New Late Oligocene to Miocene Species

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Abstract Twelve new calcareous nannofossil species ranging from Miocene to Late Oligocene in age are herein described and allow for enhanced stratigraphic subdivisions of sediments: They are *Calcidiscus gallagheri*, *Calcidiscus salomonii*, *Coronocyclus lordii*, *Coronocyclus baileyi*, *Cruciplacolithus kanungoi*, *Helicosphaera princei*, *Helicosphaera leesiae, Helicosphaera bownii*, *Helicosphaera watkinsii*, *Hughesius youngii*, *Scyphosphaera hamptonii*, *Syracosphaera? oneillii*. In addition, a new subspecies *(Coronocyclus nitescens latus)* and new combination *(Calcidiscus tanianus)* are introduced. A range chart showing the distribution of these taxa is presented (Fig. 2).

Keywords Nannofossils, New Species, Miocene, Late Oligocene

1. Introduction

During routine examination of Miocene to Late Oligocene sediments for calcareous nannofossil content, twelve new calcareous nannofossil species, a new subspecies and a new combination were identified. The sediments are distributed over a wide geographical area. Sample material from a variety of different sources, comprising Miocene to Late Oligocene sediments, were utilized in this study. Eighty-five core samples were provided by the International Ocean Drilling Program (IODP) Kochi Core Centre (KCC) in Japan and include: thirty five core samples from Deep Sea Drilling program (DSDP) Leg 25, Site 242 located in the western Indian Ocean, in the Mozambique Channel along the Davis Ridge, 15°50.65' S, 41°49.23' E. and fifty core samples from DSDP Leg 24, Site 231 located near the southern shore of the Gulf of Aden, 80 km from Somalia, at 11°53.41' N, 48°14.71' E . Twenty-five field samples of the Blue Marl Formation from the Ghajn Tuffieha Bay, Malta were supplied by Prof. Tom Barnard (formerly with University College London). Sixty-three ditch cuttings samples from the Well A in Adana Basin, Turkey and thirteen field samples from Hatay were studied. Eight core samples from Quaternary sediments of Anglesey, North Wales were also analysed.

Additional data gathered from routine analyses conducted on proprietary samples from offshore Angola, Brazil, Libya, Mauritania, Nigeria and Vietnam provided verification of species concepts and confirmed species ranges.

2. Material and methods

Samples analysed for calcareous nannofossil content were processed using a simple smear slide technique and studied using standard light microscopy techniques. The photographs were taken using a Leica DMEP and Zeiss Axiophot microscope at x1000 magnification with a JVC analogue camera (Varol Research) and Olympus DP71 digital camera (Shell). All the fossil pictures were taken

Fig. 1 MAP with Locations - outcrops and boreholes (see attachment)

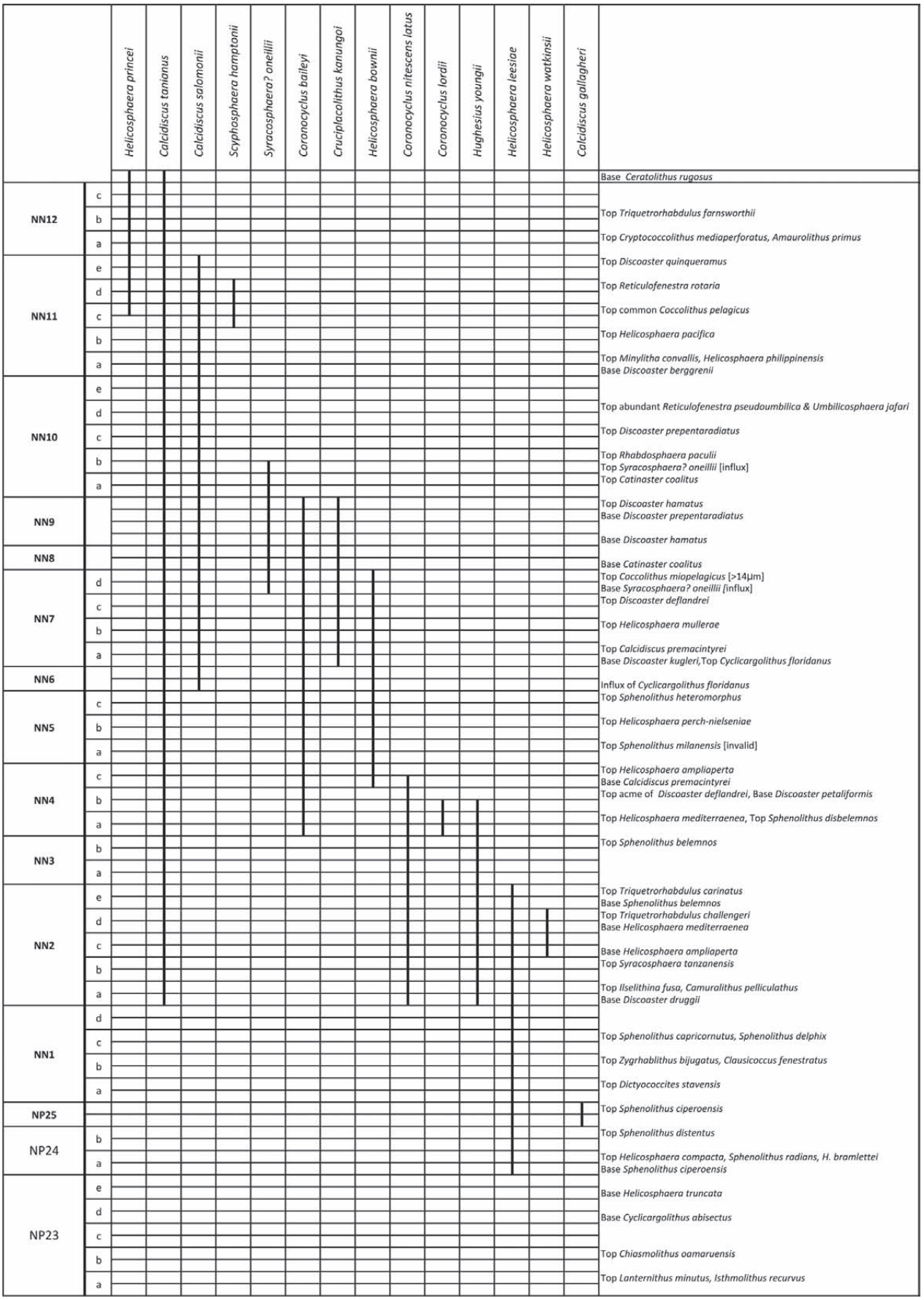


Fig. 2 A range chart showing the distribution of these taxa is presented

using polarized and phase contrast light, and a gypsum plate. Scanning Electron Microscopy (SEM) photomicrographs were taken at UCL using Cambridge Instrument's S4 SEM. The slides and samples are available through Varol Research_USA, UCL (UK) and Shell USA. Taxonomic descriptions and stratigraphic ranges (Fig. 2) of new species and combinations are herein discussed and calibrated against the standard stratigraphic markers of Martini (1971). In some cases, identification of these new species allow for enhanced stratigraphic subdivision.

