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Upper Maastrichtian ammonites and nannofossils and a Palaeocene nautiloid from Richards Bay, Kwa Zulu, South Africa

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ABSTRACT:

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Temporary exposures of Upper Maastrichtian to Palaeocene sediments of the Richard Bay area, Kwa Zulu, yielded Maastrichtian and Danian cephalopod faunas. The lower Upper Maastrichtian assemblage, dated to nannofossil standard biozone CC25b, or UC20a^{TP} of BURNETT (1998), is: *Anagaudryceras politissimum* (KOSSMAT, 1895), *Pseudophyllites indra* (FORBES, 1846) (abundant), *Desmophyllites diphylloides* (FORBES, 1846), *Pachydiscus* (*P.*) *australis* HENDERSON & MCNAMARA, 1985, *Menuites fresvillensis* (SEUNES, 1890), *Diplomoceras cylindraceum* (DEFRANCE, 1816), *Baculites ambatryensis* COLLIGNON, 1971, *Eubaculites carinatus* (MORTON, 1834), and *E. latecarinatus* (BRUNNSCHWEILER, 1966). The Danian yields a monospecific assemblage of *Hercoglossa madagascariensis* COLLIGNON, 1951. The Maastrichtian assemblage has strong similarities to the lower Upper Maastrichtian fauna of the Miria Formation of Western Australia, and is made up of cosmopolitan and latitudinally restricted taxa: there are no endemic elements.

Key words: Cretaceous, Maastrichtian, Palaeocene, Ammonites, Nannofossils, Nautiloids, South Africa.

INTRODUCTION

Recent (1997) expansions to harbour facilities at Richards Bay, 240 km north of Durban in Kwa Zulu - Natal, South Africa (Text-fig. 1) have yielded temporary exposures of Upper Maastrichtian (Cretaceous), Palaeocene, Miocene and Pleistocene sediments with diverse macrofaunal assemblages from units previously known only from exploratory boreholes in the area that had been dated by micro- and nannofossil assemblages (see ORR & CHAPMAN 1974, MAUD & ORR 1975, STAPLETON 1975, KLINGER & KENNEDY 1977, SIESSER 1982, VERHAGEN & *al.* 1990). The oldest borehole faunas recognised to date are Middle/Upper Santonian, on the basis of ammonites described by KLINGER & KENNEDY (1997). STAPLETON (1975) recognised a 49 m thick Lower and Upper Maastrichtian interval on the basis of planktonic foraminifera that he referred to *Gansserina* (*Globotruncana*) *gannseri* and *Abathomphalus* (*Globotruncana*) *mayorensis* Zones, overlain unconformably by up to 36 m of Danian sediments referred to a *Cruciplacolithus tenuis* nannofossil Zone, overlain in turn by a *Chiasmolithus danicus* nannofossil Zone. He concluded that there was an unconformity at the Cretaceous-Tertiary (Maastrichtian-Palaeocene boundary) equivalent to a part of the *Abathomphalus*

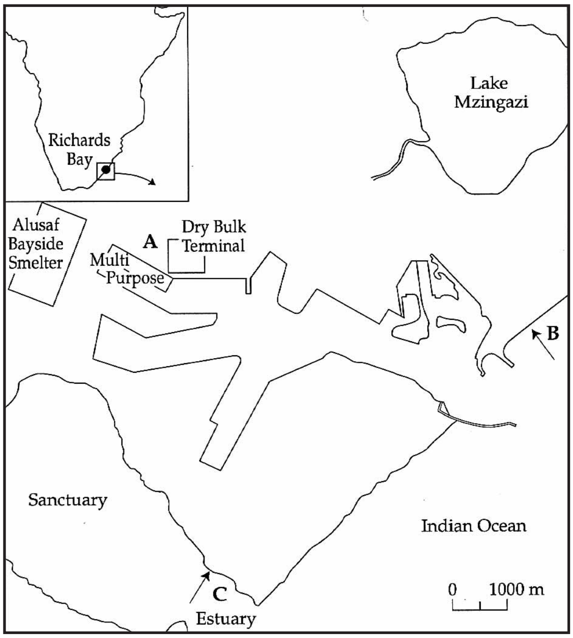

Fig. 1. Location map of the Richards Bay area of Kwa Zulu-Natal (inset), and sketch map of the harbour installations. The bulk of the fossils described here were collected from spoil heaps at A, derived from excavations for the adjacent multi-purpose dock. B, C, sites of spoil heaps of dredged material

mayaroensis planktonic foraminferal Zone of the Upper Maastrichtian, the *Globigerina triloculinoides*, and part of the *Globorotalia compressa* Subzones of the *Globoconusa daubjergensis* planktonic foraminiferal Zone of the Palaeocene.

Verhagen & *al.* (1990) also examined a borehole section in the Richards Bay area, and suggested that, locally at least, the section was more complete, with evidence for 1.6 m of the highest Maastrichtian *Micula prinsii* nannofossil Zone (CC26b) below a concretionary level with typical basal Palaeocene 'disaster' nannofossil taxa, above which indications of the upper part of the lowest Danian NP1 nannofossil Zone occur, overlain in turn by sediments belonging to the succeeding NP2 nannofossil Zone in 3.4 m of sediment above a 15 cm gap in the core. No Iridium spike, or enrichment of Co, Ni, Sb and As was recorded by these authors, so that the K/T boundary Iridium anomaly is either absent, or lies within the gap in the core.

The macrofossils described here were all collected by Kitto from spoil heaps (A in Text-fig. 1): no section was seen. The material can be dated on the basis of occurrences elsewhere as belonging to the Upper Maastrichtian and to the Lower Palaeocene: this has been confirmed in the case of the former on the basis of the rich nannofloras in the matrices of two of the ammonites.

AGE OF THE MACROFAUNAS

The Upper Maastrichtian is represented by the following ammonites preserved as internal moulds, or with aragonitic shell adhering. The matrix is a grey calcareous siltstone to fine sandstone, commonly in the form of calcareous concretions. In thin section, well-sorted angular quartz grains are accompanied by glauconite pellets, molluscan debris, and scattered planktonic forams. The assemblage is *Anagaudryceras politissimum* (Kossmat, 1895), *Pseudophyllites indra* (Forbes, 1846), *Desmophyllites diphylloides* (Forbes, 1846), *Pachydiscus* (*Pachydiscus*) *australis* Henderson & McNamara, 1985, *Menuites fresvillensis* (Seunes, 1890), *Diplomoceras cylindraceum* (Defrance, 1816), *Baculites ambatryensis* Collignon, 1971, *Eubaculites carinatus* (Morton, 1834), and *E. latecarinatus* (Brunnschweiler, 1966). The Maastrichtian stage is subdivided on the basis of belemnites in the classic areas of northern Europe and the former Soviet Union, the base of the Upper Maastrichtian being placed at the base of a *Belemnitella junior* Zone. This division cannot be recognised outside this area, and there is no direct correlation from Europe to South Africa. If the Maastrichtian stage is divided into Upper and Lower substages using ammonites, the presence of *M. fresvillensis* has been suggested as a marker for the base of an Upper Maastrichtian substage (Odin 1996; Fatmi & Kennedy 1999), although there is no universally agreed subdivision of the stage. A Late Maastrichtian age is compatible with the other ammonites present, although most first appear at lower levels in the Upper Cretaceous.

With the exception of *Baculites ambatryensis*, all of the above mentioned taxa occur in the Miria Formation of Western Australia (Henderson & McNamara 1985; Henderson & *al.* 1992), where they are associated with a planktonic foraminiferan fauna of *Globotruncana gansseri sensu lato*, *G. contusa*, *G. arca*, and *Rugoglobigerina rugosa* (Hart *in* Henderson & McNamara 1985, p. 84). A lower Upper Maastrichtian age is thus indicated, and this is compatible with the nannofossil assemblages in specimen matrices, as discussed below. Also present and of Maastrichtian date are fragments of the gastropod *Pleurotomaria*, and bivalves, including *Tenipteria* (A.V. Dhondt, personal communication, 1999).

The Maastrichtian ammonite assemblage from Richards Bay is younger than the outcropping Maastrichtian to the north, in the Lake St. Lucia area (Kennedy & Klinger 1975, 1985). There, inoceramid bivalves (*Inoceramus*, *Trochoceramus*) are abundant to the top of the exposed sequence, where they co-occur with rare *Menuites* cf. *fresvillensis*. The matrix of the Richards Bay material lacks inoceramid debris, indicating that it post-dates the global extinction of the true inoceramids in the Mid-Maastrichtian (Macleod & Ward 1990; Walaszczyk & *al.* 1996).

Danian macrofauna is indicated by the presence of the nautiloid *Hercoglossa madagascariensis* Collignon 1951 (Pl. 3, Figs 7, 8), which occurs in abundance in water-worn hard grey calcareous nodules, commonly with aragonite shell preserved. Thin section analysis of the nodules reveals a subtly different petrography from that of the ammonite-bearing sediments, and no associated nannofossils were recovered. *H. madagascariensis* was originally described by Collignon (1951) from his highest unit, G, of the Antonibe section in Madagascar. Collignon originally regarded the unit as Maastrichtian, but it lacks ammonites, the last of which occur 40 m lower in the section. The sequence was reconsidered by Besairie & Collignon (1972) who demonstrated unequivocally that it was Palaeocene.

NANNOFOSSIL DATING OF THE AMMONITE FAUNA

Samples of matrix from three macrofaunal specimens were examined for their nannofossil content in order to provide dates for the material. Matrix (Sample C) from the Danian nautiloid, *Hercoglossa madagascariensis*, was barren, the sediment being a gray, indurated limestone concretion, veined with calcite. Von Salis Perch-Nielsen (*in* Verhagen *& al*. 1990) determined the nannofloras across a Cretaceous/Tertiary (K/T) boundary sequence found in cored borehole material from this region. She also identified an interval barren of nannofossils, represented by a concretionary horizon just above the K/T boundary, the horizon being interpreted by Verhagen *& al*. (1990) as an interval of regression/non-deposition. This may indicate that the water-column containing the nautiloid was too shallow to support a nannoflora.

Samples A and B were, respectively, from the matrices of *Eubaculites latecarinatus* (Brunnschweiler 1966) (SAM PCZ 13905: Pl. 10, Figs 4-6) and *Pachydiscus* (*P.*) *australis* Henderson & McNamara, 1985 (SAM PCZ 13894: Pl. 4, Figs 8, 9): soft, beige marly nannofossiliferous calcareous sandstones.

Samples A and B both contained high-diversity nannofloras (Table 1), with a relatively high proportion of holococcoliths (~19% of the taxa in Sample A, ~21% in Sample B: see Pls 11, 12), similar to those observed in the Late Cretaceous sediments of boreholes from the region (Lees, Klinger & Kennedy, in prep.). Sample A contains a well preserved nannoflora, whilst Sample B has more background calcium carbonate, and a moderately well-preserved assemblage. In both samples, the presence of *Lithraphidites quadratus* (Pl. 13, Figs 1-5) and the absence of *Micula murus* and *Nephrolithus frequens* and indications of younger nannofossil events, date the samples to standard nannofossil biozones CC25b (of Sissingh 1977, 1978 and Perch-Nielsen 1985) or UC20a^{TP} (of Burnett 1998). Furthermore, the absence of *Ahmuellerella octoradiata* suggests top UC20a^{TP}, possibly just below the first occurrence (FO) of *Micula murus*.

The superscript 'TP' in the Burnett (1998) biozonation indicates a mid- to low-latitude subzone. In the Maastrichtian, biogeographic separation of the lower latitude nannofloras from those of the northern and southern high latitudes had an impact on the utility of nannofossils in high-resolution *global* correlation, high resolution only being achievable at subzone level using latitudinally-restricted and/or -diachronous marker-species (see Burnett 1998, p.158, Fig. 6.6). However, UC20 is a global biozone, recognisable to high latitudes. The assemblages in samples A and B place them in this Zone. Since the FO of *L. quadratus* is found in the *tegulatus*/*junior* Zone (of Schulz *& al*, 1984; Schönfeld *& al.* 1996) or *B. junior* Zone (of Jeletzky 1951, 1958; Christensen 1996) of the standard belemnite biozones of northern Europe, and in the lowest part of Member IV in the Biscay region (Burnett *& al.* 1992) which is equivalent to the Upper Maastrichtian part of the *Menuites* [*Anapachydiscus*] *fresvillensis* ammonite Zone (Ward & Kennedy 1993), a late Maastrichtian date can be assigned to the Richards Bay ammonite fauna.

The presence of coccospheres of *Neobiscutum parvulum* (Pl. 13, Figs 6, 7) in the Upper Maastrichtian is currently somewhat contentious. Although this taxon was originally described from the Tertiary, and supposed to have evolved *after* the K/T boundary extinction event, Burnett (*in* Herngreen *& al*. 1998) has reported it from Upper Maastrichtian strata in The Netherlands. It is extremely unlikely that the nannofossil assemblages reported here for samples A and B have been reworked into the Tertiary, since: (a) preservation is unusually good, as indicated by the holococcolith presence, as well as the general heterococcolith assemblages; (b) a clear post-K/T boundary nannoflora signature would be evident, with, for example, common *Thoracosphaera* and *Braarudosphaera* (Pl. 13, Figs 8-10) and/or common *Neobiscutum*. Although *Thoracosphaera* and *Braarudosphaera* are present in low numbers in the samples, they are known to range throughout the Upper Cretaceous as a rare component of assemblages, only becoming more frequently and regularly present as the K/T boundary is approached; (c) the nannofloras are from the matrices of Cretaceous ammonites; and (d) von Salis Perch-Nielsen (*in* Verhagen *& al.* 1990) report-

