

NEW SPECIES OF DINOFLAGELLATE CYSTS AND OTHER PALYNOMORPHS FROM THE LATEST MIOCENE AND PLIOCENE OF DSDP HOLE 603C, WESTERN NORTH ATLANTIC

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ABSTRACT—Detailed investigation of the essentially complete uppermost Miocene through Lower Pleistocene sequence in Deep Sea Drilling Project (DSDP) Hole 603C, western North Atlantic, has revealed the presence of the new dinoflagellate cyst species *Lejeunecysta hatterasensis*, *Lejeunecysta interrupta*, *Corrudinium devernaliae*, and *Pyxidinoopsis vesiculata*, as well as the acritarchs *Leiosphaeridia rockhallensis* Head new species and *Leffingwellia costata* new genus and species. Independent magnetobiostratigraphic control of DSDP Hole 603C constrains the ranges of these new species. *Lejeunecysta interrupta* n. sp. appears to range no higher than lowermost Pliocene at 5.2 Ma, *Pyxidinoopsis vesiculata* n. sp. has a range top at about 4.5 Ma in the Lower Pliocene, *Corrudinium devernaliae* n. sp. has a well-defined range of 4.7–4.1 Ma within the Lower Pliocene, and *Leiosphaeridia rockhallensis* n. sp. has a similarly well-defined range of 4.4–3.9 Ma within the Lower Pliocene. The presence of *Leiosphaeridia rockhallensis* n. sp. in the Ramsholt Member of the Coralline Crag Formation, eastern England, supports an Early Pliocene age for this member.

INTRODUCTION

THIS REPORT is part of a larger study to document the dinoflagellate cysts of Deep Sea Drilling Project (DSDP) Hole 603C. This section was chosen for its complete sedimentary record spanning the uppermost Miocene through Lower Pleistocene. A rich dinoflagellate and acritarch flora has been recorded in Hole 603C, of which six taxa are here described as new. Their stratigraphic ranges in Hole 603C are independently constrained by magnetobiostratigraphy, and this has allowed their stratigraphic utility to be assessed. To clarify the identity of selected species, comparative material was examined from the Pliocene of the Clinno Core, Bahamas (Head and Westphal, 1999) and Pliocene of eastern England (Head, 1997).

Hole 603C was drilled at 35°29.78'N; 70°01.86'W on the lower slope of the New Jersey continental rise at a water depth of 4,643 m (Fig. 1), as part of Deep Sea Drilling Project (DSDP) Leg 93. The hole penetrated 366 m of Lower Pleistocene and Neogene hemipelagic deposits, and terminated in the uppermost Miocene. Hole 603C deposits consist of nannofossil-bearing to nannofossil-rich clay and claystone, with calcium carbonate concentrations ranging between 1 and 30 percent and organic carbon concentrations averaging around 0.35 percent. These and other details are given in the initial reports for Leg 93 and site report for Site 603 (all in van Hinte et al., 1987).

Excellent core recovery and relatively high sedimentation rates (about 10 cm per 10³ yr; Canninga et al., 1987) have facilitated the recognition of a detailed and essentially uninterrupted paleomagnetic record extending from the early Pleistocene back to the latest Miocene (Canninga et al., 1987; Moullade, 1987; Fig. 2). Only in the lower part of the core, between about 250 and 350 m, are there intervals of poor core recovery that complicate the paleomagnetic record. Hence the base of the Sidufjall Subchron and the top of the underlying Thvera Subchron, as well as the intervening interval of reversed polarity, are not determinable in Hole 603C (Fig. 2). Biostratigraphic control is mostly based on planktonic foraminifers (Ma'alouleh and Moullade, 1987) and calcareous nannofossils (Muza et al., 1987), with all the planktonic Pliocene foraminiferal zones and subzones of Berggren (1977) and all the low-latitude Pliocene nannofossil zones and subzones of Bukry (1973, 1975; see also Okada and Bukry, 1980) being recognized.

This paper uses the time scale of Berggren et al. (1995a,

1995b), and where necessary the literature has been updated accordingly. The nannofossil biostratigraphy and magnetostratigraphy for Hole 603C agree closely with Berggren et al. (1995a, 1995b), but notable discrepancies exist with the foraminiferal biostratigraphy. For example, the Lower/Upper Pliocene boundary (base of the Gauss Chron; Berggren et al., 1995a, 1995b) is clearly delineated in Hole 603C by magnetostratigraphy and nannofossils. However, the foraminiferal placement (PL2/PL3 boundary) is about 40 m lower in the hole. In addition, the foraminiferal Zone PL4 in Hole 603C has a much longer duration within the Upper Pliocene than is accepted by Berggren et al. (1995a, 1995b). This zone is restricted to the Kaena Subchron according to Berggren et al. (1995a, 1995b) but its base extends well below the Mammoth Subchron in Hole 603C. Diachroneity apparently accounts for these discrepancies in the foraminiferal datums. The placement of the Miocene/Pliocene boundary in Hole 603C requires particular consideration. Berggren et al. (1995a, 1995b) accepted an age of 5.32 Ma for the Miocene/Pliocene boundary, which is just below the base of the Thvera Subchron at 5.23 Ma. The boundary has since been internationally ratified, and dated at 5.33 Ma (Van Couvering et al., 2000). The base of the subchron in Hole 603C is at about 316 m (Canninga et al., 1987), and the Miocene/Pliocene boundary can be estimated at about 8 m below it (i.e., at 324 m) using a sedimentation rate of 9.1 cm/10³ yr. Nannofossil biostratigraphy is in good agreement with this placement because the highest occurrence of *Discoaster quinqueramus*, marking the top of Zone CN9, occurs between 325.8 and 324.3 m (Muza et al., 1987) which is just below the estimated Miocene/Pliocene boundary in Hole 603C (see above). The time scale of Berggren et al. (1995a, 1995b) similarly places the top of Zone CN9 just below the Miocene/Pliocene boundary. The planktonic foraminiferal zonation in Hole 603C is more difficult to reconcile, however. Berggren et al. (1995a, 1995b) placed the base of Subzone PL1a just below the Miocene/Pliocene boundary (coincident with the top of calcareous nannofossil Zone CN9) and its top at about the position of the Nunivak Subchron. In Hole 603C, however, Subzone PL1a has its top close to the estimated Miocene/Pliocene boundary, this subzone extending to the base of the hole (Ma'alouleh and Moullade, 1987). The explanation for this discrepancy is not clear, although planktonic foraminifers appear to be affected by calcite dissolution and possible climatic exclusion

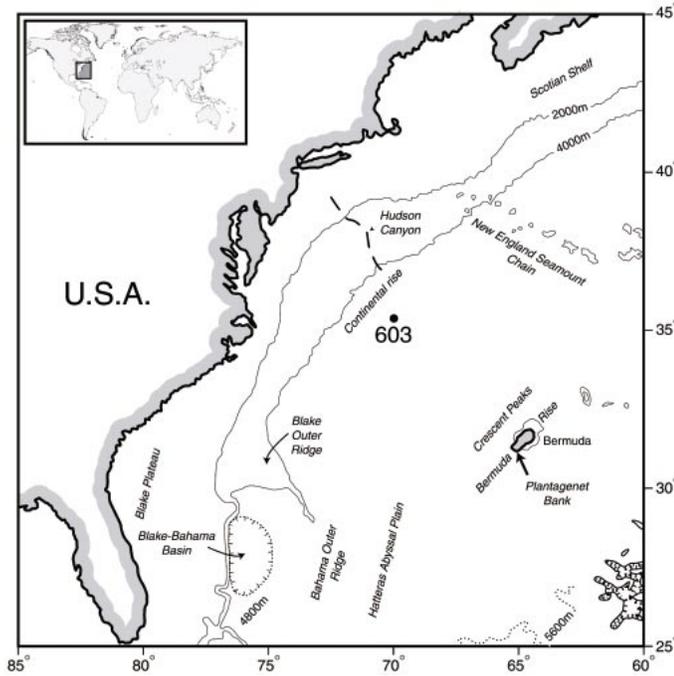


FIGURE 1—Location and bathymetry of DSDP Site 603, western North Atlantic.

in the bottom part of Hole 603C (Ma'alouleh and Moullade, 1987).

MATERIALS AND METHODS

Materials.—Fifty-seven samples, predominantly greenish or grayish clay or claystone, were analyzed from the entire interval recovered in DSDP Hole 603C (Fig. 2), representing about two samples per core. This was accomplished by re-examining microscope slides used by Kolev (1993) for his preliminary investigation of the dinoflagellates and acritarchs. Microscope slides from the study by Head (1997) of the mid-Pliocene Coralline Crag Formation of eastern England were re-examined for specimens of *Leiosphaeridia rockhallensis* Head n. sp., and microscope slides from the study by Head and Westphal (1999) of the Pliocene in the Clino Core, Bahamas were re-examined for specimens of *Lefingwellia* n. gen.

