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Palaeogene calcareous nannofossils from the Kilwa and Lindi areas of coastal Tanzania (Tanzania Drilling Project 2003-4)

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Abstract Exceptionally well-preserved and diverse Late Paleocene-Early Oligocene nannofossil assemblages are described from new onshore drilling sites in southern Tanzania. Hemipelagic claystones, at shallow burial depths, yield rare but diverse assemblages, characterised by the conspicuous presence of rhabdoliths, pentaliths, pontosphaerids and holococcoliths. Although the presence and diversity of pontosphaerids and holococcoliths is most likely the result of enhanced preservation, the occurrences of the rhabdoliths and pentaliths may represent a primarily palaeoecological signal, *i.e.* neritic, warm water. A latest Paleocene origination is confirmed for the Rhabdosphaeraceae and Pontosphaeraceae, and proposed for the Noelaerhabdaceae. New, transitional coccolith morphologies strongly support an evolutionary link between *Zygodiscus* and *Pontosphaera*. Two hundred and sixty-seven taxa are illustrated and 213 described and/or discussed, providing a comprehensive taxonomic review of Palaeogene calcareous nannofossils. One new family, two new genera, 56 new species, one new subspecies and 10 new combinations are described.

Keywords Paleocene, Eocene, Oligocene, calcareous nannofossils, diversity, taxonomy

1. Introduction

Palaeogene deposits occur in several large patches along the Tanzanian coast, and the most extensive of these is between and around the towns of Kilwa and Lindi in the south of the country (Figure 1). The predominant lithology is mudstone, with occasional carbonate or siliciclastic turbidites, although reef limestones and sand-bodies also occur in parts of the succession (Kent *et al.*, 1971; Pearson *et al.*, 2004). The area is previously known to micropalaeontologists, most notably through the foraminiferal work of Blow & Banner (1962), who named many new species of planktonic foraminifers and typified several Upper Eocene and Lower Oligocene foraminiferal biozones in the Lindi area. A new research program, the Tanzanian Drilling Project (TDP), has recently returned to this area with the primary aim of recovering pristinely-preserved foraminifera and organic biomarkers for geochemical analysis, in order to improve records of Late Mesozoic-Palaeogene tropical sea-surface temperatures and pCO_2. The work to date has comprised several field seasons (1998-2000) and, more recently, three onshore coring expeditions (2002-2004). Initial results, including preliminary microfossil biostratigraphy, lithostratigraphy and organic geochemistry, are presented in Pearson *et al.* (2004, subm.). As well as the primary palaeoclimatological objectives of the project, the material is clearly useful for a wide range of micropalaeontological, stratigraphical and palaeoceanographical purposes, and a team from the UK, Tanzania, Ireland and the US is currently collaborating on this work.

This paper documents and describes the beautifully preserved and exceptionally diverse Palaeogene calcareous nannofossils from the cores recovered during the first two years of drilling, comprising TDP Sites 1-4, 6-8 and 10. Sites 5 and 9 recovered Upper Cretaceous sequences with similarly exquisite nannofossil records that will be published separately (Pearson *et al.*, 2004, subm.; Lees, in prep.). The taxonomy presented here provides a review and revision of calcareous nannofossils of the Palaeogene interval, a time of maximum Cenozoic diversity that saw the origination of a number of important extant families (Calcidiscaceae, Helicosphaeraceae, Pontosphaeraceae, Rhabdosphaeraceae) (Bown *et al.*, 2004). A total of 270 species are illustrated, 213 described/discussed, and 60 new taxa are described ,including two new genera and one new family.

2. Palaeogene nannofossil study

Much of the early study of Palaeogene nannofossils was carried out on epicontinental, hemipelagic sequences, comparable to those of coastal Tanzania, notably by Milton N. Bramlette (Bramlette & Riedel, 1954; Bramlette & Sullivan, 1961; Bramlette & Wilcoxon, 1967), Herbert Stradner (*e.g.* Stradner, 1958, 1959, 1960, 1962, *etc.*), Erlend

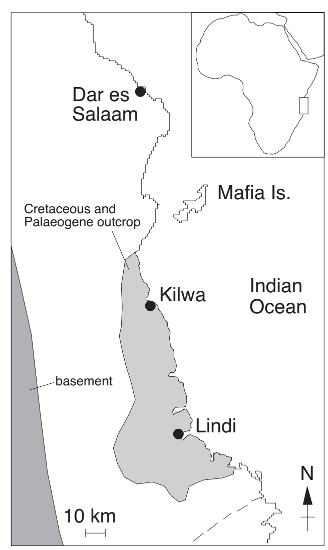

Figure 1: Location of study area (after Pearson *et al.*, 2004)

Martini (*e.g*. Martini, 1958, 1959, 1961, *etc*.), Frank Sullivan (Sullivan, 1964, 1965) and Bill Hay (Hay & Mohler, 1967; Hay *et al*., 1966, 1967). Towards the end of this period of taxonomic and stratigraphic research, deep-sea drilling augmented the earlier onshore data (*e.g*. Martini & Bramlette, 1963; Martini, 1965; Gartner, 1971) and culminated in publication of the standard Cenozoic nannofossil zonation by Martini (1970, 1971). Since then, much of the focus of Cenozoic calcareous nannofossil research has shifted from the shelves to the oceans, most obviously stimulated by the expansion of palaeoceanographic research in the Deep Sea Drilling Project and Ocean Drilling Program (ODP). Vast quantities of nannofossil data have been generated by these projects, and dedicated deep-sea biozonations have been formulated, and older schemes subsequently modified by, for example, Bukry (1973, 1975, 1981), Okada & Bukry (1980) and Perch-Nielsen (1985). More recently, interests have focussed on events of extreme palaeoclimate change, for example, the Paleocene/Eocene thermal maximum, and both high-resolution stratigraphic and assemblage data have resulted (Angori & Monechi, 1996; Aubry, 1996; Aubry *et al*., 1996; Schmitz *et al*., 1997; Bralower, 2002). Recent syntheses and studies that have included Paleogene nannofossil taxonomic work include Aubry (1984 *et seq*.), Perch-Nielsen (1985), Varol (1989), Bralower & Mutterlose (1995), Bybell & Self-Trail (1995) and de Kaenel & Villa (1996).

The nannofossil assemblages presented here most closely resemble those described in the pioneering works of Stradner, Martini and Bramlette (see above), and differ significantly from material that is typically recovered in the deep sea. The Tanzanian material demonstrates the considerable difference between Palaeogene assemblages of the shelves and oceans - in the author's experience, the most striking differentiation in the history of the group, and for reasons that must include both palaeoecology and taphonomy. The difference is most clearly demonstrated by the abundant presence of diverse rhabdoliths, pentaliths, holococcoliths and pontosphaerids, all groups that are almost completely absent in typical deep-sea sediments. Such differentiation also impacts on the stratigraphic distribution of the fossils and reliability of marker-species, but discussion of the biostratigraphic data is beyond the scope of this paper, and will be presented elsewhere (but see Pearson *et al*., 2004, subm.).

3. Material

A total of 10 sites were drilled in 2002 and 2003, eight in the vicinity of Kilwa (TDP Sites 1-3, 6-10) and two near Lindi (TDP Sites 4 and 5). Sites were selected to obtain a wide spread of sediment ages (Late Cretaceous-Early Oligocene) in the best-preserved microfossil material possible. Sites were cored using a truck-mounted rig using water and mud circulation to avoid unnecessary organic contamination. Cores were 2" (~5cm) in diameter, 3m long, and cut into sections of 1m. All cores are archived at the Tanzania Petroleum Development Corporation in Dar-es-Salaam. Core photographs and VCD sheets are archived at Cardiff University. Sample identification numbers are adapted from the procedure used by the ODP. A typical sample number refers to the site, core number, section number, and depth in cm from the top of that section. For example, Sample TDP2-27-2, 16-20cm was taken from TDP Site 2, Core 27, Section 2 between 16 and 20cm from the top of that 1m section. The depth of this sample can be calculated by adding 1.16- 1.20m to the depth from the top of the core (66.70m + 1.16m = 67.86m). Additional details concerning the coring and geological setting can be found in Pearson *et al*. (2004, subm.).

4. Methods

Samples were prepared as smear-slides (Bown & Young, 1998) and analysed using a Zeiss Axiophot microscope at x1000 magnification in cross-polarised light (XPL) and phase-contrast (PC). Assemblages were logged semiquantitatively, and slides were observed for at least 30 minutes, in most cases much longer. Images were captured using Scion Image software and macros written by Dr. Jeremy Young (Bown & Young, 1998). For the Palaeogene, the NP biozones of Martini (1971) were used, along with the additional Middle Eocene subzones of Aubry (1991). The alternative bioevents used in the Okada & Bukry (1980) CP biozonation were also considered, where appropriate.

5. Results

Although a relatively broad stratigraphic range of samples has been studied (Late Paleocene-Early Oligocene), the abundance, diversity, preservation, and even aspects of assemblage composition, are remarkably consistent throughout. The nannofossils are invariably rare to few in the sediments, being significantly diluted by clay and silt in these predominantly dark green to black claystone lithologies. At some localities nannofossils are more abundant (*e.g*. Site TDP2), and occasionally certain horizons are barren. However, preservation of the nannofossils is moderate to excellent, and usually excellent, with delicate structures, small coccoliths (<3.0μm), holococcoliths and coccospheres consistently present. The quality of the preservation results from both the nature of the sediments, *i.e*. clay-rich (see Pearson *et al*., 2001), and the fact that the sediments have never been deeply buried. The preliminary biostratigraphic results are presented in Pearson *et al*. (2004, subm.), and a summary of the zones and marker-species recognised is given in Figure 2 and Table 1.

5.1 Assemblage composition

The most striking feature of the Tanzanian assemblages is how greatly they differ from those of the routinely-studied open-ocean. Five groups in particular, the rhabdoliths (Rhabdosphaeraceae: *Blackites*), pontosphaerids (Pontosphaeraceae), holococcoliths (*Clathrolithus*, *Holodisco-*

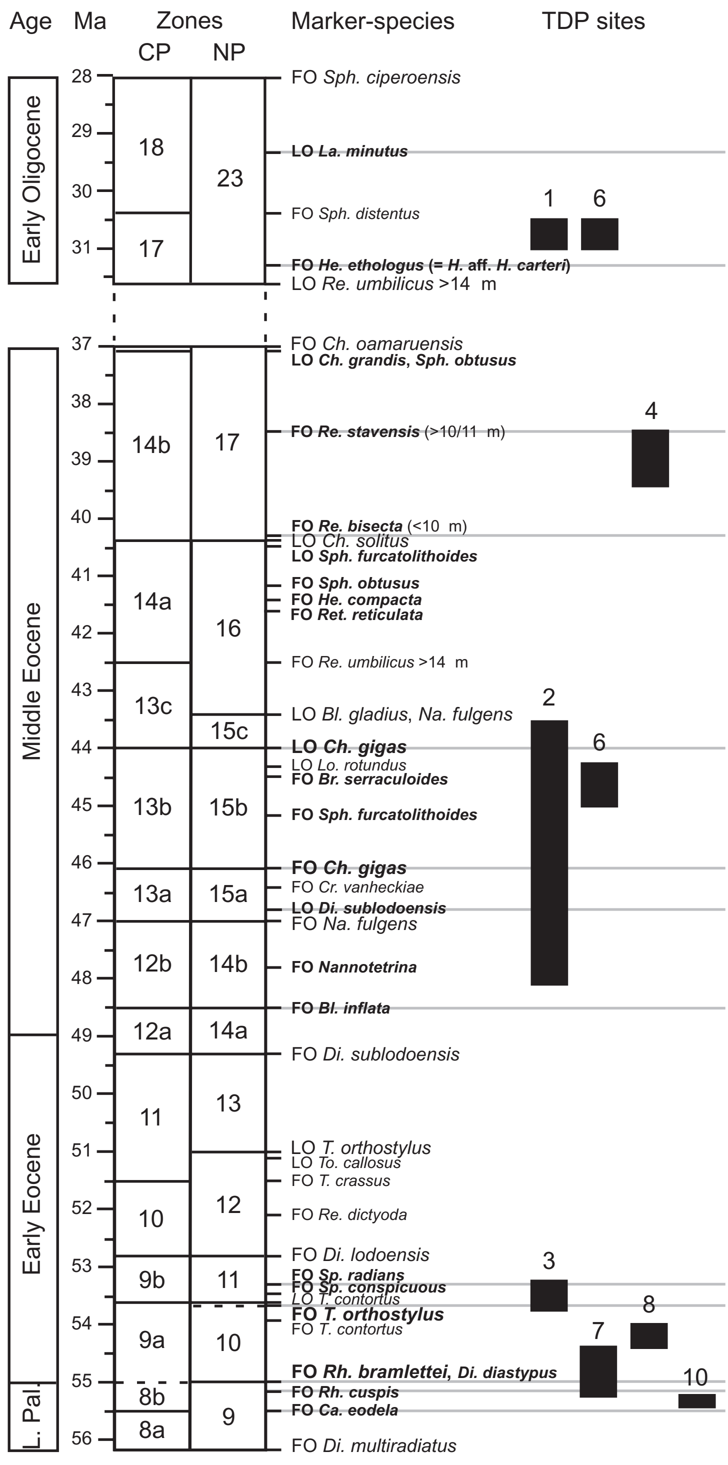

Figure 2: Nannofossil biostratigraphical schemes for the studied interval (NP and CP zones of Martini (1971) and Okada & Bukry (1980), respectively). NP zone markers in large font; species used to date the TDP cores in bold. FO = first evolutionary occurrence; LO = last occurrence. Estimated stratigraphic ranges of the TDP sections on the right. Time-scale calibrations mostly from Lyle *et al*. (2002) and Bralower & Mutterlose (1995)

lithus, Lanternithus, Zygrhablithus, *etc*.) and pentaliths (Braarudosphaeraceae: *Braarudosphaera, Micrantholithus, Pemma*) are diverse and common in most of the cores, yet they are rarely observed in oceanic samples, including those of equivalent latitude, for example, compare with the assemblages illustrated by Bralower & Mutterlose (1995). As a broad comparison, Bralower & Mutterlose (1995) described 35 species from levels in Zone NP10 and Subzone NP15b; equivalent levels from Tanzania yielded 60 and 116, respectively.

5.1.1 Braardudosphaeraceae

The abundant, neritic distribution of pentaliths was noted in some of the earliest Palaeogene studies (Sullivan, 1964, 1965; Bybell & Gartner, 1972), and the palaeoceanographical significance of this long-ranging taxon has continued to confound palaeontologists, particularly the anomalous deep-sea 'braarudosphaerid-chalk' occurrences (*e.g*. Kelly *et al*., 2003). The Early to Middle Eocene saw a striking diversity maximum for this group (18 species illustrated here), although it originated in the earliest Cretaceous and continues to be represented at present by *Braarudosphaera bigelowii*. In the earliest part of this group's history, several species of *Micrantholithus* proliferated on the Early Cretaceous shelves, but then declined and disappeared in the mid-Cretaceous, and were replaced by much rarer representatives of *Braarudosphaera*. Both genera were conspicuous again for a short interval following the Cretaceous/Tertiary boundary extinctions. However, in the Late Paleocene to Eocene, a great diversity of new morphologies appeared, including anomalously large, heavily-calcified forms (see Plates 34-36), and they were abundant in shelf settings (*e.g*. *Pemma*, *Micrantholithus*, *Braarudosphaera*). Although the distribution of the group appears to be restricted to the shelves, the species are represented worldwide, inferring continued genetic exchange across ocean basins (Bybell & Gartner, 1972). Such exchange is not easily supported by the fossil record but may be explained by loss due to preservation, although it is difficult to see this being the case for such large, robust nannoliths. Their deep-sea absence may be better explained by ecological exclusion, rarity, or the occurrence of life-cycle stages that are not routinely preserved. Similar explanations may apply to the other 'neritic' groups.

5.1.2 Holococcoliths

Holococcoliths have distinct coccolith architecture, and all extant representatives are small and prone to immediate post-mortem dissolution in all but the most favourable taphonomic settings. For example, of the 86 living holococcolith species, only one or two are seen in Pleistocene sediments (see, *e.g*., Young, 1998; Young *et al*., 2003). It is therefore likely that commonly-

TDP site	Core	Age (NP zone)
1	1	15
	2-3	barren
	5-20	23
	21-22	barren
2	1-9	15c
	10-24	15b
	26-35	14b/15a
3	1-12	11
	13-19	10/11
4	1-7	17
5	-	Upper Cret.
6	1-4	barren
	5	23
	6-8	barren
	8-9	15b
7A	2-65	10
7B	33-34	10
	44-51	9b/10
	51-53	9b
8	1-12	10
9	-	Upper Cret.
10	2-40	9b

Table 1: Age of TDP cores using NP zones of Martini (1971)

observed fossil holococcoliths represent exceptional, unusually large and robustly constructed morphologies. Even so, most of these are still only preserved in certain facies, most commonly in hemipelagic claystones, and apart from one or two notable exceptions (Palaeogene *Zygrhablithus*, Cretaceous *Lucianorhabdus*), they are never preserved in typical deep-sea oozes. The preservational control on Palaeogene holococcoliths was first noted by Gartner & Bukry (1969) and is still our best explanation for their distinct distribution, even though there is increasing evidence of ecological controls on their extant distributions (Cros *et al*., 2000). The Tanzanian material has yielded 27 holococcolith species (including two new genera, and 15 new species), doubling the known Palaeogene diversity, and has revealed extended stratigraphic ranges for many of those previously described.

5.1.3 Rhabdospheraceae

Fossil rhabdoliths are reported as having shelf, rather than oceanic, distributions (Perch-Nielsen, 1985), based largely on their absence from deep-sea sediments. However, a number of living species, including *Rhabdosphaera clavigera*, appear to be widely distributed across both oceans and marginal seas (Kleijne, 1992). Dissolution may well influence their fossil distribution, as most living rhabdolith species have low preservation potential, and are rarely seen in Pleistocene sediments (McIntyre & McIntyre, 1971; Roth & Thierstein, 1972; Roth & Berger, 1975; Roth & Coulbourn, 1982; Young *et al*., 2003). Eocene rhabdoliths are considerably larger and more robust than their extant counterparts, and their abundant neritic distribution may yet prove to be a primary palaeoecological signal. The diverse assemblages from Tanzania indicate affinities for tropical shelf environments.

The Middle Eocene saw the highest Cenozoic diversity for the Rhabdosphaeraceae, and 27 species are illustrated here, including 11 new species. Like the pentaliths, a number of these species are globally distributed and used as marker-taxa, suggesting worldwide connections that are not obvious from the fossil record.

5.1.4 Pontosphaeraceae

Fossil pontosphaerid coccoliths are generally reported as typically having shelf distributions, although some are found more widely (Perch-Nielsen, 1985). *Scyphosphaera*, in particular, is found only very rarely in Cenozoic sediments, and almost always in tropical, neritic settings (Aubry, 1990; Siesser, 1998). Both *Pontosphaera* and *Scyphosphaera* are susceptible to dissolution, despite being rather large and robust coccoliths, and dissolve in water-depths greater than 3000m (Roth & Berger, 1975; Siesser, 1998). It seems likely that the neritic distribution of fossil pontosphaerids is largely controlled by preservation.

The Middle Eocene saw the Cenozoic diversity maximum for the Pontosphaeraceae, and 23 species are illustrated here.

5.1.5 *Cruciplacolithus*

Several species of *Cruciplacolithus*, although rare, are recorded consistently at most of the Eocene sites, at stratigraphic levels significantly above their previously recorded, predominantly intra-Paleocene, ranges (Perch-Nielsen, 1985). It seems likely that this group became largely restricted to the shelves from the Eocene on, hence their consistent record here, further supported by the neritic distribution of the single living representative, *Cruciplacolithus neohelis* (Young *et al*., 2003).

5.2 Absences

As well as anomalous occurrences, the assemblages investigated record absences, or rare and infrequent occurrences, that are also considered notable. Most importantly, discoasters, which form the basis for much of the Palaeogene biozonation, are relatively rare despite the tropical setting and their being dissolution-resistant. Such an observation is unequivocally due to the shelf setting that excluded or restricted the occurrence of these tropical, oceanic taxa (Aubry, 1984, 1992; Chepstow-Lusty *et al*., 1992).

The important nannolith marker-species *Rhomboaster*, *Tribrachiatus* and *Nannotetrina* are rare and infrequent, possibly explaining earlier observations concerning their biostratigraphical reliability, but not supporting the suggestion that they are restricted to nearshore environments (Müller, 1979; Aubry, 1988, 1996).

Representatives of the genus *Chiasmolithus* are relatively consistently present, but usually rarely, and a number of marker-species are not recorded at all, *e.g*. *Chiasmolithus solitus* (Bramlette & Sullivan, 1961) and *Chiasmolithus oamaruensis* (Deflandre *in* Deflandre & Fert, 1954). Tanzania was tropical in the Eocene, and these observations support previous work that suggests *Chiasmolithus* was a typically cold- to temperate-water genus (Wei & Wise, 1992; Persico & Villa, 2004).

5.3 Originations

Finally, the Tanzanian material provides stratigraphic constraint on the divergence and origination times of some important extant coccolithophore families.

5.3.1 Pontosphaeraceae

Representatives of the Pontosphaeraceae (*Pontosphaera plana*) are present in the oldest cores (TDP Site 10) that are assigned to Subzone NP9b (latest Paleocene), confirming the record of Bramlette & Sullivan (1961). Notably, they occur alongside species that have features shared by both *Pontosphaera* and the older genus *Zygodiscus*. *Zygodiscus sheldoniae* sp. nov., for example, is *Pontosphaera*-like (thin, birefringent central-area plate) but has a remnant disjunct bar, demonstrating its *Zygodiscus* affinities, and indicating an evolutionary link between the two genera (Pl.18, figs 25-34). *Zygodiscus clausus* shows similar features (Pl.19, figs 1-5). The oldest record of *Scyphosphaera* in this material is in the Middle Eocene (NP14b/15a), at the base of TDP Site 2.

5.3.2 Rhabdosphaeraceae

Representatives of the Rhabdosphaeraceae (*Blackites herculesii*) are present towards the base of TDP Site 7B, assigned to Subzone NP9b (latest Paleocene - with *Rhomboaster cuspis* but prior to the first occurrence of *Rhomboaster bramlettei*), indicating an origination in the latest Paleocene.

5.3.3 Calcidiscaceae

A number of ring-shaped Eocene coccoliths have previously been tentatively assigned to the genus *Calcidiscus* (*e.g. Calcidiscus protoannulus*), but the Tanzanian material has also yielded more convincing *Calcidiscus*-like placolith coccoliths that are here tentatively assigned to the genus. Consistent records of *Calcidiscus*? *pacificanus* begin in Zone NP11 (Early Eocene, Site TDP 3). Another common coccolith, here tentatively assigned to the Neogene genus *Umbilicosphaera* (*U.*? *jordanii* sp. nov.), is also recorded from the Late Paleocene (NP9b, TDP Site 10).

5.3.4 Noelaerhabdaceae

Circular, birefringent placolith coccoliths, reminiscent of younger *Cyclicargolithus* coccoliths, are recorded from Subzone NP9b (latest Paleocene) and named *Cyclicargolithus luminis*. Electron microscope observation is required to substantiate their generic affinities but they may prove to be the oldest representatives of this family group.

6. Systematic palaeontology

There follows a comprehensive taxonomic review of the Tanzanian nannofossil assemblages. All recorded taxa are listed and illustrated, and remarks and short descriptions are provided for new taxa and taxa that require clarification or are taxonomically problematic. Descriptive terminology follows the guidelines of Young *et al*. (1997). The plates comprise ~1400 images of the 270 species encountered, and multiple images attempt to represent the range of morphological variation. All images are at the same magnification (x2180). The layout of the taxonomy and plates, and much of the higher taxonomic rationale, follows the recently-published guide to extant coccolithophore taxonomy (Young *et al*., 2003), together with the earlier review of Cenozoic taxonomy by Young and Bown (1997). Range information is given for stratigraphic distributions at the Tanzanian sites. Additional stratigraphical data are given when taxa have well-established ranges, or where such information is deemed relevant. Morphometric data are given for all new taxa and elsewhere where appropriate. Only bibliographic references not included in Perch-Nielsen (1985) and Bown (1998) are included in the reference list.

The following abbreviations are used: **LM** - light microscope, **XPL** cross-polarised light, **PC** - phase-contrast illumination; **FO** - first occurrence, **LO** - last occurrence; **L** - length, **W** - width, **H** - height, **CW** - coccolith width, **SW** - spine width. Type material and electronic images are stored in the Department of Earth Sciences, UCL.

6.1 Placolith coccoliths

Order ISOCHRYSIDALES **Pascher, 1910**
Family **PRINSIACEAE** Hay & Mohler, 1967 emend. Young & Bown, 1997

Toweius callosus Perch-Nielsen, 1971
Pl.1, figs 1-5
Toweius eminens (Bramlette & Sullivan, 1961) Perch-Nielsen, 1971
Pl.1, figs 6-10
Toweius occultatus (Locker, 1967) Perch-Nielsen, 1971
Pl.1, figs 11-13
Toweius pertusus (Sullivan, 1965) Romein, 1979
Pl.1, figs 14-17, 21-25

Toweius serontinus Bybell & Self-Trail, 1995

Pl.1, figs 18-20. Medium to large (6-8μm), broadly elliptical, with wide, birefringent central-area plate, pierced by 10-20 small pores. **Occurrence**: NP9b-10; TDP Sites 7A, 7B.

Toweius sp.1

Pl.1, figs 26-27. Medium to large (6-8μm), circular, with relatively narrow central-area (less than width of shields) crossed by finely-perforate plate clearly visible in XPL. Shield and tube-cycle distinctly bright in XPL. **Occurrence**: NP9b-10; TDP Sites 7A, 7B.

Toweius sp.2

Pl.1, figs 28-30. Medium-sized (4-7μm), elliptical-subcircular, with relatively wide central-area (approximately equal to width of shields) crossed by (finely-perforate?) plate visible in XPL. **Occurrence**: NP10-11; TDP Sites 3, 7A.

Toweius rotundus Perch-Nielsen *in* Perch-Nielsen *et al*., 1978

Pl.1, figs 31-32. Small (~<4μm), subcircular-circular, with narrow central-area spanned by (perforate?) plate. **Occurrence**: NP11; TDP Site 3; Varol (1989).

Prinsius martinii (Perch-Nielsen, 1969) Haq, 1971
Pl.1, fig.33

Hornibrookina arca Bybell & Self-Trail, 1995
Pl.1, figs 34-35

Family **NOELAERHABDACEAE** Jerkovic, 1970 emend. Young & Bown, 1997

Differentiation of the genera *Reticulofenestra* and *Cyclicargolithus* is problematical in this material because many of the reticulofenestrid coccoliths are subcircular with high tube-cycles and central-areas of variable width. *Cyclicargolithus* is used here for coccoliths that are predominantly circular with central-areas narrower than the width of the shields.

Cyclicargolithus luminis (Sullivan, 1965) Bukry, 1971

Pl.2, figs 1-2. Small- to medium-sized (3.0-4.5μm), circular coccoliths with birefringent shields and small, central hole. **Occurrence**: NP9b/10-11; TDP Sites 3, 7A, 7B, 8.

Cyclicargolithus floridanus (Roth & Hay *in* Hay *et al*., 1967) Bukry, 1971

Pl.2, figs 3-10. Small to large, subcircular reticulofenestrid coccoliths with high tube-cycle and narrow, vacant central-area. Great variability in size; smaller morphologies (<5μm) were logged separately. **Occurrence**: NP14b-23; TDP Sites 1, 2, 4, 6.

Reticulofenestra minuta Roth, 1970
Pl.2, figs 11-12

Reticulofenestra dictyoda (Deflandre *in* Deflandre & Fert, 1954) Stradner *in* Stradner & Edwards, 1968

Pl.2, figs 13-19. Name applied to all elliptical reticulofenestrid coccoliths <14μm, with relatively wide, vacant central-area (*e.g*. Bralower & Mutterlose, 1995). Informally grouped into small (<3μm: *Reticulofenestra minuta*), medium (3-5μm), large (5-7μm) and very large (7-14μm). *Reticulofenestra umbilicus* was reserved for those specimens >14μm, and seen only rarely.

Reticulofenestra umbilicus (Levin, 1965) Martini & Ritzkowski, 1968
Pl.2, fig.20

Reticulofenestra wadeae sp. nov.

Pl.2, figs 21-25. **Derivation of name**: After Dr. Bridget Wade (Univ. of Cardiff, UK), micropalaeontologist. **Diagnosis**: Medium- to large-sized, subcircular reticulofenestrid coccoliths with wide central-area (equal to width of shields) and no visible net or grill in LM. **Differentiation**: Subcircular outline distinguishes this species from most other reticulofenestrids, and the central area is wider than in *Cyclicargolithus*. Central-area wider than in *Reticulofenestra circus* de Kaenel & Villa, 1996, and smaller than in *Reticulofenestra hillae* Bukry & Percival, 1971. **Dimensions**: L = 5.8-10.3μm. **Holotype**: Pl.2, fig.23. **Paratype**: Pl.2, fig.24. **Type locality**: TDP Site 2, Kilwa Masoko, Tanzania. **Type level**: Middle Eocene, Sample TDP2-15-1, 89cm (Subzone NP15b). **Occurrence**: NP15b-c; TDP Site 2.

Reticulofenestra bisecta (Hay *et al*., 1966) Roth, 1970

Pl.2, figs 27-28. Used for reticulofenestrid coccoliths with a central plug that are >10μm (*NB* the holotype is ~8μm).

Reticulofenestra stavensis (Levin & Joerger, 1967) Varol, 1989

Pl.2, figs 29-30. Used for reticulofenestrid coccoliths with a central plug that are >10μm (*NB* the holotype is ~14μm). **Synonym**: *Reticulofenestra scrippsae* (Bukry & Percival, 1971) Roth, 1973 (holotype L = 9.5μm).

Reticulofenestra reticulata (Gartner & Smith, 1967) Roth & Thierstein, 1972
Pl.2, figs 31-34

Reticulofenestra lockeri Müller, 1970

Pl.2, fig.35; Pl.3, figs 1-5. Elliptical reticulofenestrids with weakly birefringent central-area nets are included in this species. **Occurrence**: NP17-23; TDP Sites 1, 4, 6.

Order COCCOSPHAERALES **Haeckel, 1894 emend. Young & Bown, 1997**

Family **COCCOLITHACEAE** Poche, 1913 emend. Young & Bown, 1997

Coccolithus pelagicus (Wallich, 1877) Schiller, 1930
Pl.3, figs 6-7; Pl.4, fig.1

Coccolithus cachaoi sp. nov.

Pl.3, figs 8-10. **Derivation of name**: After Dr. Mário Cachão (Univ. of Lisbon, Portugal), nannopalaeontologist. **Diagnosis**: Medium- to large-sized, elliptical *Coccolithus* coccoliths with narrow central-area spanned by broad, transverse, disjunct bar. **Remarks**: Some Neogene-Holocene *Coccolithus pelagicus* coccoliths have a central-area bar but are not given separate species status. The specimens observed here are considered distinct enough to warrant separate status. **Dimensions**: L = 8.7μm. **Holotype**: Pl.3, fig.8 (fig.9 same specimen). **Paratype**: Pl.3, fig.10. **Type locality**: TDP Site 2, Kilwa Masoko, Tanzania. **Type level**: Middle Eocene, Sample TDP2-28-1, 50cm (Subzone NP15a). **Occurrence**: NP14b/15a-15b; TDP Sites 2, 6.

Coccolithus eopelagicus (Bramlette & Riedel, 1954) Bramlette & Sullivan, 1961
Pl.3, fig.11

Coccolithus minimus sp. nov.
Pl.3, figs 12-15. **Derivation of name**: From *minimus*, meaning smallest, and referring to the size of this coccolith. **Diagnosis**: Small (<5μm), circular *Coccolithus* coccoliths with narrow, open central-area. **Differentiation**: Smaller than other circular *Coccolithus* coccoliths. **Dimensions**: L = 3.3-4.7μm. **Holotype**: Pl.3, fig.13 (fig.12 same specimen). **Paratype**: Pl.3, fig.14 (fig.15 same specimen). **Type locality**: TDP Site 7A, Kwamatola, Tanzania. **Type level**: Lower Eocene, Sample TDP7A-65-1, 70cm (Zone NP10). **Occurrence**: NP9b-15c; TDP Sites 2, 3, 6, 7A, 7B, 10.

Coccolithus formosus (Kamptner, 1963) Wise, 1973
Pl.3, figs 16-18; Pl.4, fig.2

Coccolithus crucis sp. nov.
Pl.3, figs 19-25. **Derivation of name**: From *crucis*, meaning cross, referring to the cross-bars that characterise this coccolith. **Diagnosis**: Large, circular *Coccolithus* coccoliths with narrow central-area spanned by thin cross-bars. **Remarks**: May represent intraspecific variation or a preservational morphotype of *Coccolithus formosus*. **Differentiation**: Like *C. formosus* but possessing central-area cross-bars. **Dimensions**: L = 8.5-9.7μm. **Holotype**: Pl.3, fig.21 (fig.22 same specimen). **Paratypes**: Pl.3, fig.23; Pl.3, fig.25 (fig.24 same specimen). **Type locality**: TDP Site 2, Kilwa Masoko, Tanzania. **Type level**: Middle Eocene, Sample TDP2-2-1, 15cm (Subzone NP15c). **Occurrence**: NP14b/15a-17; TDP Sites 2, 4, 6.

Coccolithus foraminis sp. nov.
Pl.3, figs 26-30. **Derivation of name**: From *foraminis*, meaning opening, referring to the open central-area that characterises this coccolith. **Diagnosis**: Large, subcircular *Coccolithus* coccoliths with wide, vacant central-area (less than or equal to width of shields). **Differentiation**: Like *C. formosus* but subcircular and with a wider central-area. **Dimensions**: L = 7.8-9.4μm. **Holotype**: Pl.3, fig.27 (fig.26 same specimen). **Paratype**: Pl.3 fig.29 (fig.30 same specimen). **Type locality**: TDP Site 7A, Kwamatola, Tanzania. **Type level**: Upper Paleocene, Sample TDP7A-65-1, 70cm (Zone NP10). **Occurrence**: NP10; TDP Site 7A.

Coccolithus latus sp. nov.
Pl.3, figs 31-35. **Derivation of name**: From *latus*, meaning broad or wide, referring to the wide central-area that characterises this coccolith. **Diagnosis**: Medium to large, elliptical *Coccolithus* coccoliths with wide (greater than width of shields), vacant central-area. **Differentiation**: Like *C. formosus* and *C. foraminis* but elliptical, and with a wider central-area. **Dimensions**: L = 6.8-8.1μm. **Holotype**: Pl.3, fig.33 (fig.32 same specimen). **Paratype**: Pl.3, fig.34 (fig.35 same specimen). **Type locality**: TDP Site 3, Mpara Hill, Tanzania. **Type level**: Lower Eocene, Sample TDP3-4-3, 52cm (Zone NP11). **Occurrence**: NP10/11-11; TDP Site 3.

Coccolithus mutatus (Perch-Nielsen, 1971) comb. nov.
Pl.4, figs 3-8. **Basionym**: *Cruciplacolithus mutatus* Perch-Nielsen, 1971, p.23, pl.15, fig.2; *Det Kongelige Danske Videnskabernes Selskab Biologiske Skrifter,* **18**: 1-76. **Remarks**: Very large (>14μm) *Coccolithus* with wide central-area and narrow, axial to slightly rotated cross-bars. Probably included in the *Chiasmolithus gigas* concept of Bramlette & Sullivan (1961). Not widely recorded since its first description.

The classification of Eocene Coccolithaceae coccoliths is problematical because of the presence of central-area cross-bars across generic groupings that are supposedly defined by the presence or absence of such bars, or particular orientations of bars. This species is included in *Coccolithus* because of the appearance of its rim (see also *Coccolithus staurion*). **Dimensions**: L = 14.8-19.2μm. **Occurrence**: NP14b/15a-15c; TDP Site 2.

Coccolithus staurion Bramlette & Sullivan, 1961
Pl.4, figs 9-13. **Remarks**: Large *Coccolithus* with narrow central-area and axial cross-bars. **Dimensions**: L = 7.6-15.0μm. **Occurrence**: NP10-15c; TDP Sites 2, 6, 7A, 7B, 8. **Synonym**: *Ericsonia insolita* Perch-Nielsen, 1971.

Ericsonia Black, 1964
Used here for circular, *Coccolithus*-like coccoliths that have broad upper tube-elements that dominate the distal shield. The dominance of the R-unit cycle results in a bright LM XPL image but the darker distal shield is seen clearly in PC.

Ericsonia subpertusa Hay & Mohler, 1967
Pl.4, figs 19-23. *Ericsonia* coccoliths with narrow, vacant central-area, usually narrower than the shields. **Occurrence**: NP9b; TDP10. Lower-Upper Paleocene (Perch-Nielsen, 1985).

Ericsonia robusta (Bramlette & Sullivan, 1961) Edwards & Perch-Nielsen, 1975
Pl.4, figs 24-29. Narrow rim with wide, vacant central-area that is wider than the shields. Large size-range (3.6-9.8μm, this work). **Occurrence**: NP9b; TDP10. Lower-Upper Paleocene (Perch-Nielsen, 1985).

Ericsonia staerkeri sp. nov.
Pl.4, figs 30-33. **Derivation of name**: After Scott Staerker, nannopalaeontologist (BP-Amoco, Houston, USA). **Diagnosis**: Small (<5.0μm), circular placolith dominated by a birefringent cycle in XPL, and with relatively wide central-area (just greater than shields) spanned by thin cross-bars. **Differentiation**: Similar to *E.*

robusta but smaller and with a central cross-structure. **Dimensions**: L = 4.1-4.3μm. **Holotype**: Pl.4, fig.31 (figs 30, 32 same specimen). **Paratype**: Pl.4, fig.33. **Type locality**: TDP Site 3, Mpara Hill, Tanzania. **Type level**: Lower Eocene, Sample TDP3-2-2, 64cm (Zone NP11). **Occurrence**: NP11; TDP Site 3. Rare.

Campylosphaera dela (Bramlette & Sullivan, 1961) Hay & Mohler, 1967

Pl.5, figs 1-10. Narrow, arched placoliths with axial cross-bars. High degree of variability in size (5-10μm) and outline, but do not fall easily into separate classes. There are broad trends in increasing size and increasing 'squareness' of outline, but I was unable to systematically differentiate *Campylosphaera eodela* Bukry & Percival, 1971 (smaller, more elliptical?) from *Campylosphaera dela*. In any case, the holotypes of the two species are extremely similar. The two names are used on Plate 5 only as an attempt to illustrate variations in morphology. **Occurrence**: NP9b-17; TDP Sites 2, 3, 4, 6, 7A, 7B, 8, 10.

Campylosphaera eroskayi (Varol, 1989) comb. nov.

Pl.5, figs 11-14. **Basionym**: *Clausicoccus eroskayi* Varol, 1989, pp.290-291, pl.2, fig.9; *Rev. Española de Micropaleont.*, **XXI**: 273-320. Small- to medium-sized (~4-6μm), *Campylosphaera*-like, broadly elliptical placolith (dark shields in XPL), with very narrow central-area filled with broad cross-bars. **Occurrence**: NP9b/10-10; Sites 7A, 7B.

Campylosphaera sp.2

Pl.5, figs 15-17. Medium to large (6.6-9.7μm), elliptical to oblong *Campylosphaera* with narrow central-area filled with broad cross-bars. **Occurrence**: NP9b/10-10; Sites 3, 7A, 7B, 8.

Cruciplacolithus Hay & Mohler *in* Hay *et al*., 1967

Generally considered a Paleocene genus (Perch-Nielsen, 1985) but consistently present, though typically rare, in the Early-Middle Eocene of the Tanzanian sections. The closely allied genera *Campylosphaera* and *Bramletteius* are also often common components of these assemblages.

Cruciplacolithus primus Perch-Nielsen, 1977
Pl.5, figs 18-19, 21, 24
Cruciplacolithus cf. *C. primus* Perch-Nielsen, 1977
Pl.5, figs 20, 22-23
Cruciplacolithus asymmetricus van Heck & Prins, 1987
Pl.5, figs 25-26
Cruciplacolithus edwardsii Romein, 1979
Pl.5, figs 27-29
Cruciplacolithus frequens (Perch-Nielsen, 1977) Romein, 1979
Pl.5, figs 30-32
Cruciplacolithus latipons Romein, 1979
Pl.5, figs 33-35; Pl.7, fig.16

Cruciplacolithus? *cassus* sp. nov.

Pl.6, figs 1-3. **Derivation of name**: From *cassus*, meaning empty, and referring to the apparent lack of structures in the central-area of this coccolith. **Diagnosis**: Bicyclic placolith with dark outer-cycle, slightly brighter inner-cycle and relatively wide central-area (approximately same width as shields). No central structures observed. **Dimensions**: L = 6.5μm **Holotype**: Pl.6, fig.1. **Paratype**: Pl.6, fig.2. **Type locality**: TDP Site 7A, Kwamatola, Tanzania. **Type level**: Lower Eocene, Sample TDP7A-2-1, 10cm (Zone NP10). **Occurrence**: NP10-11; TDP Sites 3, 7A.

Cruciplacolithus cruciformis (Hay & Towe, 1962) Roth, 1970

Pl.6, figs 4-10. Large (6-10μm), with narrow shields and axial to diagonal cross-bars. **Occurrence**: NP15a-17; TDP Sites 2, 4.

Bramletteius serraculoides Gartner, 1969
Pl.6, figs 11-15
Chiasmolithus bidens (Bramlette & Sullivan, 1961) Hay & Mohler, 1967
Pl.6, figs 16-20
Chiasmolithus consuetus (Bramlette & Sullivan, 1961) Hay & Mohler, 1967
Pl.6, figs 21-25
Chiasmolithus nitidus Perch-Nielsen, 1971
Pl.6, figs 26-30
Chiasmolithus gigas (Bramlette & Sullivan, 1961) Radomski, 1968
Pl.6, figs 31-35; Pl.7, figs 1-3
Chiasmolithus grandis (Bramlette & Riedel, 1954) Radomski, 1968
Pl.7, figs 4-11

Clausicoccus Prins, 1979

Used here for *Cruciplacolithus*-like coccoliths that have central-areas spanned by narrow (*Clausicoccus subdistichus*), broad (*Clausicoccus fenestratus* [syn. *C. cribellum* Bramlette & Sullivan, 1961]) or very broad (*Clausicoccus vanheckiae*) perforate plates. The species *latipons* is retained within *Cruciplacolithus* because of the clear nature of the cross, which nevertheless fills the central area.

Clausicoccus subdistichus (Roth & Hay *in* Hay *et al*., 1967) Prins, 1979
Pl.7, figs 12-15
Clausicoccus fenestratus (Deflandre & Fert, 1954) Prins, 1979
Pl.7, figs 17-21
Clausicoccus vanheckiae (Perch-Nielsen, 1986) de Kaenel & Villa, 1996
Pl.7, figs 22-26

Family **CALCIDISCACEAE** Young & Bown, 1997

Elliptical, subcircular and circular coccoliths with non-birefringent distal shields and narrow or closed central-areas. The Eocene specimens illustrated here are comparable in LM appearance to Neogene *Calcidiscus* coccoliths, hence the generic assignment below. However, further morphological analysis (in train) is necessary before this relationship can be confirmed.

6.1.1 Narrow-rimmed, circular/ring-shaped placoliths

?Family **CALCIDISCACEAE** Young & Bown, 1997

Coronocyclus bramlettei (Hay & Towe, 1962) comb. nov.

Pl.8, figs 1-7. **Basionym**: *Cyclolithus bramlettei* Hay & Towe, 1962, p.500, pl.5, fig.6; pl.7, fig.2; *Eclog. Geol. Helv.*, **55**: 497-517. **Remarks**: Small to medium (3.5-7.5μm), ring-shaped coccoliths, distinctly bicyclic in XPL. The two cycles are similar in width; the bright inner cycle is crossed by non-axial extinction lines. **Differentiation**: Like *Coronocyclus nitescens* but smaller (<7.5μm) and more distinctly bicyclic in XPL. **Occurrence**: NP9b-17; TDP Sites 2, 3, 4, 7A, 7B, 8.

Coronocyclus nitescens (Kamptner, 1963) Bramlette & Wilcoxon, 1967

Pl.8, figs 8-15. Large (>7.5μm), ring-shaped coccoliths, bicyclic in XPL. The birefringent cycle dominates the XPL image and is crossed by extinction lines that are non-axial. Outer edge typically serrated. **Occurrence**: NP17-23. LO NN6 (Young, 1998).

Umbilicosphaera? *jordanii* sp. nov.

Pl.8, figs 16-24. **Derivation of name**: After Dr. Ric Jordan, nannoplankton (palaeo)biologist. **Diagnosis**: Medium-sized (3.5-6.0μm), circular, ring-shaped placoliths with non-birefringent distal shield, narrow, bright tube-cycle crossed by non-axial extinction lines, and vacant central-area that is slightly wider than the shields. **Differentiation**: Broader shields than *C. bramlettei* and *C. nitescens*. Comparable in general morphology to *C.*? *protoannulus*, but lower-birefringent shield appearance and bright tube-cycle is less well defined in XPL. In addition, the extinction lines crossing the tube-cycle are near-axial in *C.*? *protoannulus* and near-diagonal in *U.*? *jordanii*. **Dimensions**: L = 2.4-2.8μm. **Holotype**: Pl.8, fig.18 (fig.19 same specimen). **Paratype**: Pl.8, fig.20. **Type locality**: TDP Site 8, Singino Hill, Tanzania. **Type level**: Lower Eocene, Sample TDP8-1-1, 30cm (Zone NP10). **Occurrence**: NP9b-23; TDP Sites 1, 8, 7A, 7B, 10.

Calcidiscus? *protoannulus* (Gartner, 1971) Loeblich & Tappan, 1978

Pl.8, figs 25-30. Small- to medium-sized (4.5-8.0μm), ring-shaped coccoliths that are distinctly bicyclic in XPL; bright inner-cycle narrower than outer cycle, and crossed by extinction lines that are near-axial. **Occurrence**: NP15b-23; TDP Sites 1, 2, 6.

