Wilson, P.A., Lyle, M., and Firth, J.V. (Eds.)
Proceedings of the Ocean Drilling Program, Scientific Results Volume 199

9. SILICOFLAGELLATES RECOVERED FROM THE DEEP SEA, ODP LEG 199 SITE 1219, EAST EQUATORIAL PACIFIC[1]

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ABSTRACT

Silicoflagellates ranging from middle Eocene to middle Miocene in age are present in Ocean Drilling Program Hole 1219A. The hole was drilled 250.8 meters below seafloor of which an ~120-m section primarily composed of nannofossil ooze with variable radiolarian and clay content is early Miocene and Oligocene in age, and a 95-m section is Eocene radiolarian and zeolithic clays, radiolarian and diatom oozes, and nannofossil oozes and chalks. A total of 150 samples were studied at a sample interval of one per section. Diversity of silicoflagellates is moderate, and the preservation is good. Abundance is generally low, with many samples barren of silicoflagellates, but 31 species and subspecies were identified. One new species, *Naviculopsis trigeminus*, is described.

INTRODUCTION

Silicoflagellates are planktonic, microscopic algae with siliceous skeletons characterized by their simple geometries and remarkable variability (see McCartney and Wise, 1990; McCartney et al., 1995). They can be considered the least important of the major fossil-forming plankton groups; they are also the least studied. Biostratigraphic zonations have been developed for silicoflagellates in all oceans throughout the Cenozoic, though the zones typically range over longer intervals of time than foraminiferal or diatom zones. Silicoflagellate skeletons may have considerable potential as ecophenotypic indicators (see, e.g., Cornell,

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[1] Engel, R., and McCartney, K., 2005. Silicoflagellates recovered from the deep sea, ODP Leg 199 Site 1219, east equatorial Pacific. *In* Wilson, P.A., Lyle, M., and Firth, J.V. (Eds.), *Proc. ODP, Sci. Results,* 199, 1–29 [Online]. Available from World Wide Web: <http://www-odp.tamu.edu/publications/199_SR/VOLUME/CHAPTERS/202.PDF>. [Cited YYYY-MM-DD]

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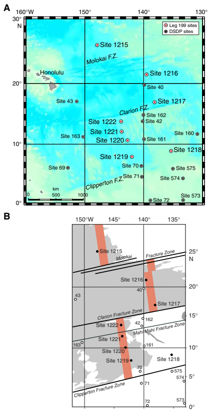
Initial receipt: 29 August 2003
Acceptance: 30 August 2004
Web publication: 6 April 2005
Ms 199SR-202

1974; McCartney and Wise, 1990, 1993). Mathematical studies (McCartney, 1988; McCartney and Loper, 1989, 1992) suggest that skeletal shape is influenced by environmental factors, with more complex skeletal morphologies resulting from a need to optimize surface area.

Eight sites were drilled in the eastern equatorial Pacific Ocean during Ocean Drilling Program (ODP) Leg 199 from October through December 2001. The sites are divided into two complementary north–south transects (Fig. **F1**) across an area that was located at the equator during the Eocene. Plate motions during the past 40 m.y. have moved this region northward, away from the equatorial upwelling region, into an area of lower productivity. The goal for Leg 199 was to drill through the relatively thin overlying Neogene sequence to recover Paleogene sediments that were not buried deep enough to be lithified. Because the region was situated at the equator during the Eocene, the expectations prior to drilling were that the Paleogene sequence would show high productivity with abundant and diverse plankton.

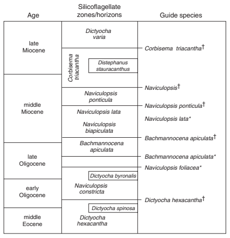
F1. Leg 199 location map, p. 20.



The drilling region for Leg 199 was also selected to complement the Neogene sequences that were recovered during ODP Leg 138, which was drilled in the same region but slightly southward, straddling the equator. Study of these cores by McCartney et al. (1995) showed silicoflagellates to be abundant and diverse at the equator and rapidly diminishing away from the equator. Silicoflagellates demonstrating unusual skeletal variability, such as in the *Bachmannocena*/*Neonaviculopsis* plexus, were very abundant in the late Miocene within 1°–2° of the equator. Sites located farther from the equator, such as in ODP Holes 845B (9°N) and 854B (11°N), were generally found to have few silicoflagellates and low diversity.

Preliminary silicoflagellate analysis of Leg 199 sites showed a continued trend of low biogenic sedimentation away from the equator, with most of the samples studied having few or no silicoflagellates. The southernmost of the eight sites, Site 1219, was selected for detailed study; a data report for Sites 1215–1218 and 1220 is published elsewhere (**McCartney et al.,** this volume). Site 1219 is situated ~3° north of the Clipperton Fracture Zone. Hole 1219A (7°48.019′N, 142°00.940′W; water depth = 5063 m) consists of a 250.8-m section, of which an ~120-m early Miocene and Oligocene section is primarily composed of nannofossil ooze with variable radiolarian and clay content. The Eocene section comprises 95 m of radiolarian and zeolithic clays, radiolarian and diatom oozes, and nannofossil oozes and chalks. Diversity of silicoflagellates is moderate, and the preservation is good. A middle Miocene to early Eocene section was recovered in Hole 1219A, with sporadic occurrences of silicoflagellates throughout (Fig. **F2**). Radiolarian and nannofossil oozes throughout the core dominate the sediments with carbonate and clay units interrupting the section.

F2. Silicoflagellate zonation, p. 21.



In the present Pacific Ocean, wind systems in the two hemispheres come together at high altitudes and are pushed to a lower elevation near sea level, where they then move back toward the pole. These winds push surface waters away from the equator, where deep nutrient-rich waters then come to the surface to produce an extraordinarily high productivity of phytoplankton and zooplankton. Investigation of the Leg 199 cores (see other papers in this volume) show that the equatorial circulation system was quite broad during the Eocene, with very low plankton productivity. The fossil assemblages are generally dominated by radiolarians. This reflects a very warm Eocene climate that transitioned to a cool Oligocene climate at ~33.7 Ma (Shipboard Scientific Party, 2002). This transition is associated with the first significant buildup of ice on Antarctica and initiated the change toward more modern oceanic circulation patterns and plankton ecologies.

SAMPLE PREPARATION AND METHODS OF STUDY

Raw samples were placed in 100-mL beakers to which 10 mL of distilled water and 10 mL of 30% hydrogen peroxide were added; more was added if it strongly effervesced. After 1–3 hr, HCl was added until the fizzing subsided and the beaker was heated for 15 min. Samples were then left overnight and were centrifuged and decanted three times and washed out before strewn slides were made. Slides were prepared by resuspending the contents and quickly using a disposable pipette, dropping 2–3 drops onto a 22 mm × 50 mm coverslip. The pipette end was used to spread the drops over the surface of the coverslip. The coverslip was then placed on a hot plate at medium heat to dry. A small amount of balsam was put on the slide, and the coverslip was turned over and placed on the balsam. The slide was heated on the hot plate until the balsam spread over the area of the coverslip and the bubbling within the balsam subsided.

All slides were completely examined, with all specimens representing more than one-half of a silicoflagellate included in the counts. The distribution is shown in Table T1 for 150 samples with an interval of one sample per section.

T1. Abundance of silicoflagellates, Hole 1219A, p. 22.

This study was done at the Micropaleontology Undergraduate Research Laboratory at the University of Maine at Presque Isle (USA). The microscope work and some of the analyses were conducted by undergraduate students who have limited experience with silicoflagellates. Participating students generally have a year of training in micropaleontology and deep-ocean drilling and then conduct micropaleontology research as a directed independent project that is closely supervised by the laboratory's director (K. McCartney). The first author of this paper (R. Engel) has previously co-authored a silicoflagellate study for Leg 183 (McCartney et al., 2003).

SILICOFLAGELLATE ZONATION

A review of silicoflagellate literature concerning deep-ocean sites (McCartney et al., 1995) shows that only a few papers provide silicoflagellate biostratigraphy of low-latitude (<25°) Paleogene sediments. Only four legs have investigated silicoflagellates from the Oligocene (see Ling, 1980 [for Deep Sea Drilling Project (DSDP) Holes 165A and 166]; Bukry, 1977, 1978d, 1985), and there have been no equatorial studies of the Eocene and Paleocene, except a data report by Bukry (1989). The low-latitude and cosmopolitan zonation provided by Bukry (1981b) uses information from middle and high latitudes for the Eocene intervals. Ciesielski (1991) presented a zonation for the Eocene and Oligocene for middle and high latitudes, which was emended by McCartney and Harwood (1992). Leg 199 provides an excellent opportunity to build on this more recent work to develop a low-latitude Eocene and Oligocene zonation. This zonation complements the low-latitude Neogene biostratigraphy provided by McCartney et al. (1995).

Dictyocha hexacantha Range Zone

Definition: Interval between the first and last occurrence of *Dictyocha hexacantha*.

Author: Bukry and Foster, 1974; modified by Bukry, 1977.

Common species: In addition to *D. hexacantha*, common species include *Corbisema bimucronata*, *Corbisema hastata,* and *Corbisema regina*. *Naviculopsis constricta* occurs sporadically and is dominant in Sample 199-1219A-21H-4, 70–71 cm.

Remarks: The interval from Sample 199-1219A-21H-6, 70–71 cm, to 21H-2, 70–71 cm, is designated the *Dictyocha spinosa* Subzone. The subzone also includes *C. bimucronata* and *C. regina*, though these taxa are not restricted to this subzone. Bukry (1981b) placed this subzone in the *Naviculopsis foliacea* Zone, a zone not recognized in this study, which he placed below the *D. hexacantha* Zone.

Naviculopsis constricta Interval Zone

Definition: Last occurrence of *D. hexacantha* to the initial occurrence of *N. foliacea*.

Author: Ciesielski (1991), emended.

Common species: *Corbisema triacantha* is present with only rare occurrences of other taxa except *N. constricta*. *Dictyocha byronalis* is present and generally dominant in the four samples that constitute the *D. byronalis* horizon, as defined below.

Remarks: The original description of this zone by Ciesielski (1991) used the last occurrence of *Dictyocha precarentis*, a taxon not found in this study, as the bottom of the zone. An equivalent of this zone is the *C. hastata*–*Corbisema apiculata* Interval Range Zone described by Perch-Nielsen (1975).