Methods.—For DSDP Hole 603C, a single 10 cc plug was collected for each sample. Samples were first cleaned of adherent drilling slurry, dried and weighed (13–18 g), and two *Lycopodium*

L. MIOCENE		EARLY PLIOCENE				LATE PLIOCENE				E. PLE		EPOCH / AGE		SAMPLE (core section, interval in cm)	Depth below sea floor (in m)	Dinoflagellate cysts <i>Lefingwellia cinctaria</i> <i>Lefingwellia intertrapa</i> n. sp. <i>Pyxidimopsis vesiculata</i> n. sp. <i>Lefingwellia hatterasensis</i> n. sp. <i>Corradium devermiliae</i> n. sp.	TOTAL DINOFLAGELLATES	Marine invertebrate sedils <i>Leiosphaeridia rockhallensis</i> Head n. sp. <i>Lefingwellia costata</i> n. gen and sp. <i>Lycopodium</i> spores (spike)	Sample dry weight (in g)
PL1a	PL1b	PL1c	PL2	PL3	PL4	PL5	PL6	"O"	P	Nannofossils	Planktonic foraminifers	CHRON	SUBCHRON						
														1-1, 90-92	0.92		250		105 13.5
														2-2, 54-56	4.06		250		710 12.1
														2-6, 100-102	10.52		250		258 15.5
														3-2, 45-47	13.57		251		202 16.5
														4-2, 68-70	23.40		250		226 14.6
														4-5, 20-22	27.42		250		179 16.4
														5-5, 100-102	37.82		249	1	456 14.4
														6-1, 103-105	41.45		251		113 15.1
														7-2, 85-87	52.27		250		145 17.6
														8-2, 100-102	61.92		250		105 15.4
														8-5, 100-102	66.42		247		90 19.5
														9-6, 130-132	76.62		245		96 15.5
														10-1, 67-69	77.99		249		313 15.2
														11-1, 100-102	85.82		249		117 15.1
														11-4, 68-70	90.00		250		144 17.2
														13-2, 68-70	99.40		251		204 14.6
														14-2, 50-52	108.02		250		229 13.6
														14-5, 55-57	113.37		250		352 13.6
														15-2, 85-87	118.77		250		185 14.6
														15-5, 66-68	123.08		249		242 14.6
														16-1, 66-68	126.68		251		300 13.7
														16-5, 50-52	132.52		252		179 14.5
														17-2, 50-52	137.62		250		96 14.6
														17-4, 80-82	140.92		250		123 15.3
														18-1, 84-86	146.06		250		162 14.5
														18-6, 50-52	153.22		250		205 15.1
														19-2, 100-102	157.32		250		238 15.5
														19-4, 85-87	160.17		250		134 17.4
														20-1, 83-85	165.25		250		312 16.9
														20-6, 85-87	172.77	1?	249		293 17.6
														21-2, 56-58	176.08		250		140 14.8
														21-6, 50-52	182.02		250		185 14.0
														22-2, 84-86	185.96		250		624 16.1
														22-5, 24-26	189.86		250		361 15.0
														23-3, 100-102	197.22		250	31	303 17.1
														24-2, 50-52	204.82		251	9	80 19.9
														24-4, 84-86	208.16		250	7	197 14.4
														25-3, 26-28	215.68		250	4	138 16.4
														25-6, 22-24	220.14		250	7	127 15.4
														26-2, 50-52	224.02		251	19	291 15.1
														26-6, 10-12	229.62		250	11	201 17.2
														27-2, 16-18	233.28		253	+	272 15.8
														27-4, 54-56	236.66		251	+	126 16.9
														28-2, 15-17	242.87		250	6	191 17.9
														28-6, 35-37	249.07		250	+	188 18.1
														30-2, 50-52	262.42		250	+	153 16.6
														31-2, 86-88	272.38		257		30 14.6
														31-5, 20-22	276.22		255		148 15.9
														33-2, 51-53	291.23		258		47 n.a.
														33-5, 45-47	295.67		281		177 n.a.
														35-3, 46-48	311.88		251		114 16.6
														35-6, 65-67	316.57		255		40 13.3
														36-5, 23-25	324.25		251		96 16.6
														37-5, 20-22	333.82		271		97 17.8
														38-5, 45-47	343.67		253		104 18.1
														39-6, 14-16	354.46		293		233 17.6
														40-6, 14-16	364.06		250		151 14.2

FIGURE 2—Stratigraphic ranges of taxa discussed herein for DSDP Hole 603C as shown by actual counts. Taxa recorded during continued searching of slides for rare occurrences (i.e., after counting was completed) are indicated by a cross (+). The recognition of planktonic foraminiferal zones is from Ma'alouleh and Moullade (1987) using the zonal scheme of Berggren (1973, 1977), the nannofossil zones from Muza et al. (1987) using the zonal scheme of Bukry (1973, 1975) and Okada and Bukry (1980), and the magnetostratigraphy from Canninga et al. (1987) and Moullade (1987). Magnetic polarity subchrons are abbreviated as follows: Olduvai = OLD, Kaena = K, Mammoth = M, Cochiti = C, Nunivak = N, Sidufjall = Sidu, and Thvera = THV. The Thvera and Sidufjall subchrons and intervening reversed polarity subchron are not separately distinguishable owing to an absence of data caused by gaps in core recovery. Ages of subchron boundaries are from Berggren et al. (1995a, 1995b). Normal polarity intervals are in black.

tablets (batch 710961, each containing 13,911 spores) were added to facilitate the calculation of cyst concentrations (numbers of cysts per gram dry weight of dry sediment). Samples were demineralised using HCl and HF and were not oxidized. The residues were given 5–8 secs ultrasound, sieved through a 10 μm Nitex screen, stained with safranin-o, and strew-mounted onto 50 \times 22 mm coverslips using Cellosize (hydroxyethyl cellulose). The coverslips were mounted onto microscope slides using the acrylic resin Elvacite. Details of processing are given in Kolev (1993). Dinoflagellate cysts and acritarchs were counted by one of us (MJH) until at least about 250 dinoflagellate cysts had been enumerated for each sample. The remainder of the slide and a second slide were then examined by MJH for rare taxa. Counts of selected species are shown in Figure 2.

Photography.—Illustrations were made in Cambridge using a Leica DMR microscope and Leica DC300 digital camera. Images are all true, i.e., not reversed. An England Finder reference follows the sample and slide number for each specimen illustrated. Slide labels are to the right.

Repository.—All illustrated specimens are housed in the Invertebrate Section of the Department of Palaeobiology, Royal Ontario Museum, under the catalog numbers ROM 52495 and ROM 55071–55093 inclusive.

RESULTS AND DISCUSSION

Four dinoflagellate cyst species, *Lejeunecysta hatterasensis* n. sp., *Lejeunecysta interrupta* n. sp., *Corrudinium devernaliae* n. sp., and *Pyxidinospis vesiculata* n. sp. are recognized as new, along with the marine acritarchs *Leiosphaeridia rockhallensis* Head n. sp. and *Leffingwellia costata* n. gen. and sp. *Lejeunecysta cinctoria* (Bujak, 1980) Lentin and Williams, 1981 also occurs in DSDP Hole 603C and is included for comparison with the superficially similar *Lejeunecysta interrupta* n. sp. Independent magnetobiostratigraphic control of DSDP Hole 603C allows the stratigraphic ranges of these species to be assessed on a numerical time scale (Berggren et al., 1995a, 1995b; Fig. 2), as follows.

Lejeunecysta interrupta n. sp. has an apparent range top in the lowermost Pliocene at 5.2 Ma, a single higher occurrence being possibly attributable to reworking.

Lejeunecysta cinctoria (Bujak, 1980) has a range top at 5.31 Ma in the lowest Pliocene, this representing the youngest age recorded anywhere for this species.

Pyxidinospis vesiculata n. sp. has a range top at about 4.5 Ma in the Lower Pliocene.

Corrudinium devernaliae n. sp. has a well-defined range of 4.7–4.1 Ma within the Lower Pliocene. It occurs persistently through this range, and abundance reaches 4 percent of the total dinoflagellates. This species has a comparable range in ODP Site 646 of the Labrador Sea (as *Corrudinium* sp. I in de Vernal and Mudie, 1989).

Leiosphaeridia rockhallensis n. sp. has a well-defined range of 4.4–3.9 Ma within the Lower Pliocene of DSDP Hole 603C. Its type stratum is the Ramsholt Member of the Coralline Crag Formation exposed at Rockhall Wood in eastern England (Head, 1997), which has been dated tentatively at between 3.6 and 3.8 Ma based on calcareous microfossils (Jenkins and Houghton, 1987). The presence of *L. rockhallensis* n. sp. supports an Early Pliocene age assessment for this member.

Lejeunecysta hatterasensis n. sp. and *Leffingwellia costata* n. gen. and sp. appear to be less useful for biostratigraphy because they occur only sporadically in Hole 603C. *Lejeunecysta hatterasensis* is known only from Hole 603C, where it occurs in the Lower and Upper Pliocene. *Leffingwellia costata* was found only in the Upper Pliocene of Hole 603C, but has been reported from the Lower Pliocene of the Clino Core, Bahamas (as *Incertae sedis* B in Head and Westphal, 1999).

SYSTEMATIC PALEONTOLOGY

- Division DINOFLAGELLATA (Butschli, 1885)
Fensome et al., 1993
Subdivision DINOKARYOTA Fensome et al., 1993
Class DINOPHYCEAE Pascher, 1914
Subclass PERIDINIPHYCIDAE Fensome et al., 1993
Order PERIDINIALES Haeckel, 1894
Suborder PERIDINIINEAE (Autonym)
Family PROTOPERIDINIACEAE Balech, 1988
Subfamily PROTOPERIDINIOIDEAE Balech, 1988

Discussion.—See Head et al. (2001) for discussion of the validation of the names Protoperidiniaceae and Protoperidinioideae.

Genus LEJEUNECYSTA Artzner and Dörhöfer, 1978 emend.
Lentin and Williams, 1976

Discussion.—Lentin and Williams (1976) emended this species under its previous name *Lejeunia* Gerlach, 1961, which is a junior homonym of *Lejeunea* Libert, 1820 (Artzner and Dörhöfer, 1978). The emendation by Lentin and Williams (1976) is favored over that by Bujak (1980; see Head, 1993, p. 30–31).

LEJEUNECYSTA CINCTORIA (Bujak, 1980)
Lentin and Williams, 1981
Figures 3, 5

Lejeunia cinctoria BUJAK, 1980, p. 68–69, pl. 18, figs. 1–4; text-fig. 17.
Lejeunecysta cinctoria (BUJAK, 1980) LENTIN AND WILLIAMS, 1981, p. 169.

Lejeunecysta cf. *cinctoria* (BUJAK, 1980) LENTIN AND WILLIAMS, 1981.
DUFFIELD AND STEIN, 1986, pl. 2, figs. 6, 7.

Measurements.—Length 34–45 μm , breadth 32–45 μm . Spinules up to 2.5 μm in length. Eight specimens measured. See also Figure 5.

