

WEALDEN OCCURRENCE OF AN ISOLATED BARREMIAN DINOCYST FACIES

by N. F. HUGHES and I. C. HARDING

ABSTRACT. Records of occurrence are presented in the form of two new taxa of peridinioid dinoflagellate cysts and twenty-three comparison records from Upper Wealden strata of Barremian age in the British Geological Survey's Warlingham Borehole, Surrey. Because these well-preserved dinocysts are not accompanied by any other dinocyst palynomorphs, their presence is interpreted as a short-lived and local record of very low palaeosalinity. Other occurrences at different levels in the Wealden usually contain three or four dinocysts of known marine taxa, and appear to represent more widespread and perhaps stronger marine incursions. Palynofacies, ostracods, and clay minerals are briefly discussed in connection with the possibility that these new dinocysts may represent the earliest known occurrences of non-marine dinoflagellates to produce fossilisable cysts.

THE purpose of this paper is to illustrate and to describe the circumstances of occurrence of a new dinoflagellate cyst which has been found in abundance in some palynomorph-bearing Wealden samples. No other dinocysts have been found in these samples which are from the upper part of the Weald Clay in the British Geological Survey (B.G.S.) Warlingham Borehole in Surrey (Worssam and Ivimey-Cook 1971) and appear to be of late Barremian age. The new dinocysts, first illustrated by Hughes (1980), have no close parallels in the literature and appear to be relatively simple peridinioids; their occurrence without other dinocysts may indicate a palaeosalinity less than the marine salinity of the time, and if so the beginning of a trend towards the fresh-water dinocysts of today. It may therefore be necessary to qualify the generally accepted view (e.g. Hughes and Moody-Stuart 1967) that through the Mesozoic any dinocyst occurrence indicates a marine environment.

PREPARATION METHOD

Samples have been treated by a standard palynologic extraction method for light microscope study: dilute HCl, HF, conc. HNO₃ oxidation (time stated with record sample description), dilute NH₄OH (to avoid using KOH which causes swelling), and zinc bromide (S.G.2.O) as heavy liquid. Although residues are now stored in glycerine/water, some early preparations twenty-five years ago were stored in glycerine jelly and have been successfully brought into use with hot water and/or HCl/HF.

Slides for light microscopy were made by a standard Hydramount/Depex method; some of the older preparations mentioned below for comparison records were mounted in Clearcol or even in glycerine jelly. Micrographs were taken on Kodak Technical Pan Film 2415 (rated 100 ASA) using a Nikon FX35A camera on Nikon Labophot microscope 01819.

SEM stubs were prepared with strew residue over a Cambridge Mark 2 nickel grid (see Hughes *et al.* 1979). Micrographs were taken on Ilford 70 mm film FP4, using a Phillips 501B Scanning Electron Microscope. All specimens and preparations are lodged in the Sedgwick Museum.

RECORD OF SPECIMENS

All specimens observed are here listed as belonging either to a biorecord (unchangeable reference taxon) or to a graded comparison record (see Hughes 1976, p. 26). To distinguish this separate treatment in which neither emendation of a taxon definition nor unqualified attribution of specimens to a taxon are admissible, the taxa are not arranged in any formal hierarchy nor are the names latinized.

Qualified attribution in the form of graded comparison records is set out as follows:

cfA = variation in the comparison record agrees with that described for the reference taxon in all qualitative aspects, but minor quantitative differences may be included. This grade (cfA) is taken to indicate such close resemblance as would indicate stratigraphic correspondence.

cfB = variation in the comparison record may differ from that of the reference taxon in one specified qualitative aspect. This comparison is taken to indicate less close stratigraphic correspondence. The grade of cfB occurrences would normally stratigraphically enclose those of cfA.

cfC = adequate resemblance to the reference taxon to be useful in discussion, but normally used for occurrences which would be made into new biorecords if such were justified by geological necessity. Any one occurrence may be compared cfC with more than one reference taxon.

Any of these records may be placed by others in attribution to a Linnean taxon if that procedure appears to be rewarding, but the records themselves are designed to remain unchanged and separately retrievable for any purpose.

Group DINOCYST PERIDINIOID CRETACEOUS
Genusbox CINCTURO-

Diagnosis. Peridinioid dinocyst with ambitus subcircular to ovoidal, without pericoels or horns. Apex usually exhibits slight asymmetry. Periphragm thickness $< 0.5 \mu\text{m}$; sculpture rugulae and/or verrucae. Paratabulation obscure except where indicated by archaeopyle, believed to be (3I) or (A_3 3I). Pericingulum distinctly sculptured; perisulcus devoid of sculpture.

Comparison. *Cyclopsella* Drugg and Loeblich is unsculptured.

Archaeopyle references. Evitt (1967) and Norris (1978, p. 303).

