

DINOFLAGELLATE CYSTS FROM THE UPPER EOCENE-LOWER OLIGOCENE OF THE ISLE OF WIGHT

by M. LIENGJARERN, L. COSTA, and C. DOWNIE

ABSTRACT. The Upper Eocene and Oligocene succession of the Isle of Wight, southern England (Headon Beds to Hamstead Beds) has been studied palynologically. Seventy-one forms of dinoflagellate cysts are recorded, including two new genera, *Gerdiocysta* and *Vectidinium*, and ten new species, *Distatodinium scariosum*, *Eocladopyxis tessellata*, *G. conopeum*, *Glaphyrocysta paupercula*, *Phelodinium pachyceras*, *P. pumilum*, *Phthanoperidinium amiculum*, *P. flebile*, *Thalassiphora fenestrata*, and *V. stoveri*. The dinoflagellates (with the exception of *Vectidinium*) are marine and indicate six marine incursions or partial incursions in the sequence; the mid-Headon Beds, the Oyster Bed of the Bembridge Marls, the *Nematura* Band, and three episodes of the Upper Hamstead Beds. Correlation with the Paris Basin indicates that the base of the Stampian lies near the *Nematura* Band.

THE importance of dinoflagellate cysts in the stratigraphy of the Palaeogene has been emphasized in several recent papers. Many long-standing problems in the Upper Palaeocene and Lower Eocene have been resolved by their application, but problems of correlation at the Eocene/Oligocene boundary remain. This account describes the dinoflagellate cysts from the classical section on the Isle of Wight in southern England. The initial work was done by M. Liengjarern (1973) and has been revised recently by L. Costa.

STRATIGRAPHY

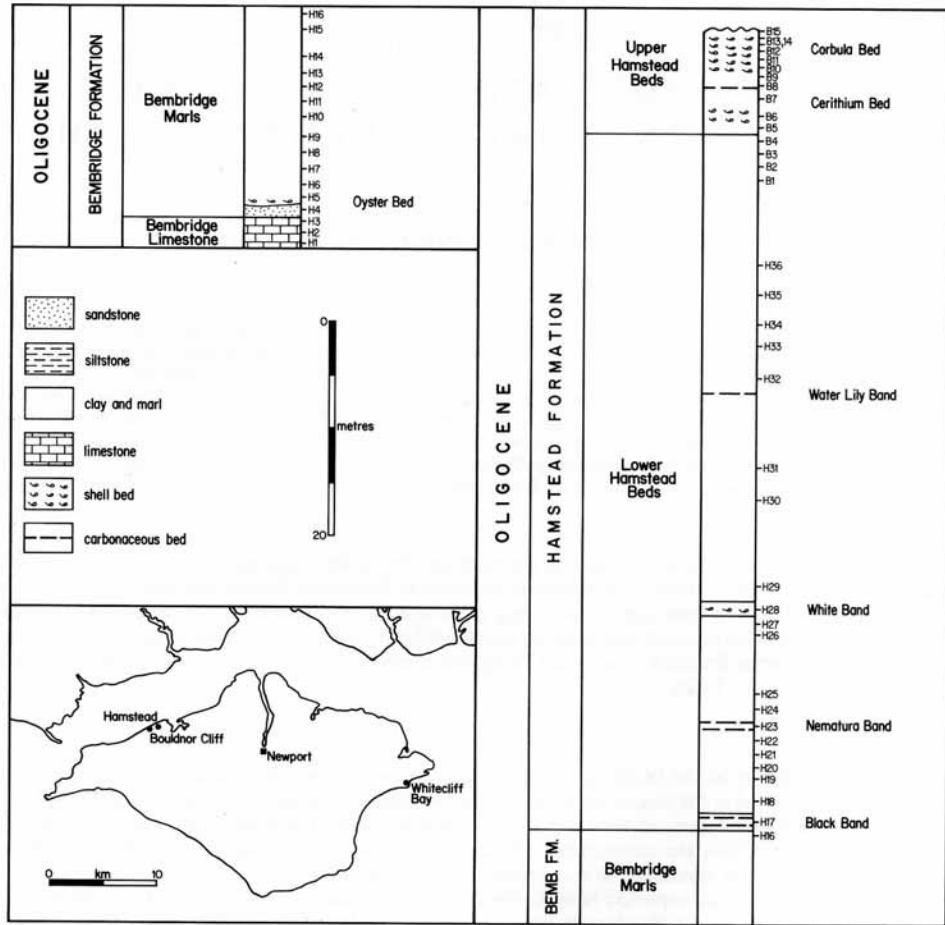
The sequences in the Isle of Wight span the Eocene/Oligocene boundary, and the placings of this boundary have varied according to the interpretation of different authors (see Curry *et al.* 1978) from the base of the Headon Beds to the base of the Hamstead Beds. The difficulties in correlation and interpretation are largely the consequence of the paralic nature of the deposits, which varied from open-sea to freshwater lacustrine in a complex coastal geography.

Two main localities are reported here. In the east of the island, the lower part of the succession, from the base of the Lower Headon Beds to the Bembridge Marls, is exposed continuously in the sea cliffs at Whitecliff Bay. In the west, the upper part of the succession (Bembridge Marls-Hamstead Beds) is exposed in Bouldnor and Hamstead cliffs as a continuous sequence (text-figs. 1 and 2).

PALYNOLOGY

All the samples were prepared by standard palynological methods. Only a few samples of fluvial sands were barren, the remainder yielded rich assemblages of palynomorphs, including pollen and spores, plant tissue, freshwater algae, dinoflagellate cysts, and acritarchs. Only the dinoflagellate cysts are dealt with in detail in this paper, but in each sample the proportions of pollen and spores, *Pediastrum*, dinoflagellates, and acritarchs based on counts of 200 individuals were noted. These results are shown in Tables 1 and 2. It should be noted that these counts were made after sieving through a 20 μm sieve and that consequently pollen is under-represented.

A complete list of the dinoflagellate taxa recorded and their distribution and relative abundances are shown in Table 1. Only new taxa or combinations, or taxa necessitating further comment are described here. The genera discussed are arranged in alphabetical order; suprageneric dinoflagellate cyst-taxa are not employed here.



TEXT-FIG. 1. Stratigraphic location of samples collected at Hamstead Cliff (prefix H) and at Bouldnor Cliff (prefix B).

The terms employed in the descriptions are those of Williams *et al.* (1973) and Evitt *et al.* (1977). In some species, the arithmetical mean of the measurements is indicated as a figure in parenthesis. The reference for holotypes and illustrated specimens is given with reference to their location in the 'England Finder' grid system.

Division PYRRHOPHYTA
 Class DINOPHYCEAE Fritsch 1935
 Order PERIDINIALES Haeckel 1894
 Genus DISTATODINIUM Eaton 1976

Type species. Distatodinium craterum Eaton 1976

Distatodinium scariosum sp. nov.

Plate 54, fig. 3

Name derivation. Latin, *scariosus*, thin, papery.

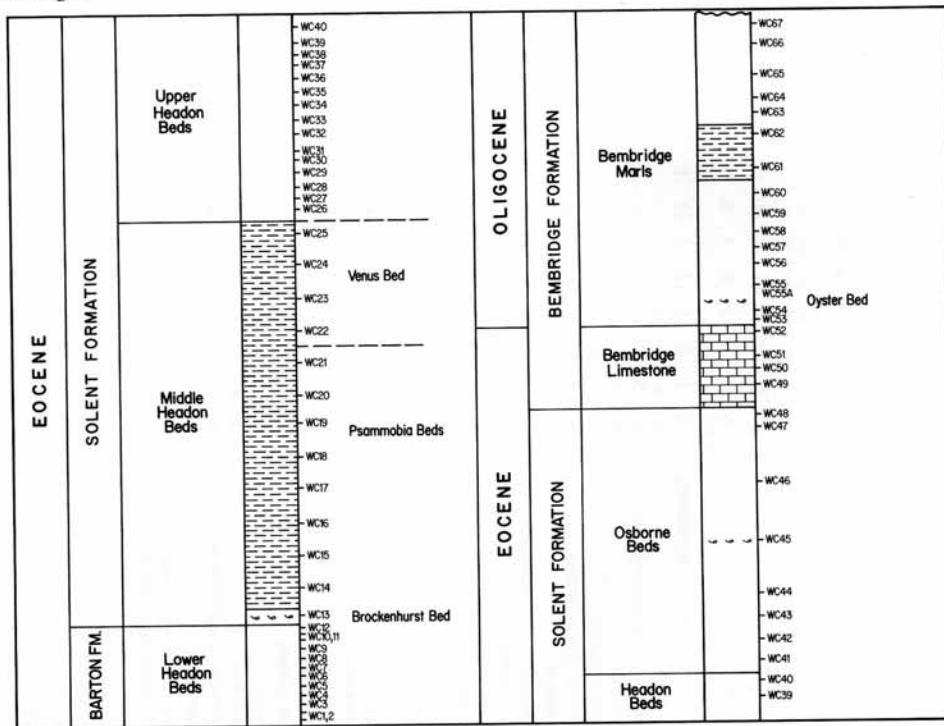
Diagnosis. *Distatodinium* with broad, hollow, intratabular processes (usually one per paraplate), oblate to subtriangular in cross-section, distally expanded, and bearing a variable number of thick secæ on their distal margin. Cingular area devoid of processes.

