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Taxonomic note: A new *Coccolithus* species that thrived during the Paleocene/Eocene Thermal Maximum

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Abstract A calcareous nannofossil study of the Paleocene/Eocene Thermal Maximum (PETM) sequence from Ocean Drilling Program Site 1259 on Demerara Rise (western equatorial Atlantic) has revealed a new species, *Coccolithus bownii*, that peaks just above the boundary. This species thrived in the PETM-related stressed environment and is considered a significant environmental indicator. Based on its ultrastructural characteristics, which are strongly reminiscent of those of the modern *Coccolithus pelagicus*, the new species is assigned to the genus *Coccolithus*, instead of *Ericsonia*, the latter of which is here considered a junior synonym. Two new combinations (*Coccolithus insolitus* and *Coccolithus occidentalis*) are validated that were originally published only in electronic media.

Keywords PETM, calcareous nannofossils, *Coccolithus bownii*, new species, new combinations

1. Introduction

A high-resolution, quantitative calcareous nannofossil biostratigraphic study of clay-rich sediments from around the Paleocene/Eocene boundary in Hole 1259B, Ocean Drilling Program (ODP) Leg 207 to the Demerara Rise, south-western equatorial Atlantic (Jiang & Wise, 2006) revealed a new species (referred to as *Markalius* cf. *M. apertus* by Jiang & Wise, 2006), which we here describe as *Coccolithus bownii* sp. nov. Based on similar peaks in abundance to those of the so-called Paleocene/Eocene Thermal Maximum (PETM) excursion taxa (*e.g. Discoaster araneus*), this new species is considered to be an opportunistic species that took advantage of the extreme environmental changes associated with this interval and thrived in these stressed environments. Similar abundance acmes have been observed in forms attributed to *Coccolithus subpertusus* in several Egyptian PETM sections (*e.g.* Dupuis *et al.*, 2003; Knox *et al.*, 2003). These may be equivalent to *C. bownii*, which has a similar, although quite distinct appearance. If so, then *C. bownii* may prove to be a significant, widespread ecological indicator of PETM-related stressed environments.

2. Material and methods

The sediments examined were sampled with a U-channel through the archive halves of ODP Sections 1259B-8R-2 through 8R-4. Sections 8R-2 and -3 consist primarily of light greenish nannofossil chalk with foraminifers, whereas Section 8R-4 contains a dark yellowish brown claystone, interbedded within the nannofossil chalk (Shipboard Scientific Party, 2004).

Preparation of smear-slides followed standard techniques (Bown & Young, 1998), using Norland 61 optical adhesive as a permanent mounting medium. Slides were analysed using a Zeiss Axioskop II microscope under cross-polarised light (XPL), transmitted light (TL), and phase-contrast light (PC) at 1000x magnification.

An FEI Nova 400 Nano scanning electron microscope (SEM) was employed to examine fine-scale structures. A settling technique (Bukry, 1969) was used in stub preparation to remove large particles and fine clays. Additionally, a freshly-broken surface was also coated to provide clean, clay-free specimens.

All materials are archived in the collections of the Calcareous Nannofossil Laboratory at the Department of Geological Sciences, Florida State University (FSU), Tallahassee, Florida, USA.

3. Systematic palaeontology

Family **COCCOLITHACEAE** Kamptner, 1928

Genus *Coccolithus* Schwarz, 1894
Coccolithus bownii sp. nov.
Pl.1, figs 1-21

2006 *Markalius* sp. cf. *M. apertus* Jiang & Wise: pp.236-237, pl.1, figs 6-9, 22-26.