Occurrence.—Middle Eocene of southern England (Bujak et al., 1980) through Upper Miocene of the Gulf of Mexico (as *L.* cf. *cinctoria* in Duffield and Stein, 1986), and Upper Miocene through lowermost Pliocene of Hole 603C (this study).

Discussion.—Specimens are mostly smaller than the type material from the Eocene of southern England (length, 44–62 μm ; Bujak, 1980). Cingular spinules are generally around 1.0 μm in length, but with some reaching 2.5 μm . Unlike *Lejeunecysta interrupta* n. sp., both anterior and posterior cingular margins are continuously spinulose, except for a wide gap in the mid-ventral area and short breaks elsewhere indicating tabulation.

LEJEUNECYSTA HATTERASENSIS new species
Figure 4

Lejeunecysta oliva (auct. non REID, 1977) TURON AND LONDEIX, 1988.
KOLEV, 1993, p. 53, pl. 4, fig. 11.

Diagnosis.—Epicyst and hypocyst of approximately equal length, apical horn tapering to rounded apex, antapical horns tapering to sharp points. Cingulum nearly planar, marked on both margins by low crests with thickened bases. Entire surface of cyst covered by dense ornament of narrow, low (less than 0.5 μm high and wide), sinuous, anastomosing ridges and scattered granules. Low, faint sutural ridges on epi- and hypocyst incompletely reflect tabulation. Archeopyle 2a intercalary, asymmetrical iso-deltaform linteloid, well-developed angles, operculum free.

Description.—Cysts proximate, medium brown in color, peridinioid, epicyst and hypocyst of approximately equal length; antapical horns of approximately equal development. Cysts have moderate dorso-ventral compression as primary feature; just two of 13 recorded specimens preserved in polar-compressed state. Sides of epicyst slightly convex, apical horn tapers to rounded

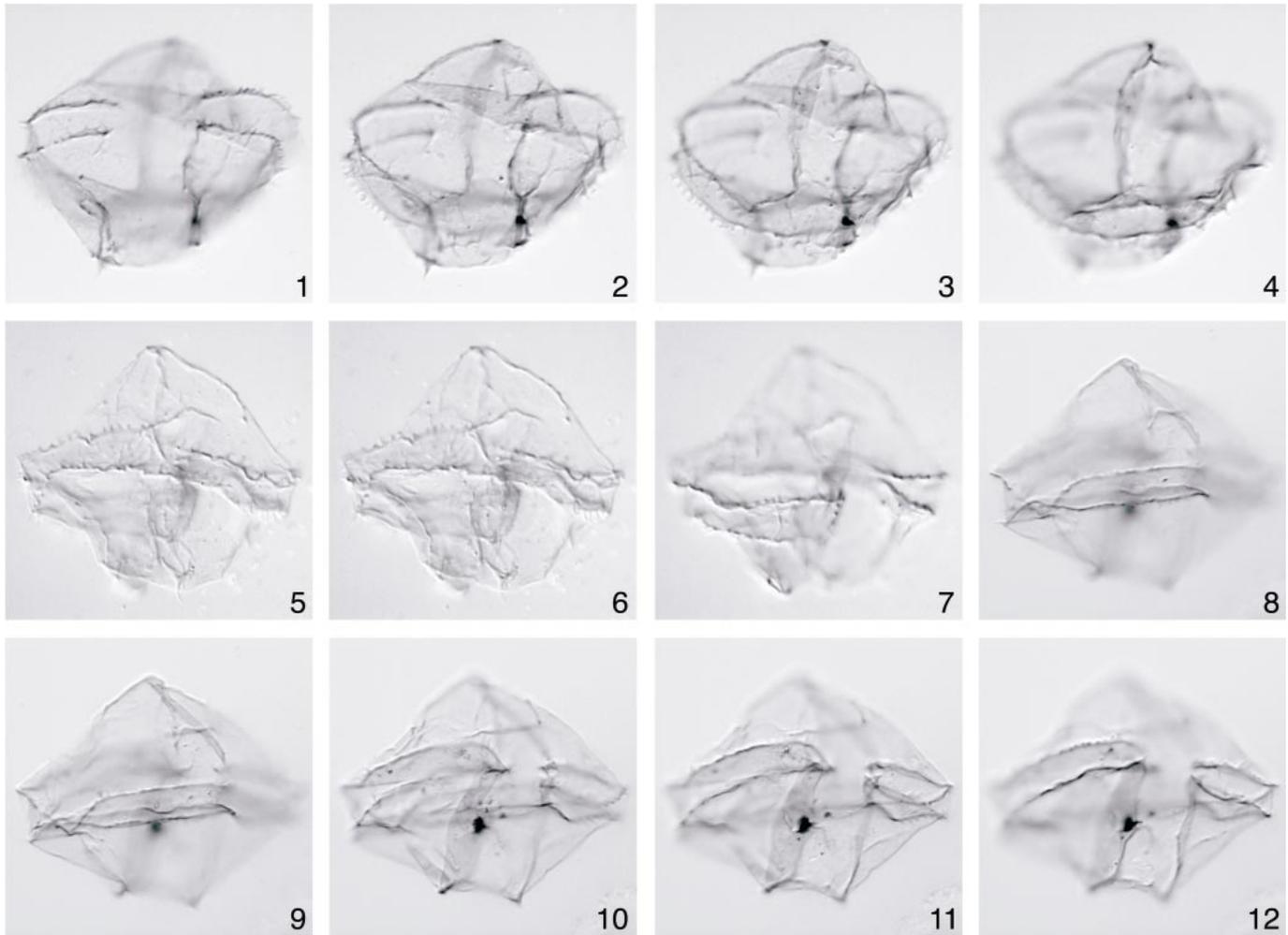


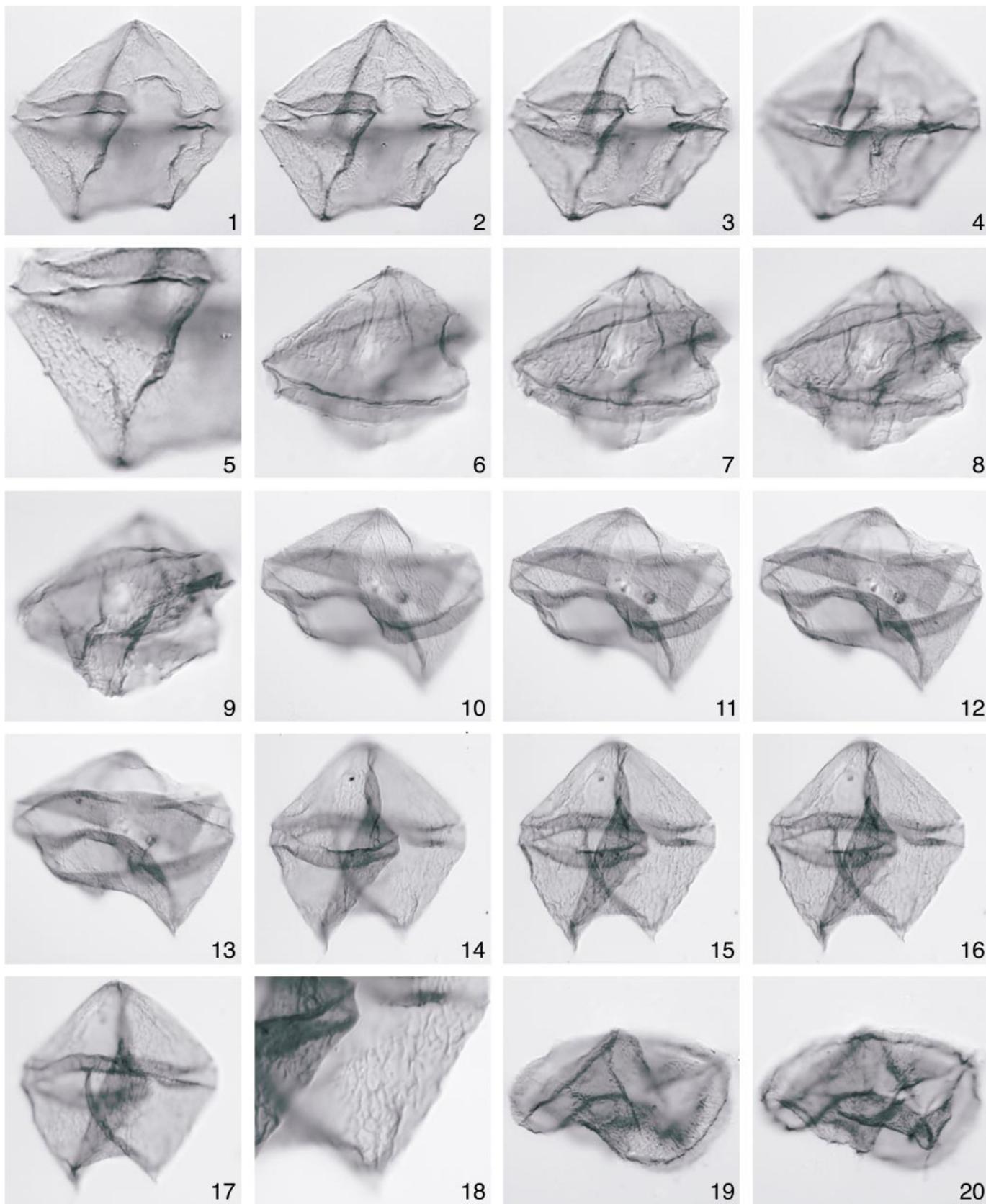
FIGURE 3—*Lejeunecysta cinctoria* (Bujak, 1980). All photomicrographs are interference contrast images. Various magnifications. Note denticulations on both anterior and posterior cingular margins (compare with *Lejeunecysta interrupta* n. sp.). 1–4, Sample DSDP 603C-35-6, 65–67 cm; slide 2 (ROM 55085); R3/1; ventral view of 1 ventral surface, 2 slightly lower focus, 3 mid focus, and 4 dorsal surface; length 36 μm . 5–7, Sample DSDP 603C-40-6, 14–16 cm; slide 1 (ROM 55091); E36/3; dorsal view of 5 dorsal surface, 6 slightly lower focus, 7 ventral surface; length 36 μm . 8–12, Sample DSDP 603C-40-6, 14–16 cm; slide 2 (ROM 55092); S31/0; dorsal view of 8 dorsal surface, 9 slightly lower focus, 10 mid focus, 11 and 12 ventral surface; length 38 μm .

