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# Electron Microscope Studies of Oxford Clay Coccoliths

By Anthony P. Rood<sup>1</sup>), William W. Hay<sup>2</sup>) and Tom Barnard<sup>1</sup>)

#### **ABSTRACT**

This paper is the first detailed work on Upper Jurassic (Callovian and Oxfordian) coccoliths since the work of Noel (1965). The research forms the basis for a later paper on the stratigraphical ranges, and evolution of these flora. Thirty-six species are described, of which eleven are new species, and six new combinations. The status of many of the orders, families, sub-families and genera is discussed. Three orders, two families, seven sub-families and two genera are proposed as new.

#### Introduction

During recent years emphasis has been given to the study of calcareous nannoplankton, particularly their systematics and stratigraphic use. Most of this research was concentrated on coccoliths from the Tertiary (HAY et al., 1967; BRAMLETTE & WILCOXON, 1967) and the Cretaceous (ČEPEK & HAY, 1969; REINHARDT 1966; GARTNER, 1968; BUKRY, 1969).

Research on the Jurassic has been sparse and consists chiefly of early optical and electron microscope studies (Deflandre & Fert, 1954) and brief mentions of Jurassic genera and species in more comprehensive works (Stradner, 1963; Reinhart, 1966). The most important recent research on Jurassic coccoliths (Noel, 1965) consists of an electron microscope study of species from selected scattered localities and horizons from NW-Europe and N-Africa. This work concentrates on the systematics, not on an overall stratigraphical approach, although the monograph forms the basis of further studies on Jurassic coccoliths.

Using optical methods, PRINS (1969) produced a short but important account of the suggested evolution of Liassic coccoliths; unfortunately a number of both the genera and species remain to be validated.

In view of the paucity of research on the Jurassic coccoliths in general, and almost complete lack of published work on those in Britain, it was considered appropriate to commence a systematic investigation in order to build up a stratigraphic framework to provide a basis for the use of these fossils for correlation.

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Earlier work (STRADNER, 1963) suggests the Callovian to Oxfordian coccolith floras to be considerably more abundant and diverse than those of the Middle and Lower Jurassic. Consideration of this, together with the availability of a new, but temporary, section at Millbrook (Bedfordshire) spanning a considerable range of the Callovian and Oxfordian, encouraged the authors to publish first on the Upper Jurassic ("Oxford Clay").

Close biostratigraphic control was obtained using the existing ammonite zones, so that this research could be used as a guide to future work.

#### Stratigraphy

Details of the stages and zones of the relevant parts of the Upper Jurassic, and the ranges covered by the localities are given in Figure 1, based on Callomon (1962).

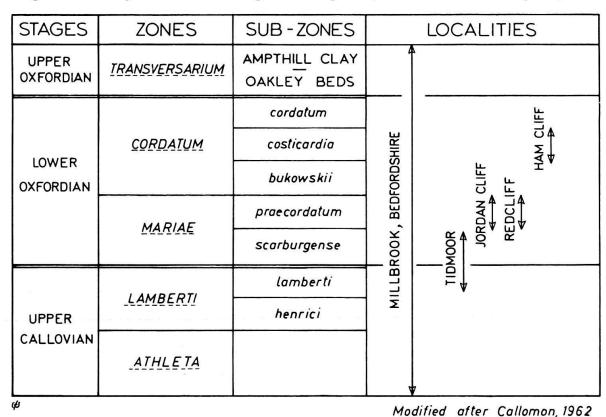


Figure 1. Comparative ranges of sections studied.

The localities which provided the samples studied can be divided into two groups:

- 1. Millbrook (Bedfordshire) where there is an almost continuous section, representing the ammonite zones *athleta-cordatum*, with remnants of the local facies, Oakley Beds and Ampthill Clay, with little ammonite control except indications of the *transversarium* zone.
- 2. Isolated exposures of Oxford Clay (clay facies) along the Dorset Coast (Fig. 3) of the Fleet and Weymouth Bay. Detailed descriptions of the sections at Tidmoor Point (lamberti zone), the promontory S.E. of Tidmoor Point (lower mariae zone), Jordan Cliff (precordatum subzone), Recliff (precordatum subzone) and Ham Cliff (cordatum zone) are all given in ARKELL (1947).

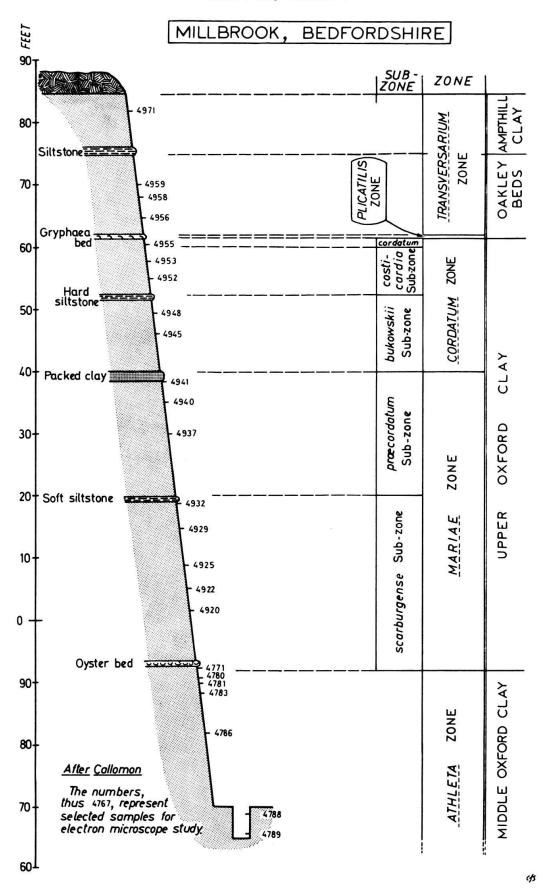


Figure 2. Temporary section at Millbrook (Bedfordshire) exposed during the Autumn of 1968.

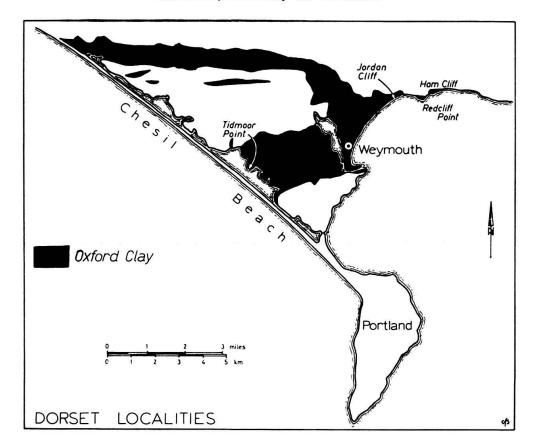


Figure 3. Localities in Dorset, Oxford Clay.

Details of the sections, together with the sample numbers (preserved in the Micropalaeontology Dept., University College, London) are given in Figures 2 and 3.

#### SYSTEMATIC PALEONTOLOGY

Kingdom PLANTAE
Division CHRYSOPHYTA
Class COCCOLITHOPHYCEAE ROTHMALER, 1951

# Order EIFFELLITHALES, new order

# Diagnosis

Coccoliths with a simple marginal area (eiffellithalid rim) consisting solely of a double cycle of elements; the two cycles are superposed in such a way that they appear as a single cycle in most proximal and distal views, a suture being visible only on the inner surface of the circlet, facing the central area. Central structures are variable, consisting of a cross, bar or more complex feature which may be surmounted by a spine.

## Family Ahmuellerellaceae Reinhardt, 1965

#### Definition

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

## Genus Vekshinella LOEBLICH & TAPPAN, 1963

Type: Ephippium acutiferra VEKSHINA, 1959.

# Synonyms

Ephippium Vekshina, 1950 (homonym of Ephippium Bolton, 1798) objective senior synonym with the same type species; Valgalapilla Bukry, 1969, subjective junior synonym (type: Vekshinella imbricata Gartner, 1968) established because Vekshina's illustration of the side view of Ephippium acutiferra indicated a slight proximal extension of the stem, a feature unknown in any of the species assigned by Gartner to Vekshinella, nor reported in any subsequent work. It now seems evident that the proximal projection indicated by Vekshina was not an integral part of the coccolith, and replacement of Vekshinella by Vagalapilla is here regarded as unwarranted.

# Vekshinella stradneri, new species Plate I, Figure 2

1968 Zygolithus crux (Deflandre & Fert) of Stradner, Adamiker & Maresch, Pl. 28, p. 36-37.

# Diagnosis

Coccoliths with an eiffellithalid rim and a central cross aligned in the major and minor axes of the ellipse; the short bar of the cross is slightly offset at the center. Description

The rim of this species is narrow, with a slightly inclined peripheral wall, and consists of about 40 strongly imbricate wedges on the distal side. The bars of the cross are constructed of large overlapping tabulae. The shorter arms of the cross are offset at the center. At the point of juncture between the arms, the cross and the rim, the arms expand slightly in the direction of inclination of the overlapping rim segments. A circular stem arises from the center of the cross.

#### Differentiation

This species is distinguished from other members of the genus by its relatively simple construction and by the offset of the shorter arms at the center.

#### Remarks

Named after Dr. H. Stradner in recognition of his pioneer work in the study of coccoliths.

