

# Dinocyst stratigraphy of the Lower Kimmeridge Clay, Westbury, England

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Dinocyst assemblages from 41 samples collected from a 40 m section of the Jurassic Lower Kimmeridge Clay in a clay-pit in Westbury, Southern England, are described.

47 dinocyst species, 1 acritarch species and 1 tasmanid species are recorded. A new genus *Protobatioladinium* and two new species *Protobatioladinium westburiensis* and *Perisseisphaeridium ingegerdii* are proposed. The species *Palaeoperidinium crassinervum* Deflandre, 1939 is redescribed and emended.

The dinocyst assemblage is confined to the *Endoscrinium luridum* Zone (Wollam & Riding, 1983) which correlates with the *Cymodoce*, *Mutabilis* and *Eudoxus* ammonite zones. The *Endoscrinium luridum* Zone is subdivided into two new dinocyst subzones, *Stephanelyton scarburghense* and *Perisseisphaeridium pannosum*.

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## Introduction

The Kimmeridge clay has its type locality on the Dorset coast of southern England (fig. 1) but in this area the Lower Kimmeridge Clay is poorly exposed. In contrast, an extremely well exposed sequence, perfect for lithostratigraphic and biostratigraphic studies, is available in the clay-pit of Blue Circle Portland Cement, at Westbury, in Wiltshire (Grid Reference ST 882528).

This section includes 40 m of Lower Kimmeridge Clay which has been divided into three ammonite zones (Birkelund, Callomon, Clausen, Nøhr-Hansen & Salinas 1983). The section contains 2.5 m of strata assigned to the upper *Cymodoce* Zone, 23.3 m of *Mutabilis* Zone and 14.5 m of *Eudoxus* Zone, all of which belong to the Lower Kimmeridgian *sensu anglico*. The sediments consist of clay, bituminous clay, oil-shale, septarian nodules and limestone. The beds dip 5°SSE.

The sequence forms the basis of this dinocyst study, the aim of which is to establish a detailed dinocyst stratigraphy relative to the established ammonite zones. 41 samples from selected beds through the 40 m sequence form the basis of this study.

## Methods

The samples were prepared using standard palynological techniques. Carbonate and silica was removed by hydrochloric and hydrofluoric acid. The organic residue was briefly oxidized by fuming nitric acid and then washed with a low concentration of potassium hydroxide.

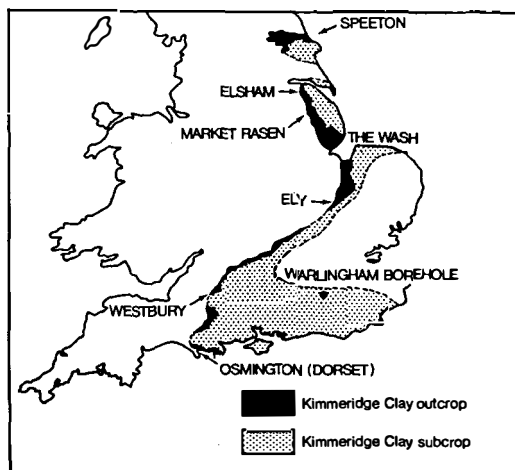


Fig. 1. Map showing the Kimmeridge Clay outcrop and distribution in England.

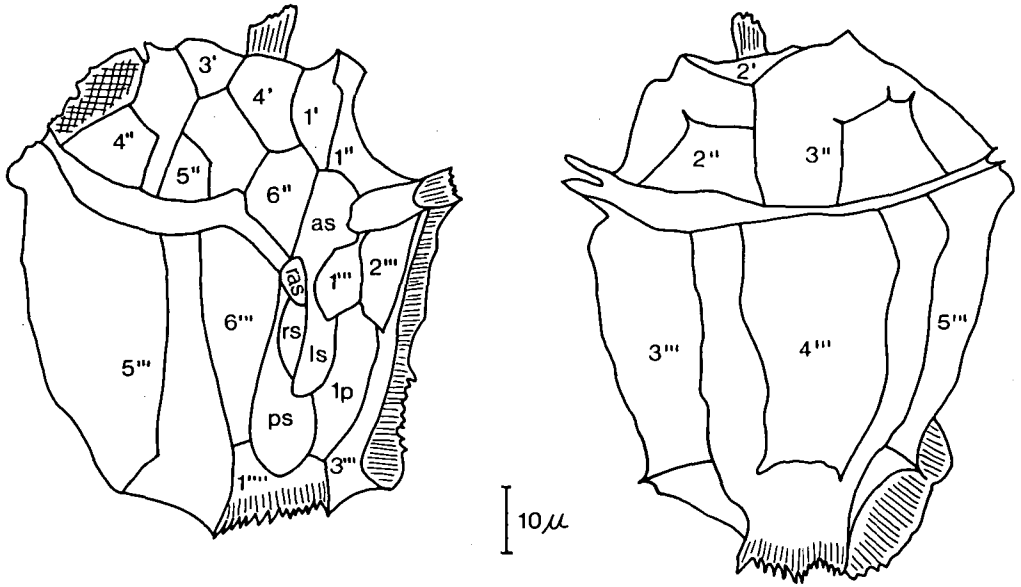


Fig. 3. *Cribroperidinium crassinervum* emend. Drawing from photograph (pl. 1, figs. 1 & 2) with interpretation of the paratabulation pattern, and secondary parasutures. Left ventral view, right dorsal view. MGUH 17008.

a vesiculate internal structure. The wall is 2–3 my thick, and gives rise to a rigid cyst, which keeps its original shape.

Wall features. Periphragm forms coherent parasutural membranes, which are hollow and tent shaped with a transverse striation and perforate surface (fig. 2 & plate 2, fig. 1). Secondary parasutures with the same construction as the parasutural membranes occur on the pre- and post-cingular paraplates 1'–5' and 2'''–5'''.

Paratabulation. Parasutural membranes indicate the paratabulation but the secondary para-

sutures mask the tabulation pattern. The tabulation formula is: 4', 6', 6c(?), 6''', 1p, 1''', 5s (as, ras, ls, rs & ps) (fig. 3) and reflects a gonyauloid tabulation pattern. Four apical paraplates are developed. Paraplate 1' and 4' are both elongate and placed in continuation of the sulcal field and paraplate 6'', respectively. The paraplates 2' and 3' are small. Parasutural membranes of the apical paraplates unite apically to form a blunt apical horn. The apical paraplates contain no secondary parasutures (fig. 4)

Six precingular paraplates are reflected. Para-

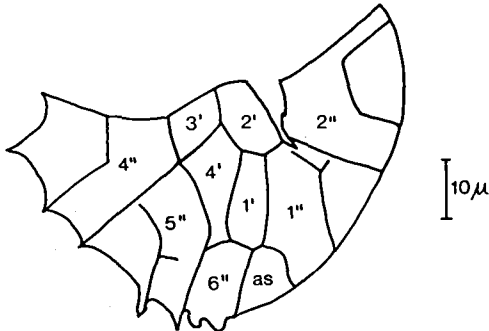


Fig. 4. *Cribroperidinium crassinervum* emend. Drawing from photograph (pl. 1, fig. 5). Apical view with interpretation of the paratabulation pattern, and secondary parasutures. MGUH 17010.

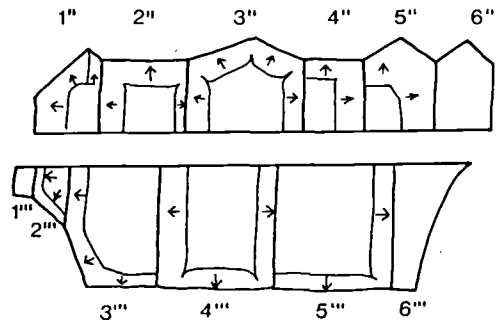


Fig. 5. *Cribroperidinium crassinervum* emend. Schematic drawing of the pre- and postcingular paraplate, with interpretation of the secondary parasutures, reflecting the thecal growth lines and directions.

*Scriniodinium* Klement 1957.

*Scriniodinium irritabile* Riley (in Fisher & Riley) 1980. (21; pl. 3, fig. 9)

*Scriniodinium* sp. (22; pl. 3, fig. 10 & pl. 4, fig. 5)

*Sentusidinium* Sarjeant & Stover 1978.