Biorecord CINCTURO-JUDITH

Plate 65, figs. 1-9; Plate 66, figs. 1-5; text-fig. 1

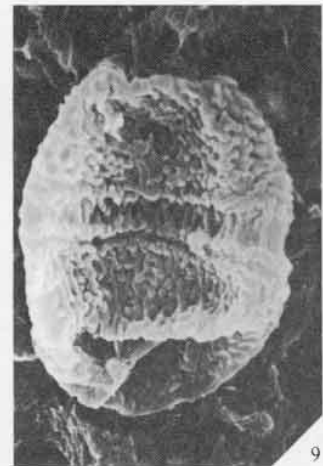
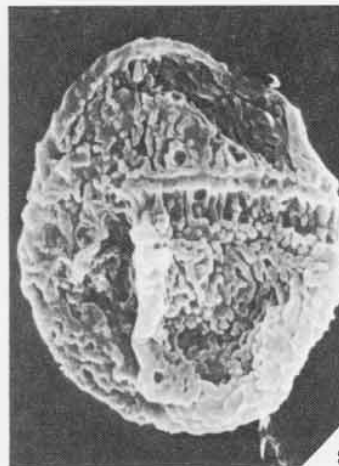
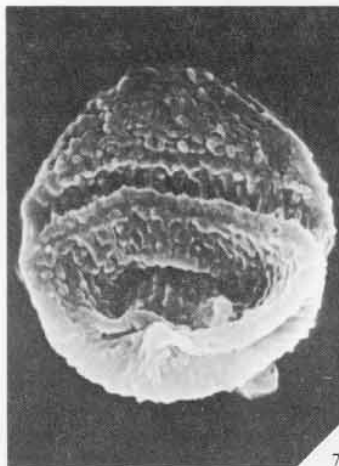
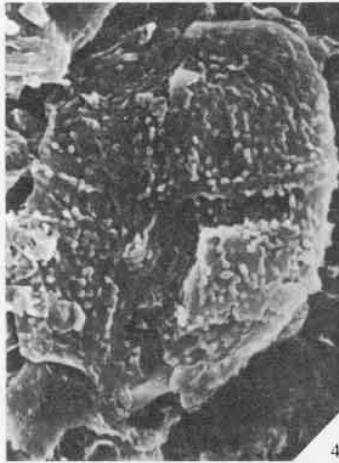
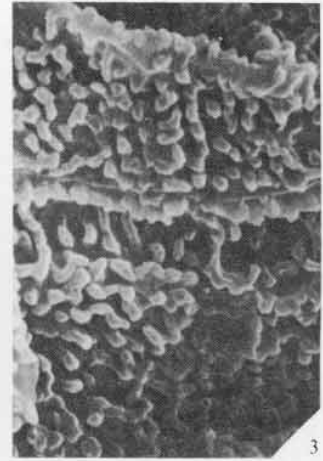
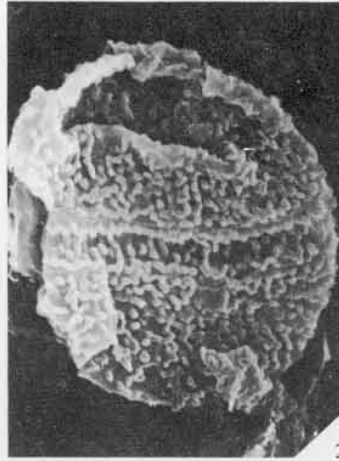
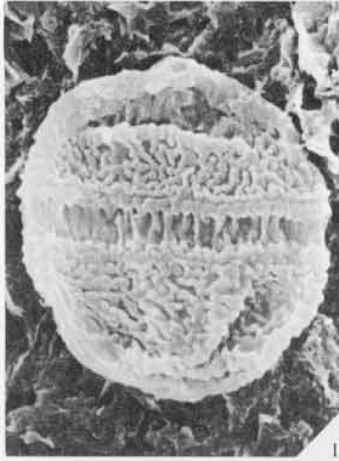
Record sample. B.G.S. Warlingham Borehole, depth (ft) 1258/2-4 (in.); greenish-grey compacted mudstone (blocky with weak lamination) with pyrite as streaks, burrow infillings and coatings on small fossils; small red-brown oxidation patches. Fauna: ostracods, small black fish spines, fish vertebrae, bone fragments, and brown spines. Preparation CH053/1(W120): oxidation 10 min cold conc. HNO_3 , centrifuged, heavy liquid mineral separation. Palynologic facies (200 counted): palynomorphs compressed, little damage, little corrosion; 48.5% Cincturo-Judith, 1% tectate-columellates, 34% saccates; 1.5% *Classopollis*, 1% *Eucommiidites*, 2.5% *Cicatricosisporites*, 11.5% other triletes.

