Frey, F.A., Coffin, M.F., Wallace, P.J., and Quilty, P.G. (Eds.)
Proceedings of the Ocean Drilling Program, Scientific Results Volume 183

11. Silicoflagellates from ODP Holes 1138A and 1140A, Kerguelen Plateau[1]

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ABSTRACT

The biostratigraphic distribution and abundance of lower Oligocene and Miocene to Pleistocene silicoflagellates are documented from Ocean Drilling Program Leg 183 Holes 1138A and 1140A, on the Kerguelen Plateau. The *Distephanus speculum speculum* forma *pseudofibula* plexus is found in the upper Miocene in Hole 1138A, but other important biostratigraphic markers are not available. Diversity and abundance of silicoflagellates vary considerably in Hole 1138A, with silicoflagellates more abundant in the Pliocene and Pleistocene and some intervals of the Miocene barren of silicoflagellates or containing only limited numbers of specimens. The silicoflagellates of Hole 1140A include a new skeletal morphology, described here as *Distephanus speculum speculum* forma *cylindrus*. Silicoflagellates were generally abundant throughout the lower and middle Miocene in Hole 1140A.

INTRODUCTION

Eight sites on the Kerguelen Plateau were drilled during Ocean Drilling Program (ODP) Leg 183. The Kerguelen Plateau is a large igneous province in the southern Indian Ocean believed to have formed over a hotspot beginning at ~120 Ma (Shipboard Scientific Party, 2000). The major objective of this leg was the study of the igneous basement. Silicoflagellates were found to be abundant in the sediments above basement at Site 1140 and abundant in the Pliocene and Pleistocene

[1]McCartney, K., Engel, R., Reed, T., Williamson, R., Bohaty, S.M., and Wise, S.W., Jr., 2003. Silicoflagellates from ODP Holes 1138A and 1140A, Kerguelen Plateau. *In* Frey, F.A., Coffin, M.F., Wallace, P.J., and Quilty, P.G. (Eds.), *Proc. ODP, Sci. Results,* 183, 1–20 [Online]. Available from World Wide Web: <http://www-odp.tamu.edu/publications/183_SR/VOLUME/CHAPTERS/011.PDF>. [Cited YYYY-MM-DD]
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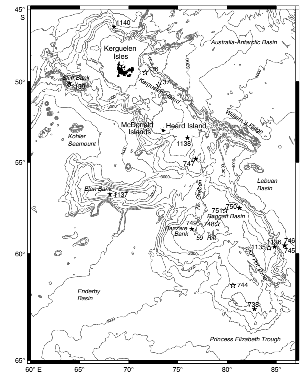
Initial receipt: 2 February 2002
Acceptance: 8 March 2003
Web publication: 28 May 2003
Ms 183SR-011

sections at Site 1138. The purpose of this study is to provide a silicoflagellate biostratigraphy for the Kerguelen Plateau that will contribute to the biostratigraphic zonation of the Southern Ocean (Ciesielski, 1975, 1991; Perch-Nielsen, 1975; Bukry, 1975b, 1976b, 1991; Haq and Riley, 1976; Shaw and Ciesielski, 1983; McCartney and Wise, 1990; McCartney and Harwood, 1992).

Site 1138 lies ~150 km north-northwest of Site 747 (Leg 120) (see Fig. F1) at 53°33.1′S, 75°58.5′E, in a water depth of 1141.4 m. The hole penetrated 842.7 m; the lowest sample examined in this study came from 269.4 meters below seafloor (mbsf). Six sedimentary lithologic units were recognized in Hole 1138A above basement, with the uppermost three of these included in the interval studied for silicoflagellates. Sediments from the Upper Cretaceous to Pleistocene (Shipboard Scientific Party, 2000) were recovered; silicoflagellates found in this study are from the upper Oligocene to Pleistocene.

Site 1140 lies ~270 km north of the Kerguelen archipelago (Fig. F1), in a water depth of 2394 m. The location of Hole 1140A is at 46°15.6′S, 68°29.5′E, on the northernmost Kerguelen Plateau. Total penetration in Hole 1140A was 321.9 m with a sediment penetration of 234.0 m; the lowest samples studied for silicoflagellates were at 207.79 mbsf. Upper Eocene to middle Miocene sediments (Shipboard Scientific Party, 2000) were recovered, with the silicoflagellates studied being from the lower Oligocene and lower and middle Miocene and one sample from the Pleistocene.

F1. Location map, p. 16.



SAMPLE PREPARATION

Samples from Hole 1138A were prepared for diatom analysis (see Bohaty et al., this volume) using standard procedures for light microscopy. Two preparations were made for each sample: an unprocessed or "raw" preparation and a processed preparation. Two subsamples (~0.25 g) for each interval were placed in 15-mL centrifuge tubes. One set of subsamples was left to soak in deionized water, and the other was chemically treated. The treated samples were initially reacted with ~5 mL of 10% hydrochloric acid in order to remove the carbonate component (i.e., nannofossils, foraminifers, and diagenetic cements). The centrifuge tubes were then shaken on a vortex stirrer and left to react for 1 hr. Following these steps, ~5 mL of 30% hydrogen peroxide was added to remove organic material and help disaggreagate biosiliceous "clumps." The samples were soaked overnight in the HCl/H_2O_2 solution and then thoroughly washed by centrifuging three times at ~1500 rpm for 10 min. The chemically treated samples were not heated during preparation.

Strewn slides of all samples were made on 20-mm × 40-mm coverslips. Each centrifuge tube was filled with ~8 mL of deionized water and then mixed on a vortex stirrer. After settling for 30 s (in order to settle the sand-sized fraction), a small aliquot was removed from the center of the suspension with a pipette. Two or three drops of sample were then dropped on a coverslip containing a thin film of deionized water. All samples were mounted in Norland optical adhesive 61 (refractive index = 1.56).