*Sentusidinium brevispinosum* Courtinat & Gaillard 1980. (23; pl. 5, figs. 3 & 11)

*Sentusidinium echinatum* (Gitmez & Sarjeant 1972) Sarjeant & Stover 1978. (24)

*Sentusidinium neophytensum* (Ioannides et al. 1976) Sarjeant & Stover 1978. (37; pl. 5, fig. 6)

*Sentusidinium rioultii* (Sarjeant 1968) Sarjeant & Stover 1978. (25; pl. 5, figs. 4 & 12)

*Sentusidinium sparsibarbatum* Erkmen & Sarjeant 1980. (32; pl. 5, fig. 5)

*Stephanelytron* Sarjeant 1961, emend. Stover et al. 1977.

*Stephanelytron scarburghense* Sarjeant 1961, emend. Stover et al. 1977. (33; pl. 5, fig. 7)

*Systematophora* Klement 1960.

*Systematophora areolata* Klement 1960. (40; pl. 2, fig. 9)

*Systematophora penicillata* (Ehrenberg 1843) Sarjeant 1980. (26)

*Systematophora* sp. (35; pl. 5, figs. 8, 13 & 14)

*Tubotuberella* Vozzhennikova 1967.

*Tubotuberella apatela* Cookson & Eisenack 1960. (27)

*Valensiella* Eisenack 1963.

*Valensiella ovula* (Deflandre 1947) Eisenack 1963. (28; pl. 2, fig. 6)

Incertae sedis

Group *Acritarcha* Evitt 1963.

Subgroup *Acanthomorphae* Downie et al. 1963.

*Baltisphaeridium* Eisenack 1958, emend. Eisenack 1969.

*Baltisphaeridium inusitatum* Klement 1960. (41)

Class *Prasinophyceae*

Family *Tasmanaceae* Sommer 1956.

*Tasmanites* Newton 1875.

*Tasmanites* sp. (46)

## Systematics

Genus *Cribroperidinium* Neale & Sarjeant 1962, emend. Davey 1969.

*Cribroperidinium crassinervum* (Deflandre 1939) emend. Pl. 1, figs. 1–5, pl. 2, fig. 1, text figs. 2–5

*Palaeoperidinium crassinervum* Deflandre 1939, p. 144, pl. 6, fig. 5

*Gonyaulacysta crassinerva* (Deflandre 1939) Sarjeant 1967, p. 248–9

*Leptodinium crassinervum* (Deflandre 1939) Sarjeant 1969 in Davey et al. p. 12

Original diagnosis: (translated from Deflandre 1939) The theca (cyst) is polygonal, divided into two very unequal parts by a profound narrow transversal furrow (paracingulum), which is slightly helicoidal.

*Epitheca* (epicyst) is a double pyramidal-stub; hypotheca (hypocyst) is bowl-shaped slightly tapering towards the antapex. The plate sutures (parasutures) are formed by very salient ribs, and in addition ornamentation exists on some plates. This ornamentation is formed by ribs similar to the ribs which exist on *Gonyaulax pachyderma* Deflandre.

Tabulation. Very incompletely known.

Dimensions. The length of the holotype is 82  $\mu$  (epicyst 56  $\mu$  and hypocyst 36  $\mu$ ) and the maximum width 69  $\mu$ .

Occurrence. Jurassic, Kimmeridgian; Orbagnoux, France.

It should be noted that Deflandre's original diagnosis is based on a cyst figured up side down compared to the present day orientation. His hypocyst is the epicyst and *vice versa*.

Emended diagnosis. Proximochorate, elongate, polygonal cysts, divided by a strongly helicoidal paracingulum. The outer surface is smooth. The cyst wall appears very spongy; this comes from the internal vesiculate construction of the periphragma. Parasutural membranes indicate a *Gonyaulax* type of paratabulation. Secondary parasutures, of the same construction as the parasutural membranes, occur on the pre- and postcingular paraplates. The archeopyle is precingular, type P.

## Description

Cyst type. Proximochorate; the parasutural membranes between 10–30% of the shortest diameter of the central body (cf. Sarjeant 1981).

Shape. The central body is elongate to ellipsoidal. Parasutural membranes form a short, blunt apical horn and an antapical flange. The cyst is wedge-shaped antapically.

Wall relationships. Periphragm and endophragm, are appressed in areas between the parasutural membranes. Surface of the periphragm is smooth with weak transverse striations on the flanks of the membranes. Periphragm has



Fig. 2. *Cribroperidinium crassinervum* emend. Drawing of a hollow tent shaped parasutural membrane.

plates 1''–5'' show secondary parasutures, which according to Gocht (1979) are interpreted as morphological imprint of thecal growth lines. Paraplate 3'' reflects thecal growth centre on this plate serie (fig. 5).

The postcingular paraplate series includes likewise six paraplates. Paraplate 1''' is very small and placed half inside the sulcal field. Paraplate 2''' is small and give room for a posterior intercalary paraplate (1p). Paraplates 3''', 4''', and 5''' are large (especially 4'''). Paraplate 6''' is reduced in proportion to the three previous paraplates. Paraplates 2''' to 5''' have secondary parasutures and paraplate 4''' reflects the thecal growth centre of this plate series (fig. 5).

Antapex is composed of an antapical paraplate of the *Gonyaulax* type (Ewitt 1976). Paraplate 1'''' is placed on the ventral surface of the cyst, which gives the antapical part of the hypocyst a narrow wedge shape. Paraplate 4'''' is separated from paraplate 1'''' by a flange composed of the parasutural membrane.

Archeopyle. This examination of *Criboperidinium crassinervum* shows that paraplate 3'' is lost (plate 1, fig. 4), and the archeopyle is of type P.

Paracingulum. Strongly helicoid; paracingulum is displaced 5 to 7 my in the sulcal field (approximately two times the width of the paracingulum). This shape of the paracingulum gives the epicyst and hypocyst nearly equal size on the ventral side, while the hypocyst is roughly twice as large as the epicyst on the dorsal side. Paracingulum is demarcated by two parallel parasutural membranes, which blur the outline of the specific paracingular plates. The outlines of two cingular paraplates are visible (pl. 2, fig. 1) and it is most likely that the paracingulum is composed of six paraplates.

Parasulcus. This area is composed of five clearly demarcated paraplates, an anterior sulcal paraplate (as), a right accessory sulcal paraplate (ras), a right sulcal paraplate (rs), a left sulcal paraplate (ls); and a large tongue shaped posterior sulcal paraplate (ps). In addition, two weakly outlined elongated depressions above each other are visible between ras and 1'''' (pl. 2, fig. 1). These depressions are reflections of the thecas flagellar pores. Parasulcus is very elongate (2/3 of the cyst length) and occupy considerable more area of the hypocyst than of the epicyst.

Dimensions. Overall length 77(81)86 my,

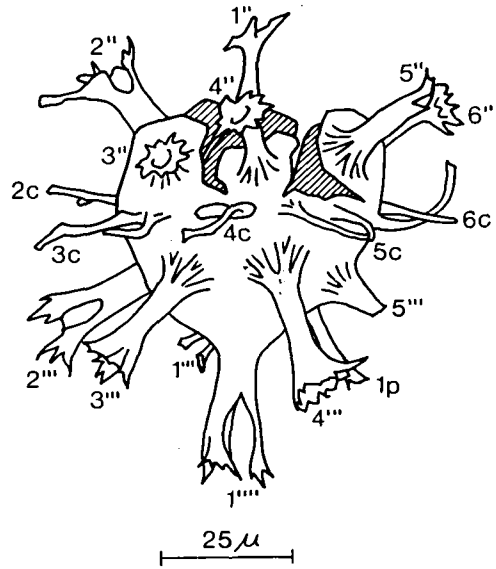


Fig. 6. Drawing of *Perisseiasphaeridium ingegerdii* sp. nov. From SEM photograph (pl. 4, fig. 8). The processes are interpreted as reflecting a paratabulation pattern. MGUH 17050.

width 50(61)70 my, maximum height of membranes 7(8)9 my (nine specimens measured).

Occurrence. *C. crassinervum* is present throughout the *Mutabilis* Zone and into the lower part of the *Eudoxus* Zone.