3. Taxonomy

We present taxonomic descriptions and discussions establishing twelve new species *(Calcidiscus gallagheri, Calcidiscus salomonii, Coronocyclus lordii, Coronocyclus baileyi, Cruciplacolithus kanungoi, Helicosphaera princei, Helicosphaera leesiae, Helicosphaera bownii, Helicosphaera watkinsii, Hughesius youngii, Scyphosphaera hamptonii* and *Syracosphaera? oneillii)*. In addition, a new subspecies *(Coronocyclus nitescens latus)* and a new combination *(Calcidiscus tanianus)* are introduced. Unless otherwise stated all the measurements were obtained under phase contrast. The terminology used in this study follows that of Young et al (1997) and Theodoridis (1984).

Calcidiscus Kamptner, 1950

Type species: *Calcidiscus quadriperforatus* Kamptner, 1950

Calcidiscus gallagheri da Gama andVarol, n. sp.

Plate 2, figures 3-8

Derivation of name: In honour of Dr. Liam Gallagher, nannofossil specialist and good friend, Network Stratigraphic Consulting Ltd, Potters Bar, UK .
Diagnosis: Elliptical species of *Calcidiscus* with large central area covered by a finely porous plate.
Description: This elliptical *Calcidiscus* has a relatively large central area covered by a finely porous plate. The distal shield and porous plate are non-birefringent whereas the proximal shield is smaller and weakly birefringent under polarised light. No tube cycle was noted. In some specimens, the central porous plate displays a longitudinal suture. However, this suture might be the result of poor preservation. **Remarks:** This species looks similar to *Calcidiscus premacintyrei* but differs from it by having a finely porous plate in the central area. Moreover, *C. premacintyrei* is restricted to upper Zone NN4 to Zone NN7 in the Miocene whilst *C. gallagheri* is restricted to Zone NP25 in the Oligocene.
Dimensions of holotype:
Length: 11.6μm, Width: 10.0μm
Length of central area: 4.0μm
Width of central area: 2.4μm
Holotype: Plate 2, figures 3-4 (same specimen)
Paratype: Plate 2, figures 5-6 (same specimen)
Type Locality: DSDP, Leg 242/9-4, 130cm
Type Level: Zone NP25, upper Oligocene
Occurrence: This species is only found in Zone NP25, Late Oligocene of DSDP, Leg 242/9-4, 130cm.

Calcidiscus salomonii da Gama and Varol, n. sp.

Plate 2, figures 13-20

Derivation of name: In honour of the late Ralph Salomon, nannofossil specialist and very good friend.
Diagnosis: Small, strictly circular *Calcidiscus* whose diameter of the central opening is always greater than the width of the shields.
Description: This small species (3-6μm) has a non-birefringent distal shield, a tube cycle and a birefringent monocyclic proximal shield. The diameter of the central area is always greater than the width of the shield.
Remarks: *Calcidiscus salomonii* is distinguished from *Calcidiscus tanianus* by being much smaller and having a central opening always greater than the width of the shields. In *C. tanianus*, the central opening is smaller than the width of the shield. *Calcidiscus tropicus* (Syn. *Calcidiscus macintyrei*) is similar to *C. tanianus* but larger (>10μm). *C. salomonii* differs from *Calcidiscus leptoporus* by having a central opening, the latter has a closed central area. Some specimens, under polarised light, can artificially resemble *Reticulofenestra rotaria*, however *C. salomonii* is non-birefringent, whereas in *R. rotaria* the distal shield is birefringent. In addition, the *Calcidiscus* type structure is readily observed under phase contrast in *C. salomonii*.
Dimensions of holotype:
Maximum diameter: 5.6μm
Diameter of the central area: 1.6μm
Diameter of the central area in polarised light: 3.6μm
Width of the proximal shield: 1.6μm
Holotype: Plate 2, figures 13-15 (same specimen)
Paratype: Plate 2, figures 19-20 (same specimen)
Type Locality: Field Sample 458, Hatay, Southern Turkey
Type Level: Zone NN6, Middle Miocene
Occurrence: *C. salomonii* is recorded from middle-upper Miocene sediments (Zone NN6 to NN11). It is reported in samples from Turkey, the Indian Ocean, the Gulf of Aden, Nigeria, Angola and offshore Vietnam.

Calcidiscus tanianus (Kamptner) da Gama and Varol, n. comb.

