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A new Oligocene *Triquetrorhabdulus* species, *T. longus* sp. nov.

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Abstract Whilst investigating the first occurrence of *Triquetrorhabdulus carinatus* at Ocean Drilling Program Leg 199 Site 1218 in the palaeo-equatorial Pacific, a form that resembles this species was observed and counted separately. Based on differences in size, shape and stratigraphic range, compared to the typical *T. carinatus*, we describe this longer morphotype as a new, and potentially biostratigraphically useful, nannolith species, *T. longus* sp. nov.

Keywords Nannolith, Oligocene, *Triquetrorhabdulus*, taxonomy, ODP Leg 199 Site 1218, palaeo-equatorial Pacific Ocean

1. Intoduction

Triquetrorhabdulus is an elongated, rod-shaped nannolith formed of three blades (Young *et al*., 1997; Young, 1998). *T. carinatus* was originally described from the western equatorial Pacific Ocean as "forms elongated with both ends more or less pointed; the three calcite rods show the same diameter when viewed from one end; they are placed at 120˚ to each other. In polarized light, forms show maximum extinction when parallel to crossed nicols" (Martini, 1965, p.408). The forms were described as varying in length, between 9 and 15μm, although morphotypes up to 24μm long were also observed (Martini, 1965).

The original description of the genus *Triquetrorhabdulus* was further developed by Bramlette & Wilcoxon (1967). They observed that "the optic axes of the calcite are parallel to the long axis of the rod" (Bramlette & Wilcoxon, 1967, p.128). Lipps (1969, p.1030) noticed that "much variation in size and shape occurs among individual specimens even in the same sample; some are short and truncated at one end, whereas others may be nearly twice as long and taper to a sharp point at each end". Several species of *Triquetrorhabdulus* have been described, based on the extent of development of the ridges, as well as their general shape, and most of these have proved of stratigraphic value (Aubry, 1988; Young, 1998).

Two main morphotypes of '*T. carinatus*' have been distinguished from Deep Sea Drilling Project (DSDP) Site 242 (Indian Ocean): long, thin specimens with parallel sides (complete specimens 25 to 50 x 1.5 to 2.5μm) and shorter, broader specimens with a distinct taper (15 to 25 x 2 to 4μm) (Young, 1987; www.nannotax.org). However, these morphotypes were not formally described as separate species. During a high-resolution biostratigraphic study of the first occurrence (FO) of *T. carinatus* from Ocean Drilling Program (ODP) Site 1218 in the palaeo-equatorial Pacific Ocean, both morphotypes were encountered (Blaj *et al*., 2009). At this site, the *Triquetrorhabdulus* morphotypes appeared to have distinct stratigraphic ranges and morphologies, and so it was decided to describe the elongate form as a new, and potentially biostratigraphically useful, species.

2. Material and methods

Originally, a suite of 537 samples was examined from a continuous Oligocene section, in order to increase the number of useful biostratigraphic events in the Upper Oligocene. The investigated section was recovered from ODP Site 1218 (8˚53.38'N, 135˚22.00'W; 4826m water-depth; Figure 1) from the tropical Pacific Ocean (Lyle *et al*., 2002; Wilson *et al*., 2006) and corresponds to the time-interval between 23.41 and 27.52Ma, based on the astronomically-calibrated time-scale of Pälike *et al*. (2006).

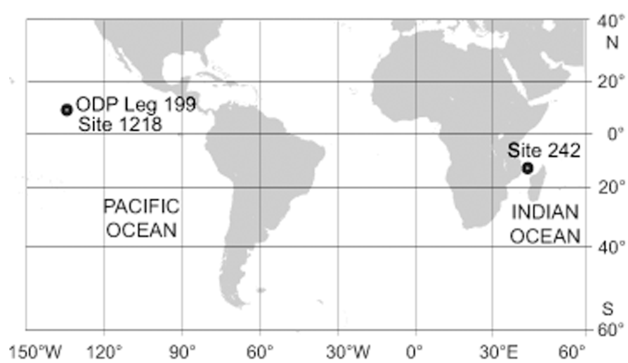


Figure 1: Location of ODP Site 1218 and DSDP Site 242. Map modified from http://www.iodp-usio.org/

Smear-slides were prepared from raw sediment samples using standard techniques, with the sediment smeared over the glass microscope slide (Perch-Nielsen, 1985). Semi-quantitative data on the *Triquetrorhabdulus* morphotypes (Figure 2) were obtained using the method of Backman & Shackleton (1983), with abundance expressed as number of specimens per mm^2. In order to study in detail the morphological differences, 10 Oligocene samples were selected for analysis using both transmitted light (LM) and scanning electron (SEM) microscopy. The SEM work was performed using a Phillips XL30 Field Emission SEM at the Natural History Museum, London. All 10 samples and the SEM and LM micrographs of the morphotypes are archived at the Natural History Museum, London.