Holotype: 34.5.1

Paratypes: 34.1.2, 34.8.1

Dimensions: length 3.2 μm, width 2.4 μm Type locality: Millbrook (Bedfordshire) Type level: transversarium zone (4971)

# Vekshinella quadriarculla NOEL, new combination Plate I, Figure 1

1965a Discolithus quadriarcullus NOEL, Fig. 7, p. 4.

1965 b Discolithus quadriarcullus NOEL, NOEL, Fig. 7, Pl. 1, Fig. 14-15, Pl. 2, Fig. 1-2, p. 74-75.

#### Remarks

NOEL (1965) refused to accept the opinion of LOEBLICH & TAPPAN (1963) that the generic name Discolithus is properly attributed to Huxley, 1868 and preferred to consider it to have been first validated by Kamptner, 1949. LOEBLICH & TAPPAN, 1963 substituted the taxon Discolithina for Discolithus as the latter is, in the Animal Kingdom, a homonym of *Discolithus* Fortis, 1802. If the name *Discolithus* is correctly attributed to HUXLEY, it was almost certainly intended to be a taxon in the Animal Kingdom, and must be replaced by Discolithina LOEBLICH & TAPPAN; if it is attributed to KAMPTNER, then it was probably intended to be a plant, and might be allowed to stand as NOEL suggested. NOEL noted that LOEBLICH & TAPPAN designated Discolithus vigintiforatus as type of Discolithina ipso facto Discolithus. As in the case of the type designation of Zygolithus, discussed below, she refused to accept the prior designation, and proposed one of her new species, Discolithus quadriarcullus as type. This is unacceptable because of 1. the prior valid type designation by LOEBLICH & TAPPAN, and 2. the species selected was not among those originally included in the genus. Of current valid genera, Vekshinella is nearest to including this species. Vekshinella quadriarculla is, however, a unique member of the genus in that the arms of the central cross have curved margins, becoming narrower between the rim and the center. The four openings are oval, but pointed at the ends, rather than having the shape of a quarter of a circle as in other members of the genus.

Hypotype: 34.6.1

Paratypes: 33.8.2, 27.8.1, 27.2.2

Dimensions: length 3.1 μm, width 2.3 μm

## Family Zygodiscaceae HAY & MOHLER, 1967

#### Definition

Coccoliths with an eiffellithalid rim and a central structure developed either (1 as a stem having quadripartite construction with sutures oriented in the equal of the ellipse and touching the margin of the ellipse in the minor axis (Subfamily *Parhabdolithoideae* Gartner, 1968), or (2) with or without a stem arising from a bar in the minor axis of the ellipse (Subfamily *Zygodiscoideae* Bukry, 1969).

# Subfamily Zygodiscoideae Bukry, 1969

## Definition

Coccoliths with an eiffellithalid rim and a bar oriented in the minor axis of the ellipse. The bar may be complex, and most commonly consists of four optically continuous regions separated along the major and minor axes of the ellipse. In many species, the bar is surmounted by a short spine having a circular cross section. Cocco-

liths of this sort superficially resemble the original concept of "zygolith" of KAMPTNER (1937, 1941).

## Genus Zeugrhabdotus REINHARDT, 1965

Type: Zygolithus erectus Deflandre, 1954 Synonym: "Zygolithus" of many authors.

### Definition

Elliptical coccoliths with an eiffellithalid rim, a bar in the minor axis of the ellipse, and a short stem or circular cross section arising from the bar.

#### Remarks

Considerable confusion has arisen over the designation or the type species of the genus Zygolithus KAMPTNER ex MATTHES, 1956. KAMPTNER (1963) designated Coccolithus sculptus Kamptner, 1952, as type species, but this cannot be accepted as this species was not among those originally included in the genus. MASLOV (1963) designated Zygolithus dubius Deflandre, 1954, as type species; this designation is valid and must be accepted according to the rules of botanical nomenclature. LOEBLICH & TAPPAN (1963) designated Zygolithus erectus Deflandre, 1954, as type species, but as noted by LOEBLICH & TAPPAN (1966), this was subsequent to the designation of Z. dubius as type species by Maslov, and must be disregarded. Noel (1965, pp. 57-58) presented a detailed account of the nomenclatural problems, noting that "en ce qui concerne la désignation de l'espèce type, celle de V.P. MASLOV (Z. dubius) étant antérieure à celle de A.R. LOEBLICH et H. TAPPAN, est seule valable". In spite of her awareness of the valid type designation of MASLOV, NOEL proceeded to designate a new type species for Zygolithus, Zygolithus bussoni NoEL, 1956, a species not among those originally included in the genus. MasLov's selection of Zygolithus dubius as type is in many ways a fortunate choice, because Z. dubius is conspecific with or very closely related to Neococcolithes lososnensis Sujkowski (Hay & Mohler, 1967; BLACK, 1967), so that Zygolithus becomes a junior synonym of Neococcolithes Suj-KOWSKI, 1931. This effectively solves the problem of the difference of the concept of the term "zygolith" as originally used by KAMPTNER (1937, 1941) and the concept of the genus Zygolithus. The term "zygolith" was originally used to refer to coccoliths of the Recent genus Zygosphaera. These coccoliths are elliptical in plan view, and also have a bridge which is oriented in the minor axis of the ellipse and is surmounted by a short spine. However in side view, the difference between coccoliths of this sort and Mesozoic coccoliths referred to Zygolithus is evident. The Recent coccoliths have a strongly curved bridge which rises high above the rim, giving the coccolith the aspect of a stirrup in side view. The short spine or knob arises from the peak of the arched ridge. In Mesozoic forms, such as "Zygolithus" erectus the bar lies in the plane of the elliptical rim. A further significant difference has been revealed by electron microscopic investigation of Recent relatives of Zygosphaera – all of the closely related forms studied thus far have been found to be holococcoliths, constructed of minute rhombs or prisms of calcite.

REINHARDT (1965) assumed that the designation of *Coccolithus sculptus* KAMPT-NER, 1952, as type of *Zygolithus* was correct, and considered the genus to be restricted

to forms with a single cycle of rim elements and a crossbar in the minor axis. For forms with a double cycle of rim elements and a crossbar in the minor axis surmounted by a stem, Reinhardt proposed the genus Zeugrhabdotus, designating Zygolithus erectus Deflandre, 1954, as type. In his monographic study, Reinhardt (1966) noted that Kamptner's designation of Coccolithus sculptus must be invalid because it was not among the species originally included in Zygolithus, and unaware of Maslov's designation of Zygolithus dubius Deflandre, 1954, he accepted Loeblich & Tappan's (1963) designation of Zygolithus erectus as type of Zygolithus, and thus concluded incorrectly that his own genus Zeugrhabdotus would be a junior objective synonym of Zygolithus.

Because Maslov's designation of Zygolithus dubius as type of Zygolithus is valid and has priority, Reinhard's genus Zeugrhabdotus, with Zygolithus erectus as its type species, is valid and the correct name for a number of Mesozoic species.

# Zeugrhabdotus erectus (Deflandre) Plate I, Figure 3

1954 Zygolithus erectus Deflandre in Deflandre & Fert, Fig. 60-61, Pl. 15, Fig. 14-17 [not Fig. 62], p. 150.

not 1965 Zygolithus erectus Deflandre of Noel, Fig. 2, Pl. 1, Fig. 3-4, p. 62-64.

1965 Zeugrhabdotus erectus (Deflandre) Reinhardt, p. 37.

1966 Zygolithus erectus Deflandre, Reinhardt, Pl. 15, Fig. 3, p. 40.

#### Remarks

Deflandre designated as holotype the specimen illustrated in his Figures 14–15, Pl. 15, and text Figure 60 (p. 150) (Note: in the explanation of plate 15, all four Figures, 14–17 are referred to as holotype, but the last two Figures are certainly micrographs of a different specimen from that illustrated in the first two Figures). From the illustrations of the holotype it is evident that the rim is very narrow, and the openings large. Electron microscope investigation shows that the two openings are spanned by a delicate perforate sheet which is indetectable with either phase contrast illumination or polarised light.

Hypotype: 26.3.2.

Dimensions: length 4.5 μm, width 3.0 μm

# Zeugrhabdotus noeli, new species Plate I, Figure 4

1954 Zygolithus erectus Deflandre in Deflandre & Fert, Fig. 62.

1955 Zygolithus erectus Deflandre of NoEL, Fig. 2, Pl. 1, Fig. 3-4, p. 62-64.

1968 Zygolithus erectus Deflandre of Stradner, Adamiker & Maresch, Pl. 25, Pl. 26, Fig. 1-2, p. 34-35.

# Diagnosis

A species of Zeugrhabdotus with a wide margin and small central openings.

# Description

The margin appears in distal view to be constructed of 16–22 overlapping wedges. The bridge is constructed of a few large elements. The stem is hollow, pierced by a circular opening. The diameter of the central openings is about  $^{1}/_{3}$  the diameter of the coccolith.

# Differentiation

This species is readily separated from Zeugrhabdotus erectus by the relative proportions of the central openings in this species the central openings are 1/3 or less the width of the coccolith, while in Z. erectus, the openings are more than 2/3 the width of the coccolith.

#### Remarks

Extensive descriptions of this species have been presented by NOEL (1955) and STRADNER, ADAMIKER & MARESCH (1968). The species is named after Dr. D. NOEL in recognition of her pioneer work into Jurassic coccoliths.

Holotype: 34.9.1. Paratype: 34.1.1.

