

New Aptian calcareous nannofossil species from Brazil

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Abstract The calcareous nannofossil genera *Braarudosphaera* and *Nannoconus* are significant biostratigraphic markers and palaeoecological indicators in Cretaceous marine sediments. This is particularly true for Brazilian basins where those nannofossils are used to provide regional biostratigraphic framework across the Aptian and Albian intervals. Recent calcareous nannofossil studies of Aptian sediments from the coastal basins and continental shelf offshore Brazil have recorded the occurrence of two new calcareous nannofossil species, *Braarudosphaera pseudobatilliformis* and *Nannoconus troelsenii*, which we describe herein. In addition, the description of one species, *Braarudosphaera batilliformis*, is emended in this work.

Keywords Calcareous nannofossils, taxonomy, Cretaceous, Aptian, *Nannoconus*, *Braarudosphaera*, Atlantic Ocean, Brazil

1. Introduction

The calcareous nannofossil genera *Braarudosphaera* and *Nannoconus* are significant in Cretaceous marine sediments, being useful in both biostratigraphic and palaeoecological studies. Those species have played an important role in the biostratigraphic zonation of the Aptian/Albian interval along the Brazilian continental margin (Cunha & Koutsoukos, 1998).

Furthermore, in palaeoecological studies conducted by Cunha & Shimabukuro (1997), and Cunha & Koutsoukos (1998) the authors argued that *Braarudosphaera* and *Nannoconus* are associated with carbonate-rich deposits, although both nannofossil groups show different paleoenvironmental parameters (for example, water-depth, trophic level, water salinity and turbidity).

Recent detailed biostratigraphic investigations of several Cretaceous sections from continental margin wells in the Brazilian sedimentary basins have revealed the presence of specimens that have not yet been formally described as species. Thus, here we describe and illustrate two new species: *Nannoconus troelsenii* and *Braarudosphaera pseudobatilliformis*. The species *Braarudosphaera batilliformis* (Troelsen & Quadros, 1971) is also reviewed and its description is emended herein.

2. Material and methods

The samples analysed came from 34 wells drilled by PETROBRAS along the Brazilian continental margin as illustrated in Figure 1. Details about the Brazilian sedimentary basins can be found in Milani *et al.* (2007).

Nannofossils are common to abundant and moderately to well preserved in the studied sections. Cretaceous calcareous nannofossil samples were prepared as smear-slides following the standard technique described by Bown & Young (1998) and mounted with coverslips using Norland optical adhesive. Temporary mobile mounts were also made using immersion oil and Norland. The adhesive was placed on the edges of the coverslips to seal them, thus preventing leakage of the immersion oil (technique modified from Bown & Young, 1998). This preparation procedure allows rotation of the specimens and observation of different views of the same specimen.

Smear-slides were examined for calcareous nannofossils using a polarising light microscope (Zeiss Axio Imager A2) at 1600X magnification. Images were taken under cross polarised light (XPL), bright field (BF) and with gypsum plate (GP), and captured using AxioVision 40x64 v.4.9 Zeiss software. Samples were also examined using the Zeiss EVO-40 model scanning electron microscope (SEM) at the Biostratigraphy and Palaeoecology Research and Development Centre, BPA/CENPES/PETROBRAS, Rio de Janeiro, Brazil (extra high tension = 20kV, working distance = 12mm, Signal A = SE1, magnification = 5.88K X).

Images and slides were deposited in the palaeoinvertebrates collection at the Museu Nacional/UFRJ, Rio de Janeiro, Brazil (*Braarudosphaera batilliformis*) or in the collection of the Biostratigraphy and Palaeoecology Research and Development Centre, BPA/CENPES/PETROBRAS (*Braarudosphaera pseudobatilliformis* and *Nannoconus troelsenii*).



Figure 1: Map showing the location and distribution of the studied continental margin wells in the Brazilian sedimentary basins, as well as the biogeographic distribution of the species discussed

3. Systematic palaeontology

The higher taxonomic classification and terminology of calcareous nannofossils is based on Bown & Young (1997), Young & Bown (1997), and Young *et al.* (1997). The formal definition of our new species follows the *International Code of Nomenclature* (McNeill *et al.*, 2012) and we also referred to van Heck (1990a, b, 1992, 1993, 1994, 2014).

Table 1 shows the assemblage composition, with common taxa identified in the present study. Stratigraphic range information is given for distributions in the Brazilian basins where the NC zonation (Roth, 1978) and CC zonation (Sissingh, 1977; Perch-Nielsen, 1985)

were applied. Only taxonomic references not included in Perch-Nielsen (1985) and Bown (1998) are provided in the reference list.