Dimensions (100 specimens). Length (31.4) 37.0 (45.7) μm ; breadth (25.7) 33.1 (42.8) μm .

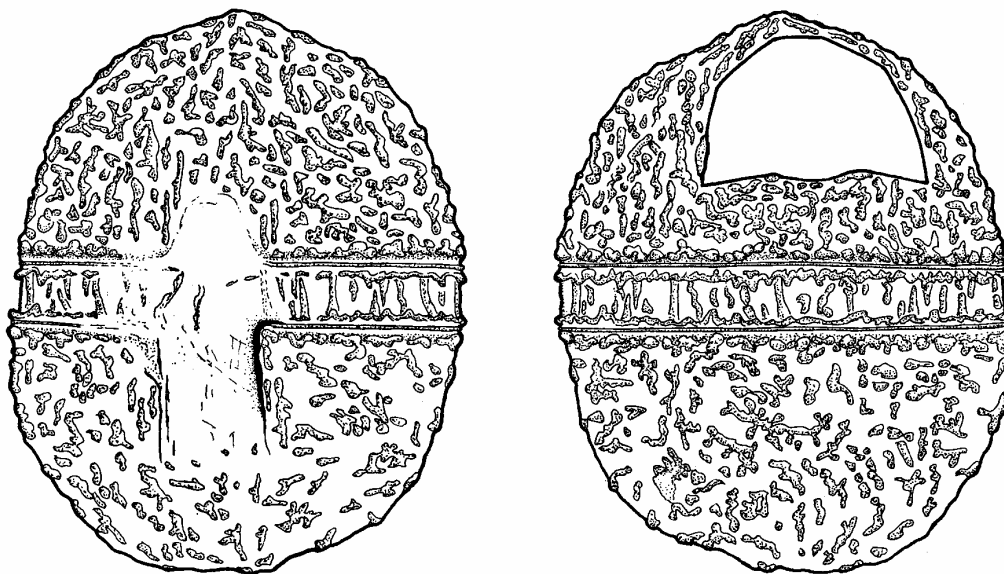
Description. Shape and structure. Pericyst: ambitus ovoidal or sub-circular, elongated anterior to posterior, widest immediately post-cingulum; slight dorsoventral flattening. Epicyst and hypocyst of approximately equal size. Apical region rounded; apex asymmetrically located in 40% of observed specimens; 24% displayed a short broad apical papilla. Antapex rounded. Periphragm thickness $0.4 \mu\text{m}$ (2 specimens; SEM photos); sculpture of rugulae (max. width $0.75 \mu\text{m}$) and verrucae (max. diameter $0.6 \mu\text{m}$). The specimens with apical papilla have 8 to 10

EXPLANATION OF PLATE 65

Figs. 1-9. Cretaceous dinoflagellate. Biorecord Cincturo-Judith: Barremian age; Upper Wealden, Warlingham Borehole, depth 1258' 2-4"; stub IC 105, preparation CH053, sample WM 1258' 2-4". Films HSF62 and 67. 1, 2, 4, 5, 7-9, $\times 1500$; 3, $\times 3000$; 6, $\times 6500$. Scanning electron micrographs. 1, ref. 213789, dorsal view (HSF67/07); 2, ref. 360823, dorsal view (HSF62/08); 3, detail of same, sculpture in pericingular region (HSF62/09); 4, ref. 238786, ventral view showing broad perisulcus (HSF62/06); 5, ref. 246892, oblique dorsal view, with prominent pericingulum (HSF62/07); 6, ref. 358875, endocyst exposed where pericyst is torn (HSF62/10); 7, ref. 315915, dorsal view (HSF62/11); 8, ref. 345910, slightly oblique ventral view showing perisulcal fold (HSF67/01); 9, ref. 337796; oblique view (HSF67/03).



