

Three new species of calcareous nannofossil from Late Palaeocene and Early Eocene assemblages (Ocean Drilling Program Site 1262, Walvis Ridge, SE Atlantic Ocean)

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Abstract At Ocean Drilling Program Site 1262 (Leg 208), a composite section spanning the Lower Palaeocene to Lower Eocene was recovered from Walvis Ridge, eastern South Atlantic Ocean. Calcareous nannofossil assemblages there are moderately well preserved. Three new species have been identified: two new species of the genus *Discoaster* (*D. backmanii*, *D. paelikei*) and a new species of *Sphenolithus* (*S. rioi*) are described and illustrated.

Keywords Calcareous nannofossils, taxonomy, *Discoaster*, *Sphenolithus*, ODP Site 1262

1. Introduction

A high-resolution biostratigraphic study has been carried out on Lower Palaeocene to Lower Eocene sediments from Walvis Ridge (SE Atlantic Ocean), recovered during Ocean Drilling Program (ODP) Leg 208 (Zachos *et al.*, 2004). Detailed analysis of ODP Site 1262 (Agnini *et al.*, 2007) revealed the presence of calcareous nannofossil specimens that are not ascribable to previously formally-described species. These new species, described below, are observed in different oceanic regions, suggesting that the new taxa have a wide palaeogeographic distribution and thus may potentially be useful in global biostratigraphic correlations.

Two of the new species belong to the genus *Discoaster* and one to the genus *Sphenolithus*. Besides the SE Atlantic Ocean, the new *Discoaster* taxa have been observed in sediment cores recovered from the NW Atlantic and Pacific Oceans and central-western Tethys. At ODP Site 1262, these taxa showed similar stratigraphic positions, with respect to previous findings, and thus could be used to improve the available biostratigraphic framework.

The new species of *Sphenolithus* has been observed for the first time in Walvis Ridge sediments, but further investigations record its presence also in Palaeocene sediments from north-eastern Italy and ODP Site 1209 (NW Pacific Ocean), indicating a broad palaeogeographic distribution. This new species, together with the coeval *Sphenolithus anarrhopus*, is characterised by having a prominent apical spine. The appearance of this morphologic feature represents a significant evolutionary change within the genus *Sphenolithus* during Palaeocene times.

2. Material and methods

Calcareous nannofossil oozes from a Lower Palaeocene-Lower Eocene carbonate-rich succession, recovered during ODP Leg 208, were analysed (Agnini *et al.*, 2007). The

calcareous nannofossil assemblages are generally rich and moderately well preserved. Specimens often show distinct euhedral crystal faces from accretion of secondary calcite, typical of carbonate chalk sediments. The early stages of overgrowth begin to blur key diagnostic traits, however recognition of the typical *Discoaster* and *Sphenolithus* features is guaranteed. Sediments from the Cicogna section (north-eastern Italy) and ODP Sites 1209 and 1215 (Pacific Ocean) were also examined to determine the species' spatial distributions.

Preparation of smear-slides followed the standard technique described in Bown & Young (1998). Norland 61 optical adhesive is used as a permanent mounting medium. All samples were studied using a Zeiss Axioscope 40 transmitting-light microscope, under parallel and crossed-polarised light with 1250x magnification. The photomicrographs were taken using the Zeiss Axioscope 40 and CamScan Mx 2500 scanning electron microscope. The holotypes and paratypes are deposited in the permanent collection of the Museo di Geologia e Paleontologia dell'Università di Padova (MGPD), Italy.

3. Systematic palaeontology

The higher taxonomic frameworks of calcareous nannofossils utilised are those of Young & Bown (1997a, b).

Order DISCOASTERALES Hay, 1977

Family DISCOASTERACEAE Tan, 1927

Genus *Discoaster* Tan, 1927

Discoaster backmanii sp. nov.

Pl.1, figs 1-6

1979 *Discoaster* sp.1 Okada & Thierstein: pl.5, fig.6; pl.15, fig.11.

1985 *Discoaster* sp.1 Monechi: pl.10, fig.2.

