INTRODUCTION

In Part I of "Non-calcareous Microplankton from the Cenomanian of England, northern France and North America", I described the location of the samples analysed and proceeded to discuss in detail the various genera and species of dinoflagellate cysts encountered in this study. Part II continues the systematics of the dinoflagellate cysts and also deals with the acritarchs—a group of relatively simple marine organisms of unknown affinities. To conclude this Part, and the paper, an appraisal is made of the use of microplankton in stratigraphy. The assemblages obtained from a number of samples from each of three localities, Fetcham Mill, Compton Bay and Escalles, were examined both qualitatively and quantitatively and assessment is made of their stratigraphic value. These results are compared with earlier stratigraphic work performed on stratigraphically comparable sediments from the same geographical region. The samples from Speeton, Hunstanton and Devon were devoid of microplankton or yielded extremely meagre assemblages, and the reasons for this are discussed.

Although the study deals mainly with Cenomanian succession in England and northern France, an attempt has been made to formulate a wider picture by the qualitative analysis of samples from Texas, the United States of America, and Saskatchewan, Canada. Comparisons between these assemblages and the results of other workers show that, although some species are long-ranging, dinoflagellate cysts may be used for both intra- and inter-regional stratigraphic correlation. Finally an attempt is made to draw some tentative palaeogeographical and palaeoecological conclusions from the data available.

I. SYSTEMATIC DESCRIPTIONS

Cyst-Family **XIPHOPHORIDIACEAE** Sarjeant & Downie 1966

Genus ***XIPHOPHORIDIUM*** Sarjeant 1966

Remarks. The diagnosis of the genus *Pyramidium* Clarke & Verdier (1967) shows that it is a synonym of *Xiphophoridium* Sarjeant (1966).

Xiphophoridium alatum (Cookson & Eisenack)

(Pl. 1, figs. 1, 2)

1962 *Hystrichodinium alatum* Cookson & Eisenack: 487, pl. 2, figs. 1–4.
1964 *Hystrichodinium alatum* Cookson & Eisenack; Cookson & Hughes: 43, pl. 5, figs. 12, 13.
1966 *Xiphophoridium alatum* (Cookson & Eisenack) Sarjeant: pl. 16, fig. 11.
1967 *Pyramidium alatum* (Cookson & Eisenack) Clarke & Verdier: 40, pl. 6, figs. 5, 6.

Description. The shell is ovoidal to subpolygonal in shape with a smooth wall commonly bearing a small number of cuspidate tubercles approximately 2 μ in height (Pl. 1, fig. 2). The periphragm also forms sutural crests, which are particularly well developed in the cingular region (8–12 μ high) and from which arise long, simple, ribbon-like processes. Although the crests are clearly sutural, the tabulation is very difficult to determine because of their height. A relatively small apical archaeopyle, with an angular margin, is occasionally seen.

DIMENSIONS. Range of observed specimens : diameter of central body 32 (47·9) 65 μ, length of processes 16 (26·5) 45 μ. Number of specimens measured, 11.

OCCURENCE. *X. alatum* has been recorded from the Upper Aptian to Cenomanian of Australia (Cookson & Eisenack) and from the Upper Albian to Lower Cenomanian of England (Cookson & Hughes). The specimens described by Sarjeant were obtained from the Cenomanian of Fetcham Mill. It is a rare to fairly common species found at most horizons throughout the Cenomanian of Fetcham Mill, Compton Bay and Escalles. It was not observed in the North American material.

Cyst-Family **DEFLANDREACEAE** Eisenack emend. Sarjeant & Downie 1966

Genus ***DEFLANDREA*** Eisenack emend. Williams & Downie 1966

REMARKS. Nine species, five of them new, are described from the Albian and Cenomanian of Saskatchewan and one from Fetcham Mill. Only one specimen attributable to *Deflandrea* was found in the Lower Chalk of Britain and France. Four specimens were obtained from the Upper Greensand (Albian) of Fetcham Mill. However, in the Albian-Cenomanian sediments (shallow water carbonaceous shales) from Saskatchewan it is very common.

Deflandrea pirnaensis Alberti

(Pl. 1, figs. 3, 4)

1959 *Deflandrea pirnaensis* Alberti: 100, pl. 8, figs. 1–5.

DESCRIPTION. This is a variable species having a broadly ovoidal shell with a fairly well developed apical horn and typically one antapical horn. Rarely a second, much reduced, antapical horn is present. The periphragm is smooth or lightly granular. The cingulum is marked by two low ledges, sometimes having knobbly margins, and is occasionally crossed by low ridges delimiting the plate boundaries. The sulcus is rarely visible. The intercalary archaeopyle, when discernible, possesses a rounded polygonal outline. The operculum is usually in position and opened as a flap. The inner body is oval, slightly thicker than the periphragm, and is occasionally concave posteriorly. It is usually separated for most of its circumference from the outer membrane by a narrow space.

DIMENSIONS. Range of observed specimens : overall length 46 (62·7) 87 μ, overall width 34 (45·5) 63 μ, length of inner body 33 (43·9) 57 μ, width of inner body 31 (38·2) 45 μ. Number of specimens measured, 15.

REMARKS. The above specimens from Saskatchewan are very similar to the type material described by Alberti from the Middle Turonian of Germany, except for their smaller size—the type material measures 80–106 μ in length and 58–64 μ in width. *D. pirnaensis* differs from *D. minor* Alberti (1959) in the possession of a well developed cingulum.

Alberti comments that an archaeopyle was not observed in any of the specimens. In most of the Saskatchewan specimens this structure is difficult to observe, but is usually present. The reason for this difficulty is that the operculum does not be-

come completely detached, but apparently acts as a flap. Thus, after excystment, the operculum seems to have returned to its original position.

Occurrence. *D. pirnaensis* is fairly common in the Cenomanian samples Sas805 and 835, but is rare in sample Sas890 (Lower Cenomanian) and also in samples Sas 967 and 1084 from the Albian. One specimen attributable to this species was located in sample FM520 from the Turonian of Fetcham Mill.

Deflandrea echinoidea Cookson & Eisenack

(Pl. 1, fig. 5)

1960 *Deflandrea echinoidea* Cookson & Eisenack: 2, pl. 1, figs. 5, 6.
1967 *Deflandrea echinoidea* Cookson & Eisenack; Clarke & Verdier: 26, pl. 3, figs. 4, 5.

Description. Three specimens from the Albian of Saskatchewan (sample Sas1084) are similar to the Australian species from the Upper Turonian and Senonian. The outer membrane is elongate-oval in shape with a stout apical horn and two antapical horns. A number of stout, curved spines (1–2 μ in length) arise from this membrane. The spines may be pointed, blunted distally, or reduced to granules ; they are often aligned along reflected plate boundaries. The cingulum (5–7 μ in width) and sulcus are well developed and are delimited by these spines. The archaeopyle is subpolygonal. The inner body is large, subspherical to ovoidal, and abuts against the shell membrane laterally.

Dimensions. Range of observed specimens : overall length 54–67 μ, overall width 41–46 μ, length of inner body 38–45 μ, width of inner body 41–46 μ. Number of specimens measured, 3.

Occurrence. The Saskatchewan specimens extend the range of this species into the Lower Cretaceous (Albian). It is also present in the Turonian and Lower Senonian of England (Clarke & Verdier 1967).

Deflandrea cf. ***echinoidea*** Cookson & Eisenack

(Pl. 1, fig. 6 ; Pl. 2, fig. 2)

Description. The specimens here compared with *D. echinoidea* possess an ovoidal shell membrane with a small apical horn and are truncated abruptly at the posterior. Arising from the outer membrane are stout, slightly curved, hollow spines (up to 3 μ in length), which tend to be aligned along reflected plate boundaries. The cingulum is well defined (5–7 μ in width), being delimited by strongly developed spines. The sulcus is deeply hollowed and extends from the antapex just onto the epitract. A subpolygonal intercalary archaeopyle is always present. The inner body is ovoidal, its longer axis lying across the cyst and sometimes touching the outer shell membrane.

Dimensions. Range of observed specimens : overall length 50–62 μ, overall width 35–49 μ, length of inner body 31–35 μ, width of inner body 34–41 μ. Number of specimens measured, 5.

Remarks. The above specimens resemble *D. echinoidea* in most respects, but differ in their smaller size and absence of antapical horns.

Occurrence. Five specimens of *D.* cf. *echinoidea* have been recorded, all from Fetcham Mill ; four from sample FM886 (Albian) and one from sample FM840 (basal Cenomanian).

Deflandrea granulifera Manum var. ***tenuis*** nov.

(Pl. 2, fig. 1)

1962 *Deflandrea granulifera* Manum: 61, pl. 3, fig. 7 only.
1964 *Deflandrea granulifera* Manum; Manum & Cookson: 8.

Derivation of name. Latin, *tenuis*, thin—with reference to the nature of the shell wall.

Diagnosis. A variety of *D. granulifera* Manum possessing smooth to lightly granular outer membrane surrounding relatively small, thin-walled inner body.

Holotype. B.M.(N.H.) V.51990(1), (Pl. 2, fig. 1). Upper Lower Colorado (top of Fish Scale Zone?), International Yarbo Borehole No. 17, Saskatchewan at 967 feet depth. Lower Cretaceous (Albian).

Dimensions. Holotype : shell diameter 85 by 60 μ, inner body diameter 39 by 60 μ. Range : overall length 85–114 μ, overall width 52–63 μ, diameter of inner body 39–60 μ. Number of specimens measured, 8.

Description. *D. granulifera* var. *tenuis* has only been obtained from the Saskatchewan samples and appears to be quite variable. The shell is elongate, typically widest in the cingular region and narrowing slightly anteriorly before broadening to form rounded " shoulders ". The epitract terminates with a conical apical horn, blunted distally. The posterior end of the shell is flat to concave, bearing one pointed conical horn and sometimes a second rudimentary one. The slightly spiral cingulum is always well developed and bordered by fairly high ridges possessing knobbly margins. At regular intervals the bordering ridges of the cingulum are absent, thus it is discontinuous. The sulcus is wide and extends anteriorly from the antapical horns. A rounded, hexagonal intercalary archaeopyle is typically present. The outer membrane is thin and may be smooth or densely granular. The inner body is subspherical, has a slightly thicker wall and is usually more heavily granular than the outer membrane. Occasionally the inner body is in contact with the lateral walls of the shell but more often its small size does not permit this.

Remarks. Manum (1962) gave a detailed analysis of *D. granulifera* from the Upper Cretaceous of Arctic Canada and noted that two forms appeared to be present. These forms differed in the density of the granulation and also in the thickness of the inner body wall. Since some intergradation between the two forms existed, Manum considered that both forms should be placed in the single species *D. granulifera*. The more typical form possesses a dense granulation with an inner body wall of approximately 2 μ in thickness. The other, rarer form, which is the only one represented in the Saskatchewan material, possesses a smooth to lightly granular outer membrane,

and an inner body with a thin wall only slightly thicker than the outer membrane. Another differentiating feature is that the inner body is smaller in this form and is not in contact with the lateral walls of the shell. This form because of these distinguishing features is here created a variety of *D. granulifera*. *D. granulifera* var. *tenuis* nov. is rather similar to *D. spectabilis* Alberti (1959), especially in some specimens when the shoulders are not particularly pronounced. The inner body of *D. spectabilis*, from the Senonian of Germany, is extremely delicate and difficult to discern. Thus *D. granulifera* var. *tenuis*, which possesses a light granulation and a thin-walled inner body, appears to occupy an intermediate position between the typical form of *D. granulifera* and *D. spectabilis* and warrants its distinction as a variety.

Moderately, well preserved specimens are extremely rare due to the thinness of the shell wall.

Occurrence. *D. granulifera* var. *tenuis* is a rare species, found in the following Albian and Cenomanian samples from Saskatchewan—Sas1084, 967, 890, 835 and 805.

Deflandrea pontis-mariae (Deflandre)

(Pl. 1, figs. 10, 11)

1936 *Gymnodinium pontis-mariae* Deflandre: 9, pl. 2, figs. 7–9.
1965 *Deflandrea pontis-maria* (Deflandre) Vozzhennikova; pl. 49, fig. 5.

Description. The shell is elongate-ovoidal, with a large, sub-conical apical horn and a similar antapical horn placed asymmetrically. The outer membrane is thin, smooth or lightly granular. The cingulum is well defined being delimited by two low ridges, and is only slightly spiral. The sulcus is weakly defined and an archaeopyle has not been observed. The inner body is subspherical, its wall being slightly thicker than that of the outer membrane.

Dimensions. Range of observed specimens : overall length 50 (65·1) 74 μ, overall width 33 (38·3) 46 μ, length of inner body 34 (35·4) 38 μ, width of inner body 31 (34·3) 39 μ. Number of specimens measured, 7.

Remarks. The present specimens resemble the type material described by Deflandre (1936), from the Upper Cretaceous, in particular the specimen illustrated in his pl. 2, fig. 8. The single specimen illustrated by Vozzhennikova is also very similar.

The species is easily distinguishable by its overall form, in particular by the presence of a single, well developed antapical horn. Although an intercalary archaeopyle has not been observed, all the other features exhibited by this species confirm Vozzhennikova's view that it should be attributed to the genus *Deflandrea*.

Occurrence. *D. pontis-mariae* occurs in two Saskatchewan samples. It is common in sample Sas805 (Cenomanian) and very rare in sample Sas1084 (Albian).

Deflandrea suspecta (Manum & Cookson) comb. nov.

(Pl. 2, fig. 5)

1964 *Hexagonifera suspecta* Manum & Cookson: 9, pl. 1, figs. 9–13.

Description. The periphragm membrane is very thin and closely surrounds the inner body, except at the apex where there is a short, blunt apical horn. The inner body is subspherical to ovoidal and possesses a thick wall (1·5–2 μ thick). The wall is densely granular and sometimes, in addition, bears small tubercles. The inner body opens by the loss of three plates beneath the apex on one surface. The central plate, of the three, is hexagonal in shape and the two side plates are pentagonal.

Dimensions. Range of observed specimens : shell length 61–68 μ, width 56–59 μ. Number of specimens measured, 5.

Remarks. The specimens are very similar in all respects to the type material from the Upper Cretaceous of Arctic Canada. The loss of three plates to form an opening just beneath the apex of the inner body is a characteristic feature. These three plates are reflections of the three anterior intercalary plates in the tabulation of the Peridinoid dinoflagellate theca and are thus situated on the dorsal surface. The hexagonal plate is the reflected plate 2a and the two pentagonal plates reflect plates 1a and 3a. The apex of the inner body and the anterior central surface of the epitract do not help to form the opening and are equivalent to the four apical plates (plate 1′–4′). Thus a Peridinoid tabulation is present as seen in a number of species of *Deflandrea* described by Manum (1962). This species is, therefore, transferred from *Hexagonifera* Cookson & Eisenack to *Deflandrea*. As yet an anterior intercalary archaeopyle has not been observed in the outer membrane, probably because of the extremely fine and transparent nature of this membrane. The genus *Hexagonifera*, by contrast, is characterised by the formation of an apical archaeopyle developed by the removal of a six-sided apical plate.

Occurrence. *D. suspecta* is a common species found at only one horizon in Saskatchewan (sample Sas835) of Cenomanian age.

Deflandrea magna sp. nov.

(Pl. 2, figs. 6–8)

Derivation of name. Latin, *magnus*, large—with reference to the size of this species.

Diagnosis. Shell elongate—ovoidal, truncated posteriorly with single, pointed antapical horn. Epitract subconical, apical horn not differentiated. Outer membrane smooth or slightly granular, enclosing subspherical inner body. Inner body and outer membrane sometimes in contact laterally but more often separated by narrow space. Cingulum, on outer membrane, well defined, weakly spiral, marked by low ledges having knobbly margin. Sulcus broad. Archaeopyle subpolygonal, operculum typically in place.

Holotype. B.M.(N.H.) V.51988(1). Second White Speckled Shale, Inter-

national Yarbo Borehole No. 17, Saskatchewan at 835 feet depth. Upper Cretaceous (Cenomanian).

Dimensions. Holotype : overall length 102 μ, overall width 67 μ, length of inner body 55 μ, width of inner body 57 μ. Range : overall length 69 (95·9) 118 μ, overall width 49 (64·7) 85 μ, length of inner body 36 (51·0) 61 μ, width of inner body 43 (51·6) 57 μ. Number of specimens measured, 12.

Description. Due to the fineness of the outer membrane, it is always folded to some extent. The cingulum (7 to 10 μ in width) is slightly concave and is sometimes crossed by low ridges marking the cingular plate boundaries. The lower boundary of the cingulum is occasionally interrupted. The archaeopyle is elongate—ovoidal anteriorly and polygonal posteriorly ; the operculum typically remains in position. The inner body possesses a slightly thicker wall, is subspherical rarely with a posterior concavity, and usually has an apical region composed of disarranged plates. Sometimes the three anterior intercalary plates are obvious. Rarely the latter plates, together with the apical plates, are absent.

Remarks. *D. magna* sp. nov. most closely resembles *D. accuminata* Cookson & Eisenack (1958) from the Cenomanian to Lower Turonian of Australia. *D. accuminata* differs in that the inner body is relatively small, it possesses an apical horn, and the cingulum is poorly defined. The forms illustrated by Manum & Cookson (1964) from Arctic Canada are more similar, but again the cingulum is very reduced. *D. pirnaensis* Alberti (1959) resembles *D. magna* but has a more pronounced apical horn and does not usually possess an obvious archaeopyle.

Occurrence. *D. magna* has only been recorded from the Cenomanian of Saskatchewan. It is a common species in sample Sas835 and rare to fairly common in samples Sas805 and 890.

Deflandrea glomerata sp. nov.

(Pl. 1, figs. 7–9)

Derivation of name. Latin, *glomeratus*, ball—with reference to the overall circular shape of the shell.

Diagnosis. Cyst smooth-walled, circular in outline with single pointed antapical horn asymmetrically placed. Apical horn absent. Inner body circular in outline and in contact with outer membrane except in apical and antapical regions. Cingulum and sulcus typically absent. Archaeopyle angular, six-sided, with similar shaped opening on inner body.

Holotype. B.M.(N.H.) V.51988(2). Second White Speckled Shale, International Yarbo Borehole No. 17, Saskatchewan at 835 feet depth. Upper Cretaceous (Cenomanian).

Dimensions. Holotype : overall length 97 μ, overall width 70 μ, length of inner body 72 μ, width of inner body 69 μ. Range : overall length 71 (82·9) 97 μ, overall width 55 (65·9) 75 μ, length of inner body 57 (67·3) 79 μ, width of inner body approximately equals overall width. Number of specimens measured, 14.

DESCRIPTION. These cysts are relatively simple and show little variation. At the apical region of the outer membrane there is typically a small number of concentric wrinkles—perhaps a very rudimentary apical horn. In one specimen a part of the cingulum is indicated by a few aligned granules. It is significant that the inner body possesses a six-sided opening directly beneath the archeopyle in the outer membrane. Both are a reflection of plate 2a in the original dinoflagellate theca.

REMARKS. The circular outline with a simple antapical horn easily differentiates *D. glomerata* sp. nov. from all previously described species.

OCCURRENCE. *D. glomerata*, a Saskatchewan species, is common in sample Sas835 (Cenomanian), only two specimens being recorded outside this horizon : in samples Sas805 (Cenomanian) and Sas967 (Albian).

Deflandrea globosa sp. nov.

(Pl. 2, fig. 3)

DERIVATION OF NAME. Latin, *globosus*, round as a ball—with reference to the circular outline of this species.

DIAGNOSIS. Shell subspherical to subpolygonal, with small number of concentric folds at apex, and very reduced single antapical horn placed asymmetrically. Apical horn, cingulum and sulcus absent. Inner body entirely in contact with outer membrane. Wall smooth to slightly granular. Intercalary archaeopyle, angular, six-sided.

HOLOTYPE. B.M.(N.H.) V.51988 (3). Second White Speckled Shale, International Yarbo Borehole No. 17, Saskatchewan at 835 feet depth. Upper Cretaceous (Cenomanian).