HUGHES and HARDING, Cretaceous dinoflagellates

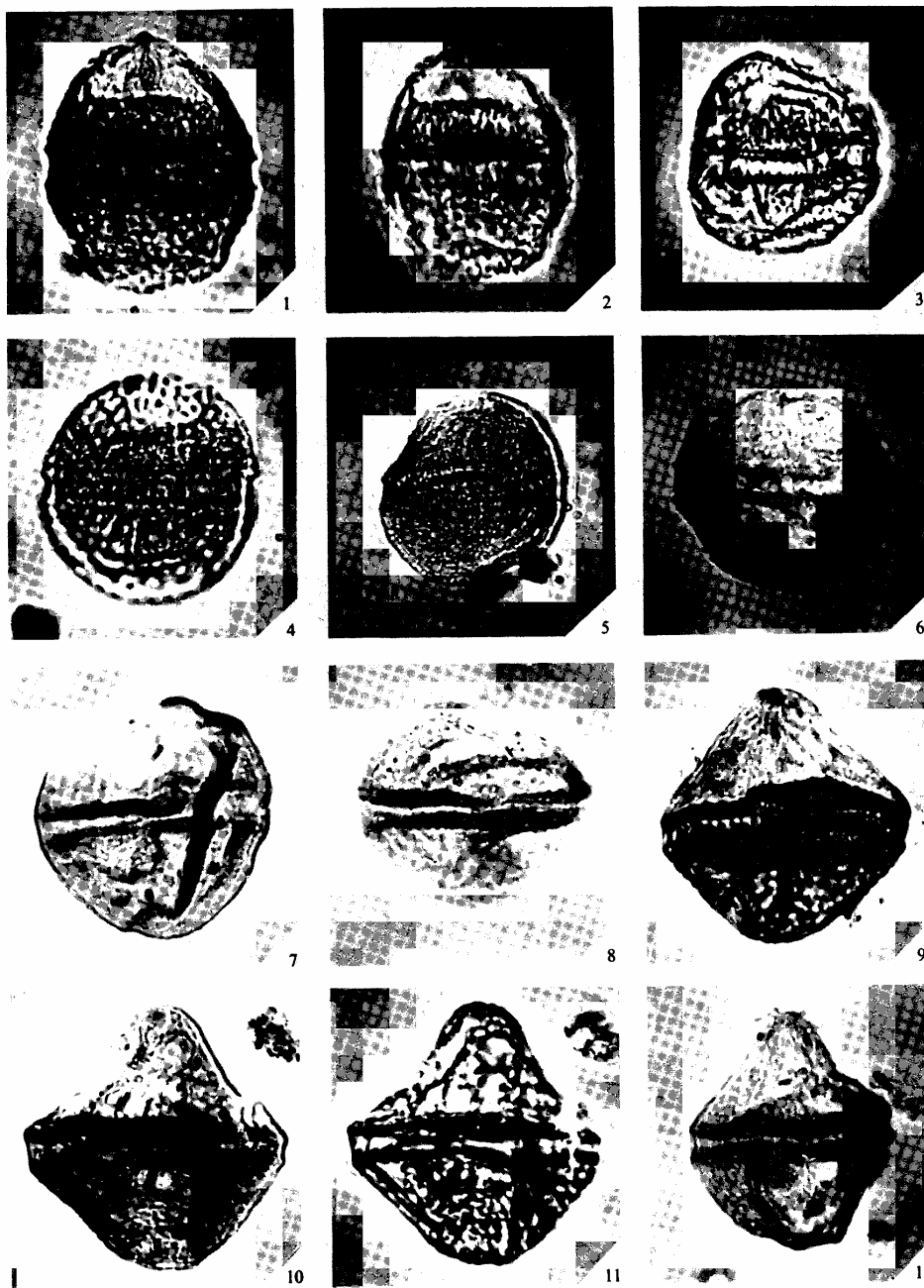


TEXT-FIG. 1. Generalized reconstruction of Cincturo-Judith, designed to show important morphological characters. *Left*, ventral view; *right*, dorsal view. $\times 1750$.

rugulae radiating irregularly from the papilla. Endocyst: distinguishable in specimens with antapical 'pericoel' (4%); closely adpressed to pericyst in most other specimens but separation of two walls seen when cyst is ruptured. Endophragm laevigate, $0.5 \mu\text{m}$ thick but considerably thinner in apical third of epicyst. Paratabulation. Pericingulum: planar, always prominent; anterior and posterior parasutures shown as continuous ridges $0.3 \mu\text{m}$ wide set in smooth pandasutural zone $0.8 \mu\text{m}$ wide; a row of papillate verrucae borders the pericingulum above and below, while the main sculpture of parallel cross striae (rugulae) fills the whole $3 \mu\text{m}$ width effectively obscuring any paratabulation. Perisulcus: strongly developed, mainly on hypocyst; depressed area of much reduced sculpture, bounded (in 59% of specimens) by prominent parallel sulcal folds $4-6 \mu\text{m}$ apart. Archaeopyle: (3I) or (A_3 3I) type, recognizable (4% of specimens) by broadly triangular opening extending almost to apex; 59% of cysts showed no excystment feature, but 35% were torn or ruptured in the apical region perhaps as a result of archaeopyle formation.