The interval placed in this zone is largely barren of silicoflagellates except for three samples at the top of the interval that include *N. constricta* and a four-sample interval from Sample 199-1219A-15H-5, 70–71 cm, to 6H-1, 70–71 cm, that contains *D. byronalis*. The latter is designated the *D. byronalis* Horizon, defined as the interval from the first to last common *D. byronalis*.

Unzoned Interval

Common species: *C. triacantha*, with sporadic occurrences of *Naviculopsis biapiculata* and rare occurrences of *Distephanus crux*. The interval is left unzoned because of a lack of diversity and the lack of key zonal species.

Remarks: There is little general agreement on how best to zone the upper Eocene and lower Oligocene interval between the middle Eocene *Corbisema hexacantha* Zone and the upper Oligocene *Bachmannocena apiculata* Zone. This is well illustrated for Leg 29 sites, where Bukry (1975b) applied the *Dictyocha deflandrei* Interval Zone, while Perch-Nielson (1975) applied the *C. hastata*–*C. apiculata* Interval Zone and other thinner zones. Martini and Müller (1976) used *C. bimucronata* and *Dictyocha quadria* as zones to cover this general interval. The interval between Samples 199-1219A-14H-6, 70–71 cm, and 8H-6, 70–71 cm, did not contain *D. deflandrei*, *C. apiculata*, or *D. quadria*. The interval also lacked taxa above the last occurrence of *N. constricta* that might be used for describing a new zone, and thus this interval is left unzoned in this study. The interval could be applied to the *N. foliacea* Zone described by Martini and Müller (1976), but *N. foliacea* is only found in abundance in the bottom sample of the interval.

Bachmannocena apiculata Range Zone

Definition: Interval from the first to last common occurrence of *B. apiculata*.
Author: Perch-Nielsen (1975).
Common species: *B. apiculata* and *Distephanus speculum speculum* are commonly present. Other species found sporadically include *D. crux* and *N. biapiculata*.
Remarks: Bukry (1981b) defines the bottom of this zone as the last occurrence of *D. hexacantha*.

Naviculopsis biapiculata Interval Zone

Definition: Interval between the last common occurrence of *B. apiculata* and the first occurrence of *Naviculopsis lata*.
Author: Bukry (1978a).
Common species: *Distephanus speculum* and *D. crux*.
Remarks: *N. biapiculata* was only found in the lowermost two samples of the interval placed in this zone.

Naviculopsis lata Range Zone

Definition: Interval between the first and last common occurrence of *N. lata*.
Author: Martini (1972).
Common species: *N. constricta*, *N. biapiculata*, and *D. crux*.
Remarks: This zone was applied in only three samples covering an interval of ~3 m (31.7–34.5 meters below seafloor [mbsf]).

Naviculopsis ponticula Partial Range Zone

Definition: Interval from the first appearance of *Naviculopsis ponticula* to the last appearance of *Naviculopsis* ssp.
Author: Bukry (1980a).
Common species: *D. crux* and *N. biapiculata*.
Remarks: Bukry (1985, see also Bukry, 1982) noted that *N. ponticula* is most abundant in the lower part of the zone, whereas *N. ponticula spinosa* is dominant in the upper part of the zone. A similar pattern was found in this study, where *N. ponticula* was found to have more prominent apical spines in the uppermost sample from the zone.

Corbisema triacantha Partial Range Zone

Definition: Interval from last occurrence of *Naviculopsis* species to last occurrence of *C. triacantha*.
Author: Martini (1971).
Common species: Common species include *Dictyocha fibula fibula*, *D. fibula ausonia*, and *Distephanus crux crux*. Both *D. speculum* and

D. crux are less abundant in this zone than in the underlying *N. ponticula* Zone.

Remarks: This zone includes the *Distephanus stauracanthus* horizon described by Martini (1972), but the horizon is only represented by a single specimen in each of the uppermost three samples of the zone. This horizon was also applied by Locker and Martini (1986), and in this study, the horizon is much thinner than the 50-m presence in Hole 844B (McCartney et al., 1995).

Dictyocha varia Interval Zone

Definition: The bottom of this zone is defined as the last occurrence of *C. triacantha*. Locker and Martini defined the top of this zone as the first consistent occurrence of *Dictyocha extensa*, which McCartney et al. (1995) modified to the first occurrence of *Distephanus speculum tenuis*. Neither *D. extensa* nor *D. speculum tenuis* were found in this study.

Author: Locker and Martini (1986; see also McCartney et al., 1995).

Common species: *D. fibula fibula* was the most common species.

Remarks: Only four taxa were found in the samples that were placed in this zone. They were *D. fibula fibula*, *D. speculum*, *D. crux*, and *D. varia*. Only two specimens of *D. varia* were identified in this interval.

SITE SUMMARY AND BIOSTRATIGRAPHIC RESULTS

Samples studied from Core 199-1219A-1H were found to be barren of silicoflagellates; calcareous nannofossils were not present in Cores 199-1219A-1H and 2H (Shipboard Scientific Party, 2002). The first downhole occurrence of silicoflagellates was in Sample 199-1219A-2H-2, 70–71 cm, representing the *D. varia* Zone of the middle Miocene. This zone is represented by four samples, one of which was barren of silicoflagellates. Silicoflagellates were fairly uncommon and of low diversity, with only four silicoflagellate taxa found in this interval. The lowermost of the samples in this interval, Sample 199-1219A-2H-5, 70–71 cm, shows a modest increase in silicoflagellate abundance that continues through the next 6.5 m.

The *C. triacantha* Zone occurs in Samples 199-1219A-2H-6, 70–71 cm, through 4H-1, 70–71 cm. Nine samples were studied in this interval, with silicoflagellates having moderate abundance (19–47 specimens per slide) in the upper five samples and showing very low abundance (7 specimens or fewer per slide) in the lower four samples. Diversity is fairly high, with 12 taxa found in the interval. *D. fibula fibula* is usually the most abundant taxon, except in the bottom two samples, 199-1219A-4H-2, 70–71 cm, and 4H-3, 70–71 cm, where *Dictyocha* is absent and *Distephanus* and *Naviculopsis* are first present in numbers greater than 10 specimens per slide.

The transition from *Dictyocha* to *Distephanus* dominance between Samples 199-1219A-4H-1, 70–71 cm, and 4H-2, 70–71 cm, suggests a change in surface water temperature or some environmental variable associated with water temperature (McCartney and Loper, 1989). Several silicoflagellate researchers (Poelchau, 1974; Ciesielski, 1975; Bukry, 1981a; Bukry and Monechi, 1985; Schrader et al., 1986; and others) have suggested that the *Distephanus*/*Dictyocha* ratio may be useful as a temperature indicator, although the several proposed scales do not compare closely, showing that there is only regional utility at best (see Perch-Nielsen, 1985). Nevertheless, the general absence of *Dictyocha* below Sample 199-1219A-4H-1, 80–81 cm, and of *Distephanus* above Sample 4H-1, 80–81 cm, strongly suggest a fairly significant change in sea-surface temperature.

The *N. ponticula* Zone is found in only three samples, 199-1219A-4H-2, 70–71 cm, through 4H-4, 70–71 cm. The zone is commonly much thicker, for example, 20 m in Hole 575A (Bukry, 1985) and at least 23 m in Hole 495A (Bukry, 1981a). However, the top and bottom of the zone appear to be preserved in Hole 1219A, as Sample 199-1219A-4H-2, 70–71 cm, includes *Naviculopsis ponticula spinosa*, which Bukry (1985) noted to be dominant in the upper part of the zone, and Sample 4H-4, 70–71 cm, has especially abundant *N. ponticula*, which is typical of the bottom part of the zone (Bukry, 1985, 1982). Thus, unless there are missing sediments in the middle part of the zone, sedimentation rates in the early Miocene were apparently lower at Site 1219 than elsewhere in the east equatorial Pacific.

The *N. lata* Zone is also very thin in this region, applied to three samples, 199-1219A-4H-5, 70–71 cm, through 4H-7, 50–51 cm (31.7–34.5 mbsf). Silicoflagellates are fairly abundant in this interval, with 39–86 specimens per slide representing nine taxa (one reworked). Sample 199-1219A-5H-1, 70–71 cm, immediately below where we place the bottom of the *N. lata* Zone, is barren, and silicoflagellates are found in significantly lower numbers through the rest of the lower Miocene section.

The abundance and diversity of silicoflagellates are relatively low in the *N. biapiculata* Zone, with four of the nine samples in this interval being barren. Eight taxa were found (one reworked). The dominant silicoflagellates in this interval are *D. crux* and *D. speculum*, with *N. biapiculata* present only in Samples 199-1219A-6H-1, 70–71 cm, and 6H-2, 70–71 cm.

Silicoflagellates were found in all 11 samples placed in the *B. apiculata* Zone, with the number of specimens per slide ranging from 2 to 64. Diversity was generally low, with *D. speculum speculum* being the dominant taxon throughout the interval. *B. apiculata* was present in all but 2 of the 11 samples. Below this zone is a lengthy unzoned interval where silicoflagellates, when present, do not include diagnostic zonal indicators. *N. biapiculata* and *N. constricta* are unusually abundant in Sample 199-1219A-14H-6, 70–71 cm, which is the lowermost sample of the unzoned interval.

The *N. constricta* Zone represents a lengthy interval of 36 samples covering >50 m. Only nine of these samples were found to contain silicoflagellates. There is a thick barren interval covering 21 sections from Sample 199-1219A-16H-3, 70–71 cm, to 19H-5, 70–71 cm (47.7–79.2 mbsf). There are two features of interest in the interval covered by this zone. The topmost sample, 199-1219A-14H-7, 70–71 cm, contains the most silicoflagellate specimens observed in this study. This sample was dominated by *N. constricta* and was also the last occurrence of that taxon. The second feature of interest is a four-sample interval dominated by *D. byronalis*, considered here as a horizon within the primary zonal interval. *D. byronalis* was described and is very abundant in the Kellogg Shale of northern California (Barron et al., 1984), although that is dated to the middle Eocene.

The lowest zone identified in this study is the *D. hexacantha* Zone, extending from Sample 199-1219A-14H-7, 70–71 cm, to 23H-5, 70–71 cm (128.2–212.2 mbsf). Most of the samples in this interval were barren, but there was a short interval of five samples that contained sporadic *D. spinosa*, which was especially abundant in Sample 199-1219A-21H-6, 70–71 cm. The *D. spinosa* Subzone also contained abundances of *C. bimucronata* and *C. hastata*. No silicoflagellates were found in the 12 sections below Sample 199-1219A-14H-7, 70–71 cm (129.7 mbsf).