DIMENSIONS. Holotype : shell length 69 μ, shell width 66 μ. Range : shell length 62 (67·5) 78 μ, shell width 48 (58·8) 66 μ. Number of specimens measured, 6.

DESCRIPTION. This species is extremely simple in form, possessing only a very rudimentary antapical horn to mar its smooth outline. The operculum is typically in place and the archaeopyle outline is only discerned with some difficulty.

REMARKS. In overall appearance *D. globosa* sp. nov. strongly resembles *D. glomerata*. They differ in that *D. globosa* possesses a very rudimentary antapical horn and that the inner body is entirely in contact with the outer membrane. The lack of an apical horn (apical wrinkles being present), any tabulation and the spherical form indicate that these two species are closely related. Because of this and the presence of an intercalary archaeopyle, *D. globosa* is placed in the genus *Deflandrea*.

OCCURRENCE. This species has only been recorded from a single sample (Sas835) Saskatchewan in which it is fairly common.

Deflandrea sp. A

(Pl. 3, fig. 1)

DESCRIPTION. The shell is elongate—ovoidal in shape. Posteriorly there are two small antapical horns, one being slightly longer than the other. An apical horn

is absent, there being present in this region a small number of concentric folds. The outer membrane is smooth, of moderate thickness (c. 1 μ), and possesses a very faintly defined cingulum. A six-sided intercalary archaeopyle is present. The inner body is subspherical and is in contact with the shell wall laterally. The wall of the inner body is of similar thickness to that of the outer membrane and is lightly granular.

FIGURED SPECIMEN. B.M.(N.H.) V.51991(2). Upper Lower Colorado (just above the top of Viking Formation), International Yarbo Borehole No. 17, Saskatchewan at 1084 feet depth. Lower Cretaceous (Albian).

DIMENSIONS. Figured specimen : overall length 93 μ, overall width 64 μ, length of inner body 59 μ, width of inner body 63 μ.

REMARKS. Although only one specimen of *Deflandrea* sp. A. was located, its distinctive nature warranted careful description. The lack of an apical horn and the presence of apical folds indicates that it is related to *Deflandrea glomerata*. However, the overall shape of the latter is different. *Deflandrea* sp.A. most closely resembles *D. pellucida* Deflandre & Cookson (1958) from the Eocene of Australia, the latter differing in the possession of an apical horn.

Cyst-Family **ENDOSCRINIACEAE** Vozzhennikova emend. Sarjeant & Downie, 1966

Genus ***PSALIGONYAULAX*** Sarjeant 1966

Psaligonyaulax deflandrei Sarjeant

(Pl. 3, figs. 4, 5)

1964 *Gonyaulax cassidata* Eisenack & Cookson; Cookson & Hughes: 42, pl. 5, fig. 11 only.
1966 *Psaligonyaulax deflandrei* Sarjeant: 137, pl. 14, figs. 7, 8; text-fig. 35.
1967 *Gonyaulacysta extensa* Clarke & Verdier: 30, pl. 4, figs. 7–9; text fig. 11.

DIMENSIONS. Range of type material : overall length 67 (76·9) 87 μ, overall width 39 (47·6) 59 μ. Number of specimens measured, 16.

REMARKS. This species was first figured by Cookson & Hughes (1964) from the Cambridge Greensand (?Albian-basal Cenomanian) as *Gonyaulax cassidata*. *P. deflandrei* is similar to the latter species except that it possesses a well defined posterior pericoel. The two species are undoubtedly closely related and it is sometimes very difficult to distinguish them when the posterior region of the shell is damaged or obscured.

OCCURRENCE. *P. deflandrei* is a rare species found throughout the Cenomanian of Fetcham Mill and Escalles. It is very rare at Compton Bay and was not observed in the North American material.

Genus ***PALAEOHYSTRICHOPHORA*** Deflandre emend. Deflandre & Cookson 1955

DIAGNOSIS. Dinoflagellate cysts with a generally thin theca furnished with a cingulum ; sulcus clear or indistinct, plates absent, membrane covered with irregularly disposed, stiff or soft spines or hairs. Archaeopyle precingular.

Remarks. The presence of a precingular archaeopyle has been added to the diagnosis.

One species attributed to this genus, *P. infusorioides*, has been recorded from the Cenomanian of England, France, Texas and Saskatchewan. It has also been recorded from material of Upper Cretaceous age in Australia (Cookson & Eisenack 1958), Germany (Alberti 1961) and Arctic Canada (Manum & Cookson 1964). It therefore has a wide geographical distribution. Detailed study of the Cenomanian in a restricted area has shown that the occurrence of this species coincides with the base of this stage, as defined by its macrofauna, and it is therefore an important index fossil. This conclusion has also been arrived at by Clarke & Verdier (1967 ; 82).

Palaeohystrichophora infusorioides Deflandre

(Pl. 3, figs. 2, 6)

1934 *Palaeohystrichophora infusorioides* Deflandre: fig. 8.
1965 *Palaeohystrichophora infusorioides* Deflandre; Vozzhennikova: pl. 9, fig. Л; pl. 21, fig. 3; pl. 43, fig. Б.
1967 *Palaeohystrichophora infusorioides* Deflandre; Clarke & Verdier: 28, pl. 4, fig. 10. (See also for earlier references).

Description. This cyst is of ovoidal to spindle-like shape, composed of a thin outer membrane surrounding a slightly thicker inner body. The outer membrane and inner body are only in contact in the cingular region, there being anterior and posterior pericoels. The cingulum is clearly marked by two ridges. The epitract is conical and usually larger than the hypotract, which may be rounded or truncated posteriorly. The outer membrane is smooth or slightly granular and usually bears a moderate number of hairlike spines ; these tend to be concentrated along the boundaries of the cingulum and sulcus and also at the apex. Occasionally the spines are very few in number and are restricted to the apex or cingular region. Very rarely the spines may be seen to be aligned along plate boundaries, demarcating the precingular and postcingular plates. The inner body is subspherical, usually slightly thicker than the outer membrane and smooth, but may sometimes be considerably thicker (up to about 1·5 μ) and densely granular. The thickening of the central body wall is usually accompanied by a decrease in the number of spines, some specimens being almost bald. Typically the shell appears to be entire but very rarely the presence of a precingular archaeopyle has been observed.

Dimensions. Range of observed specimens : shell length 33 (44·1) 63 μ, inner body length 27 (35·1) 42 μ, shell width (= width of inner body) 27 (35·7) 47 μ, maximum length of spines 4 (6·1) 10 μ. Number of specimens measures, 29.

Remarks. Most specimens of *P. infusorioides* from the Cenomanian in all respects resemble the type material from Upper Cretaceous (Senonian) as described by Deflandre. Occasionally the inner body is thicker than normal and the spines less numerous; however, there seems to be a complete gradation between the normal representatives of this species and these forms. The reduced number of spines is reminiscent of *P. paucisetosa* Deflandre (1943), but in this latter species the spines are stiff and the inner body is not in contact with the outer membrane.

The distribution of this species is fully discussed in the stratigraphic conclusions (p. 384).

Genus *STEPHODINIUM* Deflandre

EMENDED DIAGNOSIS. Cavate cysts possessing an ovoidal inner body and surrounding periphragm membrane. Inner body and outer membrane in contact on ventral surface, and at apex and antapex of shell. Maximum separation in cingular region. Apical horn usually present. Tabulation present on outer membrane, sutures marked by low ridges. Archaeopyle precingular.

TYPE SPECIES. *Stephodinium coronatum* Deflandre 1936. Upper Cretaceous; France.

REMARKS. The presence of a tabulation on the holotype of *S. coronatum*, although not described by Deflandre, has been verified by Clarke & Verdier (1967 ; 67).

Stephodinium coronatum Deflandre

(Pl. 6, figs. 1, 2, 4)

1963a *Stephodinium coronatum* Deflandre; 58, text-fig. 104.
1967 *Stephodinium coronatum* Deflandre; Clarke & Verdier: 67, pl. 12, figs. 10, 11. (See also for earlier references).

DESCRIPTION. An ovoidal inner body is surrounded by a large, smooth, tabulate, periphragm membrane. A blunt apical horn (about 8 μ in height) is present. The plate boundaries are marked by low thickenings of the periphragm membrane and typically give rise to a small spine (2–3 μ in height) when joining one another. The thickenings demarcating the cingulum are sometimes denticulate. Although the full tabulation has not been determined, there appear to be five large precingular plates of an elongate pentagonal shape. The third precingular plate is typically lost in archaeopyle formation. There are five postcingular plates and a single, more or less pentagonal antapical plate. The ventral surface is devoid of tabulation. Rarely the periphragm membrane possesses large, subcircular perforations.

DIMENSIONS. Range of observed specimens : maximum diameter of outer membrane 65 (71·2) 82 μ, minimum diameter of outer membrane 52 (61·9) 69 μ, diameter of central body 36 (45·1) 54 μ. Number of specimens measured, 12.

REMARKS. The specimens studied are identical with the type material from the Upper Albian-Lower Cenomanian of England.

OCCURRENCE. In addition to the type material, *S. coronatum* has also been recorded from the Upper Cretaceous (probably Cenomanian) of Arctic Canada by Manum & Cookson and from the Middle and Upper Albian of Roumania by Baltes (personal communication). In the material examined it is a rare to very rare species at most horizons at Fetcham Mill and Compton Bay, but only occurs in three samples from Escalles. It was also recorded from the Albian sample FM886, but was absent from the Turonian sample FM520, and from the North American material.

Cyst-Family **NELSONIELLACEAE** Eisenack emend. Sarjeant & Downie 1966

Genus ***SCRINIODINIUM*** Klement 1957

Diagnosis. Ovoid, dorso-ventrally slightly compressed shell with darker spherical to ovoid inner body. A spiral cingulum often only marginally visible. Occasionally clear tabulation with sulcus. Archaeopyle precingular.

Remarks. The presence of a precingular archaeopyle has been included in the diagnosis of this genus.

Scriniodinium campanula Gocht

(Pl. 3, figs. 7, 8)

1959 *Scriniodinium campanula* Gocht: 61, pl. 4, fig. 6; pl. 5, fig. 1.
1967 *Scriniodinium campanula* Gocht; Clarke & Verdier: 28, pl. 3, figs. 6, 7. (See also for earlier references).

Description. The shell is rhomboidal in outline ; the dorsal surface is strongly convex or pyramidal and the ventral surface practically flat. A small, stout apical horn is present, commonly truncated distally. The shell surface is smooth or slightly granular. An inner body, of similar shape to the outer shell wall, appears to be present. The cingulum, approximately 6 μ in width, is well developed on the dorsal surface and only extends onto the ventral surface for a short distance. It is delimited by two parallel folds in the shell wall, the folds occasionally bearing a few small spines. The ventral surface is almost devoid of any tabulation.

A well developed fold, reflecting a plate boundary, is present on the dorsal hypotract running from the cingulum to the antapex. The dorsal surface is pyramidal, the apex of the pyramid being where the dorsal hypotractal fold abuts against the cingulum. The dorsal surface of the epitract bears an elongate, pentagonal, precingular archaeopyle. Rarely two small folds beneath the apex are present, probably delimiting apical plates. On the ventral surface, just anterior to the antapex there is consistently a moderate sized, subcircular hole in the shell wall.

Dimensions. Range of observed specimens : length of shell 72 (90·2) 108 μ, width 62 (73·5) 86 μ. Number of specimens measured, 22.

Remarks. Sections of the cyst walls, illustrated by Cookson & Hughes, indicate that an inner body is absent and that the shell wall is only one layer thick. Cookson & Hughes argue that the inner body appearance is due to " the steepness of the gradient of the dorsal convexity ". However, in the Cenomanian specimens, if the margin of the archaeopyle is examined carefully, there appears to be an outer, very lightly granular layer and an inner smooth layer. This is as would be expected since practically all the dinoflagellate cysts examined so far are two-layered. As Cookson & Hughes points out it is possible that the two layers typically adhere closely together.

The hole in the ventral surface was first remarked upon by Cookson & Hughes and is a consistent feature of all specimens examined. Its existence possibly helps to govern the buoyancy of the cyst in some way.

Occurrence. *S. campanula* is a rare to common species of all horizons throughout the Cenomanian of Fetcham Mill, Compton Bay and Escalles. It has also been recorded from the Albian sample FM886 and the Turonian sample FM540, both from Fetcham Mill. It has not been observed in the Saskatchewan material, and only a single specimen has been recorded from Texas (Upper Woodbine). The recorded stratigraphic range of this species is Valanginian to Middle Turonian.

Cyst-Family **HEXAGONIFERACEAE** Sarjeant & Downie 1966

Genus ***HEXAGONIFERA*** Cookson & Eisenack 1961

Remarks. This genus appears to be restricted in stratigraphic range, being recorded only from the Albian and Upper Cretaceous ; it is, therefore, of stratigraphic importance.

Hexagonifera chlamydata Cookson & Eisenack

(Pl. 3, figs. 3, 9, 10)

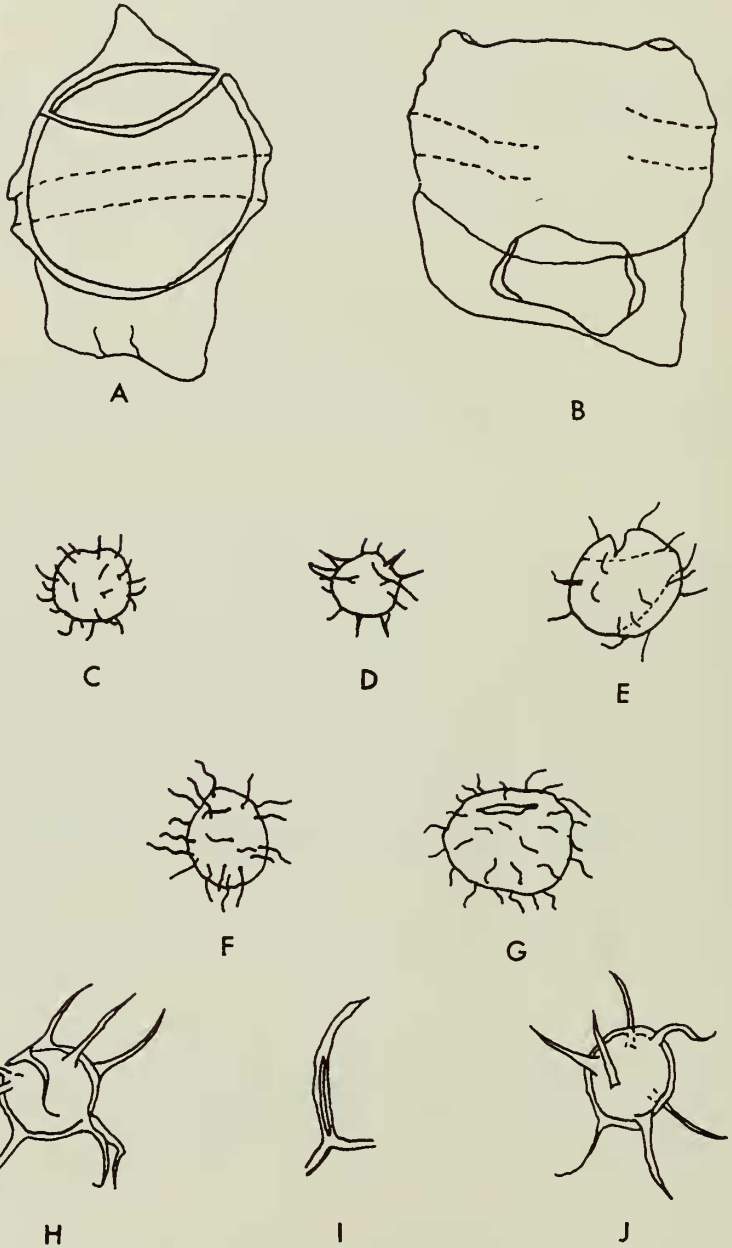
1962 *Hexagonifera chlamydata* Cookson & Eisenack: 496, pl. 7, figs. 1–3, 5–8.
1964 *Hexagonifera chlamydata* Cookson & Eisenack; Cookson & Hughes: 53, pl. 10, figs. 7–9.
1967 *Hexagonifera chlamydata* Cookson & Eisenack, Clarke & Verdier: 69, pl. 11, figs. 6–8.

Description. The inner body is ovoidal and is completely enclosed by a large, thin membrane of variable size. The inner body is thick walled (1–2 μ in thickness) and may be very lightly or densely granular, verrucose or slightly reticulate. The outer membrane is thin, may be finely granular, and is typically folded. A small apical prominence has been observed on this membrane (pl. 3, fig. 3). The apical region is usually detached in archaeopyle formation, the archaeopyle appearing to be only slightly angular sometimes with a sulcal notch. The detached operculum is six-sided.

Dimensions. Range of observed specimens : overall diameter 40–99 μ, central body length 38 (49·4) 62 μ, width 30 (44·8) 58 μ. Number of specimens measured, 17.

Remarks. The Cenomanian specimens here described strongly resemble the type material from Australia, of Albian and probably Cenomanian age. Identical specimens have been described from the basal Cenomanian of England by Cookson & Hughes. Baltes (personal communication) has also recorded this species from the Lower Cenomanian of Roumania, and Clarke & Verdier from the Turonian and Senonian of England.

Occurrence. *H. chlamydata* is infrequent at most horizons throughout the Cenomanian of Fetcham Mill, Compton Bay and Escalles. It occurs in the Lower Cenomanian material from Saskatchewan (samples Sas890, 835), but not in the Texas material.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Genus *OVOIDINIUM* nov.

Derivation of name. Latin, *ovum*, egg—with reference to the egg-shaped inner body.

Diagnosis. Bicavate dinoflagellate cysts, possessing one or two antapical horns and typically an apical horn. Periphragm and endophragm only in contact medially. Inner body subspherical, smooth or granular, commonly possessing a cingulum. Periphragm smooth or granular, forming sulcus. Tabulation absent. Archaeopyle apical with slightly angular margin.

Type species. *Ascodinium verrucosum* Cookson & Hughes 1964. Cambridge Greensand (probably basal Upper Cretaceous, Cenomanian), England.

Remarks. Two species, *Ascodinium verrucosum* Cookson & Hughes and *A. scabrosum* Cookson & Hughes, have been transferred to *Ovoidinium*. *Ascodinium* Cookson & Eisenack (1960) differs from *Ovoidinium* in that the archaeopyle is not strictly apical and that the inner body of the former is not in contact laterally with the periphragm membrane. The archaeopyle in *Ascodinium* is more or less circular, mainly situated on the dorsal surface and only just includes the apex and a small part of the ventral surface. *Deflandrea cinctum* Cookson & Eisenack (1958) from the Upper Neocomian or Lower Aptian of Australia is also transferred to *Ovoidinium*. This species is bicavate, possesses an apical archaeopyle and a well defined cingulum.

Species belonging to *Ovoidinium* have a very restricted occurrence in the samples examined. In Europe they occur only in sample FM840 (Fetcham Mill) and CB1 (Compton Bay) from the basal Cenomanian, and therefore appear to be of stratigraphic value in marking the base of the Cenomanian. In Saskatchewan this genus has been recorded from samples Sas1084, 1023 and 890. The stratigraphical significance of this genus is fully discussed in a later section (see p. 390).

Ovoidinium verrucosum (Cookson & Hughes)

(Pl. 4, figs. 1, 2; Fig. 1A)

1964 *Ascodinium verrucosum* Cookson & Hughes: 41, pl. 5, figs. 4–7.