Family BRAARUDOSPHAERACEAE Deflandre, 1947

Genus *Braarudosphaera* Deflandre, 1947
Braarudosphaera batilliformis Troelsen & Quadros, 1971, emend. Alves, Lima & Shimabukuro Pl. 1, figs 1–13; Pl. 2, fig. 15a

1971 *Braarudosphaera batilliformis* Troelsen & Quadros: p. 588, pl. 7, figs 100–102 (100 = holotype) [in Portuguese]

Common taxa identified in this study
<i>Assipetra infracretacea</i> subsp. <i>infracretacea</i>
<i>Assipetra infracretacea</i> subsp. <i>larsonii</i>
<i>Biscutum constans</i>
<i>Braarudosphaera africana</i>
<i>Chiastozygus litterarius</i>
<i>Eprolithus floralis</i>
<i>Flabellites oblongus</i>
<i>Hayesites irregularis</i>
<i>Helenea chiastra</i>
<i>Lithraphidites carniolensis</i>
<i>Manivitella pemmatoidaea</i>
<i>Microrhabdulus primitivus</i>
<i>Nannoconus circularis</i>
<i>Nannoconus elongatus</i>
<i>Nannoconus globulus</i>
<i>Nannoconus quadriangulus</i> subsp. <i>apertus</i>
<i>Nannoconus quadriangulus</i> subsp. <i>quadriangulus</i>
<i>Nannoconus truitii</i>
<i>Radiolithus planus</i>
<i>Retecapsa crenulata</i>
<i>Rhagodiscus angustus</i>
<i>Rhagodiscus asper</i>
<i>Rucinolithus terebrodentarius</i> subsp. <i>terebrodentarius</i>
<i>Rucinolithus terebrodentarius</i> subsp. <i>youngii</i>
<i>Tranolithus gabalus</i>
<i>Watznaueria barnesiae</i>
<i>Watznaueria britannica</i>
<i>Watznaueria supracretacea</i>
<i>Zeugrhabdotus diplogrammus</i>
<i>Zeugrhabdotus embergeri</i>
<i>Zeugrhabdotus erectus</i>
<i>Zeugrhabdotus noeliae</i>
<i>Zeugrhabdotus xenotus</i>

Table 1: Common taxa identified in this study

Derivation of name: From the Latin *batilliformis*, meaning ‘shovel-shaped’, referring to the general outline of the species.

Original Diagnosis: According to Troelsen & Quadros (1971), this species is composed of four rounded or slightly angular, subtriangular to subrhomboidal liths and a fifth prominent, elongated subrhomboidal lith. The longest dimension of this lith is approximately twice that of the four other liths and shows a sharp tip, aligned with the main axis of the elongated lith.

Emended description: The original diagnosis of this species (Troelsen & Quadros, 1971) did not include the description of a central ridge along the elongated lith. Our

observations show that this lith is straight-sided, with a narrow central ridge. Under XPL the lith shows maximum birefringence at 45° in relation to the plane of polarisation. This birefringence is higher in the centre of the ridge, decreasing toward the lith edges.

Differentiation: The presence of one elongated, ridged lith and four smaller liths distinguishes *B. batilliformis* from all other species of this genus.

Dimensions of illustrated specimens: maximum diameter (including the elongated segment) = 16 µm (original holotype = 10 µm). The holotype specimen (from Troelsen & Quadros, 1971) was illustrated again in the present article (Pl. 1, fig. 1).

The holotype slide is deposited in the collection of Museu Nacional/UFRJ, Rio de Janeiro, Brazil, Catalogue number MN 5032-1 (Fernandes & Fonseca, 2001).

Stratigraphic range: The holotype was described from the Aptian of the Sergipe-Alagoas Basin, Brazil, as suggested by ammonites (Schaller, 1970; *Epicheloniceras-Diadochoceras-Eodouvilleiceras* Zone - Koutsoukos & Bengston, 1993).

The geological range of Aptian-Cenomanian attributed to this species in subsequent references (Farinacci, 1979; Perch-Nielsen, 1985; Young *et al.*, 2015) is due to a mis-translation of the original article into English by Farinacci (1979). Furthermore, examination of several sections and an investigation in the literature did not detect a consistent occurrence of *B. batilliformis* in a range above the Aptian.

Occurrence: *Braarudosphaera batilliformis* was observed in the equatorial, northeastern, and southeastern Brazilian margins. In addition to the species listed in Table 1, *B. batilliformis* usually occurs in association with *Nannoconus circularis*, *N. bucheri*, *N. globulus*, and *Micrantholithus hoschulzii*. The occurrence of the species mentioned above, with *Eprolithus floralis*, may indicate the biozone CC7 (Sissingh, 1977; Perch-Nielsen, 1985) or the lower part of the biozone NC7 (Roth, 1978).

Braarudosphaera pseudobatilliformis sp. nov.

