

## MICROPLANKTON FROM THE KELLAWAYS ROCK AND OXFORD CLAY OF YORKSHIRE

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ABSTRACT. Assemblages of microplankton from the Kellaways Rock and Oxford Clay of Yorkshire are described. They consist dominantly of hystrichospheres, including new species of *Cymatiosphaera* and of *Cannospheropsis*. Dinoflagellates are also prominent, with *Gonyaulax jurassica* Deflandre most abundant: two new species of *Gonyaulax* are described. Organisms *incertae sedis*, probably microplankton, are present: three new genera, *Stephanelytron*, *Antrosphaera*, and *Netrelytron*, and a new species of *Wanaea* are described. The character and stratigraphic significance of the assemblages are discussed.

FOUR assemblages of fossil microplankton are dealt with here, all from the Upper Jurassic of the Yorkshire coast. The lowest horizon examined was the Kellaways Rock (*Sigaloceras calloviense* Zone), a rather sparse assemblage being obtained from a sample of calcareous sandstone 1 foot below the base of a thick argillaceous sandstone and approximately 45 feet below the base of the Oxford Clay, in the exposure in the cliff below Scarborough Castle (grid reference 053890). The Hackness Rock (*Quenstedtoceras lamberti* Zone) from the same locality was also examined: however, the sample of ferruginous oolite from the uppermost Hackness Rock yielded plenty remains and abundant wood fragments, but very little pollen and no microplankton. Three horizons of the Oxford Clay (*Quenstedtoceras mariae* Zone) were examined: each sample was of grey clay, quite highly calcareous, and each yielded an abundant microplankton assemblage. The lowest horizon studied was 1 foot above the top of the Hackness Rock, exposed at the base of Scarborough Castle cliff. The other samples were from High Red Cliff, Cayton Bay (grid reference 077843),  $3\frac{1}{2}$  miles south-east of the previous locality, and from horizons respectively 25 feet above and between 90 and 100 feet above the top of the Hackness Rock (henceforth referred to as the '25-foot' and '100-foot' horizons).

Each sample examined was crushed mechanically, treated with hydrochloric acid to remove carbonates, then heated in hydrofluoric acid to remove silicates. The residue was then macerated in Schultz solution for periods of between 15 minutes and 1 hour, maceration time varying according to the amount of residue and its appearance on microscopic examination; the object of maceration was to remove by oxidization the bulk of plant tissues and of structureless 'humic' substances. The resultant concentrates were mounted in various fashions; polyvinyl acetate resin, Santolite, Lakeside cement, and solid and liquid Canada balsam were experimented with, but glycerine jelly was found the most satisfactory mountant. Safranin stain, mixed with the glycerine jelly, successfully stained and gave satisfactory contrast to the rather colourless microfossils, its only disadvantage being the unavoidable masking of the original colour of the microfossils.

In the mounts of Kellaways Rock material, microplankton formed only about 5 to 10 per cent. of the total microfossil assemblage, the remainder comprising spores, pollen, and the shell linings of foraminifera. The assemblage of microplankton, domi-

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nantly hystrichospheres with dinoflagellates forming only 7 per cent., described from this material was thus numerically relatively small: it proved intermediate in character between the Oxford Clay assemblage and a Cornbrash assemblage described in an earlier paper (Sarjeant 1959). The Oxford Clay mounts proved considerably richer in microplankton, the latter making up 60–70 per cent. of the total microfossil assemblage. Hystrichospheres again dominated the microplankton, but this time the dinoflagellates proved more abundant. In the lowest horizon, dinoflagellates form 20 per cent. of the microplankton; in the 25-foot horizon, 10 per cent.; and in the 100-foot horizon, 40–45 per cent. Spores and pollen form the remainder of the assemblage, with the shell linings of foraminifera very subordinate (less than 1 per cent.). There are in addition a small number of simple sacs, probably but not certainly pollen.

The fossil microplankton are on the whole very well preserved, and in damaged forms the damage seems in many cases to have occurred before fossilization. Eight species of dinoflagellates were identified, *Gonyaulax jurassica* Deflandre being the most abundant at all horizons; twenty species of hystrichospheres were distinguished; and six species of organisms *incertae sedis* but probably also microplankton. All specimens described are now in the collection of the Micropalaeontology Laboratory of the Department of Geology, University of Sheffield.

#### DESCRIPTION OF THE ASSEMBLAGES

Class DINOFLAGELLATA

Family GONYAULACIDAE

Genus GONYAULAX Diesing

*Gonyaulax jurassica* Deflandre 1938

Plate 13, figs. 1, 9–12; text-figs. 1–3

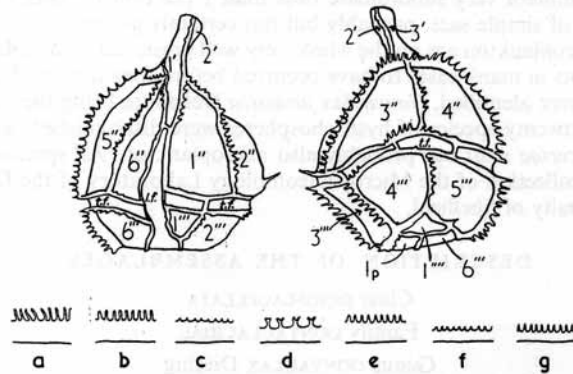
*Remarks.* This species, previously recorded from the Bathonian (Valensi 1953) and Oxfordian of France (1938) and from the Kimeridgian of England (Downie 1957), proved extremely abundant. Observed distribution: Kellaways Rock 4; Oxford Clay, lowest 40, 25-foot 6, 100-foot 79. Of these, six have been attributed to Deflandre's variety *longicornis* (see later).

The tabulation corresponds in its general features with that described by Deflandre. Plate 1", however, shows some variation in shape: in all specimens from the lowest and 25-foot horizons of the Oxford Clay where this plate can be clearly seen, its shape is triangular (the figured specimen CB56/11/29 shows this well). In specimens from the Kellaways Rock and highest Oxford Clay by contrast, plate 1" was reduced and elongate as in the type. The significance of this variation remains obscure.

Considerable variation is exhibited in height and degree of denticulation by the crests on sutures, seven principal variations being noted (see text-fig. 1). All were observable in specimens from the lower horizons, variation *d* being displayed by only one specimen (SC2/31/2). However, variation in specimens from the 25-foot and highest Oxford Clay horizons was restricted to types *a*, *b*, or *c*, i.e. high crests with widely spaced, slender denticles of varying height. Deflandre has commented on the extreme variability of general form in *G. jurassica*, noting all intermediates from specimens with convex flanks to others with concave flanks. He records a range of overall lengths from

65 to 100  $\mu$ ; this corresponds closely with the range observed from these specimens (55–102  $\mu$ ).

Eighty specimens from the Oxford Clay, comprising 37 specimens from the lowest, 5 from the 25-foot, and 38 from the 100-foot horizons, were measured; the accompanying graphs represent the results of this study. In the first (text-fig. 2) thecal length without crests is plotted against thecal breadth without crests. Whilst the deformability of the theca certainly affects these measurements in some degree, the result shows that increase in length is accompanied by increase in breadth, the correlation not being, however, very close. The second graph (text-fig. 3) shows overall length plotted against



TEXT-FIG. 1. Tabulation of a specimen of *Gonyaulax jurassica* Deflandre showing a triangular plate 1''. Left: in ventral view. Right: in dorsal view. The specimen figured is CB56/11/29,  $\times 600$ . *t.f.*, transverse furrow; *l.f.*, longitudinal furrow. Below: different forms of sutural crests developed by *G. jurassica* [based on CB81/15/12 (a), CB81/6/18 (b), CB81/12/5 (c), SC2/31/2 (d), SC2/32/16 (e), SC2/29/10 (f), and SC2/32/22 (g)],  $\times 500$ .

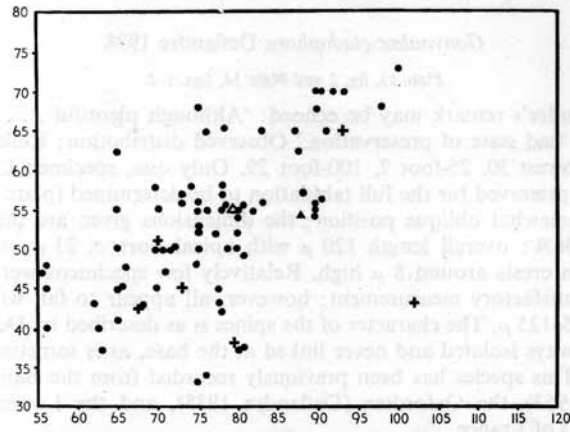
horn length: an increase of length of horn with increasing size is evidenced. Separate plotting of measurements of the faunas from each horizon produced no indication of differences between horizons.

Deflandre comments: '. . . stains fix in a very capricious manner'. He lists twelve stains, all of which were taken up in varying degree by his specimens and mentions carmine and safranin as tried without success. The Yorkshire specimens took up safranin very readily, emphasizing the validity of Deflandre's comment.

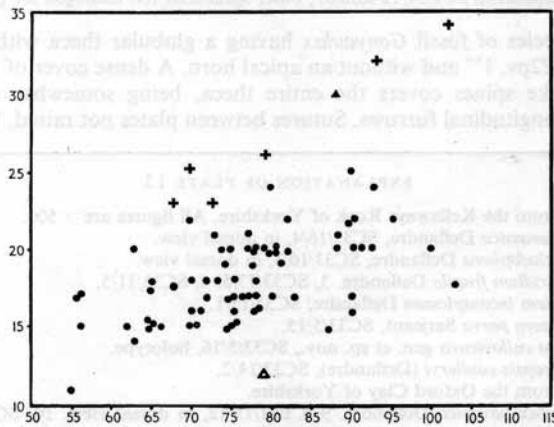
*Gonyaulax jurassica* var. *longicornis* Deflandre 1938

Text-figs. 2-3

*Remarks.* Three specimens from the lowest and three from the 100-foot Oxford Clay horizons were attributed to this variety, previously described only from the Oxfordian of France. All have a horn length at least one-third of the overall length. Their dimensions have been plotted on the graphs (text-figs. 2 and 3). On the graph on which thecal length and breadth are related they do not form any distinct group. From the second graph, where horn length is plotted against overall length, it may be seen that there is



TEXT-FIG. 2. Relationship of thecal length and breadth in *Gonyaulax jurassica*. Diagram based on an assemblage of eighty specimens from the Oxford Clay of Yorkshire. Measurements are given in  $\mu$ .  $\Delta$ , type of *G. jurassica*;  $\blacktriangle$ , type of *G. jurassica* var. *longicornis*; +, Yorkshire specimens of *G. jurassica* var. *longicornis*.



TEXT-FIG. 3. Relationship of overall length to horn length in *Gonyaulax jurassica*. Diagram based on an assemblage of eighty specimens from the Oxford Clay of Yorkshire. Measurements are given in  $\mu$ .

no clear distinction between this variety and the normal *G. jurassica* and that these are merely forms at the extreme end of the scatter.

