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Autor: Rood, Anthony P. / Hay, William W. / Barnard, Tom
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Electron Microscope Studies of Lower and Middle Jurassic Coccoliths

By ANTHONY P. ROOD[1]), WILLIAM W. HAY[2]) and TOM BARNARD[1])

ABSTRACT

This paper is the third on Jurassic coccoliths from the authors, and the first on Liassic coccoliths since PRINS (1969), and on Middle Jurassic since MEDD (1971).

The research not only deals with new genera and species, but attempts to validate many of Prins's genera and species which were not established in his paper. One new family and three new species are proposed.

Introduction

As stated by the authors (1971) little research has taken place on Jurassic coccoliths in general, and apart from Prins's paper on Lower and Middle Liassic coccoliths no other research had been published on Lower Jurassic coccoliths. MEDD (1971) deals with Middle Jurassic coccoliths in a paper on Middle and Upper Jurassic species.

Using optical methods only PRINS (1969) gave a short but informative account of the "evolution" of species from the Lower and Middle Liassic. He suggested lineages of evolving forms based on the stratigraphical occurrence of the various species, and finally produced a nannofossil zonation of the Lower and Middle Lias. Some of the material used by Prins was collected from classic sections in Southern England. The present authors have used material from the same locality as Prins, but supplemented this with material from the same stratigraphical horizons from other localities, and extended the range by including material from the Upper Lias, from surface and subsurface sections.

As stated (1971) the authors will publish a further comprehensive paper on the stratigraphical occurrence and significance of the coccolith-species through the whole Jurassic, so the detailed stratigraphy is not presented in this paper. However, the present work largely confirms Prins's stratigraphical conclusions, but on the

[1]) Micropalaentology Dept. University College London, Gower St., London W.C. 1, England.

[2]) Dept. of Marine Geology and Geophysics, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida 33149, USA. Research supported by Oceanography Section, National Science Foundation grant GA/31969 X.

zonation and evolution more evidence is now available and modifications will be suggested.

A comparison has been made, where possible, between Prins's optical work, and that carried out by the authors, the latter's study supplemented with electron microscope studies. Where possible Prins's identifications have been confirmed and validated giving Prins priority.

MEDD (1971) in part of his paper deals with a few samples from the Middle Jurassic of both Normandy and various other localities in Southern England. The present authors have obtained a wider and more detailed spread of samples collected in great detail from the Bathonian section near Port-en-Bessin (Normandy) and a new section at Dyrham (Gloucestershire). Also MEDD (1971) has not described figured specimens from the Middle Jurassic, so more details of this flora were appropriate.

Stratigraphy

Although several hundred samples were studied throughout the Lower and Middle Jurassic of Southern England and Normandy, only a limited number were included in the present paper to conform with the stratigraphical coverage of Prins and Medd. The full range will be included in the future paper on the stratigraphical significance of the coccoliths, However a full coverage of the ammonite zones is given, except where these occur in compressed limestones, representing condensed sequences, such as the Junction Bed (Lower Toarcian).

The chief localities may be divided into two groups:

1. Lias:

   a) Dorset Coast (near Lyme Regis)
   Hettangian–Toarcian
   junction with Rhaetic, *planorbis-levesquei* zones

   b) Mochras borehole (near Llanbedr, Merionethshire)
   Hettangian–Toarcian,
   planorbis-levesquei zones

2. Middle Jurassic:

   a) Port-en-Bessin (Normandy)
   zigzag zone, *circumdata* zone, *discus* zone

   b) Dyrham (Gloucestershire)
   zigzag zone, *circumdata* zone, *discus* zone

SYSTEMATIC PALEONTOLOGY

Kingdom PLANTAE

Division CHRYSOPHYTA

Class COCCOLITHOPHYCEAE ROTHMALER 1951

Order EIFFELLITHALES ROOD, HAY and BARNARD 1971

Family Ahmuelleraceae REINHARDT 1965

Genus *Crucirhabdus* PRINS

Diagnosis:

Coccoliths with an eiffellithalid rim having a central structure in the form of a symmetrical cross in the major and minor axes of the ellipse supported by one or more diagonal bars in each quadrant.

Type species: *Crucirhabdus primulus* PRINS

Remarks:

In his discussion of members of this genus, PRINS included two species, *Crucirhabdus primulus* with four "varieties", and *Crucirhabdus expansus*. As defined here, the genus *Crucirhabdus* would include with certainty only two of the forms of *Crucirhabdus primulus*. (*C. primulus primulus* and *C. primulus nanus*) mentioned by PRINS. This seems justifiable in as much as the other "varieties" of *Crucirhabdus primulus* (*C. primulus striatulus* and *C. primulus orbicularis*) and *Crucirhabdus expansus* were regarded by PRINS as having represented the beginning of different evolutionary lineages.

Crucirhabdus primulus PRINS

Pl. I, Fig. 1, 2

1969 *Crucirhabdus primulus* PRINS, p. 548 (invalid)
1969 *Crucirhabdus primulus* var. *nanus* PRINS, Pl. I, Fig. 1A–B, Pl. II, Fig. 1A–B, Pl. III, Fig. 1A–B, p. 551 (invalid)
1969 *Crucirhabdus primulus* var. *primulus* PRINS (as *Crucirhabdus primulus* s.s.), Pl. II, Fig. 2A–B, Pl. III, Fig. 2A–B, p. 552 (invalid)
1969 *Crucirhabdus primulus* var. *striatulus* PRINS, Pl. III, Fig. 3A–B, p. 554 (invalid)
1969 *Crucirhabdus primulus* var. *orbicularis* PRINS, Pl. II, Fig. 3A (invalid)

Diagnosis:

A species of *Crucirhabdus* with three to five diagonal bars in each quadrant.

Description:

The coccoliths are elliptical, with a central cross having arms aligned in the major and minor axes of the ellipse. Each arm is subdivided longitudinally into two parts having the same optical orientation, but the optical orientation of the long and short arms is opposite. A hollow spine arises from the junction of the bars; its central channel expands proximally. The cross divides the central area into four quadrants each of which is spanned by three to five smaller diagonal bars making an angle of 60° with the long axis of the ellipse.

Remarks:

Prins mentioned four varieties of this species. The first, described by him at the top of page 551 and considered to be the most primitive variety of the species was termed *C. primulus* var. *nanus*. It was stated to be distinguished by a relatively large diamond shaped aperture in the centre of the cross. This could represent a section near the base of a central spine, and may be either a real variant or an artifact of preservation. The second variety *C. primulus* var. *primulus*, briefly mentioned on page 552, was said to differ by having a smaller aperture in the centre and a short or long spine. The third variety *C. primulus* var. *striatulus* was stated on page 554 to have more clearly visible rim elements and more flattened distal and proximal rims. Illus-

trations of this variety, in contrast to the preceeding two, do not show the diagonal bars in the four quadrants of the central area here considered characteristic of the species. The fourth variety *C. primulus* var. *orbicularis*, was not mentioned in the text, but was figured (3A) on Plate II. It was evidently intended to be distinguished by its circular rather than elliptical outline. The illustrations of this variety also lack the diagonal bars in the four quadrants of the central area.

Differentiation:

Crucirhabdus primulus PRINS differs from *Crucirhabdus prinsi* n. sp. in having three to five rather than a single diagonal bar in each quadrant.