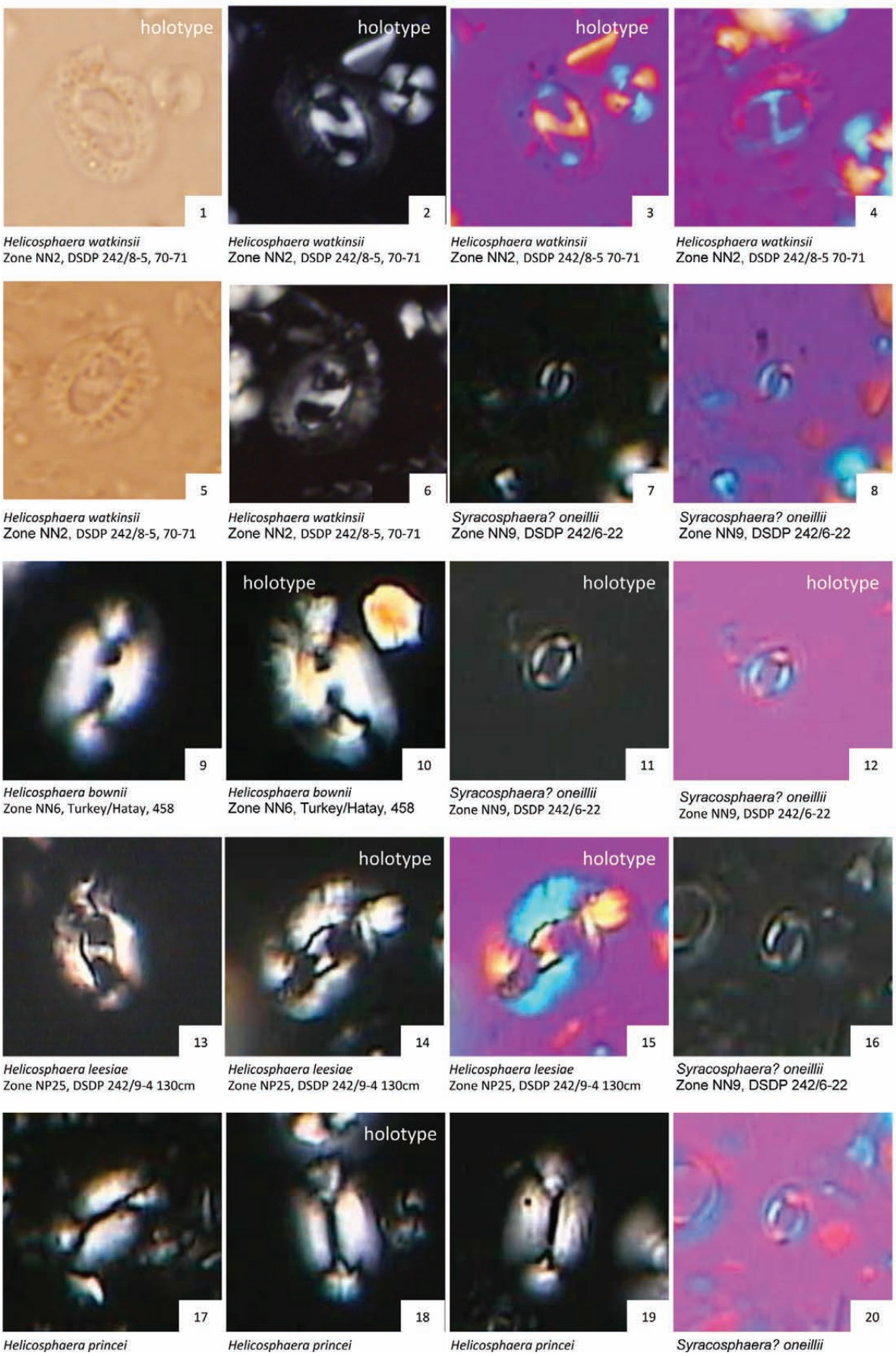
Plate 2, Figure 12

Basionym: *Cyclococcolithus tanianus* Kamptner 1955, p.31, pl6, figs. 83a-b
Remarks: A circular species of *Calcidiscus* with a wide central opening. It is distinguished from *C. tropicus* (Syn. *Calcidiscus macintyrei*) by being smaller than 10μm.
Occurrence: *C. tanianus* is recorded from Early Miocene to Pleistocene sediments (Zone NN2 to NN20). It is reported in samples from Turkey, the Indian Ocean, the Gulf of Aden, Nigeria, Angola and offshore Vietnam.

Coronocyclus Hay, Mohler and Wade, 1966 emend. da Gama and Varol, n. sp.

Type species: *Coronocyclus nitescens* Hay, Mohler and Wade, 1966

Plate 1



Helicosphaera watkinsii
Zone NN2, DSDP 242/8-5, 70-71

Helicosphaera watkinsii
Zone NN2, DSDP 242/8-5, 70-71

Helicosphaera watkinsii
Zone NN2, DSDP 242/8-5 70-71

Helicosphaera watkinsii
Zone NN2, DSDP 242/8-5 70-71

Helicosphaera watkinsii
Zone NN2, DSDP 242/8-5, 70-71

Helicosphaera watkinsii
Zone NN2, DSDP 242/8-5, 70-71

Syracosphaera? oneillii
Zone NN9, DSDP 242/6-22

Syracosphaera? oneillii
Zone NN9, DSDP 242/6-22

Helicosphaera bownii
Zone NN6, Turkey/Hatay, 458

Helicosphaera bownii
Zone NN6, Turkey/Hatay, 458

Syracosphaera? oneillii
Zone NN9, DSDP 242/6-22

Syracosphaera? oneillii
Zone NN9, DSDP 242/6-22

Helicosphaera leesiae
Zone NP25, DSDP 242/9-4 130cm

Helicosphaera leesiae
Zone NP25, DSDP 242/9-4 130cm

Helicosphaera leesiae
Zone NP25, DSDP 242/9-4 130cm

Syracosphaera? oneillii
Zone NN9, DSDP 242/6-22

Helicosphaera princei

Helicosphaera princei

Helicosphaera princei

Syracosphaera? oneillii

Emended diagnosis: This genus is here amended to include sub-circular and elliptical placoliths with a wide central opening and shields made up of dextrally imbricated lath-like elements with short spine-like projections.

Coronocyclus lordii da Gama and Varol, n. sp.
Plate 3, figures 17-19

Derivation of name: In honour of Prof. Alan Lord, good friend and mentor, Senckenberg Musuem, Frankfurt, Germany.
Diagnosis: A giant *Coronocyclus* having very large central opening and narrow shields.
Description: This comparatively large species has birefringent monocyclic distal and proximal shields of equal size and a large central opening. The elements of the distal shield have short spine-like peripheral projections. The shields are smooth but highly birefringent under polarised light.
Remarks: *Coronocyclus lordii* is easily distinguishable from other species of *Coronocyclus* by its large size and by having smooth shields under polarised light. Other species of *Coronocyclus* typically appear to be strongly serrated. *C. lordii* is easily distinguished from broken pieces of calcispheres (dinoflagellate) by having distinct shields. The naturally broken section of a calcisphere (dinoflagellate) show plate like structure and always exhibits many elements in the central area.
Dimensions of holotype:
Maximum diameter: 20.0μm
Diameter of the central area: 14.0μm
Holotype: Plate 3, figure 18
Paratype: Plate 3, figure 17
Type Locality: DSDP, Leg 242/8-1, 86-87cm
Type Level: Zone NN4, lower Miocene
Occurrence: This species is restricted to Zone NN4 and was identified only from lower Miocene sediments of DSDP, Leg 242 in the Indian Ocean.

Coronocyclus nitescens latus da Gama and Varol, n. subsp.
Plate 3, figures 9-12, Plate 4, Figure 1

Derivation of name: From the Latin latus, meaning wide – a reference to its wide shields.
Diagnosis: A subspecies of *Coronocyclus nitescens* having shields widths greater than 2μm wide.
Remarks: This circular subspecies is distinguished from *C. nitescens nitescens* by having a shield width of greater than 2μm. The separation of *C. nitescens latus* from *C. nitescens nitescens* is biostratigraphically useful. The highest occurrence of *C. nitescens latus* is within Zone NN4, between the highest abundances of *Discoaster deflandrei* and *Helicosphaera truncata* and the lowest occurrence of *Discoaster petaliformis*.
Dimensions of holotype:
Maximum diameter: 11.6μm
Shield width: 2.5μm
Diameter of central area: 6.6μm
Holotype: Plate 3, figures 14-15 (same specimen)
Paratype: Plate 3, figures 11-12 (same specimen)
Type Locality: DSDP, Leg 242/8-1, 86-87cm
Type Level: Zone NN4, Middle Miocene
Occurrence: *C. nitescens latus* is present in sediments from Zone NN4 of Turkey and Zones NN2 to NN4 of offshore Mauritania, Angola, Libya, Brazil, Vietnam and the Indian Ocean (DSDP, Leg 242).

Coronocyclus baileyi da Gama and Varol, n. sp.
Plate 3, figures 13-15, Plate 4, Figures 3-4

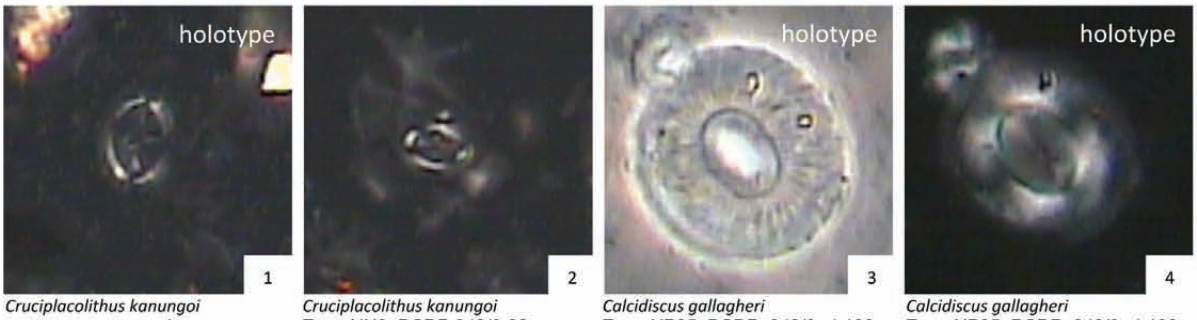
Derivation of name: In honour of Dr. Haydon Bailey, micropaleontologist and good friend at Network Stratigraphic Consulting Ltd, Potters Bar, UK.
Diagnosis: Elliptical species of *Coronocyclus*.
Description: This elliptical form has a proximal and distal shield of equal size and a large central opening. The dextrally imbricated lath-like elements of the distal shield have short spine-like projections in well-preserved specimens (more distinct under SEM, see Pl4, Fig.3-4). The proximal shield and tube cycle are also made up of dextrally imbricated wedge-shaped elements. In some specimens, spine-like distal projections are also present on the elements of the tube cycle but it is difficult to determine whether they are primary features or the result of digenetic alteration. Under polarised light the shields and tube cycle appear strongly serrated.
Remarks: *C. baileyi* is distinguished from other species of *Coronocyclus* by being elliptical in shape.
Dimensions of holotype:
Length: 5.2μm
With: 4.0μm
Holotype: Plate 3, figures 14-15 (same specimen)
Paratype: Plate 3, figure 13
Type Locality: DSDP, Leg 242/6-22, 71-72cm
Type Level: Zone NN9, Late Miocene
Occurrence: This species is present in Zones NN4 through NN10 in sediments of Southern Turkey (Adana and Antalya Basins) and offshore Vietnam. *C. baileyi* was recorded from Zones NN4-NN5 in sediments from Egypt (Northern Sinai and offshore Nile Delta), Indonesia (East Java Sea), Malta and offshore Angola. It was observed from Zones NN8 and NN10 in the Gulf of Aden (DSDP Leg 24, Site 231).