Description. The central body ambitus is oval, antero-posteriorly elongate. Apex and antapex are rounded; the antapex may be prolonged into a corona formed by the expanded bases of the antapical processes.

The insertion of the processes on the central body is subcircular, oblate, or triangular. The processes occur one per paraplate, except on the antapical paraplate (1'''), where there may be two or more processes. The degree of compression of the processes varies on a single specimen; some processes are taeniate, but more commonly they are oblate to subtriangular and are open distally. The distal margin of the processes extends into a variable number of robust secæ, sometimes prolonged into fine strands which might connect with those from near-by processes.

Two of the apical processes are considerably smaller than the other two. Cingular and sulcal zones are free of processes. When more than one antapical process occurs, their proximal sections coalesce, forming a corona which is apparently hollow.

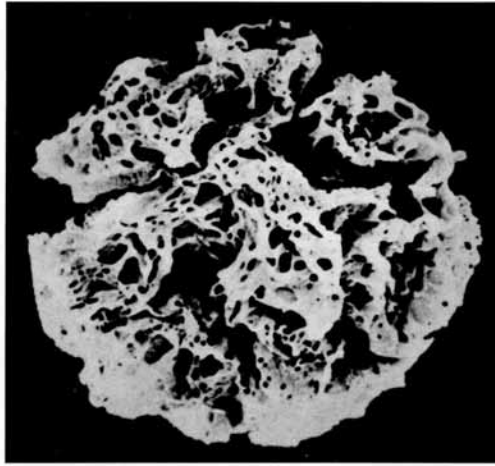
Holotype. Slide ML 1456, R37/0, sample B11, Upper Hamstead Beds, Lower Oligocene, Bouldnor Cliff, Isle of Wight.



TEXT-FIG. 2. Stratigraphic location of samples collected at Whitecliff Bay (prefix WC).

<i>H. salacium</i>	1	x	2	1	x	x	1	1	3	1	x	x	x	16
<i>H.-sphaeridium</i> cf. <i>pseudorecurvatum</i>	2	x	x	x	x	x	x	x	x	x	x	x	x	x
<i>Ampletosphaeridium insolitum</i>	4	x	7	x	2	1	5	3	3	3	7	1	1	
<i>I. ?severinii</i>	x	x	x	x	1	x	1	x				1	1	
<i>Kisselovia coleothrypta</i>	x	3	4	3	x	3	3	1	4			x		
<i>Lejeunia hyalina</i>														6
<i>L. tenella</i>														x
<i>Lingulodinium machaerophorum</i>	x	x	1	x	x	x	x	x				x		20
<i>Membranophoridium aspinatum</i>	x	x	1	1	x	5	2	1	x			x		x
<i>Miliolodinium tenuitubulatum</i>														10
<i>Operculodinium centrocarpum</i>	x	x	x	x	x	x	x	1	x	x		x		x
<i>Palaeocystodinium golzowense</i>	x	x	x	1	x	1	1	1						
<i>Pentadimum laticinctum</i> and <i>P. taeniagerum</i>														x
<i>Phelodinium pumilum</i>														1
<i>P. pachyceras</i>														8
<i>Phthanoperidinium amiculum</i>														x
<i>P. amoenum</i>														x
<i>P. comatum</i>	14	3	4	2	5	4	5	6	8	32	5	20		20
<i>P. flebile</i>														26
<i>P. levimurum</i>														3
<i>Rhombodinium draco</i>	x	x	x	3	2	x	x	x	3	4				12
<i>R. perforatum</i>	x	x	x	3	2	x	x	x	3	4				x
<i>Vectidinium stoveri</i>														75
<i>Spiniferites mirabilis</i>	x	x	x	x	x	x	x	x	1					x
<i>S. pseudofurcatus</i>	6	5	5	x	2	5	2	4	10	4	6	2		x
<i>S. ramosus</i>	x	3	x	x	2	3	x	x	x	x				3
<i>Thalassiphora fenestrata</i>	x	x	x	x	x	x	7	1	x	x				x
<i>T. pelagica</i>	x	1	x	x	x	x	7	1	x	x				x
<i>T. velata</i>														
<i>Wetzeliella articulata</i>														x
<i>W. gochtii</i>														x
<i>W. ovalis</i>														x
<i>W. symmetrica</i>														x
<i>W. symmetrica incisa</i>														x
<i>Cyclopsiella elliptica</i>														x
<i>C. vieta</i>														x
<i>Paralaceniella indentata</i>	2	x	2	x	2	5	x	3	7	3	8	8	27	x
' <i>Michrystridium</i> '													10	x
													4	84
													2	2
													2	20

x—indicates that presence is below 1%.



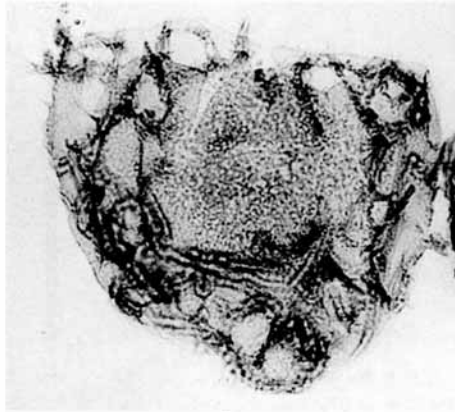
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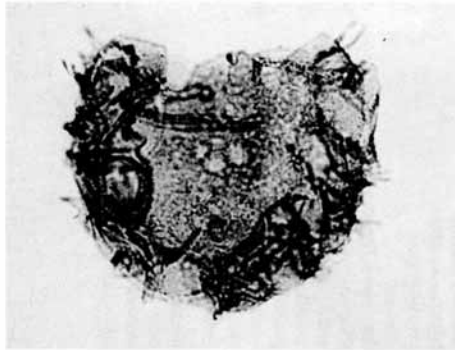
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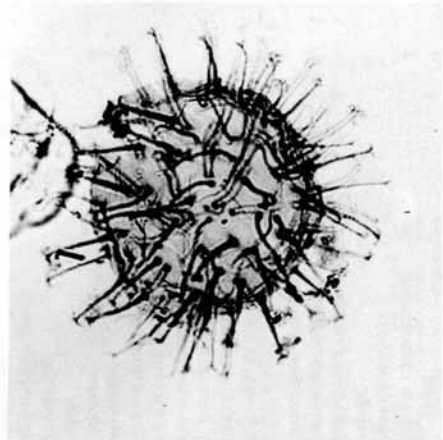
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Measurements. Holotype, central body length 51 μm including operculum (43 μm not including operculum), breadth 31 μm ; process length 5–15.5 μm .

Range. Central body length 38–49 μm (not including operculum), breadth 26–31 μm ; process length 5–16 μm . Specimens measured—8.

Comparisons. The broad, usually hollow and distally open processes, commonly unconnected distally, distinguish *D. scariosum* from other species in the genus.

Distribution. Samples B11, B15.

Genus EMSLANDIA Gerlach 1961

Type species. *Emslandia emslandensis* Gerlach 1961

Emslandia sp.

Plate 54, fig. 5

Remarks. This species of *Emslandia* has a bulging ventral hypocyst surface. The ambitus is sub-circular to ovoid. The epicyst is distally rounded and is prolonged into a very short apical horn, subrectangular in outline, with distal ending truncate, bifid or sometimes produced into a variable number of short solid processes. The hypocyst may be rounded or somewhat pointed medially (?compression) and sometimes bears a very short, solid antapical projection.

The autophragm is robust but does not exceed 2 μm in thickness, it is apparently spongy, perforate, and its outer surface is scabrate. Linear thickenings of the wall appear scattered randomly on the autocyst; sometimes these coalesce on portions of the cyst producing irregular reticulate structures. Two parallel thickenings of the autophragm mark the cingular margins.

The archeopyle is large, type P. The operculum may remain attached along its cingular suture.

Emslandia sp. differs from *E. emslandensis* by its thinner autophragm and randomly scattered ornament of linear thickenings, in part reticulate. It is clearly a distinct species, but the material is too badly preserved to provide satisfactory types.

Distribution. Samples WC 19–21, 23; Middle Headon Beds, Whitecliff Bay, Isle of Wight.

Genus EOCLADOPYXIS Morgenroth 1966b

Type species. *Eocladopyxis peniculata* Morgenroth 1966b

Eocladopyxis tessellata sp. nov.

Plate 53, fig. 6

Name derivation. Latin, *tessellatum*, tessellated.

Diagnosis. *Eocladopyxis* distinguished by abundant, long, solid, intratabular processes which end distally in fine spines repeatedly furcated and reflexed. The central body is moderately compressed dorso-ventrally and its ambitus is circular. Archeopyle type A + 3 \bar{A} + 6P. Additional sutures may occur randomly between any pair of paraplates.

EXPLANATION OF PLATE 53

Fig. 1. *Gerdicocysta conopeum* gen. et sp. nov., SEM showing the membrane connecting the distal ends of the processes, $\times 785$.

Fig. 2. *Gerdicocysta conopeum* gen. et sp. nov., holotype, dorsal view showing apical archaeopyle, $\times 500$.

Fig. 3. *Glaphyrocysta paupercula* sp. nov., holotype, $\times 1000$.

Fig. 4. *Phthanoperidinium amiculum* sp. nov., holotype, $\times 1000$.