Holotype: 42.8.1
Paratype: 44.1.2
Dimensions: length 2.85 μ, width 1.7 μ
Type locality: Black Ven, Lyme Regis, Dorset
Type level[3]): Lias. Bed 90a, Upper Sinemurian, *raricostatum* zone
Locality of Paratype: Lyme Regis, Dorset, Bed 122a, *davoei* zone

Crucirhabdus prinsi new species

Pl. I, Fig. 3

Diagnosis:

A species of *Crucirhabdus* with a single diagonal bar in each quadrant.

Description:

Elliptical coccoliths with a widely open central cross having diamond-shaped aperture. In each quadrant a single diagonal bar arises from the long axis making an angle of 60° with it. The rim is moderately deep and there is no evidence for a central spine.

Differentiation:

This species differs from *Crucirhabdus primulus* PRINS in having a single diagonal bar in each quadrant.

Holotype: 42.2.1
Dimensions: length 2 μ, width 1.6 μ
Type locality: Lyme Regis, Dorset
Type level: Lias, Bed 120d, Lower Pliensbachian (Crixian), *ibex* zone

Genus *Vekshinella* LOEBLICH and TAPPAN 1963

Vekshinella stradneri ROOD, HAY and BARNARD

Pl. I, Fig. 4

1968 *Zygolithus crux* (DEFLANDRE et FERT) of STRADNER, ADAMIKER et MARESCH, Pl. 28, p. 36–37
1971 *Vekshinella stradneri* ROOD, HAY et BARNARD Pl. I, Fig. 2, p. 249

Remarks:

Specimens from the Lias and Middle Jurassic closely resemble those previously figured from the Oxford Clay and the Lower Cretaceous. It is possible that the coc-

[3]) Bed numbers are those given by W. D. LANG (1924) in his studies of Lias stratigraphy.

coliths figured by PRINS (1969) as *Crucirhabdus primulus* var. *striatulus* (Pl. III, Fig. 3 A–B) may belong to this species.

Vekshinella quadriarculla (NOEL)

Pl. I, Fig. 5

1965a *Discolithus quadriarcullus* NOEL, Fig. 7, p.4
1965b *Discolithus quadriarcullus* NOEL, NOEL, Fig. 7, Pl. 1, Fig. 14–15, Pl. 2, Fig. 1–2, p. 74–75
1971 *Vekshinella quadriarculla* (NOEL) ROOD, HAY et BARNARD, Pl. I, Fig. 1, p. 250

Remarks:

Specimens from the Lias resemble Noel's type but have slightly more open areas in the four quadrants of the central area.

Family ZYGODISCACEAE HAY and MOHLER 1967

Subfamily Zygodiscoideae BUKRY 1969

Genus *Zeugrhabdotus* REINHARDT 1965

Zeugrhabdotus erectus (DEFLANDRE)

Pl. 1, Fig. 6

1954 *Zygolithus erectus* DEFLANDRE, in DEFLANDRE et FERT, Pl. 15, Fig. 14–17, Textfig. 60–61 (not Textfig. 62), p. 150
1965 *Zeugrhabdotus erectus* (DEFLANDRE) REINHARDT, p. 37
1971 *Zeugrhabdotus erectus* (DEFLANDRE), ROOD, HAY et BARNARD, Pl. I, Fig. 3, p. 252

Remarks:

Specimens found in Liassic and Middle Jurassic samples closely resemble the type. On some specimens traces of the finely perforate sheet spanning the two large central opening (figured by ROOD et al. 1971) are visible.

Zeugrhabdotus choffati new species

Pl. I, Fig. 7

Diagnosis:

A species of *Zeugrhabdotus* with a large hollow circular spine arising from the crossbar.

Description:

The rim of this species is narrow, about one fifth the width of the coccolith. The outline of the coccolith is broadly but smoothly elliptical. The crossbar is about the same width as the margin, but is surmounted by a circular spine having a diameter greater than the width of the bar, approximately one third of the width of the coccolith. The centre of the spine is a circular hollow channel.

Differentiation:

This species is distinguished from *Zeugrhabdotus erectus* by having a relatively large spine and a more broadly elliptical outline.

Holotype: 56.2.2
Dimensions: length 2.4 μ, width 1.8 μ
Type locality: Port-en-Bessin (Normandy)
Type level: Bathonian, Fullers Earth, *zigzag* zone

Family CHIASTOZYGACEAE, new family

Diagnosis:

Coccoliths with an eiffellithalid rim having a central structure consisting of a cross aligned in the equal axes of the ellipse.

Genus *Chiastozygus* GARTNER 1968

Remarks:

PRINS (1969) mentioned a genus *Ellipsochiastus* which was not validated and appears to be synonymous with *Chiastozygus* GARTNER.

Chiastozygus primitus PRINS

Pl. I, Fig. 8

1969 *Ellipsochiastus primitus* Prins, Pl. II, Fig. 8, Table 1

Diagnosis:

A small narrow elliptical species of *Chiastozygus* with thin parallel sided bars forming an X-shaped central structure.

Description:

The margin of this small, elongate species is narrow, the bars forming the central cross are the same width as the margin. There is no evidence of a perforation in the center of the cross, a characteristic feature of many later species of this genus.

Differentiation:

The narrow margin and absence of any opening at the center of the cross differentiate this species from other members of the genus. "*Ellipsochiastus*" *quadriserratus* WORSLEY (1971) is distinguished by a lobose margin.

Holotype: 42.7.1
Dimensions: length 2.5 μ, width 1.5 μ
Type locality: Lyme Regis, Dorset
Type level: Lias, Bed 90a, Sinemurian, *raricostatum* zone

Family ACTINOZYGACEAE ROOD, HAY and BARNARD 1971

Remarks:

A discussion of the evolution of this family in the Jurassic has been presented by ROOD and BARNARD (1972).

Subfamily Actinozygoideae ROOD, HAY and BARNARD 1971

Genus *Nodosella* PRINS

Diagnosis:

Elliptical coccoliths with an eiffellithalid rim and a central structure consisting of a longitudinal elongated central island connected to the margin by numerous bars radiating from an axis along the long dimension of the ellipse.

Type species: *Nodosella clatriata* PRINS

Nodosella clatriata PRINS

Pl. I, Fig. 9

1969 *Nodosella clatriata* PRINS, Pl. III, Fig. 5, p. 554 (invalid)

Diagnosis:

Elliptical eifellithalid coccoliths with a long, narrow central island connected to the margin by 16–20 subradial bars.

Description:

The rim is very narrow; the radial bars have approximately the same width as the margin. The central island is narrowly oval, orientated along the length of the coccolith.

Differentiation:

This species lacks the asymmetry characteristic of similarly constructed species of *Diadozygus* and has more bars than *Diadozygus dorsetense* ROOD, HAY and BARNARD and *Stradnerlithus comptus* BLACK.

Holotype: 44.11.1
Dimensions: length 2.45 μ, width 1.7 μ
Type locality: Seatown, Dorset
Type level: Upper Lias, U. Toarcian, Down Cliff Clay, *levesquei* zone

Subfamily Diadozygoideae ROOD, HAY and BARNARD 1971

Genus *Diadozygus* ROOD, HAY and BARNARD 1971

Remarks:

BLACK (1971) proposed a new genus, *Stradnerlithus*, with the type of the species, *Stradnerlithus comptus* BLACK, based on a fragment of a coccolith. There is some resemblance between Black's type and *Diadozygus dorsetense* ROOD, HAY and BARNARD, but the specimen designated *S. comptus* does not show the asymmetry characteristic of the latter species; for this reason *Stradnerlithus* and *Diadozygus* are not regarded as synonyms.