Discussion. This species is transferred to the genus *Criboperidinium* Neale & Sarjeant, 1962 emend. Davey, 1969, on the basis of the following characteristics: proximochorate to proximate cysts of intermediate size, elongate shape, small apical horn, coherent striate parasutural membranes and coherent striate secondary parasutures. Archeopyle P.

Genus *Perisseiasphaeridium* Davey & Williams 1966.

*Perisseiasphaeridium ingegerdii* sp. nov.

Pl. 3, fig. 11, pl. 4, figs. 8–9, text fig. 6

Origin of name. From Ingegerd, an old Nordic female name. Diagnosis. Skolochorate cysts with a subspherical central body. The cysts possess two types of processes; (1) large, thick, hollow, tubiform processes and (2) slender, massive processes. The processes are intratabular and proximally striate occasionally with "supporting roots". The processes indicate a gonyaulacoid type of

tabulation pattern. The wall is composed of two layers, endophragm and periphragm. The archeopyle is apical type  $\bar{t}\bar{A}$ .

#### Description

Cyst type. Chorate, as the length of the processes exceeds 30% of the shortest diameter of the central body (cf. Sarjeant 1981). Moreover, the cysts are skolochorate on account of the shape and location of the processes (cf. Sarjeant 1981).

Shape. The central body is subspherical.

Wall relationship. The cyst wall is composed of two layers. An inner layer, endophragm, forms the interior demarcation of the central body. An outer layer, periphragm, has a vesiculate structure. It forms the outer demarcation of the central body and the processes with supporting roots. Periphragm does not show any parasutural structures. Periphragm forms two types of processes; (1) large hollow, tubiform, intratabular processes which are open distally, often weakly aculeate. These processes are proximally striated, as a result of the attachment of the supporting roots. (2) Slender massive, simple processes, which occur in the parasulcal and paracingular areas. The paracingular processes are connected basally, two by two. Distally they are capitate to bifid.

Paratabulation. Paratabulation is indicated by the position and size of the intratabular processes. The paratabulation's formula: 4', 6'', 6c(?), 5''', 1p (?), 1''''', ?s.

Archeopyle. The archeopyle is apical of type  $\bar{t}\bar{A}$ . Operculum is simple and attached on some specimens, for example on the holotype (pl. 3, fig. 11), but detached on other specimens (pl. 4, fig. 8).

Paracingulum. The zone of the paracingulum is indicated by six pairs of slender massive processes.

Parasulcus. It has not been possible to count the number of processes.

Holotype. Pl. 3, fig. 11, M16 0,55 H88 As, 40,5–110,2, MGUH 17041.

Type locality. Clay-pit of Blue Circle Portland Cement Company at Westbury, Wiltshire (Grid reference St 882528).

Dimensions. The overall diameter of the holotype is 104 my. The diameter of the central body is 48 my and the maximum length of the processes is 28 my. Parameters of 8 specimens are:

overall diameter 82(98)112 my, diameter of central body 42(49)60 my, length of processes 20(25)30 my.

Occurrence. Present from the lower part of the *Mutabilis* Zone to the lower part of the *Eudoxus* Zone.

Discussion. This species is placed in the genus *Perisseiasphaeridium* Davey & Williams 1966, on the basis of the following characteristics: skolochorate cysts with large, subspheroidal central body, distally open, tubiform intratabular processes and simple, slender, paracingular processes.

*P. ingegerdii* sp.nov. differs clearly from *P. pannosum* Davey & Williams 1966, the processes of which are fenestrate with an irregular distal margin. *P. ingegerdii* sp.nov. is similar to *P. insolitum* Davey 1982, but this species deviates in having processes which are more slender with more regular aculeate spines.

*P. ingegerdii* sp.nov. differs from *Perisseiasphaeridium* sp. A. Ioannides et al. 1976 which has more slender and often fenestrate processes.

#### Genus *Protobatioladinium* gen.nov.

Diagnosis. The genus includes ovoidal to elongate, proximate cysts with an elongate slender apical horn abruptly rising apically from the cyst. Two small bulges occur antapically. The cysts are thin walled and therefore often folded and strongly compressed. Maximum width occurs in the paracingular region. The archeopyle is compound, type  $\bar{t}\bar{A}\bar{Z}\bar{I}$ , and forms a distinct sulcal notch.

Type species. *Protobatioladinium westburiensis* sp.nov.

Occurrence. The type species occurs from the top of *Cymodoce* Zone to the middle of *Eudoxus* Zone.

Origin of name. The name *Protobatioladinium* reflects the morphologically strong relationship to the genus *Batioladinium*. The prefix indicates that *Protobatioladinium* (Kimmeridgian) occurs stratigraphically earlier than *Batioladinium* (Volgian? – Lower Cretaceous) and an evolutionary relationship is possible.

Discussion. The genus belongs to the *Broomea* complex, which includes genera with an ovoidal to elongate shape, an apical horn, none, one or two antapical horns and anterior intercalary,

apical or apical/intercalary archeopyles. Davey (1982) includes the following genera in the *Broomea* complex. The archeopyle formula for each genus is given in brackets.

*Broomea* Cookson & Eisenack 1958 (2I)

*Batioladinium* Brideaux 1975 ( $\bar{t}\bar{A}$ )

*Imbatodinium* (Vozzhennikova 1967) Dörhöfer & Davies 1980 ( $\bar{t}\bar{A}$ ) or ( $\bar{t}\bar{A}2I$ )

*Gochteodinia* Norris 1978 (2I)

*Pareodinia* Deflandre 1947 (2-3I)

*Aprobolocysta* Duxbury 1977 ( $\bar{t}\bar{A}$ )

*Kalyptea* Cookson & Eisenack 1960 (1-3I)

*Cantulodinium* Alberti 1961 (2-3I)

*Protobatioladinium* gen. nov. differs from *Broomea*, *Gochteodinia*, *Pareodinia*, *Aprobolocysta*, *Kalyptea* and *Cantulodinium* in the possession of two small rounded bulges antapically and/or in the possession of a compound intercalary/apical archeopyle.

*Protobatioladinium* gen. nov. is very similar to *Batioladinium* Brideaux (1975) in general outline and with respect to the presence of a distinct sulcal notch, but differs in the possession of a compound  $\bar{t}\bar{A}2I$  archeopyle in contrast to a  $\bar{t}\bar{A}$  type. *Protobatioladinium* gen. nov. differs from *Imbatodinium* Vozzhennikova (1967) emend. Dörhöfer & Davies (1980) in the possession of a distinct sulcal notch in contrast to a distinct dorsal notch. In addition, the shape of the anterior intercalary paraplates involved in the archeopyle formation in each genus is very different.

Similarly, *Protobatioladinium* gen. nov. differs from *Imbatodinium* Vozzhennikova (1967) emend. Mehrotra & Sarjeant (1984) in the possession of a distinct sulcal notch. Mehrotra & Sarjeant illustrate only dorsal notches on all specimens of *I. fractum* Mehrotra & Sarjeant (fig. 1 a-e Plate 1 figs. 1-7 & Plate 2 figs. 1-7) which demonstrate all possible variations of plate combinations in the compound archeopyle comprising precingular, anterior intercalary and apical paraplates. Davey (1982) and Evitt (1985) are followed in their retention of the genus *Batioladinium* Brideaux 1975 because the present author is not convinced that all the species which Dörhöfer & Davies (1980) and later Mehrotra & Sarjeant (1984) transferred to the genus *Imbatodinium* have a compound archeopyle of type  $\bar{t}\bar{A}2I$ . For example, Dörhöfer & Davies do not prove or illustrate that the type species of *Batioladinium*,

*B. jaegeri* (Alberti) Brideaux, has an archeopyle of the *Imbatodinium* type.

Mehrotra & Sarjeant agree with the conclusions of Dörhöfer & Davis concerning the genus *Batioladinium* and transfer, in addition, *B. pomum* Davey (1982) and *B. radiculatum* Davey (1982) into the genus *Imbatodinium*. This transference is based only on interpretation of the illustrations of Davey (1982).

*Protobatioladinium* could be a transitional form between genera with an intercalary archeopyle, for example *Pareodinia* and genera with an apical archeopyle, for example, *Batioladinium*. I believe that the above-mentioned rejection of the genus *Batioladinium* is based on insufficient data (illustrations) without exact proof that all *Batioladinium* species have a compound archeopyle ( $\bar{t}\bar{A}2I$ ).