Slides were examined at 250×, and specimens were counted until a total of 300 specimens were reached. Where a count of 300 specimens was reached before the entire slide was examined, the portion of the slide analyzed is listed in the tables to give an understanding of the relative abundance of silicoflagellates. When specimens were rare, the survey was ended before finishing the slide, with the amount of slide examined listed in the abundance tables. Only those fragments representing more than one-half of a silicoflagellate were included in the counts. Because the number of teratoid (aberrant) specimens may be an indication of environmental stress, a separate tally was made of these. Aberrants include specimens with fused spines or struts, two struts attaching to a basal side, or distorted basal rings (see McCartney and Loper, 1989, for a discussion on the basic rules of silicoflagellate form). Because the aberrants are often counted among the specific taxa, the number of aberrants is not included in the total counts.

The Hole 1140A portion of this study was conducted by undergraduate students having limited experience with silicoflagellates. Although the work was closely supervised by the first author, the relative inexperience of these students should be taken into account when evaluating the results. For Hole 1140A, Robb Engel did the microscopic work for Cores 183-1140A-1R through 7R, Rita Williamson conducted the census for Cores 183-1140A-8R through 13R, and Tracy Reed obtained the data for Cores 183-1140A-14R through 22R. These students had frequent discussions among themselves and with their teacher (Kevin McCartney) in order to obtain as consistent a species concept as was reasonably possible.

SITE SUMMARIES AND ZONATION

Hole 1138A

The biostratigraphy for Hole 1138A is similar to that for Holes 747A and 748B of Leg 120, described by McCartney and Harwood (1992). Site 747 was the northernmost of the sites drilled during Leg 120 and is ~200 km south of Site 1138, whereas Site 748 is ~500 km farther to the southeast. For all three Leg 120 sites, the *Distephanus speculum speculum* Zone and the *D. speculum speculum* forma *pseudofibula* plexus range zone are identified above a lengthy unzoned interval in the lower to upper Miocene. The unzoned interval does not contain silicoflagellates that are consistent and distinct enough to allow zonation.

The zonation for Site 1138 is illustrated in Table T1 and should be compared to the biostratigraphy from Sites 747 and 748 (see McCartney and Harwood, 1992). Comparison might also be made to the Quaternary occurrences listed by Bukry (1991) for ODP Leg 119.

T1. Silicoflagellates, Hole 1138A, p. 17.

Silicoflagellates were generally abundant in the Pliocene and Pleistocene samples from Hole 1138A, which were dominated by six-sided distephanid morphologies with a single specimen of *Dictyocha* ssp. There was considerable range of size among the six-sided *Distephanus*, which is reflected in the taxonomic separation into *Distephanus speculum* (the smaller specimens) and *Distephanus boliviensis* (the larger specimens). There also were five-, seven-, and nine-sided variants and multiwindowed forms. *Distephanus pulchra* was abundant in Samples 183-1138A-4R-CC and 5R-CC, making up >10% of the silicoflagellate specimens.

The Pliocene and Pleistocene and several meters of the upper Miocene are included in the *D. speculum speculum* Zone, which was found in twelve samples, from Samples 183-1138A-1R-CC through 12R-2, 100–101 cm. This interval contained abundant *D. speculum speculum* and *D. boliviensis*. The lowermost three samples from this interval, from

Samples 183-1138A-11R-CC through 12R-2, 100–101 cm, contained *Dictyocha fibula fibula*.

The *D. speculum speculum* forma *pseudofibula* plexus was found in six samples, from Samples 183-1138A-12R-3, 100–101 cm, through 13R-4, 100–101 cm. The plexid morphologies were most abundant in the lowest of these samples, where there was also dominant *Bachmannocena diodon,* but never made up a majority of the silicoflagellates. In the uppermost two samples of the plexid interval, the plexid morphologies were outnumbered by *D. speculum speculum*.

Silicoflagellates were generally rare in samples from below the "*pseudofibula* plexus" interval. An exception was Sample 183-1138A-15R-CC, where there were abundant *Bachmannocena circulus*. A similar occurrence of abundant *B. circulus* and *B. diodon* below the plexus interval was found in Hole 747A (McCartney and Harwood, 1992). In the McCartney and Harwood study, the lower to upper Miocene interval below the "*pseudofibula* plexus" was left unzoned because of a lack of consistent silicoflagellates; this practice is also followed in the present study.

The lowermost two samples examined in this study, Samples 183-1138A-28R-CC and 29R-CC, are tentatively placed in the *Naviculopsis biapiculata* Zone, despite the lack of the nominative taxon, based on the presence of *Naviculopsis eobiapiculata* and *Distephanus raupii*.

Hole 1140A

Silicoflagellates were generally abundant in the lower and middle Miocene samples and are present but not abundant in lower Oligocene samples from Hole 1140A (Table T2). The flora is generally dominated by *Distephanus crux, D. speculum*, and *Corbisema triacantha*. Much of the studied interval lacked key biostratigraphic indicators and is unzoned.

T2. Silicoflagellates, Hole 1140A, p. 19.

The biostratigraphy for Hole 1140A is similar to that found for Holes 747A, 748B, and 751A of Leg 120 (McCartney and Harwood, 1992). The uppermost sample examined through Sample 183-1140A-1R-1, 25–26 cm, contained two specimens of *Dictyocha aculeata* and is thus placed in the Pleistocene *Dictyocha aculeata* Zone (see McCartney et al., 1995). This sample also includes a specimen of *D. crux*, suggesting some reworking of Miocene(?) materials into this sediment; similar reworking in this sample has also been found in the diatoms (K. Roessig, pers. comm., 2001; see **Arney et al.,** this volume).

The zonation for Samples 183-1140A-1R-2, 108–109 cm, through 2R-CC is uncertain. The presence of a few specimens of *D. speculum speculum* f. *notabilis* suggests a possible placement in the *D. speculum speculum* f. *pseudofibula* plexus Zone, but the diatom study (**Arney et al.,** this volume) shows an earlier age. An unusual silicoflagellate, described below as *D. speculum speculum* forma *cylindrus*, was found from Samples 183-1140A-1R-2, 108–109 cm, through 2R-1, 25–26 cm. This silicoflagellate has an apical ring of size similar to the basal ring and sometimes has unusually prominent apical spines situated at the corners of the apical ring.