Cruciplacolithus Hay and Mohler in Hay *et. al*., 1967
Type species: *Heliorthus tenuis* Stradner, 1961

Cruciplacolithus kanungoi da Gama and Varol, n. sp.
Plate 2, figures 1-2

Derivation of name: In honour of Dr. Sudeep Kanungo, nannofossil specialist and good friend, University of Utah, USA.
Diagnosis: A small species of *Cruciplacolithus* with an axial cross aligned with, or slightly offset from the major and minor axes of the placolith.
Description: This small placolith has an axial cross which may be aligned with the major and minor axes of the placolith. The cross is only slightly birefringent un-

Plate 2

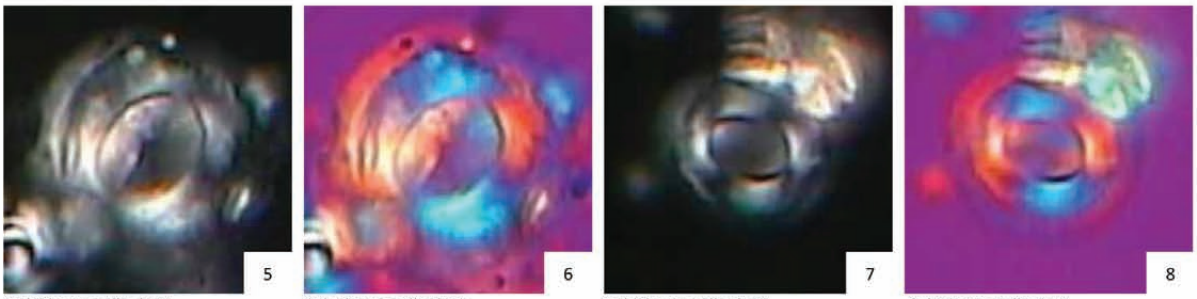


Cruciplacolithus kanungoi
Zone NN9, DSDP 242/6-22

Cruciplacolithus kanungoi
Zone NN9, DSDP 242/6-22

Calcidiscus gallagheri
Zone NP25, DSDP 242/9 -4 130

Calcidiscus gallagheri
Zone NP25, DSDP 242/9 -4 130

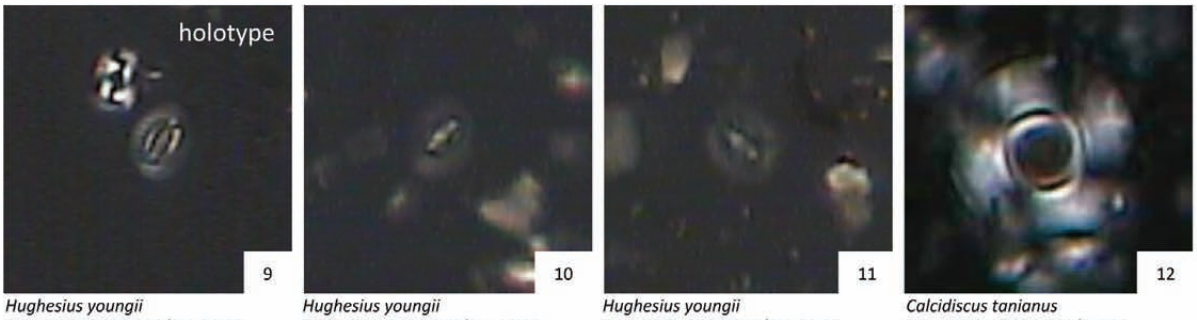


Calcidiscus gallagheri
Zone NP25, DSDP 242/9 -4 130

Calcidiscus gallagheri
Zone NP25, DSDP 242/9 -4 130

Calcidiscus gallagheri
Zone NP25, DSDP 242/9-4 130

Calcidiscus gallagheri
Zone NP25, DSDP 242/9-4 130

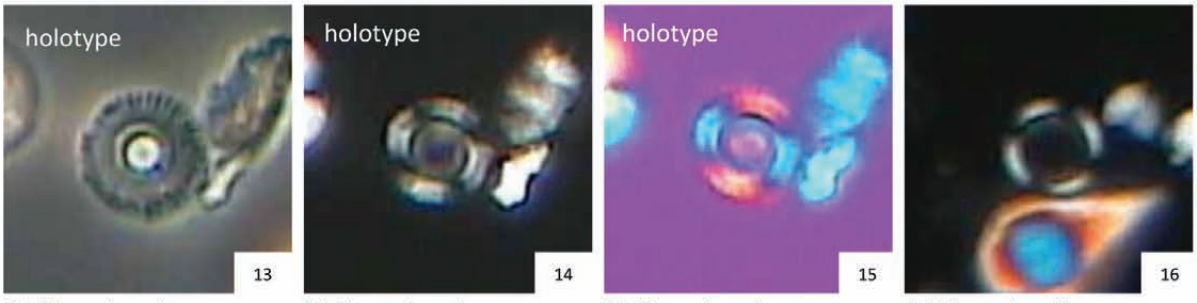


Hughesius youngii
Zone NN4, DSDP 242/8-1 86-87

Hughesius youngii
Zone NN4, DSDP 242/8-1 86-87

Hughesius youngii
Zone NN4, DSDP 242/8-1 86-87

Calcidiscus tianus
Zone NN11, DSDP 242/5-4 93

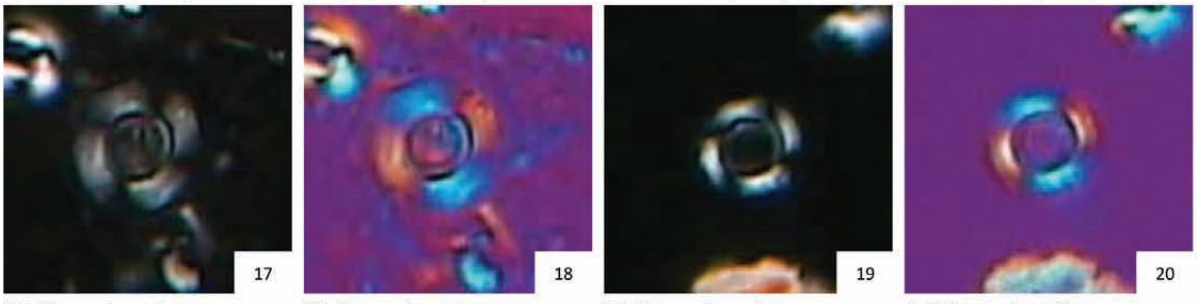


Calcidiscus salomonii
Zone NN6, Turkey/Hatay-458

Calcidiscus salomonii
Zone NN6, Turkey/Hatay-458

Calcidiscus salomonii
Zone NN6, Turkey/Hatay-458

Calcidiscus salomonii
Zone NN6, Turkey/Hatay-458



Calcidiscus salomonii
Zone NN7, DSDP 242/7-1 71-72

Calcidiscus salomonii
Zone NN7, DSDP 242/7-1 71-72

Calcidiscus salomonii
Zone NN6, Turkey/Hatay-458

Calcidiscus salomonii
Zone NN6, Turkey/Hatay-458

10µm

der polarised light. Four variations of this species are observed. Specimens with the axial cross aligned with the major axes of the placolith may be both bifurcated or plain, and specimens with alignment slightly off the major and minor axes can be both bifurcated or plain. The small size and weak birefringence of the species preclude the consistent identification of these variations.
Description: The Oligocene to Eocene species *Bramletteius serraculoides* is distinguished from the Middle Miocene restricted species *C. kanungoi* by having a distal process. The axial cross is non-birefringent and lack of any bifurcation in *Bramletteius serraculoides*.
Dimensions of holotype:
Length: 6.0μm
With: 4.8μm
Holotype: Plate 2, figures 1
Paratype: Plate 2, figure 2
Type Level: Zone NN9, Late Miocene
Type Locality: DSDP, Leg 242/6-22, cc
Occurrence: This species is present in Zones NN7 through NN9 in sediments from the Philippines, Vietnam, Malaysia, Indonesia, Gulf of Aden, Indian Ocean, West Africa, Brazil and Trinidad.

Helicosphaera Kamptner, 1954

Type species: *Coccosphaera carteri* Wallich, 1877

Helicosphaera bownii da Gama and Varol, n. sp.

Plate 1, figures 9-10, Plate 4, Figures 5-6

Derivation of name: In honour of Prof. Paul R. Bown, nannofossil specialist and good friend and mentor, UCL, UK.