*Gonyaulax cladophora* Deflandre 1938

Plate 13, fig. 2 and Plate 14, figs. 1-2

*Remarks.* Deflandre's remark may be echoed: 'Although plentiful . . . this species is most often in a bad state of preservation.' Observed distribution; Kellaways Rock 2, Oxford Clay, lowest 30, 25-foot 7, 100-foot 29. Only one, specimen CB81/10/5, was sufficiently well preserved for the full tabulation to be determined (plate 2" being missing). It is in somewhat oblique position; the dimensions given are thus taken from specimen SC2/36/4: overall length 120  $\mu$  with apical horn *c.* 23  $\mu$ , overall breadth 100  $\mu$ , spines on crests around 8  $\mu$  high. Relatively few specimens were well enough preserved for satisfactory measurement; however, all appear to fall within the range overall length 65-125  $\mu$ . The character of the spines is as described by Deflandre except that they are always isolated and never linked at the base, as is sometimes the case in his specimens. This species has been previously recorded from the Bajocian (Mercier 1938; Valensi 1953), the Oxfordian (Deflandre 1938), and the Lower Kimmeridgian (Deflandre 1941) of France.

*Gonyaulax acanthosphaera* sp. nov.

Plate 13, fig. 14; text-fig. 4

*Holotype.* SC2/32/23, lowest Oxford Clay, Scarborough Castle cliff. *Dimensions of type.* Length 65  $\mu$ , breadth 65  $\mu$ , transverse furrow *c.* 5  $\mu$  in width. Spines on sutures *c.* 1  $\mu$  in length, spines elsewhere *c.* 0.3  $\mu$  in length. Specimen SC2/34/12 similar; other specimens too damaged for measurement.

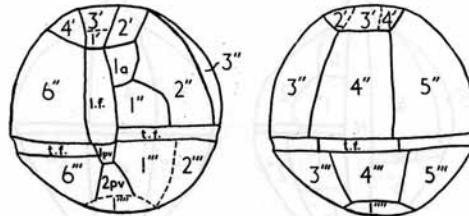
*Diagnosis.* A species of fossil *Gonyaulax* having a globular theca with the tabulation ?3', 1a, 6", ?6", ?2pv, 1"" and without an apical horn. A dense cover of extremely short, blunt, stubble-like spines covers the entire theca, being somewhat reduced on the transverse and longitudinal furrows. Sutures between plates not raised, but ornamented

EXPLANATION OF PLATE 13

- Microplankton from the Kellaways Rock of Yorkshire. All figures are  $\times 500$ .  
 Fig. 1. *Gonyaulax jurassica* Deflandre, SC33/16/4, in dorsal view.  
 Fig. 2. *Gonyaulax cladophora* Deflandre, SC33/16/3, in dorsal view.  
 Figs. 3-4. *Micrhystridium fragile* Deflandre. 3, SC33/17/5. 4, SC33/11/5.  
 Fig. 5. *Micrhystridium inconspicuum* Deflandre, SC33/15/1.  
 Fig. 6. *Cymatiosphaera parva* Sarjeant, SC33/5/15.  
 Fig. 7. *Antrosphaera calloviensis* gen. et sp. nov., SC33/5/16, holotype.  
 Fig. 8. *Cannosphaeropsis caulleryi* (Deflandre), SC33/14/2.  
 Microplankton from the Oxford Clay of Yorkshire.  
 Figs. 9-12. *Gonyaulax jurassica* Deflandre. 9, CB81/15/12, in dorsal view. 10, SC2/33/10, in dorsal view. 11, SC2/4/29, in ventral view. 12, CB56/11/29, in oblique ventral view.  
 Fig. 13. *Gonyaulax areolata* sp. nov., SC2/34/21, holotype, in ventral view.  
 Fig. 14. *Gonyaulax acanthosphaera* sp. nov., SC2/32/23, holotype, in ventral view.  
 Fig. 15. *Gonyaulax* sp., SC2/28/9.  
 Fig. 16. *Pareodinia ceratophora* Deflandre, CB81/6/4.  
 Fig. 17. *Pareodinia ceratophora* Deflandre var. *pachyceras* Sarjeant, SC2/33/25.

with rows of short spinelets, some bifurcating, longer than those of the general spine cover.

*Description.* Theca yellowish in colour. Tabulation not easy to determine since sutures are not raised and their longer spines readily escape notice against the dense background of shorter spines. Apparently three apical plates: however, plate 1' of type gives suggestion of possible subdivision into two. One anterior intercalary plate and six pre-equatorial plates, with plate 1'' reduced. Transverse furrow extends around theca in laevo-rotatory spiral such that its two ends differ in antero-posterior position by the furrow's width. Longitudinal furrow broad: small posterior ventral plate present, corresponding to its hypothecal extension and adjacent to the more posterior of the two ends of the transverse furrow. A second posterior ventral plate, somewhat larger in size, appears to be present between this and the polygonal antapical plate. Six post-equatorial plates present. Holotype somewhat damaged; tabulation of the dorsal



TEXT-FIG. 4. Tabulation of *Gonyaulax acanthosphaera* sp. nov. Left: in ventral view. Right: in dorsal view. Figures based on the holotype SC2/32/23, and a paratype, SC2/34/12. p.v., posterior ventral plate.  $\times 500$ .

surface therefore based on specimen SC2/34/12. Holotype encloses (below plate 1'') a round brownish body, apparently of organic material and with an irregular spiny margin.

*Remarks.* It is probable that this dinoflagellate is more numerous than appears from the number of specimens recorded (six); however, other specimens seen may well have been confused with the hystrichosphere *Baltisphaeridium* cf. *fimbriatum*, abundant in this material and also having a cover of short spines. All specimens recorded were from the lowest Oxford Clay horizon.

In its spherical shape and dense spine cover *G. acanthosphaera* differs from all eight described fossil species of *Gonyaulax* lacking apical horns. It finds its closest comparison in *Palaeoperidinium castanea* Deflandre 1935 from the Cretaceous of France, a globose form with a cover of short spines, but differing from *G. acanthosphaera* by possession of a denticulate apical horn and a definitely different tabulation.

*Gonyaulax areolata* sp. nov.

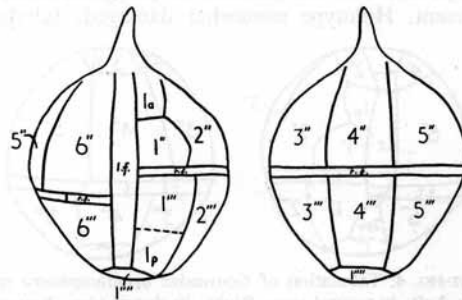
Plate 13, fig. 13; text-fig. 5

*Holotype.* SC2/34/21, lowest Oxford Clay. Scarborough Castle cliff. *Dimensions.* Holotype: overall length  $155 \mu$ , length of horn  $25 \mu$ , overall breadth  $125 \mu$ ; transverse furrow c.  $10 \mu$  wide, longitudinal

furrow *c.* 5  $\mu$  wide. Range of dimensions observed: overall length 120–170  $\mu$ , relative proportions being fairly constant.

*Diagnosis.* A species of fossil *Gonyaulax* with an ovoid theca having the tabulation ?', 1a, 6", 6"', ? 1p, 1''' and with a strong, tapering apical horn rounded at its extremity. The whole thecal surface except the longitudinal and transverse furrows is covered by low ridges forming an irregular reticulate patterning; the thecal wall is very thin but consists of two layers, the outer layer bearing the ridges. The boundaries of plates and the furrow margins bear low alveolate crests. The longitudinal furrow extends from apex to antapex; it is narrow, as is the transverse furrow.

*Description.* Theca yellowish. Tabulation not easily discerned and a composite text-figure therefore given. Apical tabulation obscure. An anterior intercalary plate clearly



TEXT-FIG. 5. Tabulation of *Gonyaulax areolata* sp. nov. Left: in ventral view. Right: in dorsal view. Diagrammatic, based on the holotype SC2/34/21 and on several paratypes.  $\times 300$ .

present, plus six pre-equatorial plates, of which the first (1') is reduced. Transverse furrow extends around theca in a strong laevo-rotatory spiral such that its two ends differ in antero-posterior position by approximately three times the furrow's width. Six post-equatorial plates certainly present; a posterior intercalary plate appears present but could not be definitely confirmed. No posterior ventral plates present, longitudinal furrow extending to polygonal antapical plate. Surface reticulation of ridges dense; fields delimited by these ridges always small, not regularly polygonal but varying considerably in relative size and shape. Reticulation extending on to apical horn but absent from furrows. Crests consist of linked processes (links sometimes broken) arising from sutures, their points of origin corresponding with junctions of ridges with sutures.

*Remarks.* Observed distribution: Oxford Clay, lowest 9, 100-foot 15. Not recorded from the Kellaways Rock.

Three fossil species previously recorded also bear reticulate patterning. One, *Gonyaulax obscura* Lejeune-Carpentier, from the Cretaceous of France and Germany (1946), differs by having a polygonal theca with a very thick membrane and a very different tabulation clearly marked by high sutures. *Palaeoperidinium ventriosum* O. Wetzel, a Cretaceous dinoflagellate recorded by the German author from the Baltic region (1933)

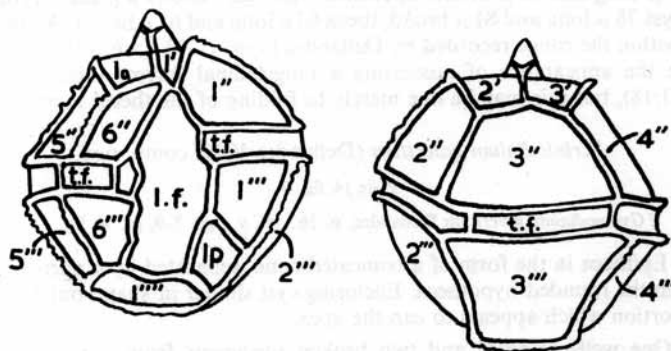
and by Deflandre from France (1936), is similar in outline, but the theca is globular and its crests bear 'thin and transparent veils'. Its tabulation, which has led Lejeune-Carpentier to suggest its attribution to the genus *Peridinium*, is quite different. Closest comparison is found in the Oxfordian *Palaeoperidinium dictyophorum* Deflandre, attributed to that genus in absence of precise knowledge of the tabulation but considered by its author probably relatable to *Gonyaulax*. This species, recorded from Villers-sur-Mer, France, differs from *G. areolata* in the shape of its apical horn, broad and very blunt, in the absence of raised crests, and in the greater breadth of the longitudinal furrow.

*Gonyaulax* sp.

Plate 13, fig. 15; text-fig. 6

*Specimen*. SC2/28/9, lowest Oxford Clay, Scarborough Castle cliff. *Dimensions*. Overall length 47  $\mu$ , length of horn 5  $\mu$ ; overall breadth 45  $\mu$ , width of transverse furrow c. 5  $\mu$ .