SYSTEMATIC PALEONTOLOGY

The synonymies shown here include the first description and representative references that illustrate the development of the species concept for the taxon.

Genus *BACHMANNOCENA* Locker, 1974; emend. Bukry, 1987

Bachmannocena apiculata (Schulz)

Mesocena oamaruensis apiculata Schulz, 1928, p. 240, fig. 11.

Bachmannocena apiculata (Schulz), Bukry, 1987, pp. 403–404; McCartney and Wise, 1990, pl. 2, figs. 6–10; McCartney and Harwood, 1992, pl. 1, fig. 9.

Remarks: *B. apiculata* is commonly present in the samples of the lower Miocene and upper Oligocene section of Hole 1219A. The specimens have three equal sides with small spines at each corner.

A single specimen of this taxon in Sample 199-1219A-5H-2, 70–71 cm (36.7 mbsf), is interpreted as reworked.

Genus *CANNOPILUS* Haeckel, 1887

Cannopilus sphaericus Gemeinhardt

Cannopilus sphaericus Gemeinhardt, 1931, p. 104, pl. 10, figs. 3, 4.

Remarks: A single specimen of this taxon was found in Sample 199-1219A-10H-4, 70–71 cm (see Ciesielski, 1975, p. 669, pl. 2, fig. 1, and Bukry, 1975b, p. 860, pl. 1, fig. 1, for photographs of a similar specimen). The orientation of the specimen did not allow for precise counting of the basal sides, but the number is probably six or seven. McCartney and Wise (1990) found this morphology to be included within a wide range of variation in *Distephanus speculum hemisphaericus*, but the specimen found in this study was an isolated occurrence, without *D. speculum* in the same sample.

Genus *CORBISEMA* Hanna, 1928

Corbisema bimucronata bimucronata (Deflandre)

Corbisema bimucronata Deflandre, 1950, p. 191, figs. 174–177.

Corbisema bimucronata bimucronata Bukry, 1975b, p. 861, pl. 1, fig. 3.

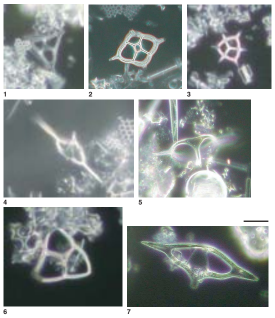
Remarks: *C. bimucronata bimucronata* is characterized by having a robust apical structure and a basal ring with blunt corners that are typically bounded by two small spines. The specimens identified in this study are different from those illustrated by Bukry (1975b, 1978a), Perch-Nielsen (1975), and McCartney and Wise (1987) in that they have straighter sides that lack an indentation of the basal ring where the ring attaches to the apical strut.

Corbisema bimucronata rotatoria (Bukry)

Corbisema bimucronata rotatoria Bukry, 1978a, p. 696, pl. 1, figs. 6, 7.

Remarks: The specimens are very similar to co-occurring *C. bimucronata bimucronata*, but each corner has one side that is extended slightly farther than the other side that forms that corner. When the specimen was viewed from the apical center, the right side was consistently extended farther. The taxon ranges from middle Eocene to lower Oligocene, but is especially abundant in a narrow interval from Sample 199-1219A-21H-4, 70–71 cm, to 21H-6, 70–71 cm (191.0–193.7 mbsf).

P1. Hole 1219A silicoflagellates, p. 28.



Corbisema flexuosa (Stradner)

(Pl. P1, fig. 1)

Corbisema triacantha flexuosa Stradner, 1961, v. 14, no. 2, p. 89, pl. 1, figs. 1–8.

Corbisema flexuosa (Stradner), Bukry, 1975b, p. 853, pl. 1, figs. 4, 5.

Remarks: A single specimen was identified in Sample 199-1219A-23H-4, 70–71 cm (210.7 mbsf).

Corbisema hastata hastata (Lemmermann)

Corbisema triacantha var. *hastata* Lemmermann, 1901, p. 259, pl. 10, figs. 16, 17.

Corbisema hastata (Lemmermann), Ling, 1972, p. 155, fig. 5.

Remarks: Specimens of *C. hastata* were found in the middle Eocene.

Corbisema inermis inermis (Lemmermann)

(Pl. P1, fig. 6)

Dictyocha triacantha var. *inermis* Lemmermann, 1901, p. 259, pl. 10, figs. 16, 17.

Corbisema inermis inermis (Lemmermann), Bukry, 1976a, p. 892, figs. 2, 3.

Remarks: *C. inermis inermis* is a large triangular species with a simple apical structure. Specimens of this study were sporadic and all were found within the Eocene. The specimens of *Corbisema inermis* found in this study have small spines at the corners (see McCartney and Wise, 1987, pl. 1, fig. 16, for a similar specimen).

Corbisema regina Bukry

Corbisema regina Bukry in Barron et al., 1984, p. 150, pl. 2, figs. 5–13.

Remarks: Specimens of *C. regina* were present in the middle Eocene and are dominant in Sample 199-1219A-21H-6, 70–71 cm. This taxon was described from the Kellogg Shale of northern California and has been rarely documented in the deep ocean literature. Barron et al. (1984) state that it is common at Site 356, where it was counted as "*C. triacantha* s. ampl." It has also been found at Sites 406, 553 (Bukry, 1984), 612, 613 (Bukry, 1987), and in Antarctic erratics (Bohaty and Harwood, 2000). The basal ring is very similar to that of *C. triacantha*, but differs in having small pikes and an apical plate. The specimens found in this study generally had thinner struts than those illustrated by Barron et al. (1984).

Corbisema triacantha (Ehrenberg)

Dictyocha triacantha Ehrenberg, 1844, p. 80.

Corbisema triacantha (Ehrenberg), Hanna, 1931, p. 198, pl. D, fig. 1; Bukry and Foster, 1974, p. 305, fig. Ie.

Remarks: This taxon is sporadic from the lower Oligocene to middle Miocene.

Genus *DICTYOCHA* Ehrenberg, 1837

Dictyocha byronalis Bukry

Dictyocha byronalis Bukry in Barron et al., 1984, p. 151, pl. 3, figs. 1–4.

Remarks: Specimens of this taxon have an apical structure that is tilted slightly away from the minor axis.

Dictyocha extensa extensa (Locker)

Dictyocha varia f. *extensa* Locker, 1975, pp. 99–101, figs. 1/2, 3/3.

Dictyocha extensa (Locker), Locker and Martini, 1986, pp. 903–904, pl. 2, figs. 10–12; pl. 11, fig. 3.

Dictyocha extensa extensa (Locker), McCartney et al., 1995, p. 146, pl. 3, figs. 2–5; pl. 5, figs. 3, 7; pl. 8, fig. 8.

Dictyocha fibula ausonia (Deflandre)

Dictyocha ausonia Deflandre, 1950, p. 195, figs. 194–196, 199–202.

Dictyocha brevispina ausonia (Deflandre), Bukry, 1978a, p. 697, pl. 1, figs. 17–19; McCartney et al., 1995, p. 147, pl. 2, figs. 2–4; pl. 3, fig. 11; pl. 5, fig. 4.

Remarks: McCartney et al. (1995) describe the changing interpretation of *Dictyocha fibula* and propose that *D. fibula* be applied to four-sided silicoflagellates that have a bridge parallel to the minor axis, and they use *D. fibula ausonia*, *D. fibula fibula*, and *Dictyocha fibula mutabilis* as subspecies. In previous papers, McCartney (see McCartney et al., 1995, for references) followed the usage of Bukry and others in applying this name to four-sided silicoflagellates that had a bridge parallel to the major axis. This paper continues the usage of McCartney et al. (1995), and the reader is referred there for information on these taxa.

Dictyocha fibula fibula Ehrenberg

Dictyocha fibula Ehrenberg, Locker, 1974, p. 636, pl. 1, fig. 6 (= lectotype).

Dictyocha fibula fibula Ehrenberg, Locker and Martini, 1986, p. 904, pl. 5, figs. 1, 2; pl. 11, figs. 8, 9.

Remarks: For a discussion on *D. fibula fibula* see McCartney et al. (1995).

Dictyocha fibula mutabilis (Deflandre)

Dictyocha mutabilis Deflandre, 1950, pl. 18, figs. 7–14.

Dictyocha brevispina (Lemmermann), Bukry, 1976c, p. 723.

Dictyocha brevispina brevispina (Lemmermann), Bukry, 1978b, p. 816, pl. 2, figs. 9, 10; McCartney et al., 1995, p. 147.

Remarks: For a discussion on *D. mutabilis*, see McCartney et al., 1995.

Dictyocha hexacantha Schulz
(Pl. P1, fig. 3)

Dictyocha hexacantha Schulz, 1928, p. 255, fig. 43; Bukry, 1975b, pl. 4, figs. 1, 2; Ciesielski, 1991, pl. 7, fig. 3 (note: good photograph of inclined specimen).

Remarks: *D. hexacantha* differs from *D. spinosa* because the extra spines are mounted on the basal ring rather than the apical structure.

Dictyocha medusa Haeckel

Dictyocha medusa Haeckel, 1887, pl. 101, figs. 13, 14; Perch-Nielsen, 1975, pl. 4, figs. 4, 5; pl. 15, figs. 5–7.

Remarks: Haeckel's (1887) illustration of this taxon shows four struts that meet to form an X intersection without a bridge. Bukry and Foster (1973) and others apply this taxon to silicoflagellate skeletons in the Miocene and Pliocene that have a rhomboid basal ring and a very short to nonexistent apical bridge. Mandra (1968) found a similar morphology in the upper Miocene of Southern California, which he called *Dictyocha staurodon*, although the type specimen for *D. staurodon* (Ehrenberg, 1844; see Loeblich et al., 1968, pl. 24, fig. 18) has a very small apical window. These occurrences are typically infrequent, and we believe that they are variants of co-occurring *D. fibula* or *D. extensa* (see McCartney et al., 1995, p. 146).

Perch-Nielsen (1975) has applied *D. medusa* to a group of silicoflagellates that have a quadrate basal ring and short apical bridge. Perch-Nielsen found this taxon to be quite abundant, composing about half the total silicoflagellates in the lower and upper Eocene of DSDP Hole 280A and less abundant at several other sites from Leg 29. She notes that *D. medusa* is quite variable, with graduations toward *D. crux*. We find a very similar silicoflagellate in the middle Miocene of Hole 1219A, which we call *D. medusa*, as applied by Perch-Nielsen. We do not believe this taxon to be the same species as the *D. medusa* used by Bukry and Foster (1973), which is from the upper Miocene.