Fig. 5. *Glaphyrocysta paupercula* sp. nov., specimen with reduced processes, $\times 1000$.

Fig. 6. *Eocladopyxis tessellata* sp. nov., holotype, $\times 1000$.

Description. The autocyst is moderately to strongly compressed dorso-ventrally with a circular ambitus. The autophragm is scabrate and is produced into solid intratabular processes, two to four, sometimes more, per paraplate. The processes are only slightly flexible, simple, somewhat expanded proximally, circular in cross-section; distally they flare into a number of fine spines which fork repeatedly; more rarely some of the processes may end in simple bifurcations. They are more or less strongly reflexed.

The archeopyle appears to be of the type $A + 3\bar{A} + 6P$ although it is possible that all apical plates separate in the formation of the archeopyle. Additional sutures commonly develop, apparently at random, between any other pair of paraplates, both on the epicyst and on the hypocyst.

The paratabulation formula may sometimes be determined on the basis of plate separation, and is $4', 6'', 6c, ?5'', 1 \text{ p.v.}, 1''', ?Xs$. Two of the apical paraplates appear to be larger than the other two. The precingular paraplates are of roughly the same size, antero-posteriorly elongate, and pentagonal in outline. The cingular paraplates are narrow and subrectangular, and frequently bear only two processes each. The hypocyst appears to be formed by five large postcingular paraplates, a prominent posterior-ventral paraplate and an antapical paraplate, but these are only rarely evident since secondary sutures are uncommon on the hypocyst; a number of smaller sulcal paraplates also appear to be present.

Holotype. Slide ML 1451, T51/2, sample WC25, Middle Headon Beds, Upper Eocene, Whitecliff Bay, Isle of Wight.

Measurements. Holotype, central body diameter, $37\mu\text{m}$; process length $8\text{--}15\mu\text{m}$.

Range. Central body diameters $31\text{--}39 \times 35\text{--}43\mu\text{m}$; process length $4\text{--}10\mu\text{m}$. Specimens measured—11.

Comparisons. The solid processes, paratabulation, and archeopyle type leave no doubt as to the generic allocation of *E. tessellata*; however, the archeopyle is not always observable, in which case the specimens closely resemble some species of the genus *Impletosphaeridium* Morgenroth 1966b.

E. tessellata differs from *E. peniculata* Morgenroth, the only other species so far allocated to the genus, in its larger size and longer processes. The process terminations in *E. tessellata* are more complex than in *E. peniculata*.

Genus GERDIOCYSTA gen. nov.

Name derivation. Latin, *gerdius*, weaver.

Type species. *Gerdiocysta conopeum* sp. nov.

Diagnosis. Cyst ambitus subcircular, posteriorly bilobed or rounded; dorso-ventral compression moderate to strong. Pericyst bearing solid penitabular to intratabular processes arranged into annular, soleate, or linear complexes. The process complexes support a reticulate or membranous ectophragm, which on the dorsal face and laterally simulate the outline of the paraplates. On the ventral face, a median area of variable size is free of ornament and ectophragm. The processes on either side tend to be linearly oriented more or less parallel to the ambitus; the ectophragm on the ventral face may link processes from different paraplates.

Inferred tabulation formula: $4', 6'', 6c, 5''', 1 \text{ p.v.}, 1''', Os$.

Archeopyle type \bar{A} , with zig-zag margins including a slightly offset sulcal notch. Operculum tetra-tabular, commonly free.

Comments. *Gerdiocysta* is similar to *Areoligera* Lejeune-Carpentier but differs strongly in the possession of an ectophragm, which, on parts or all of the dorsal surface of the cyst, simulates the shape of paraplates. In *Areoligera* the processes may be joined distally or laterally by trabeculae, but these are sparse and are loosely interconnected and do not constitute an outer reticulum or membrane.

The genus *Riculacysta* Stover 1977, resembles *Gerdiocysta* in shape and in possessing a membranous perforate to reticulate ectophragm. However, in *Riculacysta* the processes are not in complexes, and are restricted to the ventro-lateral and lateral zones of the cyst. The ectophragm on the dorsal surface of *Riculacysta* lies very close to or touches the autophragm and extends across the paraplate sutures in that region. In contrast there are the simulate dorsal complexes in *Gerdiocysta*.

Gerdiocysta conopeum sp. nov.

Plate 53, figs. 1, 2

Derivation of name. Latin, *conopeum*, mosquito net.*Diagnosis.* *Gerdiocysta* characterized by a finely reticulate to membranous perforate simulate ectophragm developed over paraplates 1'-4', 1''-5'', 2'''-4''', 1 p.v., and 1''''; an arcuate to soleate complex of very reduced processes, distally free, may be developed on paraplate 6''. The process bases are connected by microgranular thickenings of the cyst wall which form low ridges within the complexes; these thickenings are often further developed into an intratabular irregular, coarse reticulum. Individual processes are solid, slightly fibrous, and distally furcated. The median ventral area is large.*Description.* The antapical bilobation of the central body may be moderately or only weakly marked. The dorsal convexity and ventral depression are moderate. The endophragm is finely granulose, apparently perforate. The periphragm, as seen on the process walls is slightly fibrous.

The process complexes are determined proximally by basal granulose thickenings on the cyst wall, which form a more or less continuous basal ridge. Distally, the simulate ectophragm is well developed over paraplates 1'-4', 1''-5'', 2'''-4''', 1 p.v., and 1'''''. The cingular paraplates 2c-4c may bear linear complexes of processes which may or may not be distally united. A narrow ectophragm may also be developed on the ventral surface, forming an arcuate wing bordering the central area free of ornament. The ectophragm is closely perforate and finely reticulate or membranous; both types may combine in the same species.

On some individuals, the processes are greatly reduced, no ectophragm is developed, but a coarse granulate basal reticulum extends over the dorsal plate surfaces; intermediate forms between these and normal specimens with well-developed processes and ectophragm are common.

Holotype. Slide ML 1456, E 29/2, sample B11, Upper Hamstead Beds, Lower Oligocene, Bouldnor Cliff, Isle of Wight.*Measurements.* Holotype, central body length (operculum not included) 64 μm , breadth 73 μm , processes height up to 20 μm .*Range.* Central body length (operculum not included) 47(54-7)64 μm , breadth 63(68)79 μm , process length 6-23 μm . Specimens measured—15.*Comparisons.* No granulate proximal wall thickenings have been mentioned in the description of the only other species in the genus *G. cassicula* (Drugg) comb. nov., which also appears to differ from *G. conopeum* in having considerably longer processes and a more prominently bilobed antapex.Benedek (1972, pl. 1, figs. 11a-c) illustrated examples as *Cyclonephelium pastielsii* which appear to be conspecific with *G. conopeum*.*Distribution.* Samples B6, 7, 8, 11, and 15. Also in Lower Lintforter Beds and Ratinger Beds (early Rupelian), Germany and Calcaire de Sannois (early Stampian), France (Chateauneuf, pers. comm.).*Other species* allocated to the genus: *G. cassicula* (Drugg) comb. nov. = *Areoligera cassicula* Drugg 1970, p. 811, figs. 2B, 3A-B.

Genus GLAPHYROCYSTA Stover and Evitt 1978

Type species. *Glaphyrocysta retiintexta* (Cookson 1975)*Glaphyrocysta paupercula* sp. nov.

Plate 53, figs. 3, 5

Name derivation. Latin, *pauperculum*, diminutive of *pauperculus*, poor.*Diagnosis.* Central body compressed, ambitus subcircular to quadrangular, with or without antapical indentation. Autophragm microgranular, finely reticulate. Processes developed along a peripheral

band of varying width, leaving relatively prominent mid-dorsal and mid-ventral areas free. Processes solid, fibrous, simple or bifurcate. The processes may be isolated or arranged into linear, arcuate, soleate, or annular complexes. When in complexes the processes are joined by their expanded proximal parts; a few lateral (rarely distal) trabeculae may occur. The complexes have a ragged appearance distally. Processes from different complexes may be joined by basal ridge and/or medially by sparse trabeculae. Processes may be considerably reduced in number and in size.

Processes may occur on some or all of the paraplates 1'-4', 1''-5'' (rarely on 6''), 1'''-5''', 1 p.v., and 1''''.

The archeopyle is apical tetratabular, type \bar{A} ; the operculum may be free or remain attached. The archeopyle suture has a sulcal notch a little offset from the mid-body line.

Description. The central body is moderately to strongly compressed; the ambitus varies from subcircular to quadrangular, the antapex is rounded, somewhat indented or produced into one or two unequal lobes. The autophragm appears microgranular in optical section and is finely reticulate in surface view.

The processes are variable in number, size, and shape, and are developed along an ambital line of variable width. The mid-dorsal and especially the mid-ventral areas are free of ornament and relatively prominent. Individual processes, when well developed, are solid, slightly fibrous (most noticeable at and near the base), slender, simple or bifurcate.

The processes may be isolated, although some alignment may often be evident, or arranged into complexes on parts of the cyst. When in complexes, the processes are joined proximally by low ridges formed by their expanded bases; sparse ribbon-like trabeculae with smooth margins may also occur laterally, and only rarely distally. Processes from different complexes may also be united proximally by ridges and laterally by sparse trabeculae. Process complexes are normally present and better defined on the apical, dorsal precingular, and antapical zones of the cyst.