Diadozygus asymmetricus ROOD, HAY and BARNARD

1971 *Diadozygus asymmetricus* ROOD, HAY et BARNARD, Pl. I, Fig. 7, p. 255
1972 *Diadozygus asymmetricus* ROOD et BARNARD, Pl. II, Fig. 2–3, p. 335

Remarks:

This species, previously known from the Oxford Clay, is also found in the Cornbrash Beds.

Diadozygus escovillensis ROOD and BARNARD

1972 *Diadozygus escovillensis* ROOD et BARNARD, Pl. II, Fig. 4, p. 335

Remarks:

The coccolith is broadly elliptical, the rim is narrow, only one-fifth to one-sixth the width of the coccolith. Eight bars are present in the central area. Two of these are aligned along the major axis of the ellipse, two are parallel to the minor axis of the ellipse, but are offset at the centre so that when viewed down the long axis in distal view the left bar is closer to the far end of the coccolith than the right bar. Two pairs of diagonal bars occupy the approximate positions of the equal axes of the ellipse, but are offset in the same fashion as that parallel to the minor axis.

In one of the other species of *Diadozygus* with eight bars, *D. asymmetricus* ROOD, HAY and BARNARD, the bars extending into the ends of the ellipse do not lie along the major axis but are inclined to it at an angle of about 20°. The other eightbarred species *D. rhombicus* (STRADNER and ADAMIKER), has a rhomboidal rather than elliptical outline.

Diadozygus langi ROOD and BARNARD

1972 *Diadozygus langi* ROOD et BARNARD, Pl. II, Fig. 1, p. 334

Remarks:

This extremely small species of *Diadozygus* has a very narrow margin, and is distinguished by having six bars disposed according to the asymmetric mode characteristic for the genus. A vestigial central island is present.

Subfamily Parhabdolithoideae GARTNER 1968

Genus *Parhabdolithus* DEFLANDRE 1952

Parhabdolithus liasicus DEFLANDRE

Pl. II, Fig. 1

1952 *Parhabdolithus liasicus* DEFLANDRE,, Fig. 362, J. M., p. 465
1954 *Parhabdolithus liasicus* DEFLANDRE et FERT, Pl. 15, Figs. 28–31, Textfig. 104–108, p. 162
1963 *Parhabdolithus liasicus* DEFLANDRE, STRADNER, Pl. 2, Fig. 13
1965b *Parhabdolithus liasicus* DEFLANDRE, NOEL, Fig. 22a–e, Pl. 3, Fig. 7, Pl.4, Fig. 3, 4, 7, p. 92–93
1969 *Parhabdolithus liasicus* DEFLANDRE, PRINS, Pl. 2, Fig. 4 A–B
1969 *Parhabdolithus longispinus* PRINS, Pl. II, Fig. 5 (invalid)
1969 *Parhabdolithus elongatus* PRINS, Table 1, p. 555 (invalid)

Remarks:

Specimens from the Lias of England closely resemble those figured by Deflandre. The base of the coccolith is smaller in proportion to the diameter of the stem than in side views of *Crucirhabdus primulus* PRINS. Prins mentioned two taxa, *Parhabdolithus*

longispinus on Plate II (Fig. 5) and *Parhabdolithus elongatus* (on Table 1) probably intended to be used for long spined specimens of *Parhabdolithus*. Because Deflandre's holotype has a relatively long stem, and has almost the same proportions as the specimen figured as *Parhabdolithus longispinus* by Prins, it seems best not to recognize these variants as distinct species.

Parhabdolithus marthae DEFLANDRE

Pl. II, Fig. 2

1954 *Parhabdolithus marthae* DEFLANDRE, in DEFLANDRE et FERT, p. 163, Pl. 15, Fig. 22–23, Textfig. 102–103 (not 103)
1965 *Parhabdolithus robustus* NOEL, p. 95–96, Pl. 4, Fig. 1–2, Textfig. 24
1969 *Parhabdolithus marthae* DEFLANDRE, PRINS, Pl. 2, Fig. 6A–B
1965b *Parhabdolithus marthae* DEFLANDRE of NOEL, Pl. 3, Fig. 6, Pl. 4, Fig. 6, Textfig. 23a–e, p. 93–94

Remarks:

Specimens from the Lias of England closely resemble those figured by Deflandre. This species is readily distinguished from *Parhabdolithus liasicus* by its much thicker stem. Specimens referred to *P. marthae* by NOEL (1965b) resemble that termed *P.* cf. *marthae* by DEFLANDRE and FERT (1954, Textfig. 103), and are here regarded as variants of *P. liasicus* DEFLANDRE. *P. robustus* NOEL closely resembles the type of *P. marthae* DEFLANDRE.

Diagnosis:

Narrowly elliptical eiffellithalid coccoliths with a broadly oval to circular spinoid central structure in the minor axis of the margin.

Genus *Tubirhabdus* PRINS

Remarks:

In side view the central structure is seen to be a short or long spine with a very broad central channel. This genus was indicated by Prins on page 552 of his 1969 paper.

Type species: *Tubirhabdus patulus* PRINS

Tubirhabdus patulus PRINS

Pl. II, Fig. 3

1969 *Tubirhabdus patulus* PRINS, Pl. I, Fig. 10A–C (invalid)

Diagnosis:

A small species of *Tubirhabdus* with a very broadly open oval to circular central spine.

Description:

Electron micrographs reveal the rim to be very narrow, but to slope inward toward the base creating an impression of greater width when viewed in the light microscope. The spine appears to be oval at the base, becoming circular in cross section at a higher level.

Differentiation:

This species is readily distinguished from "*Parhabdolithus*" *embergeri* (NOEL) by being more delicately constructed and having a more broadly open spine.

Remarks:

Specimens from the Middle Jurassic appear to have only circular stems and tend to be slightly more broadly elliptical in outline than those from the Lias.

Holotype: 42.1.2

Dimensions: length 3.9 μ, width 2.45 μ

Type locality: Lyme Regis, Dorset

Type level: Lias, Bed 120d, Lower Pliensbachian (Carixian), *ibex* zone

Family STEPHANOLITHIONACEAE BLACK 1968

Subfamily Crepidolithoideae ROOD, HAY and BARNARD 1971

Genus *Crepidolithus* NOEL 1965

Crepidolithus crassus (DEFLANDRE)

1954 *Discolithus crassus* DEFLANDRE, in DELFANDRE et FERT, Pl. 15, Fig. 12–13, Textfig. 49, p. 144
1961 *Discolithus crassus* DEFLANDRE, STRADNER, Fig. 16–18, p. 79
1963 *Discolithus crassus* DEFLANDRE, STRADNER, Fl. 2, Fig. 14–14a, p. 7
1965a *Crepidolithus crassus* (DEFLANDRE) NOEL, Fig. 19–21, p. 5
1965b *Crepidolithus crassus* (DEFLANDRE) NOEL, Pl. 2, Fig. 3–7, Pl. 3, Fig. 1–5, Textfig. 17–21, p. 85–90
1969 *Crepidolithus crassus* (DEFLANDRE) PRINS, Pl. 1, Fig. 5A–C, p. 551
1971 *Crepidolithus crassus* (DEFLANDRE) ROOD, HAY et BARNARD, Pl. 2, Fig. 7, p. 259

Remarks:

Proximal views of this species show the base to be constructed of calcite rhombs in a variety of orientations. These contribute to the irregular appearance of the center of the coccolith when viewed between crossed nicols. This taxon is commonly used for specimens of *Crepidolithus* with a very wide margin and narrow, featureless central area.