TAXON	A	B
Acuturris scotus	F	F
Ahmuellerella regularis	F	F
Amphizygus brooksii	R	
Arkhangelskiella cymbiformis	F	F
Arkhangelskiella maastrichtiana	F	
Biscutum arrogans		R
Biscutum cf. *B. ellipticum*	F	R
Biscutum coronum	R	R
Biscutum ellipticum	F	F
Braarudosphaera bigelowii	R	R
Braarudosphaera regularis	R	
Bukrylithus ambiguus	R	
Calculites additus	F	
Calculites cf. *C. obscurus*	F	R
Calculites cf. *C. ovalis*		R
Calculites obscurus	R	
Calculites percenis	R	F
Ceratolithoides quasiarcuatus	F	R
Chiastozygus antiquus	C	F
Chiastozygus bifarius	F	F
Chiastozygus garrisonii	F	F
Chiastozygus synquadriperforatus	F	F
Chiastozygus trabalis	F	
Corollithion exiguum	F	R
Cretarhabdus conicus	F	F
Cribrocorona gallica	R	
Cribrosphaerella daniae	R	R
Cribrosphaerella ehrenbergii	C	F
Cyclagelosphaera reinhardtii	R	
Cylindralithus nudus	F	
Cylindralithus serratus	F	
Discorhabdus ignotus	F	F
Eiffellithus gorkae	F	F
Eiffellithus parallelus	F	F
Eiffellithus turriseiffelii	F	F
Gartnerago segmentatum	F	
Goniolithus fluckigeri		R
Helicolithus compactus	F	F
Helicolithus trabeculatus	C	F
Holococcolith sp.1 cf. *Calculites*	R	R
Holococcolith sp.2 cf. *Calculites*	F	R
Holococcolith sp.3 cf. *Saepiovirgata* ?	F	
Holococcolith sp.4	F	R
Indet. nannolith cf. *Nannoconus*		F
Kamptnerius magnificus	F	R
Lapideacassis mariae	R	
Lithraphidites carniolensis	F	F
Lithraphidites praequadratus	F	F
Lithraphidites quadratus	F	F
Loxolithus armilla	F	
Manivitella pemmatoidea		R
Microrhabdulus belgicus	F	F
Microrhabdulus decoratus	R	
Microrhabdulus helicoideus		F
Microrhabdulus undosus	F	F
Micula concava	R	
Micula cubiformis		F
Micula staurophora	F	F
Micula swastica	F	F
Multipartis cf. *M. ripleyensis*		R
Multipartis ripleyensis	F	F
Munarinus lesliae	F	F
Munarinus marszalekii	F	F
Neobiscutum parvulum	F	F
Nephrolithus corystus		R
Octolithus cf. *O. multiplus*	F	
Octolithus multiplus	F	F
Okkolithus australis	F	R
Orastrum cf. *O. perspicuum*		R
Ottavianus cf. *O. terrazetus* ?	R	F
Ottavianus giannus ?	R	R
Ottavianus terrazetus ?	F	F
Percivalia fenestrata	F	
Placozygus cf. *P. fibuliformis*	F	
Placozygus fibuliformis	F	F
Prediscosphaera cf. *P. grandis*	R	
Prediscosphaera cretacea	F	F
Prediscosphaera grandis	F	R
Prediscosphaera incohatus	F	
Prediscosphaera majungae		F
Prediscosphaera microrhabdulina	F	R
Prediscosphaera ponticula	F	F
Prediscosphaera spinosa		F
Prediscosphaera stoveri	C	C
Psyktosphaera firthii	R	
Repagulum parvidentatum	F	R
Retecapsa angustiforata	F	R
Retecapsa crenulata	F	F
Retecapsa schizobrachiata	F	
Retecapsa surirella	F	
Rhagodiscus angustus	F	F
Rhagodiscus plebeius		R
Rhagodiscus splendens	F	F
Rhombolithion rhombicum	F	F
Rotelapillus crenulatus	F	R
Scapholithus fossilis	F	F
Semihololithus bicornus ?	F	F
Seribiscutum cf. *S. gaultensis*	F	R
Sollasites horticus	R	
Staurolithites ellipticus	F	F
Staurolithites imbricatus	F	R
Staurolithites cf. *S. integer*	F	
Staurolithites laffittei	F	R
Staurolithites mielnicensis	R	
'Tetralithus' mississippiensis ?	F	
Tetrapodorhabdus decorus	F	F
Thoracosphaera saxea	F	
Tranolithus minimus	F	F
Watznaueria barnesiae	F	F
Watznaueria manivitiae s.l.	F	R
Watznaueria ovata	R	
Watznaueria quadriradiata	R	
Zeugrhabdotus cf. *Z. bicrescenticus*	R	R
Zeugrhabdotus cf. *Z. trivectis*		R
Zeugrhabdotus embergeri	F	
Zeugrhabdotus erectus	C	F
Zeugrhabdotus spiralis	F	R
indet. yellow rim	F	

Table 1. Nannofossil occurrences in the matrix of ammonites from the Upper Maastrichtian of Richards Bay. A: matrix of *Eubaculites latecarinatus* (Brunnschweiler, 1966), SAM PCZ 13905 (Pl. 10, Figs 4-6). B: matrix of *Pachydiscus* (*P.*) *australis* Henderson & McNamara, 1985, SAM PCZ 13894 (Pl. 4, Figs 8, 9). For full taxonomic references see Bown (1998), and Perch-Nielsen (1985). Abbreviations are as follows. Abundance: L = low; M = moderate; H = high. The assemblages indicate the standard Upper Cretaceous nannofossil biozone CC25b of Sissingh (1997, 1998), and Perch-Nielsen (1985), and the upper part of zone HC20a^{TP} of Burnett (1998)

ed the post-K/T boundary *N. parvulum* Subzone as being absent from the section she examined in the Richards Bay area and therefore downward bioturbation/reworking is unlikely to have 'contaminated' the Upper Maastrichtian sediments with a Danian nannoflora; *Neobiscutum* must thus have evolved in the Maastrichtian not in the Danian.

DISCUSSION

As noted by VERHAGEN & *al*. (1990), the Richards Bay sections provide one of the very few relatively complete onshore Cretaceous-Tertiary boundary sections in Southern Africa, and indeed the Southern Hemisphere. Macrofaunal records from the boundary interval are even rarer in the Southern Hemisphere. The Quiriquina Formation in Chile, documented by STINNESBECK (1986), unconformably overlies Palaeozoic basement rocks and is overlain unconformably by early Tertiary sediments. The presence of *Menuites* [*Pachydiscus*] *fresvillensis* indicates the Formation to be Upper Maastrichtian, but how much of the Upper Maastrichtian is absent at the sub-Tertiary unconformity is not known. Complete Cretaceous-Tertiary boundary sections with a diverse macrofauna are known from the Antarctic Peninsula, and are fully documented by MACELLARI (1986), ZINSMEISTER & *al*. (1989), and others. The phosphatised fauna from the condensed Miria Formation in the Carnarvon Basin of Western Australia is also Upper Maastrichtian (HENDERSON & MCNAMARA 1985, HENDERSON & *al.* 1992); this Formation is, however, overlain unconformably by Palaeocene Boongarooda Greensand.

In Africa south of the Sahara, onshore Maastrichtian macrofaunas are known only from Nigeria (ZABORSKI 1983, 1985), Mozambique (CRICK 1924), and the Lake St Lucia area of Zululand (KENNEDY & KLINGER 1975, 1985). In the case of the latter, we have now recognised *Menuites* cf. *fresvillensis* at a number of localities, indicating the presence of the lower part at least of the Upper Maastrichtian.

BIOGEOGRAPHIC AFFINITIES OF THE UPPER MAASTRICHTIAN AMMONITE FAUNA

There has been no comprehensive review of Maastrichtian ammonite biogeography since the work of HENDERSON (1970), MATSUMOTO (1973) and MACELLARI (1985, 1986). From these works and our own observations, Upper Maastrichtian ammonite faunas appear to be made up of three basic categories of ammonite in a biogeographic sense. Austral taxa are exemplified by the kossmaticeratid genera *Maorites, Natalites, Grossouvreites, Jacobites* and *Neograhamites*, which define a faunal region encompassing Antarctica, Patagonia, Australia, New Guinea and New Zealand, with elements extending, as rarities, to Zululand and south India. Latitudinally restricted taxa such as *Eubaculites* extend from Western Australia in the Southern Hemisphere to the Netherlands, Austria, and New Jersey, USA, in the Northern Hemisphere. Cosmopolitan taxa are exemplified by *Neophylloceras, Saghalinites, Tetragonites* and *Baculites* which extend from the Antarctic Peninsula to Greenland.

The Richards Bay assemblage comprises cosmopolitan *Pseudophyllites* and *Baculites*, plus latitudinally restricted *Anagaudryceras, Desmophyllites, Pachydiscus*, and *Eubaculites*. There are no Austral elements. With the exception of *Baculites ambindensis*, which is known only from Richards Bay, Madagascar, and Pakistan, all of the remaining species present occur in Madagascar and Western Australia, and many are also present (or have close relatives) in Chile.

PALAEOBIOGEOGRAPHIC AFFINITIES OF THE NANNOFLORAS

During the Maastrichtian, South Africa was situated in a region influenced by water-masses which supported two subtly different nannofloras. These have been defined by LEES (in prep.) as Austral and Intermediate nannofossil provinces based on a study of Indian Ocean DSDP/ODP material (approximate palaeogeographical boundaries are illustrated in BURNETT *& al.* (2000)). In the Maastrichtian, the Austral water-mass had only a weak influence here, typified by the obvious (although not abundant) presence of *Repagulum parvidentatum* (Pl. 13, Figs 31-33), common (rather than abundant) occurrence of *Prediscosphaera stoveri* (Pl. 13, Fig. 25), and only frequent (rather than common/abundant) occurrences of *Watznaueria barnesiae* in the material (note that the preservation is good, and so these relatively low abundances are not the result of preservational effects).

The stronger influence was probably from the lower latitude Intermediate Province, a biogeographic region of amalgamation of nannofloras from ultra-low to temperate latitudes, possibly representing an area across which a water-mass front oscillated through time, rather than a wide region of water-mass mixing, and containing taxa which allow a 'tethyan' (= low to intermediate palaeolatitudes) subzone to be assigned to the material. Taxa indicative of a lower-latitude water-mass include *Ceratolithoides* spp. (here represented by *C. quasiarcuatus*: Pl. 13, Figs 34, 35) and, for example, *Micula murus* and *Micula prinsii* (not observed in the present samples, which are too old, but as observed in the area by, respectively, Siesser, 1982 and von Salis Perch-Nielsen *in* Verhagen *& al*. 1990).

PALAEOECOLOGICAL AFFINITIES OF THE NANNOFLORAS

The presence of a relatively diverse and well-preserved holococcolith assemblage is possibly indicative of a relatively shallow-water but low-energy depositional environment, if the indications of the work of Kleijne (1991) can be extrapolated to this Maastrichtian scenario. Indeed, the calcareous sandstones are of shallow-water origin, as determined by Verhagen *& al.* (1990). The palaeoecology of Late Cretaceous holococcolith-rich assemblages is discussed in more detail in Lees *& al.* (in prep.), based on borehole material from an adjacent region in South Africa to that studied here.

CONVENTIONS

The following abbreviations are used to indicate the repositories of specimens mentioned in the text:
BMNH: Natural History Museum, London
NMB: National Museum, Bloemfontein
SAM: South African Museum, Cape Town

All dimensions of specimens are given in millimetres; D = diameter, Wb = whorl breadth, Wh = whorl height, U = umbilical diameter. Figures in parentheses are dimensions as a percentage of the diameter at the point of measurement.

The suture terminology is that of Wedekind (1916), as applied by Kullman & Wiedmann (1970).

Subclass Nautiloidea Agassiz, 1847
Order Nautilida Agassiz, 1847
Suborder Nautilina Agassiz, 1847
Superfamily Nautilaceae de Blainville, 1825
Family Hercoglossidae Spath, 1927
Genus *Hercoglossa* Conrad, 1866

TYPE SPECIES: *Nautilus orbiculatus* Tuomey, 1856, by the subsequent designation of Hyatt, 1883, p. 270.

Hercoglossa madagascariensis Collignon, 1951
(Pl. 3, Figs 7, 8)

1951. *Hercoglossa madagascariensis* Collignon, p. 130, Pl. 20(8), Fig 1; Text-figs 7, 8.

TYPE: Holotype, by monotypy, is the original of Collignon, 1951, p. 130, Pl. 20(8), Fig. 1, from Niveau G of the Antonibe section, Madagascar, originally in the collections of the École des Mines, Paris, and now housed in the Université Claud-Bernard, Lyon.

MATERIAL: SAM PCZ 13909, 15702-15790.

DIMENSIONS:	D	Wb	Wh	Wb:Wh	U
SAM PCZ 13909	87.4(100)	52.6(60)	55.3(63.3)	0.95	-(-)

DESCRIPTION: SAM PCZ 13909 is an internal mould of a phragmocone 87.4 mm in diameter, with traces of aragonitic shell preserved. Umbilicus tiny. Whorl section compressed, with whorl breadth to height ratio 0.95. Inner flanks broadly rounded, outer flanks flattened and convergent, ventrolateral shoulders and venter broadly rounded. The surface of the mould is smooth. Septa quite widely separated; suture with broad saddle on inner flank, deep lobe at mid-flank, ventral saddle very broad, near-transverse across venter.

DISCUSSION: The present specimens differ in no significant respects from the holotype. This species is abundant in our collections, but specimens are generally worn and poorly preserved. Comparison with the Mozambique species *Hercoglossa mozambensis* Crick, 1924 (p. 130, fig. 6, 1-4) is complicated by the very simplified sketches of the original material. It appears to be more inflated than the Richards Bay material, and is kept separate at this time. Crick (1924, p. 130) believed it to be of Eocene age.

OCCURRENCE: Collignon (1951) originally attributed this species to the Maastrichtian. Besairie & Collignon (1972, p. 171) demonstrated that the species is actually Danian. It is known from Madagascar and Richards Bay, Zululand.

Order Ammonoidea Zittel, 1884
Suborder Lytoceratina Hyatt, 1889
Superfamily Tetragonitaceae Hyatt, 1900
Family Gaudryceratidae Hyatt, 1900
Genus *Anagaudryceras* Shimizu, 1934

Anagaudryceras politissimum (Kossmat, 1895)
(Pl. 1, Figs 1-8)

1895. *Lytoceras (Gaudryceras) politissimum* Kossmat, p. 128(32), Pl. 15(1), Fig.7.
1993. *Anagaudryceras politissimum* (Kossmat, 1895); Ward & Kennedy, p. 21, Figs 17.9, 17.12, 19.1, 19.2, 19.6, 19.14, 19.15 (with full synonymy).

?*non*1995. *Anagaudryceras politissimum* (Kossmat, 1895); Matsumoto, p. 70, Figs 36, 37.
1999. *Anagaudryceras politissimum* (Kossmat, 1895); Kennedy *in* Fatmi & Kennedy, p. 646, Figs 4.7, 4.8.

TYPE: The holotype, by monotypy, is the original of Kossmat, 1895, p. 128(32), Pl. 15(1), Fig. 7, from the upper part of the Trichinopoly group of Varagur, south India.

MATERIAL: SAM PCZ 12922, 13884-13887.

DESCRIPTION: Specimens include an external mould retaining indications of morphology down to a diameter of 9 mm (SAM PCZ 13887: Pl. 1, Fig. 1), and wholly septate fragments with whorl heights of up to 52 mm, corresponding to an estimated diameter of 125 mm (SAM PCZ 13886) which retain indications of at least a further whorl when complete.