Calcidiscus? *pacificanus* (Bukry, 1971) Varol, 1989

Pl.9, figs 1-10. Medium to large (6-9μm), circular-subcircular placoliths with closed central-area. Shield elements clearly visible, and proximal shield typically significantly smaller than distal. **Occurrence**: NP11-15c; TDP Sites 2, 3.

Calcidiscus bicircus sp. nov.

Pl.9, figs 11-23. **Derivation of name**: From *bi*, meaning two, and *circus*, meaning ring, referring to the bicyclic appearance of this coccolith. **Diagnosis**: Medium to large (5-9μm), circular-subcircular placoliths with non-birefringent distal shield and narrow to closed central-area surrounded by narrow, bright tube-cycle. **Differentiation**: Like *C.*? *pacificanus* but with bright inner tube-cycle. **Dimensions**: L = 5.1-8.2μm. **Holotype**: Pl.9, fig.11 (fig.12 same specimen). **Paratype**: Pl.9, fig.14 (fig.15 same specimen). **Type locality**: TDP Site 2, Kilwa Masoko, Tanzania. **Type level**: Middle Eocene, Sample TDP2-26-1, 15cm (Subzone NP15c). **Occurrence**: NP15a-17; TDP Sites 2, 4, 6.

Calcidiscus? *parvicrucis* sp. nov.

Pl.9, figs 24-28. **Derivation of name**: From *parvus*, meaning small, and *crucis*, meaning cross, referring to the small cross-bars that characterise this coccolith. **Diagnosis**: Medium-sized (5-6μm), circular-subcircular placoliths with non-birefringent distal shield, narrow, bright tube-cycle, and narrow central-area spanned by small, axial cross. **Differentiation**: Like *C.*? *bicircus* but with a small, axial cross. **Dimensions**: L = 5.0-6.2μm. **Holotype**: Pl.9, fig.24 (fig.25 same specimen). **Paratype**: Pl.9, fig.26. **Type locality**: TDP Site 7A, Kwamatola, Tanzania. **Type level**: Lower Eocene, Sample TDP7A-26-2, 35cm (Zone NP10). **Occurrence**: NP10-11; TDP Site 3, 7A, 8.

Calcidiscus? *henrikseniae* sp. nov.

Pl.9, figs 31-34. **Derivation of name**: After Karen Henriksen (Univ. of Copenhagen, Denmark), nannoplankton palaeobiologist and biomineralogist. **Diagnosis**: Medium-sized (6-7μm), elliptical placolith with non-birefringent distal shield, and vacant central-area approximately same width as shields. **Dimensions**: L = 6.1-7.0μm. **Holotype**: Pl.9, fig.33 (fig.34 same specimen). **Paratype**: Pl.9, fig.31 (fig.32 same specimen). **Type locality**: TDP Site 2, Kilwa Masoko, Tanzania. **Type level**: Middle Eocene, Sample TDP2-4-1, 50cm (Subzone NP15c). **Occurrence**: NP15b-c; TDP Site 2.

Calcidiscus? cf. *C.*? *henrikseniae* sp. nov.

Pl.9, figs 29-30. Like *C.*? *henrikseniae* but circular.

6.1.2 Placolith coccoliths *incertae sedis*

Hayella situliformis Gartner, 1969
Pl.10, figs 6-9
Hayella? *gauliformis* Troelsen & Quadros, 1971
Pl.10, fig.35

Tetralithoides symeonidesii Theodoridis, 1984
Pl.10, figs 11-12. Dark, elliptical coccoliths with central-area filled by four dark blocks joined along diagonal sutures. Not previously recorded in sediments older than Miocene (Young, 1998). **Occurrence**: NP15b-c; TDP Sites 2, 6.

Pedinocyclus larvalis Bukry & Bramlette, 1971
Pl.10, fig.14

Ellipsolithus anadoluensis Varol, 1989
Pl.10, figs 16-23. Rather inconspicuous *Ellipsolithus* species, with XPL image dominated by highly-birefringent tube-cycle; no central-area structure visible. Most commonly and continuously occurring *Ellipsolithus* in the Tanzanian sections. **Occurrence**: NP9b-11; TDP Sites 3, 7A, 7B, 8, 10

Ellipsolithus bollii Perch-Nielsen, 1977
Pl.10, figs 24-25
Ellipsolithus distichus (Bramlette & Sullivan, 1961) Sullivan, 1964
Pl.10, figs 26-28
Ellipsolithus macellus (Bramlette & Sullivan, 1961) Sullivan, 1964
Pl.10, figs 29-30
Ilselithina fusa Roth, 1970
Pl.20, fig. 30

6.2 Murolith coccoliths
6.2.1 Mesozoic survivor muroliths

Order EIFFELLITHALES **Rood *et al*., 1971**
Family **CHIASTOZYGACEAE** Rood *et al*., 1973

Jakubowskia leoniae Varol, 1989
Pl.11, figs 1-3. Elliptical with narrow rim and wide, vacant central-area. **Occurrence**: NP9b-11; TDP Sites 3, 7A, 7B, 8, 10. Rare. NP12 (Varol, 1989).

Neocrepidolithus grandiculus sp. nov.
Pl.11, figs 4-6. **Derivation of name**: From *grandiculus*, rather large, referring to the size of this species. **Diagnosis**: Medium to large murolith-coccolith with broad rim, unicyclic in XLP, and narrow, vacant central-area. The central-area width is variable, usually around the same width as the rim, but may be narrower or closed. **Differentiation**: Similar in morphology to the Jurassic species *Crepidolithus crassus* Deflandre, 1954, and distinguished from other Palaeogene *Neocrepidolithus* species by its larger size, open central-area, and simple, unicyclic rim-image. **Dimensions**: L = 7.0-13.5μm; W = 6.0-10.0μm. **Holotype**: Pl.11, fig.4. **Paratypes**: Pl.11, fig.5; Pl.11, fig.6. **Type locality**: TDP Site 7B, Kwamatola, Tanzania. **Type level**: Upper Paleocene/Lower Eocene, Sample TDP7B-51-1, 20cm (Zone NP9b/10). **Occurrence**: NP9-11; TDP Sites 3, 7A, 7B, 8, 10.

Zeugrhabdotus sigmoides (Bramlette & Sullivan, 1961) Bown & Young, 1997
Pl.11, figs 7-10

Staurolithites primaevus sp. nov.
Pl.11, figs 11-15. **Derivation of name**: From *primaevus*, young or youthful, and referring to the age of this coccolith. **Diagnosis**: Small (<4μm), elliptical muroliths with narrow, bicyclic rim, and narrow central-area spanned by small, axial cross. **Differentiation**: Similar to Mesozoic *Staurolithites* species but the only Cenozoic representative currently recognised; characterised by its small size and compact morphology. **Dimensions**: L = 3.2-3.6μm; W = 3.3-3.9μm. **Holotype**: Pl.11, fig.12 (fig.13 same specimen). **Paratype**: Pl.11, fig.14. **Type locality**: TDP Site 7B, Kwamatola, Tanzania. **Type level**: Lower Eocene, Sample TDP7A-50-1, 30cm (Zone NP9b/10). **Occurrence**: NP9b/10-11; TDP Sites 3, 7A, 7B, 8.

6.2.2 Cenozoic muroliths

Order ZYGODISCALES **Young & Bown, 1997**
Family **HELICOSPHAERACEAE** Black, 1971

Genus *Helicosphaera* Kamptner, 1954

Helicosphaera compacta Bramlette & Wilcoxon, 1967
Pl.11, figs 16-25. Elliptical with well-defined birefringent blanket in XPL and narrow central-area spanned by conjunct bar. **Occurrence**: NP17-23; TDP Sites 1, 4,

Helicosphaera clarissima sp. nov.
Pl.11, figs 26-35. **Derivation of name**: The superlative of *clarus*, meaning clear, bright, or distinct, and referring to the LM appearance of this coccolith. **Diagnosis**: Elliptical to almond-shaped *Helicosphaera* with well-defined birefringent blanket in XPL and central-area spanned by broad, oblique, disjunct, birefringent bar. **Differentiation**: Like *H. compacta* but with a disjunct bar; similar to *Helicosphaera heezenii* Bukry, 1971 but the latter has a longitudinal bar that fills the central-area. **Dimensions**: L = 7.5-11.5μm. **Holotype**: Pl.11, fig.33 (fig.34 same specimen). **Paratype**: Pl.11, fig.30. **Type locality**: TDP Site 4, near Ras Tipuli, Tanzania. **Type level**: Middle Eocene, Sample TDP4-1-3, 60cm (Zone NP17). **Occurrence**: NP17; TDP Site 4.

Helicosphaera lophota (Bramlette & Sullivan, 1961) Locker, 1973

Pl.12, figs 1-10. Elliptical, oblong or reniform with wide flange and central-area spanned by broad, near-longitudinal, disjunct bar with a distinct median suture. **Occurrence**: NP15b-c; TDP Sites 2, 6.

Helicosphaera reticulata Bramlette & Wilcoxon, 1967
Pl.12, figs 11-15

Helicosphaera seminulum Bramlette & Sullivan, 1961

Pl.12, figs 16-25. Elliptical with relatively wide central-area spanned by broad, transverse to slightly oblique, disjunct bar. Probably intergrades with *Helicosphaera bramlettei*. **Occurrence**: NP15b-23; TDP Sites 1, 2, 4, 6.

Helicosphaera bramlettei (Müller, 1970) Jafar & Martini, 1975

Pl.12, figs 26-35. Elliptical with relatively wide central-area spanned by broad, oblique, disjunct bar. **Occurrence**: NP15b-23; TDP Sites 1, 2, 4, 6.

Helicosphaera wilcoxonii (Gartner, 1971) Jafar & Martini, 1975

Pl.13, figs 1-5. Like *H. seminulum* but with a flange that ends in a spur. **Occurrence**: NP17; TDP Site 4.

Helicosphaera sp.2

Pl.13, figs 6-10. Almond-shaped helicoliths with near-longitudinal, disjunct bar that is dark at 0° in XPL. **Occurrence**: NP15b; TDP Site 6.

Helicosphaera sp.3

Pl.13, figs 11-15. Elliptical helicoliths with broad, disjunct bar filling central-area. **Occurrence**: NP17; TDP Site 4.

Helicosphaera ethologa sp. nov.

Pl.13, figs 16-22. **Derivation of name**: From *ethologus*, meaning mimic, and referring to the similarity between this coccolith and the younger *Helicosphaera carteri*. **Diagnosis**: Large helicoliths with a flange ending in a wing. Rather diffuse blanket image in XPL, and closed central-area or with two narrow, near-longitudinal slits. **Differentiation**: Very similar to the Neogene *Helicosphaera carteri*, hence the previous informal designation as *Helicosphaera* aff. *H. carteri* by de Kaenel & Villa (1996). Stratigraphic range is distinctly different and the wing is somewhat less strongly developed. **Dimensions**: L = 10.1-11.2μm. **Holotype**: Pl.13, fig.18 (figs 16, 17 same specimen). **Paratype**: Pl.13, fig.19 (fig.20 same specimen). **Type locality**: TDP Site 1, Kilwa Masoko, Tanzania. **Type level**: Lower Oligocene, Sample TDP1-14-1, 80cm (Zone NP23). **Occurrence**: NP23; TDP Site 1. NP23-24 (de Kaenel & Villa, 1996).

Helicosphaera obliqua Bramlette & Wilcoxon, 1967

Pl.13, figs 23-27. Elliptical to oblong with a wing that ends in a spur, and two oblique slits that cross the central-area. **Occurrence**: NP23; Site TDP6. NP23-NN6 (Young, 1998). **Synonym**: *Helicosphaera perch-nielseniae* Haq, 1971.

Helicosphaera recta Haq, 1966 (Jafar & Martini, 1975)
Pl.13, figs 28-30

Family **PONTOSPHAERACEAE** Lemmermann, 1908

Genus *Pontosphaera* Lohmann, 1902

Used here for all low-rimmed pontosphaerid coccoliths (cribriliths of some authors), including those with well-defined bridges that are classified as *Transversopontis* by some authors. Divided informally into two groups, differentiated on the presence or absence of plate ornamentation.

***Pontosphaera plana* group**

Pontosphaerids with plain, unornamented rims and plates.

Pontosphaera plana (Bramlette & Sullivan, 1961) Haq, 1971

Pl.14, figs 1-6. Simple, unadorned plate, typically with two narrow, longitudinal slits. *Pontosphaera inconspicua* (Sullivan, 1964) was used for small, early specimens. **Occurrence**: NP9b-17; TDP Sites 2, 3, 4, 7A, 7B, 8, 10.

Pontosphaera versa (Bramlette & Sullivan, 1961) Sherwood, 1974

Pl.14, figs 7-13. Simple, unadorned plate, typically with two longitudinal slits, and a broad raised margin/rim. **Occurrence**: NP10-23; TDP Sites 2, 3, 4, 6, 7A, 7B, 8. **Synonym**: *Pontosphaera scissura* (Perch-Nielsen, 1971) Romein, 1979.

Pontosphaera panarium (Deflandre *in* Deflandre & Fert, 1954) Aubry, 1986

Pl.14, figs 14-15. Like *P. versa* but plate dark in XPL. **Occurrence**: NP23; TDP Sites 1, 6.

Pontosphaera ocellata (Bramlette & Sullivan, 1961) Perch-Nielsen, 1984

Pl.14, figs 16-18. Simple, unadorned plate with two closely spaced, longitudinally-arranged holes; rim/margin usually distinct from plate in XPL, but not as high as in, *e.g.*, *P. versa*. Difficult to systematically differentiate from other species, *e.g. Pontosphaera exilis*. **Occurrence**: NP11; TDP Site 3.

Pontosphaera duocava (Bramlette & Sullivan, 1961) Romein, 1979

Pl.14, figs 19-20. Simple, unadorned plate with two widely-spaced, longitudinally-arranged holes; rim usually distinct from plate in XPL, and can be relatively high.

Difficult to systematically differentiate from other species. **Occurrence**: NP11; TDP Site 3.

Pontosphaera exilis (Bramlette & Sullivan, 1961) Romein, 1979

Pl.14, figs 21-30. Simple, unadorned plate with two large holes that define a transverse bar; rim narrow and not distinct in XPL. Hole size, and thus bar-width, vary greatly. Bar typically transverse but may be slightly oblique. This species concept is similar to that of *Pontosphaera rectipons* Haq, 1968 but the holotype of the latter is poor and probably not a pontosphaerid. **Occurrence**: NP9b/10-17; TDP Sites 2, 3, 4, 7A, 7B, 8.

Pontosphaera obliquipons (Deflandre *in* Deflandre & Fert, 1954) Romein, 1979

Pl.14, figs 31-35. Simple, unadorned plate with large, central hole spanned by oblique bar that is crystallographically disjunct. Bar birefringent at 0° (*i.e.* when the coccolith is orientated parallel to the polarisers) and dark at 10°. **Occurrence**: NP14b/15a-15c; TDP Sites 1, 2, 6.

Pontosphaera rimosa (Bramlette & Sullivan, 1961) Roth & Thierstein, 1972

Pl.15, figs 1-5. Simple, unadorned plate with large, central hole; rim narrow and not distinct from plate in XPL. **Occurrence**: Intra-NP9b; TDP Site 10.

Pontosphaera multipora (Kamptner, 1948 ex Deflandre, 1954) Roth, 1970

Pl.15, figs 6-12. Simple, unadorned plate with up to three concentric cycles of small perforations; rim narrow and not distinct from plate in XPL. **Occurrence**: NP14b/15-23; TDP Sites 1, 2, 4, 6.

Pontosphaera distincta (Bramlette & Sullivan, 1961) Roth & Thierstein, 1972

Pl.15, figs 13-15. Large, thick coccolith (orange birefringence in XPL) with broad, thickened rim/margin and relatively thick, narrow, perforate central plate. **Occurrence**: NP15b-c; TDP Site 2.

***Pontosphaera pectinata* group**

Pontosphaerids with rims and plates that are adorned with depressions, furrows and slits.

Pontosphaera pectinata (Bramlette & Sullivan, 1961) Sherwood, 1974

Pl.15, figs 16-18. Plate scalloped towards outer edge and pierced by two longitudinal slits or small holes. The scalloping is defined by narrow, radial ridges and furrows that run inwards towards the centre. **Occurrence**: NP11-17; TDP Sites 2, 3, 4, 6.

Pontosphaera cf. *P. pectinata* (Bramlette & Sullivan, 1961) Sherwood, 1974

Pl.15, figs 19-20. Like *P. pectinata* but with single cycle of small holes near centre of plate. **Occurrence**: NP15b; TDP Site 2. Rare.

Pontosphaera clinosulcata sp. nov.

Pl.15, figs 21-25. **Derivation of name**: From *sulcus*, meaning furrow, and *clinatus*, meaning inclined, referring to the inclined furrows and pores that characterise this coccolith. **Diagnosis**: Medium to large, elliptical coccolith with a plate that is scalloped towards its outer edge. Scalloping defined by narrow, inclined ridges that run inwards towards the centre. There are inclined furrows between the ridges and inclined elongate pores; there may be two central, longitudinal slits. Rim narrow and difficult to distinguish in XPL. **Differentiation**: Similar to *P. pectinata* but characterised by distinctly inclined pores and furrows. **Dimensions**: L = 7.7-9.8μm. **Holotype**: Pl.15, fig.22 (fig.21 same specimen). **Paratype**: Pl.15, fig.24. **Type locality**: TDP Site 2, Kilwa Masoko, Tanzania. **Type level**: Middle Eocene, Sample TDP2-24-1, 27cm (Subzone NP15b). **Occurrence**: NP15b; TDP Site 2.

Pontosphaera punctosa (Bramlette & Sullivan, 1961) Perch-Nielsen, 1984

Pl.15, figs 26-30. Plate with marginal furrows and small pores, with larger pores towards the centre. **Occurrence**: NP10; TDP Site 7A.

Pontosphaera perforomarginata sp. nov.

Pl.15, figs 31-33. **Derivation of name**: From *marginatus*, meaning margin, and *perforo*, meaning pierced, referring to the central-area pores that characterise this coccolith. **Diagnosis**: Large, elliptical coccolith with plate pierced by small pores and two central, longitudinal holes that define a conjunct bar. Plate thickens towards edge but rim difficult to distinguish in XPL. **Differentiation**: Similar to *P. multipora* but with two longitudinal holes. **Dimensions**: L = 7.9-9.0μm. **Holotype**: Pl.15, fig.32 (fig.33 same specimen). **Paratype**: Pl.15, fig.31. **Type locality**: TDP Site 3, Mpara Hill, Tanzania. **Type level**: Lower Eocene, Sample TDP3-11-1, 56cm (Zone NP11). **Occurrence**: NP11; TDP Site 3.

Pontosphaera pulchra (Deflandre *in* Deflandre & Fert, 1954) Romein, 1979

Pl.15, figs 34-35; Pl.16, figs 1-3. Like *P. pectinata* but the two central holes larger, defining transverse bar. **Occurrence**: NP11-14b/15a; TDP Sites 2, 3.

Pontosphaera pulcheroides (Sullivan, 1964) Romein, 1979

Pl.16, figs 4-5. The central-area plate has a row of small pores towards its outer edge and a large central hole spanned by an oblique, transverse bar. **Occurrence**: NP14b/15a; TDP Site 2. Rare.

Pontosphaera formosa (Bukry & Bramlette, 1968) Romein, 1979

Pl.16, figs 6-16. Large (9-17μm), with high, flaring rim that displays discernible elements in LM. Plate thin and indistinct in XPL. **Occurrence**: NP14b/15a-17; TDP Sites 2, 4, 6.

Pontosphaera fimbriata (Bramlette & Sullivan, 1961) Romein, 1979

Pl.16, figs 17-18. Like *P. formosa* but plate has two large holes that define a transverse bar. **Occurrence**: NP14b-15a; TDP Site 2.

Genus *Scyphosphaera* Lohmann, 1902

For reviews see Aubry (1990) and Siesser (1998).

Scyphosphaera apsteinii Lohmann, 1902

Pl.16, figs 19-21; Pl.17, fig.1. Large (up to 24μm), elevated murolith (*i.e.* cup-, barrel-, or vase-shaped; lopadoliths of some authors) with variable morphology but typically broad, with curved, gently flaring walls that may narrow distally. **Occurrence**: NP14b/15b; TDP Site 2. Rare. NP12-living (Siesser, 1998).

Scyphosphaera columella Stradner, 1969

Pl.16, fig.22; Pl.17, figs 2-5. Tall (up to 26μm), narrow murolith with near-straight walls that are parallel, or very slightly flaring to a maximum width at the distal end. **Occurrence**: NP15bc; TDP Site 2. Rare. NP12-16 (Siesser, 1998).

Scyphosphaera cylindrica Kamptner, 1955

Pl.16, fig.23; Pl.17, figs 6-7. Tall (up to 26μm), relatively broad murolith with straight, parallel-sided walls. **Occurrence**: NP15b; TDP Site 2. Rare. NP12-NN21a (Siesser, 1998).

Scyphosphaera expansa Bukry & Percival, 1971

Pl.16, figs 24-25; Pl.17, figs 11-13. Tall (up to 31μm), relatively broad murolith with flaring walls. **Occurrence**: NP15b-c; TDP Site 2. Rare. NP12-NN21a (Siesser, 1998).

Scyphosphaera tercisensis Lezaud, 1969

Pl.16, fig.26

Family **ZYGODISCACEAE** Hay & Mohler, 1967

Lophodolithus acutus Bukry & Percival, 1971

Pl.18, figs 6-7

Lophodolithus nascens Bramlette & Sullivan, 1961

Pl.18, figs 1-5

Lophodolithus mochlophorus Deflandre *in* Deflandre & Fert, 1954

Pl.18, figs 11-12

Lophodolithus rotundus Bukry & Percival, 1971

Pl.18, figs 8-10, 13-14

Zygodiscus plectopons Bramlette & Sullivan, 1961

Pl.18, figs 15-24. Murolith with wide central-area spanned by parallel side-bar. Some specimens (Pl.18, figs 20-22) show more complex bar construction with crystallographically-distinct units. **Occurrence**: NP9b-11; TDP Sites 3, 7A, 7B, 10. **Synonyms**: *Zygodiscus bramlettei* Perch-Nielsen, 1981; *Zygodiscus herlynii* Sullivan, 1964.

Zygodiscus sheldoniae sp. nov.

Pl.18, figs 25-34. **Derivation of name**: After Emma Sheldon (GEUS, Denmark), nannopalaeontologist. **Diagnosis**: Medium- to large-sized murolith, with broad plate enclosing small disjunct bar. **Remarks**: Like *Zygodiscus clausus*, this species may represent intermediate morphology between the genera *Pontosphaera* and *Zygodiscus*. **Differentiation**: Like pontosphaerids but with a disjunct bar. Similar to *Z. clausus* but with broader plate and smaller bar. **Dimensions**: L = 6.6-9.5μm. **Holotype**: Pl.18, fig.27 (figs 28, 29 same specimen). **Paratype**: Pl.18, fig.32 (figs 33, 34 same specimen). **Type locality**: TDP Site 10, Singino Hill, Tanzania. **Type level**: Upper Paleocene, Sample TDP10-14-1, 50cm (Subzone NP9b). **Occurrence**: NP9b; TDP Site 10.

Zygodiscus clausus Romein, 1979

Pl.19, figs 1-5. Medium-sized, elliptical murolith comprising an unadorned plate with central hole spanned and filled by a disjunct bar; rim narrow and cannot be differentiated in XPL. The precise crystallographic orientation of the bar appears to vary. This morphology may represent a transitional form between the genera *Zygodiscus* and *Pontosphaera*. **Occurrence**: NP9b; TDP Site 10.

Neochiastozygus concinnus (Martini, 1961) Perch-Nielsen, 1971

Pl.19, figs 6-10. Diagonal cross with bars that do not flare at their ends. Cross-bars make an angle of ~40°. **Occurrence**: NP9b/10; TDP Site 7B.

Neochiastozygus rosenkrantzii (Perch-Nielsen, 1971) Varol, 1989

Pl.19, figs 11-20. Broad, diagonal cross-bars that flare at their ends. General trend towards larger coccoliths through its range. Cross-bars make an angle of ~40°. **Occurrence**: NP9b-11; TDP Sites 3, 7A, 7B, 8, 10.

Neochiastozygus substrictus sp. nov.

Pl.19, figs 21-25. **Derivation of name**: From *substrictus*, meaning narrow, referring to the outline that characterises this coccolith. **Diagnosis**: Medium-sized, narrowly elliptical murolith with slightly asymmetrical, diagonal cross. Cross-bars make an angle of 30-40°. **Dimensions**: L = 6.4-8.0μm; W = 3.3-3.9μm. **Holotype**: Pl.19, fig.24 (fig.23 same specimen). **Paratype**: Pl.19, fig.22 (fig.21 same specimen). **Type locality**: TDP Site 10, Singino Hill, Tanzania. **Type level**: Upper Paleocene, Sample TDP10-40-3, 68cm (Subzone NP9b). **Occurrence**:

NP9b-10; TDP Sites 7B, 10.

Neochiastozygus junctus (Bramlette & Sullivan, 1961) Perch-Nielsen, 1971

Pl.19, figs 26-30. Large coccoliths with diagonal cross-bars that form an angle of ~20°. **Occurrence**: NP9b/10-11; TDP Sites 3, 7A, 7B, 8.

Neochiastozygus imbriei Haq & Lohmann, 1975

Pl.19, figs 31-35. Narrow-rimmed *Neochiastozygus* with narrow, typically asymmetric, curving cross-bars that cross at an obtuse angle. Previously recorded from the Lower Paleocene only (Perch-Nielsen, 1985). **Occurrence**: NP9b-11; TDP Sites 3, 7A, 8, 7B, 10.

Neochiastozygus distentus (Bramlette & Sullivan, 1961) Perch-Nielsen, 1971

Pl.20, figs 1-5. *Neochiastozygus* with narrow central-area filled with diagonal cross-bars that are embedded into the rim. **Occurrence**: NP9b-10; TDP Sites 7A, 7B. **Synonym**: *Neocrepidolithus bukryi* Perch-Nielsen, 1981.

Neochiastozygus macilentus sp. nov.

Pl.20, figs 6-10. **Derivation of name**: From *macilentus*, meaning thin or skinny, and referring to the narrow rim and bars of these coccoliths. **Diagnosis**: Medium to large *Neochiastozygus* coccoliths with narrow rim and wide central-area spanned by narrow cross-bars that make an angle of ~30°. **Dimensions**: L = 8.4-9.1μm. **Holotype**: Pl.20, fig.8 (fig.7 same specimen). **Paratype**: Pl.20, fig.9 (fig.10 same specimen). **Type locality**: TDP Site 7B, Kwamatola, Tanzania. **Type level**: Lower Eocene, Sample TDP7B-48-1, 30cm (Zone NP10). **Occurrence**: NP9b/10-10; TDP Site 7B.

Neococcolithes protenus (Bramlette & Sullivan, 1961) Black, 1967
Pl.20, figs 11-15

Order SYRACOSPHAERALES **Hay, 1977 emend. Young *et al*., 2003**
Family **CALCIOSOLENIACEAE** Kamptner, 1927

Calciosolenia fossilis (Deflandre *in* Deflandre & Fert, 1954) Bown *in* Kennedy *et al*., 2000
Pl.20, figs 16-17

Calciosolenia aperta (Hay & Mohler, 1967) comb. nov.

Pl.20, figs 18-20. **Basionym**: *Scapholithus apertus* Hay & Mohler, 1967, p.1534, pl.201, fig.12; *Journal of Paleontology*, **41**: 1505-1541. **Remarks**: The genus *Scapholithus* is a junior synonym of the extant genus *Calciosolenia* (see discussions in Bown *in* Kennedy *et al*., 2000; Young *et al*., 2003). **Synonym**: *Scapholithus rhombiformis* Hay & Mohler, 1967.

Family **SYRACOSPHAERACEAE** Lemmermann, 1908

Syracosphaera? *tanzanensis* sp. nov.

Pl.20, figs 21-25. **Derivation of name**: From Tanzania, the type area of this material. **Diagnosis**: Medium-sized muroliths with narrow, bicyclic rim (bright inner-cycle, dark outer-cycle) and wide central-area. Central-area structure not clear in LM but may be a thin plate. **Differentiation**: Similar to larger Neogene and extant *Syracosphaera* coccoliths, hence the tentative generic designation, but the bright cycle is more dominant in the XPL image. **Dimensions**: L = 5.1-5.4μm. **Holotype**: Pl.20, fig.23 (figs 24, 25 same specimen). **Paratype**: Pl.20, fig.21 (fig.22 same specimen). **Type locality**: TDP Site 1, Kilwa Masoko, Tanzania. **Type level**: Lower Oligocene, Sample TDP1-20-2, 24cm (Zone NP23). **Occurrence**: NP23; TDP Site 1.

Family **RHABDOSPHAERACEAE** Haeckel, 1894

Genus *Blackites* Hay & Towe, 1962

Most of the Tanzanian Palaeogene rhabdolith coccoliths display comparable rim structure in LM. Two distinct units are visible: an inner cycle that is widest, thickest, and brightest in side and plan views, and an outer cycle that is darker and smaller. The outer cycle can lie distally over the inner cycle, or side by side, but always protrudes further laterally, forming the outer edge of the coccolith. All rhabdoliths showing this structure have been included in *Blackites*. There are a number of informal groupings used below but I submit that electron microscope study may reveal morphological features that allow further systematic subdivision of the group. See also Shafik (1989), Kleijne (1992) and Aubry (1999) for taxonomic reviews of the family.

***Blackites gladius* group**

Moderately tall, and narrow to wide, spines with distinct rim structure, only seen in this group (*B. creber, B. gladius, B. rotundus*), in which the outer cycle lies distally over the inner cycle (see above).

Blackites creber (Deflandre *in* Deflandre & Fert, 1954) Sherwood, 1974

Pl.21, figs 1-9. Rhabdoliths with tall, narrow, hollow, styliform spines, near-parallel for much of their length, but that may broaden slightly in the upper half. Upper quarter of spines display distinctive striated pattern. Coccolith relatively broad, spine usually less than half its width, and may show a basal collar. **Differentiation**: Similar to *Blackites gladius* but with a narrower spine that is near-parallel for much of its length; the two species probably intergrade. **Dimensions**: H = 13.1-18.4μm; CW = 4.1-5.8μm; SW = 1.0-2.3μm. **Occurrence**: NP14b/15a-c; TDP Sites 2, 4, 6.

Blackites gladius (Locker, 1967) Varol, 1989

Pl.21, figs 10-14. Rhabdoliths with hollow, flask-like spines that are narrow at their base, widen to a maximum around three-quarters of the way up, and taper to a point; upper half of spines display distinctive striated pattern. Coccoliths broad, and spine usually around half the width, with prominent basal collar. **Differentiation**: Similar to *B. creber* but with a broader, more inflated, spine; the two species probably intergrade. *Blackites rotundus* has similar morphology but a more globose spine; the two species probably intergrade. The rim structure is distinctly different to other coccoliths with similar spine morphologies, such as *Blackites bullatus*. **Dimensions**: H = 5.7-10.8μm; CW = 4.7-5.6μm; SW = 2.0-2.8μm. **Occurrence**: NP14b/15a-17; TDP Sites 2, 4, 6.

Blackites rotundus sp. nov.

Pl.21, figs 15-19. **Derivation of name**: From *rotundus*, meaning rounded, referring to the globose spine morphology. **Diagnosis**: Rhabdoliths with hollow, flask-like spines that are narrow at their base, and wide and rounded distally; inflated part of spine displays distinctive striated pattern. Coccolith broad, and outer cycle lies distally over inner cycle and forms outer edge of coccolith. Spine greater than half width of coccolith, and usually has a prominent basal collar. **Differentiation**: Similar to *B. gladius* but with a broader, rounder, more-inflated spine. **Dimensions**: H = 7.1-8.5μm; CW = 4.3-5.5μm; SW = 3.1-3.7μm. **Holotype**: Pl.21, fig.17 (figs 15, 16 same specimen). **Paratype**: Pl.21, fig.19. **Type locality**: TDP Site 2, near Kilwa, Tanzania. **Type level**: Middle Eocene, Sample TDP2-2-1, 15cm (Subzone NP15c). **Occurrence**: NP15b-c; TDP Site 2.

***Blackites morionum* group**

Short to moderately tall and wide spines, and typical *Blackites* rim-structure in which the two cycles lie side by side, the outer cycle being smaller.

Blackites morionum (Deflandre *in* Deflandre & Fert, 1954) Varol, 1989

Pl.21, figs 20-24. Rhabdolith with relatively low, wide, hollow, sacculiform spine; there may be a small, terminal papilla. Coccolith relatively broad, and typically the height and width are similar. The spine broadens slightly before tapering to a point and is always slightly narrower than the coccolith rim. **Dimensions**: H = 3.6-4.6μm; CW = 3.6-5.6μm; SW = 2.5-4.4μm. **Occurrence**: NP9b-23; TDP Sites 1, 2, 3, 4, 6, 7A, 7B 8, 10.

Blackites cf. *B. morionum* (Deflandre *in* Deflandre & Fert, 1954) Varol, 1989

Pl.21, figs 25-29. Like *B. morionum* but spine taller and terminates rather abruptly and bluntly. **Occurrence**: NP11-14b/15a; TDP Sites 2, 3.

Blackites gamai sp. nov.

Pl.21, figs 30-34; Pl.22, figs 1-5. **Derivation of name**: After Rui da Gama, nannopalaeontologist (Network Stratigraphic, UK). **Diagnosis**: Rhabdolith with broad, hollow, bullet-shaped spine that initially broadens slightly before tapering gently to a point. Typically, height of spine greater than coccolith width. **Dimensions**: H = 6.1-6.5μm; CW = 4.3-4.4μm. **Holotype**: Pl.21, fig.34 (figs 30-33 same specimen). **Paratype**: Pl.22, fig.1 (figs 2, 3 same specimen). **Type locality**: TDP Site 3, Mpara Hill, Tanzania. **Type level**: Lower Eocene, Sample TDP3-5-1, 13cm (Zone NP11). **Occurrence**: NP11; TDP Site 3.

Blackites bullatus sp. nov.

Pl.22, figs 6-10. **Derivation of name**: From *bullatus*, meaning inflated, referring to the spine shape. **Diagnosis**: Rhabdolith with hollow, bulb-shaped spine (maximum width similar to that of the coccolith); rim relatively broad and outer cycle does not lie distally over inner cycle. **Differentiation**: Similar to *Blackites globosus* but with a narrower spine, and *B. rotundus* but has a broader, more rounded spine and an outer rim-cycle that does not lie distally above the inner cycle. **Dimensions**: H = 9.9-11.0μm; CW = 3.9-4.6μm; SW = 2.2-2.9μm. **Holotype**: Pl.22, fig.6. **Paratype**: Pl.22, fig.8. **Type locality**: TDP Site 2, near Kilwa, Tanzania. **Type level**: Middle Eocene, Sample TDP2-35-2, 49cm (Subzones NP14b/15a). **Occurrence**: NP14b/15a; TDP Site 2 (several questionable specimens were also recorded from NP15b and NP15c of the same section).

Blackites globosus sp. nov.

Pl.22, figs 11-20. **Derivation of name**: From *globosus*, meaning rounded or spherical, referring to the shape of the spine. **Diagnosis**: Rhabdolith with hollow spine that rapidly expands into a sphere (maximum width almost twice that of the coccolith). Spine has a short, narrow collar, a pinched distal termination, and shows a distinctive cross-hatched pattern in its upper part. Rim relatively broad and outer cycle does not lie distally over inner cycle. **Differentiation**: Similar to *B. bullatus* but with a spine that is near spherical. **Dimensions**: H = 10.0-10.4μm; CW = 3.8-4.0μm; SW = 1.42-1.49μm. **Holotype**: Pl.22, fig.11 (figs 12, 13 same specimen). **Paratype**: Pl.22, fig.14 (fig.15 same specimen). **Type locality**: TDP Site 6, near Kilwa, Tanzania. **Type level**: Middle Eocene, Sample TDP6-8-1, 63.5cm (Subzone NP15b). **Occurrence**: NP15b; TDP Sites 2, 6.

Blackites fustis sp. nov.

Pl.22, figs 21-25. **Derivation of name**: From *fustis*, meaning club, referring to the spine shape. **Diagnosis**: Rhabdolith with relatively wide, hollow, flask-like spine that is initially near-parallel-sided, expands distally, and then terminates sharply in a domed top, often with a small papilla. The spine reaches a width similar to that of the coccolith. Rim relatively broad and outer cycle does not lie distally over inner cycle. **Differentiation**: Resembles *B. rotundus*, *B. gladius* and *B. bullatus* but has distinct spine morphology, particularly the rapid termination to form a domed spine-top. **Dimensions**: H = 6.2-6.9μm; CW = 3.7-4.5μm; SW = 3.7-4.6μm. **Holotype**: Pl.22, fig.21 (fig.22 same specimen). **Paratype**: Pl.22, fig.24. **Type locality**: TDP Site 2, near Kilwa, Tanzania. **Type level**: Middle Eocene, Sample TDP2-2-1, 15cm (Subzone NP15c). **Occurrence**: NP15b-15c; TDP Sites 2, 6.

Blackites pseudomorionum (Locker, 1967) Aubry, 1999

Pl.22, figs 26-30. Rhabdoliths with relatively tall, broad, hollow spine that widens to a maximum, and then tapers sharply to a point, forming a distinctive angular inflection point. The inflection point appears to be at the junction of two structural units that are distinct in XPL. Typically, spine much taller than (x2), but approximately same width as, coccolith. **Dimensions**: H = 5.8-9.0μm; CW = 3.8-3.9μm; SW = 3.7-4.9μm, but smaller forms also occur (3.7μm x 1.7μm x 2.2μm). **Occurrence**: NP14b/15a-c; TDP Site 2 (possibly Oligocene, TDP Site 1). Rare.

Blackites deflandrei (Perch-Nielsen, 1968) comb. nov.

Pl.22, figs 31-35. **Basionym**: *Naninfula deflandrei* Perch-Nielsen, 1968, p.2299, pl.1, fig.3; *C. R. Acad. Sci., Paris*, **267**: 2298-2300. **Remarks**: Rhabdolith with relatively low, wide, hollow, sacculiform spine, constructed from at least two distinct structural units when viewed in XPL; there may be a small, terminal papilla. Typically, height and width similar but height can be greater. Spine broadens slightly to a maximum in the lower cycle, before tapering to a point; spine always slightly narrower than coccolith. The holotype is an electron micrograph but appears to represent the same morphology as those recorded here (see also Aubry, 1999). The rim-structure appears identical to other *Blackites* rhabdoliths of this age, and the species is therefore placed within this genus. **Differentiation**: Similar to *B. morionum* but has multi-cycle spine-construction when viewed in XPL. **Dimensions**: H = 3.3-6.1μm; CW = 4.2-4.3μm; SW = 2.1-4.1μm. **Occurrence**: NP14b/15a-c; TDP Site 2.

Blackites bipartitus sp. nov.

Pl.23, figs 1-5. **Derivation of name**: From *bipartitus*, meaning divided into two, referring to the two-part construction of the spine. **Diagnosis**: Rhabdolith with flask-like spine, constructed from two distinct structural units when viewed in XPL. The short lower-spine unit broadens away from the coccolith and the longer upper-spine cycle tapers to a point. Rim dominated by inner of the two cycles; outer cycle does not lie distally over inner cycle. Typically, height is around twice width, and maximum spine width is similar to that of coccolith. **Differentiation**: The two-part spine structure is similar to that seen in *B. deflandrei* and *B. pseudomorionum*, but the lower-spine unit is smaller and the upper-spine cycle longer. **Dimensions**: H = 5.1-6.2μm; CW = 2.7-3.0μm; SW = 2.7-3.0μm. **Holotype**: Pl.23, fig.1 (figs 2, 3 same specimen). **Paratype**: Pl.23, fig.4 (fig.5 same specimen). **Type locality**: TDP Site 2, near Kilwa, Tanzania. **Type level**: Middle Eocene, Sample TDP2-28-1, 50cm (Subzone NP15b). **Occurrence**: NP14b/15a; TDP Site 2.

Blackites turritus sp. nov.

Pl.23, figs 6-10. **Derivation of name**: From *turritus*, meaning having turrets, referring to the turret-like spine morphology. **Diagnosis**: Rhabdolith with tall spine, constructed from at least two or three distinct structural/crystallographic units when viewed in XPL; there may be a small, terminal papilla. Typically, spine taller than width of coccolith, and near-parallel-sided, or slightly tapering, before terminating quite sharply; spine usually about half width of coccolith. Rim relatively broad and outer cycle does not lie distally over inner cycle. **Dimensions**: H = 3.9-5.8μm; CW = 3.6-4.6μm; SW = 2.2-2.7μm. **Holotype**: Pl.23, fig.6 (figs 7, 8 same specimen). **Paratype**: Pl.23, fig.10. **Type locality**: TDP Site 7B, near Kwamatola, Tanzania. **Type level**: Lower Eocene, Sample TDP7B-33-1, 20cm (Zone NP10). **Occurrence**: NP9b/10-10; TDP Sites 7A, 7B.

Blackites clavus sp. nov.

Pl.23, figs 11-15. **Derivation of name**: From *clavus*, meaning nail, referring to the general shape of the coccolith and spine. **Diagnosis**: Rhabdolith coccoliths with short spine that tapers rapidly to a point. Typically, spine similar in height to width of coccolith. Rim relatively broad; outer cycle small and does not lie distally over inner cycle. In overall shape, coccolith and spine resemble a short nail or pin. **Differentiation**: The spine tapers from the base and thus differs from most other morphologies in the *B. morionum* group. **Dimensions**: H = 5.2-5.5μm; CW = 3.6-3.9μm; SW = 2.1-2.2μm. **Holotype**: Pl.23, fig.11. **Paratype**: Pl.23, fig.13. **Type locality**: TDP Site 7A, near Kwamatola, Tanzania. **Type level**: Lower Eocene, Sample TDP7A-57-1, 55cm (Zone NP10). **Occurrence**: NP10; TDP Sites 7A, 7B, 8.

Blackites atanii (Varol, 1989) comb. nov.

Pl.23, figs 16-20. **Basionym**: *Cruxia atanii* Varol, 1989, p.292, pl.4, figs 25-27; *Rev. Española de Micropaleont.*, **XXI**: 273-320. **Remarks**: Small rhabdolith with relatively low, hollow, sacculiform spine that broadens rapidly from a narrow base, and then tapers to form a low, pointed dome. Typically, height and width are similar; spine similar in width to, or slightly wider than, coccolith. All specimens have identical LM rim-structure to other Palaeogene rhabdoliths and the species is therefore included in *Blackites*. **Differentiation**: Resembles *B. morionum* but the spine broadens from a narrow neck at the spine-base. **Dimensions**: H = 2.5-3.9μm; CW = 2.2-3.2μm; SW = 2.7-3.1μm. **Occurrence**: NP11-NP15b; TDP Sites 2, 3.

Cruxia mericii Varol, 1989

Pl.23, figs 21-25. Small rhabdoliths with relatively low, hollow, sacculiform spines. Spine broadens from base and is capped by curving upper surface that appears to be constructed from two parts (XPL); spine usually slightly wider than coccolith. Coccolith rim appears to be narrow, and only one cycle has been observed. **Dimensions**: H = 2.3-3.0μm; CW = 2.7-2.8μm; SW = 2.8-3.2μm. **Occurrence**: NP15b; TDP Sites 2, 6. NP12 (Varol, 1989).

***Blackites perlongus* group**

Tall, narrow spines and typical *Blackites* rim.

Blackites herculesii (Stradner, 1969) Bybell & Self-Trail, 1997

Pl.23, figs 26-30. Rhabdolith with broad, claviform spine, and with typical width only slightly less than that of coccolith. Spine displays distinctive cross-hatched pattern and outer surface may be serrated. Outer cycle of coccolith rim significantly smaller than inner. **Differentiation**: Similar to *Blackites perlongus* but with a broader spine. **Dimensions**: H = 10.1-12.0μm; CW = 3.8-4.0μm; SW = 2.8-3.9μm. **Occurrence**: NP9b/10-11; TDP Sites 3, 7A, 7B, 8.

Blackites perlongus (Deflandre, 1952) Shafik, 1981

Pl.24, figs 1-10. Rhabdolith with tall, narrow, claviform spine that is never as broad as coccolith rim. Rim usually relatively narrow and outer cycle significantly smaller than inner. Some specimens have a collar at the base of the spine. **Differentiation**: Like *B. herculesii* but with a narrower, often taller, spine; the two species probably intergrade. **Dimensions**: H = 7.8-30.3μm; CW = 1.7-3.4μm; SW = 1.3-1.7μm. **Occurrence**: NP9b-17; TDP Sites 1 2, 3, 4, 6, 8 (NP23? at TDP Site 1).

Blackites inflatus (Bramlette & Sullivan, 1961) Kapellos & Schaub, 1973

Pl.24, figs 11-15. Rhabdolith with tall, narrow, hollow, flask-like spine that broadens to a maximum width, then tapers gradually in upper portion; outer surface serrated. Width of spine variable and, typically, same as coccolith, but considerably taller (x4-7). Rim distinctly convex and relatively broad. **Dimensions**: H = 16.9-21.7μm; CW = 3.0-5.0μm; SW = 3.0-5.6μm. **Occurrence**: NP14b/15a; TDP Site 2.

Blackites spinosus (Deflandre & Fert, 1954) Hay & Towe, 1962

Pl.24, figs 16-25. Rhabdolith with tall, narrow, styliform spine that tapers gradually to a point; outer surface smooth. Width of spine around half that of coccolith but considerably taller (x4-6). Rim relatively broad and distinctly convex. **Differentiation**: *Blackites scabrosus* (Deflandre *in* Deflandre & Fert, 1954) Roth, 1970 and *Blackites tenuis* (Bramlette & Sullivan, 1961) Sherwood, 1974 have similar morphologies but could not be reliably differentiated from *B. spinosus* in this study. **Dimensions**: H = 16.8-25.2μm; CW = 2.8-4.5μm; SW =1.7-2.7μm. **Occurrence**: NP14b/15a-23; TDP Sites 1, 2, 6. Rare and sporadic.

