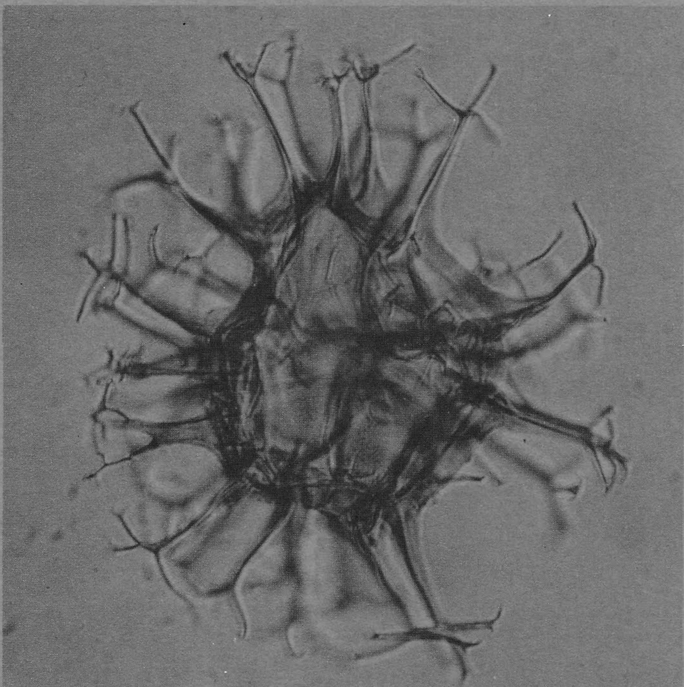
SPECIAL PAPERS IN PALAEONTOLOGY · 24

Dinoflagellate Cysts and Acritarchs from the Eocene of Southern England



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SPECIAL PAPERS IN PALAEONTOLOGY NO. 24

DINOFLAGELLATE CYSTS AND ACRITARCHS FROM THE EOCENE OF SOUTHERN ENGLAND

BY

J. P. BUJAK, C. DOWNIE, G. L. EATON,
G. L. WILLIAMS

With 22 plates and 24 text-figures

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ABSTRACT. Dinoflagellate cysts are abundant and diverse in the Eocene of southern England, with many species having restricted stratigraphic ranges. Thirteen dinoflagellate cyst assemblage zones are formally proposed, three in the London Clay, five in the Bracklesham Beds, and five in the Barton Beds. Five genera and twenty species of dinoflagellate cysts are erected, generic transfers are made for sixteen species, and the diagnoses of six genera and four species are emended. One genus and two species of acritarchs are also erected. The new genera are *Cerebrocysta*, *Dapsilidinium*, *Hemisphaeridium*, *Lentinia*, *Paucisphaeridium*, and *Quadrina*.

I. INTRODUCTION

DINOFLAGELLATE cysts are abundant in the Eocene of southern England and have been studied by the authors in the London Clay, Bracklesham Beds, and Barton Beds. Papers previously published on the dinoflagellate cysts from these beds include Bujak (1976, 1979), Costa and Downie (1976), Costa *et al.* (1976), Davey *et al.* (1966), Downie *et al.* (1971), Eaton (1971*a*, 1971*b*, 1976), and Gruas-Cavagnetto (1970, 1976*a*, 1976*b*), but the over-all ranges of dinoflagellate cyst taxa and a composite zonation have not been published.

The present paper represents a compilation of work completed by three of the authors (J. P. B., G. L. E., G. L. W.) as a series of Ph.D. studies under the supervision of Charles Downie at Sheffield University. Part III of the paper erects thirteen dinoflagellate cyst assemblage zones, three in the London Clay, five in the Bracklesham Beds, and five in the Barton Beds. The London Clay zones are based on the work of G. L. Williams (unpublished Ph.D. thesis, Sheffield University, 1963, and in Davey *et al.* 1966). The Bracklesham Beds zones follow the scheme suggested by Eaton (1976) and the Barton Beds zones are based on the studies of Bujak (unpublished Ph.D. thesis, Sheffield University, 1973).

Advances in the understanding and interpretation of dinoflagellate cyst morphology and improved optical equipment over the last decade have necessitated various taxonomic changes to the work of Davey *et al.* (1966). These are presented in Part IV of this paper and include two new dinoflagellate cyst genera, one new species, and fourteen new combinations.

Bujak (1976, 1979) described several dinoflagellate cyst species from the Barton Beds of the Hampshire Basin, but has not systematically described the total assemblage. This is done in Part V, which includes three new dinoflagellate cyst genera, nineteen new species, and two new combinations. One acritarch genus and two species are described as new.

All the species present in the London Clay, Bracklesham Beds, and Barton Beds are listed alphabetically in the Appendix (Part VIII); where a species has been illustrated in the present paper, the plate and figure numbers are included. The plates include illustrations of fifty-four holotypes of previously described Eocene taxa (see Plates 1–12). The photographs were mainly taken under interference contrast and often include several focal planes.

II. STRATIGRAPHY

by J. P. BUJAK, C. DOWNIE, G. L. EATON, *and* G. L. WILLIAMS

A variety of marine and non-marine sediments were deposited in the Anglo-Paris-Belgian Basin during the Palaeogene. Subsequent folding of this depositional basin has resulted in the isolation of four structural basins, these being the Hampshire and London Basins of southern England (text-fig. 1) and the Belgian and Paris Basins. Palaeogene sediments have been preserved in all these basins to a varying degree, but in the intervening areas they have been almost completely removed. The Hampshire Basin provides a more completely exposed section through the Palaeogene than the London Basin (text-figs. 1 and 2).

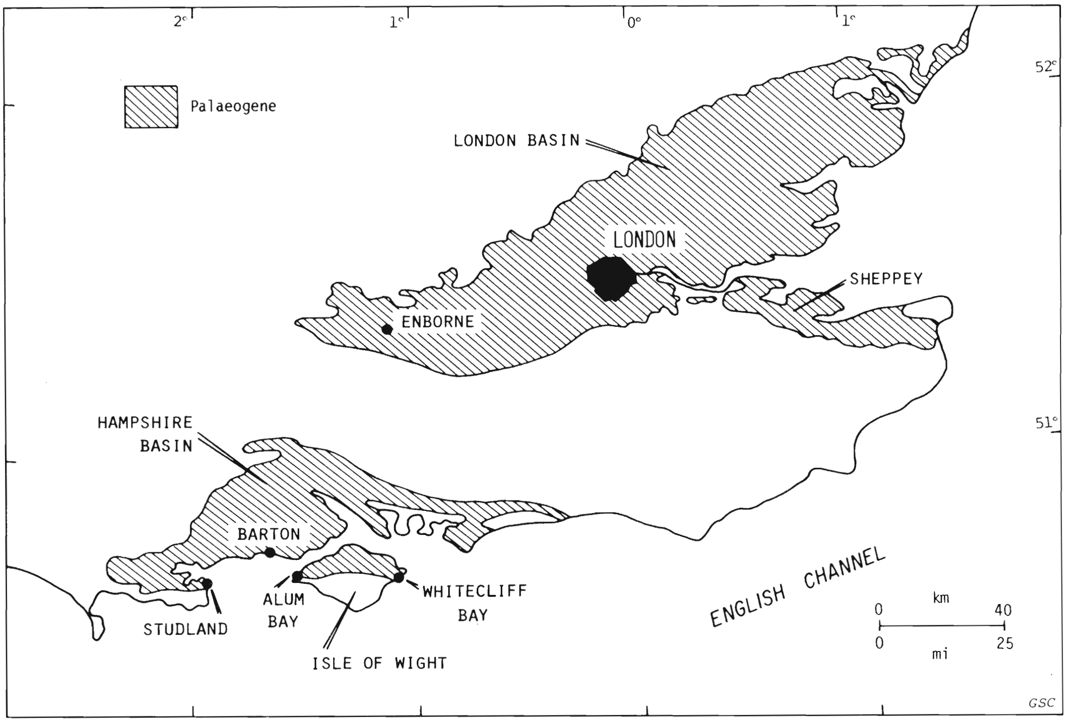
Eocene sediments are well exposed in the Hampshire Basin along cliff sections. The oldest sediments studied, the London Clay, outcrop at Studland Bay on the mainland and at Alum and Whitecliff Bays on the Isle of Wight (text-figs. 1 and 2). The Whitecliff Bay and Studland sections were sampled in 1960 (text-figs. 3 and 4). The London Clay of the London Basin was sampled from the outcrop section on the Isle of Sheppey and two boreholes at Enborne (text-figs. 1 and 4). The Bagshot Sands and Bracklesham Beds were sampled at Alum and Whitecliff Bays in 1966 (text-fig. 5). The Barton Beds were sampled in 1969 from the Barton section on the mainland and Alum and

Whitecliff Bays on the Isle of Wight (text-fig. 6). With the exception of the London Clay at Studland Bay and the Barton Beds at Whitecliff Bay, all of the Hampshire Basin sections were well exposed throughout the sampled sequences at the time of sampling. Details of the sampled horizons are shown in text-figs. 3 to 6.

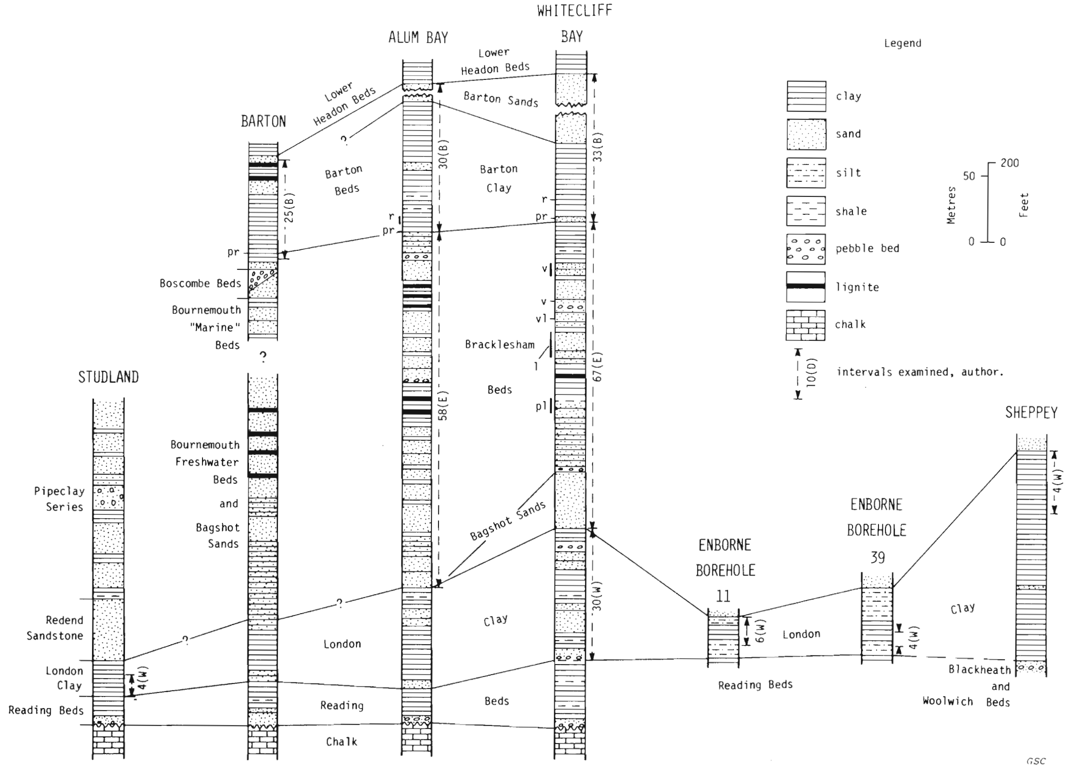
London Clay

The London Clay consists of a monotonous succession of blue-grey clays in the London Basin, where it attains a maximum thickness of over 500 feet (152 metres) at Sheppey. It thins to the west, in the Hampshire Basin, being 300 feet (91 metres) at Whitecliff Bay, less than 100 feet (30 metres) at Studland, and it is absent from Dorchester 45 miles (72 kilometres) to the west of Studland. The London Clay of the Hampshire Basin was probably deposited in a shallow marine environment, in contrast to the deeper-water clays of the London Basin, since it is more varied with clays, sands, and interspersed pebble beds.