Description. The specimens examined strongly resemble the type material from the basal Cenomanian of England. The inner body is thick-walled (c. 2 μ), finely granular and possesses a distinct cingulum. The periphragm membrane bears numerous large tubercles and forms a distinct sulcus confined mainly to the

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Fig. 1. *Ovoidinium verrucosum* (Cookson & Hughes). A. Complete specimen—operculum partially detached (×900). *Ovoidinium ostium* sp. nov., B. Paratype illustrating subrectangular opening in the posterior pericoel (×900). *Micrhystridium inconspicuum* (Deflandre). C. Specimen with opening towards the north (×1500). D. Specimen with longer spines than usual (×1800). E. Specimen having a crescentic opening (×1500). *Micrhystridium piliferum* Deflandre. F. Entire specimen (×1500). G. Specimen with slit-like opening (×1500). *Micrhystridium alveospinum* sp. nov. H. Specimen illustrating crescentic opening (×900). I. Enlargement of a spine illustrating spinal cavity (×900). J. Holotype (×900).

hypotract. At the antapex this membrane is typically extended into a single horn, asymmetrically placed, and at the apex gives rise to a small horn. The operculum occasionally remains attached. The specimens from Compton Bay are more symmetrical antapically, have a less well defined cingulum and fewer tubercles than the Fetcham Mills examples. The tubercles are sometimes in the form of small truncated processes.

Dimensions. Range : overall length 60–61 μ (2 complete specimens) ; shell length (operculum missing) 43 (47·8) 58 μ, length of inner body 32 (36·6) 42 μ, width of inner body 34 (43·4) 53 μ. Number of specimens measured, 10.

Remarks. *O. verrucosum* may be distinguished from *O. scabrosum* (Cookson & Hughes 1964) by the surface ornamentation, shape of hypotract and distinct cingulum.

Occurrence. In the Cenomanian material examined this species was recorded in the lowermost samples from Fetcham Mill (FM840) and from Compton Bay (CB1).

Ovoidinium scabrosum (Cookson & Hughes)

(Pl. 4, figs. 3, 4)

1964 *Ascodinium scabrosum* Cookson & Hughes: 40, pl. 5, figs. 1–3.

Description. *O. scabrosum* was only recorded from a single sample in the Cenomanian, sample CB1 from Compton Bay, where it is fairly common. In all respects these specimens are extremely similar to the type material described by Cookson & Hughes (1964) from the Upper Gault and Cambridge Greensand of England. The inner body is minutely, but densely, granular and is surrounded by a thin, hyaline outer membrane. The latter is in contact with the inner body only in the cingular region, thus there is an anterior and a posterior pericoel. The outer membrane forms a short apical horn and usually two small antapical horns of approximately the same size. The cingulum is extremely faint, if visible at all. An apical archaeopyle is always present, the operculum sometimes remaining attached to the main body of the cyst. The archeopyle margin is only very slightly angular, there being no sharp indentations indicating the positions of the precingular plates.

Dimensions. Range of observed specimens : overall length 63–65 μ (2 complete specimens) ; shell length (operculum missing) 42 (47·1) 52 μ, length of inner body (operculum missing) 30 (35·2) 41 μ, width of inner body 34 (40·3) 50 μ. Number of specimens measured, 9.

Remarks. *O. scabrosum* may be distinguished from other species in this genus by the inner body ornamentation, the hyaline outer membrane and the presence of two antapical horns of approximately equal size.

Occurrence. It is noteworthy that *O. scabrosum* was only recorded from sample CB1 and not from sample FM840, the lowest sample from Fetcham Mill. This probably indicates that sample CB1 was obtained from a slightly lower horizon than sample FM840 since *O. scabrosum* was not obtained from the Chalk Marl by Cookson & Hughes (1964) whereas *O. verrucosum* was.

Ovoidinium ostium sp. nov.

(Pl. 4, figs. 5, 6 ; Fig. 1B)

Derivation of name. Latin, *ostium*, entrance or opening—with reference to the opening in the wall of the posterior pericoel.

Diagnosis. Inner body subspherical, lightly but densely granular, with moderately thick wall. Periphragm slightly granular, sometimes bearing tubercles. Apical pericoel small, with poorly developed horn ; posterior pericoel asymmetrical, possessing sub-rectangular opening on ventral surface. Cingulum and sulcus moderately well defined. Apical region generally lost in archaeopyle formation.

Holotype. B.M.(N.H.) V.51987(1). Upper Lower Colorado (Fish Scale Zone?), International Yarbo Borehole No. 17, Saskatchewan at 1023 feet depth. Lower Cretaceous (Albian).

Paratype. B.M.(N.H.) V.51991(1). Upper Lower Colorado (just above top of Viking Formation), International Yarbo Borehole No. 17, Saskatchewan at 1084 feet depth. Lower Cretaceous (Albian).

Dimensions. Holotype : overall length 59 μ, length of inner body 39 μ, width of inner body 40 μ. Paratype : length (operculum missing) 50 μ, length of inner body 35 μ, width of inner body 48 μ. Range : length (operculum missing) 37 (46·2) 63 μ, length of inner body 28 (34·4) 45 μ, width of inner body 37 (43·1) 54 μ. Number of specimens measured, 9.

Description. The inner body wall (1–1·5 μ thick) is surrounded by an outer membrane (approximately 0·5 μ thick), the two being in contact only in the cingular region. A characteristic sub-rectangular shaped opening is always developed on the ventral surface of the posterior pericoel membrane (text-fig. 1B). The opening lies towards the posterior end of the sulcus and is typically closed by an operculum. The operculum of the apical archaeopyle is usually detached and the archaeopyle margin is only sightly angular.

Remarks. *O. ostium* sp. nov. is similar to *O. scabrosum* and *O. verrucosum* and tends to grade into the one or the other depending on the form of ornamentation. The opening is the posterior pericoel membrane, however, is distinctive and quite characteristic. The operculum closing this opening is always attached and, therefore, acted as a lid. The purpose of this structure can only be surmised. The most probable explanation is perhaps that this opening allowed sea water into the posterior pericoal so regulating the bouyancy of the cyst in some manner.

Occurrence. *O. ostium* has only been recorded from Saskatchewan, in samples Sas1084 and 1023 (Albian), and sample Sas890 (Lower Cenomanian). It is fairly common in the lower two samples but rare in the Cenomanian sample.

Other Species

The following species is here attributed to the genus *Ovoidinium* on the basis of the apical archaeopyle, and anterior and posterior pericoels:

Ovoidinium cinctum (Cookson & Eisenack 1958) comb. nov. = *Deflandrea cincta* Cookson & Eisenack : 1958 Proc. R. Soc. Vict. **70**(1), 26 ; pl. IV, figs. 1–3.

Cyst-Family **PSEUDOCERATIACEAE** Eisenack emend. Sarjeant & Downie 1966.

Genus ***PSEUDOCERATIUM*** Gocht 1957

Subgenus ***PSEUDOCERATIUM*** Gocht

Pseudoceratium dettmannae Cookson & Hughes

(Pl. 5, fig. 1)

1964 *Pseudoceratium dettmannae* Cookson & Hughes: 51, pl. 7, figs. 1–4.

Description. One specimen attributable to this species was observed in the lowest Cenomanian sample from Fetcham Mill (sample FM840). The specimen possesses an apical archaeopyle with a slightly angular margin. The operculum is still attached and is conical in shape with a well developed apical horn. The main part of the shell has four sides of approximately equal length and bears an apical and two lateral horns. Two membranes of similar height (15–20 μ) are situated around the circumference of the shell. They are densely pitted and sometimes possess large circular perforations. The shell wall is very lightly granular. The cingulum is extremely faintly marked by an aligned concentration of granules.

Dimensions. Overall length 101 μ, width 92 μ.

Remarks. The specimen described is very similar to the type material from the Upper Gault and Cambridge Greensand (Upper Albian—? Lower Cenomanian) of England.

Occurrence. *P. dettmannae* has only been recorded from the Upper Albian and basal Cenomanian of England.

Genus ***ODONTOCHITINA*** Deflandre emend.

Emended diagnosis. Cavate cysts consisting of spherical inner body and outer membrane. Outer membrane extended into long tapering apical horn and two shorter tapering antapical horns. Very rarely, short, branching precingular and postcingular processes are present. Archaeopyle apical.

Type species. *Ceratium operculatum* O. Wetzel 1933. Upper Cretaceous ; Germany.

Remarks. The overall shape of these cysts strongly resembles that of species in the modern genus *Ceratium* Shrank. This was first noticed by O. Wetzel (1932), who originally placed the type species in the genus *Ceratium*. Thus it appears probable that *Odontochitina* is the cyst-genus of *Ceratium*, but this is unlikely to be proved since *Odontochitina* is purely Mesozoic and *Ceratium* is present-day. No intermediate cyst types are obvious. One species, *O. blastema* sp. nov., possesses small precingular and postcingular processes but unfortunately the tabulation

formula could not be determined. The thecal tabulation of *Ceratium* is characteristic (4′, 0a, 5″, 5‴, 2⁗) and if obtained would verify a relationship.

Odontochitina operculata (O. Wetzel)

(Pl. 4, figs. 7 ; Pl. 5, fig. 2)

1933 *Ceratium* (*Euceratium*) *operculatum* O. Wetzel: 170, pl. 11, figs. 21, 22.
1966 *Odontochitina operculata* (O. Wetzel); Sarjeant: 208, pl. 21, fig. 2. (See also for earlier references).
1967 *Odontochitina operculata* (O. Wetzel); Clarke & Verdier: 59, pl. 13, figs. 1, 7.

Description. The endophragm and periphragm of these cysts are thin and smooth. The antapical horns may be of almost equal size but typically one is appreciably longer than the other. Usually the longer process is situated just to one side of the antapex, while the other arises from approximately half way along the opposite side, in specimens possessing an anchaeopyle. An apical archaeopyle is commonly present, the margin being only slightly angular.

Dimensions. Range of observed specimens : length of apical region (operculum) 188–275 μ (2 specimens) ; length of antapical horns 51 (84·7) 130 μ, width of central body 39 (51·2) 67 μ. Number of specimens measured, 9.

Remarks. *O. operculata* is an easily recognisable species and appears to be widespread geographically. The earliest record is by Pocock (1962) from the Upper Jurassic of Canada. Many authors, such as Gocht 1959, Alberti 1961 and Górka 1963, have described it from the Cretaceous System (Upper Hauterivian—Senonian).

Occurrence. *O. operculata* is a common species at all horizons throughout the Cenomanian of Fetcham Mill, Compton Bay and Escalles. It has also been recorded in two samples from Saskatchewan (Sas1084 and 805) and in the Upper Woodbine of Texas.

Odontochitina costata Alberti

(Pl. 4, figs. 8, 9 ; Pl. 5, fig. 3)

1961 *Odontochitina costata* Alberti: 31, pl. 6, figs. 10–13.
1967 *Odontochitina costata* Alberti: Clarke & Verdier: 58, pl. 13, figs. 4–6. (See also for earlier references).

Description. The shape of the shell is very similar to that of *O. operculata.* The shell surface may be smooth or very lightly punctate. The central body commonly possesses a small apical protruberance and more rarely a small protruberance opposite each of the antapical horns. Both apical and antapical horns possess 2 to 4 striations along their entire length and typically have a small number of large circular to elongate perforations. The striations are low ridges formed by a slight thickening of the horn periphragm. On one specimen, a small process is situated at the proximal end of the small antapical horn. The apical region is typically removed in archaeopyle formation.

Dimensions. Range of observed specimens : length of apical region (operculum) 88 (227·7) 290 μ, length of antapical horns 69 (90·5) 118 μ, width of central body 38 (57·7) 76 μ. Number of specimens measured, 12.

Occurrence. *O. costata* is rare to common at most horizons throughout the Cenomanian of Fetcham Mill, Compton Bay and Escalles. It was also recorded in three samples from Saskatchewan—samples Sas1084 and 1023 (Albian) and Sas890 (Lower Cenomanian). The specimens studied, resemble the type material from the Cenomanian–Turonian of Germany in all respects.

Odontochitina blastema sp. nov.

(Pl. 5, figs. 4, 5)

Derivation of name. Greek, *blastema*, offshoot or sucker—with reference to the subsidiary processes.

Diagnosis. Central body ovoidal ; outer membrane forming long tapering apical horn and two shorter tapering antapical horns. Periphragm smooth or slightly punctate ; in region of central body gives rise to small number of branched precingular and postcingular processes. Apical region commonly lost in archaeopyle formation.

Holotype. B.M.(N.H.) V.51989(1). Chalk, Bureau de Recherches Géologiques et Minières Borehole, Escalles, Pas de Calais at 159 metres depth. Upper Cretaceous (Cenomanian).

Dimensions. Holotype : width of central body 48 μ, length of antapical horns 54 and 61 μ, length of subsidiary processes 8–20 μ. Range : length of apical horn 78 μ (one specimen) ; length of antapical horns 50 (55·7) 61 μ, width of central body 41 (44·4) 51 μ, length of subsidiary processes 4–23 μ. Number of specimens measured, 5.

Description. *O. blastema* sp. nov. is of the typical *Odontochitina* shape but possesses a number of subsidiary processes. These processes vary considerably in size and shape. They may be finely acuminate or more usually they branch, either distally or proximally, and terminate with a small bifurcation. When well developed they are seen to be in two series encircling the central body. One series (precingular) lies just posterior to the archeopyle margin, while the other series (postcingular) is situated towards the posterior end of the central body. Between the two series, corresponding approximately to the widest part of the central body, there is an area devoid of processes marking the position of the cingulum. In one specimen (pl. 5, fig. 5) two processes are present also on the proximal part of the larger antipical horn.

Remarks. The presence of well developed subsidiary processes easily differentiates *O. blastema* from all previous described species in this genus. Since the overall form of the shell is identical to that of other members of *Odontochitina*, it was considered proper that this species should be placed in this genus. *Hystrichosphaera ceratioides* Deflandre (1937) is similar in size, overall form and posesses precingular and postcingular processes. However, this species possesses a distinct tabulation

and, therefore, is easily distinguished from *O. blastema*.

Occurrence. Only five specimens of *O. blastema* have been recorded. These occur in the following samples : FM730 (2 specimens) and FM690 from Fetcham Mill, and E165 and E159 from Escalles. Thus this species has not been observed in the Lower Cenomanian.

Cyst-Family **MEMBRANILARNACIACEAE** Sarjeant & Downie 1966

Genus ***CHLAMYDOPHORELLA*** Cookson & Eisenack 1958

Diagnosis. Shell enclosed in delicate membrane supported by closely arranged, slender, bifurcating spines of approximately equal length. Archaeopyle apical.

Remarks. The presence of an apical archaeopyle has been added to the original diagnosis as given by Cookson & Eisenack (1958).

This genus appears to be very similar to *Gardodinium* Albert (1961), both possessing an outer membrane supported by fine processes, an apical archaeopyle and an apical horn. *Gardodinium* however, possesses a definite subpolygonal outline, and precingular and postcingular plate boundaries are lightly defined. *Chlamydophorella nyei* as figured by Cookson & Eisenack (1958) sometimes has a subpolygonal outline but a tabulation has never been observed.

Chlamydophorella nyei Cookson & Eisenack

(Pl. 6, figs. 5, 7, 8)

1958 *Chlamydophorella nyei* Cookson & Eisenack: 36, pl. 11, figs. 1–3.
1962 *Chlamydophorella nyei* Cookson & Eisenack; Cookson & Eisenack: 496, pl. 7, figs. 14–16.
1964 *Chlamydophorella nyei* Cookson & Eisenack; Manum & Cookson; 10, pl. 5, fig. 3.

Description. The shell is subspherical, with a rounded apical horn. Processes numerous, delicate (less than 0·5 μ wide), widening slightly proximally and bifurcating distally to give two small spines. These spines support a very fine membrane which completely surrounds the shell. Apical archaeopyle occasionally visible.

Dimensions. Range of observed specimens : shell diameter 32 (40·0) 52 μ, maximum length of processes 3 (6·0) 8 μ. Number of specimens measured, 13.

Remarks and Occurrence. *C. nyei* is common in the Albian and Cenomanian samples from Saskatchewan—samples Sas1084, 967, 890, 835 and 805—and strongly resembles the type material from Australia, of Aptian to Lower Turonian age. However, the angular outline clearly shown in the photographs of the type material was not observed. This species has previously also been recorded from the ? Cenomanian of Arctic Canada by Manum & Cookson. *C. nyei* as described by Cookson & Hughes (1964) has been discussed earlier under *Cleistophaeridium huguonioti*, to which species their forms have been reattributed.

Cyst-Family Uncertain

Genus DOROCYSTA nov.

Derivation of name. Greek, *doros*, leather bag or purse ; *kystis*, bladder or sac—with reference to the purse-like shape of this dinoflagellate cyst.

Diagnosis. Shell small, broad-based with sides converging anteriorly to small apical face. Cingulum typically present and occasionally precingular and postcingular plate boundaries. Small number of processes, simple or branched, usually 4 at anterior and 5 at posterior of shell. Angular archaeopyle commonly present in centre of anterior face.

Type species. *Dorocysta litotes* sp. nov. Upper Cretaceous (Cenomanian) ; France.

Remarks. The size, shape of the shell and the presence of a cingulum differentiates this genus from all previously described genera.

Dorocysta litotes sp. nov.

(Pl. 5, figs. 6, 7 ; Fig. 2A)

Derivation of name. Greek, *litotes*, simple—with reference to the simple nature of the cyst.

Diagnosis. Shell wall smooth or lightly granular. Four anterior and four or five posterior processes, forked medially, occasionally terminating in small bifurcation. Cingulum commonly present and occasionally one or two precingular and postcingular plate boundaries. Angular apical archaeopyle typically present.

Holotype. B.M.(N.H.) V.51982(4). Chalk, Bureau de Recherches Géologiques at Minières Borehole, Escalles, Pas de Calais at 159 metres depth. Upper Cretaceous (Cenomanian).

Dimensions. Holotype : shell length 25 μ, width 23 μ, length of processes 9–11 μ, number of processes 9. Range : shell length 19 (22·7) 26 μ, width 13 (18·2) 23 μ. maximum length of processes 8 (13·0) 17 μ. Number of specimens measured, 9.

Description. The anterior face of the shell is rectangular, with a process arising from each corner. In the centre of this face there is a small angular archaeopyle, perhaps formed by the loss of a single apical plate. At the posterior end of the shell there are 4, or more usually 5, processes arranged around the broad base. The cingular and plate boundaries are delimited by low thickenings of the periphragm. The cingulum usually possesses a normal circular perforation (1–2 μ wide) in the centre of one surface.

Remarks. This distinctive species is entirely different from all previously described forms of dinoflagellate cysts.

Occurrence. Two specimens were recorded from the Lower Cenomanian of Compton Bay (samples CB1 and CB5). The other specimens occurred in the Escalles material—one in sample E159, 2 in sample E201 and 5 in sample E183.

Thus this species, although occurring only very spasmodically, is distributed throughout the Cenomanian of Escalles.

Genus *ASTROCYSTA* nov.

Derivation of name. Greek, *astron*, star ; *kystis*, sac or cell—with reference to the pentagonal shape of the cyst.

Diagnosis. Proximate cyst of pentagonal shape, composed of two layers, typically in contact. One apical and two antapical horns. Tabulation lightly marked, peridinoid. Cingulum circular and archaeopyle, when seen, intercalary.

Type species. *Palaeoperidinium cretaceum* Pocock 1962. Lower Cretaceous (Barremian) ; Canada.

Remarks. This genus differs from *Deflandrea* in that the endophragm is, for the most part, in contact with the periphragm. The two membranes may diverge slightly in the extremities of the antapical horns. In contrast, the endophragm in *Deflandrea* typically forms a well defined central body which is in contact with the outer membrane mainly in the cingular region.

Astrocysta cretacea (Pocock)

(Pl. 2, fig. 4)

?1936 *Palaeoperidinium* sp. Deflandre: 31, pl. 4, fig. 7.
1962 *Palaeoperidinium cretaceum* Pocock: 80, pl. 14, figs. 219–221.

Emended diagnosis. Shell pentagonal ; epitract triangular, with broadly conical apical horn ; hypotract bearing two conical antapical horns of unequal length. Outer membranes thin, enclosing inner body of similar shape. Cingulum marked by low ridges. Weak tabulation sometimes developed, marked by low thickenings of periphragm. Outline of anterior intercalary plate 2a usually present, but plate typically in place.