EXPLANATION OF PLATE 66

Figs. 1-12. Cretaceous dinoflagellates. Barremian age; Upper Wealden, Warmingham Borehole. Films HOF 13 and 14. 1-5, depth 1258' 2-4", slide CH053/1, biorecord Cincturo-Judith; 6-8, depth 1209' 9", slide W124/1, cf B Cincturo-Judith; 9-12, depth 1198' 2", slide BP556/3, biorecord Cincturo-Domed. All figures $\times 1000$, light micrographs. 2, 3, 10, phase contrast. Microscope reference SM306(OR3)Leitz646388. 1, 2, ref. 52.9/122.3, specimen focussed to show archaeopyle (HOF13/32, 13/35); 3, ref. 35.3/120.4, specimen showing asymmetry of apex (HOF13/12); 4, ref. 44.0/116.6, subcircular specimen with ?archaeopyle (HOF13/24); 5, ref. 38.3/124.6, focussed on pericingulum (HOF13/17); 6, ref. 29.5/124.1, slightly oblate specimen (HOF14/16); 7, ref. 28.1/126.2, specimen with reduced sculpture and thin apical region (HOF14/18); 8, ref. 50.4/123.1, showing prominent pericingular folds (HOF14/14); 9, ref. 43.5/119.9, specimen showing 'domed' epicyst and perisulcal fold (HOF14/19); 10, 11, ref. 49.7/113.2, showing general morphology (HOF14/33, 14/34); 12, ref. 59.2/118.3, displaying broad perisulcus (HOF14/32).



HUGHES and HARDING, Cretaceous dinoflagellates

Distinction. The single unnamed peridinacean cyst (Batten 1982, fig. 8.11f) with a prominent sculptured pericingulum appears to have a (4A3I) archaeopyle and dissimilar sculpture.

Comparison. Taxa in the genusbox *Cincturo-* are readily distinguishable from those in such genera as *Palaeoperidinium* (Deflandre) Sarjeant and *Subtilisphaera* (Jain and Millepied) Lentin and Williams, by their lack of apical and antapical horns. They can also be distinguished from the Tertiary genus *Saeptodinium* Harris by the strongly developed pericingulum, and from *Geiselodinium* Krutzsch by the lack of pericoels. The overall morphology bears some resemblance to *Cyclopsiella mura* Duxbury, although this is an unsculptured species of a genus which Stover and Evitt (1978) regarded as acritarchs.

Name. The first observations were made by Mrs. Judith C. Moody-Stuart in 1966.

COMPARISON RECORDS

cfA *Cincturo-Judith*: Warlingham Borehole; lithology as for WM1258/2-4, except for differences noted. Specimen counts represent whole content of one slide in each case.

WM 1254/1-3	(18 specimens):	plus bivalves, <i>Euestheria</i> . Prep. W067/1.
WM 1254/8	(56 specimens):	darker and more brownish colour. Prep. K127/1.
WM 1255/3-6	(309 specimens):	Prep. W100/1.
WM 1255/7-8	(34 specimens):	plus bivalves, gastropods. Prep. W121/1.
WM 1256/3-4	(95 specimens):	darker and more brownish colour. Prep. M68/1.
WM 1258/2-4	(428 specimens):	Biorecord (see above).
WM 1258/9	(401 specimens):	Prep. Z212/3.
WM 1259/0	(63 specimens):	plus <i>Euestheria</i> . Prep. Z182/3.
WM 1259	(2 specimens):	Prep. CH009/2.
WM 1259/6-9	(78 specimens):	Prep. Z207/1.
WM 1260/-	(210 specimens):	Prep. W119/2.
WM 1261/10-11	(588 specimens):	plus <i>Euestheria</i> . Prep. W068/1.
WM 1262/0-1	(294 specimens):	plus <i>Euestheria</i> . Prep. W069/1.
WM 1262/2-3	(490 specimens):	Prep. K098/2.
WM 1262/6	(126 specimens):	plus <i>Euestheria</i> . Prep. W108/1.
WM 1277/9	(21 specimens):	brownish; flaser bedding, pale brown; rare ostracods. Prep. Z216/3.
WM 1278/8	(7 specimens):	brownish; no ostracods. Prep. BP558/1.
WM 1279/2	(2 specimens):	brownish; no ostracods. Prep. W118/1.
WM 1279/3	(5 specimens):	brownish; no ostracods. Prep. Z217/3.
WM 1297/10	(11 specimens):	brownish; flaser bedding, pale brown; no ostracods. Prep. Y563/4.