Samples 183-1140A-3R-CC through 7R-CC are placed in the *Distephanus raupii–Corbisema triacantha* Zone (see McCartney and Harwood, 1992) on the basis of the absence of *D. raupii* and the presence of *C. triacantha* in low abundance. Samples 183-1140A-8R-CC through 22R-CC are unzoned; silicoflagellates were abundant, but there was an absence of biostratigraphically useful taxa such as *Naviculopsis biapicu-*

lata and *Corbisema archangelskiana* (see Hole 747A, McCartney and Harwood, 1992).

The diatom study (**Arney et al.,** this volume) suggests an early Oligocene age for Samples 183-1140A-20R-CC through 22R-CC, but the lack of biostratigraphically important silicoflagellates, such as *Corbisema archangelskiana* and *Naviculopsis trispinosa* (see McCartney and Harwood, 1992) prevented the clear determination of a silicoflagellate zone.

SYSTEMATIC PALEONTOLOGY

The taxonomy used here follows McCartney and Harwood (1992) and McCartney et al. (1995), particularly in the use of genus designations.

Silicoflagellates

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

Remarks: For discussion on our use of *Bachmannocena* see McCartney and Wise (1990).

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: This taxon is not subdivided into multiple subspecies (see Bukry, 1987) in this study because of the low number of specimens that were observed and the lack of biostratigraphic significance.

Bachmannocena circulus (Ehrenberg)

Mesocena circulus (Ehrenberg), Ehrenberg, 1844, p. 65.

Bachmannocena circulus (Ehrenberg); Bukry, 1987, p. 404; McCartney and Harwood, 1992, pl. 2, figs. 1, 2; McCartney et al., 1995, pl. 4, figs. 1, 7; pl. 8, fig. 8.

Remarks: *B. circulus* has a large polygonal ring with small pointed spines. It was the dominant taxon in Sample 183-1138A-15R-CC, occurring two cores below the base of the *Distephanus speculum speculum* forma *pseudofibula* plexus. Similar occurrences of dominant *B. circulus* in a narrow horizon beneath the "*pseudofibula* plexus" have been found in ODP Hole 689B of Leg 113 (McCartney and Wise, 1990) and Holes 747A and 751A of Leg 120 (McCartney and Harwood, 1992), although the distance beneath the plexus varies considerably, suggesting that these acmes are not biostratigraphically relevant. In lower latitudes, *B. circulus* can be abundant in the Pliocene but is less common in the Miocene (McCartney et al., 1995).

Three specimens on this taxon were also found in Sample 183-1140A-15R-CC.

Bachmannocena diodon diodon (Ehrenberg)

Mesocena diodon Ehrenberg, 1844, pp. 71, 84.

Bachmannocena diodon (Ehrenberg); Bukry, 1987, p. 404.

Bachmannocena diodon diodon (Ehrenberg); McCartney et al., 1995, pl. 4, figs. 2, 8.

Remarks: This taxon was abundant in Sample 183-1138A-21R-CC and co-occurs with the dominant *B. circulus*.

Bachmannocena elliptica **(Ehrenberg)**

Dictyocha (Mesocena) elliptica Ehrenberg, 1840, p. 208; Ehrenberg, 1854, pl. 20(1), fig. 44a, b.

Mesocena elliptica (Ehrenberg); Bukry, 1978a, p. 819, pl. 6, figs. 6–13.

Bachmannocena elliptica (Ehrenberg); McCartney et al., 1995, p. 145.

Remarks: Only three specimens of this taxon were found in Sample 183-1138A-21R-CC. These specimens were fairly small, 30–50 µm, in comparison with other silicoflagellates viewed in this study, which placed them in *B. elliptica* rather than the somewhat larger and typically younger *Bachmannocena quadrangula* (see McCartney et al., 1995, for further discussion).

Genus *CORBISEMA* Hanna, 1928, emend. Frenguelli, 1940

Corbisema triacantha **(Ehrenberg)**

Dictyocha triacantha Ehrenberg, 1844, p. 80.

Corbisema triacantha (Ehrenberg); Busen and Wise, 1977, p. 713.

Genus *DICTYOCHA* Ehrenberg, 1837

Dictyocha aculeata **(Lemmermann)**

Dictyocha fibula var. *aculeata* Lemmermann, 1901, p. 261, pl. 11, figs. 1, 2.

Dictyocha aculeata (Lemmermann); Dumitrica, 1973, p. 907, pl. 9, figs. 5–10; McCartney et al., 1995, pl. 9, fig. 2.

Dictyocha calida calida **Poelchau**

Dictyocha calida Poelchau, 1976, p. 169, pl. 1, figs. c, d; pl. 3, figs. a–f.

Dictyocha calida calida Poelchau; Bukry, 1979a, p. 560, pl. 1, fig. 7; McCartney et al., 1995, p. 146.

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; McCartney et al., 1995, pl. 3, figs. 2–5; pl. 5, figs. 3, 7; pl. 8, fig. 8.

Remarks: This is an important taxon in the late Miocene and Pliocene of low latitudes, where it and *D. varia* form an evolutionary transition (see McCartney et al., 1995, and sources cited therein). It was found in the upper Miocene and lower Pliocene, with a single specimen in the lower Miocene. This taxon is typically more abundant at lower latitudes (see McCartney et al., 1995).

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; McCartney et al., 1995, pl. 2, fig. 1; pl. 5, fig. 5.

Remarks: This group of dictyochid silicoflagellates, having the bridge parallel to the minor axis, are abundant in Miocene sediments of low and middle latitudes; they are less abundant in higher latitudes. The basal ring tends to be rather equant, making determination of the major axis difficult for tilted specimens. Specimens of *D. extensa* were smaller in size and had a higher basal ring aspect ratio than those of *D. fibula*. In this study, we accept Locker's (1974) designation of a large skeleton with a short-axis bridge as the lectotype for *D. fibula*; note that there is an error in the remarks for this taxon in McCartney et al. (1995), which states that the lectotype has a long-axis bridge.