*Protobatioladinium westburiensis* sp. nov. indicate the possibility of *Batioladinium* species possessing a  $\bar{t}\bar{A}$  archeopyle of a shape very similar to the shape of the  $\bar{t}\bar{A}2I$  archeopyle in the genus *Imbatodinium*.

*Protobatioladinium westburiensis* sp. nov.

Pl. 3, figs. 5-8, text fig. 7.

Origin of name. From Westbury, the type locality of the species.

Diagnosis. The species is represented by ovoid proximate cysts with an elongate, slender apical horn abruptly raising from the cyst. A constriction on the apical horn is common. Two antapical horns are indicated by two small rounded bulges.

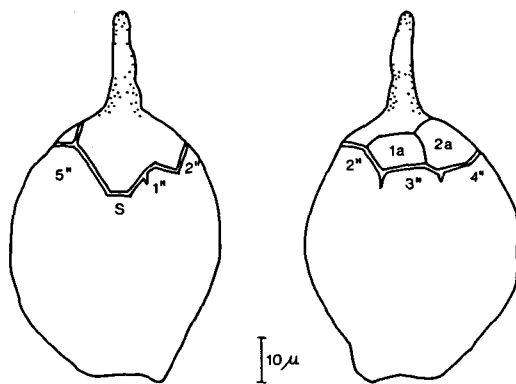


Fig. 7. *Protobatioladinium westburiensis* sp. nov. Drawing of the holotype (pl. 3, fig. 5) with interpretation of the shape of the archeopyle as reflecting the paratabulation pattern. Left; ventral view, right; dorsal view. MGUH 17035.

The cysts are often dorso-ventrally flattened, and widest in the paracingular region. The wall is thin and without any internal structure except vesiculae in the apical horn. The surfaces of the cysts are psilate without any ornamentation. The archeopyle sutures reflect a distinct sulcal notch. The archeopyle is compound; type  $\overline{\text{A2I}}$ .

### Description

**Cyst type.** The cyst is proximate with a single wall-layer and no surface ornamentation.

**Shape.** The cyst is ovoid with a prominent apical horn (1/4 to 1/3 of the overall length). The horn is slender, weakly tapering and rises abruptly from the cyst; it is hollow and often has a constriction (fig. 7). Two small rounded bulges occur antapically. These bulges do not exceed 1/15 of the overall length. The cyst is often dorso-ventral compressed and folded.

**Wall relationships.** The wall is apparently composed of one layer; the autophragm. The surface is psilate, smooth without any granula. The wall forming the apical horn is about 1 my thick; it is vesiculate, but otherwise without internal structures.

**Paratabulation.** Paratabulation is only indicated by archeopyle sutures. The apical demarcation of six precingular paraplates is visible. On the basis of their shape these paraplates are interpreted as paraplate 1'' to 5'' and one anterior sulcal paraplate, probably as.

On the dorsal side of the cysts the archeopyle sutures completely demarcate two paraplates. These are located right above the precingular paraplate series, and are interpreted as two anterior intercalary paraplates, respectively 1a and 2a (fig. 7)

**Archeopyle.** The archeopyle is formed of three opercular pieces. One piece confines the apical paraplate series and two pieces confine an intercalary paraplate each.

Although the archeopyle sutures are very distinct (pl. 3, fig. 5), and the operculum should be easily lost, all observed specimens have their operculum *in situ*. A possible explanation is that the wall is double layered and that the visible archeopyle suture is confined to one of these layers only. The other wall layer is then able to retain the operculum attached *in situ*.

**Holotype.** Pl. 3, fig. 5, M11 0.20, H76 As, 45,0-128,1, MGUH 17035.

**Type locality.** Clay-pit of Blue Circle Portland Cement Company at Westbury, Wiltshire (Grid reference ST 882582), England.

**Dimensions.** The total length of the holotype is 80 my, width is 46 my. The length of the apical horn is 23 my. Parameters of 7 complete specimens are: total length 67(74)80 my, width 34(40)46 my, length of apical horn 20(22)26 my.

**Occurrence.** Present from the top of the *Cymodoce* Zone to the middle of the *Eudoxus* Zone.

### Dinocyst biostratigraphy

The 41 samples collected through the measured sequence at Westbury have yielded 47 dinocyst species, 1 acritarch species and 1 tasmanid species. All 49 species are listed alphabetically (see list of species and their stratigraphic occurrence is shown in fig. 9).

In recent years several dinocyst range charts covering the three Lower Kimmeridgian ammonite zones (*Cymodoce*, *Mutabilis* and *Eudoxus*) have been published. Gitmez & Sarjeant (1972) described microplankton covering the interval from the *Baylei* Zone (lowest Kimmeridgian) to the *Pallasioides* Zone (Upper Kimmeridgian) based on samples from England, Scotland and France. Some corrections to this work were published by Riley & Sarjeant (1977). Lam & Porter (1977) described palynomorphs covering the interval from Lias to Kimmeridgian based on samples from NE Scotland. Williams (1977) established a dinocyst range chart covering the interval from Trias to Tertiary. His dinocyst zonation of the Kimmeridgian were based on data from Gitmez & Sarjeant (1972). Raynaud (1978) described Callovian to Portlandian dinocysts from samples from North Europe. Sarjeant (1979) established dinocyst zonation covering the interval from Middle to Upper Jurassic based on worldwide data, exclusive North America.

Fisher & Riley (1980) established 7 dinocyst zones around the Jurassic/Cretaceous boundary based on data from the boreal area, these zones were not correlated with ammonite zones. Wolam & Riding (1983) proposed a dinocyst zonation covering all the English Jurassic.