*Description*. Theca globular to polyhedral, yellowish in colour and lacking any pronounced granulation, divided into plates by raised sutures. Apex occupied by strong



TEXT-FIG. 6. Tabulation of *Gonyaulax* sp. Left: in ventral view. Right: in dorsal view. Holotype SC2/28/9.  $\times 1,000$ .

tapering horn, appearing to comprise three apical plates. Anterior intercalary plate present, situated on right-hand side of posterior extension of plate 1'; six pre-equatorial plates present, plate 6" reduced. Transverse furrow extends around theca in a laevorotatory spiral such that its two ends differ in antero-posterior position by the furrow's width. The more posterior of its two ends separated from longitudinal furrow by a small pentagonal plate. Longitudinal furrow very broad extending to antapex. Six post-equatorial plates, the first being reduced to accommodate a posterior intercalary plate. A single polygonal plate occupies the antapex. Character of the raised sutures obscure in the single specimen found; the suture between plates 5" and 6" appears high and with a denticulate edge, resembling sutures of *Gonyaulax jurassica*, but other sutures appear low, with isolated simple spines.

*Remarks*. In its shape, the character of its apical horn, and its tabulation this specimen is distinctive. In view of the obscure nature of its sutural crests and the fact that only



one specimen of it has been found (from the lowest Oxford Clay horizon) it was thought inadvisable to erect a new species until further specimens become available.

? Family DEFLANDREIDAE

Genus SCRINIODINIUM Klement 1957

*Scriniodinium crystallinum* (Deflandre 1938) Klement 1957

Plate 14, figs. 9-12

*Remarks.* This species has been recorded from the Oxfordian of France (Deflandre 1938), from the Upper Jurassic of Germany (Klement 1957), and from the Upper Jurassic of Western Australia and Papua (Cookson and Eisenack 1958).

Observed distribution: Oxford Clay, lowest 14, 25-foot 3, 100-foot 33; absent from the Kellaways Rock. Specimen CB81/10/8 exhibits typical dimensions: length of cyst 78  $\mu$ , breadth 75  $\mu$ , length of theca 62  $\mu$ , breadth 55  $\mu$ , transverse furrow *c.* 5  $\mu$  wide. The largest seen was specimen SC2/15/30, with a cyst 95  $\mu$  long and 80  $\mu$  broad, and a theca 65  $\mu$  long and 65  $\mu$  broad. Specimen CB81/22/7 shows a greater proportionate breadth: cyst 78  $\mu$  long and 81  $\mu$  broad, theca 63  $\mu$  long and 63  $\mu$  broad. All these dimensions are within the range recorded by Deflandre (cyst 65-92  $\mu \times$  65-85  $\mu$ ). Some specimens have the appearance of possessing a longitudinal furrow (notably CB81/7/16 and SC2/11/18), but this may be due merely to folding of the thecal membrane.

*Scriniodinium galeritum* (Deflandre 1938) *comb. nov.*

Plate 14, fig. 6

1938 ? *Gymnodinium galeritum* Deflandre, p. 167, pl. v, figs. 7-9, pl. vi, fig. 1.

*Diagnosis.* Epithea in the form of a truncated cone, separated by a narrow transverse furrow from the rounded hypotheca. Enclosing cyst similar in shape but having a protuberant portion which appears to cap the apex.

*Remarks.* One well-preserved and two broken specimens from the 100-foot Oxford Clay horizon have been attributed to this species, previously recorded only from the Oxfordian of Villers-sur-Mer, France. Specimen CB81/23/17 (figured) has an overall length 118  $\mu$  and overall breadth 103  $\mu$ , dimensions considerably greater than those recorded by Deflandre (length 78 to 87  $\mu$ , breadth 60 to 65  $\mu$ ). The theca gives suggestion of a broad longitudinal furrow: however, this may be due entirely to folding of the thecal membrane. In view of its possession of an enclosing cyst this species has been

EXPLANATION OF PLATE 14

Microplankton from the Oxford Clay of Yorkshire. All figures are  $\times 500$ .

- Figs. 1-2. *Gonyaulax cladophora* Deflandre. 1, CB81/10/5, in dorsal view. 2, SC2/36/4, in ventral view.  
 Figs. 3-5. *Baltisphaeridium pilosum* (Ehrenberg) *comb. nov.* 3, CB81/24/2. 4, CB81/15/7. 5, SC2/35/9.  
 Fig. 6. *Scriniodinium galeritum* (Deflandre) *comb. nov.* CB81/23/17.  
 Fig. 7. *Polystephanosphaera calathus* sp. nov., SC2/11/9, holotype.  
 Fig. 8. *Baltisphaeridium pilosum* (Ehrenberg) var. *longispinosum* nov., SC2/4/10, holotype.  
 Figs. 9-12. *Scriniodinium crystallinum* (Deflandre). 9, SC2/15/30. 10, CB81/18/7. 11, CB81/10/8. 12, CB81/22/7.  
 Fig. 13. *Baltisphaeridium* cf. *fimbriatum* (White). CB81/18/17.

removed from the genus *Gymnodium* Stein in which Deflandre tentatively put it, and attributed to the newer genus *Scriniodinium* Klement.

## Family PAREODINIDAE

## Genus PAREODINIA Deflandre

*Pareodinia ceratophora* Deflandre 1947

Plate 13, fig. 16

*Remarks.* The typical specimens of this species have a horn tapering to a point. Twelve specimens seen, all from the 100-foot Oxford Clay horizon, show this character: all have a coarsely granular pale-yellowish membrane. Specimen CB81/6/4 is among the best preserved: it has a length of 75  $\mu$ , of which the horn comprises 15  $\mu$ , and a breadth of c. 40  $\mu$ . The other specimens seen are of similar dimensions, falling well within the range of dimensions (length 65–78  $\mu$ ) recorded by Deflandre from specimens from the Callovian of the Baltic region and the Bajocian of France.

*Pareodinia ceratophora* Deflandre var. *pachyceras* Sarjeant 1959

Plate 13, fig. 17

*Remarks.* This variety was originally described from the Cornbrash of Cayton Bay. Four specimens attributable to it were found, all from the lowest Oxford Clay horizon. Specimen SC2/33/25 is typical: overall length 59  $\mu$ , of which the horn comprises c. 12  $\mu$ , and breadth 34  $\mu$ , dimensions within the range exhibited by the Cornbrash specimens. No representatives of the genus *Pareodinia* were noted from the Kellaways Rock.

## Order HYSTRICHOSPHAERIDIA

## Family HYSTRICHOSPHAERIDAE

## Genus HYSTRICHOSPHAERIDIUM Deflandre 1937 emend. Eisenack 1958

*Hystrichosphaeridium salpingophorum* (Deflandre 1935)

Plate 15, fig. 7

*Remarks.* A long-ranging species, described already from the Oxfordian (Deflandre 1938: France), the Lower to Upper Cretaceous (Deflandre 1935 and 1937 and others from France, Lejeune-Carpentier 1940 from Belgium, and Deflandre and Cookson 1955 from Papua), from the Eocene (Pastiels 1948: Belgium), and from the Oligocene (Gocht 1952: Germany).

Observed distribution: Oxford Clay, lowest 8, 25-foot 3. The illustrated specimen (SC2/28/6) has an overall diameter 100  $\mu$ , shell diameter 50  $\mu$ , and processes around 25  $\mu$  long, dimensions closely comparable with those of the French Oxfordian specimens.

*Hystrichosphaeridium* cf. *truncigerum* Deflandre 1937

Plate 15, fig. 6

*Specimen.* CB81/12/20, 100-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* Overall long diameter 68  $\mu$ , overall short diameter 56  $\mu$ , long diameter of shell 58  $\mu$ , short diameter of shell 48  $\mu$ , spines c. 5  $\mu$  long, tubes c. 7.5  $\mu$  long

*Description.* Shell oval, yellowish, with thin walls bearing a very faint granulation. Processes of two kinds: *a*, Hollow conical spines, closed, thickening (slightly) at the tip to form a knob. *b*, Short, broad, roughly parallel-sided tubes not widened at their extremity, bearing very faint striations. Slightly longer than the spines.

Processes quite widely separated and without apparent arrangement. On a complete specimen it is estimated that there would be thirty to forty processes: of these about one-third would be tubes.

*Remarks.* Only one damaged specimen was seen of this interesting microfossil. In the general appearance of its processes it accords well with Deflandre's *Hystrichosphaeridium truncigerum* from the Cretaceous of France (1937). In four respects it differs from this species, however; in the oval, rather than spherical, shape of the shell, in the somewhat knobbed tips of some spines, in the absence of denticulations on the outer margins of the tubes, and in the smaller relative length of the processes (one-sixth to one-quarter short diameter, as against nearly half diameter). It is thus probable that this single specimen will be attributed to a new species when further specimens of similar type are found.

Genus *BALTISPHAERIDIUM* Eisenack 1958

*Baltisphaeridium stimuliferum* (Deflandre 1938) comb. nov.

Plate 15, fig. 5; text-fig. 8g

1938 *Hystrichosphaeridium stimuliferum* Deflandre, p. 192, pl. x, fig. 10.

*Diagnosis.* A species of *Baltisphaeridium* having a globular shell bearing a small number (about fifteen) of simple spines, generally curved, in length of the order of the diameter of the shell. The spines are inserted in such fashion that there is no mark at their base and the wall of the shell appears continuous with each spine.

EXPLANATION OF PLATE 15

Microplankton from the Oxford Clay of Yorkshire. All figures are  $\times 500$ .

- Fig. 1. *Cannosphaeropsis aemula* (Deflandre), CB81/7/15.  
 Fig. 2. *Micrhystridium stellatum* Deflandre, CB81/14/20.  
 Fig. 3. ? *Micrhystridium* sp., CB81/17/22.  
 Fig. 4. *Cannosphaeropsis caulleryi* (Deflandre), CB56/8/4.  
 Fig. 5. *Baltisphaeridium stimuliferum* (Deflandre) comb. nov., SC2/10/17.  
 Fig. 6. *Hystrichosphaeridium* cf. *truncigerum* Deflandre, CB81/12/20.  
 Fig. 7. *Hystrichosphaeridium salpingophorum* Deflandre, SC2/28/6.  
 Fig. 8. *Baltisphaeridium ehrenbergi* (Deflandre) var. *brevispinosum* nov., SC2/34/8, holotype.  
 Fig. 9. *Cymatiosphaera teichophera* sp. nov., CB81/19/17, holotype.  
 Fig. 10. ? *Cymatiosphaera* sp. indet., CB56/12/18.  
 Fig. 11. *Stephanellytron redcliffense* gen. et sp. nov., CB81/26/6, holotype.  
 Figs. 12-13. *Stephanellytron scarburghense* gen. et sp. nov. Two views of the holotype, SC2/31/2 (obliquely positioned) at different focal planes.  
 Fig. 14. *Wanaea fimbriata* sp. nov., CB56/8/15, holotype.  
 Fig. 15. *Netrelytron stegastum* gen. et sp. nov., CB81/16/10, holotype.  
 Fig. 16. *Stephanellytron caytonense* gen. et sp. nov., CB56/14/1, holotype.

*Remarks.* This species has been described from the Bajocian and Bathonian (Deflandre 1947; Valensi 1953) and Oxfordian (1938) of France. Observed distribution: Oxford Clay, lowest 6, 25-foot 3, 100-foot 2.