Coiling slightly involute, with 57% of the previous whorl covered. The original umbilical diameter ratio cannot be established; umbilical wall broadly rounded, of moderate elevation. The whorls expand slowly, notably in early growth, to give a distinctive polygyral shell (Pl. 1, Fig. 1). The whorl section varies from slightly compressed to slightly depressed, with the maximum whorl breadth low on the flanks; inner to middle flanks feebly and broadly convex; outermost flanks converge to the broadly and evenly rounded venter. Internal moulds (Pl. 1, Figs 1-6) are smooth, but for feeble, widely spaced constrictions that are strongly prorsiradiate across the umbilical wall, convex on the inner flank, flexed back and concave on the outer flank, flexed forwards and concave across the ventrolateral shoulder to cross the venter in a broad convexity. These constrictions correspond to strong collars on the shell surface, preserved on external mould SAM PCZ 13887 (Pl. 1, Fig. 1), and in part in SAM PCZ 13885 (Pl. 1, Fig. 8), where recrystallized shell is preserved. The collars are followed by a weak adapertural constriction. The surface of the shell is finely lirate, both between and over the collars (Pl. 1, Fig. 1); the course of the lirae parallels that of the collars. Sutures are well-exposed, deeply and intricately subdivided, with narrow-stemmed bifid lobes and narrow-necked bifid saddles; the umbilical lobe is strongly retracted. The septal face of several specimens shows the well-developed septal lobe (Pl. 1, Figs 3, 7).

DISCUSSION: The present specimens compare well with the material from the Upper Maastrichtian of Western Australia described by Henderson & McNamara (1985), and from the Biscay region of France and Spain by Ward & Kennedy (1993), but extend to much greater diameters than previously know specimens, making *politissimum* among the largest-known *Anagaudryceras*. As noted by Kennedy (*in* Fatmi & Kennedy 1999), specimens from the Coniacian of Hokkaido, Japan, described by Matsumoto (1995) that have narrow fold-ribs at whorl heights of as little as 18 mm, belong to some other species.

OCCURRENCE: Turonian to Santonian of south India, Santonian of Zululand, Maastrichtian of Madagascar, western Australia, Pakistan, and the Biscay region of France and Spain. *Gaudryceras* cf. *politissimum* was recorded from the Maastrichtian of Chile by Stinnesbeck (1986).

Family Tetragonitidae Hyatt, 1900
Genus *Pseudophyllites* Kossmat, 1895

TYPE SPECIES: *Ammonites indra* Forbes, 1846, p. 105, Pl. 11, Fig. 7, by original designation.

Pseudophyllites indra (Forbes, 1846)
(Pl. 2, Figs. 1-7)

1846. *Ammonites Indra* Forbes, p. 105, Pl. 11, Fig. 7.
1846. *Ammonites Garuda* Forbes, p. 102, Pl. 7, Fig. 1.
1977. *Pseudophyllites indra* (Forbes, 1846); Kennedy & Klinger, p. 182, Figs. 19a-f, 20-22 (with full synonymy).
1985. *Pseudophyllites indra* (Forbes, 1846); Henderson & McNamara, p. 50, Pl. 2, Figs 7, 8, Pl. 3, Figs 4, 5, Text-figs 5a, d.
1986. *Pseudophyllites indra* (Forbes); Stinnesbeck, p. 199, Pl. 8, Fig. 4.
1986. *Pseudophyllites indra* (Forbes, 1846); Kennedy, p. 19, Pl. 1, Figs 1-5; Text-figs 4e, 5a, 6a-e (with additional synonymy).
1986. *Pseudophyllites* cf. *indra* (Forbes, 1846); Kennedy & Summesberger, p. 187, Pl. 1, Figs 1, 8, Pl. 3, fig 5, Tex-fig 4 (with additional synonymy).
1989. *Pseudophyllites;* Kennedy, Fig. 17b.
1991. *Pseudophyllites indra* (Forbes); Cobban & Kennedy, p. E2, Pl. 1, Figs 1-5.
1993. *Pseudophyllites indra* (Forbes, 1846); Ward & Kennedy, p. 22, Figs 17.8, 18.9, 18.10, 19.7, 19.9, 19.13, 21.1, 21.2, 22.1, 22.2, 27.6.
1993. *Pseudophyllites indra* (Forbes, 1846); Hancock & Kennedy, p. 153, Pl. 1, Figs 3, 4.
1993. *Pseudophyllites indra* (Forbes, 1846); Kennedy & Hancock, p. 577, Pl. 1, Figs 4, 7.
1995. *Pseudophyllites indra* (Forbes, 1846); Cobban & Kennedy, p. 4, Figs 2.1-2.4, 2.10.
1997. *Pseudophyllites indra* (Forbes, 1846); Kennedy & Christensen, p. 85, Fig. 6D.
1997. *Pseudophyllites indra* (Forbes, 1846); Kennedy & Kaplan, p. 37, Pls 1-3.

1997. *Pseudophyllites indra* (Forbes, 1846); Alabushev & Wiedmann, p. 7, Pl. 1, Figs 6-7.

Dimensions	D	Wb	Wh	Wb:Wh	U
PCZ 13535	413.0	159.0(38.5)	-	-	-
PCZ 13536	372	139(37.4)	-	-	-
PCZ 13538	384	135(35.2)	-	-	-
PCZ 13541	-	175	221	0.79	-
PCZ 13548	-	163	192	0.85	-
PCZ 13568	438	-	192(43.8)	-	-
PCZ 13569	-	-	153	-	-
PCZ13571	429	189(44.1)	221(51.5)	0.85	59(13.8)
PCZ 13572	357	146(40.9)	177(49.6)	0.82	64(17.9)

LECTOTYPE: The lectotype is BMNH C51068, the original of Forbes, 1846, Pl. 11, Figs 7a, b, from the Valudavur Formation of Pondicherry, south India, designated by Kennedy & Klinger 1977, p. 182.

MATERIAL: SAM PCZ 12923, 13888-13890, 13535-13586.

DESCRIPTION: All specimens are wholly septate fragments, preserved as internal moulds with traces of aragonitic shell. Coiling was very involute, with a small, deep umbilicus, the umbilical wall broadly convex and outwardly inclined, the umbilical shoulder broadly rounded. The greatest whorl breadth is below mid-flank, the inner to middle flanks broadly convex, the outer flanks converging to a broadly and evenly rounded venter. The only surviving traces of ornament are narrow, prorsiradiate, irregularly developed fold-like ribs, most prominent on the umbilical shoulder and innermost flank (Pl. 2, Fig. 7). Suture deeply and intricately subdivided, with L deeper than E, and asymmetrically bifid; the external saddle is narrow, and lanceolate. There is a massive septal lobe (Pl. 2, Figs 1, 2, 4-6).

DISCUSSION: Differences between *Pseudophyllites indra* and other species of the genus are discussed by Kennedy & Klinger (1977) and Kennedy (1986). The whorl section, septal lobe, and form of the external saddle all indicate that these specimens belong to the type species, *P. indra*.

OCCURRENCE: *Pseudophyllites indra* may appear as early as the Santonian, and has a definite range from Lower Campanian to uppermost Maastrichtian. The geographic range is Sweden, Northern Ireland, Germany, Poland, Austria, southwest France, Spain, New Jersey, the U.S. Gulf Coast, British Columbia, Alaska, Saghalin, Japan, Chile, Brazil, western Australia, New Zealand, Zululand, South India, and Madagascar.

Suborder Ammonitina Hyatt, 1889
Superfamily Desmocerataceae Zittel, 1895
Family Desmoceratidae Zittel, 1895
Subfamily Desmoceratinae Zittel, 1895
Genus *Desmophyllites* Spath, 1929

(= *Schlüteria* de Grossouvre, 1894 (*non* Fritsch *in* Fritsch & Kafka 1887)); *Schluetericeras* Collignon, 1938 (*non* Hyatt, 1903)).

TYPE SPECIES: *Desmoceras larteti* Seunes, 1891, p. 19, Pl. 12(3), Fig. 2; Pl. 13(4), Figs 2-3 by subsequent designation by Spath (1921, p. 46) as type species of *Schluteria* of which *Desmophyllites* is the replacement name.

Desmophyllites diphylloides (Forbes, 1846)

(Pl. 3, Figs 1-3)

1846. *Ammonites diphylloides* Forbes, p. 105, Pl. 8, Fig. 8.

1985. *Desmophyllites diphylloides* (Forbes); Henderson & Mcnamara, p. 54, Pl. 4, Figs 1-4 (with synonymy).

1992. *Desmophyllites diphylloides* (Forbes); Kennedy & Henderson, p. 405, Pl. 6, Figs 1-9; Pl. 16, Figs 1-3, 7-8; Pl. 17, Figs 4-7; Text-fig. 3f (with full synonymy).

1995. *Desmophyllites diphylloides* (Forbes, 1846); Kennedy *in* Kennedy, Bilotte & Melchior, p. 397, Pl. 4, Figs 1, 2, 6, 7, 14; Text-fig. 16.

DIMENSIONS:	D	Wb	Wh	Wb:Wh	U
SAM PCZ 12921	70.7(100)	32.1(45.4)	38.3(54.2)	0.34	7.0(9.9)

DESCRIPTION: SAM PCZ 12921 is a well-preserved internal mould retaining traces of aragonitic shell. It is septate to a diameter of 64.8 mm, and retains parts of a further 120° sector of body chamber. Coiling is very involute. The tiny, deep umbilicus comprises only 9.9% of the diameter. The umbilical wall is flattened, the umbilical shoulder narrowly rounded. The whorl section is compressed, with a whorl breadth to height ratio of 0.84. The flanks are flattened and subparallel, the ventrolateral shoulders and venter broadly and evenly rounded. The surface of the internal mould bears prominent constrictions, 3 on the last half whorl of the phragmocone, and a further 3 on the 120° sector of body chamber, where they are much deeper and more prominent (Pl. 3, Fig. 2). The constrictions are concave on the umbilical wall, shoulder and inner flank, markedly prorsiradiate, and feebly flexuous on the flanks, feebly convex at mid-flank and feebly concave on the outer flank, projected forwards on the ventrolateral shoulder, to cross the venter in a broadly convex, linguoid peak. The suture has a trifid L, equal in depth to U, with five minor lobes on the dorsal part of the flanks.

DISCUSSION: This near-complete specimen is identical to the Western Australian specimens referred to this species by Henderson & McNamara (1985). *Desmophyllites larteti* (Seunes, 1891) (see description by Kennedy & Summesberger 1984, p. 156; Kennedy & Hancock 1993, p. 154) has a more compressed whorl section and prominent biconcave constrictions. As shown by Henderson & Mcnamara (1985, p. 56), the Pondoland specimens described respectively as *Schlüteria woodsi* by Spath (1921, p. 15, Pl. 7, Fig. 1) and as *Desmoceras simplex* and *Desmoceras crassum* by van Hoepen (1921, p. 19, Pl. 3, Figs 11-16; Text-fig. 10; p. 20, Pl. 4, Figs 3, 5; Text-fig. 11) are clear synonyms of *D. diphylloides*.

OCCURRENCE: The species ranges from Lower Santonian to Upper Maastrichtian, with records from south India, Western Australia, Japan, Alaska, British Columbia, California, Argentina, Pondoland and Zululand, Tunisia and south-eastern France.

Family Pachydiscidae Spath, 1922
Genus and subgenus *Pachydiscus (Pachydiscus)* Zittel, 1884

TYPE SPECIES: *Ammonites neubergicus* von Hauer, 1858, p. 12, Pl. 2, Figs 1-3; Pl. 3, Figs 1-2) by the subsequent designation of de Grossouvre (1894, p. 177).

Pachydiscus (Pachydiscus) australis Henderson & McNamara, 1985
(Pls 4-7; Text-fig. 2)

1941. *Pachydiscus* sp. nov? Spath, p. 46.
1985. *Pachydiscus (Pachydiscus) jacquoti australis* Henderson & McNamara, p. 76, Pl. 8, Figs 1, 2, 7-10; Text-figs 12a, 13b, 14, 15a.

TYPES: The holotype is no. 80.1004 in the collections of the Western Australia Museum, the original of Henderson & McNamara, 1985, p. 76, Text-fig. 15a, from the Upper Maastrichtian Miria Formation 3-6 km NNW of Whitlock Dam, Giralia Station, Giralia Range, Western Australia. There are 15 paratypes.

MATERIAL: SAM PCZ 12924, 12925, 13892-13904, 15817-16007.

DIMENSIONS

(costal):	D	Wb	Wh	Wb:Wh	U
SAM PCZ 13892	62.0(100)	28.9(46.6)	28.9(46.6)	1.0	16.0(25.8)
SAM PCZ 13894	80.4(100)	-(-)	35.2(43.8)	-	21.9(27.2)
SAM PCZ 12924	84.2(100)	31.7(37.6)	37.2(44.2)	0.85	24.6(29.2)
SAM PCZ 13896		35.9(-)	36.2(-)	0.99	
SAM PCZ 13895		37.5(-)	37.6(-)	1.0	
SAM PCZ 12925		44.5(-)	45.7(-)	0.97	
SAM PCZ 13897	104.6(100)	42.4(40.5)	45.2(43.2)	0.93	29.9(28.5)
SAM PCZ 13898		54.4(-)	61.3(-)	0.89	
SAM PCZ 13899	145.0(100)	-(-)	64.9(44.7)	-	36.9(25.4)
SAM PCZ 13900	147.0(100)	60.3(41.0)	72.0(49.0)	0.84	34.4(23.4)
SAM PCZ 13902	151.0(100)	57.1(37.8)	65.0(43.6)	0.87	41.9(27.7)
SAM PCZ 13904	175.0(100)	-(-)	78.6(44.9)	-	50.5(28.9)

DESCRIPTION: Coiling moderately involute, with 70% approximately of the previous whorl covered. Umbilicus small (23-29% of diameter), of moderate depth, with a broadly rounded wall and more narrowly rounded umbilical shoulder. The whorls expand slowly. Whorl breadth to height ratio varies from 0.84 to 1.0, the whorl section ovoid, with the greatest breadth just outside the umbilical shoulder in intercostal section, and at the umbilical bullae in costal section.

The earliest growth stages are smooth. The first ornament to appear is blunt umbilical bullae, 5-6 per half whorl, which are present from 15 mm diameter and perhaps earlier.