Derivation of name: After Dr. Paul Bown (University College London) in honour of his many valuable contributions to this subdiscipline of micropalaeontology.
Diagnosis: A broadly elliptical to subcircular *Coccolithus* with a large central opening.
Description: The subcircular placolith consists of two relatively widely separated shields (Pl.1, figs 3-5), each composed of ~44-48 imbricated elements (Pl.1, figs 3, 4, 14, 15). In distal view, the distal shield is dextrogyre with its inner margin covered by a shingling of thin central-area laths (Pl.1, figs 14-16). The proximal shield consists of two closely-appressed and superimposed cycles of elements that both extend out to its margin, the proximal-most being strongly dextrogyre in proximal view (Pl.1, figs 1, 4, 5). This structure of upper and lower tiers of the proximal shield, though somewhat difficult to discern in our specimens, is strongly reminiscent of that shown in

the naturally etched specimens of *Coccolithus pelagicus* figured by Young (1992, p.4, figs 1-5).

The central opening is large, occupying about 40-50% of the coccolith's diameter along the minor axis (Pl.1, figs 1-21). Only the proximal shield and the distal shield elements appear bright in XPL (Pl.1, figs 17-19), producing a herringbone birefringence pattern characteristic of the genus. In etched specimens, the birefringence pattern does not change, except that the central opening appears much larger.

Differentiation: *Coccolithus bownii* resembles, in outline, *Coccolithus occidentalis* comb. nov. However, the latter species has a striking chevron-pattern of elements, formed by the two cycles of elements of the proximal shield, of which the proximal-most is only half the width of the underlying cycle. The central-area opening is also considerably smaller, occupying only a quarter of the total width, measured along the minor axis (see Black, 1964, pl.52, fig.1). The large central opening and subcircular outline differentiate *C. bownii* from other *Coccolithus* species, most of which are more elliptical. *Coccolithus formosus*, on the other hand, is circular, but has a much smaller central opening (about 20% or less of the total minor-axis diameter; see Black, 1964, pl.50, fig.2, as '*C. lusitanicus*').

Remarks: As pointed out above, construction of the proximal shield of *C. bownii* resembles closely that of the modern *C. pelagicus*, that is, it consists of two thin, closely-appressed, superimposed layers of near equal width. The presence of this construction in the Lower Eocene shows that this feature occurs in the older as well as the younger parts of the *Coccolithus* lineage. This construction contrasts with other contemporaneous forms, such as *C. occidentalis* comb. nov. and *C. muiri* (= '*Ericsonia ovalis*'; see Roth, 1970, p.841), which Black (1964) placed in a separate genus, *Ericsonia*, based on the much shorter widths of the proximal-most tier of the proximal shield. The relative widths of those two tiers, however, vary significantly among species and over time (Wise, 1983, p.505). Consequently, it is difficult to draw a non-arbitrary dividing line between the genus *Coccolithus* and Black's *Ericsonia*. Following the lead of Bukry (1973) and Wise (1973, 1983), we continue to place all such species in the genus *Coccolithus*.

Occurrence: *C. bownii* is common to abundant within Zone NP10 of Martini (1971) in ODP Hole 1256B. Specifically, it shows an acme within the PETM interval, and decreases in abundance thereafter, upsection (Jiang & Wise, 2006, fig.2). Should the acmes of *C. subpertusus* in Egypt actually be of *C. bownii*, then this new species would have at least a low-latitude distribution.

Dimensions: 6-8μm diameter (holotype = 6.2μm).

Holotype: Pl.1, fig.1.

Paratypes: Pl.1, figs 3, 4, 8, 10, 14, 15.

Type locality: ODP Hole 1259B, Demerara Rise, off South America (9°18.0485'N, 54°11.9448'W), Sample 1259B-8R-4, 57-58cm.

Coccolithus insolitus (Perch-Nielsen, 1971) Jiang, Ladner & Wise comb. nov.

Basionym: *Ericsonia insolita* Perch-Nielsen, 1971, p.13, pl.1, fig.1; pl.7, figs 4, 6; pl.61, figs 14, 15; Elektronenmikroskopische Untersuchungen an Coccolithen und verwandten Formen aus dem Eozän von Dänemark. *Det Kongelige Danske Videnskabernes Selskab Biologiske Skrifter*, **18**: 1-76.

Remarks: See remarks under *C. bownii*. This combination was previously made by Ladner & Wise *in* Wise *et al.* (2002), in a publication distributed *via* CD-ROM only. New combinations published in electronic media are invalid under provisions of the *International Code of Botanical Nomenclature* published in 2000 (Article 29.1; Greuter *et al.*, 2000).