All apical paraplates bear processes, normally arranged into four or three annular or soleate complexes; when four, two are smaller and tend to coalesce into a single elliptical complex. Linear to arcuate complexes may occur on the precingular paraplates 1''-5'' (occasionally, processes occur on paraplate 6''). Towards the periphery of the dorsal face (2'' and 4'') the complexes may be soleate. On the ventral face, linear or somewhat arcuate complexes may be clear but sometimes the peripheral processes may coalesce with those from postcingular paraplates and become part of a more or less continuous complex parallel to the ambitus. On the postcingular paraplates process complexes tend to lose definition and to form a number of lines running antero-posteriorly near the periphery of both dorsal and ventral faces. The posterior ventral processes may join in these lines or be separate as an arcuate complex. A soleate complex is frequently observable on paraplate 1''''.

These forms with more or less well-defined complexes of well-developed processes constitute one end of the range of variation observed in this species. The other end includes forms with some isolated processes reduced to simple spines scattered along the peripheral and dorsal precingular zones, tending to form two to four loosely defined lines parallel to the cyst ambitus. The variability between both extreme types is continuous in the same assemblage and cannot be applied to further taxonomic division.

The archeopyle is apical, tetratabular; the opercula may be free or may remain in place. A rather shallow sulcal notch, relatively little offset from the mid-cyst line is observable on the archeopyle margin.

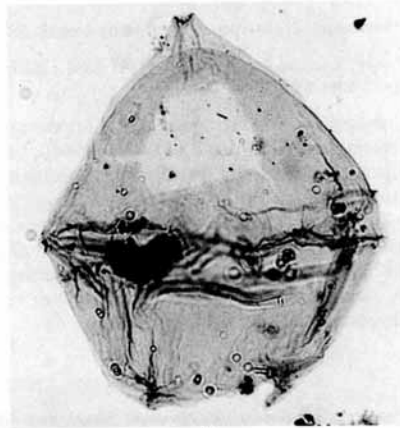
Holotype. Slide ML 1455 P44/1, sample B8, Upper Hamstead Beds, Lower Oligocene, Bouldnor Cliff, Isle of Wight.

EXPLANATION OF PLATE 54

- Fig. 1. *Thalassiphora fenestrata* sp. nov., holotype, dorsal view, showing archaeopyle and fenestrations, $\times 250$.
 Fig. 2. *Phelodinium pumilum* sp. nov., holotype, dorsal view showing archaeopyle and small cavities at the horns, $\times 1000$.
 Fig. 3. *Distatodinium scariosum* sp. nov., holotype, $\times 1000$.
 Fig. 4. *Phelodinium pachyceras* sp. nov., holotype, $\times 1000$.
 Fig. 5. *Emslandia* sp. Middle Headon Beds, sample WC20, showing precingular archaeopyle and cingulum, $\times 500$.
 Fig. 6. *Phthanoperidinium flebile* sp. nov., holotype, $\times 1000$.
 Fig. 7. *Vectidinium stoveri* gen. et sp. nov., holotype, $\times 1000$.



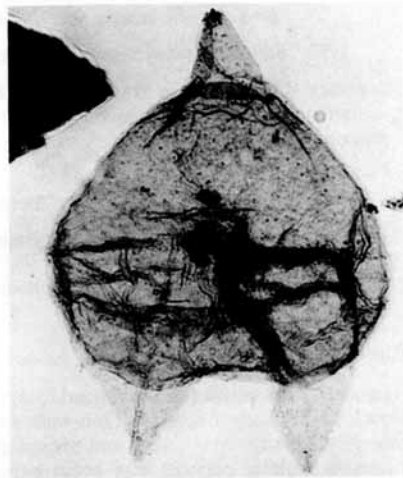
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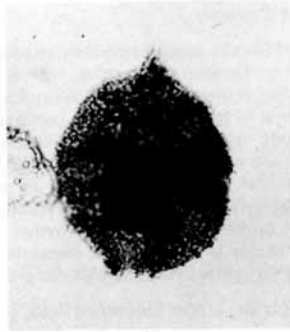
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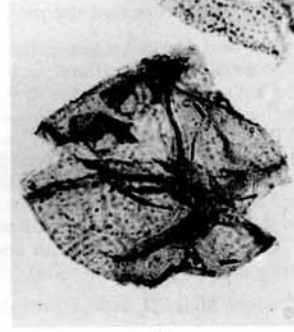
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Dimensions. Holotype, central body length 50 μm , breadth 59 μm , maximum length of processes 10 μm .

Range. Central body length 41(47.6)52 μm , breadth 48(57.4)64 μm , processes length (maximum) 6–20 μm . Specimens measured—20.

Comparison. In the ragged distal appearance of the ornament, this species resembles *Glaphyrocysta divaricata* (Williams and Downie 1966), but no process complexes are defined in the latter where the processes are united distally by trabeculae bearing free aculei and/or by perforated membranes in a more complex fashion than in *G. paupercula*.

G. paupercula also resembles *G. intricata* (Eaton 1976), *G. texta* (Bujak 1977), and *G. microfenestrata* (Bujak 1977), where individual process complexes may also be distinguished. However, the distal connections between processes in those species are always more complex than in *G. paupercula*, while the processes are rarely, if at all, united distally. *G. paupercula* may be a degenerate offshoot of this lineage.

Genus IMPLETOSPHAERIDIUM Morgenroth 1966b

Type species. *Impletosphaeridium transfodum* Morgenroth 1966b

Impletosphaeridium severinii (Cookson and Cranwell 1967) comb. nov.

1967 *Baltisphaeridium severinii* Cookson and Cranwell, p. 208, pl. 3, figs. 1, 2.

Comments. This species is transferred to *Impletosphaeridium* in view of its solid processes. Some specimens appear to show archeopyle sutures; if these eventually prove to be consistent, then *I. severinii* may have to be transferred once more possibly to *Eocladopyxis*.

Genus PHELODINIUM Stover and Evitt 1978

Type species. *Phelodinium pentagonale* (Corradini 1973) Stover and Evitt 1978

Phelodinium pachyceras sp. nov.

Plate 54, fig. 4

Name derivation. Greek, *pachys*, large, *keros*, horn.

Diagnosis. *Phelodinium* characterized by apical and antapical horns, triangular in outline, proximally broad, and distally rounded. Thin-walled cysts moderately compressed dorso-ventrally. Endocyst sub-circular, with low apical and antapical lobes. Apical and antapical pericoels well developed; a narrow ambital pericoel may occur between the horns.

Pericyst ornament atabular of reduced spinules. Pericingulum margins indicated by folds on the periphragm. Perisulcus broad and shallow.

Description. The cyst is thin-walled and usually compressed dorso-ventrally. The ambitus has convex sides and is projected into three prominent horns; these are triangular, with a broad base and a blunt distal ending, and are subequal in size. The epipericyst is more or less conical and somewhat larger than the hypopericyst; the posterior margin of the hypopericyst is straight or slightly concave.

The endocyst is rounded, only weakly bilobed posteriorly; a rounded, low projection into the base of the apical horn may occur. The pericoels are well developed beneath the horns, a narrow pericoel is commonly present between the antapical horns. The ornament is reduced to small spinules or granules, apparently atabular in distribution. Cingulum relatively wide, not indented; its margins are marked by two parallel folds on the periphragm. The sulcus is very broad posteriorly but narrows markedly towards the cingular zone.

The archeopyle is difficult to observe due to the opercula remaining nearly always in place, but the wide posterior archeopyle suture (H4), lying very close to the cingular margin, is evident on most specimens observed.

Holotype. Slide ML 1454, H19/0, sample B6, Upper Hamstead Beds, Lower Oligocene, Bouldnor Cliff, Isle of Wight.

Dimensions. Holotype, pericyst length 75 μm , breadth 53 μm , endocyst length 46 μm , breadth 53 μm , apical horn 12 μm , left antapical horn 15 μm , right antapical horn 13 μm .

Range. Pericyst length 57(65)77 μm , breadth 45(51.6)56 μm , apical horn 6(9)12 μm , left antapical horn 9(12)14 μm , right antapical horn 8(10)13 μm . Specimens measured—12.

Distribution. Upper Hamstead Beds (B6, B8), ?Middle Headon Beds WC19.

Comparisons. The prominent broad horns and reduced ornament, as well as a strong dorso-ventral compression, distinguish *P. pachyceras* from the other species allocated to this genus.

Phelodinium pumilum sp. nov.

Plate 54, fig. 2

Name derivation. Latin, *pumilus*, dwarf.

Diagnosis. *Phelodinium* of small size, ambitus bilaterally asymmetrical with reduced antapical horns, right antapical broadly rounded, may be absent. Apical horn small, cylindrical with prominent distal pore. Pericingulum relatively wide, marked by folds. Sulcus distinct.

Description. The ambitus varies from subcircular to distinctly peridinioid: the bilateral asymmetry of the cyst is nearly always evident. The dorso-ventral compression is strong. The pericoels, if observable, are restricted to the cavities beneath the horns. The cylindrical apical horn is distinctive, its truncated distal tip bears a prominent pore bordered by a thickening of the periphragm. The left antapical horn is always developed and is sharply pointed distally. The right antapical horn is often absent but commonly it is represented by a broad lobe.

The periphragm is very thin and transparent and is often folded. The cingulum is only very slightly helicoid, wide in relation to the over-all size of the cyst; anterior and posterior cingular sutures are indicated by low smooth ridges formed by folding of the periphragm. The perisulcus is distinct.