Dictyocha messanensis Haeckel

Dictyocha fibula var. b Ehrenberg, 1843, p. 312, pl. 2, fig. IV 11.

Dictyocha fibula var. *messanensis* (Haeckel); Ling, 1970, pl. 18, fig. 14.

Dictyocha messanensis (Haeckel); McCartney et al., 1995, pl. 3, figs. 12, 13.

Remarks: *D. messanensis* is applied to a variety of skeletal morphologies that have a bridge inclined sinistrally when seen from apical view (note that flatlying silicoflagellates are commonly viewed abapically, since they lay on a coverslip that has been turned over.) Locker and Martini (1986) and other workers divided this taxon into several subspecies and forms, but the number of specimens did not warrant subdivision in this study.

Dictyocha perlaevis perlaevis Frenguelli

Dictyocha perlaevis Frenguelli, 1951, p. 279, fig. 4b, c.

Dictyocha fibula perlaevis (Frenguelli); Bukry, 1975b, p. 855, pl. 3, fig. 5.

Dictyocha perlaevis perlaevis Frenguelli; Bukry, 1979b, p. 984, pl. 3, figs. 6–11.

Remarks: This taxon was only found in Sample 183-1138A-18R-CC.

Dictyocha pumila (Ciesielski) McCartney n. comb.

Dictyocha fibula var. *pumila* Ciesielski, 1975, p. 656, pl. 5, figs. 5–10; pl. 6, figs 1, 2.

Dictyocha aspera var. *pygmaea* Ciesielski, 1975, p. 655, pl. 4, figs. 1, 3, 4, 6.

Dictyocha pumila (Ciesielski); Bukry, 1978c, p. 642; McCartney and Harwood, 1992, p. 824, pl. 2, fig. 4.

Dictyocha pygmaea (Ciesielski), McCartney and Harwood, 1992, p. 824.

Remarks: Ciesielski (1975) described a group of interesting silicoflagellates with nearly square basal rings and basal spines often longer than the diameter of the basal ring from the lower Pliocene of Site 266. Ciesielski described the group as variations of two separate species, depending on whether the bridge was aligned with the long or short axis. McCartney and Harwood (1992) continued the practice of separating the long-axis and short-axis forms into two taxa, but noted that the biostratigraphic range and variation suggested that they were conspecific.

In this study, 50 specimens of *D. pumila* were found in Sample 183-1138A-12R-1, 100–101 cm, and 14 specimens were found in Sample 12R-2, 100–101 cm. They were rarely found elsewhere. The skeletons are consistently of small size, with spines that are often longer than the diameter of the basal ring. The basal ring is nearly square, making determination of the major axis and discrimination between the *pumila* and *pygmaea* forms difficult and probably influenced by the tilting of the specimen. *D. pumila* includes both forms. The *D. pumila* taxon is here given priority, instead of *pygmaea*, because it has been more frequently used and is the more abundant of the two forms. Where there was a determinable major axis, the bridge is parallel to the major axis in about two-thirds of the specimens.

Dictyocha varia Locker

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

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

Remarks: See McCartney et al., 1995 for discussion of *D. varia*.

Genus *DISTEPHANUS* Stöhr, 1880

Distephanus antarcticus Ciesielski

Cannopilus antarcticus Ciesielski, 1975, p. 654, pl. 1, figs. 1–9.

Distephanus antarcticus (Ciesielski); Ciesielski, 1991, pp. 80, 81.

Remarks: We follow the practice used by Bukry and Monechi (1985) and Ciesielski (1991) of not recognizing the genus *Cannopilus* and applying multiwindowed skeletal morphologies to *Distephanus*. Twelve specimens of this species were found in the lower Miocene of Hole 1040A.

Distephanus boliviensis boliviensis (Frenguelli)

Dictyocha boliviensis Frenguelli, 1940 (in part), p. 44, fig. 4a.

Distephanus boliviensis boliviensis (Frenguelli); Bukry, 1979b, p. 985, pl. 4, fig. 12; pl. 5, fig. 1; McCartney and Harwood, 1992, p. 824, pl. 3, figs. 1 (top), 2, 3.

Remarks: *D. boliviensis* is distinguished from *D. speculum speculum* by the larger basal ring, more equant basal spines, and an apical window that proportionally smaller in comparison to the basal ring. In some samples the two taxa are distinctly different, making their identification rather easy, but in other samples the range of variation overlaps, and identification becomes difficult and, perhaps, arbitrary. *D. boliviensis* specimens with five, seven, eight, and nine sides were counted separately to show the range of variation. Multiwindowed forms with six and more sides were also counted separately.

Distephanus crux crux (Ehrenberg)

Dictyocha crux Ehrenberg, 1840, p. 207; Ehrenberg, 1854, pl. 18, figs. 5, 6; pl. 33(XV), fig. 9.

Distephanus crux crux (Ehrenberg); McCartney and Harwood, 1992, p. 824.

Remarks: Specimens of *D. crux crux* occur sporadically and in low abundance in the upper Oligocene and lower Miocene.

Distephanus depressus (Ehrenberg) n. comb.

Halicalyptra depressa Ehrenberg, 1854, pl. 18, fig. 110.

Cannopilus depressus (Ehrenberg); Perch-Nielsen, 1975, p. 685, pl. 1, figs. 1–5.

Remarks: In this study, we counted specimens that had an almost spherical skeleton with many windows and more than six basal sides as *D. depressus*. The apical structure has a diameter larger than the basal ring, which sometimes prevented the precise determination of the number of basal sides.

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.

Distephanus pulchra (Schiller)

Octactis pulchra Schiller, 1925, pp. 67, 68, fig. c.

Distephanus pulchra (Schiller); Ling and Takahashi, 1985, p. 80, pls. 1, 2.

Remarks: Specimens of *D. pulchra* were typically eight-sided but there were some nine- and ten-sided forms, although these were not counted separately.