Pl. 2, figs 1–14, 15b

Derivation of name: After the Greek *pseudos*, meaning ‘false’, referring to the difference from *B. batilliformis*.

Diagnosis: *Braarudosphaera* with four rounded to slightly angular, subtriangular to subrhomboidal liths and a fifth pointed, rhomboidal lith, the longest dimension of which is only slightly larger than that of the other liths. This rhomboidal lith gives an asymmetrical appearance to the outline.

Differentiation: Similar to *B. batilliformis*, but different due to the slightly elongated segment with an asymmetrical appearance to the outline, with a wide tip and diffuse edge, being less extended and lacking a central ridge (Pl. 2, fig. 15b).

Remarks: The larger lith in *B. pseudobatilliformis* is relatively shorter than in *B. batilliformis* (Pl. 2, fig. 15). In XPL, the larger lith shows maximum birefringence when

positioned at 45° relative to the plane of polarisation, but there is no ridge on the larger lith in *B. pseudobatilliformis*.

Dimensions: Holotype maximum diameter (including the elongated segment) = 14 µm; Holotype larger lith = 7.5 µm long.

Holotype: Pl. 2, figs. 1–5; well 1-VF-4, core 2, 746.45m, Sergipe-Alagoas Basin. Catalogue number: PETROBRAS CB-2014-01-13081-1. England Finder: N75/1. Collection of BPA/CENPES, PETROBRAS, Rio de Janeiro, Brazil.

Paratypes: Pl. 2, figs 6–10; well Campos-1, sidewall core sample, 3652m, Campos Basin. Catalogue number: PETROBRAS CB-200700086. England Finder: D57/2. Collection of BPA/CENPES, PETROBRAS, Rio de Janeiro, Brazil.

Type locality: Well 1-VF-4, Sergipe-Alagoas Basin, Brazil.

Type level: Aptian: well 1-VF-4. Core 2, 746.45m. Previous studies of ammonites in the Sergipe-Alagoas basin indicate an Aptian age in this section (Zone 300-*Cheloniceras* spp. - Schaller, 1970; *Epicheloniceras-Diadochoceras-Eodouvilleiceras* Zone - Koutsoukos & Bengston, 1993).

Occurrence: *Braarudosphaera pseudobatilliformis* was observed in the equatorial, northeastern, and southeastern Brazilian margins. At present, base *B. pseudobatilliformis* is recorded just above the extinction of *B. batilliformis* and its occurrence is restricted to the Aptian CC7 biozone (Sissingh, 1977; Perch-Nielsen, 1985) or NC7 (Roth, 1978). Common taxa usually identified with *B. pseudobatilliformis* are listed in Table 1 and contribute to the recognition of these biozones.

Family NANNOCONACEAE Deflandre, 1959

Genus *Nannoconus* Kamptner, 1931

Nannoconus troelsenii sp. nov.

Pl. 3, figs 1–14; Pl. 4, figs 1–16

Derivation of name: In honour of Johannes Christian Troelsen, former palaeontologist at PETROBRAS, and the first to report nannoconids in the late 1960s.

Diagnosis: Relatively short (height < width), cylindrical *Nannoconus*. In side view this species has a rectangular outline with parallel sides. In plan view the rim is approximately half the width of the central-area and the central-area comprises a depression rather than a cavity, which, in XPL, shows cross-shaped extinction lines that fill the central-area depression.

Differentiation: Distinguished from other *Nannoconus* species by the combination of its short, rectangular outline and the central-area depression and cross-shaped extinction lines. This diagnostic feature can be considered distinctive of this species, along with other characteristic features in longitudinal view, such as the relatively thick wall and a height less than the diameter.

Dimensions: Height = 2–4 µm; Width = 4–12 µm; Central-area = 1.5–3 µm; Rim = 1.5–3 µm.

Holotype: Pl. 3, figs 1–3; well Ceará-1, Ceará Basin. Sidewall core sample, depth: 3574m. Catalogue number: PETROBRAS CB-2012-01-14338-1. England Finder: S69/3. Collection of BPA/CENPES, PETROBRAS, Rio de Janeiro, Brazil.

Paratypes: Pl. 3, figs. 5–7; well Ceará-1, Ceará Basin. Sidewall core sample, depth: 3574m. Catalogue number: PETROBRAS CB-2012-01-14338-1. England Finder: N47/1. Collection of CENPES, PETROBRAS, Rio de Janeiro, Brazil.

Type locality: Well Ceará-1, Ceará Basin, Brazil.

Type level: Aptian, well Ceará-1, Ceará Basin. Sidewall core sample, depth: 3574m.