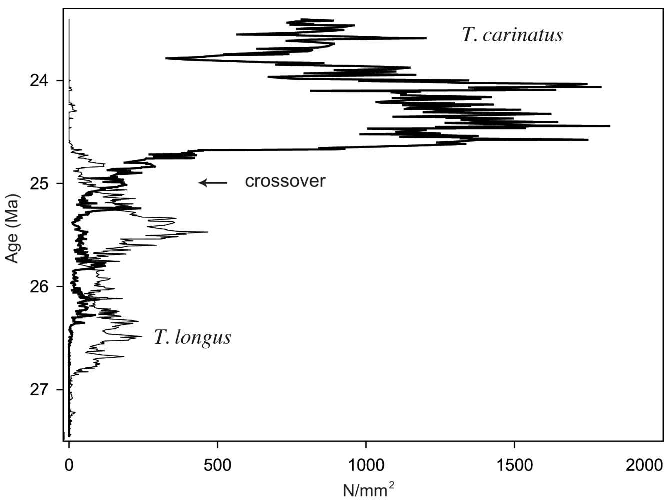


Figure 2: Abundance patterns of *Triquetrorhabdulus longus* (grey line) and *T. carinatus* (black line) at Site 1218, expressed as number of specimens per mm^2 (from Blaj *et al.*, 2009)

3. Results and discussion

While investigating the FO of *Triquetrorhabdulus carinatus* from Site 1218, a form that resembles this species was observed and counted separately (Blaj *et al.*, 2009, fig.8). This morphotype differs from typical *T. carinatus* in having a larger size. It can be up to 45μm long, in contrast to typical *T. carinatus*, which has a maximum length of 15μm. Most observed specimens of the longer morphotype show moderate calcite overgrowth. The ridges are present in some specimens, but are often too poorly preserved to be clearly observed. In cross-polarised light (XPL), the longer morphotype appears greyish and less bright, suggesting that it is less heavily calcified than *T. carinatus*. However, both morphotypes display similar optical behaviour, and show maximum birefringence at 45° to the polarisers when observed in XPL. Complete specimens of this longer morphotype are needle shaped, with one end being thicker and brighter, narrowing throughout its length and becoming progressively less bright. Even when the specimens ascribable to the longer morphotype are broken, they are still distinguishable from typical specimens of *T. carinatus* because their fragments are narrower and less bright.

T. carinatus and the longer morphotype show different stratigraphic ranges (Figure 2) in the palaeo-equatorial Pacific Ocean. A crossover in abundance occurs just prior to 25Ma, at which time the abundance of the longer morphotype decreases gradually, while *T. carinatus* increases distinctly in abundance. At Site 1218, the stratigraphic distribution of the longer morphotype encompasses more than 3Myr (from 27.5 to 24.0Ma, based on the Pälike *et al.*, 2006, time-scale), representing the first reliable total range documented for this morphotype. This morphotype has also been observed in the Indian Ocean at DSDP Site 242 (www.nannotax.org), suggesting a wide distribution. The beginning of the peak abundance interval of *T. carinatus* coincides with the decline in abundance of the longer morphotype. It seems reasonable to assume that ecological conditions at that time became more favourable to the dominance of *T. carinatus*.

4. Taxonomic description

The terminology used here follows the guidelines for calcareous nannofossil terminology proposed by Young *et al.* (1997).