The presence of this taxon is associated with high productivity (Murray and Schrader, 1983; Pisias et al., 1986).

Distephanus raupii Bukry

Distephanus raupii Bukry, 1978b, p. 785, pl. 2, fig. 15; McCartney and Harwood, 1992, p. 825.

Remarks: Two specimens of this species were found in Sample 183-1138A-29R-CC and were sometimes abundant in samples from Hole 1040A. The specimens were differentiated from *Distephanus speculum pentagonus* by their smaller basal ring and the location where the struts intersect the basal ring, known as the strut attachment (see McCartney and Loper, 1989). The location of the strut attachment for *D. raupii* is at about the midpoint between the sides, whereas the attachments for *D. speculum pentagonus* are closer to the basal corners.

Distephanus speculum hemisphaericus (Ehrenberg)

Dictyocha hemisphaerica Ehrenberg, 1844, pl. 17, fig. 5.

Distephanus speculum hemisphaericus (Ehrenberg); Bukry, 1975b, p. 854; McCartney et al., 1995, pl. 6, figs. 2, 5, 8; pl. 7, fig. 6.

Distephanus speculum pentagonus Lemmermann

Distephanus speculum var. *pentagona* Lemmermann, 1901, p. 264, pl. 11, fig. 19.

Distephanus speculum pentagonus Lemmermann; Bukry, 1976a, pp. 895, 896; McCartney and Wise, 1990, pl. 3, figs. 3–6; McCartney et al., 1995, pl. 7, fig. 4.

Remarks: *D. speculum pentagonus* is applied to five-sided silicoflagellates with apical rings of the same general size as co-occurring *D. speculum*. No special effort was made to distinguish this taxon from *Distephanus quinquangellus*, and the counts listed in this study may include examples of *D. quinquangellus*.

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: In the present study, seven- and eight-sided specimens and multi-windowed skeletons of *D. speculum speculum* were counted separately to illustrate the range of variation. The *D. speculum speculum* counts for Sample 183-1138A-1R-CC include 32 specimens with long spines (typically longer than the diameter of the basal ring.)

As noted above for *D. boliviensis*, there are some samples where there is overlapping taxonomic variation between the two common six-sided distephanid species. This subject deserves a detailed morphometric study. For this study, intermediate forms that had more pronounced long-axis spines were counted as *D. speculum speculum*, sometimes even though they were fairly large. There are two lines of evidence that suggest to us that these are two separate species. The first line of evidence is that they form distinctly separate size ranges in the Pliocene and Pleistocene. The second is that the unusual plexus morphologies occur exclusively among the small *D. speculum speculum* group; similar skeletons among the *D. boliviensis* are rare.

What might constitute a true species among the silicoflagellates is controversial, and opinions differ considerably among and between biologists and paleontologists. Recent biological study (Moestrup and Thomsen, 1990; Henriksen at al., 1993) shows that silicoflagellates have a life cycle that includes several skeleton-bearing stages. It remains to be determined if the skeletal morphologies might vary in size or shape during the course of the life cycle.

Distephanus speculum speculum f. *notabilis* Locker and Martini

Distephanus speculum f. *varians* Gran and Braarud, 1935, p. 390, fig. 68a.

Distephanus speculum varians Gran and Braarud; Bukry, 1976a, p. 896, pl. 8, fig. 10.

Distephanus speculum notabilis f. *notabilis* Locker and Martini, 1987, p. 46, pl. 5, figs. 40, 41.

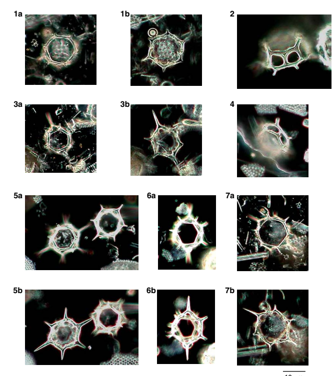
Distephanus speculum speculum f. *notabilis* Locker and Martini; McCartney and Wise, 1990, pl. 5, figs. 10–13; pl. 6, figs. 5, 7.

Remarks: This and the following two taxa represent variation within the *D. speculum speculum* forma *pseudofibula* plexus (McCartney and Wise, 1990; McCartney and Harwood, 1992). McCartney and Wise (1993) have shown that the amount of time interval during which the plexus occurs diminishes northward and defined three classes of plexid abundance. The plexid abundance in this study was Class II as defined by McCartney and Wise, and the geographical location is within the area shown as Class II on their figure 5.

Distephanus speculum speculum f. *cylindrus* McCartney and Engel n.f.

(Plate P1, figs. 1–7)

P1. *Distephanus speculum speculum* forma *cylindrus* n.f., p. 20.



Diagnosis: Six-sided basal ring with an apical ring nearly as large as the basal ring.

Description: Apical ring of diameter similar to or slightly smaller than the basal ring diameter. Skeletal elements of the apical ring are of smaller thickness than the basal elements and can have apical spines at the juncture where the strut meets the apical ring. Basal ring typically has six sides, but specimens with five, seven, and eight basal sides were observed. Basal ring may have major- and minor-axis spines. The corners of the apical ring are often positioned above the midpoint of the basal sides. The strut that connects the apical and basal rings are typically short, being less than the length of the basal radius.

Occurrence: Found in the middle Miocene of ODP Hole 1140A. Also found in the middle Miocene, Sample 120-747A-7H-6, 98–100 cm.

Size: Holotype, length of basal ring, 20 mm.

Repository: The microscope slide containing the holotype is located at the California Academy of Sciences Diatom Collection, slide #221057.

Holotype: Plate P1, fig. 1.

Type locality: ODP Sample 183-1140A-1R-CC.

Remarks: Although there is typically considerable variability in the size of the apical ring in comparison to the basal ring for *D. speculum speculum*, the apical ring of this taxon is unusual. Also unusual is the location of the apical spines, when present, which occur where the struts meet the corners of the apical ring. McCartney (1988) and McCartney and Loper (1989, 1992) have observed as a general rule for silicoflagellate skeletal morphology that intersections of skeletal elements are almost always triple junctions, either of three skeletal rods or of two rods and a spine. The apical spines on this taxon, however, appear to occur as part of a quadruple junction or a strut, two apical ring elements, and an apical spine. This unusual occurrence needs to be further examined using a scanning electron microscope.