Derivatio nominis: In honour of Jan Backman, full Professor at the Department of Geology & Geochemistry, University of Stockholm (Sweden), geoscientist, calcareous nannofossil palaeontologist, and true friend.

Diagnosis: 5-7 rays, star-shaped, flat *Discoaster* with a poorly-developed central-area, lacking any prominent ornamentation. Although euhedral crystal faces of secondary calcite could have partially obscured the morphologic features of *D. backmanii*, its simple morphology is most likely original, rather than the result of massive overgrown.

Description: We adopt here the description of Okada & Thierstein (1979, p.523), who observed this discoasterid in Atlantic Deep Sea Drilling Project (DSDP) Site 384 sediments and referred to it as *Discoaster* sp.1. It is a "medium sized *Discoaster* with 5 to 7 thick rays whose inner parts are joined together. The outer half of each ray is tapered and terminates in cut off straight edges. The generally straight rays are symmetrically arranged". The rays are linear, and have a free length of 2/3 of the total ray length. No knob is evident in the central-area, but deep sutures are present on both sides of the discoasterid. The sutures are asymmetrically arranged and broadly curved counter-clockwise on one side, whereas they appear to be straight on the other side.

Differentiation: *Discoaster backmanii* differs from *D. okadai* Bukry, 1981, which has longer and more slender rays with pointed tips, and a very small central-area. *D. backmanii* differs from *D. nobilis* Martini, 1961 and *D. falcatus* Bramlette & Sullivan, 1961, which have more serrated outlines, a greater number of rays and more developed central-areas with a boss or a knob. A discoasterid form similar to *D. backmanii* has been described from Lower Eocene sediments by Brönniman & Stradner (1960), who referred to it as *D. geometricus*. Although *D. backmanii* and *D. geometricus* are very similar, *D. geometricus* has a more serrated outline and squat rays. The different morphologies and stratigraphic ranges suggest considering the two taxa as distinct species.

Holotype: Pl.1, fig.1.

Size: Longest dimension = 7-15 μ m (holotype = 14.3 μ m).

Paratype: Pl.1, fig.3; Sample ODP 208-1262B-17H-2W, 135-136cm.

Type locality: Walvis Ridge, SE Atlantic Ocean, ODP Leg 208, Site 1262.

Type level: Zone CP6, Thanetian (Upper Palaeocene); Sample ODP 208-1262A-15H-5W, 64-65cm.

Range: CP6-CP7, Thanetian (Upper Palaeocene).

Remarks: The species was first recorded and described as *Discoaster* sp.1 by Okada & Thierstein (1979) from the NW Atlantic Ocean (DSDP Leg 43, Site 384), and by Monechi (1985) from the NW Pacific Ocean (DSDP Leg 86, Site 577). *D. backmanii* is the earliest representative of star-shaped forms among the *Discoaster* genus that originate in the Palaeocene. A phylogenetic relationship between *D. backmanii* and *D. okadai* is suggested by the presence of

forms with intermediate morphological features just before the first occurrence (FO) of the new species.

Occurrence: *Discoaster backmanii* occurs consistently, with high frequencies, in the interval between the FO of *Discoaster mohleri* Bukry & Percival, 1971 and the FO of *D. multiradiatus* Bramlette & Riedel, 1954, that is, in CP6-CP7 (Palaeocene) of Okada & Bukry (1980). It has been observed in the SE (Walvis Ridge) and NW (Sohm Abyssal Plain) Atlantic Ocean, and in the NW Pacific Ocean (Shatsky Rise). At Site 1262, located on Walvis Ridge, the species is common to abundant in the upper part of CP6 and shows an abrupt decrease in abundance just below the FOs of *D. okadai* and the *D. delicatus* group. Very rare and scattered specimens of *D. backmanii* have also been observed in the lower part of the Lower Eocene (CP8-9a).

Discoaster paelikei sp. nov.

Pl.1, figs 7-14; Pl.2, figs 1, 2

1978 *Discoaster* sp.1 Proto Decima *et al.*: pl.12, fig.9; non pl.12, figs 10, 11.

