J. Nannoplankton Res. **29** (1), 2007, pp.39-65 © 2007 International Nannoplankton Association
ISSN 1210-8049 Printed by Cambridge University Press, UK

New and rarely reported calcareous nannofossils from the Late Cretaceous of coastal Tanzania: outcrop samples and Tanzania Drilling Project Sites 5, 9 and 15

Jackie A. Lees
Department of Earth Sciences, University College London, Gower Street, London, WC1E 6BT, UK; j.lees@ucl.ac.uk

Manuscript received 20th February, 2007; revised manuscript accepted 8th March, 2007

Abstract Field sampling and subsurface drilling in Tanzania, in and near to the coastal towns of Lindi and Kilwa, and connected to the NERC-funded Tanzania Drilling Project, have provided a wealth of Cretaceous material for analysis. The clay-rich lithologies contain nannofloras that are generally very well preserved and diverse. Consequently, several new calcareous nannofossil taxa have been discovered, and a number of taxa that are rarely reported have been recorded. These taxa are described and/or illustrated here. They include: seven new genera (*Bilapillus*, *Duocameratus*, *Nicholasia*, *Pearsonia*, *Singanoa*, *Tanzanella*, *Thecatus*); 17 new species of heterococcolith (*Calciosolenia*? *huberi*, *Corollithion karegae*, *Eiffellithus lindiensis*, *Gartnerago*? *coxalliae*, *Miravetesina bergenii*, *Percivalia*? *dunkleyjonesii*, *P.*? *pearsonii*, *Placozygus banneri*, *Prediscosphaera mgayae*, *Rhagodiscus pancostii*, *Rotelapillus msakyae*, *Staurolithites halfanii*, *S. handleyi*, *S. ngurumahambaensis*, *Truncatoscaphus macmillanii*, *Zeugrhabdotus blowii*, *Z. simplex*); 22 new species of holococcolith (*Bifidalithus mchanae*, *Bilapillus wadeae*, *Calculites cenomanicus*, *C. cyclops*, *C. juliae*, *C. maghredaswampensis*, *C. paulus*, *C. proscissus*, *C. rosalyniae*, *C. turonicus*, *Duocameratus leariae*, *D. sianiae*, *Lucianorhabdus*? *boudagherfadeliae*, *L.*? *tabernus*, *L. turris*, *Metadoga ampulla*, *Munarinus mkeremei*, *Nicholasia baileyi*, *Orastrum robinsonii*, *Pearsonia ecclesiata*, *Tanzanella bownii*, *Thecatus varolii*); four new species of nannolith (*Ceratolithoides dongenii, C. ohalloraniae*, *Micrantholithus*? *nicholasii*, *Singanoa scapus*); two new combinations (*Cribrosphaerella circula* (Risatti, 1973), *Lucianorhabdus compactus* (Verbeek, 1976)); and one taxon of elevated status (*Ceratolithina capitanea* (Burnett, 1997a)).

Keywords Calcareous nannofossils, holococcoliths, Cenomanian, Turonian, Campanian, Maastrichtian, taxonomy, Tanzania

1. Introduction

The Tanzania Drilling Project (TDP) was funded after three years of fieldwork (1998-2000) in the coastal Tanzania region, focussed on the towns of Kilwa and Lindi (Figure 1). The main aims of the project were to recover Paleogene and Cretaceous planktonic foraminifera of unprecedented preservation, as well as organic biomarkers, from the sediments, primarily in order to gain meaningful palaeotemperatures and atmospheric CO_2 estimates via isotopic analyses (*e.g.* Pearson *et al.*, 2001; van Dongen *et al.*, 2006). Among the ~500 outcrop samples initially collected were several of Cretaceous age. To date, those examined for calcareous nannofossils provide a discontinuous record of the Albian-Cenomanian, Turonian and Campanian-Maastrichtian (Lees, unpubl. data). Furthermore, three of the 20 sites drilled (with the collaboration of the Tanzania Petroleum Development Corporation – TPDC), between 2002 and 2005, also provided Cretaceous material. TDP Sites 5 and 9 (described in Pearson *et al.*, 2004, 2006; Nicholas *et al.*, 2006) recovered sediments from around the Campanian/Maastrichtian boundary, whilst TDP15 (Nicholas *et al.*, 2006; Pearson *et al.*, in prep.) was drilled specifically to try to recover the Cenomanian/Turonian boundary, although this proved to be elusive (Lees, unpubl. data).

Bown (2005), Bown & Dunkley Jones (2006) and Bown *et al.* (2007) have published extensively on taxonomic aspects of the Paleogene nannofloras, the dozens of new species described testifying to the fact that theirs is exceptionally well preserved material. Preservation of the Cretaceous material, especially from the cores, is variable, but overall seems not to be as pristine as that of the Paleogene cores, based on both planktonic foraminiferal and nannofossil scanning electron microscope observations (B.T. Huber, pers. comm., 2006; JAL pers. obs., 2004-2006). The calcareous nannofossil preservation in the Cretaceous is governed by the domination of clay in the sediment, but possibly tempered by having suffered from tropical weathering, even at depth. Having said that, there are many new calcareous nannofossil taxa in the Cretaceous material, and

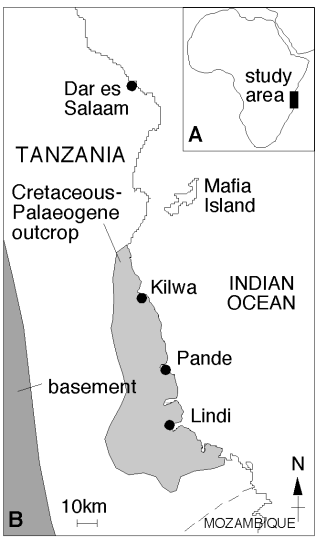


Figure 1: General location of the study area, coastal Tanzania (after Pearson *et al.*, 2004; Bown, 2005). Detailed maps can be found in Nicholas *et al.* (2006)

this is a preliminary description of the exceptional diversity that I have observed so far.

2. Material

The Upper Cretaceous sediments belong to the Nangurukuru Formation of the Kilwa Group (as described in Nicholas *et al*., 2006). They represent the onset of increased subsidence across the shelf, but the sediment actually varies very little from the Cretaceous through Paleogene, being predominantly represented by dark clay, claystones and siltstones (Nicholas *et al*., 2006). Outcrop material included herein was collected as spot-samples from around Kilwa and Lindi (as described below; grid references refer to maps shown in Nicholas *et al*., 2006). Locality and age details for the outcrop spot-samples mentioned here are given in Table 1. The nannofossil biozonation of Burnett (1998a) has been applied to these samples. (Full biostratigraphical information will be provided in a separate publication.)

sample	age	biozone
Around Lindi town, ~UTM 37L 573393, 8894643		
Lindi-99-2	Campanian/Maastrichtian	UC16
Lindi-99-3	Early Maastrichtian	UC17
Lindi-99-9a	Early Maastrichtian	UC17
Lindi-99-11	Early Maastrichtian	UC17
Lindi-99-12	Early Maastrichtian	UC18
Nguru-mahamba, SW of Lindi town, UTM 37L 561739, 8891339		
Nguru-99-1	Middle-Late Cenomanian	UC3a-b
Nguru-99-2	Early Cenomanian	UC1a-2a
Nguru-99-3	Early Cenomanian	UC1a-2a
Nguru-99-4	Early Cenomanian	UC1a-2a
Nguru-99-5	Middle-Late Cenomanian	UC3a-b
Nguru-99-9	Early Maastrichtian	UC17
Nguru-99-10	Late Campanian	UC15e^{TP}
Nguru-99-12	Late Maastrichtian	UC20a^{TP}
Matandu Bridge, west of Kilwa Kivinje (UTM 37L 531458, 9033532)		
PP04-K1	Middle-Late Turonian	UC9a
PP04-K9	Early Maastrichtian	UC17
PP04-K17	Late Campanian	UC15d^{TP}
PP04-K19	Late Campanian	UC15e^{TP}
PP04-K20	Late Campanian	UC15d^{TP}

Table 1: Outcrop sample locations and biostratigraphy

TDP5 was drilled in 2002 at Machole, next to the road between Lindi and Mtwara, south of Kitulo Hill (10˚01.646'S, 39˚41.375'E: Pearson *et al*., 2004). TDP9 was drilled in 2003 near the road junction at Nangurukuru, WSW of Singino Hill, near Kilwa Kivinje (UTM 37L 538987, 9027049: Pearson *et al*., 2006). TDP15 was drilled in 2005 in Maghreda Swamp, NW of Kilwa Kivinje (UTM 37L 528437, 9046105: Nicholas *et al*., 2006; Pearson *et al*., in prep.). Sample notation from these cores (*e.g*. TDP9/29-1, 99cm) refers to the site (TDP9), followed by the core and section number (29-1) and then the centimetre depth from the top of that section.

3. Methods

The species described here are based on light-microscope (LM) observation only. This was performed on smear-slides, prepared as described in Bown & Young (1998). Examination was performed on a Zeiss Axio Imager.A1 at 1250x magnification. Digital images were captured with a Leica DFC280 digital camera at 640x480 pixels, using Leica *FireCam* software. Plates were made using *Canvas* software on a Mac PowerBook, as follows. In a new *Canvas* file, the TIFF images were first acquired (Image->Acquire->TIFF), then scaled down to 25% (Object->Scale) and cropped (Image->Area->Crop), generally to 3x3cm or 2x2cm. The resolution can also be boosted (Image->Area->Resolution->Best). These images were then arranged into plates, and scale-bars, figure numbers, taxon names, sample numbers and image-identifying numbers added. All images on the plates were taken in cross-polarised light (XPL), except for those taken with phase-contrast (PC) or bright-field (BF), these being indicated on the plates. Typically, each specimen is figured at 0˚ and ~45˚ to the polarisers.

4. Gross assemblage composition

Species richness is typically very high in this material, comparing favourably with the global diversity estimates of Bown *et al*. (2004), and preservation varies from good to moderate. Holococcoliths and very small (<3μm) taxa are frequent components of the assemblages, although individual holococcolith species are usually rare to few in abundance.

Coccospheres are also frequently represented, particularly those of taxa with placolith morphology (*e.g*. *Biscutum*, which shows a plethora of coccosphere shapes (Pl.5, figs 2-10, 12-15), *Cribrosphaerella* and *Discorhabdus*). Whilst the nannofloras are not particularly dominated by any one taxon, *Corollithion*, *Cribrosphaerella*, *Discorhabdus*, *Prediscosphaera*, *Watznaueria* and *Zeugrhabdotus* are the most common assemblage components. Notably, the typically common Campanian lucianorhabdids and *Calculites obscurus* seen elsewhere are absent from, or very rare in, these assemblages. This may indicate that they are not tropical taxa.

The seldom reported *Prolatipatella multicarinata* occurs as a rare, yet quite consistent component, in sediments from TDP9 (Upper Campanian-Lower Maastrichtian). Lees (2002) indicated its status as a Tropical taxon, and this is supported by its unusually consistent presence in Tanzania. *Repagulum parvidentatum* is a rare, but sometimes consistent, component of these low-latitude nannofloras also. This underlines the fact that, whilst an increase in its abundance may be used as a proxy for cooler water, its mere presence in an assemblage may not. Its occurrence in these well-preserved samples may also involve a preservational bias.

5. Systematic palaeontology

The terminology used in the descriptions below follows

the guidelines of Young *et al*. (1997). The biozonation is that of Burnett (1998a). Only details of taxa and taxonomic references that do not appear in Bown (1998) are provided here. In the taxonomic descriptions below, 'L' = length, 'W' = width, 'H' = height. The taxonomic section is arranged in three parts: heterococcoliths, holococcoliths and nannoliths. Within each part, taxa are arranged alphabetically, first according to the order, then family, then genus, then species.

5.1 Heterococcoliths

Order ARKHANGELSKIALES **Bown & Hampton *in* Bown & Young, 1997**
Family **KAMPTNERIACEAE** Bown & Hampton *in* Bown & Young, 1997

Gartnerago chiasta Varol, 1991
Pl.3, figs 19, 20

Gartnerago? *coxalliae* sp. nov.
Pl.6, figs 34-37. **Derivation of name**: After Dr. Helen Coxall (Cardiff University), Cenozoic micropalaeontologist on the TDP team. **Diagnosis**: A medium-sized species with a rim that is reminiscent of that of *Gartnerago* (bright outer cycle, dark inner cycle, but lacking a central plate). The wide central area is open and spanned by a complex bar, aligned with the short axis, that remains quite dark in XPL. The bar bifurcates where it joins the rim. **Differentiation**: The bars in other species of *Gartnerago* are of simple construction and do not bifurcate. **Holotype**: Pl.6, figs 36, 37. **Holotype dimensions**: L = 7.04μm, W = 4.84μm. **Paratype**: Pl.6, figs 34, 35. **Type locality**: TDP5, Machole, south of Kitulo Hill, near Lindi, coastal Tanzania. **Type level**: TDP5/10-2, 15-16cm; UC15e^{TP}, Late Campanian. **Occurrence**: TDP5 and TDP9, Late Campanian-Early Maastrichtian (UC15e^{TP}-17); Matandu Bridge (Kilwa), Late Campanian (UC15e^{TP}).

Gartnerago cf. *G. praeobliquum* Jakubowski, 1986
Pl.3, figs 21-24
Remarks: These specimens appear to differ from the holotype in having only simple arms making up the cross, rather than double, and in lacking clear 'arrow-head' terminations to the bars where they join the rim.

Order EIFFELLITHALES **Rood *et al*., 1971**
Family **CHIASTOZYGACEAE** Reinhardt, 1965

Amphizygus brooksii Bukry, 1969
Pl.6, figs 38-42
Chiastozygus spissus Bergen *in* Bralower & Bergen, 1998
Pl.9, figs 13-16

Gorkaea pseudanthophorus (Bramlette & Martini, 1964) Varol & Girgis, 1994
Pl.7, figs 13-18

Placozygus banneri sp. nov.
Pl.7, figs 19-22. **Derivation of name**: After Prof. Fred Banner (deceased), whose work on the planktonic foraminifera of coastal Tanzania in the 1960s, with Prof. Walter Blow, eventually led to the search for pristine preservation that resulted in the TDP. **Diagnosis**: A small species of *Placozygus* that has the spiral-rim extinction pattern that is typical of the genus, a distinctive wide, bright inner cycle, and a dark short-axis bar, apparently composed of two blocks, that almost fills the small central area. **Differentiation**: This new species is distinguished from other placozygids by its wide, bright inner cycle, narrow central area and almost indistinguishable short-axis bar. **Holotype**: Pl.7, figs 21, 22. **Holotype dimensions**: L = 4.4μm, W = 3.08μm. **Paratype**: Pl.7, figs 19, 20. **Type locality**: Nguru-mahamba, SW of Lindi town, coastal Tanzania. **Type level**: Sample Nguru-99-10; UC15e^{TP}, Late Campanian. **Occurrence**: Nguru-mahamba, Late Campanian-Early Maastrichtian (UC15e^{TP}-17).

Placozygus fibuliformis (Reinhardt, 1964) Hoffmann, 1970
Pl.7, figs 27-30
Placozygus sp.
Pl.7, figs 31, 32

Placozygus spiralis (Bramlette & Martini, 1964) Hoffmann, 1970
Pl.7, figs 23-26
Remarks: Burnett (1998a) has been somewhat responsible for confusing the placozygid taxonomy. The original description of *spiralis* includes small size and small perforations either side of the bar; thus Burnett's (1998a, pl.6.2, fig.26a) illustration of *P. fibuliformis* is actually *P. spiralis*. *P. fibuliformis* (illustrated here in Pl.7, figs 27-30) has more open perforations and a bar in which the elements can be easily discerned. This species equates to Burnett's (1998a) illustrations (in pl.6.2, figs 26b-27b) of *P*. cf. *P. fibuliformis*. The larger and more highly birefringent form illustrated by Burnett (1998a, pl.6.2, fig.28) as *P. spiralis*, and here in Pl.7, figs 31 and 32 (as *Placozygus* sp.), is possibly a new species.

Staurolithites ellipticus (Gartner, 1968) Lambert, 1987
Pl.8, figs 28-35
Staurolithites flavus Burnett, 1998b
Pl.8, figs 40-43

Staurolithites halfanii sp. nov.
Pl.6, figs 13-21. **Derivation of name**: After Mr. Halfani R. Halfani (TPDC, Dar-es-Salaam), TDP facilitator. **Diagnosis**: A small species of *Staurolithites* with an indistinct, unicyclic rim that possesses a dark, thin, axial cross

with a delicate spine and a small, distinctively highly birefringent spine-top, visible when the coccolith is rotated away from 0˚. **Differentiation**: This new species is distinguished by its bright spine-top and low-birefringence bars. **Holotype**: Pl.6, figs 19-21. **Holotype dimensions**: L = 3.96μm, W = 3.08μm. **Paratypes**: Pl.6, figs 13-18. **Type locality**: TDP15, Maghreda Swamp, NW of Kilwa Kivinje, coastal Tanzania. **Type level**: TDP15/31-1, 10cm; UC6b, Early Turonian. **Occurrence**: TDP15, Early Turonian (UC6b).

Staurolithites handleyi sp. nov.

Pl.6, figs 28-33. **Derivation of name**: After Mr. Luke Handley (Bristol University), organic geochemist on the TDP team. **Diagnosis**: A small species of *Staurolithites* with a bicyclic rim, the inner cycle of which is bright. The axial cross appears to be composed of single bars that are bright at 0˚, becoming dark upon rotation. **Differentiation**: This new species is distinguished by its bicyclic rim and the particular simplicity of its cross. **Holotype**: Pl.6, figs 30, 31. **Holotype dimensions**: L = 3.96μm, W = 3.08μm. **Paratypes**: Pl.6, figs 28, 29, 32, 33. **Type locality**: TDP9, Nangurukuru junction, SW of Singino Hill, near Kilwa Kivinje, coastal Tanzania. **Type level**: TDP9/14-1, 36cm; UC17, Early Maastrichtian. **Occurrence**: TDP9, Late Campanian-Early Maastrichtian (UC15e^{TP}-17).

Staurolithites ngurumahambaensis sp. nov.