In middle growth (Pl. 4, Figs 1-3, 8, 9), 5-6 coarse bullae per half whorl perch on the umbilical shoulder, and give rise to low, broad, coarse prorsiradiate ribs that efface on the outer flanks and are absent over the venter. The change to the succeeding growth stage occurs at 50-60 mm diameter (Pl. 4, Figs 4, 9; Pl. 5). Ten to twelve coarse, strong umbilical bullae perch on the umbilical shoulder. They give rise to low, broad, coarse, recti- to feebly prorsiradiate ribs. These are straight on the inner to mid-flank region, weaken at mid-flank, before strengthening and passing slightly forwards across the outer flank and ventrolateral shoulder to cross the venter in a very shallow convexity. Ribs may occasionally be loosely linked in pairs to umbilical bullae. Coarse intercalated ribs arise on the outer flank, and strengthen to match the primary ribs on ventrolateral shoulders and venter, where they number 35-37 per whorl (Pls 6, 7). From 100-120 mm onwards, there is a progressive change in ornament; bullae may elongate and weaken progressively, and flank ribbing may efface (Pl. 6).

Only one specimen (SAM PCZ 13904: Text-fig. 2) retains the adult body chamber. The last septum is at an estimated diameter of 120 mm; the 240° sector of body chamber extends to a maximum preserved diameter of 175 mm. The coiling becomes slightly eccentric, the umbilical seam migrating outwards. The umbilical wall is feebly convex and outward-inclined, the ventrolateral shoulders broadly rounded. The flanks are flattened and convergent, the venter wide and very feebly convex. There are eight primary ribs on the body chamber. At the adapical end they are weakly bullate: towards the aperture the bullae weaken to leave widely separated concave ribs on umbilical shoulder and inner flank. They are markedly prorsiradiate on the inner flank, efface across the mid-flank region and are represented by low, obscure folds across the venter. Suture intricately and complexly subdivided; typical for genus.

DISCUSSION: This is the commonest ammonite in the collection from Richards Bay, but most of the specimens listed above are either fragments of phragmocone or parts of external moulds only. HENDERSON &

Fig. 2. *Pachydiscus* (*Pachydiscus*) *australis* HENDERSON & MCNAMARA, 1985. SAM PCZ 13904, a nearly complete adult. The maximum preserved diameter is 175 mm. Figure × 1

McNamara (1985) distinguished *australis* as a subspecies of *Pachydiscus (P.) jacquoti* Seunes, 1890, noting that the inner whorls of the two species were indistinguishable to a diameter of 80 mm, but that above that diameter, intercalated ribs were absent in *jacquoti*, but persisted in *australis*. This same difference is apparent in the present material referred to *australis*, but the appearance of the two taxa in middle and late growth, *jacquoti* with only feeble mid to outer flank ornament and very distant ribs that efface on the venter (Kennedy 1986b, Pl. 6) is so different from the coarsely and robustly ribbed shell of *australis* at the same diameter (for example Pls 5-7) that they are afforded specific status here. Henderson & McNamara (1985) illustrated phragmocones only of their *australis*; the single adult in the present collections (Text-fig. 2), 275 mm in diameter, reaches maturity at a smaller size than the holotype of *australis*, which is still septate at 250 mm diameter. The present assemblage appears to have equidimensional to slightly compressed whorls; the Australian type material includes substantially stouter individuals with whorl breadths of up to 1.19.

OCCURRENCE: Upper Maastrichtian of Western Australia and Zululand, South Africa.

Genus *Menuites* Spath, 1922

(= *Anapachydiscus* Yabe & Shimizu, 1926, p. 172; *Neopachydiscus* Yabe & Shimizu, 1926; *Besaireites* Collignon, 1931; *Cobbanoscaphites* Collignon, 1969).

TYPE SPECIES: *Ammonites menu* Forbes, 1846, p. 111, pl. 10, fig. 1, by original designation by Spath 1922, p. 123.

DISCUSSION: The type species of *Menuites* is a small form developing prominent ventral tubercles on the body chamber, originally described from the Upper Maastrichtian of South India, and here regarded as a microconch. No associated macroconch has been recognized in association with the type species, but other tuberculate microconchs referrable to *Menuites* have been described in association with larger, nontuberculate individuals that have been assigned to the genus *Anapachydiscus* and regarded as macroconchs. The microconch/macroconch pairs have identical early whorls, differing in their later whorls and size at maturity. This relationship has been recognized in *Menuites portlocki complexus* (Hall & Meek, 1856) and *Menuites oralensis* Cobban & Kennedy, 1993, and the same relationship exists between the type species of *Anapachydiscus*, *A. fascicostatus* (Yabe *in* Yabe & Shimizu 1921) and *Menuites sandai* Matsumoto, 1984, and it is likely that all small, bituberculate pachydiscids are microconchs with a corresponding larger, nontuberculate macroconch (see Kennedy & Summesberger 1984, Kennedy 1986a, Cobban & Kennedy 1993, Davis *& al*. 1996 and Kennedy & Kaplan 1997).

Menuites fresvillensis (Seunes, 1890)
(Plate 8; Text-fig. 3)

1890. *Pachydiscus fresvillensis* Seunes, p. 3, Pl. 2(1), fig. 1.
1986b. *Anapachydiscus fresvillensis* (Seunes, 1890a); Kennedy, p. 42, Pl. 7; Pl. 8; Pl. 9, Figs 1-3; Text-figs 3m, n, 1, 4a (with synonymy).
1993. *Anapachydiscus fresvillensis* (Seunes, 1890a); Ward & Kennedy, p. 39, Text-figs 35.3, 35.5, 35.6, 36.1, 36.2, 37.1-37.6, 38.1-38.3, 40.8, 45.1 (with synonymy).
1993. *Menuites fresvillensis* (Seunes, 1890a); Kennedy & Hancock, p. 588, Pl. 3, Figs 4, 5, 7; Pl. 4, Figs 3, 4, 6; Pl. 5, Figs 1-5; Pl. 6, Figs 4, 5; Pl. 7, Figs 1-6.
1999. *Menuites fresvillensis* (Seunes, 1890a); Kennedy *in* Fatmi & Kennedy, p. 651, Text-figs 5.6, 5.7.

TYPES: Lectotype, by the subsequent designation of Kennedy, 1986, p. 44, is the original of Seunes 1890, Pl. 2(1), no. A1186 in the collections of the Université Claude-Bernard, Lyon, from the Upper Maastrichtian Calcaire à *Baculites* of Fresville, Manche, France.

MATERIAL: NMB D3080; SAM PCZ 13891.

DIMENSIONS:	D	Wb	Wh	Wb:Wh	U
NMB 3080	147.0(100)	69.7(47.4)	79.2(53.9)	0.88	22.0(15.0)

DESCRIPTION: NMB 3080 (Pl. 8) is a phragmocone 147 mm in diameter, with traces of aragonitic shell preserved. Coiling is very involute, with 88% of the previous whorl covered. The umbilicus is small (15% of the diameter), deep, with a convex, undercut wall on the internal mould. The umbilical shoulder is broadly rounded, the whorl section compressed (whorl breadth to height ratio 0.88), with the greatest breadth below mid-flank. The inner to mid-flank region is broadly convex, the outer flanks convergent, the ventrolateral shoulders and venter broadly and evenly rounded.

Little is visible of the ornament of the penultimate whorl other than coarse umbilical bullae, five per half whorl. On the outer whorl, ten progressively effacing bullae perch on the umbilical shoulder. At the adapical end of the outer whorl they are coarse, circular, and flat-topped. As size increases, the ribs elongate and become much less conspicuous. The bullae extend across the umbilical wall as a low, broad rib. On the flanks the ribs give rise to one or two narrow, straight, prorsiradiate primary ribs, separated by one or two long or short intercalated ribs, to give a total of approximately 40 ribs per whorl. The ribs are straight on the inner to middle flanks, effacing somewhat on the mid-flank region. They sweep forwards, strengthen, and are feebly convex on the outermost flanks and ventrolateral shoulder. They strengthen further on the venter, which they cross in a broad convexity. The ribs are interrupted by a pronounced narrow siphonal groove on the internal mould that corresponded to a narrow ridge on the shell interior. The incompletely exposed suture line is deeply and intricately subdivided.

SAM PCZ 13891 (Text-fig. 3) is still septate at 180 mm diameter, and retains the same type of ornament as the adapertural part of the outer whorl of NMB 3080.

DISCUSSION: The present specimens differ in no significant respects from the lectotype (refigured by KENNEDY 1986, Pl. 7), and well-preserved Australian specimens figured by HENDERSON & MCNAMARA (1985).

OCCURRENCE: Upper Maastrichtian, Manche, Haute-Garonne and Landes in France, northern Spain, The Netherlands, the former Yugoslavia, Armenia, Pakistan, south India, Zululand, South Africa, Madagascar, western Australia, Chile, and possibly Brazil.

Suborder Ancyloceratina WIEDMANN, 1966
Family Diplomoceratidae SPATH, 1926
Subfamily Diplomoceratinae SPATH, 1926
Genus *Diplomoceras* HYATT, 1900

TYPE SPECIES: *Baculites cylindracea* DEFRANCE 1816, p. 160, by original designation by HYATT 1900, p. 571.

Diplomoceras cylindraceum (DEFRANCE, 1816)
(Pl. 9, Figs 8-11)

1816. *Baculites cylindracea* DEFRANCE, p. 160.

1992. *Diplomoceras cylindraceum* (DEFRANCE, 1816); HENDERSON, KENNEDY & MCNAMARA, p. 140, Figs 5, 6a-e, h, k (with synonymy).

1993. *Diplomoceras cylindraceum* (DEFRANCE, 1816); KENNEDY, p. 106, Pl. 2, Fig. 20.

1993. *Diplomoceras cylindraceum* (DEFRANCE, 1816); HANCOCK & KENNEDY, p. 164, Pl. 15, Fig. 15; Pl. 17, Figs 1-4.

1993. *Diplomoceras cylindraceum* (DEFRANCE, 1816); WARD & KENNEDY, p. 49, Text-figs 42, 43.16, 43.17 (with additional synonymy).

1993. *Diplomoceras cylindraceum* (DEFRANCE, 1816); BIRKELUND, p. 51, Pl. 3, Figs 3, 4; Pl. 9, Fig. 1; Pl. 11, Figs 1-5; Pl. 12.

1996. *Diplomoceras cylindraceum* (DEFRANCE, 1816); MACHALSKI, p. 953, Text-fig. 2.

1999. *Diplomoceras cylindraceum* (DEFRANCE, 1816); KENNEDY *in* FATMI & KENNEDY, p. 653, Text-figs 12.1-12.5

TYPE: Neotype, designated by KENNEDY 1987, p. 183, is no. 10511 in the collections of the Institut Royal des Sciences Naturelles de Belgique, from the Upper Maastrichtian of St. Pietersberg, Maastricht, the Netherlands, figured by KENNEDY 1987, Pl. 24, Figs 1-3.

MATERIAL: SAM PCZ 13910-13911.

DESCRIPTION: SAM PCZ 13910 (Pl. 9, Figs 8-11) is a wholly septate internal mould 66.3 mm long, with a whorl height of 41.7 mm, and a whorl breadth to height ratio of 0.97. The whorl section is slightly subcircular; there is no ornament. SAM PCZ 13911 (not figured) is also wholly septate, 117 mm long, with a whorl height of 70.1 mm, and a whorl breadth to height ratio of 0.99. This specimen retains traces of aragonitic shell, with crowded, dense, even ribs that are feebly prorsiradiate on the flanks, and transverse on both dorsum and venter; the rib index is 16. The internal mould is smooth. Suture deeply incised, typical for genus.

DISCUSSION: These fragments are altogether typical of *D. cylindraceum*, and fall well within the limits of variation of the material from Maastricht, the Netherlands documented by KENNEDY (1987), where the whorl breadth to height ratio varies from 0.77-1.02, the rib index from 15-17 at whorl heights of 55-60 mm, and up to 20 in larger fragments. See WARD & KENNEDY (1993, p. 51) for further discussion.

OCCURRENCE: *Diplomoceras cylindraceum* first occurs in the Upper Campanian (e.g. MACHALSKI 1996) and ranges to the top of the Maastrichtian. The geographic distribution is north and southwest France, northern Spain, Belgium, The Netherlands, Germany, Denmark, Poland, Austria, Ukraine, Bulgaria, Zululand, South Africa, Madagascar, Pakistan, south India, western Australia, possibly New Zealand, the Antarctic Peninsula, Chile, Argentina, Brazil, Japan, California, Alaska, British Columbia (Canada), and Greenland. ALABUSHEV & WIEDMANN (1997, p. 15) recorded what they identified as *D. notabile* from the Lower Campanian of Sakhalin.

Family Baculitidae GILL, 1871
Genus *Baculites* LAMARCK, 1799

TYPE SPECIES: *Baculites vertebralis* LAMARCK, 1801, p. 103, by the subsequent designation of MEEK, 1876, p. 391.

Baculites ambatryensis COLLIGNON, 1971
(Pl. 2, Figs 4-6; Text-fig. 4)

1971. *Baculites ambatryensis* COLLIGNON, p. 15, Pl. 645, Fig. 2392.

1999. *Baculites ambatryensis* COLLIGNON, 1971; KENNEDY *in* FATMI & KENNEDY, p. 657, Text-figs 13.1-13.18, 13.23-13.28, 16.1, 16.4, 16.5.

MATERIAL: SAM PCZ 12926, 13912.

DESCRIPTION: Both specimens are internal moulds of body chambers that retain traces of aragonitic shell.

Fig. 3. *Menuites fresvillensis* (SEUNES, 1890). SAM PCZ 13891. The maximum preserved diameter is 180 mm. Figure × 0.9

SAM PCZ 13912 (Pl. 3, Figs 4-6) is 97 mm long, with a maximum preserved whorl height of 28.8 mm, and a whorl breadth to height ratio of 0.7. The whorl section is compressed ovoid, the dorsum feebly convex, the flanks broadly rounded, converging to a relatively narrowly rounded venter. The dorsum and flanks are smooth, the venter bears coarse, low, broad, rounded ribs. PCZ 12926 is a 105.7 mm long fragment with a maximum preserved whorl height of 38.7 mm, and a whorl breadth to height ratio of 0.72. The dorsum is flattened, perhaps as a result of *post-mortem* distortion; there is no ornament.

DISCUSSION: *Baculites ambatryensis* was recently reviewed and intraspecific variation described by Kennedy (*in* FATMI & KENNEDY 1999); the present specimens clearly fall into the variation range of the Pakistan material; SAM PCZ 13912 (Pl. 2, Figs 4-6) corresponds closely to the Madagascan holotype (Text-fig. 4).

OCCURRENCE: Maastrichtian (?Upper) of Madagascar; Upper Maastrichtian of Zululand, South Africa, and Pakistan.

Genus *Eubaculites* SPATH, 1926
(= *Giralites* BRUNNSCHWEILER, 1966; *Cardabites* BRUNNSCHWEILER, 1966; *Eubaculiceras* BRUNNSCHWEILER, 1966)

TYPE SPECIES: *Baculites vagina* FORBES var. *ootacodensis* STOLICZKA, 1866, p. 199, Pl. 90, Fig. 14, by original designation of SPATH 1926, p. 80, = *Baculites labyrinthicus* MORTON, 1834, p. 44, Pl. 13, Fig. 10.