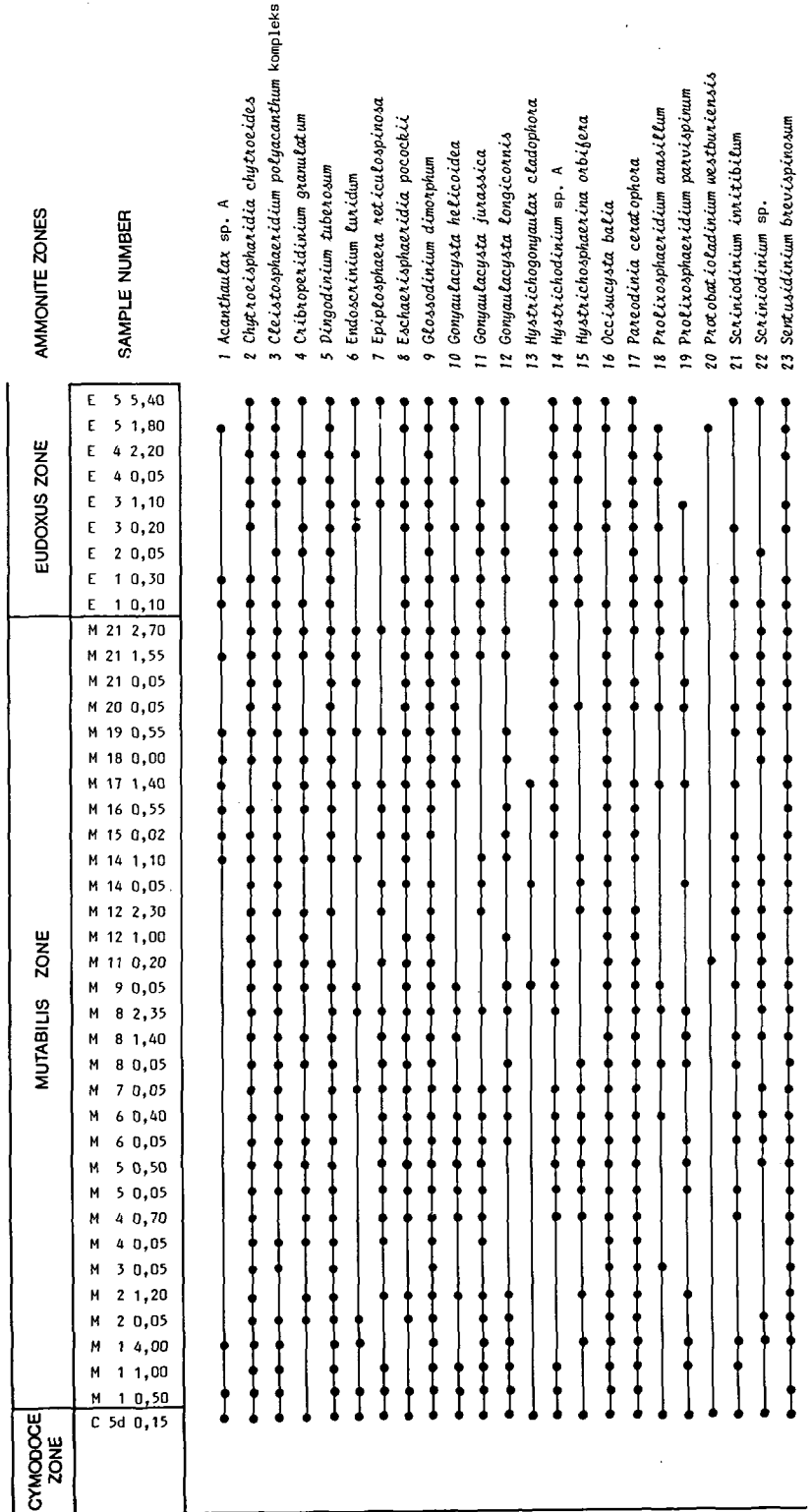
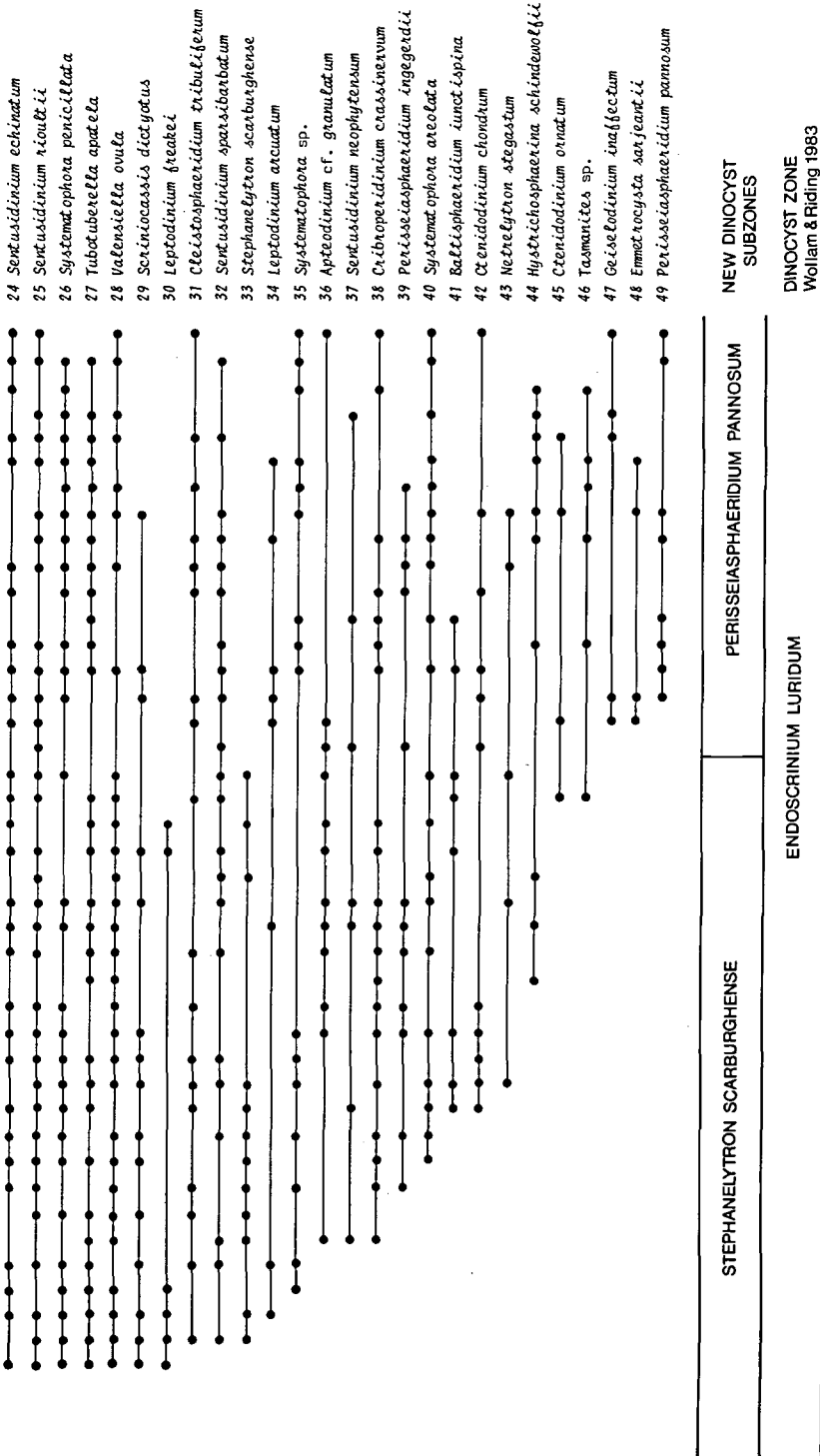


Fig. 9. Distribution of dinocysts in the Lower Kimmeridge clay from Westbury clay-pit. Sample numbers correlate with the bed numbers used in Birkelund et al. 1983 (M 21 1,55 indicates 1,55 m above base of bed 21 in the *Mutabilis* Zone).



## Plate 1.

Figs. 1–5. *Cribroperidinium crassinervum* MGUH 17008–17010

Fig. 1. Exterior ventral view.

Fig. 2. Interior dorsal view showing secondary parasutures on plate 4'''.

Fig. 3. Exterior ventral view.

Fig. 4. Interior dorsal view showing a P archeopyle.

Fig. 5. Fragment showing the epicystal paraplates minus the operculum paraplate: 3''.