Pl.6, figs 22-27. **Derivation of name**: From Nguru-mahamba, where the species is described from. **Diagnosis**: A small species of *Staurolithites* with a dark, unicyclic rim, wherein the bars aligned with the long axis of the ellipse are dark, whilst the short-axis bars are highly birefringent. **Differentiation**: This new species is distinguished by its bright short-axis bars and dark long-axis bars. **Holotype**: Pl.6, figs 24, 25. **Holotype dimensions**: L = 3.08μm, W = 2.2μm. **Paratypes**: Pl.6, figs 22, 23, 26, 27. **Type locality**: Nguru-mahamba, SW of Lindi town, coastal Tanzania. **Type level**: Sample Nguru-99-5; UC3a-b, Middle-Late Cenomanian. **Occurrence**: Nguru-mahamba, Middle-Late Cenomanian (UC3a-b); TDP15, Early Turonian (UC6b).

Staurolithites zoensis Burnett, 1998b
Pl.8, figs 36-39

Zeugrhabdotus acanthus Reinhardt, 1965
Pl.7, figs 33-42; Pl.8, figs 1, 2

Zeugrhabdotus bicrescenticus (Stover, 1966) Burnett *in* Gale *et al*., 1996
Pl.9, figs 1, 2

Zeugrhabdotus cf. *Z. bicrescenticus* (Stover, 1966) Burnett *in* Gale *et al*., 1996
Pl.9, figs 3-7

Remarks: *Z.* cf. *Z. bicrescenticus* has two miniscule crystals, that are bright in XPL, inserted between the bars where the bars join the rim, such as is seen in *Z. diplogrammus*. These are not apparent in *Z. bicrescenticus*.

Zeugrhabdotus biperforatus (Gartner, 1968) Burnett, 1998b
Pl.9, figs 8, 9

Zeugrhabdotus cf. *Z. biperforatus* (Gartner, 1968) Burnett, 1998b
Pl.9, figs 10, 11

Remarks: *Z.* cf. *Z. biperforatus* is generally more narrowly elliptical, has a more-open central area and a narrower inner cycle than *Z. biperforatus*.

Zeugrhabdotus blowii sp. nov.

Pl.8, figs 20-27. **Derivation of name**: After Prof. Walter Blow (deceased), whose work on the planktonic foraminifera of coastal Tanzania in the 1960s, with Prof. Fred Banner, eventually led to the search for pristine preservation that resulted in the TDP. **Diagnosis**: A small species of *Zeugrhabdotus* with quite low birefringence that has a simple, disjunct bar composed of two elements. The bar is almost invisible at 0˚. At 45˚, the bar and rim have the same birefringence. **Differentiation**: This new species is distinguished from other zeugrhabdotids by the simplicity of its bar and by the way in which the bar goes into extinction at 0˚. The Jurassic *Z. fissus* is superficially similar to the new species, but has a bar with higher birefringence and a perforation in the centre of the bar that the new species lacks. **Holotype**: Pl.8, figs 22, 23. **Holotype dimensions**: L = 3.52μm, W = 2.64μm. **Paratypes**: Pl.8, figs 20, 21, 24, 25. **Type locality**: TDP5, Machole, south of Kitulo Hill, near Lindi, coastal Tanzania. **Type level**: TDP5/10-2, 15-16cm; UC15e^{TP}, Late Campanian. **Occurrence**: TDP5, Late Campanian (UC15e^{TP}); TDP15, Early Turonian (UC6b).

Zeugrhabdotus embergeri (Noël, 1958) Perch-Nielsen, 1984
Pl.7, figs 1-12

Remarks: This heavily calcified species has a rhomb-shaped, composite bar and very small to no perforations in the central area. The ragged-looking specimens in Pl.7, figs 1-6 are interpreted as showing the proximal view of this species, with the rhomb-shaped base to the bar being discernable, surrounded by the base-plate.

Zeugrhabdotus erectus (Deflandre *in* Deflandre & Fert, 1954) Reinhardt, 1965
Pl.9, figs 21-24; Pl.9, figs 19, 20?

Zeugrhabdotus noeliae Rood *et al*., 1971
Pl.8, figs 10-17

Zeugrhabdotus praesigmoides Burnett, 1998b
Pl.8, figs 3-9

Zeugrhabdotus simplex sp. nov.

Pl.8, figs 18, 19. **Derivation of name**: From the Latin

'*simplex*', meaning 'plain' or 'simple', referring to the simplicity of the bar. **Diagnosis**: A large species of *Zeugrhabdotus* in which the slender, disjunct bar, which is crystallographically uniform, divides the wide, open central area. **Differentiation**: This new species is distinguished from other zeugrhabdotids in having a simple, slender bar dividing the wide, open central area. **Holotype**: Pl.8, figs 18, 19. **Holotype dimensions**: L = 8.80μm, W = 6.16μm. **Type locality**: TDP9, Nangurukuru junction, SW of Singino Hill, near Kilwa Kivinje, coastal Tanzania. **Type level**: TDP9/47-2, 30cm; UC15e^{TP}, Late Campanian. **Occurrence**: TDP9, Late Campanian (UC15e^{TP}).

Zeugrhabdotus xenotus (Stover, 1966) Burnett *in* Gale *et al*., 1996
Pl.9, figs 12, 17, 18

Family **EIFFELLITHACEAE** Reinhardt, 1965

Eiffellithus lindiensis sp. nov.
Pl.6, figs 1-12. **Derivation of name**: After the town of Lindi, near which the species was first identified. **Diagnosis**: A small species of *Eiffellithus* in which the small, indistinct central cross is axially aligned. The inner cycle fills the central area. **Differentiation**: This new species is easily distinguished from *E. eximius*, which is much larger, and has a distinctive, bifurcating cross that takes up more of the central area. Furthermore, *E. lindiensis* ranges up into the Maastrichtian. It is distinct from other Late Cretaceous eiffellithids in being small and having an axial cross. **Holotype**: Pl.6, figs 3, 4. **Holotype dimensions**: L = 4.4μm, W = 3.08μm. **Paratypes**: Pl.6, figs 5-10. **Type locality**: TDP5, Machole, south of Kitulo Hill, near Lindi, coastal Tanzania. **Type level**: TDP5/6-3, 36-37cm; UC15e^{TP}, Late Campanian. **Occurrence**: TDP5 and TDP9, Late Campanian-Early Maastrichtian (UC15e^{TP}-17); Lindi area, Campanian-Maastrichtian (UC16).

Family **RHAGODISCACEAE** Hay, 1977

Percivalia? *dunkleyjonesii* sp. nov.
Pl.3, figs 29-42. **Derivation of name**: After Mr. Tom Dunkley Jones (UCL), Cenozoic nannopalaeontologist and roustabout on the TDP team. **Diagnosis**: This medium-sized species possesses a narrow, bicyclic rim and a central plate of laterally-oriented laths at the centre of which is an indistinct cross. This axial cross has two distinctive 'buttons', outlined by dark extinction lines, making up the short-axis bars. The 'buttons' are visible when the coccolith is oriented both at 0° and 45°. The entire central area shows low birefringence. **Differentiation**: This new species is distinguished from all other *Percivalia* species by the distinctive 'buttons' and central-area laths. **Remarks**: The rim and inner cycle of this species are somewhat reminiscent of *Percivalia*, although scanning electron microscopy is needed to confirm the generic assignment. **Holotype**: Pl.3, figs 40-42. **Holotype dimensions**: L = 6.82μm, W = 4.84μm. **Paratypes**: Pl.3, figs 31-34, 37-39. **Type locality**: TDP15, Maghreda Swamp, NW of Kilwa Kivinje, coastal Tanzania. **Type level**: TDP15/25-1, 10cm; UC6b, Early Turonian. **Occurrence**: TDP15, Early Turonian (UC6b); Nguru-mahamba, Early Cenomanian (UC1a-2a).

Percivalia? *pearsonii* sp. nov.
Pl.3, figs 25-28. **Derivation of name**: After Prof. Paul Pearson (Cardiff University), co-chief and Cenozoic micropalaeontologist on the TDP team. **Diagnosis**: This medium-sized species possesses a narrow, bicyclic rim, a central-area plate, and a central, axially-aligned cross, each bar of which is divided into two. The cross is located in the centre of a central plate. The cross and plate show very low birefringence in XPL. **Differentiation**: This new species is distinguished from other *Percivalia* species by its distinctive axial cross and its lack of perforations in the central plate. **Remarks**: The rim, inner cycle, and characteristically dark central area of this new species are somewhat reminiscent of *Percivalia*, although scanning electron microscopy is needed to confirm the generic assignment. **Holotype**: Pl.3, figs 27, 28. **Holotype dimensions**: L = 6.60μm, W = 4.40μm. **Paratype**: Pl.3, figs 25, 26. **Type locality**: TDP9, Nangurukuru junction, SW of Singino Hill, near Kilwa Kavinje, coastal Tanzania. **Type level**: TDP9/21-1, 50cm; UC17, Early Maastrichtian. **Occurrence**: TDP9 and Nguru-mahamba, Early Maastrichtian (UC17).

Rhagodiscus pancostii sp. nov.
Pl.4, figs 1-4; Pl.4, figs 5, 6? **Derivation of name**: After Dr. Richard Pancost (Bristol University), organic geochemist and palaeoceanographer on the TDP team. **Diagnosis**: A small, elliptical species of *Rhagodiscus* that bears a very small, delicate spine. The spine-tip appears bright in XPL. **Differentiation**: Similar to *R. achlyostaurion*, but with a spine-base/top that is much smaller, and does not occupy most of the central area. *R. gallagheri* is somewhat similar, but has no spine and is more narrowly elliptical. The specimen in Pl.4, figs 5, 6 has a narrower, brighter rim, which differs from that seen in *R. pancostii*; this specimen may be *Orastrum partitum*. **Holotype**: Pl.4, figs 1, 2. **Holotype dimensions**: L = 3.96μm, W = 2.86μm. **Paratype**: Pl.4, figs 3, 4. **Type locality**: TDP15, Maghreda Swamp, NW of Kilwa Kivinje, coastal Tanzania. **Type level**: TDP15/15-1, 10cm; UC6b, Early Turonian. **Occurrence**: TDP15, Early Turonian (UC6b).

Order PODORHABDALES **Rood *et al*., 1971, emend. Bown, 1987**

Family **AXOPODORHABDACEAE** Bown & Young, 1997

Cribrocorona echinus (Burnett, 1998b) Lees & Bown, 2005
Pl.4, figs 39-42
Cribrosphaerella circula (Risatti, 1973) comb. nov.
Pl.4, fig.37
Basionym: *Cribrosphaera circula* Risatti, 1973, p.24, pl.8, figs 20, 21 (holotype). Risatti, J.B. 1973. Nannoplankton biostratigraphy of the Upper Bluffport Marl-Lower Prairie Bluff Chalk interval (Upper Cretaceous), in Mississippi. *In*: L.A. Smith & J. Hardenbol (Eds). *Proceedings of Symposium on Calcareous Nannofossils. SEPM, Gulf Coast section, Houston, Texas, October 26 1973*: 8-57.

Cribrosphaerella ehrenbergii (Arkhangelsky, 1912) Deflandre *in* Piveteau, 1952
Pl.4, figs 32-34 – typical subrectangular, coarse-grilled forms; Pl.4, figs 35, 36 – irregularly-rimmed forms; Pl.4, fig.38 – elliptical, fine-grilled form

Family **BISCUTACEAE** Black, 1971

Biscutum ellipticum (Górka, 1957) Grün *in* Grün & Allemann, 1975
Pl.5, figs 1-10, 12-15
Biscutum notaculum Wind & Wise *in* Wise & Wind, 1977
Pl.5, figs 18-21
Crucibiscutum hayi (Black, 1973) Jakubowski, 1986
Pl.5, figs 22, 23
Crucibiscutum salebrosum? (Black, 1971) Jakubowski, 1986
Pl.5, figs 24-31
Discorhabdus ignotus (Górka, 1957) Perch-Nielsen, 1968
Pl.5, figs 11, 16, 17

Family **CRETARHABDACEAE** Thierstein, 1973

Miravetesina bergenii sp. nov.
Non 1966 *Coccolithites ficula* Stover: p.138, pl.5, figs 5, 6; pl.9, fig.11.
Non 1998b *Retecapsa ficula* (Stover) Burnett: pp.138-139; *non* Burnett, 1998a, p.180, pl.6.7, fig.8.
1998 *Miravetesina ficula* (Stover, 1966) Bergen *in* Bralower & Bergen: p.75, pl.1, figs 13a, 13b; pl.2, fig.11.
Pl.5, figs 32-35, 38-40. **Derivation of name**: After Dr. Jim Bergen (BP, Houston), seasoned calcareous nannofossil taxonomist and biostratigrapher. **Diagnosis**: A medium-sized species of *Miravetesina* with a wide, granulate central area bearing a slightly sigmoidal, delicate, axial cross. **Differentiation**: Distinguished from *M. favula* (*e.g.* see Bown & Cooper, 1998, pl.4.13, fig.17) by its more pronounced and slightly sigmoidal, axial cross, and its much younger age. **Remarks**: *Retecapsa ficula*, as illustrated by Burnett (1998a), bears closest resemblance to Stover's (1966) line-drawing of *ficula* (pl.9, fig.11), whilst his light-micrographs (including the holotype) show specimens with a narrow central area. Consequently, the form illustrated as *M. ficula* by Bergen *in* Bralower & Bergen (1998) is not *ficula*, but a new species, *bergenii*. **Holotype**: Pl.5, figs 32-35. **Holotype dimensions**: L = 6.82μm, W = 5.28μm. **Paratypes**: Pl.5, figs 38-40. **Type locality**: Lindi area, coastal Tanzania. **Type level**: Sample Lindi-99-11; UC17, Early Maastrichtian. **Occurrence**: Lindi area, Early Maastrichtian (UC17); TDP9, Late Campanian-Early Maastrichtian (UC15e^{TP}-17); TDP15, Early Turonian (UC6b); Bounds core, western Kansas (Bralower & Bergen, 1998), Middle-Late Turonian (UC8b-9b).

Family **PREDISCOSPHAERACEAE** Rood *et al*., 1971

Prediscosphaera mgayae sp. nov.
Pl.5, figs 36, 37, 41-44. **Derivation of name**: After Mr. Elvis Mgaya ('Mr. K') (TPDC, Dar-es-Salaam), field driver and drilling assistant on the TDP team. **Diagnosis**: A small, elliptical species of *Prediscosphaera* with a delicate axial cross and a very narrow, low-birefringence inner rim-cycle. **Differentiation**: *P. spinosa* has a thicker, bright inner rim-cycle and a subrectangular outline. *P. stoveri* is small, with a bright inner cycle that almost fills the central area. *P. arkhangelskyi* has a distinctive cross and thick, bright inner cycle. Other species of the genus have either circular outlines or crosses at 45˚ to the ellipse axes. **Holotype**: Pl.5, figs 36, 37. **Holotype dimensions**: L = 4.84μm, W = 3.08μm. **Paratypes**: Pl.5, figs 41-44. **Type locality**: TDP9, Nangurukuru junction, SW of Singino Hill, near Kilwa Kivinje, coastal Tanzania. **Type level**: TDP9/19-1, 30cm; UC17, Early Maastrichtian. **Occurrence**: TDP9 and Lindi area, Early Maastrichtian (UC17).

Order STEPHANOLITHIALES **Bown & Young, 1997**
Family **CALCIOSOLENIACEAE** Kamptner, 1927

Calciosolenia fossilis (Deflandre *in* Deflandre & Fert, 1954) Bown *in* Kennedy *et al*., 2000
Pl.1, figs 1-6

Calciosolenia? *huberi* sp. nov.
Pl.1, figs 7-13; Pl.1, figs 14-18? **Derivation of name**: After Dr. Brian Huber (Smithsonian, Washington), Mesozoic micropalaeontologist on the TDP team. **Diagnosis**: A medium-sized species of *Calciosolenia*? possessing a distally-orientated spur-like extension to the rim, located at one end of the coccolith, observable in side view. **Differentiation**: No other species of *Calciosolenia* possess a spur-like rim extension. This species is questionably placed in *Calciosolenia* based on a slightly oblique view (Pl.1, fig.11) that suggests this assignment, although it is unusual to observe *Calciosolenia* specimens in side view. Specimens with thickened rims, shown on

Pl.1, figs 14-18, may represent distal/proximal views of this species. **Holotype**: Pl.1, figs 9, 10. **Holotype dimensions**: L = 7.04μm, W = 1.1μm. **Paratypes**: Pl.1, figs 11-13. **Type locality**: TDP15, Maghreda Swamp, NW of Kilwa Kivinje, coastal Tanzania. **Type level**: TDP15/37-1, 10cm; UC6b, Early Turonian. **Occurrence**: TDP15, Early Turonian (UC6b); TDP9, Early Maastrichtian (UC17).

Family **STEPHANOLITHIACEAE** Black, 1968

Corollithion completum Perch-Nielsen, 1973
Pl.1, figs 19, 20
Corollithion exiguum Stradner, 1961
Pl.1, figs 33, 34

Corollithion karegae sp. nov.
Pl.1, figs 25-32. **Derivation of name**: After Ms. Amina Karega (TPDC, Dar-es-Salaam), nanno- and micropalaeontologist on the TDP team. **Diagnosis**: A small species of *Corollithion* with very low birefringence, a very narrow, slightly brighter inner rim-cycle, and an almost indistinguishable, dark outer cycle, in which a plate composed of six segments completely fills the central area. **Differentiation**: This new species has distinctively low birefringence. In other species, the bright inner-cycle is thicker and much more visible. The dark central plate that fills the central area of the new species is composed of six segments, whilst in *C. kennedyi* (Pl.1, figs 21, 22) and *C. completum* (Pl.1, figs 19, 20) the central plates have higher birefringence and are divided into four blocks. **Holotype**: Pl.1, figs 31, 32. **Holotype dimensions**: L = 3.96μm, W = 3.08μm. **Paratype**: Pl.1, figs 25, 26. **Type locality**: TDP5, Machole, south of Kitulo Hill, near Lindi, coastal Tanzania. **Type level**: TDP5/9-3, 55-57cm; UC15e^{TP}, Late Campanian. **Occurrence**: TDP5, Late Campanian/Early Maastrichtian (UC15e^{TP}-UC16); TDP9, Late Campanian-Early Maastrichtian (UC15e^{TP}-UC17); Matandu Bridge (Kilwa), Late Campanian (UC15d^{TP}); Lindi area, Campanian/Maastrichtian (UC16).