Eubaculites carinatus (MORTON, 1834)
(Pl. 9, Figs 1-7; Pl. 10, Figs 1-3; Text-fig. 5)

1834. *Baculites carinatus* MORTON, p. 44, Pl. 13, Fig. 1.

1995. *Eubaculites labyrinthicus* (MORTON, 1834); COBBAN & KENNEDY, p. 26, Text-figs 14.1, 14.5-14.7, 15.4, 15.6-15.8, 16.13-16.15, 16.23, 16.24, 16.28-16.30, 17.52-17.59, 18.1-18.44 (with full synonymy).

2000. *Eubaculites carinatus* (MORTON, 1834); KENNEDY & COBBAN, p. 180, Pl. 2, Figs 1-23, 27, 28; Text-figs 3, 4.

TYPES: Lectotype, by the subsequent designation of KENNEDY & COBBAN 1995, p. 23, is no. 72868 in the collections of the Academy of Natural Sciences of Philadelphia, the original of MORTON 1834, Pl. 13, Fig. 10. Paralectotype 72869 is in the same collections. Both specimens are from the Maastrichtian Prairie Bluff Chalk of Alabama.

Fig. 4. *Baculites ambatryensis* COLLIGNON, 1971. The holotype, the original of COLLIGNON, 1971, p. 15, Pl. 645, Fig. 2392, from the Maastrichtian of the Côte d'Ambatry, Madagascar; figures are × 1

MATERIAL: SAM PCZ 12927, 13905-13908.

DESCRIPTION: Specimens are all internal moulds with traces of the original aragonitic shell adhering. SAM PCZ 13905 is in part body chamber with a maximum preserved whorl height of 23 mm, as is SAM PCZ 13907, with a maximum preserved whorl height of 32 mm. SAM PCZ 13906 and 12927 are wholly septate with whorl heights of 29.7 and 50.1 mm respectively. SAM PCZ 13908 is body chamber with a maximum preserved whorl height of 43.4 mm. The shell is straight to slightly curved; the whorl expansion rate is low, the whorl section compressed (whorl breadth to height ratios vary from 0.69-0.71), the dorsum feebly convex to feebly concave, the dorsolateral margin narrowly rounded, dorsal flanks flattened, divergent, mid-flank region broadly convex, ventral flanks convergent, markedly concave adjacent to a narrow tabulate venter with very narrowly rounded margins. Flank ornament comprises weak to strong coarse transverse concave ribs that extend across the dorsal 75% of the flanks; on the ventral 25% they efface markedly and project strongly forwards to intersect the line of the venter at an acute angle. The rib index is 2-3. Suture (Text-fig. 5) with broad, moderately incised bifid L and L/U.

DISCUSSION: This species is comprehensively described and discussed by KLINGER & KENNEDY (1993) and COBBAN & KENNEDY (1995).

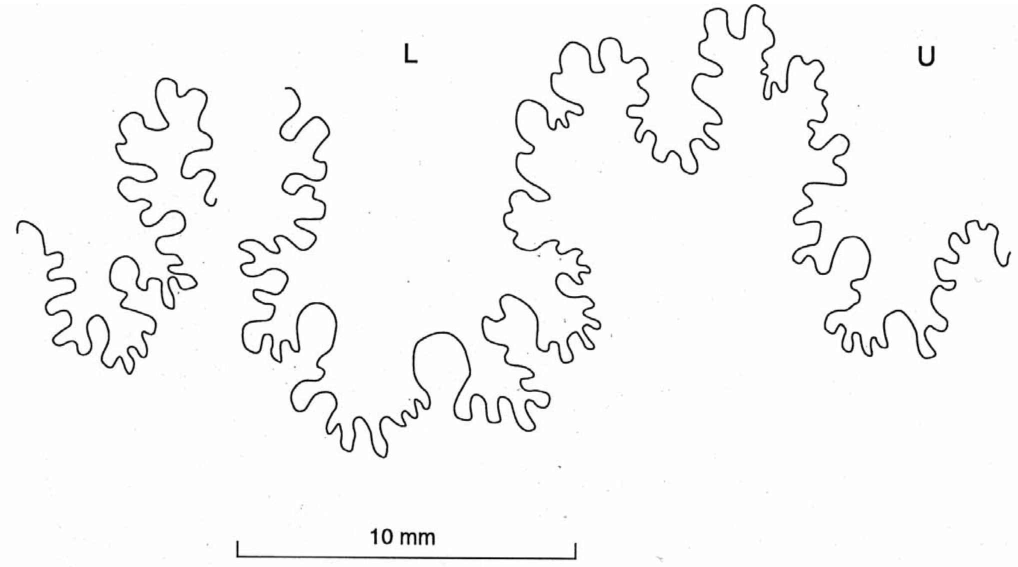

Fig. 5. Partial suture of *Eubaculites carinatus* (MORTON, 1834), SAM PCZ 13906

OCCURRENCE: Upper Lower to upper Upper Maastrichtian, The Netherlands, SW France and NW Spain, Austria, Mozambique, Zululand, South Africa, south India, Western Australia, Argentina, Chile, California, the U.S. Gulf Coast and Atlantic Seaboard.

Eubaculites latecarinatus (BRUNNSCHWEILER, 1966)
(Pl. 10, Figs 4-9; Text-fig. 6)

1993. *Eubaculites latecarinatus* (BRUNNSCHWEILER); KLINGER & KENNEDY, p. 238, Figs 26a, 39-41, 42b-c, 43-49, 50a, 53a (with full synonymy).

1997. *Eubaculites latecarinatus* (BRUNNSCHWEILER); KENNEDY & *al*., p. 20, Figs 15-16, 19.

TYPE: Holotype is the original of BRUNNSCHWEILER 1966, Pl. 4, Figs 2-4, from the nodule Bed at the top of the Korojong Calcarenite, Carnarvon Basin, Western Australia.

MATERIAL: SAM PCZ 12928-12929.

DESCRIPTION: SAM PCZ 12929 (Pl. 10, Figs 4-6) is the internal mould of a fragmentary body chamber 55.4 mm long, with a maximum preserved whorl height of 23.9 mm, and a whorl breadth to height ratio of 0.59. The dorsum is feebly convex, the dorsolateral margin narrowly rounded, the inner to mid-flank region broadly convex, the ventral flanks convergent. A narrow groove separates the flanks from the very narrowly rounded shoulders of the narrow, tabulate venter. There is no ornament. Much larger is SAM PCZ 12928 (Pl. 10, Figs 7-9), a wholly septate fragment with a maximum preserved whorl height of

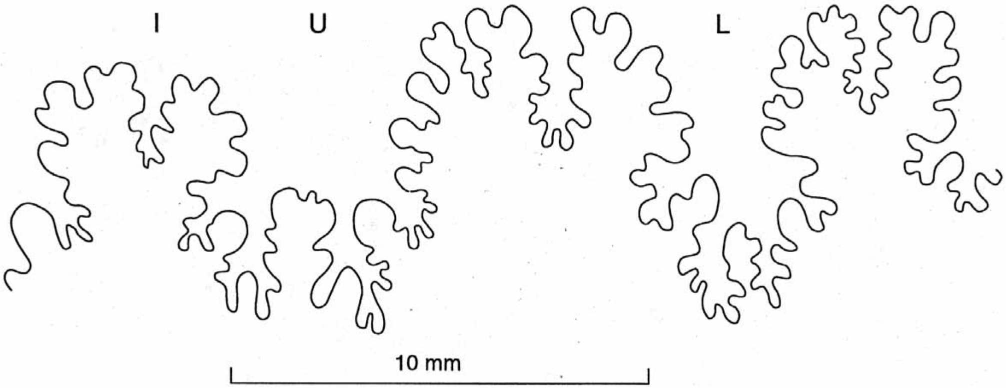

Fig. 6. *Eubaculites latecarinatus* (BRUNNSCHWEILER, 1966), SAM PCZ 13905

47.5 mm. The flanks bear irregular folds and constrictions (perhaps an artefact of *post-mortem* crushing?); the venter bears low, coarse, transverse corrugations. The suture (Text-fig. 6) has bifid, moderately incised elements with U narrower than L/U, and L and L/E relatively narrow.

OCCURRENCE: Upper Lower to upper Upper Maastrichtian, Zululand, South Africa, and offshore Alphard Group; Madagascar and western Australia.

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PLATE 1

1-8 – *Anagaudryceras politissimum* (KOSSMAT, 1895)
1 SAM PCZ 13887 (artificial cast from an external mould), 2-3 – SAM PCZ 13884, 4-5 – SAM PCZ 12922, 6-8 – SAM PCZ 13885.

All figures are × 1


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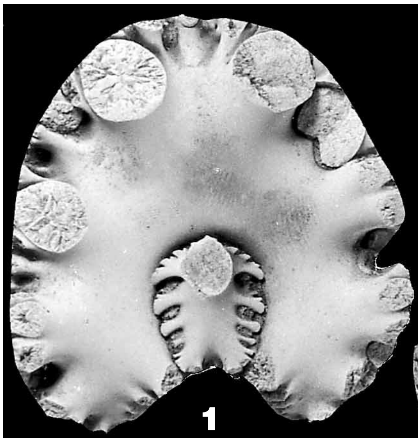
PLATE 2

1-5 – *Pseudophyllites indra* (FORBES, 1846)
1-2– SAM PCZ 13888, 3, 6, 7– SAM PCZ 13890, 4-5– SAM PCZ 13889

All figures are × 1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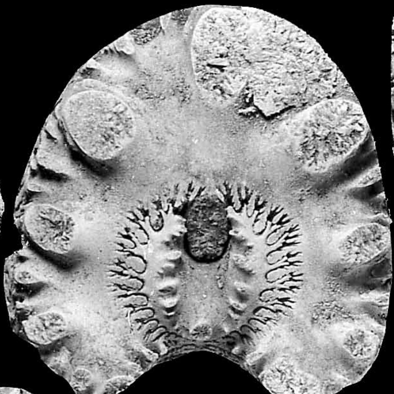
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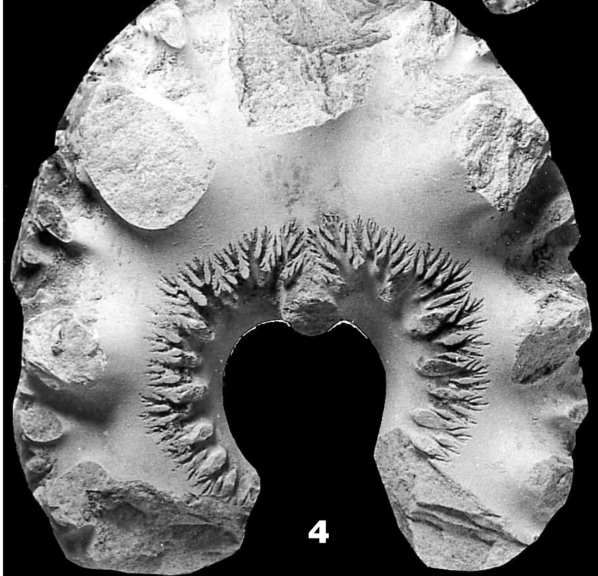
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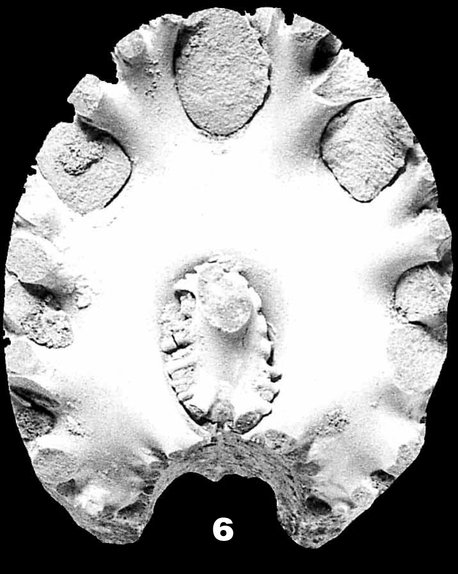
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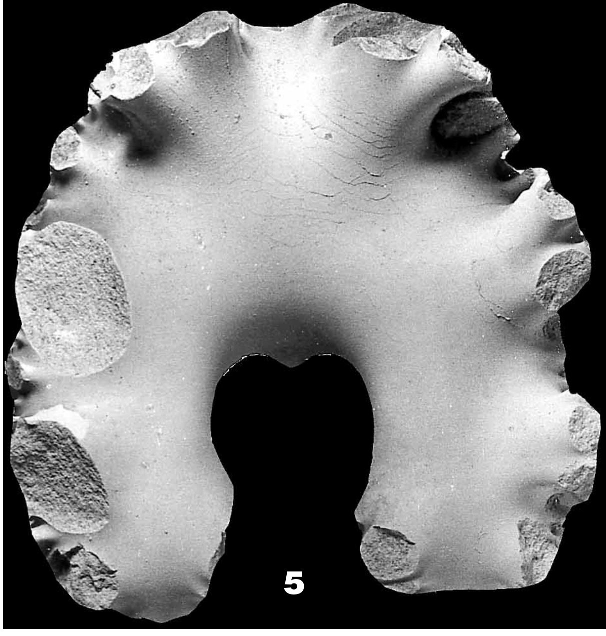
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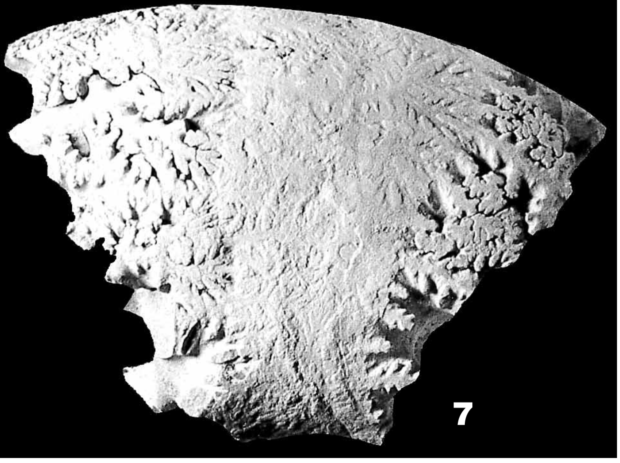
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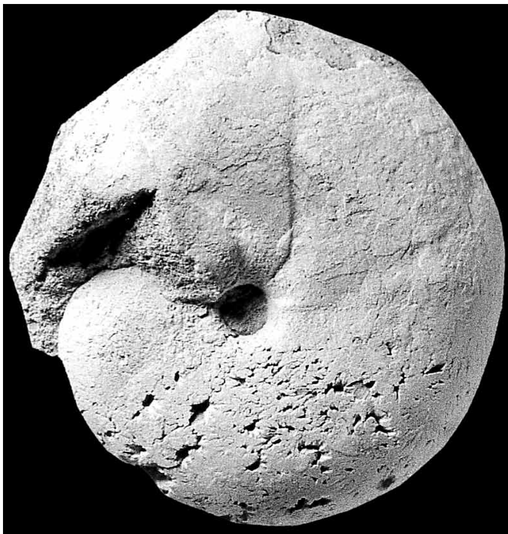
PLATE 3

1-3 – *Desmophyllites diphylloides* (FORBES, 1846); SAM PCZ 12921.
4-6 – *Baculites ambatryensis* COLLIGNON, 1971; SAM PCZ 13912.
7-8 – *Hercoglossa madagascariensis* COLLIGNON, 1949; SAM PCZ 13090.