Dictyocha spinosa (Deflandre)

Corbisema spinosa Deflandre, 1950, p. 193, figs. 178–182; Glezer, 1966, p. 238, pl. 10, figs. 6–8; McCartney and Wise, 1987, pl. 1, fig. 6; McCartney and Wise, 1990, pl. 2, fig. 2.

Remarks: *D. spinosa* has three spines on the apical structure. This taxon is found in a short interval from Sample 199-1219A-21H-6, 70–71 cm, to 21H-4, 70–71 cm, and is included here as a subzone of the *D. hexacantha* Zone. There is a probable evolutionary connection between *D. spinosa*, *D. hexacantha*, *Dictyocha deflandrei*, and *Dictyocha frenguellii*, but a core sequence in which most or all of these taxa occur that could be used to document the evolutionary relationships has so far not been found. *D. spinosa* usually appears earlier and disappears later than *D. hexacantha* (McCartney and Wise, 1987), but, in this study, *D. spinosa* is observed over a more narrow interval than *D. hexacantha*.

Dictyocha varia Locker

Dictyocha varia Locker, 1975, pp. 99–101, figs 3–7.

Dictyocha pulchella Bukry, 1975a, p. 687, pl. 4, figs. 1–3.

Dictyocha varia Locker, McCartney et al., 1995, p. 148, pl. 3, fig. 1; pl. 5, fig. 2; pl. 8, fig. 6.

Remarks: Specimens of *D. varia* were much less abundant in this study than for Leg 138 (McCartney et al., 1995), wherein this taxon was very abundant and predominant.

Genus *DISTEPHANUS* Stohr, 1880

Distephanus crux crux Ehrenberg

Distephanus crux Ehrenberg, 1840, p. 207; Ehrenberg, 1854, pl. 18, fig. 56; pl. 33(XV), fig. 9.

Distephanus crux hannai Bukry

(Pl. P1, fig. 2)

Distephanus crux hannai Bukry, 1975b, p. 855, pl. 4, figs. 4–6; see also Bukry, 1975a, pl. 2, figs. 2, 3.

Remarks: *D. crux hannai* is distinguished by a very small apical ring. The taxon was found in a narrow interval, Sample 199-1219A-6H-4, 70–71 cm, to 6H-1, 70–71 cm (44.7–49.2 mbsf), from the lower Miocene. The specimens found in this study typically had a rhomboid basal ring.

Distephanus longispinus (Schulz)

Distephanus crux f. *longispinus* Schulz, 1928, p. 256, fig. 44.

Distephanus longispinus (Schulz), Bukry and Foster, 1973, p. 828, pl. 4, figs. 7, 8.

Remarks: Only rare specimens of this taxon were found in the middle Miocene of Hole 1219A.

Distephanus speculum speculum (Ehrenberg)

Dictyocha speculum Ehrenberg, 1840; Ehrenberg, 1854, pl. 18, fig. 57; pl. 19, fig. 41; pl. 21, fig. 44; pl. 22, fig. 47.

Distephanus speculum (Ehrenberg), Haeckel, 1887, p. 1565.

Distephanus speculum speculum (Ehrenberg), Bukry and Foster, 1973, p. 828, pl. 5, fig. 8.

Remarks: Multi-windowed skeletons of this taxon were not counted separately, as only five specimens were found and all were found in the upper Oligocene section.

Distephanus stauracanthus f. *stauracanthus* (Ehrenberg)

Distephanus stauracanthus (Ehrenberg), Haeckel, 1887, v. 18, p. 1564; Locker and Martini, 1986, p. 907.

Remarks: One specimen of this unusual taxon was found in Sample 199-1219A-2H-7, 70–71 cm (middle Miocene). This occurrence is of similar age to a horizon described by Martini (1972, see also Locker and Martini, 1986) and found in the middle Miocene section of Leg 138 (McCartney et al., 1995).

Distephanus stauracanthus f. *octagonus* (Tsumara)

Dictyocha fibula var. *octagona* Tsumara, 1963, pl. 2, fig. 4; pl. 10, figs. 11–13; pl. 23, figs. 8–10.

Dictyocha octagona (Tsumara), Martini, 1971, p. 1697, pl. 1, fig. 15.

Distephanus stauracanthus f. *octagonus* (Tsumara), Locker and Martini, 1986, p. 907, pl. 6, fig. 8.

Remarks: This taxon is distinguished by its eight-sided basal ring which displays eight equant spines. It differs from *D. stauracanthus stauracanthus* because it has an inclined dictyochid bridge rather than a cruxoid apical ring, characteristic of *D. crux*.

Genus *NAVICULOPSIS* Frenguelli, 1940

Naviculopsis biapiculata (Lemmermann)
(Pl. P1, fig. 5)

Dictyocha navicula biapiculata Lemmermann, 1901, p. 258, pl. 10, figs. 14, 15.

Naviculopsis biapiculata (Lemmermann), Bukry, 1978c, p. 787, pl. 3, figs. 9, 10; McCartney and Harwood, 1992, p. 825, pl. 1, figs. 3, 7, 8.

Remarks: This taxon has considerable variability, especially in the width and size of the basal ring and the size of the basal spines. The basal ring is oval to elongate with spine lengths that are less than length of the basal ring. The bridge extends higher in comparison to *N. constricta* and *Naviculopsis eobiapiculata*. The apical bridge width is usually ~5 µm with a gradual increase toward the basal ring. Some specimens (see Pl. P1, fig. 5) possess a portal in the expanded area where the bridge attaches to the basal ring.

Transitional specimens between *N. constricta* and *N. lata* were also found. Multiple specimens were found to have windows within the bridge near the basal ring as illustrated by Bukry (1980b, p. 565, pl. 5, fig. 11). Bukry called these "*Dictyocha* sp. (naviculopsoid)," but we consider them as a variation within the *Naviculopsis* species. Also, Bachmann (1970, p. 295, pl. 2, figs. 6–8, 11, 13) illustrates windows within variations of *N. lata* that are very similar to the specimens of *N. biapiculata,* illustrated in this study. Ciesielski (1991, p. 96, pl. 10, figs. 8, 9) has two very similar figures of the windowed varieties of *N. biapiculata*.

Bukry (1978a) provides a drawing showing the proportional difference between *N. biapiculata*, *N. lata*, and *Naviculopsis quadrata*.

Naviculopsis constricta (Schulz)

Dictyocha navicula biapiculata constricta Schulz, 1928, p. 246, fig. 21.

Naviculopsis constricta (Schulz), Bukry, 1975b, p. 856, pl. 7, figs. 1, 2; McCartney and Wise, 1987, p. 807, pl. 5, figs. 1, 2.

Remarks: *N. constricta* is characterized by an elongate basal ring with sides that are parallel but slightly constricted at the apical bridge. The basal spines are half the length of the basal ring maximum or longer. The width of the apical bridge varies considerably among our specimens. *N. constricta* was differentiated from *N. foliacea* in having windows that were longer than the width of the bridge.

Specimens of *N. constricta* were very abundant in Sample 199-1219A-14H-6, 70–71 cm (128.2 mbsf), with some skeletons having a narrow basal ring with very long basal spines.

Naviculopsis foliacea Deflandre

Naviculopsis foliacea Deflandre, 1950, p. 204, figs. 235–240; McCartney and Wise, 1987, p. 807, pl. 5, figs. 3, 4; see also p. 807, fig. 2.

Remarks: *N. foliacea* is typified by an apical bridge that has a width of two-thirds or more of the interior length of the basal ring. *N. foliacea* was very abundant in Sample 199-1219A-14H-6, 70–71 cm (128.2 mbsf), but otherwise was very rare.

A single specimen of this taxon in Sample 199-1219A-4H-7, 70–71 cm (34.5 mbsf), is interpreted as reworked.

Naviculopsis lacrima Bukry

Naviculopsis lacrima Bukry, 1982, p. 443, pl. 7, figs. 1–10.

Remarks: Two unusual specimens that we identify as *N. lacrima* were observed in Sample 199-1219A-14H-6, 70–71 cm (128.2 mbsf). The shape of these skeletons is very similar to what Bukry (1982) described and illustrated, although the bridge is connected to the basal ring by struts that create a window on each side. The basal ring is elongate (90 µm), slender (15 µm), and biconvex. The spines are ~20 µm, and the length of the basal ring is 45 µm.

Naviculopsis lata (Deflandre)

Dictyocha biapiculata lata Deflandre, 1932, p. 500, figs. 30, 31.

Naviculopsis lata (Deflandre), Ling, 1972 (in part), p. 185, pl. 30, figs. 12–14; Bukry, 1975b, p. 856, pl. 7, fig. 4.

Remarks: Like *N. biapiculata* (see **"*Naviculopsis biapiculata* [Lemmermann],"** p. 12), *N. lata* was found to have considerable variability, with the shape of the basal ring ranging from elongate to circular. Bukry (1978a, p. 698, fig. 3) proposed morphometric criteria to assist in distinguishing *N. lata*, *N. biapiculata*, and *N. quadrata*. He suggested that *N. lata* has a spine length less than half the length of the basal ring. We used this criterion for separating the species, but there were transitional forms in which the separation was difficult. We did not observe specimens with the sharply angled corners typical of *N. quadrata*.

Naviculopsis ponticula (Ehrenberg)

Dictyocha ponticulus Ehrenberg, 1844, pp. 258, 267; Bailey, 1845, pl. 4, fig. 21.

Naviculopsis ponticula (Ehrenberg), Bukry, 1978b, p. 821, pl. 8, figs. 9, 10.

Naviculopsis obtuscarca Bukry, 1978b, p. 821; type specimen in Bukry, 1978a, p. 709, pl. 3, fig. 4.

Naviculopsis ponticula ponticula Bukry, 1982, p. 431, pl. 8, figs. 11, 12; pl. 9, fig. 1.

Naviculopsis ponticula spinosa Bukry, 1982, p. 434, pl. 9, figs. 2–6.