The spines were originally thought by the author to be solid; after repeated examination, however, it was established that they are hollow but closed at the tips. The species has therefore been transferred to Eisenack's genus *Baltisphaeridium*.

Specimen SC2/10/17 (figured) has an overall diameter of  $47\ \mu$  and shell diameter of  $26.5\ \mu$ , with spines *c.*  $12\ \mu$  long. This spine length is proportionately shorter than that of typical forms, and the greatest length observed was only three-quarters the diameter. However, Valensi has already included specimens of similar relative dimensions (shell  $20\ \mu$ , spines  $10\text{--}15\ \mu$  long) within the species (1953).

*Baltisphaeridium pilosum* (Ehrenberg 1843) comb. nov.

Plate 14, figs. 3-5

- 1843 *Xanthidium pilosum* Ehrenberg, pp. 61-63.  
 1854 *Xanthidium pilosum* Ehrenberg, pl. 37, fig. viii, no. 4.  
 1904 *Ovum hispidum* (*Xanthidium pilosum* (Ehr.) Lohmann, Ergebnisse der Planktonexpedition der Humboldt-Stiftung, pp. 21-25.  
 1933 *Hystrichosphaera pilosa* (Ehr.) O. Wetzel, p. 43.  
 1937 *Hystrichosphaeridium pilosum* (Ehr.) Deflandre, p. 31.

*Figured specimen* CB81/15/7, 100-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* Figured specimen: overall long diameter  $62\ \mu$ , short diameter  $40\ \mu$ ; long diameter of shell  $55\ \mu$ , short diameter  $33\ \mu$ , spines around  $3\frac{1}{2}\ \mu$  long. Relatively complete specimens from which both major dimensions could be taken were few: the range of overall long diameters was  $40\text{--}60\ \mu$ . Ehrenberg's holotype ( $53\ \mu$ ) falls within this range.

*Diagnosis.* A species of *Baltisphaeridium* having a shell ellipsoidal to oval in shape, frequently broken at one termination. Shell wall very thin. Processes short (between one-quarter and one-eighth of short diameter in length), slender, pointed, and hollow (connecting directly to the interior of the shell); very numerous.

*Description.* Shell yellowish; all specimens seen in some degree broken, one extremity usually being missing, although quite frequently also the shell is split longitudinally. Processes very densely set, the spacing none the less being such as to allow each to be seen throughout its length;  $150\text{--}200$  present around the periphery in relatively complete specimens.

*Remarks.* This hystrichosphere was listed by Ehrenberg from the Corallian of Kraków, Poland (1843); in 1854 a figure of it was included in his massive *Mikrogeologie*. All subsequent generic reattributions of this species were on taxonomic grounds only: the form *nanum* of this species described by O. Wetzel from the Cretaceous (1933), distinguished by small size (shell diameter less than  $16\ \mu$ ) and a frequently spherical shape, is perhaps better attributed to the genus *Micrhystridium*. Ehrenberg gave no full diagnosis of this species and his holotype appears to be lost; however, the Yorkshire specimens correspond exactly with his figure. Observed distribution: Oxford Clay, lowest 33, 25-foot 9, 100-foot 43. All seen are broken in some degree (see above); this may well

indicate that eggs or cysts of microplankton are being dealt with here, a suggestion already made by O. Wetzel.

*Baltisphaeridium pilosum* (Ehrenberg 1843) var. *longispinosum* nov.

Plate 14, fig. 8

*Holotype*. SC2/4/10, lowest Oxford Clay, Scarborough Castle cliff. *Dimensions*. Holotype: overall long diameter 70  $\mu$ , short diameter 47  $\mu$ ; long diameter of shell 51  $\mu$ , short diameter 28  $\mu$ ; spines around 12  $\mu$  long.

*Diagnosis*. A variety of *Baltisphaeridium pilosum* having spines between one-quarter and one-third the short diameter of the shell in length.

*Remarks*. The single specimen dealt with here is in appearance quite distinct from all others seen. The shell shows no signs of breakage; its spines are more than three times longer than those of the figured specimen of *B. pilosum* and considerably in excess of the range of relative lengths exhibited. This distinctive specimen from the lowest Oxford Clay may well be a representative of a species distinct from *B. pilosum*. However, in the absence of further specimens the making of such a major distinction was not thought justifiable.

*Baltisphaeridium* cf. *fimbriatum* (White 1842)

Plate 14, fig. 13

*Figured specimen*. CB81/18/17, 100-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions*. Figured specimen: overall diameter 70  $\mu$ , diameter of shell 58  $\mu$ , spines c. 6  $\mu$  in length. The range exhibited is from 50 to 75  $\mu$  overall diameter.

*Description*. Shell yellowish-brown, spherical to oval in shape, very frequently damaged. Processes very numerous, typically 100–150 observable around the periphery: short, sometimes simple but more frequently forked or capitate, their length typically around 10 per cent. of the shell diameter.

*Remarks*. Hystrichospheres of this type proved frequent. Observed distribution: Kellaways Rock 3, Oxford Clay, lowest 18, 25-foot 5, 100-foot 22. However, despite examination at magnifications of  $\times 2,000$ , whether or not the spines are hollow could not be decisively determined and their attribution to this genus remains doubtful.

The closest comparison is found in *Baltisphaeridium fimbriatum* (White), originally described from Cretaceous flints from England (1842) and subsequently redescribed by Deflandre and Cookson from the Lower Cretaceous of New South Wales (1955). This species has spines of comparable length and with capitate or furcate apices; it differs in the total absence of simple spines and the somewhat longer spine branches. Another described character of this species is the constancy of the length of the spines, giving almost the aspect of an outer shell: two of the Kellaways Rock specimens have somewhat this appearance, but the Oxford Clay specimens do not give it, their spines being slightly variable in length. It is likely that these Upper Jurassic specimens are not

genetically related to the Cretaceous species, but the morphological distinctions listed above are not adequate to justify nomenclatural separation. In dimensions, the Jurassic assemblage is closer to White's specimens (overall diameter 51–77  $\mu$ ) than to the Australian specimens (31–46  $\mu$ ).

*Baltisphaeridium ehrenbergi* (Deflandre 1947) comb. nov.

1938 *Hystrichosphaeridium* cf. *hirsutum* (Ehrenberg) Deflandre, pl. x, fig. 9.

1947 *Hystrichosphaeridium ehrenbergi* Deflandre, fig. 1, no. 5.

1955 *Hystrichosphaeridium ehrenbergi* Valensi, p. 587, pl. iii, fig. 1.

*Diagnosis.* Shell globular, bearing simple processes, straight or slightly curving, about one-third the shell diameter in length. Points of insertion of processes equidistant.

*Remarks.* On the basis of Valensi's description of the processes this species is transferred to *Baltisphaeridium* on taxonomic grounds.

*Baltisphaeridium ehrenbergi* (Deflandre) var. *brevispinosum* nov.

Plate 15, fig. 8; text-fig. 8a

*Holotype.* SC2/34/8, lowest Oxford Clay, Scarborough Castle cliff. *Dimensions.* Holotype: overall diameter 34  $\mu$ , shell diameter 25  $\mu$ , length of spines 5  $\mu$ .

*Diagnosis.* A variety of *Baltisphaeridium ehrenbergi* having shorter spines, one-fifth to one-quarter of the shell diameter in length.

*Description.* Shell yellowish-brown in colour, not granulous. Spines regularly spaced, about 3.5  $\mu$  apart in the holotype. Shell wall thin.

*Remarks.* A single specimen from the lowest Oxford Clay, excellently preserved, was found to correspond with Deflandre's species *B. ehrenbergi*, from the Oxfordian of Villers-sur-Mer, France, in the character and regularity of spacing of its spines. Since the sole difference is in the length of its spines, it has been created a new variety of this species.

Genus CANNOSPHAEROPSIS O. Wetzel 1933 emend. Deflandre 1947

*Cannosphaeropsis caulleryi* (Deflandre 1938)

Plate 13, fig. 8 and Plate 15, fig. 4

*Remarks.* This species was originally recorded from the Oxfordian of Villers-sur-Mer, France (1938), and subsequently from the Kimeridgian of Dorset, England (Downie 1957), the Neocomian of Germany (Gocht 1959), and the Eocene of Australia (Deflandre and Cookson 1955). Observed distribution: Kellaways Rock 1, Oxford Clay, lowest, 28, 25-foot 22, 100-foot 15.

There was considerable variation in size, overall diameter varying from 55 to 120  $\mu$ ; the figured specimen (CB56/8/4) has average dimensions, with an overall diameter of 92  $\mu$  and shell diameter 50  $\mu$ . This range is not exceptional: the French specimens range from about 65 to 85  $\mu$  and the Australian from 67 to 115  $\mu$ .

*Cannosphaeropsis aemula* (Deflandre 1938)

Plate 15, fig. 1

*Remarks.* This species was originally described from the Oxfordian of Villers-sur-Mer, France (1938), and subsequently from the Upper Jurassic of Papua and Western Australia (Cookson and Eisenack 1958). It was found only in the 100-foot Oxford Clay horizon (9). The figured specimen (CB81/7/15) has average dimensions (overall diameter 106  $\mu$ , shell diameter 52  $\mu$ ), the range being from 95 to 120  $\mu$  overall diameter; this is somewhat larger than that exhibited by the French specimens (60 to 100  $\mu$ ).

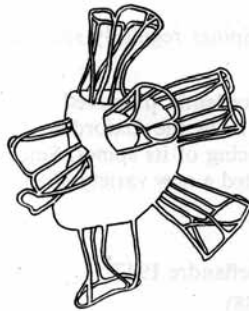
## Genus POLYSTEPHANOSPHAERA Sarjeant 1960

*Polystephanosphaera calathus* sp. nov.

Plate 14, fig. 7; text-fig. 7

*Holotype.* SC2/11/9, lowest Oxford Clay, Scarborough Castle cliff. *Dimensions.* Holotype: overall diameter 88  $\mu$ , shell diameter 45  $\mu$ , length of process clusters c. 22  $\mu$ . Paratype (CB56/8/24): overall diameter 90  $\mu$ , shell diameter 45  $\mu$ , length of process clusters c. 23  $\mu$ .

*Diagnosis.* A species of *Polystephanosphaera* in which the processes are solid and are arranged in circles and connected together by trabeculae in the form of a ring, each cluster of processes thus forming an open-walled and open-ended tube. It is estimated that on a complete specimen there would be twelve to sixteen such tubes, each ring trabecula borne by five to ten processes.



TEXT-FIG. 7. *Polystephanosphaera calathus* sp. nov., showing the form of the groups of processes. Holotype SC2/11/9.  $\times 600$ .

*Description.* The trabecula linking each group of processes appears to arise from the bifurcation of one process in Y-shaped fashion, the tips of the two arms of the Y being extended parallel to the shell surface and meeting the extremities of the other processes of the group almost at right angles. Shell membrane brownish-yellow in colour, processes pale-yellowish.