Derivatio nominis: In honour of Heiko Pälke, Reader at the School of Ocean & Earth Sciences, National Oceanography Centre, University of Southampton (UK), geoscientist, palaeoceanographer, and person with natural brightness.

Diagnosis: Star-shaped *Discoaster* with 5-6 (rarely 7) rays, tapering toward pointed tips. The central-area is characterised by sutures curved clockwise on one side, whereas the other side shows a flower-like knob. In 5-rayed specimens, rays can be slightly asymmetrical.

Description: A medium-sized *Discoaster* characterised by a quite delicate structure, with rays overlapping the inner halves in the central-area on one side of the discoasterid. The sutures curve toward the centre of the *Discoaster*, showing a windmill-like structure. The outer half of each ray is tapered and the free length of the rays varies from 1/2 to 2/3 of the total ray length.

Differentiation: A discoasterid form similar to *D. paelikei* was described from Middle Eocene sediments by Stradner (1961), referred to as *D. strictus*, but *D. paelikei* differs in the presence of windmill-like sutures, allowing easy morphological distinction between the two species. *D. paelikei* differs from *D. mahmoudii*, which is characterised by a prominent, star-shaped knob and more slender rays. *D. paelikei* differs from *D. okadai* in having a more developed central-area, squat rays and a prominent knob.

Holotype: Pl.1, fig.7.

Size: Longest dimension = 3.5-12 μ m (holotype = 11.4 μ m).

Paratype: Pl.1, fig.9; Sample ODP 208-1262A-13H-3W, 128-129cm.

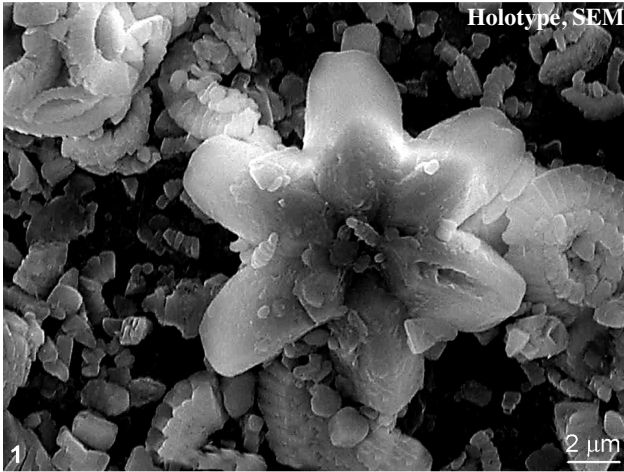
Type locality: Walvis Ridge, SE Atlantic Ocean, ODP Leg 208, Site 1262.

Type level: Zone CP8b, Ypresian (Lower Eocene); Sample ODP 208-1262A-13H-3W, 128-129cm.

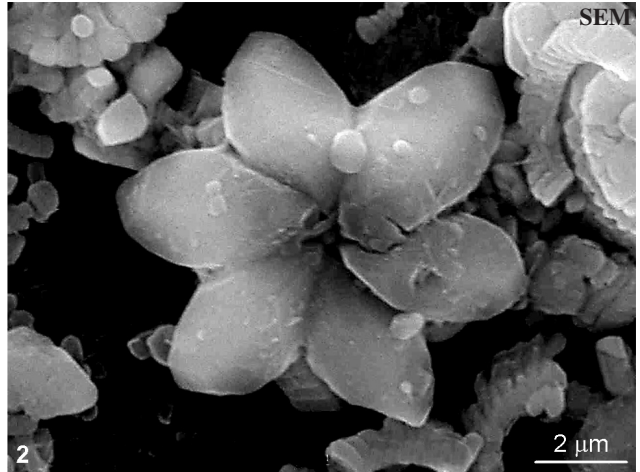
Range: CP8b, Ypresian (Lower Eocene).