We can find only one other similar specimen illustrated in the literature, that being by Perch-Nielsen, 1975 (pl. 6, fig. 13), which is from the lower Miocene. The common occurrence of this from Sample 183-1140A-1R-2, 108–109 cm, through 2R-1, 25–26 cm, suggests possible biostratigraphic use. This taxon was not found by McCartney and Harwood (1992), though subsequent work by Bohaty found specimens in Sample 120-747A-7H-6, 98–100 cm.

Distephanus speculum speculum f. *pseudofibula* Schulz

Distephanus speculum f. *pseudofibula* Schulz, 1928, p. 262, fig. 51a, b.

Distephanus speculum speculum f. *pseudofibula* Schulz; Locker and Martini, 1986, p. 907, pl. 7, fig. 5; McCartney and Wise, 1992, pl. 5, figs. 1–4; pl. 6, figs. 2, 3.

Distephanus speculum speculum f. *pseudopentagonus* McCartney and Wise

Distephanus speculum speculum f. *pseudopentagonus* McCartney and Wise, 1990, p. 750, pl. 5, fig. 6.

Remarks: This is an unusual five-sided variant of the "*pseudofibula* plexus." One specimen in Sample 183-1138A-12R-2, 100–101 cm, was identified as being a member of the plexid group because its size was consistent with other *D. speculum speculum* and smaller than dictyochid specimens in the same sample. Bohaty and Harwood (2000) have found some similar Eocene skeletal morphologies, but these are most likely derived from a different lineage than the Miocene forms.

Distephanus speculum speculum f. *varians* Gran and Braarud

Distephanus speculum f. *varians* Gran and Braarud, 1935, p. 390, fig. 68b.

Distephanus speculum speculum f. *varians* Gran and Braarud; McCartney and Wise, 1992, pl. 5, figs. 8, 9, 13a; pl. 6, figs. 4, 6.

Distephanus xenus Bukry

Distephanus xenus Bukry, 1984, p. 557, pl. 1, figs. 11, 12; pl. 2, figs. 1–8; McCartney et al., 1995, pl. 10, figs. 4, 7.

Remarks: This species has a large hexagonal-shaped basal ring with a large apical ring that either lacks spines or has only rudimentary spines. A single specimen was found in Sample 183-1138A-12R-2,100–101 cm, during diatom study.

Genus *NAVICULOPSIS* Frenguelli, 1940

Naviculopsis biapiculata (Lemmermann)

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

Naviculopsis biapiculata (Lemmermann); Bukry, 1978b, p. 787, pl. 3, figs. 9, 10.

Naviculopsis eobiapiculata Bukry

Naviculopsis eobiapiculata Bukry, 1978b, p. 787, pl. 4, figs. 9–16; McCartney and Wise, 1987, p. 807, pl. 5, figs. 5–8.

Naviculopsis lata (Deflandre)

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

Naviculopsis lata (Deflandre); Frenguelli, 1940, p. 61, fig. 11h; Bukry, 1982, p. 431, pl. 7, figs. 11–14.

ACKNOWLEDGMENTS

The authors wish to thank Kristeen Roessig, Brian Ladner, and James Arney for preparation of the Hole 1140A samples and Jack Baldauf for review. This research used samples and data provided by the Ocean Drilling Program (ODP). The ODP is sponsored by the U.S. National Science Foundation (NSF) and participating countries under management of Joint Oceanographic Institutions (JOI), Inc. This work was supported by USSAC funds to S.W. Wise Jr. using laboratory facilities provided by NSF grant 94-22893. Support for the preparation of the Hole 1138A samples was provided by David Harwood at the University of Nebraska-Lincoln. Photographic assistance was provided by Robert Longlais. Equipment for the Micropaleontology Undergraduate Research Lab was provided by NSF Grant OCE-9113073, with a digital camera provided by the Department of Science and Mathematics, University of Maine at Presque Isle. This is Publication No. 6 of the Micropaleontology Undergraduate Research Laboratory.

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Figure F1. Location map showing sites drilled during Legs 119, 120, and 183 (from Shipboard Scientific Party, 2000).