Crepidolithus crucifer PRINS

Pl. II, Fig. 4

1969 *Crepidolithus crucifer* PRINS, Pl. I, Fig. 3A–B, p. 551 (invalid)

Diagnosis:

A species of *Crepidolithus* with a cruciform structure in the central area.

Description:

The elliptical eiffellithalid coccoliths have a moderatey wide margin, varying from one fourth to one-third the width of the coccolith. A weakly developed, somewhat irregular cruciform structure is developed in the central area, the axes of the cross aligned along the major and minor axes of the ellipse.

Differentiation:

The central cross, best observed between crossed polarizers serves to distinguish this species from others of the genus *Crepidolithus.*

Holotype: 44.2.2

Dimensions: length 4.35 μ, width 3.3 μ

Type locality: Lyme Regis, Dorset

Type level: Lias, Bed 122a, Lower Plienchachian (Crixian), *davoei* zone

Crepidolithus cavus PRINS

Pl. II, Fig. 5

1969 *Crepidolithus cavus* PRINS, Pl. I, Fig. 4A–C (invalid)

Diagnosis:

A species of *Crepidolithus* with a bridge in the minor axis of the elliptical central area.

Description:

The elliptical eiffellithalid coccoliths have a rim only about one-fourth as wide as the coccolith. A transverse bridge is situated in the minor axis of the elliptical central areas. The bridge may support a short centrally located spine. The base of the coccolith shows two perforations, one in either end.

Remarks:

Prins's drawings of a transmitted light microscopic view of this species gives the faintest suggestion of a transverse bridge in the center of the coccolith, but this view between crossed polarizers clearly indicates some sort of feature occupying the minor axis.

Typical specimens of this species occur in Middle Jurrassic as well as Liassic strata.

Differentiation:

This is the only species of *Crepidolithus* with a transverse bridge.

Holotype: 44.1.1

Dimensions: length 5.2 μ, width 3.25 μ

Type locality: Lyme Regis, Dorset

Type level: Lias, Bed 122a, Lower Pliensbachian (Carixian), *davoei* zone

Subfamily Stephanolithionoideae VEKSHINA 1959

Remarks:

A discussion of the evolution of this group has been presented by ROOD and BARNARD (1972).

Genus *Stephanolithion* DEFLANDRE 1939

Stephanolithion speciosum DEFLANDRE

1954 *Stephanolithion speciosum* DEFLANDRE, in DEFLANDRE et FERT, Pl. 15, Fig. 7–8 Textfig. 56, p. 146
1971 *Stephanolithion speciosum* MEDD, p. 827
1972 *Stephanolithion speciosum* ROOD et Barnard, Pl. I, Fig. 1–7, p.330

Remarks:

Characteristic of this species are the short knobs along the outer margin of the ring. DEFLANDRE (1954) correctly suggested that this species might be intermediate between typical *Stephanolithion* and more classic "discolithes". The asymmetry of the bars in the central area suggests that this species arose from one of the species of *Diadozygus*, probably *D. asymmetricus.*

Stephanolithion speciosum var. *octum* ROOD and BARNARD 1972

1972 *Stephanolithion speciosum var. octum* ROOD et BARNARD, Pl. I, Fig. 2, 8, p. 330

Remarks:

The ring is broadly elliptical. Inside the ring eight bars are disposed asymmetrically about the major and minor axes in such a way that they form four pairs of "V's" centered on the axes with the left bar of each (viewed from the center) closer to the axes than the right.

Eight to ten lateral spines project from the ring; they may or may not be located opposite the junction of the central bars with the ring. This species differs from *S. speciosum* in having spines rather than knobs exending peripherally from the ring.

Stephanolithion hexum ROOD and BARNARD 1972

1972 *Stephanolithion hexum* ROOD et BARNARD, Pl. I, Fig. 3, 4, 9, 10, p. 329

Diagnosis:

An elliptical species of *Stephanolithion* with six asymmetrically disposed bars in the centre and a variable number of peripheral spines.

Description:

The ring is broadly elliptical; it encloses a large central area with six asymmetrically disposed bars. Four bars radiate from the centre of the coccolith, two are asymmetrically arranged on opposite sides of the minor axis of the ellipse, two occupy the site of the major axis but bifurcate almost immediately to join the ring on either side of the major axis, usually being asymmetrically offset in the same direction as those parallel to the minor axis. A variable number, but usually seven or eight, spines extend peripherally from the ring.

Differentiation:

This species is readily distinguished from the other six-rayed species of *Stephanolithion laffittei* NOEL, by being elliptical rather than circular in outline.

Order PODORHABDINALES ROOD, HAY and BARNARD 1971

Family PODORHABDACEAE Noel 1965

Subfamily Podorhabdoideae ROOD, HAY and BARNARD 1971

Genus *Podorhabdus* NOEL 1965

Podorhabdus cylindratus NOEL

Pl. II, Fig. 6

1965a *Podorhabdus cylindratus* NOEL, Fig. 30, p. 6 (invalid)
1965b *Podorhabdus cylindratus* NOEL, Pl. 19, Fig. 3, 7, Textfig. 30, p. 103–104
1969 *Podorhabdus cylindratus* NOEL, PRINS, Pl. 3, Fig. 7A–B
1971 *Podorhabdus cylindratus* NOEL, ROOD, HAY et BARNARD, Pl. III, Fig. 1–2, p. 261

Remarks:

Specimens from the Lias and Middle Jurassic are almost identical to the types (from the Oxford Clay) and very similar to that illustrated by Prins.

Podorhabdus macrogranulatus PRINS

Pl. II, Fig. 7

1969 *Podorhabdus macroganulatus* PRINS, Pl. III, Fig. 6 (invalid)

Diagnosis:

A species of *Podorhabdus* with four relatively small apertures in the central area, each spanned by several diagonal bars.

Description:

The coccoliths are elliptical; the proximal cycle of elements of the podorhabdid rim is wider than the distal cycle, extending further in toward the center than the distal cycle when observed in distal view. The central cross is aligned in the major and minor axes of the ellipse and a spine arises from its centre, the edges of the arms of the cross diverge toward the center so that the four apertures of the central area are narrowly elliptical. Three or four diagonal bars extend from the long bar of the cross to the rim, at an angle of 60° to the long axis of the coccolith.

Differentiation:

This species is intermediate between typical *Striatomarginis* and *Podorhabdus* species. It seem to be the ancestral form of *Podorhabdus*; and is placed in that genus because of the well developed central cross and spine which are much more heavily constructed than the diagonal bars. It is unique among *Podorhabdus* species in having diagonal bars spanning the four apertures.

Holotype: 43.11.2

Dimensions: length 4.8 μ, width 3.35 μ

Type locality: Seatown, Dorset

Type level: Upper Lias, Upper Toarcian, *levesquei* zone

Genus *Hexapodorhabdus* NOEL 1965

Hexapodorhabdus cuvillieri NOEL

Pl. II, Fig. 8

1965b *Hexapodorhabdus cuvillieri* NOEL, Pl. 9, Fig. 4–6, p. 105–106
1971 *Hexapodorhabdus cuvillieri* NOEL, ROOD, HAY et BARNARD, Pl. III, Fig. 3, p. 261

Remarks:

Typical specimens of this species are found in Middle Jurassic strata.