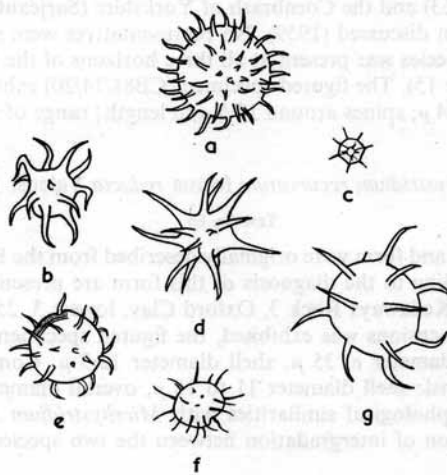
*Remarks.* Only two specimens found of this very characteristic microfossil, one each from the lowest and 25-foot horizons.

The processes of *Cannosphaeropsis caulleryi* are similar in basic type but are not arranged in circles. Those of *P. urnaformis* from the Oligocene of Australia (Cookson 1953) differ in that this latter species has processes whose bases coalesce, giving the impression rather of a perforated tubular process than of a group of linked processes. It might be suggested purely on morphological grounds that *P. calathus* represents an intermediate stage in evolutionary development from *C. caulleryi* to *P. urnaformis*. However, the geographic and chronologic separation is immense and an actual genetic relationship must be at present considered improbable.

Genus MICRHYSTRIDIUM Deflandre 1936  
*Micrhystridium inconspicuum* (Deflandre 1935)

Plate 13, fig. 5; text-fig. 8f

*Remarks.* A long-ranging species, previously recorded from the Middle Jurassic of France (Valensi 1953), the Cornbrash of England (Sarjeant 1959), and the Cretaceous of France (Deflandre 1935). Observed distribution: Kellaways Rock 3, Oxford Clay, lowest 2, 25-foot 8, 100-foot 9. Specimen CB81/14/12 (illustrated) has an overall diameter  $25\ \mu$  and shell diameter  $12\ \mu$ , spines being around  $7\ \mu$  long. This is rather larger than specified by Deflandre: however, a range of shell diameters from  $15\ \mu$  down to  $8\ \mu$  was observed and in all other characters these specimens agree with Deflandre's definition of the species.



TEXT-FIG. 8. Smaller hystrichospheres from the Oxford Clay. *a*, *Baltisphaeridium ehrenbergi* (Defl.) var. *brevispinosum* nov. (Holotype SC2/34/8); *b*, *Micrhystridium recurvatum* forma *reducta* Valensi (CB81/26/10); *c*, *M. cf. mendax* Deflandre (SC2/30/11); *d*, *M. stellatum* Deflandre (CB81/14/20). *e*, ?*M. sp.*, showing the two layers of the shell wall (CB81/17/22); *f*, *M. inconspicuum* (Deflandre CB81/14/12); *g*, *Baltisphaeridium stimulfiferum* (Deflandre) (SC2/10/17).  $\times 600$ .

*Micrhystridium fragile* Deflandre 1947

Plate 13, figs. 3-4

*Remarks.* Two specimens found in the Kellaways Rock, but this species is absent from the Oxford Clay horizons studied. It has previously been described from the Bajocian



and Bathonian of France (Deflandre 1947, Valensi 1953) and from the Cornbrash of England (Sarjeant 1959).

Specimen SC33/17/5 is the better preserved; its dimensions are overall diameter 52  $\mu$ , shell diameter 24  $\mu$ . These dimensions are considerably larger than those recorded by Deflandre (overall diameter 12 to 14  $\mu$ ); however, Valensi noted a considerable range of dimensions, the diameter of the shell alone in one case attaining 40  $\mu$ , so that the Kellaways specimens are not exceptional.

*Micrhystridium stellatum* Deflandre 1942

Plate 15, fig. 2; text-fig. 8d

*Remarks.* This species was originally recorded from the Silurian (1942). Morphologically similar forms, probably not genetically related, have been recorded from the Bajocian of France (Valensi 1953) and the Cornbrash of Yorkshire (Sarjeant 1959). Their significance has already been discussed (1959). No representatives were seen from the Kellaways Rock, but the species was present at all three horizons of the Oxford Clay (lowest 16, 25-foot 7, 100-foot 15). The figured specimen (CB81/14/20) exhibited typical dimensions: shell diameter 14  $\mu$ , spines around 12.5  $\mu$  in length; range of shell diameters from 10 to 25  $\mu$ .

*Micrhystridium recurvatum* forma *reducta* Valensi 1953

Text-fig. 8b

*Remarks.* This species and form were originally described from the Bathonian of France. Specimens corresponding to the diagnosis of this form are present in low numbers in all horizons studied (Kellaways Rock 3, Oxford Clay, lowest 3, 25-foot 1, 100-foot 3). Little variation in dimensions was exhibited, the figured specimen (CB81/26/10) being typical with overall diameter c. 35  $\mu$ , shell diameter 12.5  $\mu$ . Comparable dimensions are recorded by Valensi: shell diameter 11 to 15  $\mu$ , overall diameter 20–30  $\mu$ . Despite the considerable morphological similarities with *Micrhystridium stellatum* Deflandre, there was no suggestion of intergradation between the two species in the assemblages examined.

*Micrhystridium* cf. *mendax* Deflandre 1945

Text-fig. 8c

*Figured specimen.* SC2/30/11, lowest Oxford Clay, Scarborough Castle cliff. *Dimensions.* Figured specimen: shell 11  $\mu$  in cross measurement, spines 1.5  $\mu$  long. The two other specimens seen were similar in dimension.

*Description.* Shell polygonal, pale-yellowish in colour, composed of a series of more or less flat fields whose intersections form low ridges. Short simple spines arise at the junctions of ridges; they are hollow and connected directly to the interior.

*Remarks.* One specimen showing these characters was found in the lowest and two in the 25-foot Oxford Clay horizons. The closest comparison is found in *Micrhystridium mendax* Deflandre, from the Silurian of the Montagne Noire, France. This has the characters listed in the description: its spines are, however, proportionately shorter,

only one-seventh to one-eighth the cross measurement as against one-fifth; the shell is also somewhat smaller, the Silurian specimens measuring 14 to 16  $\mu$ . These differences are by no means sufficient to justify the setting up of a new species, but the tremendous chronologic separation makes any genetic relationship unlikely.

? *Micrhystridium* sp.

Plate 15, fig. 3; text-fig. 8e

*Figured specimen.* CB81/17/22, 100-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* Figured specimen: shell diameter 21  $\mu$  with walls c. 2  $\mu$  thick. Spines 7  $\mu$  long. The other specimens seen have closely similar dimensions.

*Description.* Shell exactly spherical, brownish-yellow, composed of two layers, a thick outer layer (striate) and a thin inner layer (not striate). Spines short (c. one-third to one-quarter diameter), simple, usually curving, solid and embedded in the outer layer of the shell wall.

*Remarks.* The forms included here, in their possession of a two-layered shell wall, differ from all other Mesozoic hystrichospheres described to date, and resemble certain Palaeozoic forms (cf. Sannemann 1958). Their attribution to the Order Hystrichosphaeridia is not necessarily correct; many pollen possess a two-layered body wall and the differentiation of the simpler pollen grains from hystrichospheres at this order of size is by no means easy. For this reason they have been only tentatively allotted to this order and genus.

Microfossils of this type occur at all three Oxford Clay horizons (lowest 15, 25-foot 7, 100-foot 9) but were not noted from the Kellaways Rock.

Family PTEROSPERMOPSIDAE

Genus *Cymatiosphaera* O. Wetzel 1933 emend. Deflandre 1954

*Cymatiosphaera teichophera* sp. nov.

Plate 15, fig. 9; text-figs. 9a,b

*Holotype.* CB81/19/17, 100-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* Holotype: overall long diameter 50  $\mu$ , overall short diameter 40  $\mu$ , crests around 9  $\mu$  high.

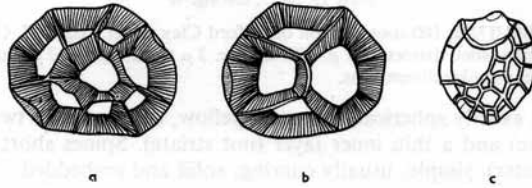
*Diagnosis.* A species of *Cymatiosphaera* having a broadly ellipsoidal shell divided into a low number (12–16) of polygonal fields. The membranes delimiting fields are high, their height equal to about one-third of the short diameter; they bear striations normal to the shell surfaces.

*Description.* Shell walls of moderate thickness and of brownish-yellow colour. Fields vary considerably in size; their separating membranes are thin and relatively readily crumpled, lacking supporting spines at the junctions but having a distinct outer edge on to which striations do not extend.

*Remarks.* A single specimen only was found of this distinctive microfossil. Four known species have crests of similar proportional height. All are very much smaller in size

than *C. teichophera*, lack striations on their crests, and also differ as follows: *Cymatiosphaera eupeplos* Valensi, from the Middle Jurassic of France (1948), has membranes supported by spines at their junction. The other three comparable species have been described by Deunff from the Devonian of Canada. *C. cornifera* (1955) has fields with a short spine at their centre. *C. cubus* (1954) has a distinctly cubic outline and fewer fields. *C. prismatica* (1954) has a prismatic outline.

Thus this new species is seen to be clearly distinct from all others of this genus so far described.



TEXT-FIG. 9a, b, *Cymatiosphaera teichophera* sp. nov., showing the two opposed surfaces, with the structure and arrangement of crests; the striations are less prominent than the drawing suggests. Holotype CB81/19/17. c, *Membranilarnax ovulum* Deflandre (SC2/24/1).  $\times 600$ .

*Cymatiosphaera parva* Sarjeant 1959

1959 *Cymatiosphaera parva* Sarjeant, pp. 342-3, pl. xiii, fig. 6, text-fig. 8.

*Emended diagnosis.* A species of *Cymatiosphaera* with a low number (c. 12-25) of polygonal fields demarcated by low ridges. Short slender spines arise at the junctions of the ridges.

*Remarks.* This species, originally described from the Cornbrash (1959), was the most abundant in the Kellaways Rock (31 specimens seen), but was not observed from the Oxford Clay. The number of plates is generally twelve to fifteen. Specimen SC33/5/15 shows characteristic dimensions—overall diameter 13  $\mu$ , shell diameter 10  $\mu$ . There was little variation in dimensions exhibited; the shell diameters of the Kellaways specimens are thus almost exactly half that of the type specimen (20  $\mu$ ). The rather low plate number (12-15 as against 17-20) appears merely a function of size. The definition of a new variety on the basis of size alone seems scarcely warranted, particularly since size may be merely a reflection of age or environmental conditions. The diagnosis of the species has therefore been modified slightly to accommodate the Kellaways assemblage.

? *Cymatiosphaera* sp. indet.

Plate 15, fig. 10

*Remarks.* Two poorly preserved specimens from the 25-foot Oxford Clay horizon may be attributable to this genus. Their shape was probably originally spherical; the test surface is divided into very numerous polygonal fields by low membranes sustained by spines at their junctions, these spines being sometimes bifurcate. The overall diameter of the better specimen (CB56/12/18) is 65  $\mu$ , the spines being 4  $\mu$  in height. In view of

their poor preservation these two specimens cannot be attributed with any certainty to this genus, particularly since certain Mesozoic pollen grains, such as *Lycopodium-sporites clavatooides* Couper (present in this material), have a similar ornament.