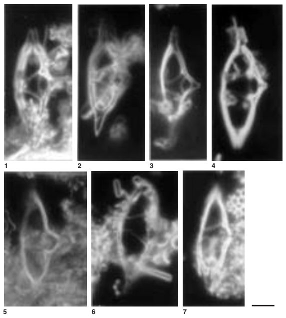
Remarks: There is considerable variation in this group, which Bukry (1978b, 1982) has subdivided into several taxa. In the Hole 1219A assemblages, we observe most of the range of variation listed in the synonymy but were unable to consistently divide into the taxa described by Bukry (1982). This variation, also discussed by McCartney and Wise (1990), occurs on the axial end of the basal ring. There is typically a flattened termination of the axial end of the basal ring, although some specimens with a round axial end (see Bukry, 1982, pl. 9, fig. 6) were counted as *N. ponticula* because of the presence of a spine. The counts for *N. ponticula* also include some skeletons that are similar to *Naviculopsis contraria* (Bukry, 1982, p. 442, pl. 6, figs. 5–13), but we believe these morphologies to be part of the range of variation for *N. ponticula*.

Specimens that appeared to be transitional between *N. ponticula* and *Naviculopsis navicula* were found in Sample 199-1219A-4H-4, 70–71 cm (30.2 mbsf). *N. navicula* has an elongate basal ring with a rounded termination of the long-axis ends, without a spine, although Bukry (1976a) states that rare specimens with spines do occur. Bukry (1982) shows that this morphology occurs at the bottom of the *N. ponticula* Zone, suggesting that *N. navicula* has some biostratigraphic value and may be the evolutionary ancestor of *N. ponticula*.

Naviculopsids of similar shape, with large basal ring and long spines, have been illustrated in the early DSDP literature (e.g., Bukry and Foster, 1973, pl. 3, figs. 6, 7) but are here believed to be *Neonaviculopsis neonautica* (Locker and Martini, 1986). *Neonaviculopsis* was found by McCartney et al. (1995) in the upper Miocene section of Hole 850B, which is of similar age to the occurrence documented by Bukry and Foster.

Naviculopsis trigeminus McCartney and Engel n. sp.

(Pl. P1, fig. 7; Pl. P2, figs. 1–7)



P2. *Naviculopsis trigeminus* n. sp., p. 29.

Diagnosis: Elongate, asymmetrical basal ring with two major spines and a minor spine on one side of the ring, surmounted by a wide Y-shaped apical bridge.

Description: *Naviculopsis trigeminus* has an elongate basal ring typical of *Naviculopsis,* with both major axis spines and one minor axis spine positioned at the midpoint along one side of the specimen. The major-axis spines are unusually wide where they attach to the end of the basal ring and sometimes appear to be flattened. The minor-axis spine is much smaller. The side with the minor-axis spine is more representative of the genus *Dictyocha* than *Naviculopsis*, in having two struts with a portal. From an abapical view, there are pikes directly beneath the strut attachments on the "*Dictyocha*" side of the specimen but not on the side that lacks struts. The struts support a wide flattened bridge that has the shape of a triangular plate. The portal between the struts is typically small. The side without the struts and spine is elongate and usually has a constriction at the connection to the bridge similar to that of *N. constricta*.

Remarks: Sixteen specimens were found in two microscope slides. This number and similarity among the specimens preclude the possibility that this unusual morphology is teratoid. There were no intermediates between *N. trigeminus* and *N. constricta* found in Sample 199-1219A-23H-5, 70–71 cm (212.2 mbsf), in the middle Eocene.

N. trigeminus is distinguished from *Dictyocha elongata* Glezer (1966; see also Bukry, 1978b, pl. 1, fig. 18; pl. 2, figs. 1–3, from the late Paleocene) by a wider apical apparatus and a narrower minor-axis width. Most of the *D. elongata* specimens illustrated by Bukry (1978b) have three much more equal sized sides and spines, although the specimen illustrated by Bukry (1978b, pl. 2, fig. 3) is generally similar to *N. trigeminus* but lacks the larger apical plate and flattened basal major-axis spines. *Naviculopsis danica* (Perch-Nielsen, 1976; see also Bukry, 1978b, pl. 3, fig. 15) has a morphology similar to *N. trigeminus* but has a narrow bridge with three or four narrow struts, longer major-axis spines, and no third spine. Both *D. elongata* and *N. danica* are found in the upper Paleocene, which could suggest possible ecophenotypic or evolutionary relationships.

Perch-Nielson (1976) described two unusual *Naviculopsis* from the *D. hexacantha* Zone. *Naviculopsis punctilia* (see also Bukry, 1976b, pl. 2, fig. 3) is strutted on both sides but has much longer and narrower basal spines and commonly lacks minor-axis spines, although some specimens do have small minor-axis spines. *N. punctilia* also has a bar extending across the width of the skeleton rather than the wide triangular plate typical of *N. trigeminus*. *Naviculopsis vemae* has extraordinary variability, both in the shape of the basal ring and the apical bridge, although the struts are typically not at the midpoint of the basal ring and do not have the plate found on *N. trigeminus*. *N. punctilia* and *N. vemae* appear more closely related to one another than either specimen is to *N. trigeminus*.

Martini (1976) described an ebridian, *Micromarsupium rostovense* from the lower Oligocene of the Rostov area of Russia, that has a general configuration similar to *N. trigeminus*. The ebridian is elongate with two attaching struts on one side that are close together and form a small portal and a longer strut that attaches to the other side of the ring. The ebridian, however, does not have spines of any type and the "apical structure" is not centered between the two ends of the ring. There are other obvious differences, but the general similarities are interesting.

Occurrence: *N. trigeminus* is found in the middle Eocene in the equatorial Pacific Ocean.

Size: Most of the observed specimens were measured. The length between the tips of the two major spines ranged from 36 to 50 µm and from 12 to 22 µm across the width of the basal ring including the minor spine. The length of the portal opening between the two struts was 4–8 µm. The holotype has a major-axis length of 44 µm and a minor-axis length of 18 µm.

Holotype: Plate **P1,** fig. 7.

Repository: The microscope slide containing the holotype is located at the California Academy of Sciences (CAS) Diatom Collection, slide CAS #221085.

Type Locality: Equatorial Pacific Ocean, Sample 199-1219A-23H-5, 70–71 cm.

Naviculopsis trispinosa

(Pl. **P1,** fig. 4)

Dictyocha navicula trispinosa Schulz, 1928, p. 246, fig. 23a, 23b.

Naviculopsis trispinosa (Schulz), Glezer, 1966, v. 7, p. 277, pl. 17, fig. 7; Bukry, 1975b, p. 857, pl. 7, figs. 5–7.

Remarks: The two specimens assigned to *N. trispinosa* in this study are closely similar to *N. biapiculata* but possess a long apical spine of a length approximately similar to the basal spine lengths. Excellent photographs of this unusual species can be found in Perch-Nielsen (1976, pl. 13). McCartney and Wise (1990) noted a possible correlation between the presence of this taxon and five-sided *Distephanus*, but no similar correlation was found in this study.

ACKNOWLEDGMENTS

This research used samples provided by the Ocean Drilling Program (ODP). ODP is sponsored by the U.S. National Science Foundation (NSF) and participating countries under management of Joint Oceanographic Institutions (JOI), Inc. Funding for this research was provided by U.S. Science Advisory Committee (USSAC). Preliminary study of the samples was part of a sabbatical at the University of Maine at Presque Isle. We thank Tracy Reed and Rita Williamson for assistance in preparing samples, Robert Longlais for assistance in developing the pictures used on Plate P2, and Steven Bohaty and Reed Scherer for their thorough reviews of the manuscript. The detailed analysis of the samples was part of an undergraduate research study at the Micropaleontology Undergraduate Laboratory at the University of Maine at Presque Isle. This is publication No. 7 of the Micropaleontology Undergraduate Research Lab.

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Figure F1. Location maps (Shipboard Scientific Party, 2002) showing (**A**) sites drilled during Leg 199, including other ODP and DSDP holes in the region superimposed on the bathymetry and (**B**) Leg 199 drill sites superimposed on the approximate position of magnetic Anomaly An25n (58.9–56.4 Ma; red). Gray shading = seafloor depths >5000 mbsl. F.Z. = fracture zone.

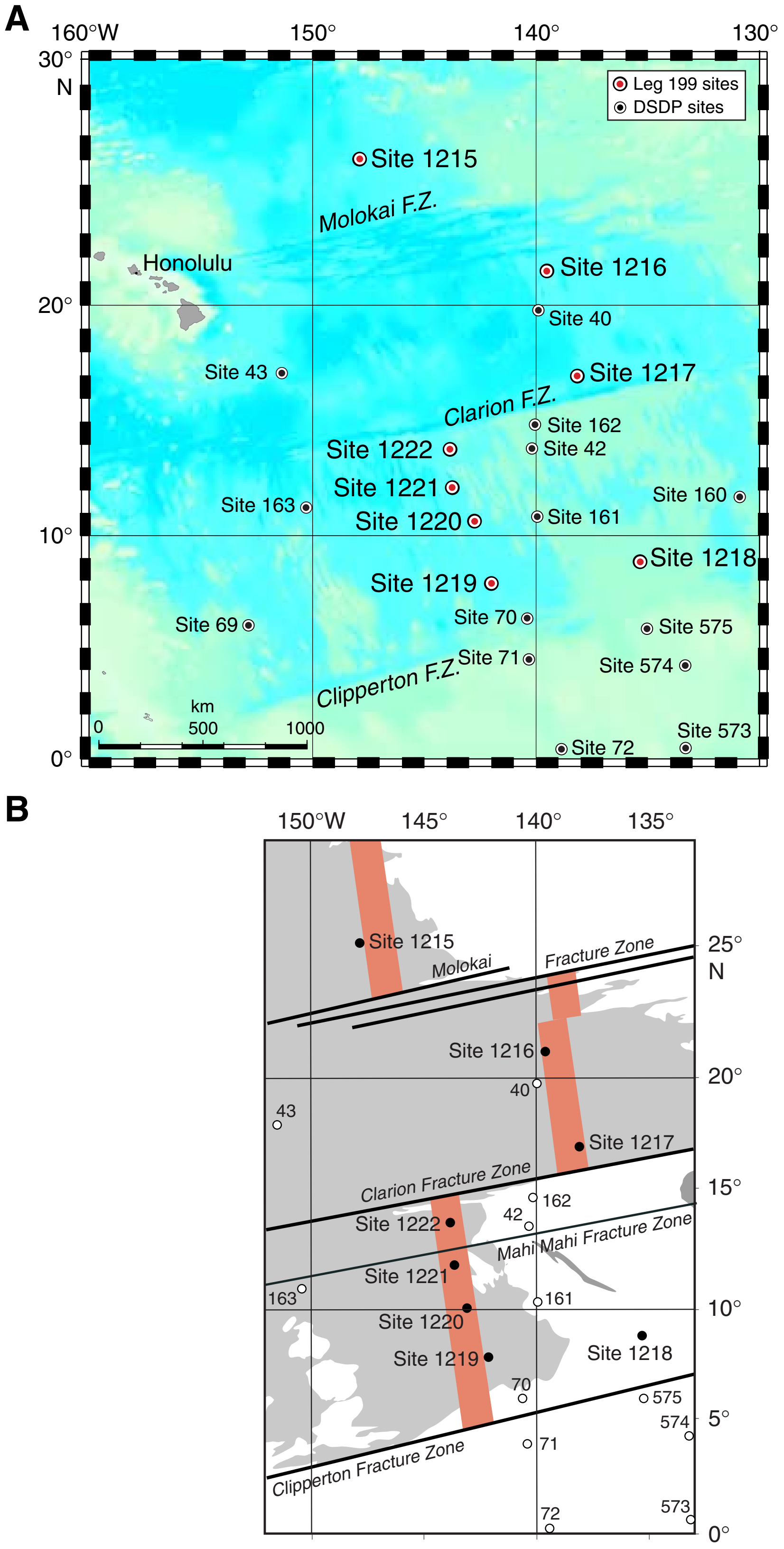

Figure F2. Silicoflagellate zonation used for Leg 199. * = first appearance, † = last appearance.