Plate 1

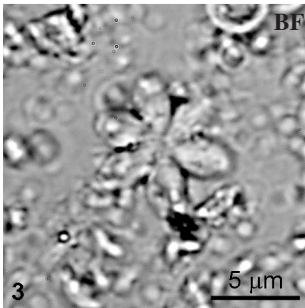
Calcareous nannofossils from ODP Sites 1262 (Atlantic) and 1215 (Pacific) and from the Cicogna section (north-eastern Italy)
 Scale-bars = 2µm (figs 1, 2) or 5µm (figs 3-14). BF = bright-field



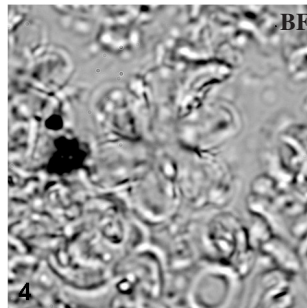
1 *Discoaster backmanii* Sample ODP 208-1262A-15H-5W, 64-65cm



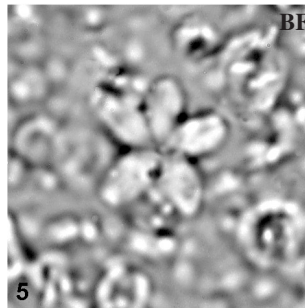
2 *D. backmanii* Sample ODP 208-1262A-15H-5W, 64-65cm



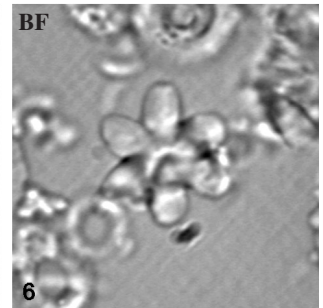
3 *D. backmanii* Sample ODP 208-1262B-17H-2W, 135-136cm



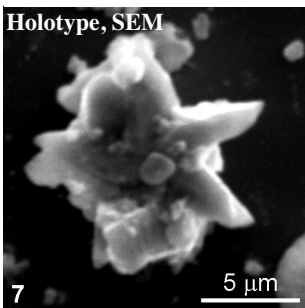
4 *D. backmanii* Sample ODP 208-1262B-17H-2W, 135-136cm



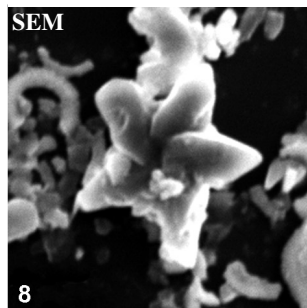
5 *D. backmanii* Sample ODP 208-1262B-17H-2W-135-136cm



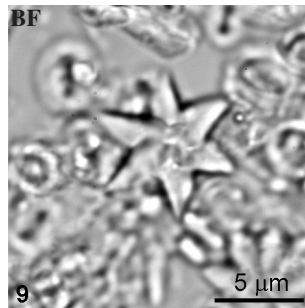
6 *D. backmanii* Sample ODP 208-1262B-17H-2W-135-136cm



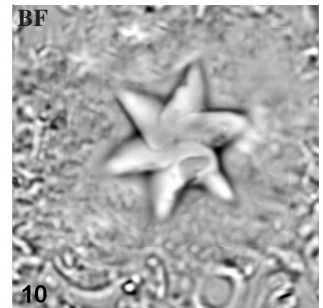
7 *Discoaster paelikei* Sample ODP 208-1262A-13H-3W, 128-129cm



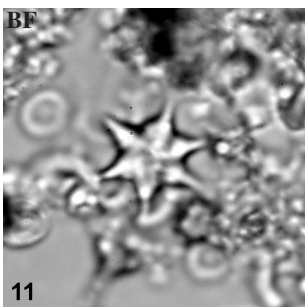
8 *D. paelikei* Sample ODP 208-1262A-13H-3W, 128-129cm



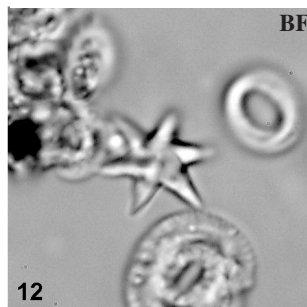
9 *D. paelikei* Sample ODP 208-1262A-13H-3W, 128-129cm



