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A new genus and two new species of dinoflagellate cysts from lower Eocene marine sediments of the Wilkes Land Margin, Antarctica

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ABSTRACT

Integrated Ocean Drilling Program (IODP) Expedition 318 recovered lower Eocene sediments in Hole U1356A from the continental rise of the Wilkes Land Margin, Antarctica. These sediments yielded a new genus of organic-walled dinoflagellate cysts (*Adeliesphaera* gen. nov.). We tentatively place this new genus within the suborder Gonyaulacineae, family Areoligeraceae, based on the obligate apical archeopyle, the asymmetric antapical geometry and the left-side offset sulcal notch. We herein describe the type species of *Adeliesphaera* gen. nov., *Adeliesphaera ohanlonii* sp. nov., as well as a new species of *Turbiosphaera*, *Turbiosphaera guersteinae* sp. nov. The short stratigraphic range of both species (53.7–53.4 Ma and 53.1–52.9 Ma, respectively) qualifies them as potentially important regional Southern Ocean stratigraphic markers for high-resolution age control.

1. Introduction

Organic-walled dinoflagellate cysts (dinocysts) provide a critical micropaleontological tool for the analysis of high-latitude marginal marine sedimentary records, not only as a biostratigraphic tool but also for paleoenvironmental reconstructions. Studies of on-land sections around the Southern Ocean and ocean drill cores from the various Ocean Drilling Programs (Deep Sea Drilling Project, Ocean Drilling Program, Integrated Ocean Drilling Program and the current Integrated Ocean Discovery Program, IODP) over the last decades has resulted in a broad overview of the biogeographic and biostratigraphic patterns of Paleogene dinocysts (~66–34 Ma) in the Southern Ocean and adjacent ocean basins (e.g, Wilson, 1967, 1988; Wrenn and Beckman, 1982; Askin, 1988, 1999; Wrenn and Hart, 1988; Levy and Harwood, 2000; Brinkhuis et al., 2003a,b; Crouch and Brinkhuis, 2005; Guerstein et al., 2008, 2014; Warnaar et al., 2009; Bijl et al., 2011, 2013a,b). A regionally dominant Eocene endemic–Antarctic dinocyst association (originally referred to as the 'Trans-Antarctic Flora' (Wrenn and Beckman, 1982)) is typically recorded from mostly middle and upper Eocene sediments from the southwest Pacific Ocean, the southwest Atlantic Ocean (Guerstein et al., 2008, 2010, 2014) and around Prydz Bay (see Bijl et al., 2011 for a review). However, lower Eocene sedimentary successions from the Australo–Antarctic Gulf are typically devoid of taxa belonging to this endemic-Antarctic 'community', but instead yield dinocyst assemblages that have notable resemblance to Northern Hemisphere mid-latitude sites such as England and the North Sea (e.g., Eaton, 1976; Bujak et al., 1980; see Bijl et al., 2011, 2013a, b). This pattern is consistent throughout the Australo-Antarctic Gulf until 50–49 Ma, when the Antarctic Margin in the Australo-Antarctic Gulf also begins to see a dominance of these endemic dinocyst species, likely as a result of the early, southern opening of the Tasmanian Gateway (Bijl et al., 2013a). The coeval onset in cooling of Southern Ocean surface waters (Bijl et al., 2009, 2013a; Hollis et al., 2009, 2012) and Antarctic coastal regions (Pross et al., 2012; Bijl et al., 2013a), concomitant to the termination of the Early Eocene Climatic Optimum (EECO; Zachos et al., 2001) suggests that the early opening of the Tasmanian Gateway had a profound effect on at least regional climates (Bijl et al., 2013a).

The climate dynamics of the early Paleogene Southern Ocean have attained a broad scientific interest because the Southern Ocean is considered as a major driver of deep ocean circulation in that time interval (Thomas et al., 2003; Hollis et al., 2012). In the future, ocean drilling expeditions will be undertaken to better understand the paleoceanographical history of the Southern Ocean. In order to date the sediments recovered during such expeditions, a high-resolution dinocyst zonation scheme is required, particularly because in the Paleogene Southern Ocean, dinocysts are often the only microfossil group preserved. Sediments of Eocene age from IODP Site U1356, from the Wilkes Land Margin (Fig. 1; Escutia et al., 2011) were crucial in developing a dinocyst biostratigraphic framework for the early Eocene (Tauxe et al., 2012; Bijl et al., 2013b, 2014). To date, the sedimentary record from Site U1356 is the only chronostratigraphically well-calibrated early Eocene record from the East Antarctic Margin, which makes it an important site in light of future drilling and studies around Antarctica. During

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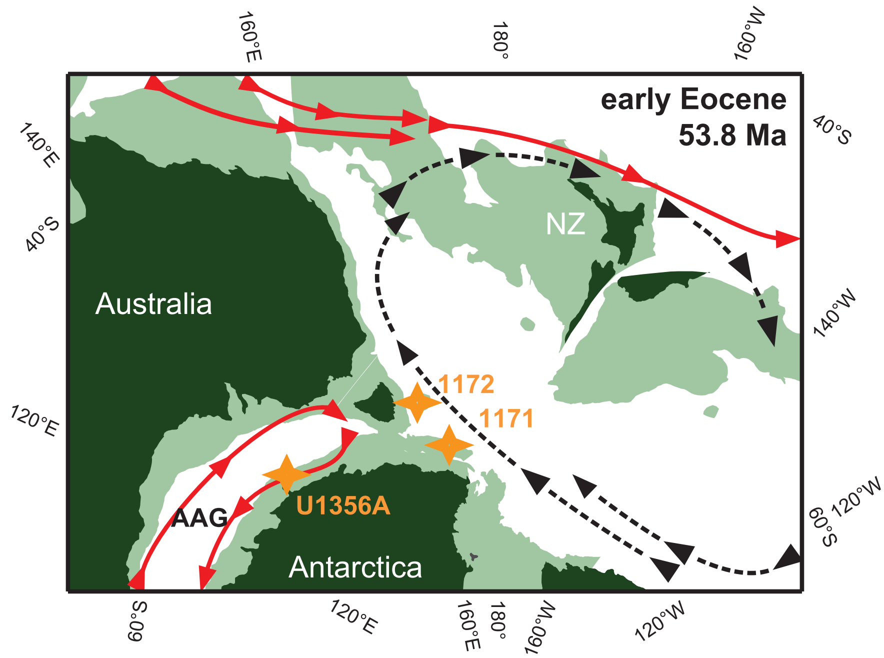