Other *Blackites* coccoliths

Blackites piriformis (Pavsic *in* Khan *et al*., 1975) Aubry, 1999

Pl.25, figs 1-5. Rhabdoliths with wide, hollow, flask-like spine that broadens rapidly to a maximum width, then tapers to a narrow upper portion; inflated part of spine displays distinctive cross-hatched pattern; outer surface serrated. Spine much taller (x3) and wider than coccolith. **Dimensions**: H = 11.0-12.7μm; CW = 3.6-3.8μm; SW = 5.0-6.6μm. **Occurrence**: NP14b/15a-23; TDP Sites 1 2. Rare and sporadic.

Blackites virgatus sp. nov.

Pl.25, figs 6-15. **Derivation of name**: From *virgatus*, meaning striped, referring to the distinct appearance of the spine. **Diagnosis**: Large rhabdoliths with tall, hollow spine that is widest at its base, tapers to a point, and is distinctively coarsely striated in XPL. Rim broad and outer cycle does not lie distally over inner cycle. Screw-like in overall appearance. **Differentiation**: *Blackites* spines are often striated in distal parts but never as strongly or as completely as in this species. **Dimensions**: H = 15.6-17.2μm; CW = 5.4-5.5μm; SW = 2.3-2.7μm. **Holotype**: Pl.25, fig.11 (figs 12, 13 same specimen). **Paratype**: Pl.25, fig.14. **Type locality**: TDP Site 2, near Kilwa, Tanzania. **Type level**: Middle Eocene, Sample TDP2-2-1, 15cm (Subzone NP15c). **Occurrence**: NP15b-c; Site TDP2.

Blackites dupuisii (Steurbaut, 1990) comb. nov.

Pl.25, figs 16-19. **Basionym**: *Naninfula dupuisii* Steurbaut, 1990, p.267, pl.4, fig.3; *Bull. de la Soc. Belge de Géol*., **97**: 251-285. **Remarks**: Rhabdoliths with a tall, tapering, hollow spine that is broad at its base but tapering and narrow in its upper half. Two or three spine-cycles are seen low on the spine, along with striated ornamentation. The spine is usually around two to three times taller the coccolith. **Dimensions**: H = 5.1-9.8μm; CW = 3.0-4.4μm; SW = 2.4-3.3μm. **Occurrence**: NP9b-NP15b; TDP Sites 2, 6, 7A, 7B, 10. Upper NP11 (Steurbaut, 1990).

Blackites cf. *B. dupuisii* (Steurbaut, 1990) comb. nov.

Pl.25, fig.20. Like *B. dupuisii* but the spine tapers uniformly from its wide base. **Dimensions**: H = 7.4μm; CW = 4.6μm; SW = 3.5μm. **Occurrence**: NP15b; TDP Site 2.

Blackites vitreus (Deflandre *in* Deflandre & Fert, 1954) Shafik, 1981

Pl.25, figs 21-25. Rhabdoliths with very narrow, styliform spine that typically has a prominent basal collar. Coccolith broad and thin, and dominated by inner cycle, with outer cycle forming only the outermost edge. **Differentiation**: Spine much thinner than most other

Palaeogene rhabdoliths. **Dimensions**: H = 2.5-13.5μm; CW = 2.4-5.2μm. **Occurrence**: NP11-23; TDP Sites 1, 2, 3, 4.

Blackites kilwaensis sp. nov.

Pl.25, figs 26-30. **Derivation of name**: From the village of Kilwa, near the type locality of Site TDP2. **Diagnosis**: Rhabdoliths with tall, narrow, salpingiform spine that terminates in a sharply tapering spine top; rim small and only one cycle is visible in LM. **Differentiation**: Similar to *Rhabdolithus poculi* Bóna & Kernerné-Sümegi, 1966, described from the Hungarian Miocene, but generally taller and narrower in overall form. **Dimensions**: H = 6.3-10.6μm; CW = 0.7-1.1μm; SW = 1.5-3.4μm. **Holotype**: Pl.25, fig.26 (figs 27, 28 same specimen). **Paratype**: Pl.25, fig.30. **Type locality**: TDP Site 2, near Kilwa, Tanzania. **Type level**: Middle Eocene, Sample TDP2-21-2, 70cm (Subzone NP15b). **Occurrence**: NP14b/15a-15c; TDP Sites 2, 6.

Blackites? *stilus* sp. nov.

Pl.26, figs 1-10. **Derivation of name**: From *stilus*, meaning stake, referring to the distinct shape of this nannolith. **Diagnosis**: A rhabdolith-like nannofossil, comprising tapering, spine-like structure with narrow to broad central canal. No basal coccolith yet observed at wider end, although a distinct widening occurs. **Dimensions**: H = 13.3-22.3μm; W = 2.0-4.2μm. **Holotype**: Pl.26, fig.3 (fig.4 same specimen). **Paratypes**: Pl.26, fig.9; Pl.26, fig.5. **Type locality**: TDP Site 2, near Kilwa, Tanzania. **Type level**: Middle Eocene, Sample TDP2-23-1, 1cm (Subzone NP15b). **Occurrence**: NP14b/15a-15c; TDP Sites 2, 6.

Blackites bases

Pl.26, figs 16-25. Bases of *Blackites* rhabdolith coccoliths were found throughout the studied sections but were not logged as distinct species, and have not been linked to the side views described above. A number of specimens are figured but the taxonomy is informal. All are circular and characterised by two visible cycles, an outer dark cycle (in XPL) (V unit) and an inner bright cycle (R unit), crossed by curving, but approximately N-S-trending, extinction lines. **Dimensions**: W = 4.0-6.6μm.

'*Anacanthoica mitra*' Varol, 1989

Pl.26, figs 26-28; Pl.46, figs 16-20. Small, nail-like, two-dimensional objects constructed from single calcite crystals, and almost always observed in clusters. Although superficially resembling rhabdoliths, they appear instead to be fragments of calcisphere tests of the genus *Scrippsiella* (see Janofske, 2000). **Dimensions**: H = 2.1-5.0μm; W = 2.1-3.7μm. **Occurrence**: NP9b/10-15b; TDP Sites 6, 8, 7A, 7B, 8. Rare and infrequent. **Synonym**: *Zygrhablithus sagittus* Varol, 1989.

Pseudotriquetrorhabdulus inversus (Bukry & Bramlette, 1969) Wise *in* Wise & Constans, 1976
Pl.26, figs 29-30

6.3 Holococcoliths

Family **CALYPTROSPHAERACEAE** Boudreaux & Hay, 1967

The higher taxonomy (genera and above) of holococcoliths is problematical at best due both to their rather generalised morphologies and more recent advances demonstrating that many extant holococcolithophores have a separate heterococcolith life-cycle equivalent. The taxonomy applied here attempts to maintain consistency with previous taxonomic monographs (*e.g.* Perch-Nielsen, 1985; Aubry, 1988), applying established generic names where possible, and for the most part inferring only limited phylogenetic information.

Holodiscolithus macroporus (Deflandre *in* Deflandre & Fert, 1954) Roth, 1970

Pl.27, figs 1-15. Elliptical, non-birefringent holococcoliths that appear as a dark plate pierced by a variable number of pores (10-16); a distinct rim is sometimes discernible. In side view, a rim and proximal plate can be distinguished from the central, perforate plate. **Occurrence**: NP9b/10-23; TDP Sites 1, 2, 3, 4, 7A, 7B, 8.

Holodiscolithus solidus (Deflandre *in* Deflandre & Fert, 1954) Roth, 1970

Pl.27, figs 16-28. Elliptical holococcoliths comprising a rim and six central-area bars that are typically weakly- or non-birefringent. The bars merge centrally to form an elongate structure that bifurcates at either end, and is crossed by a transverse bar. In side view, the cavate structure of the holococcolith is evident, along with the rim, proximal plate, distal cover and bar structures. Some specimens resemble *H. macroporus*, having six circular perforations rather than holes delineated by distinct bars; these are recorded as *Holodiscolithus* cf. *H. solidus* (Pl. 27, figs 29-30). **Occurrence**: NP9b-23; TDP Sites 1, 2, 3, 4, 7A, 7B, 8, 10.

Holodiscolithus serus sp. nov.

Pl.27, figs 31-35. **Derivation of name**: From *sera*, meaning bar, referring to the distinct central-area bar of this holococcolith. **Diagnosis**: Small, elliptical holococcolith with narrow rim and small, bright, transverse bar spanning central-area. **Dimensions**: L = 3.3-3.6μm. **Holotype**: Pl.27, fig.31 (figs 32-34 same specimen). **Paratype**: Pl.27, fig.35. **Type locality**: TDP Site 7B, Kwamatola, Tanzania. **Type level**: Upper Paleocene, Sample TDP7B-50-3, 65cm (Subzone NP9b). **Occurrence**: NP9b-10; TDP Sites 7A, 7B, 8, 10.

Holodiscolithus geisenii sp. nov.

Pl.28, figs 1-5. **Derivation of name**: After Dr. Markus

Geisen (AWI, Germany), nannopalaeontologist. **Diagnosis**: Small, elliptical, rather inconspicuous coccolith with narrow, dark rim and complexly-constructed, weakly-birefringent, central-area plate. Central plate characterised by gently curving axial sutures (*i.e.* black lines), flanked by small blocks of higher birefringence. **Dimensions**: L = 3.2-3.8μm. **Holotype**: Pl.28, fig.1 (figs 2, 3 same specimen). **Paratype**: Pl.28, fig.4. **Type locality**: TDP Site 1, near Kilwa, Tanzania. **Type level**: Lower Oligocene, Sample TDP1-10-2, 76cm (Zone NP23). **Occurrence**: NP11-23; TDP Sites 1, 2, 3, 6. Rare.

Holodiscolithus minolettii sp. nov.

Pl.28, figs 6-10. **Derivation of name**: After Dr. Fabrice Minolettii (Univ. Pierre et Marie Curie, Paris, France), geochemist and nannopalaeontologist. **Diagnosis**: Small, elliptical coccolith with narrow, dark rim (visible in PC) and complexly-constructed, birefringent central-area plate with bright blocks towards each end. **Dimensions**: L = 3.9-4.3μm. **Holotype**: Pl.28, fig. 6 (figs 7, 8 same specimen). **Paratype**: Pl.28, fig.10 (fig.9 same specimen). **Type locality**: TDP Site 4, near Ras Tipuli, Tanzania. **Type level**: Middle Eocene, Sample TDP4-5-1, 1cm (Zone NP17). **Occurrence**: NP15b-17; TDP Sites 2, 4.

Orthozygus aureus (Stradner, 1962) Bramlette & Wilcoxon, 1967

Pl.28, figs 11-22. Elliptical, non-birefringent holococcolith, comprising narrow rim spanned by arched perforate bridge. Bridge broad and pierced by large, central hole and has a distal covering that is finely perforate. Distinguishable in both plan and side views. **Occurrence**: NP23 (one questionable NP17 specimen); TDP Sites 1, 4.

Orthozygus brytika (Roth, 1970) Aubry, 1988

Pl.28, figs 23-25. Small, narrowly-elliptical, non-birefringent holococcolith, comprising narrow rim spanned by diagonal cross-bars. **Occurrence**: NP23; TDP Sites 1, 6. Rare.

Corannulus horridulus sp. nov.

Pl.28, figs 26-30. **Derivation of name**: From *horridulus*, meaning somewhat rough and unadorned, referring to the overall morphology of this coccolith. **Diagnosis**: Small- to medium-sized, elliptical coccolith with broad rim and narrow vacant central-area. Rim thick and ragged in overall appearance. **Dimensions**: L = 4.4-6.4μm. **Holotype**: Pl.28, fig.26 (figs 27, 28 same specimen). **Paratype**: Pl.28, fig.29. **Type locality**: TDP Site 3, Mpara Hill, Tanzania. **Type level**: Lower Eocene, Sample TDP3-4-3, 52cm (Zone NP11). **Occurrence**: NP10-11; TDP Sites 3, 8.

Lanternithus minutus Stradner, 1962

Pl.28, figs 31-35; Pl.29, figs 1-8. Unusual holococcolith that has typical coccolith morphology in plan view but nannolith-like appearance in side view. Slightly rectangular in plan view, it has distinct lateral and end rim blocks and a large, central pore. In side view, it has a box-like appearance that tapers slightly to one (the distal?) end, where it is capped by a distal cover. **Dimensions**: L = 5.2-5.5μm; H = 3.3-4.2μm. **Occurrence**: NP14b/15a-23; TDP Sites 1, 2, 4, 6. FO NP14 (Varol, 1989); LO NP23 (de Kaenel & Villa, 1996).

Lanternithus procerus sp. nov.

Pl.29, figs 11-15. **Derivation of name**: From *procerus*, meaning tall, referring to the tall morphology of this holococcolith. **Diagnosis**: Medium to large holococcolith seen in side view, comprising basal coccolith formed from two plates, the upper of which extends distally to form a tall process that tapers to a termination, capped by a distal cover. Spine taller than maximum width of coccolith. **Remarks**: More box-like morphologies are named *Lanternithus* cf. *L. procerus* (Pl.29, figs 9-10). **Differentiation**: Similar to side views of *L. minutus* but taller than the maximum width. **Dimensions**: H = 4.8-6.8μm; W = 4.0-5.0μm. **Holotype**: Pl.29, fig.15. **Paratype**: Pl.29, fig.13. **Type locality**: TDP Site 2, near Kilwa, Tanzania. **Type level**: Middle Eocene, Sample TDP2-22-1, 62cm (Subzone NP15b). **Occurrence**: NP15b-23; TDP Sites 1, 2, 6.

Lanternithus arcanus sp. nov.

Pl.29, figs 16-25, 30. **Derivation of name**: From *arcanus*, meaning closed, referring to the closed central-area of this holococcolith. **Diagnosis**: Medium-sized holococcolith, comprising several distinct crystallographic blocks that change appearance on rotation in XPL. At 0°, six blocks are visible: four major quadrants, alternating dark and light, delineated by axial sutures, and one small block at each end. At 5°, the four quadrants are bright and a small pore is visible in the centre. At 45°, the coccolith is bright and crossed by diagonal extinction lines. **Differentiation**: Similar to *L. minutus* but with narrower central-area. **Dimensions**: L = 4.6-5.5μm. **Holotype**: Pl.29, fig.16 (figs 17-20 same specimen). **Paratype**: Pl.29, fig.21 (figs 22-24 same specimen). **Type locality**: TDP Site 2, near Kilwa, Tanzania. **Type level**: Middle Eocene, Sample TDP2-7-1, 38cm (Subzone NP15c). **Occurrence**: NP15b-c; TDP Site 2, 6.

Lanternithus simplex sp. nov.

Pl.29, figs 26-29, 31-35; Pl.30, figs 1-5. **Derivation of name**: From *simplex*, meaning plain or simple, referring to the relatively simple construction of this holococcolith. **Diagnosis**: Medium-sized holococcolith, comprising several distinct crystallographic blocks. At 0°, four blocks are visible, four major quadrants demarcated by dark extinction lines. There is a small pore visible at the centre of the coccolith. **Differentiation**: Simpler in appearance than other species of the genus, with fewer 'crystallographically'-distinct blocks. Similar to *L. arcanus* but slightly smaller, more broadly elliptical, and with a larger central-area/pore. **Dimensions**: L = 4.6-4.9μm. **Holotype**: Pl.29, fig.31 (figs 32-34 same specimen). **Paratype**: Pl.29, fig.26 (figs 27-29 same specimen). **Type locality**: TDP Site 10, Singino Hill, Tanzania. **Type level**: Upper Paleocene, Sample TDP10-12-2, 26cm (Subzone NP9b). **Occurrence**: NP9b-14b/15a; TDP Sites 2, 7B, 10.

Youngilithus gen. nov.

Type species: *Youngilithus oblongatus* sp. nov. **Derivation of name**: After Dr. Jeremy Young (Natural History Museum, London, UK), nannopalaeontologist. **Diagnosis**: Geometrically-shaped, non-birefringent holococcoliths, typically possessing lateral rim spines and central-area bars.

Youngilithus arcaeformis sp. nov.

Pl.30, figs 6-8. **Derivation of name**: From *arca*(*e*), meaning box, chest or coffin, and *formis*, meaning in the shape of, referring to the distinct outline of this holococcolith. **Diagnosis**: A polygonal, medium-sized, non-birefringent holococcolith with narrow rim spanned by diagonal cross-bars. Rim coffin-shaped (like a diamond with flattened ends) and usually shows small, marginal projections. **Differentiation**: Similar to *O. brytika* but with more geometric outline and with lateral rim spines. **Dimensions**: L = 4.3-5.3μm. **Holotype**: Pl.30, fig.6 (fig.7 same specimen). **Paratype**: Pl.30, fig.8. **Type locality**: TDP Site 2, near Kilwa, Tanzania. **Type level**: Middle Eocene, Sample TDP2-15-1, 89cm (Subzone NP15b). **Occurrence**: NP15b-c; TDP Site 2. Rare.

Youngilithus oblongatus sp. nov.

Pl.30, figs 9-15. **Derivation of name**: From *oblongus*, meaning oblong, referring to the distinct outline of this holococcolith. **Diagnosis**: Rectangular, medium-sized, non-birefringent holococcolith with lateral rim projections. Sides of rectangle formed from narrow, crystallographically-distinct units, and some specimens have an internal, transverse bar. **Dimensions**: L = 6.0-8.2μm; W = 3.1-6.1μm. **Holotype**: Pl.30, fig.11 (figs 12, 13 same specimen). **Paratype**: Pl.30, fig.9 (fig.10 same specimen). **Type locality**: TDP Site 2, near Kilwa, Tanzania. **Type level**: Middle Eocene, Sample TDP2-15-1, 89cm (Subzone NP15b). **Occurrence**: NP15b-c; TDP Sites 2, 6.

Youngilithus quadraeformis sp. nov.

Pl.30, figs 16-20. **Derivation of name**: From *quadra(e)*, meaning square, and *formis*, meaning in the shape of, referring to the distinct shape of this holococcolith. **Diagnosis**: Square, medium-sized, non-birefringent holococcolith with narrow rim bearing small, marginal projections, spanned by cross-bars parallel with sides. **Dimensions**: L = 3.4-3.7μm. **Holotype**: Pl.30, fig.16 (fig.17 same specimen). **Paratype**: Pl.30, fig.18 (figs 19, 20 same specimen). **Type locality**: TDP Site 2, near Kilwa, Tanzania. **Type level**: Middle Eocene, Sample TDP2-4-1, 50cm (Subzone NP15c). **Occurrence**: NP15c; TDP Site 2.

Varolia gen. nov.

Type species: *Varolia cistula* sp. nov. **Derivation of name**: After Dr. Osman Varol (Varol Research, UK), nannopalaeontologist. **Diagnosis**: Cavate, thin-walled, box-like holococcoliths, usually seen in side view.

Varolia cistula sp. nov.

Pl.30, figs 21-25. **Derivation of name**: From *cistula*, meaning little box, referring to the distinct shape of this holococcolith. **Diagnosis**: Small- to medium-sized, thin-walled, box-like structure with gently curved upper surface. Thin, birefringent walls comprise at least four crystallographically-distinct blocks. The structure broadens distally from basal plate, is typically wider than it is high and may be circular in plan view (see Pl.30, fig.25). **Differentiation**: Similar in overall structure to *Varolia gracilimura* but usually not so high, and less domed. **Dimensions**: H = 2.9-3.9μm; W = 4.3-4.7μm. **Holotype**: Pl.30, fig.21 (fig.22 same specimen). **Paratype**: Pl.30, fig.24. **Type locality**: TDP Site 1, near Kilwa, Tanzania. **Type level**: Lower Oligocene, Sample TDP1-10-2, 76cm (Zone NP23). **Occurrence**: NP23; TDP Sites 1, 6.

Varolia gracilimura sp. nov.

Pl.30, figs 26-30. **Derivation of name**: From Latin *gracilis*, meaning slender, and *murus*, meaning wall, referring to the narrow walls of this holococcolith. **Diagnosis**: Medium-sized, thin-walled, dome-like structure. Thin, birefringent walls form proximal plate and domed upper surface. Dome broadens distally from basal plate and is of similar height and width, or taller. **Differentiation**: Similar in overall structure to *V. cistula* but usually higher and domed. **Dimensions**: H = 3.5-5.5μm; W = 3.5-5.0μm. **Holotype**: Pl.30, fig.26 (fig.27 same specimen). **Paratype**: Pl.30, fig.28 (fig.29 same specimen). **Type locality**: TDP Site 4, near Ras Tipuli, Tanzania. **Type level**: Middle Eocene, Sample TDP4-5-1, 1cm (Zone NP17). **Occurrence**: NP15b-17; TDP Sites 2, 4, 6.

Genus *Semihololithus* Perch-Nielsen, 1971

Used here for Palaeogene holococcoliths usually seen in side view, comprising a thick proximal plate, and spine or process, typically with a cavity or axial canal.

Semihololithus biscayae Perch-Nielsen, 1971

Pl.30, figs 31-35. Holococcoliths seen in side view, comprising thick, proximal plate and solid, domed, distal process. **Dimensions**: H = 4.4-5.3μm; W = 4.4-6.2μm. **Occurrence**: NP9b/10-10; TDP Sites 7A, 7B.

Semihololithus cf. *S. biscayae* Perch-Nielsen, 1971

Pl.31, figs 1-5. Similar to *S. biscayae* but considerably smaller and with relatively larger central cavity. **Dimensions**: H = 2.1-3.2μm; W = 3.0-4.5μm. **Occurrence**: NP9b; TDP Site 10.

Semihololithus dimidius sp. nov.

Pl.31, figs 6-10. **Derivation of name**: From *dimidius*, meaning divided in half, referring to the partitioned nature of this holococcolith. **Diagnosis**: Small holococcolith seen in side view, comprising thin proximal plate and thin-walled, tapering distal process that surrounds central cavity divided in half by narrow wall. **Dimensions**: H = 2.4-2.8μm; W = 3.3-3.9μm. **Holotype**: Pl.31, fig.7 (figs 6, 8 same specimen). **Paratype**: Pl.31, fig.9. **Type locality**: TDP Site 10, Singino Hill, Tanzania. **Type level**: Upper Paleocene, Sample TDP10-40-3, 68cm (Subzone NP9b). **Occurrence**: NP9b; TDP Site 10.

Semihololithus tentorium sp. nov.

Pl.31, figs 11-20. **Derivation of name**: From *tentorium*, meaning tent, referring to the distinct shape of this holococcolith. **Diagnosis**: Medium-sized holococcolith seen in side view, comprising thin proximal plate, thick walls and relatively thick-walled, rapidly tapering, cavate, distal process/spine. **Dimensions**: H = 4.6-5.6μm; W = 4.7-5.0μm. **Holotype**: Pl.31, fig.11 (figs 12, 13 same specimen). **Paratypes**: Pl.31, fig.16 (figs 17, 18 same specimen). **Type locality**: TDP Site 10, Singino Hill, Tanzania. **Type level**: Upper Paleocene, Sample TDP10-40-3, 68cm (Subzone NP9b). **Occurrence**: NP9b; TDP Site 10.

Semihololithus kanungoi sp. nov.

Pl.31, figs 21-25. **Derivation of name**: After Sudeep Kanungo (UCL, UK), nannopalaeontologist. **Diagnosis**: Small- to medium-sized, cavate holococcolith seen in side view, comprising thin proximal plate, thick walls, and thin-walled, hollow, distal process/spine that tapers initially, then becomes parallel-sided. **Dimensions**: H = 3.6-5.8μm; W = 3.6-5.1μm. **Holotype**: Pl.31, fig.21 (figs 22, 23 same specimen). **Paratype**: Pl.31, fig.24. **Type locality**: TDP Site 7A, Kwamatola, Tanzania. **Type level**: Lower Eocene, Sample TDP7A-62-1, 70cm (Zone NP10). **Occurrence**: NP9b/10-10; TDP Sites 7A, 7B.

Daktylethra punctulata Gartner *in* Gartner & Bukry, 1969

Pl.31, figs 26-35. Holococcolith seen in side view, comprising thin, proximal plate and rim, and large, hollow, perforate, domed distal process. The Tanzanian specimens display some variability, particularly in distal process shape, and are not identical to the type images, but are deemed similar enough to warrant inclusion in this species. **Dimensions**: H = 3.6-6.5μm; W = 3.6-7.7μm. **Occurrence**: NP14b/15a-b; TDP Sites 2, 6. NP16-17 (Gartner, 1971).

Zygrhablithus Deflandre, 1959

The most common Palaeogene holococcolith, and variable in morphology. The genus is divided here based on details of the spine/process shape. I use *Zygrhablithus bijugatus bijugatus* for coccoliths with tapering spines, *Z. bijugatus nolfii* for those with short, squat spines and a distinct lateral notch, and *Z. bijugatus cornutus* for spines with prominent lateral projections. Unfortunately, the holotype of the principle species, *Z. bijugatus*, is a plan view, and thus difficult to reconcile with the different side views. In plan view, the coccoliths are non-birefringent and the central structure is figure-of-eight-shaped.

Zygrhablithus bijugatus bijugatus (Deflandre *in* Deflandre & Fert, 1954) Deflandre, 1959

Pl.32, figs 1-10. Medium to large, spinose holococcolith, comprising rim and central process; spine has narrow, axial canal and tapers uniformly to a distal point or blunt termination. **Dimensions**: H = 2.7-16.4μm; W = 3.2-6.1μm. **Occurrence**: NP9b-23; TDP Sites 1, 2, 3, 4, 6, 7A, 7B, 8, 10. **Synonym**: *Semihololithus kerbayi* Perch-Nielsen, 1971.

Zygrhablithus bijugatus (Deflandre *in* Deflandre & Fert, 1954) Deflandre, 1959 *cornutus* ssp. nov.

Pl.32, figs 11-15. **Derivation of name**: From *cornutus*, meaning horned, referring to the distinct spine morphology of this holococcolith. **Diagnosis**: Medium-sized, spinose holococcolith, comprising rim and central process; spine relatively long, with narrow axial canal, and short lateral protrusions or horns at its distal end (two in side view). **Dimensions**: H = 7.7-7.8μm; W = 5.1-6.1μm. **Holotype**: Pl.32, fig.11. **Paratype**: Pl.32, fig.12 (fig.13 same specimen). **Type locality**: TDP Site 1, near Kilwa, Tanzania. **Type level**: Lower Oligocene, Sample TDP1-7-3, 75cm (Zone NP23). **Occurrence**: NP23; TDP Site 1.

Zygrhablithus cf. *Z. bijugatus* (Deflandre *in* Deflandre & Fert, 1954) Deflandre, 1959 *cornutus* ssp. nov.

Pl.32, figs 16-20. Like *Z. bijugatus cornutus* but with broader, near-parallel-sided spine. **Occurrence**: NP15b; Site TDP 2.

Zygrhablithus bijugatus (Deflandre *in* Deflandre & Fert, 1954) Deflandre, 1959 *nolfii* Steurbaut, 1990

Pl.32, figs 21-28. Small- to medium-sized, spinose holococcolith, comprising rim and central process; spine short and broad (coccoliths typically wider than high), with notch just above height of rim, and rather broad, axial canal. **Dimensions**: H = 4.4-6.3μm; W = 5.1-7.6μm. **Occurrence**: NP10-15b; TDP Sites 2, 3, 7A. Upper NP11 (Steurbaut, 1990).

Zygrhablithus cf. *Z. bijugatus* (Deflandre *in* Deflandre & Fert, 1954) Deflandre, 1959 *nolfii* Steurbaut, 1990

Pl.32, figs 29-30. Like *Z. bijugatus nolfii* but with smaller, more rounded spine that has a less pronounced notch. **Dimensions**: H = 3.2-4.1μm; W = 4.6-4.9μm. **Occurrence**: NP9b/10; TDP Site 7B.

Clathrolithus Deflandre *in* Deflandre & Fert, 1954

Applied here to unusual holococcoliths with non-coccolith morphology, comprising domed, perforate framework (see electron micrographs in Gartner & Bukry, 1969).

Clathrolithus arenarius (Stradner, 1962) comb. nov.

Pl.33, figs 1-5. **Basionym**: *Corannulus arenarius* Stradner, 1962, p.366, pl.1, figs 14-20; *Sonderabdruck aus den Verhandlungen der Geologischen Bundesanstalt*, **2**: 363-377. **Remarks**: Large (~9μm), non-birefringent, elliptical holococcolith, comprising perforate framework with large central pore and 9-13 marginal pores. **Occurrence**: NP15b-17; TDP Sites 2, 4. Rare.

Clathrolithus ellipticus Deflandre *in* Deflandre & Fert, 1954

Pl.33, figs 6-23. *Clathrolithus ellipticus* and *Peritrachelina ornata* were described from the same Lower Eocene sample by Deflandre (*in* Deflandre & Fert, 1954), and represent two different views of the same, rather strangely constructed, holococcolith (ostensibly plan and side views, respectively). The holococcolith is a non-birefringent, large (11-13μm), domed, perforate structure that curves strongly in side view. In plan view, structure roughly elliptical and framework honey-comb-like and pierced by 8-18 pores. It is often broken into fragments. Most of the specimens observed here are more-coarsely constructed than the holotypes (of both species) but I have applied the same name. Only specimens with much smaller pores were included in *Clathrolithus minutus*. **Occurrence**: NP9b-15b; TDP Sites 2, 3, 4, 6, 7A, 7B, 8, 10.

Clathrolithus minutus Bramlette & Sullivan, 1961

Pl.33, figs 24-25. Like *Clathrolithus ellipticus* but with greater number of smaller perforations (~<0.5μm); not observed in side view. **Occurrence**: NP9b; TDP Site 10. Rare.

Clathrolithus joidesa (Bukry & Bramlette, 1968) comb. nov.

Pl.33, figs 26-30. **Basionym**: *Peritrachelina joidesa* Bukry & Bramlette, 1968, p.154, pl.2, fig.8; *Tulane Studies in Geology*, **6**: 149-155. **Remarks**: C-shaped nannoliths only observed in side view. Similar in appearance to *C. ellipticus* but pores not visible. **Occurrence**: NP23; TDP Site 1. Upper Eocene-Oligocene (Bukry & Bramlette, 1968).

6.4 Nannoliths

Family **BRAARUDOSPHAERACEAE** Deflandre, 1947

Braarudosphaera bigelowii (Gran & Braarud, 1935) Deflandre, 1947

Pl.34, figs 1-7, 10, 11. Large variability in size (3.7-25.6μm), with larger forms having more-rounded apices. Elevated forms and side views are named *Braarudosphaera* aff. *B. bigelowii* or *Braarudosphaera stylifera* (Pl.34, figs 16-22).

Braarudosphaera aff. *B. bigelowii* (Gran & Braarud, 1935) Deflandre, 1947
Pl.34, figs 20-22

Braarudosphaera cf. *B. hockwoldensis* Black, 1973

Pl.34, figs 8, 13-15. *Braarudosphaera* with protruding pentalith segments, first described from the Lower Cretaceous. Used tentatively here due to large stratigraphic gap between observations. **Occurrence**: NP10-23; TDP Sites 1, 2, 3, 7A. Rare. FO Upper Aptian (Black, 1973).

Braarudosphaera stylifera Troelsen & Quadros, 1971
Pl.34, figs 18-19

Braarudosphaera aff. *B. stylifera* Troelsen & Quadros, 1971
Pl.34, figs 16-17

Micrantholithus discula (Bramlette & Riedel, 1954) comb. nov.

Pl.34, figs 23-27. **Basionym**: *Braarudosphaera discula* Bramlette & Riedel, 1954, p.394, pl.38, fig.7; *J. Paleont.*, **28**: 385-403. **Remarks**: Simple, elevated *Micrantholithus* morphology with rounded outline and elliptical side views. **Occurrence**: NP9b-15b; TDP Sites 2, 3, 7A, 7B, 8, 10.

Micrantholithus flos Deflandre *in* Deflandre & Fert, 1954

Pl.34, figs 28-29. Following the illustrations in Deflandre & Fert (1954), I use this name for simple *Micrantholithus* morphologies with relatively straight edges. Comparable to *Micrantholithus hoschulzii* (Reinhardt, 1966) Thierstein, 1971, described from the Lower Cretaceous. Cretaceous *Micrantholithus* species are not usually recorded above the Aptian (Bown et al., 1998; Burnett, 1998), and thus the Palaeogene species observed herein are considered to be separate taxa. **Occurrence**: NP15c-23; TDP Sites 1, 2.

Micrantholithus crenulatus Bramlette & Sullivan, 1961

Pl.34, figs 30-32; Pl.35, figs 1-2. Like *M. flos* but with crenulate edges. **Occurrence**: NP9b/10-11; TDP Sites 3, 7A, 7B.

Micrantholithus bulbosus Bouché, 1962

Pl.35, figs 3-5. Similar to *M. flos* but with raised ridges around the sutures that widen at their ends. **Occurrence**: NP14b/15a-15b; TDP Sites 2, 6.

Micrantholithus breviradiatus sp. nov.

Pl.35, figs 6-10. **Derivation of name**: From *brevis*, short, and *radiatus*, meaning ray, and referring to the outline of this pentalith. **Diagnosis**: Small to large *Micrantholithus* with shallowly-indented sides and rounded apices.

Comparable to *Micrantholithus obtusus* Stradner, 1963, described from the Lower Cretaceous. **Dimensions**: L = 2.7-9.1μm. **Holotype**: Pl.35, fig.8. **Paratype**: Pl.35, fig.7. **Type locality**: TDP Site 8, Singino Hill, Tanzania. **Type level**: Lower Eocene, Sample TDP8-5-1, 40cm (Zone NP10). **Occurrence**: NP9b-11; TDP Sites 3, 7B, 8, 10.

Micrantholithus astrum sp. nov.

Pl.35, figs 11-15. **Derivation of name**: From *astrum*, meaning a star, referring to the distinct outline of this pentalith. **Diagnosis**: Medium-sized *Micrantholithus* with deeply indented sides and rounded apices. Similar to *Micrantholithus stellatus* Aguado *in* Aguado *et al*., 1997, described from the Lower Cretaceous. Rays are broader than *Micrantholithus aequalis* Sullivan, 1964. **Dimensions**: L = 6.7-10.8μm. **Holotype**: Pl.35, fig.14. **Paratype**: Pl.35, fig.12. **Type locality**: TDP Site 2, Kilwa Masoko, Tanzania. **Type level**: Middle Eocene, Sample TDP2-22-1, 62cm (Subzone NP15b). **Occurrence**: NP10-15b; TDP Sites 2, 3, 6, 7A, 7B.

Micrantholithus pinguis Bramlette & Sullivan, 1961

Pl.35, figs 16-17. Similar to *M. astrum* but with more-elevated structure. **Occurrence**: NP10-15b; TDP Sites 2, 7A, 7B, 8.

Micrantholithus hebecuspis sp. nov.

Pl.35, figs 18-25. **Derivation of name**: From *hebes*, blunt, and *cuspis*, meaning point, and referring to the distinct shape of this pentalith. **Diagnosis**: Large *Micrantholithus* with deeply indented sides and blunt, flat-ended apices. **Dimensions**: L = 7.1-12.7μm. **Holotype**: Pl.35, fig.21. **Paratype**: Pl.35, fig.22. **Type locality**: TDP Site 3, Mpara Hill, Tanzania. **Type level**: Lower Eocene, Sample TDP3-12-2, 27cm (Zone NP11). **Occurrence**: NP11-15c; TDP Sites 2, 3.

Micrantholithus bramlettei Deflandre *in* Deflandre & Fert, 1954

Pl.35, figs 26-30; Pl.36, fig.31. General morphology like *Micrantholithus*, *ie*. pointed rays (in this case with indented and notched sides), but segments joined along sutures with *Braarudosphaera*-like orientation, *i.e*. they meet the outer edge on the sides, rather than at the points. **Occurrence**: NP9b-11; TDP Sites 3, 7A, 7B, 8.

Micrantholithus attenuatus Bramlette & Sullivan, 1961

Pl.34, figs 9, 12; Pl.35, figs 31-33; Pl.36, fig.27. Stellate *Micrantholithus* with deeply indented sides and gracile, long rays. *Micrantholithus aequalis* is similar but smaller. **Occurrence**: NP9b/10-11; TDP Sites 3, 7A, 7B, 8.

Micrantholithus excelsus sp. nov.

Pl.35, figs 34-35; Pl.36, figs 1-4. **Derivation of name**: From *excelsus*, meaning high, referring to the elevated morphology of this pentalith. **Diagnosis**: Large, elevated *Micrantholithus,* with deeply indented sides and gracile, long rays. Height of pentalith results in ragged LM appearance. **Differentiation**: Like *M. attenuatus* but with a higher morphology. **Dimensions**: L = 9.0-17.7μm. **Holotype**: Pl.35, fig.34. **Paratype**: Pl.36, fig.1 (fig.2 same specimen). **Type locality**: TDP Site 4, near Ras Tipuli, Tanzania. **Type level**: Middle Eocene, Sample TDP4-4-1, 46cm (Zone NP17). **Occurrence**: NP11-23; TDP Sites 1, 2, 3, 4, 6.

Pemma Klumpp, 1953

Pl.36, figs 13-26, 28-30. Pentaliths with a perforation in each segment; often elevated, robust structures, commonly observed in side view. **Occurrence**: NP14b/15a-17; TDP Sites 2, 4, 6.

Pemma papillatum Martini, 1959
Pl.36, figs 13-14, 30
Pemma basquense (Martini, 1959) Báldi-Beke, 1971
Pl.36, figs 15-19

Family **DISCOASTERACEAE** Tan, 1927

Five- to six-rayed discoasters

Discoaster mahmoudii Perch-Nielsen, 1981

Pl.37, figs 1-10; Pl.38, fig.1. Highly distinctive discoaster, usually with 5 or 6 tapering, free rays and a central-area crossed by exceptionally high, inter-ray ridges that form a stellate boss. Arms frequently broken off, leaving a *Catinaster*-like central area. **Occurrence**: NP9b/10-10; TDP Sites 7A, 7B. Rare specimens found in TDP 2 (NP15) may be reworked (see below).

Discoaster cf. *D. mahmoudii* Perch-Nielsen, 1981

Pl.37, figs 11-15. Six- to 8-rayed discoasters always observed obliquely due to a large, narrow spine/boss on one side. *Catinaster*-like appearance reminiscent of *D. mahmoudii*. **Occurrence**: NP15; Site TDP 2.

Discoaster saipanensis Bramlette & Riedel, 1954
Pl.37, fig.16
Discoaster sublodoensis Bramlette & Sullivan, 1961
Pl.37, fig.17
Discoaster tanii Bramlette & Riedel, 1954
Pl.37, figs 18-19
Discoaster martinii Stradner, 1959
Pl.37, fig.20

Discoaster nodifer (Bramlette & Riedel, 1954) Bukry, 1973

Pl.37, figs 23-25; Pl.38, fig.4. *Discoaster stradneri* Noël, 1960 and *Discoaster binodosus hirundus* Martini, 1958 both have 7-rayed *Discoaster nodifer* specimens as their holotypes. Here, I include 6-9-rayed forms in *nodifer*. **Occurrence**: NP14b/15a-17; Site TDP 2, 4, 6.

Discoaster ornatus Bramlette & Wilcoxon, 1967 stat. nov.

Pl.37, fig.26. **Basionym**: *Discoaster tani ornatus* Bramlette & Wilcoxon, 1967, p.112, pl.7, fig.8; *Tulane Studies in Geology*, **5**: 93-131. **Remarks**: Morphology considered distinct enough to warrant species status.

Discoaster distinctus Martini, 1958

Pl.37, figs 27-28. Five-rayed, stellate discoasters with heavily-noded, ray-tip bifurcations that resemble spanners. Identical to some of the drawings of *Discoaster gemmifer* Stradner, 1961. **Occurrence**: NP14b/15a-c; Site TDP 2.

Discoaster deflandrei Bramlette & Riedel, 1954
Pl.37, fig.29
Discoaster colletii (Parejas, 1934) Bersier, 1939
Pl.37, fig.30

Discoaster acutus sp. nov.

Pl.37, figs 31-34. **Derivation of name**: From *acuo*, meaning pointed, referring to the rays of this discoaster. **Diagnosis**: Typically 6-rayed, stellate discoaster with relatively long, tapering, free rays, comparable in length to central-area width. Central area has inter-ray ridges and small but prominent central boss on one side. Rays look rather ragged and sometimes appear to be asymmetrically arranged. **Differentiation**: Similar to *Discoaster araneus* Bukry, 1971 (7-9 rays) but with fewer, and more regularly-arranged, rays. **Dimensions**: L = 11.8μm. **Holotype**: Pl.37, fig.33 (fig.34 same specimen). **Paratype**: Pl.37, fig.31 (fig.32 same specimen). **Type locality**: TDP Site 7A, Kwamatola, Tanzania. **Type level**: Lower Eocene, Sample TDP7A-62-1, 20cm (Zone NP10). **Occurrence**: NP10-?11; TDP Sites 3?, 7A.

Discoaster sp.

Pl.38, figs 2-3. Six- to 8-rayed discoasters with long, curving, free rays that may be asymmetrically arranged. **Occurrence**: NP9b-10; TDP Sites 7B, 10.

Multi-rayed discoasters

Discoaster megastypus (Bramlette & Sullivan, 1961) Perch-Nielsen, 1984
Pl.38, figs 5-7
Discoaster mohleri Bramlette & Percival, 1971
Pl.38, figs 10-11
Discoaster lenticularis Bramlette & Sullivan, 1961
Pl.38, figs 12-13
Discoaster wemmelensis Achuthan & Stradner, 1969
Pl.38, figs 15-16
Discoaster multiradiatus Bramlette & Riedel, 1954
Pl.38, figs 14, 20-23

Discoaster salisburgensis Stradner, 1961

Pl.38, figs 24-28. Used in a broad sense here for multiradiate, rosette discoasters with prominent boss on one side only. **Occurrence**: NP9b/10-10; TDP Sites 7A, 7B, 8.

Discoaster diastypus Bramlette & Sullivan, 1961

Pl.38, figs 29-33; Pl.39, figs 1, 6-8. Used here for medium to very large (7.1-19.1μm), multiradiate, rosette discoasters with prominent bosses on both sides and short, free rays that typically curve. **Occurrence**: NP10-11; TDP Sites 3, 7A, 7B, 8.

Discoaster pacificus Haq, 1969

Pl.39, figs 2-5, 9. Like *D. diastypus* but fewer (8-10) and longer, curving free rays. **Occurrence**: NP11; TDP Site 3.

Discoaster kuepperi Stradner, 1959
Pl.39, figs 10-16
Discoaster barbadiensis Tan, 1927
Pl.39, figs 17-19
Discoaster falcatus Bramlette & Sullivan, 1961
Pl.39, figs 20-25
Discoaster splendidus Martini, 1960
Pl.39, figs 26-29

Discoaster mediosus Bramlette & Sullivan, 1961

Pl.39, figs 30-34; Pl.40, figs 1-7. Eight to 10 near-parallel rays, with rounded to pointed tips (Bramlette & Sullivan, 1961) that radiate with little free length from large, circular central area. Many show inter-ray ridges, a low central boss, and development of nodes towards ray-tips. In the Tanzanian material, there is complete intergradation between this species and *Discoaster binodosus*. The two are distinguished here as follows: *D. mediosus* usually has 10 rays or more, with free rays less than half length of central-area; *D. binodosus* usually has 8 rays with longer free length, prominent lateral nodes and pointed ray-tips. **Occurrence**: NP9b/10-10; TDP Sites 7A, 7B, 8.

Discoaster binodosus Martini, 1958

Pl.40, figs 8-15. Usually 8 rays with free ray length that approaches half diameter of central-area or greater, prominent lateral nodes and pointed ray-tips. **Occurrence**: NP10-15c; TDP Sites 2, 3, 7A, 8.

Family **FASCICULITHACEAE** Hay & Mohler, 1967

Fasciculithus aubertae Haq & Aubry, 1981

Pl.40, figs 16-17. Small (H = <3μm), gently tapering column, and visible fenestrae in XPL. Proximal and distal surfaces gently concave and convex, respectively. **Occurrence**: NP9b/10; TDP Sites 7A, 7B, 10.

Fasciculithus thomasii Perch-Nielsen, 1981

Pl.40, figs 18-20. Small to medium (H = 2.7-4.1μm), with tapering column, pointed apical termination and deeply concave proximal surface. Fenestrae visible in XPL. **Occurrence**: NP9b/10; TDP Sites 7A, 7B, 10.

Fasciculithus tympaniformis Hay & Mohler *in* Hay *et al*., 1967

Pl.40, figs 21-23. Used here for small- to medium-sized (H = 3.8-4.5μm) forms with gently tapering, or near-parallel-sided, column, small apical cycle, and smooth outline. The smoothness may be a diagenetic feature, in which case the species is a junior synonym of *Fasciculithus involutus*. **Occurrence**: NP9b/10; TDP Sites 7A, 7B, 10.

Fasciculithus involutus Bramlette & Sullivan, 1961

Pl.40, figs 24-27. Used here for small- to large-sized (H = 3.5-7.6μm) forms, with gently tapering, or near-parallel-sided, column, small apical cycle and visible fenestrae. **Occurrence**: NP9b/10; TDP Sites 7A, 7B, 10.

Fasciculithus sidereus Bybell & Self-Trail, 1995
Pl.40, fig.28
Fasciculithus richardii Perch-Nielsen, 1971
Pl.40, figs 31-32
Fasciculithus tonii Perch-Nielsen, 1971
Pl.40, fig.33
Fasciculithus schaubii Hay & Mohler, 1967
Pl.40, figs 34-35

Family **RHOMBOASTERACEAE** fam. nov.