Occurrence: *N. troelsenii* was observed in the equatorial, northeastern, and southeastern Brazilian margins. In addition to the species listed in Table 1, *N. troelsenii* also occurs in association with *Braarudosphaera batilliformis*, *B. pseudobatilliformis*, *Nannoconus circularis*, *N. bucheri*, *N. globulus*, *Micrantholithus hoschulzii*, and *Rhagodiscus achlyostaurion*. The presence of *N. troelsenii* together with the above taxa suggests that this occurrence is related to the Aptian biozones CC7 (Sissingh, 1977; Perch-Nielsen, 1985) or NC7 (Roth, 1978).

Observation: At present, the top of *Nannoconus troelsenii* coincides with the extinctions of *Nannoconus quadriangulus* subsp. *apertus* and *Nannoconus quadriangulus* subsp. *quadriangulus*, which were described as being restricted to the Aptian (Deflandre & Deflandre-Rigaud, 1967; Barrier, 1977; Deres & Achéritéguy, 1980, and Perch-Nielsen, 1985).

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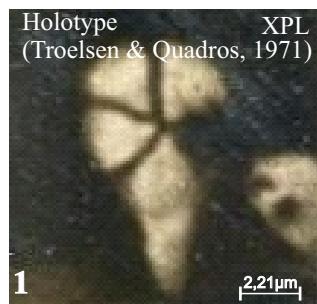
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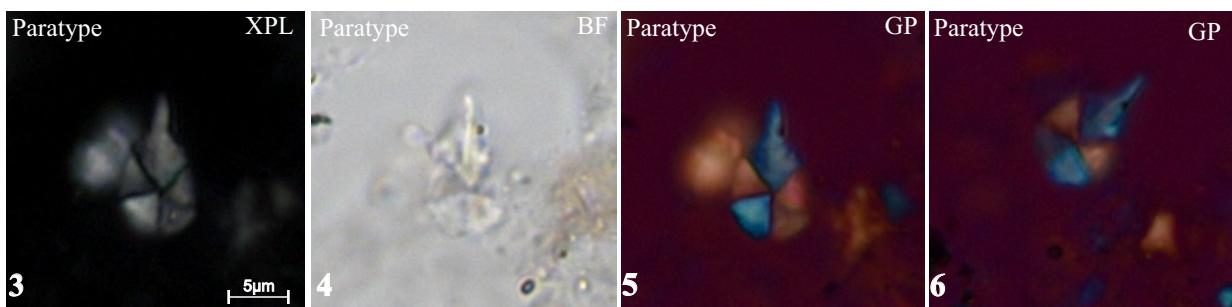
Plate 1. *Braarudosphaera batilliformis*

XPL = cross polarised light
 BF = bright field

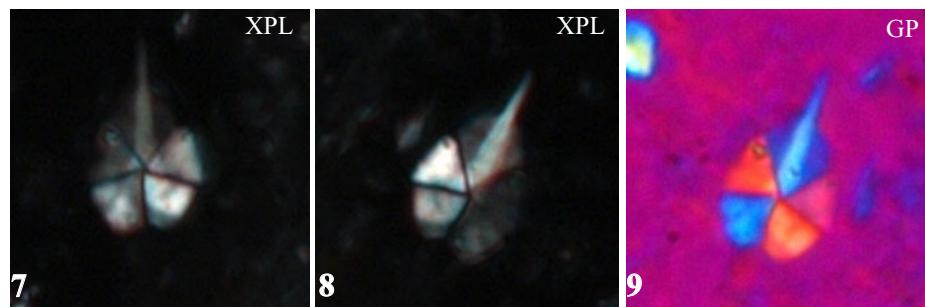
GP = gypsum plate
 SEM = SEM image



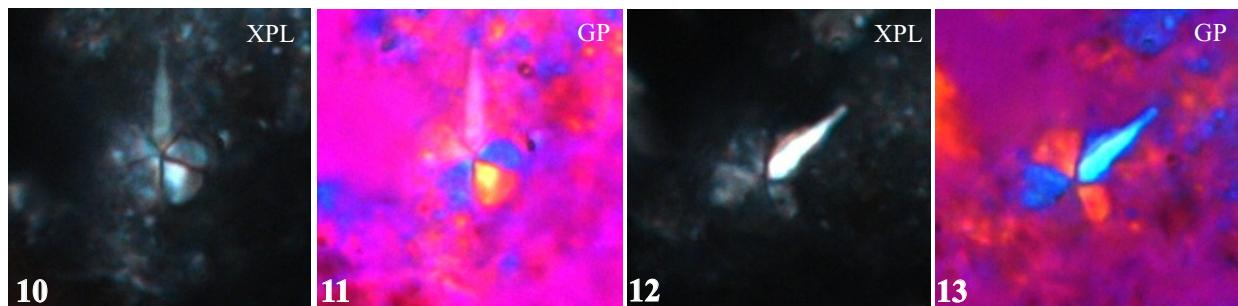
Braarudosphaera batilliformis 1-VF-4, 764-767 m