Fig. 1. Paleogeographic reconstruction according to Cande and Stock (2004) of the early Eocene (58.5 Ma) South Pacific and South Indian Ocean. IODP Site U1356, ODP site 1171 and 1172 are indicated in orange. Map modified from Bijl et al. (2013b). Dark green areas reflect present day land above sea level, light green areas indicate ocean floor at present above 3.000 meter water depth (Cande and Stock, 2004). Red and black arrows are a schematic representation of low-latitude-derived and Antarctic-derived surface ocean currents, as observed in numerical ocean current model experiments (Huber et al., 2004). NZ = New Zealand; AAG = Australo-Antarctic Gulf.

our preliminary studies, we encountered several new, undescribed species of dinocysts. In order to further improve stratigraphic resolution for an existing Southern Ocean dinocyst zonation (Bijl et al., 2013b, 2014) we here describe two stratigraphically important species. We can directly calibrate the stratigraphic ranges of both new species against the Geomagnetic Polarity Time Scale (Vandenberghe et al., 2012) using the available magnetostratigraphy (Escutia et al., 2011; Tauxe et al., 2012; Bijl et al., 2013b, 2014).

2. Material and methods

2.1. Material

Integrated Ocean Drilling Program Hole U1356A was drilled in 2010 on the Wilkes Land Margin, Antarctica (Fig. 1; Escutia et al., 2011). A rotary drill was used for drilling. The lowermost 61 meters (m) of the Hole, between 939 and 1000 m below sea floor (mbsf; Core 100R to Core 106R; Lithological Unit XI; Fig. 2) consist predominantly of faintly laminated, dark green bioturbated claystones (Escutia et al., 2011). The core recovery was ~50% in this interval. Of the recovered ~30 m, a total of 177 samples were taken for palynology. Combining the dinocysts and paleomagnetism (Escutia et al., 2011; Tauxe et al., 2012; Bijl et al., 2013b, 2014) preserved in the sediments yielded a robust age model for these cores, and suggest an early Eocene age (Fig. 2; ~54.0–50.0 Ma).

2.2. Methods

Standard palynological processing techniques of the Laboratory of Palaeobotany and Palynology, Utrecht University were applied on the samples. A detailed description of the processing steps can be found in Bijl et al. (2013a). Briefly, it involves digestion of the sample in hydrochloric acid and hydrofluoric acid to dissolve and remove carbonates and silicates, respectively. Subsequently, the residues were sieved to obtain a 10–250 μm fraction, which was mounted on a microscope slide using glycerin jelly. Microscope slides were sealed with nail polish and stored in the collection of the Laboratory of Palaeobotany and Palynology. For light microscope images we used a Leica DFC320 camera mounted on A Leitz Aristoplan light microscope, with a 400 times magnification. Scanning Electron Microscopy (SEM) was performed on the type material as well.

2.3. Terminology for taxonomy and cyst description

We here follow the International Code for International Code of Nomenclature for algae, fungi, and plants (Melbourne Code; McNeill et al., 2012). Furthermore, we follow Fensome et al. (1993) for the systematic paleontology and nomenclature, and use the Kofoid tabulation pattern (Kofoid, 1907, 1909; see Evitt, 1985). We follow Evitt (1985) in cyst characterization and nomenclature.

2.3.1. A note on dorso-ventral compression

The type species of the cyst genus we describe below features two antapical horns, a left-side offset sulcal notch and a consistent archeopyle in all specimens observed, which involves the loss of the apical series. These features are typically seen in cyst genera that are dorso-ventrally compressed. However, the general globular geometry of the cyst, as opposed to a more lenticular geometry as is common for dorso-ventrally compressed cysts, does not suggest primary dorso-ventral flattening. Evitt (1985) describes primary dorso-ventral compression (or flattening), as opposed to secondary compression (due to post-depositional pressure in the sediment column) as 'a deviation of sphericity' (p. 57), and is associated with a 'displacement of the parasulcus toward the left of the ventral midline and the consequent appearance in the archeopyle margin of an [leftside] offset sulcal notch.' He further states that with such cysts 'paraplate 1i [6″ in the Kofoid tabulation scheme] tends to be especially broad as if in compensation for the position of the notch' (p. 139, 186). He also schematically shows that the archeopyle of dorso-ventrally flattened (or compressed) cysts show 'transverse elongation' (Fig. 3), as opposed to 'equidimensional' cyst geometry in spherical cysts, and in agreement with the general 'lenticular' geometry of dorso-ventrally compressed cysts. Further, all gonyaulacoid cysts that are dorso-ventrally compressed (Gv and Gc cysts in Evitt, 1985) seem to have one or two antapical horns. While Evitt's notes on dorso-ventral compression may suffice for many