INCERTAE SEDIS

Family **TRIQUETRORHABDULACEAE** Lipps, 1969

Genus *Triquetrorhabdulus* **Martini, 1965**

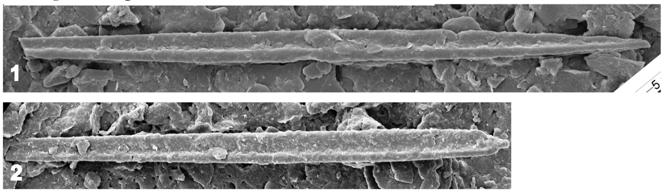
Triquetrorhabdulus longus sp. nov.
Pl.1, figs 1-13, 19-21

Derivation of name: From the Latin '*longus*', meaning 'long', referring to the great length of the nannolith.
Diagnosis: A thin (<2μm), elongate (>15μm) species of *Triquetrorhabdulus* formed of three calcite rods of similar width. The *c*-axis is parallel to the length of the nannolith.
Differentiation: *T. longus* is primarily distinguishable from *T. carinatus* Martini, 1965 by its greater length (compare Pl.1, figs 14-19 with figs 22-24). The completely preserved specimens are double the size of *T. carinatus*. *T. longus* is narrower and less bright in XPL than *T. carinatus*, and differs from planktonic foraminifera spines in showing distinct taper.
Comments: Most observed specimens taper gradually towards one end, with the other end having a rather abrupt V-shaped termination (see Pl.1, figs 2-5, 8-13, 19-20). However, a few of the longest specimens show a gradual tapering towards both ends (Pl.1, figs 1, 6).
Holotype: Pl.1, fig.20 (length = 25μm, width = 1.5μm).
Paratype: Pl.1, fig.4 (length = 28μm, width = 1.5μm).
Type locality: ODP Leg 199, Site 1218, central Pacific Ocean (8°53.38'N, 135°22.00'W).
Type level: Sample ODP 199, Hole 1218A-12H-04, 35-36cm, Upper Oligocene.
Range: Restricted to NP24-25, Chattian, Upper Oligocene.
Occurrence: At Site 1218, *T. longus* occurs over a 3Myr interval (based on the time-scale of Pälike *et al.*, 2006) in the Late Oligocene. Its FO has an age estimate of 27.5Ma. This biohorizon is characterised by an interval of low and discontinuous abundance of the taxon, followed by its continuous and common presence at around 26.9Ma (Figure

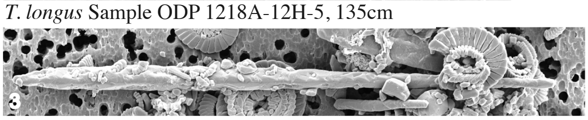
Plate 1

5μm (SEM)