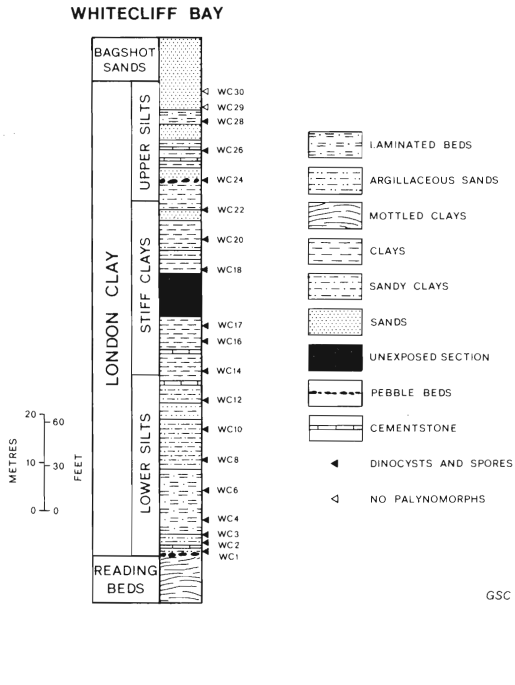
The London Clay is well exposed in the Whitecliff Bay section, where its lower and upper contacts are visible and a complete sequence is exposed (text-fig. 3). It is divisible into three lithological units equivalent to the Lower Silts, the Stiff Clays, and the Upper Silts of the Enborne Valley (Hawkins 1954). Within each of these units alternations of clays and sands occur, with septarian nodules, lignites, and iron pyrites being common throughout. According to Prestwich (1847) the thickness of his Beds 3 and 4 at Whitecliff Bay (which he called the Bognor Beds and which are equivalent to the London Clay) is 307 feet (93·6 metres). Reid and Strahan (1889) gave an approximate thickness of 320 feet (97 metres). The first detailed description of these beds at Whitecliff Bay was by White (1921) who measured a total of 322 feet (98·1 metres). Measurements carried out by one of the authors (G. L. W.) total 300 feet (91·4 metres). All but two of the nineteen samples analysed from the London Clay of Whitecliff Bay yielded dinoflagellate cysts.



TEXT-FIG. 1. Location map of southern England showing the Palaeogene of the London and Hampshire Basins and the sample localities.



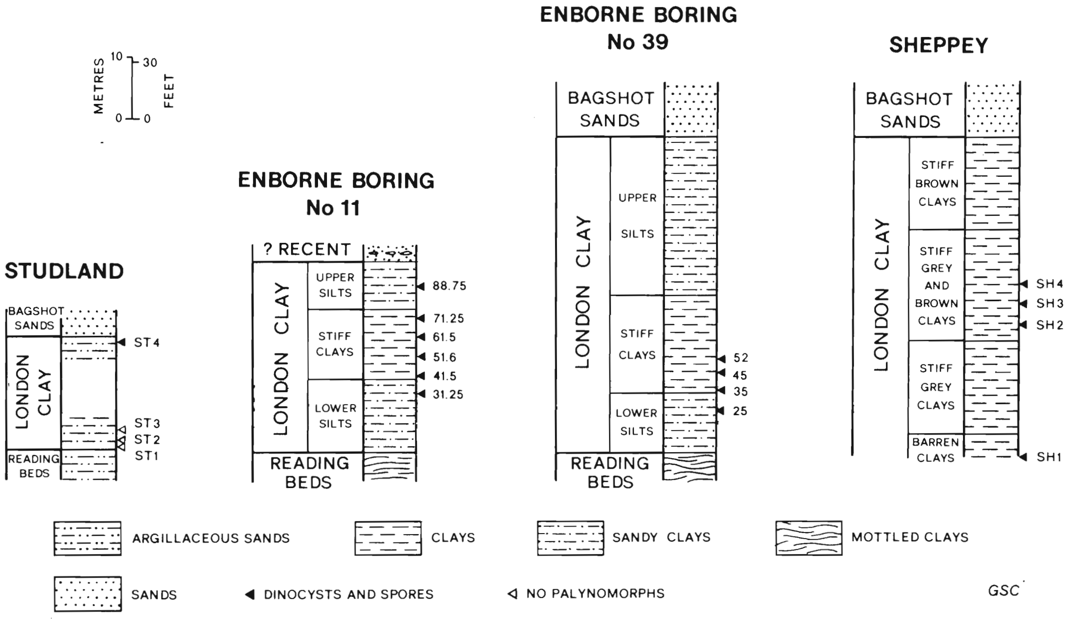
TEXT-FIG. 2. Lithostratigraphical correlation of the localities sampled in the present study. (Partly after Curry, 1965, courtesy of the Geologists' Association.) The examined intervals are shown and the number of samples indicated together with the palynologist responsible. (B = Bujak, E = Eaton, W = Williams.) *Nummulites* occurrences are indicated as follows: l = *N. laevigatus*, pl = *N. planatus*, pr = *N. prestwichianus*, r = *N. rectus*, v = *N. variolarius*.



TEXT-FIG. 3. Position of samples studied by G. L. Williams from the London Clay of Whitecliff Bay. (After Davey *et al.*, 1966.)

The other London Clay section studied from the Hampshire Basin is at Studland Bay in Dorset (text-fig. 4). This locality is one of the most westerly outcrops of the London Clay and lay close to the shoreline of the London Clay sea. The section thus includes a variety of marine and non-marine London Clay deposits. Slumping obscures most of the London Clay at this locality but the lower and upper contacts are exposed. The three samples collected within 10 feet (3 metres) of the base do not contain dinoflagellate cysts. The single sample from 3 feet (0·9 metres) below the top of the London Clay yielded dinoflagellate cysts.

In the London Basin, the London Clay at Enborne can be correlated with the three lithological units seen at Whitecliff Bay (text-figs. 3 and 4). Six samples were analysed from Metropolitan Waterboard Borehole no. 11 and four from Borehole no. 39. All contain dinoflagellate cysts. The London Clay attains its maximum thickness at Sheppey, where Davis (1936) estimated it to be 518 feet (158 metres) thick. The upper 160 feet (49 metres) are exposed in the Sheppey cliff section. The lithology at this locality is a uniform stiff blue-grey clay with frequent beds of septarian nodules (text-fig. 4). The upper boundary of the London Clay is exposed but slumping obscures much of the remaining section, so that only four samples were collected. Davey *et al.* (1966) described in detail the taxonomy of the dinoflagellate cyst assemblages from all of the above London Clay sections.

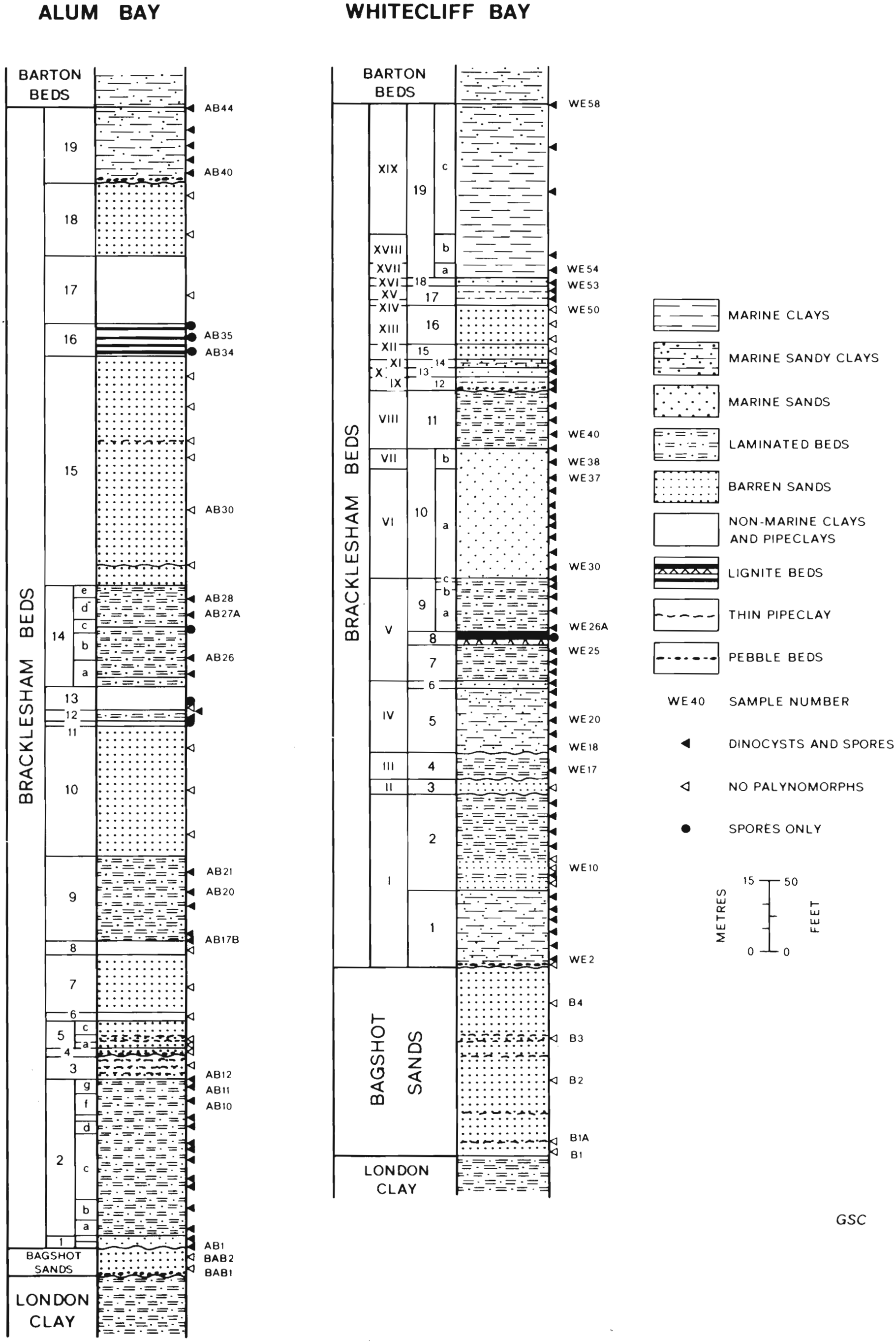


TEXT-FIG. 4. Position of samples studied by G. L. Williams from the London Clay of Studland, Enborne Boring no. 11, Enborne Boring no. 39, and Sheppey. (After Davey *et al.*, 1966.)

Bagshot Sands and Bracklesham Beds

The series of sands above the London Clay in the Hampshire Basin are known as the Bagshot Sands. Eaton (1976) examined samples from the Bagshot Sands at Alum Bay and Whitecliff Bay, but all were barren of palynomorphs.

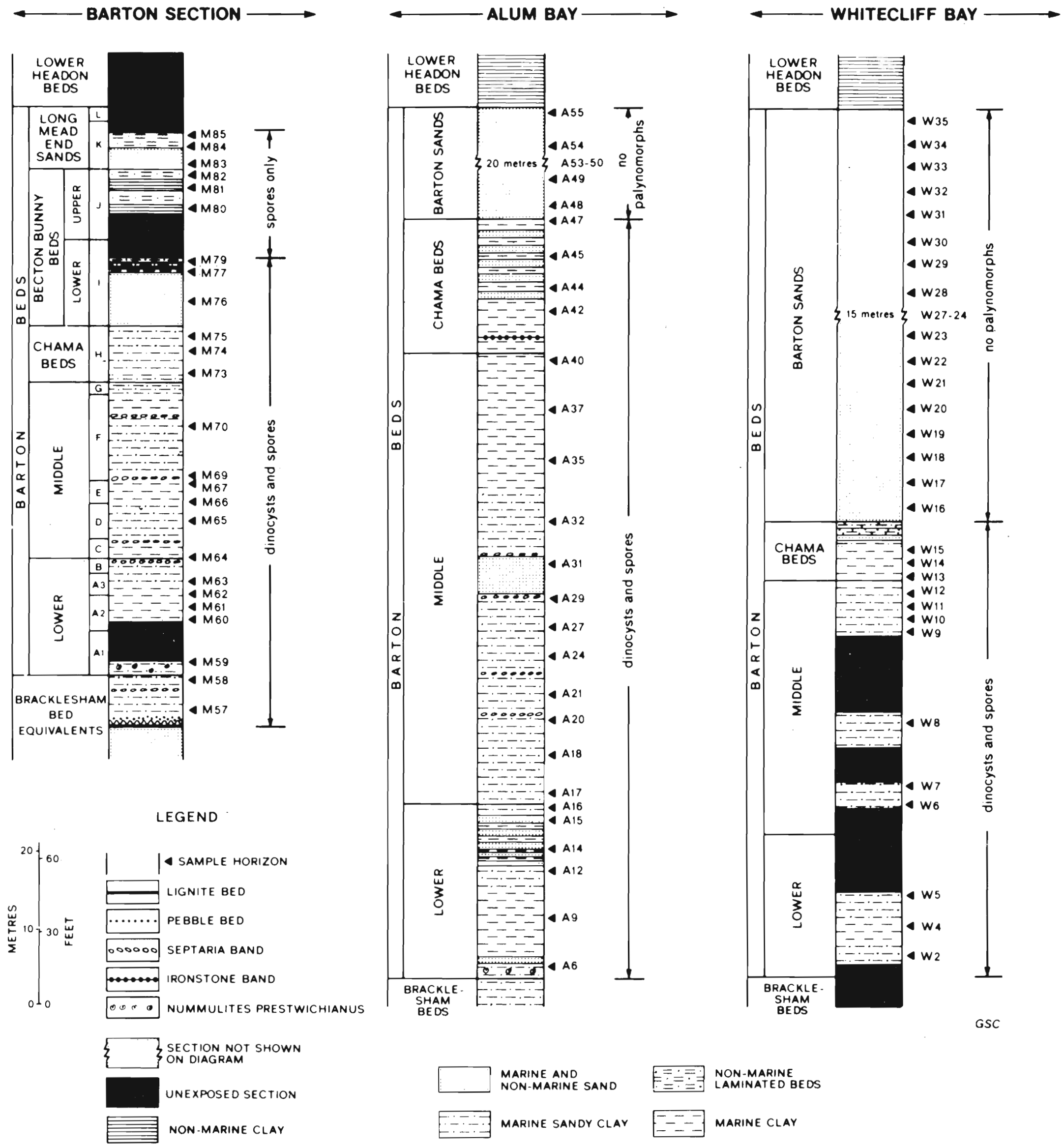
The Bagshot Sands of the Hampshire Basin are overlain by the Bracklesham Beds. At both Alum and Whitecliff Bays, the Bracklesham Beds are exposed in a vertical to near-vertical attitude and include a variety of sediments, with marine sands and clays, finely laminated alternating sands and clays, pebble beds, non-marine sands and clays, pipeclays, and lignite beds. In their type section at Whitecliff Bay (Fisher 1862), the Bracklesham Beds are 598 feet (182 metres) thick. Fifty-one collected samples contain dinoflagellate cysts (text-fig. 5). At Alum Bay the Bracklesham Beds are



TEXT-FIG. 5. Position of samples studied by G. L. Eaton from the Bagshot Sands and Bracklesham Beds of Alum Bay and Whitecliff Bay, Isle of Wight. The Roman numerals I–XIX in the Whitecliff Bay Section refer to the subdivisions of Fisher (1862). The numbers 1–19 represent the lithological subdivisions of Eaton (1976). (After Eaton, 1976.)