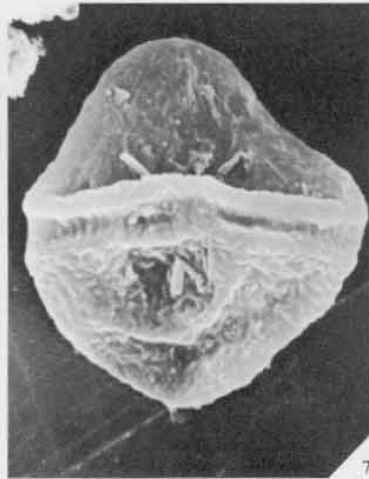
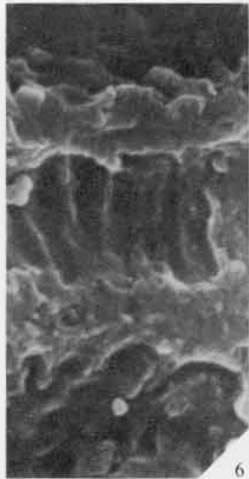
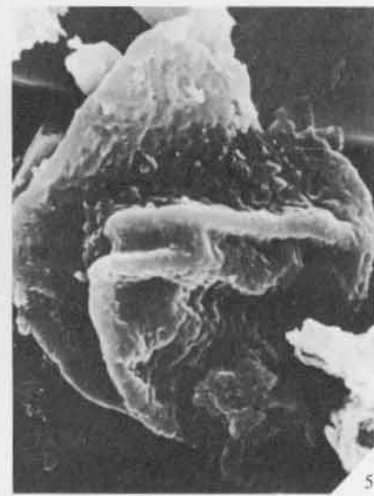
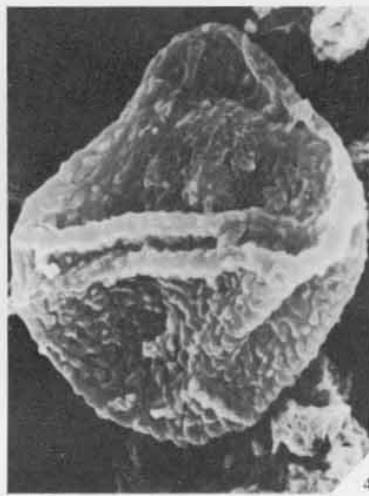
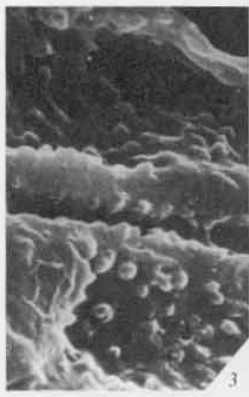
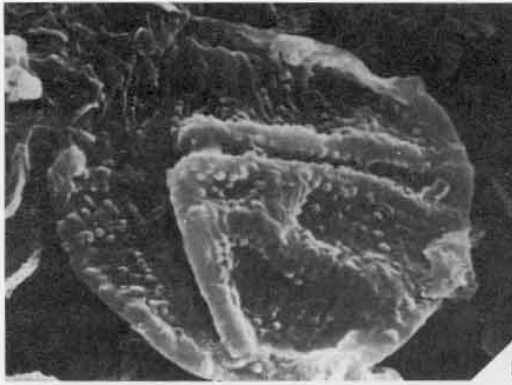
cfB. CINCTURO-JUDITH

Plate 66, figs. 6-8; Plate 67, figs. 1-3

Record sample. B.G.S. Warlingham Borehole, depth (ft) 1209/9 (in); olive green compacted mudstone with brownish tint (blocky with very weak lamination); few pyrite patches. Fauna: numerous fish fragments, black

EXPLANATION OF PLATE 67

Figs. 1-8. Cretaceous dinoflagellates. Barremian age; Upper Wealden, Warlingham Borehole. 1-3, stub IC112, preparation W124, sample WM1209' 9", cfB *Cincturo-Judith*; 4-8, stub IC161, preparation BP556, sample WM1187' 2", biorecord *Cincturo-Domed*. Films HSF62, 63, and 66. 1, 4, 5, 7, 8, $\times 1500$; 3, 6, $\times 3000$. 1, 3, ref. 232754, 1, oblique ventral view showing perisulcal fold (HSF62/15); 3, detail of sculpture (HSF62/16); 2, ref. 236784, showing reduced size of epicyst (HSF62/14); 4, ref. 363771, dorsal view showing domed epicyst (HSF63/09); 5, ref. 361775, oblique ventral view showing epicystal archaeopyle (HSF63/08); 6, ref. 365760, detail of sculpture (HSF66/02); 7, ref. 350761, dorsal view (HSF63/13); 8, ref. 351762, oblique apico-ventral view (HSF63/12).



HUGHES and HARDING, Cretaceous dinoflagellates

bones, vertebrae, spines. Preparation W124/1: oxidation 10 min cold conc. HNO_3 , centrifuged, heavy liquid mineral separation. Palynologic facies: 31% cfB. Cincturo-Judith, 1% tectate-columellates and monosulcates, 28.5% saccates, 10% *Classopollis*, 3% *Eucommiidites*, 3.5% *Cicatricosisporites*, 22% other triletes, 1% fungal debris.

Dimensions (50 specimens). Length (45.6) 38.5 (34.2) μm ; breadth (45.6) 38.3 (31.4) μm .