Diagnosis: Species of *Helicosphaera* with *Helicosphaera carteri* type blanket (fully covers distal surface of species = blanket type III of Theodoridis, 1984), moderate flange and two large holes separated by a conjunct bar.
Description: This species has a *H. carteri* type blanket that fully covers the distal surface of the species and therefore appears uniformly birefringent under polarised light. The size of the wing is variable. The central area has two large holes separated by a conjunct bar aligned with the short axis of species.
Remarks: *H. bownii* is distinguished from *Helicosphaera carteri* by having a distinct conjunct bar and larger holes. Moreover, *H. bownii* is restricted to Middle Miocene whilst *H. carteri* occurs from Early Miocene to Recent sediments. It differs from *Helicosphaera wallichii* by having two large pores separated by a conjunct bar parallel to the short axis of helicolith. In the latter species the bar and holes are oblique. *Helicosphaera burkei* has no holes or bar in the central area.
Dimensions of holotype:
Maximum Length: 11.6μm
Maximum With: 7.2μm
Holotype: Plate 1, figure 10
Paratype: Plate 1, figure 9
Type Locality: Turkey, Hatay, Sample 458
Type Level: Zone NN6, Middle Miocene
Occurrence: *H. bownii* is restricted to Zones NN7 to NN4 upper, Middle Miocene in Turkey, Vietnam, Philippines, Malaysia, Indian Ocean, West Africa, Brazil and Gulf of Mexico.

Helicosphaera leesiae da Gama and Varol, n. sp.

Plate 1, figures 13-15

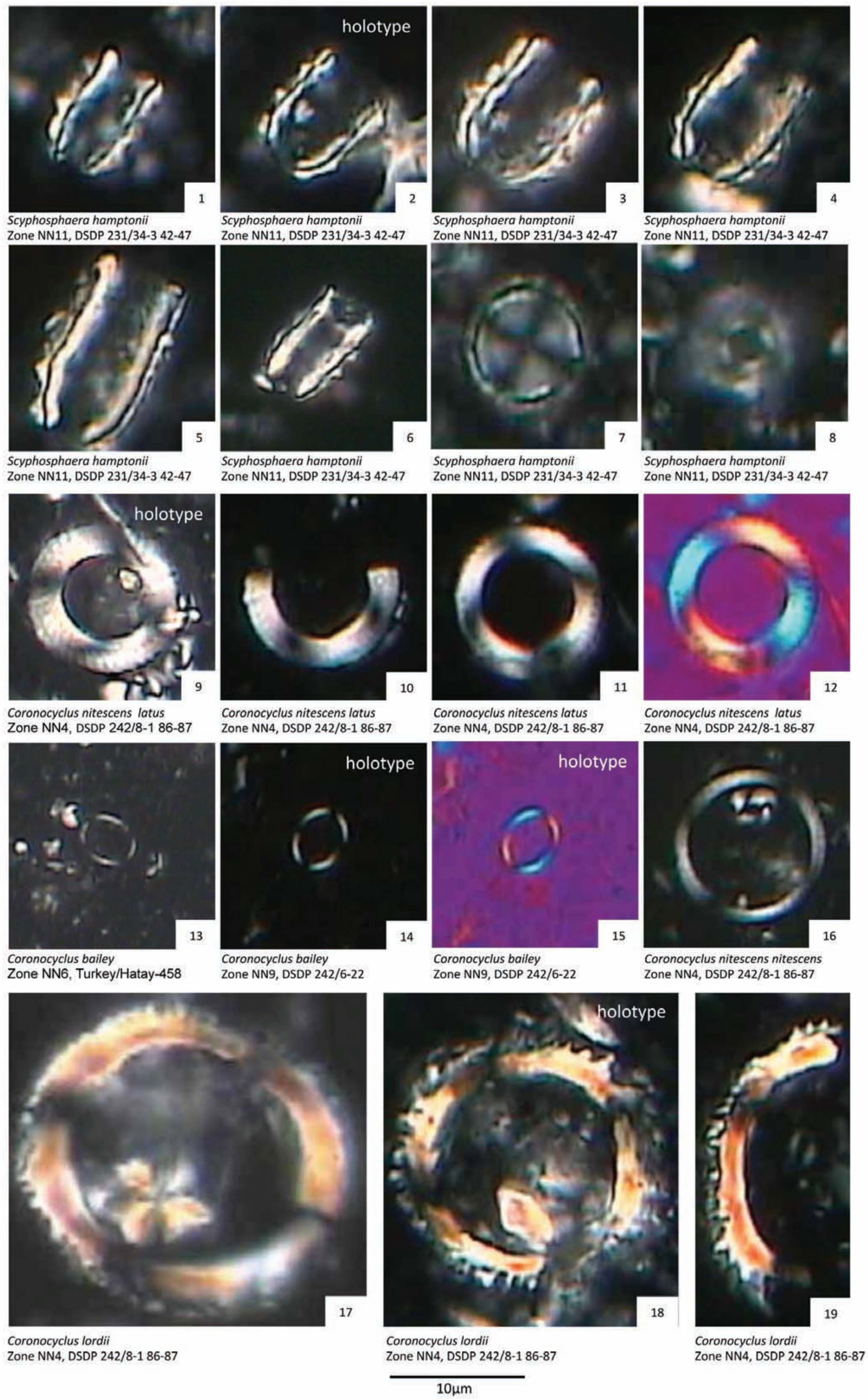
Derivation of name: In honour of Dr. Jackie A. Lees, nannofossil specialist and good friend, UCL, UK.
Diagnosis: Species of *Helicosphaera* with *Helicosphaera carteri* type blanket (fully covers distal surface of species = blanket type III of Theodoridis, 1984), a moderately sized wing and a disjunct bar (acute angle with less than 10 degrees inclination) parallel to the short axis of the helicolith.
Description: *H. leesiae* has an *H. carteri* type blanket and therefore appears uniformly birefringent under polarised light. The central opening is spanned by a disjunct bar parallel to the short axis of helicolith. It has a moderate sized wing.
Remarks: *H. leesiae* is similar to *Helicosphaera intermedia* but differs from it by having a disjunct bar aligned with the short axis of the helicolith whilst the latter has an oblique disjunct bar. It is distinguished from *Helicosphaera bramlettei* by having *H. carteri* type blanket whereas *H. bramlettei* has *Helicosphaera recta* type blanket (asymmetrical blanket confined the central area= blanket type II of Theodoridis, 1984) and a truncated wing (see holotype in Muller, 1970 and the Pl15, Figures 2-7 in Theodoridis,1984).
Dimensions of holotype:
Maximum Length: 10.0μm
Maximum With: 6.8μm
Holotype: Plate 1, figures 14-15 (same specimen)
Paratype: Plate 1, figure 13
Type Locality: DSDP 242/9-4 130cm
Type Level: Zone NP25, Late Oligocene
Occurrence: *H. leesiae* is recorded from Upper Oligocene to Lower Miocene (NP24-NN2) sediments of Vietnam, Philippines, Malaysia, Indian Ocean, Turkey, West Africa, Brazil and Gulf of Mexico.