793 feet (242 metres) thick and consist mainly of unfossiliferous sands and laminated beds. Thirty samples collected from this section contain dinoflagellate cysts. The base of the Bracklesham Beds at Alum Bay used in this study differs from that of White (1921) who included the Bagshot Sands and the lower part of the Bracklesham Beds (*sensu* Eaton) in the London Clay.

Bujak (1976) also studied dinoflagellate cysts in two samples from the 10 feet (3 metres) of strata immediately underlying the Barton Beds at Highcliff near Barton (text-fig. 6). These strata correlate with the uppermost Bracklesham Beds of the Isle of Wight.



TEXT-FIG. 6. Position of samples studied by J. P. Bujak from the Barton Beds of Barton, Alum Bay, and Whitecliff Bay. The letters A to L in the Barton Section refer to the subdivisions of Burton (1933). (After Bujak, 1976.)

Barton Beds

The Barton Beds were sampled from three cliff sections in the Hampshire Basin. These are, from the west, the Barton section on the mainland and Alum and Whitecliff Bays on the Isle of Wight (text-figs. 1 and 6). At the time of sampling the Barton Beds were well exposed in the Barton and Alum Bay sections but poorly exposed at Whitecliff Bay, so that the base of the beds could only be located at Barton and Alum Bay. The boundary between the Barton and overlying Lower Headon Beds was exposed on the Isle of Wight at Alum and Whitecliff Bays, but not in the Barton section because of slumping.

The type section of the Barton Beds is at Barton where they are 246 feet (75 metres) thick. Twenty-three samples were analysed, the lowermost sixteen containing indigenous dinoflagellate cysts. Two samples were also collected from the underlying 10 feet (3 metres) of the Bracklesham Bed equivalents.

At Alum Bay the Barton Beds are approximately 440 feet (134 metres) thick. Thirty samples were analysed from the Barton Beds of Alum Bay, all containing dinoflagellate cysts except for the eight Barton Sands samples which were devoid of palynomorphs.

Thirty-four samples were analysed from the 430 feet (131 metres) of Barton Beds at Whitecliff Bay. All contain dinoflagellate cysts except for the twenty Barton Sands samples which are devoid of palynomorphs.

III. DINOFLAGELLATE CYST ZONATION OF THE EOCENE, SOUTHERN ENGLAND

by J. P. BUJAK, C. DOWNIE, G. L. EATON, *and* G. L. WILLIAMS

Previous palynological studies

Dinoflagellate cysts from the Eocene of England were noted by Eager and Sarjeant (1963) and figured by Macko (1963), but the earliest extensive study was published by Davey *et al.* (1966). The Eocene data included in that publication were based on the thesis of G. L. Williams (unpublished Ph.D. thesis, Sheffield University, 1963). Davey *et al.* (1966) was primarily a taxonomic study with minimal discussion of biostratigraphy.

Downie *et al.* (1971) distinguished four dinoflagellate cyst associations in the Palaeogene of south-east England which they related to lithology and palaeoenvironment.

Eaton (1971*a*) described a morphogenetic series of dinoflagellate cysts from the Bracklesham Beds of the Isle of Wight and figured the stratigraphic ranges of five species. He correlated the Alum and Whitecliff Bay Bracklesham Beds using a fivefold dinoflagellate cyst zonation. This correlation was also discussed in Eaton (1971*b*). He later (1976) published the systematics of all Bracklesham Bed dinoflagellate cysts from the Isle of Wight, defined five informal microplankton zones (1–5), and compared his assemblages with those described from Belgium, Germany, and France.

Bujak (1976) described the continuation in the Barton Beds of the morphogenetic series documented by Eaton (1971*a*) and figured the stratigraphic ranges of seven dinoflagellate cyst species in the Barton Beds at Barton, Alum, and Whitecliff Bays. Bujak (1979) subsequently described a second morphogenetic series and figured the stratigraphic ranges of five dinoflagellate cyst species in the Barton Beds of the Hampshire Basin.

Gruas-Cavagnetto (1970) studied twenty-eight horizons from the Palaeogene of southern England, including several from the London Clay at Southampton, the Lower Bracklesham Beds at Whitecliff Bay, the Upper Bracklesham Beds at Selsey, the Lower Barton Beds at Highcliff, and the Middle Barton Beds at Barton, but gave insufficient details of sample horizons and species occurrences to permit comparison with the present study.

Gruas-Cavagnetto (1976*a*) recorded fifty-two dinoflagellate cyst taxa from the London Clay, Bracklesham Beds, and Barton Beds of southern England. Since a range chart was not given, it is again not possible to compare the data from her paper with that in the present study.

Gruas-Cavagnetto (1976*b*) studied the dinoflagellate cysts from several outcrops in the Paris Basin and eastern Manche. She selected forty species with limited stratigraphic ranges, compared the dinoflagellate cysts in her study areas with those in southern England, and suggested correlations between these three areas and the Belgian succession.

Costa *et al.* (1976) used dinoflagellate cysts for correlating local sequences in the Eocene of the Hampshire Basin. They listed Eaton's informal zones as 'partial range biozones', and named them after their characteristic species, without considering the imminent publication of Eaton (1976). This led to nomenclatural inconsistencies relative to the species recorded in the latter paper. Costa *et al.* also referred to the five partial range biozones in the Barton Beds delineated by Bujak (unpublished Ph.D. thesis, Sheffield University, 1973). These are formally defined for the first time in the present paper as assemblage zones.

Costa and Downie (1976) established eight *Wetzeliella* zones in the north-west European Palaeogene. Only species then included in *Wetzeliella* were utilized and only the lowest stratigraphic occurrence of taxa were used, since Costa and Downie stated (p. 600), 'The first occurrence of taxa . . . are taken to be more reliable than the extinction of species.' These authors correlated Upper Palaeocene to Oligocene strata in southern England, Belgium, northern Germany, France, and Spain, but did not consider genera other than *Wetzeliella*.

Costa *et al.* (1978) correlated the beds adjacent to the Palaeocene–Eocene boundary in the Anglo-Paris Basin using the zonation of Costa and Downie (1976).

Definition of zones

The thirteen dinoflagellate cyst zones defined in the Eocene of southern England are discussed below from oldest to youngest. Within each, data are presented on the type section, other localities at which the zone has been recognized and diagnostic species that have their first or last occurrence in the zone. The biostratigraphic importance of dinoflagellate cyst species present within each of the zones is also discussed.

All thirteen zones are assemblage zones as defined in the American Commission on Stratigraphic Nomenclature (1961, Articles 20g, 21). The following notation is used to distinguish the zones. Zones LC-1 to LC-3 indicate the three zones recognized in the London Clay from oldest to youngest. The five Bracklesham Beds zones from oldest to youngest are B-1 to B-5. BAR-1 to BAR-5 represent the five zones from oldest to youngest of the Barton Beds. No dinoflagellate cysts were recorded from the Bagshot Sands. Each zone is also named after a selected species first appearing at the base of the zone, but it is stressed that all thirteen zones are assemblage zones and are defined by the total dinoflagellate cyst assemblage present. The species listed as defining each zone by their first or last occurrences have been selected because the authors feel that these species occurrences are biostratigraphically significant in the Eocene of southern England. Those species not listed, but shown on the range charts, have less certain stratigraphic ranges.

Authors of dinoflagellate cyst species discussed in the text and shown on the range charts (text-fig. 7A–D) are given in the alphabetical species list (Part VIII). This includes all indigenous dinoflagellate cyst species recorded by the authors from the London Clay, Bracklesham Beds, and Barton Beds of southern England. It also lists several species which are not shown on the range charts because they either range through the discussed sections or have stratigraphic ranges that are uncertain.

Deflandrea phosphoritica Assemblage Zone (LC-1)

Type section. London Clay, 0–141 feet (0–43 metres) above the base at Whitecliff Bay, Isle of Wight. Sample numbers WC1 to WC14 (text-fig. 3).

Other localities. Studland Bay, Dorset; Core holes 11 and 39, Enborne Valley, Berkshire (text-fig. 4).

Definition. Species first appearing at the base of the zone: *Wetzeliella* cf. *W. meckelfeldensis*, *W. similis*. Species first appearing within the zone: *Achilleodinium biformoides*, *Cordosphaeridium cracenospinosum*, *D. denticulata*, *Homotryblium pallidum*, *Hystrichokolpoma rigaudiae*, *Lanternosphaeridium axiale*, *Lentinia wetzelii*, *W. articulata*, *W. lunaris*. The following species occurring in this zone were also recorded by Hussain (unpublished thesis, Sheffield University, 1967) from strata older than the London Clay in the London Basin: *Apectodinium homomorphum*, *C. fibrospinosum*, *C. gracile*, *C. inodes*, *Cyclonephelium divaricatum*, *C. ordinatum*, *D. denticulata*, *D. phosphoritica*, *Diphyes colligerum*, *Eocladopyxis peniculatum*, *Hystrichosphaeridium salpingophorum*, *H. tubiferum*, *Lingulodinium machaerophorum*, *Melitasphaeridium pseudorecurvatum*, *Palaeocystodinium gol-*

zowense, and *Spiniferites pseudofurcatus*. No species have their last occurrence within the *D. phosphoritica* Assemblage Zone. Species last occurring at the top of the zone: *Cordosphaeridium cracenospinosum*, *Hystrichokolpoma unispinum*.

Discussion. The basal Eocene zone recognized by Costa and Downie (1976), the *Apectodinium hyperacanthum* Zone, included not only the Woolwich and Oldhaven Beds of the Palaeocene, but also the basal London Clay at Whitecliff Bay. Costa *et al.* (1978) subsequently inserted the *W. astra* Zone, marked by the earliest occurrence of *W. astra* Costa *et al.*, at the base of the London Clay at Whitecliff Bay. Costa and Downie's (1976) overlying zone, the *W. meckelfeldensis* Zone, was defined at Herne Bay and is also present at Studland Bay, Alum Bay, and Whitecliff Bay. According to Costa and Downie, the top of the *W. meckelfeldensis* Zone at Whitecliff Bay coincides with the boundary between the lower and upper dinoflagellate cyst assemblages recognized by G. L. Williams (unpublished Ph.D. thesis, Sheffield University, 1963). Since the *Deflandrea phosphoritica* Zone is equated with the lower dinoflagellate cyst assemblage of Williams, it also equates with the *W. meckelfeldensis* Zone at Whitecliff Bay.

Wetzeliella cf. *W. meckelfeldensis*, which first appears at the base of the *D. phosphoritica* Zone, was originally included in *W. symmetrica* Weiler by Williams and Downie (1966*a*). Costa and Downie (1976) have demonstrated the presence of *W. meckelfeldensis* in the London Clay, thus suggesting that *W.* cf. *W. meckelfeldensis* of the present paper is synonymous with *W. meckelfeldensis*.

Costa and Downie (1976) defined their *W. similis* Zone immediately above their *W. meckelfeldensis* Zone within the London Clay. *W. similis* and *W.* cf. *W. meckelfeldensis* occur in the lowest London Clay sample examined in the present study (G. L. Williams, pers. obs.). The recognition of different earliest occurrences for these species by Costa and Downie may be due to closer sampling of the critical intervals by G. L. Williams.