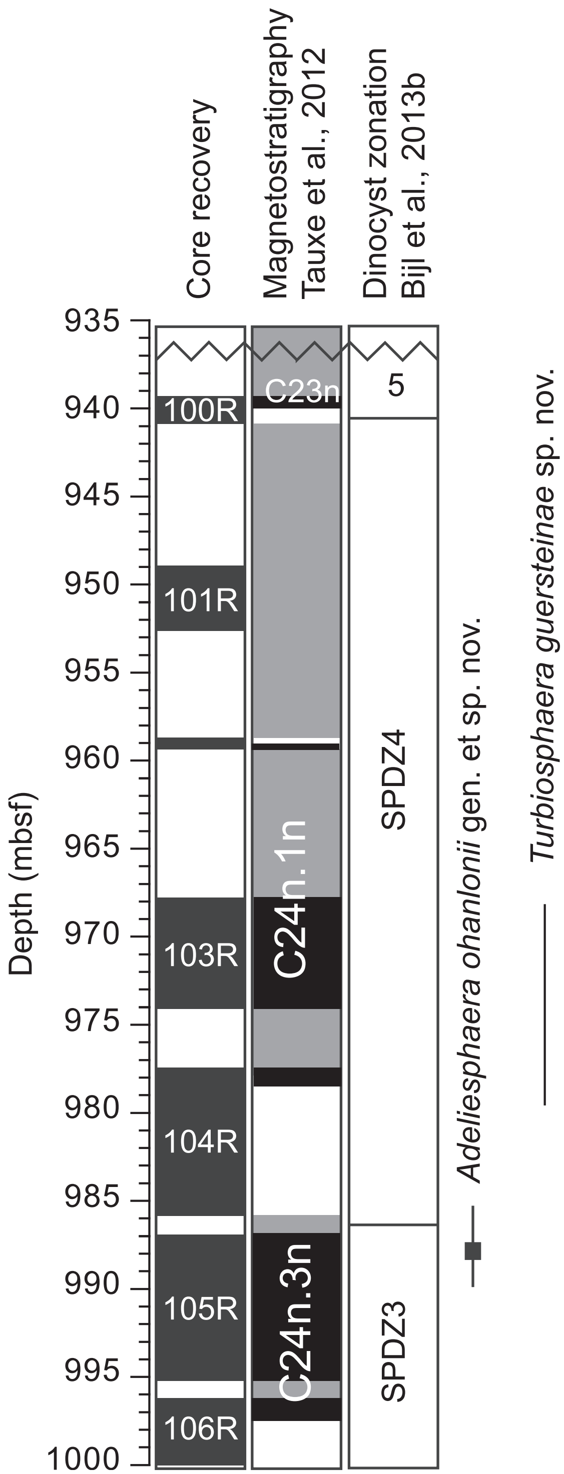

Fig. 2. Core recovery (Escutia et al., 2011), magnetostratigraphy (Tauxe et al., 2012) and dinocyst zonation (Bijl et al., 2013b) for the lowermost part of Site U1356A. Stratigraphic ranges of the new dinocyst species are shown. The thicker line section for *Adeliesphaera ohanlonii* sp. nov. reflects common (>25%) occurrence.

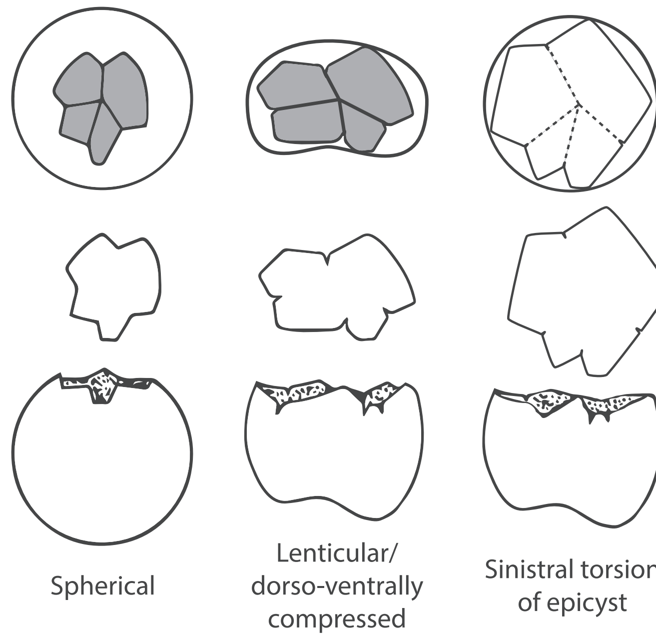

Fig. 3. Schematic representation of spherical gonyaulacoid cysts with an apical archeopyle (e.g., *Stoveracysta*, *Batiacasphaera*), versus lenticular, dorso-ventrally compressed gonyaulacoid cysts (e.g., *Glaphyrocysta*, *Areoligera*) and cysts with a sinistral torsion of the epicyst (*Adeliesphaera* gen. nov.). Spherical cysts have a round hypocyst, an equidimensional operculum and a mid-ventral position of the sulcal notch. Lenticular cysts have transverse elongated operculae, a left-side offset sulcal notch and one or two antapical horns. Cysts with a sinistral torsion have a spherical geometry apart from antapical horns, a left-side offset sulcal notch but an equidimensional archeopyle. Partly redrawn after Evitt (1985).

dinocyst genera, we had difficulties deciding upon these statements whether the genus described herein is actually dorso-ventrally compressed or not: the only feature that contradicts dorso-ventral compression is a lenticular outline of the cyst. Based on the observations made by Evitt (1985), and the difficulties we faced when applying them to the genus described herein, we here define dorso-ventral compression as a dinocyst feature that involves all of the following characteristics (1) a lenticular geometry of the cyst, (2) a transverse elongation of the apical operculum (as opposed to an equidimensional operculum outline), (3) a left-side offset sulcal notch, resulting in the mid-ventral position of a broad 6″ plate, and (4) the presence of one or two antapical horn(s) (Fig. 3).

3. New dinocyst taxa

3.1. A new species of Turbiosphaera

In the sediments recovered from Hole U1356A we found a new dinocyst species which agrees with the description of the genus *Turbiosphaera*, including the modified description by Stover and Evitt (1978) referring for paracingular features to "a transverse shelf-like ridge delineating which may be subdivided to the extent that individual segments are completely separated and form distinct processes" (Stover and Evitt, 1978). Also the characteristic dextral torsion of the epicyst, aligning the 3″ plate with the boundary between the 4‴ and 5‴, which is typical for cribroperidinioid dinocysts, is clearly visible from the process distribution. Although unlike the original description of *Turbiosphaera*, the new species described here does not seem to have extraordinarily large apical processes, however the antapical process is typical for *Turbiosphaera*. The characteristic solid, unperforated slightly doming distal ends of the fibrous processes, the fact that all specimens feature processes that are consistently disconnected distally and, the absence of any additional small processes make the new species found in the sediments from the Wilkes Land Margin distinctively different from other *Turbiosphaera* species.

3.2. Adeliesphaera: a new dinoflagellate cyst genus

We here describe a dinocyst species with an unusual set of characteristics which necessitates the erection of a new genus: *Adeliesphaera* gen. nov. The obligate apical archeopyle, the left-side offset sulcal notch and the presence of antapical horns place this species within the suborder Gonyaulacineae, family Areoligeraceae. However, the species cannot be assigned to other genera within this family because the species lacks dorso-ventral compression in the strictest sense (see a note on dorso-ventral compression under 2.3.1); there is no lenticular geometry, and thus no dorso-ventral flattening. Rather than flattened dorso-ventrally, the epicyst seems to be torqued sinistrally, causing the left-side offset sulcal notch, and a strongly asymmetrical first apical plate, but maintains a globular dorso-ventral geometry. This feature necessitates the erection of a new genus.