apex that may be thickened (as on the holotype), although a thickened protuberance occasionally present. Lateral margins of hypocyst straight to slightly convex; antapical margin weakly to deeply incised. Antapical horns taper to sharp hollow points. Cingulum not indented to moderately indented and approximately planar; each margin marked by low (<1.0 μm) thin crest with thickened base. Sulcus broad and moderately incised; midventral

flagellar scar sometimes present (e.g., Fig. 4.4). Dense ornament of narrow (less than 0.5 μm), sinuous, anastomosing ridges and scattered granules less than 0.5 μm high, appearing as dark lines, covers entire surface. These lines form a pattern radiating outwards from horn tips. Some radial lines on epicyst and hypocyst straighter and more prominent, presumably indicating plate boundaries. Wall layers closely appressed except for occasional

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FIGURE 4—*Lejeunecysta hatterasensis* n. sp. All photomicrographs are interference contrast images. Red filter used to compensate for dark brown color of cysts. Various magnifications. 1–5, Sample DSDP 603C-13-2, 68–70 cm; slide 1 (ROM 55072); L14/3; ventral view of 1 ventral surface, 2 slightly lower focus showing operculum in place, 3 mid focus, 4 dorsal surface but also showing flagellar scar in midventral area, 5 close-up of 1 showing detail of wall ornament; length 46 μm . 6–9, Sample DSDP 603C-14-2, 50–52 cm; slide 2 (ROM 55074); O12/0; right-lateral view of 6 right-lateral surface showing operculum in place, 7 slightly lower focus, 8 mid focus, and 9 left-lateral surface, breadth 46 μm . 10–13, Holotype, sample DSDP 603C-28-6, 35–37 cm; slide 3 (ROM 55082); K34/0; ventral view of 10 ventral surface, 11 slightly lower focus showing the asymmetrical outline of the displaced operculum, 12 mid focus (note that the posterior margin of the operculum is folded back on itself), 13 dorsal surface; breadth 67 μm . 14–18, Sample DSDP 603C-30-2, 50–52 cm; slide 1 (ROM 55083); J38/0; ventral view of 14 ventral surface, 15 and 16 mid focus, 17 dorsal surface, 18 close-up of 14 showing detail of wall ornament; length 61 μm . 19–20, Sample DSDP 603C-13-2, 68–70 cm; slide 2; U35/1 (ROM 55073); apical view of 19 apical surface, and 20 antapical surface; breadth 47 μm .



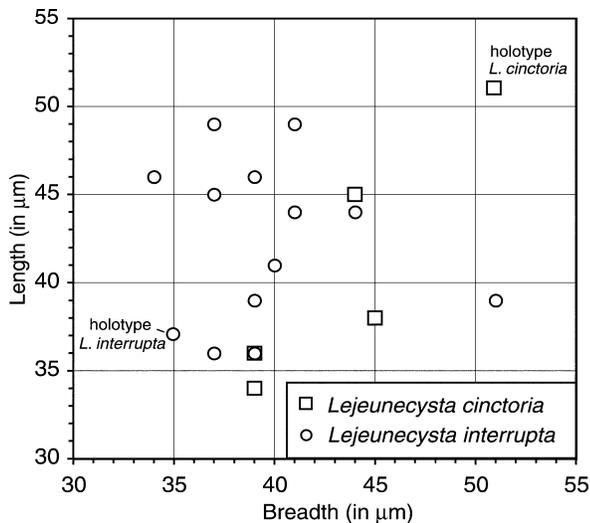


FIGURE 5—*Lejeunecysta interrupta* n. sp. and *Lejeunecysta cinctoria* (Bujak, 1980) showing length vs. breadth for specimens from DSDP Hole 603C. The holotype of *Lejeunecysta cinctoria* from the Eocene of southern England (measured from Bujak, 1980, pl. 18, figs. 1, 2) is also shown for comparison with DSDP Hole 603C specimens.

separation at antapical horn tips into layers, where thickening is apparently restricted to inner wall layer. Archeopyle 2a intercalary, iso-deltaform linteloid with very short H3 and H5 slides (almost trapezoidal) and asymmetrical (e.g., Fig. 4.10–4.13) with right archeopyle margin more nearly vertical than left. Archeopyle shows no obvious offset relative to middorsal line.

Etymology.—Named after the Hatteras Outer Ridge, an Upper Cenozoic sedimentary drift deposit into which Hole 603C was drilled.

Type.—Holotype, sample DSDP 603C-28-6, 35–37 cm, slide 3 (ROM 55082); England Finder reference K34/0. Lower Pliocene. Figure 4.10–4.13.

Measurements.—Holotype: Length 55 μm ; breadth 67 μm . Range: Length 41(52.9)64 μm , standard deviation 8.9 μm ; breadth 46(53.3)67 μm , standard deviation 6.3 μm . Thirteen specimens were measured.

Occurrence.—Present in two separate intervals of the Lower and Upper Pliocene of DSDP Hole 603C, implying ecological control on its distribution.

Comparison.—This species differs from all others of the genus in its distinctive ornament. *Selenopemphix warriensis* Biffi and Grignani, 1983, described from the Oligocene of the Niger Delta,

has greater polar compression, appears to be less densely ornamented (“wrinkled” according to Biffi and Grignani, 1983), and is larger (breadth, 85–120 μm).

LEJEUNECYSTA INTERRUPTA new species

Figures 5, 6

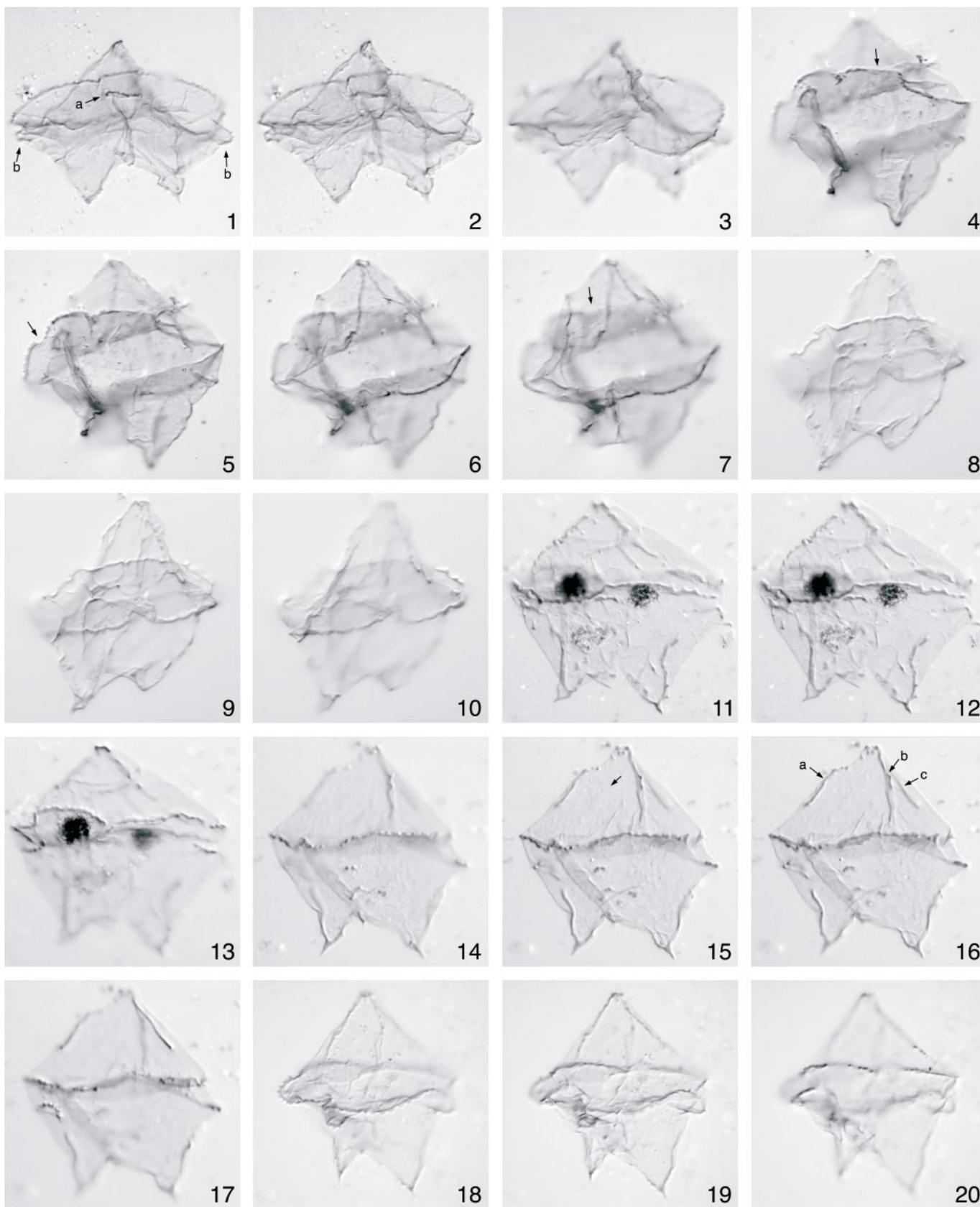
Diagnosis.—Cyst surface smooth to shagreenate, apical horn forms truncated point, symmetrical antapical horns taper to solid points. Cingular margins marked by low, thickened crests bearing spinules, indentations, and/or irregular serrations; crests nearly continuous on anterior margin but restricted to middorsal and lateral locations on posterior margin. Several sutural ridges, which may or may not bear spinules/coni, present on epi- and hypocyst where they converge generally towards horn tips. Archeopyle 2a intercalary, iso-deltaform linteloid with rounded angles; operculum free.