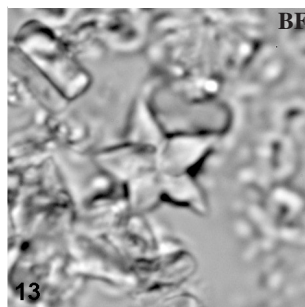
10 *D. paelikei* Sample ODP 208-1262A-13H-3W, 128-129cm



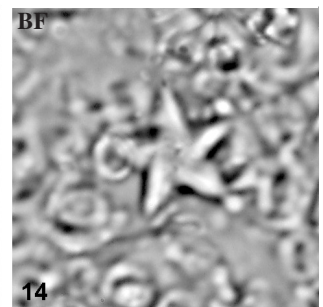
11 *D. paelikei* Sample ODP 199-1215B-7H-1W, 144-145cm



12 *D. paelikei* Sample ODP 199-1215B-7H-1W, 144-145cm



13 *D. paelikei* Sample CIC/07-191, Cicogna section



14 *D. paelikei* Sample CIC/07-191, Cicogna section

Remarks: *D. paelikei* has a relatively short stratigraphic range in the earliest Eocene. This species, together with *D. mahmoudii*, is characterised by a distinctive morphology, with respect to all the other discoasterids present in the calcareous nannofossil assemblages within CP8b.

Occurrence: *D. paelikei* occurs consistently in the lowermost Eocene, from the Palaeocene/Eocene boundary to the last occurrence of *Fasciculithus tympaniformis* Hay & Mohler, 1967, in the lower part of CP8b. It has been recorded in the SE Atlantic Ocean (Angola Basin, DSDP Site 364: Proto Decima *et al.*, 1978; Walvis Ridge: this study), Pacific Ocean (Site 1215, ODP Leg 199: Raffi, unpublished data; Site 1209, ODP Leg 198, Shatsky Rise: De Bernardi, pers. comm., 2007) and north-eastern Italy (this study).

Order DISCOASTERALES Hay, 1977

Family SPHENOLITHACEAE Deflandre *in* Grassé, 1952

Genus *Sphenolithus* Deflandre *in* Grassé, 1952

Sphenolithus rioi sp. nov.

Pl.2, figs 3-12

Derivatio nominis: In honor of our mentor, Domenico Rio, full professor at the Department of Geosciences, University of Padova (Italy), geologist and calcareous nannofossil palaeontologist.

Diagnosis: Medium-sized *Sphenolithus* with a prominent apical spine, extending symmetrically from the basal part.

Description: The basal part is constructed of regularly-placed calcite elements, and in crossed-polarised light (XPL), with the long axis at 0° to the nicols, has a square-shaped outline with equal quadrants. A solid, prominent, straight apical spine extends symmetrically, with respect to the basal elements. In XPL, with the long axis at 0° to the nicols, the basal part shows birefringence, whereas the apical spine has its maximum birefringence at 20-30° and 45° to the nicols.

Differentiation: In the light microscope, *S. rioi* differs from *S. anarrhopus* (Pl.2, figs 13-16) in having a straight, and generally longer, apical spine. *S. rioi* differs from *S. conspicuus* Martini, 1976 in having a different apical spine: *S. rioi* has a triangular-shaped spine, whereas *S. conspicuus* is characterised by a slender, spearhead-shaped spine.

Holotype: Pl.2, fig.3.

Size: Height = 4.5-7µm (holotype = 6.7µm); width of base = 3.6µm; height of base = 2.1µm.

Paratype: Pl.2, figs 5-7; Sample ODP 208-1262A-15H-3W, 128-129cm.

Type locality: Walvis Ridge, SE Atlantic Ocean, ODP Leg 208, Site 1262.

Type level: Zone CP6, Thanetian (Upper Palaeocene); Sample ODP 208-1262A-15H-4W, 44-45cm.