All figures are × 1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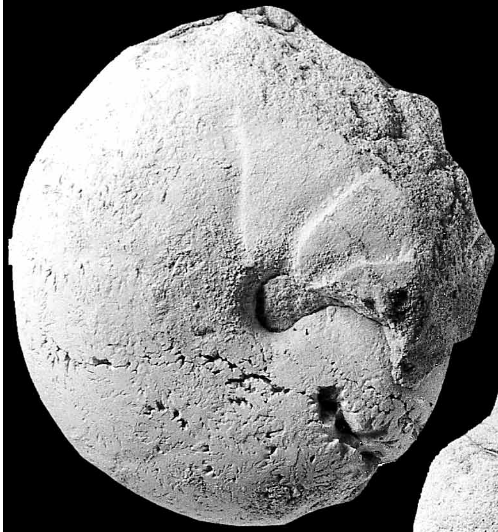
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PLATE 4

1-11 – *Pachydiscus* (*Pachydiscus*) *australis* HENDERSON & MCNAMARA, 1985
1-3– SAM PCZ 13892; 4-6– SAM PCZ 12924; 7– SAM PCZ 13896;
8-9– SAM PCZ 13894; 10-11– SAM PCZ 12925.

All figures are × 1


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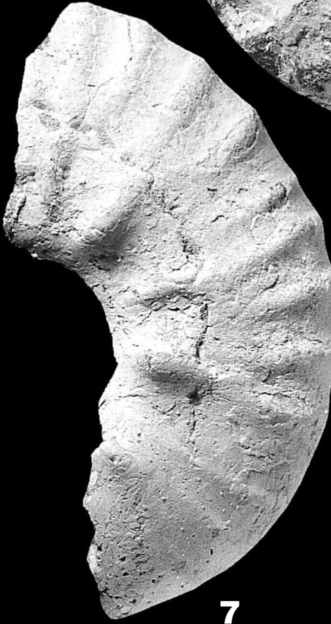
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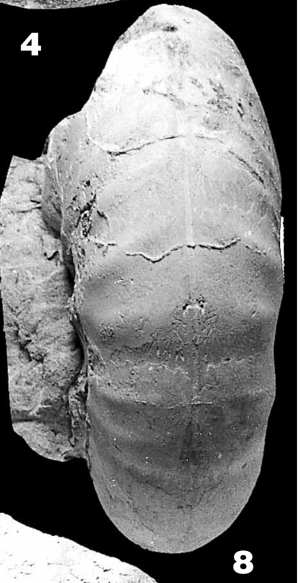
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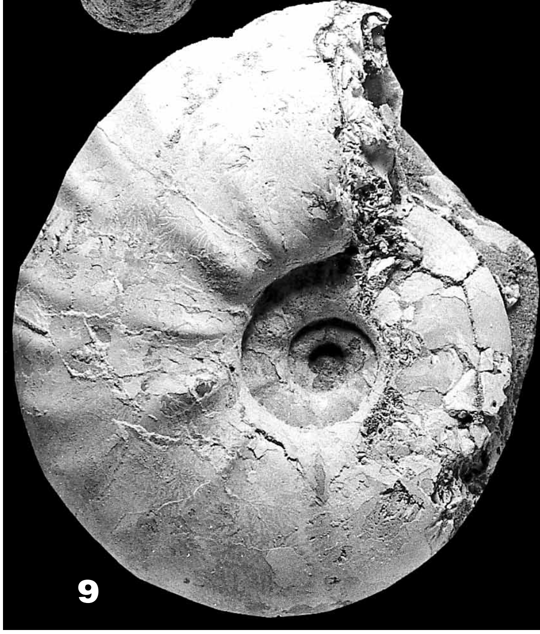
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PLATE 5

1-5 – *Pachydiscus* (*Pachydiscus*) *australis* HENDERSON & MCNAMARA, 1985
1-3– SAM PCZ 13897; 4-5– SAM PCZ 13898.

All figures are × 1


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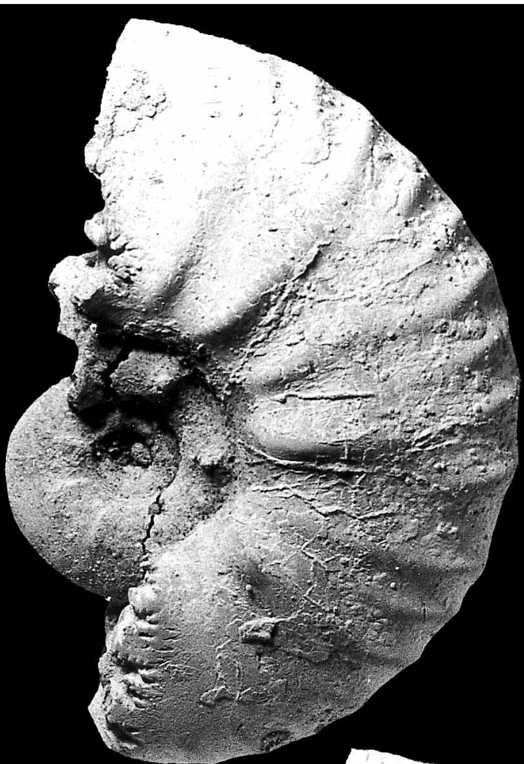
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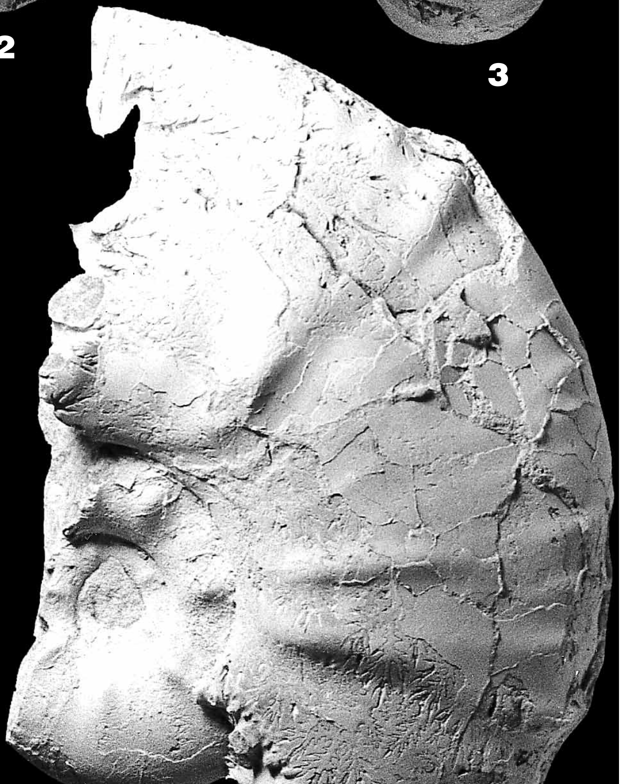
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PLATE 6

1-3 – *Pachydiscus* (*Pachydiscus*) *australis* HENDERSON & MCNAMARA, 1985
1-3 – SAM PCZ 13899

All figures are × 1

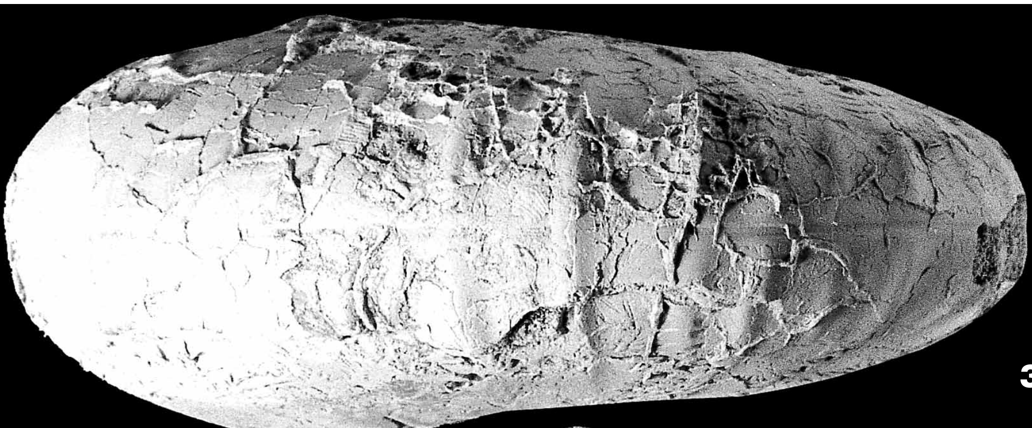

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PLATE 7

1-3 – *Pachydiscus* (*Pachydiscus*) *australis* HENDERSON & MCNAMARA, 1985
1-3 – SAM PCZ 13902.

All figures are × 1

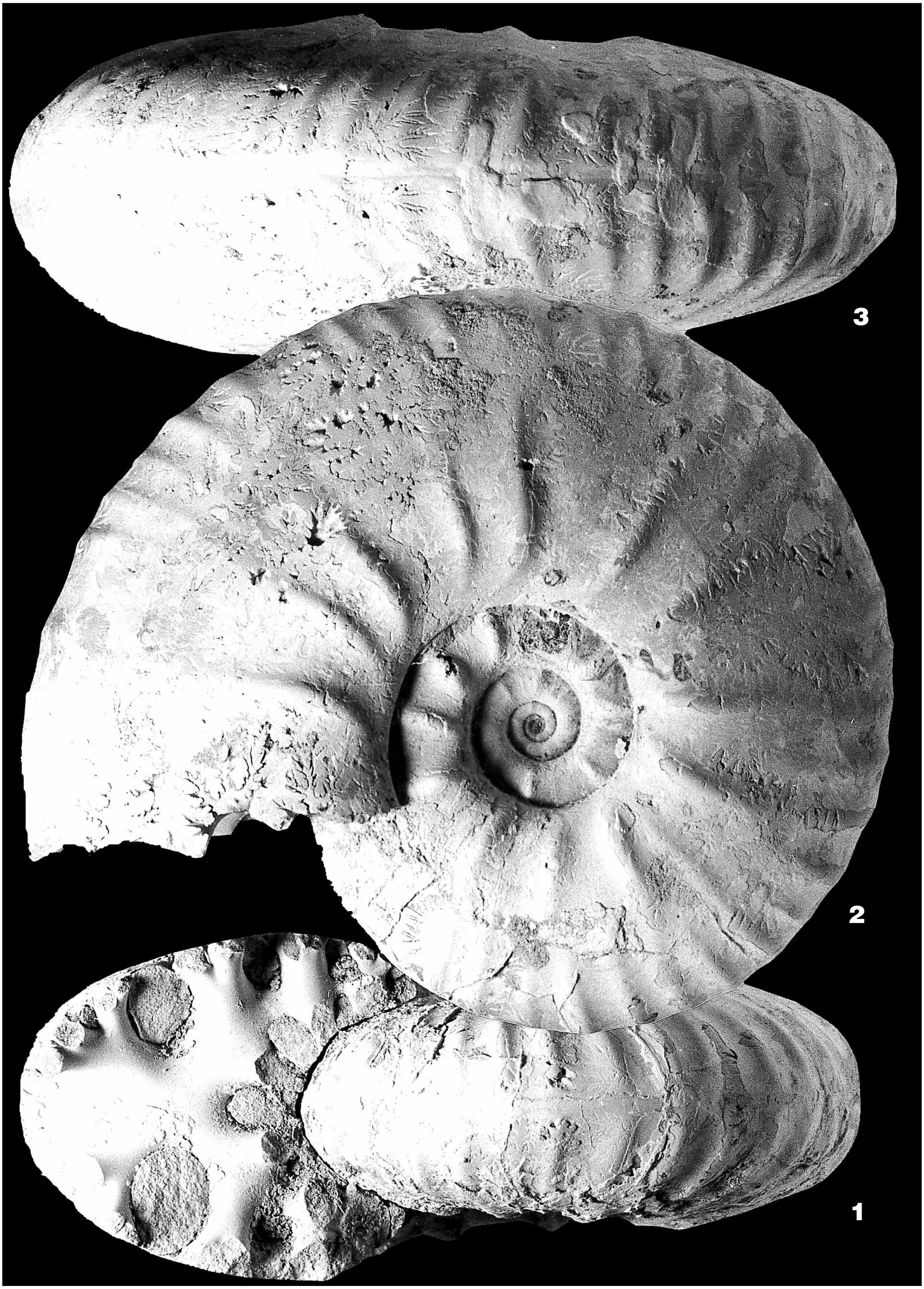
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PLATE 8

1-3 – *Menuites fresvillensis* (SEUNES, 1890)
1-3 – NMB D3080.