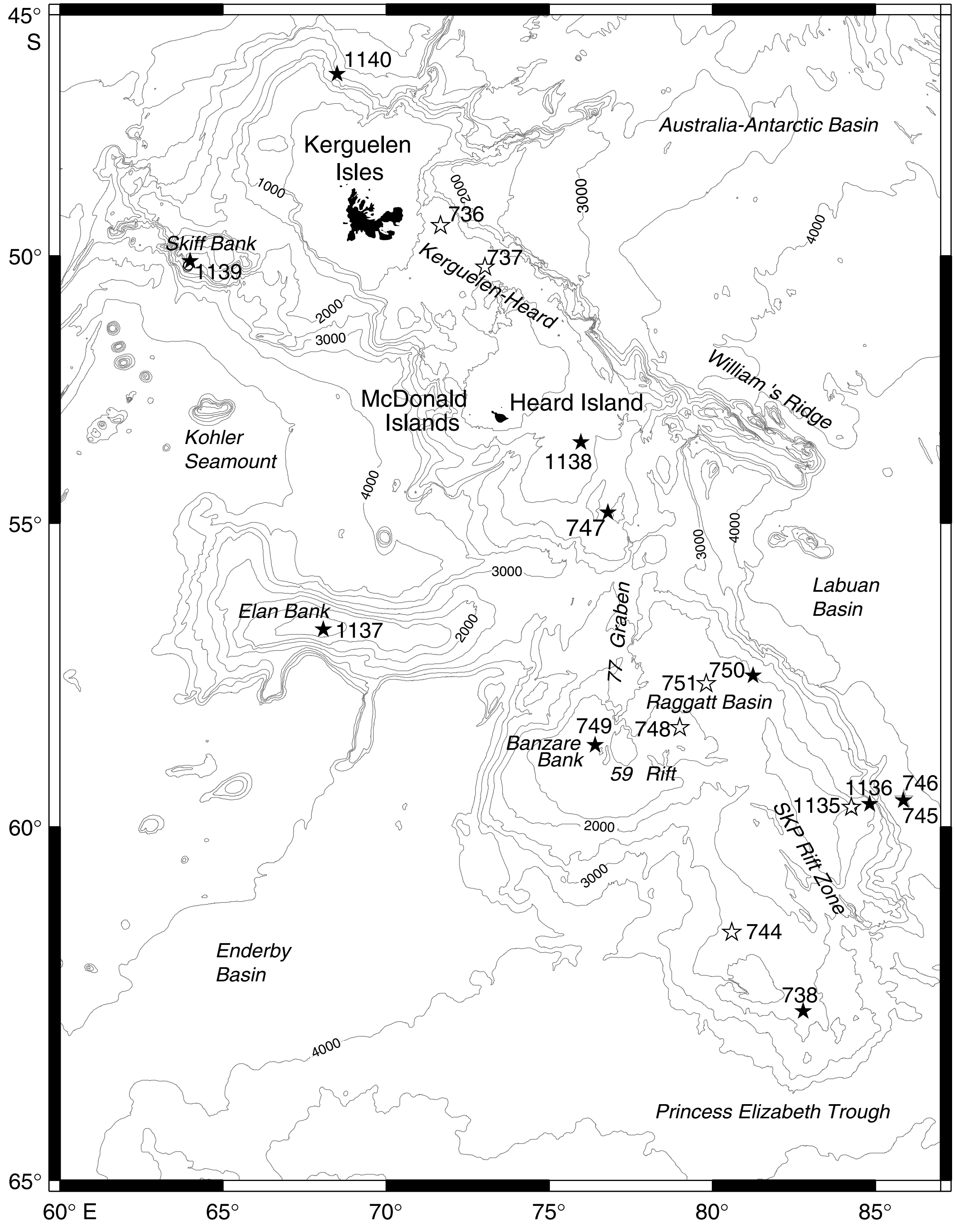

Table T1. Abundance of silicoflagellates, Hole 1138A. (Continued on next page.)

Age	Zone	Core, section, interval (cm)	Depth (mbsf)	Slide	*Bachmannocena apiculata*	*Bachmannocena circulus*	*Bachmannocena diodon*	*Bachmannocena elliptica*	*Dictyocha calida*	*Dictyocha extensa*	*Dictyocha fibula fibula*	*Dictyocha messanensis*	*Dictyocha perlaevis*	*Dictyocha pumila*	*Dictyocha varia*	*Distephanus boliviensis*	*Distephanus boliviensis* (seven-sided)	*Distephanus boliviensis* (eight-sided)	*Distephanus boliviensis* (nine-sided)	*Distephanus boliviensis* (five-sided)	*Distephanus boliviensis* (multiwindowed)	*Distephanus boliviensis* (seven- or eight-sided)	*Distephanus crux*	*Distephanus pulchra*	*Distephanus raupii*	*Distephanus speculum hemisphaericus*	*Distephanus speculum pentagonus*	*Distephanus speculum speculum*	*Distephanus speculum speculum* (seven- or eight-sided)	*Distephanus speculum speculum* var. *notabilis*	*Distephanus speculum speculum* var. *pseudofibula*	*Distephanus speculum speculum* var. *varians*	*Distephanus speculum speculum* var. *pseudopentagona*	*Naviculopsis eobiapiculata*	*Naviculopsis lata*	Aberrants	Total silicoflagellates
		183-1138A-																																			
		1R-CC	8.53	0.2												16											1	281	1	1						4	300
		2R-CC	12.78	0.4					1																	3	6	281	7	1		1				7	300
Pleistocene		3R-CC	25.57	0.4																							5	284	10		1					16	300
		4R-CC	34.94	0.8												187	9	22			3	5		74												6	300
		5R-CC	45.58	0.1												74	1			1								224								0	300
	Distephanus speculum speculum	6R-CC	49.65	0.1												112	3	18	2	2								138				1				4	276
late Pliocene		7R-CC	62.31	0.4												42	1		1					33				220		3							300
		8R-CC	74.04	0.5												8					1							2									11
		9R-CC	79.21	0.5												12	2											56									70
early Pliocene		10R-CC	87.53	0.3												10	3		2									283			2					1	300
		11R-CC	102.39	1.0			1			5	2					11			1								6	271		1	1	1				1	300
		12R-1, 100–101	102.30	0.6							82			50		54												74		1		1	1			3	263
		12R-2, 100–101	104.80	1.0							8			14		26												34		1						1	83
		12R-3, 100–101	106.30	0.5						13					24													28	1	8	4	12					90
		12R-CC	107.03	0.5							2	5				1												17		1	3	4					33
	Pseudofibula plexus	13R-1, 100–101	113.00	1.0			1			4					1	1										1		1		1	1						11
late Miocene		13R-2, 100–101	114.50	1.0			20			1	2				9								1					8	1	6	4	18				1	70
		13R-3, 100–101	116.00	1.0			30			1	3				6																1	10					51
		13R-4, 100–101	117.50	1.0			213			1																	1	2	3	27	13	40				3	300
		13R-CC	118.59	0.4			2																					1	1								4
		15R-CC	134.23	0.5		143	33									2		1	1									6									186
		16R-CC	145.85	1.0						10	4	8		4													2	62								1	90
		17R-CC	158.27	0.5								2															1										3
		18R-CC	168.84	1.0									7										2				1	6									16
	Unzoned	19R-CC	174.75	0.5							2			1																						1	3
		20R-CC	186.14	0.5																																	0
early Miocene		21R-CC	191.26	0.5				3															2														5
		22R-CC	201.60	0.5						1	5												1					1									8
		23R-CC	210.85	0.5	2																		1														1
		24R-CC	221.34	0.5																																	0
		25R-CC	230.02	0.5																																	0

Table T1 (continued).