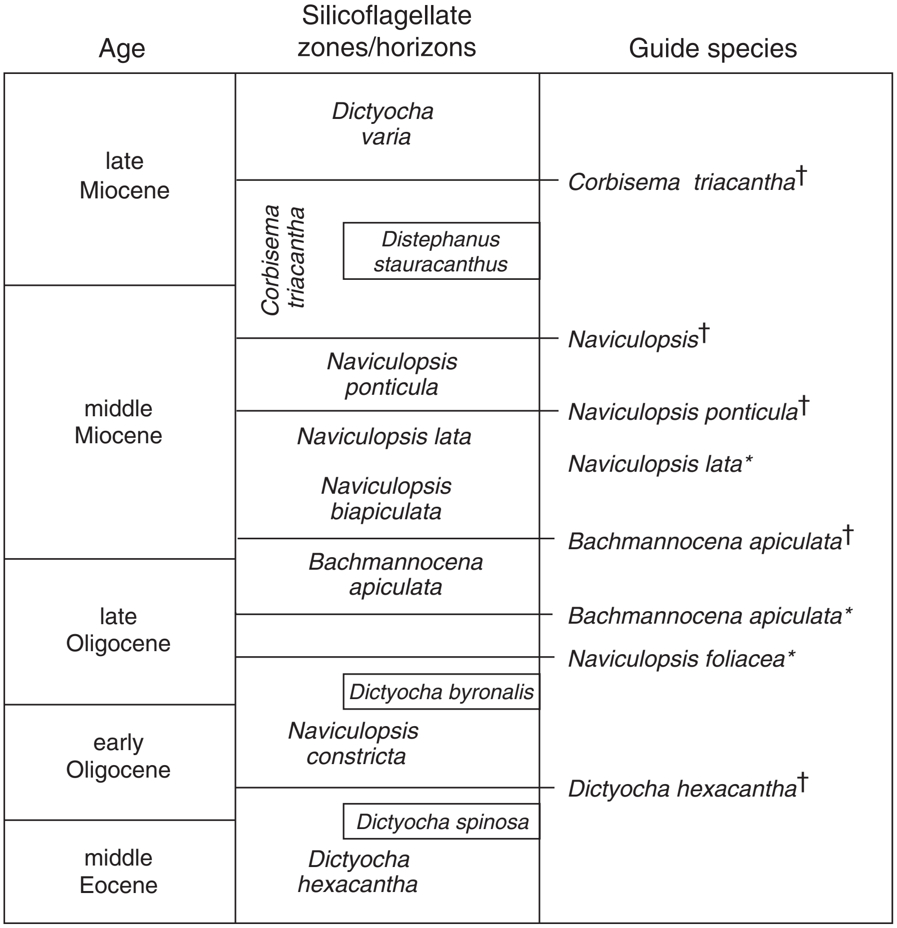

Table T1. Abundance of silicoflagellates in selected samples, Hole 1219A. (Continued on next five pages.)

Age	Zone	Lithologic unit	Core, section, interval (cm)	Depth (mbsf)	Slide	*Bachmannocena apiculata*	*Cannopilus sphaericus*	*Corbisema bimucronata*	*Corbisema bimucronata rotatoria*	*Corbisema flexuosa*	*Corbisema hastata*	*Corbisema hexacantha*	*Corbisema inermis inermis*	*Corbisema regina*	*Corbisema triacantha*	*Dictyocha byronalis*	*Dictyocha extensa*	*Dictyocha fibula ausonia*	*Dictyocha fibula fibula*	*Dictyocha fibula mutabilis*	*Dictyocha medusa*	*Dictyocha spinosa*	*Dictyocha varia*	*Distephanus crux crux*	*Distephanus crux hannai*
middle Miocene	*Dictyocha varia*	Unit I	199-1219A-																						
			1H-1, 70–71	0.7	1.0																				
			1H-2, 70–71	2.2	1.0																				
			1H-3, 70–71	3.7	1.0																				
			1H-4, 70–71	5.2	1.0																				
			2H-1, 70–71	6.7	1.0																				
			2H-2, 70–71	8.2	1.0														11					1	
			2H-3, 70–71	9.7	1.0														5				2		
			2H-4, 70–71	11.2	1.0																				
			2H-5, 70–71	12.7	1.0														36					6	
	Corbisema triacantha		2H-6, 70–71	14.2	1.0										2				25		1			1	
	Distephanus stauracanthus Horizon		2H-7, 70–71	15.7	1.0												1	1	13		1			2	
	Corbisema triacantha		3H-1, 70–71	16.2	1.0										2			16	22	5	1				
			3H-2, 70–71	17.7	1.0										2			2	12		3				
			3H-3, 70–71	19.2	1.0										1		10	2	15				7		
			3H-4, 70–71	20.7	1.0												2		4						
early Miocene			3H-5, 70–71	22.2	1.0										1				2						
			3H-6, 70–71	23.7	1.0														2						
			4H-1, 80–81	25.8	1.0													1	3					3	
	Naviculopsis ponticula		4H-2, 70–71	27.2	1.0										2									5	
			4H-3, 66–67	28.7	1.0																			1	
		Unit II	4H-4, 70–71	30.2	1.0																			14	
	Naviculopsis lata		4H-5, 70–71	31.7	1.0														2	13				2	
			4H-6, 70–71	33.2	1.0																			8	
			4H-7, 50–51	34.5	1.0																				
	Naviculopsis biapiculata		5H-1, 70–71	35.2	1.0																				
			5H-2, 70–71	36.7	1.0	1																	8		
			5H-3, 70–71	38.2	1.0																		8	2	
			5H-4, 70–71	39.7	1.0																				
			5H-5, 70–71	41.2	1.0																				
			5H-6, 70–71	42.7	1.0																			1	
			5H-7, 70–71	44.2	1.0																				
			6H-1, 70–71	44.7	1.0												1								4
			6H-2, 70–71	46.2	1.0																			2	9
	Bachmannocena apiculata		6H-3, 70–71	47.7	1.0	1																			2
			6H-4, 70–71	49.2	1.0	2													1				1	2	3
late Oligocene			7H-3, 70–71	57.0	1.0	5																			
			7H-4, 70–71	58.5	1.0	9																			
			7H-5, 70–71	60.0	1.0																			6	
			7H-6, 29–30	61.1	1.0	2																			
			8H-1, 69–70	63.7	1.0																				
			8H-2, 70–71	65.2	1.0	1																			
			8H-3, 70–71	66.7	1.0	3																			
			8H-4, 70–71	68.2	1.0	3																			
			8H-5, 70–71	69.7	1.0	2																			
	UNZONED		8H-6, 70–71	71.2	1.0																				
			8H-7, 70–71	72.7	1.0										5										
			9H-1, 70–71	73.2	1.0										1										
			9H-2, 70–71	74.7	1.0										3										
			9H-3, 70–71	76.2	1.0																				

Table T1 (continued).

Age	Zone	Lithologic unit	Core, section, interval (cm)	Depth (mbsf)	Slide	*Distephanus longispinus*	*Distephanus speculum speculum*	*Distephanus stauracanthus* f. *octagonus*	*Distephanus stauracanthus* f. *stauracanthus*	*Naviculopsis biapiculata*	*Naviculopsis* cf. *biapiculata*	*Naviculopsis biapiculata/foliacea*	*Naviculopsis constricta*	*Naviculopsis foliacea*	*Naviculopsis lacrima*	*Naviculopsis lata*	*Naviculopsis* cf. *lata*	*Naviculopsis ponticula*	*Naviculopsis trigeminus* n. sp.	*Naviculopsis trispinosa*	Total silicoflagellates
middle Miocene	*Dictyocha varia*	Unit I	199-1219A-																		
			1H-1, 70–71	0.7	1.0																0
			1H-2, 70–71	2.2	1.0																0
			1H-3, 70–71	3.7	1.0																0
			1H-4, 70–71	5.2	1.0																0
			2H-1, 70–71	6.7	1.0																0
			2H-2, 70–71	8.2	1.0		1														13
			2H-3, 70–71	9.7	1.0																7
			2H-4, 70–71	11.2	1.0																0
			2H-5, 70–71	12.7	1.0		1														43
	Corbisema triacantha		2H-6, 70–71	14.2	1.0	3			1												33
	Distephanus stauracanthus Horizon		2H-7, 70–71	15.7	1.0			1													19
	Corbisema triacantha		3H-1, 70–71	16.2	1.0			1													47
			3H-2, 70–71	17.7	1.0	1															20
			3H-3, 70–71	19.2	1.0		1														36
			3H-4, 70–71	20.7	1.0																6
early Miocene			3H-5, 70–71	22.2	1.0																3
			3H-6, 70–71	23.7	1.0																2
			4H-1, 80–81	25.8	1.0																7
	Naviculopsis ponticula		4H-2, 70–71	27.2	1.0		17											11			35
			4H-3, 66–67	28.7	1.0		1			20								9			31
		Unit II	4H-4, 70–71	30.2	1.0	3				2								32			51
	Naviculopsis lata		4H-5, 70–71	31.7	1.0		1			12						9					39
			4H-6, 70–71	33.2	1.0		4			64						10					86
			4H-7, 50–51	34.5	1.0		3			17				1		14					35
	Naviculopsis biapiculata		5H-1, 70–71	35.2	1.0						13			1			17				31
			5H-2, 70–71	36.7	1.0		4														13
			5H-3, 70–71	38.2	1.0		22														32
			5H-4, 70–71	39.7	1.0																0
			5H-5, 70–71	41.2	1.0																0
			5H-6, 70–71	42.7	1.0																1
			5H-7, 70–71	44.2	1.0																0
			6H-1, 70–71	44.7	1.0		1			3											9
			6H-2, 70–71	46.2	1.0					3					2						16
	Bachmannocena apiculata		6H-3, 70–71	47.7	1.0		2														5
			6H-4, 70–71	49.2	1.0		7														16
late Oligocene			7H-3, 70–71	57.0	1.0		8														13
			7H-4, 70–71	58.5	1.0		15														24
			7H-5, 70–71	60.0	1.0		5			2											13
			7H-6, 29–30	61.1	1.0		7														9
			8H-1, 69–70	63.7	1.0		2														2
			8H-2, 70–71	65.2	1.0		6														7
			8H-3, 70–71	66.7	1.0		12			2											17
			8H-4, 70–71	68.2	1.0		17			4											24
			8H-5, 70–71	69.7	1.0		17			45											64
	UNZONED		8H-6, 70–71	71.2	1.0		1			3											4
			8H-7, 70–71	72.7	1.0		6														11
			9H-1, 70–71	73.2	1.0		7														8
			9H-2, 70–71	74.7	1.0																3
			9H-3, 70–71	76.2	1.0																0

Table T1 (continued).