The archeopyle is of a type and shape seen in species of *Phelodinium*. Peri- and endopericulum are indistinguishable. The operculum may remain attached along its posterior suture.

Holotype. Slide ML 1450, Q45/4, sample WC 23, Middle Headon Beds, Upper Eocene, Whitecliff Bay, Isle of Wight.

Dimensions. Holotype, pericyst length 64 μm , breadth 54 μm , apical horn 6 μm , left antapical horn 5 μm , right antapical horn 8 μm .

Range. Pericyst length 50(55)62 μm , breadth 41(46.5)54 μm , apical horn 3.5(4.5)6.4 μm , left antapical horn 2.7(4.5)6.5 μm , right antapical horn 0(1)3 μm . Specimens measured—11.

Comparisons. The small size, rounded ambitus, bilateral asymmetry, and distinctive apical horn distinguish this species from all known *Phelodinium* species. Allocation to *Phelodinium* is based on the archeopyle shape and relative size, the absence of well-defined pericoels and the very strong dorso-ventral compression.

Distribution. Samples WC18, 20, 21, 23, and 25.

Genus PHTHANOPERIDINIUM Drugg and Loeblich 1967

Type species. *Phthanoperidinium amoenum* Drugg and Loeblich 1967.

Phthanoperidinium amiculum sp. nov.

Plate 53, fig. 4

Name derivation. Latin, *amiculum*, cloak.

Diagnosis. *Phthanoperidinium* with ambitus rounded-pentagonal to suboval. Epicyst with convex sides, terminating in a short apical horn, hypocyst also rounded, produced into one, very occasionally two, antapical horns. Peri- and endophragm very closely appressed except beneath the horns,

where restricted pericoels develop. Periphragm ornamented with intratabular spinules and penitabular to hyaline sutural ridges with smooth to slightly denticulate free edges. Laevigate to striate pandasutural lines may be distinct. Pericingulum and perisulcus laevigate, bordered by membranes.

Description. The pericyst is fusiform in lateral view; the ambitus is rounded-peridinoïd to subcircular or sub-oval. The apical horn is short, triangular and distally blunt. The left antapical horn is usually well developed. On some specimens, a right antapical horn, very much reduced, may occur; on most specimens, a projection of the sutural ridges takes the place of the right antapical horn.

The intratabular spines are small and solid, distally short or somewhat capitate; those closer to the paraplate periphery may be arranged in a penitabular ring. The ridges are hyaline and imperforate, their free margins are entire or very slightly serrate to denticulate; the height of the ridges normally does not exceed 3 μm , except along the cingular sutures where they may be up to 5 μm in height. The ridges may be parasutural or penitabular in position. Narrow laevigate pandasutural zones are normally observable on parts of the pericyst and, on some specimens, very faint striations, perpendicular to the margin of the paraplate, may be observable.

The paratabulation formula and shape of the paraplates are normal for the genus. The pericingulum is helicoid, its ends being offset about one pericingular width; its surface is laevigate. The perisulcus is relatively narrow, moderately excavated, extending anteriorly to nearly a half of the epicyst height. The archeopyle is formed by the detachment of paraplate 2a, but it is only rarely observable. Occasionally, additional sutures occur along the margins of all three intercalary plates.

Holotype. Slide ML 1451, K23/4, sample WC25, Middle Headon Beds, Upper Eocene, Whitecliff Bay, Isle of Wight.

Dimensions. Holotype, pericyst length 63 μm , breadth 48 μm , apical horn 7 μm , left antapical horn 5.5 μm .

Range. Pericyst length 47(55-5)63 μm , breadth 40(43)48 μm , apical horn 3(5.5)7 μm , left antapical horn 3(5.5)7 μm . Specimens measured—10.

Comparisons. *P. eocenicum* (Cookson and Eisenack 1965) appears to have sutural ridges and intratabular granules, and thus resembles *P. amiculum* in the style of ornament; but the ambitus in *P. eocenicum* is fusiform to subpolygonal, less rounded than *P. amiculum* and the left antapical horn lies closer to the median axis; in addition both intratabular granules and sutural ridges are much more reduced than on the present species.

P. alectrolophum Eaton 1976 resembles *P. amiculum* in possessing sutural-penitabular ridges, but these bear well-developed spines on their free margins and the intratabular paraplate surfaces are smooth.

Distribution. Only in sample WC25.

Phthanoperidinium flebile sp. nov.

Plate 54, fig. 6

1978 *Geiselodinium* cf. *geiseltense* Krutzsch, Chateaufneuf 1978.

Name derivation. Latin, *flebilis*, pathetic.

Diagnosis. *Phthanoperidinium* with ?partial (not continuous) endophragm occasionally developed beneath the horns. Ornament intratabular of small echinae or setae, laevigate sutural bands may be observable. Cingulum indicated by a relatively broad equatorial band free of ornament.

Description. The autocyst ambitus is subcircular to oval, but is frequently folded and the ambitus may appear somewhat fusiform; the ambital outline is little affected by the horns. The apical horn is very short, sub-triangular to rectangular in outline; its apical margin may be smooth or may bear a tuft of short spines, to which sometimes the entire horn is reduced. The hypocyst is posteriorly rounded, and may bear a very short, sharp, antapical horn slightly to the left of the median line.

The autophragm is thin and bears a variable number of small setae or echinae, sometimes reduced to granules, atabular to intratabular in distribution; on some specimens the number of spines is reduced, and these may adopt a penitabular arrangement. Sutural bands, when observable, are smooth and of variable width.

The cingulum, observable on some specimens, appears as a relatively wide band free of ornament; it is not indented. The sulcus has only been seen on one specimen, appearing as a very broad, slightly depressed area with ornament more sparse than on the rest of the ventral autocyst face.

The archeopyle, rarely observable, is intercalary and formed by the loss of paraplate 2a; additional splitting may sometimes develop along the lateral sutures of paraplate 3', but only very rarely, along the sutures of the remaining paraplates in the intercalary series.

Holotype. Slide ML 1453, X27/3, sample H24, Lower Hamstead Beds, Lower Oligocene, Hamstead, Isle of Wight.

Dimensions. Holotype, autocyst length 39 μm , breadth 28 μm , apical horn 5 μm , antapical horn 1 μm .

Range. Autocyst length 31(35)42 μm , breadth 22(27)31 μm , apical horn 1(3)5 μm , antapical horn 0(1)2 μm . Specimens measured—20.

Distribution. Sample H24; Lower Hamstead Beds.

Discussion. *P. echinatum* most closely resembles *P. flebile* in its ornament of spines, but in *P. echinatum* these are sutural to penitabular (distribution as a single simulate ring), whereas they are intratabular to atabular in *P. flebile*.

Occurrence. Sample H24, and at base of Sannoisian in Paris Basin (Argile Verte de Romainville).

Genus THALASSIPHORA Eisenack and Gocht 1960

Type species. *Thalassiphora pelagica* (Eisenack 1938) Eisenack and Gocht 1960

Thalassiphora fenestrata sp. nov.

Plate 54, fig. 1

Name derivation. Latin, *fenestratus*, windowed.

Diagnosis. *Thalassiphora* with partial fenestration of the periphragm. The fenestration is restricted to the lateral and ventral areas of the periphragm. The extent of the fenestrated area is variable, but it never extends over the whole dorsal region. The perforations are large, more or less circular, and may be closely packed forming an irregular reticulum. The ventral flange of the pericyst is narrow and is fenestrated throughout.

Description. This species is similar to *T. pelagica* in shape and in wall structure but the extension of the periphragm on the ventral side appears to be more reduced than is common in *T. pelagica*, that is, the ventral lacuna is larger. Perforations develop in the periphragm in ventral and lateral areas and disappear towards the mid-dorsal area. Between these perforations, the fibres are more loosely packed. A large number of smaller perforations occur between the larger fenestrations, the latter are of variable diameter tending to be larger closer to the ambitus. Ventrally, the pericyst occurs as a relatively narrow flange which is strongly fenestrate throughout. The antapical keel may often be reduced or, sometimes, absent.

Holotype. Slide ML 1449 U16/2, sample WC14, Middle Headon Beds, Whitecliff Bay, Isle of Wight.

Measurements. Holotype, endocyst $81 \times 67 \mu\text{m}$, pericyst diameter 150 μm .

Range. Endocyst 73(77)89 \times 59(67)77 μm , pericyst diameter 126(154)182 μm . Specimens measured—10.

Comments. This species, which is apparently restricted in distribution to the latest Eocene and ?early Oligocene, seems to be an intermediate form between *T. reticulata* Morgenroth 1966a, which is characteristic of younger Oligocene deposits and whose pericoel is fenestrate virtually all over, and *T. pelagica*.

Distribution. Samples WC13–23.

Genus VECTIDINIUM gen. nov.

Name derivation. Latin, *Vectis*, Roman name for the Isle of Wight.

Type species. *Vectidinium stoveri* sp. nov.

Diagnosis. Single-walled proximate peridinioid cysts, moderately compressed dorso-ventrally, ambitus subpentagonal or subcircular to oval or somewhat fusiform. Epicyst and hypocyst of approximately equal size. Epicyst may or may not extend into a short apical horn; apical pore always present. Hypocyst semicircular or bilobed; left antapical horn present or absent, right antapical horn commonly present.