Fig. 6. *Cleistosphaeridium tribuliferum* MGUH 17011

Fig. 7. *Ctenidodinium chondrum* MGUH 17012

Fig. 8. *Ctenidodinium ornatum* MGUH 17013

Fig. 9. *Cleistosphaeridium polyacanthum* complex MGUH 17014

Fig. 10. *Epiplosphaera reticulospinosa* MGUH 17015

Fig. 11–13. *Geiselodinium inaffectum* MGUH 17016–17018

Fig. 14. *Gonyaulacysta helicoidea* specimen with operculum inside MGUH 17019

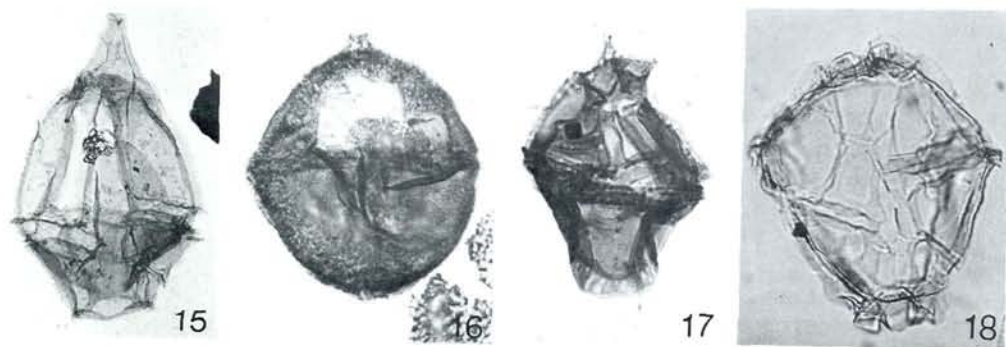
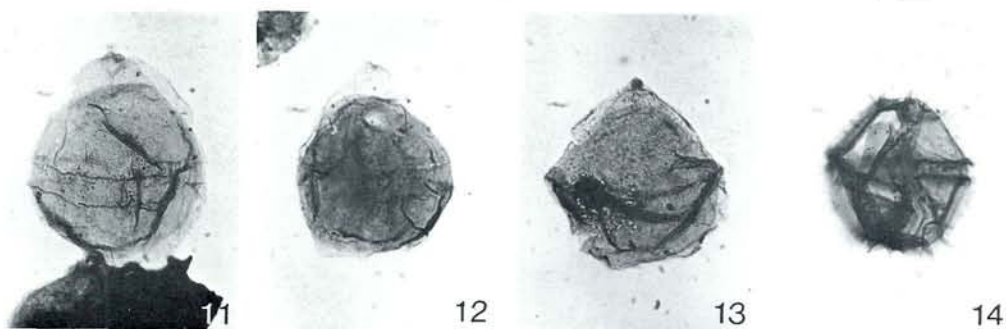
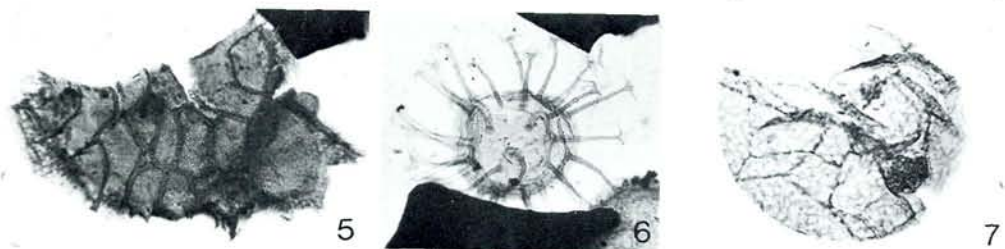
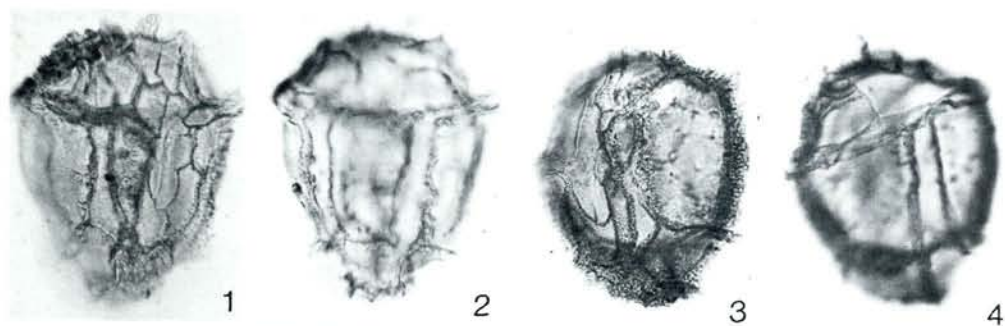
Fig. 15. *Gonyaulacysta jurassica* specimen with operculum inside MGUH 17020

Fig. 16. *Apteodinium* cf. *granulatum* specimen with operculum inside MGUH 17021

Fig. 17. *Leptodinium freakei* MGUH 17022

Fig. 18. *Leptodinium arcuatum* MGUH 17023

All photographs are x500



*chogonyaulax cladophora* and *Gonyaulacysta jurassica* occur continuously.

Sarjeant's (1979) *Epiplosphaera bireticulatum* Parazone, Fisher & Riley's (1980) *Leptodinium subtile* Subzone and Wollam & Riding's (1983) *Endoscrinium luridum* Zone, all represent the same stratigraphical time interval. In the present paper use of the *E. luridum* Zone is preferred, according to Wollam & Riding's definition, based on very common species.

In the sediments from Westbury all the stratigraphical important species from the *E. luridum* Zone (Wollam & Riding 1983) are represented and support an assignment to this zone (fig. 9). Diagnostic species are *Dingodinium tuberosum* (5), *Endoscrinium luridum* (6), *Epiplosphaera reticulospinosa* (7), *Glossodinium dimorphum* (9), *Gonyaulacysta jurassica* (11), and *Occiscysta balia* (16), which all occur throughout the sequence. The following stratigraphically important species occur only in part of the sequence: *Hystrichogonyaulax cladophora* (13), *Scriniocassis dictyotus* (29), *Stephanelytron scarburghense* (33), *Leptodinium arcuatum* (34), and *Systematophora areolata* (40).

Furthermore, the ammonite stratigraphy of the Westbury sequence (Birkelund et al. 1983) confirms that the dinocyst zone of *E. luridum* correlates with the ammonite zones *Cymodoce*, *Mutabilis* and *Eudoxus* as earlier indicated by Wollam & Riding (1983).

Most of the recorded dinocyst species occur through the entire sequence. A few important

species, however, have limited occurrence, which is regarded as being of stratigraphical importance. These are *Stephanelytron scarburghense* (33), which has its last occurrence in sample M15 0,02 and *Leptodinium freakei* (30), which has its last occurrence in sample M14 0,05. *Geiselodinium inaffectum* (47) has its first occurrence in sample M17 1,40 and *Perisseiasphaeridium pannosum* (49) has its first occurrence in sample M18 0,00.

Stover, Sarjeant & Drugg (1977) wrote that *S. scarburghense* occurs stratigraphically from the *Jason* Zone, Middle Callovian to the *Eudoxus* Zone, but is absent in the *Mutabilis* Zone. A single specimen is recorded from the *Eudoxus* Zone, and Stover et al. indicated themselves the possibility of a redeposited specimen. The observation by Stover et al. 1977 differs from the present investigation where *S. scarburghense* occurs in the *Mutabilis* Zone but not in the *Eudoxus* Zone.

*L. freakei* is only recorded from the *Cordatum* Zone, Lower Oxfordian (Sarjeant 1963 and 1979). In the sequence from Westbury *L. freakei* occurs from the upper part of the *Cymodoce* Zone to the middle of the *Mutabilis* Zone, 8 m below the boundary between the *Mutabilis* and the *Eudoxus* Zone.

*Geiselodinium inaffectum* is only previously recorded from the *Eudoxus* and the *Autissiodorensis* Zones (Drugg 1978). In Westbury this species has its first occurrence in the *Mutabilis* Zone, 4,5 m below the boundary with the *Eudoxus* Zone. Moreover, this species is recorded in three samples from the *Eudoxus* Zone.

#### Plate 2 SEM photographs

Fig. 1. *Cribooperidinium crassinervum* MGUH 17024 showing ventral side, all the sulcal paraplates and the parasutural membranes with a transvers striation (x500)

Fig. 2 & 3. *Epiplosphaera reticulospinosa* MGUH 17025 Fig. 2 (x1000) Fig. 3 showing a close-up of the archeopyle suture and the reticulate surface pattern (x2500)

Fig. 4. *Gonyaulacysta helicoidea* MGUH 17026 ventral view (x800)

Fig. 5. *Leptodinium freakei* MGUH 17027 showing paratabulation pattern (x600)

Fig. 6. *Valensiella ovula* MGUH 17028 (x1000)

Fig. 7 & 8. *Apteodinium* cf. *granulatum* MGUH 17029

Fig. 7 dorsal view showing the archeopyle: 3P (x600)