4. Systematic paleontology

Division DINOFLAGELLATA (Bütschli, 1885) Fensome et al., 1993
Subdivision DINOKARYOTA Fensome et al., 1993
Class DINOPHYCEAE Pascher, 1914
Subclass PERIDINIPHYCIDAE Fensome et al., 1993
Order GONYAULACALES Taylor, 1980
Suborder GONYAULACINEAE (autonym)

Family GONYAULACACEAE Lindemann, 1928
Subfamily CRIBROPERIDINIOIDEAE Fensome et al., 1993
Genus *Turbiosphaera* Archangelsky, 1969.
Turbiosphaera guersteinae sp. nov. Plate I, A–G

Holotype: IODP Hole U1356A-103R-1 W, 90–92 cm Slide 1, England Finder coordinates U58-4. Plate I; A, B
Paratype: IODP Hole U1356A-103R-1 W, 130–132 cm Slide 2, England Finder coordinates F42. Plate I; D, E
Type locality: Lower Eocene of IODP Hole U1356A, Wilkes Land Margin, Antarctica. Lithological unit XI (Escutia et al., 2011).
Etymology: The species name was erected in recognition of the work of Dr. G. Raquel Guerstein, for her work on organic-walled dinocyst taxonomy and paleoecology in Argentina.
Synonymy: *Cordosphaeridium* sp. A (Bijl et al., 2013b) plate VII, m
Diagnosis: A relatively small species of *Turbiosphaera* characterized by a typical long, slender, solid, fibrous, antapical process and large, thick, solid, fibrous, processes marking the post- and precingular plates which end in a solid, non-fibrous, smooth, bulbous, slightly doming distal edge. Cingular processes are rectangular, shelf-like. All processes are disconnected distally.
Dimensions: Holotype cyst body (excluding processes): 48.6 × 40.0 μm (length (l) × width (w)); including processes: 82.9 × 57.1 μm (l × w). Paratype cyst body (excluding processes): 68.6 × 61.4 μm (l × depth (d)); including processes: 68.6 × 61.4 μm (l × d). Average dimensions ($n = 10$) cyst body (excluding processes): 51.1 (42.9–61.4) × 38.6 (25.7–45.7) × 41.4 (34.3–48.6) μm (l × w × d); including processes: 83.6 (68.6–108.6) × 55.2 (37.1–65.7) × 55.0 (51.4–61.4) μm (l × w × d).

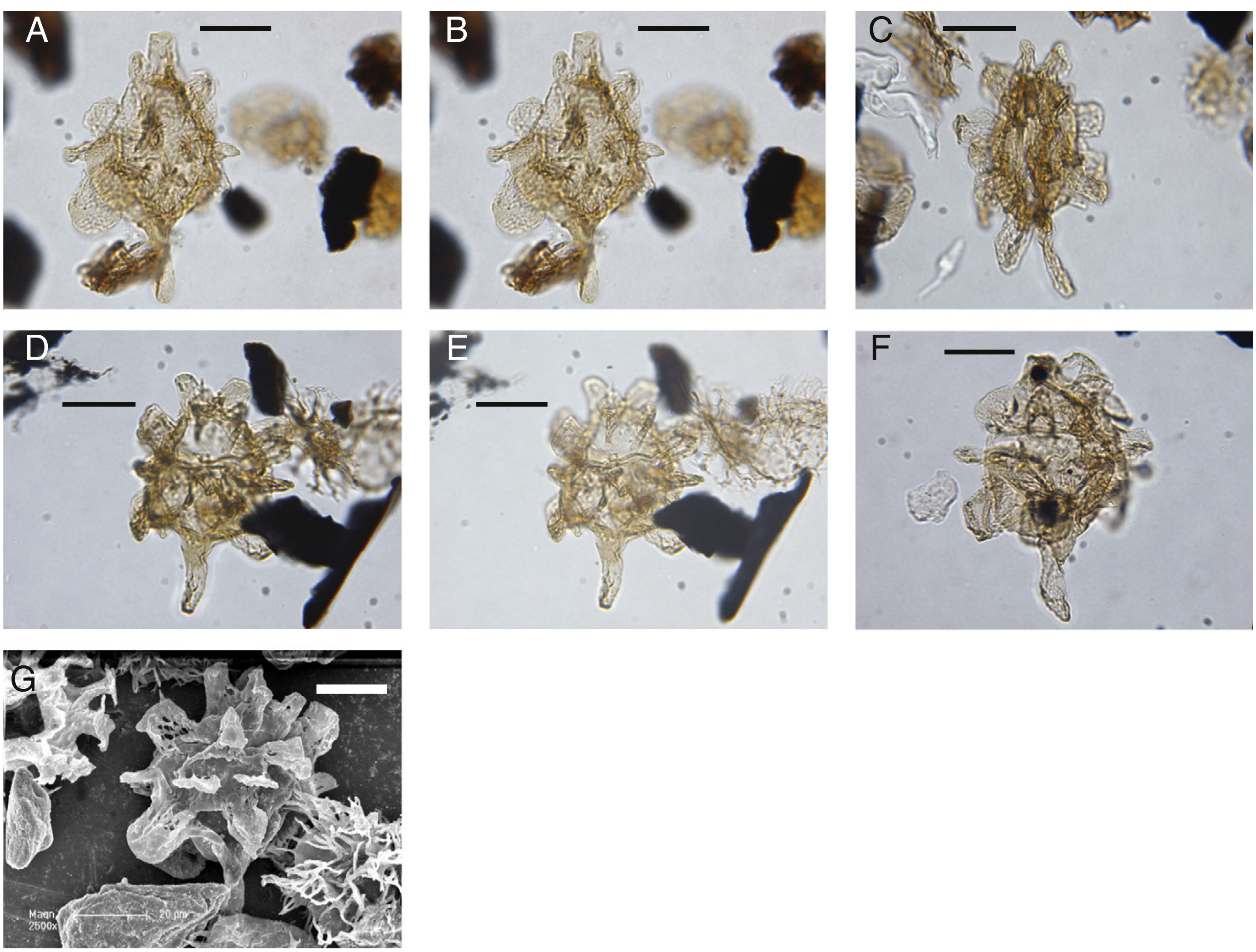

Plate I. A-G. *Turbiosphaera guersteinae* sp. nov. A, B. Holotype U1356A-103R-1 W, 90–92 cm Slide 1, England Finder Coordinates (EFC) U58-4. C. U1356A-103R-1 W, 90–92 cm Slide 1EFC W58-3. D, E. Paratype U1356A-103R-1 W, 130–132 cm Slide 2, EFC F42. F. U1356A-103R-1 W, 90–92 cm Slide 1 EFC W51. G. Scanning Electron Microscope (SEM) image previously published in Bijl et al. (2013b). G. *Turbiosphaera guersteinae*, sp. nov. U1356A-103R-1 W, 90–92 cm. Scale bar represents 25 μm.