The present study indicates that *W. articulata* occurs in the lowest London Clay samples examined in the *D. phosphoritica* Zone, equivalent to the *W. meckelfeldensis* Zone of Costa and Downie. These authors placed the earliest occurrence of *W. articulata* in the Hampshire Basin higher in the London Clay, within their *W. varielongituda* Zone, but indicated uncertainty over its precise position.

Membranilarnacia ursulae Assemblage Zone (LC-2)

Type section. London Clay, 141–295 feet (43–90 metres) above the base at Whitecliff Bay, Isle of Wight. Sample numbers WC16 to WC28 (text-fig. 3).

Other localities. Core hole 11, Enborne Valley, Berkshire; Sheppey, Kent (text-fig. 4).

Definition. Species first appearing at the base of the zone: *Adnatosphaeridium multispinosum*, *Dapsilidinium pastielsii*, *Homotryblium tenuispinosum*, *M. ursulae*, *Spiniferites monilis*. Species first appearing within the zone: *Thalassiphora pelagica*. No species have their last occurrence at the top of this zone.

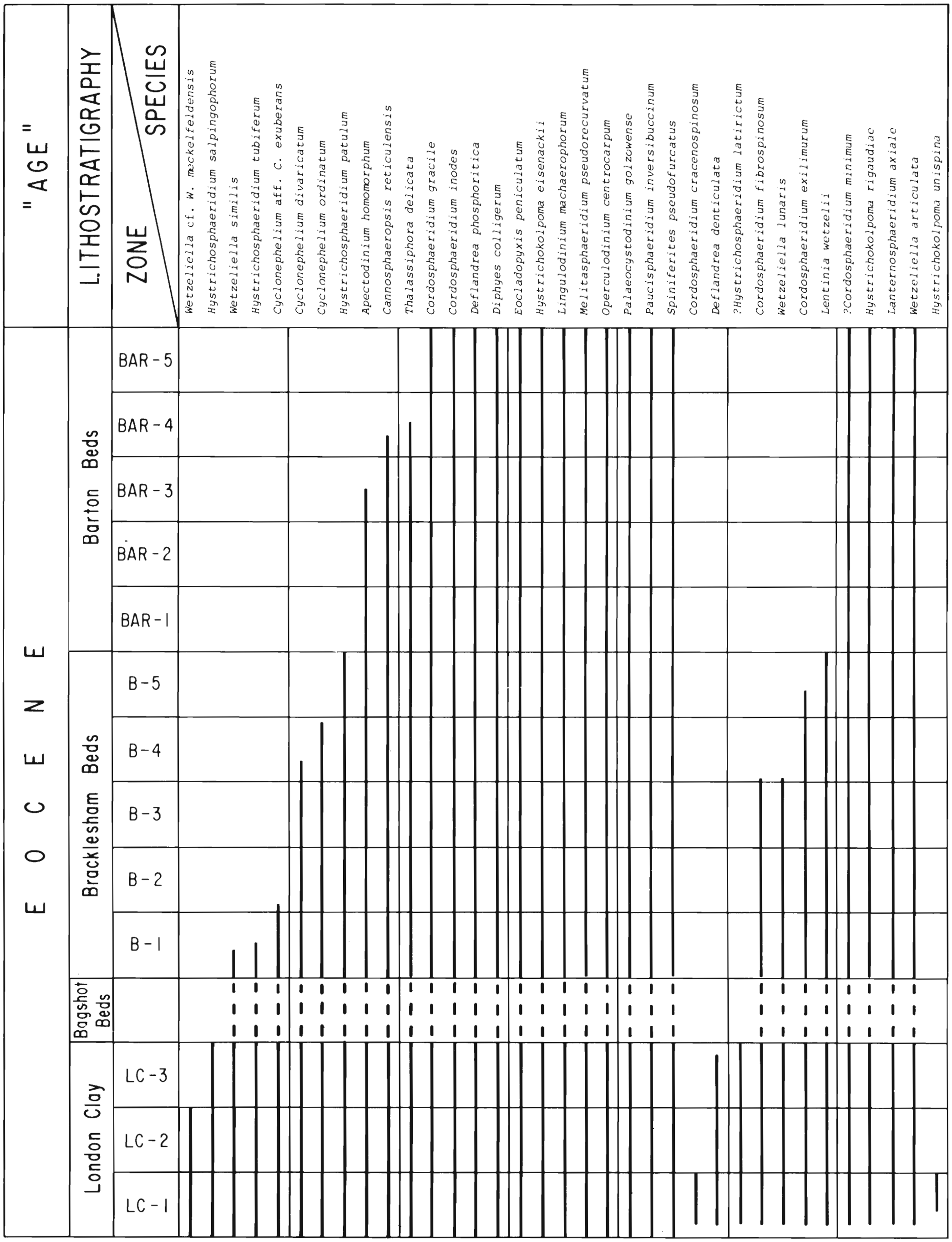
Discussion. Sediments assigned to the *M. ursulae* Zone are recognized in both the Hampshire and London Basins.

Costa and Downie (1976) defined the *W. similis* Zone above the *W. meckelfeldensis* Zone as the interval from the appearance of *W. similis* to the first occurrence of *W. varielongituda*. Above this they recognized the *W. varielongituda* Zone, defined as the interval from the first appearance of *W. varielongituda*, to the appearance of *Kisselovia coleothrypta*. Although the zone is also present at Sheppey, no type section was designated. The *W. varielongituda* Zone is presumably equivalent to the upper part of the *M. ursulae* Zone.

Kisselovia reticulata Assemblage Zone (LC-3)

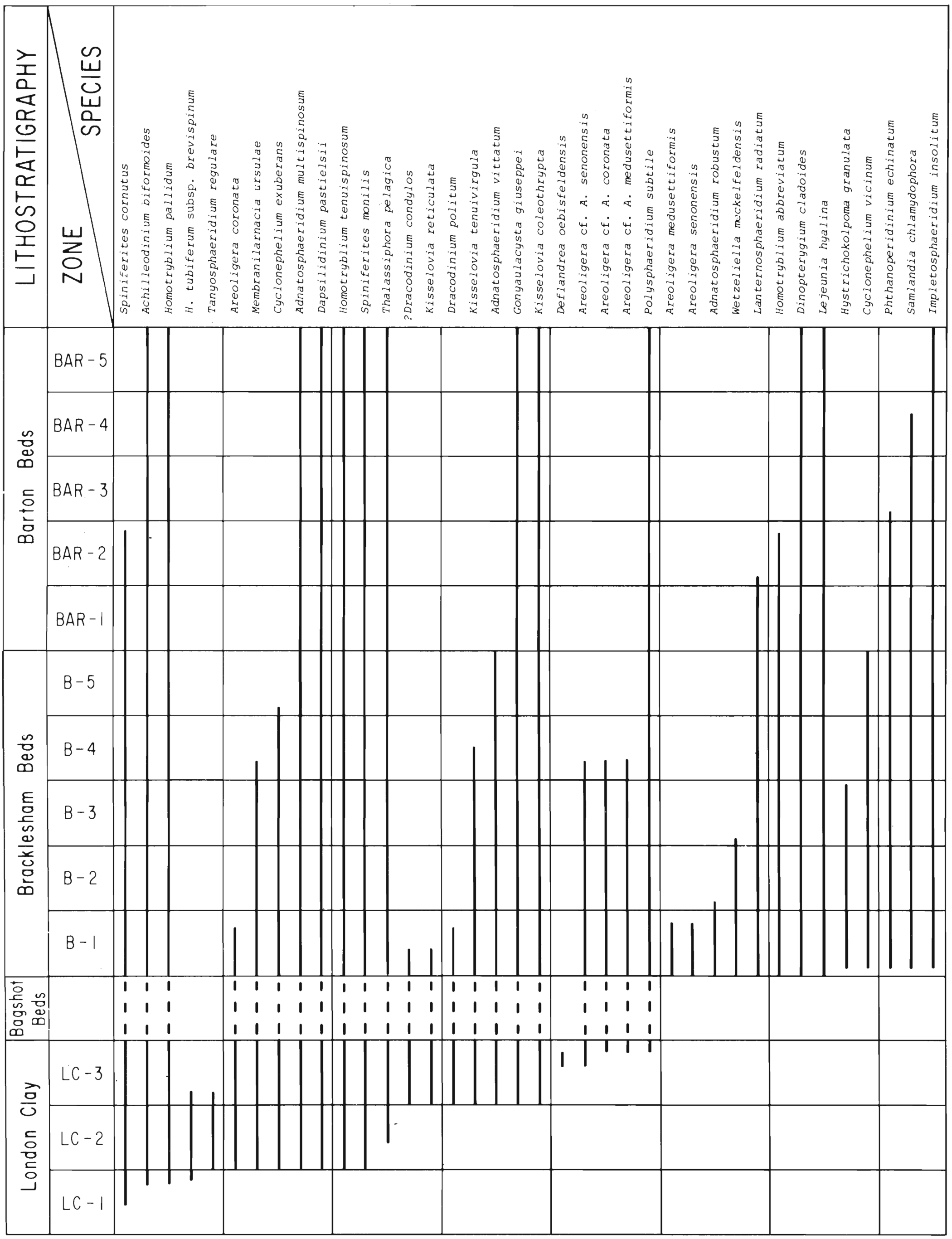
Type section. London Clay, 100–110 feet (30–33 metres) below the top of the exposed section at the Isle of Sheppey, Kent. Sample numbers SH2 to SH4 (text-fig. 4).

Other localities. None.