Helicosphaera princei da Gama and Varol, n. sp.

Plate 1, figures 17-19

Derivation of name: In honour of Dr. Iain Prince, palynologist, Shell international E & P Inc., Houston, USA.
Diagnosis: Species of *Helicosphaera* with *H. carteri* type blanket (fully covers distal surface of species = blanket type III of Theodoridis, 1984), moderate wing and a long longitudinal slit in the central area.
Description: *Helicosphaera princei* is a relatively large helicolith having an *Helicosphaera carteri* type blanket. It has a moderate wing and a long longitudinal slit in the central area. The species is uniformly birefringent under polarised light.
Remarks: *H. princei* is distinguished from *H. carteri*, *Helicosphaera wallichii* and *H. burkei* by having a long longitudinal slit. The central opening in *Helicosphaera neogranulata* is irregular and much wider. *H. princei* is

Plate 3


holotype
1
Scyphosphaera hamptonii
Zone NN11, DSDP 231/34-3 42-47
2
Scyphosphaera hamptonii
Zone NN11, DSDP 231/34-3 42-47
3
Scyphosphaera hamptonii
Zone NN11, DSDP 231/34-3 42-47
4
Scyphosphaera hamptonii
Zone NN11, DSDP 231/34-3 42-47
5
Scyphosphaera hamptonii
Zone NN11, DSDP 231/34-3 42-47
6
Scyphosphaera hamptonii
Zone NN11, DSDP 231/34-3 42-47
7
Scyphosphaera hamptonii
Zone NN11, DSDP 231/34-3 42-47
8
Scyphosphaera hamptonii
Zone NN11, DSDP 231/34-3 42-47
holotype
9
Coronocyclus nitescens latus
Zone NN4, DSDP 242/8-1 86-87
10
Coronocyclus nitescens latus
Zone NN4, DSDP 242/8-1 86-87
11
Coronocyclus nitescens latus
Zone NN4, DSDP 242/8-1 86-87
12
Coronocyclus nitescens latus
Zone NN4, DSDP 242/8-1 86-87
13
Coronocyclus bailey
Zone NN6, Turkey/Hatay-458
holotype
14
Coronocyclus bailey
Zone NN9, DSDP 242/6-22
holotype
15
Coronocyclus bailey
Zone NN9, DSDP 242/6-22
16
Coronocyclus nitescens nitescens
Zone NN4, DSDP 242/8-1 86-87
17
Coronocyclus lordii
Zone NN4, DSDP 242/8-1 86-87
holotype
18
Coronocyclus lordii
Zone NN4, DSDP 242/8-1 86-87
19
Coronocyclus lordii
Zone NN4, DSDP 242/8-1 86-87
10µm

distinguished from *Helicosphaera hyalina* by having a long longitudinal slit in the central area whilst *H. hyalina* has a closed central area.
Dimensions of holotype:
Maximum Length: 10.0μm
Maximum With: 5.6μm
Holotype: Plate 1, figures 18
Paratype: Plate 1, figures 19
Type Locality: Anglesey, SOS B3614 13cm
Type Level: Zone NN21, Quaternary
Occurrence: *H. princei* ranges from the Upper Miocene to the Quaternary (NN11-NN21). It is found in Quaternary core samples from Anglesey, North Wales, Late Miocene cores of DSDP Leg 25 Site 242, Late Miocene to Pleistocene core of DSDP Leg 24 Site 231 and Pleistocene sediments of Trinidad and Brazil.

Helicosphaera watkinsii da Gama and Varol, n. sp.
Plate 1, figures 1-6

Derivation of name: In honour of Prof. David Watkins, nannofossil specialist, Nebraska, USA
Diagnosis: Species of *Helicosphaera* with *Helicosphaera mullerae* type blanket (symmetrical blanket confined to the central area = blanket type I of Theodoridis, 1984), truncated wing and a conjunct bar parallel or slightly oblique to short axis of the helicolith.
Description: *Helicosphaera watkinsii* has a symmetrical blanket confined the central area and therefore only the central area is birefringent. The wing is truncated. The central area is spanned by a conjunct bar parallel or slightly oblique to the short axis of the helicolith. The bar has a split in it that is parallel to the long axis, as in *Helicosphaera mediterraenea* and *Helicosphaera crouchii*.
Remarks: *H. watkinsii* is similar to the informal *H. recta* group but differs by having a symmetrical blanket whilst the *H. recta* group has an asymmetrical blanket. Moreover, *H. watkinsii* has a split in the bar which is lacking in the *H. recta* group.
Dimensions of holotype:
Maximum Length: 10.0μm
Maximum With: 7.2μm
Holotype: Plate 1, figures 1-3
Paratype: Plate 1, figures 5-6
Type Locality: DSDP, Leg 242/8-5, 70-71cm
Type Level: Zone NN2, Early Miocene
Occurrence: *Helicosphaera watkinsii* is recorded from NN2 sediments of Leg 25 Site 242. It is very rare in similarly aged sediments in West Africa and Brazil.