Dimensions: length 2.9 μm, width 1.8 μm. Type locality: Millbrook (Bedfordshire) Type level: transversarium zone (4971)

# Zeugrhabdotus salillum (NOEL), new combination Plate I, Figure 5

1965a Discolithus salillum Noel, Fig. 5-6, p. 4.
1965b Discolithus salillum Noel, Noel, Fig. 5-6, Pl. 1, Fig. 8-12, p. 72-74.

# Remarks

The reason why Noel placed this species in the genus Discolithus rather than in Zygolithus (= Zeugrhabdotus) is not clear. The structure of the rim of Z. salillum appears to be more complex, but this is due in part to the fact that the width of the marginal rim at its proximal and distal surfaces is markedly different, the distal surface being almost three times the width of the proximal surface. The view through the replica of the long sutures between the imbricate wedges of the peripheral surface of the rim creates a complex image, best understood by viewing stereoscopic pairs of electron micrographs. In Zeugrhabdotus erectus, the width of the rim varies only slightly between the proximal and distal surfaces, so that the micrographs indicate a simply constructed coccolith. The major difference between this species and the type of the genus is the slope of the perphery of the rim therefore this species is transferred to Zeugrhabdotus.

Hypotype: 24.4.2.

Dimension: length 3.3 μm, width 2.5 μm.

# Family Actinozygaceae, new family

## Diagnosis

Elliptical coccoliths with an eiffellithalid rim and a complex central structure consisting of either (1) six or more bars disposed symmetrically with respect to the major and minor axes (Subfamily *Actinozygoideae*, new subfamily), or, (2) four or more bars disposed asymmetrically in such a way that one end of the coccolith may be duplicated by rotation of the other end through 180 degrees (subfamily *Diadozygoideae*, new subfamily).

# Subfamily Actinozygoideae, new subfamily

# Diagnosis

Elliptical coccoliths with an eiffellithalid rim and six or more bars disposed symmetrically with respect to the axes of symmetry of the ellipse. A spine may arise from the point of juncture of the bars in the center of the coccolith. In addition to the type of genus, *Pontilithus* Gartner, 1968, belongs here.

# Genus Actinozygus GARTNER, 1968

Type: Tremalithus regularis GORKA, 1957

### Definition

Elliptical eiffellithalid coccoliths with 6–10 symmetrically arranged bars. Remarks

LOEBLICH & TAPPAN (1969) considered this genus to be invalid because the type species (*Rhabdolithus splendens* Deflandre, 1954) of a previously described genus (*Rhabdolithina* Reinhardt, 1967) was included in it by Gartner. Gartner was unaware of Reinhardt's (1967) paper, and inasmuch as the type species of *Rhabdolithina* and *Actinozygus* are markedly different, recognition of both genera is warranted.

# Actinozygus geometricus (GORKA), new combination Plate I, Figure 6

1957 Discolithus geometricus GORKA, Pl. 4, Fig. 8, p. 259, 279.

1968 Zygolithus geometricus (GORKA) STRADNER, ADAMIKER & MARESCH, Pl. 36, Pl. 37, Fig. 1–4, p. 40.

#### Remarks

This species is readily recognized by its strict symmetry, with six bars: two in the minor axis of the ellipse, and four arranged at 60 degrees on either side of the minor axis.

Hypotype: 28.6.2.

Dimension: length 3.1  $\mu$ m, width 2.1  $\mu$ m.

# Subfamily Diadozygoideae, new subfamily

# Diagnosis

Elliptical or rhomboidal coccoliths with an eiffellithalid rim and a central structure constructed of four or more bars distribued so that rotation of one half of the coccolith by 180 degrees repeats the other half.

#### Remarks

Members of this subfamily probably gave rise to the calciosoleniids before the Albian.

# Genus Diadozygus, new genus

Type: Diadozygus rotatus, n. sp.

# Diagnosis

Elliptical to rhomboidal coccoliths, with six or more bars disposed asymmetrically so that one end of the coccolith may be repeated by diad (180 degrees) rotation of the other. A pair of bars extending part of the length of the coccolith but offset at the center, are diagnostic of most species of the genus.

# Diadozygus asymmetricus, new species

# Plate I, Figure 7

# Diagnosis

A species of *Diadozygus* with elliptical outline and eight asymmetrically disposed bars.

## Description

The eight bars extend from the center of the ellipse to the margin in an asymmetrical manner, not occupying any of the axes of symmetry of the ellipse. The openings between the bars in the ends of the coccolith are larger than those closer to the minor axis. The bars fuse in a large elliptical central platform from which a spine having circular cross section arises.

# Differentiation

This species differs from the only other eight rayed member of the genus, *Diadozygus emendatus* (LYUL'EVA) [= *Dictyolithus emendatus* LYUL'EVA, 1967, Geol. Zhurnal, v. 27, p. 92, 96, Pl. 4, Fig. 41; *Corolithion emendatus* (LYUL'EVA) ČEPEK & HAY, 1969, Gulf Coast Assoc. Geol. Socs., Trans., v. 19, p. 327] in being elliptical rather than rhomboidal in outline.

#### Remarks

The name asymetricus was given to the species, because of its diagnostic asymmetry.

Holotype: 24.5.1 Paratype: 24.10.1

Dimensions: length 3.3 μm, width 2.5. μm Type locality: Millbrook (Bedfordshire)

Type level: athleta zone (4789)

# Diadozygus callomoni, new species Plate I, Figure 8

## Diagnosis

An elliptical species of *Diadozygus* with ten asymmetrically arranged radial bars. Description

The six central radial bars extend from a central platform to the periphery; the four radial bars in the ends of the ellipse are joined to the central platform by two short sublongitudinal bars tangential to the platform. The central platform supports a spine.

## Differentiation

This species differs from the only other ten-rayed outline of *Diadozygus*, *D. rotatus*, n. sp., in having an elliptical, not rhombic, outline.

#### Remarks

The species was named after Dr. J. H. Callomon in recognition of his assistance in placing the samples in a definite ammonite control, and for his help in the field.

Holotype: 31.1.1.

Dimensions: length 3.1 μm, width 1.9 μm Type locality: Tidmoor Point (Dorsetshire)

Type level: lamberti zone (4653)

Diadozygus rotatus, new species Plate I, Figure 9; Plate II, Figure 1

# Diagnosis

A rhombical species of *Diadozygus* with ten asymmetrically arranged radial bars; the four bars in the ends of the rhomb are connected to the center by short sublongitudinal bars.

## Description

Six of the radial bars extend from the central platform to the margin; two of these meet the margin at corners of the rhomb. The four radial bars in the ends of the rhomb are connected to the central platform by short sublongitudinal bars tangential to the central platform. The central platform supports a spine.

## Differentiation

This species differs from the other ten-rayed species of the genus *D. callomoni* n. sp., in having a rhomboidal rather than elliptical outline. It differs from the similar rhomboidal form *D. emendatus* LYUL'EVA (common in the Cretaceous) in having ten rather than eight radial bars.

#### Remarks

The species was named *rotatus* because by rotating half the coccolith through 180 degrees the two halves are the coincident.

Holotype: 30.9.2.

Paratypes: 29.2.2, 30.7.2

Dimensions: length 3.8  $\mu m$ , width 2.5  $\mu m$ , stem length 13  $\mu m$ .

Type locality: Millbrook (Bedfordshire)

Type level: lamberti zone (4771)

# Diadozygus dorsetense, new species Plate II, Figures 2, 3

# Diagnosis

 $An elliptical species of {\it Diadozygus} \ with four teen asymmetrically arranged radial bars.$ 

# Description

Two pairs of radial bars extend from the central platform to the margin; four other pairs of radial bars extend from two longer sublongitudinal bars to the margin. The sublongitudinal bars are tangential to the central platform, but extend to join the rim near the ends, where they are offset in the direction of overlap of the rim elements.

#### Differentiation

This is the only recorded member of the genus with fourteen bars.

#### Remarks

The species was named after the type locality.

Holotype: 27.3.2.

Paratypes: 19.11.2, 29.11.1

Dimensions: length 2.8 μm, width 1.7 μm Type locality: Redcliff Point (Dorsetshire)

Type level: mariae zone - praecordatum subzone (4659)

# Genus Truncatoscaphus, new genus

Type: Zygolithus delftensis STRADNER & ADAMIKER, 1966

## Diagnosis

Elongate coccoliths with an eiffellithalid rim and truncate ends; the longer sides are curved or broadly obtusely angled, the ends are flat so that the overall outline is that of an elongate subhexagonal ring.

#### Remarks

This genus is probably derived from *Diadozygus*, but intermediate forms are unknown.

# Truncatoscaphus delftensis (STRADNER & ADAMIKER), new combination Plate II, Figures 4, 5

1966 Zygolithus delftensis Stradner & Adamiker, Fig. 8-11, Pl. 2, Fig. 3, p. 338.

1968 Zygolithus delftensis Stradner & Adamiker, Stradner, Adamiker & Maresch, Pl. 39, p. 41.

#### Remarks

The overlapping elements of the rim of this species present a sawtooth pattern in oblique or side views. Specimens from the Oxfordian resemble those from the Albian except that the sides appear to be more curved than angled. This is a subtile difference, and erection of a new name for the Oxfordian forms seems unwarranted.

Hypotypes: 27.11.2, 25.8.2

Dimensions: length 2.6 μm, width 1.3 μm

### Genus Diadorhombus Worsley, 1971

Type: Diadorhombus rectus Worsley, 1971

# Diagnosis

Rhombic coccoliths with an eiffellithalid rim and four or more internal bars supporting a central stem.