Genus MEMBRANILARNAX O. Wetzel 1933

*Membranilarnax ovulum* Deflandre 1947

Text-fig. 9c

*Remarks.* This species has been described from the Bajocian and Bathonian of France (Deflandre 1947, Valensi 1953). A single poorly preserved specimen (SC/224/1) attributable to it was found in the lowest Oxford Clay horizon; its dimensions, long diameter 30  $\mu$ , short diameter 25  $\mu$ , with crests around 4  $\mu$  high, are smaller than the range quoted by Valensi (long diameter 38–60  $\mu$ , short diameter 34–50  $\mu$ ).

INCERTAE SEDIS

Genus STEPHANELYTRON gen. nov.

*Type species.* *Stephanelytron redcliffense* sp. nov.

*Diagnosis.* Organic shells of spherical to ovoidal shape, bearing on one face (at one end in ovoidal forms) one or more structures consisting of a circular membrane rising upwards from the shell surface and everted, surrounding a mat of short hairs or spines; this structure is henceforth termed a 'corona'. Elsewhere the shell bears tubular processes of varied character and arrangement.

*Remarks.* In view of the uncertain function and character of the corona, any orientation imposed must be quite arbitrary. By analogy with other members of the marine plankton in which groups of cilia confined to one surface act as propellants it has been decided to term the surface bearing the corona or coronas the antapex, and the opposed surface the apex; it must be realized, however, that no comparison of function is implied. The presence of tubular processes makes it possible to relate this genus to the Order Hystrichosphaeridia, but the corona has no parallel in any known hystrichosphere, so that it seems best for the present that this genus should remain *incertae sedis*.

*Stephanelytron redcliffense* sp. nov.

Plate 15, fig. 11; text-fig. 10

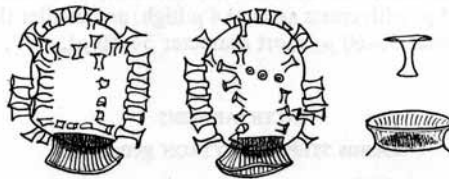
*Holotype.* CB81/2/66, 100-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* Holotype: overall length 50  $\mu$ , breadth 40  $\mu$ , length of shell c. 36  $\mu$ , breadth c. 30  $\mu$ ; height of corona 10  $\mu$ , outer diameter c. 27  $\mu$ . Tubes around 5  $\mu$  in length. Two other relatively complete specimens, similar in dimensions, were seen, and in addition several broken specimens.

*Diagnosis.* A species of *Stephanelytron* having an oval shell, neither granular nor perforate, bearing six rows of tubular processes extending from the apex to the corona, a transverse row of tubular processes extending around the apex in a broad circle, and a further row of processes, incomplete in all specimens seen, surrounding the antapex

close to the base of the corona. The processes have everted lips and their walls are not perforate. All specimens seen had a single corona, broad-based and bearing striations.

*Description.* The surrounding membrane of the corona seems to show a somewhat thickened lip on to which the striations do not extend. The matted fibres within seem to vary in length, with those at the centre longer than those at the fringes, but this appearance may result entirely from the curvature of the shell surface from which they arise.

*Remarks.* Each of the three Oxford Clay horizons studied seems characterized by a particular species of *Stephanelytron*, the genus not having been recorded from the Kellaways Rock. The representatives of this species occur only in the 100-foot horizon.



TEXT-FIG. 10. *Stephanelytron redcliffense* gen. et sp. nov. Upper and lower surfaces ( $\times 600$ ); an individual tube ( $\times 1,250$ ); and a sketch to illustrate the structure of the corona. Holotype CB81/26/6.

*Stephanelytron caytonense* sp. nov.

Plate 15, fig. 16; text-fig. 11

*Holotype.* CB56/14/1, 25-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* The holotype has a somewhat damaged shell: its overall dimensions, length  $65 \mu$  and breadth  $60 \mu$ , probably do not therefore reflect its true shape. The corona is  $17 \mu$  high; its outer diameter is  $25 \mu$ , its basal diameter about  $14 \mu$ . The tubes are around  $8 \mu$  in length.

*Diagnosis.* A species of *Stephanelytron* having a spherical to oval shell, not granular or punctate, bearing rows of tubes similar in distribution to those of *S. redcliffense* but with lips less pronouncedly everted and having about eight to ten rows of perforations aligned parallel to the length of the tube and quite closely spaced. The corona has a relatively small base and flares out widely; its membrane is somewhat folded, with a coarsely granular surface and a distinct outer lip devoid of granulation.

TEXT-FIG. 11. *Stephanelytron caytonense* sp. nov. ( $\times 600$ ) and an isolated tube ( $\times 1,00$ ). Holotype CB56/14/1.

*Remarks.* The single specimen found of this species was the only representative of the genus noted at this horizon. However, its perforate tubes and the character of its corona afford a ready distinction from all other specimens of the genus and warrant specific status.

*Stephanelytron scarburghense* sp. nov.

Plate 15, figs. 12-13

*Holotype.* SC2/31/2, lowest Oxford Clay, Scarborough Castle cliff. *Dimensions.* Holotype: overall length 41  $\mu$ , overall breadth 30  $\mu$  (oblique view). Specimen SC2/31/12, seen in lateral view, gives more satisfactory dimensions (overall length 45  $\mu$ , breadth 40  $\mu$ , corona 12  $\mu$  high and 28  $\mu$  in outer diameter, tubes about 5  $\mu$  in length) but was unfortunately damaged. These dimensions appear typical.

*Diagnosis.* A species of *Stephanelytron* having a spherical to oval shell, not granular or punctate, bearing tubes similar in character and distribution to those of *S. redcliffense* but with in addition further tubes of similar character distributed in an irregular scatter within the fields delimited by these tube rows. The everted lips of the tubes in the rows overlap to some extent, giving an appearance of linkage. The corona or coronas have a surrounding membrane striated in similar fashion to that of *S. redcliffense*: however, the membrane slopes regularly outwards instead of having a distinctly everted lip.

*Description.* Whereas all other specimens seen of this genus have a single large corona, as does the type of *S. scarburghense*, one specimen seen (SC2/33/6) has two smaller coronas, situated together on the antapical surface. In the character of these coronas and in the type and distribution of tubes this specimen corresponds to *S. scarburghense* and it has therefore been attributed to this species, the drawing of a varietal distinction not being considered warranted in view of the absence of knowledge of the character and functions of the corona.

*Remarks.* This species, typical of the lowest Oxford Clay, is proportionately more abundant than the species of *Stephanelytron* of the higher horizons. Broken specimens are relatively numerous, an estimated thirty to fifty being seen, but only five relatively complete specimens were noted. The character of the corona and tubes suggests a closer relation to *S. redcliffense* than to *S. caytonense*, so that no evolutionary sequence can be postulated satisfactorily.

## Genus ANTROSPHAERA gen. nov.

*Type species.* *Antrosphaera calloviensis* sp. nov.

*Diagnosis.* Organic shells of spherical shape, hollow, without processes, patterned with depressions of varied shape, size, and arrangement.

*Remarks.* The extreme simplicity in form of the representatives of this genus makes their attribution to any group uncertain. In the organic nature of the test there is a resemblance to both spores and pollen and to microplankton. However, there are no traces of a trilete or monolete mark; moreover, some specimens (including the type of *A. calloviensis*) were seen to contain irregular greenish bodies considered probably chloroplasts, and if these were indeed chloroplasts then these organisms could not be pollen.

The absence of any trace of tabulation or of traces of a transverse furrow makes a relationship with the Order Dinoflagellata unlikely. The absence of processes is a distinction from the majority of genera and species of the Order Hystrichosphaeridia: the genus *Leiosphaeridia* comprises simple, spherical to ovoidal bodies without processes or ornamentation (other than granules), but comparison with specimens of that

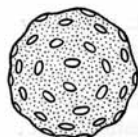
genus suggested that the cell wall of *Antrosphaera* was composed of a quite different substance. Nevertheless, the possibility of a relationship with *Leiosphaeridia* remains. Until more evidence of relationship becomes available, therefore, this genus must remain *incertae sedis*.

*Antrosphaera calloviensis* sp. nov.

Plate 13, fig. 7; text-fig. 12

*Holotype*. SC33/5/16. Kellaways Rock, Scarborough Castle cliff. *Dimensions*. Holotype: diameter 14  $\mu$ ; the six other specimens seen were of comparable dimensions.

*Diagnosis*. A species of *Antrosphaera* of small size, having a granular shell surface ornamented with small ovoid depressions, regularly spaced, in arrangement as shown on the figure; about thirty such depressions appear present on either surface.



TEXT-FIG. 12. *Antrosphaera calloviensis* gen. et sp. nov.  $\times 1,425$ . Holotype SC33/5/16.

*Description*. Shell moderately thick, greenish in colour; outline undulose, there being some indication that the depressions are situated in the crests of slight bulges in the shell surface. Focusing indicated that the holes in the surface become smaller with depth and appear to close; they are thus considered depressions and not perforations. The type specimen contains a greenish body with a somewhat irregular surface; this was thought probably a chloroplast (discussed earlier).

*Remarks*. Representatives of this species were found only in the Kellaways Rock assemblage. In view of its extremely small size this organism readily escapes notice; it may well be considerably more abundant at this horizon than the numbers recorded would suggest.

Genus WANAEA Cookson and Eisenack 1958

*Wanaea fimbriata* sp. nov.

Plate 15, fig. 14; text-fig. 13

*Holotype*. CB56/8/15, 25-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions*. Holotype: height of shell c. 65  $\mu$ , diameter of base 100  $\mu$ , fringe up to 20  $\mu$  broad. The other specimens seen vary little from these dimensions.

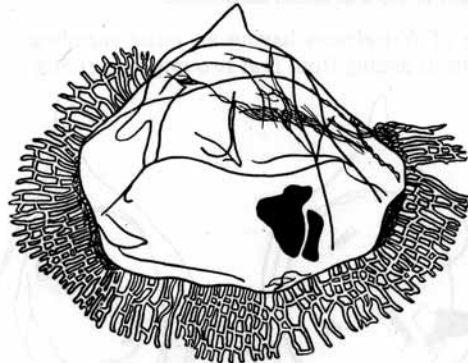
*Diagnosis*. A species of *Wanaea* with a shell broadly cone-shaped, narrowing to a short, rounded apex. The edge is ornamented for four-fifths of its length by a fringe, relatively broad but narrowing towards the gap; this fringe is in the form of a small-meshed network of irregular structure, its edges free.

*Description*. Fringe meshwork extremely variable in character; in some cases two adjacent processes anastomose only twice in their length, in others, they do so four times. Mesh fragile and frequently torn; it is not rigid, its surface frequently being undulose.

*Remarks*. Three species of this genus have so far been erected, *W. spectabilis* (Deflandre and Cookson), *W. digitata* Cookson and Eisenack, and *W. clathrata* Cookson and Eisenack. On the basis of time sequence Cookson and Eisenack have suggested that

these represent an evolutionary series with *W. spectabilis* the simplest and *W. clathrata* the most highly developed (1958). All are from successive horizons in the Upper Jurassic of Australia and Papua.