Genus *Octopodorhabdus* NOEL 1965

Octopodorhabdus decussatus (MANIVIT)

Pl. II, Fig. 9

1959 (1961) *Discolithus decussatus* MANIVIT, Pl. 1, Fig. 7, p. 14
1963 *Rhabdolithus decussatus* (MANIVIT), STRADNER, Pl. 5, Fig. 8–8a, p. 9
1971 *Octopodorhabdus decussatus* (MANIVIT), ROOD, HAY et BARNARD, Pl. III, Fig. 1, p. 262

Remarks:

Specimens from the Cornbrash Beds resemble those previously figured from the late Jurassic.

Subfamily Paleopontosphaeroideae ROOD, HAY and BARNARD 1971

Genus *Paleopontosphaera* NOEL 1965

Paleopontosphaera dubia NOEL

Pl. III, Fig. 1

1965a *Paleopontosphaera dubia* NOEL, Fig. 8, p. 4
1965b *Paleopontosphaera dubia* NOEL, Pl. 7, Fig. 1–12 (not 13), Textfig. 8, p. 76–78
1971 *Paleopontosphaera dubia* NOEL, ROOD, HAY et BARNARD, Pl. IV, Fig. 9, p. 265

Remarks:

Liassic specimens so closely resemble those of the late Jurassic that no specific distinction is warranted.

Paleopontosphaera veterna PRINS

Pl. III, Fig. 2–3

1965b *Paleopontosphaera dubia* NOEL, of NOEL, Pl. 7, Fig. 13
1969 *Paleopontosphaera veterna* PRINS, Pl. II, Fig. 9, p. 554 (invalid)

Diagnosis:

A species of *Paleopontosphaera* with a spine supported on a cross with four short arms.

Description:

The margin is about one third the width of the coccolith. The central spine is short, and contains a circular longitudinal channel. This spine is supported on a cross with four short arms aligned in the major and minor axes of the ellipse. Some electron

micrographs suggest the presence of diagonal bars in each of the four minute apertures formed by the central cross.

Remarks:

PRINS (1969) indicated that the specimen he figured as *Paleopontosphaera veterna* has some sort of central cross beneath a more distinct central spine.

Holotype: 55.11.1
Paratype: 55.10.2
Dimensions: length 3.2 μ, width 2.5 μ
Type locality: Port-en-Bessin (Normandy)
Type level: Bathonian, Fullers Earth, *zigzag* zone

Genus *Striatomarginis* PRINS

Diagnosis:

Elliptical coccolith with a coccolithid margin having a narrow tube cycle and a central structure consisting of a longitudinal bar from which four groups of diagonally disposed bars extend to the margin; a cross bar in the short axis of the ellipse may be developed.

Types species: *Striatomarginis primitivus*, new species

Striatomarginis primitivus new species

Pl. III, Fig. 4

Diagnosis:

A species of *Striatomarginis* with a weakly developed longitudinal bar and four quadrants with four to five diagonal bars extending to the margin.

Description:

The margin of this species is about one fourth the width of the coccolith. The proximal cycle of rim elements is only slightly wider than the distal cycle, being exposed in the center of the coccolith. The central structure consists of a longitudinal bar from which four groups of bars radiate to the margin. The radial bars are of equal width to the longitudinal bar, and in each quadrant are parallel to each other, making an angle of 60° with the long axis of the ellipse.

Differentiation:

The construction of this species is similar to that of *Podorhabdus macrogranulatus* PRINS, but the latter has a robust central cross.

Remarks:

PRINS (1969) figured a coccolith termed "*Striatomarginis speciosus*". It was indicated to have a distinct central cross, although a faint suggestion of distal bifurcation of the transverse arms was indicated. In as much as it is possible that Prins's specimens may differ significantly from those described here, a different name has been chosen.

Holotype: 44.10.1
Dimensions: length 3.15 μ, width 2.25 μ
Type locality: Seatown, Dorset
Type level: Upper Lias, Upper Toarcian, *levesquei* zone

Subfamily Ethmorhabdoideae Rood, Hay and Barnard 1971

Genus *Ethmorhabdus* Noel 1965

Ethmorhabdus gallicus Noel

Pl. III, Fig. 5

1965a *Ethmorhabdus gallicus* Noel, Fig. 33–34, p. 6
1965b *Ethmorhabdus gallicus* Noel, Pl. 10, Fig. 1, 2, 5, p. 110–112, Textfig. 33–34
1968 *Ethmorhabdus gallicus* Noel, Black, Pl. 150, Fig. 3, p. 806
1971 *Ethmorhabdus gallicus* Noel, Rood, Hay et Barnard, Pl. II, Fig. 7, p. 263

Remarks:

Typical specimens occur in the late Liassic and Middle Jurassic samples; this species is already known from late Jurassic strata.

Ethmorhabdus anglicus Rood, Hay and Barnard

1971 *Ethmorhabdus anglicus* Rood, Hay et Barnard, Pl. III, Fig. 8, p. 263

Remarks:

Typical specimens of this species occur in Middle Jurassic samples.

Subfamily Sollasiteoideae Rood, Hay and Barnard 1971

Genus *Sollasites* Black 1967

Sollasites lowei (Bukry)

Pl. III, Fig. 6

1969 *Costacentrum lowei* Bukry, Pl. 22, Fig. 5–6, p. 44
1969 *Paleopontosphaera inconspicua* Prins, Pl. II, Fig. 13, p. 554 (invalid)
1971 *Sollasites lowei* (Bukry) Rood, Hay et Barnard, Pl. IV, Fig. 1, p. 264

Remarks:

Liassic specimens of this species are very close to the Cretaceous type and to Oxford Clay specimens previously figured. Prins (1969) noted that the coccoliths he termed "*Paleopontosphaera inconspicua*" and "*Paleopontosphaera bindosa*" might belong to the genus *Sollasites*. The shape and occurrence of "*Paleopontosphaera inconspicua*" suggest that it is conspecific with *Sollasites lowei*.

Sollasites horticus (Stradner, Adamiker and Maresch)

1966 *Coccolithus horticus*, Stradner, Adamiker et Maresch, Pl. 2, Fig. 4, p. 337
1967 *Sollasites barringtonensis*, Black, Fig. 4, p. 144
1968 *Coccolithus horticus*, Stradner, Adamiker et Maresch, Gartner, Pl. 10, Fig. 2, Pl. 25, Fig. 6–8, Pl. 26, Fig. 1, p. 18
1968 *Sollasites horticus* (Stradner, Adamiker et Maresch) Black, Pl. 144, Fig. 1–2, p. 798

1969 *Costacentrum horticus* (STRADNER, ADAMIKER et MARESCH), BUKRY, Pl. 21, Fig. 12, Pl. 22, Fig. 1–4, p. 44
1969 *Sollasites horticus* (STRADNER, ADAMIKER et MARESCH) CEPEK et HAY, p. 325
1971 *Sollasites barringtonensis*, BLACK, p. 412

Remarks:

BLACK (1971) stated that *S. horticus* is smaller (3 μ) than *S. barringtonensis* (5–7 μ) and has fewer elements (28 vs. 36–45) in the rim. Jurassic specimens appear to be intermediate in size and number of rays, and the two taxa here are regarded as synonyms. The oldest specimens of this species occur in the Middle Jurassic.

Family PREDISCOSPHAERACEAE ROOD, HAY and BARNARD 1971

Subfamily Discorhabdoideae NOEL 1965

Genus *Discorhabdus* NOEL 1965

Discorhabdus biperforatus new species

Pl. III, Fig. 7

Diagnosis:

A species of *Discorhabdus* in which the stem has two large openings at its junction with the base.