Distinction from biorecord. Pericyst shape: high proportion (42%) broader than long; hypocyst larger, about six-tenths of whole. Periphragm: thickness 0.5 μm (one SEM photo); sculpture less prominent as verrucae (max. diameter 0.6 μm) or short rugulae (max. length 3 μm). Paratabulation: pericingulum wider, up to 4 μm , but often reduced by secondary folding; cingular sculpture of less distinct uneven vertical corrugations; pandasutural zone bordered by discrete verrucae; parasulcus emphasized by folds (70% of specimens); archaeopyle not seen, but apical rupture frequent.

Other cfB records

WM 1180/6 (36 specimens): Prep. K345/1.

WM 1181/2-10 (85 specimens): same lithology as biorecord, more fish remains. Prep. M679/1.

WM 1184/0-2 (40 specimens): more fish remains. Prep. K125/1.

WM 1209/9 (672 specimens): (see above).

Palynofacies. All of the cfA and cfB records occur in palynofacies rich in amorphous finely comminuted organic matter ('mush'). This material may be a partial case of the greenish colouration of the samples. *Botryococcus* has rarely been observed in these preparations and without it there is no reason to regard the 'mush' as indicative of an anoxic lacustrine environment in the sense of Sladen and Batten (1984).

Biorecord CINCTURO-DOMED

Plate 66, figs. 9-12; Plate 67, figs. 4-8

Record sample. B.G.S. Warlingham Borehole, depth (ft) 1187/2 (in.); khaki greenish compacted blocky mudstone, almost conchoidal fracture, 'greasy' to touch, weak lamination, small pyrite patches. Fauna: fish vertebrae and spines (brown), *Euetheria*. Preparation BP556/3; oxidation 60 min cold conc. HNO_3 , centrifuged; mounted in glycerine jelly. Palynologic facies (200 counted): 51.5% Cincturo-Domed, 4.5% tectate-columellates, 15.5% saccates, 10% *Classopollis*, 1% *Eucommiidites*, 3% *Cicatricosisporites*, 3% other triletes, 6.5% *Celyphus rallus*.

Dimensions. (50 specimens). Length (48.5) 42.3 (31.4) μm , breadth (48.5) 39.6 (28.5) μm .

Description. Shape and structure. Pericyst: ambitus pear-shaped, elongated anterior to posterior; epicyst blunt-ended concave-sided; hypocyst rounded, of comparable overall dimensions with epicyst; greatest width immediately post-cingular; slight dorsoventral flattening. Periphragm: thickness 0.3-0.4 μm (observed on two SEM photos); sculpture more pronounced on hypocyst, short rugulae (up to 5 μm long) and/or verrucae; epicyst rugulae of low relief, continuous, radiating from blunt apex. Endocyst: laevigate, 0.4-0.5 μm thick (SEM photos), thinning rapidly in apical third of epicyst. Paratabulation. Pericingulum: planar, narrow, distinct; width (3-4 μm), sculpture uneven vertical corrugations and striae obscuring tabulation; width reduced by secondary compression; pandasutural zones without sculpture. Perisulcus: mainly on hypocyst, 4 μm wide; bounded by parallel ridges, secondarily developed into folds. Archaeopyle: not clearly observed, but frequent dorsal rupturing of cyst wall in 'intercalary' position, affecting up to one-third of epicyst.

Distinction. Only known from this sample (1258 specimens); differs in shape and excystment feature from *Cyclopsiella mura* Duxbury 1983. Accompanied by very rare *Veryhachium*-type acritarchs.

STRATIGRAPHIC POSITION OF SAMPLES

Succession. The main occurrences of Cincturo-Judith are in the strata immediately below Topley's Bed 6 'Large Paludina' at 1252 ft (Worssam and Ivimey-Cook 1971, p. 22). The occurrence of Cincturo-Domed and most of the cfB records of Cincturo-Judith are from just above Topley's

Bed 7 'Sandstone' at 1210–1238 ft. The base of the Lower Greensand (Aptian) is taken at 1047 ft, making all these samples Barremian or earlier.

Ostracods. F. W. Anderson (in Worssam and Ivimey-Cook 1971) placed all these beds in his *Cypridea bogdenensis* beds of his *C. clavata* Zone, and further placed his Gillmans Cycle of 'C' and 'S' phases between 1248 and 1263 ft. Our samples (1254–1263 ft), which were taken from the cores after those used by Anderson, included identifications of *C. clavata* (spinose), *C. valdensis* (large, punctate), *C. rotundata* (medium size, punctate), *C. spinigera* (unispinose), *Theriosynoecum fittoni* (especially from WM1258/9 in great numbers), *Darwinula leguminella*, and *D. oblonga*. Less certain identifications were of rare *Mantelliana mantelli* and ?*Fabanella boloniensis* (both from WM1258/9) and ?*Miocytheridea henfieldensis* (from WM1255/7–8). Of these all the *Cypridea*, *Darwinula*, and *Miocytheridea* species form part of Anderson's 'C' phase of fresh/brackish water; *Theriosynoecum* is found in association with *Cypridea* and is probably from fresh-water (Kilenyi and Allen 1968, and our data); the others relate to Anderson's 'S' phase, which he regarded as 'marine'. The age indication by Anderson (1973) and Kilenyi and Neale (1978) for these samples would be Late Hauterivian to Early Barremian.