Type genus: *Rhomboaster* Bramlette & Sullivan, 1961. **Diagnosis**: Nannoliths with rhombic and triradiate morphologies, and non-birefringent images in XPL. Incorporating the genera *Rhomboaster* and *Tribrachiatus*. **Remarks**: *Rhomboaster* and *Tribrachiatus* nannoliths comprise an evolutionary lineage from the oldest, rhombic nannoliths (*cuspis*-type), through intermediate forms with two superimposed triradiate cycles (*bramlettei*-type), to the youngest, single-cycled triradiate forms (*orthostylus*-type). Bybell & Self-Trail (1995, 1997) argued for the use of one genus only, whereas others have retained both (*e.g*. Aubry, 1996). Both genera are used here: *Rhomboaster* for nannoliths with three-dimensional, rhombic to bicyclic, triradiate morphologies, and *Tribrachiatus* for flatter morphologies with a single triradiate cycle.

Rhomboaster cuspis Bramlette & Sullivan, 1961

Pl.41, figs 1-20. Rhombic *Rhomboaster* nannoliths that display variable morphology, in particular in the length of extensions from the points of the rhomb. Bybell & Self-Trail (1995, 1997) considered the length of these extensions, and also the distinction between *R. cuspis* and *Rhomboaster bramlettei*, to be a function of preservation (see also discussion in Wei and Zhong, 1996, and von Salis *et al*., 1999). However, the relatively constant preservation observed herein suggests that the differences may be original, and therefore stratigraphically significant. **Occurrence**: NP9b/10-10; TDP Sites 7A, 7B, 8.

Rhomboaster bramlettei (Brönnimann & Stradner, 1960) Bybell & Self-Trail, 1995

Pl.41, figs 21-35. Two symmetrically-offset and superimposed triradiate cycles. Three-dimensional but flatter than *R. cuspis*. **Occurrence**: NP10; TDP Sites 7A, 7B, 8.

Tribrachiatus digitalis Aubry, 1996

Pl.42, figs 1-9. Single-cycled, triradiate forms, with long ray-tip bifurcations. Rays in same plane and bifurcations only slightly deviate from that plane. *T. digitalis* clearly intergrades with *Tribrachiatus orthostylus*, as shown by the transitional morphologies in Site TDP3 (Pl.42, figs 9, 15), but the stratigraphic range recorded by Aubry (1996), and used to define Subzone NP10b, appears to contradict this ancestor/descendant relationship. The results here indicate a rather younger range for this species and I apply *T. digitalis* to *Tribrachiatus* nannoliths that have bifurcations that are deeply indented to around 25%, or more, of the total arm length.

Tribrachiatus orthostylus Shamrai, 1963

Pl.42, figs 10-22. Large, single-cycled, triradiate nannoliths with little or no ray-end bifurcation (<25% of total arm length).

Nannotetrina cristata (Martini, 1958) Perch-Nielsen, 1971

Pl.43, figs 1-9. Large, three-dimensional nannolith, broadly cross-shaped, with arms that widen towards their ends. Somewhat comparable LM appearance to *Rhomboaster* but probably no phylogenetic link. Relationship with zygodiscids suggested by Perch-Nielsen (1985). **Occurrence**: NP14b/15a-15c; Site TDP 2.

Family **SPHENOLITHACEAE** Deflandre, 1952

Sphenolithus moriformis (Brönnimann & Stradner, 1960) Bramlette & Wilcoxon, 1967

Pl.43, figs 10-12. Small- to medium-sized (H = 4-7μm), non-spined sphenolith with domed upper surface. **Synonym**: *Sphenolithus primus* Perch-Nielsen, 1971.

Sphenolithus acervus sp. nov.

Pl.43, figs 13-19. **Derivation of name**: From *acervus*, meaning a heap or mass, referring to the coarsely-constructed, robust appearance of this sphenolith. **Diagnosis**: Large (>8.0μm), globular, coarsely-constructed sphenolith without spine. **Differentiation**: Like *S. moriformis* but larger (>8.0μm). **Dimensions**: W = 8.5-11.6μm. **Holotype**: Pl.42, fig.15. **Paratype**: Pl.42, fig.19. **Type locality**: TDP Site 3, Mpara Hill, Tanzania. **Type level**: Lower Eocene, Sample TDP3-19-3, 4cm (Zone upper NP10/11). **Occurrence**: NP9b-11; TDP Sites 3, 8, 7A, 7B, 10. Similar forms seen rarely in NP15b, TDP Site 6.

Sphenolithus editus Perch-Nielsen *in* Perch-Nielsen *et al*., 1978

Pl.43, figs 20-24. Small- to medium-sized (H = 4.5-

7.8μm), with short spine, broad triangular shape (dart-shaped), and wide base in which lower quadrants dominate. Compound spine dark at 0°. **Occurrence**: NP11; TDP Site 3.

Sphenolithus spiniger Bukry, 1971

Pl.43, figs 25-29. Small- to medium-sized (H = 4.0-9.4μm), with short spine, narrow, triangular (dart-shaped) shape. Lower quadrants largest and compound spine dark at 0°. **Differentiation**: Similar to *S. editus* but with narrower base. **Occurrence**: NP14b/15a-c; TDP Site 2.

Sphenolithus anarrhopus Bukry & Bramlette, 1969

Pl.43, figs 30-34; Pl.44, figs 1-5. Medium-sized (H = 6.2-9.2μm), with short to relatively long spine that is slightly asymmetrical and dark at 0°. Square-shaped base with near-equidimensional quadrants and deep spine insertion. **Differentiation**: Similar to *Sphenolithus radians* but spine completely dark at 0°. Base broader and squarer than *Sphenolithus villae*. **Occurrence**: NP9b-10; TDP Sites 7A, 7B, 10.

Sphenolithus conspicuus Martini, 1976

Pl.44, figs 6-10. Medium-sized (H = 5.0-6.7μm), narrow sphenolith with tall spine that is dark at 0° and conspicuously bright at 45°. Tall base with long upper quadrants that form part of spine. **Differentiation**: Similar to *Sphenolithus villae* but smaller, with longer upper quadrant extensions and shorter lower quadrants. **Occurrence**: NP11; TDP Site 3.

Sphenolithus villae sp. nov.

Pl.44, figs 11-24. **Derivation of name**: After Dr. Giuliana Villa (Univ. of Parma, Italy), nannopalaeontologist. **Diagnosis**: Large (H = 7.5-19.8μm), narrow sphenolith with tall spine that is dark at 0°. Relatively tall base, with roughly equidimensional upper and lower quadrants. Spine indents deeply into upper quadrants, appears to be monocrystalline, and is brightest at 45°. **Differentiation**: Comparable in general morphology to the Miocene *Sphenolithus belemnos*, however *S. villae* is larger, more robustly constructed, with blockier spine and base. **Dimensions**: H = 7.5-19.8μm. **Holotype**: Pl.44, fig.19 (fig.18 same specimen). **Paratypes**: Pl.44, fig.24 (fig.23 same specimen); Pl.44, fig.11 (fig.12 same specimen). **Type locality**: TDP Site 3, Mpara Hill, Tanzania. **Type level**: Lower Eocene, Sample TDP3-4-3, 52cm (Zone NP11). **Occurrence**: NP11; TDP Site 3.

Sphenolithus radians Deflandre *in* Grassé, 1952

Pl.44, figs 25-32. Medium- to large-sized (H = 6.6-12.1μm), with tall, compound spine and square-shaped base with equidimensional quadrants. Spine dark but visible at 0° and characterised by median suture line; at 45°, the spine is brightest. Narrow spine endings, up to 3x length of main sphenolith, have been rarely observed, *i.e.* up to 38μm. **Occurrence**: NP11-17; TDP Sites 2, 3, 4, 6.

Sphenolithus pseudoradians Bramlette & Wilcoxon, 1967

Pl.44, figs 33-34

Sphenolithus furcatolithoides Locker, 1967

Pl.45, figs 1-5. Small (base H = 3.6-4.8μm), with two long spines that are bright at 0° (dark at 45°), extending from upper quadrants (up to 20μm in length). Base dark and inconspicuous at 45°. **Occurrence**: NP15b-c; TDP Sites 2, 6.

Sphenolithus cuniculus sp. nov.

Pl.45, figs 6-10. **Derivation of name**: From *cuniculus*, meaning rabbit, referring to the rabbit-ear-like upper quadrants/spine of this sphenolith. **Diagnosis**: Medium to large sphenolith, with short lower quadrants and long upper quadrants that bifurcate. **Differentiation**: Similar to *S. furcatolithoides* but lower quadrants shorter and upper quadrants broader: conceivably a preservational variant. **Dimensions**: H = 5.2-~14.0μm. **Holotype**: Pl.45, fig.6. **Paratype**: Pl.45, fig.7 (fig.8 same specimen). **Type locality**: TDP Site 2, Kilwa Masoko, Tanzania. **Type level**: Middle Eocene, Sample TDP2-2-1, 15cm (Subzone NP15c). **Occurrence**: NP15c-?23; TDP Sites 1, 2.

Sphenolithus obtusus Bukry, 1971

Pl.45, figs 11-20. Medium to large (H = 5.1-11.3μm), with tall spine and low base, comprising single cycle of triangular quadrants. Spine dark at 0° and brightest at 45°. Most spines monocrystalline, but some duocrystalline; this may be orientation-related. **Occurrence**: NP17; TDP Site 4.

Sphenolithus conicus Bukry, 1971

Pl.45, figs 21-25. Large (H = 6.2-8.4μm), with short, blunt spine and broad, robust base. Lower quadrants large and spine dark at 0°. **Occurrence**: Lower Oligocene (NP23); TDP Site 6.

Sphenolithus predistentus Bramlette & Wilcoxon, 1967

Pl.45, figs 26-35. Small- to medium-sized (H = 3.4-7.5μm, excluding bifurcations), with tall, narrow, bifurcating spine and very short lower quadrants. **Occurrence**: NP23; TDP Sites 1, 6. NP17-24 (Perch-Nielsen, 1985).

Family **LAPIDEACASSACEAE** Bown & Young, 1997

Lapideacassis glans? Black, 1971

Pl.46, figs 1-2. Very rare and may be reworked.

Incertae sedis nannoliths

Biantholithus flosculus sp. nov.

Pl.46, figs 3-7. **Derivation of name**: From *flosculus*, meaning little flower, referring to petaloid morphology of this nannolith. **Diagnosis**: Medium-sized, circular, rosette-shaped nannolith with 11-16 radial rays. Weakly birefringent in XPL. **Differentiation**: Similar to rosette discoasters but with birefringence in XPL. Similar to other *Biantholithus* species but more numerous and with thinner rays. **Dimensions**: W = 4.5-6.3μm. **Holotype**: Pl.46, fig.6 (fig.7 same specimen). **Paratypes**: Pl.46, fig. 4; Pl.45, fig.5. **Type locality**: TDP Site 10, Singino Hill, Tanzania. **Type level**: Upper Paleocene, Sample TDP10-35-3, 58cm (Subzone NP9b). **Occurrence**: NP9b; TDP Site 10.

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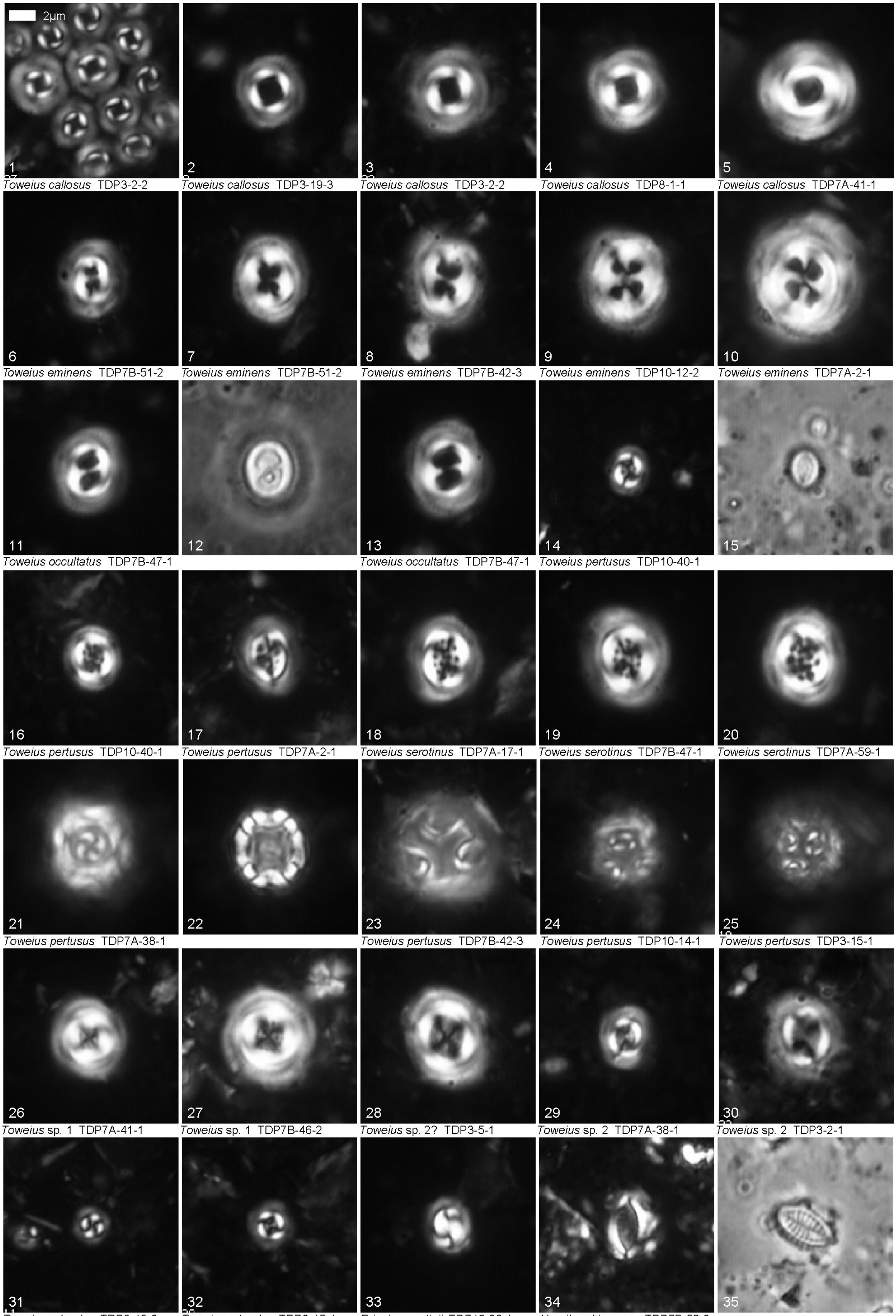
Plate 1

Prinsiaceae: *Toweius, Prinsius, Hornibrookina*



1 *Toweius callosus* TDP3-2-2
2 *Toweius callosus* TDP3-19-3
3 *Toweius callosus* TDP3-2-2
4 *Toweius callosus* TDP8-1-1
5 *Toweius callosus* TDP7A-41-1
6 *Toweius eminens* TDP7B-51-2
7 *Toweius eminens* TDP7B-51-2
8 *Toweius eminens* TDP7B-42-3
9 *Toweius eminens* TDP10-12-2
10 *Toweius eminens* TDP7A-2-1
11 *Toweius occultatus* TDP7B-47-1
13 *Toweius occultatus* TDP7B-47-1
14 *Toweius pertusus* TDP10-40-1
16 *Toweius pertusus* TDP10-40-1
17 *Toweius pertusus* TDP7A-2-1
18 *Toweius serotinus* TDP7A-17-1
19 *Toweius serotinus* TDP7B-47-1
20 *Toweius serotinus* TDP7A-59-1
21 *Toweius pertusus* TDP7A-38-1
23 *Toweius pertusus* TDP7B-42-3
24 *Toweius pertusus* TDP10-14-1
25 *Toweius pertusus* TDP3-15-1
26 *Toweius* sp. 1 TDP7A-41-1
27 *Toweius* sp. 1 TDP7B-46-2
28 *Toweius* sp. 2? TDP3-5-1
29 *Toweius* sp. 2 TDP7A-38-1
30 *Toweius* sp. 2 TDP3-2-1
31 *Toweius rotundus* TDP3-19-3
32 *Toweius rotundus* TDP3-15-1
33 *Prinsius martinii* TDP10-28-1
34 *Hornibrookina arca* TDP7B-50-3

Plate 2

Noelaerhabdaceae: *Cyclicargolithus, Reticulofenestra*

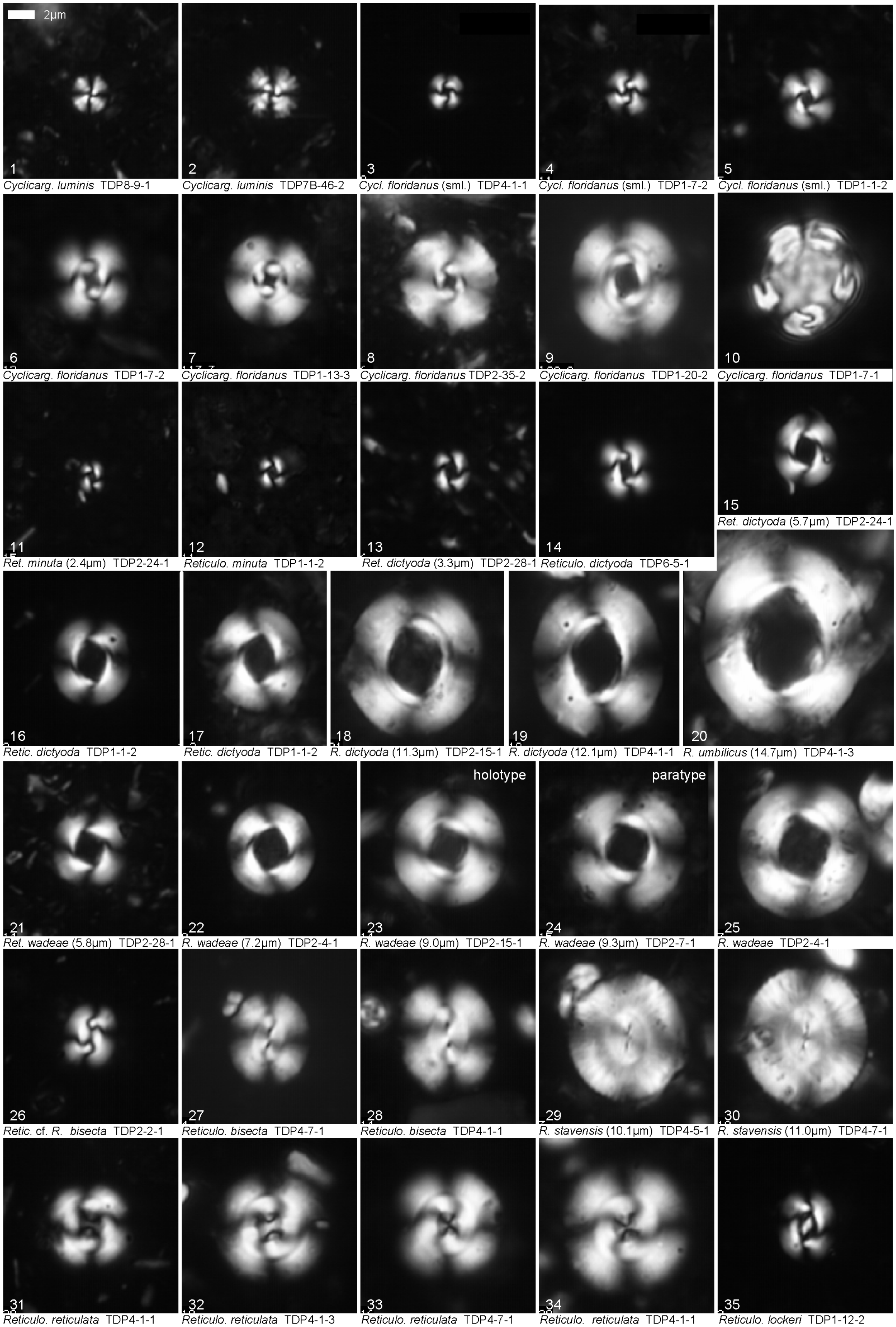
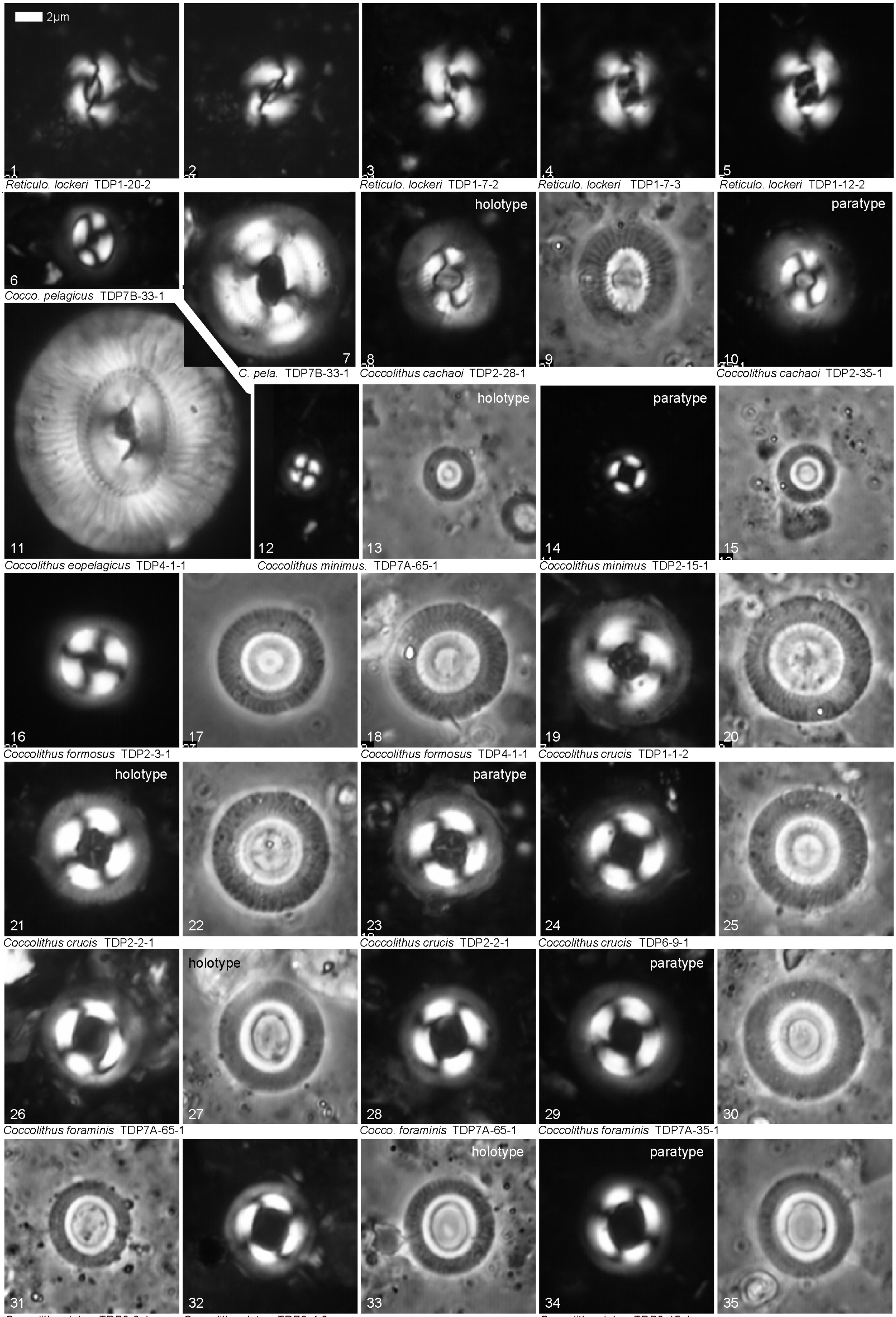


Plate 3

Noelaerhabdaceae: *Reticulofenestra*; Coccolithaceae: *Coccolithus*



1–2 *Reticulo. lockeri* TDP1-20-2; 3 *Reticulo. lockeri* TDP1-7-2; 4 *Reticulo. lockeri* TDP1-7-3; 5 *Reticulo. lockeri* TDP1-12-2

6 *Cocco. pelagicus* TDP7B-33-1; 7 *C. pela.* TDP7B-33-1; 8–9 *Coccolithus cachaoi* TDP2-28-1; 10 *Coccolithus cachaoi* TDP2-35-1

11 *Coccolithus eopelagicus* TDP4-1-1; 12–13 *Coccolithus minimus.* TDP7A-65-1; 14–15 *Coccolithus minimus* TDP2-15-1

16–17 *Coccolithus formosus* TDP2-3-1; 18 *Coccolithus formosus* TDP4-1-1; 19–20 *Coccolithus crucis* TDP1-1-2

21–22 *Coccolithus crucis* TDP2-2-1; 23 *Coccolithus crucis* TDP2-2-1; 24–25 *Coccolithus crucis* TDP6-9-1

26–27 *Coccolithus foraminis* TDP7A-65-1; 28 *Cocco. foraminis* TDP7A-65-1; 29–30 *Coccolithus foraminis* TDP7A-35-1

31 *Coccolithus latus* TDP3-2-1; 32–33 *Coccolithus latus* TDP3-4-3; 34–35 *Coccolithus latus* TDP3-15-1

Plate 4

Coccolithaceae: *Coccolithus, Ericsonia*

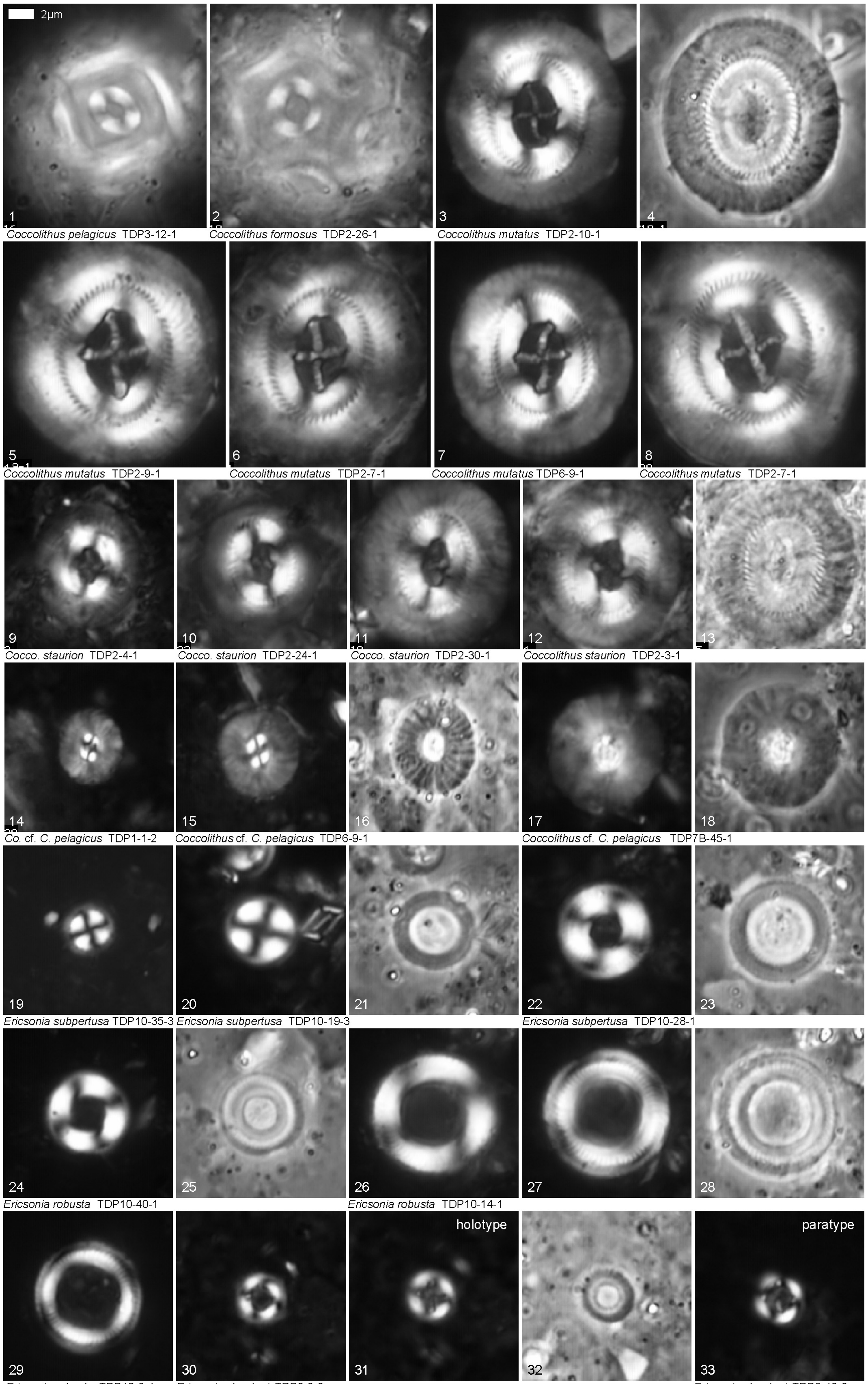
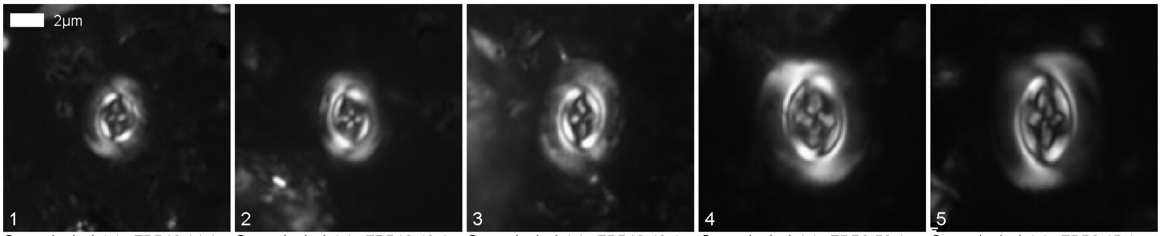
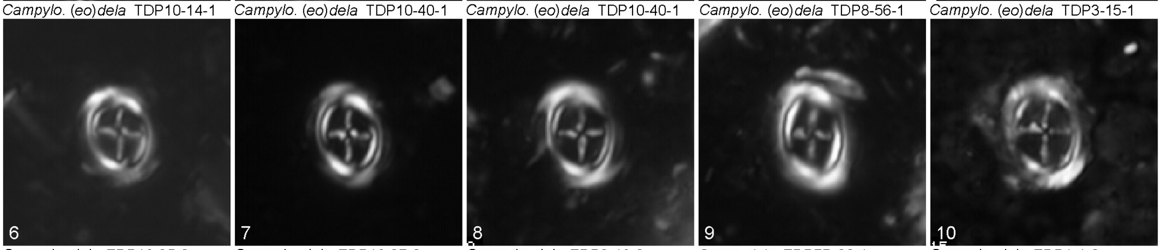


Plate 5

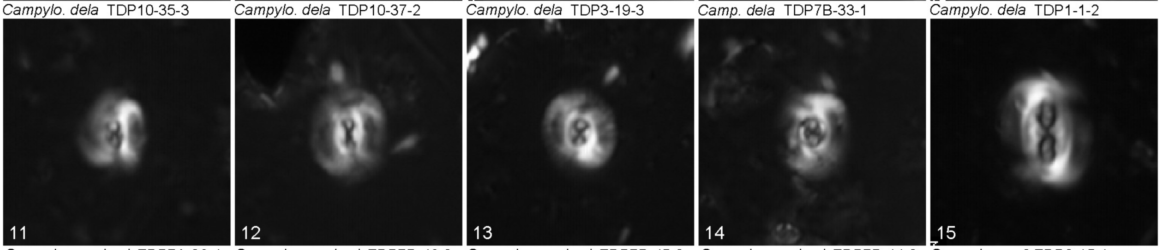
Coccolithaceae: *Campylosphaera, Cruciplacolithus*



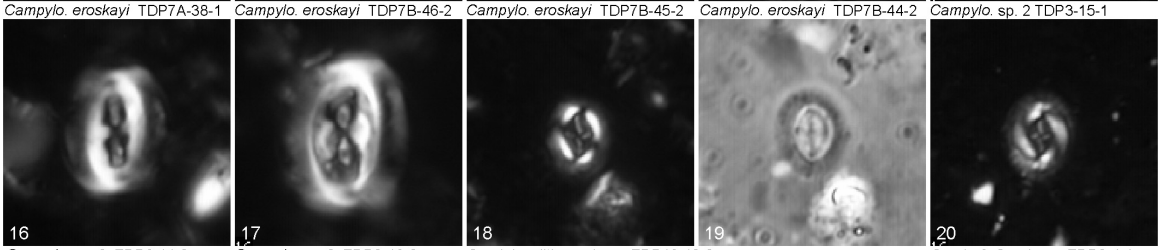
Campylo. (*eo*)*dela* TDP10-14-1 *Campylo.* (*eo*)*dela* TDP10-40-1 *Campylo.* (*eo*)*dela* TDP10-40-1 *Campylo.* (*eo*)*dela* TDP8-56-1 *Campylo.* (*eo*)*dela* TDP3-15-1



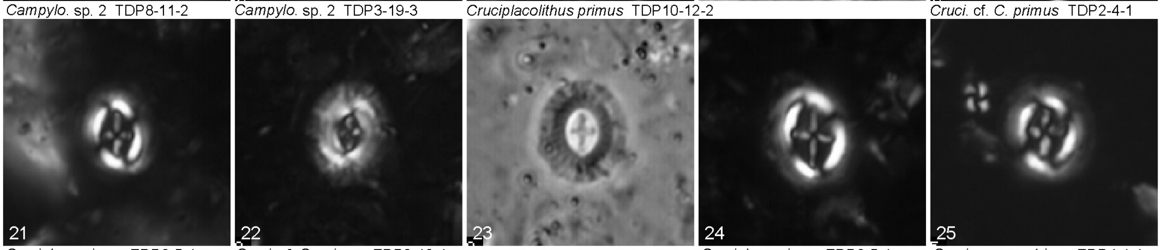
Campylo. dela TDP10-35-3 *Campylo. dela* TDP10-37-2 *Campylo. dela* TDP3-19-3 *Camp. dela* TDP7B-33-1 *Campylo. dela* TDP1-1-2



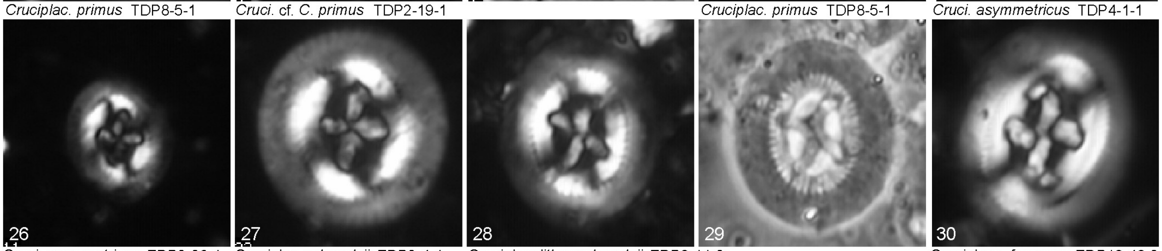
Campylo. eroskayi TDP7A-38-1 *Campylo. eroskayi* TDP7B-46-2 *Campylo. eroskayi* TDP7B-45-2 *Campylo. eroskayi* TDP7B-44-2 *Campylo.* sp. 2 TDP3-15-1



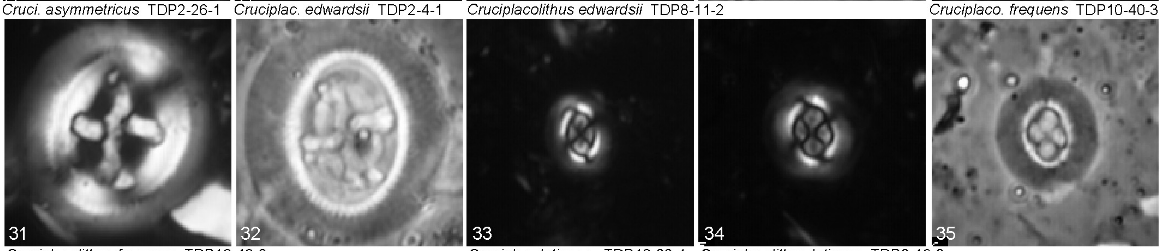
Campylo. sp. 2 TDP8-11-2 *Campylo.* sp. 2 TDP3-19-3 *Cruciplacolithus primus* TDP10-12-2 *Cruci.* cf. *C. primus* TDP2-4-1



Cruciplac. primus TDP8-5-1 *Cruci.* cf. *C. primus* TDP2-19-1 *Cruciplac. primus* TDP8-5-1 *Cruci. asymmetricus* TDP4-1-1



Cruci. asymmetricus TDP2-26-1 *Cruciplac. edwardsii* TDP2-4-1 *Cruciplacolithus edwardsii* TDP8-11-2 *Cruciplaco. frequens* TDP10-40-3



Cruciplacolithus frequens TDP10-40-3 *Cruciplac. latipons* TDP10-33-1 *Cruciplacolithus latipons* TDP3-19-3

Plate 6

Coccolithaceae: *Cruciplacolithus, Bramletteius, Chiasmolithus*

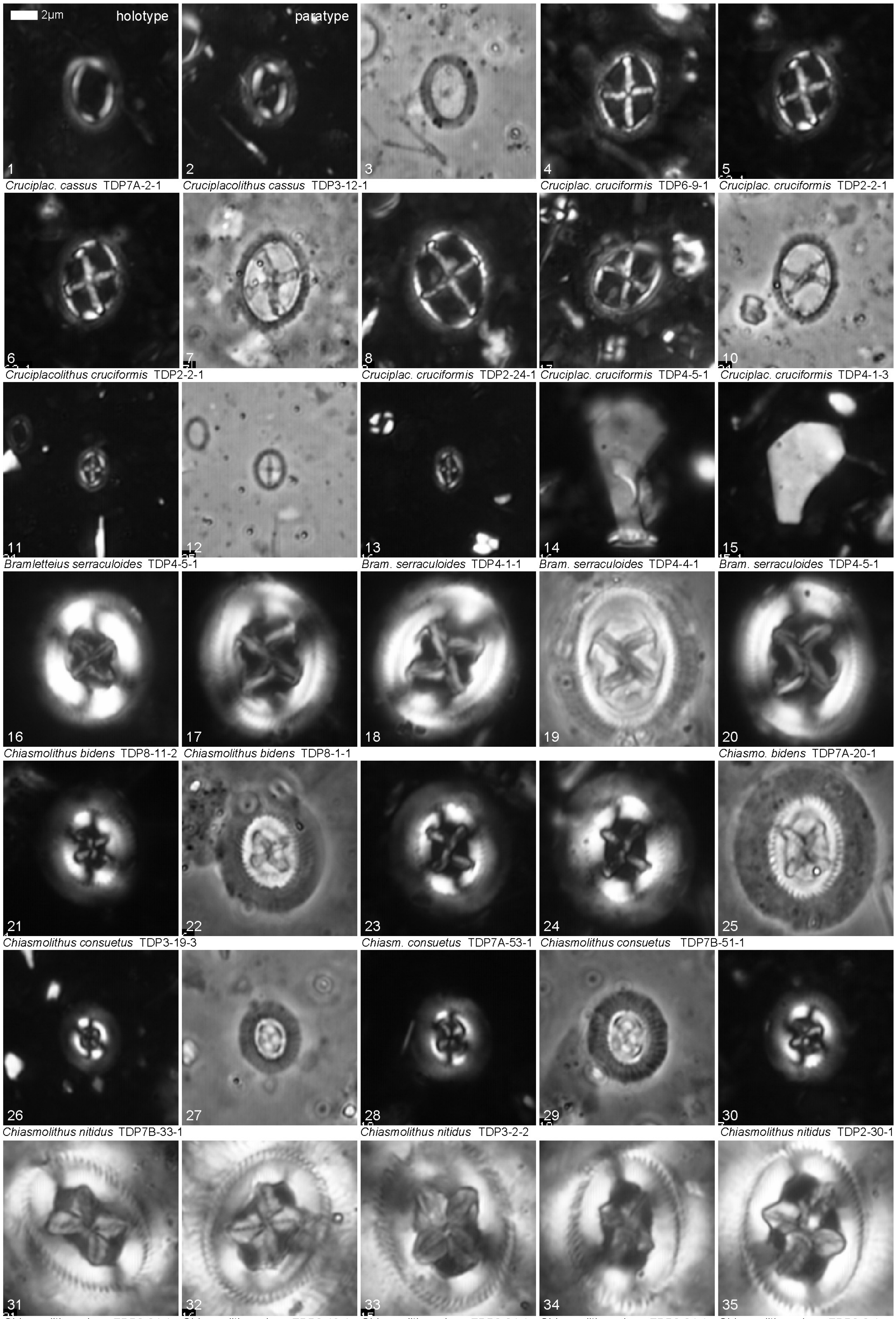
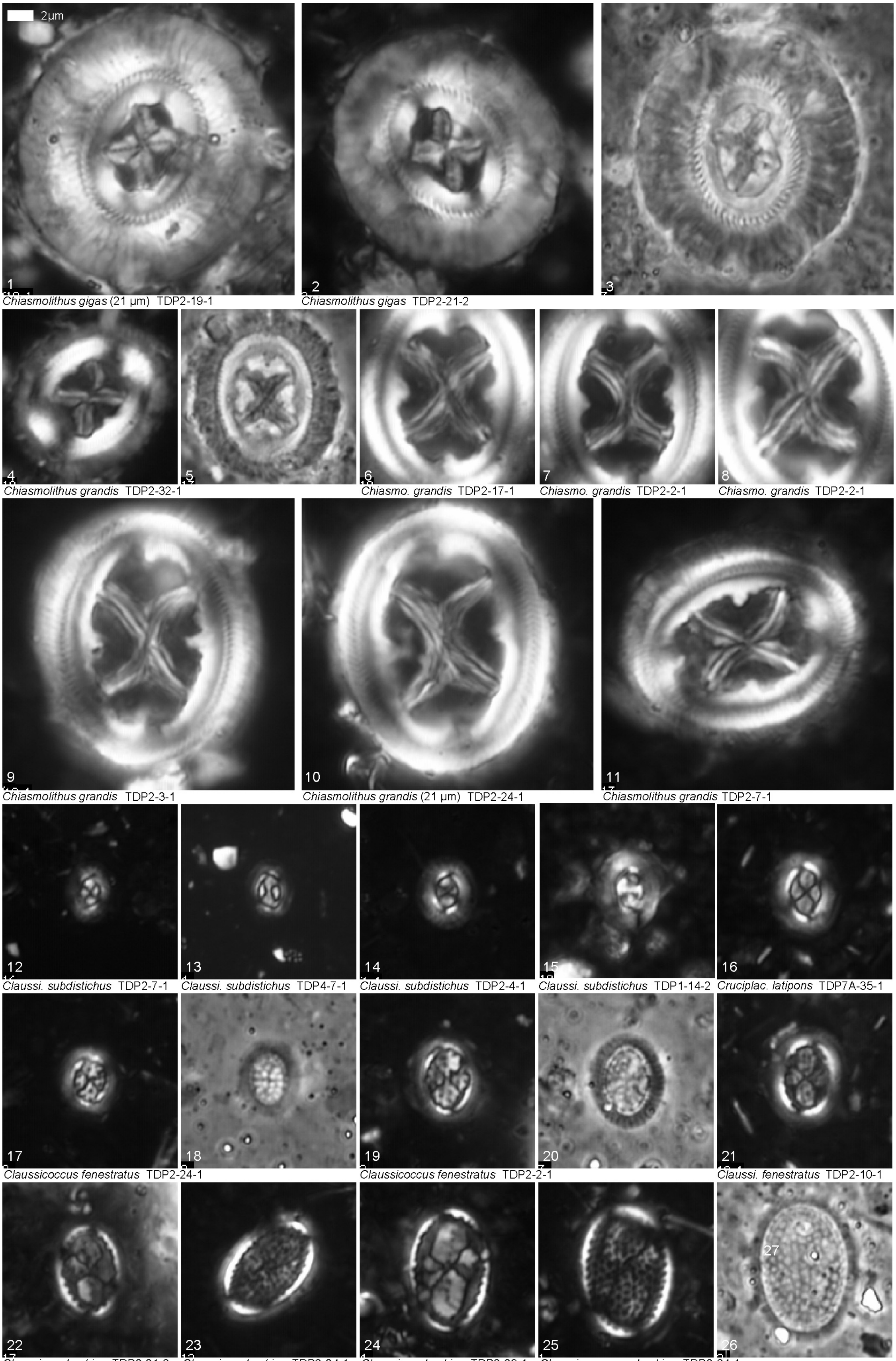


Plate 7

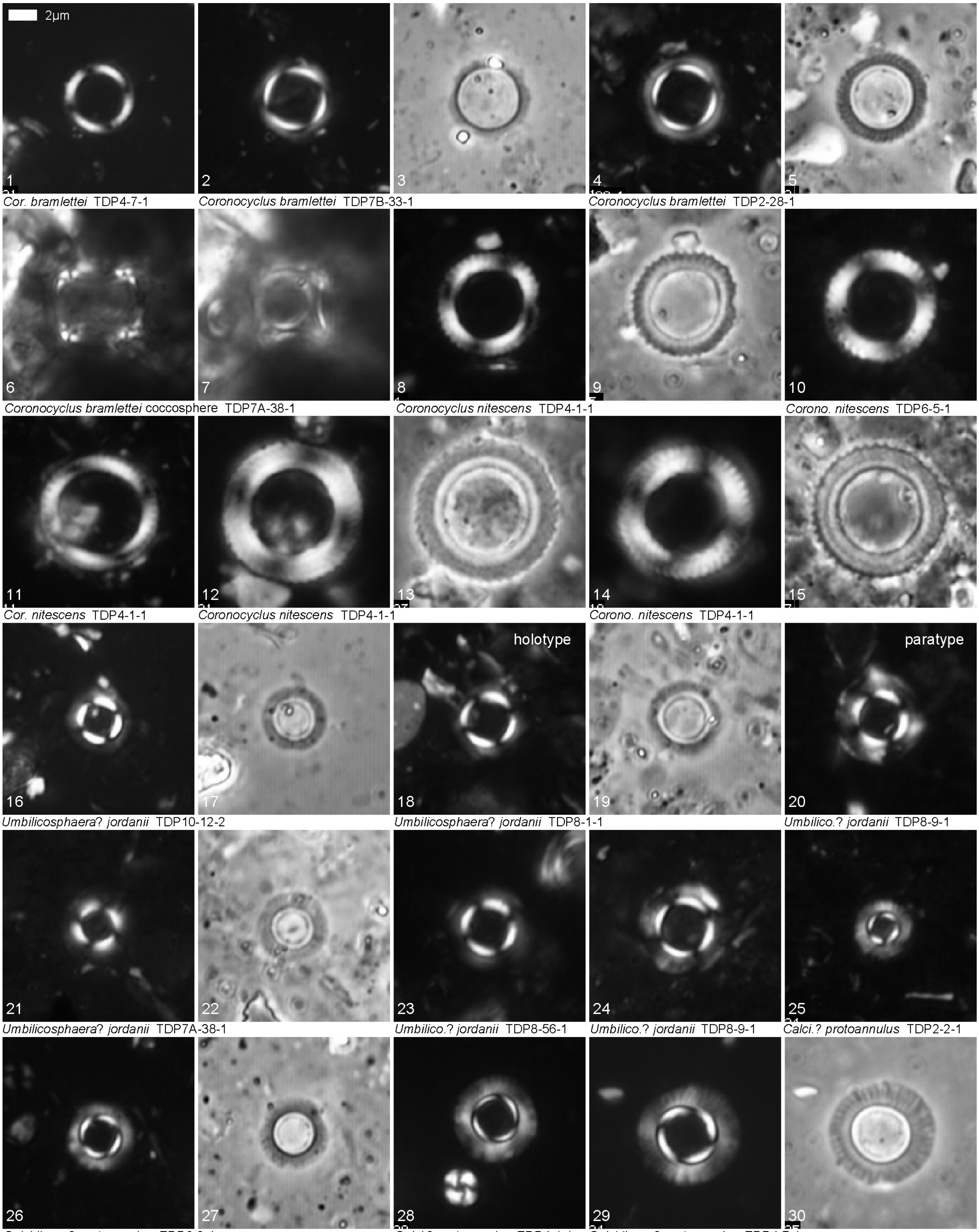
Coccolithaceae: *Chiasmolithus, Cruciplacolithus, Clausicoccus*



1 *Chiasmolithus gigas* (21 µm) TDP2-19-1
2 *Chiasmolithus gigas* TDP2-21-2
4 *Chiasmolithus grandis* TDP2-32-1
6 *Chiasmo. grandis* TDP2-17-1
7 *Chiasmo. grandis* TDP2-2-1
8 *Chiasmo. grandis* TDP2-2-1
9 *Chiasmolithus grandis* TDP2-3-1
10 *Chiasmolithus grandis* (21 µm) TDP2-24-1
11 *Chiasmolithus grandis* TDP2-7-1
12 *Claussi. subdistichus* TDP2-7-1
13 *Claussi. subdistichus* TDP4-7-1
14 *Claussi. subdistichus* TDP2-4-1
15 *Claussi. subdistichus* TDP1-14-2
16 *Cruciplac. latipons* TDP7A-35-1
17 *Claussicoccus fenestratus* TDP2-24-1
19 *Claussicoccus fenestratus* TDP2-2-1
21 *Claussi. fenestratus* TDP2-10-1
22 *Claussi. vanheckiae* TDP2-21-2
23 *Claussi. vanheckiae* TDP2-24-1
24 *Claussi. vanheckiae* TDP2-23-1
25 *Claussicoccus vanheckiae* TDP2-24-1

Plate 8

Calcidiscaceae: *Coronocyclus, Umbilicosphaera*?, *Calcidiscus*?