#### Remarks

The asymmetry and rhomboidal outline of this genus suggests a close affinity to *Diadozygus*, n. gen., but intermediate forms are as yet unpublished.

# Diadorhombus minutus, new species Plate II, Figure 6

## Diagnosis

Equilateral rhombic rims with and asymmetric central cross oriented at 30° to the axes joining the corners of the rhomb.

# Description

The rhomboidal rim displays typical eiffellithalid construction, with nearly vertical sides; the central cross is asymmetrically disposed to the axes of the rhomb, its bars form an angle of about 30 degrees with the axes joining the corners of the rhombic rim. At the point of juncture between the arms of the cross and the rim, there is an extension of the arm into the acute angle between the arm and the rim so that the cross has a slight swastika-like shape. A stem arises from the center of the cross.

#### Differentiation

This species is distinguished from members of the genus *Corollithion* by its asymmetry. Rhombic rims have been described from the Upper Cretaceous under the generic term *Dictyolithus* by GORKA, but the details of their structure are unknown, and GORKA did not illustrate any species with a central cross.

## Remarks

The species is named *minutus* on account of its diminutive size.

Holotype: 26.11.1

Paratype: 27.1.1, 28. 4.2

Dimensions: Side length 1.4 µm

Type locality: Millbrook (Bedfordshire)

Type level: mariae zone (4932)

# Family Stephanolithionaceae Black, 1968, emended

# Diagnosis

Elliptical, circular, or polygonal coccoliths with a rim constructed of large, thick slightly overlapping elements; at least two cycles of elements are present, although one cycle may be very large and the other very small.

## Subfamily Crepidolithoideae, new subfamily

#### Definition

Elliptical coccoliths of the Family Stephanolithionaceae with no external projections.

# Genus Crepidolithus NOEL, 1965

Type: Discolithus crassus Deflandre, 1954

#### Definition

Coccoliths with a broad elliptical rim constructed of a proximal cycle of thin tabular elements extending into the center of the coccolith, and a much thicker distal cycle of slightly prismatic elements. As noted by Prins (1969), a vestige of a central cross is usually visible between crossed polarizers.

# Crepidolithus crassus (Deflandre)

# Plate II, Figure 7

1954 Discolithus crassus Deflandre in Deflandre & Fert, Fig. 49, Pl. 15, Fig. 12-13, p. 144.

1965a Crepidolithus crassus (Deflandre), Noel, p. 5, Fig. 17-21.

1965 b Crepidolithus crassus (Deflandre), Noel, Fig. 17-21, Pl. 2, Fig. 3-7, Pl. 3, Fig. 1-5, p. 85-91.

#### Remarks

Specimens from Millbrook seem to be better preserved than those from Anncot and Vassy figured by Noel. The center of the coccoliths is spanned by a grille with polygonal openings. Between crossed nicols, the center appears to be roughly cruciform, as noted by Prins (1969), suggesting that the grille is constructed of four optically continuous areas.

Hypotype: 27.5.1

Dimensions: length 13.0 µm, width 9.1 µm

Locality: Millbrook (Bedfordshire)

Level: mariae zone - praecordatum subzone (4941)

### Subfamily Stephanolithionoideae Vekshina, 1959

#### Definition

Circular, hexagonal, or polygonal coccoliths of the Family *Stephanolithionaceae* with external projections.

### Genus Stephanolithion Deflandre, 1939

Type: Stephanolithion bigoti Deflandre, 1939

#### Definition

Coccoliths with a hexagonal or polygonal rim constructed of one cycle of thin tabular elements and a much thicker cycle of slightly imbricate prismatic elements; lateral projections extend outward from the rim.

# Stephanolithion bigoti Deflandre Plate II, Figure 8

1939 Stephanolithion bigoti Deflandre, Fig. 1-9, p. 1332.

1965a Stephanolithion bigoti Deflandre, Noel, Fig. 9-14, p. 5.

1965 b Stephanolithion bigoti Deflandre, Noel, Fig. 9-14, Pl. 5, Fig. 1-10, Pl. 6, Fig. 1-2, p. 78-83.

1968 Stephanolithion bigoti Deflandre, Black, Pl. 152, Fig. 1, p. 807-808.

#### Remarks

The structure of this species has been discussed at length by Noel. The number of lateral spines is variable, ranging from six to ten, although the vast majority of specimens have six. Stradner (1963, p. 13) has noted that this species tends to break up, so that some samples have numerous fragments resembling minute letters, especially E's, T's, and U's.

Hypotype: 38.7.2

Dimensions: Diameter across spines, 10.0 µm.

# Order PODORHABDINALES, new order

#### Diagnosis

Coccoliths with a marginal area constructed of two petaloid cycles of elements which are not at all, or only very slightly, imbricate. The marginal areas of members of this order have a characteristic appearance in bright phase field phase contrast illumination, being much darker than the background.

#### Family Podorhabdaceae Noel, 1965

## Definition

Elliptical coccoliths with a podorhabdid rim.

#### Subfamily Podorhabdoideae, new subfamily

#### Diagnosis

Elliptical coccoliths with a podorhabdid rim and four or more radial bars supporting a central stem.

Genus Podorhabdus NoEL, 1965

Type: Podorhabdus grassei NOEL, 1965

#### Definition

Coccoliths with a podorhabdid rim and a central stem supported by four bars.

Podorhabdus (?) rahla NOEL Plate II, Figure 9

1965b Podorhabdus rahla NOEL, Pl. 9, Fig. 8, p. 105.

#### Remarks

This species is recognized by the appearance of the stem in side view. At a height above the base approximately equal to the diameter of the base, four broad and short

projections extend outward from the stem. NoEL did not figure the plan view of this species, but in the Oxfordian material, it has been noted that it may have four or six supporting arms. Transitional forms have two additional small openings added in the ends of the elliptical base. Observation of the base is frequently hampered by the large projections of the stem. According to the definitions of the genera proposed by NOEL, some of the four-armed specimens of this species should belong to *Podorhabdus*, and the six-armed specimens to *Hexapodorhabdus*.

Hypotype: 27.2.1

Dimensions: length approximately 18 µm.

# Podorhabdus cylindratus Noel Plate III, Figure 1, 2

1965a Podorhabdus cylindratus NOEL, Fig. 30, p. 6 [invalid].

1965 b Podorhabdus cylindratus NOEL, Fig. 30, Pl. 9, Fig. 3, 7, p. 103-104.

1968 Podorhabdus cylindratus NOEL, BLACK, Pl. 150, Fig. 1, p. 806.

#### Remarks

This species is distinguished from *Podorhabdus grassei* NOEL, 1965, by having a relatively narrower stem.

Hypotypes: 31.10.2, 32.10.1

Dimensions: length 6.0 µm, width 5.1 µm

# Genus Hexapodorhabdus NOEL, 1965

Type: Hexapodorhabdus cuvillieri NOEL, 1965.

#### Definition

Coccoliths with a podorhabdid rim and a stem supported by six bars.

# Hexapodorhabdus cuvillieri NOEL Plate III, Figure 3

1965 b Hexapodorhabdus cuvillieri Noel, Pl. 9, Fig. 4-6, p. 105-106.

#### Remarks

This is the only species of *Hexapodorhabdus* described by Noel, and is recognized in top view only. There is no way of differentiating six-rayed specimens of *Podorhabdus* rahla, from which the upper part of the stem has been broken away, from specimens of *Hexapodorhabdus* cuvillieri.

Hypotype: 33.9.1

Dimensions: length 5.2 µm, width 4.0 µm

### Genus Octopodorhabdus NOEL, 1965

Type: Octopodorhabdus praevisus NOEL, 1965.

## Definition

Coccoliths with a podorhabdid rim and a stem supported by eight bars.

# Octopodorhabdus decussatus (MANIVIT) new combination Plate III, Figure 4

1959 [1961] Discolithus decussatus Manivit, Pl. 1, Fig. 7, p. 14.
1963 Rhabdolithus decussatus (Manivit), Stradner, Pl. 5, Fig. 8–8a, p. 9.

#### Remarks

This species differs from the type of the genus in having arms which lie in the major and minor axis of the ellipse. The other four arms do not extend from the center margin, but join the longitudinal bar near the foci of the ellipse.

Hypotype: 28.3.1.

Paratypes: 30.8.1, 35. 3.1.

Dimensions: length approximately 7 µm, width 5.6 µm.

# Genus Polypodorhabdus NOEL, 1965

Type: Polypodorhabdus escaigi NOEL, 1965

Definition

Coccoliths with a podorhabdid rim, a stem, and many bars in the central area.

# Polypodorhabdus escaigi NOEL Plate III, Figures 5, 6

1965a Polypodorhabdus escaigi NOEL, Fig. 32, p. 6.

1965 b Polypodorhabdus escaigi NOEL, NOEL, Fig. 32, Pl. 10, Fig. 6-8, p. 109-110.

#### Remarks

Oxfordian specimen have bars in the major and minor axes of the ellipse, bars in the equal axis of the ellipse, and two additional pairs of bars extending from the midlengths of the major and minor axes to the margin. The stem is prominent in many specimens. Noel's specimens from Niort show an extra pair of bars extending from that in the major axis to the margin in the ends of the ellipse.

Hypotypes: 27.3.1, 27.10.2

Dimensions: length 6.7 µm, width 5.0 µm.

#### Subfamily Ethmorhabdoideae, new subfamily

#### Diagnosis

Coccoliths with a podorhabdid rim and a solid or cribrate center.