Description.—Cysts have peridinioid outline, moderate dorsoventral compression, light brown wall with smooth to shagreenate surface. Apical horn forms truncated point usually bearing two spinules/coni. Antapical horns symmetrically located and taper to solid points. Cingulum nearly planar. Anterior cingular margin marked by almost continuous, low (ca. 1.0 μm), thickened crest bearing spinules, indentations, and/or irregular serrations, although there may be short breaks indicating tabulation (e.g., Fig. 6.5); and ornament is reduced or not present in mid-ventral position (e.g., Fig. 6.4). Posterior cingular margin marked by same ornament but restricted to three distinct crests, again reflecting tabulation: a linear crest positioned mid dorsally, and an arcuate crest located at each lateral margin (e.g., Fig. 6.1). These crests variable in length but usually less than 10 μm long. Middorsal crest occasionally very short (ca. 2 μm long on holotype). Epicyst has three long, low (less than 1.0 μm high) sutural ridges. Two, approximately lateral in position, converge upon apex and usually bear low spinules/coni (e.g., Fig. 6.16a and 6.16c). Third ridge positioned to right of archeopyle on dorsal surface usually bears one prominent spinule although other spinules may also be present (e.g., two on holotype; see Fig. 6.16b). Antapical horns each have two low sutural ridges that converge upon horn tips and may or may not bear spinules/coni; one ridge follows lateral margin of horn, the other the posterior margin. Scattered spinules/coni, sometimes aligned, may also occur on hypocyst. Archeopyle 2a intercalary, iso-deltaform linteloid with rounded angles, as shown by specimens in Figure 6.4 and 6.15. Archeopyle slightly offset to left of dorsoventral midline on holotype (6.15).

Etymology.—Latin, *interruptus*, broken apart, interrupted; with reference to the discontinuous expression of the posterior cingular margin.

Type.—Holotype, sample DSDP 603C-37-5, 20–22 cm; slide

FIGURE 6—*Lejeunecysta interrupta* n. sp. All photomicrographs are interference contrast images. Various magnifications. Note discontinuous denticulate ridges on posterior cingular margin (compare with *Lejeunecysta cinctoria*). 1–3, Sample DSDP 603C-35-6, 65–67 cm; slide 3 (ROM 55086); T15/0; dorsal view of 1 dorsal surface showing denticulate ridges restricted to middorsal (a) and lateral (b) areas of the posterior cingular margin, 2 mid focus, 3 ventral surface; length 39 μm . 4–7, Sample DSDP 603C-37-5, 20–22 cm; slide 1 (ROM 55087); Q53/1; ventral view of 4 ventral surface showing absence of ornament on anterior cingular margin in mid-ventral area as indicated by arrow, but also showing posterior margin of archeopyle with slightly displaced operculum, 5 slightly lower focus showing small breaks in ornament (e.g., as arrowed) along the anterior cingular margin that apparently correspond to tabulation, 6 mid focus, and 7 dorsal surface showing anterior margin of archeopyle as indicated by arrow; length 44 μm . 8–10, Sample DSDP 603C-37-5, 20–22 cm; slide 1 (ROM 55087); S39/1; dorsal view of 8 dorsal surface, 9 slightly lower focus, 10 ventral surface; length 45 μm . 11–13, Sample DSDP 603C-37-5, 20–22 cm; slide 2 (ROM 55088); V6/0; dorsal view of 11 dorsal surface, 12 mid focus, 13 ventral surface; length 39 μm . 14–17, Holotype, sample DSDP 603C-37-5, 20–22 cm; slide 2 (ROM 55088); W46/2; dorsal view of 14 dorsal surface, 15 slightly lower focus showing operculum in place, but rounded anterior margin of archeopyle suture just visible as indicated by arrow, 16 mid focus showing (a) and (c) sutural ridges approximately lateral in position, and (b) sutural ridge on dorsal surface bearing in this case two spinules, 17 ventral surface; length 37 μm . 18–20, Sample DSDP 603C-37-5, 20–22 cm; slide 3 (ROM 55089); M5/2; dorsal view of 18 dorsal surface, 19 mid focus, 20 ventral surface; length 49 μm .



2 (ROM 55088); England Finder reference W46/2. Upper Miocene. Figure 6.14–6.17.

Measurements.—Holotype: length 37 μm ; breadth, including spinules/serrations 35 μm . Range: length 36(42.5)49 μm , standard deviation 4.5 μm ; breadth, including spinules/serrations 32(40.3)55 μm , standard deviation 5.2 μm . Spinules/serrations generally up to ca. 1.0 μm in length. Twenty-six specimens measured. See also Figure 5.

Occurrence.—Upper Miocene through lowermost Pliocene of DSDP Hole 603C. A single questionable specimen in the lower Upper Pliocene of this hole is possibly reworked.

Comparison.—*Lejeunecysta interrupta* differs from *L. cinctoria* (see above) in having its posterior cingular margin always indicated by just three short rows of spinules/serrations, this margin being more continuous in *L. cinctoria*. Also the anterior cingular margin is more continuously delineated in *Lejeunecysta interrupta* than in *L. cinctoria*.

Order GONYAULACALES Taylor, 1980
Family GONYAULACACEAE Lindemann, 1928
Genus CORRUDINIUM Stover and Evitt, 1978
CORRUDINIUM DEVERNALIAE new species
Figure 7

Corrudinium harlandii auct. non MATSUOKA, 1983. MUDIE, 1987, pl. 3, fig. 9a, 9b.

Corrudinium sp. I. DE VERNAL AND MUDIE, 1989, p. 413, pl. 3, figs. 14–16.

Corrudinium sp. I of DE VERNAL AND MUDIE, 1989. KOLEV, 1993, p. 41, pl. 1, figs. 10, 11.

Diagnosis.—Small, ovoid, proximate cysts having smooth surface and ridges that form coarse irregular reticulum, reflecting tabulation only obscurely. Ridges of even height arise from wide bases and narrow distally towards crests that are entire. Small vesicles occur at bases of some or most ridges, and may also occur upwards through ridges at ridge junctions. Archeopyle precingular 1P, formed by loss of plate 3", has unornamented margins, well defined angles. Operculum free.

Description.—Ovoid proximate cysts lacking apical protuberance. Wall is an autophragm and has smooth surface. Color varies from light yellow-brown to colorless. Between ridges, wall appears unstructured and has thickness less than ca. 0.5 μm . Ridges form complete or incomplete irregular reticulum over entire surface of cyst. Reticulation for each cyst contains lumina in a range of sizes, smallest mostly about 2–4 μm and largest about 7–14 μm . Ridges have smooth surface, arise from wide (ca. 1.0 μm) bases, narrow distally towards crests that are entire and of generally even height. Clusters of small (mostly less than 0.5 μm) vesicles occur at bases of some or most ridges, and may also occur upwards through ridges at ridge junctions. Occasionally these vesicles occur elsewhere on ridges along with occasional minute perforations of ridge. Tabulation generally obscure, but

ridges occasionally reflect tabulation around cingulum and in ventral area. Archeopyle surrounded by unornamented margin about 1–3 μm wide; angles of archeopyle well defined.

Etymology.—Named for Anne de Vernal who first recognized the stratigraphic significance of this species (de Vernal and Mudie, 1989).

Type.—Holotype, sample DSDP 603C-28-6, 35–37 cm; slide 1 (ROM 55080); England Finder reference Q15/2. Lower Pliocene. Figure 7.14–7.17.

Measurements.—Holotype: length of central body 28 μm , breadth of central body 26 μm ; ridge height 1.5 μm . Range: length of central body 27(30.7)35 μm , standard deviation 2.3 μm ; equatorial diameter of central body 23(26.7)30 μm , standard deviation 2.1 μm ; ridge height 1.5(2.2)3.5 μm . Twenty-one specimens measured.

Occurrence.—Lower Pliocene (nannofossil zones NN12 though NN15) of ODP Site 646, Labrador Sea, being common in nannofossil zones NN13 though NN15 (as *Corrudinium* sp. I in de Vernal and Mudie, 1989; Knüttel et al., 1989). Sporadic higher occurrences that extend into the Upper Pliocene of the Labrador Sea (de Vernal and Mudie, 1989, figs. 3 and 6) possibly represent reworking. A specimen has also been recorded from the Lower Pliocene (nannofossil zone NN15) of DSDP Site 611 in the northern North Atlantic (as *Corrudinium harlandii* in Mudie, 1987). *Corrudinium devernaliae* has a narrow and well-defined range within the Lower Pliocene of DSDP Hole 603C.