Corollithion kennedyi Crux, 1981
Pl.1, figs 21, 22
Corollithion signum Stradner, 1963
Pl.1, figs 23, 24
Darwinilithus pentarhethum Watkins *in* Watkins & Bowdler, 1984
Pl.4, figs 19-28
Rhombolithion rhombicum (Stradner & Adamiker, 1966) Black, 1973
Pl.1, figs 35, 36
Rhombolithion rotatum (Rood *et al*., 1971) Black, 1973
Pl.1, figs 37, 38

Rotelapillus msakyae sp. nov.
Pl.4, figs 29-31. **Derivation of name**: After Ms. Emma Msaky (TPDC, Dar-es-Salaam), palynologist on the TDP team. **Diagnosis**: A medium-sized species of *Rotelapillus* that is elliptical, both in outline and central area. The central area contains a non-axially-aligned, low-angled cross that is dark in XPL. **Differentiation**: This new species is distinguished from all other cross-bearing *Rotelapillus* species by its elliptical outline and central area; all other species are circular in outline. **Holotype**: Pl.4, figs 29, 30. **Holotype dimensions**: L = 6.16μm, W = 3.96μm. **Paratype**: Pl.4, fig.31. **Type locality**: TDP9, Nangurukuru junction, SW of Singino Hill, near Kilwa Kivinje, coastal Tanzania. **Type level**: TDP9/9-2, 39cm; UC17, Early Maastrichtian. **Occurrence**: TDP9, Early Maastrichtian (UC17).

Truncatoscaphus macmillanii sp. nov.
Pl.1, figs 39-41. **Derivation of name**: After Dr. Ian McMillan (Cardiff University), micropalaeontologist on the TDP team. **Diagnosis**: A small, low-birefringence species of *Truncatoscaphus* with a relatively short and broad polygonal rim, containing a clearly discernable longitudinal bar from which four very barely discernable, transverse bars extend down each side of the end thirds of the coccolith. Centrally, four further, clearly discernable bars interlock to form a distinctive cross. **Differentiation**: The new species most closely resembles the Jurassic *T. intermedius* and *T. delftensis*, but both of these have more elongated and narrower outlines, and the latter has more bars. Neither possesses the distinctively-arranged central bars. The new species is the youngest *Truncatoscaphus* recorded. **Holotype**: Pl.1, figs 39-41. **Holotype dimensions**: L = 3.52μm, W = 2.2μm. **Type locality**: TDP15, Maghreda Swamp, NW of Kilwa Kivinje, coastal Tanzania. **Type level**: TDP15/15-1, 10cm; UC6b, Early Turonian. **Occurrence**: TDP15, Early Turonian (UC6b).

PLACOLITHS OF UNCERTAIN AFFINITY

Prolatipatella multicarinata Gartner, 1968
Pl.3, figs 13-16
Repagulum parvidentatum (Deflandre & Fert, 1954) Forchheimer, 1972
Pl.3, figs 11, 12, 17, 18

5.2 Holococcoliths

Family **CALYPTROSPHAERACEAE** Boudreaux & Hay, 1969

Remarks: The classification of Mesozoic holococcoliths is problematical. The majority are very small, therefore rim-structure details and some central-area features are at the very limits of light-microscopic observation. Because of their very low preservation potential, they are typically rare in occurrence, and so scanning electron microscope observation is often not practicable. Generic classification is consequently subjective, being predominantly reliant on central-area features. Additionally, matching side

views of rare holococcoliths with their base-plate views is not easy; most biostratigraphic analysis or reconnaissance work is done on permanently-mounted slides. This may result in multiple taxonomic designations for the same species.

Several previously unreported taxa are present in the Tanzanian material. Whilst I attempted to match side views with base-plate views, the specimens are generally rare and these images were taken on permanently-mounted smear-slides.

Acuturris scotus (Risatti, 1973) Wind & Wise *in* Wise & Wind, 1977
Pl.11, figs 22-24

Bifidalithus mchanae sp. nov.
Pl.10, figs 66-71. **Derivation of name**: After Mr. Ephrem Mchana (TPDC, Dar-es-Salaam), for expert technical assistance during TDP drilling. **Diagnosis**: A small species of *Bifidalithus* Varol, 1991 in which the two main constituent elements contain a single perforation each, arranged around the short-axis junction between the elements. The junction between these elements appears raised. **Differentiation**: This species is distinct from *B. geminicatillus* in possessing perforations. In side view (Pl.10, figs 70, 71), the raised area where the elements join appears to arch over a cavity above a monoperforate proximal plate. **Holotype**: Pl.10, figs 68, 69. **Holotype dimensions**: L = 4.62μm, W = 3.08μm. **Paratypes**: Pl.10, figs 66, 67, 70, 71. **Type locality**: TDP5, Machole, south of Kitulo Hill, near Lindi, coastal Tanzania. **Type level**: TDP5/9-1, 48-49cm; UC15e^{TP}, Late Campanian. **Occurrence**: TDP5, Late Campanian (UC15e^{TP}); TDP9, Early Maastrichtian (UC17).

Bilapillus gen. nov.
Type species: *Bilapillus wadeae* gen. et sp. nov. **Derivation of name**: From the Latin '*bi*', meaning 'two', and '*lapillus*', meaning 'little stone', referring to the central structure of this genus. **Diagnosis**: A holococcolith with a simple rim that is bright in XPL. At 0˚ in XPL, extinction lines form v-shapes at the ends of the lith. On rotation, the extinction lines become aligned with the polarising directions, whilst the short-axis line is offset on either side of the centre. Two adjacent polygonal blocks fill the central area.

Bilapillus wadeae gen. et sp. nov.
Pl.13, figs 34-43; Pl.13, figs 44, 45? **Derivation of name**: After Dr. Bridget Wade (Rutgers University), Cenozoic micropalaeontologist on the TDP team. **Diagnosis**: A small species of *Bilapillus*. The illustrations in Pl.13, figs 44, 45 appear to show perforations in the central blocks. **Holotype**: Pl.13, figs 36, 37. **Holotype dimensions**: L = 3.30μm, W = 2.20μm. **Paratypes**: Pl.13, figs 34, 35, 38, 39. **Type locality**: TDP15, Maghreda Swamp, NW of Kilwa Kivinje, coastal Tanzania. **Type level**: TDP15/5-1, 10cm; UC6b, Early Turonian. **Occurrence**: TDP15, Early Turonian (UC6b); Matandu Bridge (Kilwa), Middle-Late Turonian (UC9a); Nguru-mahamba, Early Cenomanian (UC1a-2a).

Genus *Calculites* Prins & Sissingh *in* Sissingh, 1977
Remarks: New species that, in XPL, are bright across the entire holococcolith have here been placed in *Calculites*.

Calculites axosuturalis Bergen *in* Bralower & Bergen, 1998
Pl.9, figs 33-36, Pl.9, figs 37, 38?

Calculites cenomanicus sp. nov.
Pl.10, figs 37-42. **Derivation of name**: After the Cenomanian, from which it is described. **Diagnosis**: A small species of *Calculites* with an irregular-looking, elongated central perforation. At 0˚ in XPL, the extinction lines are aligned with the polarising directions. On rotation, the extinction lines form v-shapes at the ends of the lith that are truncated by the ends of the perforation. The central perforation appears to contain a structure (Pl.10, figs 37, 38), but this is not resolvable. **Differentiation**: The elongated, irregular-looking central perforation and vague central structure distinguish this from other *Calculites* species. **Holotype**: Pl.10, figs 37, 38. **Holotype dimensions**: L = 4.40μm, W = 2.64μm. **Paratypes**: Pl.10, figs 39-42. **Type locality**: Nguru-mahamba, SW of Lindi town, coastal Tanzania. **Type level**: Nguru-99-1; UC3a-b, Middle-Late Cenomanian. **Occurrence**: Nguru-mahamba, Middle-Late Cenomanian (UC3a-b).

Calculites cyclops sp. nov.
Pl.10, figs 10-13; Pl.10, figs 14-17? **Derivation of name**: From the Latin '*Cyclops*', the mythical race of one-eyed giants, referring to the single, relatively wide central perforation. **Diagnosis**: A small species of *Calculites* that has a relatively wide central perforation. At 0˚ in XPL, the extinction lines are aligned with the polarising directions. On rotation, the lines become v-shaped and occupy the ends of the lith. **Differentiation**: The wide central perforation distinguishes it from other species of *Calculites*. **Holotype**: Pl.10, figs 10, 11. **Holotype dimensions**: L = 4.84μm, W = 3.52μm. **Paratype**: Pl.10, figs 12, 13. **Type locality**: TDP15, Maghreda Swamp, NW of Kilwa Kivinje, coastal Tanzania. **Type level**: TDP15/15-1, 10cm; UC6b, Early Turonian. **Occurrence**: TDP15, Early Turonian (UC6b); ?Nguru-mahamba, Middle-Late Cenomanian (UC3a-b).

Calculites juliae sp. nov.
Pl.13, figs 32, 33. **Derivation of name**: After Ms. Julia Pearson, member of the TDP support team. **Diagnosis**: A small species of *Calculites*, comprising a narrow rim enclosing a multiperforate plate (six perforations, two larger ones situated at each end of the lith and four smaller ones arranged around the outsides of the middle of the

plate). The plate goes dark upon rotation. **Differentiation**: The new species is smaller than most *Calculites* species and has symmetrically-distributed perforations around the central plate, which distinguishes it from other species. **Holotype**: Pl.13, figs 32, 33. **Holotype dimensions**: L = 3.30μm, 2.20μm. **Type locality**: Nguru-mahamba, SW of Lindi town, coastal Tanzania. **Type level**: Nguru-99-9; UC17, Early Maastrichtian. **Occurrence**: Nguru-mahamba, Early Maastrichtian (UC17).

Calculites maghredaswampensis sp. nov.

Pl.10, figs 19-22; Pl.10, figs 23-26? **Derivation of name**: After Maghreda Swamp, where TDP15 was drilled. **Diagnosis**: A medium-sized species of *Calculites* with a small central perforation. In XPL at 0˚, the extinction lines are are aligned with the polarising directions, but kink as they move into the central area, where they meet in the middle. On rotation, these form a sigmoidal x-shape across the lith. **Differentiation**: Distinguished from other *Calculites* by its kinked extinction lines and central perforation. **Holotype**: Pl.10, figs 19, 20. **Holotype dimensions**: L = 5.28μm, W = 3.52μm. **Paratype**: Pl.10, figs 21, 22. **Type locality**: TDP15, Maghreda Swamp, NW of Kilwa Kivinje, coastal Tanzania. **Type level**: TDP15/7-1, 10cm; UC6b, Early Turonian. **Occurrence**: TDP15, Early Turonian (UC6b); ?TDP5, Late Campanian (UC15e^{TP}).

Calculites obscurus (Deflandre, 1959) Prins & Sissingh *in* Sissingh, 1977

Pl.9, figs 29-32

Calculites paulus sp. nov.

Pl.10, figs 18, 27. **Derivation of name**: From the Latin '*paulus*', meaning 'little', referring to the size of this species. **Diagnosis**: A very small species of *Calculites* that has an elongate, narrow central perforation. At 0˚ in XPL, two extinction lines are aligned with the polarising directions, but the short-axis line is offset. On rotation, the lines become v-shaped and occupy the ends of the lith. **Differentiation**: The very small size and elongate, narrow central perforation distinguish this species from other species of *Calculites*. **Holotype**: Pl.10, figs 18, 27. **Holotype dimensions**: L = 2.64μm, W = 1.76μm. **Type locality**: TDP9, Nangurukuru junction, SW of Singino Hill, near Kilwa Kivinje, coastal Tanzania. **Type level**: TDP9/9-2, 39cm; UC17, Early Maastrichtian. **Occurrence**: TDP9, Early Maastrichtian (UC17).

Calculites percernis Jeremiah, 1996

Pl.10, figs 46-53

Calculites proscissus sp. nov.

Pl.10, figs 43, 44; Pl.10, figs 45, 54? **Derivation of name**: From the Latin '*proscissus*', meaning 'slit', referring to the central slit-like perforation typical of this species. **Diagnosis**: A small species of *Calculites* with an elongated, very narrow central perforation (or slit). At 0˚ in XPL, the extinction lines are aligned with the polarising directions. On rotation, the extinction lines join with the central slit to form an H-shape. **Differentiation**: The central slit distinguishes this from other *Calculites* species. **Holotype**: Pl.10, figs 43, 44. **Holotype dimensions**: L = 4.18μm, W = 2.86μm. **Type locality**: TDP15, Maghreda Swamp, NW of Kilwa Kivinje, coastal Tanzania. **Type level**: TDP15/25-1, 10cm; UC6b, Early Turonian. **Occurrence**: TDP15, Early Turonian (UC6b).

Calculites rosalyniae sp. nov.

Pl.13, figs 30, 31. **Derivation of name**: After Ms. Rosalyn Pearson, member of the TDP support team. **Diagnosis**: A small species of *Calculites* comprising four blocks divided by wavy sutures that form an H-shape. Each plate has a perforation towards the centre. The blocks appear to go into extinction separately. The lith appears similar at all angles of rotation in XPL. **Differentiation**: The new species is superficially similar to *C. obscurus*, but bears a perforation in each quadrant, and the extinction pattern is dissimilar. **Holotype**: Pl.13, figs 30, 31. **Holotype dimensions**: L = 4.40μm, W = 3.08μm. **Type locality**: TDP5, Machole, south of Kitulo Hill, near Lindi, coastal Tanzania. **Type level**: TDP5/5-1, 66-67cm; UC15e^{TP}-16, Late Campanian-Early Maastrichtian. **Occurrence**: TDP5, Late Campanian-Early Maastrichtian (UC15e^{TP}-16).

Calculites turonicus sp. nov.

Pl.10, figs 33-36. **Derivation of name**: After the Turonian, from which it is described. **Diagnosis**: A small species of *Calculites* which bears a very small central perforation and in which the central part is slightly darker in XPL than the outer part (there is no discernable rim). At 0˚ in XPL, the extinction lines are aligned with the polarising directions and bifurcate (indicating a rim block in extinction?) at each end of the lith. The central perforation is not obvious in this direction, where the extinction lines meet. On rotation, the extinction lines form v-shapes that do not join in the centre of the lith. The small perforation is then clear. **Differentiation**: The new species bears a resemblance to *C. percernis* (see Pl.10, figs 46-53), but the latter is generally smaller and the central area is not slightly darker than the rim. The extinction lines of *C. percernis* are also different, with the short axis line being kinked, so as to appear offset, rather than straight, as in the new species. **Holotype**: Pl.10, figs 33, 34. **Holotype dimensions**: L = 3.96μm, W = 2.86μm. **Paratype**: Pl.10, figs 35, 36. **Type locality**: TDP15, Maghreda Swamp, NW of Kilwa Kivinje, coastal Tanzania. **Type level**: TDP15/25-1, 10cm; UC6b, Early Turonian. **Occurrence**: TDP15, Early Turonian (UC6b).

Duocameratus gen. nov.

Type species: *Duocameratus leariae* gen. et sp. nov. **Derivation of name**: From the Latin '*duo*', meaning two, '*camera*', meaning 'vaulted chamber' and '*atus*', mean-

ing 'like', referring to the double-chambered, vaulted nature of the holococcolith in side view. **Diagnosis**: In side view, delicate-looking, cavate, polygonal holococcoliths with thin rims and proximal plates. A central septum divides the cavity into two. Where the septum meets the external structure, the joints are thickened and appear bright in most orientations.

Duocameratus leariae gen et sp. nov.
Pl.13, figs 51-59. **Derivation of name**: After Dr. Carrie Lear, Cenozoic palaeoceanographer on the TDP team. **Diagnosis**: A small species of *Duocameratus* in which the distal(?) end of the septum is brightest and thickest, forming a subtriangular apex that distinguishes this species. **Holotype**: Pl.13, figs 51-53. **Holotype dimensions**: H = 4.40μm, W = 3.52μm. **Paratype**: Pl.13, figs 54-57. **Type locality**: Nguru-mahamba, SW of Lindi town, coastal Tanzania. **Type level**: Nguru-99-1; UC3a-b, Middle-Late Cenomanian. **Occurrence**: Nguru-mahamba, Middle-Late Cenomanian (UC3a-b).

Duocameratus sianiae gen et sp. nov.
Pl.13, figs 60-65. **Derivation of name**: After Dr. Siani Pearson (Cardiff), member of the TDP support team. **Diagnosis**: A small species of *Duocameratus* that is irregularly pentagonal and house-shaped, with an almost flat base/proximal plate and a pointed 'roof'. Bright points mark where the septum dividing the cavity joins the rim. These bright points are situated in the middle of the base and the peak of the 'roof'. **Holotype**: Pl.13, figs 60, 61. **Holotype dimensions**: H = 3.08μm, W = 3.52μm. **Paratypes**: Pl.13, figs 62-65. **Type locality**: TDP15, Maghreda Swamp, NW of Kilwa Kivinje, coastal Tanzania. **Type level**: TDP15/5-1, 10cm; UC6b, Early Turonian. **Occurrence**: TDP15, Early Turonian (UC6b).

Holococcolith indeterminate 1 side view
Pl.11, figs 47-49
Holococcolith indeterminate 2 side view
Pl.11, figs 50-52
Holococcolith indeterminate 3 side view
Pl.13, figs 48-50
Holococcolith? indeterminate side view
Pl.13, figs 66-68

Genus *Lucianorhabdus* Deflandre, 1959
Remarks: New species that have significant spines that are most frequently observed in side view are here placed in *Lucianorhabdus*.

Lucianorhabdus? *boudagherfadeliae* sp. nov.
Pl.11, figs 43-46. **Derivation of name**: After Dr. Marcelle Boudagher-Fadel (UCL), planktonic and larger benthic foraminifera expert. **Diagnosis**: A small species of *Lucianorhabdus*? with a relatively short, hollow spine that terminates bluntly and at an angle. The angled termination is visible when the lith is rotated, in XPL. The small base-plate rim is relatively thick and the plate has a thin proximal cycle. The base-plate is perforate and contains a structure that is not discernable. **Differentiation**: Other lucianorhabdids do not possess the central structure that is hinted at as lying beneath the spine-base. The short spine and its angled termination is distinctive. **Holotype**: Pl.11, figs 43-46. **Holotype dimensions**: H = 4.40μm, W = 4.40μm. **Paratype**: Pl.11, figs 43, 44. **Type locality**: Nguru-mahamba, SW of Lindi town, coastal Tanzania. **Type level**: Nguru-99-1; UC3a-b, Middle-Late Cenomanian. **Occurrence**: Nguru-mahamba, Middle-Late Cenomanian (UC3a-b).