Autophragm with atabular or intratabular to penitabular ornament of small granules, spinules or baculae, which may be reduced in size and/or number. Narrow laevigate pandasutural zones may be observable. Paratabulation formula, when determinable, 4', 3a, 7'', Oc, 5'', 2''', Os. When observable paraplate 1'' is rhombic, antero-posteriorly elongate, and relatively large.

Cingulum and sulcus distinct. The cingulum is wide relative to over-all autocyst size, not indented, non- or moderately helicoid. Sulcus shallow and broad on the hypocyst. Archeopyle combination type 3I 3P 3''-5'', accessory sutures may occur along cingular margin of the remaining precingular paraplates. Opercula free.

Comparisons. *Vectidinium* differs from *Palaeoperidinium* Deflandre 1934, and from *Saeptodinium* Harris 1975, in that the apical paraplate 3' is not included in the archeopyle. From *Saeptodinium* it also differs in being single walled and usually having intratabular or penitabular ornament. From *Palaeoperidinium* it differs in the presence of ornament and its much smaller size.

Ginginodinium Cookson and Eisenack 1960, *Laciniadinium* McIntyre 1975, and *Lunatodinium* Brideaux and McIntyre 1973, all have a 3I 3P 3''-5'' archeopyle, and they also resemble *Vectidinium* in the type of ornament. *Ginginodinium* is double walled, and in the formation of the archeopyle the three dorsal precingular paraplates (3''-5'') always remain attached along their cingular margins (Lentin and Williams 1975, p. 95). *Laciniadinium* has a single opercular piece 3I 3P 3''-5'' which always remains attached to the cyst along its posterior margin, like a flap. In *Vectidinium* whenever the archeopyle is present, the operculum is detached and some doubt remains as to whether this is simple or compound. *Lunatodinium* (a Lower Cretaceous genus) was described as having an archeopyle formed by the loss of the three dorsal precingular paraplates. However, Lentin and Williams (1975, pp. 96 and 116) included this genus in the pericysts, possessing a 3I 3P archeopyle. This appears to be so from the original illustration of *Lunatodinium* (Brideaux and McIntyre 1973, figs. 1-13). The genus is stated to have a circular or subcircular outline.

Cysts of the Recent freshwater dinoflagellate *Peridinium* resemble *Vectidinium* in the type and distribution of the ornament, but they are normally cavate and the archeopyle is formed by the detachment of plates along a transapical suture, type A3I3P.

Vectidinium stoveri sp. nov.

Plate 54, fig. 7

Name derivation. This species has been named after Lew Stover.

Diagnosis. As for the genus.

Description. The dorso-ventral compression of these cysts is normally slight, and some specimens may be oriented in apical or antapical view; in lateral view the cysts are somewhat fusiform or oval. The epicyst has strongly convex sides which may merge imperceptibly in a very short, blunt apical horn with a solid tip on which sits a pore; the apical horn may be absent, and the epicyst apex is then invaginate. The hypocyst is commonly broadly rounded posteriorly, but some specimens may show a weak bilobation on the antapex. The short, eccentrically located left antapical horn may be present or absent.

The ornament varies in density and shape. When the ornament is baculate or of short processes their distal endings are often T-shaped and may be linked to those from near-by processes, giving the appearance of a

tectum supported by columellae in optical section; sometimes the ornament is very reduced in size and mostly consisting of granules. The ornament may be densely or sparsely arranged on the paraplate surface, the most peripheral elements tending to be arranged along simulate rings. Laevigate pandasutural zones, usually narrow, are present but are not always clearly visible.

Cingulum and sulcus are distinct, both being marked by low ridges or folds on the autophragm. The cingulum is relatively wide, slightly helicoid or circular, not indented; intratabular ornament and smooth pandasutural zones may be observable on the cingular surface, but the number of cingular paraplates has not been determined with certainty. The sulcus is also broad and shallow, and extends approximately half-way to the apex. The shape and relative size of individual paraplates are difficult to determine because of very small size and transparent autophragm of these cysts.

When present, the archeopyle is formed by complete detachment of plates 1a-3a, 3''-5''. On some specimens, accessory archeopyle sutures develop along most of the anterior margin of the cingulum, but both portions of the cyst usually remain attached along a narrow band, presumably corresponding to the sulcus. The operculum is always free, but it has not been possible to determine whether this is formed by a single piece or is compound, since isolated opercula have not been observed—a fact suggesting that the operculum may be compound, disintegrating into the very small individual paraplates which would easily be lost in sieving of the organic residue during preparation.

Holotype. Slide ML 1452, U43/3, sample WC34, Upper Headon Beds, Upper Eocene, Whitecliff Bay, Isle of Wight.

Measurements. Holotype, autocyst length 37 μm , breadth 42 μm , apical horn 1 μm , left antapical horn 1 μm , width of cingulum 4 μm .

Range. Autocyst length 30(35-5)41 μm , breadth 24.5(31)42 μm , apical horn 0(2)4.2 μm , left antapical horn 0(1)4.5 μm , width of cingulum 2.7(3-6)4 μm . Specimens measured—24.

Distribution. The distribution of *Vectidinium stoveri* in the section studied deserves some special attention since it constitutes monospecific assemblages at some horizons, and has not been found in association with any other dinoflagellate cysts. These horizons yield ostracod assemblages of type III (Keen 1972, 1977); these have been stated by Keen to indicate brackish-water conditions (salinity 3-9‰). *V. stoveri* is thought to be a non-marine dinoflagellate cyst, and possibly a good indicator of oligohaline conditions; it is recorded from samples WC34, 35, and H19.

PALYNOLOGICAL ASSEMBLAGES AND DEPOSITIONAL ENVIRONMENTS

The Upper Eocene-Lower Oligocene of the Isle of Wight was deposited under widely variable environmental conditions. The area of deposition has been likened to an embayment, limited to the north and south by the Portsdown and the Sandown-Brixton anticlines respectively, and opening towards the sea to the east and south-east. At times this sea penetrated into the basin. At other times an eastward flowing river system occupied the area (Keen 1977). The conditions ranged from shallow, near-shore open sea, to brackish-water lagoons—with or without connection to the sea—to freshwater lacustrine or fluvial environments. These changes are reflected in the palyno-assemblages, and are especially noticeable in the relative proportions of different classes of palynomorphs as well as in the composition of the microplankton assemblages where these occur.

Palaeoecological studies of palynomorph assemblages and particularly of dinoflagellate cysts are currently in their preliminary stages, and no work on the palaeoenvironmental interpretation of Tertiary palyno-assemblages from paralic areas has yet been published. However, the assemblages recovered here may be correlated to particular environmental conditions by using, as a control, the existing information on the distribution of dinocysts in Tertiary to Recent sediments, as well as the sedimentological and faunal evidence available from the sections studied. The foraminifera (Murray and Wright 1974), molluscs (Daley 1973), and ostracods (Keen 1972, 1977; Haskins 1969) from the Upper Eocene-Lower Oligocene sections of the Isle of Wight have yielded a considerable volume of data that can be used in assessing the meaning of the palynological assemblages recovered.

The major components of the palynological assemblages are indicated in Table 2. They clearly fall into two groups, one with marine dinoflagellates present; the other non-marine samples contain only terrigenous freshwater or lagoonal elements.

The non-marine group shows considerable variation, particularly in the proportions of *Pediastrum* Meyen, which may contribute from 0 to over 90% of the assemblage. In some samples there is also a considerable contribution from non-marine dinoflagellates. These non-marine samples are associated with various lithologies ranging from limestone through to sands and no particular pattern has so far been determined. It is evident, particularly from the work of Keen, that the salinities vary from fresh to oligohaline water. The environments of deposition include evidently freshwater lacustrine, fluvial, flood-plain, and bay-head situations. The control over the relative abundance of *Pediastrum* Meyen is not understood. It is notably more common in the Bembridge Marls in the west of the island. In marine sediments it is present only in very small numbers and is probably allochthonous. It is most abundant in situations that could be interpreted as oligohaline water.

TABLE 2. General character of palynological assemblages. P & S—pollen and spores; Ped—*Pediastrum* spp.; MD—marine dinoflagellates; fd—freshwater dinoflagellates; 'r' indicates that dinoflagellates are all reworked from older strata.