Braarudosphaera batilliformis 1-VF-4, 764-767 m



Braarudosphaera batilliformis 1-VF-4, 764-767 m



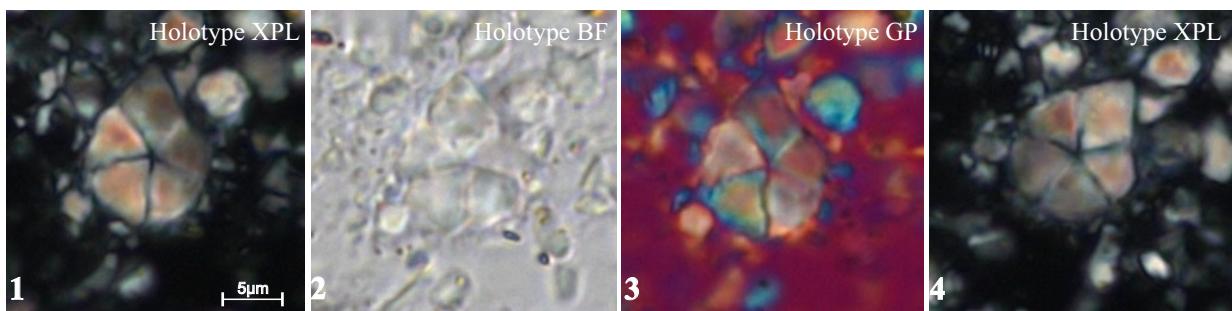
Braarudosphaera batilliformis SE-1378/76

Plate 1. **Fig. 1:** holotype specimen from Troelsen & Quadros (1971). **Fig. 2:** paratype specimen from Troelsen & Quadros (1971)

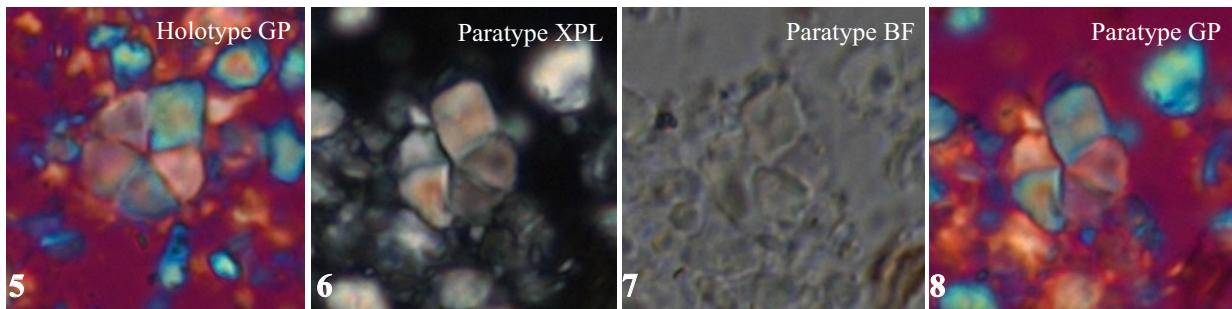
Plate 2. *Braarudosphaera pseudobatilliformis*