Range: CP4-CP7, Upper Selandian-Thanetian (Middle-Upper Palaeocene).

Remarks: In previous studies, *S. rioi* has been probably

considered a morphotype of *S. anarrhopus*. The morphologic differences highlighted here are distinct enough to warrant taxonomic differentiation.

Occurrence: The FO of *Sphenolithus rioi* is recorded in the upper part of CP4 (Upper Selandian). The species is rare and scattered within CP5, whereas it is common and continuous in CP6 and CP7. The stratigraphic range of *S. rioi* is virtually the same as for *S. anarrhopus*, with the FO of *S. rioi* slightly predating the FO of *S. anarrhopus*.

Acknowledgements

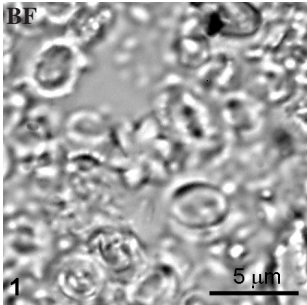
This research used samples and data provided by the ODP. ODP is sponsored by the US National Science Foundation (NSF) and participating countries under management of the Joint Oceanographic Institution inc. (JOI). CA, EF and IR were supported by MIUR /PRIN COFIN 2005-2007, coordinated by I. Premoli Silva (national), Domenico Rio (Padova) and IR (Chieti). We would like to thank Stefano Castelli for preparing plates of calcareous nannofossils. A special thanks to Bianca De Bernardi for providing us with useful material. We are grateful to R.A. Denne, P.R. Bown, S. Jiang and the Editor (J.A. Lees) for helpful comments.

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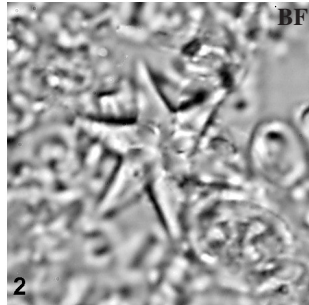
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Plate 2

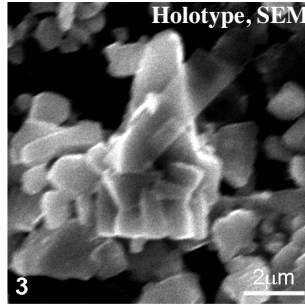
Calcareous nannofossils from ODP Sites 1262 and 1209 and from the Cicogna section (north-eastern Italy)
 Scale-bars = 5 μ m (figs 1, 2, 5-12, 14-16) or 2 μ m (figs 3, 4, 13). BF = bright-field, XPL = crossed-polarised light



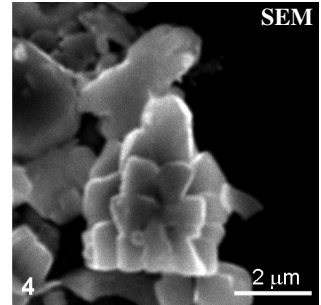
1 *Discoaster paelikei* Sample CIC/07-191, Cicogna section



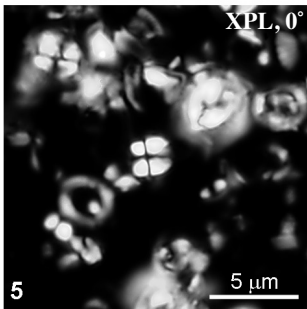
2 *D. paelikei* Sample CIC/07-191, Cicogna section



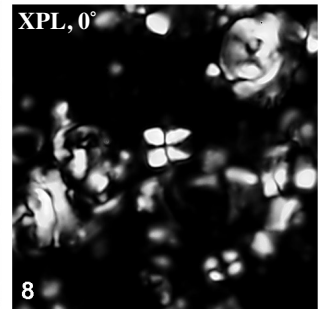
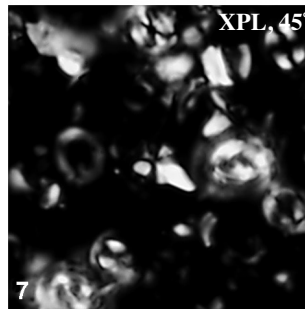
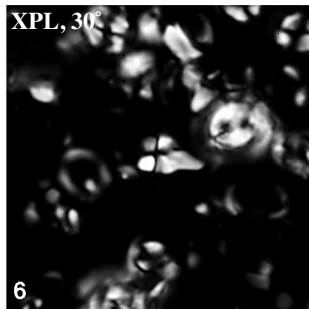
3 *Sphenolithus rioi* Side view, long-spined morphotype. Sample ODP 208-1262A-15H-4W, 44-45cm