Angiospermid pollen. Various tectate-columellate pollen from lower levels in the Warlingham Borehole down to 1415 feet (Hughes *et al.* 1979) are believed from correlation with similar occurrences from north of the London–Brabant uplift to be of early Barremian age.

PALYNOMORPHS AND WEALDEN PALAEO-SALINITIES

Hitherto the presence of dinocysts in Mesozoic palynomorph assemblages in which reworking was considered unlikely, has normally been taken as straightforward indication of marine conditions.

Recently it has been pointed out (Hughes 1980; Batten 1982; Batten and Eaton 1980) that several horizons through the otherwise fresh-water Wealden provide restricted dinocyst assemblages; individual horizons may contain up to four dinocyst species normally found in marine rocks of comparable age. These horizons have been interpreted as resulting from marine incursions; but presumably these incursions were both incomplete and short-lived because stenohaline marine megafossils have not been found except in one case at the very top of the Weald Clay in Kent, just below the main Aptian incursion (Casey 1961).

The occurrences described in this paper differ in each featuring only one dinocyst taxon that is in abundance up to 75% and that is not known to exist elsewhere in any fully marine circumstances.

Finally the great majority of Wealden palynomorph assemblages include no dinocysts or acritarchs at all and are consequently interpreted as of fresh-water origin.

It is tempting to regard these occurrences as a gradation from fully marine, through major fluctuations say down to one half salinity (with three or four dinocyst taxa) to minor fluctuations with say some such low level as one quarter salinity (with one unique taxon) to fresh water. No salinity percentage figures could be suggested because the Cretaceous general marine salinity was probably not 34.4‰. In addition it is perhaps more likely that incursive water-masses bearing living dinocysts were both local and transient, and that no sector of the Wealden 'lake' settled down to a distinct geographical salinity gradient as in the present Baltic Sea with steady conditions and organism representation for any length of time.

OTHER INDICATIONS OF WEALDEN PALAEO-SALINITY

It is important that in the Wealden of Southern England from beginning Berriasian to end Barremian no cephalopod, echinoderm, coral, foraminiferan, or brachiopod has been recorded and there were thus no fully marine situations.

Anderson (1973) claimed that his 'S' phase ostracods represented marine conditions, alternating with his more usual 'C' phase ostracods representing fresh/brackish water. All of our samples from

Warlingham 1254 to 1263 contained ostracods in quantity and of these only rare specimens of ?*Mantelliana* and ?*Fabanella* at WM1258/9 could be taken to represent 'S' phase; all others were 'C' phase ostracods. Anderson (1971) regarded the triple 'S' phase, styled by him, Gillman's cycle, as a distinct incursion; our ostracod fossils from fifteen samples in these 10 ft of strata do not indicate anything dramatic. Possibly there was a minor fluctuation as indicated by the dinocysts, which is also in keeping with the findings of Kilenyi and N. W. Allen (1968) but scarcely with those of P. Allen and Keith (1965).

Dr. C. V. Jeans has kindly examined by X-ray diffraction the clay mineral assemblages ($< 2 \mu\text{m}$ e.s.d.) from a series of eight samples spanning the horizons of occurrence of these dinocysts (Jeans 1978, p. 625 for method). Identification was carried out at the level of clay mineral groups and he concluded that no systematic variations within these assemblages could be related to these particular horizons. Such a view does not conflict with our interpretation that these consistently greenish samples bearing ostracods, fish fragments, and pyrite, in addition to abundance of a unique dinocyst, represent a minor salinity fluctuation. We further do not accept the suggestion of Sladen and Batten (1984, p. 161) that these salinity changes could reflect evaporation cycles in the basin.

Clearly, chemical investigations should have been and have been attempted (Allen *et al.* 1973) but the results are cautious and appear inconclusive in the context of our present observations. The bivalve *Filosina* referred to by Allen *et al.* (1973) as marine, has not been observed in the borehole sector we are studying.

CONCLUSIONS

Our evidence and that of previous papers suggests that in general early Cretaceous dinocysts were confined to marine conditions which their presence may be taken to indicate.

On the other hand the dinocysts Cincturo-Judith and Cincturo-Domed as described above appear to be genuine dinocysts which occur in a facies which is distinct from the rocks above and below and represented perhaps some slight degree of salinity. The occurrence of these dinocysts in abundance, without any others present, suggests the beginning of a trend that may have led in late Tertiary and Recent time to the freshwater armoured dinoflagellate thecae.

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