XPL = cross polarised light
BF = bright field

GP = gypsum plate
SEM = SEM image

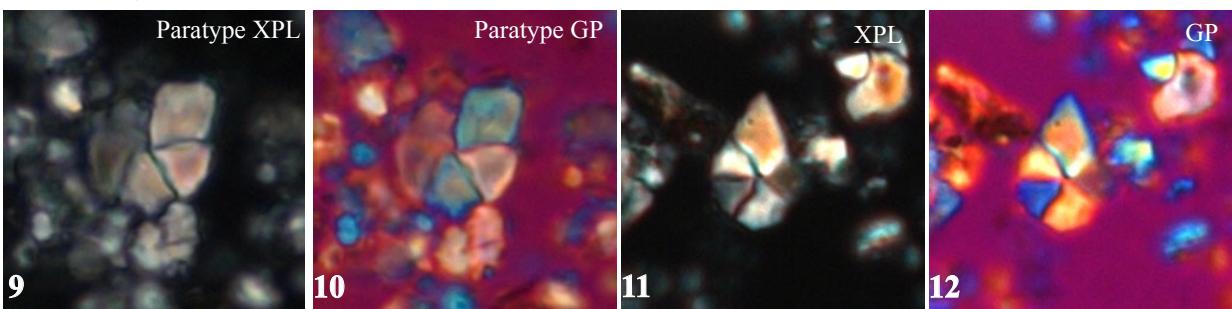


Braarudosphaera pseudobatilliformis 1-VF-4, 746.45 m



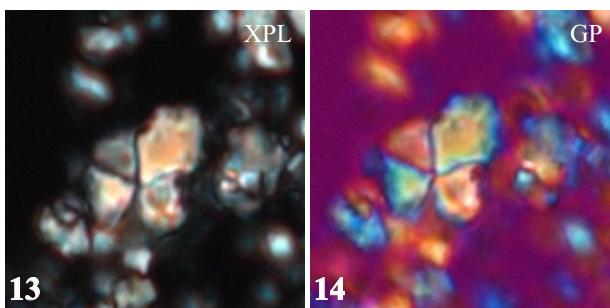
B. pseudobatilliformis
1-VF-4, 746.45 m

Braarudosphaera pseudobatilliformis Campos-1, 3652 m

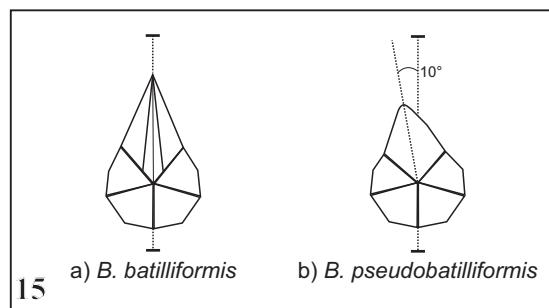


Braarudosphaera pseudobatilliformis Campos-1, 3652 m

Braarudosphaera pseudobatilliformis CB-200914406-1