Lucianorhabdus compactus (Verbeek, 1976) comb. nov.
Basionym: *Isocrystallithus compactus* Verbeek, 1976, p.78, pl.2, figs 1-4 (3 = holotype). Verbeek, J.W. 1976. Upper Cretaceous calcareous nannoplankton from Ballon and Théligny in the type area of the Cenomanian stage (Sarthe, France). *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen*, **B79**: 69-82.

Lucianorhabdus maleformis Reinhardt, 1966
Pl.11, figs 17, 18

Lucianorhabdus? *tabernus* sp. nov.
Pl.12, figs 45-47. **Derivation of name**: From the Latin '*taberna*', meaning 'hut', referring to the simple hut-shaped outline of the species. **Diagnosis**: A cavate species of *Lucianorhabdus*? with a medium-sized base-plate and short, conical spine. In XPL at 0˚, the lith is of low birefringence, and the thin base-plate is almost invisible. On rotation, the spine becomes bright and the base-plate just visible. **Differentiation**: Shorter than other lucianorhabdids, with a wider spine and equilateral-triangular outline. The new species bears some resemblance to the Paleocene *Semihololithus tentorium* Bown, 2005 (pl.31, figs 11-20), however, the new species has a much thinner, simpler base-plate and goes completely into extinction at 0˚, unlike *S. tentorium*. **Holotype**: Pl.12, figs 45-47. **Holotype dimensions**: H = 5.28μm, W = 5.72μm. **Type locality**: Nguru-mahamba, SW of Lindi town, coastal Tanzania. **Type level**: Nguru-99-5; UC3a-b, Middle-Late Cenomanian. **Occurrence**: Nguru-mahamba, Middle-Late Cenomanian (UC3a-b).

Lucianorhabdus turris sp. nov.
Pl.11, figs 1-6. **Derivation of name**: From the Latin '*turris*', meaning 'tower', referring to the solid base and long, tapering spine of the species. **Diagnosis**: A species of *Lucianorhabdus* with a relatively long, hollow spine, that tapers to a point. The spine may be straight or may lean to one side. In XPL, the medium-sized base-plate has a narrow rim and appears as a solid block in the middle when rotated, whilst at 0˚, there appears to be a central perforation in the plate, as it becomes optically discontinuous. **Differentiation**: The new species differs from other lucianorhabdids in having a pointed spine, that may or

may not lean, without a terminal plug or plate. It is distinguished from *Acuturris scotus* by its larger size and thick, solid base-plate. **Holotype**: Pl.11, figs 1-4. **Holotype dimensions**: H = 8.36μm, W = 5.72μm. **Paratype**: Pl.11, figs 5, 6. **Type locality**: Nguru-mahamba, SW of Lindi town, coastal Tanzania. **Type level**: Nguru-99-5; UC3a-b, Middle-Late Cenomanian. **Occurrence**: Nguru-mahamba, Middle-Late Cenomanian (UC3a-b).

Metadoga ampulla Lees & Varol sp. nov.

Pl.11, figs 25-28. **Derivation of name**: From the Latin '*ampulla*', meaning 'flask', referring to the similarity of the coccolith in side view to a standard laboratory flask. **Diagnosis**: A small species of *Metadoga* that has a simple flask-shaped outline in side-view. The holococcolith is cavate and the upper half of the lith goes into extinction in XPL at 0˚. **Differentiation**: The new species differs from other species of *Metadoga* in having the distinctive standard flask outline and in lacking a mid-lith collar. **Holotype**: Pl.11, figs 25, 26. **Holotype dimensions**: H = 4.40μm, W = 4.18μm. **Type locality**: TDP5, Machole, south of Kitulo Hill, near Lindi, coastal Tanzania. **Type level**: TDP5/9-1, 48-49cm; UC15e^{TP}, Late Campanian. **Occurrence**: TDP5, Late Campanian (UC15e^{TP}); Nguru-mahamba, Middle-Late Cenomanian (UC3a-b); Arabian Peninsula, Early Campanian (Varol, pers. obs., 2007).

Munarinus keadyi Risatti, 1973

Pl.13, figs 14, 15, 18-25; Pl.13, figs 16, 17 side view?

Munarinus lesliae Risatti, 1973

Pl.13, figs 10-13

Munarinus mkeremei sp. nov.

Pl.13, figs 8, 9. **Derivation of name**: After Mr. Michael Mkereme (TPDC, Dar-es-Salaam), for expert technical assistance during TDP drilling. **Diagnosis**: A small species of *Munarinus* possessing a relatively wide central perforation that is spanned by a disjunct bar that joins the rim with straight edges and spans the short axis. At 0˚ in XPL, the extinction lines are aligned with the polarising directions, and on rotation these form v-shapes at the ends of the lith. The bar is not visible at 0˚, becoming bright on rotation. **Differentiation**: *M. keadyi* is smaller, with a narrower central perforation and with a short-axis bar that is subrhombic. The pointed ends of that bar slot into the rim. **Holotype**: Pl.13, figs 8, 9. **Holotype dimensions**: L = 4.84μm, W = 3.52μm. **Type locality**: TDP5, Machole, south of Kitulo Hill, near Lindi, coastal Tanzania. **Type level**: TDP5/9-1, 48-49cm; UC15e^{TP}, Late Campanian. **Occurrence**: TDP5, Late Campanian (UC15e^{TP}).

Nicholasia gen. nov.

Type species: *Nicholasia baileyi* gen. et sp. nov. **Derivation of name**: After Dr. Chris Nicholas (Trinity College, Dublin University), sedimentologist, structural geologist and TDP co-chief. **Diagnosis**: Delicate-looking holococcoliths that, in side view, have the outline of a hollow isosceles triangle. The base-plate is virtually invisible. Where the spine joins the base-plate, there are two bright spots.

Nicholasia baileyi gen et sp. nov.

Pl.13, figs 69-73. **Derivation of name**: After Dr. Trevor Bailey (Natural History Museum of Wales, Cardiff), Cenozoic palaeoceanographer on the TDP team. **Diagnosis**: As for the genus. This species is very small. The 'spine' appears to terminate bluntly and is generally dark. **Holotype**: Pl.13, fig.71. **Holotype dimensions**: H = 2.20μm, W = 1.76μm. **Paratypes**: Pl.13, figs 69, 70, 72, 73. **Type locality**: Nguru-mahamba, SW of Lindi town, coastal Tanzania. **Type level**: Nguru-99-10; UC15e^{TP}, Late Campanian. **Occurrence**: Nguru-mahamba, Late Campanian (UC15e^{TP}); TDP15, Early Turonian (UC6b); Matandu Bridge (Kilwa), Middle-Late Turonian (UC9a).

Genus *Orastrum* Wind & Wise in Wise & Wind, 1977

Remarks: New species with bright rims and dark central plates have here been placed in *Orastrum*.

Orastrum perspicuum Varol *in* Al-Rifaiy *et al*., 1990

Pl.10, figs 55-58 – nonperforate forms; Pl.10, figs 59, 60 - monoperforate form; Pl.10, figs 61, 62 – monoperforate form?; Pl.10, figs 63-65, 72 – biperforate forms

Orastrum robinsonii sp. nov.

Pl.10, figs 1-9. **Derivation of name**: After Dr. Stuart Robinson (UCL), Cretaceous palaeoenvironmental specialist. **Diagnosis**: A medium-sized species of *Orastrum* that in XPL has a bright rim and dark central plate, bearing a usually barely-discernable x-shaped structure. At 0˚ in XPL, the extinction lines are aligned with the polarising directions, appearing darker on the rim and barely discernable on the plate. On rotation, these become v-shaped on the rim, occupying the ends of the lith, but bend where they move onto the plate, where again they are barely discernable. In PC, the plate appears to be multiperforate (Pl.10, fig.3). **Differentiation**: The size and relatively wide rim and central area are distinctive. The x-shaped central structure distinguishes it from other species of the genus. **Holotype**: Pl.10, figs 4, 5. **Holotype dimensions**: L = 6.16μm, 4.84μm. **Paratypes**: Pl.10, figs 1-3, 6, 7. **Type locality**: Nguru-mahamba, SW of Lindi town, coastal Tanzania. **Type level**: Nguru-99-1; UC3a-b, Middle-Late Cenomanian. **Occurrence**: Nguru-mahamba, Early-Late Cenomanian (UC1a-3b).

Ottavianus terrazetus Risatti, 1973

Pl.13, figs 1-7

Owenia dispar? (Varol *in* Al-Rifaiy *et al*., 1990) Bown *in* Kennedy *et al*., 2000

Pl.12, figs 14-17

Owenia hillii Crux, 1991

Pl.12, figs 1-8, 10-13; Pl.12, figs 19-36? side views

Owenia cf. *O. hillii*? Crux, 1991 side view
Pl.12, figs 48, 49

Remarks: Unlike *O. hillii* side view, *O.* cf. *O. hillii*? side view has a much shorter spine that either flares at the end, or is capped by a plug that overhangs the top of the spine.

Pearsonia gen. nov.

Type species: *Pearsonia ecclesiata* gen. et sp. nov. **Derivation of name**: After Prof. Paul Pearson (Cardiff University), TDP co-chief and Cenozoic micropalaeontologist on the TDP team. **Diagnosis**: Cavate holococcoliths with thin rims and small spines, which act as a single crystal in XPL.

Pearsonia ecclesiata gen et sp. nov.

Pl.11, figs 29-42. **Derivation of name**: From the Latin '*ecclesia*', meaning 'church', and '*atus*', meaning 'likeness to', referring to its resemblance to a church with a spire in side view. **Diagnosis**: A very small species of *Pearsonia* with a church-plus-spire-shaped outline in side view. At 0˚, the liths are dark in XPL, becoming bright when rotated, with the base-plate and spine behaving as a single crystal. **Holotype**: Pl.11, figs 29-32. **Holotype dimensions**: H = 3.08μm, L = 2.64μm. **Paratype**: Pl.11, figs 34, 35. **Type locality**: Matandu Bridge, west of Kilwa Kivinje, coastal Tanzania. **Type level**: PP04-K1; UC9a, Middle-Late Turonian. **Occurrence**: Matandu Bridge (Kilwa), Middle-Late Turonian (UC9a); TDP15, Early Turonian (UC6b).

Petrobrasiella venata Troelsen & Quadros, 1971
Pl.9, figs 25-28
Russellia bukryi Risatti, 1973
Pl.10, figs 28-32
Russellia laswellii Risatti, 1973
Pl.13, figs 26-29

Tanzanella gen. nov.

Type species: *Tanzanella bownii* gen. et sp. nov. **Derivation of name**: After Tanzania, where the genus is described from. **Diagnosis**: Holococcoliths with a complex structure, as seen in side view. In XPL, rotated to 45˚, the rim and proximal plate are thin, birefringent and clearly visible. Encased within these is a blocky structure, from the distal surface of which emanate four 'prongs'.

Tanzanella bownii gen et sp. nov.

Pl.12, figs 37-44. **Derivation of name**: After Dr. Paul Bown (UCL) in recognition of his sterling Cenozoic calcareous nannofossil taxonomic work on the TDP material. **Diagnosis**: A medium-sized species of *Tanzanella*. **Holotype**: Pl.12, figs 43, 44. **Holotype dimensions**: L = 5.72μm, H = 2.64μm. **Paratypes**: Pl.12, figs 37-42. **Type locality**: Nguru-mahamba, SW of Lindi town, coastal Tanzania. **Type level**: Nguru-99-1; UC3a-b, Middle-Late Cenomanian. **Occurrence**: Nguru-mahamba, Middle-Late Cenomanian (UC3a-b).

Thecatus gen. nov.

Type species: *Thecatus varolii* gen. et sp. nov. **Derivation of name**: From the Latin '*theca*', meaning 'box', and '*atus*' meaning 'like', referring to the boxy, cavate shape of this holococcolith in size view. **Diagnosis**: A cavate, box-shaped holococcolith. At 0˚, in side view in XPL, the rim is relatively tall and the proximal plate thin. A bipartite structure/short spine sits atop the rim, completing the box shape. The spine is not visible on rotation.

Thecatus varolii gen. et sp. nov.

Pl.13, figs 46, 47. **Derivation of name**: After Dr. Osman Varol (Varol Research, Llandudno), seasoned calcareous nannofossil biostratigrapher and taxonomist. **Diagnosis**: As for the genus. This species is small. **Holotype**: Pl.13, figs 46, 47. **Holotype dimensions**: H = 3.08μm, W = 3.52μm. **Type locality**: TDP15, Maghreda Swamp, NW of Kilwa Kivinje, coastal Tanzania. **Type level**: TDP15/29-1, 10cm; UC6b, Early Turonian. **Occurrence**: TDP15, Early Turonian (UC6b).

5.3 Nannoliths

Family **BRAARUDOSPHAERACEAE** Deflandre, 1947

Braarudosphaera bigelowii (Gran & Braarud, 1935) Deflandre, 1947
Pl.2, fig.28
Goniolithus fluckigeri Deflandre, 1957
Pl.2, figs 29, 30

Micrantholithus? *nicholasii* sp. nov.

Pl.2, figs 23-27. **Derivation of name**: After Dr. Chris Nicholas (Trinity, Dublin University), co-chief, general geologist and lithostratigrapher on the TDP team. **Diagnosis**: Possible segments of pentaliths of *Micrantholithus*, each segment having a median depression, bordered by ridges, occupying the central third of the segment. The expression of this depression at the outer edge of the segment creates a very shallow 'w'-shape. **Differentiation**: This new species is composed of distinctively-shaped segments with a ridge-bordered central depression and crenulated outer edge that has not been seen in any other species. **Remarks**: Although no entire pentaliths have yet been found, the segment angles suggest a pentalith structure, and so this new species is questionably placed into *Micrantholithus*. **Holotype**: Pl.2, fig.27. **Holotype dimensions**: Central lith point to outside edge = 4.40μm, point to point across outside edge = 3.96μm. **Paratype**: Pl.2, fig.25. **Type locality**: TDP15, Maghreda Swamp, NW of Kilwa Kivinje, coastal Tanzania. **Type level**: TDP15/15-1, 10cm; UC6b, Early Turonian. **Occurrence**: TDP15, Early Turonian (UC6b).

Family **MICRORHABDULACEAE** Deflandre, 1963

Lithraphidites acutus Verbeek & Manivit *in* Manivit *et al*., 1977
Pl.2, figs 21, 22
Lithraphidites carniolensis Deflandre, 1963
Pl.2, figs 1-3; Pl.2, figs 4-7 – thick form
Rhabdolithus aquitanicus Manivit, 1971
Pl.2, figs 8-20

Family **INCERTAE SEDIS**

'*Anacanthoica mitra*' Varol, 1989
Pl.12, figs 9, 18
Remarks: As Bown (2005, p.38) remarked, these forms may be fragments of a calcisphere test.

Ceratolithina capitanea (Burnett, 1997a) stat. nov.
Pl.2, figs 31-34
1997a *Ceratolithina cruxii* Perch-Nielsen, 1988 subsp. *capitanea* Burnett: p.59, pl.1, fig.4 (holotype).
Basionym: *Ceratolithina cruxii* Perch-Nielsen, 1988 subsp. *capitanea* Burnett, 1997a. Burnett, J.A. 1997a. 'Middle' Cretaceous morphological diversity within the genus *Ceratolithina* Martini, 1967. *Journal of Nannoplankton Research*, **19**(1): 57-65. **Remarks**: This species is clearly distinct from *C. cruxii*, having a much longer horn that is concave along the edges, rather than straight or convex, as in *C. cruxii*. Consequently, *capitanea* is herein elevated to species status.

Ceratolithoides ohalloraniae sp. nov.
Pl.2, figs 35-40. **Derivation of name**: After Ms. Aoife O'Halloran (Trinity, Dublin University), sedimentologist/clay mineralogist and geochemist on the TDP team. **Diagnosis**: A small species of *Ceratolithoides* with an almost equilateral-triangular outline and a shallow inter-horn angle. The cone extends halfway down the length of the nannolith and is bright at 45°. **Differentiation**: This new species is smaller than the majority of *Ceratolithoides* species. Its almost equilateral-triangular outline distinguishes it from all other species. **Holotype**: Pl.2, figs 39, 40. **Holotype dimensions**: Cone-tip to inter-horn angle = 2.2μm, side and horn-point to horn-point = 3.08μm. **Paratype**: Pl.2, figs 35, 36. **Type locality**: TDP9, Nangurukuru junction, SW of Singino Hill, near Kilwa Kivinje, coastal Tanzania. **Type level**: TDP9/9-2, 39cm; UC17, Early Maastrichtian. **Occurrence**: TDP9 and Lindi area, Early Maastrichtian (UC17).

Ceratolithoides prominens? Burnett, 1997b
Pl.3, figs 1-4
Remarks: *C. prominens* is distinguished by its prominent cone, isosceles-triangular shape, short internal cone length, and obtuse inter-horn angle. The specimens illustrated here are similar but with less prominent cones, possibly because they are etched specimens.

Ceratolithoides dongenii sp. nov.
Pl.3, figs 5-10. **Derivation of name**: After Dr. Bart van Dongen (Stockholm University), organic geochemist on the TDP team. **Diagnosis**: A medium-sized species of *Ceratolithoides* with an almost equilateral-triangular outline, a prominent cone, almost entirely enclosed by the horns, occupying half the length of the ceratolith, and an inter-horn angle approaching 90°. **Differentiation**: This new species has a shorter, broader cone (*e.g*. Pl.3, fig.5) and a more equilateral-triangular shape than *C. aculeus*. It somewhat resembles *C. prominens*, but the cone is entirely enclosed by the horns, the outline is triangular, rather than subtriangular, the inter-horn angle is more acute, and the cone is less prominent in the new species. The cone in *C. sagittatus* Lees & Bown, 2005 is not enclosed by the horns, and the cone divides into two elements, which distinguishes this from the new species. **Holotype**: Pl.3, figs 7, 8. **Holotype dimensions**: Cone-tip to inter-horn angle = 3.08μm, side = 5.06μm, horn-point to horn-point = 4.40μm. **Paratype**: Pl.3, figs 9, 10. **Type locality**: TDP5, Machole, south of Kitulo Hill, near Lindi, coastal Tanzania. **Type level**: TDP5/9-3, 55-57cm; UC15e^{TP}, Late Campanian. **Occurrence**: TDP5, Late Campanian (UC15e^{TP}); TDP9, Early Maastrichtian (UC17); Kitulo Hill (Lindi), Early Maastrichtian (UC18).