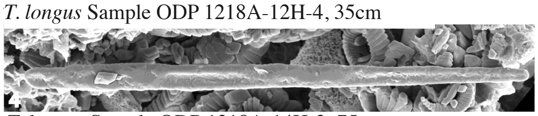
T. longus Sample DSDP 242-8-2, 30-31cm



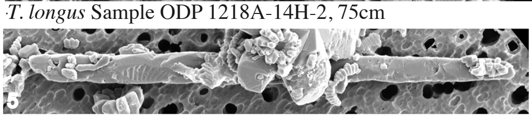
T. longus Sample ODP 1218A-12H-5, 135cm



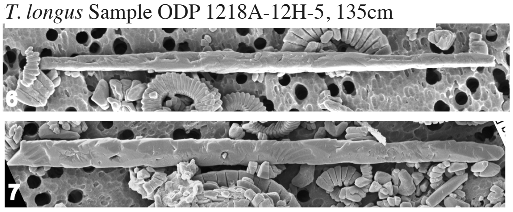
T. longus Sample ODP 1218A-12H-4, 35cm



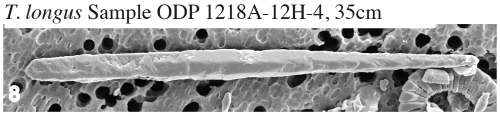
T. longus Sample ODP 1218A-14H-2, 75cm



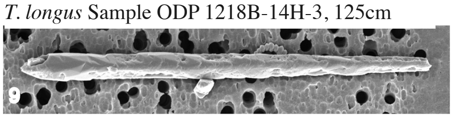
T. longus Sample ODP 1218A-12H-5, 135cm



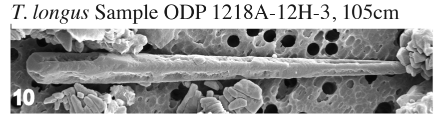
T. longus Sample ODP 1218A-12H-4, 35cm



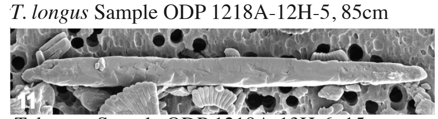
T. longus Sample ODP 1218B-14H-3, 125cm



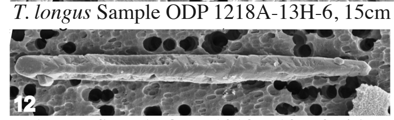
T. longus Sample ODP 1218A-12H-3, 105cm



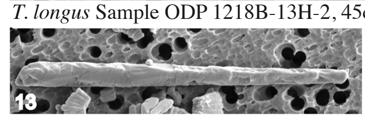
T. longus Sample ODP 1218A-12H-5, 85cm



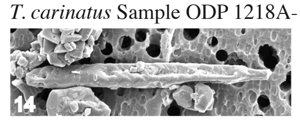
T. longus Sample ODP 1218A-13H-6, 15cm



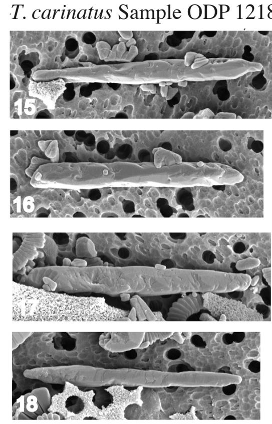
T. longus Sample ODP 1218B-13H-2, 45cm



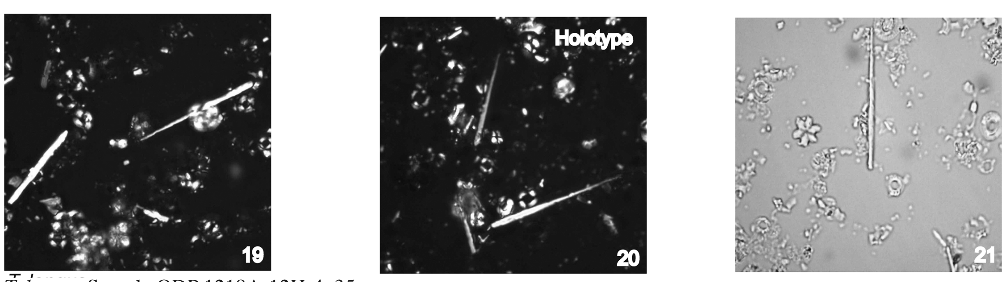
T. carinatus Sample ODP 1218A-14H-2, 75cm



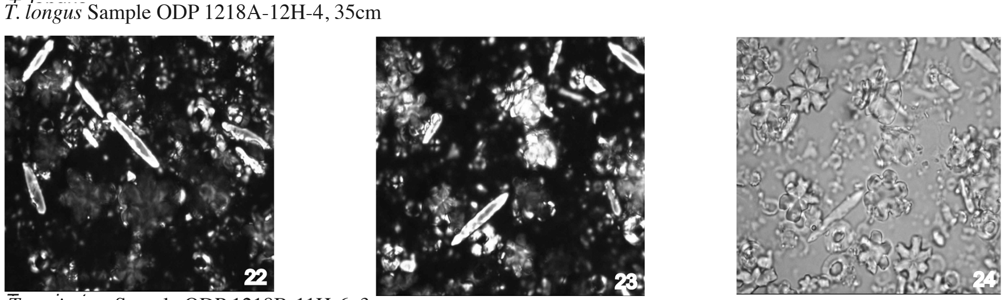
T. carinatus Sample ODP 1218B-13H-2, 45cm



5μm (LM)



T. longus Sample ODP 1218A-12H-4, 35cm



T. carinatus Sample ODP 1218B-11H-6, 3cm

2). The last specimens of *T. longus* were observed at 24.0Ma. Remarkably, the two nannoliths have different stratigraphic ranges at Site 1218. Although *T. longus* and *T. carinatus* show a partial overlap in the lower parts of their ranges, the former is always more abundant compared to the latter (Figure 2). Towards the end of its range, *T. longus* shows a decrease in abundance virtually coincident with the onset of the peak abundance interval of *T. carinatus*.

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