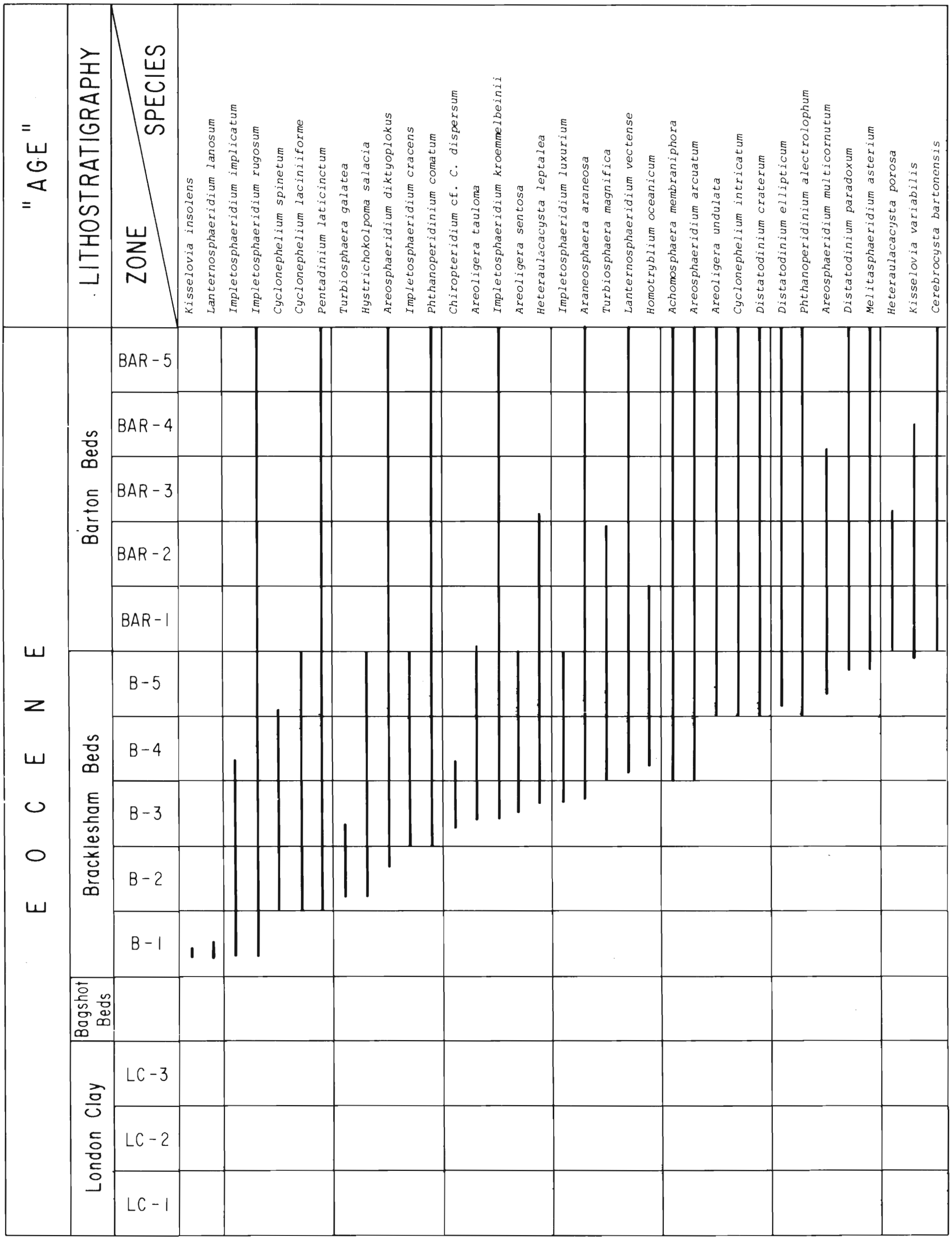


7A

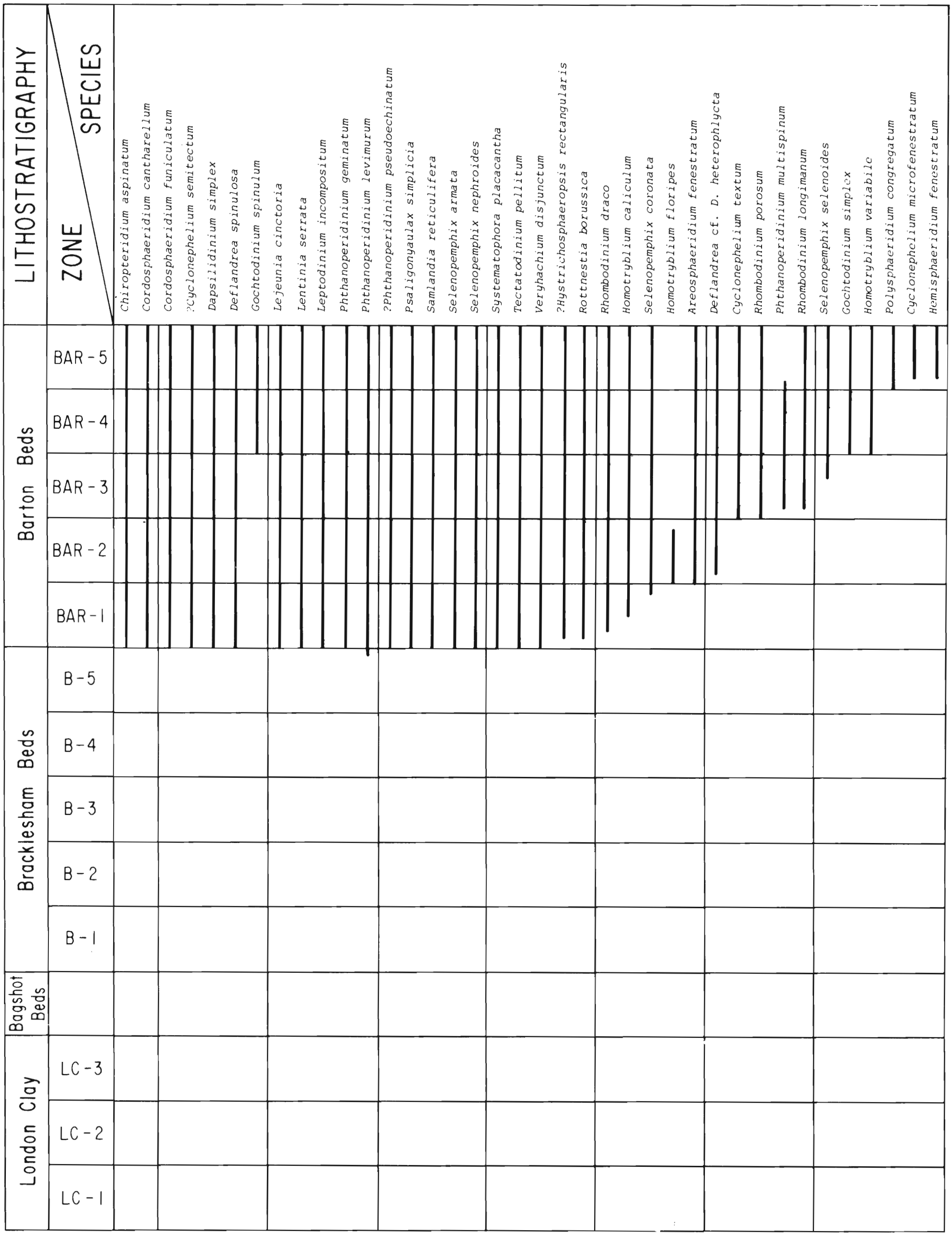
TEXT-FIG. 7A–D. Stratigraphical ranges of selected dinoflagellate cysts and acritarchs in the Eocene of southern England. The zones shown are those defined in the present paper. The ranges shown are based on the sections examined in the present study. They are not intended to represent composite, worldwide ranges for the species.


LITHOSTRATIGRAPHY
ZONE
SPECIES
London Clay
Bagshot Beds
Bracklesham Beds
Barton Beds
LC - 1
LC - 2
LC - 3
B - 1
B - 2
B - 3
B - 4
B - 5
BAR - 1
BAR - 2
BAR - 3
BAR - 4
BAR - 5
Spiniferites cornutus
Achilleodinium biformoides
Homotryblium pallidum
H. tubiferum subsp. brevispinum
Tanyosphaeridium regulare
Areoligera coronata
Membranilarnacia ursulae
Cyclonephelium exuberans
Adnatosphaeridium multispinosum
Dapsilidinium pastielsii
Homotryblium tenuispinosum
Spiniferites monilis
Thalassiphora pelagica
?Dracodinium condylos
Kisselovia reticulata
Dracodinium politum
Kisselovia tenuivirgula
Adnatosphaeridium vittatum
Gonyaulacysta giuseppei
Kisselovia coleothrypta
Deflandrea oebisfeldensis
Areoligera cf. A. senonensis
Areoligera cf. A. coronata
Areoligera cf. A. medusettiformis
Polysphaeridium subtile
Areoligera medusettiformis
Areoligera senonensis
Adnatosphaeridium robustum
Wetzeliella meckelfeldensis
Lanternosphaeridium radiatum
Homotryblium abbreviatum
Dinopterygium cladoides
Lejeunia hyalina
Hystrichokolpoma granulata
Cyclonephelium vicinum
Phthanoperidinium echinatum
Samlandia chlamydophora
Impletosphaeridium insolitum

7B


"AGE"
LITHOSTRATIGRAPHY
ZONE
SPECIES
EOCENE
London Clay
Bagshot Beds
Bracklesham Beds
Barton Beds
LC-1
LC-2
LC-3
B-1
B-2
B-3
B-4
B-5
BAR-1
BAR-2
BAR-3
BAR-4
BAR-5
Kisselovia insolens
Lanternosphaeridium lanosum
Impletosphaeridium implicatum
Impletosphaeridium rugosum
Cyclonephelium spinetum
Cyclonephelium laciniiforme
Pentadinium laticinctum
Turbiosphaera galatea
Hystrichokolpoma salacia
Areosphaeridium diktyoplokus
Impletosphaeridium cracens
Phthanoperidinium comatum
Chiropteridium cf. C. dispersum
Areoligera tauloma
Impletosphaeridium kroemmelbeinii
Areoligera sentosa
Heteraulacacysta leptalea
Impletosphaeridium luxurium
Araneosphaera araneosa
Turbiosphaera magnifica
Lanternosphaeridium vectense
Homotryblium oceanicum
Achomosphaera membraniphora
Areosphaeridium arcuatum
Areoligera undulata
Cyclonephelium intricatum
Distatodinium craterum
Distatodinium ellipticum
Phthanoperidinium alectrolophum
Areosphaeridium multicornutum
Distatodinium paradoxum
Melitasphaeridium asterium
Heteraulacacysta porosa
Kisselovia variabilis
Cerebrocysta bartonensis

7c


LITHOSTRATIGRAPHY
ZONE
SPECIES
Chiropteridium aspinatum
Cordosphaeridium cantharellum
Cordosphaeridium funiculatum
?Cyclonephelium semitectum
Dapsilidinium simplex
Deflandrea spinulosa
Gochtodinium spinulum
Lejeunia cinctoria
Lentinia serrata
Leptodinium incompositum
Phthanoperidinium geminatum
Phthanoperidinium levimurum
?Phthanoperidinium pseudoechinatum
Psaligonyaulax simplicia
Samlandia reticulifera
Selenopemphix armata
Selenopemphix nephroides
Systematophora placacantha
Tectatodinium pellitum
Veryhachium disjunctum
?Hystrichosphaeropsis rectangularis
Rottnestia borussica
Rhombodinium draco
Homotryblium caliculum
Selenopemphix coronata
Homotryblium floripes
Areosphaeridium fenestratum
Deflandrea cf. D. heterophlycta
Cyclonephelium textum
Rhombodinium porosum
Phthanoperidinium multispinum
Rhombodinium longimanum
Selenopemphix selenoides
Gochtodinium simplex
Homotryblium variabile
Polysphaeridium congregatum
Cyclonephelium microfenestratum
Hemisphaeridium fenestratum
Barton Beds
BAR-5
BAR-4
BAR-3
BAR-2
BAR-1
Bracklesham Beds
B-5
B-4
B-3
B-2
B-1
Bagshot Beds
London Clay
LC-3
LC-2
LC-1

7D

Definition. Species first appearing at the base of the zone: *Adnatosphaeridium vittatum*, ?*Dracodinium condylos*, *Dracodinium politum*, *Gonyaulacysta giuseppei*, *K. coleothrypta*, *K. reticulata*, *K. tenuivirgula*. Species first appearing within the zone: *Areoligera* cf. *A. coronata*, *sensu* Williams and Downie, 1966*b*, *Areoligera* cf. *A. medusettiformis*, *sensu* Williams and Downie, 1966*b*, *Areoligera* cf. *A. senonensis*, *sensu* Williams and Downie, 1966*b*, *Polysphaeridium subtile*. Species last occurring within the zone: *Deflandrea denticulata*, *D. oebisfeldensis*, *Hystrichosphaeridium tubiferum* subsp. *brevispinum*, *Tanyosphaeridium regulare*. Species last occurring at the top of the zone: ?*Hystrichosphaeridium latirictum*, *Hystrichosphaeridium salpingophorum*.

Discussion. The *K. reticulata* Zone, the youngest zone recognized in the London Clay, is present only at Sheppey. Costa and Downie (1976) erected the *K. coleothrypta* Zone which is partly time equivalent. The latter zone was defined as the interval from the first appearance of *K. coleothrypta* to the first appearance of *Rhombodinium draco*. This zone also includes all of the Bracklesham Beds of Whitecliff Bay and Alum Bay. Costa and Downie equated their zone with the four calcareous nannoplankton zones NP12 to NP15 of Martini (1971). The *K. reticulata* Assemblage Zone is therefore coeval with the lowermost part of Costa and Downie's *K. coleothrypta* Zone.

Homotryblium abbreviation Assemblage Zone (B-1)

Type section. Bracklesham Beds as defined by Eaton (1976), 2–134 feet (0·6–41 metres) above the base at Whitecliff Bay, Isle of Wight (Beds I to III in part of Fisher 1862, equivalent to Beds 1 to 4 of Eaton 1976). Sample numbers WE2 to WE17 (text-fig. 5).

Other localities. Bracklesham Beds, 1–104 feet (0·3–32 metres) above the base as defined by Eaton (1976) at Alum Bay, Isle of Wight (Beds 1 to 2*f* of Eaton 1976).

Definition. Species first appearing at the base of the zone: *Adnatosphaeridium robustum*, *Dinopterygium cladoides sensu* Morgenroth, 1966*a*, *H. abbreviatum*, *Lanternosphaeridium radiatum*, *Lejeunia hyalina*. Species first appearing within the zone: *Cyclonephelium vicinum*, *Hystrichokolpoma granulata*, *Impletosphaeridium implicatum*, *I. insolitum*, *I. rugosum*, *Kisselovia insolens*, *Lanternosphaeridium lanosum*, *Phthanoperidinium echinatum*, *Samlandia chlamydophora*. Species last occurring within the zone: *Areoligera coronata*, *A. medusettiformis*, *A. senonensis*, ?*Dracodinium condylos*, *Dracodinium politum*, *Hystrichosphaeridium tubiferum*, *K. insolens*, *K. reticulata*, *W. similis*. No species have their last occurrence at the top of this zone.

Discussion. This zone corresponds to microplankton zone 1 of Eaton (1976). Several of the species described by Eaton as first appearing in this zone are now considered to appear in older zones in the London Clay. These are *Achilleodinium biformoides*, *Eocladopyxis peniculatum*, and *L. axiale* (*Deflandrea phosphoritica* Zone, LC-1), *Adnatosphaeridium vittatum*, *Polysphaeridium subtile*, *K. coleothrypta*, and *K. tenuivirgula* (*K. reticulata* Zone, LC-3). The possibility that the definition of the basal zone of the Bracklesham Beds might be modified in this way was suggested by Eaton (1976, p. 314). Additional species now interpreted as appearing in the *H. abbreviatum* Zone are *A. robustum*, *Dinopterygium cladoides sensu* Morgenroth, 1966*a*, *L. radiatum*, and *Lejeunia hyalina*. This zone and the other four zones in the Bracklesham Beds are together equivalent to most of the *K. coleothrypta* Zone of Costa and Downie (1976).