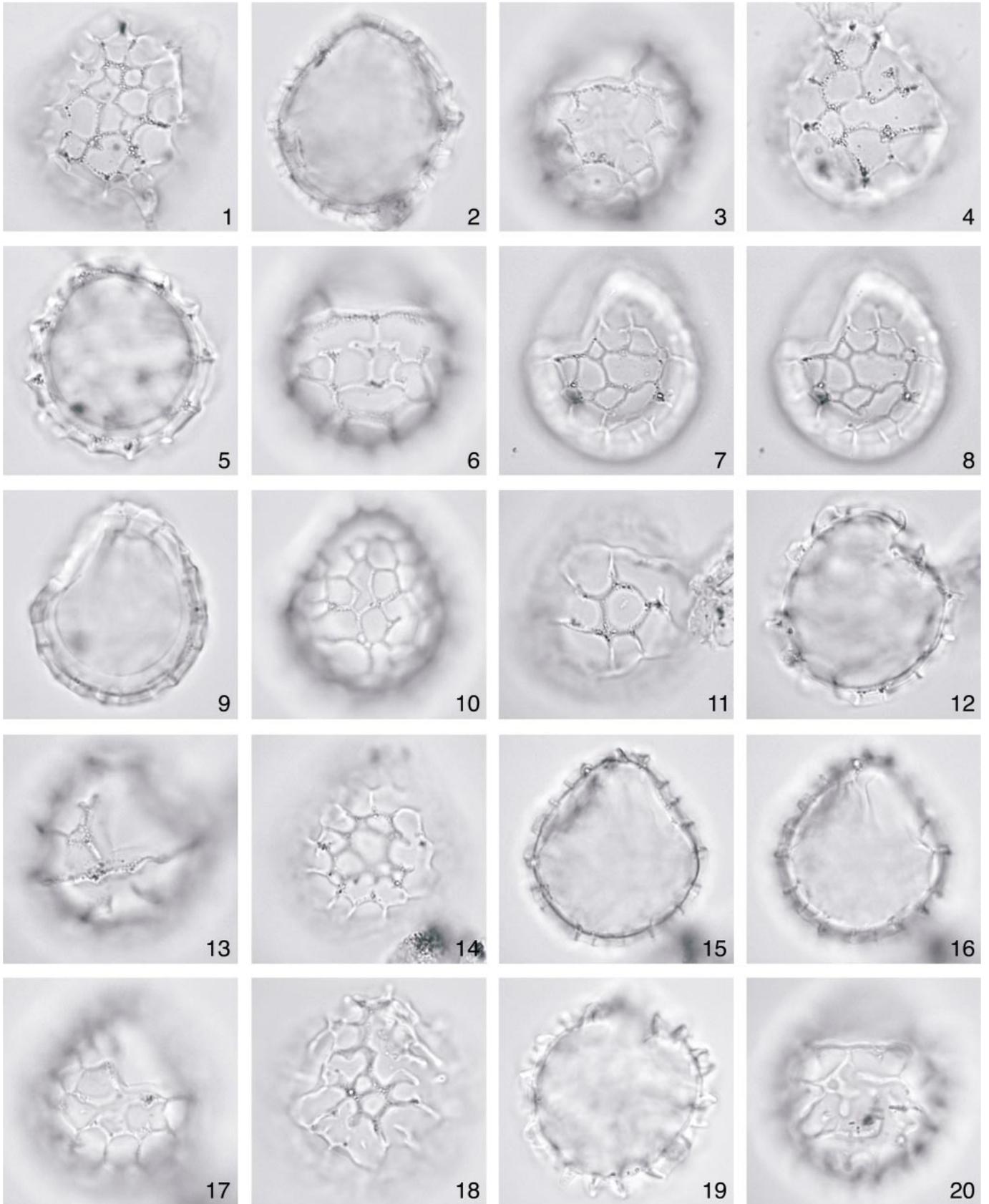
Comparison.—*Cerebrocysta perforocresta* (MS name) Zevenboom and Santarelli in Zevenboom, 1995, from the Upper Miocene of Italy (which Zevenboom and Santarelli synonymised with *Cerebrocysta* sp. A of Powell, 1986; and *Cerebrocysta* sp. A of Powell, 1986 in Engel, 1992), is similar in overall morphology but much larger (length, 60–85 μm ; Zevenboom, 1995). *Cerebrocysta perforocresta* (op. cit.) does not occur in DSDP Hole 603C. *Corrudinium harlandii* Matsuoka, 1983, described from the Pliocene or Lower Pleistocene of Japan, differs from *Corrudinium devernaliae* n. sp. in being thinner walled (and hence greater propensity for folding), and in having more delicate septa, more complete expression of tabulation, and a coarsely striate surface.

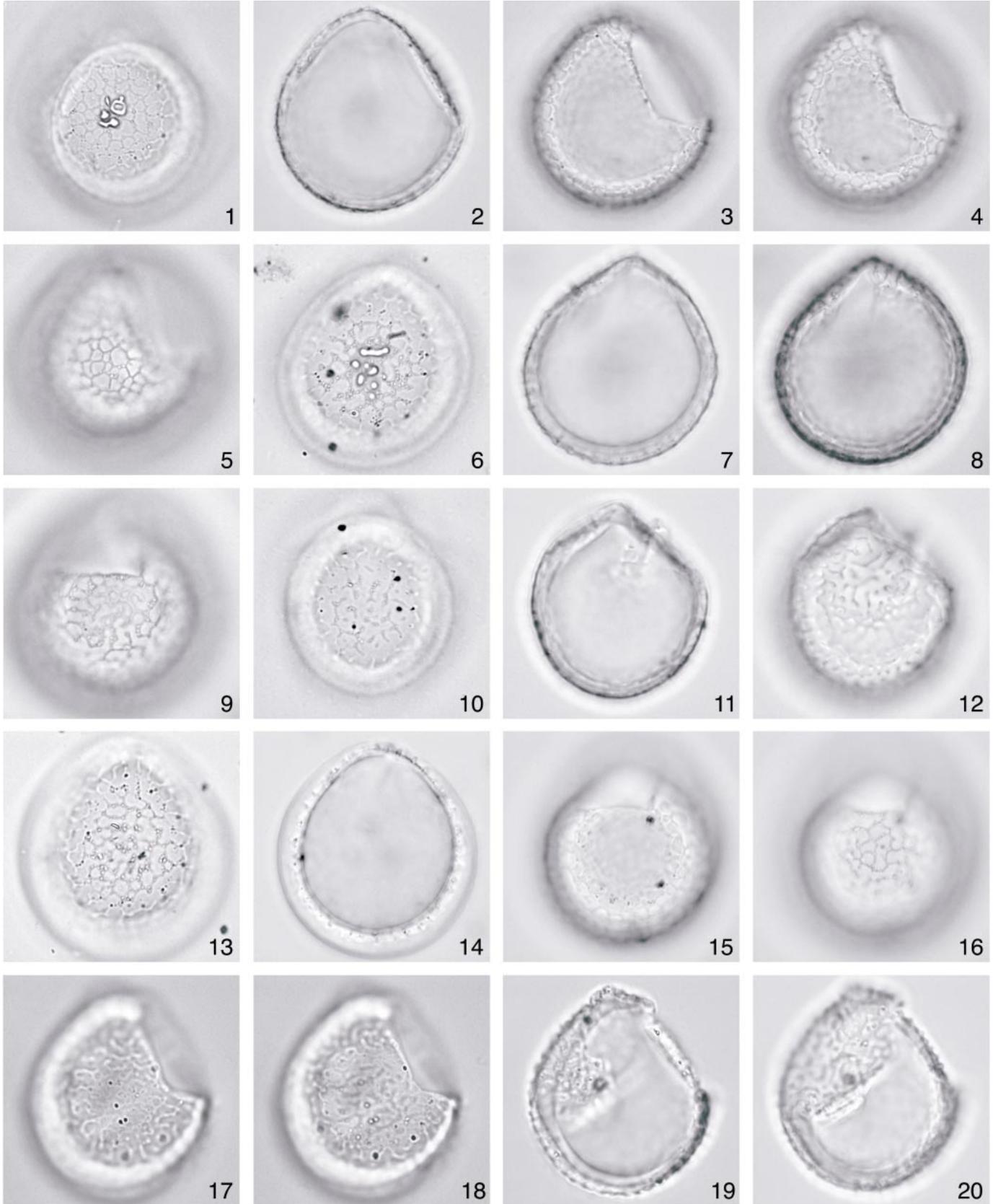
Genus PYXIDINOPSIS Habib, 1976
PYXIDINOPSIS VESICULATA new species
Figure 8

Diagnosis.—Small ovoid proximate cysts, with or without apical protuberance; surface smooth with ridges that interconnect to varying degrees to form fine irregular, non-tabular reticulum. Ridges of even height arise from widened bases and narrow distally towards crests that are entire. Small vesicles occur at the bases of some or most ridges. Archeopyle precingular 1P, formed by loss of plate 3", has well defined angles. Operculum free.

Description.—Cysts ovoid, apical protuberance of about 1 μm is rarely present (seen in three specimens, e.g., Fig. 8.19). Wall

FIGURE 7—*Corrudinium devernaliae* n. sp. All photomicrographs are bright field images. Various magnifications. Note vesicles at base of crests, and broad unornamented margin of archeopyle. 1–3, Sample DSDP 603C-25-3, 26–28 cm; slide 1 (ROM 55077); R36/3; ventral view of 1 ventral surface, 2 mid focus, 3 dorsal surface; length, excluding ridges 32 μm . 4–6, Sample DSDP 603C-27-2, 16–18 cm; slide 1 (ROM 55078); R37/1; ventral view of 4 ventral surface, 5 mid focus, 6 dorsal surface; length, excluding ridges 28 μm . 7–10, Sample DSDP 603C-28-2, 15–17 cm; slide 1 (ROM 55079); Q29/0; right-lateral view of 7 right-lateral surface, 8 slightly lower focus on archeopyle margin, 9 mid focus, 10 left-lateral surface; length, excluding ridges 31 μm . 11–13, Sample DSDP 603C-28-6, 35–37 cm; slide 1 (ROM 55080); N16/0; left-ventral view of 11 left-ventral surface, 12 mid focus, 13 right-dorsal surface; length, excluding ridges 28 μm . 14–17, Holotype, sample DSDP 603C-28-6, 35–37 cm; slide 1 (ROM 55080); Q15/2; left-ventral view of 14 left-ventral surface, 15 mid focus, 16 slightly lower focus, 17 right-dorsal surface; length, excluding ridges 28 μm . 18–20, Sample DSDP 603C-28-6, 35–37 cm; slide 1 (ROM 55080); R14/1; ventral view of 18 ventral surface, 19 mid focus, 20 dorsal surface; length, excluding ridges 28 μm .