Holotype. Slide No. 3382–10 (44·8–119·8), Imperial Oil Ltd., Calgary, Alberta. Lower Cretaceous (Barremian) ; Imperial McMurray Test Hole No. 6, at 640 feet depth.

Dimensions. Range of type material 81 (88) 95 μ, breadth 50 (59) 69 μ, length of longer hypotractal horn 12 (19) 25 μ, length of shorter hypotractal horn 4 (8) 10 μ. Range of Saskatchewan specimens : overall length 86 (102·5) 118 μ, overall width 57 (73·0) 82 μ. Number of specimens measured, 8.

Description. The apical and two antapical horns are well developed, the latter differing in size from one another. The outer membrane is extremely thin, wrinkled and often possesses slight thickenings which occasionally bear small pointed spines. These thickenings partially outline a tabulation which resembles the *Peridinium*-type tabulation described by Manum (1963). The cingulum is bordered to two low ridges and is only slightly laevo-rotatory. An archaeopyle has never been observed but the outline of plate 2a is usually present.

Remarks. Manum & Cookson (1964) describe a similar species, *Palaeoperidinium* cf. *cretaceum*, from the Upper Cretaceous of Arctic Canada. This form differs from *Astrocysta cretacea* by being more circular in outline, possessing a reduced apical horn and two rather small antapical horns of similar size. *A. cretacea* is also rather similar to *Lejeunia tricuspis* O. Wetzel but the latter possesses a more pronounced cingulum.

Occurrence. This species was originally described from the Upper Jurassic of Western Canada by Pocock as *Palaeoperidinium cretaceum*. The specimens here described from Saskatchewan are identical with the type material and occur at only one horizon (Sas 1023) where they are common. This sample is of Lower Cretaceous (Albian) age. *Palaeoperidinium* spec., figured by Deflandre (1936 ; pl. 4, fig. 7) is very similar and may be conspecific.

Other species

The following species are here included in *Astrocysta* on the basis of similarity in structure:

Astrocysta kozlowskii (Górka 1963) comb. nov.

= *Lejeunia kozlowskii* Górka, 1933 Acta palaeont. polon., **8** (1), 41 : pl. V, fig. 4.

Astrocysta tricuspis (O. Wetzel 1933) comb. nov.,

= *Peridinium tricuspis* O. Wetzel, 1933 Palaeontographica, **77**, 166 : pl. 2, fig. 14.

Cyst-Family **GYMNODINIACEAE** Bergh

Genus ***DINOGYMNIUM*** Evitt, Clarke & Verdier 1967

Dinogymnium sp. A

(Pl. 6, fig. 6)

Description. The shell is more or less fusiform, the hypotract being considerably longer than the epitract. The epitract is conical, with a rounded apex ; the hypotract narrows gradually towards the posterior and terminates abruptly at the truncated apex. The cingulum forms the widest region of the shell and is up to 9 μ wide. The shell bears a moderate number of crests which run longitudinally along the shell and terminate against the cingulum. The crests (up to 3 μ in height) have an undulating outer margin.

Figured specimen. B.M.(N.H.) V.51985(1). Upper Lower Colorado (just above the top of the Viking Formation), International Yarbo Borehole No. 17, Saskatchewan at 1084 feet depth. Lower Cretaceous (Albian).

Dimensions. Single specimen : overall length 68 μ, length of epitract 25 μ, length of hypotract 43 μ, overall width 40 μ.

Remarks. *Dinogymnium* sp. A. closely resembles *D. nelsonense* Cookson (1956), in particular the specimen figured by Cookson & Eisenack (1958 ; pl. 1, fig. 8). It differs in the possession of well defined crests, having an undulatory outer margin, instead of a longitudinal folding of the shell wall. The specimen figured by Vozzhennikova (1965 ; pl. 49, fig. A) is also similar but possesses folds in place of crests.

Dinogymnium sp. B

(Pl. 6, fig. 3)

DESCRIPTION. The shell is biconical, epitract and hypotract being of similar size, with a pronounced medial cingulum demarcated by two transverse folds of the shell wall. The shell apex is bluntly pointed and the apex rounded. The shell surface is puckered into a small number of ridges which run from the cingulum to the apex or antapex of the shell. These ridges are better developed on the epitract than on the hypotract.

FIGURED SPECIMEN. B.M.(N.H.) V.51979(4). Second White Speckled Shale, International Yarbo Borehole No. 17, Saskatchewan at 835 feet depth. Upper Cretaceous (Cenomanian).

DIMENSIONS. Single specimen : overall length 16 μ, overall width 11 μ.

REMARKS. This extremely small form of *Dinogymnium* most closely resembles *D. cretaceum* Deflandre (1934), from the Upper Cretaceous of France, in general appearance. However, the shell length in the type material of the latter ranges from 33 to 42 μ.

Group *ACRITARCHA* Evitt 1963

Subgroup *ACANTHOMORPHITAE* Downie, Evitt & Sarjeant, 1963

Genus ***MICRHYSTRIDIUM*** Deflandre emend. Sarjeant 1966

G. & M. Deflandre (1965) first commented on the shell openings in *Micrhystridium*. Examples possessing openings have been observed in the Cenomanian but are not common—most specimens apparently being entire. There appear to be two principle types of opening, one being slit-like and the other being an irregularly shaped hole. In the former type the slit is generally crescentic (Test-fig. 1H), commonly extending to the centre of the shell. In this case it is probable that the encysted organism forced its way out, the cyst splitting and the two halves gaping apart. It is possible that a crescentic sliver of shell is lost but this is thought to be unlikely. Similar but smaller crescentic or horseshoe shaped slits have been described by Sarjeant (1966), the organism in this case escaping by pushing aside a flap-like portion of the shell wall. In these types of opening the shell is apparently complete, so that after the organism has made its exit the two parts of the shell may spring together again, cellulose being semi-elastic, and the shell would then appear to be unbroken. This is probably the reason why so many specimens appear to be without an opening. It is possible that some or all of these slit-like openings are due to rupture of the cyst during compaction of the sediment.

The second type of opening is an irregular hole, a portion of the shell being definitely missing, as in *M. parvispinum* Deflandre (1946; text-fig. 6). The margin of the opening may be smooth or partially ragged but is never angular, as in dinoflagellate cysts, or circular, as in *Baltisphaeridium*. The formation of such a hole may be by the liberation of a cellulose solvent, but this is purely conjectural. At

present it is impossible to say whether or not the opening always occupies the same position on the shell, due to the difficulty in orienting specimens.

Wall (1965) after a thorough study of the Lower Jurassic of England concluded that representatives of the genus *Micrhystridium* appear to favour an inshore and possibly a partly enclosed environment. The inshore environment of these organisms seems to be substantiated by their abundance in the Lower Cenomanian of Fetcham Mill and especially Compton Bay, whereas they decrease in the higher horizons.

Micrhystridium minutispinum Wall

(Pl. 6, fig. 14)

1965 *Micrhystridium minutispinum* Wall: 158, pl. 3, figs. 8–10; pl. 7, fig. 12.

Description. This species possesses a thin-walled, spherical to subpolygonal shell which bears a small number of minute conical spines. An opening, represented as a curved split, was well developed in one specimen.

Dimensions. Range of Cenomanian forms : diameter of shell 6–8 μ, length of spines 0·5–1 μ. Number of specimens measured, 4.

Remarks. The Cenomanian representatives of this species appear to be identical with the specimens described by Wall from the Lower Jurassic of England. Since this species had not been recorded from the Upper Jurassic or Lower Cretaceous, the Cenomanian specimens may be reworked, may simply have been overlooked in these horizons or may only be morphologically similar and not genetically related.

Occurrence. *M. minutispinum* is a very rare species, only four specimens being located in samples FM770 and FM650 from Fetcham Mill.

Micrhystridium deflandrei Valensi

(Pl. 6; figs 10, 11; Figs. 2J, K)

1948 *Micrhystridium deflandrei* Valensi: 545, text-fig. 5, Nos. 3, 5.
1953 *Micrhystridium deflandrei* Valensi; Valensi: 51, pl. 7, figs. 19, 21, 22.
1955 *Micrhystridium deflandrei* Valensi; Valensi: 589, pl. 3, fig. 18.
1960 *Micrhystridium deflandrei* Valensi; Sarjeant: 400, text-fig. 1q.
1962 *Micrhystridium deflandrei* Valensi; Sarjeant: text-fig. 9e.

Description. The shell of this species is spherical to subspherical and bears

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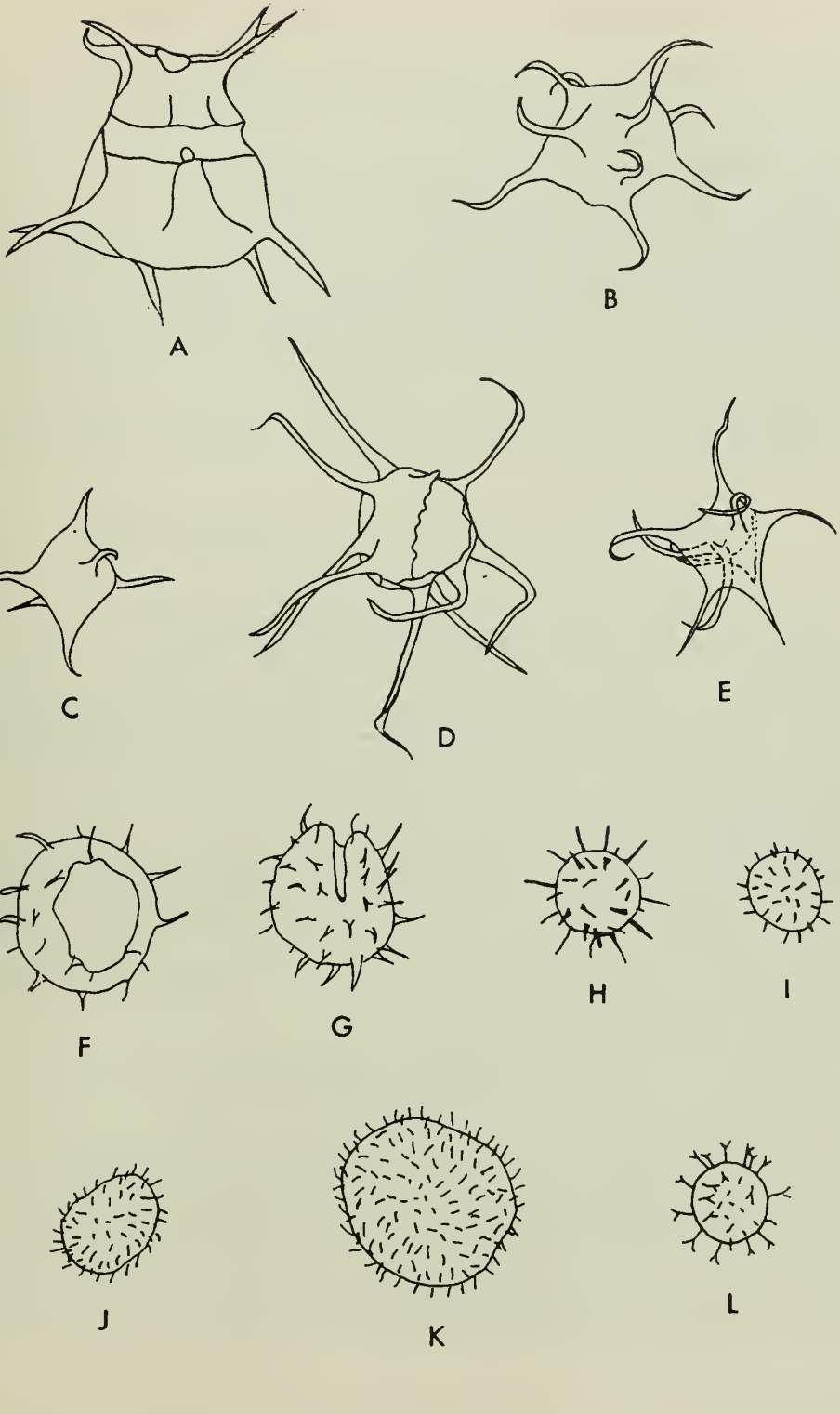
Fig. 2. *Dorocysta litotes* sp. nov. A. Holotype illustrating lightly marked tabulation and cingular perforation (×1100). *Veryhachium* sp. C. B. Specimen illustrating process arrangement (×900). *Micrhystridium singulare* Firtion. Specimens C, D and E showing extremes of variation (×900). *Micrhystridium recurvatum* forma *brevispina* Valensi. F. Specimen with subcircular opening (×1500). G. Opening to the north (×1500). *Micrhystridium rigidum* sp. nov. H. Specimen with unusually long spines (×1500). I. Holotype (×1500). *Micrhystridium deflandrei* Valensi. Specimens J and K illustrating size variation (×1500). *Micrhystridium bifidum* sp. nov. L. Holotype (×1500).


A
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a large number of small spines. The spines are very fine but rigid, straight or slightly curved, and are of an equal distance from one another. The length of the spines on a specimen is approximately constant.

Dimensions. Range of Cenomanian forms : diameter of shell 5 (11·6) 16 μ, length of spines 0·75–1 μ. Number of specimens measured, 5.

Remarks. The Cenomanian examples of *M. deflandrei* are very similar to the type material from the Middle Jurassic (Bathonian) of France. Valensi observed that the spines were arranged in parallel rows so that a lozenge-shaped chequer-work pattern was formed. This alignment is difficult to see in the forms studied and may well be absent. The specimens of *M. deflandrei* illustrated by Sarjeant (1960, 1962) from the Upper Jarassic (Oxfordian) are identical with the observed Cenomanian examples.

Occurrence. *M. deflandrei* was found only in the sample from the Upper Woodbine Formation of Texas and was there fairly common.

Micrhystridium recurvatum forma ***brevispinosa*** Valensi

(Pl. 6, figs. 12, 13; Figs. 2F, G)

1953 *Micrhystridium recurvatum*, forma *brevispinosa* Valensi: 44, pl. 6, figs. 9, 10.

Description. This form possesses a spherical to ovoidal shell, from which arise a moderate number (25–45) of slightly curved, short spines. The length of the spines is between 12 and 25% of the shell diameter. They are rigid and are probably hollow, although this is difficult to tell with any degree of certainty. Most specimens possess a well developed opening. Both forms of opening are present—the subcircular opening and the curved, slit-like opening (Text-figs. 2F, G).

Dimensions. Range of Cenomanian forms : diameter of shell 10·5 (13·7) 21 μ, length of spines 2 (2·7) 3·5 μ. Number of specimens measured, 9.

Remarks. The Cenomanian specimens cannot be differentiated morphologically from *M. recurvatum* forma *brevispinosa* as described by Valensi from the Middle Jurassic of France.

Occurrence. This is a rare species of all horizons throughout the Cenomanian of England, France and North America.

Micrhystridium cf. ***variabile*** Valensi

(Pl. 7, figs. 1, 2)

Description. This species has an ovoidal to subspherical thin-walled shell, which bears a moderate number of spines (35–50). The spines of *M.* cf. *variabile* are distinctive and characteristic. The proximal one-third to one-half of a spine is columnal ; it widens slightly proximally and to a more marked extent distally. At the distal widening the spine divides into one, two or three fine branches which may occasionally branch again. The spines on a single specimen are extremely variable but the basic bipartite form is always retained.

Dimensions. Range of Cenomanian forms : diameter of shell 6·5–9 μ, length of spines 2–3 μ. Number of specimens measured, 4.

Remarks. Only four specimens of *M.* cf. *variabile* have been observed, all in the Lower Cenomanian. These appear to be very similar to the type material described by Valensi (1953) from the Middle Jurassic (Bajocian) of France. They are, however, smaller—range for the diameter of the shell given by Valensi is 12 to 18 μ—and the spines are less numerous. As so few specimens were found, the characteristic form of the spines warrants that they should be compared with the species *M. variabile* ; the size difference and stratigraphic separation prevent confident assignation. The scarcity of this species in the Cenomanian and that it only occurs in the lower horizons indicates the possibility that it is a derived form.

Occurrence. *M.* cf. *variabile* has been found in the following lower Cenomanian samples : CB3, E213, and E207. It has not been observed in the North American Cenomanian.

Micrhystridium piliferum Deflandre

(Pl. 7, figs. 3, 4 ; Figs. 1F, G)

1937 *Micrhystridium piliferum* Deflandre: 80, pl. 15, fig. 11.
1947 *Micrhystridium piliferum* Deflandre; Deflandre: text-fig. 1, No. 16.
1952 *Micrhystridium piliferum* Deflandre; Deflandre: text-fig. 20.
1957 *Micrhystridium piliferum* Deflandre; Downie: text-fig. 5e.

Description. The Cenomanian specimens belonging to this species possess smooth, subspherical shells, from which arise fairly numerous, hair-like spines. The latter vary in length between 20 and 50% of the shell diameter. A slit-like opening has been observed in a few specimens (Text-fig. 1G).

Dimensions. Range of Cenomanian forms : diameter of shell 6 (9·6) 16 μ, length of spines 2·5 (3·3) 5 μ. Number of specimens measured, 11.

Remarks. The observed specimens strongly resemble *M. piliferum* as described by Deflandre from the Upper Cretaceous. This species is based on a single specimen of shell diameter 20 to 22 μ, this being appreciably larger than any of the Cenomanian specimens. The surface of the shell is also finely punctate. It is considered that the Cenomanian specimens would fall into the range of variation of *M. piliferum* and have, therefore, been placed in this species.

M. aff. *fragile*, as described by Brosius & Bitterli (1961) from the Middle Triassic, strongly resembles the Cenomanian specimens of *M. piliferum* and possibly belongs to this species.

Occurrence. *M. piliferum* is a rare species at most horizons throughout the Cenomanian of Fetcham Mill, Compton Bay and Escalles.

Micrhystridium inconspicuum (Deflandre)

(Pl. 7, figs. 5–7 ; Figs. 1C, D, E)

1935 *Hystrichosphaera inconspicua* Deflandre : 233, pl. 9, figs. 11, 12.
1937 *Micrhystridium inconspicuum* (Deflandre) Deflandre : 32, pl. 12, figs. 11–13.
1947 *Micrhystridium inconspicuum* (Deflandre) ; Valensi : 817, text-fig. 8.
1947 *Micrhystridium inconspicuum* (Deflandre) ; Deflandre : 6, text-figs. 7, 12.
1952 *Micrhystridium inconspicuum* (Deflandre) ; Deflandre : text-figs. 26–29.
1953 *Micrhystridium inconspicuum* (Deflandre) ; Valensi : pl. 2, fig. 10 ; pl. 7, figs. 14, 15, 20, 23–36 ; pl. 8, figs. 1–5, 7–10, 14, 15, 17–20, 23–29 ; pl. 14, figs. 8–11.
1959 *Micrhystridium inconspicuum* (Deflandre) ; Sarjeant : 340, text-fig. 7b.
1960 *Micrhystridium inconspicuum* (Deflandre) ; Sarjeant 398, pl. 14, fig. 18 ; text-figs. 1f. 1g.
1961 *Micrhystridium inconspicuum* (Deflandre) ; Brosius & Bitterli : 40, pl. 2, figs. 17, 18 ; text-fig. 8.
1961 *Micrhystridium inconspicuum* (Deflandre) ; Sarjeant : 105, pl. 13, fig. 5 ; text-fig. 8f.
1962 *Micrhystridium inconspicuum* (Deflandre) ; Sarjeant : pl. 2, fig. 13, text-fig. 8b.

Description. This species has a spherical to subpolygonal, thin-walled shell from which arise a moderate number of simple, rigid, apparently solid spines (25–45), varying in length from 25 to 50% of the shell diameter. The shell surface is usually smooth; however, in two specimens, a faint reticulation was observed. The spines, apparently arranged haphazardly over the shell surface, may be erect, but are more commonly curved to some extent. Proximally the spines may either arise abruptly or gradually from the shell. In the latter case the spines have wide bases, giving the shell a subpolygonal outline. Distally the spines terminate in a point.