Coccolithus occidentalis (Black, 1964) Jiang, Ladner & Wise comb. nov.

Basionym: *Ericsonia occidentalis* Black, 1964, pp.311-312, pl.52, figs 1, 2: Cretaceous and Tertiary coccoliths from Atlantic seamounts; *Palaeontology*, **7**(2), pl.52, figs 1, 2.

Remarks: See remarks under *C. bownii*. This combination was previously made by Ladner & Wise *in* Wise *et al.* (2002) and is invalid (see remarks under *C. insolitus*).

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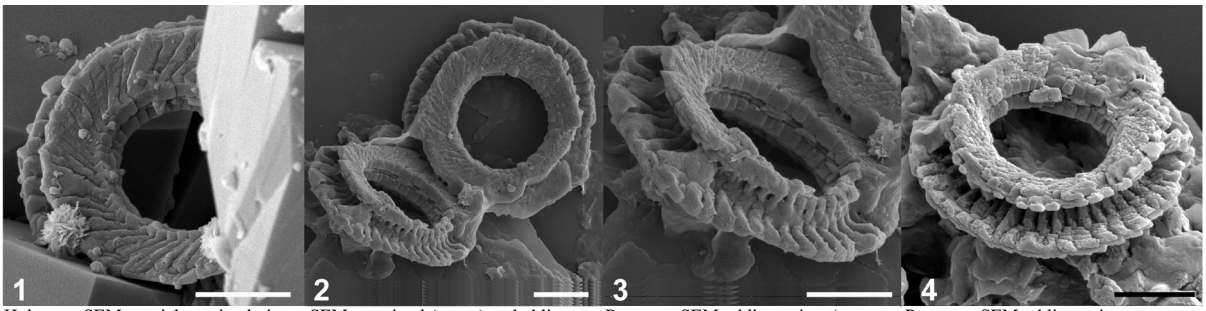
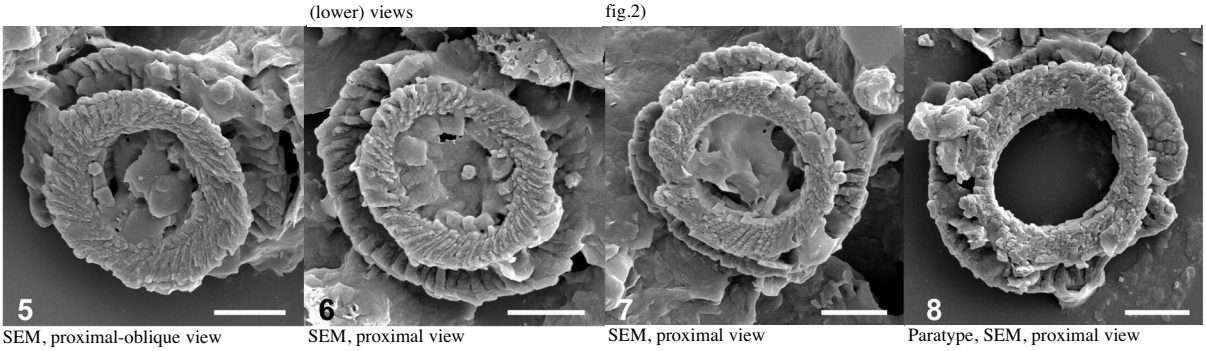
Plate 1