#### Remarks

In addition to the type genus, Cretarhabdus Bramlette & Martini, 1964, and Rhagodiscus Reinhardt, 1967, belong here.

#### Genus Ethmorhabdus NOEL, 1965

Type: Ethmorhabdus gallicus NOEL, 1965

Definition

Coccoliths with a podorhabdid rim and a cribrate center.

# Ethmorhabdus gallicus NOEL Plate III, Figure 7

1965 a Ethmorhabdus gallicus NOEL, Fig. 33-34, p. 6.

1965 b Ethmorhabdus gallicus NOEL, NOEL, Fig. 33-34, Pl. 10, Fig. 1-2, 5, p. 110-112.

1968 Ethmorhabdus gallicus NOEL, BLACK, Pl. 150, Fig. 3, p. 806.

#### Remarks

Specimens from the British Callovian and Oxfordian closely resemble the holotype.

Hypotype: 33.2.1

Dimensions: length 6.6 µm, width 4.9 µm

# Ethmorhabdus anglicus, new species

# Plate III, Figure 8

# Diagnosis

A species of *Ethmorhabdus* with only two cycles of large perforations.

## Description

Elliptical podorhabdid coccoliths with two cycles of perforations, the outer cycle with about 16 openings, the inner cycle with about 8. The openings are polygonal, about 0.5 µm in diameter. A central stem is present.

#### Differentiation

This species is distinguished from *E. gallicus* NOEL by having only about half as many perforations.

#### Remarks

The species was named anglicus because of its occurrence in England.

Holotype: 36.11.1 Paratype: 32.1.2

Dimensions: length 5.0 μm, width 4.1 μm Type locality: Millbrook (Bedfordshire)

Type level: mariae zone - scarburgense subzone (4780)

#### Subfamily Sollasiteoideae, new subfamily

### Diagnosis

Elliptical coccoliths with a podorhabdid rim, a transverse bar, and three or more longitudinal or sublongitudinal bars. No central stem is present.

### Genus Sollasites BLACK, 1967

Type: Sollasites barringtonensis Black, 1967 (= Coccolithus horticus Stradner, Adamiker, and Maresch, 1966)

## Synonyms

Costacentrum Bukry, 1969, subjective junior synonym with Coccolithus horticus STRADNER, AKADEMIKER & MARESCH, 1966, as type.

#### Definition

Elliptical coccoliths with a podorhabdid rim, a transverse bar, and three or more longitudinal to sublongitudinal bars.

# Sollasites horticus (STRADNER, ADAMIKER & MARESCH) Plate III, Figure 9

- 1966 Coccolithus horticus Stradner, Adamiker & Maresch, Pl. 2, Fig. 4, p. 337.
- 1967 Sollasites barringtonensis BLACK, Fig. 4, p. 144.
- 1968 Coccolithus horticus Stradner, Adamiker & Maresch, Gartner, Pl. 10, Fig. 2, Pl. 25, Fig. 6-8, Pl. 26, Fig. 1, p. 18.
- 1968 Sollasites horticus (Stradner, Adamiker & Maresch) Black, Pl. 144, Fig. 1-2, p. 798.
- 1969 Costacentrum horticum (Stradner, Adamiker & Maresch) Bukry, Pl. 21, Fig. 12, Pl. 22, Fig. 1-4, p. 44.
- 1969 Sollasites horticus (Stradner, Adamiker & Maresch) Čepek & Hay, p. 325.

#### Remarks

This species is distinguished by having three parallel longitudinal bars.

Hypotype: 28.8.2

Dimensions: length 2.9 µm, width 2.4 µm

# Sollasites lowei (BUKRY) new combination Plate IV, Figure 1

1969 Costacentrum lowei BUKRY, Pl. 22, Fig. 5-6, p. 44.

#### Remarks

This species has a central straight longitudinal bar flanked by two curved sublongitudinal bars which join the central bar at its outer extremities.

Hypotype: 29.8.2

Dimensions: length 4.5 µm, width 3.3 µm

### Sollasites concentricus, new species

Plate IV, Figure 2

#### Diagnosis

A species of *Sollasites* with a straight longitudinal bar flanked by four curved sublongitudinal bars.

# Description

The central area is large, and the transverse bar is wide. The central longitudinal bar is straight. The four curved sublongitudinal bars remain equidistant from the marginal rim, and join the straight longitudinal bar at regular spaced intervals.

# Differentiation

This species differs from S. lowei BUKRY in having four rather than two sublongitudinal bars.

#### Remarks

The diagnostic concentric arrangement of the bars suggests this species name.

Holotype: 27.8.2

Dimensions: length 2.3 μm, width 1.7 μm Type locality: Millbrook (Bedfordshire)

Type level: mariae zone - praecordatum subzone (4941)

# Sollasites bipolaris, new species Plate IV, Figure 3

## Diagnosis

A species of *Sollasites* with two pairs of concentric bars surrounding the foci of the elliptical central area.

# Description

The central structure consists of a transverse bar which expands towards the margin, but may not be complete at the center. In each end of the coccolith, symmetrical about the foci of the elliptical central area, are two concentric curved bars. The inner pair of concentric bars forms a figure 8, the outer pair a more open figure.

#### Remarks

The arrangement of the central bars resembles a bipolar magnetic field, hence the name *bipolaris*.

#### Differentiation

The bipolar nature of the bars of this species serves to distinguish it readily from other members of the genus.

Holotype: 27.6.1

Paratypes: 28.13.1, 32.12.2

Dimensions: length 3.0 μm, width 2.0 μm Type locality: Millbrook (Bedfordshire)

Type level: mariae zone - praecordatum subzone (4941)

# Subfamily Paleopontosphaeroideae, new subfamily

#### Diagnosis

Elliptical coccoliths with a wide podorhabdid rim and a narrow central area lacking prominent bars, but with a central spine commonly present.

# Genus Paleopontosphaera NOEL, 1965

Type: Paleopontosphaera dubia NoEL, 1965.

## Definition

Elliptical coccoliths with a wide podorhabdid rim and no supplementary cycles of elements around the central depression of the distal shield.

# Paleopontosphaera dubia NOEL

Plate IV, figure 9

1965a Paleopontosphaera dubia NOEL, Fig. 8, p. 4.

1965b Paleopontosphaera dubia NOEL, NOEL, Fig. 8, Pl. 7, Figs. 1-13, pp. 76-78.

## Remarks

Specimens investigated in this study frequently have a short knob or spine in the center of the depression in the distal shield.

Hypotype: 28.9.2

Dimensions: length 3.1  $\mu$ m, width 2.5  $\mu$ m

## Family Prediscosphaeraceae, new family

# Diagnosis

Circular coccoliths with a podorhabdid rim.

#### Remarks

BLACK (1967) proposed a Family Deflandriaceae including the single genus Deflandrius BRAMLETTE & MARTINI 1964. Deflandrius is here regarded as a synonym of Prediscosphaera Vekshina, 1959. The family name proposed here is not a nomen substitutum for the Family Deflandriaceae of Black, but is more broadly defined and includes several genera.

# Subfamily Prediscosphaeroideae Gartner, 1968, emended.

# Diagnosis

Circular coccoliths with four buttresses supporting a square stem constructed of a few long laths.

#### Remarks

The original definition of this subfamily corresponds closely to the current definition of the Order *Podorhabdinales*. The emended definition of the subfamily indicated above corresponds to the definition of the Family *Deflandriaceae* BLACK. The genus *Prediscosphaera* VEKSHINA is the sole member of this subfamily as emended; it is not known to range below the Albian.

#### Subfamily Discorhabdoideae Noel, 1965

Diagnosis: Circular coccoliths with a circular stem constructed of many short laths. Ramarks: A single genus, *Discorhabdus* NOEL, 1965, is referred to this family.

#### Genus Discorhabdus NOEL, 1965

Type: Rhabdolithus patulus (DEFLANDRE), 1954.

#### Definition

Coccoliths with a circular podorhabdid bar and a circular stem constructed of numerous small laths.

#### Remarks

The species of this genus are distinguished by the shape and size of the stem as seen in side view.

## Discorhabdus patulus (DEFLANDRE)

### Plate IV, Figure 4

- 1954 Rhabdolithus patulus Deflandre in Deflandre & Fert, Fig. 97-98, Pl. 15, Fig. 40-45, p. 163.
- 1965a Discorhabdus patulus (Deflandre), Noel, Fig. 55-57, p. 10.
- 1965 b Discorhabdus patulus (Deflandre), Noel, Fig. 55-57, Pl. 21, Fig. 6-8, 10-11, Pl. 22, Fig. 1-2, 7, 9-10, p. 141-144.

#### Remarks

Diagnostic for this species is the moderately thick stem which flares slightly distally.

Hypotype: 32.7.2.

Dimensions: Stem length 4.6 µm

# Discorhabdus jungi NOEL Plate IV, Figures 5, 6

1965 b Discorhabdus jungi NOEL, Pl. 22, Fig. 5, p. 144-145.

#### Remarks

The stem of this species is thicker than in *D. patulus*, and flares distally to become almost as wide as the base.

Hypotypes: 6.1.2., 25.7.1.

Dimensions: Diameter of base, 10 µm

# Discorhabdus tubus NOEL Plate IV, Figure 7

1965 b Discorhabdus tubus NOEL, Pl. 21, Fig. 4, 15, p. 145-146.