Hughesius Varol, 1989
Type species: Hughesius gizoensis Varol, 1989

Hughesius youngii da Gama and Varol, n. sp.
Plate 2, figures 9-11

Derivation of name: In honour of Dr. Jeremy R. Young, Nannofossil specialist and good friend, UCL, UK.
Diagnosis: Species of *Hughesius* with two elongated elements in the central area.
Description: This elliptical placolith has elongated two plates in the central area. When the species is aligned 45° to the polarizers, the elements of the shield become birefringent where the long axis of the plates touches the shield. In this respect it artificially resembles *Cryptococcolithus biparteoperculata*.
Remarks: *Hughesius youngii* is distinguished from *Hughesius gizoensis* by having strongly elongated central elements. The central plate is also made up of two pieces but rounded in *H. gizoensis*. The primary distinguishing characteristic is the birefringence of shield elements where apex of plates touches the shield.
Dimensions of holotype:
Maximum Length: 4.0μm
Maximum With: 2.4μm
Holotype: Plate 2, figures 9
Type Locality: DSDP, Leg 242/8-5, 70-71cm
Type Level: Zone NN2, Early Miocene
Occurrence: *H. youngii* is recorded NN2-NN4, in Lower Miocene sediments of the Philippines, Vietnam, Malaysia, Indonesia, Gulf of Aden, West Africa, Brazil, Trinidad and Gulf of Mexico.

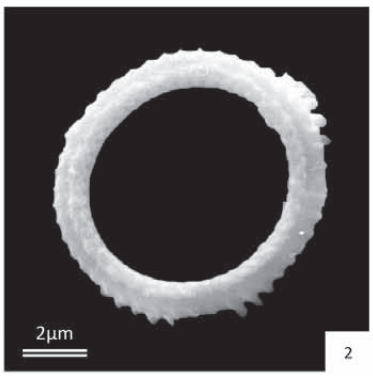
Scyphosphaera Lohmann, 1902
Type species: Scyphosphaera apsteinii Lohmann, 1902

Scyphosphaera hamptonii da Gama and Varol, n. sp.
Plate 3, figures 1-8

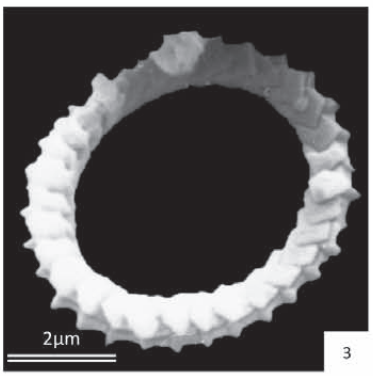
Derivation of name: In honour of Matthew Hampton, nannofossil specialist and good friend, Network Stratigraphic Consulting Ltd, Potters Bar, UK.
Diagnosis: A lophadolith in which the wall extends from a circular proximal base at an angle outwards a short distance and then vertically upwards.
Description: This small species of *Scyphosphaera* has a circular and flat proximal base with a short but distinct outward jutting edge. A cylindrical wall extends from the edge and terminates without any outer flaring or inward curvature. The outer surface of the wall is heavily ornamented. The minimum diameter of the species lies at the proximal base.
Remarks: *Scyphosphaera hamptonii* is distinguished from *Scyphosphaera cylindrica* by having a circular proximal base whereas the latter has an elliptical proximal base. Moreover, the outer surface of this new species is more heavily ornamented and it is much smaller than *S. cylindrica*. The proximal base of *Scyphosphaera globulata* is also circular but the overall shape is globular whereas the overall shape of *S. hamptonii* is cylindrical.
Dimensions of holotype:
Maximum Length: 10.0μm
Maximum With: 6.8μm
Holotype: Plate 3, figures 2
Type Locality: DSDP, Leg 231/34-3, 42-47cm
Type Level: Zone NN11, Late Miocene
Occurrence: *S. hamptonii* was recovered from NN11 sediments and is Late Miocene in age. It was recorded from the Gulf of Aden, Vietnam, Malaysia, Indonesia, Philippines, West Africa, North Africa, Brazil and Trinidad.

Plate 4

Coronocyclus nitescens latus
G. Mihmandar Well, Turkey, 114



Coronocyclus nitescens nitescens
Ghajn Tuffieha Bay, Malta, 5296

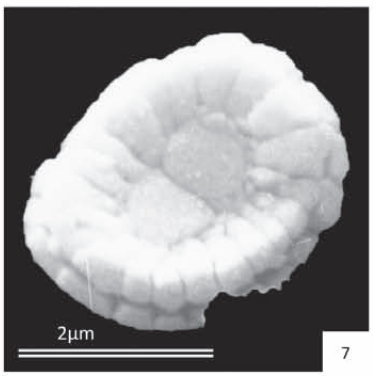


Coronocyclus bailey
Fomm Ir Rih Bay, Malta, 5435

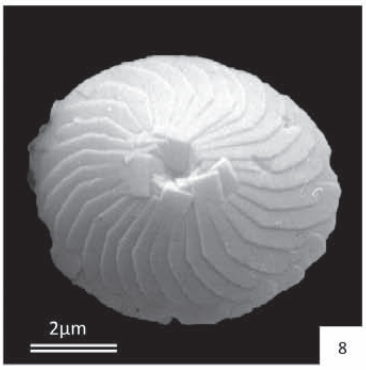
Coronocyclus baileyi
Adana Basin, Turkey, 130

Helicosphaera bownii
Adana Basin,Turkey, 130

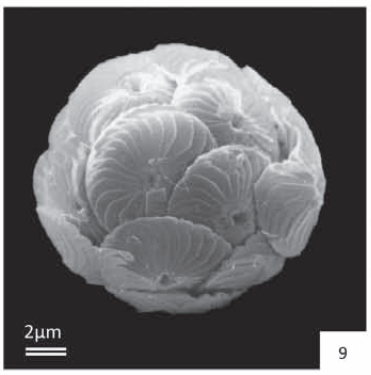
Helicosphaera bownii
Adana Basin, Well, Turkey, 119



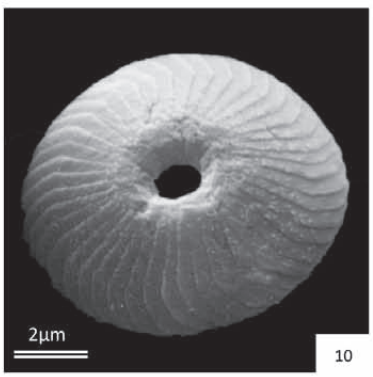
Hughesius gizoensis
Hatay, Turkey, 457



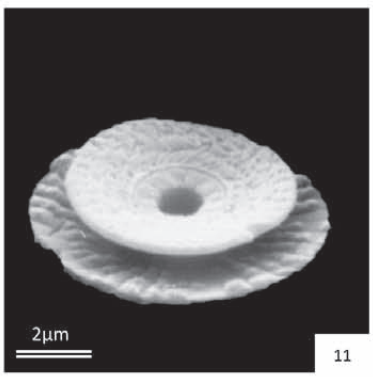
Calcidiscus leptoporus
Ghajn Tuffieha Bay, Malta, 5287



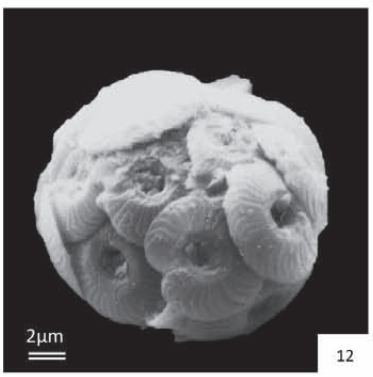
Calcidiscus leptoporus
Ghajn Tuffieha Bay, Malta, 5299