Singanoa gen. nov.
Type species: *Singanoa scapus* gen. et sp. nov. **Derivation of name**: After Dr. Joyce Singano (TPDC, Dar-es-Salaam), micropalaeontologist, general facilitator and 'mother' of the TDP team. **Diagnosis**: Nannolith of various lengths, comprising four narrow blocks, arranged end-to-end in two pairs. Diagonal blocks go into extinction together, and a dark extinction area in the centre gives the appearance of a constriction in the nannolith (like a scroll tied at the middle).

Singanoa scapus gen. et sp. nov.
Pl.4, figs 7-18. **Derivation of name**: From the Latin '*scapus*', meaning 'a scroll', referring to the scroll-like appearance of the nannolith. **Diagnosis**: As for the genus. May be medium-sized to very small. **Differentiation**: The short form of this species bears a slight resemblance to the birefringent blades of *Lithraphidites*? *charactozorro* Self-Trail, 1999, as seen in XPL. *S. scapus* is distinct, however, in not having the tapering ends possessed by that species, and in being much smaller. **Holotype**: Pl.4, figs 11, 12. **Holotype dimensions**: L = 6.16μm, W = 0.88μm. **Paratype**: Pl.4, figs 7-10, 13-18. **Type locality**: TDP9, Nangurukuru junction, SW of Singino Hill, near Kilwa Kivinje, coastal Tanzania. **Type level**: TDP9/15-1, 21cm; UC17, Early Maastrichtian. **Occurrence**: TDP9, Late Campanian-Early Maastrichtian (UC15e^{TP}-UC17).

Acknowledgements

The author is very grateful to the NERC for funding (Grant NE/C510508/1), and also to the TDP team, especially Dr. Joyce

Singano (TPDC), Prof. Paul Pearson (Cardiff University) and Dr. Chris Nicholas (Trinity College, Dublin University), for being a joy to work with. Prof. Paul Pearson is especially thanked for inviting me to be involved. As ever, Dr. Paul Bown (UCL) was indispensable, especially as the manuscript neared completion. Finally, many, many thanks to the reviewers: Drs Osman Varol (Varol Research), Jean Self-Trail (USGS) and Paul Bown; you all accomplished a heroic feat in reviewing this much taxonomy so quickly for me, and I certainly owe you.

References

Bown, P.R. (Ed.) 1998. *Calcareous Nannofossil Biostratigraphy*. British Micropalaeontological Society Publications Series. Chapman & Hall/Kluwer Academic Publishers, London: 315pp.

Bown, P.R. 2005. Palaeogene calcareous nannofossils from the Kilwa and Lindi areas of coastal Tanzania (Tanzania Drilling Project 2003-4). *Journal of Nannoplankton Research*, **27**: 21-95.

Bown, P.R. & Cooper, M.K.E. 1998. Jurassic. *In*: P.R. Bown (Ed.). *Calcareous Nannofossil Biostratigraphy*. British Micropalaeontological Society Publications Series. Chapman & Hall/Kluwer Academic Publishers, London: 34-85.

Bown, P.R. & Dunkley Jones, T. 2006. New Palaeogene calcareous nannofossil taxa from coastal Tanzania: Tanzania Drilling Project Sites 11 to 14. *Journal of Nannoplankton Research*, **28**: 17-34.

Bown, P.R., Dunkley Jones, T. & Young, J.R. 2007. *Umbilicosphaera jordanii* Bown, 2005 from the Paleogene of Tanzania: confirmation of generic assignment and a Paleocene origination for the Family Calcidiscaceae. *Journal of Nannoplankton Research*, **29**: 25-30.

Bown, P.R., Lees, J.A. & Young, J.R. 2004. Calcareous nannoplankton evolution and diversity through time. *In*: H.R. Thierstein & J.R. Young (Eds). *Coccolithophores - From Molecular Processes to Global Impact*. Springer, Berlin: 481-508.

Bown, P.R. & Young, J.R. 1998. Techniques. *In*: P.R. Bown (Ed.). *Calcareous Nannofossil Biostratigraphy*. British Micropalaeontological Society Publications Series. Chapman & Hall/Kluwer Academic Publishers, London: 16-28.

Bralower, T.J. & Bergen, J.A. 1998. Cenomanian-Santonian calcareous nannofossil biostratigraphy of a transect of cores drilled across the Western Interior Seaway. *Stratigraphy and Paleoenvironments of the Cretaceous Western Interior Seaway, USA. SEPM Concepts in Sedimentology and Paleontology*, **6**: 59-77.

Burnett, J.A. (with contributions from Gallagher, L.T. & Hampton, M.J.) 1998a. Upper Cretaceous. *In*: P.R. Bown (Ed.). *Calcareous Nannofossil Biostratigraphy*. British Micropalaeontological Society Publications Series. Chapman & Hall/Kluwer Academic Publishers, London: 132-199.

van Dongen, B.E., Talbot, H.M., Schouten, S., Pearson, P.N. & Pancost, R.D. 2006. Well preserved Palaeogene and Cretaceous biomarkers from the Kilwa area, Tanzania. *Organic Geochemistry*, **37**: 539-557.

Kennedy, W.J., Gale, A.S., Bown, P.R., Caron, M., Davey, R.J., Gröcke, D. & Wray, D.S. 2000. Integrated stratigraphy across the Aptian-Albian boundary in the Marnes Bleues, at the Col de Pré-Guittard, Arnayon (Drôme), and at Tartonne (Alpes-de-Haute-Provence), France: a candidate Global Boundary Stratotype Section and Boundary Point for the base of the Albian Stage. *Cretaceous Research*, **21**: 591-720.

Lees, J.A. 2002. Calcareous nannofossil biogeography illustrates palaeoclimate change in the Late Cretaceous Indian Ocean. *Cretaceous Research*, **23**: 537-634.

Lees, J.A. & Bown, P.R. 2005. Upper Cretaceous calcareous nannofossil biostratigraphy, ODP Leg 198 (Shatsky Rise, northwest Pacific Ocean). *In*: T.J. Bralower, I. Premoli Silva & M.J. Malone (Eds). *Proc. ODP, Sci. Results*, **198**: 1-60 (online). http://www-odp.tamu.edu/publications/198_SR/VOLUME/CHAPTERS/114.PDF

Nicholas, C.J., Pearson, P.N., Bown, P.R., Dunkley Jones, T., Huber, B.T., Karega, A., Lees, J.A., McMillan, I.K., O'Halloran, A., Singano, J.M. & Wade, B.S. 2006. Stratigraphy and sedimentology of the Upper Cretaceous to Paleogene Kilwa Group, southern coastal Tanzania. *Journal of African Earth Sciences*, **45**: 431-466.

Pearson, P.N., Ditchfield, P.W., Singano, J., Harcourt-Brown, K.G., Nicholas, C.J., Olsson, R.K., Shackleton, N.J. & Hall, M.A. 2001. Warm tropical sea surface temperatures in the Late Cretaceous and Eocene epochs. *Nature*, **414**: 470.

Pearson, P.N., Nicholas, C.J., Singano, J.M., Bown, P.R., Coxall, H.K., van Dongen, B.E., Huber, B.T., Karega, A., Lees, J.A., McLeod, K., McMillan, I.K., Pancost, R.D., Pearson, M., Msaky, E. 2006. Further Paleogene and Cretaceous sediment cores from the Kilwa area of coastal Tanzania: Tanzania Drilling Project Sites 6-10. *Journal of African Earth Sciences*, **45**: 279-317.

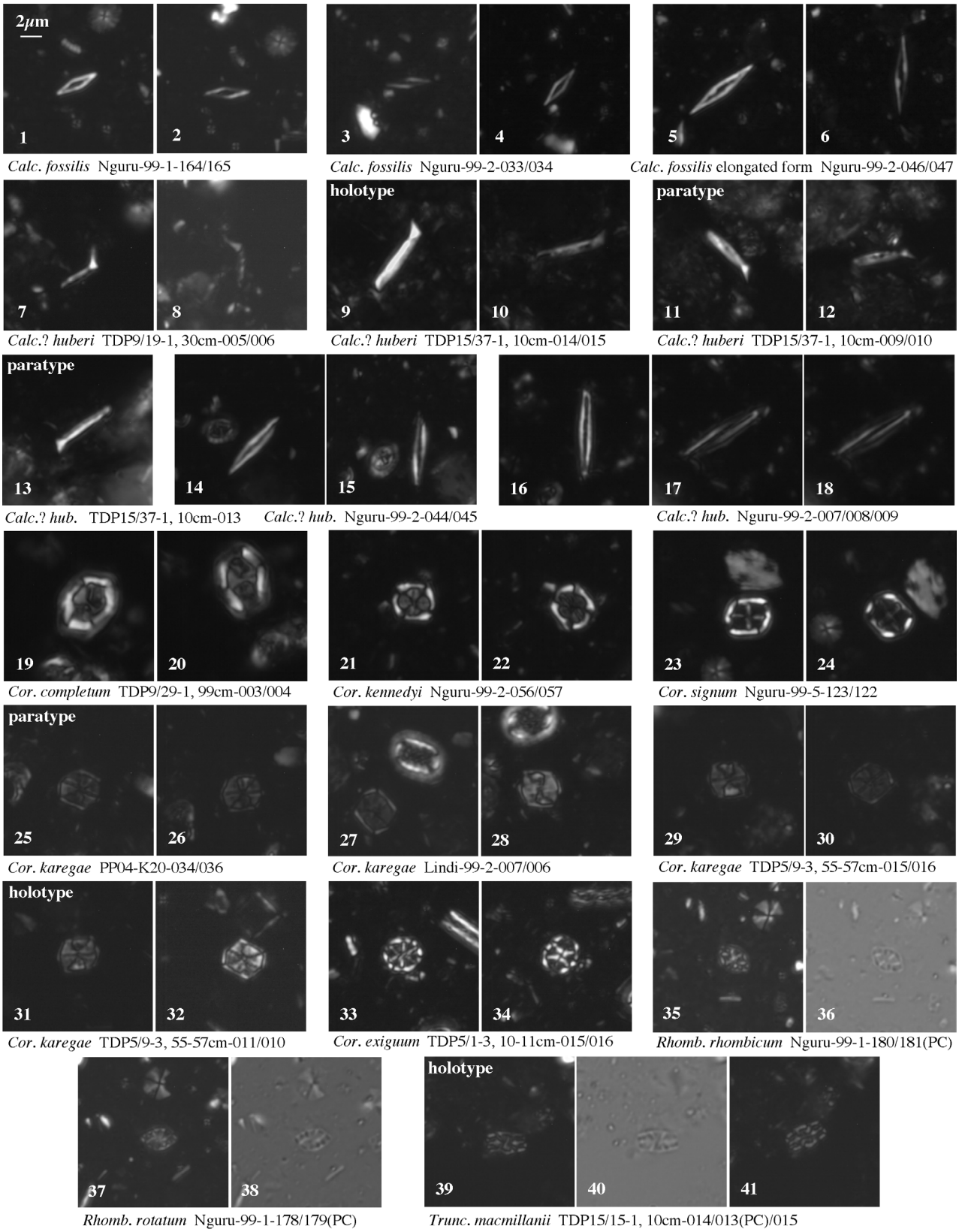
Pearson, P.N., Nicholas, C.J., Singano, J.M., Bown, P.R., Coxall, H.K., van Dongen, B.E., Huber, B.T., Karega, A., Lees, J.A., Msaky, E., Pancost, R.D., Pearson, M., Roberts, A.P. 2004. Paleogene and Cretaceous sediment cores from the Kilwa and Lindi areas of coastal Tanzania: Tanzania Drilling Project Sites 1-5. *Journal of African Earth Sciences*, **39**: 25-62.

Self-Trail, J.M. 1999. Some new and rarely documented Late Cretaceous calcareous nannofossils from subsurface sediments in South Carolina. *J. Paleont.*, **73**: 952-963.

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

Plate 1

Calciosoleniaceae, Stephanolithiaceae



Calc. fossilis Nguru-99-1-164/165

Calc. fossilis Nguru-99-2-033/034

Calc. fossilis elongated form Nguru-99-2-046/047

Calc.? huberi TDP9/19-1, 30cm-005/006

Calc.? huberi TDP15/37-1, 10cm-014/015

Calc.? huberi TDP15/37-1, 10cm-009/010

Calc.? hub. TDP15/37-1, 10cm-013

Calc.? hub. Nguru-99-2-044/045

Calc.? hub. Nguru-99-2-007/008/009

Cor. completum TDP9/29-1, 99cm-003/004

Cor. kennedyi Nguru-99-2-056/057

Cor. signum Nguru-99-5-123/122

Cor. karegae PP04-K20-034/036

Cor. karegae Lindi-99-2-007/006

Cor. karegae TDP5/9-3, 55-57cm-015/016

Cor. karegae TDP5/9-3, 55-57cm-011/010

Cor. exiguum TDP5/1-3, 10-11cm-015/016

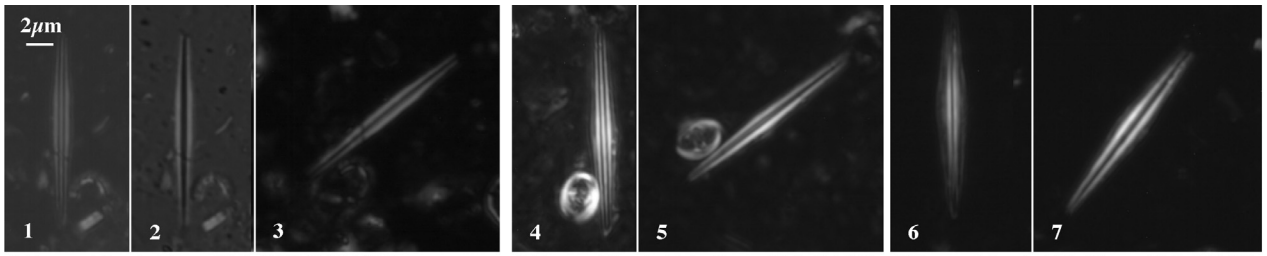
Rhomb. rhombicum Nguru-99-1-180/181(PC)

Rhomb. rotatum Nguru-99-1-178/179(PC)

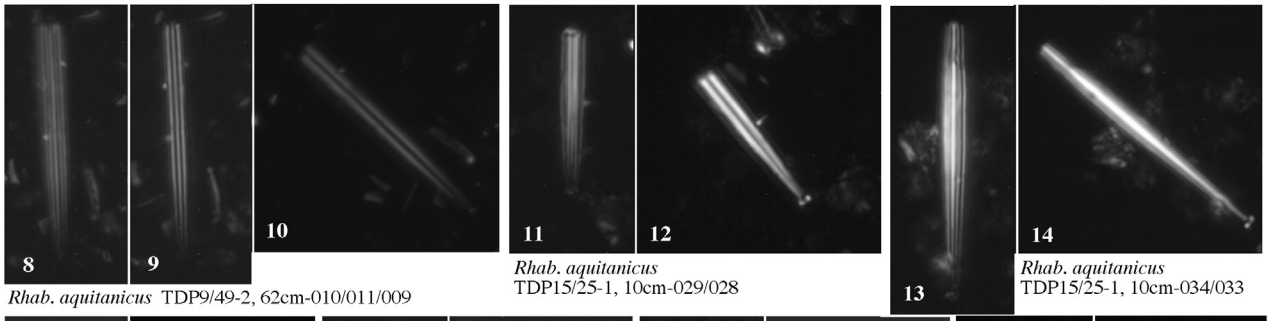
Trunc. macmillanii TDP15/15-1, 10cm-014/013(PC)/015

Plate 2

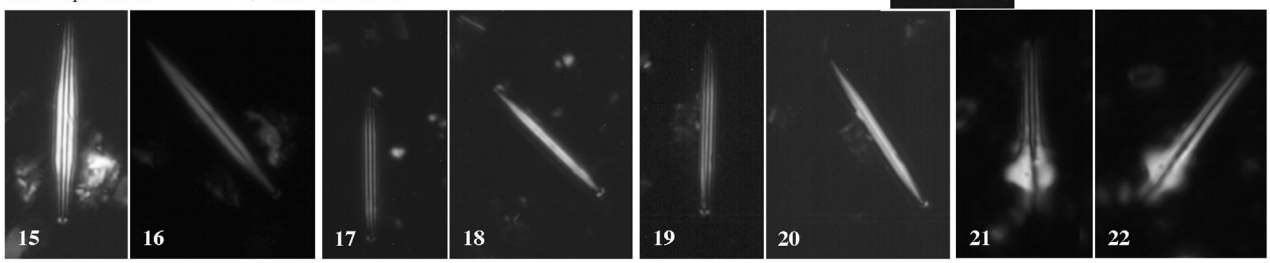
Microrhabdulaceae, Braarudosphaeraceae, incertae sedis



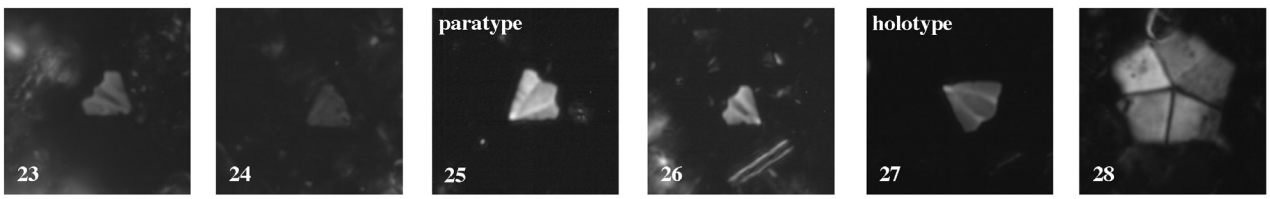
Lith. carniolensis Nguru-99-2-065/064(BF)/066 — *Lith. carniolensis* thick Nguru-99-3-004/003 — *Lith. carniolensis* thick Nguru-99-5-172/173