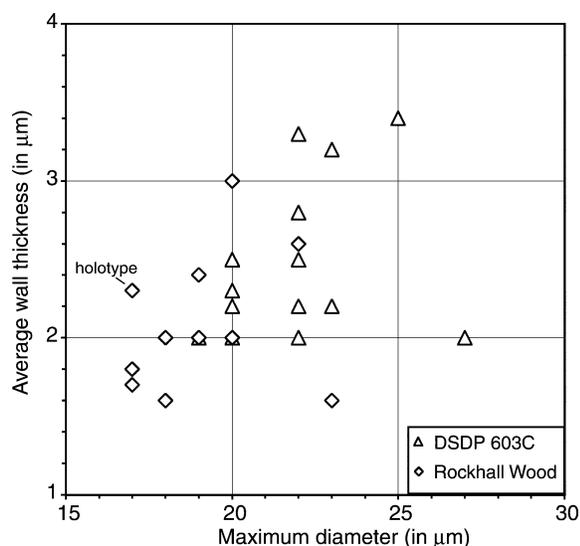


FIGURE 9—*Leiosphaeridia rockhallensis* Head n. sp. showing average wall thickness vs. maximum diameter for specimens from DSDP Hole 603C (this study) and the mid-Pliocene Coralline Crag Formation at Rockhall Wood, eastern England (as Algal cyst type 2 in Head, 1997). The Hole 603C specimens are preservationally compressed whereas those of Rockhall Wood are not, and this at least partly explains the generally larger dimensions of the Hole 603C specimens. Even so, there is clear overlap between the Rockhall Wood and Hole 603C assemblages.

is an autophragm and has smooth surface. Continuous or discontinuous ridges form a fine, complete or incomplete irregular reticulum over entire surface of cyst. Scattered conical verrucae may be present on specimens whose ridges are particularly discontinuous. For individual specimens with relatively complete reticulation, lumina occur in a range of sizes: smaller about 0.5–1.0 μm and larger about 1.5–3.5 μm. Ridges have smooth surface, arise from expanded (width up to about 0.5–1.0 μm) bases, and narrow distally towards crests that are entire and of generally even height, ca. 0.4–1.5 μm. Small (less than 0.5 μm) vesicles occur along bases of some or most ridges, and particularly at ridge junctions where they may occur singly or in small clusters. Ridges appear not to reflect tabulation. Between ridges, wall appears unstructured and has thickness of ca. 0.3 μm. Archeopyle precingular Type 1P (3^o) and ornament extends to its borders.

Etymology.—Named with reference to the presence of vesicles at ridge bases.

Type.—Holotype, sample DSDP 603C-31-5, 20–22 cm; slide 2 (ROM 55084); England Finder reference F9/3. Lower Pliocene. Figure 8.6–8.9.

Measurements.—Holotype: length, excluding ridges 34 μm; breadth, excluding ridges 30 μm; ridge height, ca. 0.8 μm. Range:

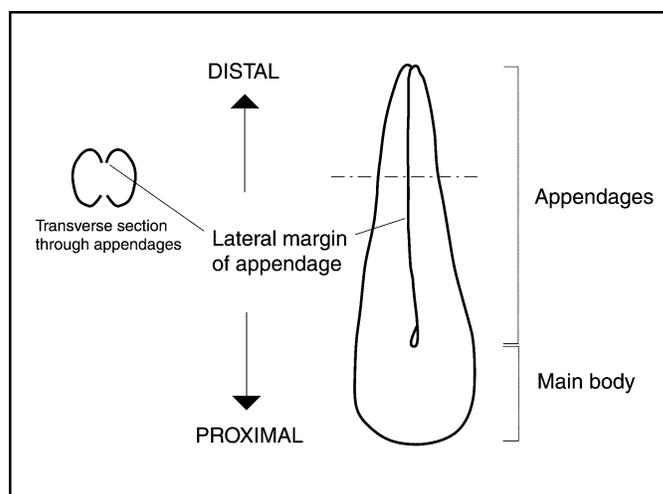


FIGURE 10—*Leffingwellia costata* n. gen. and sp. Sketch showing constituent parts, comprising main body and appendages, as discussed in the text.

maximum diameter, excluding ridges 23(29.1)37 μm, standard deviation, 3.2 μm; ridge height, ca. 0.4(0.8)1.5 μm. Thirty-nine specimens measured.

Occurrence.—Upper Miocene through lower Lower Pliocene in DSDP Hole 603C.

Comparison.—*Corrudinium devernaliae* n. sp. has coarser reticulation (smaller lumina ca. 2–4 μm, larger lumina ca. 7–14 μm) than *P. vesiculata* n. sp. (smaller lumina ca. 0.5–1.0 μm, larger lumina ca. 1.5–3.5 μm), and ornament reflecting some tabulation. The archeopyle margins are unornamented in *Corrudinium devernaliae* n. sp.

Marine algae incertae sedis

Genus LEIOSPHAERIDIA Eisenack, 1958 emend. Turner, 1984

LEIOSPHAERIDIA ROCKHALLENSIS Head new species

Figures 9, 12.1–12.15

Algal cyst type 2. HEAD, 1997, p. 190, fig. 13.18–13.22.

Non Algal cyst type 2 HEAD, 1997; LOUWYE, 2002, tab. 1, pl. 2, figs. 3 and 4.

Diagnosis.—Small, spherical, proximate palynomorph having thin smooth inner wall layer, and thick, cancellous or spongy outer wall layer. Outer surface irregular, covered with small circular depressions. Aperture is a simple split in the wall.

Description.—Cysts small, spherical when uncompressed. Outer wall layer thick (ca. 1.4–3.2 μm), cancellous or spongy, with large (up to about 1.0 μm) and small vesicles apparently randomly packed together; outer surface irregular, covered with small circular depressions up to about 1.0 μm wide, best seen using interference contrast microscopy. Inner wall layer solid with

←

FIGURE 8—*Pyxidinosopsis vesiculata* n. sp. All photomicrographs are bright field images. Various magnifications. Note vesicles at base of crests. 1–5, Sample DSDP 603C-28-6, 35–37 cm; slide 2 (ROM 55081); O34/0; left-lateral view of 1 left-lateral surface, 2 mid focus, 3 right-lateral surface, 4 and 5 progressively lower foci; length, excluding ridges 34 μm. 6–9, Holotype, sample DSDP 603C-31-5, 20–22 cm; slide 2 (ROM 55084); F9/3; ventral view of 6 ventral surface showing well-developed vesicles, 7 mid focus, 8 slightly lower focus, 9 ventral surface showing well-defined archeopyle angles; length, excluding ridges 34 μm. 10–12, Sample DSDP 603C-31-5, 20–22 cm; slide 2 (ROM 55084); G9/2; left-lateral view of 10 left-lateral surface, 11 mid focus, 12 right-lateral surface; length, excluding ridges 29 μm. 13–16, Sample DSDP 603C-31-5, 20–22 cm; slide 2 (ROM 55084); H42/3; dorsal view of 13 dorsal surface showing well-developed vesicles, 14 mid focus, 15 ventral surface, 16 slightly lower focus; length, excluding ridges 30 μm. 17–20, Sample DSDP 603C-38-5, 45–47 cm; slide 1 (ROM 55090); S30/2; left-lateral view of 17 left-lateral surface, 18 slightly lower focus, 19 mid focus showing apical protuberance, 20 right-lateral surface; length, excluding ridges 30 μm.

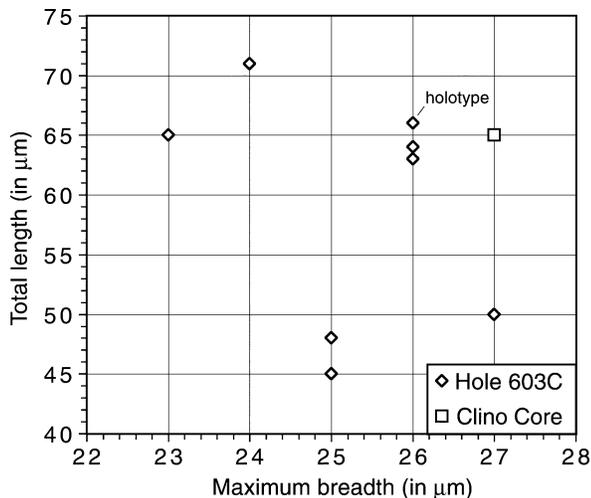


FIGURE 11—*Leffingwellia costata* n. gen. and sp. showing total length (main body length + appendage length) vs. maximum breadth for specimens from DSDP Hole 603C (this study), and a single specimen from the upper Lower Pliocene of the Clino Core, Bahamas (as *Incertae sedis* B in Head and Westphal, 1999, fig. 15.3, 15.4). Note the wide variation in length.

smooth inner surface, about 0.2 μm or less in thickness and barely discernible under high magnification. Wall layers equivalent to luxuria and pedium in dinoflagellate cysts, no separation occurring between them. Aperture interpreted as a simple split, visible only in ruptured specimens.

Etymology.—Named after Rockhall Wood, Suffolk, England, the type locality of this species.

Type.—Holotype, sample NQ1; slide 1 (ROM 55093); England Finder reference Q38/0 (also figured in Head, 1997, fig. 13.18–13.20). Ramsholt Member of the Coralline Crag Formation, Rockhall Wood, Suffolk, eastern England (Head, 1997). Lower Pliocene. Figure 12.6–12.11.

Measurements.—Holotype: maximum diameter 17 μm; wall thickness ca. 2.3 μm. Range based on eastern England specimens: maximum diameter 17(18.9)23 μm, standard deviation 2.02 μm; wall thickness ca. 1.6(2.1)3.0 μm, standard deviation 0.43 μm. Twelve specimens were measured. Range based on Hole 603C specimens: maximum diameter 19(22.2)27 μm, standard deviation 2.03 μm; wall thickness ca. 2.0(2.5)3.4 μm, standard deviation 0.47 μm. Sixteen specimens were measured. See also Figure 9.

Material examined.—Sixteen specimens were examined from DSDP Hole 603C, and 12 from the Lower Pliocene Ramsholt Member of the Coralline Crag Formation, eastern England (Head, 1997).

Occurrence.—Lower Pliocene of eastern England (as Algal cyst type 2 in Head, 1997), and a well-defined range within the Lower Pliocene of DSDP Hole 603C.