Many of the specimens in the Cenomanian possess a well defined opening which appears as a curved slit extending inwards from the outer margin of the shell (Text-fig. 1E).

Dimensions. Range of Cenomanian specimens : shell diameter 6 (8·1) 13 μ, length of spines 1 (2·9) 5 μ. Number of specimens measured, 18.

Remarks. Valensi (1953) divided *M. inconspicuum*, as found in the Middle Jurassic of France, into six series based on the relative length and form of the spines and the dimensions of the shell. The Cenomanian specimens appear to belong in the third and fourth series, the remaining variants being absent. It is, however, debatable that all the specimens which Valensi placed in this species actually belong there. The specimens described by Sarjeant (1960, 1961, 1962) of *M. inconspicuum* from the Upper Jurassic (Oxfordian) are extremely similar to the Cenomanian examples.

Occurrence. *M. inconspicuum*, as found in the Cenomanian of England and France, is very similar to the type material described by Deflandre from the Senonian of France. This species is most abundant in the Lower Cenomanian, comprising 65% of the microplankton in one sample (sample CB1), and although it becomes less abundant in the Upper Cenomanian it is always common. It has not been recorded from North America.

Micrhystridium singulare Firtion

(Pl. 6, fig. 9 ; Figs. 2C, D, E)

1952 *Micrhystridium singulare* Firtion : 160, pl. 8, figs. 1, 2.

EMENDED DIAGNOSIS. Shell moderately large, subpolygonal to polygonal, thin-walled. Spines, few in number, hollow with broad bases, the cavity being continuous with that of the shell.

HOLOTYPE. As illustrated by Firtion (1952 ; pl. 8, fig. 1). Place of lodgement unknown. Cenomanian : France.

DIMENSIONS. Holotype : shell diameter 14·5 by 18·5 μ, length of spines 14·6–19·7 μ. Range of Cenomanian specimens : shell diameter 7 (15·4) 21 μ, length of processes 7·5 (17·2) 30 μ. Number of specimens measured, 15.

DESCRIPTION. The shell, being thin-walled, is often distorted giving specimens the appearance of having bilateral symmetry. In undistorted specimens the diamter of the shell is constant in all directions. The spines are typically longer than the shell diameter and may be curved or, more rarely, flexuous. The number of spines present usually varies from 6 to 9, but one specimen with eleven and two specimens with twelve have been observed. An opening, in the form of a large circular hole with an irregular margin, was only observed in one specimen (Text-fig. 2D).

REMARKS AND OCCURRENCE. Firtion appears to have diagnosed this species by describing a single specimen, figured on his pl. 8, fig. 1. The " equatorial pad " described by Firtion is almost certainly a fold in the wall of the shell and, therefore, cannot be used in the orientation of a specimen. As in most other species of *Micrhystridium* a definite line of bilateral symmetry is absent.

Specimens very similar to the examples illustrated by Firtion have been observed at Fetcham Mill, Compton Bay and Escalles. The Text-figure examples show extremes of variation within this species and also the gradation of some specimens to forms belonging to the genus *Veryhachium* Deunff. *M. singulare* is also comparable to *M. stellatum* Deflandre (1945) from the Silurian. However, the spines of the former are constantly less numerous and usually relatively longer.

Micrhystridium alveospinum sp. nov.

(Pl. 7, figs. 8, 9 ; Figs. 1H, I, J)

DERIVATION OF NAME. Latin, *alveus*, cavity or channel, and *spina*, thorn—with reference to the hollow spines or processes.

DIAGNOSIS. Shell spherical to subspherical ; shell wall moderately thick, smooth, bearing small number of processes varying between 60 and 120% of shell diameter. Processes may be rigid, straight or curved, or flexuous ; commonly possessing tubule not connecting with shell cavity, rarely solid. Opening in form of curved split commonly present.

HOLOTYPE. Geol. Surv. Colln. slide PF.3043(2). Chalk, H.M. Geological Survey Borehole, Fetcham Mill, Surrey at 810 feet depth. Upper Cretaceous (Cenomanian).

Dimensions. Holotype: shell diameter 16 by 16μ, length of processes 12–13μ, number of processes 8. Range: shell diameter 10 (14·9) 21μ, length of processes 7 (13·3) 25μ, number of processes 6 (9) 12. Number of specimens measured, 23.

Description. The shell wall of *M. alveospinum* is smooth and relatively thick (c. 0·75–1·5 μ). It is possible that the wall is two layered but it is very difficult to be certain of this. The processes taper gradually from a slightly widened base to a fine point distally. Occasionally there is a slight constriction or " neck " just above the base of the process—the process being solid at this point (Text-fig. 11). Thereafter the process may widen slightly and the central part is occupied by a fine tubule. Intermittently the wall of the process may thicken thus obstructing the lumen of the tubule. Solid processes are occasionally present on a specimen possessing mainly hollow ones.

Remarks. The distinctive nature of the processes distinguishes *M. alveospinum* sp. nov. from all previous described species. *M. lymensis* var. *lymensis* Wall (1965), from the Lower Jurassic, is very similar but possesses narrower processes which are usually solid.

Occurrence. *M. alveospinum* is a rare species and appears to be restricted to the Lower and Middle Cenomanian at Fetcham Mill, Compton Bay and Escalles. Two specimens have been found in sample Sas 1084 from Saskatchewan.

Micrhystridium bifidum sp. nov.

(Pl. 7, figs. 10, 11 ; Fig. 2L)

Derivation of name. Latin, *bifidus*, split into two parts, with reference to the forked processes.

Diagnosis. Shell spherical to subspherical ; shell wall smooth bearing moderate number of forked processes, all of approximately equal length. Process length equivalent to between 20 and 30% of shell diameter : these divide distally into two spinelets perpendicular to each other.

Holotype. Geol. Surv. Colln. slide PF.3994(1). Chalk, H.M. Geological Survey Borehole, Fetcham Mill, Surrey at 690 feet depth. Upper Cretaceous (Cenomanian).

Dimensions. Holotype : shell diameter 6 by 7 μ, length of processes c. 1·5 μ. Range : shell diameter 6 (7·5) 10 μ, length of processes 1 (1·8) 3 μ. Number of specimens measured, 9.

Description. The processes usually divide producing spinelets of the same length, but occasionally one is longer and may be recurved. In one specimen observed some of the processes do not fork but are capitate, terminating with a bulbous extremity. A slit-like opening is sometimes present.

Remarks. The simple form of the forked processes distinguishes *M. bifidum* sp. nov. from all other described species of *Micrhystridium*. *M. ambiguum* Deflandre (1937) from the Upper Cretaceous and ?*M. incertum* Deunff (1958) from the Ordovician both possess forked processes, but the two spinelets lay parallel to the shell

surface. The former has a shell diameter 20–22 μ and is thus considerably larger than *M. bifidum*. ?*M. incertum* however, appears to possess an outer membrane and is doubtfully a member of this genus.

Occurrence. *M. bifidum* was present in five samples, all from the Upper Cenomanian—samples FM690, 670, 650 and E171, 165. In sample FM690 it is common but rare in the others.

Micrhystridium rigidum sp. nov.

(Pl. 7, figs. 12, 13 ; Figs. 21H, I)

Derivation of name. Latin, *rigidus*, stiff or inflexible—with reference to the rigid nature of the spines.

Diagnosis. Shell spherical to subspherical ; shell wall thin, smooth bearing moderate number of rigid straight spines. Spines equivalent to less than half shell diameter of length (constant on an individual) and regularly spaced.

Holotype. Geol. Surv. Colln. slide PF.3993(1). Chalk, H.M. Geological Survey Borehole, Fetcham Mill, Surrey, at 690 feet depth. Upper Cretaceous (Cenomanian).

Dimensions. Holotype : shell diameter 6 by 7 μ, length of spines c. 1 μ. Range : shell diameter 5 (6·8) 7 μ, length of spines 1 (1·8) 3 μ. Number of specimens measured, 10.

Description. The spines are straight and quite sturdy. Proximally they widen only slightly when joining the shell and thereafter are parallel sided. Distally the spines are blunt. This may be especially well seen in specimens possessing longer than average spines (Tex-fig. 1H).

Remarks. The characteristic rod-like spines differentiate *M. rigidum* sp. nov. from all previously described species contained within the genus with the exception of the Carboniferous *M. bacilliferum* Deflandre (1946), the validity of which is doubtful since a drawing was published without a description. In this species, the spines are somewhat similar but are not equally spaced over the surface of the shell.

Occurrence. *M. rigidum* is a rare species in most horizons throughout the Cenomanian of Fetcham Mill. Only one specimen was found in the Compton Bay material and it was not observed from Escalles and North America.

Subgroup *POLYGONOMORPHITAE* Downie, Evitt & Sarjeant 1963

Genus ***VERYHACHIUM*** Deunff emend. Downie & Sarjeant 1963

Remarks. Sarjeant (1967) described for the first time the presence of slit-like openings in *Veryhachium* which are, within a species, always orientated in the same manner with respect to the spines. Such an opening has only occasionally been observed in the Cenomanian specimens studied.

Examples of *Veryhachium* range throughout this stage and are always relatively

rare, although they are slightly more common in the lower horizons of the Cenomanian. Wall (1965) deduced that *Veryhachium* favoured an open-sea environment as opposed to the near-shore one of *Micrhystridium*. Because of the rarity of *Veryhachium* in the Cenomanian the above statement cannot be verified or refuted on the evidence available.

Veryhachium reductum Deunff

(Pl. 7, figs. 14, 15 ; Fig. 3C)

1958 *Veryhachium trisculum* var. *reductum* Deunff : 27, pl. 1, figs. 1, 3, 8, 10–12, 14, 15, 17, 22, 23.
1961 *Veryhachium reductum* Deunff ; Jekhowsky : 210, pl. 2, figs. 33–37.
1961 *Veryhachium reductum* Deunff ; Brosius & Bitterli : 36, pl. 1, figs. 3–6 ; text-figs. 1a–e.
1962 *Veryhachium reductum* Deunff ; Cookson & Eisenack : 492, pl. 4, fig. 17.
1963 *Veryhachium reductum* Deunff ; Stockmans & Willière : 455, pl. 1, fig. 16 ; pl. 3, figs. 3, 4 ; text-fig. 8 ; pl. 1, fig. 11? ; text-fig. 9.
1963 *Veryhachium reductum* Deunff ; Downie & Sarjeant : 94.
1964 *Veryhachium reductum* Deunff ; Cookson & Hughes : 56, pl. 11, fig. 8.
1965 *Veryhachium reductum* Deunff ; Wall : 160, pl. 4, fig. 10, 11.

Description. The Cenomanian examples are very similar to the type material from the Ordovician of France. The central body is triangular, slightly inflated, bearing a process at each corner. The processes blend into the central body and may be hollow or partly solid. In length they measure between 75 and 125% of the diameter of the central body. The central body sometimes possesses an elongate slit (Text-fig. 3C). This may be formed by compaction or may possibly be an opening through which the encysted organism escaped.

Dimensions. Range of Cenomanian specimens : diameter of central body (measured from base of process to side opposite) 12 (16.1) 21 μ, length of processes 10 (14·7) 20 μ. Number of specimens measured, 10.

Occurrence. *V. reductum* has been previously recorded from the Ordovician, Silurian, Permo-Trias, Jurassic and Lower Cretaceous by various authors. It, therefore, appears to be a long-ranging morphospecies of little stratigraphic use. In the Cenomanian of Fetcham Mill, Compton Bay and Escalles it is a rare species, found only in the lower horizons.

Veryhachium cf. *reductum* Deunff

(Pl. 6, fig. 16 ; Figs. 3D, E)

Description. Two specimens were closely similar to *V. reductum* Deunff but possessed slightly elongate central bodies, thus imparting a bilateral symmetry to the cyst.

Dimensions. Text-fig. 3D : slide PF3040 : diameter of central body 12 by 16 μ, maximum length of processes 10 μ. Text-fig. 3E : slide PF3040 : diameter of central body 12 by 15 μ, maximum length of processes 18 μ.

Remarks. *V.* cf. *reductum* differs from *V. reductum* only by the possession of a

slightly elongate central body. It appears to be intermediate in morphology between *V. reductum* and *Domasia liassica* Wall (1965 ; pl. 5, figs. 2, 3).

Occurrence. Both specimens of *V.* cf. *reductum* were found in sample FM670 from the Upper Cenomanian of Fetcham Mill.

Veryhachium reductum forma ***breve*** Jekhowsky

(Pl. 7, fig. 17 ; Fig. 3J)

1957 Hystrichospheres, Kara-Murza : 7, pl. 1, figs. 31, 34, 35.
1961 *Veryhachium reductum* forma *breve* Jekhowsky : 212, pl. 2, figs. 38–44.

Description. A form of *V. reductum* possessing reduced processes.

Dimensions. Figured specimen (Pl. 7, fig. 17) : diameter of central body 21 μ, length of processes 2–5 μ.

Remarks. Only one specimen of *V. reductum* forma *breve* was found, this in sample E201 from Escalles. The test is poorly preserved, appearing to have been oxidised, and certainly differs in preservation from other microplankton in the same sample, thus indicating that the specimen is derived.

Veryhachium cf. ***hyalodermum*** Cookson

(Pl. 7, fig. 18 ; Figs. 3A, B)

Description. A form of *Veryhachium* possessing a large, slightly inflated central body, from which radiate five or six hollow, curved processes. The processes are longer than the diameter of the central body, have broad bases and taper distally to a fine point. Although the test wall is of moderate thickness all specimens have been broken or distorted to some extent. One specimen (Text-fig. 3B) is unusual in that it possesses an hour-glass shaped central body from which arise six processes.

Dimensions. Range of observed specimens : diameter of central body c. 20–29 μ, maximum length of processes 23–37 μ.

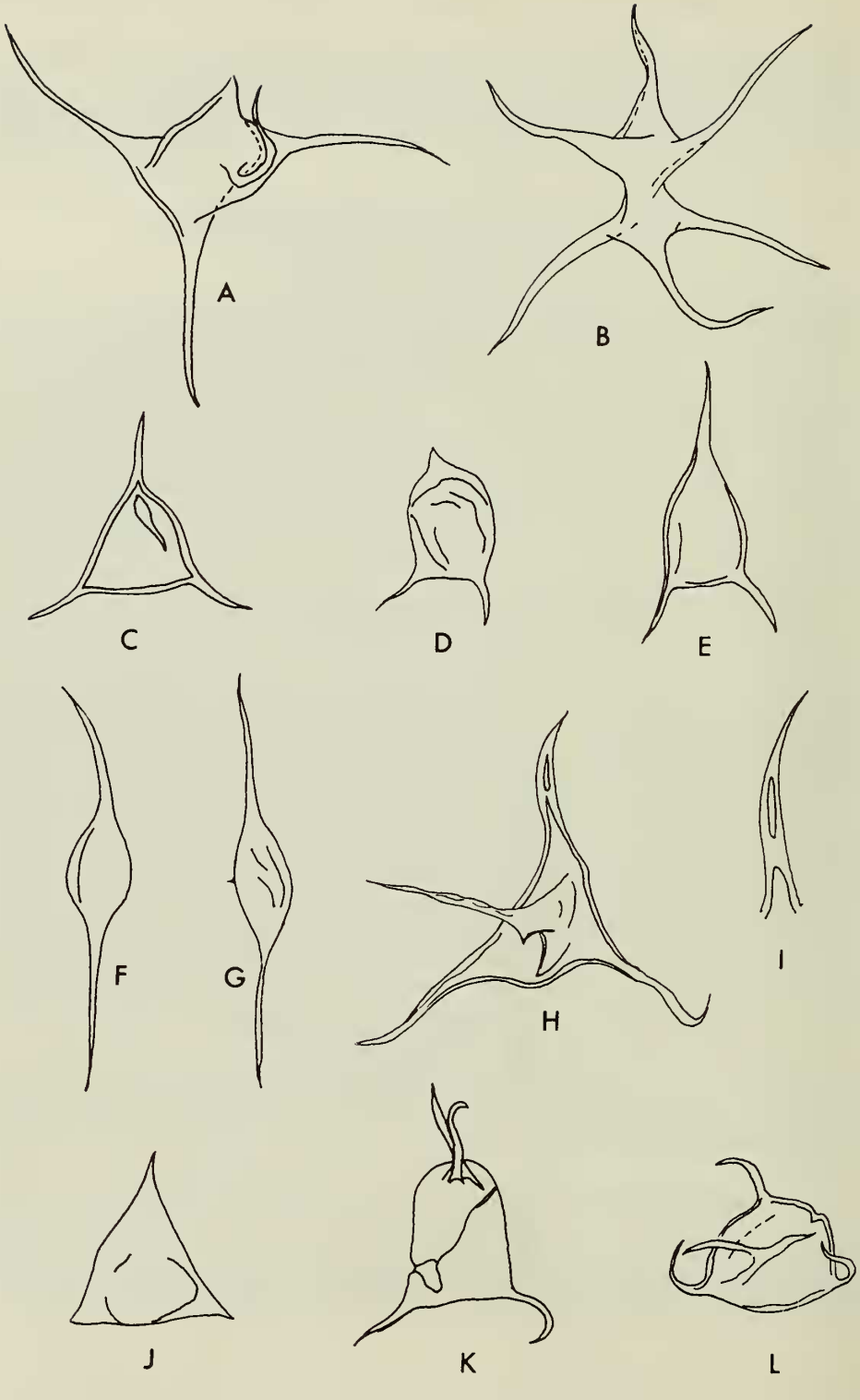
Remarks. *V. eisenacki* Deunff (1961), from the Devonian, is of similar appearance, but the wall is microperforate and the processes are closed proximally. The forms described above are most closely related to *V. hyalodermum* from the Albian–?Turonian of Australia, although this species according to Cookson possesses only four processes, fewer than in the material studied here.

Occurrence. *V.* cf. *hyalodermum* is a rare species found mainly at the base of the Cenomanian at Fetcham Mill and Compton Bay, only one specimen being found at a higher horizon—sample FM730.

Veryhachium irregulare forma ***subtetraedron*** Jekhowsky

(Pl. 8, fig. 1 ; Fig. 3L)

1961 ? *Veryhachium irregulare* forma *subtetraedron* Jekhowsky : 208, pl. 1, figs. 4–9.
1963 *Veryhachium irregulare* forma *subtetraedron* Jekhowsky ; Downie & Sarjeant : 94.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DESCRIPTION. The form of the central body is tetrahedral and inflated. The corners of the tetrahedron give rise to hollow, rather slender, curved processes.

DIMENSIONS. Figured specimen (Pl. 8, fig. 1) : diameter of central body 16 by 20 μ, length of processes c. 10 μ, width of process at base c. 1·5 μ.

REMARKS. One specimen attributable to this species was found in the Cenomanian of Fetcham Mill. The processes appear to be slightly finer than those seen in the type material from the Permo-Trias of Yugoslavia, but in all other respects it is very similar.

Veryhachium rhomboidium Downie

(Pl. 8, figs. 2, 3)

1959 *Veryhachium rhomboidium* Downie : 62, pl. 12, fig. 10.
1960 *Veryhachium rhomboidium* Downie ; Stockmans & Willière : 2, pl. 1, fig. 9 ; pl. 2, fig. 23.
1963 *Veryhachium rhomboidium* Downie ; Downie & Sarjeant : 94.
1963 *Veryhachium rhomboidium* Downie ; Wall & Downie : 781, pl. 114, figs. 1–3.
1963 *Veryhachium rhomboidium* Downie ; Downie : 636.

DESCRIPTION. Specimens possess a square to rectangular central body which bears six to nine hollow processes. There is always one spine situated at each end of the four corners, the subsidiary processes being arranged fairly symmetrically on the medial region of the central body. The processes are fairly sturdy and measure between 60 and 120% of the smaller central body diameter in length.

DIMENSIONS. Range of observed specimens : diameter of central body 14 (19·4) 25 μ, length of processes 13 (14·6) 19 μ. Number of specimens measured, 7.