#### Remarks

The diagnostic features of this species are the long slender cylindrical stem which does not flare distally.

Hypotype: 28.6.1.

Dimensions: Diameter of base, 9.5 µm

# Discorhabdus sp. Plate IV, Figure 8

#### Remarks

Isolated bases of *Discorhabdus* are not yet assignable to the species recognized above.

Hypotype: 33.12.1.

Dimensions: Diameter 3.5 µm.

Type Locality: Millbrook (Bedfordshire) Type Level: transversarium zone (4959)

# Order COCCOLITHALES, new order

## Diagnosis

Coccoliths with a marginal area constructed of three cycles of elements; two cycles extend outward peripherally to form proximal and distal shields, connected by an intermediate cycle forming a tube or girdle (coccolithid rim).

#### Family Watznaueriaceae, nom. subst.

#### Definition

Elliptical or circular coccolithids having a coccolithid rim with crystallites oriented so that both shields produce an interference figure between crossed polarizers.

#### Remarks

NOEL (1965) proposed a Family *Ellipsagelosphaeraceae*, but because *Ellipsagelosphaera* NOEL, 1965, is a junior subjective synonym of *Watznaueria* REINHARDT, 1964, the taxon *Watznaueriaceae* is proposed as a replacement. The genera *Actinosphaera* NOEL, 1965, and *Calolithus* NOEL, 1965, are here regarded as fragments of *Watznaueria* and hence junior subjective synonyms, so that neither the Subfamily *Actinosphaeroideae* NOEL, 1965, nor the Subfamily *Ellipsagelosphaeroideae* NOEL, 1965, is recognised.

#### Genus Watznaueria REINHARDT, 1964

Type: Watznaueria angustoralis Reinhardt, 1964

## Synonyms

Colvillea Black, 1964 (homonym of Colvillea Bojer & Hooker, 1834) subjective senior synonym because the type, Tremalithus barnesae Black, 1966 is probably conspecific with W. angustoralis; Maslovella Loeblich & Tappan, 1966, nomen. subst. pro Colvillea Black with the same type, subjective junior synonym; Ellipsage-losphaera Noel, 1965, subjective junior synonym because the type, Ellipsagelosphaera frequens, Noel, 1965, is closely related to W. angustoralis; Actinosphaera Noel, 1965, subjective junior synonym because the type, Actinosphaera deflandrei Noel, 1965, is a Watznaueria from which the central cycle of elements on the distal shield has been removed; Calolithus Noel, 1965, subjective junior synonym because the type, Calolithus martelae Noel, 1965, is based on a fragment of a species of Watznaueria.

#### Definition

Elliptical coccoliths with a coccolithid rim and one or more supplementary cycles of elements in the central area of the distal shield.

#### Watznaueria communis Reinhardt

Plate V, Figures 1, 2, 3, 4

1964 Watznaueria communis REINHARDT, Pl. 2, Fig. 5, p. 756.

1965a Ellipsagelosphaera frequens NoEL, Fig. 35-39, 42, p. 8.

1965b Ellipsagelosphaera frequens Noel, Noel, Fig. 35-40, Pl. 11, Fig. 7-10, Pl. 12, Fig. 1-10, Pl. 13, Fig. 1-10, p. 119-126.

1966 Watznaueria communis Reinhardt, Fig. 3, Pl. 4, Fig. 3, 5-6, Pl 23, Fig 5, p 17-18

#### Remarks

This is the most abundant species in all the samples studied. It is distinguished by the relatively small central area.

Hypotypes: 15.8.1, 11.8.1., 29.10.2.

Dimensions: length typically 5.0 µm, width typically 4.0 µm

# Watznaueria britannica (STRADNER)

Plate V, Figure 5

1963 Coccolithus britannicus STRADNER, Pl 1, Fig 7-7a, p 10

1964 Watznaueria britannica (STRADNER) REINHARDT, Fig. 5, Pl 2, Fig 3, p 753

1965a Ellipsagelosphaera lucasi NOEL, Fig. 40-41, p 8.

1965 b Ellipsagelosphaera lucasi Noel, Noel (pars), Fig. 41-42, Pl. 11, Fig. 1-3, 5, 6, p. 126-129.

1966 Watznaueria britannica (Stradner) Reinhardt, Reinhardt, Fig. 4a-b, Pl. 4, Fig. 7a-b, p. 17.

#### Remarks

The type of *Ellipsagelosphaera lucasi* Noel closely resembles the type of *W.britannica* and two are here regarded as conspecific. This species is distinguished by a large central opening by a brige in the minor axis of the ellipse.

Hypotype: 20.9.1.

Dimensions: length 7.0 µm, width 6.0 µm.

# Watznaueria reinhardti, new species

Plate V, Figure 6

1965b Ellipsagelosphaera lucasi NOEL (pars), Pl. 11, Fig. 4, p. 126-129.

### Diagnosis

A species of Watznaueria with a very large central opening spanned by a bridge in the minor axis.

# Description

The rim is unusually narrow, and the central opening very large. The bar in the minor axis bifurcates as it joins the rim.

Differentiation: The relative proportions of the width of the rim and large central opening distinguish this species from W. britannica (STRADNER).

Holotype: 33.4.1. Paratype: 28.10.1

Dimensions: length 4.7 μm, width 4.1 μm. Type Locality: Millbrook (Bedfordshire).

Type Level: cordatum zone - bukowskii subzone (4945).

# Watznaueria sp.

Plate V, Fig. 7.

#### Remarks

A species of *Watznaueria* in which the major and minor axes are almost equal in size. The relatively small central opening, typical of *Watznaueria communis* (REINHARDT), is spanned by a delicate bridge.

Hypotype: 33.5.1

Dimensions: length 5.6 μm, width 5.0 μm. Type Locality: Millbrook (Bedfordshire).

Type Level: cordatum zone – bukowskii subzone (4945).

## Genus Cyclagelosphaera NOEL, 1965

Type: Cyclagelosphaera margereli Noel, 1965

#### Definition

Circular coccoliths with a coccolithid rim and one or more supplementary cycles of elements in the central area of the distal shield.

# Cyclagelosphaera margereli NOEL, 1965

Plate V, Figures 8, 9

1965a Cyclagelosphaera margereli NoEL, Fig. 45-48, p. 12.

1965b Cyclagelosphaera margeli NOEL, NOEL, Fig. 44-46, Pl. 17, Fig. 4-9, Pl. 18, Fig. 1, 2, Pl. 20, Fig. 2-4, p. 130-132.

1968 Cyclagelosphaera margereli NOEL, BLACK, Pl. 144, Fig. 5, p. 798.

#### Remarks

A circular coccolith falling within the Family Watznaueriaceae. The innermost cycle of elements often closes the central tube.

Hypotypes: 34.7.2, 11.10.2

Dimensions: Diameter typically 4 µm.

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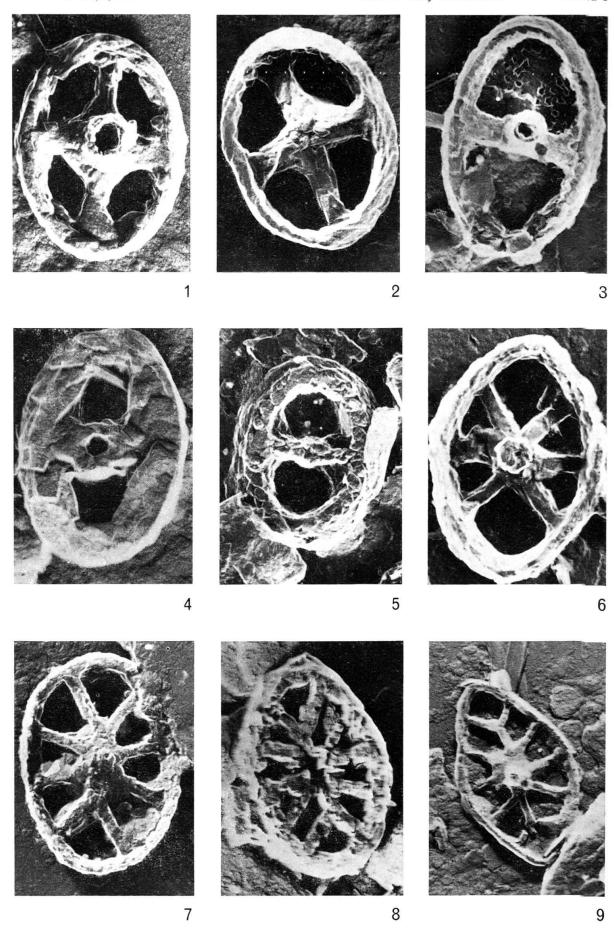
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# Plate I\*