Description: A cyst with two wall layers, which are closely appressed between processes. The central, inner cyst wall is oval, longer than wide. The outer wall is fibrous and gives rise to disconnected intratabular processes marking all plates, including the cingular and sulcal plates. The size of the processes varies relative to plate size. The stems of processes rising up from pre- and postcingular plates are fibrous, perforate, solid and broad, and end distally into a smooth, non-perforate, slightly doming surface. The process marking the antapical plate is longer than the other processes (about a third of the total length of the cyst), fibrous and perforate, slender. The cingular processes are rectangular, shelf-like. Dorsal plate configuration indicates dextral torsion. Archeopyle precingular type P, indicated by the loss of 3″. Plate configuration 4′, 6″, 6c, 4s, 1p, 6‴, 1⁗.

Stratigraphic distribution: The stratigraphic range of *Turbiosphaera guersteinae* sp. nov. in the type material is relatively short and well constrained by magnetostratigraphy (Tauxe et al., 2012; Bijl et al., 2013b, 2014). The first occurrence is between sample U1356A-104R-2 W, 40–42 cm (979.47 mbsf) and 50–52 cm (979.57 mbsf), correlating to mid-magnetochron C24n.1r. The species occurs consistently (i.e. in almost every available sample), albeit in low relative abundance, until its last occurrence between samples U1356A-103R-1 W, 20–22 cm (968.21 mbsf) and 10–12 cm (968.11 mbsf), correlating to mid-chron C24n.1n (Tauxe et al., 2012; Bijl et al., 2013b, 2014). In the Geomagnetic Polarity Time Scale of Vandenberghe et al. (2012) this equates to an age-range between 53.1 and 52.9 Ma.

Geographic distribution: To date, *Turbiosphaera guersteinae* has only been recognized in the type section.

Comparison: *Turbiosphaera guersteinae* sp. nov. differs from *Turbiosphaera filosa* in lacking distal connections of processes, lacking additional fine processes and has a characteristic fibrous process stems while the distal ends of the processes are solid. *Turbiosphaera guersteinae* differs from species of *Cordosphaeridium* e.g., *Cordosphaeridium fibrospinosum* Davey and Williams, 1966, *Cordosphaeridium cantharellus* (Brosius, 1963) Gocht, 1969, *Cordosphaeridium funiculatum* Morgenroth, 1966 and *Cordosphaeridium gracile* (Eisenack, 1954) Davey and Williams, 1966 in having processes that terminate in a solid, doming distal surface rather than a flared distal end. In the type material, *T. guersteinae* sp. nov. is relatively small and thin-walled, giving it a more transparent appearance.

Family AREOLIGERACEAE Evitt, 1963

Genus *Adeliesphaera* gen. nov.

Etymology: Named after Terre Adélie, the sector of East Antarctica closest to the *locus typicus* of the type species, IODP Site U1356

Type: *Adeliesphaera ohanlonii* sp. nov. Plate II, Fig. A–L; Plate III, Fig. A–N.

Diagnosis: Spherical, proximate cysts of intermediate size. The cyst is bi-layered, with the two layers closely appressed. Outer wall is characterized by non-tabular ornamentation. While the globular geometry of the cyst and equidimensional outline of the operculum suggests no dorsal-ventral compression, *Adeliesphaera* gen. nov. does feature one or two antapical horns, typical for Areoligeraceae. Tabulation is only indicated by the archeopyle. The shape of the archeopyle reflects a strongly asymmetrical 1′ apical plate (Plate III, A–D; Fig. 3) and the position of the sulcal notch shows a strong left-side offset, both suggestive of strong sinistral torsion of the epicyst. The archeopyle is single polyplacoid, and involves the total loss of the apical series.

Description: Proximate cysts with two closely appressed wall layers. The geometry of the cyst is quasi-spherical, with two marked antapical horns, of which the left antapical horn is always the largest. Because the wall ornamentation is non-tabular, the reflected sulcal, cingular and hyposomal tabulation of the cyst is unknown. Tabulation 4′, 6″, Xc, Xs, X‴, X⁗. The archeopyle is single polyplacoid, involves the loss of the apical series, and the operculum is usually free. Operculum shape is equidimensional, with slight angular edges.

Differential diagnosis: *Adeliesphaera* gen. nov. differs from morphologically similar proximate genera such as *Batiacasphaera* Drugg, 1970 in the presence of one or two antapical horns, and the left-side offset sulcal notch. Areoligeraceae genera such as *Areoligera* (Lejeune-Carpentier, 1938) Williams and Downie, 1966 and *Glaphyrocysta* Stover and Evitt, 1978 have a lenticular geometry (Fig. 3) while *Adeliesphaera* is globular. Moreover, *Areoligera* and *Glaphyrocysta* feature distinct processes (Lejeune-Carpentier, 1938; Williams and Downie, 1966; Stover and Evitt., 1978), while *Adeliesphaera* gen. nov. is proximate. *Schematophora* Deflandre and Cookson, 1955 lacks processes but has penitabular ornamentation and is 'subsphaerical' (Deflandre and Cookson, 1955), both features that are absent on *Adeliesphaera*. *Hemiplacophora* Cookson and Eisenack, 1965 and *Stoveracysta* Clowes, 1985 are not dorso-ventrally flattened, but lack an offset sulcal notch, have a rather symmetric 1′ plate and generally lack prominent antapical horns. Moreover, these genera feature either penitabular or parasutural ornamentation, which *Adeliesphaera* gen. nov. lacks.

Adeliesphaera ohanlonii sp. nov. Plate I, G–R; Plate II, A–L, N, O; Plate III, A–F; Plate IV.

Holotype: Sample 318-U1356A-105R-1 W, 35–37 cm, Slide 2, England Finder coordinates S50 Plate II, A, B

Paratype: Sample 318-U1356A-105R-1 W, 75–77 cm, Slide 2, England Finder coordinates K42-2 Plate II; D, E

Type locality: Eocene strata from IODP Hole U1356A, Wilkes Land Margin, Antarctica. Lithological Unit XI.