REMARKS. The Cenomanian examples of this species appear to be more comparable to the type material from the Silurian than to the Permian specimens described by Downie (1963). This is because the Permian forms possess very slender processes which are usually flexuous.

OCCURRENCE. *V. rhomboidium* has been described from the Silurian, Devonian and Permian, and is here recorded for the first time from the Mesozoic. It is a very sparsely distributed species in the Cenomanian and has been recorded from the following samples : FM730, CB1, E213 and also from sample Sas1084 (Albian).

FIG. 3. *Veryhachium* cf. *hyalodermum* Cookson. A. (×900). B. " Hour-glass " shaped specimen (×900). *Veryhachium reductum* Deunff. C. Specimen possessing an elongate opening (×600). *Veryhachium* cf. *reductum* Deunff. D. Specimen with short " apical " process (×1000). E. (×1000). *Leiofusa* cf. *jurassica* Cookson & Eisenack. F. (×900). G. Specimen with reduced medial process (×900). *Veryhachium metum* sp. nov. H. Holotype (×900). I. Enlargement of spine to show spinal cavity (×1500). *Veryhachium reductum* forma *breva* Jekhowsky. J. (×900). *Veryhachium* sp. A., K. (×900). *Veryhachium irregulare* forma *subtetraedron* Jekhowsky. L. (×900).

Veryhachium metum sp. nov.

(Pl. 8, figs. 5, 6 ; Figs. 3H, I)

Derivation of name. Latin, *meta*, conical column at the end of the Rome circus —with reference to the form of the processes.

Diagnosis. Central body tetrahedral slightly inflated. Four simple processes arise from corners of central body ; these are of moderate length, always partly solid, but hollow proximally.

Holotype. Geol. Surv. Colln. Slide PF. 3045(2). Chalk, H.M. Geological Survey Borehole, Fetcham Mill, Surrey at 840 feet depth. Upper Cretaceous (Cenomanian).

Dimensions. Holotype : diameter of central body 15 μ, length of processes 23–25 μ. Range : diameter of central body 14 (15·9) 18 μ, length of processes 11 (18·3) 25 μ. Number of specimens measured, 9.

Description. All the specimens have been compressed flat, so that three processes now lie in one plane and the fourth is bent over into a slightly higher or lower plane. The processes are solid for the distal one-half to three-quarters of their length, there sometimes being a fine tubule in this region (Text-fig. 3I). The length of the processes is usually greater than the diameter of the central body.

Remarks. The form of the central body and the nature of the processes make *V. metum* sp. nov. an easily identifiable species. *V. hyalodermum* Cookson (1956) and *V. europaeum* Stockmans & Willière (1960) are similar but possess processes that are entirely hollow. At present it is considered unnecessary to erect a new genus to accommodate those forms possessing processes which are partly solid.

Occurrence. *V. metum* is found sparsely throughout the Cenomanian of Fetcham Mill and Compton Bay and is slightly more common in the lower horizons. At Escalles specimens have only been obtained from the lowermost sample (E213).

Veryhachium sp. A

(Pl. 8, fig. 4 ; Fig. 3K)

Description. The central body is elongate—triangular and bears four processes —one arising from each corner of the base of the triangular central body and one on either side of the apex (posterior). The processes are slender with fairly narrow bases and appear to be hollow.

Dimensions. Figured specimen (Pl. 8, fig. 4): diameter of central body 14 by 20 μ, length of processes c. 14 μ.

Remarks. The shape of the central body is very similar to *V. delmeri* and *V. limaciforme* described by Stockmans & Willière (1963) from the Silurian. However, these species only possess one posterior process. *Veryhachium*? sp. Wall (1965) is also similar but possesses processes with broad bases. Wall infers that this form may be a transitional type between *Veryhachium* and *Dormasia liassica* Wall (1965).

One specimen only of this distinctive form was recorded in the material examined and this was from Compton Bay. The test wall is lightly pitted, indicating an

unusual amount of oxidation and suggesting the possibility that this specimen is derived.

Veryhachium sp. B

(Pl. 7, fig. 19)

DESCRIPTION. Three specimens have been recorded possessing sub-polygonal central bodies and eight processes. The processes are hollow, usually slightly curved, have wide bases which blend into the central body and are regularly arranged.

DIMENSIONS. Diameter of central body 17–24 μ, length of processes 23–25 μ.

REMARKS. The three specimens described above lie at the transition between two genera, *Micrhystridium* and *Veryhachium*. They fall just within the size limit of *Micrhystridium* and are similar to some forms described as *M. stellatum* Deflandre (1942). However, they are referable to *Veryhachium* because of the broad bases of the processes, which give the central body a subpolygonal outline, and the processes are relatively low in number.

OCCURRENCE. The three specimens are from samples FM690 (Fetcham Mill) and E213 (Escalles).

Veryhachium sp. C

(Pl. 8, fig. 10 ; Fig. 2B)

DESCRIPTION. A single specimen possessing eleven processes was recorded from the lower Cenomanian of Escalles. Five of the processes lie on a medial plane at the corners of a pentagon, the remaining processes being arranged symmetrically three above and three below this plane.

DIMENSIONS. Diameter of central body 17 by 17 μ, length of processes 10–13 μ.

REMARKS. *Veryhachium* sp. C, like *Veryhachium* sp. B, is similar to *Micrhystridium stellatum* Deflandre but is considered to belong to *Veryhachium* because of the broad bases to the processes which give the central body a subpolygonal outline.

OCCURRENCE. The single specimen was obtained from sample E213, from Escalles.

Genus ***TUBULOSPINA*** nov.

DERIVATION OF NAME. Latin, *tubulus*, tubular ; *spina*, thorn, or spine—with reference to the tubular nature of the processes.

DIAGNOSIS. Acritarchs with triangular, tetragonal or polygonal tests, with corners drawn out into tapering processes. Small number of subsidiary processes (usually 1–6) symmetrically arranged on test surface. Spines simple, closed both distally and proximally and typically hollow.

TYPE SPECIES. *Tubulospina oblongata* sp. nov. Upper Cretaceous (Cenomanian); England.

Remarks. This genus has been erected for forms differing from *Veryhachium* principally in that they possess processes which are closed proximally. The basal portion of the process wall is greatly thickened so forming a " plug " which separates the process cavity from the central body cavity.

Tubulospina oblongata sp. nov.

(Pl. 8, figs. 7–9 ; Fig. 4)

Derivation of name. Latin, *oblongus*, longer than broad—with reference to the rectangular shape of the central body.

Diagnosis. Central body rectangular, smooth and thick-walled. Each corner gives rise to one process and there are, in addition, a small number of symmetrically arranged subsidiary processes. Processes simple, stout and usually hollow.

Holotype. B.M.(N.H.) V.51984(1). Chalk, Compton Bay, Isle of Wight at 44 feet above the base of the Cenomanian. Upper Cretaceous (Cenomanian).

Dimensions. Holotype : diameter of central body 22 by 27 μ, length of processes c. 30 μ, number of processes 7. Range : diameter of central body 13 (20·9) 32 μ, length of processes 14 (26·6) 40 μ, number of processes 5 (7) 10. Number of specimens measured, 17.

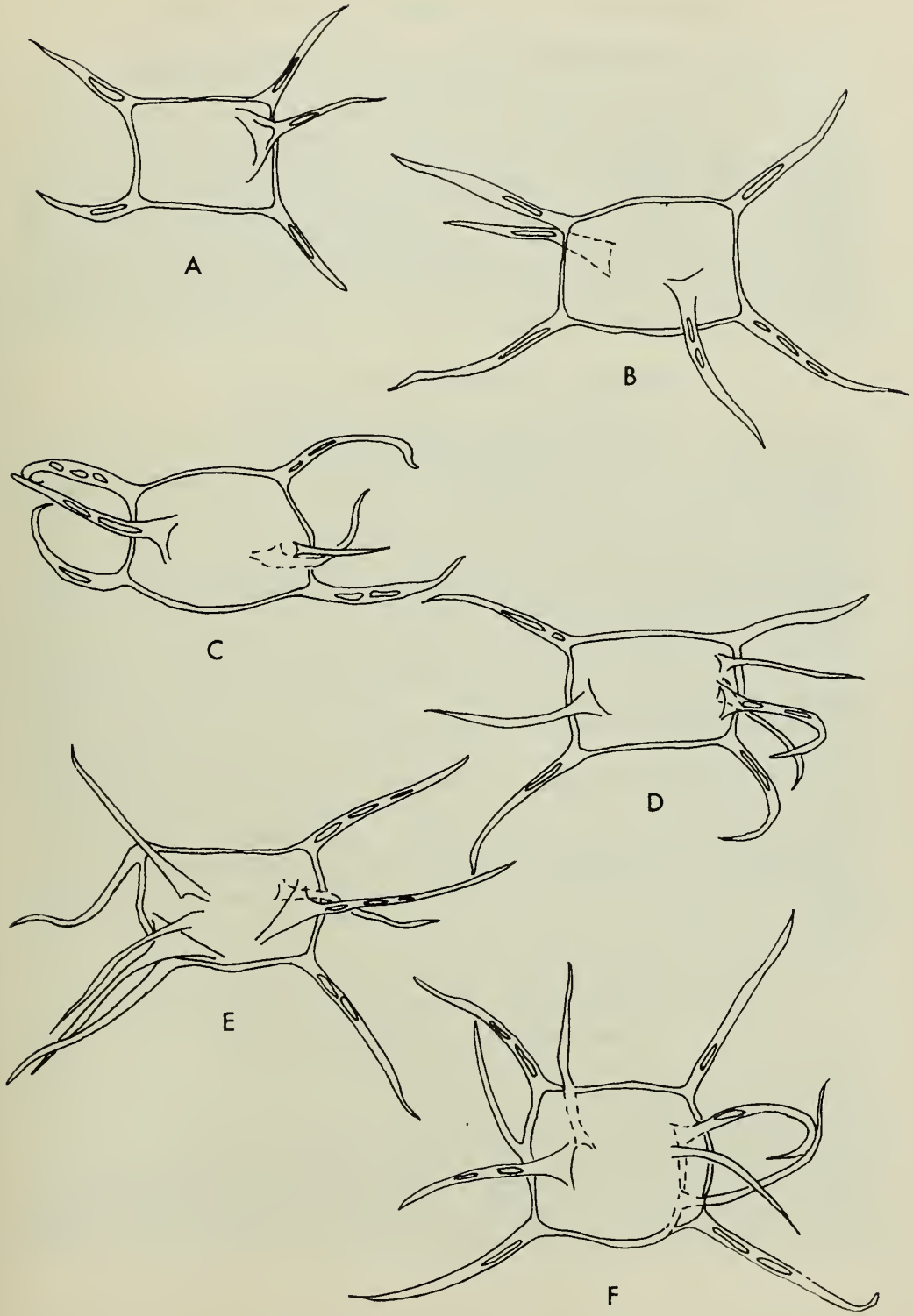
Description. The majority of processes possess a fine tabule which is not in connection with the central body cavity. At the base of a process its wall is greatly thickened, so forming a basal " plug ". The subsidiary processes are symmetrically arranged on the surface of the central body ; that is they are never concentrated on one side or at one end of the central body but are distributed so that they balance one another. The number of subsidiary spines range from one to six and their arrangement has been shown on a series of drawings (Text-figs. 4A–F).

Remarks. The form of the central body, the thick wall and the structure of the processes easily differentiates *T. oblongata* sp. nov, from all previously described species. The most similar species are *V. rhomboidium* and *Acanthodiacrodium sukatschevi* Timofeyev (1959), both from the Palaeozoic. These species possess a rectangular central body which is, however, thin-walled and gives rise to hollow processes.

Micrhystridium (?) sp. C, illustrated by Balteş (1963) from the Albian, is rather similar, although smaller, and may belong to *T. oblongata*.

Occurrence. *T. oblongata* is a rare species found throughout the Cenomanian of Fetcham Mill, but only in the Lower Cenomanian of Compton Bay and Escalles. It has not been observed in the North American material studied.

Fig. 4. *Tubulospina oblongata* sp. nov. This figure illustrates a series of specimens with a progressive increase in the number of subsidiary spines. A. 1 subsidiary spine (×900). B. 2 subsidiary spines (×900). C. 3 subsidiary spines (×900). D. 4 subsidiary spines (×900). E. 5 subsidiary spines (×900). F. 6 subsidiary spines (×900).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Subgroup *NETROMORPHITAE* Downie, Evitt & Sarjeant 1963

Genus ***LEIOFUSA*** Eisenack 1938

REMARKS. The genus *Leiofusa* was originally diagnosed only for spindle-shaped acritarchs most having a ratio of overall length to central body length of 1–1·5 : 1. In these forms it is difficult to differentiate the central body from the processes accurately. Wall (1965), in a study of *L. jurassica*, found all gradations from the spindle-shaped forms to forms with a distinct central body. These latter forms only are found in the Cenomanian and they appear to be a simple type of *Veryhachium* bearing only two processes. The occasional presence of a third reduced process on the central body concurs with this idea.

Leiofusa cf. ***jurassica*** Cookson & Eisenack

(Pl. 8, fig. 11 ; Pl. 9, fig. 1 ; Figs. 3F, G)

DESCRIPTION. This species possesses a small elongate central body with simple, elongate processes extending from each pole. Ratio of overall length to length of central body is 2–3 : 1. In two specimens a small spine (2–3 μ long) was seen to arise from the middle of the central body (Text-fig. 3F).

DIMENSIONS. Range of observed specimens : overall length 35 (59·2) 76 μ, length of central body 15 (20·3) 25 μ, breadth of central body 10 (11·9) 14 μ. Number of specimens measured, 10.

REMARKS. *L.* cf. *jurassica* possesses a relatively short central body when compared with the type material from the Upper Jurassic of Australia and for this reason it is only comparable with *L. jurassica.*

Wall (1965) figures specimens of *L. juassica* (pl. 5, figs. 10, 11) from the Lower Jurassic of England which appear to be very similar to the Cenomanian forms, the central body being relatively small. He also shows that there is in the Lower Jurassic a complete gradation from this form to the spindle-shaped forms of the type material. However, such a gradation was not observed in the Cenomanian.

OCCURRENCE. *L.* cf. *jurassica* is fairly common in samples FM840 and CB1 from the basal Cenomanian; only two other examples being found and these in samples FM670.

Subgroup *HERKOMORPHITAE* Downie, Evitt & Sarjeant 1963

Genus ***CYMATIOSPHAERA*** O. Wetzel emend. Deflandre 1954

Cymatiosphaera radiata O. Wetzel

(Pl. 8, figs. 12, 13)

1932 *Cymatiosphaera radiata* O. Wetzel : pl. 2, fig. 13.
1933 *Cymatiosphaera radiata* O. Wetzel : 27, pl. 4, fig. 8.
1960 *Cymatiosphaera radiata* O. Wetzel ; Cookson & Eisenack : 9, pl. 2, figs. 21, 22.

DESCRIPTION. The shell is spherical to subspherical, smooth walled and bears a network of fairly high fine membranes which delimit subpolygonal areas. The membranes are supported by radial columns which may bifurcate distally. There

appears to be some variation in the density of the membranes and further study may lead to a subdivision using this as a basis. However, as yet, this is not possible.

Dimensions. Range of observed specimens : shell diameter 13 (22·1) 38 μ, height of membranes 3 (8·1) 11 μ. Number of specimens measured, 18.

Remarks. *C. radiata* was first described from the Upper Chalk of Germany and later from the Albian and Cenomanian of Australia by Cookson & Eisenack. All forms are very similar and of small size.

Occurrence. *C. radiata* is infrequent at most horizons throughout the Cenomanian of Fetcham Mill, Compton Bay and Escalles, but has not been recorded in the North American samples.

Cymatiosphaera costata sp. nov.

(Pl. 9, figs. 2, 3)

Derivation of name. Latin, *costa*, rib—with reference to the low membranes covering the shell surface.

Diagnosis. Shell spherical with thick smooth wall, its surface divided into number of subpolygonal areas by low membranes supported at corners of polygons by spines not extending beyond membrane. Membranes undulatory or wavy in plan view.

Holotype. B.M.(N.H.) V.51988(4). Second White Speckled Shale, International Yarbo Borehole No. 17, Saskatchewan at 835 feet depth. Upper Cretaceous (Cenomanian).

Dimensions. Holotype : shell diameter 17 μ. Range: shell diameter 9 (14·1) 17 μ. Number of specimens measured, 7.

Description. The shell wall is relatively thick, 0·5–1 μ ; its surface being divided by fine membranes into approximately 25 subpolygonal areas, each about 4–5 μ in width. These membranes are weak and only stand perpendicular to the shell surface at the corners of the polygons where they are supported by the small spines. Between the spines they lie at an angle to the surface and in plan view appear to be wavy. The spines are short (about 1 μ in height) and appear to be hollow. Some specimens are split, but a pylome has not been observed.

Remarks. *C. costata* sp. nov. most closely resembles *C. parva* Sarjeant (1959) from the Middle Jurassic of England. However, the membranes of the latter are straight and never undulatory in plan view. *C. costata* is also very similar to a Canadian Jurassic form, described by Pocock (1964) in an unpublished report under the name of *Dictyotidium eastendense*, but the former possesses fewer delimited areas.

Occurrence. This distinctive species is common in three samples from Saskatchewan, samples Sas890, 835 and 805, of Cenomanian age. It has not been recorded elsewhere.

Cymatiosphaera asarota sp. nov.

(Pl. 9, figs. 6, 7)

Derivation of name. Latin, *asarotum*, floor laid in mosaic—with reference to the subpolygonal fields covering the shell surface.

Diagnosis. Shell large, spherical to subspherical ; shell wall smooth, thin. Shell surface divided into number of subpolygonal areas by low stout ridges, rarely fine membranes. Ridges undulatory in plan view.

Holotype. B.M.(N.H.) V.51983(1). Top of Second White Speckled Shale, International Yarbo Borehole No. 17, Saskatchewan at 805 feet depth. Upper Cretaceous (Cenomanian).

Dimensions. Holotype : shell diameter 46 μ. Range : shell diameter 44 (47·8) 53 μ. Number of specimens measured, 7.

Description. The shell is subdivided into approximately 30–40 areas by stout ridges (c. 1 μ in width and 1·5 μ in height) which undulate over the shell surface. Occasionally fine membranes replace the ridges. The areas delimited are subpolygonal and fit together rather like pieces of a jig-saw puzzle. Shell openings have not been observed.

Remarks. *C. asarota* sp. nov. is very similar to *C. costata* in general appearance but is considerably larger and ridges, rather than membranes, typically delimit the shell areas. *C. asarota* also resembles *Dictyotidium eastendense* (Pocock 1964, unpublished), but possesses fewer delimited areas.

Occurrence. *C. asarota* is common in two Cenomanian samples (Sas835 and 805) from Saskatchewan.

Cymatiosphaera conopa sp. nov.

(Pl. 9, figs. 4, 5)

Derivation of name. Latin, *conopium*, mosquito-net—with reference to the net-like pattern on the shell surface.

Diagnosis. Shell spherical to subspherical ; shell wall smooth, thick. Shell surface subdivided by network of low ridges, rarely membranes, into large number of regular polygonal areas. Short, hollow spines situated at corners of polygons.

Holotype. B.M.(N.H.) V.51983(2). Top of Second White Speckled Shale, International Yarbo Borehole No. 17, Saskatchewan at 805 feet depth. Upper Cretaceous (Cenomanian).

Dimensions. Holotype : shell diameter 26 by 27 μ. Range : shell diameter 26–34 μ. Number of specimens measured, 4.

Description. The shell wall is relatively thick, approximately 1·5 μ. The shell surface bears a polygonal network of low ridges, usually under 0·5 μ in height, with low (c. 1 μ) hollow spines situated at the corners of the polygons. The latter are usually perfectly symmetrical, being 5, 6 or 7 sided, of approximately 3 μ in width aud 80–100 in number. Shell openings have not been observed.

Remarks. *C. conopa* sp. nov. is easily distinguished from all previously described species by its large number of symmetrical polygons and the lack of a papilla in the centre of the polygons.