Description:

The stem is broadly circular, about three-fourths the diameter of the coccolith at the base. It tapers upward to become only about one-fourth the diameter of the base at its narrowest point. Two hemicircular openings, each about the width of the stem at its narrowest point, are present where the stem joins the base. The elements of the base are flat on their upper surfaces peripheral to the stem, but through the opening in the stem can be seen to slope toward the center from the point of junction between the stem and the base.

Differentiation:

This species differs in having two hemicircular openings.

Holotype: 56.5.2
Dimensions: length 8 μ, width 6.8 μ
Type locality: Port-en-Bessin (Normandy)
Type level: Bathonian, Fullers Earth, *zigzag* zone

Discorhabdus sp.

Pl. III, Fig. 8

Remarks:

Isolated circular coccoliths closely resemble the bases of *Discorhabdus* known from younger Jurassic strata. Prins figured three circular coccoliths: "*Paleopontosphaera repleta*", "*Striatoccoccus nebulosus*", and "*Cyclagelosphaera pygmaea*" any or all of which might be identified as bases of *Discorhabdus* in the electron microscope.

Incertae sedis

Genus *Alvearium* BLACK 1967

Alvearium dorsetense BLACK

Pl. III, Fig. 9

1965 *Alvearium dorsetense* BLACK, Fig. 5, p. 133, 136 (invalid)
1967 *Alvearium dorsetense* BLACK, p. 139

Remarks:

PRINS (1969, p. 552) has suggested that these objects are the isolated spines of *Mitrolithus elegans* DEFLANDRE. *Mitrolithus* has not been found with certainty in the British Liassic using either light or electron microscopy.

Acknowledgments

The authors appreciate the help given by Miss V. Russell in the collection of Bathonian material from Normandy, also Dr. M. K. Curtis, Bristol Museum, for supplying material from Dyrham. Thanks are due to Miss. S. James for preparing the plates. Financial support by the Esso Petroleum Company, during the collection of the material in N. France, is gratefully acknowledged. Material from the Mochras Borehole, Llanbedr, was kindly supplied by Prof. A. Wood, University College Aberystwyth, and his colleagues.

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Plate I

Fig. 1 — *Crucirhabdus primulus* PRINS, distal side
Holotype 42.8.1
Lyme Regis (Dorsetshire): Lias, Upper Sinemurian, Bed 90a, *raricostum* zone–*densinodulum* subzone. × 14,000

Fig. 2 — *Crucirhabdus primulus* PRINS, oblique view
Paratype 44.1.2
Lyme Regis (Dorsetshire): Lias, Lower Pliensbachian (Carixian), Bed 122a, *davoei* zone–*maculatum* subzone. × 9,000

Fig. 3 — *Crucirhabdus prinsi* n.sp. proximal side
Holotype 42.2.1
Lyme Regis (Dorsetshire): Lias, Lower Pliensbachian (Carixian), Bed 120a, *ibex* zone–*valdani* subzone. × 18,000

Fig. 4 — *Vekshinella stradneri* ROOD, HAY et BARNARD, distal side
Hypotype 42.3.1
Lyme Regis (Dorsetshire): Lias, Lower Pliensbachian (Carixian), Bed 120a, *ibex* zone–*valdani* subzone. × 12,000

Fig. 5 — *Vekshinella quadriarculla* (NOEL), distal side
Hypotype 42.7.2
Lyme Regis (Dorsetshire): Lias, Upper Sinemurian, Bed 90a, *raricostatum* zone–*densinodulum* subzone. × 20,000

Fig. 6 — *Zeugrhabdotus erectus* (DEFLANDRE), distal side
Hypotype 44.3.1
Lyme Regis (Dorsetshire): Lias, Lower Pliensbachian (Carixian) Bed 122a, *davoei* zone–*macalatum* subzone. × 20,000

Fig. 7 — *Zeugrhabdotus choffati* n.sp., distal side
Holotype 56.2.2
Port-en-Bessin (Normandy), Bathonian, Fullers Earth, *zigzag* zone. × 15,000

Fig. 8 — *Chiastozygus primitus* PRINS, proximal side
Holotype 42.7.1
Lyme Regis (Dorsetshire): Lias, Upper Sinemurian, Bed 90a, *raricostatum* zone–*densinodulum* subzone. × 14,000

Fig. 9 — *Nodosella clatriata* PRINS, distal side
Holotype 44.11.1
Seatown (Dorsetshire): Lias, Upper Toarcian, Down Cliff Clay, *levesquei* zone–*levesquei* subzone. × 11,500

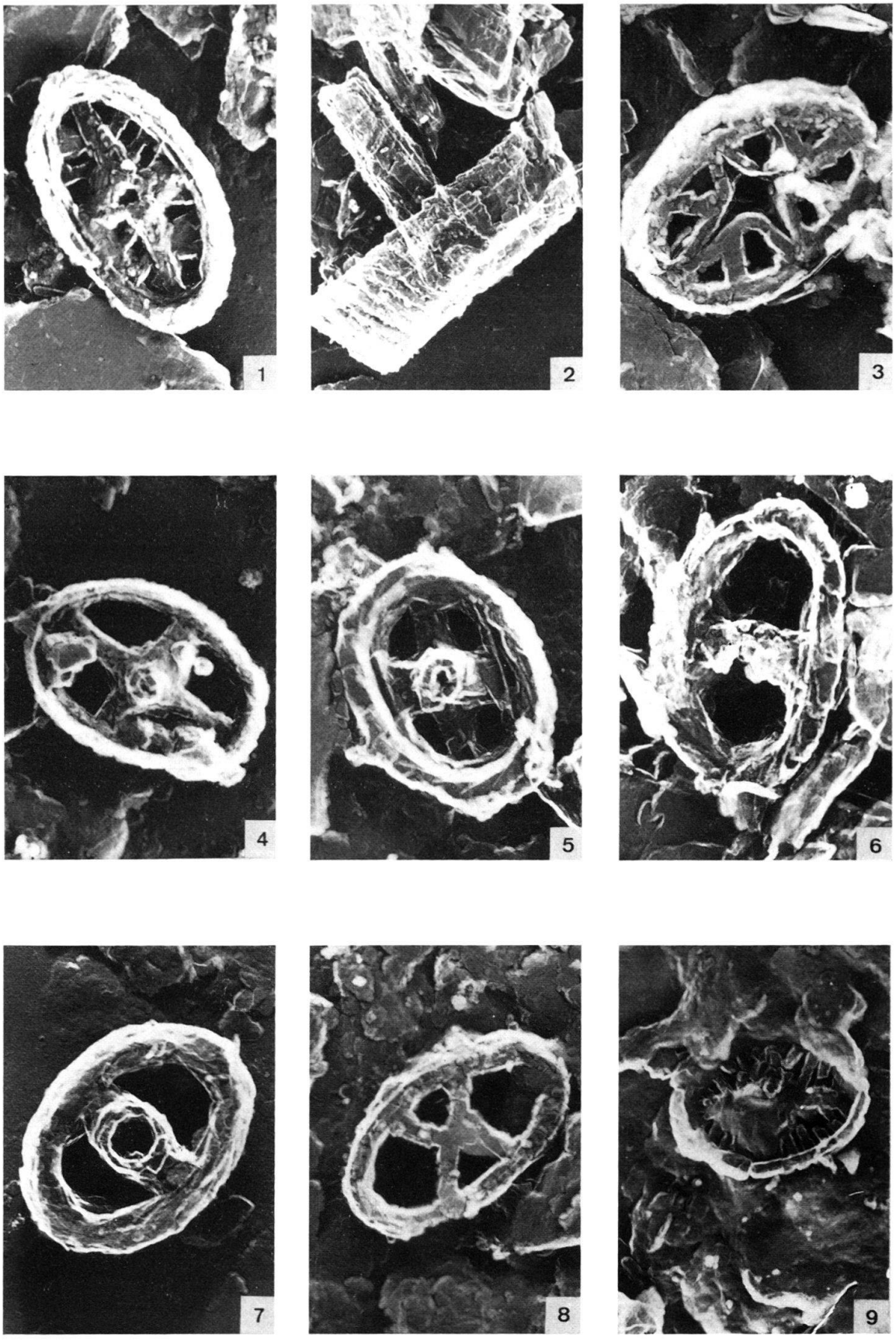
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Plate II