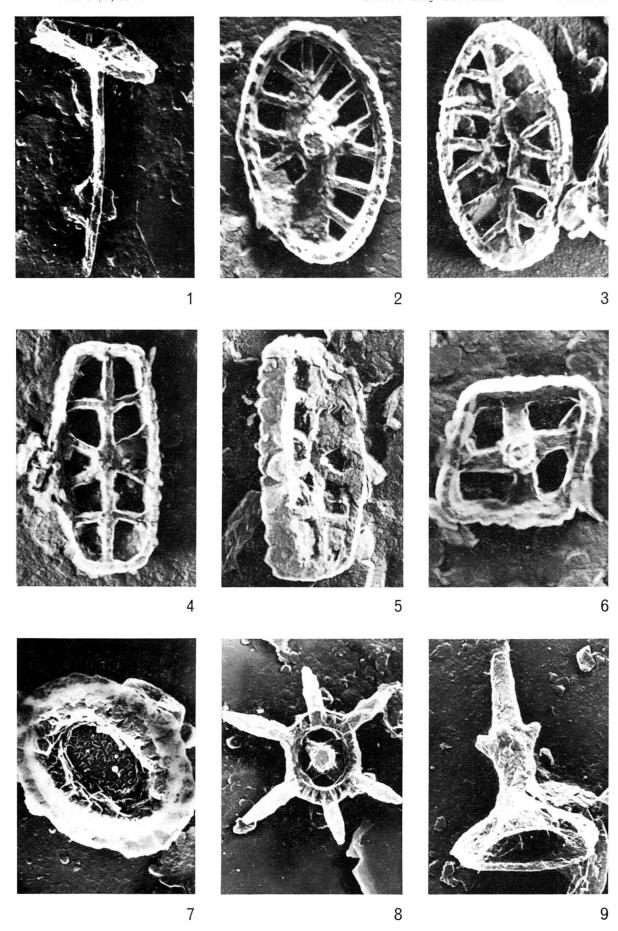
Fig. 1	Vekshinella quadriarcullus (NOEL), distal side Hypotype 34.6.1 Millbrook (Bedfordshire); transversarium zone (4971) 15,900 ×
Fig. 2	Vekshinella stradneri, n. sp., distal side Holotype 34.5.1 Millbrook (Bedfordshire); transversarium zone (4971) 15,600 ×
Fig. 3	Zeugrhabdotus erectus (DEFLANDRE), distal side Hypotype 26.3.2 Millbrook (Bedfordshire); mariae zone – scarburgense subzone (4932) 11,900 ×
Fig. 4	Zeugrhabdotus noeli, n. sp., distal side Holotype 34.9.1 Millbrook (Bedfordshire); transversarium zone (4971) 18,300 ×
Fig. 5	Zeugrhabdotus salillum (NOEL), distal side Hypotype 24.4.2 Millbrook (Bedfordshire); athleta zone (4789) 12,400 ×
Fig. 6	Actinozygus geometricus (GORKA), distal side Hypotype 28.6.2 Millbrook (Bedfordshire); cordatum zone – bukowskii subzone (4948) 16,600 ×
Fig. 7	Diadozygus asymmetricus, n. gen., n. sp., distal side Holotype 24.5.1 Millbrook (Bedfordshire); athleta zone (4789) 13,400 ×
Fig. 8	Diadozygus callomoni, n. gen., n. sp., proximal side Holotype 31.1.1 Tidmoor Point (Dorsetshire); lamberti zone (4653) 14,900 ×
Fig. 9	Diadozygus rotatus, n. gen., n. sp., distal side Holotype 30.9.2 Millbrook (Bedfordshire); lamberti zone (4771) 11,400 ×
* Plates I V	are electron migrographs of plotinum shadowed carbon realizes

<sup>\*</sup> Plates I-V, are electron micrographs of platinum-shadowed carbon replicas.



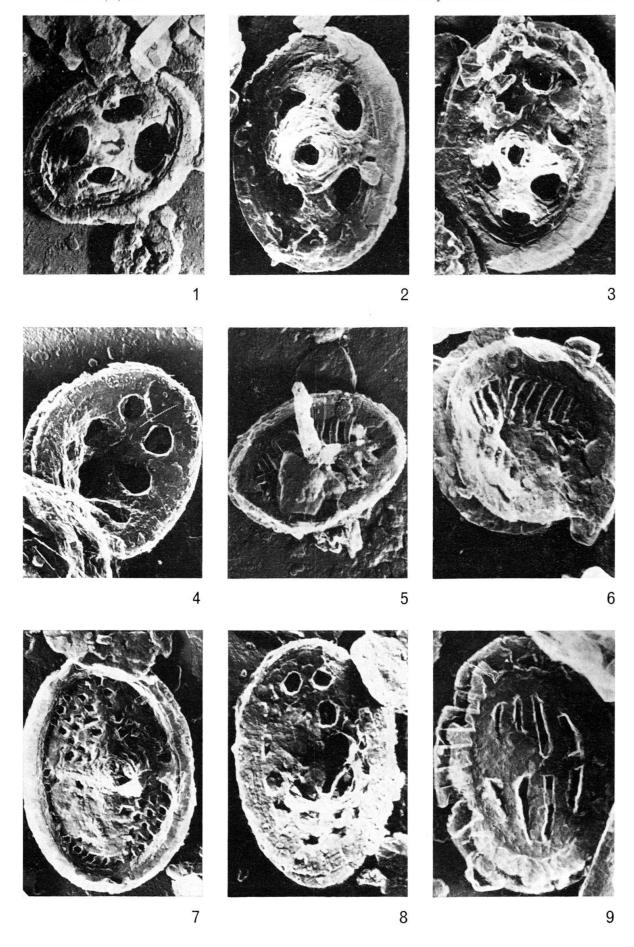
# Plate II

Fig. 1  Diadozygus rotatus, n. gen., n. sp., oblique view. Holotype 29.2.2 Millbrook (Bedfordshire); lamberti zone (4771) 4,500 ×  Fig. 2  Diadozygus dorsetense, n. gen., n. sp., distal side Holotype 27.3.2 Redcliff Point (Dorsetshire); mariae zone – praecordatum subzone (4659) 19,000 ×  Fig. 3  Diadozygus dorsetense, n. gen., n. sp., proximal side Holotype 29.11.1 Redcliff Point (Dorsetshire); mariae zone – praecordatum subzone (4659) 18,000 ×  Fig. 4  Truncatoscaphus delftensis (Stradner and Adamiker), distal side Hypotype 27.11.2 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 17,800 ×  Fig. 5  Truncatoscaphus delftensis (Stradner and Adamiker), oblique view Hypotype 25.8.2 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 18,000 ×  Fig. 6  Diadorhombus minutus, n. gen., n. sp., distal side Holotype 26.11.1 Millbrook (Bedfordshire); mariae zone (4932) 20,300 ×  Fig. 7  Crepidolithus crassus (Deflandre), plan view Hypotype 27.5.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 4,000 ×  Fig. 8  Stephanolithion bigoti Deflandre, distal side Hypotype 38.7.2 Millbrook (Bedfordshire); cordatum zone – costicardia subzone (4952) 4,800 ×  Fig. 9  Podorhabdus rahla Noel, oblique view Hypotype 27.2.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4936) 3,800 ×		
Holotype 27.3.2 Redcliff Point (Dorsetshire); mariae zone – praecordatum subzone (4659) 19,000 ×  Fig. 3  Diadozygus dorsetense, n. gen., n. sp., proximal side Holotype 29.11.1 Redcliff Point (Dorsetshire); mariae zone – praecordatum subzone (4659) 18,000 ×  Fig. 4  Truncatoscaphus delftensis (STRADNER and ADAMIKER), distal side Hypotype 27.11.2 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 17,800 ×  Fig. 5  Truncatoscaphus delftensis (STRADNER and ADAMIKER), oblique view Hypotype 25.8.2 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 18,000 ×  Fig. 6  Diadorhombus minutus, n. gen., n. sp., distal side Holotype 26.11.1 Millbrook (Bedfordshire); mariae zone (4932) 20,300 ×  Fig. 7  Crepidolithus crassus (Deflandre), plan view Hypotype 27.5.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 4,000 ×  Fig. 8  Stephanolithion bigoti Deflandre, distal side Hypotype 38.7.2 Millbrook (Bedfordshire); cordatum zone – costicardia subzone (4952) 4,800 ×  Fig. 9  Podorhabdus rahla Noel, oblique view Hypotype 27.2.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4936)	Fig. 1	Holotype 29.2.2 Millbrook (Bedfordshire); lamberti zone (4771)
Holotype 29.11.1 Redcliff Point (Dorsetshire); mariae zone – praecordatum subzone (4659) 18,000 ×  Fig. 4  Truncatoscaphus delftensis (STRADNER and ADAMIKER), distal side Hypotype 27.11.2 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 17,800 ×  Fig. 5  Truncatoscaphus delftensis (STRADNER and ADAMIKER), oblique view Hypotype 25.8.2 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 18,000 ×  Fig. 6  Diadorhombus minutus, n. gen., n. sp., distal side Holotype 26.11.1 Millbrook (Bedfordshire); mariae zone (4932) 20,300 ×  Fig. 7  Crepidolithus crassus (Deflandre), plan view Hypotype 27.5.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 4,000 ×  Fig. 8  Stephanolithion bigoti Deflandre, distal side Hypotype 38.7.2 Millbrook (Bedfordshire); cordatum zone – costicardia subzone (4952) 4,800 ×  Fig. 9  Podorhabdus rahla Noel, oblique view Hypotype 27.2.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4936)	Fig. 2	Holotype 27.3.2 Redcliff Point (Dorsetshire); mariae zone – praecordatum subzone (4659)
Hypotype 27.11.2 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 17,800 ×  Fig. 5  Truncatoscaphus delftensis (Stradner and Adamiker), oblique view Hypotype 25.8.2 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 18,000 ×  Fig. 6  Diadorhombus minutus, n. gen., n. sp., distal side Holotype 26.11.1 Millbrook (Bedfordshire); mariae zone (4932) 20,300 ×  Fig. 7  Crepidolithus crassus (Deflandre), plan view Hypotype 27.5.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 4,000 ×  Fig. 8  Stephanolithion bigoti Deflandre, distal side Hypotype 38.7.2 Millbrook (Bedfordshire); cordatum zone – costicardia subzone (4952) 4,800 ×  Fig. 9  Podorhabdus rahla Noel, oblique view Hypotype 27.2.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4936)	Fig. 3	Holotype 29.11.1 Redcliff Point (Dorsetshire); mariae zone – praecordatum subzone (4659)
Hypotype 25.8.2 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 18,000 ×  Fig. 6  Diadorhombus minutus, n. gen., n. sp., distal side Holotype 26.11.1 Millbrook (Bedfordshire); mariae zone (4932) 20,300 ×  Fig. 7  Crepidolithus crassus (Deflandre), plan view Hypotype 27.5.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 4,000 ×  Fig. 8  Stephanolithion bigoti Deflandre, distal side Hypotype 38.7.2 Millbrook (Bedfordshire); cordatum zone – costicardia subzone (4952) 4,800 ×  Fig. 9  Podorhabdus rahla Noel, oblique view Hypotype 27.2.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4936)	Fig. 4	Hypotype 27.11.2 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941)
Holotype 26.11.1 Millbrook (Bedfordshire); mariae zone (4932) 20,300 ×  Fig. 7  Crepidolithus crassus (Deflandre), plan view Hypotype 27.5.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 4,000 ×  Fig. 8  Stephanolithion bigoti Deflandre, distal side Hypotype 38.7.2 Millbrook (Bedfordshire); cordatum zone – costicardia subzone (4952) 4,800 ×  Fig. 9  Podorhabdus rahla Noel, oblique view Hypotype 27.2.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4936)	Fig. 5	Hypotype 25.8.2 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941)
Hypotype 27.5.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 4,000 ×  Fig. 8  Stephanolithion bigoti Deflandre, distal side Hypotype 38.7.2 Millbrook (Bedfordshire); cordatum zone – costicardia subzone (4952) 4,800 ×  Fig. 9  Podorhabdus rahla Noel, oblique view Hypotype 27.2.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4936)	Fig. 6	Holotype 26.11.1 Millbrook (Bedfordshire); mariae zone (4932)
Hypotype 38.7.2  Millbrook (Bedfordshire); cordatum zone – costicardia subzone (4952) 4,800 ×  Fig. 9  Podorhabdus rahla Noel, oblique view Hypotype 27.2.1  Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4936)	Fig. 7	Hypotype 27.5.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941)
Hypotype 27.2.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4936)	Fig. 8	Hypotype 38.7.2 Millbrook (Bedfordshire); cordatum zone – costicardia subzone (4952)
	Fig. 9	Hypotype 27.2.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4936)