Coccolithus bownii

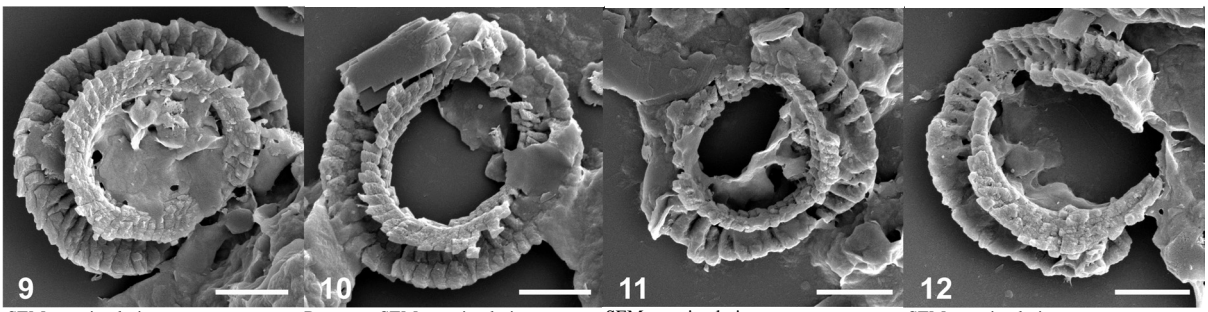
Sample ODP 206-1256B-6H-2, 115-117cm. Scale-bar = 2μm



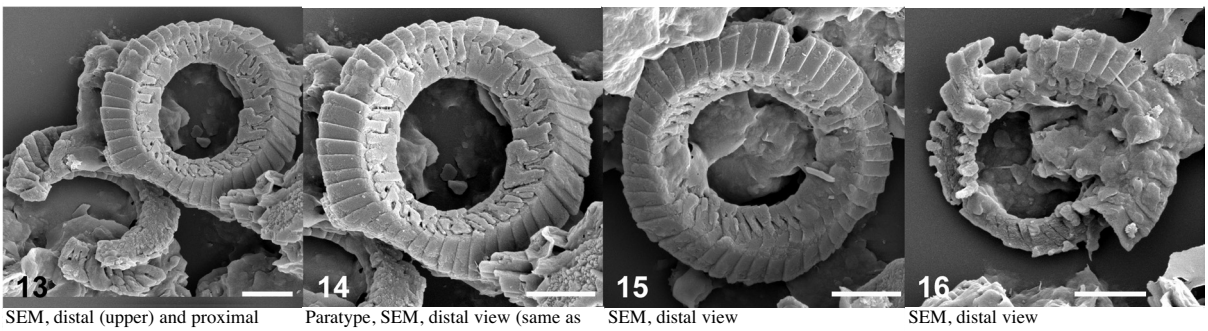
Holotype, SEM, partial proximal view | SEM, proximal (upper) and oblique (lower) views | Paratype, SEM, oblique view (same as fig.2) | Paratype, SEM, oblique view



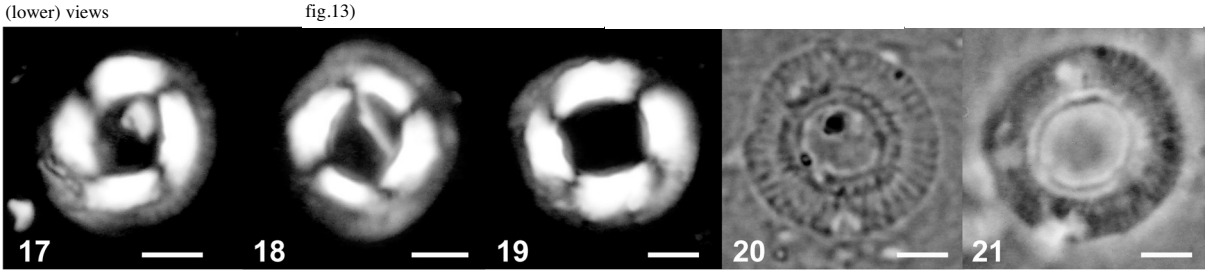
SEM, proximal-oblique view | SEM, proximal view | SEM, proximal view | Paratype, SEM, proximal view



SEM, proximal view | Paratype, SEM, proximal view | SEM, proximal view | SEM, proximal view



SEM, distal (upper) and proximal (lower) views | Paratype, SEM, distal view (same as fig.13) | SEM, distal view | SEM, distal view



XPL, plan view | XPL, plan view | Paratype, XPL (19), TL (20), PC (21) plan view