Calcidiscus tanianus
Adana Basin, Turkey, 130



Calcidiscus tanianus
Ghajn Tuffieha Bay, Malta, 5300



Calcidiscus tanianus
Ghajn Tuffieha Bay, Malta, 5305

***Syracosphaera* Lohmann, 1902**
Type species: Syracosphaera pulchra Lohmann, 1902

***Syracosphaera? oneillii* da Gama and Varol, n. sp.**
Plate 1, figures 7-8, 11-12, 16, 20

Derivation of name: In honour of the late Dr. Brian J. O'Neill, colleague, Shell international E&P, Houston, Texas, USA
Diagnosis: Small elliptical coccolith consisting of a non-birefringent outer cycle and birefringent inner cycle.
Description: This elliptical coccolith is made up of two cycles of elements. The outer cycle is non-birefringent whilst the inner cycle is birefringent. No structure was observed in the central area. Examination under SEM is necessary to understand the true structure of this small species.
Remarks: An influx of this small species was recorded between NN7 and lower NN10 in all studied locations.
Dimensions of holotype:
Maximum diameter: 4.4μm
Maximum diameter of central area: 3.6μm
Holotype: Plate 1, figures 11-12 (same specimen)
Type Locality: DSDP, Leg 242/6-22, 70-71cm
Type Level: Zone NN9, Late Miocene
Occurrence: This species is restricted to Zones NN7-NN10 where it is in great abundance. *Syracosphaera? oneillii* is observed in sediments from the Philippines, Vietnam, Malaysia, Indonesia, the Gulf of Aden, West Africa, Brazil and Trinidad.

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List of species
Bramletteius serraculoides Gartner, 1969
Calcidiscus Kamptner, 1950
Calcidiscus gallagheri da Gama and Varol, n. sp.
Calcidiscus leptoporus Murray and Blackman, 1898; Loeblich and Tappan, 1978
Calcidiscus macintyrei Bukry and Bramlette, 1969; Loeblich and Tappan, 1978
Calcidiscus premacintyrei Theodoridis, 1984
Calcidiscus quadriperforatus Kamptner, 1950
Calcidiscus salomonii da Gama and Varol, n. sp.
Calcidiscus tanianus Kamptner, 1954; da Gama and Varol, n. comb.
Calcidiscus tropicus Kamptner, 1954
Coccosphaera carteri Wallich, 1877
Coronocyclus Hay, Mohler and Wade, 1966; emend. da Gama and Varol, n. sp.
Coronocyclus baileyi da Gama and Varol, n. sp.
Coronocyclus lordii da Gama and Varol, n. sp.
Coronocyclus nitescens nitescens Hay, Mohler and Wade, 1966
Cruciplacolithus Hay and Mohler in Hay *et. al*., 1967
Cruciplacolithus kanungoi da Gama and Varol, n. sp.
Cryptococcolithus biparteoperculata Varol, 1991
Cyclococcolithus tanianus Kamptner, 1955
Discoaster deflandrei Bramlette & Riedel, 1954
Discoaster petaliformis Moshkovitz and Ehrlich, 1980
Helicosphaera Kamptner, 1954
Helicosphaera bownii da Gama and Varol, n. sp.
Helicosphaera bramlettei Miiller, 1970
Helicosphaera burkei Black, 1971
Helicosphaera carteri (Wallich 1877) Kamptner, 1954
Helicosphaera crouchii. Bukry, 1981
Helicosphaera leesiae da Gama and Varol, n. sp.
Helicosphaera mediterraenea Muller, 1981
Helicosphaera princei da Gama and Varol, n. sp.
Helicosphaera recta (Haq, 1966) Jafar & Martini, 1975
Helicosphaera truncata Bramlette and Wilcoxon, 1967
Helicosphaera wallichii (Lohmann, 1902) Okada & McIntrye, 1977
Helicosphaera watkinsii da Gama and Varol, n. sp.
Heliorthus tenuis Stradner, 1961
Hughesius gizoensis Varol, 1989
Hughesius Varol, 1989
Hughesius youngii da Gama and Varol, n. sp.
Reticulofenestra rotaria Theodoridis, 1984
Scyphosphaera Lohmann, 1902
Scyphosphaera apsteinii Lohmann, 1902
Scyphosphaera cylindrica Kamptner, 1955
Scyphosphaera globulata Bukry and Percival, 1971
Scyphosphaera hamptonii da Gama and Varol, n. sp.
Syracosphaera Lohmann, 1902
Syracosphaera pulchra Lohmann, 1902
Syracosphaera? oneillii da Gama and Varol, n. sp.

References
Hay, W.W., Mohler, H.P. & Wade, M.E. 1966. Calcareous nannofossils from Nal'chik (northwest Caucasus). *Eclogae Geologicae Helvetiae*, **59**: 379-399.

Hay, W.W., Mohler, H.P., Roth, P.H., Schmidt, R.R. & Boudreaux, J.E. 1967. Calcareous nannoplankton zonation of the Cenozoic of the Gulf Coast and Caribbean-Antillean area, and transoceanic correlation. *Transactions of the Gulf Coast Association of Geological Societies*, **17**: 428-480.

Kamptner, E., 1950. Ü ber den submikroskopischen Aufbau der Coccolithen. Anzeiger der Ä sterreichische Akademie der Wissenschaften in Wien. Mathematische-Naturwissenschaftliche Klasse 87, 152–158.

Kamptner, E., 1954. Untersuchungen über den Feinbau der Coccolithen. Arch. Protistenkunde 100, 1–90.

Kamptner, E., 1955. Fossile Coccolithineen-Skelettreste aus Insulinde. Eine mikropalaontologische Untersuchung. Verh. K. Nederl. Akad. Wet., Afd. Natuurk Ser. 2, 50(2):1-105

Lohmann, H., 1902. Die Coccolithophoridae, eine mongraphie der Coccolithen bildenden Flagellaten, zugleich ein Beitrag zur Kenntnis des Mittelmeer auftriebs. *Arch. Protistenkd*., 1:89-165.

Martini, E. 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *In:* A. Farinacci (Ed.). *Proceedings of the Second Planktonic Conference, Roma, 1970*. Edizioni Tecnoscienza, Rome, **2**: 739–785.Stradner, H. 1961. Vorkommen von nannofossillen im Mesozoikum und Alttertiar. Erdoel-Zeitschrift, 77(3):77-78

Muller, C. 1970. Nannoplankton-Zonen der Unteren Meeresmolasse Bayerns. *Geol. Bavrica*, **63**:107-118

Theodoridis, S., 1984. Calcareous nannofossil biozonation of the Miocene and revision of the helicoliths and discoasters. Utrecht Micropaleontol. Bull. 32, 3–271.

Varol, O., 1989. Calcareous nannofossil study of the Central and Western Solomon Islands.- Circum Pacific Council for Energy and Mineral Resources, Earth Science Series, 12 : 239-268

Wallich, G.C., 1877. Observations on the coccosphere. Ann. Mag. Natural History (Ser. 4) 19, 342–350.

Young, J.R., Bergen, J.A., Bown, P.R., Burnett, J.A., Fiorentino, A., Jordan, R.W., Kleijne, A., van Niel, B.E., Romein, A.J.T. & von Salis, K. 1997. Guidelines for coccolith and calcareous nannofossil terminology. *Palaeontology*, **40**: 875-912.

ONLINE PUBLICATION

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