*Wanaea fimbriata* occurs in all three Oxford Clay horizons examined (lowest 7, 25-foot 1, 100-foot 3) but was not recorded from the Kellaways Rock. In the form of the shell it resembles *W. digitata* and *W. spectabilis* and differs from *W. clathrata*; its fringe on the other hand shows closest similarity with that of *W. clathrata* but differs in that it lacks an outer edge. On morphological considerations alone an evolutionary



TEXT-FIG. 13. *Wanaea fimbriata* sp. nov. Holotype CB56/8/15.  $\times 600$ .

position might be tentatively assigned after *W. digitata* and possibly before *W. clathrata*; but without more precise knowledge of the comparative ages of the Australasian horizons in relation to the Oxford Clay this remains no more than a possibility.

#### Genus NETRELYTRON gen. nov.

*Type species. Netrelytron stegastum* sp. nov.

*Diagnosis.* Micro-organisms formed of a spherical, ovoidal, or ellipsoidal central body enclosed in a spindle-shaped outer membrane.

*Remarks.* Four existing genera possess a central body surrounded by an outer membrane. The new genus differs from *Pterocystidiopsis* Deflandre in the distinctive and well-defined shape of its outer membrane; from *Deflandrea* Eisenack, *Scriniodinium* Klement, and *Muderongia* Cookson and Eisenack in that the outer membrane has only two opposed prominences (*Scriniodinium* lacks horns; *Deflandrea* has one extremity, a single horn, and the other, two horns; *Muderongia* has four equidistant horns) and from *Deflandrea* and *Scriniodinium* also in that the central body lacks a transverse furrow, these latter genera being undoubtedly encysted dinoflagellates.

The affinities of this genus are doubtful. It is possible that it comprises encysted dinoflagellates; however, as stated above, the central body shows no transverse furrow or girdle. Deflandre comments on the equally problematical genus *Pterocystidiopsis* (1941): 'Should one see in this organism some peculiar member of the microplankton,



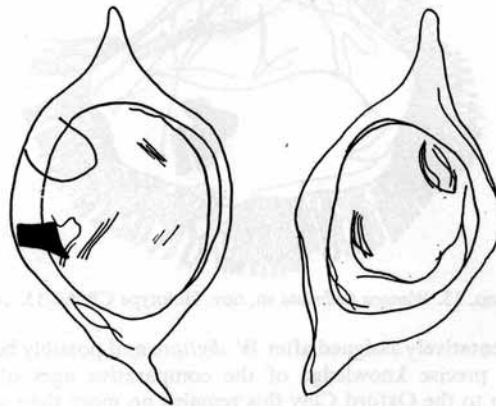
or is this on the contrary a spore of a being higher in the organisation? Nothing permits the solving of that question, for the moment.' This comment is equally applicable to the genus *Netrelytron*.

*Netrelytron stegastum* sp. nov.

Plate 15, fig. 15; text-fig. 14

*Holotype*. CB81/16/10, 100-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions*. Holotype: overall length 125  $\mu$ , breadth 55  $\mu$ , long diameter of inner shell 55  $\mu$ , short diameter 45  $\mu$ ; the paratype figured (CB81/23/18) is of similar dimensions.

*Diagnosis*. A species of *Netrelytron* having an outer membrane of almost spherical shape, with conical horns arising from it at two opposed extremities. These horns have



TEXT-FIG. 14. *Netrelytron stegastum* gen. et sp. nov. The holotype CB81/16/10 and a paratype, CB81/23/18, figured without the investing material.  $\times 600$ .

rounded tips and tend to be inclined rather than vertical in their relation to the surface of the ovoidal central body, to whose long axis their position corresponds.

*Description*. All specimens found are invested almost completely in a mass of formless organic matter; this follows the rough outline of the outer membrane and may represent a protective envelope formed around itself by the living organism. Outer membrane thin, devoid of ornamentation. In two specimens seen it is perforated by a roughly oval aperture on one flank, a corresponding gap in the cloak of extraneous material being noted. Character of the ovoidal inner shell difficult to determine; it appears of moderate thickness and devoid of ornamentation save possibly for a very faint granulation. Both inner shell and outer membrane frequently folded in some degree. The type specimen and a paratype are both stained with safranin; however, the two other specimens seen are unstained, having a yellowish-brown hue, the inner shell more strongly coloured than the outer membrane.

*Remarks*. The perforation in the outer membrane may be interpreted as a pylome, in

which case this surface would be termed dorsal (cf. Eisenack 1958). If this interpretation were correct, a relationship to the Order Dinoflagellata would be suggested; however, no aperture was observable in the two other specimens seen, and its constancy cannot be affirmed. Similarly, since only four specimens of this distinctive microfossil have been seen, the constancy of the envelope of organic matter cannot be vouched for. All specimens found derived from the 100-foot Oxford Clay horizon, the material from which was very well oxidized; other microfossils from this horizon rarely show any degree of investment in extraneous material, and it is improbable that all specimens of a relatively smooth form such as this should have become fortuitously enwrapped when hystrichospheres bearing complex spines, such as the two species of *Cannosphaeropsis* present, remain free.

#### CONCLUSIONS

In the assemblages described eight species of dinoflagellates and sixteen species of hystrichospheres were recognized. *Gonyaulax jurassica* Deflandre proved by far the most abundant dinoflagellate at all horizons, *G. cladophora* Deflandre coming second in abundance. Of the hystrichospheres *Cymatiosphaera parva* Sarjeant is the commonest species in the Kellaways Rock assemblage but is not present in the Oxford Clay assemblages; in these assemblages *Baltisphaeridium pilosum* (Ehrenberg) is the most common species. In addition four genera of organisms *incertae sedis*, presumed microplankton, are present, three of the genera and all six species being described for the first time. Text-fig. 15 shows the distribution of species in the horizons considered, in comparison with their distribution as previously recorded. Progressive change in the character of the microplankton with time is indicated.

Some assessment may be made of the stratigraphic value of the fossil microplankton by comparing this assemblage as a whole with other assemblages described. On the basis of previous published records three species have ranges spanning the Callovian and Lower Oxfordian: *Gonyaulax jurassica* (Bathonian to Kimeridgian) and *G. cladophora* (Bajocian to Kimeridgian), both of which species probably attained their acme in the Oxfordian, and *Micrhystridium inconspicuum* (Bajocian to Upper Cretaceous). Five species were previously known only from lower horizons: *Micrhystridium fragile* and *M. stellatum* (Bajocian to Lower Callovian [Cornbrash]), *M. recurvatum* f. *reducta* (Bathonian), *Membranilarnax ovulum* (Bajocian to Bathonian), and *Cymatiosphaera parva* (Lower Callovian [Cornbrash]). Two species have known ranges from the Middle Jurassic to the Callovian or Lower Oxfordian, but are not recorded from younger sediments: *Pareodinia ceratophora* (Bajocian to Callovian) and *Baltisphaeridium stimuliferum* (Bajocian to Lower Oxfordian). Two species have known ranges from the Lower Oxfordian upwards: *Cannosphaeropsis caulleryi* (Lower Oxfordian to Eocene) and *Hystrichosphaeridium salpingophorum* (Lower Oxfordian to Oligocene). Finally four species have been recorded only from comparable horizons elsewhere: *Scriniodinium crystallinum* (Lower Oxfordian and 'Upper Jurassic' of Australia), *S. galeritum* (Lower Oxfordian), *Baltisphaeridium pilosum* ('Corallian'), and *Cannosphaeropsis aemula* (Lower Oxfordian and 'Upper Jurassic' of Australia).

Thus the known stratigraphic occurrences of fossil microplankton would indicate a position for these horizons within the stratigraphic range Bathonian–Lower Oxfordian;

	Pre-Callovian horizons	Lower Callovian— Cornbrash of Yorkshire	Lower Callovian— Kellaways Rock of Yorkshire	Middle—Upper Callovian	Lower Oxfordian Oxford Clay of Yorkshire			Lower Oxfordian of France	Post-Oxfordian horizons
					Lowest	25-foot	100-foot		
<i>Gonyaulax jurassica</i>	×	..	×	..	×	×	×	×	×
<i>G. jurassica</i> var. <i>longicornis</i>	..	..	..	..	×	..	×	×	..
<i>G. cladophora</i>	×	..	×	..	×	×	×	×	×
<i>G. cladophora</i> var. <i>multispinosa</i>	..	..	..	..	..	..	×	..	..
<i>G. acanthosphaera</i>	..	..	..	..	×	..	..	..	..
<i>G. areolata</i>	..	..	..	..	×	..	×	..	..
<i>G. sp.</i>	..	..	..	..	×	..	×	..	..
<i>Scriniodinium crystallinum</i>	..	..	..	..	×	×	×	×	..
<i>S. galeritum</i>	..	..	..	..	..	..	×	×	..
<i>Pareodinia ceratophora</i>	×	..	..	?	..	..	×	..	..
<i>P. ceratophora</i> var. <i>pachyceras</i>	..	×	..	..	×	..	..	..	..
<i>Hystriosphæridium salpingo-</i> <i>phorum</i>	..	..	..	..	×	×	..	×	×
<i>H. cf. truncigerum</i>	..	..	..	..	..	..	×	..	..
<i>Baltisphaeridium stimuliferum</i>	×	..	..	..	×	×	×	×	..
<i>B. pilosum</i>	..	..	..	..	×	×	×	..	..
<i>B. pilosum</i> var. <i>longispinosum</i>	..	..	..	..	×	..	..	..	..
<i>B. cf. fimbriatum</i>	..	..	×	..	×	×	×	..	..
<i>B. ehrenbergi</i> var. <i>brevispinosum</i>	..	..	..	..	×	..	..	..	..
<i>Cannosphaeropsis caulleryi</i>	..	..	×	..	×	×	×	×	×
<i>C. aemula</i>	..	..	..	..	..	..	×	×	..
<i>Polystephanosphaera calathus</i>	..	..	..	..	×	×	..	..	..
<i>Micrhystridium inconspicuum</i>	×	×	×	..	×	×	×	..	×
<i>M. fragile</i>	×	×	×	..	..	..	..	..	..
<i>M. stellatum</i>	×	×	×	..	×	×	×	..	..
<i>M. recurvatum</i> f. <i>reducta</i>	×	..	×	..	×	×	×	..	..
<i>M. cf. mendax</i>	..	..	..	..	×	×	..	..	..
? <i>M. sp.</i>	..	..	..	..	×	×	×	..	..
<i>Cymatiosphaera teichophera</i>	..	..	..	..	..	..	×	..	..
<i>C. parva</i>	..	×	×	..	..	..	..	..	..
? <i>C. sp. indet.</i>	..	..	..	..	..	×	..	..	..
<i>Membranilarnax ovulum</i>	×	..	..	..	×	..	..	..	..
<i>Stephanelytron scarburghense</i>	..	..	..	..	×	..	..	..	..
<i>S. caytonense</i>	..	..	..	..	..	×	..	..	..
<i>S. redcliffense</i>	..	..	..	..	..	..	×	..	..
<i>Antrosphaera calloviensis</i>	..	..	×	..	..	..	..	..	..
<i>Wanaea fimbriata</i>	..	..	..	..	×	×	×	..	..
<i>Ntrelytron stegastum</i>	..	..	..	..	..	..	×	..	..