Braarudosphaera pseudobatilliformis CB-2013-01-01212-1



Sketch of *B. batilliformis* and *B. pseudobatilliformis*

Plate 3. *Nannoconus troelsenii*

XPL = cross polarised light
BF = bright field

GP = gypsum plate
SEM = SEM image

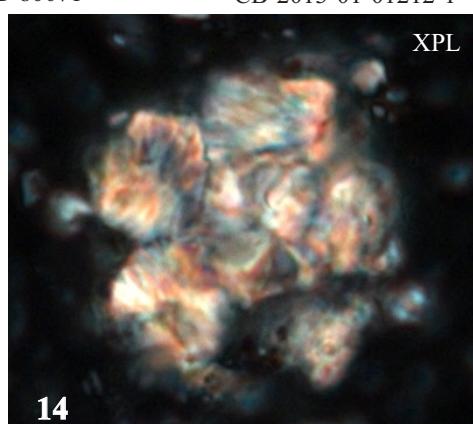
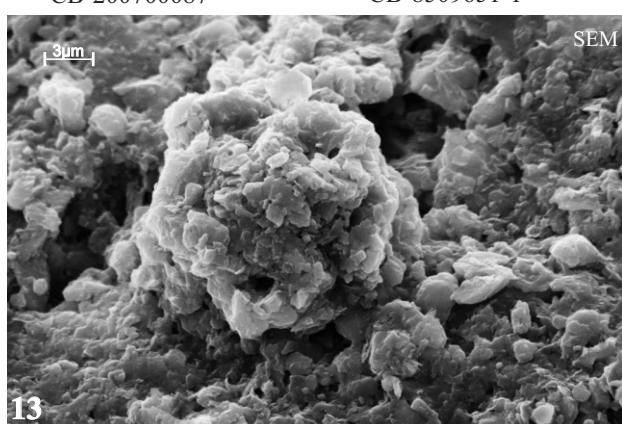
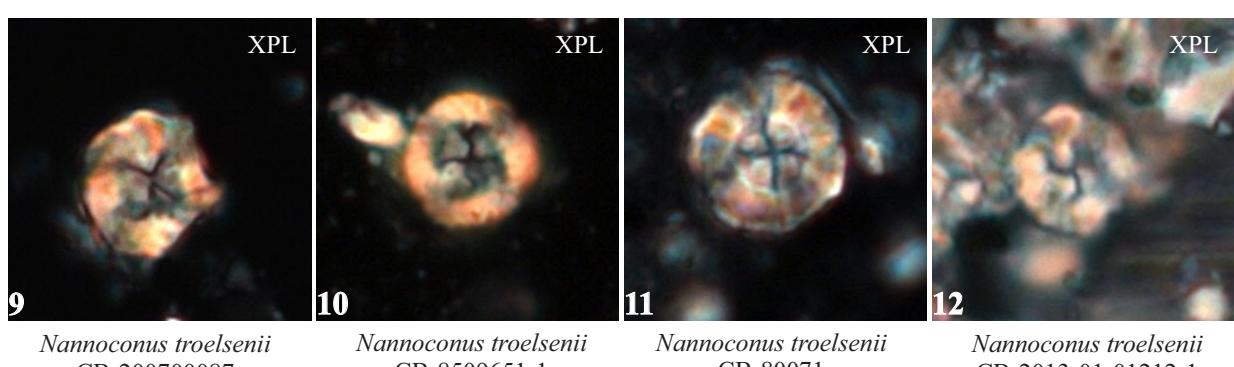
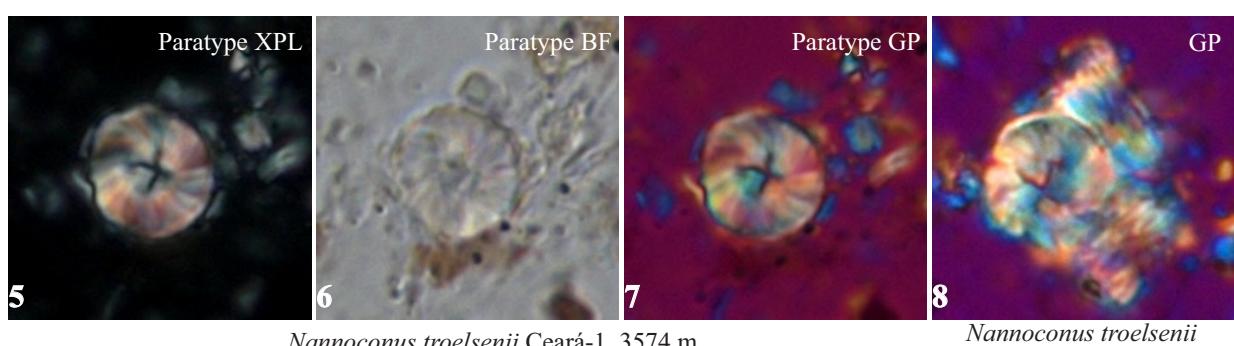
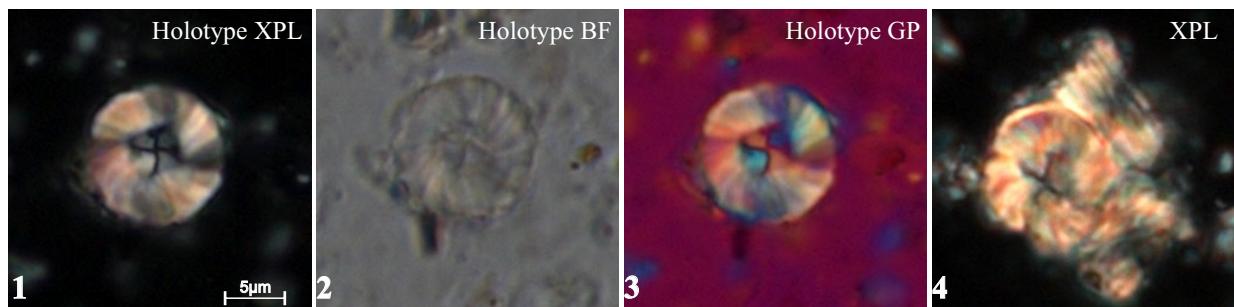
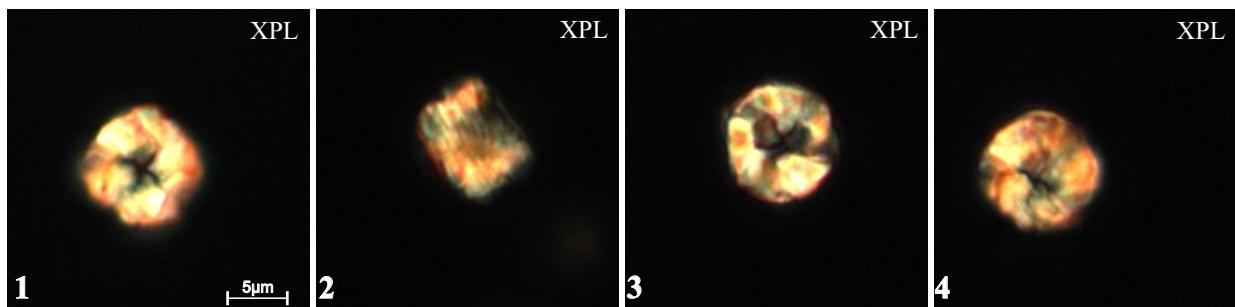