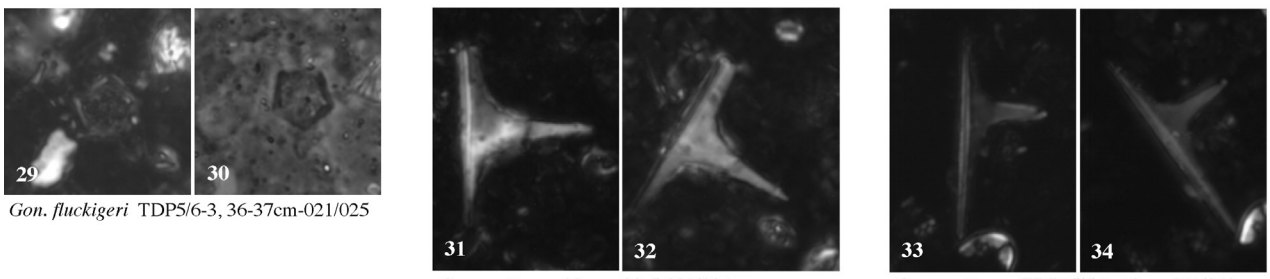
Rhab. aquitanicus TDP9/49-2, 62cm-010/011/009 — *Rhab. aquitanicus* TDP15/25-1, 10cm-029/028 — *Rhab. aquitanicus* TDP15/25-1, 10cm-034/033



Rhab. aquitanicus TDP15/15-1, 10cm-063/062 — *Rhab. aquitanicus* TDP15/15-1, 10cm-005/004 — *Rhab. aquitanicus* TDP15/15-1, 10cm-068/069 — *Lith. acutus* Nguru-99-1-096/097

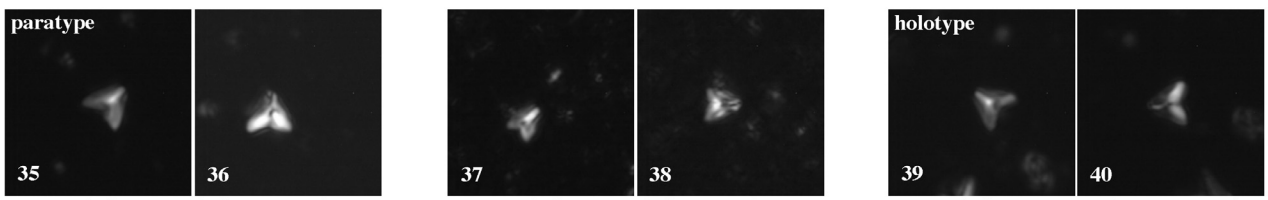


Mic.? nicholasii TDP15/15-1, 10cm-043 — *Mic.? nicholasii* TDP15/15-1, 10cm-044 — *Mic.? nicholasii* TDP15/15-1, 10cm-047 — *Mic.? nicholasii* TDP15/15-1, 10cm-072 — *Mic.? nicholasii* TDP15/15-1, 10cm-073 — *Braa. bigelowii* TDP5/8-2, 2-3cm-025



Gon. fluckigeri TDP5/6-3, 36-37cm-021/025

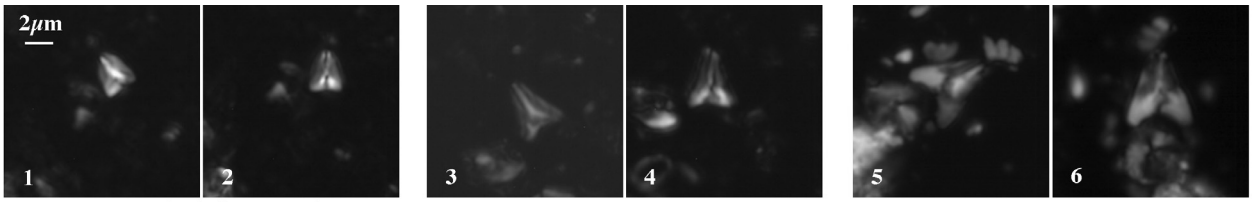
Cer. capitanea Nguru-99-5-003/004 — *Cer. capitanea* TDP15/5-1, 10cm-041/042



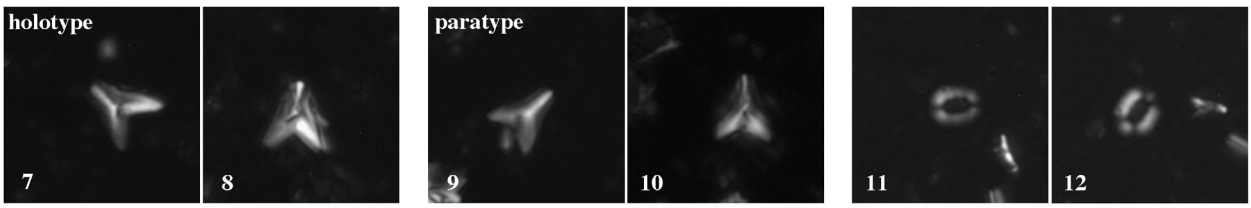
Cerato. ohalloraniae Lindi-99-9a-010/011 — *Cerato. ohalloraniae* Lindi-99-3-002/001 — *Cerato. ohalloraniae* TDP9/9-2, 39cm-030/031

Plate 3

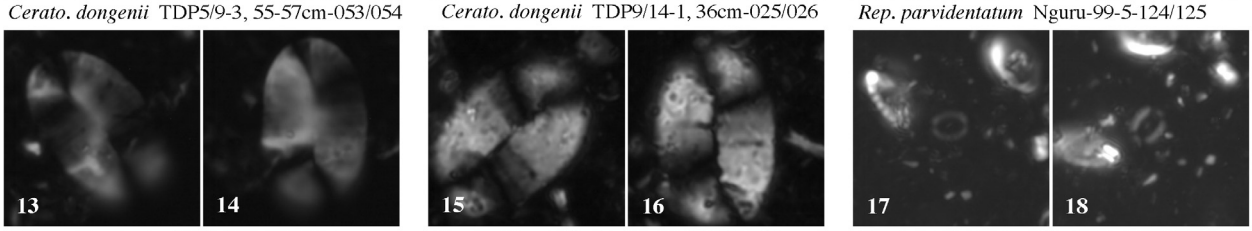
Incertae sedis, placoliths (uncertain affinity), Kamptneriaceae, Rhagodiscaceae



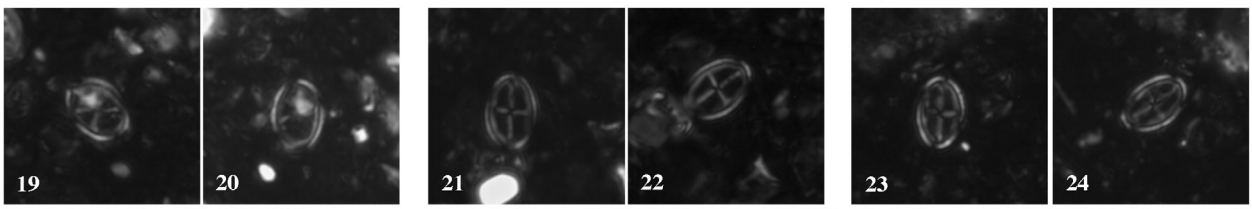
Cerato. prominens? Lindi-99-2-019/020 — *Cerato. prominens*? PP04-K20-050/051 — *Cerato. dongenii* Lindi-99-12-001/002



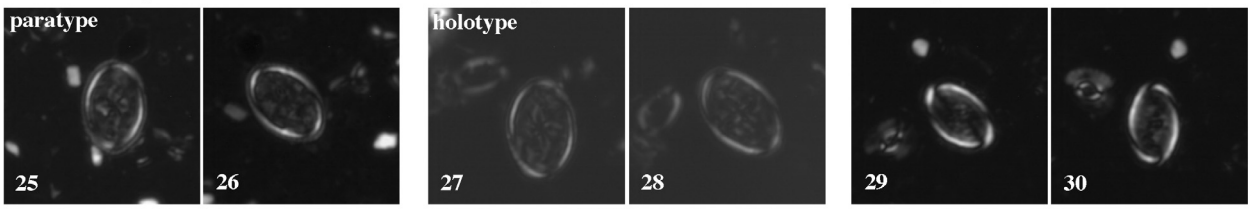
Cerato. dongenii TDP5/9-3, 55-57cm-053/054 — *Cerato. dongenii* TDP9/14-1, 36cm-025/026 — *Rep. parvidentatum* Nguru-99-5-124/125



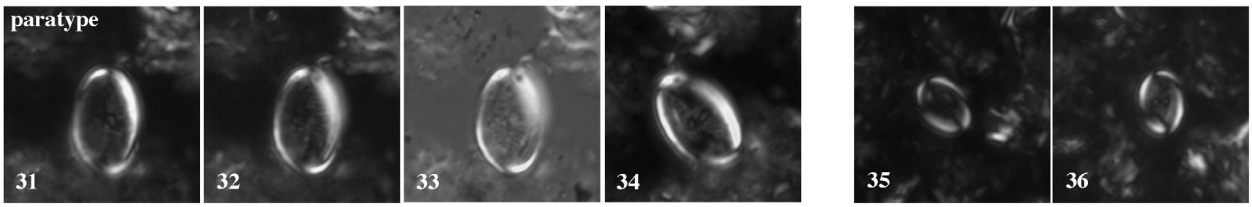
Pro. multicarinata PP04-K19-056/057 — *Pro. multicarinata* Nguru-99-10-037/038 — *Rep. parvidentatum* Nguru-99-2-060/061



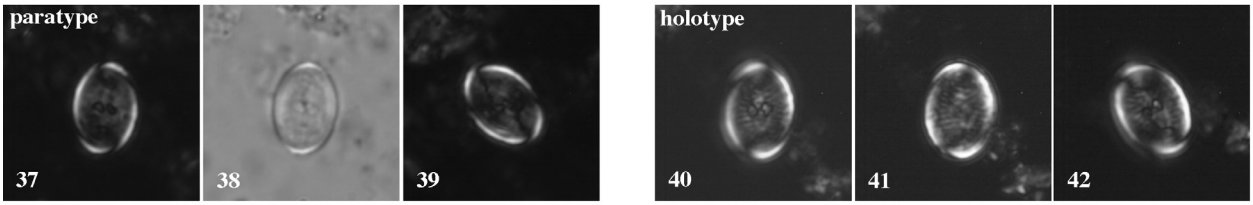
Gart. chiasta Nguru-99-5-035/036 — *Gart.* cf. *G. praeobl.* TDP15/9-1, 10cm-001/002 — *G.* cf. *G. praeobl.* TDP15/15-1, 10cm-112/113



Perc.? *pearsonii* Nguru-99-9-069/070 — *Perc.*? *pearsonii* TDP9/21-1, 50cm-008/010 — *Perc.*? *dunkleyjonesii* Nguru-99-4-030/031



Perc.? *dunkleyjonesii* TDP15/9-1, 10cm-049/050/051(PC)/052 — *Perc.*? *dunkleyjonesii* TDP15/15-1, 10cm-086/087



Perc.? *dunkleyjonesii* TDP15/25-1, 10cm-020/022(PC)/023 — *Perc.*? *dunkleyjonesii* TDP15/25-1, 10cm-024/025/026

Plate 4

Rhagodiscaceae, incertae sedis, Stephanolithiaceae, Axopodorhabdaceae

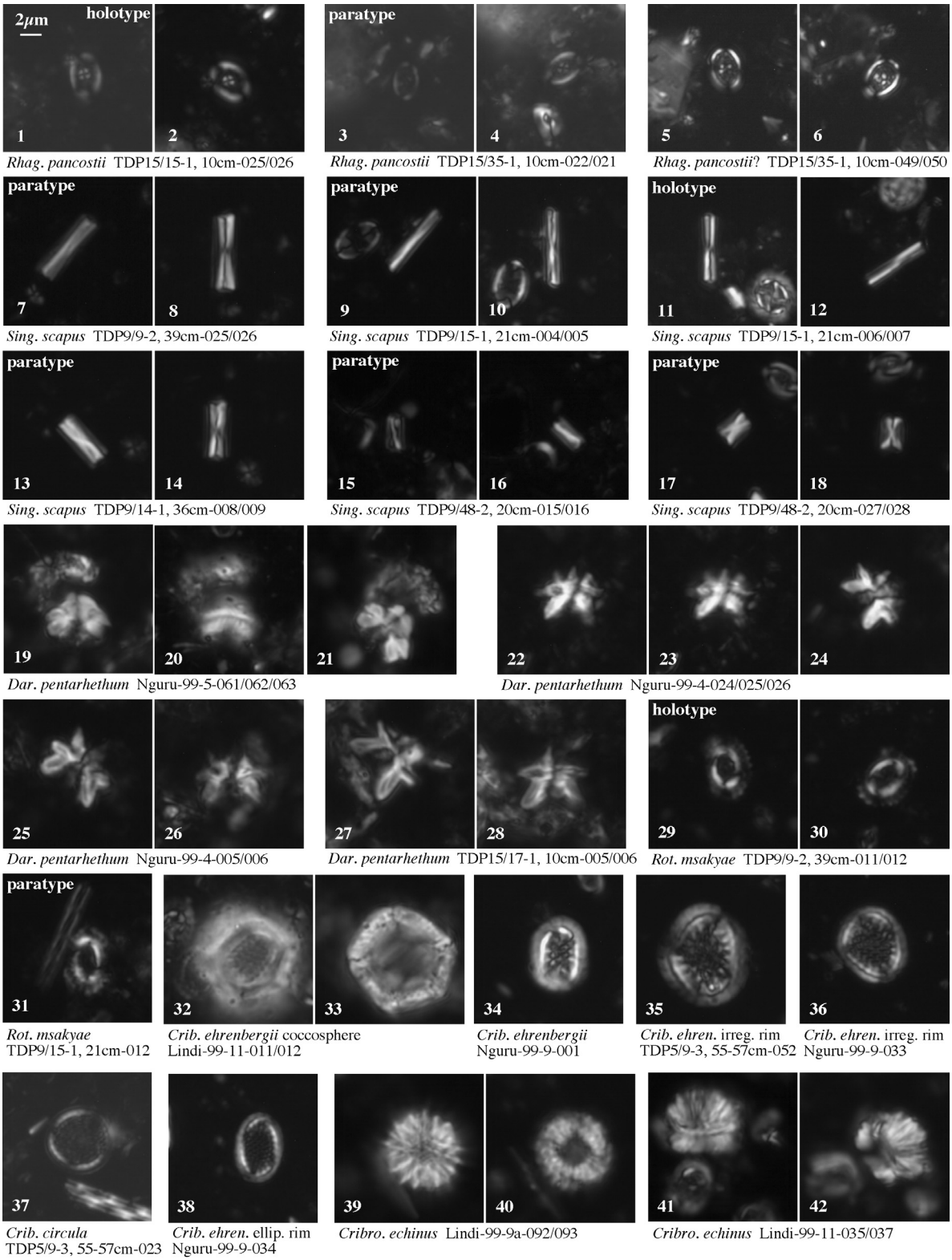
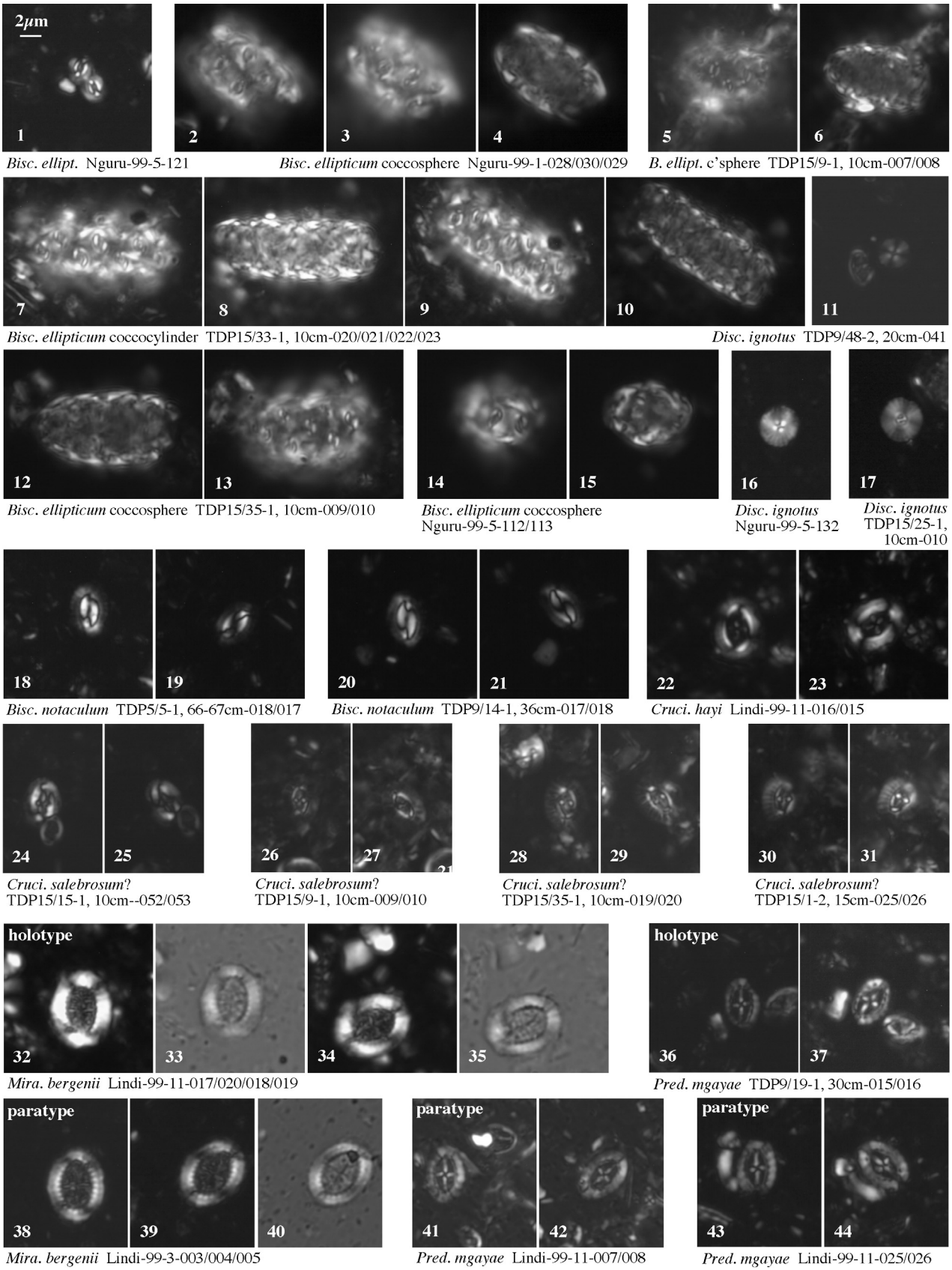