TEXT-FIG. 15. Known stratigraphic distribution of fossil microplankton species present in the Yorkshire assemblages.

this, of course, corresponds with the stratigraphic position as determined by macro-fossils, a satisfactory degree of correlation in view of the present paucity of knowledge of the fossil organic-shelled microplankton.

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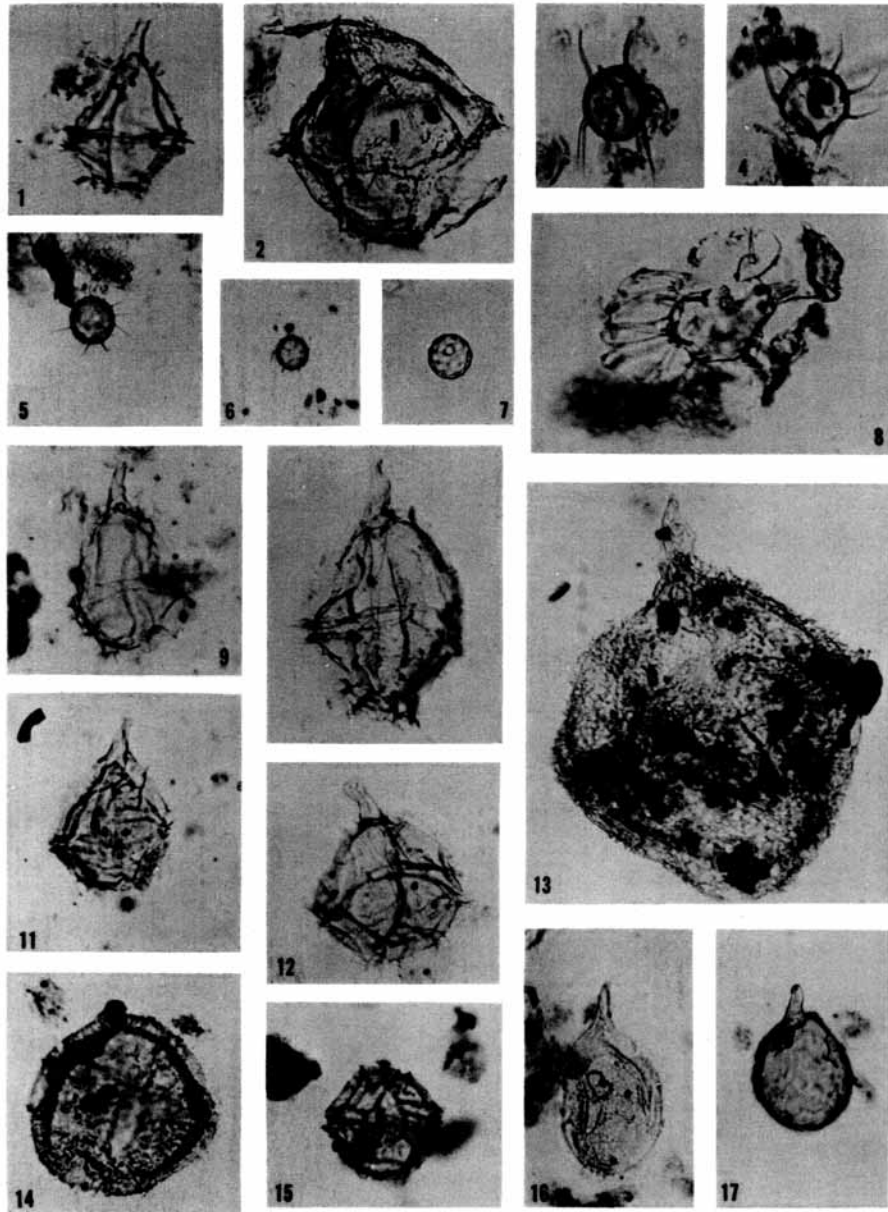
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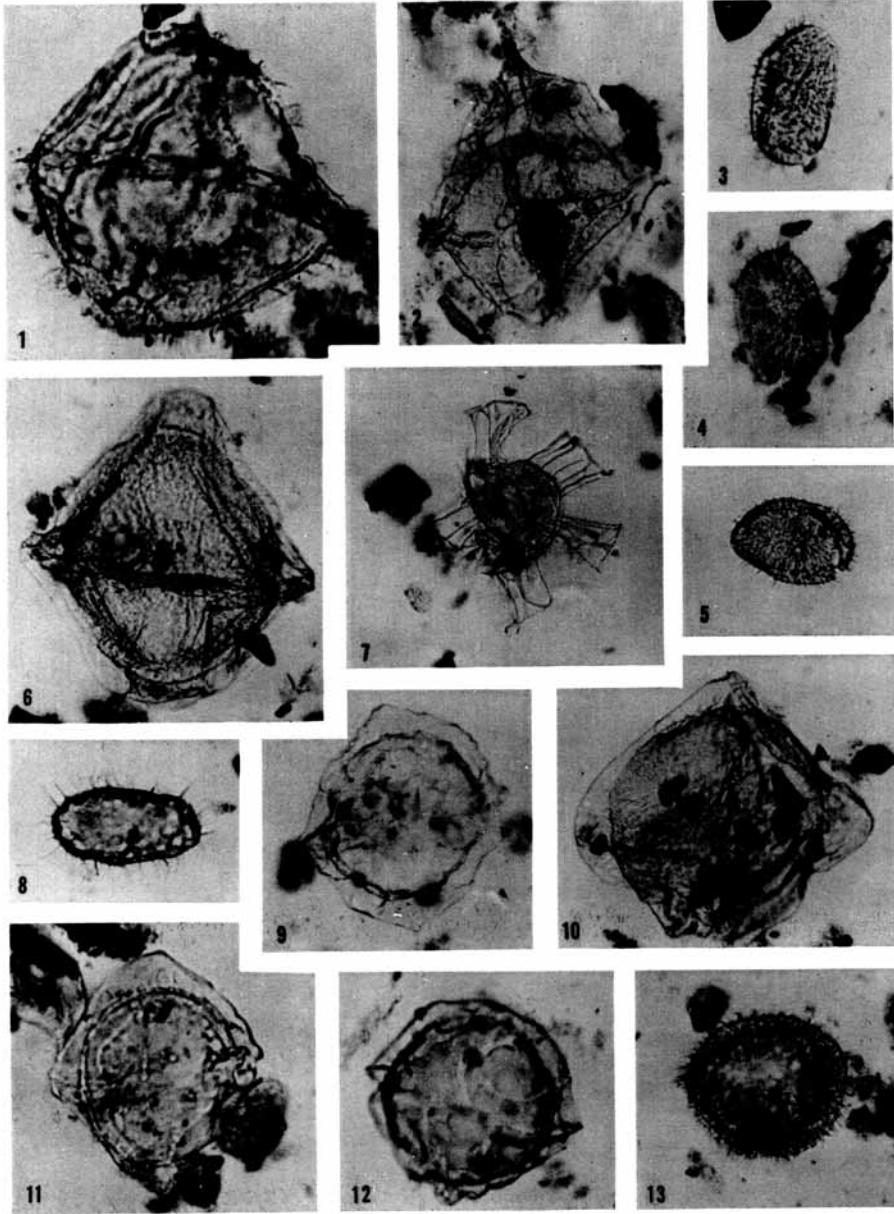
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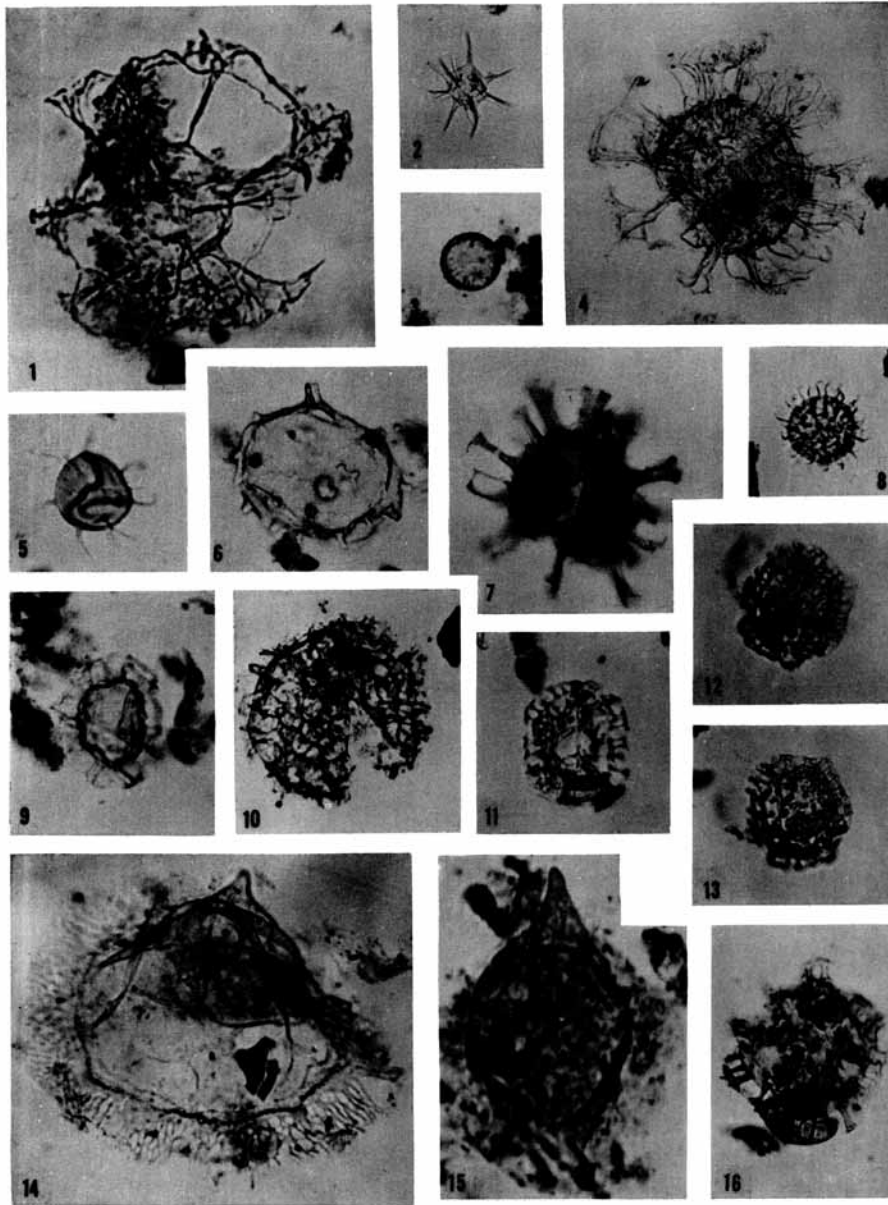
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SARJEANT, Jurassic microplankton



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