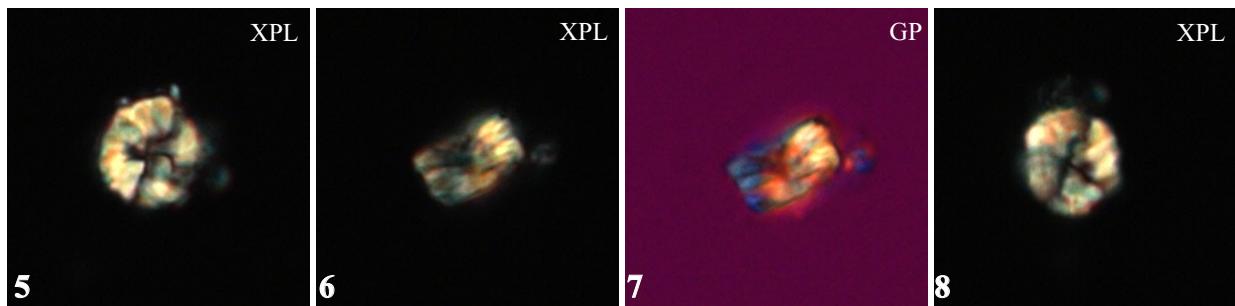
Plate 4. *Nannoconus troelsenii*

XPL = cross polarised light
BF = bright field

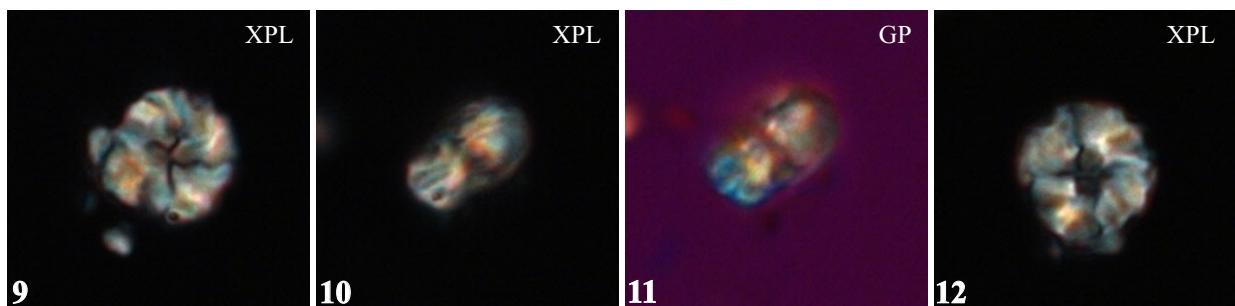
GP = gypsum plate
SEM = SEM image



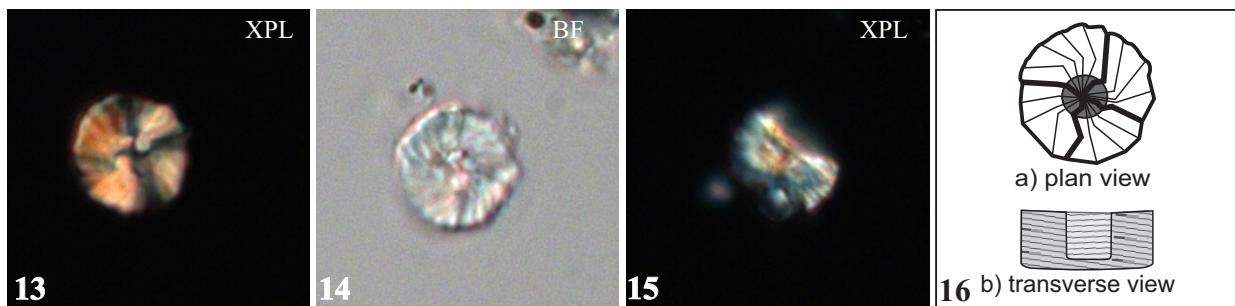
N. troelsenii CB-2013-01-04556 (Figs 1-4 = same specimen: figs 1, 3, and 4 = plan view; fig. 2 = longitudinal view)



N. troelsenii CB-2013-01-04556 (Figs 5-8 = same specimen: figs 5 and 8 = plan view; figs 6 and 7 = longitudinal view)



N. troelsenii CB-2013-01-04556 (Figs 9-12 = same specimen: figs 9 and 12 = plan view; figs 10 and 11 = longitudinal view)



N. troelsenii CB-2013-01-04556 (Figs 13-15 = same specimen: figs 13 and 14 = plan view; fig 15 = longitudinal view)

Sketch of
Nannoconus troelsenii

Plate 4. All species of this plate were photographed from temporary mobile mounts: **Figs 1-4:** different views of the same specimen (figs 1, 3, and 4 = plan view; fig. 2 = longitudinal view). **Figs 5-8:** different views of the same specimen (figs 5, 8 = plan view; figs 6, 7 = longitudinal view). **Figs 9-12:** different views of the same specimen (figs 9, 12 = plan view; figs 10, 11 = longitudinal view). **Figs 13-15:** different views of the same specimen (figs 13, 14 = plan view; fig. 15 = longitudinal view). **Fig. 16:** sketch of *N. troelsenii*