All figures are × 1

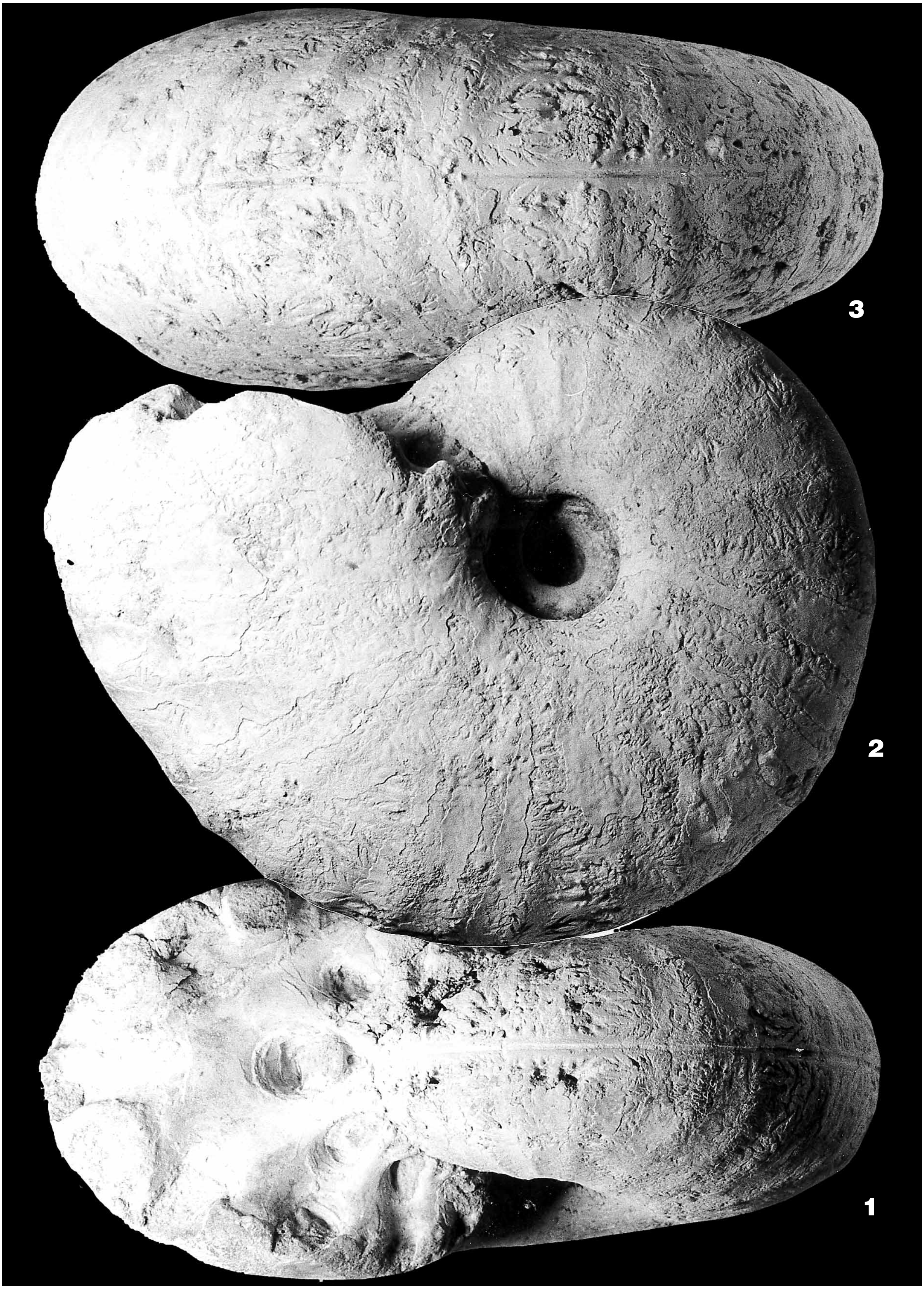
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PLATE 9

1-7 – *Eubaculites carinatus* (Morton, 1834); 1-3 – SAM PCZ 13907;
5-7 – SAM PCZ 13906.
8-11 – *Diplomoceras cylindraceum* (Defrance, 1816); SAM PCZ 13910.

All figures are × 1


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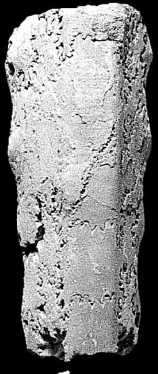
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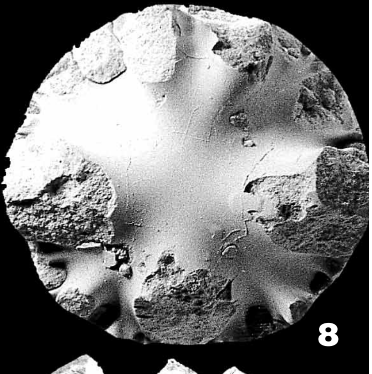
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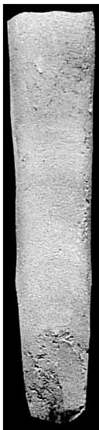
PLATE 10

1-3, 10-12 – *Eubaculites carinatus* (MORTON, 1834); 1-3 – SAM PCZ 13905; 10-12 – SAM PCZ 12927.

4-9 – *Eubaculites latecarinatus* BRUNNSCHWEILER, 1966; 4-6 – SAM PCZ 12929; 7-9 – SAM PCZ 12928.

All figures are × 1



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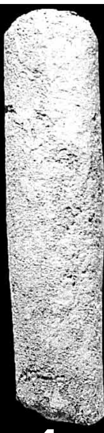

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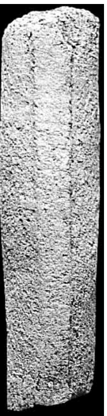

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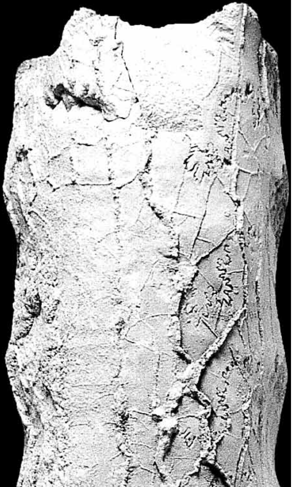

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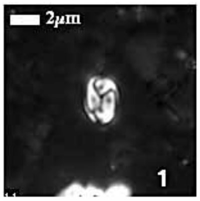
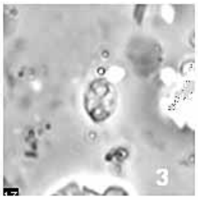
PLATE 11

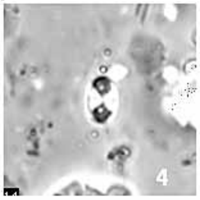
1-6 – Holococcolith sp.1 cf. *Calculites* Prins & Sissingh *in* Sissingh, 1977
    1-4 – same specimen, different rotation.
    1-2 – XP, 3-4 PC, from Sample A.
    5-6 – same specimen, different rotation, both XP, from Sample B
7-12 – Holococcolith sp.2 cf. *Calculites* Prins & Sissingh *in* Sissingh, 1977
    7-9 – same specimen, different rotation; 7-8, 10 XP, 9 PC, from sample B.
    10-12 – same specimen, different rotation, all XP, from sample A.
13-18 – *Okkolithus australis* Wind & Wise *in* Wise & Wind, 1977
    13-15 – same specimen, different rotation, 13-14 XP, 15 PC.
    16-18 – same specimen, different rotation, 16-17 XP, 18 PC, from sample A.
19-24 – *Ottavianus giannus*? Risatti, 1973
    19-20 – same specimen, different rotation, both XP, from Sample A.
    21-24 – same specimen, different rotation, 21-22 XP , 23-24, PC, from Sample B.
25-30 – *Ottavianus terrazetus*? Risatti, 1973
    25-27 – same specimen, different rotation, all XP.
    28-30 – same specimen, different rotation, all XP, from Sample A.
31-36 – *Ottavianus* cf. *O. terrazetus*? Risatti, 1973; same specimen, different rotation, all XP, from Sample A.
37-40 – *Multipartis ripleyensis*? Risatti, 1973; same specimen, different rotation, all XP, from Sample A.
41-42 – *Acuturris scotus* (Risatti, 1973) Wind & Wise *in* Wise & Wind, 1977; same specimen, different rotation, both XP, from Sample A.

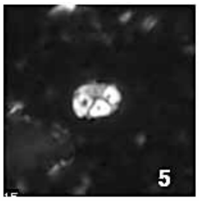
All images were captured at the same magnification. XP denotes cross-polarised image, PC denotes phase-contrast image. A 2μm bar appears on Figure 1 for scale. This plate is archived on disc in the UCL Micropalaeontology Unit as UCL-NF-1.

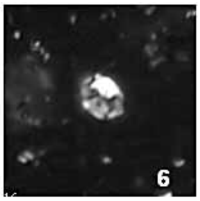
Quadriperforate





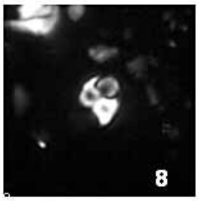


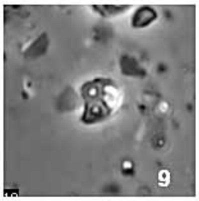


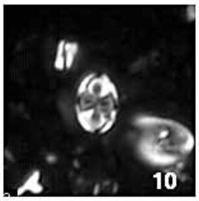


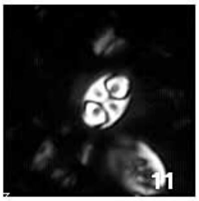
Holococcolith sp.1 cf *Calculites* (A)

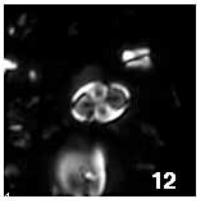
Holococcolith sp.1 cf *Calculites* (B)







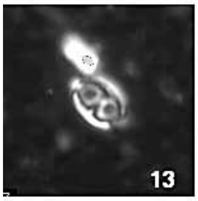


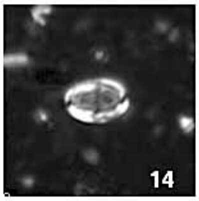


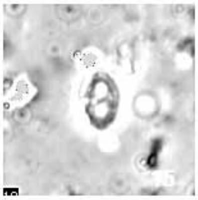
Holococcolith sp.2 cf. *Calculites* (B)

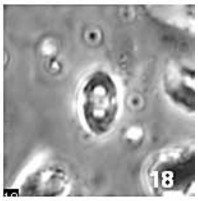
Holococcolith sp.2 cf. *Calculites* (A)

Biperforate/conjunct bar



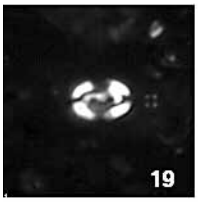


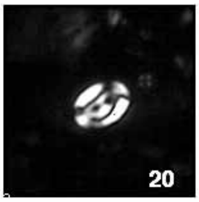


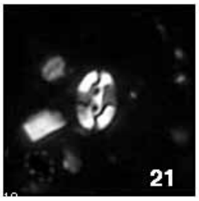


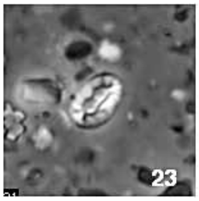
Okkolithus australis (A)

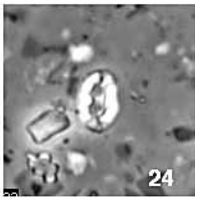
Okkolithus australis (A)





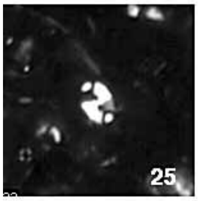


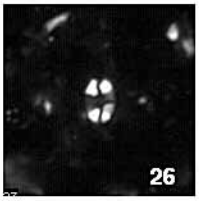


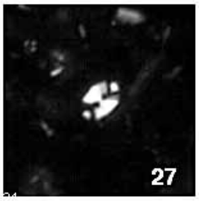


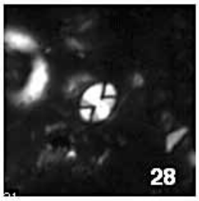
Ottavianus giannus ? (A)

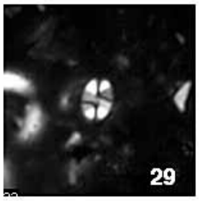
Ottavianus giannus ? (B)

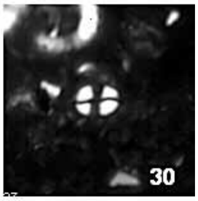






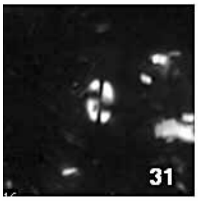


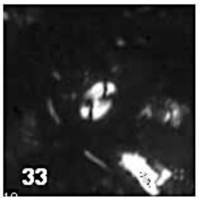


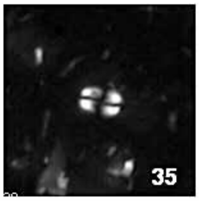


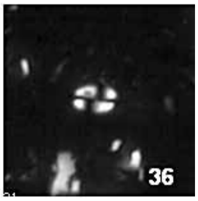
Ottavianus terrazetus ? (A)

Ottavianus terrazetus ? (A)



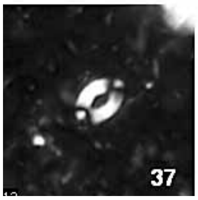


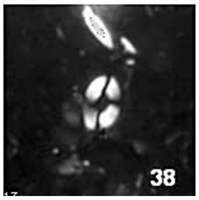


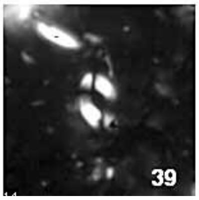


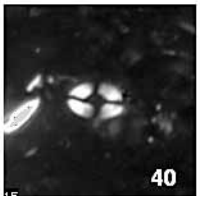
Ottavianus cf. *O. terrazetus* ? (A)

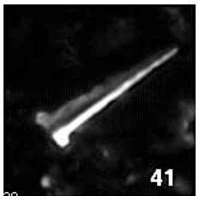
Monoperforate

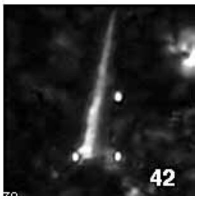












Multipartis ripleyensis ? (A)

PLATE 12

1-3 – *Multipartis* cf. *M. ripleyensis*? RISATTI, 1973; same specimen, different rotation, all XP, from Sample B.

4-9 – *'Tetralithus' mississippiensis*? RISATTI, 1973
- 4-6 – same specimen, different rotation, all XP.
- 7-9 – same specimen, different rotation, all XP, from Sample A.

10-18 – *Octolithus* cf. *O. multiplus* (PERCH-NIELSEN, 1973) ROMEIN, 1979
- 10-12 – same specimen, different rotation, all XP.
- 13-16 – same specimen, different rotation, all XP, 17-18 same specimen, different rotation, both XP, from sample A.

19-21 – *Octolithus multiplus* (PERCH-NIELSEN, 1973) ROMEIN, 1979; same specimen, different rotation, all XP, from Sample A.

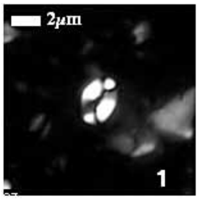
22-24 – Holococcolith sp.3 cf. *Saepiovirgata*? VAROL, 1991; same specimen, different rotation, all XP, from Sample A.

25-36 – *Munarinus lesliae* RISATTI, 1973; 25-27 same specimen, different rotation, all XP.
- 28-30 – same specimen, different rotation, all XP.
- 31-34 – same specimen, different rotation, all XP, 35-36 same specimen, different rotation, both XP, from sample A.

