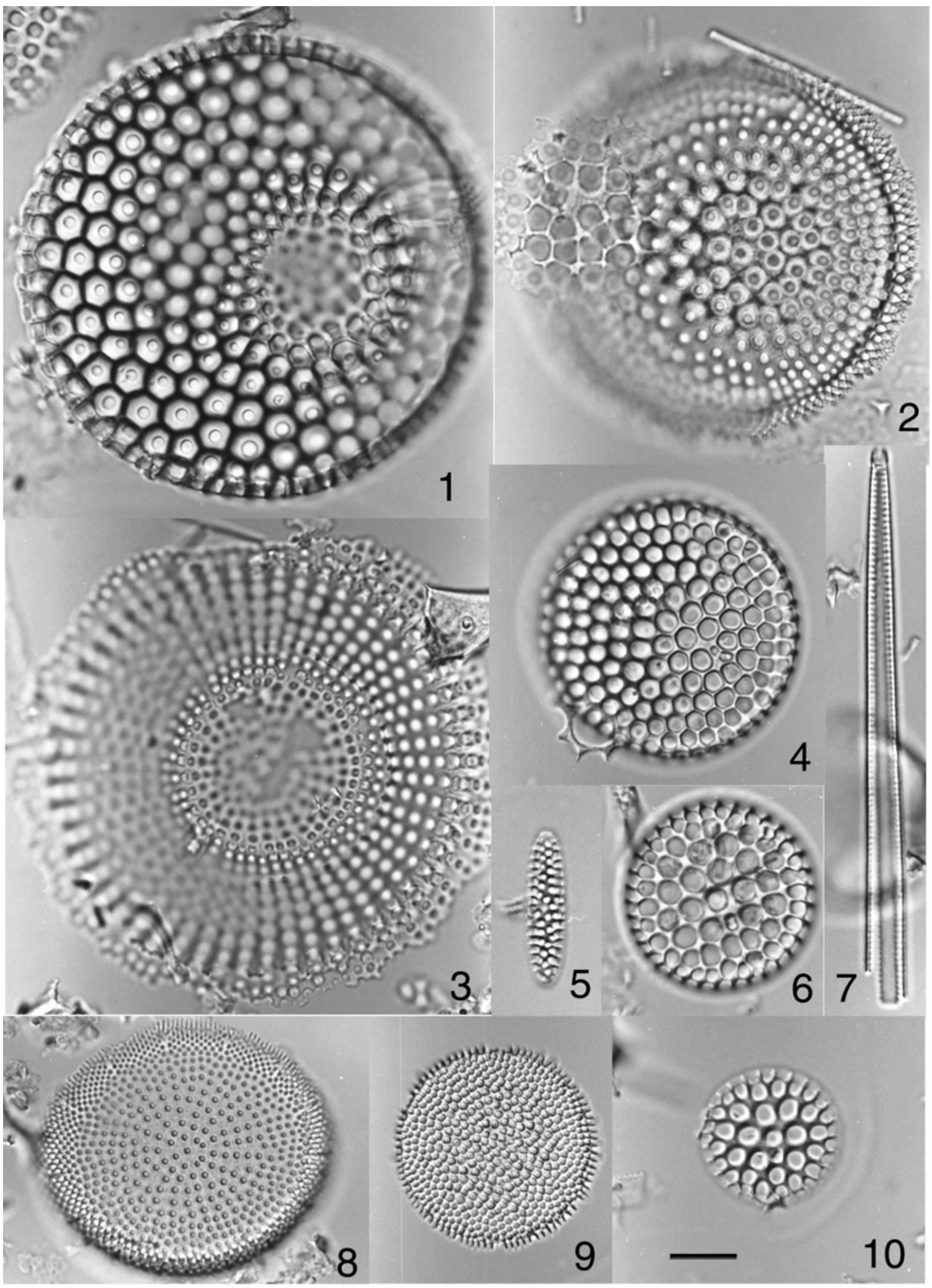

Plate P3. Specimens from Sample 199-1220A-7H-5, 60–61 cm. Scale bar = 10 µm. **1, 2.** *Cestodiscus trochus* Castracane with marginal labiate processes. **3, 4.** *Cestodiscus robustus* Jousé, high and low focus of the same specimen. **5.** *Azpeitia oligocenica* Jousé. **6.** *Cestodiscus reticulatus* Fenner. **7.** *Cestodiscus trochus* Castracane, with the margin broken off.