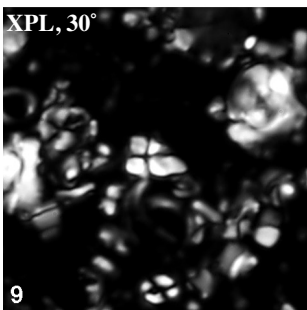
4 *S. rioi* Side view, short-spined morphotype. Sample ODP 208-1262A-16H-1W, 132-133cm



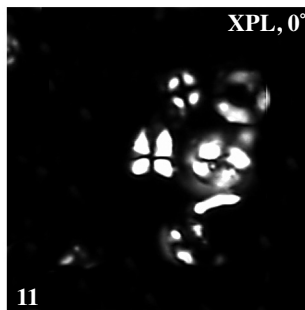
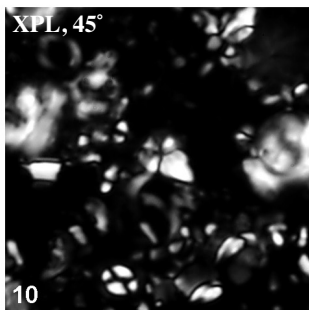
5 *S. rioi* Sample 1262A-15H-3W, 128-129cm



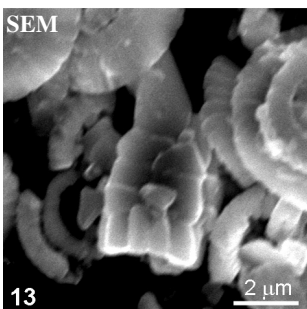
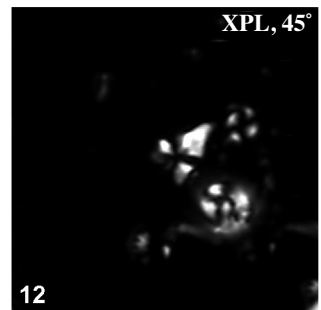
8 *S. rioi* Sample 1262A-15H-3W, 128-129cm



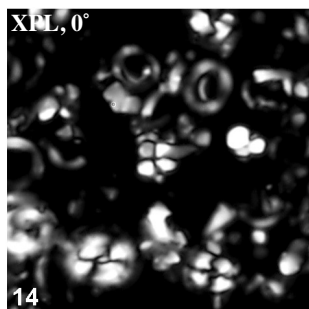
9 *S. rioi* Same specimen as fig.8



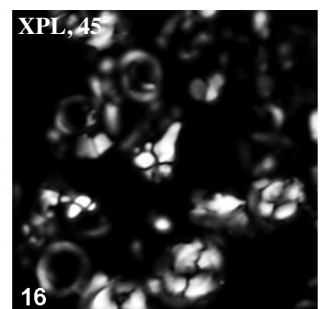
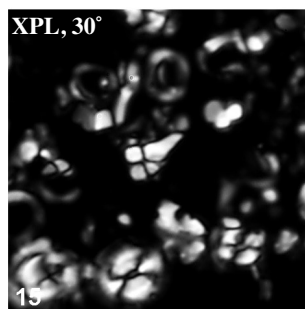
11 *S. rioi* Sample 1209B-23H-4W, 1-2cm



13 *Sphenolithus anarrhopus* Side view, long-spined morphotype. Sample ODP 208-1262A-16H-1W, 132-133cm



14 *S. anarrhopus* Sample 1262A-15H-3W, 128-129cm



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