Etymology: Named for Dr. Redmond O'Hanlon, writer and historian, in recognition of his endeavors to popularize the history of natural sciences, in particular in the fields of biology, geology and evolution.

Synonymy: Dinocyst gen et sp. indet. (Bijl et al., 2013b plate VII, h, i; plate VIII, n, o)

Diagnosis: A species of *Adeliesphaera* gen. nov. with a relatively thin cyst wall that is ornamented with non-tabular granulae, giving it a papillate appearance. Tabulation is not discernable, apart from the archeopyle margin. Archeopyle is equidimensional, simple polyplacoid and involves the loss of the apical series.

Dimensions: Holotype: 48.6 × 50.0 μm (length (l) × width (w)). Paratype: 45.7 × 50.0 μm (l × depth (d)). Average dimensions ($n = 22$): 47.1 (40.0–57.1) × 47.8 (42.9–57.1) × 45.4 (41.4–51.4) μm (l × w × d).

Description: The specimens of the type material show only small variations in size and the expression of the antapical horn, and all lack secondary compression. All specimens observed have an equidimensional operculum/archeopyle, and the overall geometry of the cyst is globular. Cysts of *Adeliesphaera ohanlonii* sp. nov. lack sutural or penitabular ornamentation reflecting tabulation; the granulae on the cyst wall seem non-tabular.

Stratigraphic distribution: The stratigraphic range of *Adeliesphaera ohanlonii* sp. nov. in the type material is relatively short and well constrained by magnetostratigraphy (Tauxe et al., 2012; Bijl et al., 2013b, 2014). The first occurrence is between sample U1356-105R-3 W, 40–42 cm and 20–22 cm (990.52–990.32 mbsf) and the first common occurrence is between U1356A-105R–1 W, 125–127 cm and 115–116 cm (988.46 and 988.36 mbsf). The last common occurrence is between sample U1356A-105R-1 W, 15–16 cm and 5–7 cm (987.36–987.26 mbsf) and the last occurrence is between sample U1356A-104R-6 W, 50–52 cm and 30–32 cm (985.22 and 985.02 mbsf). This stratigraphic range correlates to the top half of chron C24n.3n (Tauxe et al., 2012; Bijl et al., 2013b, 2014). In the Geomagnetic Polarity Time Scale of Vandenberghe et al. (2012) this equates to a range between 53.7 and 53.4 Ma.

Geographic distribution: Thus far, *Adeliesphaera ohanlonii* has only been observed in the type section.

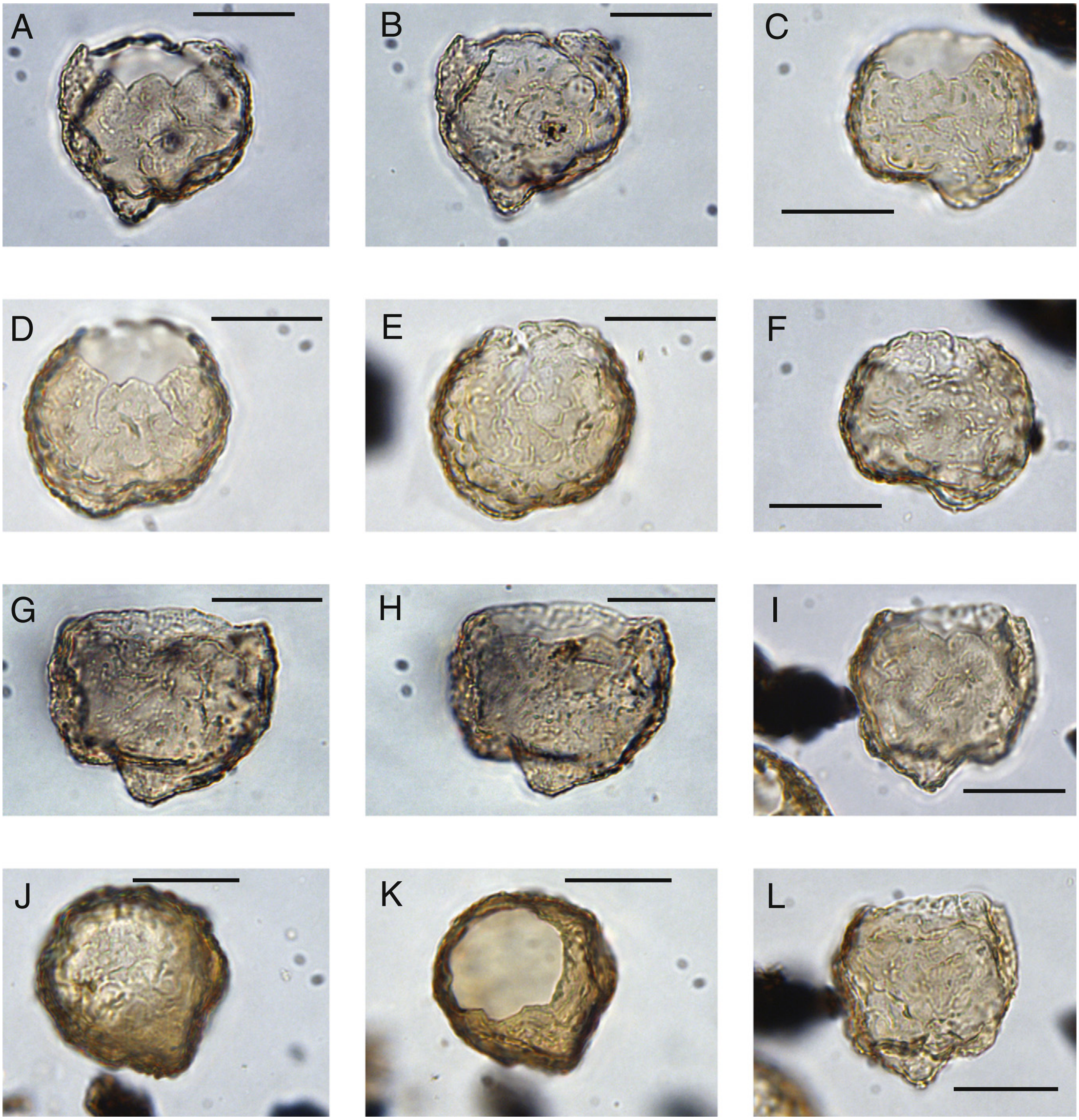

Plate II. A–L. *Adeliesphaera ohanlonii* gen. et sp. nov. A, B. Holotype U1356A-105R-1 W, 35–37 cm Slide 1 England Finder Coordinates (EFC) S50. C, F. U1356A-105R-1 W, 95–97 cm Slide 2 EFC P51-4. D, E. Paratype U1356A-105R-1 W, 75–77 cm, Slide 2 EFC K42-2. G, H. U1356A-105R-1 W, 95–97 cm Slide 2 EFC V43-3. I, L. U1356A-105R-1 W, 75–77 cm Slide 2 EFC R42. J, K. U1356A-105R-1 W, 95–97 cm Slide 1 EFC R45-3. Scale bar represents 25 μm.