Cor. bramlettei TDP4-7-1; *Coronocyclus bramlettei* TDP7B-33-1; *Coronocyclus bramlettei* TDP2-28-1

Coronocyclus bramlettei coccosphere TDP7A-38-1; *Coronocyclus nitescens* TDP4-1-1; *Corono. nitescens* TDP6-5-1

Cor. nitescens TDP4-1-1; *Coronocyclus nitescens* TDP4-1-1; *Corono. nitescens* TDP4-1-1

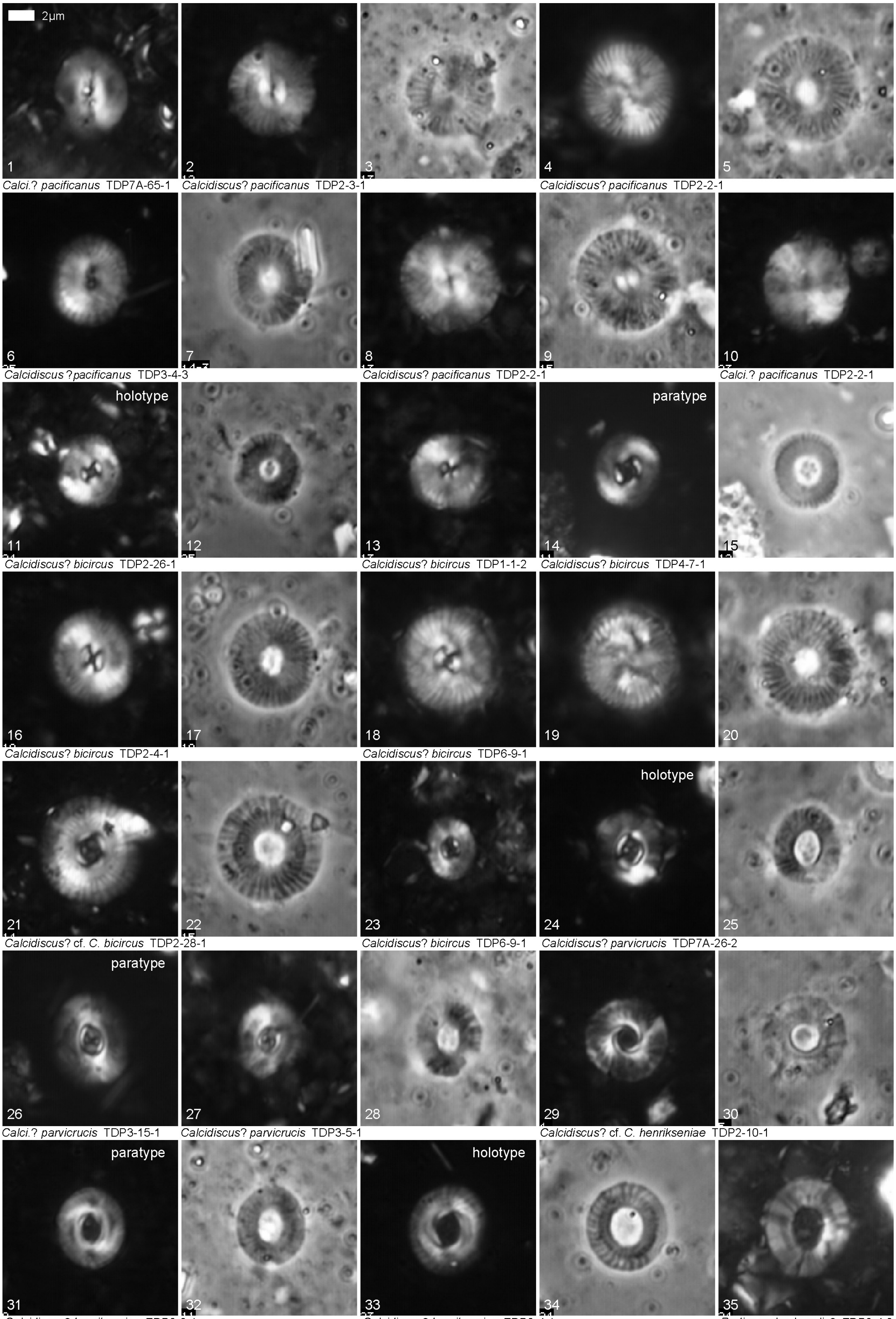
Umbilicosphaera? *jordanii* TDP10-12-2; *Umbilicosphaera*? *jordanii* TDP8-1-1; *Umbilico.*? *jordanii* TDP8-9-1

Umbilicosphaera? *jordanii* TDP7A-38-1; *Umbilico.*? *jordanii* TDP8-56-1; *Umbilico.*? *jordanii* TDP8-9-1; *Calci.*? *protoannulus* TDP2-2-1

Calcidiscus? *protoannulus* TDP6-8-1; *Calci.*? *protoannulus* TDP4-1-1; *Calcidiscus*? *protoannulus* TDP4-7-1

Plate 9

Calcidiscaceae: *Calcidiscus*?; *Incertae sedis* placoliths: *Pedinocyclus*



Calci.? pacificanus TDP7A-65-1; *Calcidiscus? pacificanus* TDP2-3-1; *Calcidiscus? pacificanus* TDP2-2-1

Calcidiscus ?pacificanus TDP3-4-3; *Calcidiscus? pacificanus* TDP2-2-1; *Calci.? pacificanus* TDP2-2-1

Calcidiscus? bicircus TDP2-26-1; *Calcidiscus? bicircus* TDP1-1-2; *Calcidiscus? bicircus* TDP4-7-1

Calcidiscus? bicircus TDP2-4-1; *Calcidiscus? bicircus* TDP6-9-1

Calcidiscus? cf. *C. bicircus* TDP2-28-1; *Calcidiscus? bicircus* TDP6-9-1; *Calcidiscus? parvicrucis* TDP7A-26-2

Calci.? parvicrucis TDP3-15-1; *Calcidiscus? parvicrucis* TDP3-5-1; *Calcidiscus?* cf. *C. henrikseniae* TDP2-10-1

Calcidiscus? henrikseniae TDP2-3-1; *Calcidiscus? henrikseniae* TDP2-4-1; *Pedinocyclus larvalis?* TDP3-4-3

Plate 10

Incertae sedis placoliths: *Hayella, Pedinocyclus, Ellipsolithus, etc.*

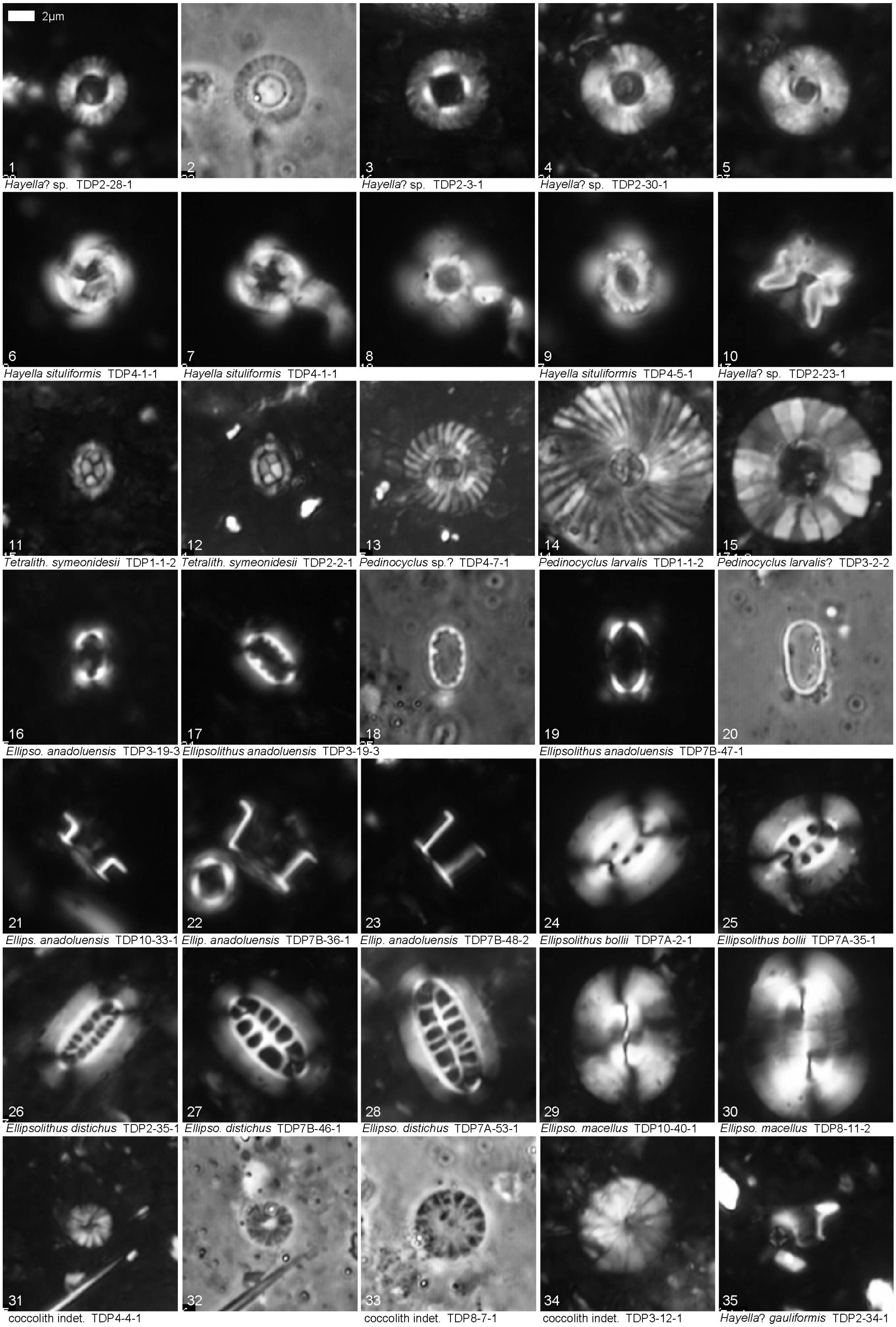


Plate 11

Chiastozygaceae; Helicosphaeraceae: *Helicosphaera*

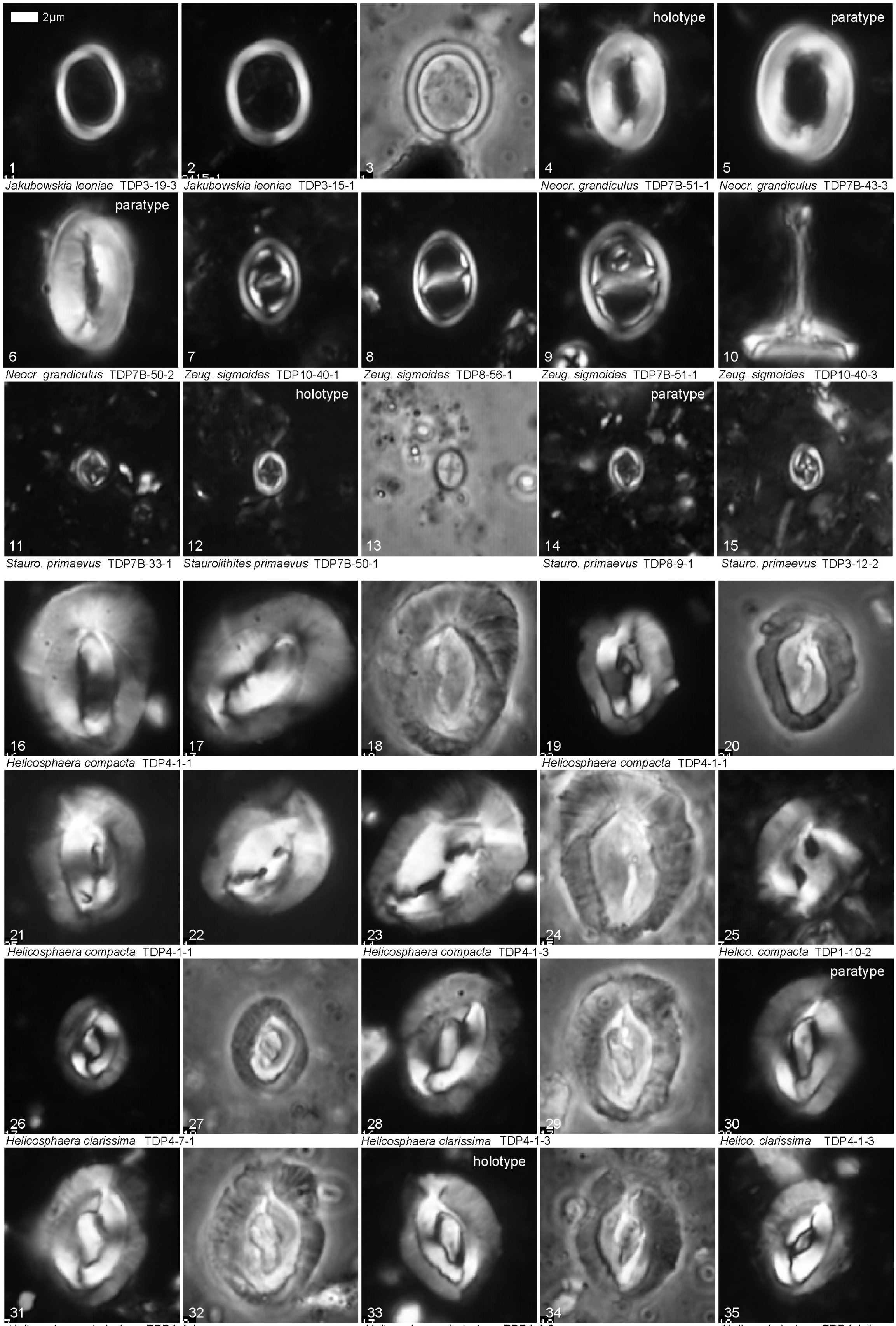
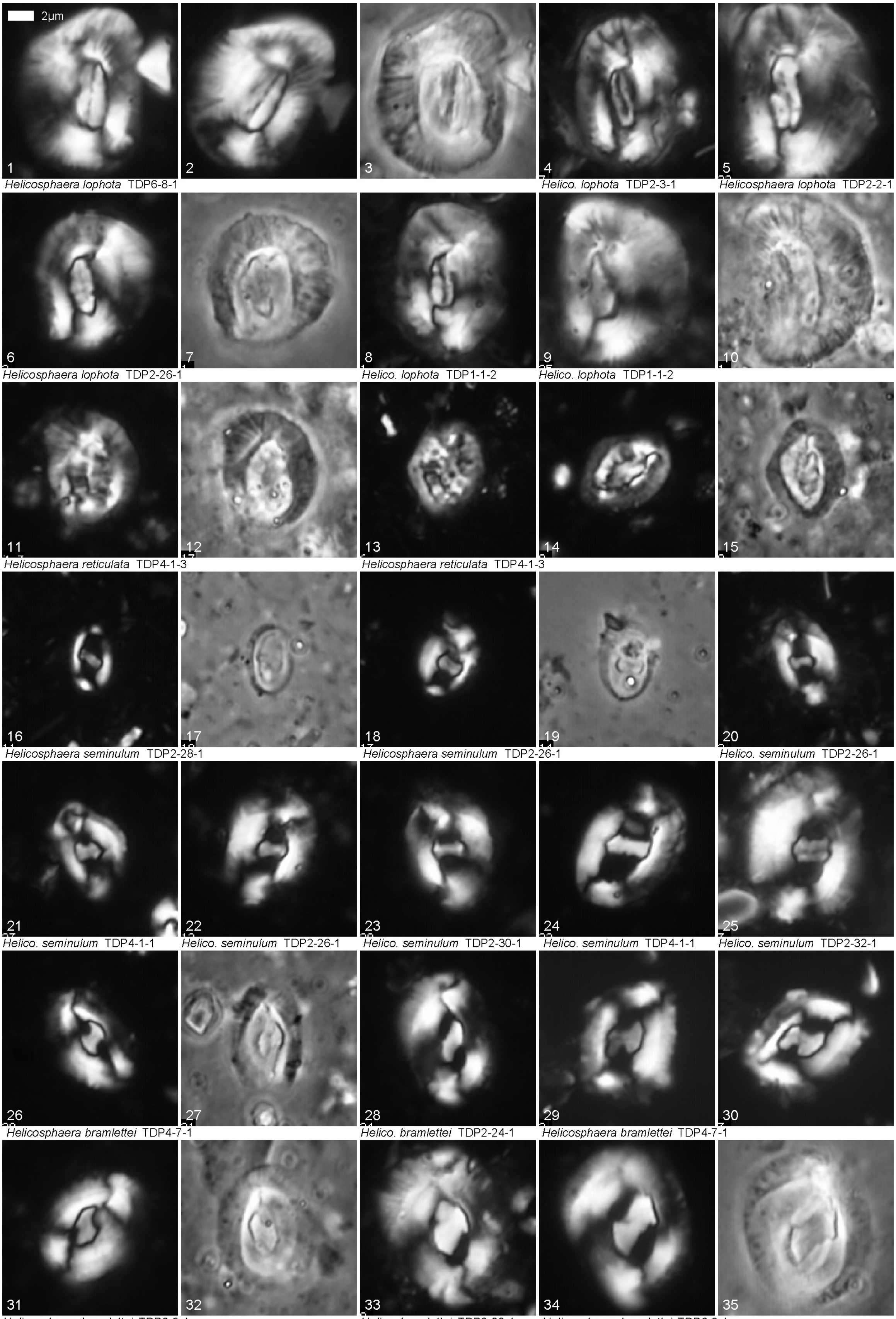


Plate 12

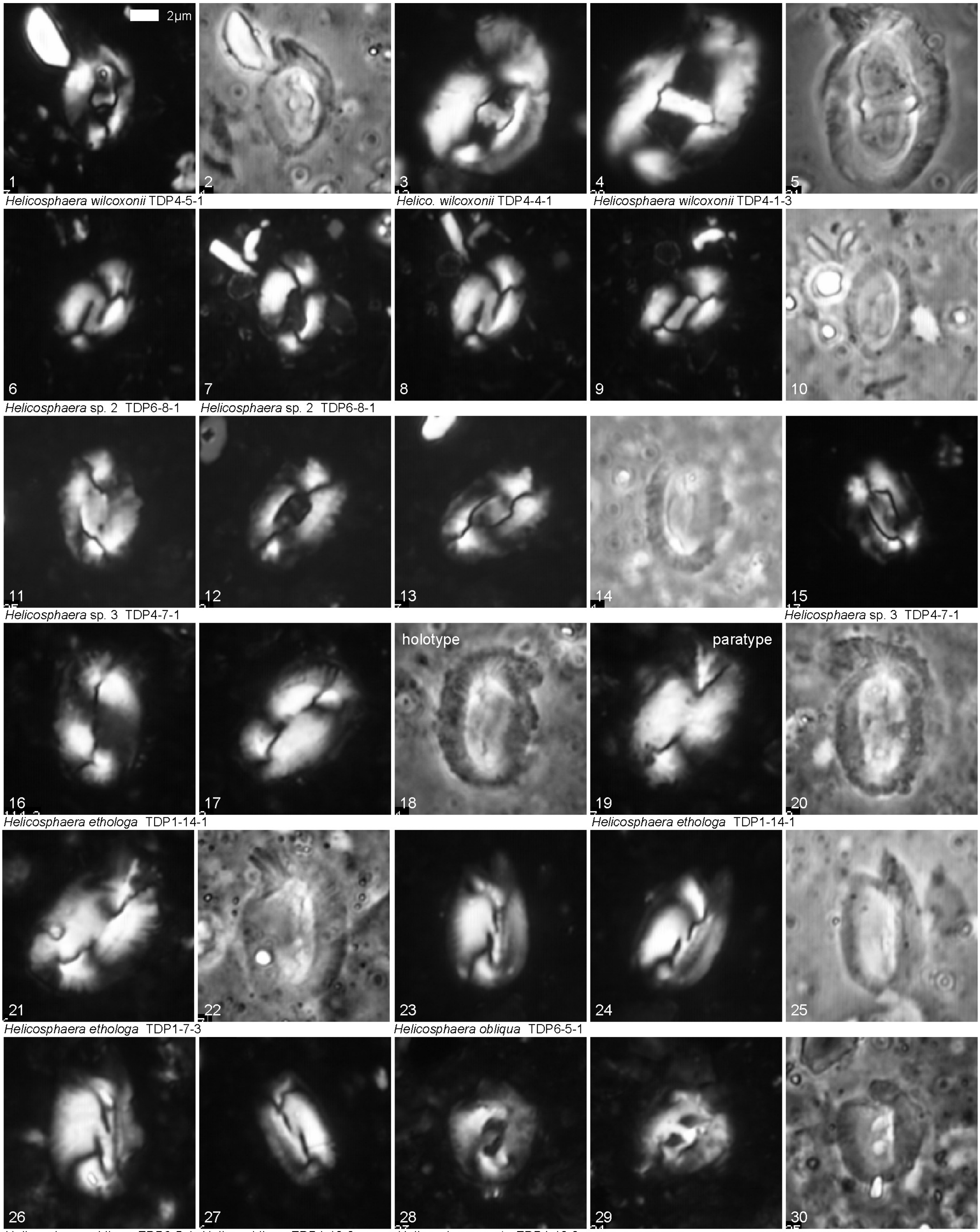
Helicosphaeraceae: *Helicosphaera*



Helicosphaera lophota TDP6-8-1
Helico. lophota TDP2-3-1
Helicosphaera lophota TDP2-2-1
Helicosphaera lophota TDP2-26-1
Helico. lophota TDP1-1-2
Helico. lophota TDP1-1-2
Helicosphaera reticulata TDP4-1-3
Helicosphaera reticulata TDP4-1-3
Helicosphaera seminulum TDP2-28-1
Helicosphaera seminulum TDP2-26-1
Helico. seminulum TDP2-26-1
Helico. seminulum TDP4-1-1
Helico. seminulum TDP2-26-1
Helico. seminulum TDP2-30-1
Helico. seminulum TDP4-1-1
Helico. seminulum TDP2-32-1
Helicosphaera bramlettei TDP4-7-1
Helico. bramlettei TDP2-24-1
Helicosphaera bramlettei TDP4-7-1
Helicosphaera bramlettei TDP6-9-1
Helico. bramlettei TDP2-23-1
Helicosphaera bramlettei TDP6-8-1

Plate 13

Helicosphaeraceae: *Helicosphaera*



Helicosphaera wilcoxonii TDP4-5-1 *Helico. wilcoxonii* TDP4-4-1 *Helicosphaera wilcoxonii* TDP4-1-3

Helicosphaera sp. 2 TDP6-8-1 *Helicosphaera* sp. 2 TDP6-8-1

Helicosphaera sp. 3 TDP4-7-1 *Helicosphaera* sp. 3 TDP4-7-1

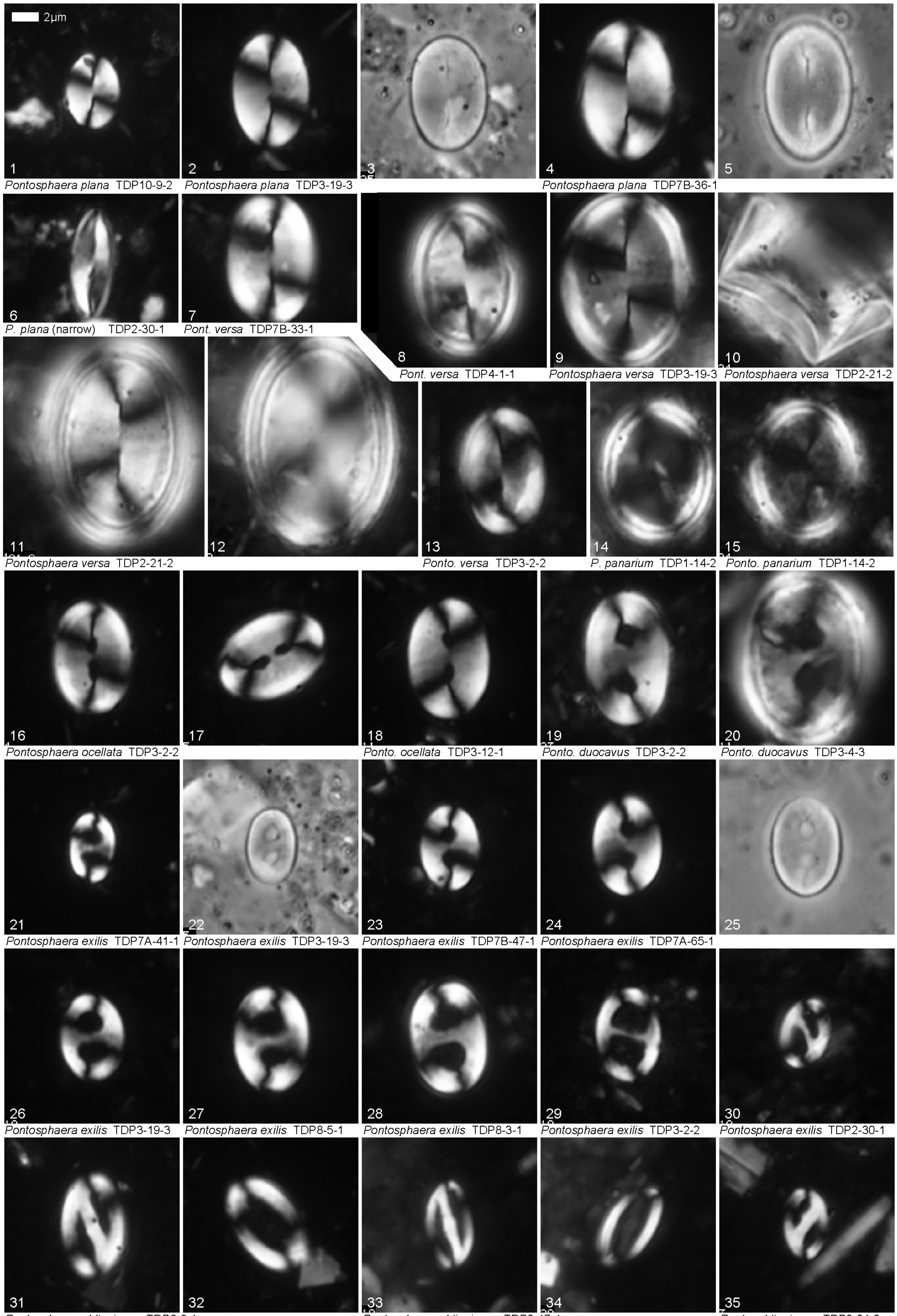
Helicosphaera ethologa TDP1-14-1 *Helicosphaera ethologa* TDP1-14-1

Helicosphaera ethologa TDP1-7-3 *Helicosphaera obliqua* TDP6-5-1

Helicosphaera obliqua TDP6-5-1 *Helico. obliqua* TDP1-13-3 *Helicosphaera recta* TDP1-13-3

Plate 14

Pontosphaeraceae: *Pontosphaera*



1 *Pontosphaera plana* TDP10-9-2; 2 *Pontosphaera plana* TDP3-19-3; 4 *Pontosphaera plana* TDP7B-36-1

6 *P. plana* (narrow) TDP2-30-1; 7 *Pont. versa* TDP7B-33-1; 8 *Pont. versa* TDP4-1-1; 9 *Pontosphaera versa* TDP3-19-3; 10 *Pontosphaera versa* TDP2-21-2

11 *Pontosphaera versa* TDP2-21-2; 13 *Ponto. versa* TDP3-2-2; 14 *P. panarium* TDP1-14-2; 15 *Ponto. panarium* TDP1-14-2

16 *Pontosphaera ocellata* TDP3-2-2; 18 *Ponto. ocellata* TDP3-12-1; 19 *Ponto. duocavus* TDP3-2-2; 20 *Ponto. duocavus* TDP3-4-3

21 *Pontosphaera exilis* TDP7A-41-1; 22 *Pontosphaera exilis* TDP3-19-3; 23 *Pontosphaera exilis* TDP7B-47-1; 24 *Pontosphaera exilis* TDP7A-65-1

26 *Pontosphaera exilis* TDP3-19-3; 27 *Pontosphaera exilis* TDP8-5-1; 28 *Pontosphaera exilis* TDP8-3-1; 29 *Pontosphaera exilis* TDP3-2-2; 30 *Pontosphaera exilis* TDP2-30-1

31 *Pontosphaera obliquipons* TDP6-8-1; 33 *Pontosphaera obliquipons* TDP2-17-1; 35 *Ponto. obliquipons* TDP2-21-2

Plate 15

Pontosphaeraceae: *Pontosphaera*

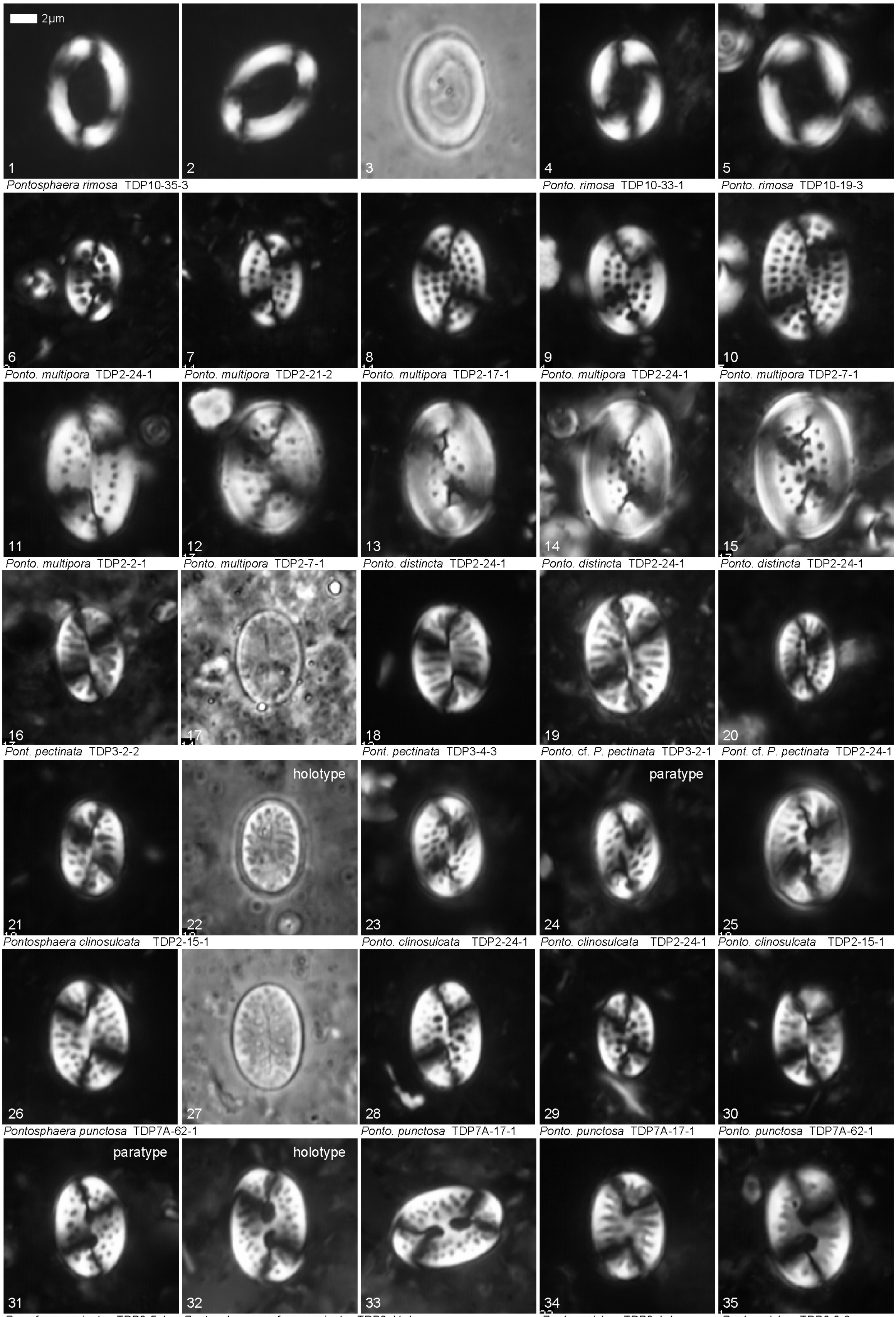
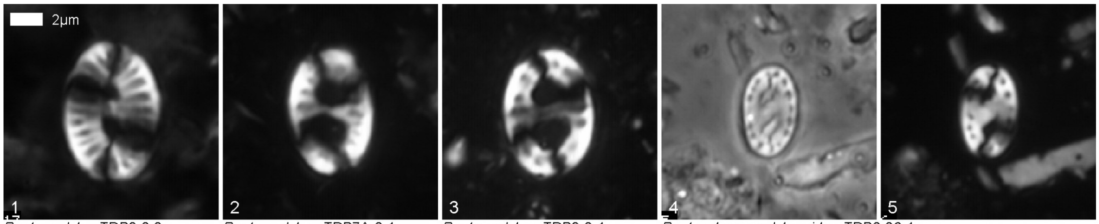
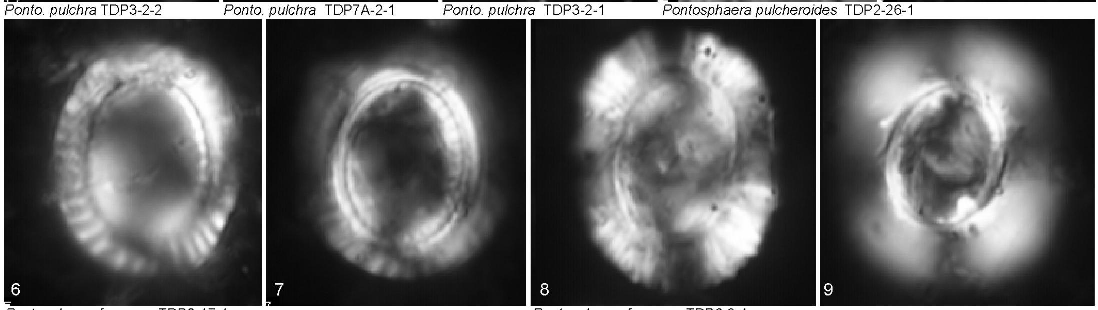


Plate 16

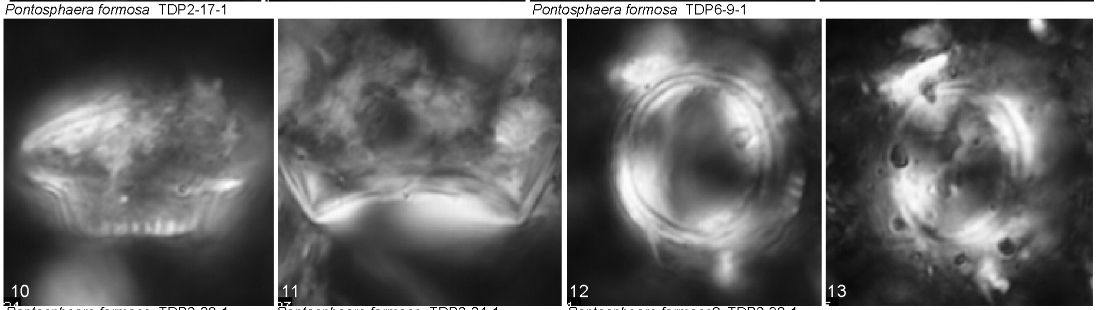
Pontosphaeraceae: *Pontosphaera, Scyphosphaera*



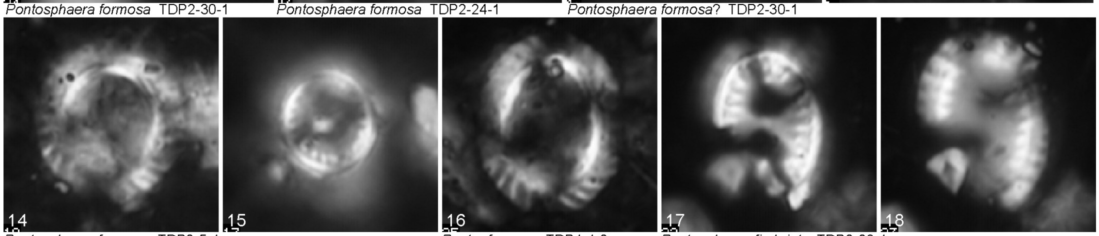
Ponto. pulchra TDP3-2-2 *Ponto. pulchra* TDP7A-2-1 *Ponto. pulchra* TDP3-2-1 *Pontosphaera pulcheroides* TDP2-26-1



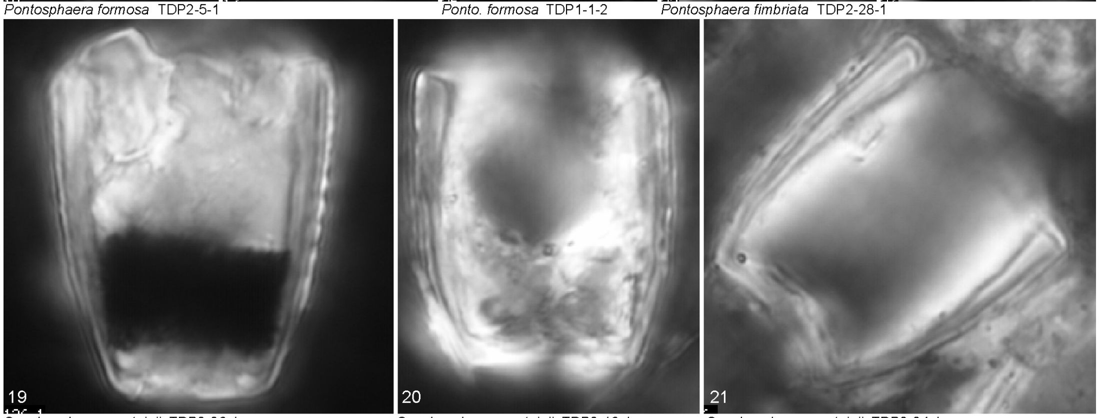
Pontosphaera formosa TDP2-17-1 *Pontosphaera formosa* TDP6-9-1



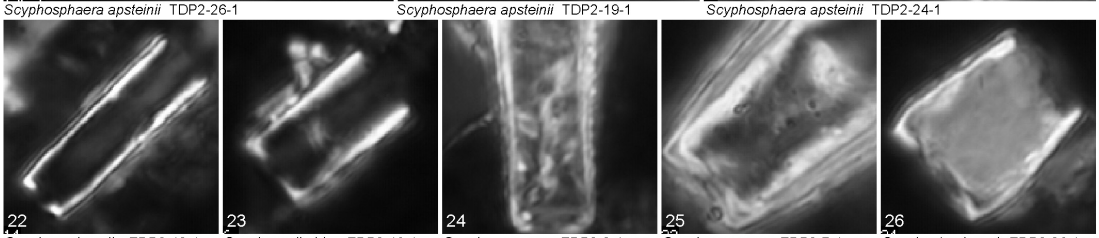
Pontosphaera formosa TDP2-30-1 *Pontosphaera formosa* TDP2-24-1 *Pontosphaera formosa*? TDP2-30-1



Pontosphaera formosa TDP2-5-1 *Ponto. formosa* TDP1-1-2 *Pontosphaera fimbriata* TDP2-28-1



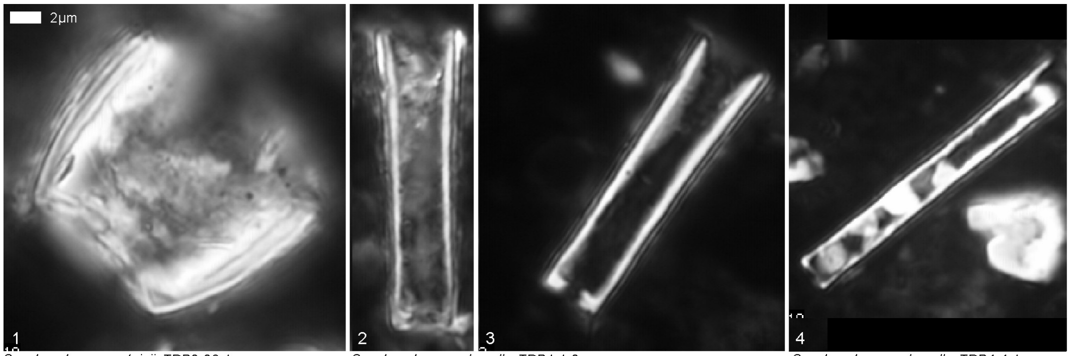
Scyphosphaera apsteinii TDP2-26-1 *Scyphosphaera apsteinii* TDP2-19-1 *Scyphosphaera apsteinii* TDP2-24-1



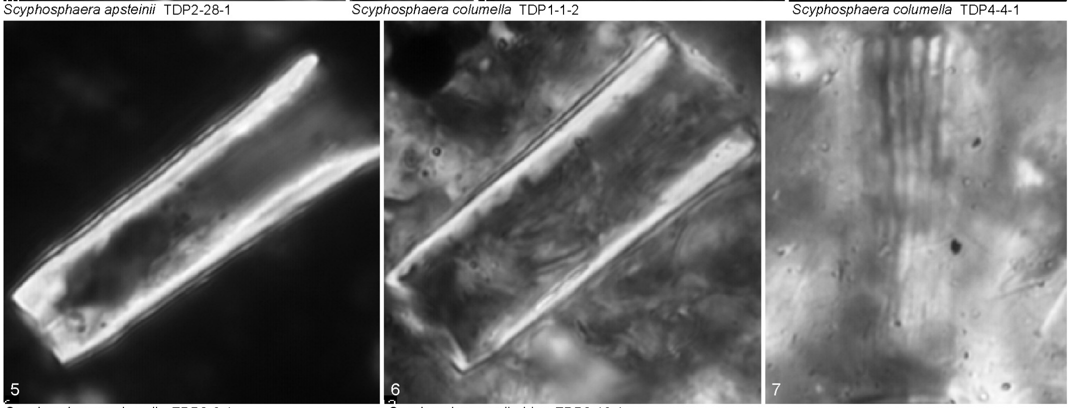
Scypho. columella TDP2-13-1 *Scypho. cylindrica* TDP2-19-1 *Scypho. expansa* TDP2-2-1 *Scypho. expansa* TDP2-7-1 *Scypho. tercisensis* TDP2-26-1