Sample	% P & S	% Ped	% MD	% fd	Sample	% P & S	% Ped	% MD	% fd
Whitecliff Bay					WC36	99	1	—	×
Bembridge Marls					WC35	62	1	—	37
WC67	99	—	1(r)	—	WC34	73	14	—	13
WC66	99	1	×(r)	—	WC33	94	6	—	—
WC65	94	2	4(r)	—	WC31	62	38	—	—
WC64	99	1	×(r)	—	WC30	100	—	—	—
WC63	91	8	1(r)	—	WC29	61	39	—	—
WC62	74	26	—	—	WC28	90	10	—	—
WC61	100	—	—	—	WC26	100	—	—	—
WC60	100	—	—	—	Middle Headon Beds				
WC59	97	3	—	—	WC25	74	—	26	—
WC58	100	—	—	—	WC24	84	—	16	—
WC56	99	1	—	—	WC23	54	—	46	—
WC55	13	80	7	—	WC21	58	2	40	—
WC55A	16	84	×	—	WC20	40	—	60	—
WC54	100	—	—	—	WC19	31	—	69	—
WC53	100	—	—	—	WC18	28	—	72	—
Bembridge Limestone					WC17	38	—	62	—
WC51	100	—	—	—	WC16	29	—	71	—
WC49	100	—	—	—	WC15	25	—	75	—
Osborne Beds					WC14	20	—	80	—
WC47	100	—	—	—	WC13	37	×	37	—
WC46	58	42	—	—	Lower Headon Beds				
WC45	36	64	—	—	WC12	72	28	—	—
WC44	100	—	—	—	WC9	80	20	—	—
WC43	100	—	—	—	WC8	45	55	—	—
WC42	10	90	—	—	WC7	25	75	—	—
WC41	97	3	—	—	WC6	100	—	—	—
Upper Headon Beds					WC5	7	93	—	—
WC40	22	78	—	—	WC4	80	20	—	—
WC39	86	14	—	—	WC3	96	4	—	—
WC38	97	3	—	—	WC2	100	—	—	—
WC37	93	6	—	1	WC1	98	2	—	—

Sample	% P & S	% Ped	% MD	% fd	Sample	% P & S	% Ped	% MD	% fd
Hamstead Cliff					H9	57	43	—	×
Lower Hamstead Beds					H8	75	25	—	×
H36	54	46	—	—	H7	73	27	—	—
H35	55	45	—	—	H6	35	6	59	—
H34	88	12	—	—	H4	49	×	51	—
H33	82	18	—	—	H3	44	56	—	—
H32	75	25	—	—	Bembridge Limestone				
H31	63	37	—	—	H2	16	84	—	—
H30	81	19	—	—	H1	100	—	—	—
H29	41	59	—	—	Bouldnor Cliff				
H28	64	36	—	—	Upper Hamstead Beds				
H27	97	3	—	—	B15	92	—	8	—
H26	96	4	—	—	B14	94	—	6	—
H25	96	3	—	—	B13	96	4	—	—
H24	94	1	6	—	B12	100	—	—	—
H23	42	13	45	—	B11	24	2	74	—
H22	84	16	—	—	B10	75	25	—	—
H21	87	13	×	—	B9	42	58	—	—
H20	78	22	—	—	B8	8	3	89	—
H19	63	29	—	8	B7	28	2	70	—
H18	76	24	—	—	B6	52	29	19	—
H17	73	27	—	—	B5	63	37	×	—
Bembridge Marls					Lower Hamstead Beds				
H16	76	24	—	—	B4	100	—	—	—
H15	34	66	—	—	B3	100	—	—	—
H14	67	33	—	—	B2	100	—	—	—
H13	64	36	—	—	B1	52	48	—	—
H12	36	64	—	—					
H10	34	66	—	×					

Non-marine dinoflagellates are represented by a single species, *Vectidinium stoveri* which is present only in three samples, WC34, 35, and H19. It is associated with ostracod assemblage III of Keen, indicating brackish-water conditions.

Marine samples are characterized by the presence of marine dinoflagellate cysts and acritarchs. They can be classified into a number of types according to their diversity and the dominant species. Since these types occur in stratigraphic order and are associated with a series of marine incursions it is convenient to discuss them in stratigraphic sequence.

The Middle Headon Beds transgression

Four assemblage types are present:

Assemblage 1. The Brockenhurst Bed and *Psammbia* Beds (samples WC13–21) are characterized by assemblages with forty or more species of dinoflagellate cysts dominated by *Homotryblium plectilum* which makes up 30–70% of the microplankton; other abundant species are *Spiniferites ramosus*, *Adnatosphaeridium reticulense*, and *Phthanoperidinium cometum*. These assemblages are associated with ostracod assemblage type VI and indicate open-sea conditions, the major transgressive episode in the sequence studied.

Assemblages 2–4. The succeeding *Venus* Bed contains three different assemblage types showing a marked reduction in the number of species present and in their relative abundance.

Type 2, occurring in sample WC23, has less than thirty species and is dominated by *H. pallidum* and *P. cometum*, the latter a species evidently tolerant of reduced salinities in estuarine or lagoonal environments.

Type 3, occurring in sample WC24, has only seventeen species and is dominated by broken species of *H. plectilum* associated in assemblage 1 with open-sea conditions. Here these are thought to be allochthonous. *H. pallidum* is the next most common species.

Type 4, occurring in sample WC25, is dominated by *Eocladopyxis tessellata* and *P. cometum*.

These three assemblages appear to indicate a period of regression with restriction of marine access to the area. Keen refers the ostracod assemblages in these beds to his type V, indicating salinities in the range of 16.5–33‰.

The Lower Bembridge Marl transgression

Assemblage types 5–7 are associated with the Oyster Bed.

In the east, sample WC55 yielded assemblage type 5, where dinoflagellates made up only 7% of the palynomorphs. No clearly dominant species was present, the commonest being *Chiropteridium aspinatum*, *Glaphyrocysta microfenestrata*, *Homotryblum pallidum*, and *Paralecaniella indentata*.

In the west, assemblage type 6 is monospecific; *Phthanoperidinium levimurale* makes up 51% of the palynomorphs in sample H4. Assemblage type 7 is also monospecific, *G. microfenestrata* making up 59% of the palynomorphs in sample H6.

The significance of these three diverse assemblages from the Oyster Bed is made clearer by consideration of the fauna. Molluscs, foraminifera, and ostracods all indicate brackish estuarine conditions. Assemblage type 5 is associated with Keen's type V indicating near-marine conditions; the assemblages from the west, however, are associated with his type IV, indicating lower salinities (9–16‰). This seems to mean that the monospecific assemblages with *P. levimurale* and *G. microfenestrata* are composed of more or less stenohaline species, since both also occur in open marine conditions. They appear to have flourished in this estuarine situation since they are particularly abundant, more so than any of the species in the east, where the assemblage, although poorer in relative numbers, has a greater variety of marine species and, although still estuarine, appears to have better connection with the open sea.

The Lower Hamstead Bed transgression

Assemblage types 8 and 9 are associated with a marine incursion at the horizon of the *Nematura* Band.

Assemblage type 8, sample H23, contains only four species and is dominated by *Adnatosphaeridium reticulense*. Only 13% of the palynomorphs are dinoflagellates. Assemblage type 9, an even poorer assemblage from H24 immediately above, is on the other hand dominated by *P. flebile*. Ostracods from the *Nematura* Band show the presence of assemblage type IV characteristic of mesohaline conditions.

The Upper Hamstead Bed transgressions

Six different dinoflagellate assemblages (types 10–15) have been found in the Upper Hamstead Beds and the palynology appears to show the presence of three different invasions of saline water.

The first incursion corresponds to the *Cerithium* Bed and contains assemblage types 10–12. Assemblage type 10, sample B6, contains 19% dinoflagellates with only a few species represented and is dominated by *G. microfenestratum* and *P. cometum*, both of which, although known from other marine sediments, have previously been noted in assemblage types 7 and 4 and 2, with reduced salinities associated with Keen's types IV and V. Keen (1972) finds that the *Cerithium* Bed also yields assemblages of types IV and V. Assemblage type 11 in sample B7 is also impoverished in species, but is dominated by small acritarchs of the *Micrhystridium* group, which accounts for about 60% of the palynomorphs. Assemblage type 12, sample B8, is more varied and richer in numbers, but *G. paupercula* accounts for most of these.

Taken together these three samples indicate a marine influence, which, however, did not achieve fully marine conditions in this locality, the area remaining meso- to polyhaline.

The second incursion is represented only by assemblage type 13, sample B11. That it is a separate episode is indicated by the intervention of samples B9 and 10 which contain only terrigenous

pollen and spores and the ?freshwater alga *Pediastrum*. Assemblage type 13 appears to represent more fully marine conditions with many new species appearing. The dominant species is *H. pallidum*, which also dominates in assemblage type 2 (*Venus* Bed) and is abundant in type 5 (Oyster Bed, Whitecliff Bay). Here it is associated with *Gerdicysta conopeum*. The conditions indicated are still not yet fully marine, but must closely approach that condition.

The third incursion is represented by assemblage types 14 (sample B14) and 15 (sample B15). That this is a separate episode is indicated by the intervention of the purely terrigenous palynological assemblages in samples B12 and 13. The second and third incursions together form the *Corbula* Bed. Assemblage type 14 is a poor monospecific one comprising only *Phthanoperidinium cometum*. It probably indicates low salinities. Type 15, however, is somewhat richer and is particularly so in the variety and lack of any clearly dominant species. *Michystridium*, *Lejeunia tenella*, *Hystrichokolpoma salacium*, and *P. amoenum* are prominent, the last three being known only from open marine sediments. It is believed that these two samples B14 and B15 represent the beginning of a major transgression, the culmination of which is not represented due to erosion of the succeeding beds.

DINOFLAGELLATE CYST STRATIGRAPHY

The distribution of dinoflagellates is shown in Table 1.

The first dinoflagellate assemblages appear in the Brockenhurst Bed associated with the Middle Headon transgression. Detailed comparison between the dinoflagellate assemblages from the Solent Formation and the marine sediments of the underlying Barton Formation is not possible at present, since little information on the dinoflagellate content of the Barton Beds has so far been published (Bujak 1976). However, from unpublished evidence (Bujak 1973), it appears that, notwithstanding the intervening regression represented by the Becton and Lower Headon Beds, only minor changes take place in the composition of the assemblages between the uppermost marine beds of the Barton Formation and the lower part of the Solent Formation (Middle Headon Beds). The number of species that first appear in the Middle Headon Beds is very small, but they include *Rhombodinium perforatum* and *Thalassiphora fenestrata*, and the possibility remains that some of these may also occur in the Barton Beds; the number of apparent extinctions is also limited, and their stratigraphic significance, which may be only local, cannot be assessed at this stage.