5. Discussion

5.1. Endemism of new species

Dinocyst assemblages of the Eocene Southern Ocean are regionally characterized by endemic Antarctic dinocysts (Bijl et al., 2011). Originally described by Wrenn and Beckman (1982) as Transantarctic Flora, these taxa are on the species level, and in some cases even on the higher taxonomic levels, endemic to the Southern Ocean. Studies on Northern Hemisphere sections found species which were originally (Wrenn and Beckman, 1982; Bijl et al., 2011) thought to be endemic (e.g., *Hystrichosphaeridium truswelliae*; see Sluijs and Brinkhuis, 2009): this technically renders such species non-endemic. Regions of dominance of the endemic Antarctic community seem to be concentrated in the southwest Pacific and Atlantic Oceans, and from 49–50 Ma on the Antarctic Margin (Bijl et al., 2013a). While the new species described here have thus far been identified only on the Antarctic Margin of the Australo-Antarctic Gulf, both could in principle be considered endemic. The dinocyst assemblages that these new taxa were recorded have a strong low-latitude affinity, with a dominance of *Apectodinium*

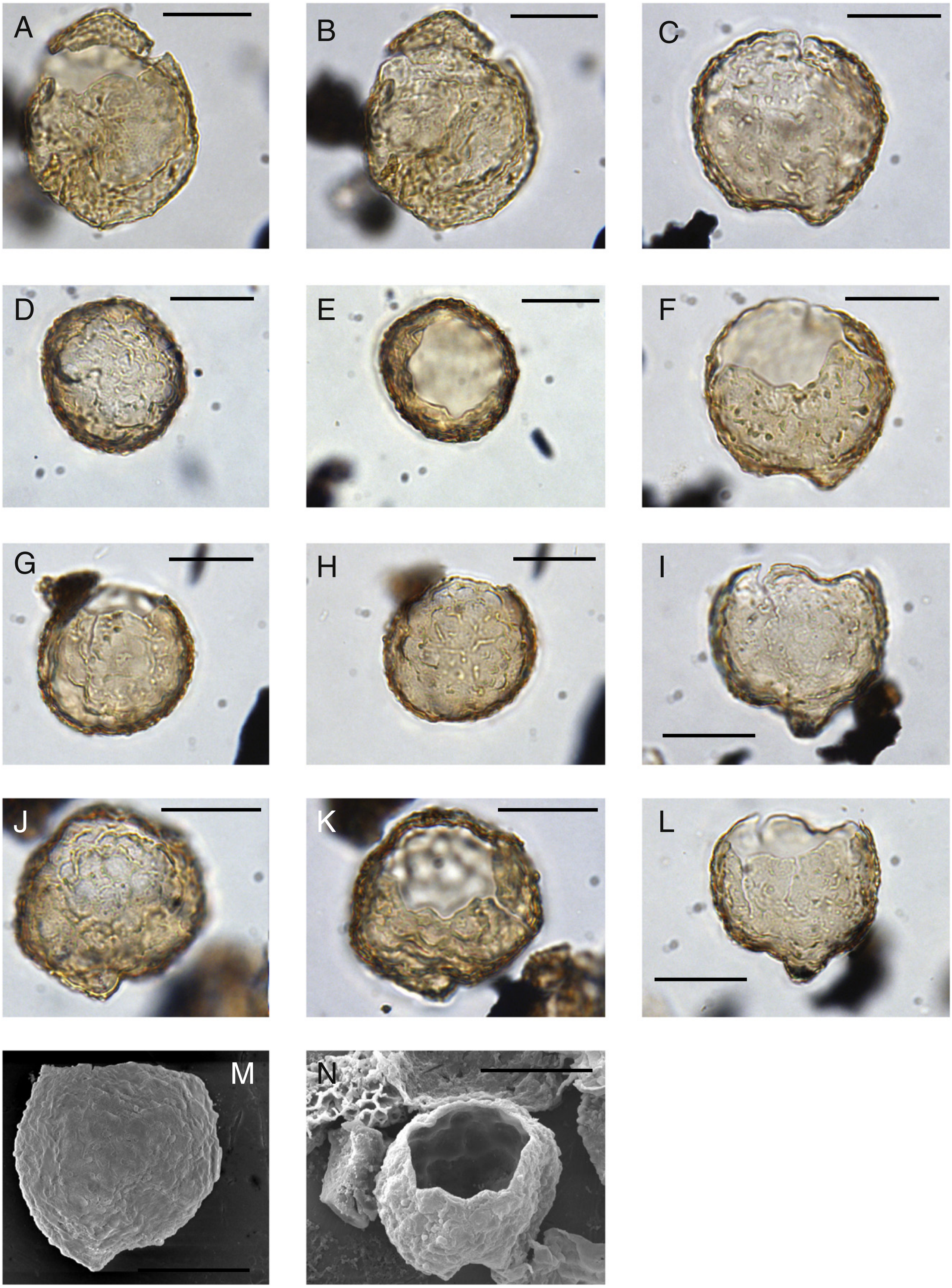

Plate III. A–N. *Adeliesphaera ohanlonii* gen. et sp. nov. A, B. U1356A-105R-1 W, 35–37 cm Slide 2 England Finder Coordinates (EFC) L55-4. C, F. U1356A-104R-6 W, 70–72 cm, Slide 1 EFC F52-4. D, E. U1356A-105R-1 W, 35–37 cm Slide 1 EFC J50. G, H. U1356A-105R-1 W, 115–116 Slide 1, EFC S47-1. I, L. U1356A-105R-1 W, 75–77 cm, Slide 1 EFC N42-3/4. J, K. U1356A-105R-1 W, 35–37 cm Slide 2 EFC M54-1. M, N. Scanning Electron Microscope (SEM) images previously published in Bijl et al. (2013b). M. *Adeliesphaera ohanlonii* gen. et sp. nov. U1356A-105R-1 W, 75–77 cm. N. *Adeliesphaera ohanlonii* gen. et sp. nov. U1356A-104R-6 W, 70–72 cm. Scale bar represents 25 μm.