Comparison.—"Algal cyst type 2 Head, 1997" as reported from the Upper Miocene of Belgium by Louwye (in press) is very similar to *Leiosphaeridia rockhallensis* Head n. sp. but differs in possessing a thicker inner wall layer and not having depressions covering the surface of the outer layer (S. Louwye and MJH, unpublished observation).

Discussion.—Specimens from eastern England are slightly smaller in size (maximum diameter, 17–23 μm) than those from DSDP Hole 603 (maximum diameter 19–27 μm; Fig. 9), and this may be attributable to greater preservational flattening in the latter.

Marine palynomorph incertae sedis

Genus LEFFINGWELLIA new genus

Figures 10, 11, 12.16–12.25

Diagnosis.—Elongate palynomorph resembling u-tube whose wall is not joined together along inside length of tube. Main body proximally round-ended, and may bear ornament such as ridges or verrucae. Distal part drawn into two tube-like tapering appendages that become progressively less ornamented towards distal end.

Etymology.—Named for Harry A. Leffingwell under whose visionary leadership the Palynology Oil Company Consortium, which partly supported the present study, was established.

Type.—The holotype of *Leffingwellia costata* n. sp. (Fig. 12.16–12.18).

Other accepted species.—None formally described. *Incertae sedis* B of Head in Head and Westphal (1999) is considered synonymous with *Leffingwellia costata* n. sp., whereas *Incertae sedis* A of Head in Head and Westphal (1999), characterized by an ornament of low verrucae, is clearly a separate species of *Leffingwellia*.

Occurrence.—Upper Lower Pliocene (3.6–4.1 Ma) of the Bahamas (as *Incertae sedis* A and B of Head in Head and Westphal, 1999), and a single sample from the upper Upper Pliocene (Olduvai Subchron) of DSDP Hole 603C.

Discussion.—*Leffingwellia* is considered a marine palynomorph, as it has been found only in marine sediments, notably those of the Clino Core, Bahamas, where terrestrial palynomorphs typically comprise less than 1 percent of the total. It is here treated for convenience under the International Code of Botanical Nomenclature, although a botanical affinity is not established with any certainty.

LEFFINGWELLIA COSTATA new species

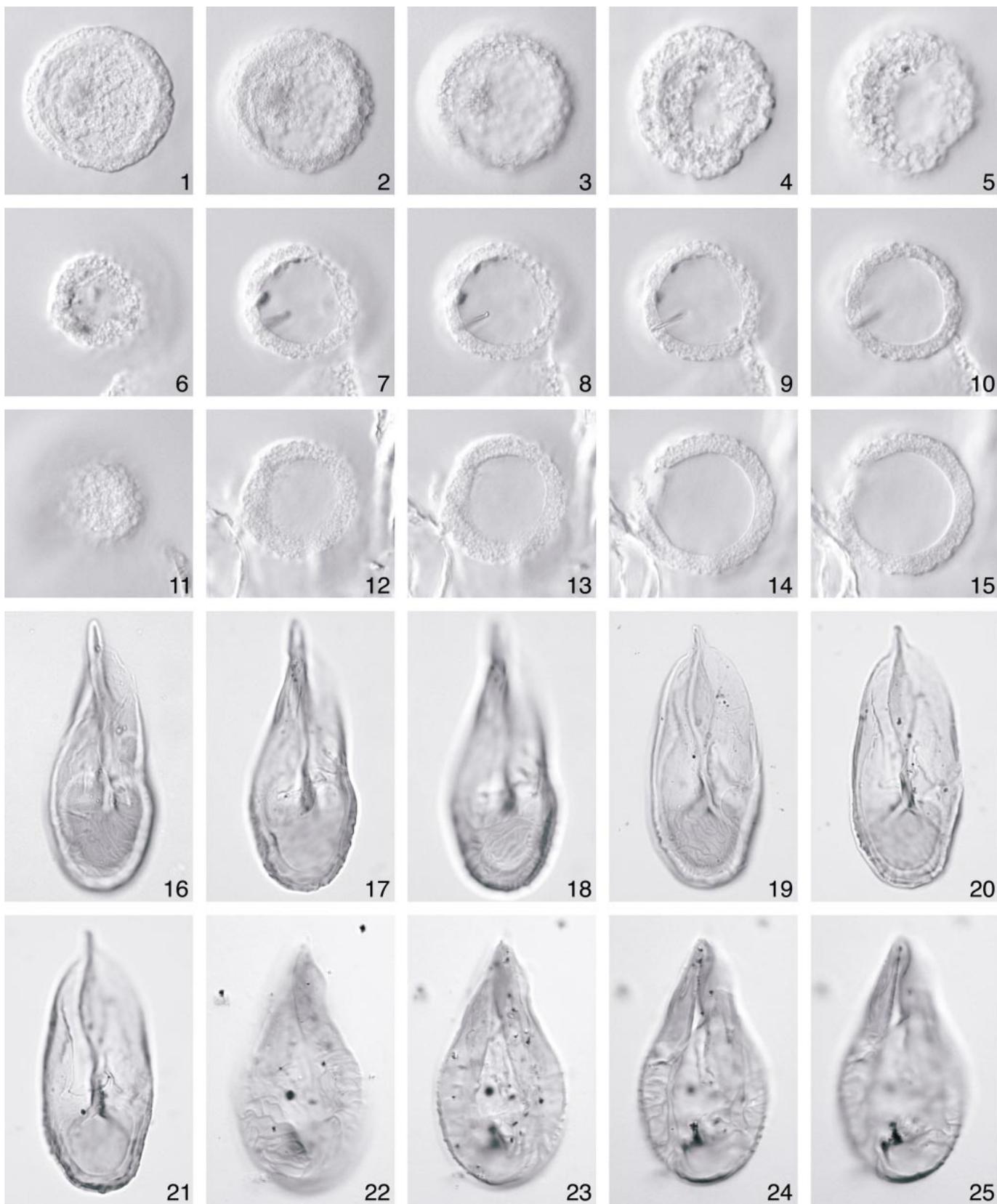
Figures 10, 11, 12.16–12.25

Incertae sedis B. HEAD IN HEAD AND WESTPHAL, 1999, p. 22, fig. 15.3, 15.4.

Diagnosis.—Main body ornamented with low, sinuous to subparallel anastomosing ridges that often extend onto appendages.

Description.—Elongate palynomorph; main body proximally round-ended, and bears low (about 1.0 μm or less in width and

FIGURE 12—1–15, *Leiosphaeridia rockhallensis* Head n. sp. from DSDP Hole 603C (1–5) and the mid-Pliocene Coralline Crag Formation of eastern England (6–15), and 16–25, *Leffingwellia costata* n. gen. and sp. Photomicrographs are interference contrast (1–15, 22–25) or bright field (16–21) images. Various magnifications. 1–15, *Leiosphaeridia rockhallensis* Head n. sp. 1–3, Sample DSDP 603C-24-4, 84–86 cm; slide 1 (ROM 55076); S16/4; upper, middle, and lower foci respectively, maximum diameter 27 μm. 4–5, Sample DSDP 603C-23-3, 100–102 cm; slide 1 (ROM 55075); R37/4; middle and lower foci; maximum diameter 23 μm. 6–11, Holotype, sample NQ1; slide 1 (ROM 55093); Q38/0; upper through lower foci; maximum diameter 17 μm. 12–15, Sample NQ4; slide 1 (ROM 52495); J39/0; upper through middle foci; maximum diameter 20 μm. 16–25, *Leffingwellia costata* n. gen. and sp. 16–18, Holotype, sample DSDP 603C-5-5, 100–102 cm; slide 1 (ROM 55071); Q41/2; showing 16 upper surface, 17 mid focus, 18 lower surface; total length 66 μm. 19–21, Sample DSDP 603C-5-5, 100–102 cm; slide 1 (ROM 55071); P39/1; showing 19 upper surface, 20 mid focus, 21 lower surface; total length 63 μm. 22–25, Sample DSDP 603C-5-5, 100–102 cm; slide 1 (ROM 55071); N25/0; showing 22 upper surface, 23 mid focus, 24 lower surface, 25 slightly lower focus; total length 48 μm.



height) sinuous to subparallel anastomosing ridges on outer surface. Ridge crests appear sharp. Ornament extends onto proximal ends of appendages, becoming progressively less well developed or smooth distally. Wall of main body usually considerably thicker than of appendages (e.g., holotype, Fig. 12.16–12.18), but thicknesses may be similar in some specimens (e.g., Fig. 12.22–12.25). Each appendage tapers distally; has u- or c-shaped transverse section (Fig. 10); thinning of wall often occurs towards lateral margins which are entire.

Etymology.—Latin, *costa*, ridge; with reference to the ridged ornament on this species.

Type.—Holotype, sample DSDP 603C-5-5, 100–102 cm; slide 1 (ROM 55071); England Finder reference Q41/2. Upper Pliocene. Figure 12.16–12.18.

Measurements.—Holotype: total length 66 μm , breadth 26 μm , maximum wall thickness 2.5 μm , ratio of main body length/total length 0.30. Range of Hole 603C specimens: total length 45(59.0)71 μm , breadth 23(25.3)27 μm , maximum wall thickness 1.0(2.3)3.0 μm , ratio of main body length/total length 0.26(0.30)0.37. Eight specimens measured. See also Figure 11.

Material examined.—Eight specimens from a single sample from DSDP 603C (603C-5-5, 100–102 cm). One specimen from the Clino Core, Bahamas, illustrated in Head and Westphal (1999, p. 22, fig. 15.3, 15.4).

Occurrence.—Upper Pliocene of DSDP 603C, and upper Lower Pliocene of the Clino Core, Bahamas (as *Incertae sedis* B of Head in Head and Westphal, 1999).

Comparison.—*Incertae sedis* A of Head in Head and Westphal (1999), represented by two specimens from the Lower Pliocene of the Bahamas, differs from *Leffingwellia costata* n. sp. in having an ornament of low verrucae on the main body.

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