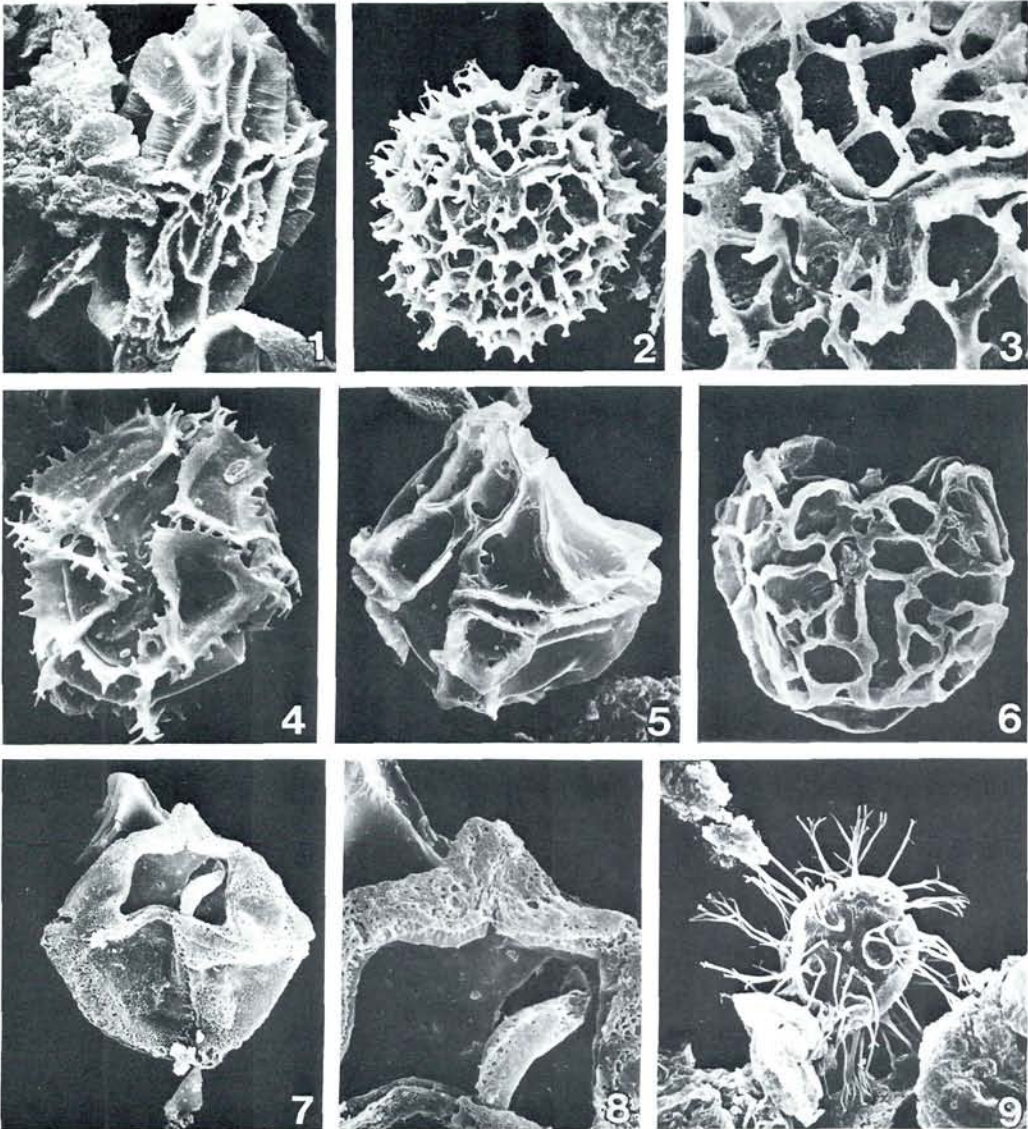
Fig. 8 close-up showing the wall structure (x1500)

Fig. 9. *Systematophora areolata* MGUH 17030 operculum attached (x500)

*Perisseiasphaeridium pannosum* is reported to have its first occurrence in the Ypresian, Lower Eocene in England (Davey, Downie, Sarjeant & Williams (1966). Fensome (1979) reported *Perisseiasphaeridium* cf. *P. pannosum* in one sample from Jameson Land, East Greenland. This sample is dated as Lower Kimmeridgian (*Mutabilis* to the *Eudoxus* Zone). Fensome considered that the *P. pannosum* originally described by Davey & Williams (1966) from Tertiary sediments is a re-worked Jurassic species. Piasecki (1980) reported *P. pannosum* from Milne Land, East Greenland,

where it has its first occurrence at the base of the *Eudoxus* Zone. Gitmez & Sarjeant (1972) reported specimens of *Oligosphaeridium pulcherrimum* (Deflandre & Cookson 1955) from the Bailey Zone (fig. 8) in England and from the *Eudoxus* Zone in France (Riley & Sarjeant 1979). Fensome (1979) considered these specimens to correspond to *P.* cf. *P. pannosum* as Vigran & Thusu (1976) reported from Lower Kimmeridgian beds at Andøya in Norway.

The above-mentioned observations are supported by the present investigation, where the



first occurrence of *P. pannosum* is recorded in the uppermost part of the *Mutabilis* Zone, 4 m below the boundary of the *Eudoxus* Zone. Moreover, the species is recorded scattered through the interval of the *Eudoxus* Zone.

Present observations suggest that the *E. luridum* Zone could be subdivided into two subzones; the *Stephanelytron scarburghense* Subzone and the *Perisseiasphaeridium pannosum* Subzone.

The *Stephanelytron scarburghense* Subzone is defined as the interval from the last occurrence of *Scriniodinium crystallium* to the last occurrence of *Stephanelytron scarburghense*. This subzone includes the *Cymodoce* Zone and the lower and middle part of the *Mutabilis* Zone.

The *Perisseiasphaeridium pannosum* Subzone is defined as the interval between the common first occurrence of *Perisseiasphaeridium pannosum* and *Geiselodinium inaffectum* and the last occurrence of *Scriniodinium luridum*. This subzone corresponds to the upper part of the *Mutabilis* Zone and the entire *Eudoxus* Zone.

In the sequence of Westbury Clay-pit the boundary between the two subzones is situated in the *Mutabilis* Zone, approximately 6 m below the boundary to the *Eudoxus* Zone.

Acknowledgements. I am grateful to Messrs. M. A. Easton and E. D. Knights, General Works Managers, and their colleagues at the Blue Circle Portland Cement Company's Westbury Works for admitting me to their pit, and for their hospitality during two prolonged field visits.

I also thank S. Piasecki, K. Raunsgaard Petersen, and T. Birkelund for discussions and suggestions to improve the manuscript; J. S. Peel improved the English at the manuscript.

J. Laurrup prepared the photographs, B. Sikker Hansen produced the figures; A. T. Bruun and B. Larsen typed the manuscript.

The Geological Institute, University of Copenhagen is thanked for fieldwork grants and permission to use the scanning electron microscope.

## Dansk sammendrag

Fra Westbury i syd England er en 40 m mægtig Nedre Kimmeridge, Jura, seksvns undersøgt for dinoflagellat cyster.

På baggrund af 47 observerede dinoflagellat arter er Kimmeridge sekvensen henført til *Endoscrinium luridum* Zonen (Wollam & Riding 1983) som korrelerer med ammonit zonerne *Cymodoce*, *Mutabilis* og *Eudoxus*, hvilket svarer til en tidligere ammonit datering foretaget af Birkelund, Callomon, Clausen, Nøhr-Hansen & Salinas (1983).

Desuden opdeles dinoflagellat cyst zonen *Endoscrinium luridum* i to nye subzoner (fig. 8 og 9) *Stephanelytron scarburghense* Subzonen og *Perisseiasphaeridium pannosum* Subzonen.

Desuden er en ny dinoflagellat slægt beskrevet, *Protobatioladinium* gen.nov. og dens variation fra slægterne *Batioladinium* og *Imbatodinium* er diskuteret. To nye arter *Protobatioladinium westburiensis* sp.nov. og *Perisseiasphaeridium ingegerdii* sp.nov. er beskrevet og arten *Cribroperidinium crassinervum* (Deflandre 1939) emend. er genbeskrevet og redefineret.

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### Plate 3.

Fig. 1. *Occisucysta balia* MGUH 17031 showing the archeopyle: 2P

Fig. 2. *Prolixosphaeridium parvispinum* MGUH 17032

Fig. 3. *Prolixosphaeridium anasillum* MGUH 17033

Fig. 4. *Netrelytron stegastum* MGUH 17034

Fig. 5–8. *Protobatioladinium westburiensis* sp. nov. MGUH 17035–17038 Fig. 5 Holotype showing archeopyle sutures and a constriction on the apical horn.