Pentadinium laticinctum Assemblage Zone (B-2)

Type section. Bracklesham Beds as defined by Eaton (1976), 149–219 feet (45–67 metres) above the base at Whitecliff Bay, Isle of Wight (Beds IV to V in part of Fisher 1862, equivalent to Beds 5 to 7 of Eaton 1976). Sample numbers WE18 to WE25 (text-fig. 5).

Other localities. 113–118 feet (34–36 metres) above the base of the Bracklesham Beds as defined by Eaton (1976) at Alum Bay, Isle of Wight (Bed 2*g* of Eaton 1976).

Definition. Species first appearing at the base of the zone: *Cyclonephelium laciniiforme*, *C. spinetum*, *P. laticinctum*. Species first appearing within the zone: *Areosphaeridium diktyoplokus*, *Hystrichokolpoma salacia*, *Turbiosphaera galatea*. Species last occurring within the zone: *Adnatosphaeridium robustum*, *Cyclonephelium* aff. *C. exuberans*. No species have their last occurrence at the top of this zone.

Discussion. This zone corresponds to microplankton zone 2 of Eaton (1976).

Phthanoperidinium comatum Assemblage Zone (B-3)

Type section. Bracklesham Beds as defined by Eaton (1976), 233–341 feet (71–104 metres) above the base at Whitecliff Bay, Isle of Wight (Beds V in part to VI of Fisher 1862, equivalent to Beds 9*a* to 10*a* of Eaton 1976). Sample numbers WE26A to WE37 (text-fig. 5).

Other localities. 214–432 feet (65–132 metres) above the base of the Bracklesham Beds as defined by Eaton (1976) at Alum Bay, Isle of Wight (Beds 9 to 14*c* of Eaton 1976).

Definition. Species first appearing at the base of the zone: *Impletosphaeridium cracens*, *P. comatum*. Species first appearing within the zone: *Araneosphaera araneosa*, *Areoligera sentosa*, *A. tauloma*, *Chiropteridium* cf. *C. dispersum*, *Heteraulacacysta leptalea*, *Impletosphaeridium kroemmelbeinii*, *I. luxurium*. Species last occurring within the zone: *Hystrichokolpoma granulata*, *Turbiosphaera galatea*, *Wetzeliella meckelfeldensis*. No species have their last occurrence at the top of this zone.

Discussion. This zone corresponds to microplankton zone 3 of Eaton (1976). There are two changes in the list of species appearing in this zone. ?*Cordosphaeridium minimum* is now believed to first appear in the *Deflandrea phosphoritica* Zone, LC-1. *P. comatum* is considered to be a senior synonym of *P. tritonium* Eaton 1976.

Areosphaeridium arcuatum Assemblage Zone (B-4)

Type section. Bracklesham Beds as defined by Eaton (1976), 348–474 feet (106–144·5 metres) above the base of Whitecliff Bay, Isle of Wight (Beds VII to XVI of Fisher 1862, equivalent to Beds 10*b* to 18 of Eaton 1976). Sample numbers WE38 to WE53 (text-fig. 5).

Other localities. 440–451 feet (134–137·5 metres) above the base of the Bracklesham Beds as defined by Eaton (1976) at Alum Bay, Isle of Wight (Beds 14*d* to 14*e* of Eaton 1976).

Definition. Species first appearing at the base of the zone: *Achomosphaera membraniphora*, *Areosphaeridium arcuatum*, *Turbiosphaera magnifica*. Species first appearing within the zone: *Homotryblium oceanicum*, *Lanternosphaeridium vectense*. Species last occurring within the zone: *Areoligera* cf. *A. coronata sensu* Williams and Downie, 1966*b*, *Areoligera* cf. *A. medusettiformis sensu* Williams and Downie, 1966*b*, *Areoligera* cf. *A. senonensis sensu* Williams and Downie, 1966*b*, *Chiropteridium* cf. *C. dispersum sensu* Eaton, 1976, *Cordosphaeridium fibrospinosum*, *Cyclonephelium divaricatum*, *C. ordinatum*, *Impletosphaeridium implicatum*, *Kisselovia tenuivirgula*, *Membranilarnacia ursulae*, *Wetzeliella lunaris*. No species have their last occurrence at the top of this zone.

Discussion. This zone corresponds to microplankton zone 4 of Eaton (1976). There is one change in the list of species having their last occurrence in this zone. *Eocladopyxis peniculatum* is now known to range into the *Polysphaeridium congregatum* Zone (BAR-5).

Cyclonephelium intricatum Assemblage Zone (B-5)

Type section. Bracklesham Beds as defined by Eaton (1976), 484–596 feet (147·5–182 metres) above the base at Whitecliff Bay, Isle of Wight (Beds XVII to XIX in part of Fisher 1862, equivalent to Beds 19*a* to 19*c* of Eaton 1976). Sample numbers WE54 to WE58 (text-fig. 5).

Other localities. 746–792 feet (227–241·5 metres) above the base of the Bracklesham Beds as defined by Eaton (1976) at Alum Bay, Isle of Wight (Bed 19 of Eaton 1976).

Definition. Species first appearing at the base of the zone: *Areoligera undulata*, *C. intricatum*, *Distatodinium craterum*, *Phthanoperidinium alectrolophum*. Species first appearing within the zone: *Areosphaeridium multicornutum*, *D. ellipticum*, *D. paradoxum*, *Kisselovia variabilis*, *Melitasphaeridium asterium*, *P. levimurum*. Species last occurring within the zone: *Cordosphaeridium exilimurum*, *Cyclonephelium exuberans*, *C. spinetum*. Species last occurring at the top of the zone: *Adnatosphaeridium vittatum*, *Areoligera sentosa*, *C. laciniiforme*, *C. vicinum*, *Hystrichokolpoma salacia*, *Hystrichosphaeridium patulum*, *Impletosphaeridium cracens*, *I. luxurium*, *Lentinia wetzelii*.

Discussion. This zone corresponds to microplankton zone 5 of Eaton (1976). There are several changes in the list of species last occurring in this zone. *Achomosphaera membraniphora* and *Lanternosphaeridium vectense* are now known to range into the *Polysphaeridium congregatum* Zone (BAR-5). *L. wetzelii* is now included as an additional species.

This zone is present in the Hampshire mainland sections. Comparable dinoflagellate cyst assemblages were recorded in the uppermost part of the Bournemouth Marine Beds, the Boscombe Sands, and the Hengistbury Beds below the *Nummulites prestwichianus* horizon (Costa *et al.* 1976). These authors also recorded *Areoligera sentosa* from beds probably equivalent to the Barton Beds at Hengistbury Head.

Heteraulacacysta porosa Assemblage Zone (BAR-1)

Type section. Barton Beds, 0–39 feet (0–12 metres) above the base at Barton, Hampshire (Beds A1 to A3 in part of Burton 1933). Sample numbers M58 [located 2 feet (0·6 metres) below base of Barton Beds] to M62 (text-fig. 6).

Other localities. 0–69 feet (0–21 metres) above the base of the Barton Beds at Alum Bay, Isle of Wight. Sample numbers A6 to A14. ?0–?37 feet (?0–?11 metres) above the base of the Barton Beds at Whitecliff Bay, Isle of Wight. Sample numbers W2 to W5.

Definition. Species first appearing at the base of the zone: *Cerebrocysta bartonensis, Chiropteridium aspinatum, Cordosphaeridium cantharellum, C. funiculatum, ?Cyclonephelium semitectum, H. porosa, Lejeunia cinctoria, Leptodinium incompositum, Phthanoperidinium geminatum, ?Phthanoperidinium pseudoechinatum, Selenopemphix armata, S. nephroides, Tectatodinium pellitum.* Species first appearing within the zone: *Homotryblium caliculum, Rhombodinium draco, Rottnestia borussica, S. coronata.* Species last occurring within the zone: *Areoligera tauloma.* Species last occurring at the top of the zone: *H. oceanicum.*

Discussion. The top of this zone may be higher at Whitecliff Bay, but lack of exposure of part of the Barton Beds during collecting resulted in a large sampling gap between sample W5 and the overlying sample W6.

Costa and Downie (1976) defined the *Rhombodinium draco* Zone at Alum Bay from the base to 36 metres above the base of the Barton Beds (samples A6 to A20 of the present study). The lower part of the *R. draco* Zone is equivalent to the *Heteraulacacysta porosa* Zone and the upper part is equivalent to the overlying *Areosphaeridium fenestratum* Zone.

Costa *et al.* (1976) recorded *Cordosphaeridium cantharellum* from beds below the *Nummulites prestwichianus* band at Hengistbury Head that are probably equivalent with the Bracklesham Beds.

Areosphaeridium fenestratum Assemblage Zone (BAR-2)

Type section. Barton beds, 39–76 feet (12–23 metres) above the base at Barton, Hampshire (Beds A3 in part to D of Burton 1933). Sample numbers M63 to M65 (text-fig. 6).

Other localities. 69–121 feet (21–37 metres) above the base of the Barton Beds at Alum Bay, Isle of Wight. Sample numbers A15 to A20.

Definition. Species first appearing at the base of the zone: *A. fenestratum, Homotryblium floripes.* Species last occurring within the zone: *H. abbreviatum, Turbiosphaera magnifica.* No species have their last occurrence at the top of this zone.

Discussion. This zone was not seen at Whitecliff Bay, probably because of lack of exposure during sample collection.

H. floripes was only recorded in the Barton Beds at Barton and Alum Bay where it is restricted to the *A. fenestratum* Assemblage Zone; its absence from the Barton Beds at Whitecliff Bay is probably due to the corresponding sediments not being exposed during sampling. This species occurs in the Headon Beds of the Isle of Wight (Leingjarern, unpublished Ph.D. thesis, Sheffield University, 1973), indicating that its highest occurrence within the Barton Beds cannot be used to define the *A. fenestratum* Zone.

Rhombodinium porosum Assemblage Zone (BAR-3)

Type section. Barton Beds, 76–131 feet (23–40 metres) above the base at Barton, Hempshire (Beds E to H in part of Burton 1933). Sample numbers M66 to M70 (text-fig. 6).

Other localities. 121–246 feet (37–75 metres) above the base of the Barton Beds at Alum Bay, Isle of Wight. Sample numbers A21 to A35. ?72–112 feet (?22–34 metres) above the base of the Barton Beds at Whitecliff Bay, Isle of Wight. Sample numbers W6 to W7.

Definition. Species first appearing at the base of the zone: *Cyclonephelium textum*, *R. porosum*. Species first appearing within the zone: *Phthanoperidinium multispinum*, *R. longimanum*, *Selenopemphix selenoides*. Species last occurring within the zone: *Heteraulacacysta leptalea*, *H. porosa*, *Phthanoperidinium echinatum*. No species have their last occurrence at the top of this zone.

Discussion. The base of this zone may be lower at Whitecliff Bay, but non-exposure of part of the Barton Beds during collecting resulted in a large sampling gap between W6 and the underlying sample W5.

R. perforatum (Jan du Chêne and Chateauneuf) Lentin and Williams, which is an important biostratigraphic marker in north-west Europe (Costa and Downie 1976), is morphologically similar to *R. porosum*. The two species are, however, distinct and have different stratigraphic ranges in the Hampshire Basin. *R. porosum* is restricted to the Barton Beds, not being recorded by Leingjarern (unpublished Ph.D. thesis, Sheffield University, 1973) from the overlying Headon Beds. *R. perforatum* does not occur in the Barton Beds but it is present in the Headon Beds (Leingjarern thesis; pers. obs.). The base of the *R. perforatum* Zone, defined by Costa and Downie (1976) within the Barton Beds in the Hampshire Basin, was thus redefined at the base of the Middle Headon Beds (Bujak 1979). The *R. porosum* Zone was erected by Bujak (1979) to replace the lower part of Costa and Downie's *R. perforatum* Zone. The *R. perforatum* Zone as redefined by Bujak (1979) is restricted to the Headon Beds and possibly younger strata. The *R. porosum* Zone of Bujak (1979) is equivalent to the *R. porosum* Assemblage Zone as defined herein.

Homotryblium variabile Assemblage Zone (BAR-4)

Type section. Barton Beds, 112–161 feet (34–49 metres) above the base at Whitecliff Bay, Isle of Wight. Sample numbers W8 to W10 (text-fig. 6).

Other localities. 131–?174 feet (40–?53 metres) above the base of the Barton Beds at Barton, Hampshire (Beds H in part to I in part of Burton 1933). Sample numbers M73 to M77. 246–?328 feet (75–?100 metres) above the base of the Barton Beds at Alum Bay, Isle of Wight. Sample numbers A37 to A47.

Definition. Species first appearing at the base of the zone: *Gochtodinium simplex*, *G. spinulum*, *H. variabile*. Species last occurring within the zone: *Areosphaeridium multicornutum*, *Kisselovia variabilis*. No species have their last occurrence at the top of this zone.