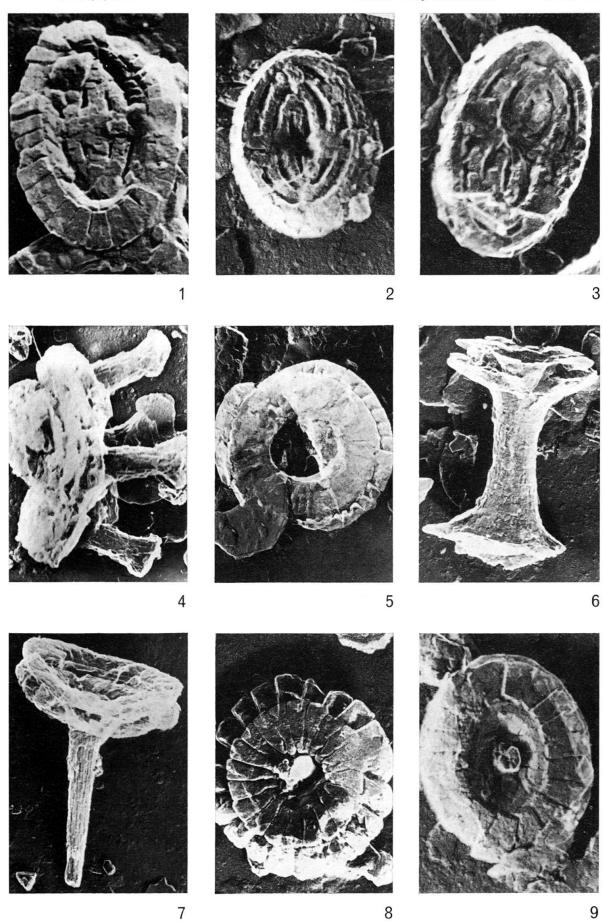
# Plate III

Fig. 1	Podorhabdus cylindratus NOEL, distal side Hypotype 31.10.2 Millbrook (Bedfordshire); athleta zone (4781) 6,300 ×
Fig. 2	Podorhabdus cylindratus NOEL, distal side Hypotype 32.10.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 8,000 ×
Fig. 3	Hexapodorhabdus cuvillieri NOEL, distal side Hypotype 33.9.1 Millbrook (Bedfordshire); cordatum zone – bukowskii subzone (4945) 9,800 ×
Fig. 4	Octopodorhabdus decussatus (MANIVIT), oblique proximal view Hypotype 28.3.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4943) 3,700 ×
Fig. 5	Polypodorhabdus escaigi Noel, distal side Hypotype 27.10.2 Millbrook (Bedfordshire); cordatum zone – bukowskii subzone (4945) 13,000×
Fig. 6	Polypodorhabdus escaigi Noel, proximal side Hypotype 27.3.1 Millbrook (Bedfordshire); cordatum zone – bukowskii subzone (4945) 13,000 ×
Fig. 7	Ethmorhabdus gallicus NOEL, distal side Hypotype 33.2.1 Millbrook, (Bedfordshire); cordatum zone – bukowskii subzone (4945) 8,100 ×
Fig. 8	Ethmorhabdus anglicus n. sp., proximal side Holotype 36.11.1 Millbrook (Bedfordshire); mariae zone – scarburgense subzone (4780) 10,100 ×
Fig. 9	Sollasites horticus (STRADNER, ADAMIKER, MARESCH) proximal side Hypotype 28.8.2 Millbrook (Bedfordshire); cordatum zone – bukowskii subzone (4945) 19,200 ×



# Plate IV

Fig. 1	Sollasites lowei (BUKRY), distal side Hypotype 29.8.2 Millbrook (Bedfordshire); transversarium zone (4959) 11,400 ×
Fig. 2	Sollasites concentricus, n. sp., proximal side Holotype 27.8.2 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 17,000 ×
Fig. 3	Sollasites bipolaris, n. sp., proximal side Holotype 27.6.1 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 13,500 ×
Fig. 4	Discorhabdus patulus (Deflandre), coccosphere fragment. viewed obliquely Hypotype 32.7.2 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 4,500 ×
Fig. 5	Discorhabdus jungi Noel, axial view Hypotype 6.1.2 Millbrook (Bedfordshire); mariae zone – scarburgense subzone (4920) 4,800 ×
Fig. 6	Discorhabdus jungi Noel, oblique view Hypotype 25.7.1 Millbrook (Bedfordshire); mariae zone – scarburgense subzone (4920) 3,300 ×
Fig. 7	Discorhabdus tubus NOEL, oblique view Hypotype 28.6.1 Millbrook (Bedfordshire); cordatum zone – bukowskii subzone (4948) 3,400 ×
Fig. 8	Discorhabdus sp., proximal view Hypotype 33.12.1 Millbrook (Bedfordshire); transversarium zone (4959) 12,200 ×
Fig. 9	Paleopontosphaera dubia (NOEL), distal side Hypotype 28.9.2 Millbrook (Bedfordshire); mariae zone – praecordatum subzone (4941) 14,700 ×



# Plate V

Fig. 1	Watznaueria communis Reinhardt, distal side; inner cycle of platlets missing Hypotype 15.18.1 Jordan Cliff (Dorsetshire); mariae zone – praecordatum subzone (4657) $5,500 \times$
Fig. 2	Watznaueria communis REINHARDT, proximal side Hypotype 11.8.1 Jordan Cliff (Dorsetshire); mariae zone – praecordatum subzone (4654) 9,800 ×
Fig. 3	Watznaueria communis REINHARDT, distal side Hypotype 28.7.1 Millbrook (Bedfordshire); transversarium zone (4971) 7,400 ×
Fig. 4	Watznaueria communis Reinhardt, proximal side Hypotype 29.10.2 Millbrook (Bedfordshire); transversarium zone (4971) 8,000 ×
Fig. 5	Watznaueria britannica (STRADNER), distal side Hypotype 20.9.1 Redcliff Point (Dorsetshire); mariae zone – praecordatum (4660) 5,800 ×
Fig. 6	Watznaueria reinhardti, n. sp., distal side Hypotype 33.4.1 Millbrook (Bedfordshire); cordatum zone – bukowskii subzone (4945) 8,100 ×
Fig. 7	Watznaueria sp., distal side Hypotype 33.5.1 Millbrook (Bedfordshire); cordatum zone – bukowskii subzone (4945) 7,000 ×
Fig. 8	Cyclagelosphaera margereli NOEL, distal side Hypotype 34.7.2 Millbrook (Bedfordshire); transversarium zone (4971) 8,500 ×
Fig. 9	Cyclagelosphaera margereli NOEL, distal side Hypotype 11.10.2 Jordan Cliff (Dorsetshire); mariae zone – praecordatum subzone (4654) 8,000 ×