Age	Zone	Lithologic unit	Core, section, interval (cm)	Depth (mbsf)	Slide	*Bachmannocena apiculata*	*Cannopilus sphaericus*	*Corbisema bimucronata*	*Corbisema bimucronata rotatoria*	*Corbisema flexuosa*	*Corbisema hastata*	*Corbisema hexacantha*	*Corbisema inermis inermis*	*Corbisema regina*	*Corbisema triacantha*	*Dictyocha byronalis*	*Dictyocha extensa*	*Dictyocha fibula ausonia*	*Dictyocha fibula fibula*	*Dictyocha fibula mutabilis*	*Dictyocha medusa*	*Dictyocha spinosa*	*Dictyocha varia*	*Distephanus crux crux*	*Distephanus crux hannai*
late Oligocene	UNZONED	Unit II	199-1219A-												11										
			9H-4, 70–71	77.7	1.0																				
			9H-5, 70–71	79.2	1.0																				
			9H-6, 70–71	80.7	1.0																				
			9H-7, 70–71	82.2	1.0										1										
			10H-3, 70–71	85.7	1.0		1								45										
			10H-4, 70–71	87.2	1.0																				
early Oligocene			10H-5, 70–71	88.7	1.0										1										
			10H-6, 70–71	90.2	1.0																				
			11H-1, 70–71	92.2	1.0																				
			11H-2, 70–72	93.7	1.0																				
			11H-3, 70–71	95.2	1.0																				
			11H-4, 70–71	96.7	1.0																				
			11H-5, 70–71	98.2	1.0																				
			11H-6, 70–71	99.7	1.0																				
			12H-1, 70–71	101.7	1.0																				
			12H-2, 70–71	103.2	1.0																				
			12H-3, 70–71	104.7	1.0																				
			12H-4, 70–71	106.2	1.0																				
			12H-5, 70–71	107.7	1.0																				
			12H-7, 70–71	110.7	1.0											3									
			13H-1, 70–71	111.2	1.0										1	5									
			13H-2, 70–71	112.7	1.0																			1	
			13H-3, 70–71	113.8	1.0																				
			13H-4, 70–71	115.2	1.0																			1	
			13H-5, 70–71	116.8	1.0																				
			13H-6, 70–71	118.3	1.0																				
			13H-7, 29–30	119.4	1.0																				
			14H-1, 70–71	120.7	1.0										8										
			14H-2, 71–72	122.2	1.0																				
			14H-3, 70–71	123.7	1.0																				
			14H-4, 70–71	125.2	1.0										7										
			14H-5, 70–71	126.7	1.0										4										
	Dictyocha hexacantha		14H-6, 70–71	128.2	1.0										85						1				
			14H-7, 70–71	129.7	1.0										3									2	
			15H-1, 71–72	130.2	1.0										1										
			15H-2, 71–72	131.7	1.0																				
			15H-3, 70–71	133.2	1.0																				
			15H-4, 71–72	134.7	1.0											1									
	Dictyocha byronalis Horizon		15H-5, 71–72	136.2	1.0										2	24									
			15H-6, 71–72	137.7	1.0			5	1				1		2	22								1	
			15H-7, 55–56	139.1	1.0											14									
	Dictyocha hexacantha		16H-1, 70–71	139.7	1.0														2						
			16H-2, 70–71	141.3	1.0																				
			16H-3, 70–71	142.8	1.0																				
			16H-4, 70–71	144.2	1.0																				
			16H-5, 70–71	145.8	1.0																				
			16H-6, 70–71	147.3	1.0																				
middle Eocene		Unit III	17H-1, 70–71	149.2	1.0																				
			17H-2, 70–71	150.7	1.0																				
			17H-3, 70–71	151.7	1.0																				
			17H-4, 70–71	152.6	1.0																				
			17H-5, 70–71	154.1	1.0										11										

Table T1 (continued).

Age	Zone	Lithologic unit	Core, section, interval (cm)	Depth (mbsf)	Slide	*Distephanus longispinus*	*Distephanus speculum speculum*	*Distephanus stauracanthus* f. *octagonus*	*Distephanus stauracanthus* f. *stauracanthus*	*Naviculopsis biapiculata*	*Naviculopsis* cf. *biapiculata*	*Naviculopsis biapiculata/foliacea*	*Naviculopsis constricta*	*Naviculopsis foliacea*	*Naviculopsis lacrima*	*Naviculopsis lata*	*Naviculopsis* cf. *lata*	*Naviculopsis ponticula*	*Naviculopsis trigeminus* n. sp.	*Naviculopsis trispinosa*	Total silicoflagellates
			199-1219A-																		
late Oligocene	UNZONED	Unit II	9H-4, 70–71	77.7	1.0		1														12
			9H-5, 70–71	79.2	1.0																0
			9H-6, 70–71	80.7	1.0																0
			9H-7, 70–71	82.2	1.0																0
			10H-3, 70–71	85.7	1.0																1
			10H-4, 70–71	87.2	1.0					2											48
early Oligocene			10H-5, 70–71	88.7	1.0																0
			10H-6, 70–71	90.2	1.0																1
			11H-1, 70–71	92.2	1.0																0
			11H-2, 70–72	93.7	1.0																0
			11H-3, 70–71	95.2	1.0																0
			11H-4, 70–71	96.7	1.0																0
			11H-5, 70–71	98.2	1.0																0
			11H-6, 70–71	99.7	1.0						6										6
			12H-1, 70–71	101.7	1.0																0
			12H-2, 70–71	103.2	1.0																0
			12H-3, 70–71	104.7	1.0																0
			12H-4, 70–71	106.2	1.0																0
			12H-5, 70–71	107.7	1.0							14									14
			12H-7, 70–71	110.7	1.0																0
			13H-1, 70–71	111.2	1.0						1	1				1					6
			13H-2, 70–71	112.7	1.0					5										1	13
			13H-3, 70–71	113.8	1.0																0
			13H-4, 70–71	115.2	1.0																1
			13H-5, 70–71	116.8	1.0																0
			13H-6, 70–71	118.3	1.0																0
			13H-7, 29–30	119.4	1.0																0
			14H-1, 70–71	120.7	1.0																0
			14H-2, 71–72	122.2	1.0																8
			14H-3, 70–71	123.7	1.0																0
			14H-4, 70–71	125.2	1.0																0
			14H-5, 70–71	126.7	1.0					20											27
	Dictyocha hexacantha		14H-6, 70–71	128.2	1.0					61				205							270
			14H-7, 70–71	129.7	1.0								202							1	291
			15H-1, 71–72	130.2	1.0								9								12
			15H-2, 71–72	131.7	1.0								1								2
			15H-3, 70–71	133.2	1.0																0
			15H-4, 71–72	134.7	1.0																0
	Dictyocha byronalis Horizon		15H-5, 71–72	136.2	1.0																1
			15H-6, 71–72	137.7	1.0																27
			15H-7, 55–56	139.1	1.0																31
			16H-1, 70–71	139.7	1.0																14
	Dictyocha hexacantha		16H-2, 70–71	141.3	1.0																2
			16H-3, 70–71	142.8	1.0																0
			16H-4, 70–71	144.2	1.0																0
			16H-5, 70–71	145.8	1.0																0
			16H-6, 70–71	147.3	1.0																0
middle Eocene		Unit III	17H-1, 70–71	149.2	1.0																0
			17H-2, 70–71	150.7	1.0																0
			17H-3, 70–71	151.7	1.0																0
			17H-4, 70–71	152.6	1.0																0
			17H-5, 70–71	154.1	1.0																0

Table T1 (continued).