As the assemblages become impoverished towards the upper part of the Middle Headon Beds, among the dinoflagellate species disappearing from the assemblages are *Areosphaeridium diktyoplokus*, *Cordosphaeridium funiculatum*, *Distatodinium ellipticum*, *Palaeocystodinium golzowense*, *R. draco*, *R. perforatum*, and *T. velata*.

Other taxa, *Emslandia* sp., *Eocladopyxis tessellata*, and *Phelodinium pumilum*, make their first appearance in the section here. These species first appearing within the upper part of the Middle Headon Beds are all new and so their stratigraphic value, if any, cannot be stated.

The Bembridge transgression, represented by the Oyster Bed, yields poorly diversified assemblages. These, in terms of their species content, show a somewhat closer relationship to the Middle Headon Beds than to the Upper Hamstead Beds. The Bembridge Oyster Bed at Whitecliff Bay registers the last known occurrence in England of *Chiropteridium aspinatum*, *Impletosphaeridium severinii*, *Homotryblium oceanicum*, and *Leptodinium incompositum*.

The Lower Hamstead Bed transgression, represented by a thin sequence including the *Nematura* Bed, also provides a poor assemblage consisting mainly of long-ranging species. One species, *Phthanoperidinium flebile* is, however, apparently confined to this horizon.

A very pronounced break in the dinocyst succession is evident in the final transgressions of the Upper Hamstead Beds. Out of a total of sixty-eight dinoflagellate species recorded, only nineteen are common to the Solent and Hamstead Formations; thirty-four species disappear below the base of the Hamstead Beds, and fifteen species are first recorded within the latter. The marked renewal of the assemblages registered between the two main marine episodes in the sequence is to some extent environmentally controlled, since some of the species missing in the Headon Bed are known to persist elsewhere into the Oligocene, such as *C. aspinatum*, *Cordosphaeridium cantharellum*, *D. ellipticum*,

Hystrichokolpoma rigaudiae, *Kisselovia coleothrypta*, *R. draco*, *T. velata*, and *T. pelagica*. Two species, however, which fail to reappear are *R. perforatum* and *A. diktyoplokus*, whose absence seems to be stratigraphically important.

A number of species make their first appearance here and some of them are thought to be stratigraphically important. These are *Gerdicysta conopeum*, *Heteraulacacysta* cf. *companula*, *Phthanoperidium amoenum*, *Wetzeliella gochtii*, and *W. symmetrica incisa*. Other appearances of possible significance are *Phelodinium pachyceras* and *D. scariosum*.

CORRELATION WITH OTHER EUROPEAN AREAS

Paris Basin

Curry *et al.* (1978) correlate the Middle Headon Beds with part of the Marnes à Pholadomya ludensis, i.e. with the deposits of the Ludian transgression of the Paris Basin. Both formations yield rich dinoflagellate assemblages. A description of those from France has been given by Chateauneuf (1978). Most of the species recorded by him are present in the Middle Headon Beds but there is none of sufficiently restricted range to allow confident correlation on the basis of the dinoflagellates, except that *R. perforatum* (which appears for the first time in the mid-Headon Beds in England) also appears for the first time in small numbers in the top Marneesian and more commonly in the Ludian. *R. perforatum*, previously mentioned from the Barton Beds (Costa and Downie 1976) is in fact a separate species (Bujak, in press). A marked distinction between the Ludian assemblages and those from the Headon Beds is the remarkable abundance of *H. plectilum* in the Isle of Wight and its apparent absence from the Ludian.

The impoverished assemblages from the Bembridge Oyster Bed yield little of correlative value, but the abundance of *C. aspinatum* does correspond with the prominence of this species in assemblages from the Ludian Marnes à Lucines (Chateauneuf 1978).

The equally poor assemblages from the vicinity of the *Nematura* Band do, however, show some marked similarities to those of the Argile Verte de Romainville at the base of the Stampian. The lower of the English samples (H23) is dominated by *Adnatosphaeridium reticulense*, which is also a dominant form in the Argile Verte. The upper English sample (H24) is dominated by *Phthanoperidium flebile*, which is restricted to this horizon in England and has also been found to be abundant in the Argile Verte by Chateauneuf (1978) and recorded by him under the name of *Geiselodinium* cf. *geiseltalense*. This strongly suggests a correlation between the *Nematura* Band and a horizon within the Argile Verte de Romainville.

The Upper Hamstead Beds can be correlated with the Calcaire de Sannois and the lower part of the Marnes à Huitres. This correlation is supported by the appearance of *Gerdicysta conopeum* (= *Cyclonephelium reticulosum* Gerlach, Chateauneuf 1978), *W. gochtii* (Chateauneuf, pers. comm.), *P. amoenum*, and the increased abundances of *W. symmetrica* and *Pentadinium taenigerum* (Chateauneuf 1978) in both areas.

The overlying Sables de Fontainebleau have a rich and varied dinoflagellate assemblage with species such as *Chiropteridium lobospinosum* and *C. partispinatum* (Chateauneuf 1978). In England there is no representative of this assemblage, which has marked similarities to those from the Rupelian of Germany (Benedek 1972).

Belgium

Weyns (1970) described two assemblages from the Sables de Grimmeringen (Lower Tongrian). He listed forty-seven forms of dinoflagellate cysts. Of these thirty-six are apparently present in the Middle Headon Beds, and the assemblages have a general similarity, particularly in the prominence of *Homotryblum* and *Spiniferites*.

In comparison with the Hamstead Beds assemblages, there are major differences. The many species appearing for the first time in the Hamstead Beds are not listed in Weyns's assemblages. Only a few of the species listed by Weyns appear to have stratigraphic significance. *Glaphrocysta microfenestrata* (= *C. semicirculatum* in Weyns) does not appear until late in the Chama Beds of the

Bartonian (Bujak 1976). *G. exuberans ellipsoidalis* and *Areosphaeridium diktyoplokus* are absent above the Middle Headon Beds. The correlation that best fits these circumstances is between the Sables de Grimmeringen and the Middle Headon Beds. This is in agreement with recent work on the nanoplankton correlation (Cavelier 1975). A notable difference between the Belgian and English assemblages is the presence of *Leptodinium* and *Nematosphaeropsis* in the former. These are forms found to be more prominent in open-sea situations.

Two samples, one from 20 m and the other from 30 m above the base of the Rupel Clay in the type section, yielded rich dinoflagellate assemblages. These showed marked similarities to those from the Upper Hamstead Beds, in particular containing *W. gochtii*. However, they also contain *C. lobo-spinosum*, *C. partispinatum* and other species which are not present in the Isle of Wight, but are characteristic of the Sables de Fontainebleau in the Paris Basin, and the Rupelton in Germany. These samples are clearly younger than any from the Isle of Wight.

THE EOCENE/OLIGOCENE BOUNDARY IN THE ISLE OF WIGHT

Establishment of a standard for this stratigraphic boundary is the subject of continuing debate. In France, it has commonly been placed at the base of the Stampian Stage, i.e. at the base of the Argile Verte de Romainville (Chateaufneuf 1978). Accepting this, the correlations between the Isle of Wight succession and the Paris Basin based on dinoflagellates indicate that the boundary lies closely below the *Nematura* Band. The boundary clearly lies between the *Nematura* Band and the Middle Headon Beds. The Oyster Bed, although it has a poor assemblage, has greater similarity to the Headon Beds than to the succeeding assemblage.

Therefore, if the French view is accepted the boundary lies between the base of the *Nematura* Band and the top of the Oyster Bed. Since the Argile Verte de Romainville marks the first important marine incursion after the episode of the Marnes a Lucines it seems very likely that the *Nematura* Band represents the same transgression. The Bembridge Marls then correlate with the Supra- and Upper Gypsiferous Groups (1st and 2nd mass) and the Osborne Beds with the 3rd mass of gypsum. The base of the Oligocene could conveniently be taken at the base of the Hamstead Beds, some 9 km below the *Nematura* Band.

An alternative, widely held, view is that the base of the Oligocene originally selected in Germany should be adopted. This is marked by the transgression associated with the Latdorf (Lattorf) Sands (NP21), which correlate readily with the Sables de Grimmeringen in Belgium.

Dinoflagellates have not been described from the Latdorf Sands, but from the Sable de Grimmeringen assemblages very like those from the Middle Headon Beds have been described by Weyns (1970). If this correlation is accepted the Middle Headon Beds would be Oligocene. However, the Brockenhurst Bed has given evidence of an NP20 age, which indicates that the base should be higher. There is, however, no apparent break in the Middle Headon Beds sequence, only a progressive increase in terrigenous influence in the *Venus* Beds (samples WC22-25). No suitable location for a boundary is evident.

The next marine incursion in the Isle of Wight succession, the Bembridge Oyster Bed, did not yield any dinoflagellates of much value in correlation. Those that are present are not inconsistent with a correlation with the Sables de Grimmeringen and consequently with the placing of the base of the Oligocene immediately above the Bembridge Limestone, as is done by Curry *et al.* (1978).

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