Plate 5

Biscutaceae, Cretarhabdaceae, Prediscosphaeraceae



Bisc. ellipt. Nguru-99-5-121

Bisc. ellipticum coccosphere Nguru-99-1-028/030/029

B. ellipt. c'sphere TDP15/9-1, 10cm-007/008

Bisc. ellipticum coccocylinder TDP15/33-1, 10cm-020/021/022/023

Disc. ignotus TDP9/48-2, 20cm-041

Bisc. ellipticum coccosphere TDP15/35-1, 10cm-009/010

Bisc. ellipticum coccosphere Nguru-99-5-112/113

Disc. ignotus Nguru-99-5-132

Disc. ignotus TDP15/25-1, 10cm-010

Bisc. notaculum TDP5/5-1, 66-67cm-018/017

Bisc. notaculum TDP9/14-1, 36cm-017/018

Cruci. hayi Lindi-99-11-016/015

Cruci. salebrosum? TDP15/15-1, 10cm--052/053

Cruci. salebrosum? TDP15/9-1, 10cm-009/010

Cruci. salebrosum? TDP15/35-1, 10cm-019/020

Cruci. salebrosum? TDP15/1-2, 15cm-025/026

Mira. bergenii Lindi-99-11-017/020/018/019

Pred. mgayae TDP9/19-1, 30cm-015/016

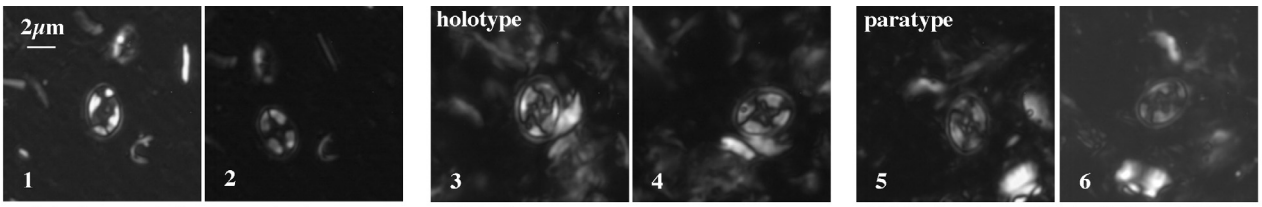
Mira. bergenii Lindi-99-3-003/004/005

Pred. mgayae Lindi-99-11-007/008

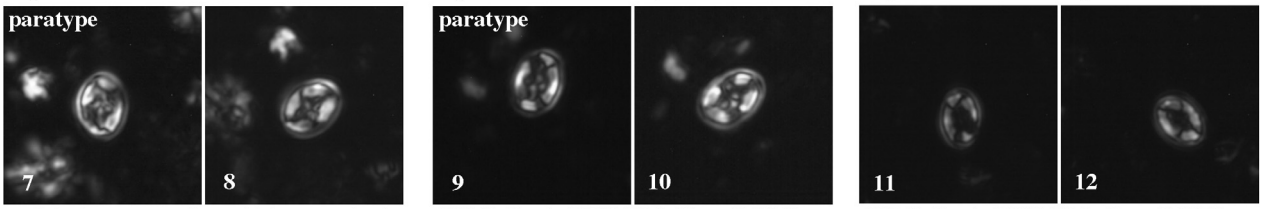
Pred. mgayae Lindi-99-11-025/026

Plate 6

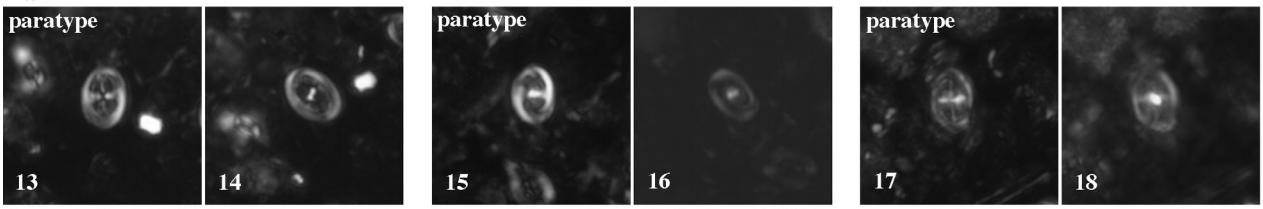
Eiffellithaceae, Chiastozygaceae, Kamptneriaceae



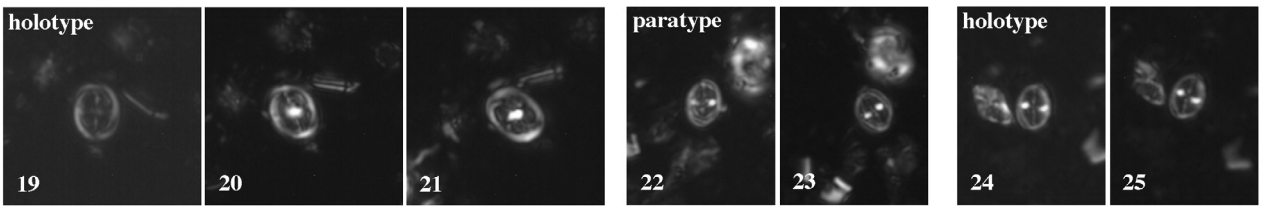
Eiff. lindiensis Lindi-99-2-004/005 | *Eiff. lindiensis* TDP5/6-3, 36-37cm-020/019 | *Eiff. lindiensis* TDP5/9-1, 48-49cm-055/054



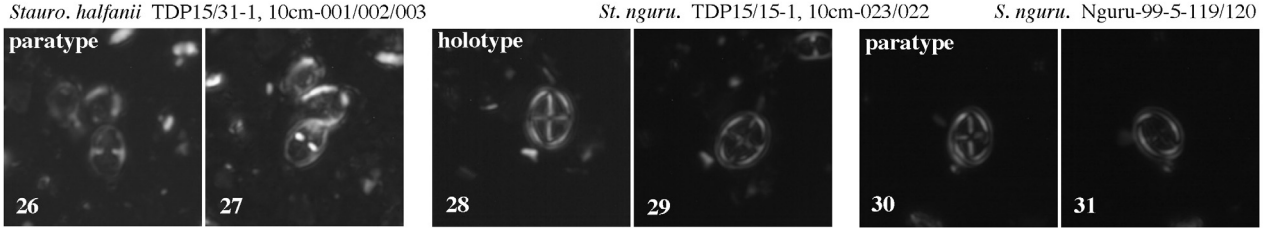
Eiff. lindiensis TDP5/9-3, 55-57cm-004/005 | *Eiff. lindiensis* TDP9/48-2, 20cm-039/040 | *Eiff. lindiensis* TDP9/49-2, 62cm-019/018



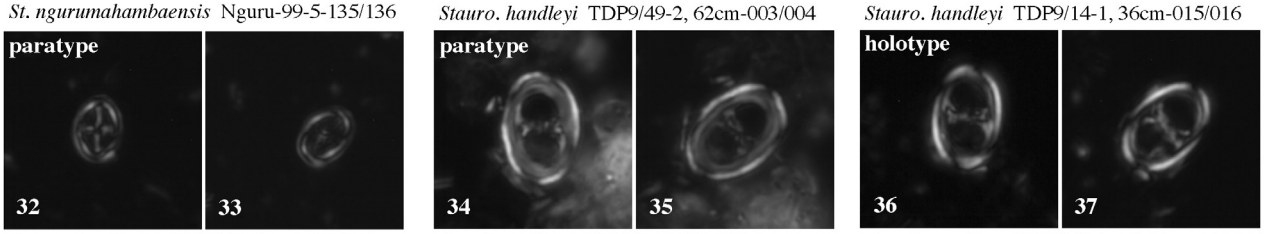
Stauro. halfanii TDP15/35-1, 10cm-032/031 | *Stauro. halfanii* TDP15/45-1, 10cm-005/006 | *Stauro. halfanii* TDP15/3-1, 10cm-002/003



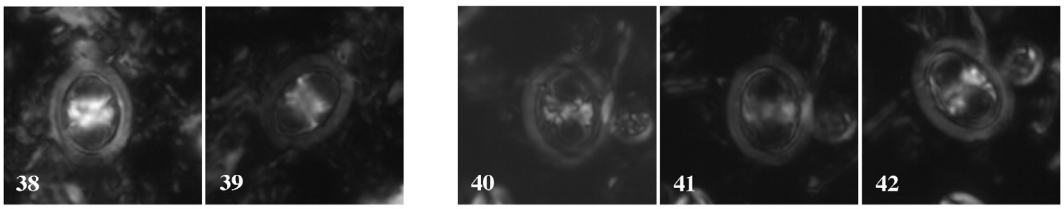
Stauro. halfanii TDP15/31-1, 10cm-001/002/003 | *St. nguru.* TDP15/15-1, 10cm-023/022 | *S. nguru.* Nguru-99-5-119/120



St. ngurumahambaensis Nguru-99-5-135/136 | *Stauro. handleyi* TDP9/49-2, 62cm-003/004 | *Stauro. handleyi* TDP9/14-1, 36cm-015/016



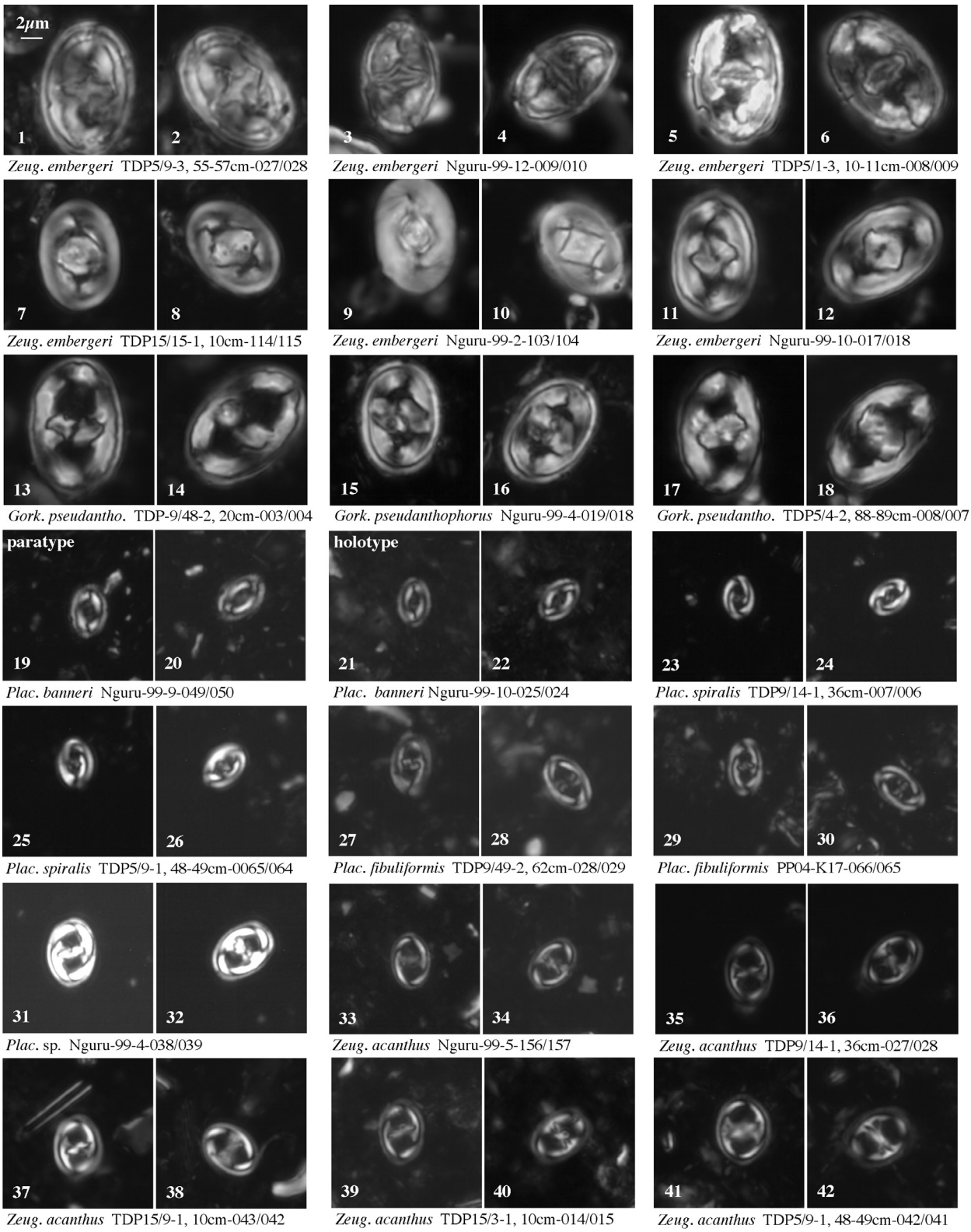
Stauro. handleyi TDP9/9-2, 39cm-001/002 | *Gart.? coxalliae* PP04-K19-002/001 | *Gart.? coxalliae* TDP5/10-2, 15-16cm-039/038



Amph. brooksii TDP5/9-3, 55-57cm-036/037 | *Amph. brooksii* TDP9/29-1, 99cm-008/007/009

Plate 7

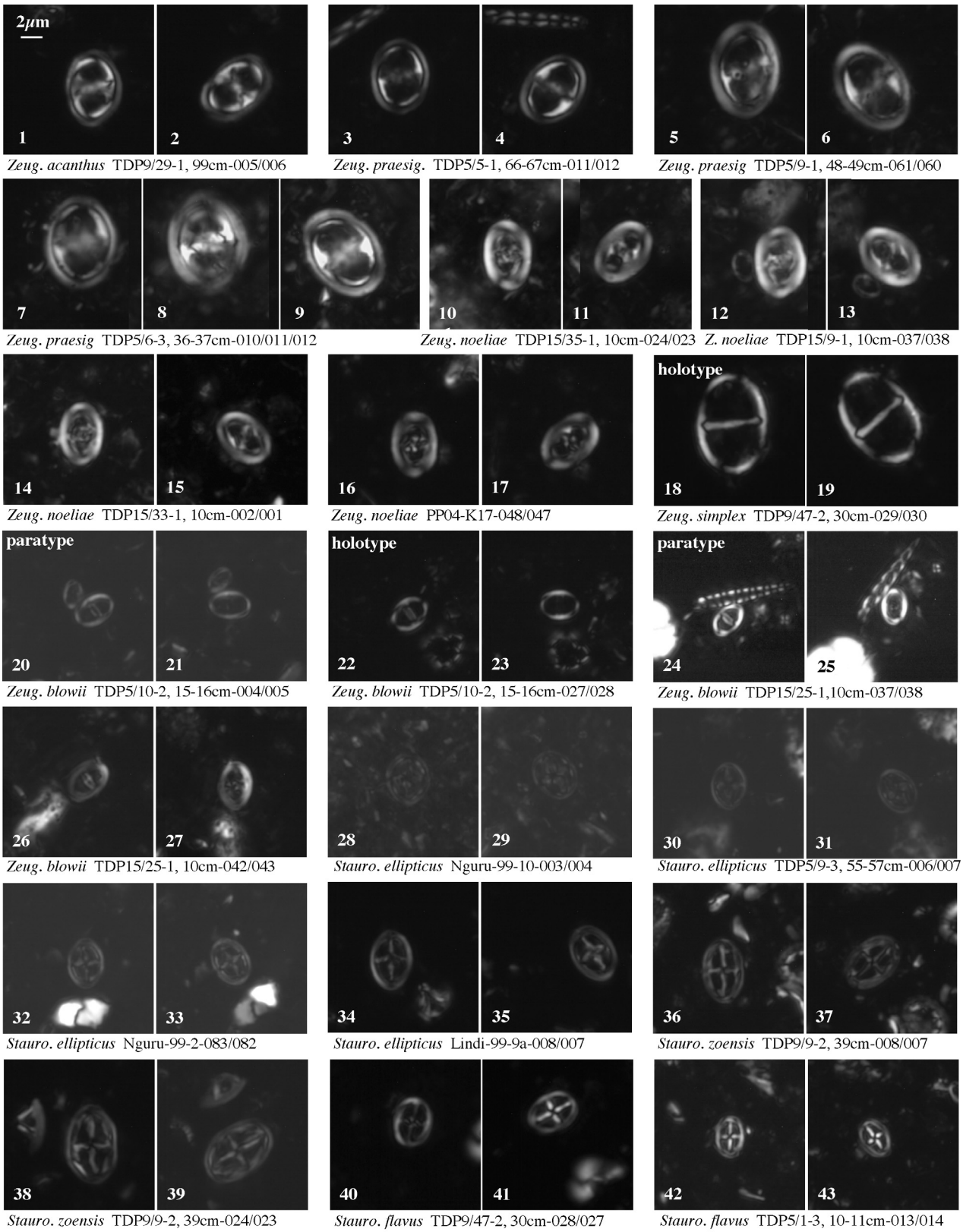
Chiastozygaceae



Zeug. embergeri TDP5/9-3, 55-57cm-027/028
Zeug. embergeri Nguru-99-12-009/010
Zeug. embergeri TDP5/1-3, 10-11cm-008/009
Zeug. embergeri TDP15/15-1, 10cm-114/115
Zeug. embergeri Nguru-99-2-103/104
Zeug. embergeri Nguru-99-10-017/018
Gork. pseudantho. TDP-9/48-2, 20cm-003/004
Gork. pseudanthophorus Nguru-99-4-019/018
Gork. pseudantho. TDP5/4-2, 88-89cm-008/007
Plac. banneri Nguru-99-9-049/050
Plac. banneri Nguru-99-10-025/024
Plac. spiralis TDP9/14-1, 36cm-007/006
Plac. spiralis TDP5/9-1, 48-49cm-0065/064
Plac. fibuliformis TDP9/49-2, 62cm-028/029
Plac. fibuliformis PP04-K17-066/065
Plac. sp. Nguru-99-4-038/039
Zeug. acanthus Nguru-99-5-156/157
Zeug. acanthus TDP9/14-1, 36cm-027/028
Zeug. acanthus TDP15/9-1, 10cm-043/042
Zeug. acanthus TDP15/3-1, 10cm-014/015
Zeug. acanthus TDP5/9-1, 48-49cm-042/041