Plate 17

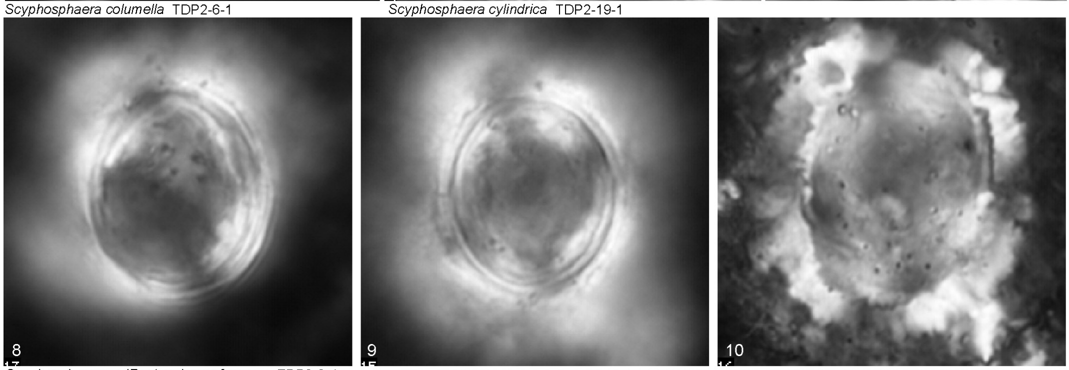
Pontosphaeraceae: *Scyphosphaera*



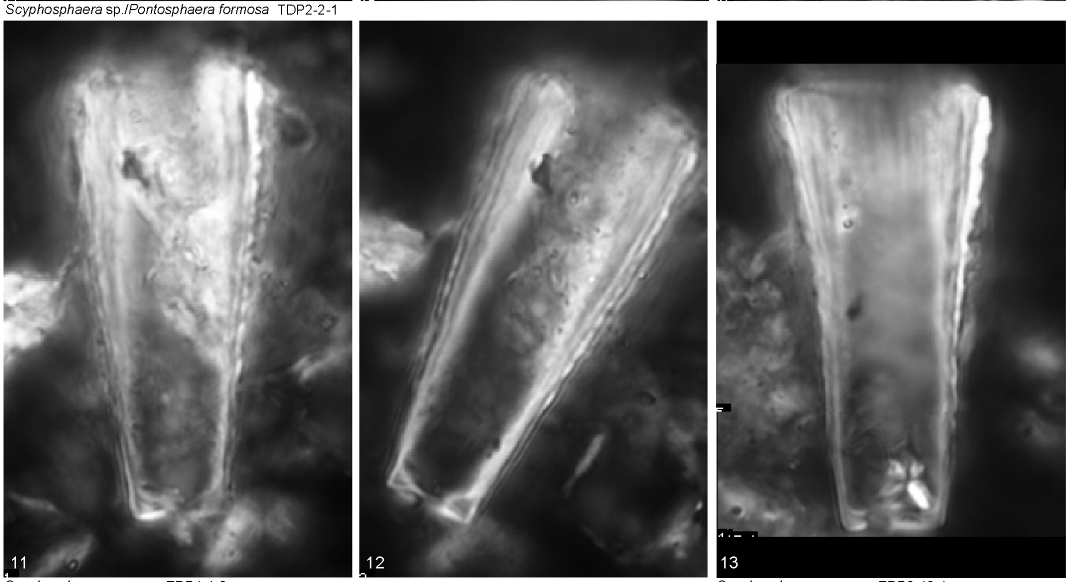
Scyphosphaera apsteinii TDP2-28-1 *Scyphosphaera columella* TDP1-1-2 *Scyphosphaera columella* TDP4-4-1



Scyphosphaera columella TDP2-6-1 *Scyphosphaera cylindrica* TDP2-19-1



Scyphosphaera sp./*Pontosphaera formosa* TDP2-2-1



Scyphosphaera expansa TDP1-1-2 *Scyphosphaera expansa* TDP2-13-1

Plate 18

Zygodiscaceae: *Lophodolithus, Zygodiscus*

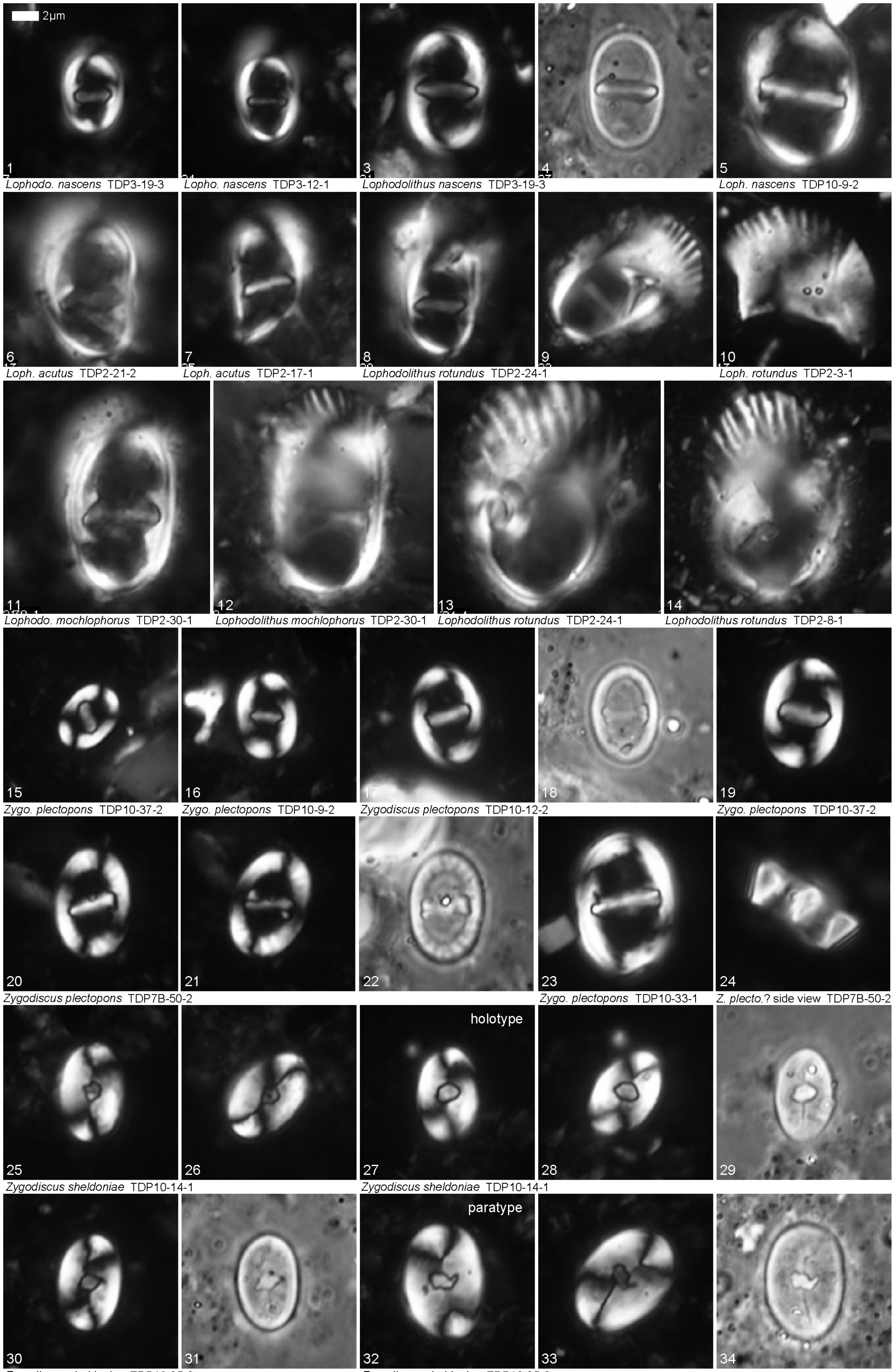


Plate 19

Zygodiscaceae: *Zygodiscus, Neochiastozygus*

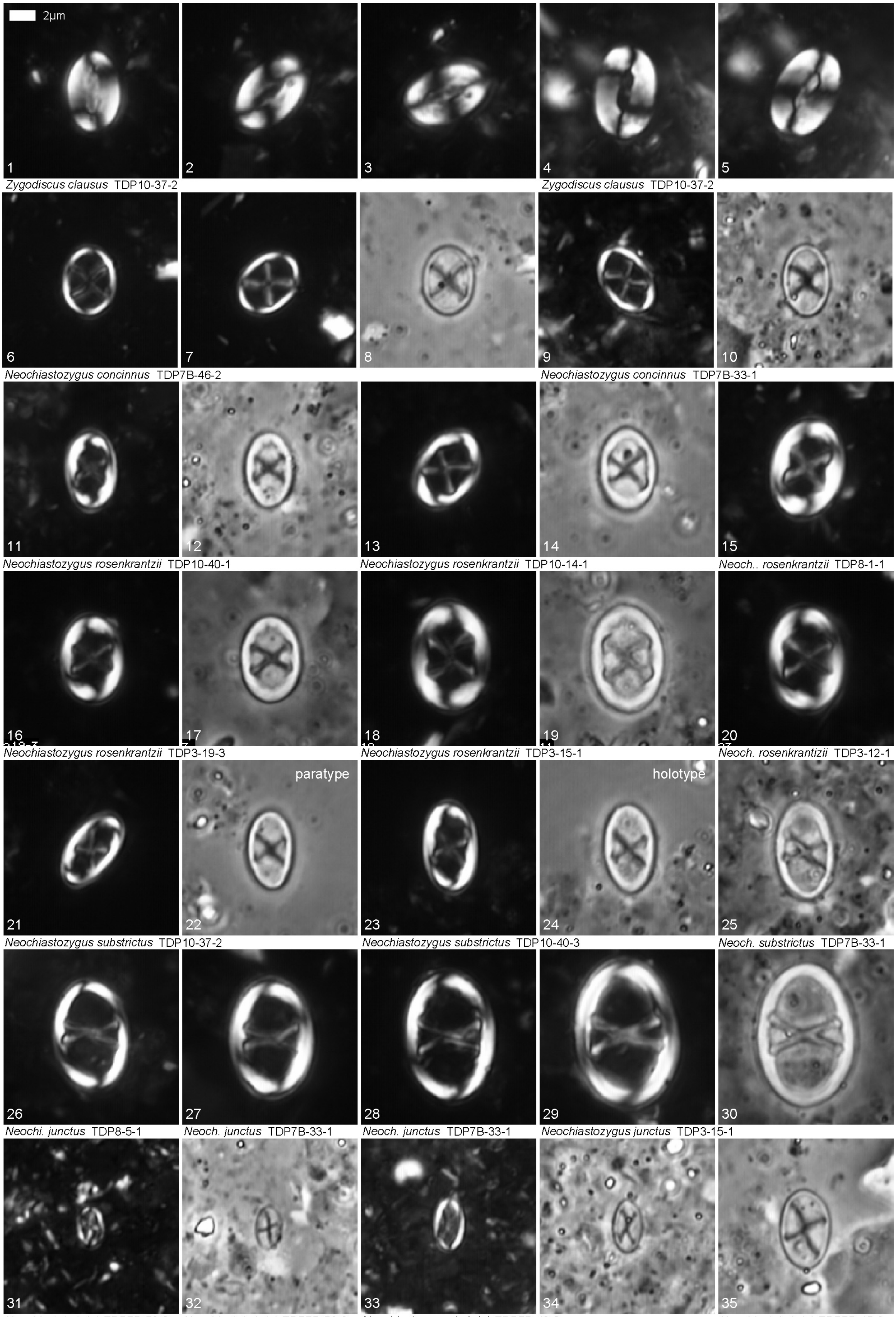
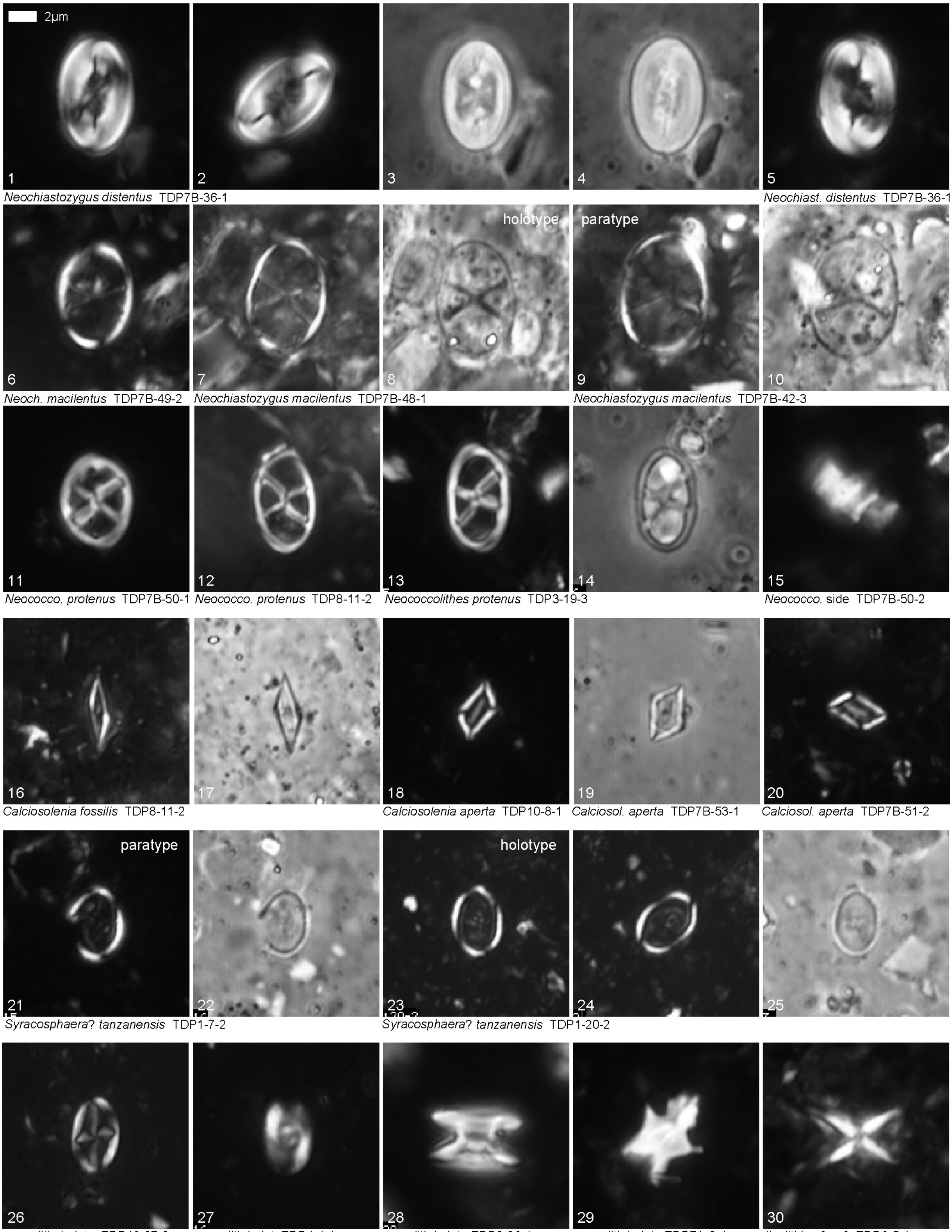


Plate 20

Zygodiscaceae; Calciosoleniaceae; Syracosphaeraceae; *Incertae sedis*



Neochiastozygus distentus TDP7B-36-1 (1–4)

Neochiast. distentus TDP7B-36-1 (5)

Neoch. macilentus TDP7B-49-2 (6)

Neochiastozygus macilentus TDP7B-48-1 (7, 8)

Neochiastozygus macilentus TDP7B-42-3 (9, 10)

Neococco. protenus TDP7B-50-1 (11)

Neococco. protenus TDP8-11-2 (12)

Neococcolithes protenus TDP3-19-3 (13, 14)

Neococco. side TDP7B-50-2 (15)

Calciosolenia fossilis TDP8-11-2 (16, 17)

Calciosolenia aperta TDP10-8-1 (18)

Calciosol. aperta TDP7B-53-1 (19)

Calciosol. aperta TDP7B-51-2 (20)

Syracosphaera? *tanzanensis* TDP1-7-2 (21, 22)

Syracosphaera? *tanzanensis* TDP1-20-2 (23–25)

coccolith indet. TDP10-37-2 (26)

coccolith indet TDP4-4-1 (27)

coccolith indet. TDP2-26-1 (28)

coccolith indet. TDP7A-2-1 (29)

Ilselithina fusa? TDP6-5-1 (30)

Plate 21

Rhabdosphaeraceae: *Blackites, B. gladius* & *B. morionum* groups

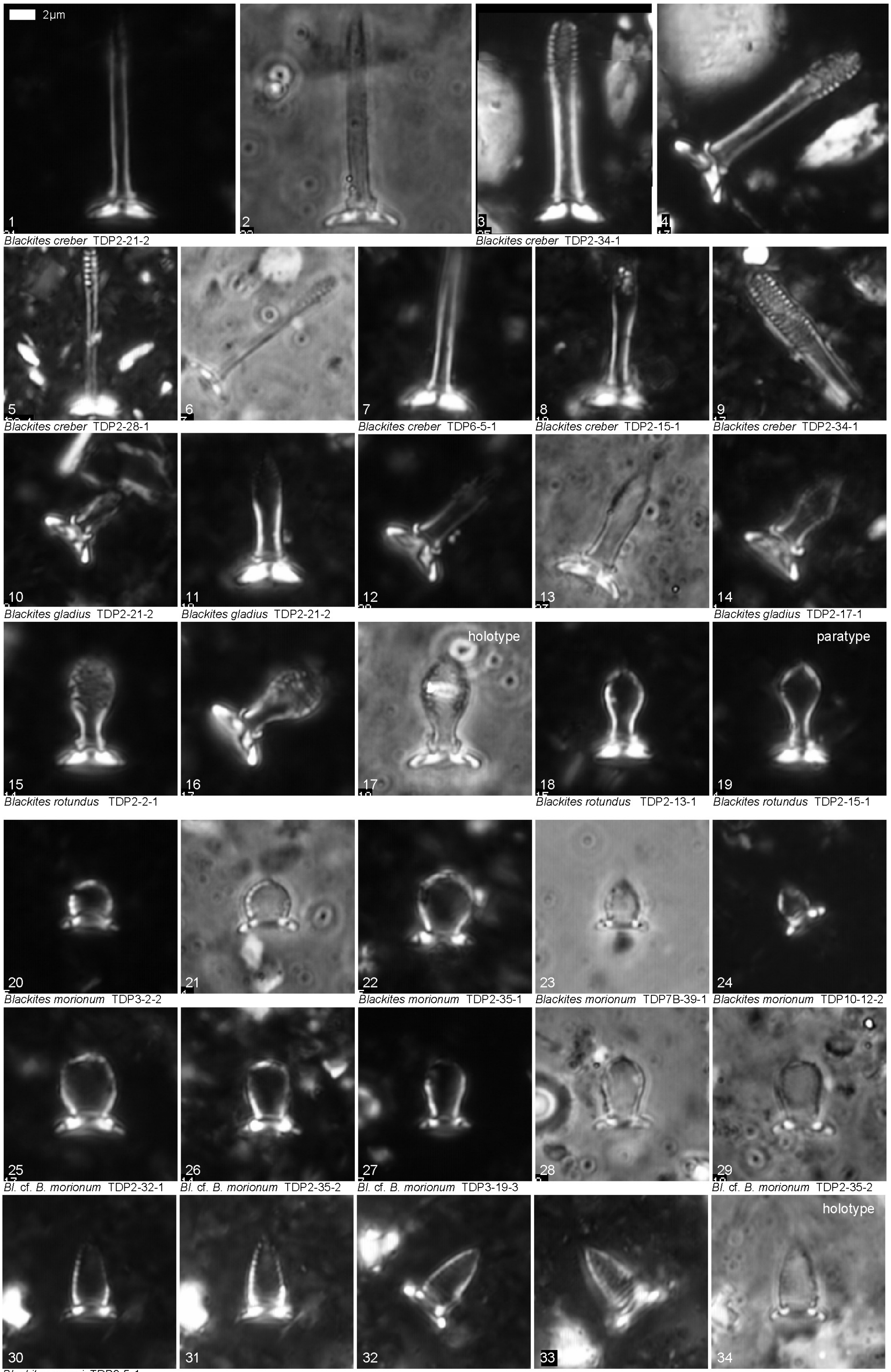
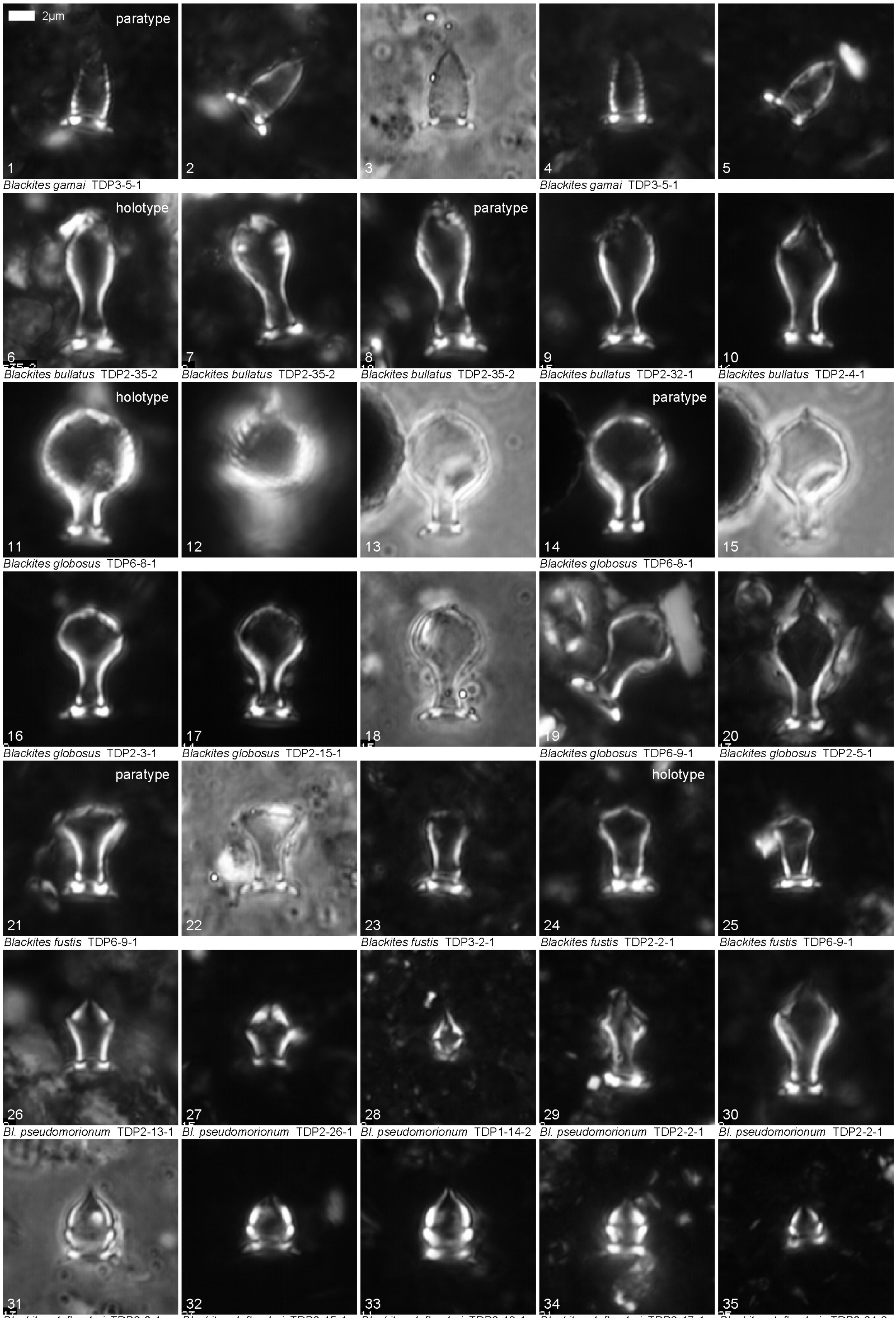


Plate 22

Rhabdosphaeraceae: *Blackites, B. morionum* group



Blackites gamai TDP3-5-1 (1–3); *Blackites gamai* TDP3-5-1 (4–5)

Blackites bullatus TDP2-35-2 (6); *Blackites bullatus* TDP2-35-2 (7); *Blackites bullatus* TDP2-35-2 (8); *Blackites bullatus* TDP2-32-1 (9); *Blackites bullatus* TDP2-4-1 (10)

Blackites globosus TDP6-8-1 (11–13); *Blackites globosus* TDP6-8-1 (14–15)

Blackites globosus TDP2-3-1 (16); *Blackites globosus* TDP2-15-1 (17–18); *Blackites globosus* TDP6-9-1 (19); *Blackites globosus* TDP2-5-1 (20)

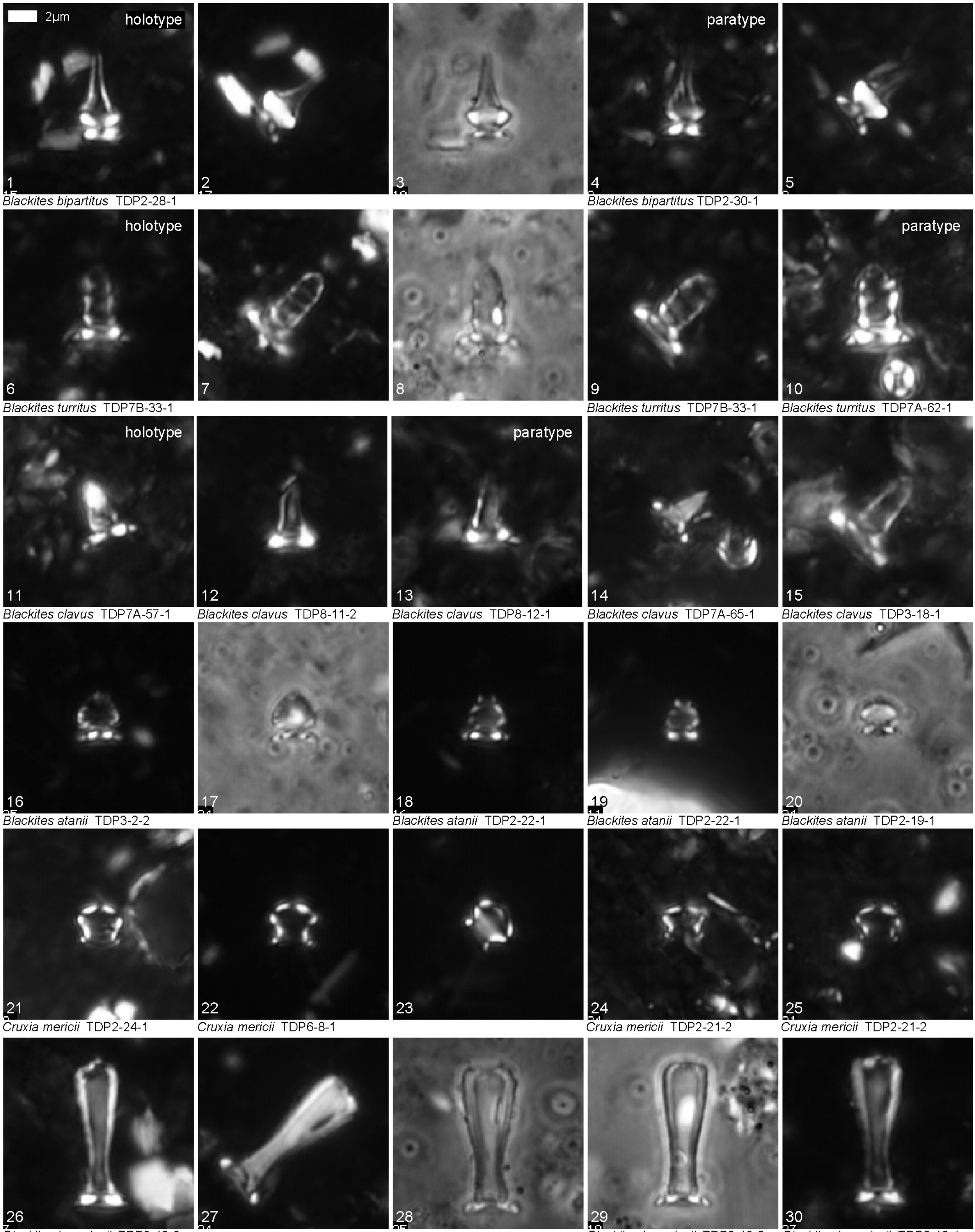
Blackites fustis TDP6-9-1 (21–22); *Blackites fustis* TDP3-2-1 (23); *Blackites fustis* TDP2-2-1 (24); *Blackites fustis* TDP6-9-1 (25)

Bl. pseudomorionum TDP2-13-1 (26); *Bl. pseudomorionum* TDP2-26-1 (27); *Bl. pseudomorionum* TDP1-14-2 (28); *Bl. pseudomorionum* TDP2-2-1 (29); *Bl. pseudomorionum* TDP2-2-1 (30)

Blackites deflandrei TDP2-2-1 (31); *Blackites deflandrei* TDP2-15-1 (32); *Blackites deflandrei* TDP2-10-1 (33); *Blackites deflandrei* TDP2-17-1 (34); *Blackites deflandrei* TDP2-21-2 (35)

Plate 23

Rhabdosphaeraceae: *Blackites, B. morionum* & *B. herculesii* groups



Blackites bipartitus TDP2-28-1 *Blackites bipartitus* TDP2-30-1

Blackites turritus TDP7B-33-1 *Blackites turritus* TDP7B-33-1 *Blackites turritus* TDP7A-62-1

Blackites clavus TDP7A-57-1 *Blackites clavus* TDP8-11-2 *Blackites clavus* TDP8-12-1 *Blackites clavus* TDP7A-65-1 *Blackites clavus* TDP3-18-1

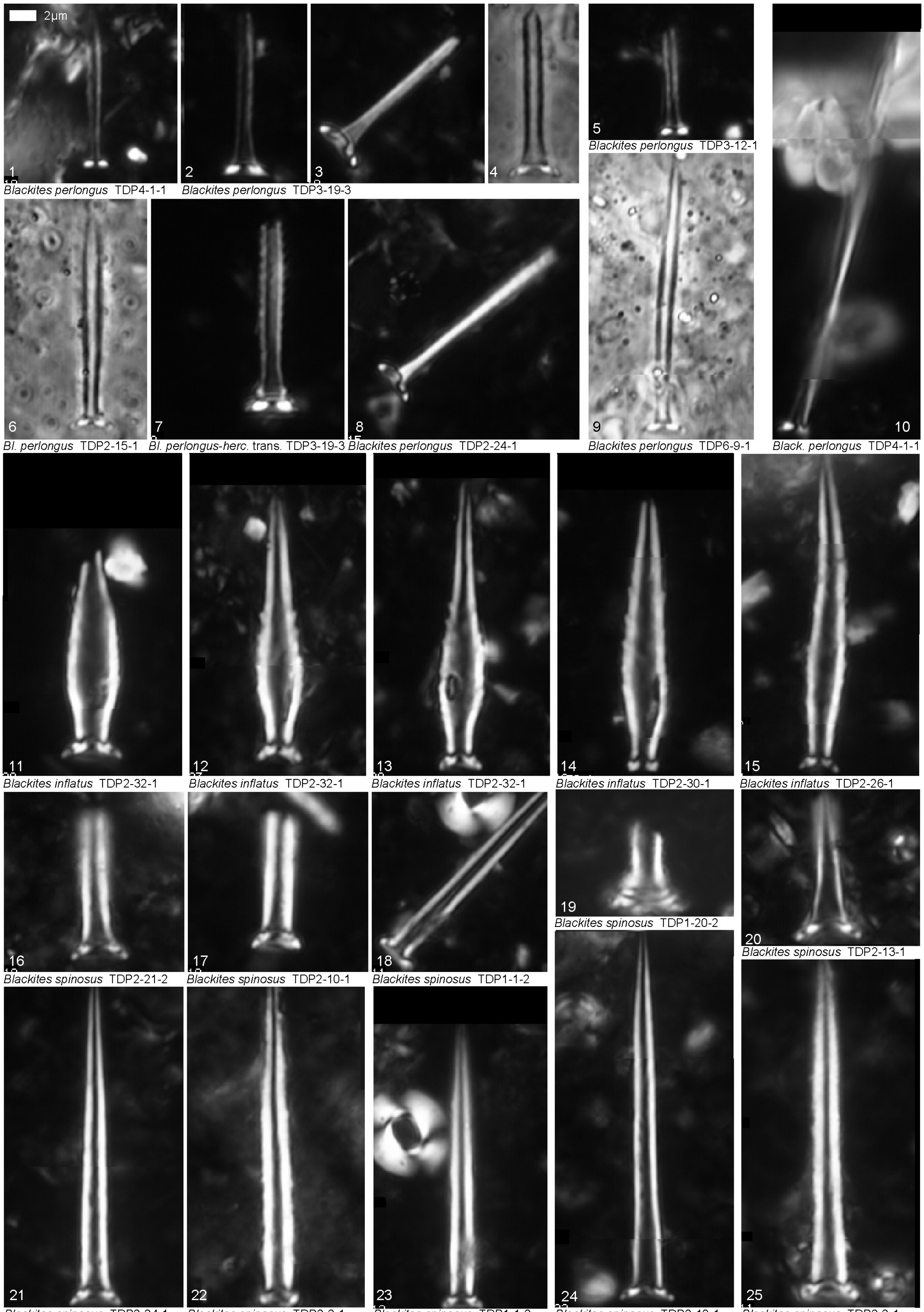
Blackites atanii TDP3-2-2 *Blackites atanii* TDP2-22-1 *Blackites atanii* TDP2-22-1 *Blackites atanii* TDP2-19-1

Cruxia mericii TDP2-24-1 *Cruxia mericii* TDP6-8-1 *Cruxia mericii* TDP2-21-2 *Cruxia mericii* TDP2-21-2

Blackites herculesii TDP3-19-3 *Blackites herculesii* TDP3-19-3 *Blackites herculesii* TDP3-12-1

Plate 24

Rhabdosphaeraceae: *Blackites, B. herculesii* group



Blackites perlongus TDP4-1-1 *Blackites perlongus* TDP3-19-3 *Blackites perlongus* TDP3-12-1

Bl. perlongus TDP2-15-1 *Bl. perlongus-herc.* trans. TDP3-19-3 *Blackites perlongus* TDP2-24-1 *Blackites perlongus* TDP6-9-1 *Black. perlongus* TDP4-1-1

Blackites inflatus TDP2-32-1 *Blackites inflatus* TDP2-32-1 *Blackites inflatus* TDP2-32-1 *Blackites inflatus* TDP2-30-1 *Blackites inflatus* TDP2-26-1

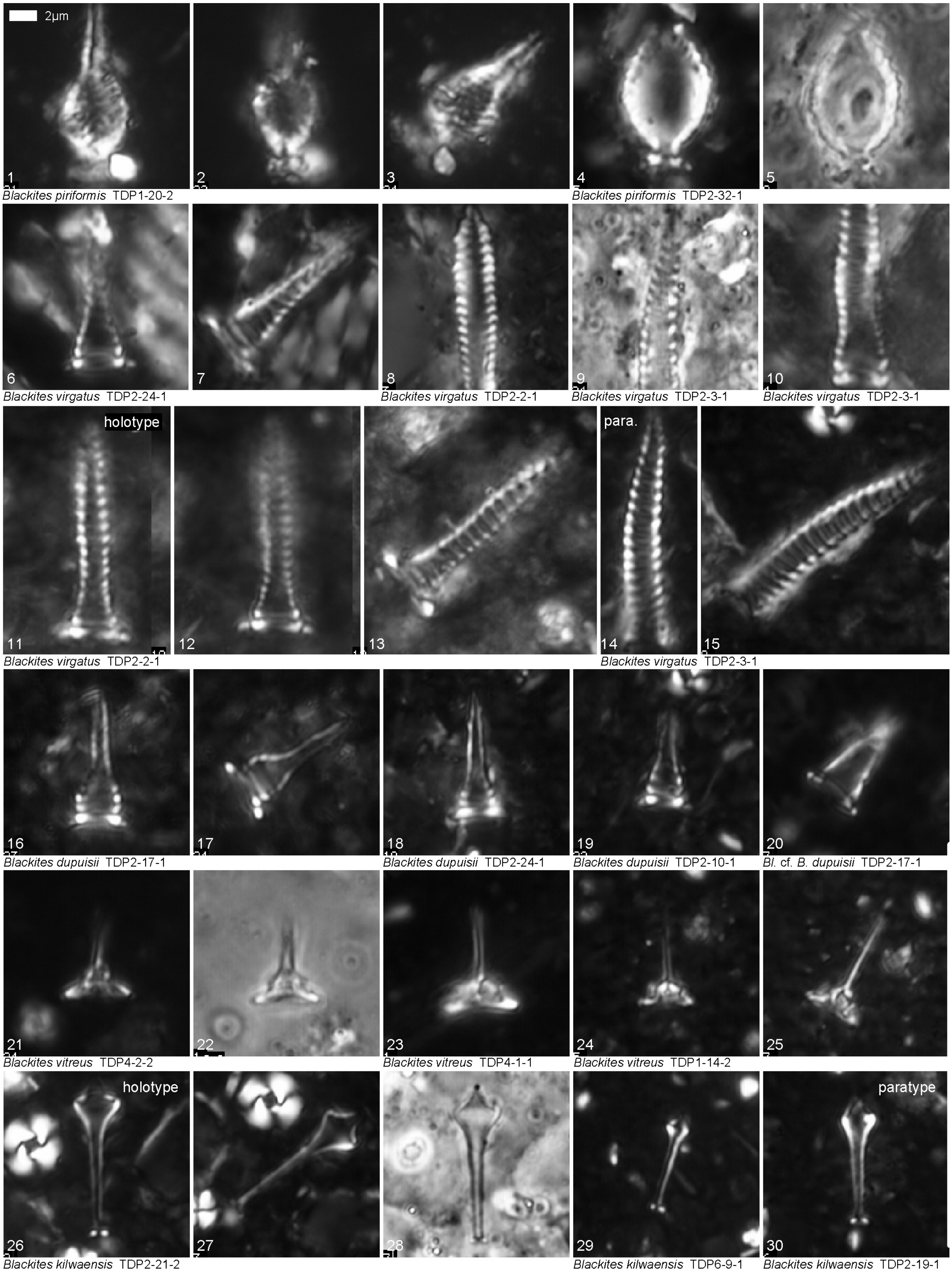
Blackites spinosus TDP1-20-2 *Blackites spinosus* TDP2-13-1

Blackites spinosus TDP2-21-2 *Blackites spinosus* TDP2-10-1 *Blackites spinosus* TDP1-1-2

Blackites spinosus TDP2-24-1 *Blackites spinosus* TDP2-2-1 *Blackites spinosus* TDP1-1-2 *Blackites spinosus* TDP2-13-1 *Blackites spinosus* TDP2-2-1

Plate 25

Rhabdosphaeraceae: *Blackites*



Blackites piriformis TDP1-20-2; *Blackites piriformis* TDP2-32-1

Blackites virgatus TDP2-24-1; *Blackites virgatus* TDP2-2-1; *Blackites virgatus* TDP2-3-1; *Blackites virgatus* TDP2-3-1

Blackites virgatus TDP2-2-1; *Blackites virgatus* TDP2-3-1

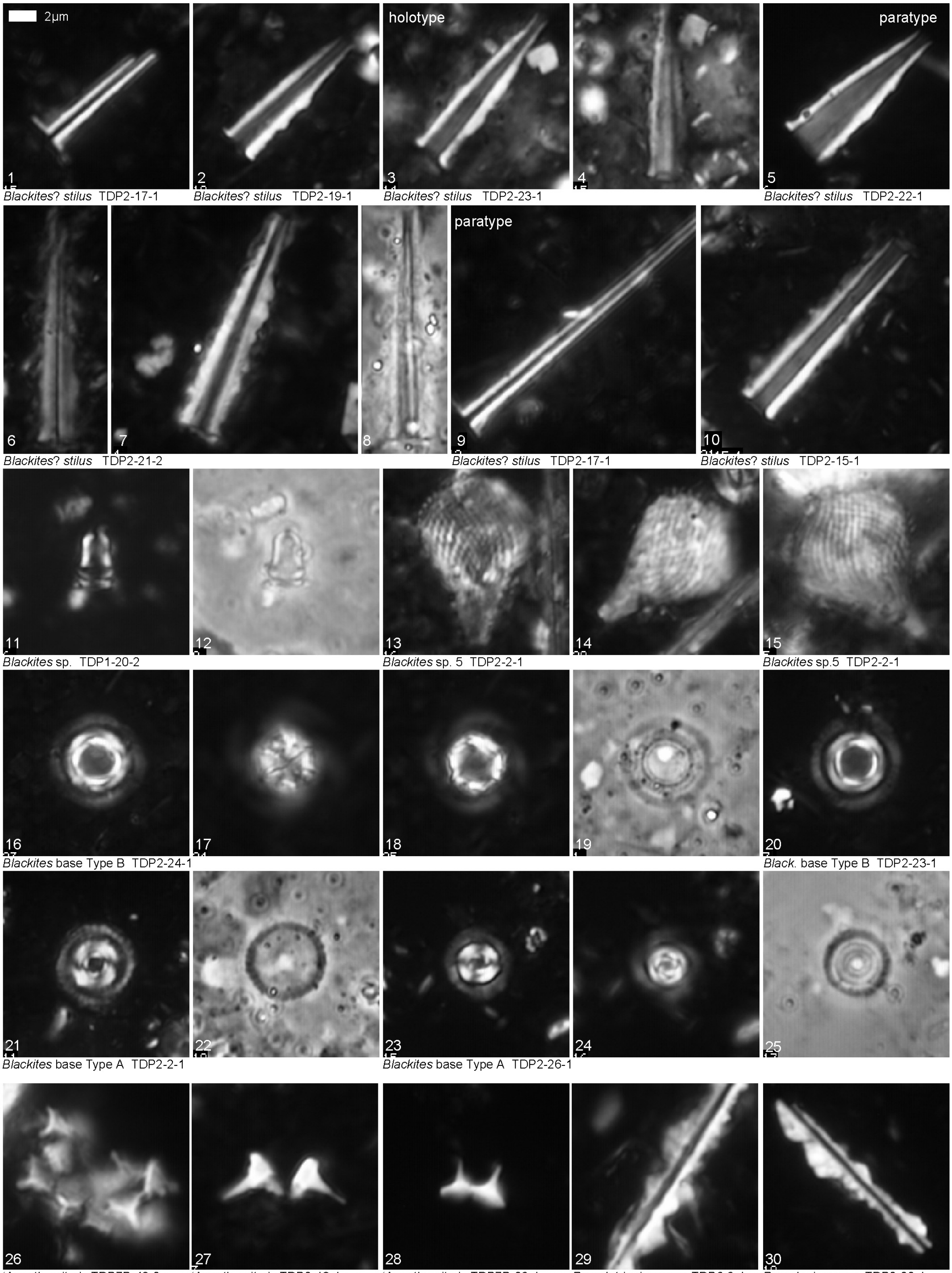
Blackites dupuisii TDP2-17-1; *Blackites dupuisii* TDP2-24-1; *Blackites dupuisii* TDP2-10-1; *Bl.* cf. *B. dupuisii* TDP2-17-1

Blackites vitreus TDP4-2-2; *Blackites vitreus* TDP4-1-1; *Blackites vitreus* TDP1-14-2

Blackites kilwaensis TDP2-21-2; *Blackites kilwaensis* TDP6-9-1; *Blackites kilwaensis* TDP2-19-1

Plate 26

Rhabdosphaeraceae: *Blackites*



Blackites? stilus TDP2-17-1 · *Blackites? stilus* TDP2-19-1 · *Blackites? stilus* TDP2-23-1 · *Blackites? stilus* TDP2-22-1

Blackites? stilus TDP2-21-2 · *Blackites? stilus* TDP2-17-1 · *Blackites? stilus* TDP2-15-1

Blackites sp. TDP1-20-2 · *Blackites* sp. 5 TDP2-2-1 · *Blackites* sp.5 TDP2-2-1

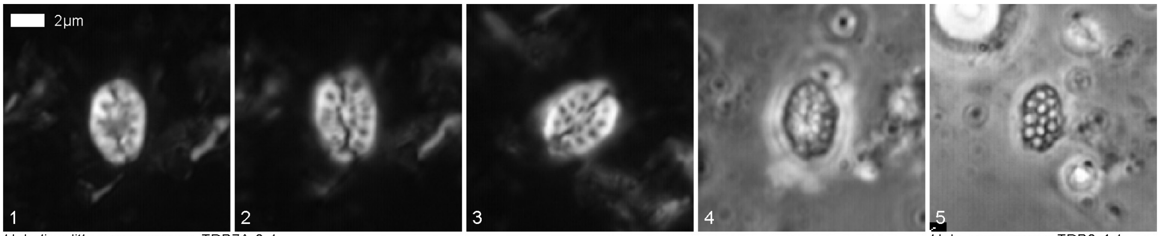
Blackites base Type B TDP2-24-1 · *Black.* base Type B TDP2-23-1

Blackites base Type A TDP2-2-1 · *Blackites* base Type A TDP2-26-1

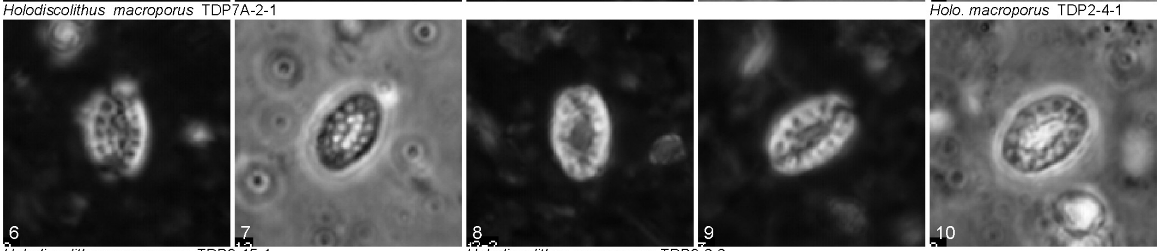
'*Acanth. mitra*' TDP7B-48-2 · '*Acanth. mitra*' TDP2-10-1 · '*Acanth. mitra*' TDP7B-39-1 · *Pseudotriq. inversus* TDP6-9-1 · *Pseudo. inversus* TDP2-32-1