Occurrence. This is a fairly common species found in only one sample Sas805 from Saskatchewan.

Subgroup *PTEROMORPHITAE* Downie, Evitt & Sarjeant 1963

Genus ***PTEROSPERMOPSIS*** O. Wetzel 1952

Remarks. Members of this genus have only been recorded from the Saskatchewan material.

Pterospermopsis cf. ***helios*** Sarjeant

(Pl. 9, figs. 8, 9)

Description. The subspherical central body is surrounded by a circular equatorial membrane. Both the central body and the equatorial membrane are smooth. The membrane is traversed radially by a small number of folds and thickenings.

Dimensions. Range of observed specimens : diameter of central body 11 (22·7) 34 μ, overall diameter 24 (39·4) 51 μ. Number of specimens measured, 8.

Remarks. *P.* cf. *helios* is considerably larger than *P. helios* Sarjeant (1959)—overall diameter 25 μ—and the folds and thickenings in the equatorial membrane are not as regularly positioned. The outer margin of the membrane is generally entire ; it is occasionally seen to be puckered due to folding. This entire margin indicates that the majority of the radial markings are thickenings, and probably to support the membrane.

Occurrence. *P.* cf. *helios* is an infrequent to common species in all the samples from Saskatchewan.

Subgroup *DINETROMORPHITAE* Downie, Evitt & Sarjeant 1963

Genus ***DIPLOTESTA*** Cookson & Eisenack 1960

Remarks. Definite dinoflagellate features are absent in this genus which is therefore treated as an acritarch until further systematic evidence becomes available.

Diplotesta angelica Cookson & Hughes

(Pl. 9, figs. 10–12)

1964 *Diplotesta angelica* Cookson & Hughes : 56, pl. 11, figs. 1–5.
1964 *Diplotesta angelica* Cookson & Hughes ; Manum & Cookson : 25, pl. 5, fig. 7.

Description. The shell is thin-walled and elongate, one side being strongly convex, the other being usually weakly concave or more rarely straight. The shell narrows towards both ends, terminating with rounded apices. One apex is typically open. The margin of the opening is irregular and the operculum may bear a few

small spines (pl. 9, fig. 10). The inner body is ovoidal in shape and stains more easily than the outer shell wall, probably indicating that it is slightly thicker. It appears to be entire.

Dimensions. Range of observed specimens : shell length 50 (68·2) 104 μ, width 31 (36·7) 48 μ. Number of specimens measured, 13.

Remarks. The Cenomanian specimens are identical with the type material from the Upper Gault, Cambridge Greensand and Chalk Marl (Upper Albian–Lower Cenomanian) of England.

Occurrence. *D. angelica* is a rare species occurring at most horizons throughout the Cenomanian of Fetcham Mill, Compton Bay and Escalles. Two specimens have also been recorded in the Cenomanian from Saskatchewan (samples Sas835 and 805).

Class *CHLOROPHYCEAE*

Order CHLOROCOCCALES?

Family **UNCERTAIN**

Genus ***PALAMBAGES*** O. Wetzel 1961

Remarks. O. Wetzel (1933) gave the first description of these organisms under the name of " Morulosae " comparing them with certain colonial algae and with the egg-balls of certain planktonic crustaceans. Manum & Cookson (1964) fully reviewed the *Palambages* and concluded that they represented green algal colonies. They drew attention to the fact that these organisms increased their cell number by factors of 2, there being 2, 4, 8, 16, 32 . . . etc., cells in a colony. They found *Palambages* colonies possessing approximately 16, 32, 64 and 128 cells, thus indicating that increase by a factor of 2 also occurs in this fossil group. Forms possessing 8 and approximately 64 and 128 cells have been observed in the Albian and Cenomanian samples examined. They also suggested, probably correctly, that the number of cells per colony should not be used as a distinction between species. Size of an individual cell also appears to be quite variable. It was considered, in view of this, that the surface ornamentation provided the most useful distinguishing character.

Palambages Form A Manum & Cookson

(Pl. 10, figs. 1–3)

1964 *Palambages* Form A Manum & Cookson : 24, pl. 7, figs. 3–6.

Description. The colonies are always flattened and the individual cells distorted. (The original shape of the colonies and individual cells was probably spherical.) The maximum cell diameter ranges from 15 to 35 μ and the entire colony measuring from 44 to 119 μ in diameter. In the colonies possessing a small number of cells, the latter tend to be larger. The cell wall is typically smooth, only one specimen being slightly granular. Most of the cells are irregularly split.

Remarks. The specimens described here all appear to belong to *Palambages* Form A described by Manum & Cookson. This form is characterized by possessing cells 20–30 μ in diameter and having a smooth to lightly granular shell wall. Only two colonies observed are composed of individual cells of greater diameter than 20 μ, these being approximately 28 and 35 μ in diameter.

Occurrence. *Palambages* Form A is a rare species occurring in four samples from Saskatchewan—Sas1084 and 967 from the Albian, and Sas835 and 805 from the Cenomanian.

Palambages Form D nov.

(Pl. 10, figs. 4, 5)

Description. One specimen has been observed possessing 8 ovoidal cells of diameter 16 to 21 μ. The cell walls are smooth. Three cells in the colony are seen each to possess a single small, hollow, thorn-like spine opposite the larger axis of the cell. All the cells are split irregularly.

Figured specimen. Geol. Surv. Colln. slide PF.3046(3). Chalk, H.M. Geological Survey Borehole, Fetcham Mill, Surrey at 840 feet depth. Upper Cretaceous (Cenomanian).

Dimensions. Diameter of individual cells 16 to 21 μ ; diameter of colony 39 by 47 μ.

Remarks. The shape of the colony is typical of all *Palambages*. However, the presence of spines has not been observed previously and differentiates this form from all previously described types.

Unidentifiable Algal Remains

(Pl. 10, figs. 8–10)

Description. In a number of samples, from Devon, Hunstanton and Speeton, simple algal cells are the only organic constituent present. They may be rare or exceedingly common as in the highest sample from Hunstanton (H3). In the samples containing abundant dinoflagellate cysts, such as in the normal Cenomanian Chalk, these algal remains are absent.

The algal cells, although typically spherical to subspherical, may be variously shaped. Some have small daughter cells budding from the larger parent cell (Pl. 10, fig. 9), and others seem to be in the act of division (Pl. 10, fig. 10). They possess relatively thick, granular walls and are stained red by safranin.

Dimensions. Examples from the Hunstanton sample H3 : cell diameter 12–46 μ.

II. CONCLUSIONS

1. *Fetcham Mill, Compton Bay and Escalles*

The chalk samples analysed from the above three localities are entirely fine-grained, except for the ones obtained from the very basal horizons of the Ceno-

manian. All samples were productive and yielded well preserved and varied microfloral assemblages. Thus, during the Cenomanian, the chalk sea environment at these localities was a favourable one for the deposition and for the preservation of organic-shelled microfossils.

At each locality the percentage of microplankton increases at the expense of the miospores, from the basal Cenomanian towards the top of this stage. In the topmost samples the miospore content is below 1% at all three localities, whereas in the lowest sample from Compton Bay it is 20%, 12% at Fetcham Mill and 10% at Escalles. The Upper Greensand sample (FM 886) contains 45% miospores and the Turonian sample (FM 520) less than 1%. This percentage decrease of terrestrially-derived miospores in comparison with the marine microplankton as the succession is ascended, indicates an increase in the distance between the position of sedimentation and the positions of the landmasses during the lower part of the Cenomanian. Other factors possibly involved are changes in terrestrial vegetation, and in direction of prevailing winds and marine currents.

Foraminiferal shell linings (pl. 10, fig. 5–7), biserial and trochoid, are present only in samples from Escalles. They are common in all the samples from this locality except the lower three (E.213, 207 and 201), where they are absent. They have been observed in palynological preparations by a number of authors—for example McKee, Chronic and Leopold (1959) in lagoonal deposits, Muller (1959) in deltaic sediments and Sarjeant (1960, 1961, 1962) from the Upper Jurassic and Lower Cretaceous of England—and appear to be very cosmopolitan in distribution. The reason for their absence from Fetcham Mill, Compton Bay, and also from Texas and Saskatchewan, is not known at present, but it must be related to an environmental factor.

Both quantitative and qualitative analyses were performed on all the assemblages obtained from Fetcham Mill, Compton Bay and Escalles samples.

The percentage abundance of each species in the microplankton assemblage was calculated for each sample from the above three localities. The majority of the assemblages are dominated by a small number of forms—four forms together usually composing 75% or more of the assemblage. Thus, only the percentage abundance of these four forms can be compared and contrasted with any degree of accuracy. The remaining species in each assemblage, sometimes as many as 50, each usually form 1% or less of the assemblage and cannot be compared quantitatively. The four forms that are able to be compared quantitatively are *Palaeohystrichophora infusorioides*, *Cleistosphaeridium huguonioti*, *Micrhystridium* species (predominantly *M. inconspicuum*) and the *Hystrichosphaera ramosa* group.

P. infusorioides is by far the most abundant species at the majority of horizons, as indicated in text-fig. 5. In only two samples is this not so—the lowest Cenomanian samples from Fetcham Mill and Compton Bay (samples FM840 and CB 1)—in which it is very rare. The lowermost sample from Escalles (sample E 213) is not located at the base of the Cenomanian and the assemblage contains 16% of this species. However, in sample E 213 the percentage abundance of *P. infusorioides* appears to be declining towards the base of this stage and it is considered probably that at the base of the Cenomanian at this locality this species would be very rare. Thus at the base of this stage in southern England, and probably northern France,

P. infusorioides is extremely rare and, thereafter, in higher horizons rapidly becomes very common. The appearance of this distinctive species in this region is therefore considered to coincide with the base of the Upper Cretaceous (Cenomanian).

The samples analysed were taken at 15–20 ft. intervals. Thus the correlation of the peaks and troughs shown on the percentage abundance graphs may not be more accurate than within 10 ft.

With reference of the graph of *P. infusorioides*, there is a prominent peak (peak 1) near the top of the *varians* Zone which is present at each locality. This peak probably marks similar stratigraphic horizons and probably indicates that samples CB 7, FM 750 and E 195 are of similar age. The percentage of *P. infusorioides* in these samples is respectively 56, 58 and 79. Two more peaks (peaks 2 and 3) may also be of stratigraphic value.

Cleistosphaeridium huguonioti is a common species throughout the Cenomanian of Fetcham Mill, Compton Bay and Escalles except for the topmost samples from Compton Bay (CB 21), where it is rare, and Escalles (E.153), where it has not been recorded. It is absent from Turonian sample FM 520. The percentage abundance graphs of this species (including its variety *pertusum*) for Compton Bay and Escalles appear to be remarkably similar (text-fig. 6), but correlation with Fetcham Mill is more problematical. Prominent peaks (peak 1) occur in the Compton Bay and Escalles graphs at the *varians/subglobosus* zonal boundary. The samples at these horizons are CB 9 (26% *C. huguonioti*) and E 183 (35·5%). Less obvious markers may be indicated by peak 2 and plateau 3.

The percentage abundance of the varieties of *Hystrichosphaera ramosa* were plotted graphically but correlation between the three localities was not possible.

Dinoflagellate cysts outnumber acritarch remains in all samples except one, the lowest sample from Compton Bay (CB 1), where the latter total 69% of the microplankton assemblage. *Micrhystridium* is by far the most abundant acritarch and the percentage abundance for each sample is shown in text-fig. 7.

In the lowest sample from Compton Bay (CB 1)the *Micrhystridium* percentage is 65 ; in the remainder of the *varians* Zone it varies between 14 and 20%. This genus in the *subglobosus* Zone at Compton Bay undergoes a rapid decline and varies between under 1 and 4%. This distribution may indicate that *Micrhystridium* favour the relatively near shore, and perhaps shallow water environment of the *varians* Zone, or that dinoflagellates were unsuited to this environment and the cysts are therefore scarce compared with *Micrhystridium*. The former conclusion is probably more correct since the dinoflagellate cyst assemblage obtained from sample CB 1 is as rich in species as any other sample. Hence the percentage abundance graphs of this genus are difficult to interpret and perhaps only one peak (peak 1) may possibly be used in correlation.

The above quantitative results are summarized in text-fig. 8, and show that correlation, using the percentage abundance of certain species within a restricted sedimentary area (southern England and northern France), is possible.

Many species of dinoflagellate at the present time have a world-wide distribution (Wood 1953) and it is probable that many fossil species, especially during the relatively uniform climatic conditions of the Cretaceous, were of similar wide-spread

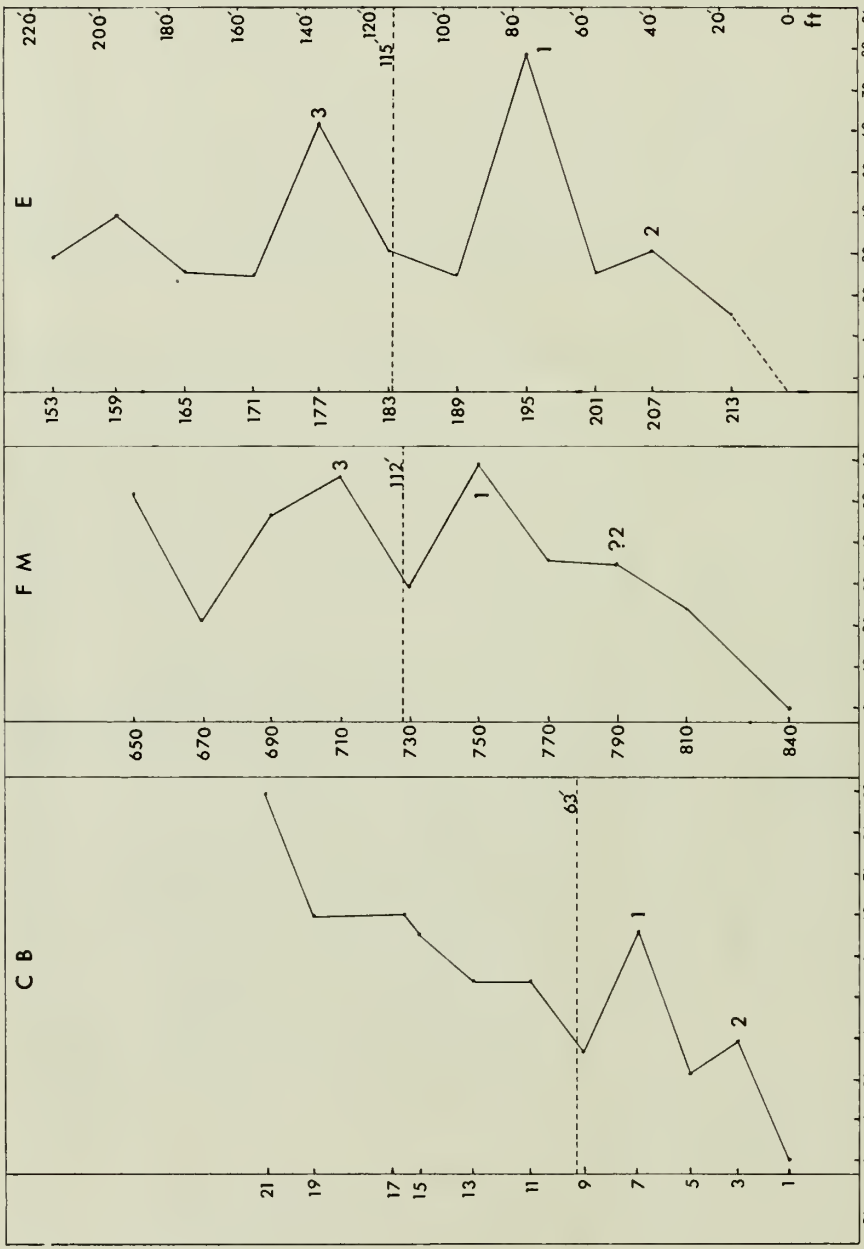

FIG. 5. Percentage abundance graphs for *Palaeohystrichophora infusorioides* at the three localities—Compton Bay, Fetcham Mill and Escalles.

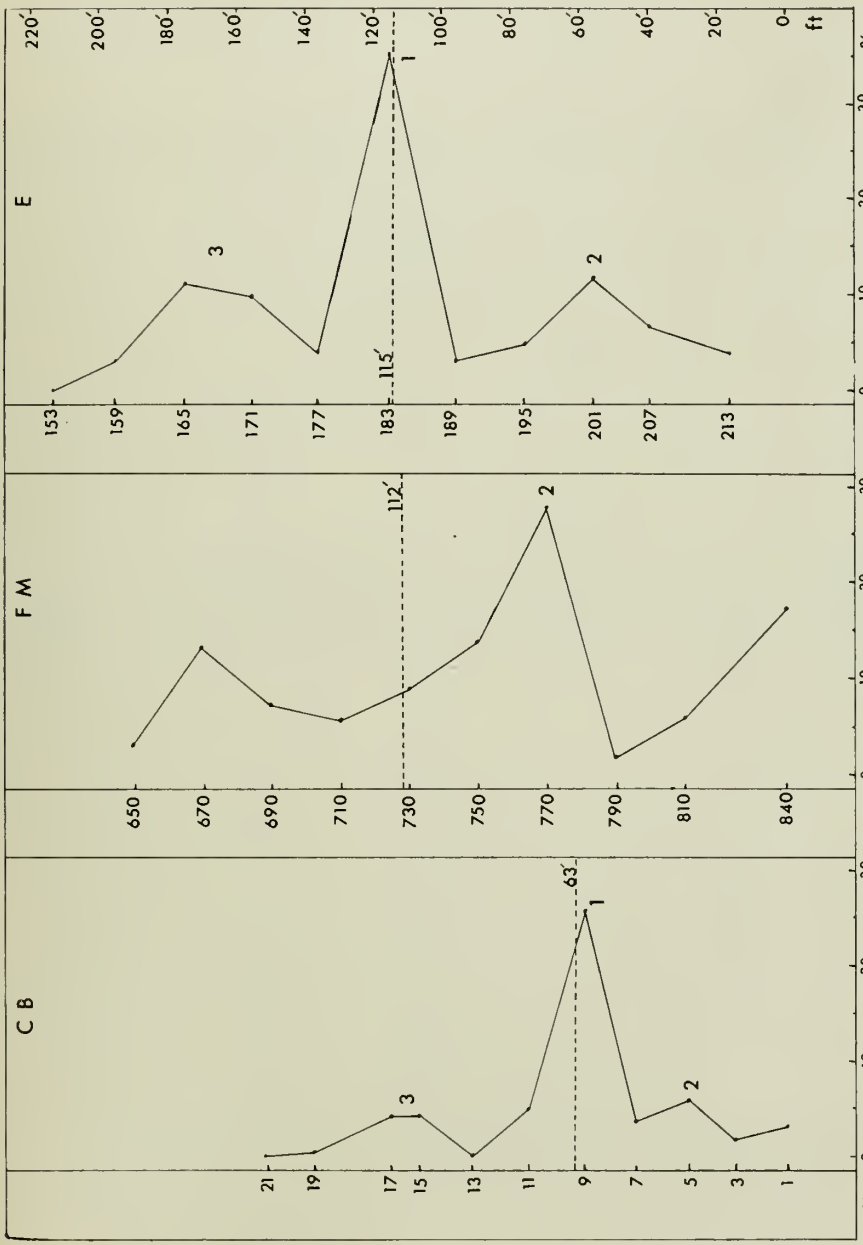

FIG. 6. Percentage abundance graphs for *Cleistosphaeridium huguonioti* at the three localities—Compton Bay, Fetcham Mill and Escalles.