Fig. 1 *Parhabdolithus liasicus* DEFLANDRE, oblique view
Hypotype 41.5.1
Lyme Regis (Dorsetshire): Lias, Lower Sinemurian, Bed 48, *semicostatum* zone–*reynesi* subzone. × 6,500

Fig. 2 *Parhabdolithus marthae* DEFLANDRE, oblique view
Hypotype 41.8.1
Lyme Regis (Dorsetshire): Lias, Lower Sinemurian, Bed 48, *semicostatum* zone–*reynesi* subzone. × 4,500

Fig. 3 *Tubirhabdus patulus* PRINS, distal view
Holotype 42.1.2
Lyme Regis (Dorsetshire): Lias, Lower Pliensbachian (Carixian), Bed 120d, *ibex* zone–*valdani* subzone. × 13,000

Fig. 4 *Crepidolithus crucifer* PRINS, distal view
Holotype 44.2.2
Lyme Regis (Dorsetshire): Lias, Lower Pliensbachian (Carixian), Bed 122a, *davoei* zone–*maculatum* subzone. × 9,000

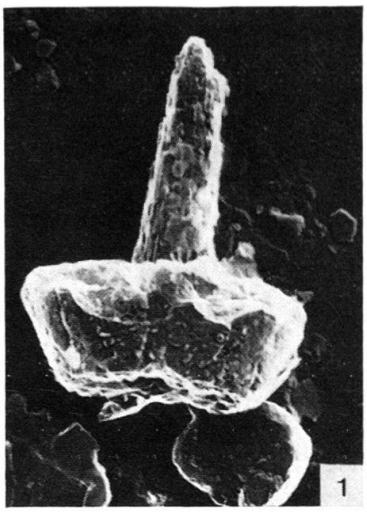
Fig. 5 *Crepidolithus cavus* PRINS, distal view
Holotype 44.1.1
Lyme Regis (Dorsetshire): Lias, Lower Pliensbachian (Carixian), Bed 122a, *davoei* zone–*maculatum* subzone. × 9,200

Fig. 6 *Podorhabdus cylindratus* NOEL, proximal view
Hypotype 43.12.1
Seatown (Dorsetshire) Lias, Upper Toarcian, Down Cliff Clay, *levesquei* zone–*levesquei* subzone. × 10,000

Fig. 7 *Podorhabdus macrogranulatus* PRINS, distal view
Holotype 43.11.2
Seatown (Dorsetshire): Lias, Upper Toarcian, Down Cliff Clay, *levesquei* zone–*levesquei* subzone. × 9,000

Fig. 8 *Hexapodorhabdus cuvillieri* NOEL, distal view (*Watznaueria communis* REINHARDT also in figure)
Hypotype 55.9.2
Port-en-Bessin (Normandy), Bathonian Fullers Earth, *zigzag* zone. × 13,500

Fig. 9 *Octopodorhabdus decussatus* (MANIVIT) distal view
Hypotype 56.12.1
Port-en-Bessin (Normandy), Bathonian, Fullers Earth, *zigzag* zone. × 9,000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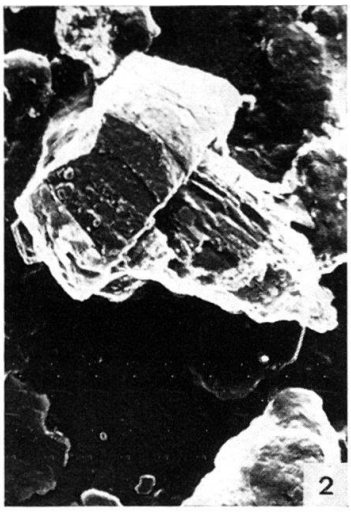
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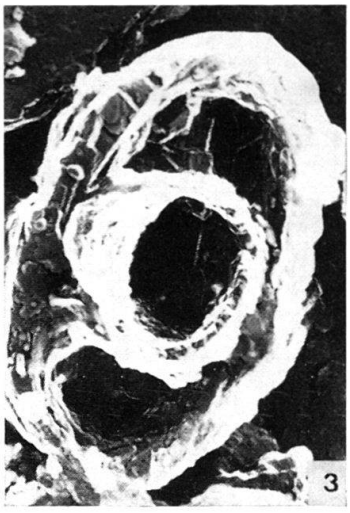
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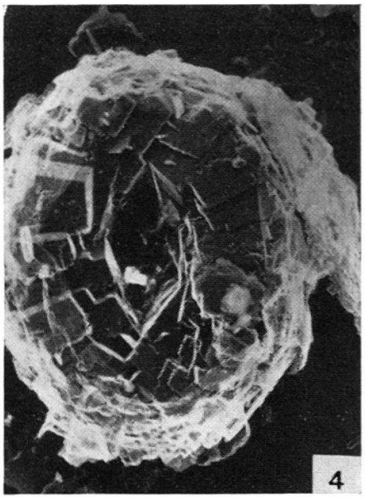
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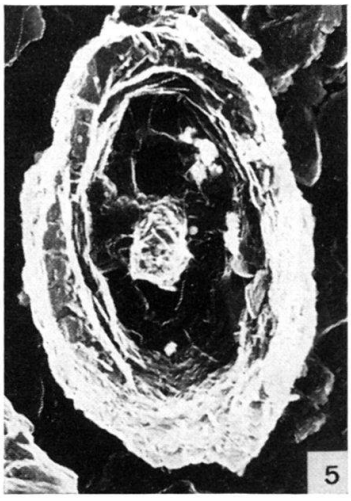
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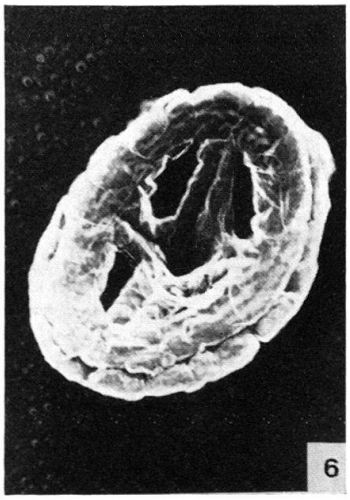
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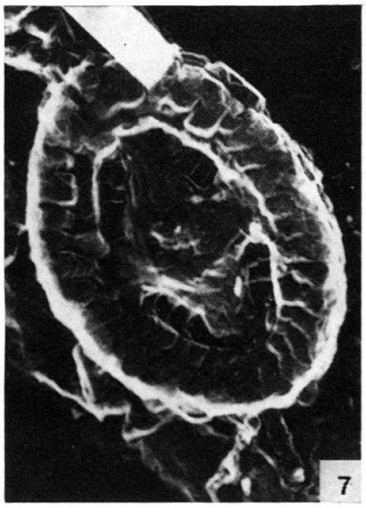
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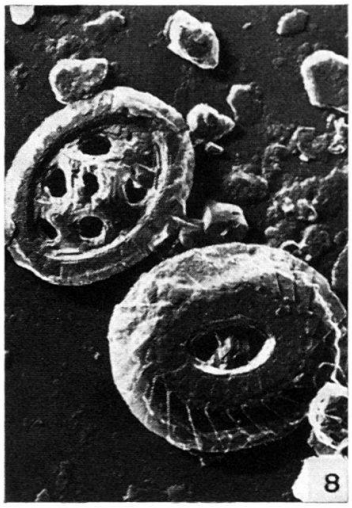
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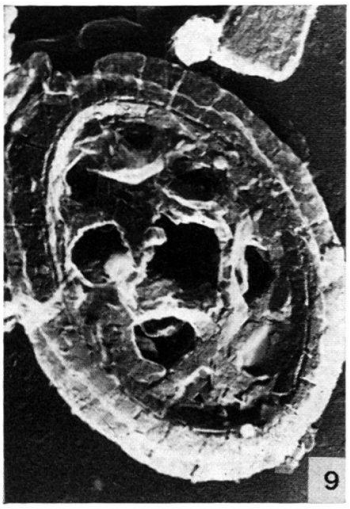
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Plate III