Age	Zone	Lithologic unit	Core, section, interval (cm)	Depth (mbsf)	Slide	*Bachmannocena apiculata*	*Cannopilus sphaericus*	*Corbisema bimucronata*	*Corbisema bimucronata rotatoria*	*Corbisema flexuosa*	*Corbisema hastata*	*Corbisema hexacantha*	*Corbisema inermis inermis*	*Corbisema regina*	*Corbisema triacantha*	*Dictyocha byronalis*	*Dictyocha extensa*	*Dictyocha fibula ausonia*	*Dictyocha fibula fibula*	*Dictyocha fibula mutabilis*	*Dictyocha medusa*	*Dictyocha spinosa*	*Dictyocha varia*	*Distephanus crux crux*	*Distephanus crux hannai*
middle Eocene	*Corbisema hastata–Corbisema apiculata*	Unit III	199-1219A-																						
			17H-6, 70–71	155.6	1.0																				
	Dictyocha hexacantha		18H-1, 70–71	158.7	1.0																				
			18H-2, 70–71	160.2	1.0																				
			18H-3, 70–71	161.7	1.0																				
			18H-4, 70–71	163.2	1.0																				
			18H-5, 70–71	164.7	1.0																				
			18H-6, 70–71	166.2	1.0																				
			19H-1, 70–71	168.2	1.0																				
			19H-2, 70–71	169.7	1.0																				
			19H-3, 70–71	171.2	1.0																				
			19H-4, 70–71	172.7	1.0																				
			19H-5, 70–71	174.2	1.0																				
			19H-6, 70–71	175.7	1.0						3														
			20H-1, 67–68	177.7	1.0																				
			20H-2, 70–71	179.2	1.0																				
			20H-3, 70–71	180.7	1.0																				
			20H-4, 70–71	181.7	1.0																				
			20H-5, 70–71	183.3	1.0							46													
			20H-6, 70–71	184.8	1.0																				
			20H-7, 70–71	186.3	1.0																				
			21H-1, 70–71	187.2	1.0																				
	Dictyocha spinosa Subzone		21H-2, 70–71	188.7	1.0			1														7			
			21H-3, 67–68	190.2	1.0																				
			21H-4, 70–71	191.0	1.0			9	3		5			6											
			21H-5, 70–71	192.2	1.0			4	2		7				1							4			
			21H-6, 70–71	193.7	1.0			4	10		29	19		73								33			
	Dictyocha hexacantha		21H-7, 70–71	195.2	1.0																				
			22H-1, 70–71	196.7	1.0			1					2												
			22H-2, 70–71	198.2	1.0																				
			22H-3, 70–71	199.7	1.0																				
			22H-4, 70–71	201.2	1.0																				
			22H-5, 70–71	202.7	1.0																				
			22H-6, 70–71	204.2	1.0																				
			22H-7, 37–38	205.4	1.0																				
			23H-1, 70–71	206.2	1.0																				
			23H-2, 70–71	207.7	1.0																				
			23H-4, 70–71	210.7	1.0					1	7	7		1											
			23H-5, 70–71	212.2	2.0						9	4													
			23H-6, 70–71	213.7	1.0																				
			23H-7, 70–71	215.2	1.0																				
			24H-1, 70–71	215.7	1.0																				
			24H-2, 70–71	217.2	1.0																				
			24H-3, 70–71	218.7	1.0																				
			24H-4, 70–71	220.2	1.0																				
			24H-5, 70–71	221.8	1.0																				
			24H-6, 70–71	223.3	1.0																				
			25X-1, 71–72	225.2	1.0																				
early Eocene		Unit IV	26X-1, 71–72	234.8	1.0																				
			26X-2, 83–84	236.4	1.0																				
			27X-1, 66–67	244.4	1.0																				

Table T1 (continued).

Age	Zone	Lithologic unit	Core, section, interval (cm)	Depth (mbsf)	Slide	*Distephanus longispinus*	*Distephanus speculum speculum*	*Distephanus stauracanthus* f. *octagonus*	*Distephanus stauracanthus* f. *stauracanthus*	*Naviculopsis biapiculata*	*Naviculopsis* cf. *biapiculata*	*Naviculopsis biapiculata/foliacea*	*Naviculopsis constricta*	*Naviculopsis foliacea*	*Naviculopsis lacrima*	*Naviculopsis lata*	*Naviculopsis* cf. *lata*	*Naviculopsis ponticula*	*Naviculopsis trigeminus* n. sp.	*Naviculopsis trispinosa*	Total silicoflagellates
middle Eocene	*Corbisema hastata*–*Corbisema apiculata*	Unit III	199-1219A- 17H-6, 70–71	155.6	1.0																0
	Dictyocha hexacantha		18H-1, 70–71	158.7	1.0																0
			18H-2, 70–71	160.2	1.0																0
			18H-3, 70–71	161.7	1.0																0
			18H-4, 70–71	163.2	1.0																0
			18H-5, 70–71	164.7	1.0																0
			18H-6, 70–71	166.2	1.0																0
			19H-1, 70–71	168.2	1.0																0
			19H-2, 70–71	169.7	1.0																0
			19H-3, 70–71	171.2	1.0																0
			19H-4, 70–71	172.7	1.0																0
			19H-5, 70–71	174.2	1.0																0
			19H-6, 70–71	175.7	1.0																3
			20H-1, 67–68	177.7	1.0																0
			20H-2, 70–71	179.2	1.0																0
			20H-3, 70–71	180.7	1.0																0
			20H-4, 70–71	181.7	1.0																0
			20H-5, 70–71	183.3	1.0								7								53
			20H-6, 70–71	184.8	1.0																0
			20H-7, 70–71	186.3	1.0																0
			21H-1, 70–71	187.2	1.0																0
	Dictyocha spinosa Subzone		21H-2, 70–71	188.7	1.0																8
			21H-3, 67–68	190.2	1.0																0
			21H-4, 70–71	191.0	1.0								26								49
			21H-5, 70–71	192.2	1.0								1								19
			21H-6, 70–71	193.7	1.0																168
	Dictyocha hexacantha		21H-7, 70–71	195.2	1.0																0
			22H-1, 70–71	196.7	1.0								2								5
			22H-2, 70–71	198.2	1.0																0
			22H-3, 70–71	199.7	1.0																0
			22H-4, 70–71	201.2	1.0																0
			22H-5, 70–71	202.7	1.0																0
			22H-6, 70–71	204.2	1.0																0
			22H-7, 37–38	205.4	1.0																0
			23H-1, 70–71	206.2	1.0																0
			23H-2, 70–71	207.7	1.0																0
			23H-4, 70–71	210.7	1.0								1								17
			23H-5, 70–71	212.2	2.0								13	1					16		43
			23H-6, 70–71	213.7	1.0																0
			23H-7, 70–71	215.2	1.0																0
			24H-1, 70–71	215.7	1.0																0
			24H-2, 70–71	217.2	1.0																0
			24H-3, 70–71	218.7	1.0																0
			24H-4, 70–71	220.2	1.0																0
			24H-5, 70–71	221.8	1.0																0
			24H-6, 70–71	223.3	1.0																0
			25X-1, 71–72	225.2	1.0																0
early Eocene		Unit IV	26X-1, 71–72	234.8	1.0																0
			26X-2, 83–84	236.4	1.0																0
			27X-1, 66–67	244.4	1.0																0

Plate P1. Silicoflagellates from Hole 1219A. All figures are from Sample 199-1219A-123H-5, 70–71 cm. Scale bar = 10 µm. **1.** *Corbisema flexuosa*. **2.** *Dictyocha crux hannai*. **3.** *Dictyocha hexacantha*. **4.** *Naviculopsis trispinosa* (tilted specimen showing apical bridge and spine). **5.** *Naviculopsis trispinosa* (tilted specimen showing portal). **6.** *Corbisema inermis inermis*. **7.** *Naviculopsis trigeminus* n. sp. (abapical view).

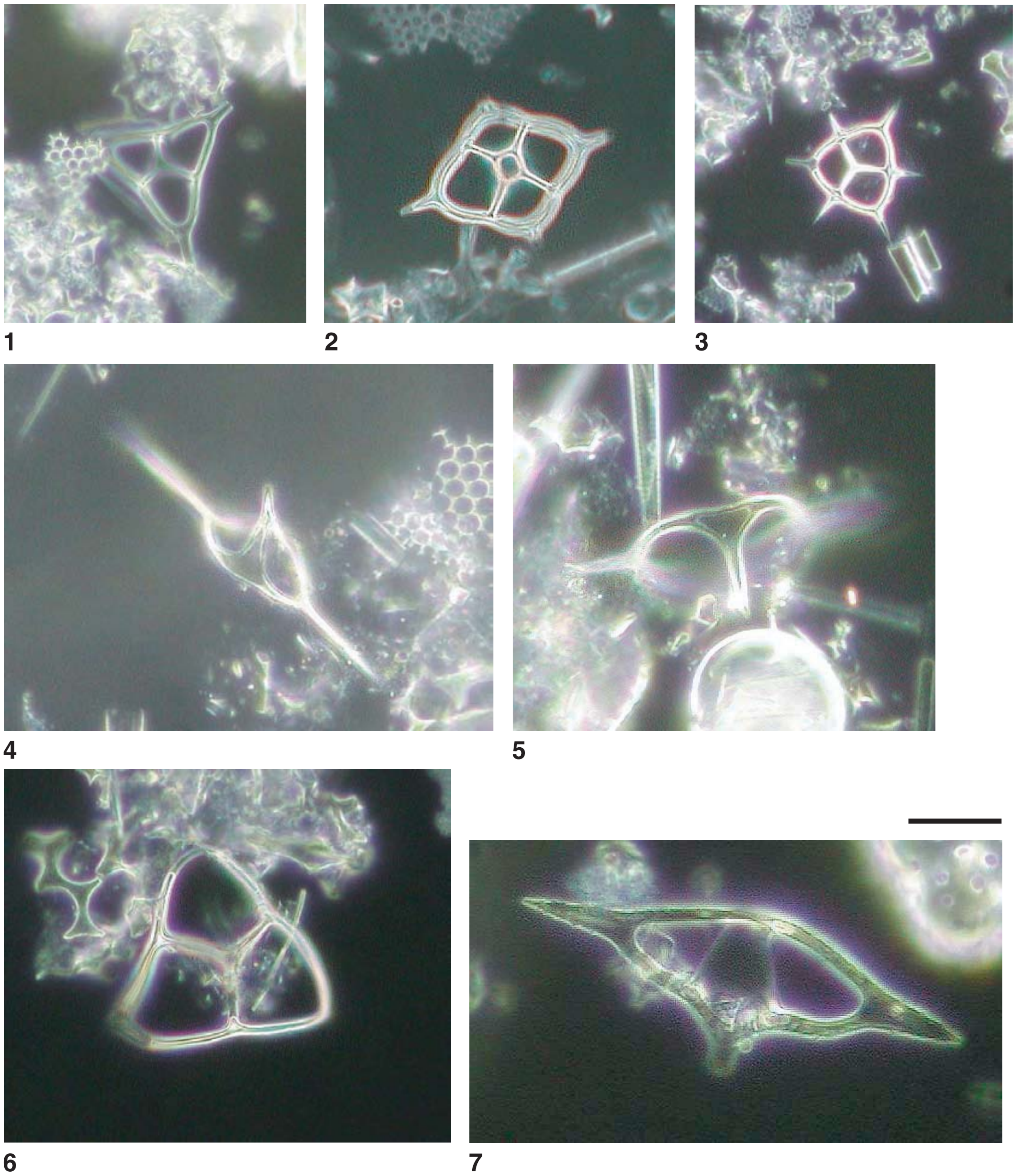

Plate P2. Specimens of *Naviculopsis trigeminus* n. sp. from Hole 1219A. All figures are from Sample 199-1219A-123H-5, 70–71 cm. Scale bar = 10 µm. Figures 3, 4, and 5 show abapical views.