Discussion. This is the highest zone delineated in the Barton Beds at Barton and Alum Bay. Higher Barton Beds of Zone 4 are devoid of palynomorphs at Alum Bay and contain no indigenous dinoflagellate cysts at Barton, so that the type section is defined at Whitecliff Bay. The *H. variabile* Zone equates with the lower part of the *G. simplex* Zone of Bujak (1979).

Martini (1971) defined the *Discoaster saipanensis* Zone (NP 17) within the *Chama* Beds at Barton (Bed H of Burton 1933), within the lower part of the *H. variabile* Zone.

Costa and Downie (1976, p. 595) noted the earliest occurrence in the Barton Beds of 'an unpublished species which is apparently related, if not synonymous, to *W.* (*W.*) *symmetrica*'. The unpublished species, formally described as *G. simplex* by Bujak (1979), has similar pericyst shape to that of *W. symmetrica*, but the latter species differs in having aculeate processes.

Polysphaeridium congregatum Assemblage Zone (BAR-5)

Type section. Barton Beds, 161–184 feet (49–56 metres) above the base at Whitecliff Bay, Isle of Wight. Sample numbers W11 to W15 (text-fig. 6).

Definition. Species first appearing at the base of the zone: *P. congregatum*. Species first appearing within the zone: *Cyclonephelium microfenestratum*, *Hemisphaeridium fenestratum*. Species last occurring at the top of the zone: *Araneosphaera araneosa*, *Areosphaeridium fenestratum*, *Cyclonephelium intricatum*, *C. textum*, *Distatodinium craterum*, *Gochtodinium simplex*, *G. spinulum*, *Hemisphaeridium fenestratum*, *Homotryblium caliculum*, *H. variabile*, *Lejeunia cinctoria*, *Phthanoperidinium alectrolophum*, *Polysphaeridium congregatum*, *Rhombodinium longimanum*, *R. porosum*, *Selenopemphix coronata*. The following species were not recorded by Leingjarern (unpublished thesis, Sheffield University, 1973) from strata younger than the Barton Beds in the Hampshire Basin, but have been previously noted in Oligocene strata: *Dapsilidinium simplex*, *Leptodinium incompositum*, *P. congregatum*, *R. draco*, *Rottnestia borussica*, *S. nephroides*, *S. selenoides*, *Systematophora placacantha*, *Tectatodinium pellitum*, *Veryhachium disjunctum* [by Benedek 1972, as *Lagerheimia* aff. *L. longiseta* (Lemmern) Printz].

Discussion. The *P. congregatum* Zone was not seen at Barton or Alum Bay, probably because of the absence of marine strata of this age in these sections. Samples are devoid of palynomorphs in the Barton Sands above sample W15 at Whitecliff Bay, but dinoflagellate cysts again occur in the marine Middle Headon Beds.

The *P. congregatum* Zone equates with the upper part of the *G. simplex* Zone of Bujak (1979).

IV. TAXONOMY OF SOME EOCENE DINOFLAGELLATE CYST SPECIES FROM SOUTHERN ENGLAND

by J. P. BUJAK, C. DOWNIE, G. L. EATON, *and* G. L. WILLIAMS

Introduction

One of the authors (J. P. B.) examined and photographed much of the Eocene type material housed at the British Museum (Natural History) and described in Davey *et al.* (1966) and Eaton (1976). Some of the new photographs illustrate details that are not evident in the original photographs and are included in the present paper.

In some instances the recognition of new morphological characters has necessitated taxonomic changes or emendations. These are listed in the following systematic section. The terminology used is defined in Downie and Sarjeant (1966), Williams *et al.* (1973), Lentin and Williams (1976), and Evitt *et al.* (1977.)

Locations of holotypes which are illustrated in the plates are given by the B.M.(N.H.) slide number followed by the England Finder co-ordinates.

Systematic Palaeontology

Division PYRRHOPHYTA Pascher, 1914
Class DINOPHYCEAE Fritsch, 1929
Order PERIDINIALES Haeckel, 1894
Genus ACHILLEODINIUM Eaton, 1976

Achilleodinium latispinosum (Davey and Williams, 1966) comb. nov.

Plate 8, figs. 7–9

1966 *Cordosphaeridium latispinosum* Davey and Williams, p. 88, pl. 5, fig. 8. Early Eocene.

Discussion. One of the authors (J. P. B.) has re-examined the holotype of *C. latispinosum*. This specimen has two types of processes, slender cingular and sulcal processes, and broad precingular, postcingular, and antapical processes. The archaeopyle is precingular with a displaced operculum. These features are characteristic of the genus *Achilleodinium*, to which this species is herein transferred.

Genus CERATIOPSIS Vozzhennikova, 1967, emend.

Emended diagnosis. Pericyst ambitus rounded, ovoidal, pentagonal or peridinioid, elongated longitudinally, and produced into one distinct apical and two distinct antapical horns. The antapical horns are of approximately equal length. Endocyst spherical to ovoidal, or occasionally weakly peridinioid. Apical and antapical pericoels always present, sometimes connected by an ambital pericoel. Periphragm smooth, chagrinate, granulate, denticulate, rugulate, verrucate, or striate, the ornament commonly being aligned longitudinally. Endophragm smooth, chagrinate, or granulate. Paratabulation not evident. Pericingulum present, commonly indented and planar or slightly helicoidal. Perisulcus, when visible, longer and broader on the hypocyst. Endocingulum and endosulcus not observed. Periarchaeopyle intercalary, involving the second anterior intercalary paraplate (2a), hexa, with the archaeopyle length approximately equal to the breadth. Perioperculum typically detached. Endoarchaeopyle intercalary, involving between one and three of the anterior intercalary paraplates (1a–3a). Endoperculum detached or remaining partially attached. Archaeopyle formula I/I (2a/2a) to I/3I (2a/1a–3a).

Type species. *Ceratiopsis leptoderma* Vozzhennikova, 1963.

Discussion. Lentin and Williams (1976, p. 153) considered *Ceratiopsis* to be a junior synonym of *Deflandrea* Eisenack, 1938. This view was rejected by Lentin and Williams (1977, p. 20), 'because of the nature of the hexa 2a archaeopyle'. The present authors agree with Lentin and Williams (1977) in retaining *Ceratiopsis* as a separate genus, which is characterized by having a periarchaeopyle whose length approximates the breadth, an endoarchaeopyle which may be 3I, pericyst ornament that is longitudinal when aligned, and distinct horns. *Trithyrodinium* Drugg differs from *Ceratiopsis* in having short horns and a 3I/3I archaeopyle.

Ceratiopsis wardenensis (Williams and Downie, 1966*b*) comb. nov.

Plate 11, fig. 3

1966*b* *Deflandrea wardenensis* Williams and Downie, p. 233, pl. 26, fig. 5. Early Eocene.

Discussion. The holotype of *D. wardenensis* has a 3I endoarchaeopyle. The species is herein transferred from *Deflandrea* to *Ceratiopsis*.

Genus DAPSILIDINIUM gen. nov.

Derivation of name. Latin, *dapsilis*, abundant, with reference to the numerous processes.

Diagnosis. Chorate cysts with a subspherical to ovoidal central body bearing numerous processes. Processes intratabular, generally exceeding one per paraplate, mostly uniform in length but sometimes varying slightly in width. Processes hollow, open distally, tubiform or tapering. Periphragm ornament smooth, chagrinate, granulate, or spinate, often extending on to the processes. Archaeopyle apical, tetratabular. Operculum detached.

Type species. *Dapsilidinium pastielsii* (Davey and Williams, 1966) comb. nov.

Discussion. The genus *Polysphaeridium* Davey and Williams, 1966, was erected for chorate cysts with numerous tubiform processes and an apical archaeopyle. Davey and Williams designated *Polysphaeridium subtile* Davey and Williams, 1966, as type of the genus. Eaton (1976, p. 280) stated that the holotype of *P. subtile* appears to have an epicystal archaeopyle and recommended that the diagnoses of *Polysphaeridium* and *P. subtile* should be emended accordingly. Bujak subsequently examined and photographed (present paper, pl. 3, figs. 9, 12) the holotype of *P. subtile*. Although the operculum, which consists of the apical and precingular paraplates, is still attached, principal and accessory archaeopyle sutures are developed and demonstrate that the archaeopyle is epicystal. Topotype material unequivocably confirms that the archaeopyle of this species is epicystal. This has necessitated the present emendation of the genus *Polysphaeridium*. Species known to have an apical archaeopyle that were previously included in *Polysphaeridium* are herein transferred to the new genus *Dapsilidinium*.

Dapsilidinium asperum (Maier, 1959) comb. nov.

1959 *Hystrichosphaeridium asperum* Maier, p. 319, pl. 33, fig. 2. Middle Miocene.

Dapsilidinium multispinosum (Davey, 1974) comb. nov.

1974 *Polysphaeridium multispinosum* Davey, p. 60, pl. 7, fig. 4. Early Barremian.

Dapsilidinium pastielsii (Davey and Williams, 1966) comb. nov.

Plate 6, figs. 6, 9

1966 *Polysphaeridium pastielsi* Davey and Williams, pp. 92–93, pl. 4, fig. 10. Early Eocene.

Dapsilidinium pseudocolligerum (Stover, 1977) comb. nov.

1977 *Polysphaeridium pseudocolligerum* Stover, pp. 74–75, pl. 1, figs. 14–19. Early Oligocene–Early Miocene.

Dapsilidinium simplex (White, 1842) comb. nov.

Plate 14, figs. 11–12

1842 *Xanthidium simplex* White, p. 38, pl. 4, fig. 10. Late Cretaceous.

Genus DRACODINIUM Gocht, 1955, emend.

Emended diagnosis. Pericyst ambitus triangular to subtriangular. Apex rounded or with a greatly reduced apical horn. Pericingular horns well developed. Antapex prolonged into one prominent left antapical horn that is usually acuminate. The right antapical horn is strongly reduced or absent. Length of epipericyst considerably less than length of hypopericyst. Endocyst ambitus circular to oval. Cornucavate pericoels always present, sometimes connected by an ambital pericoel of variable width. Periphragm smooth, chagrinate, granulate, verrucate; may possess simple or branched processes that are distally open or closed. Endophragm of variable thickness up to several microns, surface laevigate, chagrinate, granulate, or verrucate. Paratabulation indeterminate except for the archaeopyle. Pericingulum and perisulcus poorly defined. Pericingulum sometimes indicated by an indentation at the extremities of the pericingular horns. Periarchaeopyle intercalary, resulting from the loss of the second anterior intercalary paraplate 2a. Perioperculum detached. Endoarchaeopyle the same size as the periarchaeopyle and involving intercalary paraplate 2a, or considerably broader than the periarchaeopyle and resulting from the loss of three intercalary paraplates (1a–3a). Endoperculum detached.

Type species. *Dracodinium solidum* Gocht, 1955.

Discussion. Gocht (1955, p. 87) erected the genus *Dracodinium* for forms differing from *Wetzeliella* Eisenack, 1938, in not having an apical horn. He stated that the archaeopyle was variable and could be apical. Williams and Downie (1966*a*, p. 195) transferred the single species of *Dracodinium*, *D. solidum*, to *Wetzeliella*, thus making *Dracodinium* a junior synonym of *Wetzeliella*.

Lentin and Williams (1976, p. 158) also considered *Dracodinium* to be a junior synonym of *Wetzeliella* and Gocht's specimens of '*Dracodinium solidum*' with an apical archaeopyle were interpreted as being quadra 2a intercalary. The present authors advocate retention of the genus *Dracodinium* for forms differing from *Wetzeliella* in having a triangular to subtriangular pericyst outline with a single prominent antapical horn, and in lacking a distinct apical horn.

Dracodinium differs from *Rhombodinium* Gocht, 1955, as emended by Bujak (1979), in pericyst and endocyst outline and mode of archaeopyle formation. *Rhombodinium* has a rhomboidal pericyst and endocyst and a soleiform periarchaeopyle and endoarchaeopyle in which the opercula remain attached anteriorly along side Q1.

?*Dracodinium condylos* (Williams and Downie, 1966*a*) comb. nov.

Plate 11, figs. 5–6.

1966*a* *Wetzeliella condylos* Williams and Downie, pp. 193–194, pl. 20, figs. 1–2. Early Eocene.

Discussion. ?*D. condylos* is herein assigned to the genus *Dracodinium* because it has a rounded apex and a poorly developed apical horn. This assignment is tentative since ?*D. condylos* has a rhomboidal to peridinioid pericyst outline with two distinct antapical horns, and a tendency towards reduced pericingular horns (Williams and Downie 1966*a*, pl. 20, fig. 1; Eaton 1976, pl. 18, fig. 5).

Dracodinium politum sp. nov.

Plate 11, fig. 1

1966*a* *Wetzeliella* (*Rhombodinium*) *glabra* Cookson; Williams and Downie, pp. 197–198, pl. 20, figs. 9–10.