Fig. 1 — *Paleopontosphaera dubia* NOEL, distal view
Hypotype 42.10.2
Lyme Regis (Dorsetshire); Lias, Lower Pliensbachian (Carixian), Bed 120a, *ibex* zone–*valdani* subzone. × 9,000

Fig. 2 — *Paleopontosphaera veterna* PRINS, distal view
Holotype 55.11.1
Port-en-Bessin (Normandy), Bathonian, Fullers Earth, *zigzag* zone. × 12,000

Fig. 3 — *Paleopontosphaera veterna* PRINS, proximal view
Paratype 55.10.2
Port-en-Bessin (Normandy), Bathonian, Fullers Earth, *zigzag* zone. × 12,000

Fig. 4 — *Striatomarginis primitivus* n.sp., distal view
Holotype 44.10.1
Seatown (Dorsetshire) Lias, Upper Toarcian, Down Cliff Clay, *levesquei* zone–*levesquei* subzone. × 12,000

Fig. 5 — *Ethmorhabdus gallicus* NOEL, proximal view
Hypotype 55.7.1
Port-en-Bessin (Normandy), Bathonian, Fullers Earth, *zigzag* zone. × 5,000

Fig. 6 — *Sollasites lowei* (BUKRY), distal view
Hypotype 43.12.2
Seatown (Dorsetshire) Lias, Upper Toarcian, Down Cliff Clay, *levesquei* zone–*levesquei* subzone. × 14,500

Fig. 7 — *Discorhabdus biperforatus* n.sp., distal view
Holotype 56.5.2
Port-en-Bessin (Normandy), Bathonian, Fullers Earth, *zigzag* zone. × 5,000

Fig. 8 — *Discorhabdus* sp., proximal view
Hypotype 44.11.2
Seatown (Dorsetshire) Lias, Upper Toarcian, Down Cliff Clay, *levesquei* zone–*levesquei* subzone. × 5,500

Fig. 9 — *Alvearium dorsetense* BLACK
Hypotype 42.4.2.
Lyme Regis (Dorsetshire) Lias, Lower Pliensbachian (Carixian), *ibex* zone–*valdani* subzone. × 9,000


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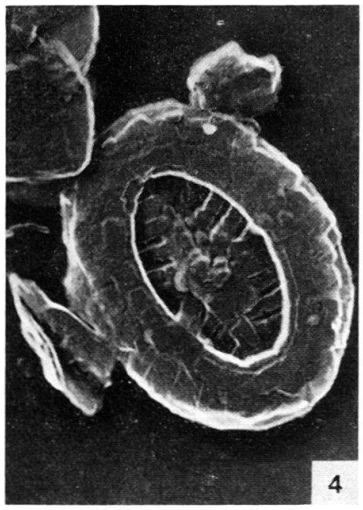
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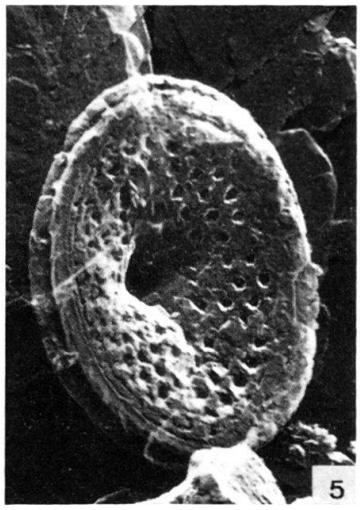
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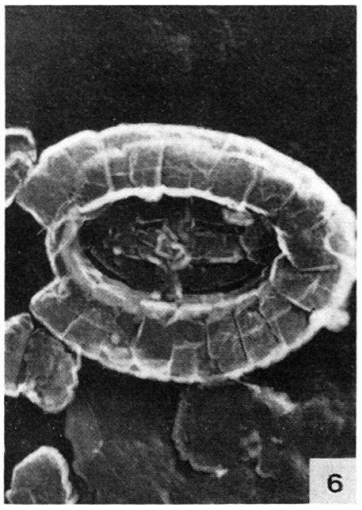
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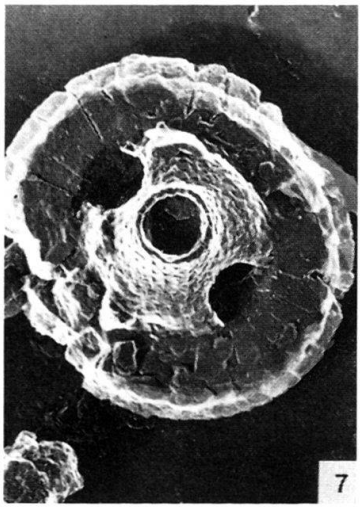
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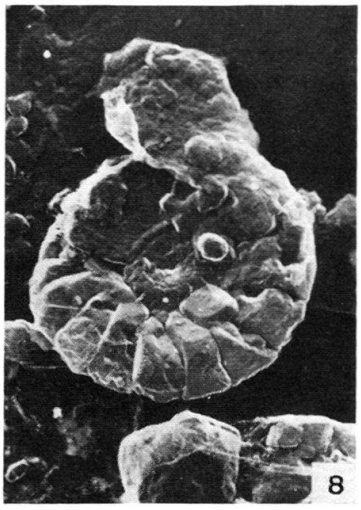
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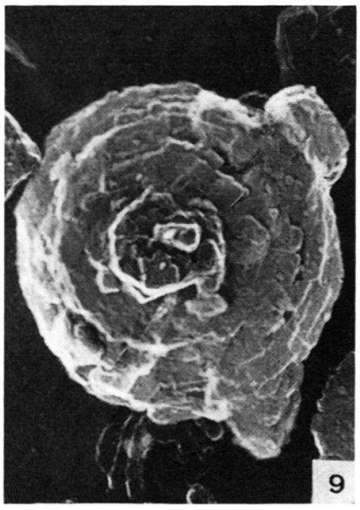
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