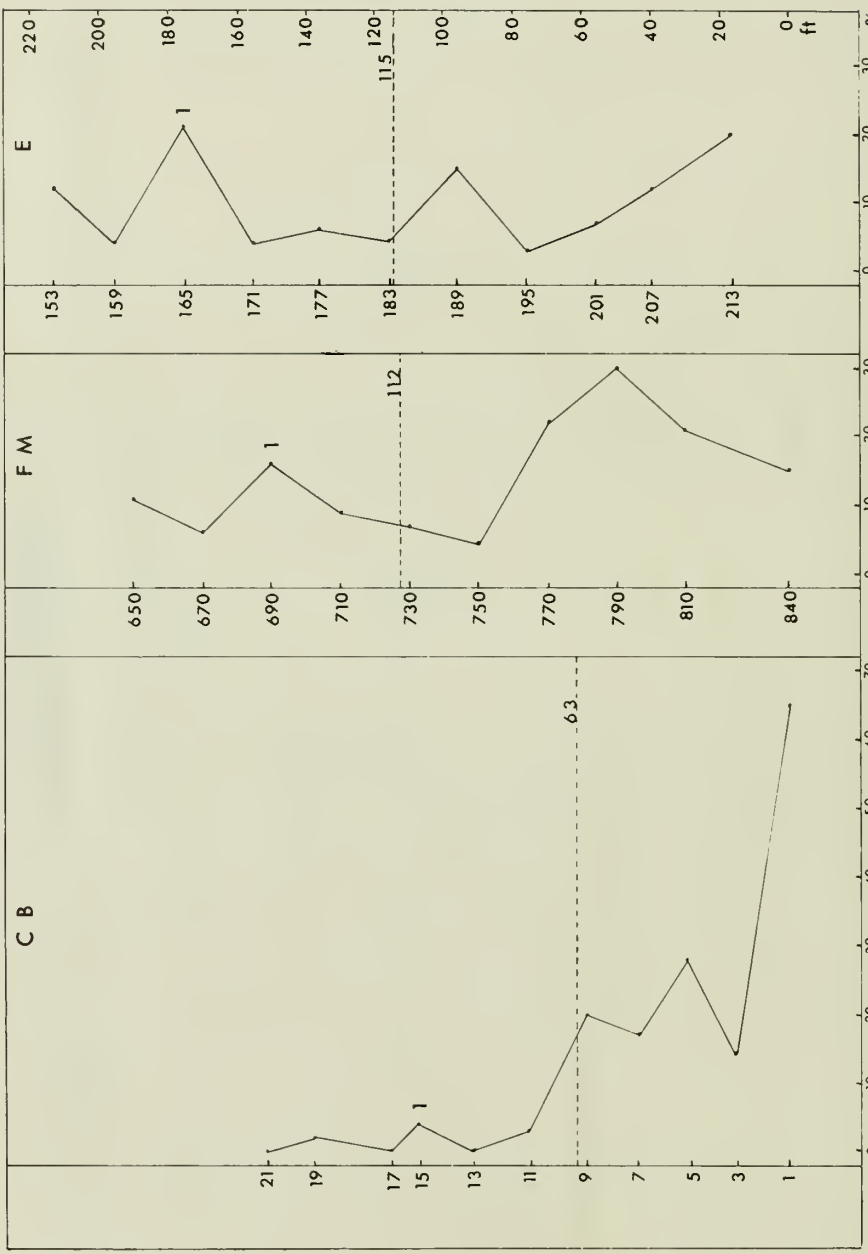

FIG. 7. Percentage abundance graphs for *Micrhystridium* at the three localities—Compton Bay, Fetcham Mill and Escalles.

Fig. 8. Correlation between Compton Bay, Fetcham Mill and Escalles based on the quantitative results. 1. Base of Stage marked by first appearance of *P. infusorioides*. 2. *P. infusorioides* peak 2. 3. *C. huguonioti* peak 2. 4. *P. infusorioides* peak 1. 5. *C. huguonioti* peak 1. 6. *P. infusorioides* peak 3. 7. *Micrhystridium* peak 1. 8. Top of the Stage marked by the *Actinocamax plenus* Marls.

distribution and so of use in long distance correlation. The percentage abundance graphs produced indicate certain horizons of maximum abundance and these may be used cautiously in correlating the three localities. The results obtained are reasonably satisfactory and indicate that if samples had been analysed at intervals of 10 ft. or less, correlation would have been correspondingly better.

The stratigraphic distribution of all the less abundant species present in the samples examined has been discussed in the remarks at the end of each specific description in the systematic section. The distribution of the stratigraphically useful microplankton in the Cenomanian is shown for each locality in text-fig. 9A–C. From these distribution charts, using the quantitative analysis results to correlate the samples, an idealised Cenomanian section for this region has been constructed (of equal thickness to that of Fetcham Mill) to show the overall distribution of these species (text-fig. 9D).

The base of the Cenomanian sequence is clearly marked by the presence of four species which are not recorded higher in the succession. Of these species two, *Ovoidinium scabrosum* and *Gonyaulacysta fetchamensis*, have also been recorded in the Albian sample from Fetcham Mill (FM 886). The two species of *Ovoidinium* (*O. scabrosum* and *O. verrucosum*) were first described from the Upper Albian—basal Cenomanian sediments of Cambridgeshire, England (Cookson and Hughes 1964). The fourth species only present in the lowermost Cenomanian is *Cleistosphaeridium polypes* var. *calvulum*. This was also recorded by Cookson and Hughes (as *Hystrichosphaeridium recurvatum* subsp. *polypes*) from the Upper Gault and Cambridge Greensand but not from the Chalk Marl. Thus it appears probable that the matrix of the Cambridge Greensand is the lateral equivalent of the Chlorotic Marl and is of basal Cenomanian age.

Of the remaining species shown in text-fig. 9 many are found in the topmost horizon of the Cenomanian and probably extend into Turonian. However, only five of these were observed in the Turonian sample from Fetcham Mill (FM 520). These were *P. infusorioides, Microdinium veligerum, Exochosphaeridium pseudohystrichodinium, Hystrichodinium dasys* and *Hystrichosphaeridium deanei*.

Clarke and Verdier (1967), after a detailed examination of microplankton of the Upper Cretaceous (Cenomanian–Senonian) from the Isle of Wight, formulated five zones, together with five subzones, and seven palynological " intervals " based on the extinction points of species. The Cenomanian constitutes a single zone which is divided into three subzones. The zonal fossil selected is *Litosphaeridium siphoniphorum*. This is a distinctive microfossil and is present in all Cenomanian samples from the three localities in the present study, but is absent from the Albian and Turonian samples examined. The base of the zone is marked by the first appearance of *Palaeohystrichophora infusorioides*. In the present study it is not possible to define accurately the top of the Cenomanian since sampling did not continue systematically into the Turonian. Clarke and Verdier, however, note the disappearance of six distinctive species at the top of this zone, none of which were recorded from the Turonian sample analysed.

The index fossil of the lower subzone, *Dinopterygium perforatum*, was not located by the author in the present study. Other fossils characteristic of this subzone are

Microdinium veligerum (*M. irregulare* of Clarke and Verdier), found only in the middle and upper Cenomanian by the author : *Canningia reticulata* and *Hystrichosphaera cingulata* var. *granulata* were both absent. The base of the middle subzone is characterised by the first appearance of *Hystrichosphaera crassimurata* and the top by the last appearance of *Epelidosphaeridium spinosum*. The former appears to be an excellent marker (text-fig. 9) and the latter was not recorded from the upper two to five samples from the three localities (p. 42). The base of the upper subzone, that of *Cleistosphaeridium huguonioti*, is taken as being from the last appearance of *E. spinosum* to the disappearance of six distinctive species ; in particular *C. huguoniti*, *L. siphoniphorum*, and *Microdinium setosum*.

The present study verifies many of Clarke and Verdier's stratigraphic results and supports the hypothesis that the Cenomanian may be adequately defined utilising the first appearance of *P. infusorioides* for the base and the last appearance of *C. huguonioti* for the top. Of the subzones the middle one, that of *E. spinosum*, and the upper one, that of *C. huguonioti*, appear to be practical units of subdivision. However, the lower subzone, that of *D. perforatum*, could not be recognised at Fetcham Mill, Compton Bay or at Escalles and does not appear to be of wide application.

A small number of species that may perhaps be derived have been noted in the systematics section ; in particular species belonging to the genus *Michrystridium*. These species suggest a Lower to Middle Jurassic or perhaps a Silurian source, but no obviously derived dinoflagellate cysts are recorded here. Clarke and Verdier (1967), in their extensive study of microplankton from the Upper Cretaceous, similarly did not observe derived forms.

2. *Speeton*

Microplankton and miospores were completely absent from the samples processed from this locality, the only organic constituent being small, thick-walled algal remains (p. 383). These are rare in the lower samples, becoming more common in samples 6 and 7.

This absence of practically all organic matter at Speeton strongly suggests that relatively intensive oxidation has removed these constituents from the sediment. The Speeton chalk does not seem to be unusual in its macro-fauna, although at certain horizons it is relatively abundant ; brachiopods and lamellibranchs in the lower part of the succession, and higher up together with echinoids, are quite common. Thus before any penecontemporaneous and post-depositional oxidation took place, the number of microplankton and miospores that could be incorporated in the sediment was probably greatly depleted by the action of the above scavengers.

3. *Hunstanton*

The two samples from the *varians* Zone at Hunstanton were found to be completely devoid of microplankton and miospores and to contain only a very few of the thick-walled algal remains. Thus these samples are comparable to those of Speeton and the microfossils under study are probably absent for the same reasons.

The third sample (H 3) analysed, from the base of the *subglobosus* Zone, contains a small number of hystrichosphere fragments comprising approximately 2% of the

assemblage. The remainder of the assemblage is composed of the thick-walled algal cells. Three forms of microplankton have been identified—*Oligosphaeridium complex*, *Hystrichosphaeridium tubiferum* and *Cymatiosphaera* sp.—and also one disaccate pollen grain.

4. *Devon*

Microplankton were completely absent from the seven samples analysed. One disaccate pollen grain was found (sample D 1), and algal remains were present in two samples (D 3 and D 5).

The sediment from these localities was deposited in shallow water, near land, and is often of quite coarse grains. Thus a combination of shallow water, with current action, and oxidation probably prevented the preservation of microplankton.

5. *Texas*

The two samples analysed consist of relatively near shore, fine-grained sediments containing abundant land plant fragments, approximately 90% miospores and 10% microplankton. The microplankton assemblage consists of 25 species and varieties, all of which have been recorded from the Cenomanian of England and France. Thus it is highly probable that in the Upper Cretaceous there was free communica-

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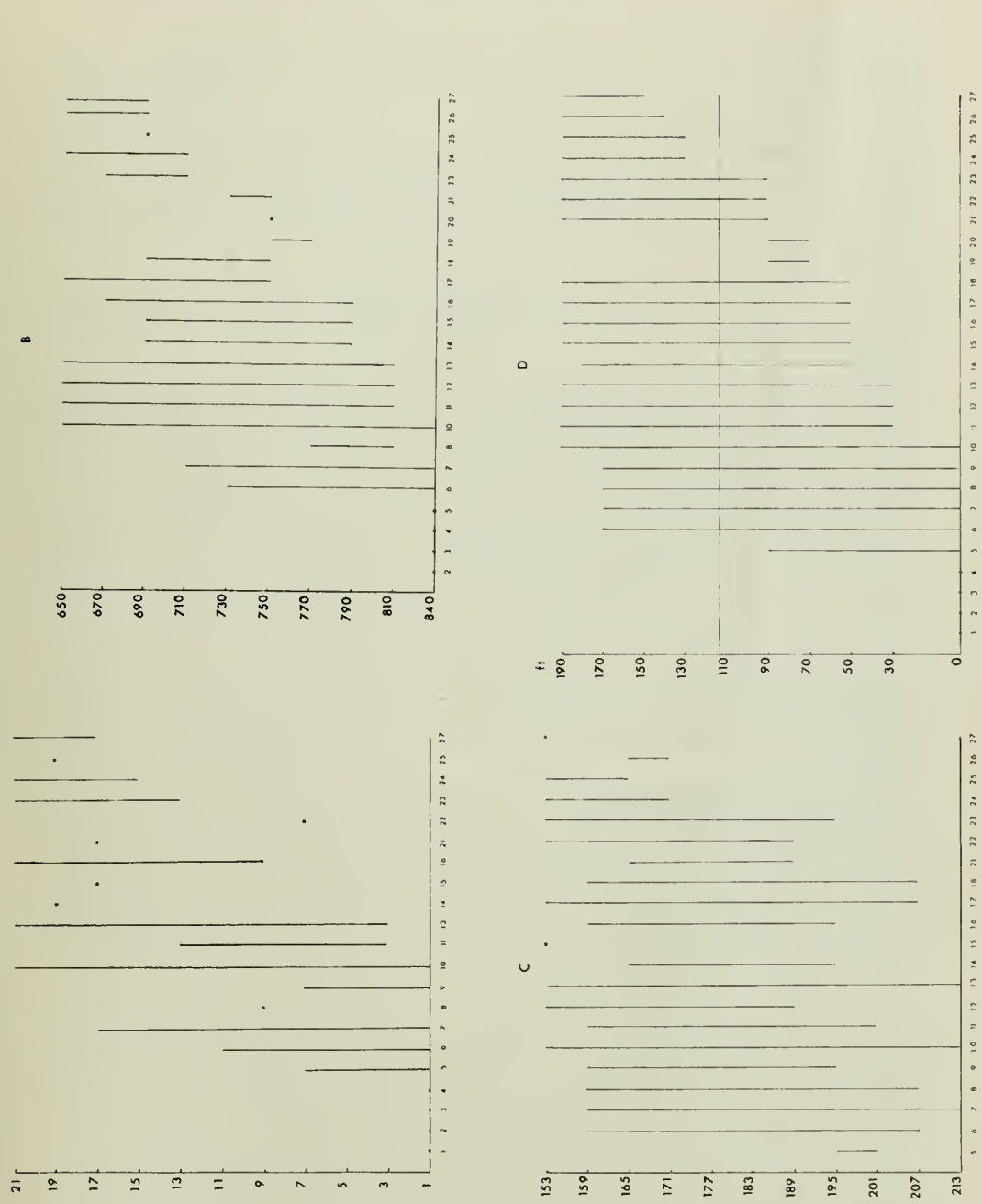
Fig. 9. Chart to show the distribution of the restricted species at the three localities: A. Compton Bay. B. Fetcham Mill. C. Escalles.
The overall distribution of the restricted species is shown as in D.

1. *Ovoidinium scabrosum* (Cookson & Hughes)
2. *Ovoidinium verrucosum* (Cookson & Hughes)
3. *Gonyaulacysta fetchamensis* Sarjeant
4. *Cleistosphaeridium polypes* var. *clavulum* nov.
5. *Cribroperidinium intricatum* sp. nov.
6. *Gonyaulacysta exilicristata* sp. nov.
7. *Cleistosphaeridium multifurcatum* (Deflandre)
8. *Hystrichosphaeridium readei* Davey & Williams
9. *Microdinium variospinum* sp. nov.
10. *Palaeohystrichiophora infusorioides* Deflandre
11. *Histiocysta palla* sp. nov.
12. *Microdinium* cf. *ornatum* Cookson & Eisenack
13. *Microdinium veligerum* (Deflandre)
14. *Adnatosphaeridium chonetum* (Cookson & Eisenack)
15. *Microdinium distinctum* sp. nov.
16. *Hystrichosphaera crassimurata* Davey & Williams
17. *Cassiculosphaeridia reticulata* sp. nov.
18. *Exochosphaeridium pseudohystrichodinium* (Deflandre)
19. *Gonyaulacysta whitei* Sarjeant
20. *Polysphaeridium pumilum* Davey & Williams
21. *Cleistosphaeridium polypes* (Cookson & Eisenack)
22. *Hystrichodinium dasys* sp. nov.
23. *Hystrichosphaeridium deanei* Davey & Williams
24. *Cleistosphaeridium huguonioti* var. *pertusum* nov.
25. *Prolixosphaeridium coniculum* sp. nov.
26. *Micrhystridium bifidum* sp. nov.
27. *Cleistosphaeridium heteracanthum* (Deflandre & Cookson)


A
B
C
D
ft

tion of forms between Europe and the Gulf region of the United States by means of sea currents.

Three stratigraphically restricted species of microplankton were identified—*P. infusorioides*, *Hystrichosphaera crassimurata* and *Cleistosphaeridium polypes*. The last species has only been recorded from the Middle and Upper Cenomanian of Europe (text-fig. 9D) and suggests that these samples are probable of this age. Ammonites collected from these horizons indicate the same age for these samples.

6. *Saskatchewan*

The six samples analysed are cabonaceous mudstones, land plant debris being extremely abundant, and contain approximately 80% miospores and 20% microplankton.

The microplankton flora is well preserved ; acritarchs, in particular *Micrhystridium Cymatiosphaera* and *Pterospermopsis*, are common. The dinoflagellate cyst flora obtained is distinctive and very different from that found in England, France or Texas. *Deflandrea* is by far the most abundant genus in the Saskatchewan assemblages, and is conspicuously absent from the English and French assemblages.

A small number of species are common to this locality and to England and France. *P. infusorioides* is a common species in samples Sas 805 and 835 but rare in sample Sas 890. The genus *Ovoidinium* is represented in Saskatchewan by *O. ostium*, a species rather similar to *O. verrucosum*. *O. ostium* is common in samples Sas 1084, 1023 and 967 but rare in sample Sas 890. Thus the rare occurrence of *P. infusorioides* and the genus *Ovoidinium* in sample Sas 890 appears to be comparable to their distribution in samples FM 840 and CB 1 from the basal Cenomanian of England. For this reason the base of the Cenomanian has been placed just below sample Sas 890 at a depth of 900 ft. at the base of the Second White Speckled Shale (Upper Colorado).

Other species of stratigraphic value common to Saskatchewan, England and France are *Cleistosphaeridium polypes*, found in sample Sas 835 indicating a Middle to Upper Cenomanian age for this sample ; *Cribroperidinium intricatum*, found in samples Sas 1023 and 1084 probably mainly an Albian species but ranging up into the Lower Cenomanian ; and *Microdinium variospinum* found only in sample Sas 1084 and previously recorded throughout the major part of the Cenomanian of England and France, except for the uppermost 20 ft.

The abundance of the genus *Deflandrea* in the Albian–Cenomanian samples from Saskatchewan is an interesting phenomenon. *Deflandrea* occurs in assemblages of similar age in northern Germany, Arctic Canada and eastern Australia. The assemblages from Arctic Canada (Manum and Cookson 1964) and Saskatchewan are similar and in Cretaceous time were brought into direct contact by the Arctic Sea. In northern Germany the Cenomanian was deposited north of the Anglo–Belgium Ridge in the North-Eastern Sea, the latter being connected to the Boreal Ocean. It is possible that the genus *Deflandrea* has a preference for cooler water and that the Arctic Sea of northern Canada and the Boreal Ocean of Europe were connected and contained similar microplankton assemblages during the Cenomanian. The Tethyan assemblages of England, France and Texas are very different and *Deflandrea* is

absent. Clarke and Verdier (1967), in their study of assemblages from the Upper Cretaceous of the Isle of Wight, first record *Deflandrea* from the Senonian. This possibly indicates a change in the palaeo-environmental conditions in the Chalk Sea at that time.

Wood (1953) states that in cooler water the total number of species of phytoplankton is less than in warm water. This reiterates the above idea that the Saskatchewan sea was cooler than the sea in the British region, since the number of species present in the Lower Chalk is far greater than that obtained from Saskatchewan. However, the absolute number of specimens (number of specimens per gram of sample) in each region is approximately the same.

An interesting corollary to this question of temperature is that with an increase of temperature, the density of sea water decreases. Hence dinoflagellates inhabiting warm water produce cysts with relatively large surface area so as to retard the rate of sinking, for once the encysted organism enters the aphotic zone (approximately at 300 ft. depth) it has little chance of survival. Thus in warm sea water the cysts are predominantly chorate and as the temperature of the water decreases the proportion of proximate and cavate cysts increases. The Cenomanian assemblages from England and France contain very few proximate and cavate cysts, and chorate cysts are by far the most abundant. Conversely, as would be expected, the cool water Saskatchewan assemblages are composed predominantly of *Deflandrea*, a cavate cyst genus and to a lesser extent of proximate cysts.

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