Plate 8

Chiastozygaceae



Zeug. acanthus TDP9/29-1, 99cm-005/006

Zeug. praesig. TDP5/5-1, 66-67cm-011/012

Zeug. praesig TDP5/9-1, 48-49cm-061/060

Zeug. praesig TDP5/6-3, 36-37cm-010/011/012

Zeug. noeliae TDP15/35-1, 10cm-024/023

Z. noeliae TDP15/9-1, 10cm-037/038

Zeug. noeliae TDP15/33-1, 10cm-002/001

Zeug. noeliae PP04-K17-048/047

Zeug. simplex TDP9/47-2, 30cm-029/030

Zeug. blowii TDP5/10-2, 15-16cm-004/005

Zeug. blowii TDP5/10-2, 15-16cm-027/028

Zeug. blowii TDP15/25-1,10cm-037/038

Zeug. blowii TDP15/25-1, 10cm-042/043

Stauro. ellipticus Nguru-99-10-003/004

Stauro. ellipticus TDP5/9-3, 55-57cm-006/007

Stauro. ellipticus Nguru-99-2-083/082

Stauro. ellipticus Lindi-99-9a-008/007

Stauro. zoensis TDP9/9-2, 39cm-008/007

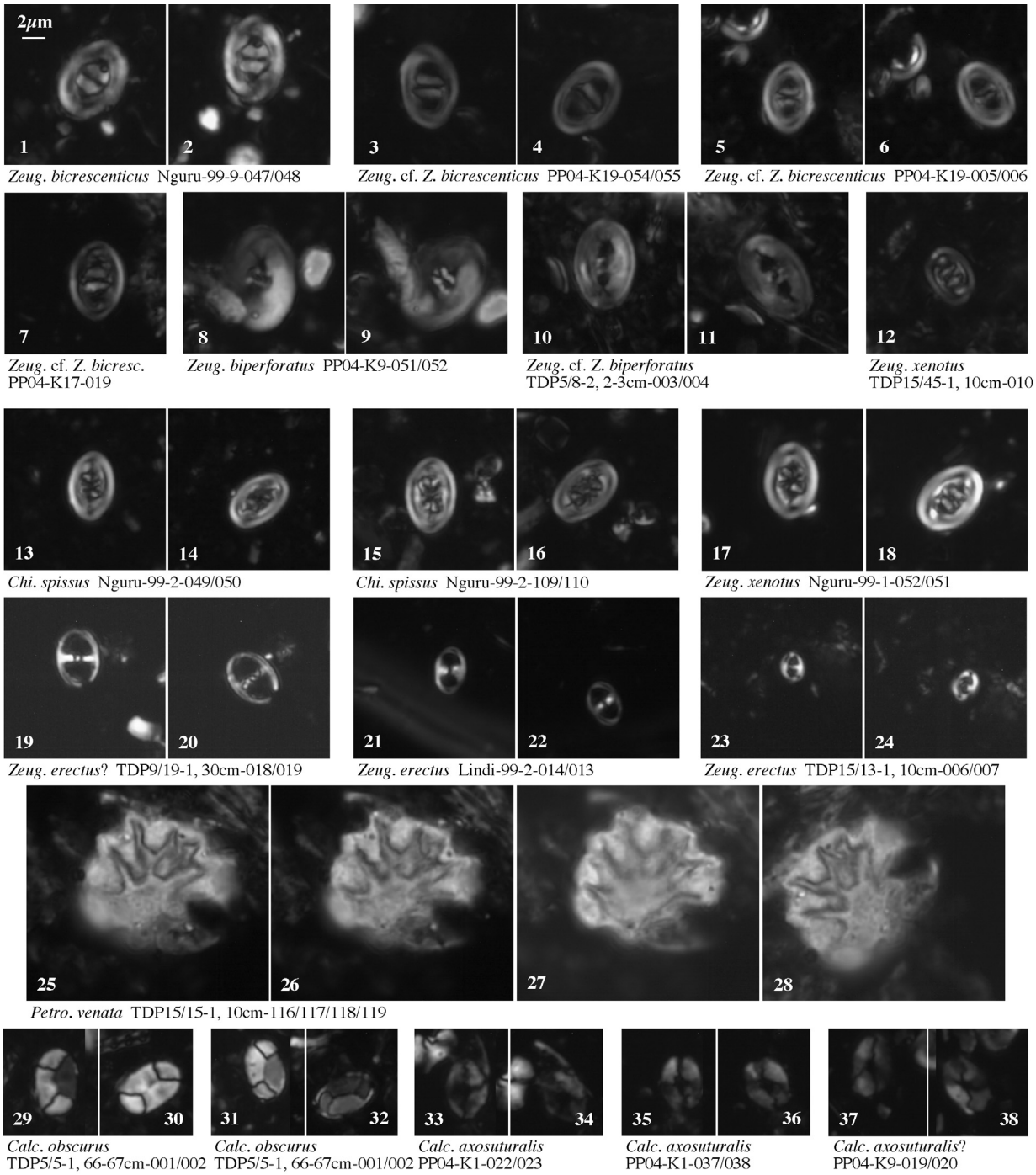
Stauro. zoensis TDP9/9-2, 39cm-024/023

Stauro. flavus TDP9/47-2, 30cm-028/027

Stauro. flavus TDP5/1-3, 10-11cm-013/014

Plate 9

Chiastozygaceae, Calyptrosphaeraceae



Zeug. bicrescenticus Nguru-99-9-047/048

Zeug. cf. *Z. bicrescenticus* PP04-K19-054/055

Zeug. cf. *Z. bicrescenticus* PP04-K19-005/006

Zeug. cf. *Z. bicresc.* PP04-K17-019

Zeug. biperforatus PP04-K9-051/052

Zeug. cf. *Z. biperforatus* TDP5/8-2, 2-3cm-003/004

Zeug. xenotus TDP15/45-1, 10cm-010

Chi. spissus Nguru-99-2-049/050

Chi. spissus Nguru-99-2-109/110

Zeug. xenotus Nguru-99-1-052/051

Zeug. erectus? TDP9/19-1, 30cm-018/019

Zeug. erectus Lindi-99-2-014/013

Zeug. erectus TDP15/13-1, 10cm-006/007

Petro. venata TDP15/15-1, 10cm-116/117/118/119

Calc. obscurus TDP5/5-1, 66-67cm-001/002

Calc. obscurus TDP5/5-1, 66-67cm-001/002

Calc. axosuturalis PP04-K1-022/023

Calc. axosuturalis PP04-K1-037/038

Calc. axosuturalis? PP04-K9-019/020

Plate 10

Calyptrosphaeraceae

Plate 11

Calyptrosphaeraceae

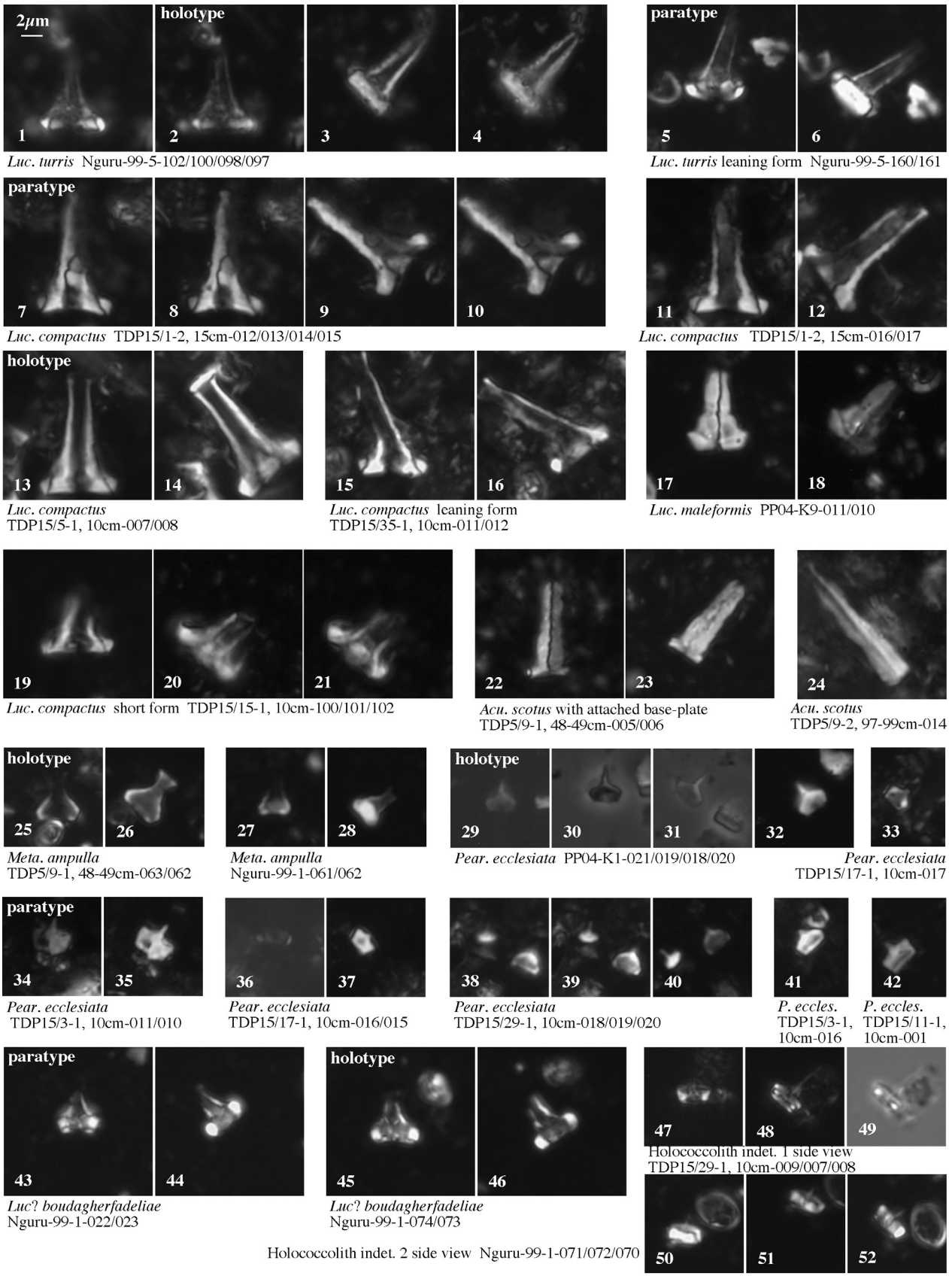
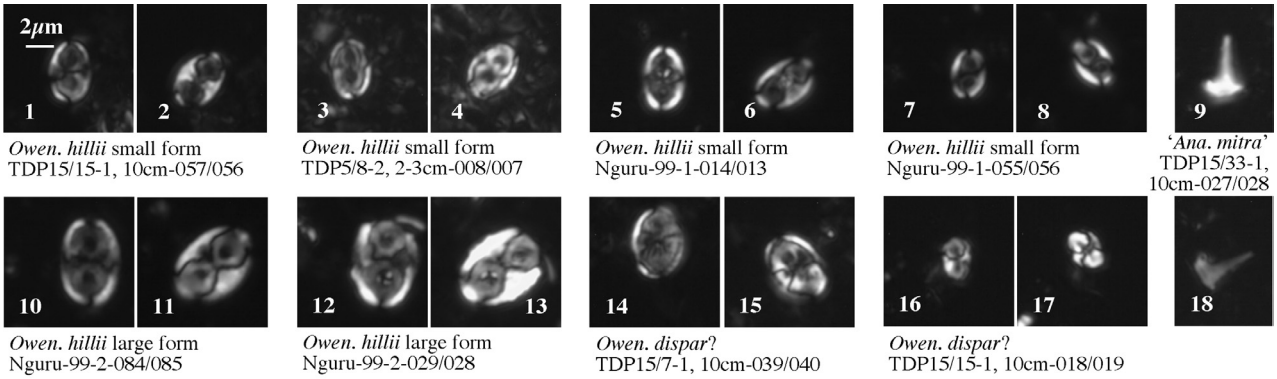


Plate 12

Calyptrosphaeraceae



Owen. hillii small form TDP15/15-1, 10cm-057/056

Owen. hillii small form TDP5/8-2, 2-3cm-008/007

Owen. hillii small form Nguru-99-1-014/013

Owen. hillii small form Nguru-99-1-055/056

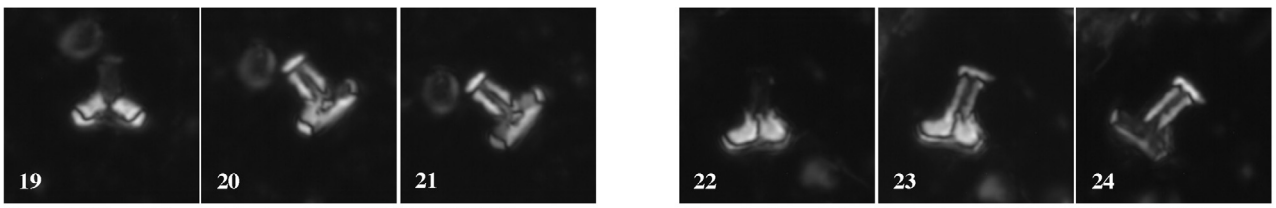
'*Ana. mitra*' TDP15/33-1, 10cm-027/028

Owen. hillii large form Nguru-99-2-084/085

Owen. hillii large form Nguru-99-2-029/028

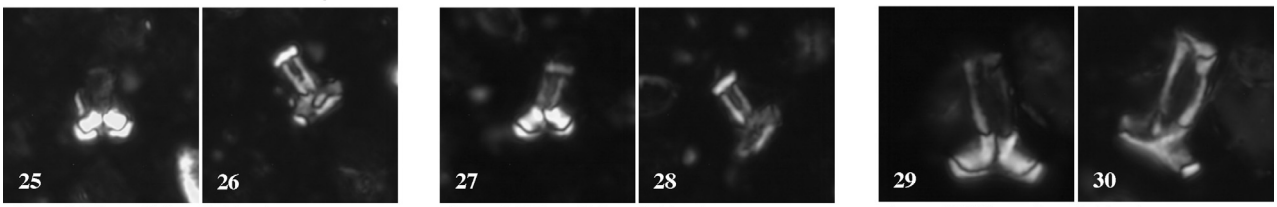
Owen. dispar? TDP15/7-1, 10cm-039/040

Owen. dispar? TDP15/15-1, 10cm-018/019



Owen. hillii small form? side view Nguru-99-5-084/085/086

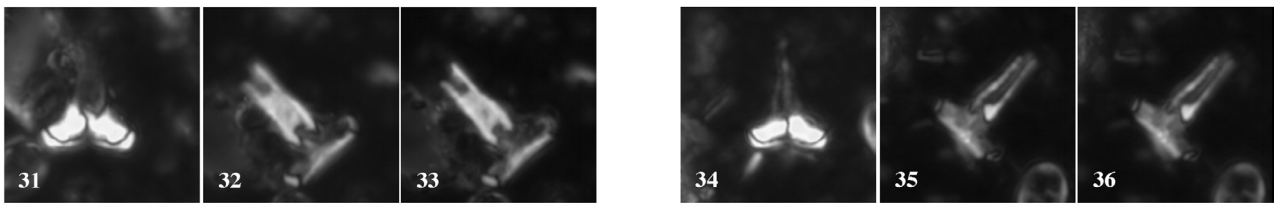
Owen. hillii small form? side view TDP15/1-2, 15cm-024/023/022



Owen. hillii small form? side view Nguru-99-5-152/153

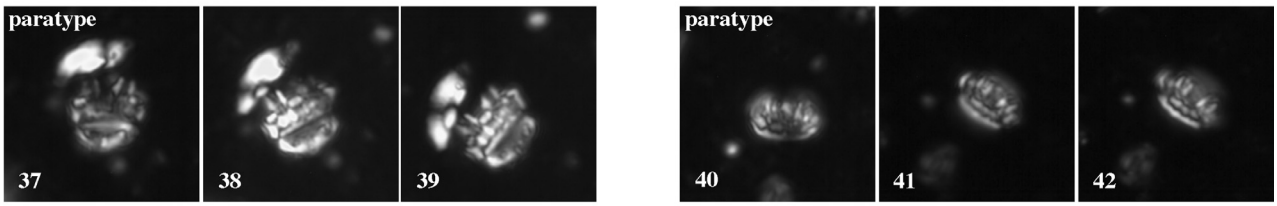
Owen. hillii small form? side view Nguru-99-5-151/150

Owen. hillii large form? side view Nguru-99-5-145/144



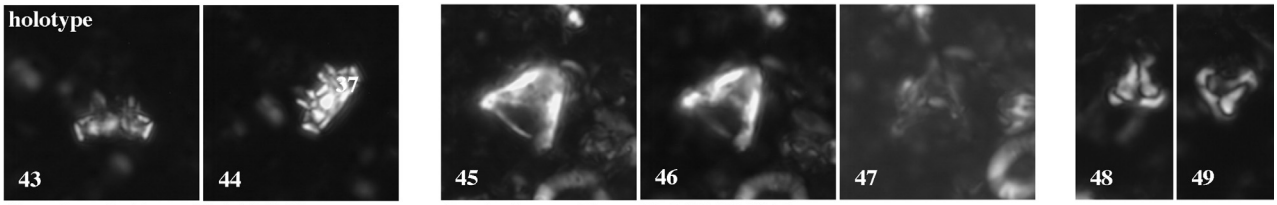
Owen. hillii large form? side view Nguru-99-5-076/077/078

Owen. hillii large form? side view Nguru-99-5-022/020/021



Tanz. bownii Nguru-99-1-121/122/123

Tanz. bownii Nguru-99-1-151/149/150



Tanz. bownii Nguru-99-1-127/128

Luc.? *tabernus* Nguru-99-5-023/024/025

Owen. cf. *O. hillii* side view TDP15/1-2, 15cm-030/029

Plate 13

Calyptrosphaeraceae