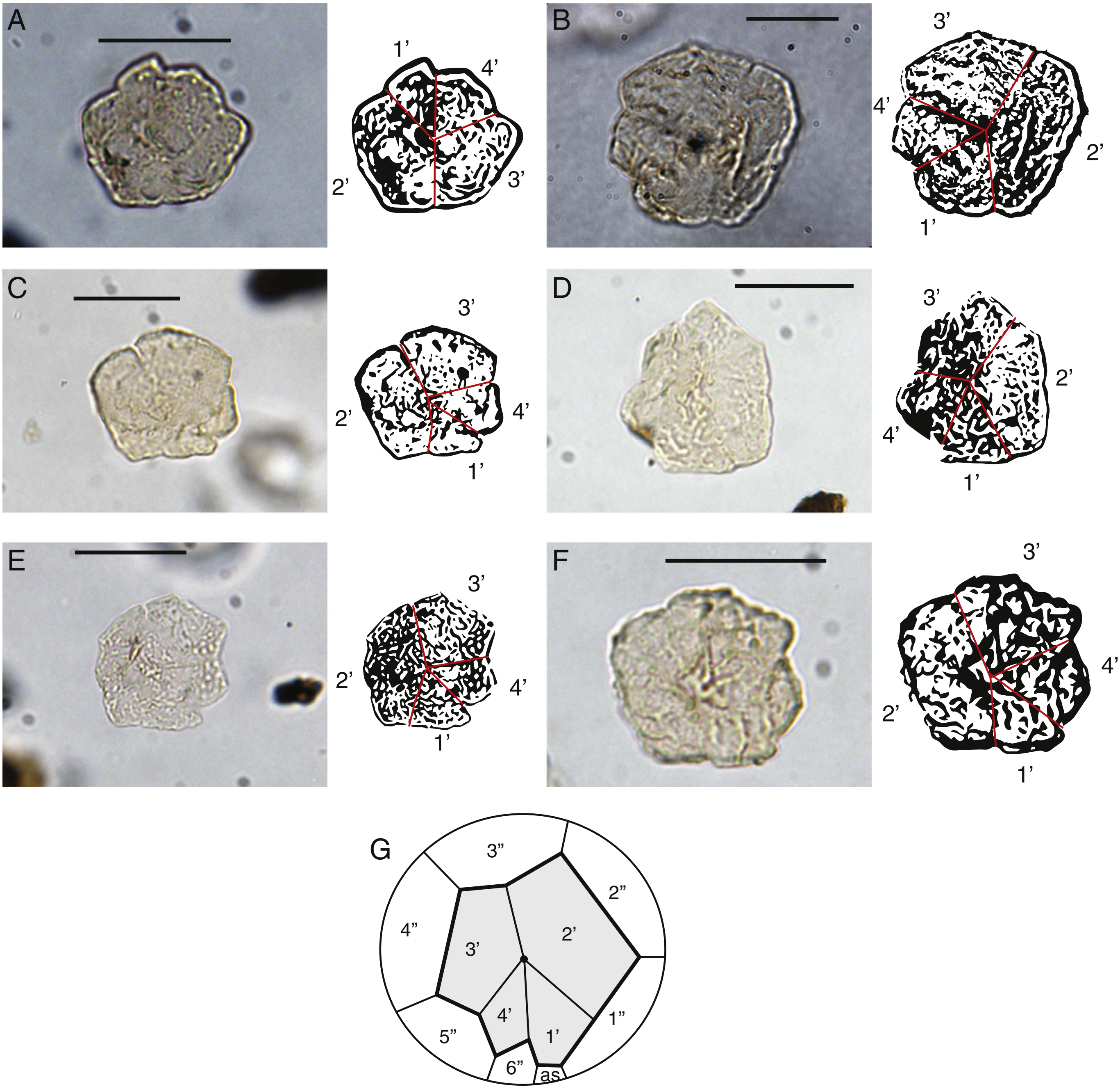

Plate IV. A–F. Operculae of *Adeliesphaera ohanlonii* gen. et sp. nov., with line drawings and an of the tabulation. A. U1356A-105R-1 W, 95–97 Slide 1 England Finder Coordinates (EFC) S43-2. B. U1356A-105R-1 W, 75–77 cm, Slide 2 EFC V47. C. U1356A-105R-1 W, 95–97 cm Slide 1 EFC V42. D. U1356A-105R-1 W, 95–97 cm Slide 1 EFC O41-4. E. U1356A-105R-1 W, 35–37 cm Slide 2 EFC P53. F. U1356A-105R-1 W, 95–97 cm Slide 2 EFC U55-1. Scale bar represents 25 μm. G. schematic drawing of an apical view on *Adeliesphaera ohanlonii*, including tabulation.

homomorphum (Bijl et al., 2013a). Unlike ODP sites in the southwest Pacific Ocean, where endemic dinocyst abundances reach 15% in the early Eocene, dinocyst assemblages from the early Eocene strata in the Australo-Antarctic Gulf are almost completely devoid of these endemic species (Bijl et al., 2013a). It is possible that, due to the short stratigraphic range of the two species described here, they were missed in other sections within or outside the Australo-Antarctic Gulf. Despite high-resolution sediment sampling both species were never reported from ODP Site 1172 and 1171 (Brinkhuis et al., 2003a,b; Bijl et al., 2013a,b, 2014). Therefore these new species should be considered endemic to the Australo-Antarctic Gulf rather than to the Southern Ocean, and are not considered part of the Eocene endemic Antarctic dinocyst association as described by Wrenn and Beckman (1982) and as reviewed by Bijl et al. (2011).

6. Conclusions

The two species described here fit existing taxonomic classification of dinocysts, although a new genus had to be erected for one new dinocyst species, *Adeliesphaera ohanlonii* sp. nov. The short stratigraphic ranges of *Turbiosphaera guersteinae* sp. nov. and *A. ohanlonii* sp. nov. were directly calibrated with existing magnetostratigraphy in the type section. If these species are found to have a wide geographic extent, their restricted temporal ranges may help to refine existing early Paleogene dinocyst zonations of the Southern Ocean, and allow for well-constrained age control in sediments that lack alternative stratigraphic tools.

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