Plate 27

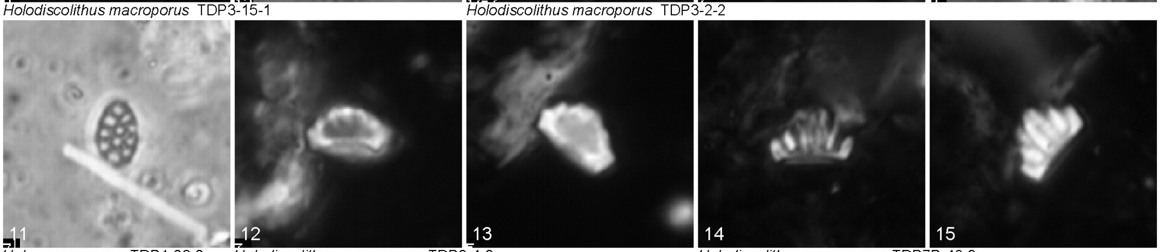
Holococcoliths: *Holodiscolithus*



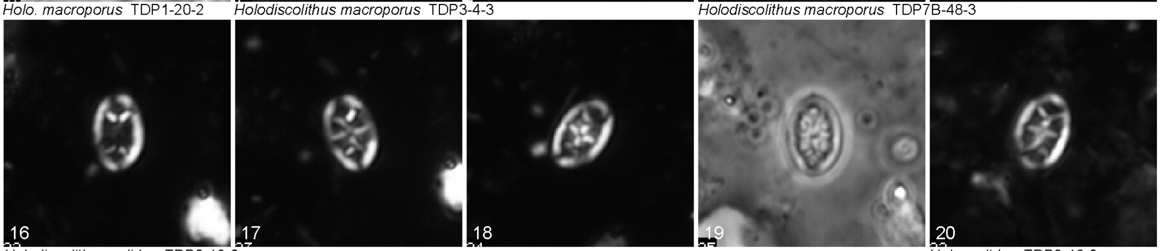
Holodiscolithus macroporus TDP7A-2-1 *Holo. macroporus* TDP2-4-1



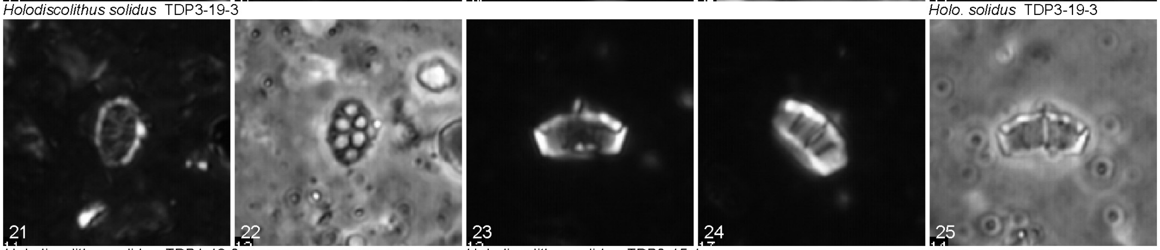
Holodiscolithus macroporus TDP3-15-1 *Holodiscolithus macroporus* TDP3-2-2



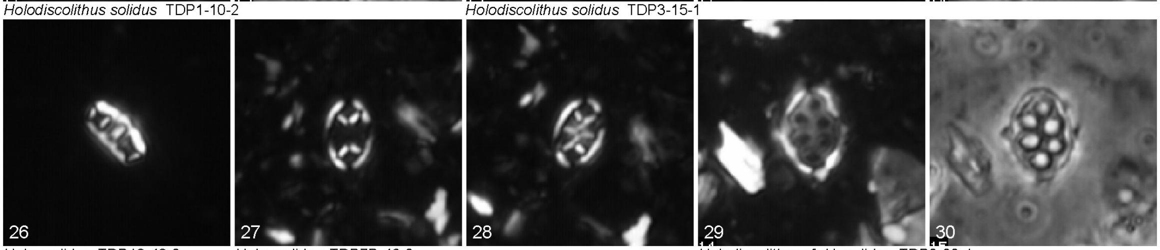
Holo. macroporus TDP1-20-2 *Holodiscolithus macroporus* TDP3-4-3 *Holodiscolithus macroporus* TDP7B-48-3



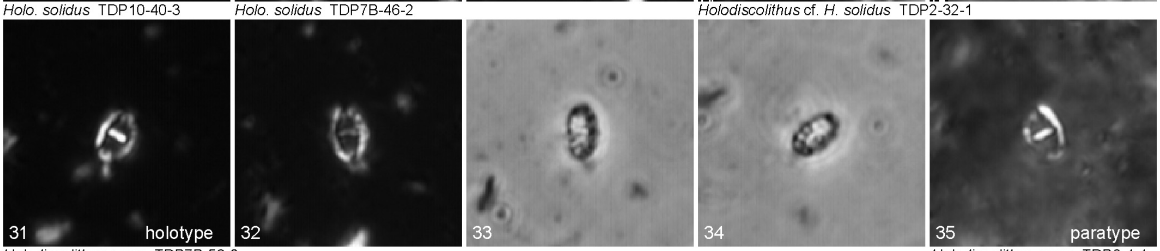
Holodiscolithus solidus TDP3-19-3 *Holo. solidus* TDP3-19-3



Holodiscolithus solidus TDP1-10-2 *Holodiscolithus solidus* TDP3-15-1



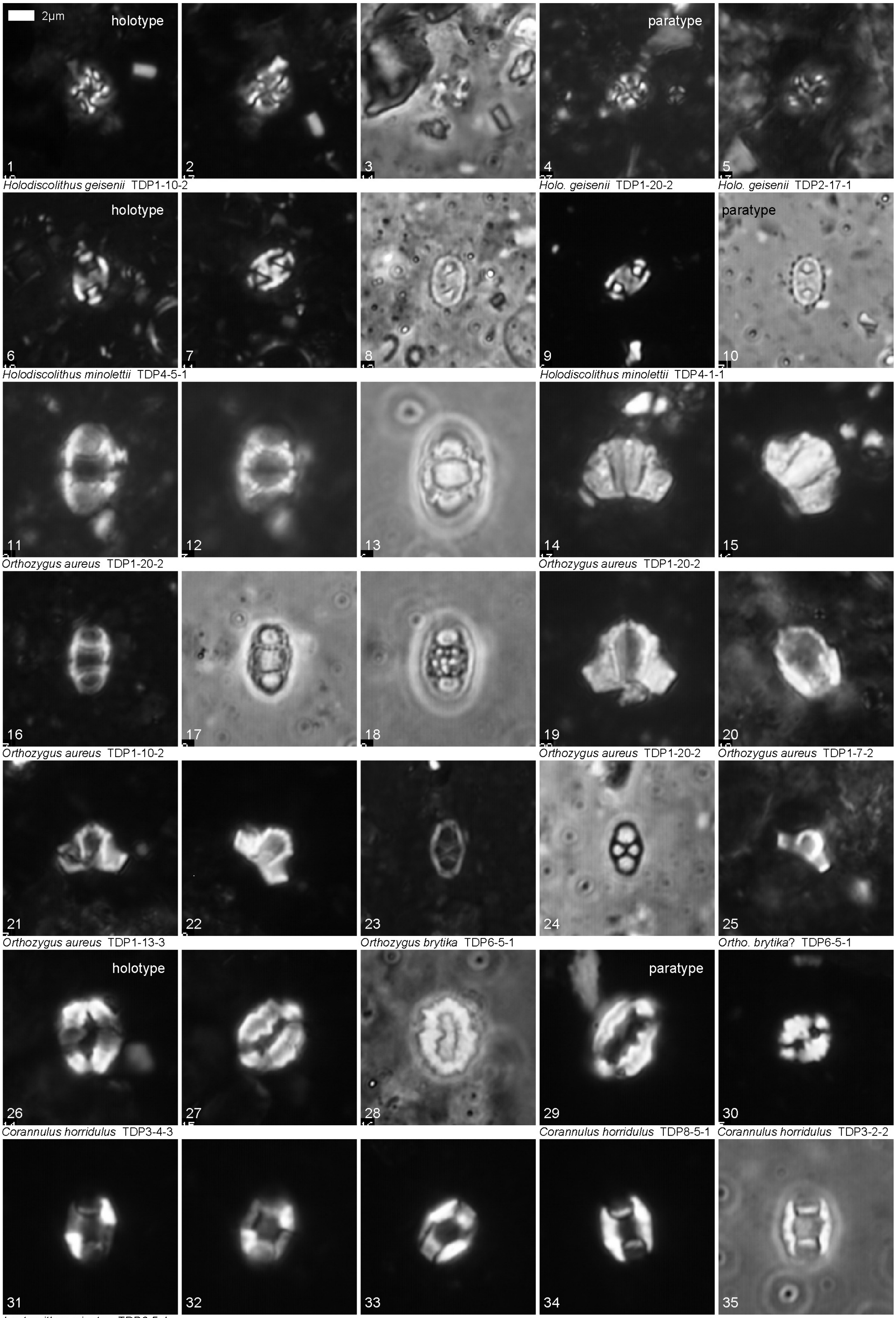
Holo. solidus TDP10-40-3 *Holo. solidus* TDP7B-46-2 *Holodiscolithus* cf. *H. solidus* TDP2-32-1



Holodiscolithus serus TDP7B-50-3 *Holodiscolithus serus* TDP8-1-1

Plate 28

Hololcoccol.: *Holodiscolithus, Orthozygus, Corannulus, Lanternithus*



Holodiscolithus geisenii TDP1-10-2; *Holo. geisenii* TDP1-20-2; *Holo. geisenii* TDP2-17-1

Holodiscolithus minolettii TDP4-5-1; *Holodiscolithus minolettii* TDP4-1-1

Orthozygus aureus TDP1-20-2; *Orthozygus aureus* TDP1-20-2

Orthozygus aureus TDP1-10-2; *Orthozygus aureus* TDP1-20-2; *Orthozygus aureus* TDP1-7-2

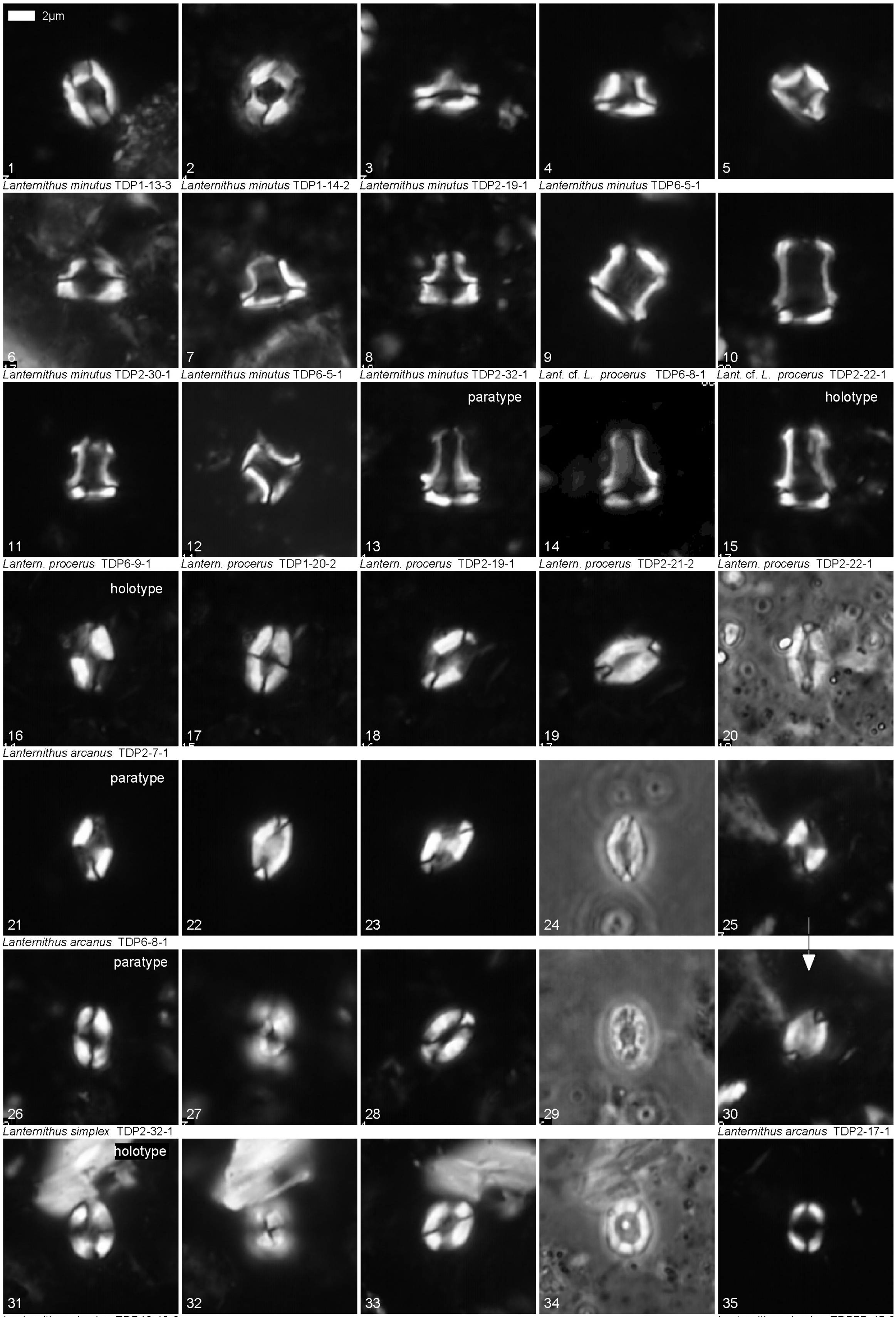
Orthozygus aureus TDP1-13-3; *Orthozygus brytika* TDP6-5-1; *Ortho. brytika*? TDP6-5-1

Corannulus horridulus TDP3-4-3; *Corannulus horridulus* TDP8-5-1; *Corannulus horridulus* TDP3-2-2

Lanternithus minutus TDP6-5-1

Plate 29

Holococcoliths: *Lanternithus*



Lanternithus minutus TDP1-13-3 *Lanternithus minutus* TDP1-14-2 *Lanternithus minutus* TDP2-19-1 *Lanternithus minutus* TDP6-5-1

Lanternithus minutus TDP2-30-1 *Lanternithus minutus* TDP6-5-1 *Lanternithus minutus* TDP2-32-1 *Lant.* cf. *L. procerus* TDP6-8-1 *Lant.* cf. *L. procerus* TDP2-22-1

Lantern. procerus TDP6-9-1 *Lantern. procerus* TDP1-20-2 *Lantern. procerus* TDP2-19-1 *Lantern. procerus* TDP2-21-2 *Lantern. procerus* TDP2-22-1

Lanternithus arcanus TDP2-7-1

Lanternithus arcanus TDP6-8-1

Lanternithus simplex TDP2-32-1 *Lanternithus arcanus* TDP2-17-1

Lanternithus simplex TDP10-12-2 *Lanternithus simplex* TDP7B-45-2

Plate 30

Holococcoliths: *Lanternithus, Youngilithus, Varolia, Semihololithus*

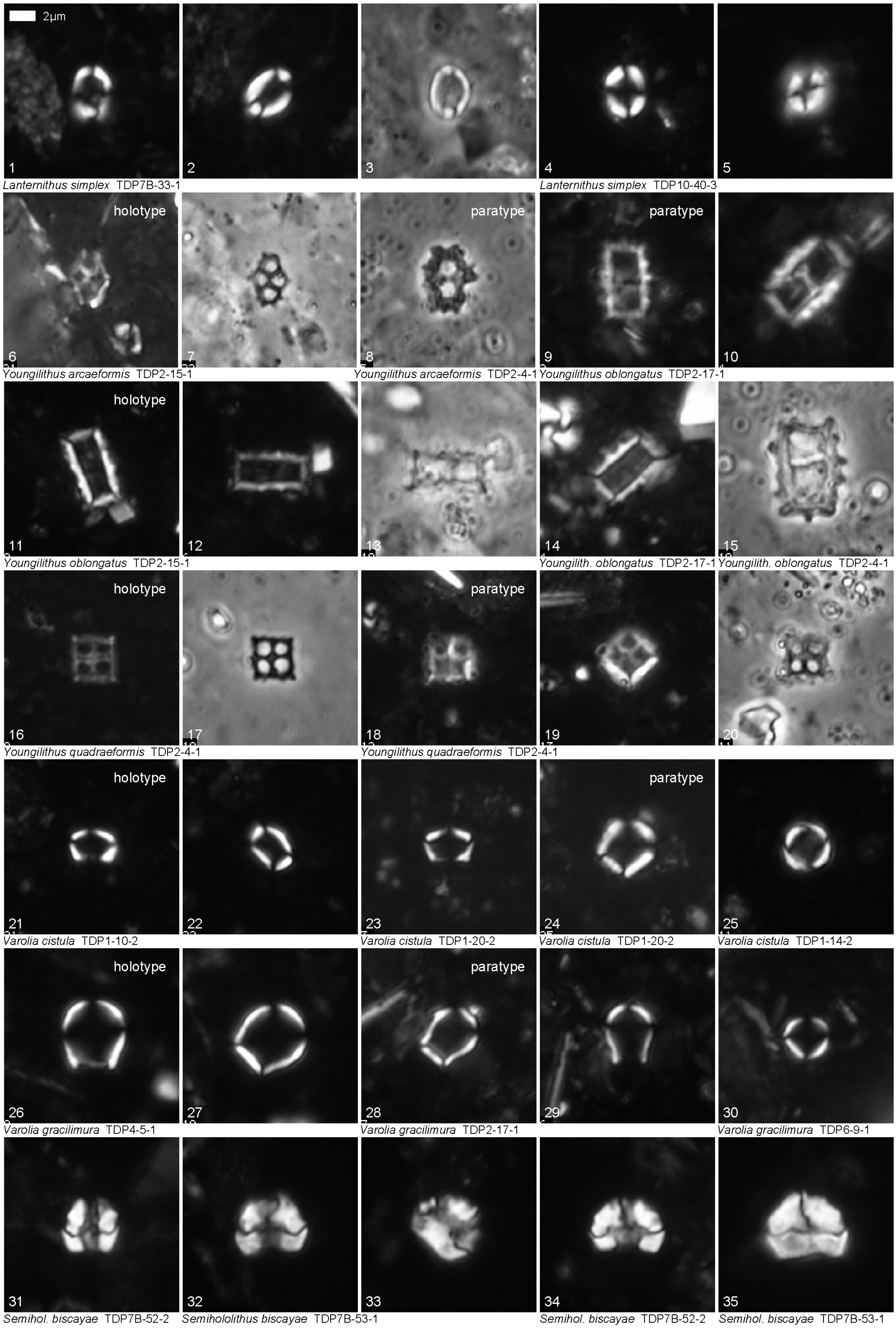
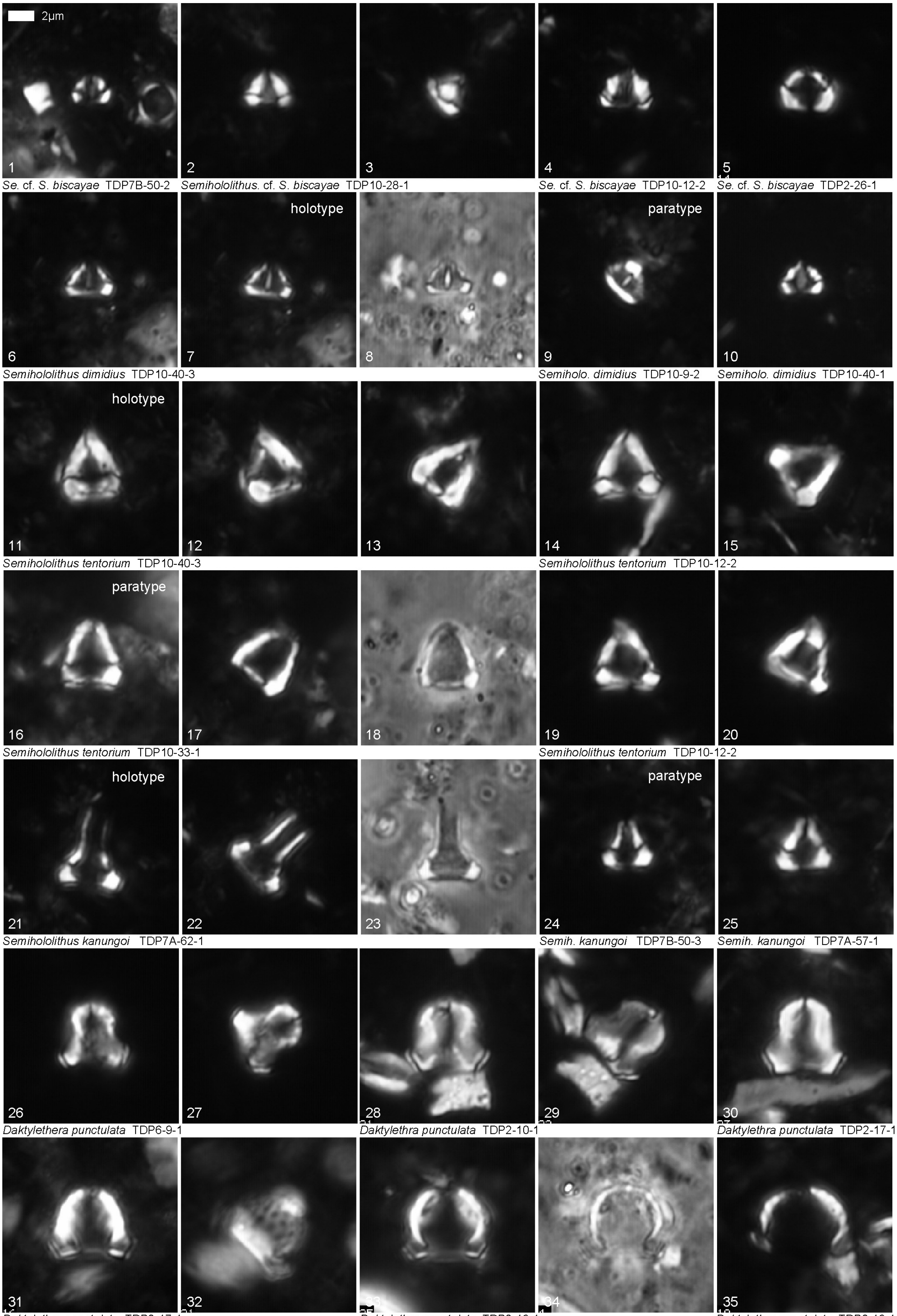


Plate 31

Holococcoliths: *Semihololithus, Daktylethra*



Se. cf. *S. biscayae* TDP7B-50-2 | *Semihololithus.* cf. *S. biscayae* TDP10-28-1 | *Se.* cf. *S. biscayae* TDP10-12-2 | *Se.* cf. *S. biscayae* TDP2-26-1

Semihololithus dimidius TDP10-40-3 | *Semiholo. dimidius* TDP10-9-2 | *Semiholo. dimidius* TDP10-40-1

Semihololithus tentorium TDP10-40-3 | *Semihololithus tentorium* TDP10-12-2

Semihololithus tentorium TDP10-33-1 | *Semihololithus tentorium* TDP10-12-2

Semihololithus kanungoi TDP7A-62-1 | *Semih. kanungoi* TDP7B-50-3 | *Semih. kanungoi* TDP7A-57-1

Daktylethera punctulata TDP6-9-1 | *Daktylethra punctulata* TDP2-10-1 | *Daktylethra punctulata* TDP2-17-1

Daktylethra punctulata TDP2-17-1 | *Daktylethra punctulata* TDP2-19-1 | *Daktylethra punctulata* TDP2-19-1

Plate 32

Holococcoliths: *Zygrhablithus*

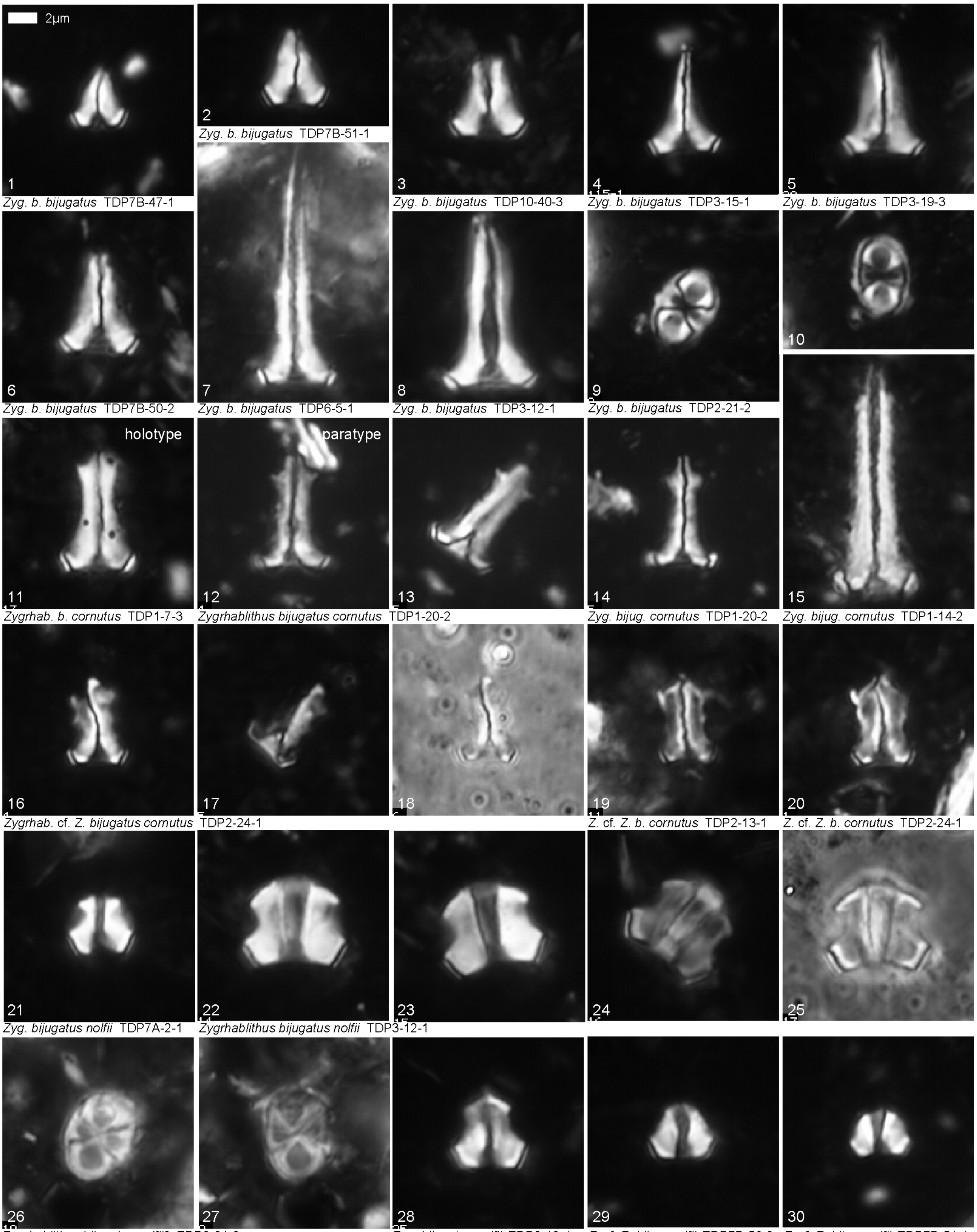
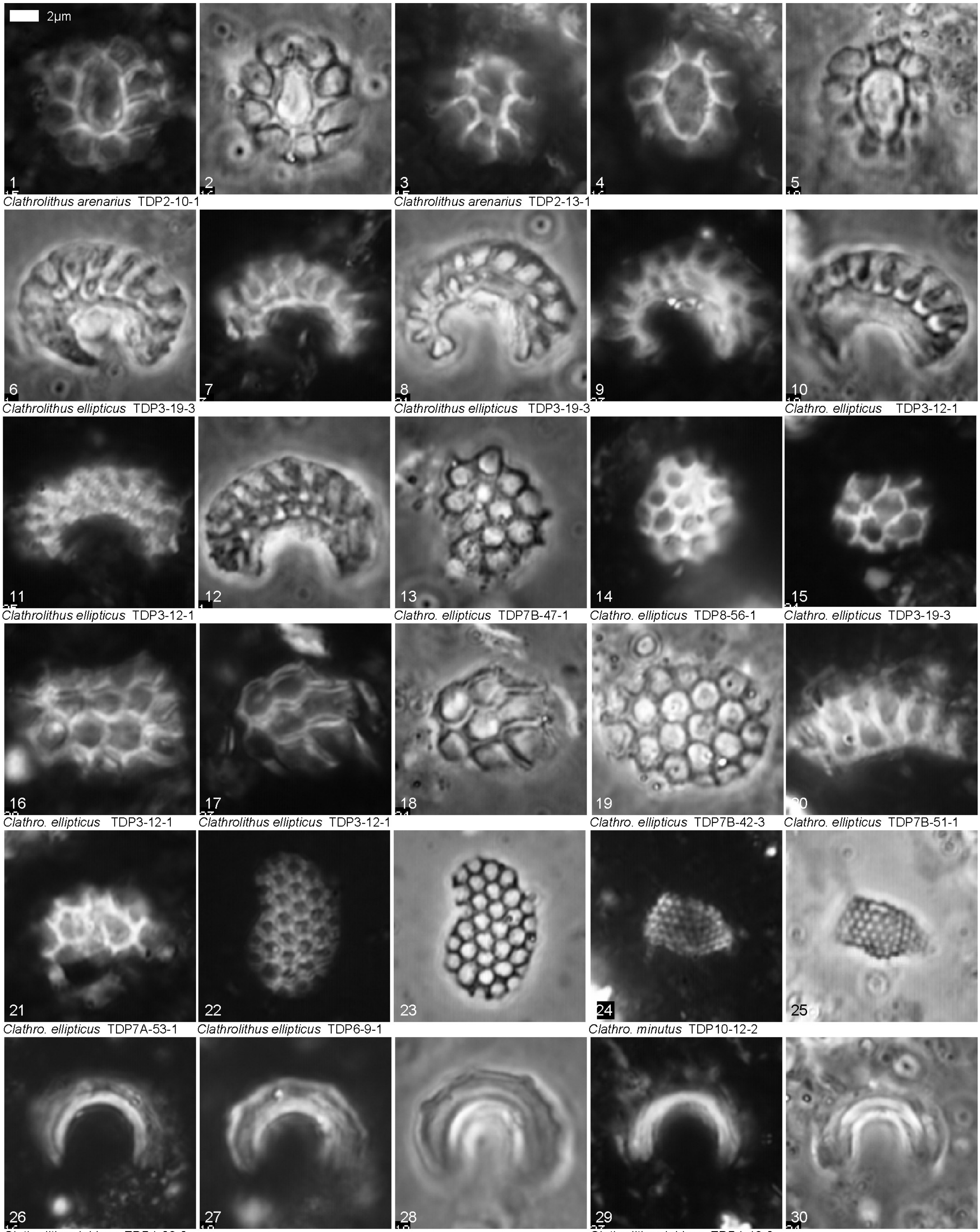


Plate 33

Holococcoliths: *Clathrolithus*



Clathrolithus arenarius TDP2-10-1

Clathrolithus arenarius TDP2-13-1

Clathrolithus ellipticus TDP3-19-3

Clathrolithus ellipticus TDP3-19-3

Clathro. ellipticus TDP3-12-1

Clathrolithus ellipticus TDP3-12-1

Clathro. ellipticus TDP7B-47-1

Clathro. ellipticus TDP8-56-1

Clathro. ellipticus TDP3-19-3

Clathro. ellipticus TDP3-12-1

Clathrolithus ellipticus TDP3-12-1

Clathro. ellipticus TDP7B-42-3

Clathro. ellipticus TDP7B-51-1

Clathro. ellipticus TDP7A-53-1

Clathrolithus ellipticus TDP6-9-1

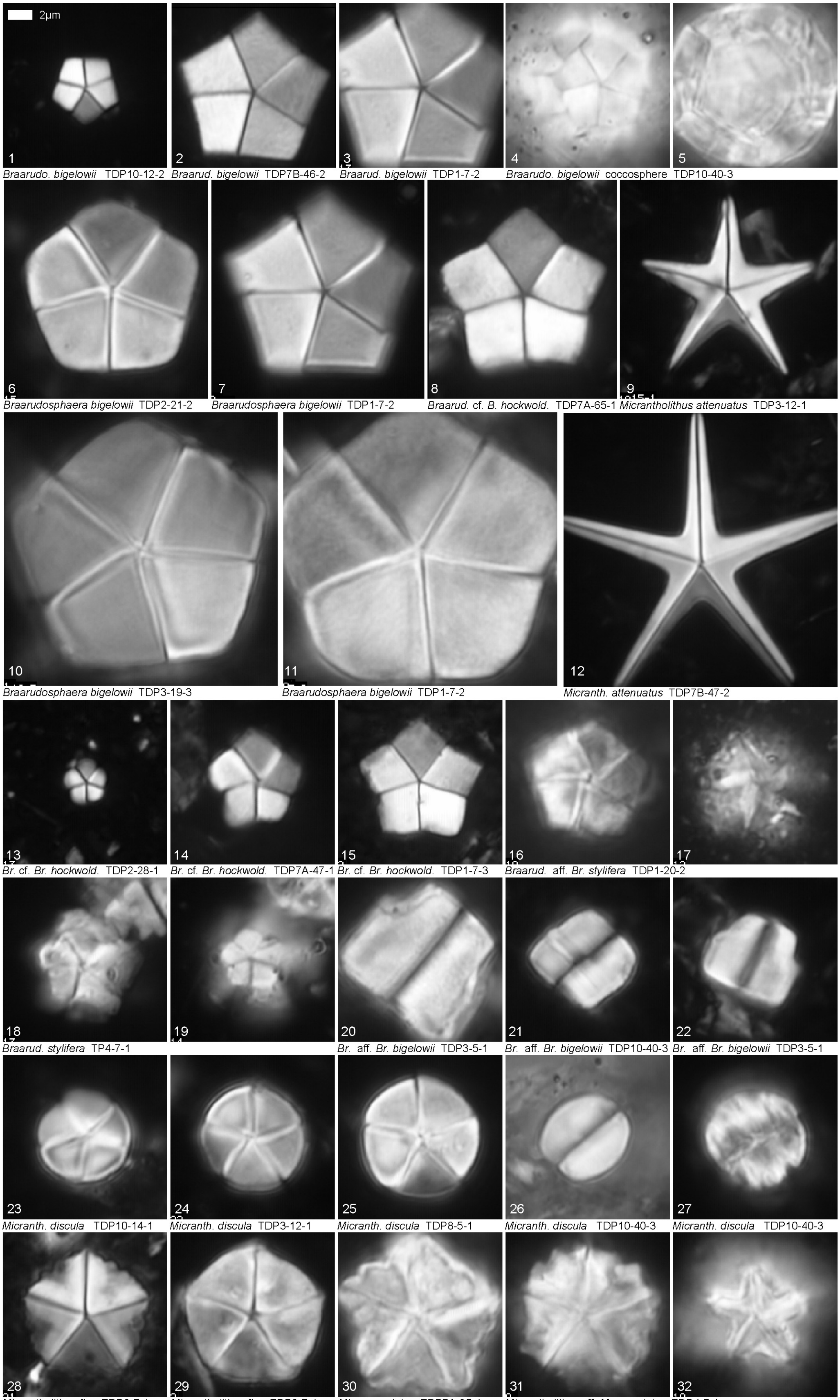
Clathro. minutus TDP10-12-2

Clathrolithus joidesa TDP1-20-2

Clathrolithus joidesa TDP1-10-2

Plate 34

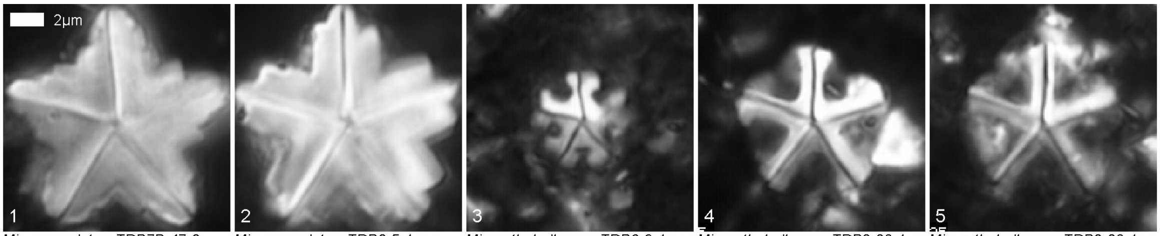
Nannoliths: Braarudosphaeraceae



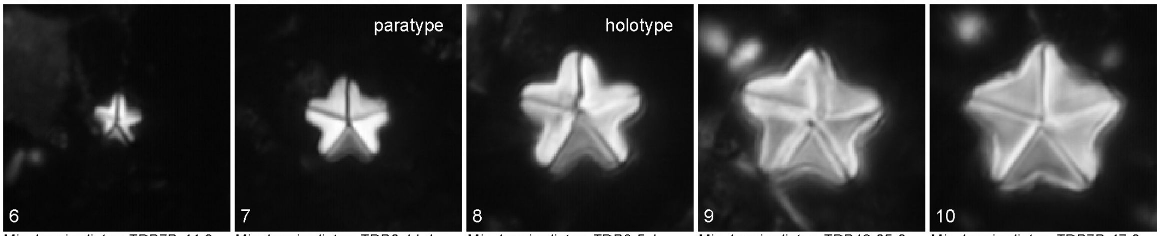
1 *Braarudo. bigelowii* TDP10-12-2
2 *Braarud. bigelowii* TDP7B-46-2
3 *Braarud. bigelowii* TDP1-7-2
4 *Braarudo. bigelowii* coccosphere TDP10-40-3
5
6 *Braarudosphaera bigelowii* TDP2-21-2
7 *Braarudosphaera bigelowii* TDP1-7-2
8 *Braarud.* cf. *B. hockwold.* TDP7A-65-1
9 *Micrantholithus attenuatus* TDP3-12-1
10 *Braarudosphaera bigelowii* TDP3-19-3
11 *Braarudosphaera bigelowii* TDP1-7-2
12 *Micranth. attenuatus* TDP7B-47-2
13 *Br.* cf. *Br. hockwold.* TDP2-28-1
14 *Br.* cf. *Br. hockwold.* TDP7A-47-1
15 *Br.* cf. *Br. hockwold.* TDP1-7-3
16–17 *Braarud.* aff. *Br. stylifera* TDP1-20-2
18–19 *Braarud. stylifera* TP4-7-1
20 *Br.* aff. *Br. bigelowii* TDP3-5-1
21 *Br.* aff. *Br. bigelowii* TDP10-40-3
22 *Br.* aff. *Br. bigelowii* TDP3-5-1
23 *Micranth. discula* TDP10-14-1
24 *Micranth. discula* TDP3-12-1
25 *Micranth. discula* TDP8-5-1
26 *Micranth. discula* TDP10-40-3
27 *Micranth. discula* TDP10-40-3
28 *Micrantholithus flos* TDP2-7-1
29 *Micrantholithus flos* TDP2-7-1
30 *Mic. crenulatus* TDP7A-35-1
31–32 *Micrantholithus* aff. *M. crenulatus* TDP4-7-1

Plate 35

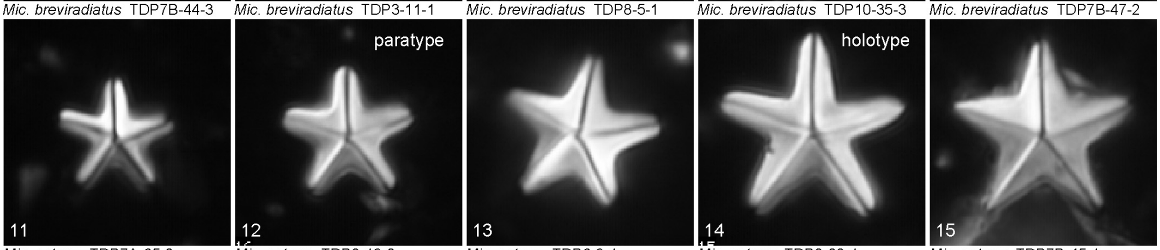
Nannoliths: Braarudosphaeraceae



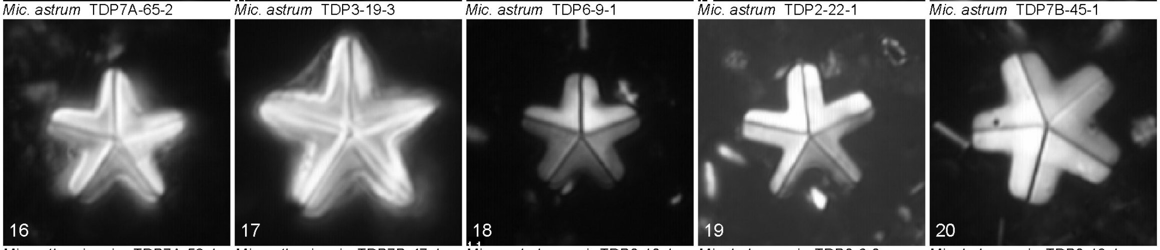
Mic. crenulatus TDP7B-47-2 | *Mic. crenulatus* TDP3-5-1 | *Micranth. bulbosus* TDP6-9-1 | *Micranth. bulbosus* TDP2-28-1 | *Micranth. bulbosus* TDP2-28-1



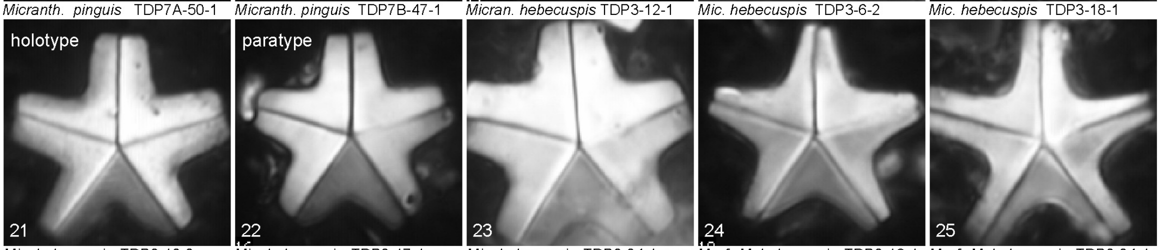
Mic. breviradiatus TDP7B-44-3 | *Mic. breviradiatus* TDP3-11-1 | *Mic. breviradiatus* TDP8-5-1 | *Mic. breviradiatus* TDP10-35-3 | *Mic. breviradiatus* TDP7B-47-2



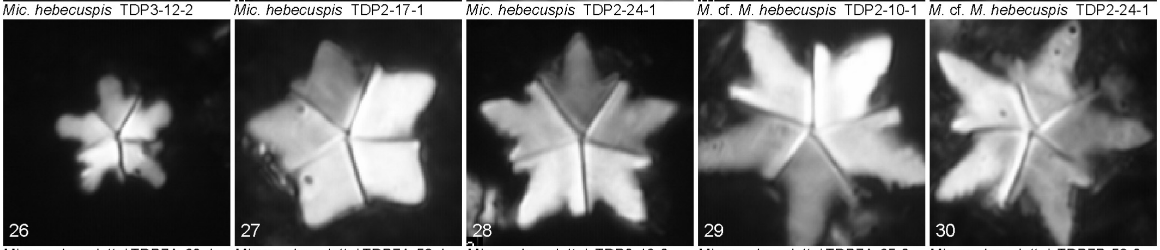
Mic. astrum TDP7A-65-2 | *Mic. astrum* TDP3-19-3 | *Mic. astrum* TDP6-9-1 | *Mic. astrum* TDP2-22-1 | *Mic. astrum* TDP7B-45-1



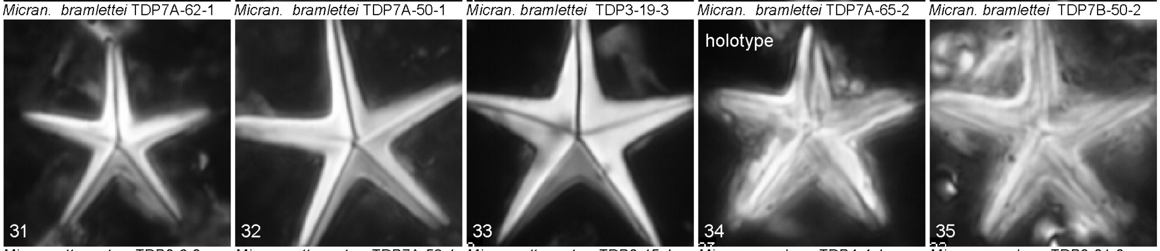
Micranth. pinguis TDP7A-50-1 | *Micranth. pinguis* TDP7B-47-1 | *Micran. hebecuspis* TDP3-12-1 | *Mic. hebecuspis* TDP3-6-2 | *Mic. hebecuspis* TDP3-18-1



Mic. hebecuspis TDP3-12-2 | *Mic. hebecuspis* TDP2-17-1 | *Mic. hebecuspis* TDP2-24-1 | *M.* cf. *M. hebecuspis* TDP2-10-1 | *M.* cf. *M. hebecuspis* TDP2-24-1



Micran. bramlettei TDP7A-62-1 | *Micran. bramlettei* TDP7A-50-1 | *Micran. bramlettei* TDP3-19-3 | *Micran. bramlettei* TDP7A-65-2 | *Micran. bramlettei* TDP7B-50-2



Micran. attenuatus TDP3-6-2 | *Micran. attenuatus* TDP7A-50-1 | *Micran. attenuatus* TDP3-15-1 | *Micran. excelsus* TDP4-4-1 | *Micran. excelsus* TDP2-21-2