Age	Zone	Core, section, interval (cm)	Depth (mbsf)	Slide	*Bachmannocena apiculata*	*Bachmannocena circulus*	*Bachmannocena diodon*	*Bachmannocena elliptica*	*Dictyocha calida*	*Dictyocha extensa*	*Dictyocha fibula fibula*	*Dictyocha messanensis*	*Dictyocha perlaevis*	*Dictyocha pumila*	*Dictyocha varia*	*Distephanus boliviensis*	*Distephanus boliviensis* (seven-sided)	*Distephanus boliviensis* (eight-sided)	*Distephanus boliviensis* (nine-sided)	*Distephanus boliviensis* (five-sided)	*Distephanus boliviensis* (multiwindowed)	*Distephanus boliviensis* (seven- or eight-sided)	*Distephanus crux*	*Distephanus pulchra*	*Distephanus raupii*	*Distephanus speculum hemisphaericus*	*Distephanus speculum pentagonus*	*Distephanus speculum speculum*	*Distephanus speculum speculum* (seven- or eight-sided)	*Distephanus speculum speculum* var. *notabilis*	*Distephanus speculum speculum* var. *pseudofibula*	*Distephanus speculum speculum* var. *varians*	*Distephanus speculum speculum* var. *pseudopentagona*	*Naviculopsis eobiapiculata*	*Naviculopsis lata*	Aberrants	Total silicoflagellates
early Miocene	Unzoned	26R-CC	239.85	0.5																																	0
		27R-CC	248.71	0.7	1																		1												1		2
	Naviculopsis biapiculata?	28R-CC	261.81	1.0	3																		2			1		1						1	2		7
late Oligocene		29R-CC	269.41	1.0	1																		1		2	1		3							14		21

Table T2. Abundance of silicoflagellates, Hole 1140A.

Age	Zone	Core, section, interval (cm)	Depth (mbsf)	Slide	*Bachmannocena apiculata*	*Bachmannocena circulus*	*Bachmannocena diodon*	*Bachmannocena elliptica*	*Distephanus depressus*	*Distephanus antarcticus*	*Corbisema triacantha*	*Corbisema hastata*	*Dictyocha aculeata*	*Dictyocha extensa*	*Dictyocha fibula fibula*	*Distephanus boliviensis*	*Distephanus crux*	*Distephanus longispinus*	*Distephanus raupii*	*Distephanus speculum hemisphaericus*	*Distephanus speculum pentagonus*	*Distephanus speculum speculum*	*Distephanus speculum speculum* (seven- or eight-sided)	*Distephanus speculum speculum* f. *cylindrus*	*Distephanus speculum speculum* f. *notabilis*	*Naviculopsis biapiculata*	*Naviculopsis eobiapiculata*	*Naviculopsis lata*	Aberrants	Total silicoflagellates
		183-1140A-																												
Pleistocene	*D. aculeata*	1R-1, 25–26	0.25	1.0									2				1					30								33
middle Miocene	Unzoned	1R-2, 108–109	2.58	0.6							3				9		4			2		11		280						309
		1R-3, 75–76	3.75	1.0											1							45		35						81
		1R-4, 23–24	4.73	1.0							2				3		12					8	54	147						226
		1R-5, 26–27	5.66	0.5							2			8	5		10					20	82	188					1	315
		1R-CC	6.15	1.0			6				3			6	9		7					91	1	41	2				4	166
		2R-1, 25–26	9.75	1.0																		2		1						3
		2R-CC	15.70	1.0			1							1	1		3					59			3				4	68
early Miocene	*Distephanus raupii*–*Corbisema triacantha*	3R-CC	20.77	1.0					1		11				3		104			2	6	54							10	181
		4R-CC	29.99	0.4													1													1
		5R-CC	37.65	0.2	3		1	28	2	1	11				1		92	3			26	132							1	300
		6R-CC	49.33	1.0	12			1	2		45						19					29							1	108
		7R-CC	57.84	1.0							22				25		105	8				28								188
	Unzoned	8R-CC	64.87	1.0			1			11	21				55		9	7		1		5	2			2			1	114
		9R-CC	75.29	1.0	15	3			2		70				60	1	131	31				29				5				332
		10R-CC	84.94	0.5		2		7	6		38				53		149					23				1				279
		11R-CC	92.98	1.0	3			1	1		18				4		40	1				13							1	78
		12R-CC	102.70	0.2	2						3				12		153			45	13	74								302
		13R-CC	114.39	1.0	9		3				4	1					143	2	87	11		38								298
		14R-CC	127.03	1.0			1								3		28	7			5	1								45
		15R-CC	131.72	1.0	2	3	1		3						1	8	177	100				6						1	1	302
		16R-CC	142.71	0.5							13					2	52					13								80
early Oligocene	Unzoned	20R-CC	185.00	0.7													2										1			3
		21R-CC	197.49	1.0							3						14				5						7			29
		22R-CC	207.79	0.5											1															1

Plate P1. Specimens of *Distephanus speculum speculum* forma *cylindrus* n.f. from Holes 747A and 1140A (scale bar = 10 mm). **1a, b.** Holotype (Sample 183-1140A-1R-5, 26–27 cm); (a) apical ring in focus, (b) basal ring in focus. **2.** Tilted specimen showing strut connection apical and basal rings (Sample 120-747A-7H-6, 98–100 cm). **3a, b.** Sample 183-1140A-1R-5, 26–27 cm; (a) apical ring in focus, (b) basal ring in focus. **4.** Tilted specimen showing strut connection apical and basal rings (Sample 183-1140A-1R-4, 23–24 cm). **5a, b.** Sample 183-1140A-1R-4, 23–24 cm; (a) apical/basal in focus, (b) basal/apical in focus. **6a, b.** Sample 183-1140A-1R-4, 23–24 cm; (a) apical ring in focus, (b) basal ring in focus. **7a, b.** Sample 183-1140A-1R-5, 26–27 cm; (a) apical ring in focus, (b) basal ring in focus.