37-42 – *Munarinus marszalekii*? RISATTI, 1973
- 37-39 – same specimen, different rotation, 37-38 XP, 39 PC, from Sample A.
- 40-42 – same specimen, different rotation, 40-41 XP, 42 PC, from Sample B.

All images were captured at the same magnification. XP denotes cross-polarised image, PC denotes phase-contrast image. A 2μm bar appears on Figure 1 for scale. This plate is archived on disc in the UCL Micropalaeontology Unit as UCL-NF-2.

Monoperforate



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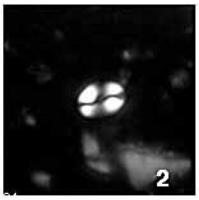
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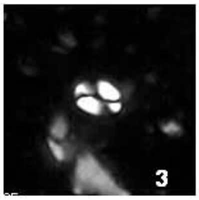
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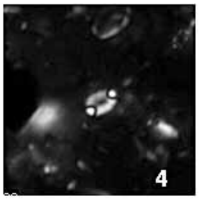
Multipartis cf. *M. ripleyensis* ? (A)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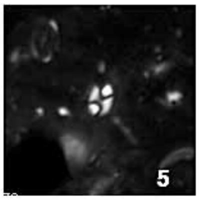
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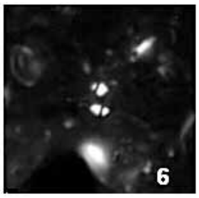
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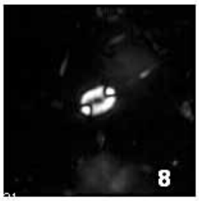
'Tetralithus' mississippiensis ? (A)


7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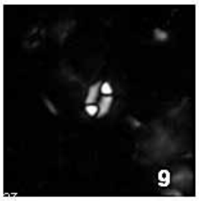
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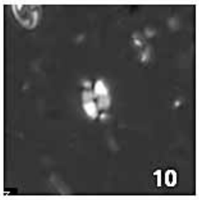
'Tetralithus' mississippiensis ? (A)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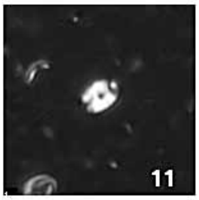
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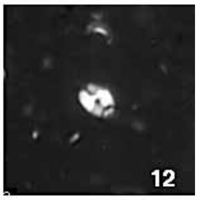
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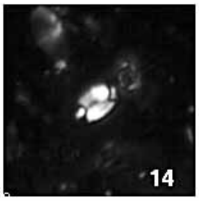
Octolithus cf. *O. multiplus* (A)


13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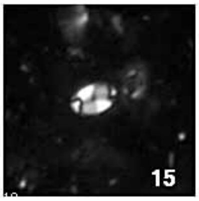
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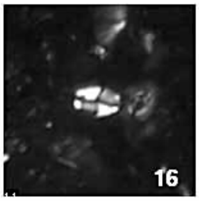
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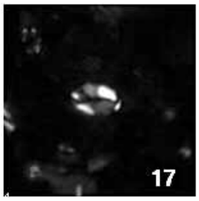
Octolithus cf. *O. multiplus* (A)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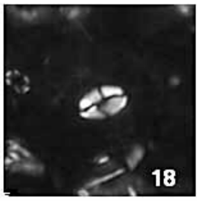
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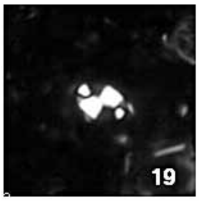
Octolithus cf. *O. multiplus* (A)

Non-perforate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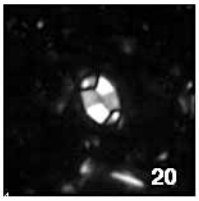
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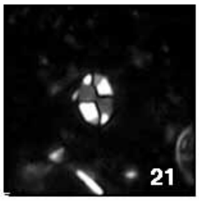
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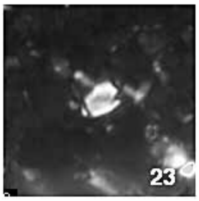
Octolithus multiplus (A)


22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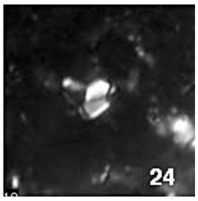
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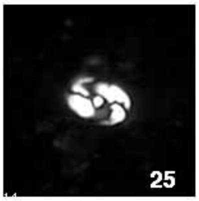
Holococcolith sp.3 cf. *Saepiovirgata* ? (A)

With bars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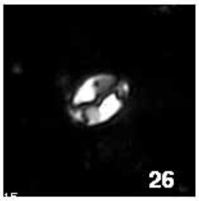
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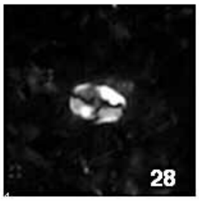
27

Munarinus lesliae (A)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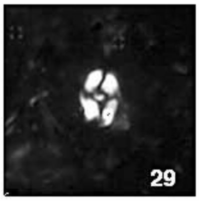
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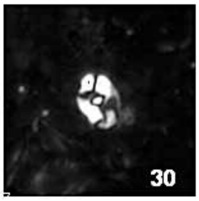
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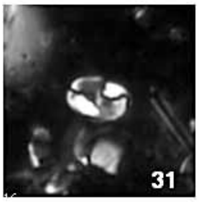
Munarinus lesliae (A)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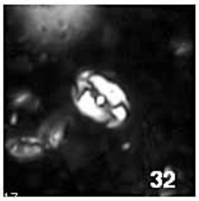
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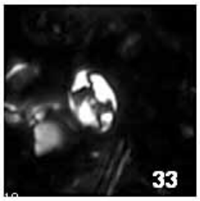
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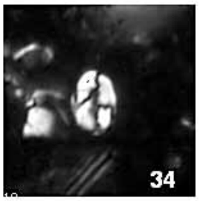
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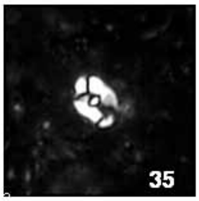
Munarinus lesliae (A)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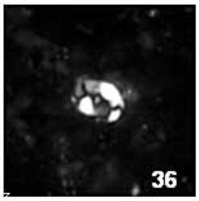
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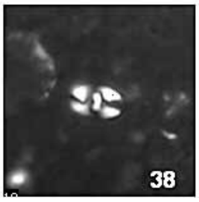
Munarinus lesliae (A)


37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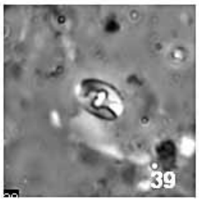
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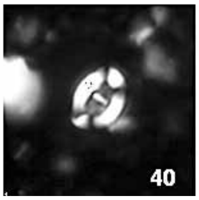
Munarinus marszalekii ? (A)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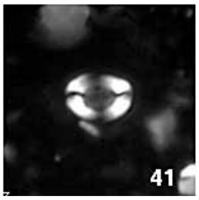
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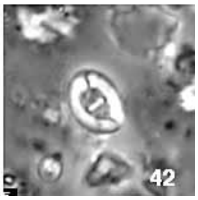
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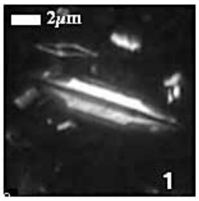
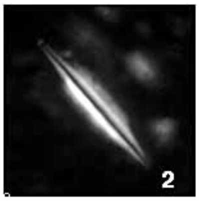
Munarinus marszalekii ? (A)

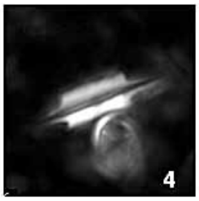
PLATE 13

1-5 – *Lithraphidites quadratus* Bramlette & Martini, 1964
1-3 – same specimen, different rotation, 1-2 XP, 3 PC.
4-5 – same specimen, different rotation, both XP, from Sample A.
6-7 – *Neobiscutum parvulum* (Romein, 1979) Varol, 1989; same specimen, different rotation, both XP, from sample A.
8 – *Thoracosphaera saxea* Stradner, 1961; fragment, XP, from sample A.
9 – *Braarudosphaera bigelowii* (Gran & Braarud, 1935) Deflandre, 1947; XP, from sample B.
10 – *Braarudosphaera regularis* Black, 1973; XP, from sample A.
11-13 – *Chiastozygus antiquus* (Perch-Nielsen, 1973) Burnett, 1998a; same specimen, different rotation, all XP, from sample A.
14-15 – *Psyktosphaera firthii* Pospichal & Wise, 1990; same specimen, different rotation, both XP, from sample A.
16-17 – *Percivalia fenestrata* (Worsley, 1971) Wise, 1983; same specimen, different rotation, both XP, from sample A.
18 – Indeterminate rim; XP, from sample A.
19-20 – *Goniolithus fluckigeri* Deflandre, 1957; 19 XP, 20 PC, from sample B.
21-22 – *Zeugrhabdotus erectus* (Deflandre *in* Deflandre & Fert, 1954) Reinhardt, 1965; same specimen, different rotation, both XP, from sample A.
23 – *Cribrosphaerella ehrenbergii* (Arkhangelsky, 1912) Deflandre *in* Piveteau, 1952; XP, from sample A.
24 – *Helicolithus trabeculatus* (Górka, 1957) Verbeek, 1977; XP, from sample A.
25 – *Prediscosphaera stoveri* (Perch-Nielsen, 1968) Shafik & Stradner, 1971; XP, from sample A.
26-27 – *Rhombolithion rhombicum* (Stradner & Adamiker, 1966) Black, 1973; same specimen, different rotation, both XP, from sample A.
28 – *Corollithion exiguum* Stradner, 1961; XP, from sample A.
29-30 – Indeterminate nannolith cf. *Nannoconus* Kamptner, 1931; same specimen, different rotation, both XP, from sample B.
31-33 – *Repagulum parvidentatum* (Deflandre & Fert, 1954) Forchheimer, 1972;
31-32 – same specimen, different rotation, all XP, from sample A.
34-35 – *Ceratolithoides quasiarcuatus* Burnett, 1998b; same specimen, different rotation, both XP, from sample A.

All images were captured at the same magnification. XP denotes cross-polarised image, PC denotes phase-contrast image. A 2μm bar appears on Figure 1 for scale. This plate is archived on disc in the UCL Micropalaeontology Unit as UCL-NF-3.

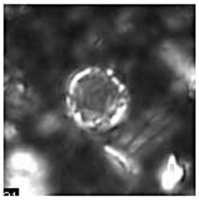


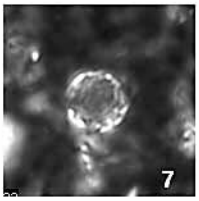


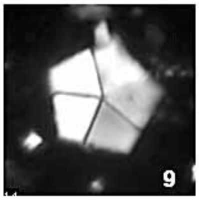


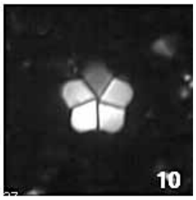
L. quadratus (A)

L. quadratus (A)







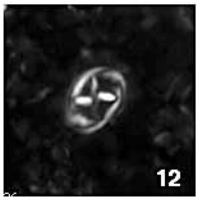


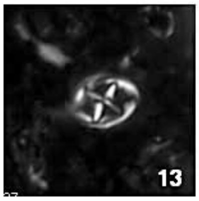
N. parvulum coccosphere (A)

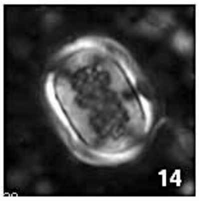
T. sexea fragment (A)

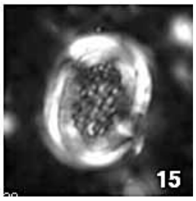
B. bigelowii (A)

B. regularis (A)



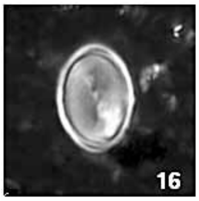


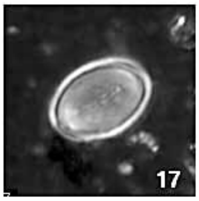


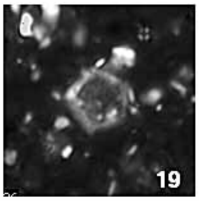


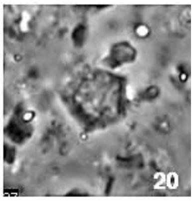
C. antiquus (A)

P. firthii (A)





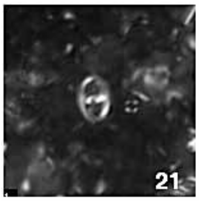


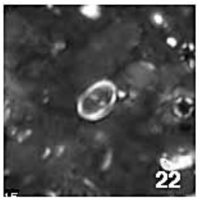


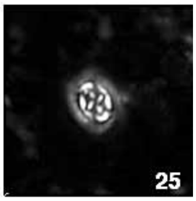
P. fenestrata (A)

Indet. rim (A)

G. fluckingeri (B)





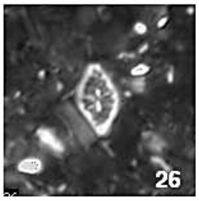


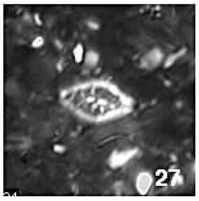
Z. erectus (A)

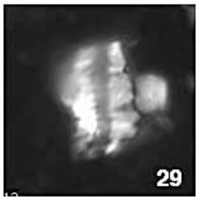
C. ehrenbergii (A)

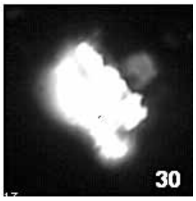
H. trabeculatus (A)

P. stoveri (A)





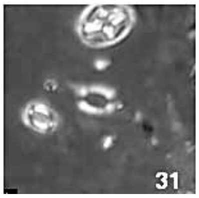


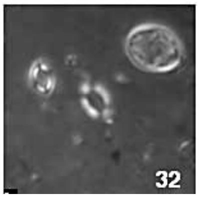


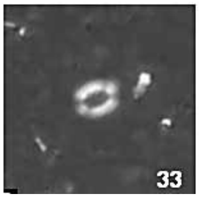
R. rhombicum (A)

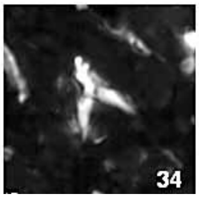
C. exiguum (A)

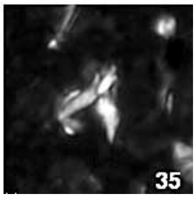
Indet. nanolith cf. *Nannoconus* (B)











R. parvidentatum (A)

R. parvidentatum (A)

C. quasiarcuatus (A)