Plate 36

Nannoliths: Braarudosphaeraceae

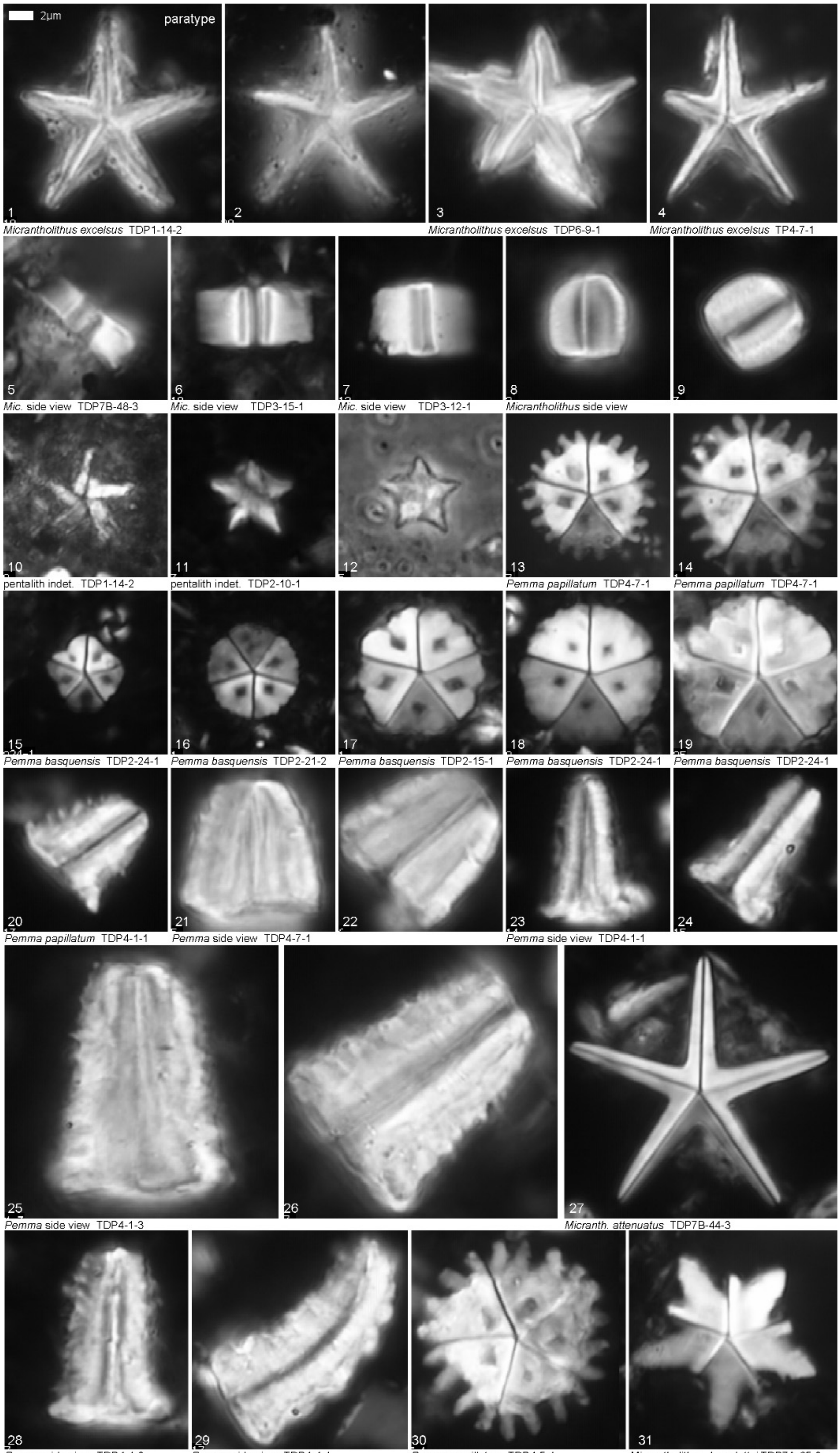
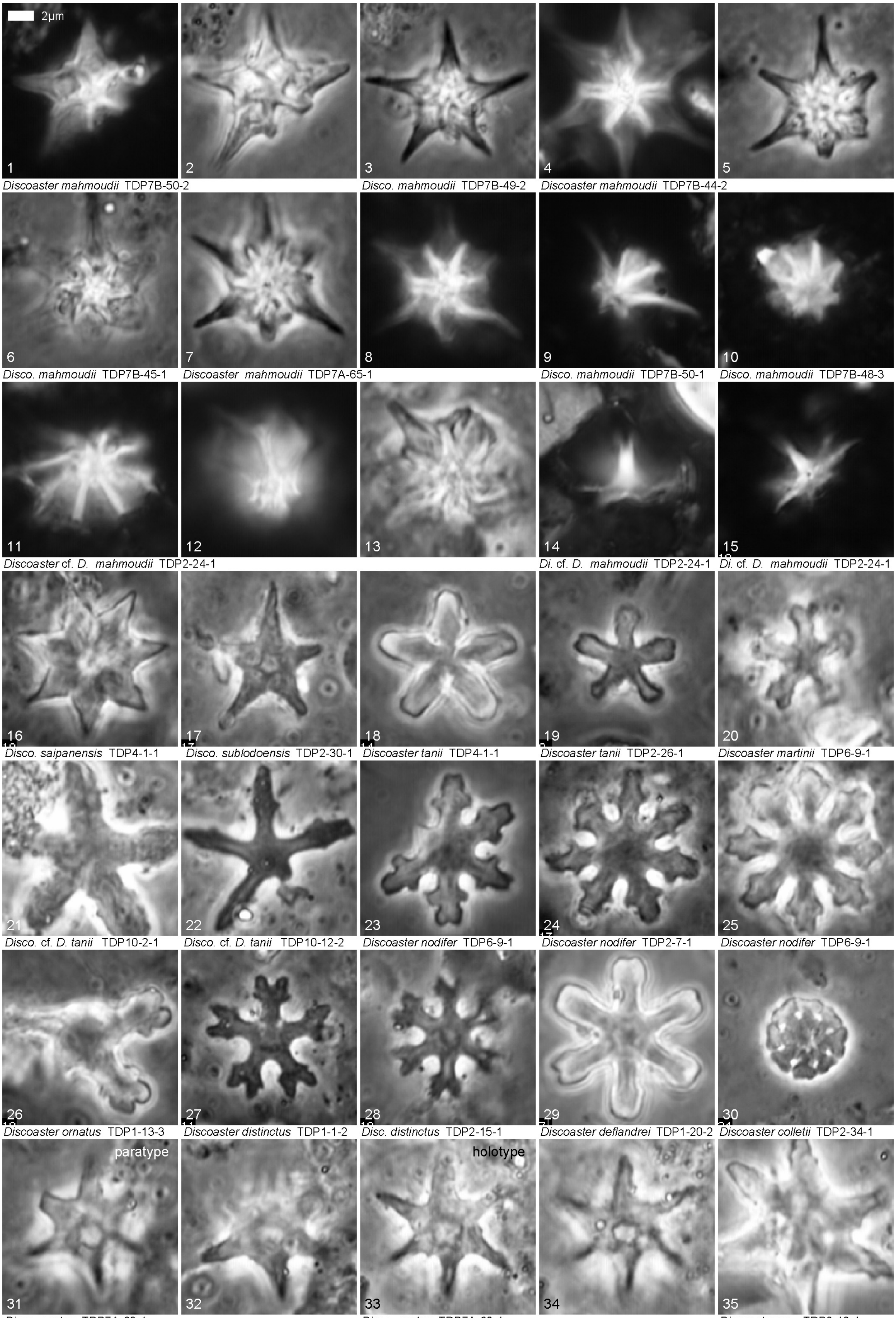


Plate 37

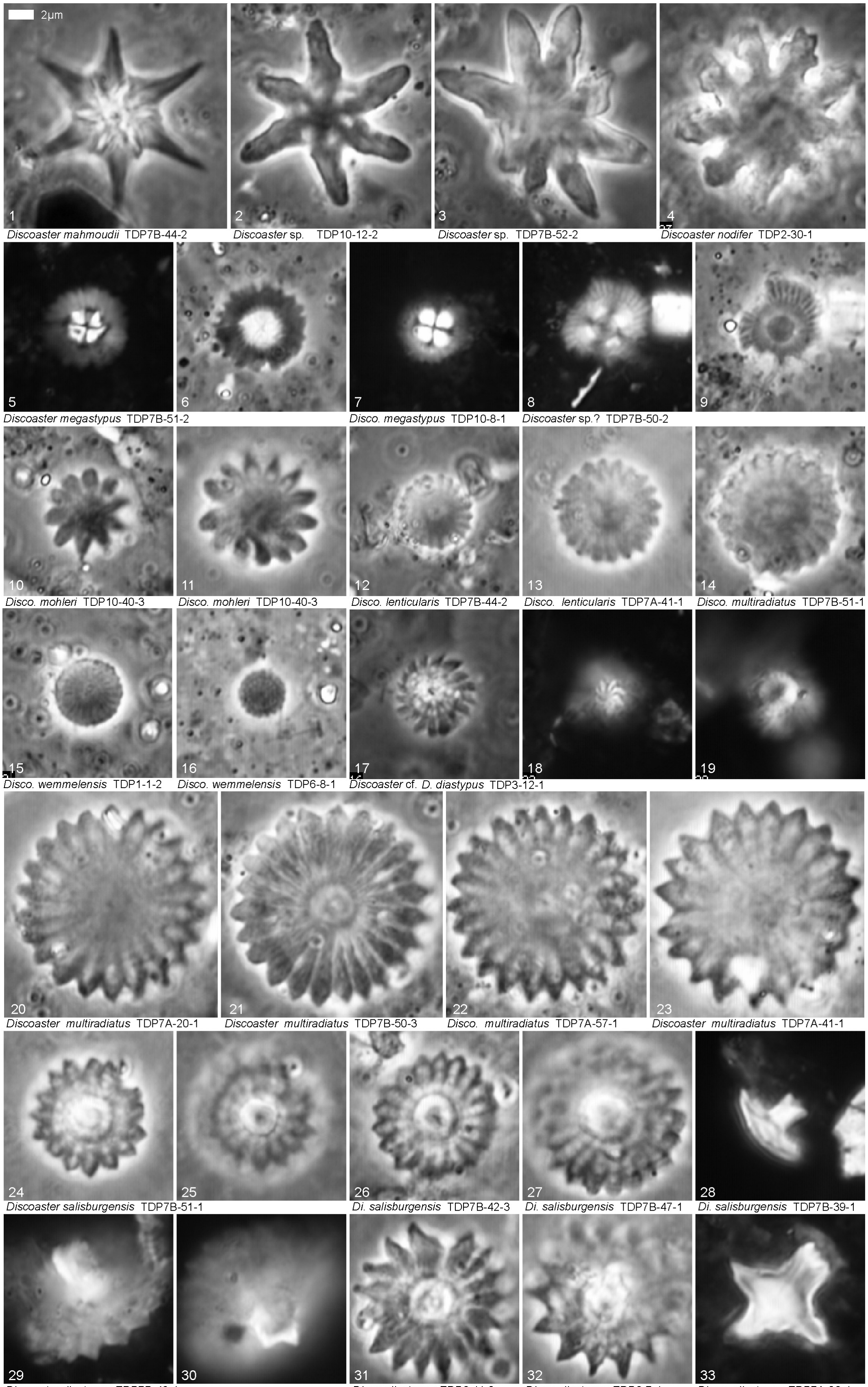
Nannoliths: Discoasteraceae



Discoaster mahmoudii TDP7B-50-2
Disco. mahmoudii TDP7B-49-2
Discoaster mahmoudii TDP7B-44-2
Disco. mahmoudii TDP7B-45-1
Discoaster mahmoudii TDP7A-65-1
Disco. mahmoudii TDP7B-50-1
Disco. mahmoudii TDP7B-48-3
Discoaster cf. *D. mahmoudii* TDP2-24-1
Di. cf. *D. mahmoudii* TDP2-24-1
Di. cf. *D. mahmoudii* TDP2-24-1
Disco. saipanensis TDP4-1-1
Disco. sublodoensis TDP2-30-1
Discoaster tanii TDP4-1-1
Discoaster tanii TDP2-26-1
Discoaster martinii TDP6-9-1
Disco. cf. *D. tanii* TDP10-2-1
Disco. cf. *D. tanii* TDP10-12-2
Discoaster nodifer TDP6-9-1
Discoaster nodifer TDP2-7-1
Discoaster nodifer TDP6-9-1
Discoaster ornatus TDP1-13-3
Discoaster distinctus TDP1-1-2
Disc. distinctus TDP2-15-1
Discoaster deflandrei TDP1-20-2
Discoaster colletii TDP2-34-1
Disco. acutus TDP7A-62-1
Disco. acutus TDP7A-62-1
Discoaster sp. TDP3-12-1

Plate 38

Nannoliths: Discoasteraceae



1 *Discoaster mahmoudii* TDP7B-44-2; 2 *Discoaster* sp. TDP10-12-2; 3 *Discoaster* sp. TDP7B-52-2; 4 *Discoaster nodifer* TDP2-30-1

5, 6 *Discoaster megastypus* TDP7B-51-2; 7 *Disco. megastypus* TDP10-8-1; 8, 9 *Discoaster* sp.? TDP7B-50-2

10 *Disco. mohleri* TDP10-40-3; 11 *Disco. mohleri* TDP10-40-3; 12 *Disco. lenticularis* TDP7B-44-2; 13 *Disco. lenticularis* TDP7A-41-1; 14 *Disco. multiradiatus* TDP7B-51-1

15 *Disco. wemmelensis* TDP1-1-2; 16 *Disco. wemmelensis* TDP6-8-1; 17–19 *Discoaster* cf. *D. diastypus* TDP3-12-1

20 *Discoaster multiradiatus* TDP7A-20-1; 21 *Discoaster multiradiatus* TDP7B-50-3; 22 *Disco. multiradiatus* TDP7A-57-1; 23 *Discoaster multiradiatus* TDP7A-41-1

24, 25 *Discoaster salisburgensis* TDP7B-51-1; 26 *Di. salisburgensis* TDP7B-42-3; 27 *Di. salisburgensis* TDP7B-47-1; 28 *Di. salisburgensis* TDP7B-39-1

29, 30 *Discoaster diastypus* TDP7B-49-1; 31 *Disco. diastypus* TDP8-11-2; 32 *Disco. diastypus* TDP8-7-1; 33 *Disco. diastypus* TDP7A-38-1

Plate 39

Nannoliths: Discoasteraceae

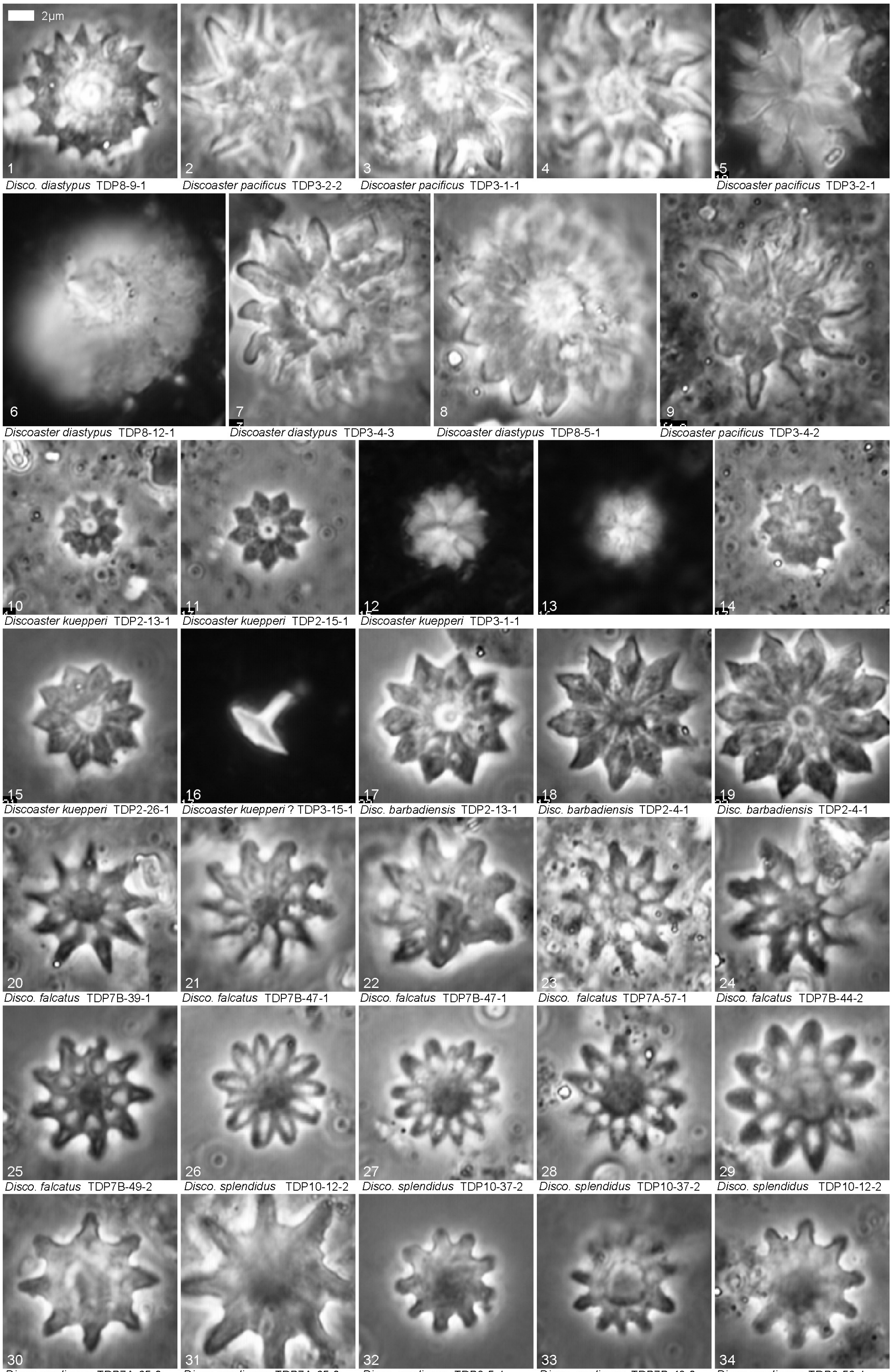
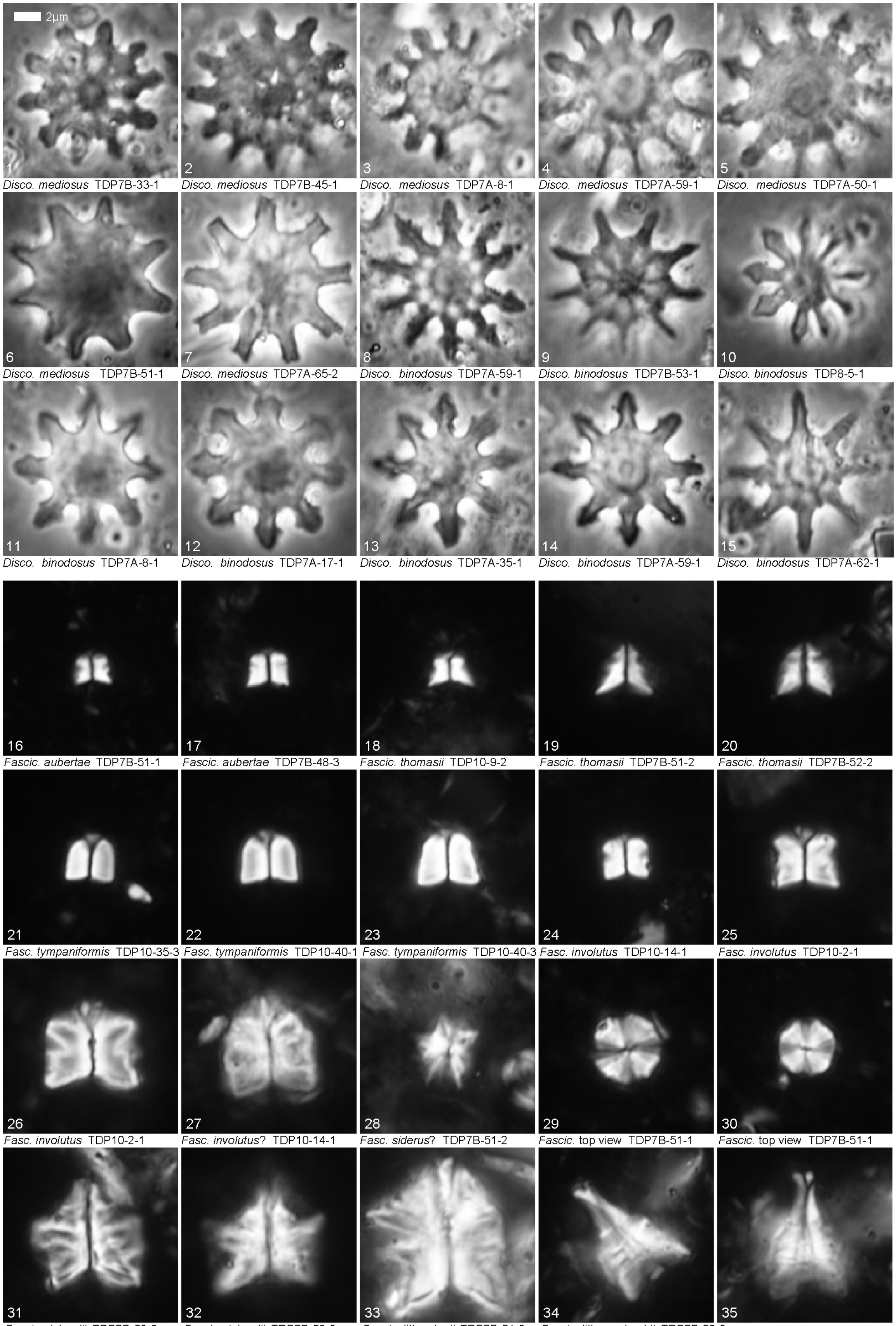


Plate 40

Nannoliths: Discoasteraceae, Fasciculithaceae



1 *Disco. mediosus* TDP7B-33-1
2 *Disco. mediosus* TDP7B-45-1
3 *Disco. mediosus* TDP7A-8-1
4 *Disco. mediosus* TDP7A-59-1
5 *Disco. mediosus* TDP7A-50-1
6 *Disco. mediosus* TDP7B-51-1
7 *Disco. mediosus* TDP7A-65-2
8 *Disco. binodosus* TDP7A-59-1
9 *Disco. binodosus* TDP7B-53-1
10 *Disco. binodosus* TDP8-5-1
11 *Disco. binodosus* TDP7A-8-1
12 *Disco. binodosus* TDP7A-17-1
13 *Disco. binodosus* TDP7A-35-1
14 *Disco. binodosus* TDP7A-59-1
15 *Disco. binodosus* TDP7A-62-1
16 *Fascic. aubertae* TDP7B-51-1
17 *Fascic. aubertae* TDP7B-48-3
18 *Fascic. thomasii* TDP10-9-2
19 *Fascic. thomasii* TDP7B-51-2
20 *Fascic. thomasii* TDP7B-52-2
21 *Fasc. tympaniformis* TDP10-35-3
22 *Fasc. tympaniformis* TDP10-40-1
23 *Fasc. tympaniformis* TDP10-40-3
24 *Fasc. involutus* TDP10-14-1
25 *Fasc. involutus* TDP10-2-1
26 *Fasc. involutus* TDP10-2-1
27 *Fasc. involutus*? TDP10-14-1
28 *Fasc. siderus*? TDP7B-51-2
29 *Fascic.* top view TDP7B-51-1
30 *Fascic.* top view TDP7B-51-1
31 *Fascic. richardii* TDP7B-52-2
32 *Fascic. richardii* TDP7B-52-2
33 *Fasciculithus tonii* TDP7B-51-2
34 *Fasciculithus schaubii* TDP7B-52-2
35

Plate 41

Nannoliths: Rhomboasteraceae

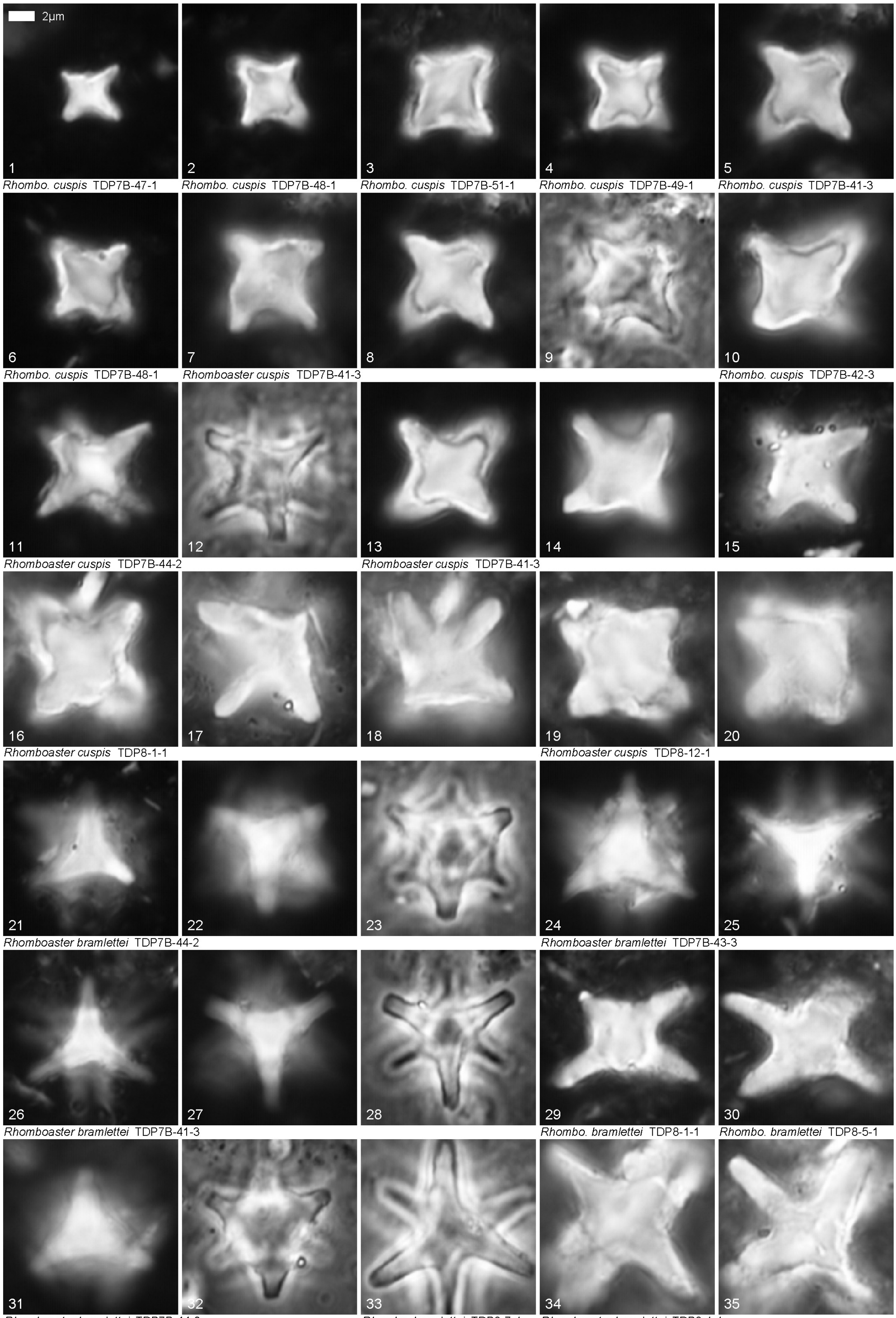
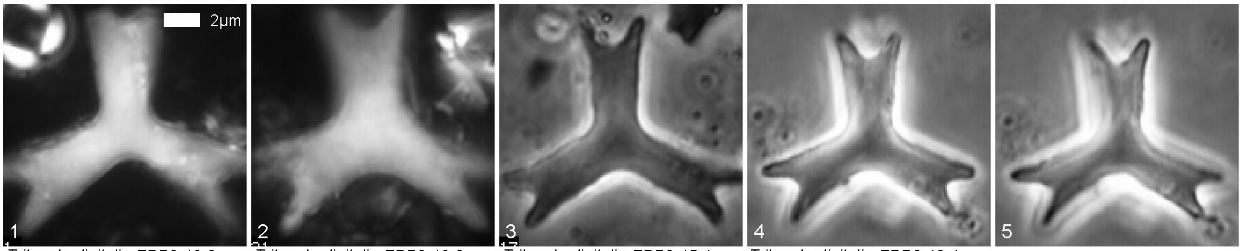
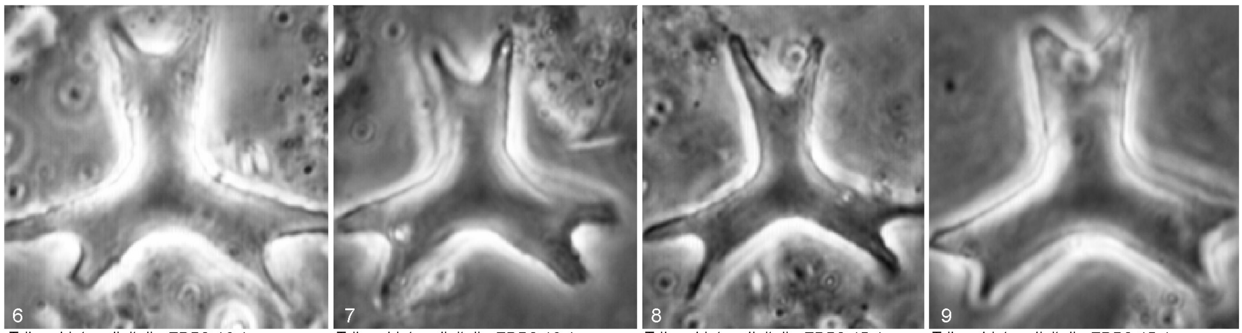


Plate 42

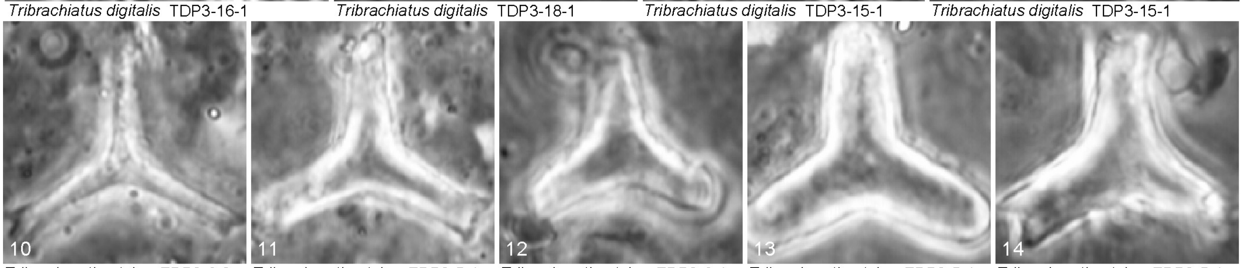
Nannoliths: Rhomboasteraceae



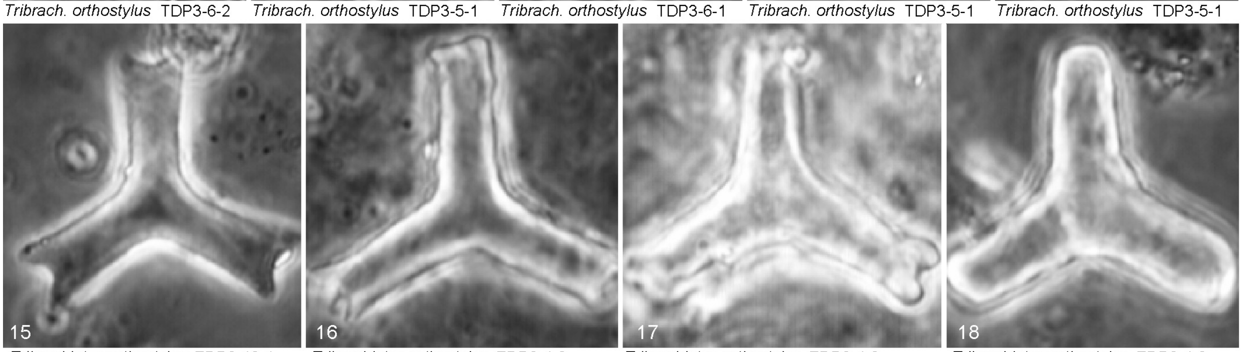
Tribrach. digitalis TDP3-19-3 *Tribrach. digitalis* TDP3-19-3 *Tribrach. digitalis* TDP3-15-1 *Tribrach. digitalis* TDP3-18-1



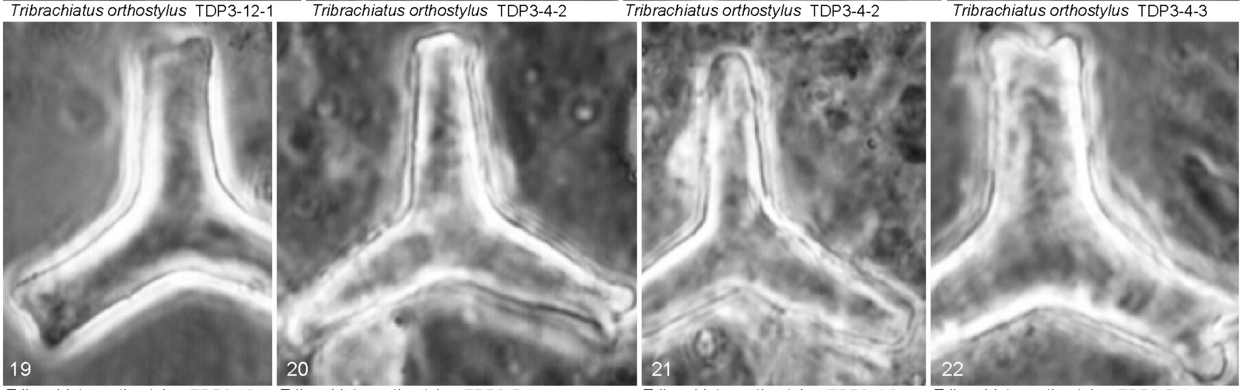
Tribrachiatus digitalis TDP3-16-1 *Tribrachiatus digitalis* TDP3-18-1 *Tribrachiatus digitalis* TDP3-15-1 *Tribrachiatus digitalis* TDP3-15-1



Tribrach. orthostylus TDP3-6-2 *Tribrach. orthostylus* TDP3-5-1 *Tribrach. orthostylus* TDP3-6-1 *Tribrach. orthostylus* TDP3-5-1 *Tribrach. orthostylus* TDP3-5-1



Tribrachiatus orthostylus TDP3-12-1 *Tribrachiatus orthostylus* TDP3-4-2 *Tribrachiatus orthostylus* TDP3-4-2 *Tribrachiatus orthostylus* TDP3-4-3



Tribrachiatus orthostylus TDP3-12-1 *Tribrachiatus orthostylus* TDP3-5-1 *Tribrachiatus orthostylus* TDP3-4-2 *Tribrachiatus orthostylus* TDP3-5-1

Plate 43

Nannoliths: *Nannotetrina*, Sphenolithaceae

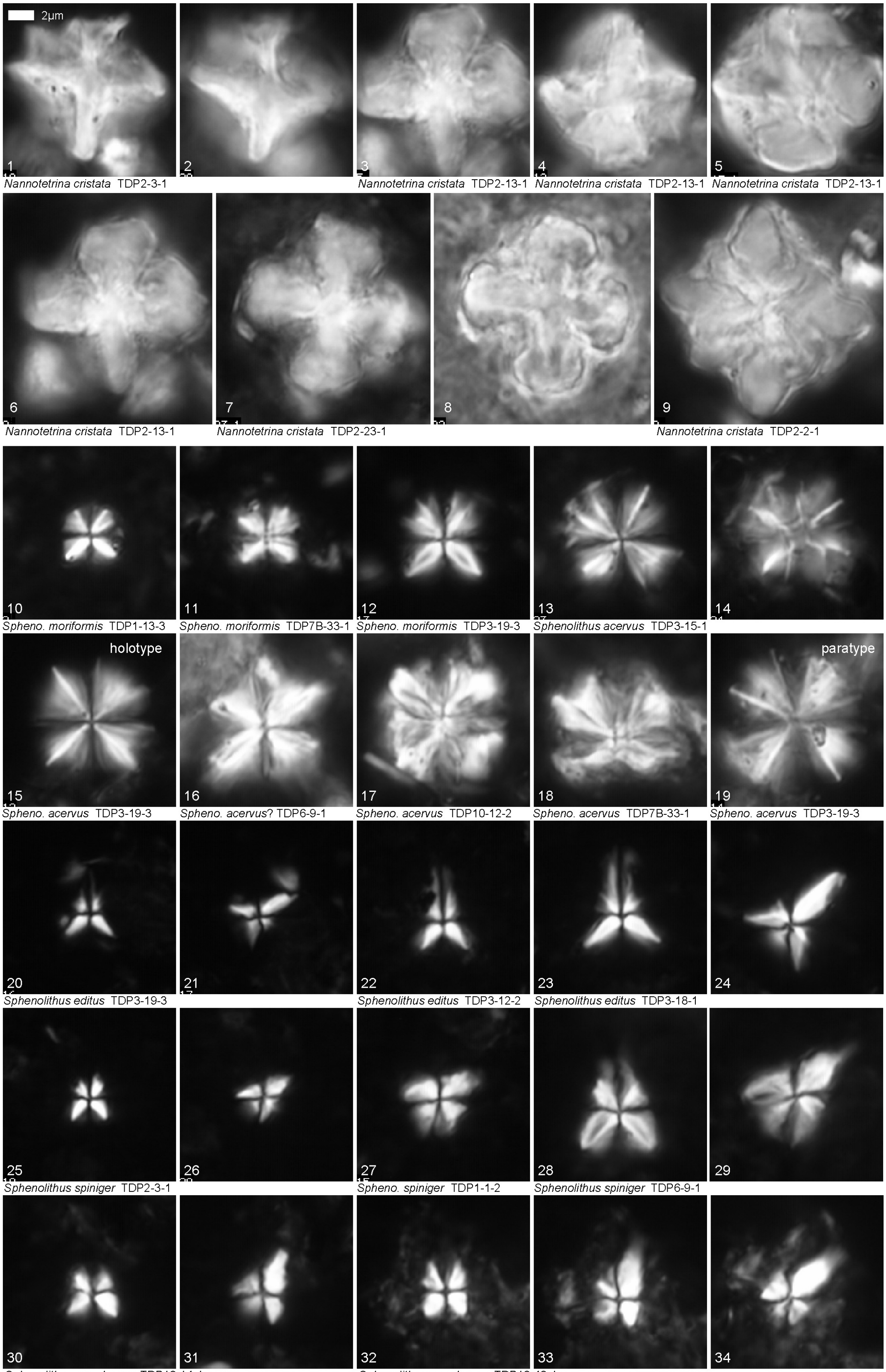


Plate 44

Nannoliths: Sphenolithaceae

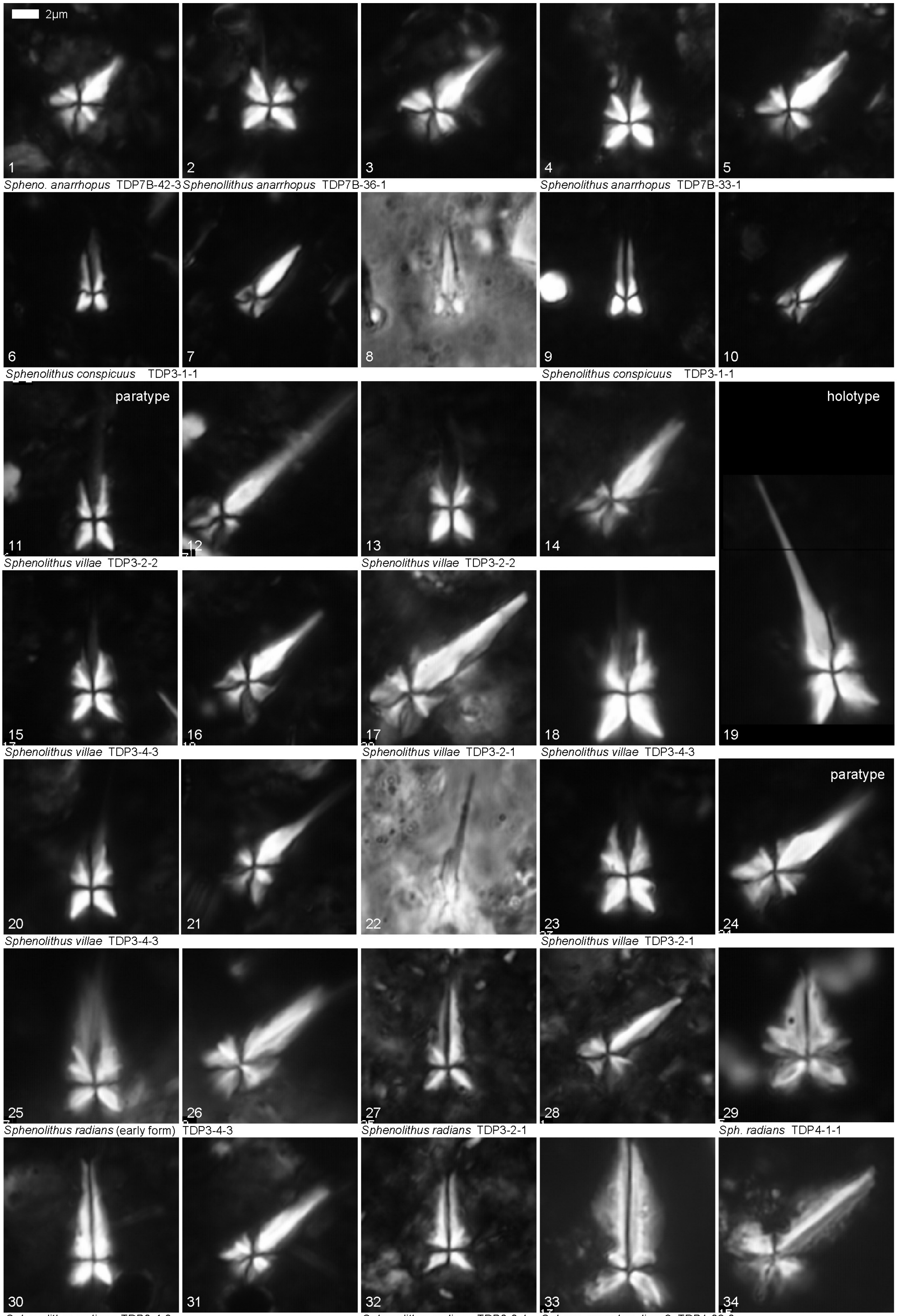


Plate 45

Nannoliths: Sphenolithaceae

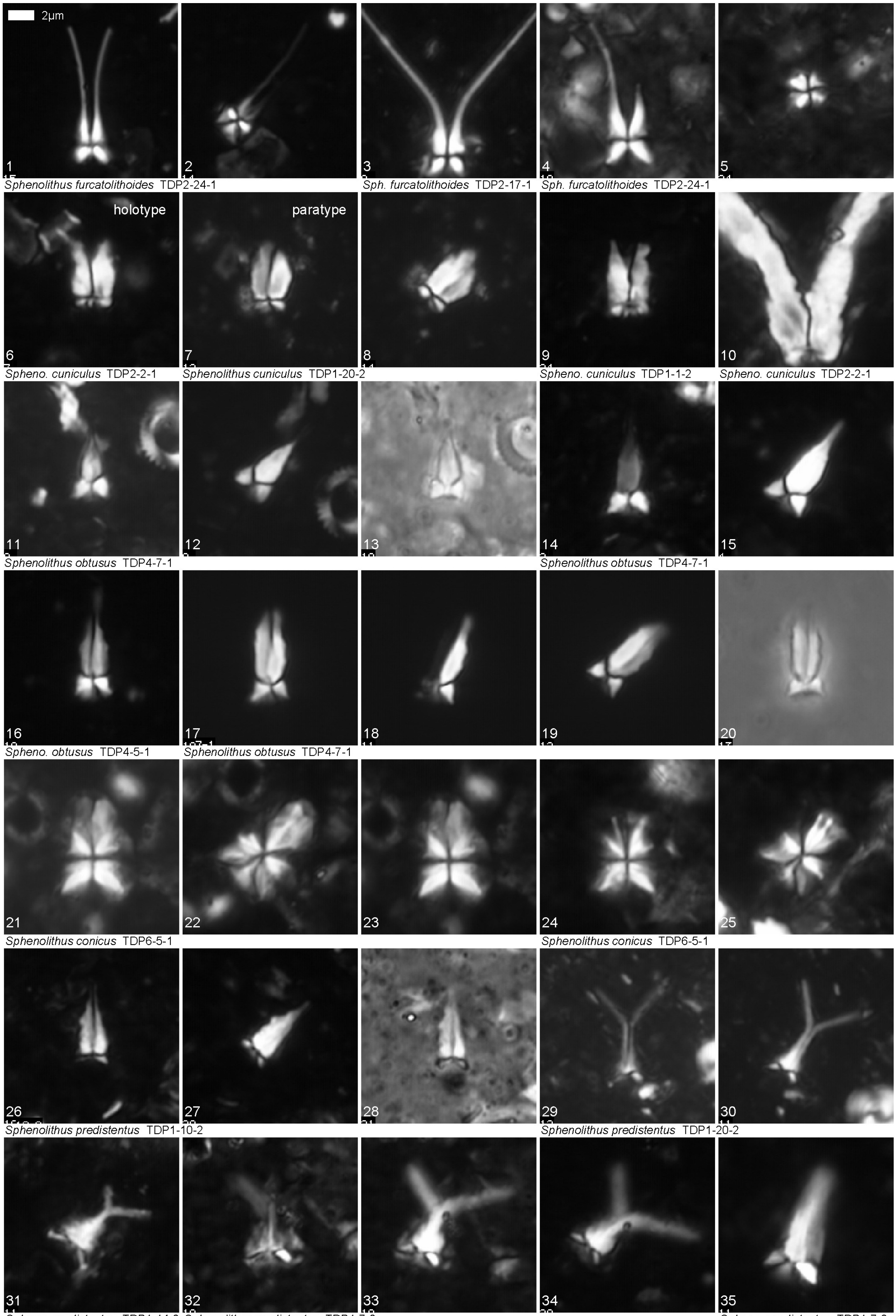


Plate 46

Nannoliths, ascidians, calcispheres