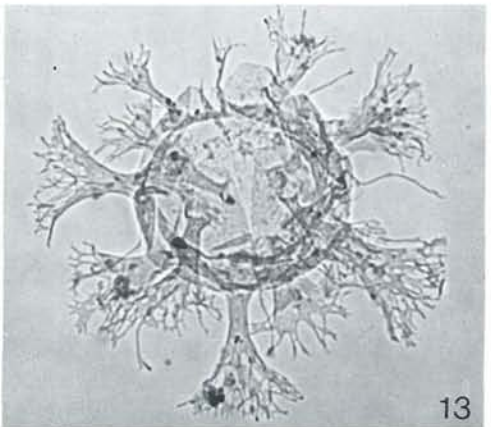
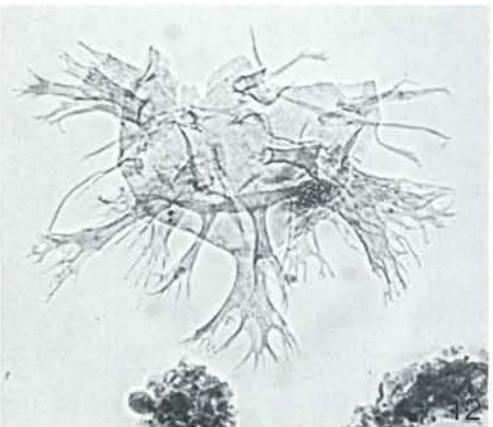
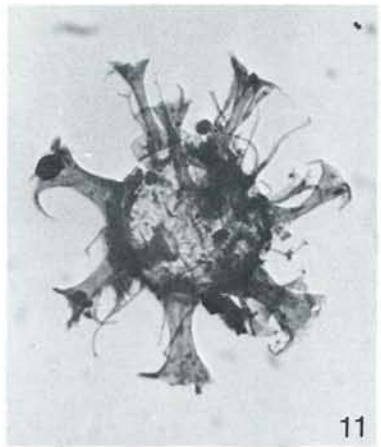
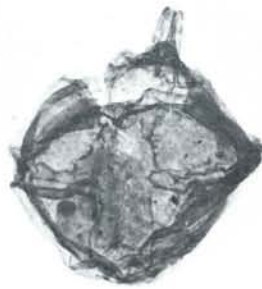
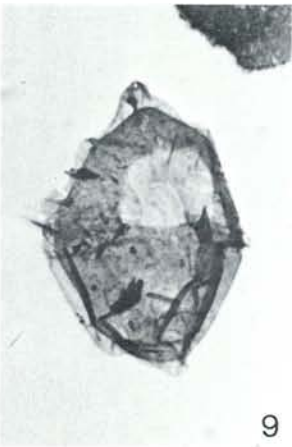
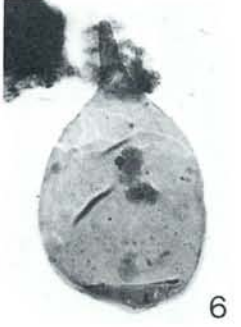
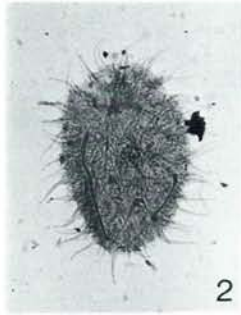
Fig. 9. *Scriniodinium inritibulum* MGUH 17039

Fig. 10. *Scriniodinium* sp. MGUH 17040

Fig. 11. *Perisseiasphaeridium ingegerdii* sp. nov. MGUH 17041 holotype, operculum attached.

Fig. 12–13. *Perisseiasphaeridium pannosum* MGUH 17042–17043

All photographs x500





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#### Plate 4 SEM photographs

Figs. 1-4. *Occisucysta balia* MGUH 17044-17046

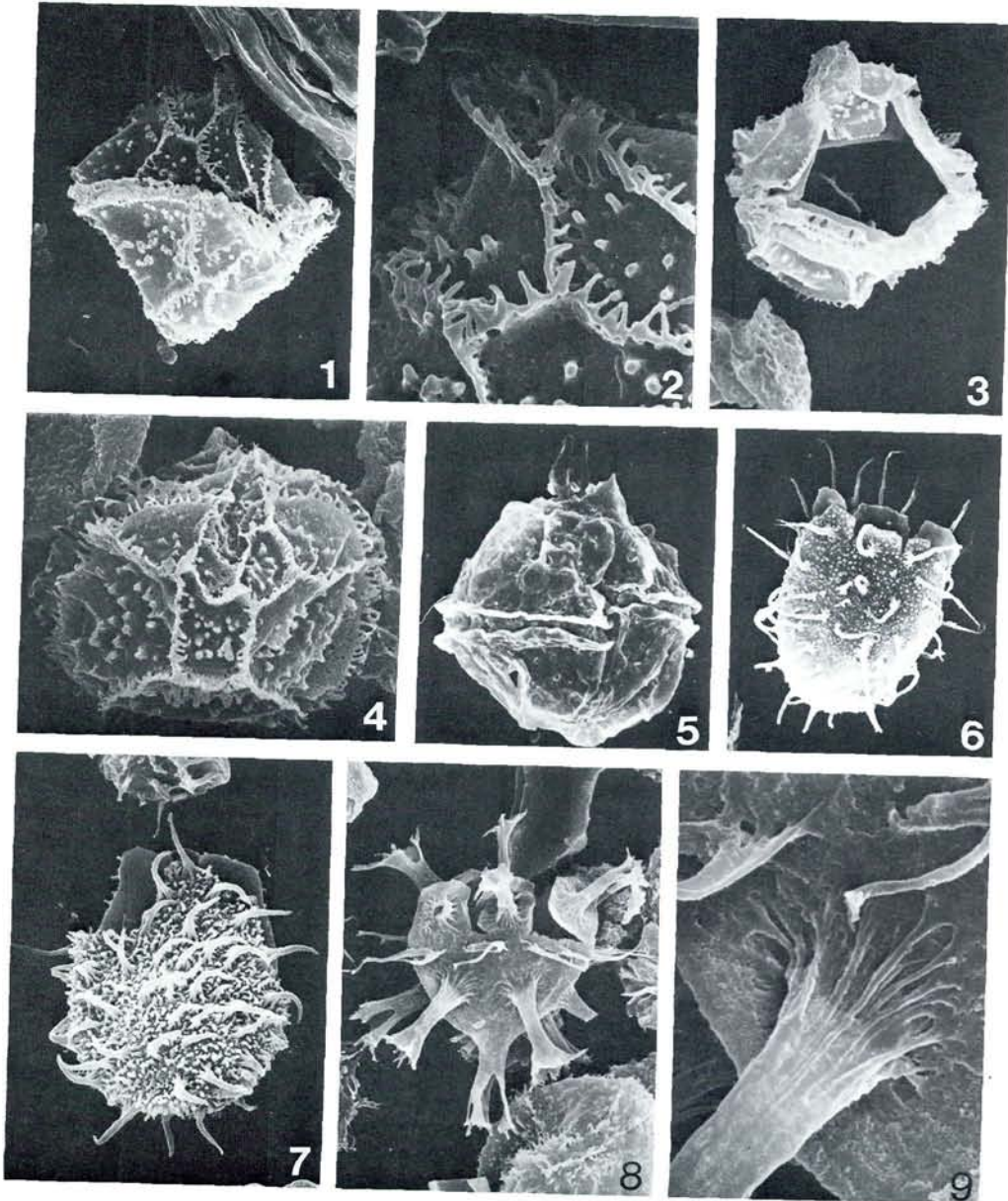
Fig. 1 (x800), Fig. 2 close-up showing the apical horn (x2500), Fig. 3 showing the archeopyle: 2P (x800), Fig. 4 Antapical view (x1100)

Fig. 5. *Scriniodinium* sp. MGUH 17047 (x800)

Fig. 6. *Prolixosphaeridium anasillum* MGUH 17048 (x600)

Fig. 7. *Prolixosphaeridium parvispinum* MGUH 17049 (x800)

Fig. 8 & 9. *Perisseiasphaeridium ingegerdii* sp. nov. MGUH 17050 Fig. 8 (x600) Fig. 9 close-up showing process with supporting roots (x2500)



## Plate 5.

Figs. 1 & 9. *Chytroeisphaeridia chytroeides* Fig. 1 MGUH 17051, specimen with operculum inside (x500), Fig. 9 MGUH 17052 (x800)

Figs. 2 & 10. *Escharisphaeridia pocockii* Fig. 2 MGUH 17053 (x500), Fig. 10 MGUH 17054 (x800)

Figs. 3 & 11. *Sentusidinium brevispinosum* Fig. 3 MGUH 17055 (x500), Fig. 11 MGUH 17056 (x600)

Figs. 4 & 12. *Sentusidinium rioultii* Fig. 4 MGUH 17057 (x500), Fig. 12 MGUH 17058 (x700)

Fig. 5. *Sentusidinium sparsibarbatum* MGUH 17059 (x500)

Fig. 6. *Sentusidinium neophytensum* MGUH 17060 (x500)

Fig. 7. *Stephanelytron scarburghense* MGUH 17061 specimen showing the corona (x500)

Fig. 8, 13 & 14. *Systematophora* sp. Fig. 8 MGUH 17062 (x500), Figs. 13 & 14 MGUH 17063, Fig. 13 ventral view (x500), Fig. 14 close-up showing the processes (x1200)

Figs. 9–14. SEM photographs