1976 *Wetzeliella* (*Rhombodinium*) *glabra* Cookson; Eaton, pp. 304–305, pl. 20, fig. 5.

Derivation of name. Latin, *politus*, smooth, with reference to the periphragm.

Diagnosis. Pericyst ambitus subtriangular with a convex epipericyst. Apex rounded, occasionally with the suggestion of a small apical protrusion. Pericingular horns and left antapical horn well developed. Right antapical horn absent or denoted by a slight swelling of the pericyst. Length of epipericyst considerably less than length of hypopericyst. Endocyst ambitus circular. Pericoel well developed, being broad and continuous in ambital view. Periphragm smooth to chagrinate, without processes. Endophragm smooth or granulate, occasionally verrucate around the ambital periphery. Paratabulation indeterminate. Pericingulum only visible at the extremities of the pericingular horns. Perisulcus not seen. Periarchaeopyle resulting from the loss of the second anterior intercalary paraplate 2a. Perioperculum detached. Endoarchaeopyle of similar size and shape to the periarchaeopyle posteriorly, but does not underlie it anteriorly. Endoperculum detached.

Holotype. Sample SH3, B.M.(N.H.) Palaeont. slide V51958(3). London Clay, Isle of Sheppey, Kent, England. Early Eocene.

Dimensions. Pericyst length = 130–151 μm, breadth = 140–168 μm. Endocyst length = 66–80 μm, breadth = 69–76 μm. Number of specimens measured = 9.

Discussion. Williams and Downie (1966*a*, p. 197) assigned specimens of *D. politum* from the London Clay to *Rhombodinium glabrum* (Cookson, 1956) Vozzhennikova, 1967. They noted that the London Clay specimens differed from the type material in having only one well-developed antapical horn. The two species also differ in the shape and relative size of the epipericyst, which is much larger in *R. glabrum*.

Wilson (1967*c*) suggested that the London Clay forms could represent a separate species. Eaton (1976, pp. 304–305) recorded specimens from the Bracklesham Beds identical to the London Clay forms, that he assigned to *R. glabrum*. The forms from southern England are herein accommodated in the new species *D. politum* because of the differences between the two morphotypes.

Genus KISSELOVIA Vozzhennikova, 1967

Kisselovia coleothrypta (Williams and Downie, 1966*a*) Lentin and Williams 1976

Plate 12, figs. 7–8

Discussion. Holotype and topotype material has been re-examined by one of the authors (J. P. B.) using interference light microscopy. This shows a distal process ornament on the dorsal side that is reduced to membranous ribbons (pl. 12, fig. 7) rather than membranes that extend over most of the paraplate (pl. 12, fig. 8).

Specimens from the Barton Beds seem to show a reduction in apical horn length, when compared with those from the London Clay and Bracklesham Beds.

Genus MELITASPHAERIDIUM Harland and Hill, 1979

Type species. Melitasphaeridium choanophorum (Deflandre and Cookson, 1955) Harland and Hill, 1979.

Discussion. Harland and Hill (1979) erected the genus *Melitasphaeridium* for chorate cysts with one intratabular tubular process per paraplate and a precingular archaeopyle formed by the loss of paraplate 3″. They designated *M. choanophorum*, originally described by Deflandre and Cookson (1955) as *Hystrichosphaeridium choanophorum*, as the type species.

The following species conform to the diagnosis of *Melitasphaeridium* and are herein transferred to this genus.

Melitasphaeridium asterium (Eaton, 1976) comb. nov.

Plate 2, fig. 3

1976 *Hystrichosphaeridium asterium* Eaton, p. 273, pl. 11, figs. 7–10. Eocene.

Melitasphaeridium pseudorecurvatum (Morgenroth, 1966*a*) comb. nov.

Plate 2, figs. 1–2

1966*a* *Hystrichosphaeridium pseudorecurvatum* Morgenroth, pp. 30–31, pl. 8, figs. 5–6. Early Eocene.
1966*b* *Hystrichosphaeridium sheppeyense* Davey and Williams, pp. 68–69, pl. 11, fig. 3. Early Eocene.

Discussion. H. sheppeyense is herein considered to be a junior synonym of *Melitasphaeridium pseudorecurvatum*.

M. pseudorecurvatum, *M. asterium*, and *M. choanophorum* probably represent a stratigraphic sequence of morphotypes, with the oldest having distally aculeate processes and the youngest having entire distal process platforms. This may be paralleled by a reduction in the number of cingular and sulcal processes.

Genus PAUCISPHAERIDIUM gen. nov.

Derivation of name. Latin, *paucus*, few, with reference to the number of processes.

Diagnosis. Chorate cysts with a spherical to subspherical central body. The processes are proximally expanded, hollow, and constricted near the distal end. Process formula ?4′, 6″ Oc, 6‴, O⁗, xs. When present, the sulcal processes are slender. Archaeopyle apical, presumably tetratabular. Operculum not observed.

EXPLANATION OF PLATE 1

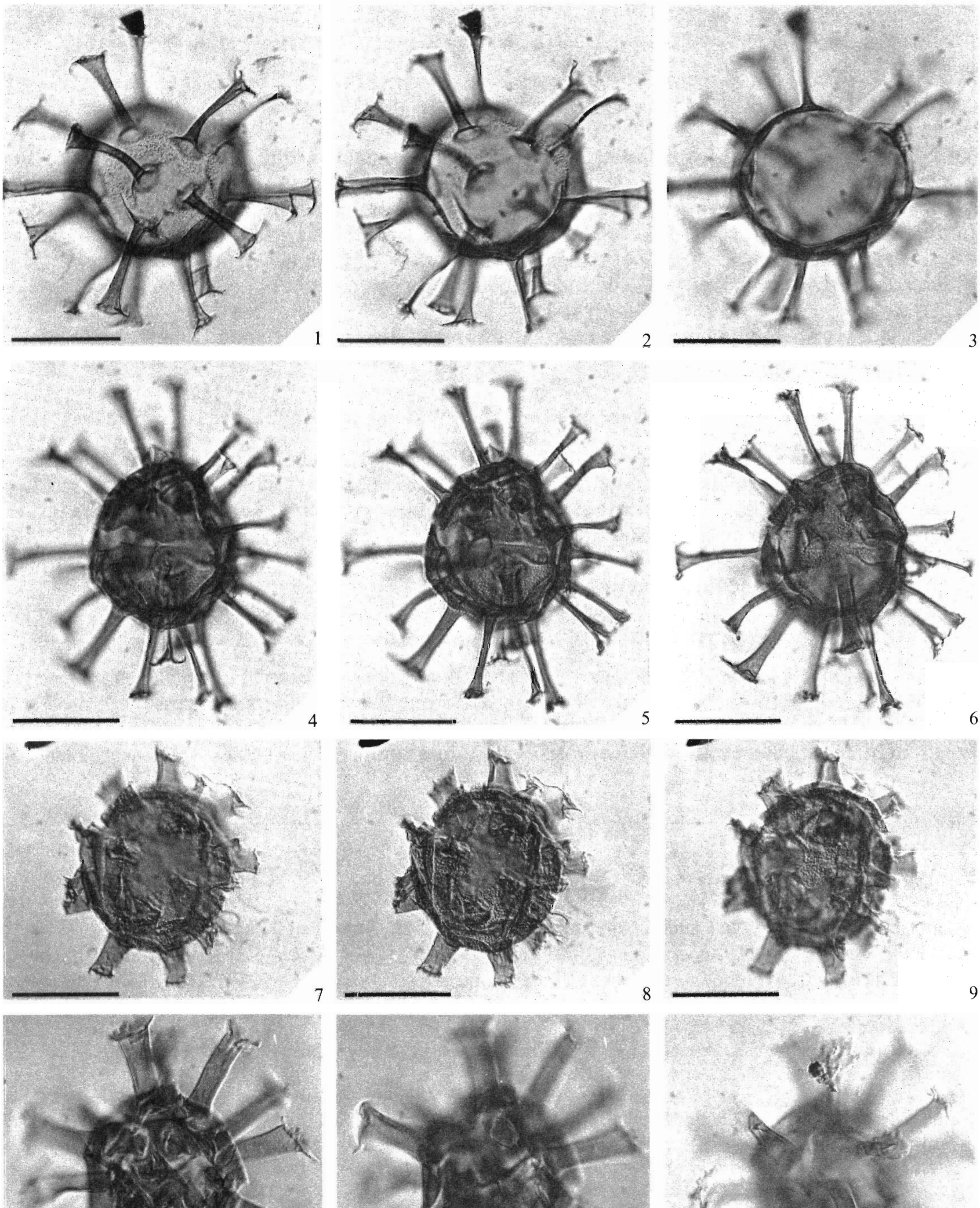
Dinoflagellate cysts from the London Clay and Bracklesham Beds. Bar on all figures equals 30 μm.

Figs. 1–3. *Homotryblium pallidum* Davey and Williams. Holotype, London Clay, Enborne, V51756(2) R56/0 (not V51756(1) as published in Davey and Williams 1966). 1. Upper, antapical surface. 2. Postcingular and cingular processes in focus. 3. Epicystal archaeopyle suture in focus.

Figs. 4–6. *Homotryblium tenuispinosum* Davey and Williams. London Clay, Enborne. 4–5. Lower surface showing the principal archaeopyle suture and partial separation of the epicystal paraplates. 6. Upper surface.

Figs. 7–9. *Homotryblium abbreviatum* Eaton. Holotype, Bracklesham Beds, Alum Bay, V57782(1) J34/1. 7–8. Upper surface showing the principal archaeopyle suture and cingular processes. 9. Lower surface.

Figs. 10–12. *Homotryblium oceanicum* Eaton. Holotype, Bracklesham Beds, Alum Bay, V57794(1) U38/0. 10. Lower surface showing partial opening of the principal and some of the accessory archaeopyle sutures. 11. Optical section. 12. Upper surface.



BUJAK *et al.*, Dinoflagellate cysts

Type species. Paucisphaeridium inversibuccinum (Davey and Williams, 1966) comb. nov.

Discussion. Davey and Williams (1966) erected the species ?*Litosphaeridium inversibuccinum* and distinguished it by its small size and distinctive process distribution and shape. They tentatively assigned it to *Litosphaeridium* Davey and Williams, 1966, although the process formula was unknown. Eaton (1976) also tentatively assigned this species to *Litosphaeridium*, but noted that specimens from the Bracklesham Beds have twelve to fourteen processes arranged in two rings, which he presumed to be the precingular and postcingular series. He did not observe an antapical process. *Litosphaeridium* has processes that are bulbous, inflated, or tubular without a median constriction, and has an antapical process. One of the present authors (J. P. B.) has re-examined the holotype of *P. inversibuccinum* (pl. 2, figs. 4–5) and confirmed the process formula ?4′, 6″, Oc, 6‴, 0⁗, xs.

Paucisphaeridium inversibuccinum (Davey and Williams, 1966) emend. comb. nov.

Plate 2, figs. 4–5

1966 ?*Litosphaeridium inversibuccinum* Davey and Williams, p. 82, pl. 12, fig. 3. Early Eocene.

Emended diagnosis. Chorate cysts with a spherical to subspherical central body of less than 20 μm. The processes are proximally expanded and hollow, constricted near the distal end and are expanded distally with a denticulate or aculeate margin. Processes may be proximally connected within the precingular and postcingular series. Process length is 4 to 12 μm. Process formula is ?4′, 6″, Oc, 6‴, 0⁗, xs. When present the sulcal processes are slender. Archaeopyle apical, presumably tetratabular. Operculum detached and not observed.

Genus POLYSPHAERIDIUM Davey and Williams, 1966, emend.

Emended diagnosis. Chorate cysts with a spherical to subspherical central body bearing numerous processes that are demonstrably intratabular in some species. The tubular processes are mostly of uniform length on a specimen and are distally open. Processes isolated or forming proximally united linear, arcuate, soleate, or annulate complexes. Within a complex, processes may converge distally,

EXPLANATION OF PLATE 2

Dinoflagellate cysts from the London Clay and Bracklesham Beds. Bar on all figures equals 30 μm.

Figs. 1–2. '*Hystrichosphaeridium sheppeyense*' Davey and Williams. Holotype, London Clay, Sheppey, V51741(1) K32/1. 1. Dorsal surface showing the 3″ precingular archaeopyle. 2. Ventral surface. This species is herein considered to be a junior synonym of *Melitasphaeridium pseudorecurvatum* (Morgenroth) Bujak *et al.*, comb nov.

Fig. 3. *Melitasphaeridium asterium* (Eaton) comb. nov. Holotype, Bracklesham Beds, Whitecliff Bay, V57772(3) P51/2.

Figs. 4–5. *Paucisphaeridium inversibuccinum* (Davey and Williams) comb. nov. Holotype, London Clay, Enborne, V51744(1) N17/0. 4. Epicyst showing the apical archaeopyle. 5. Hypocyst showing the connected postcingular processes and absence of antapical, posterior sulcal, and posterior intercalary processes.

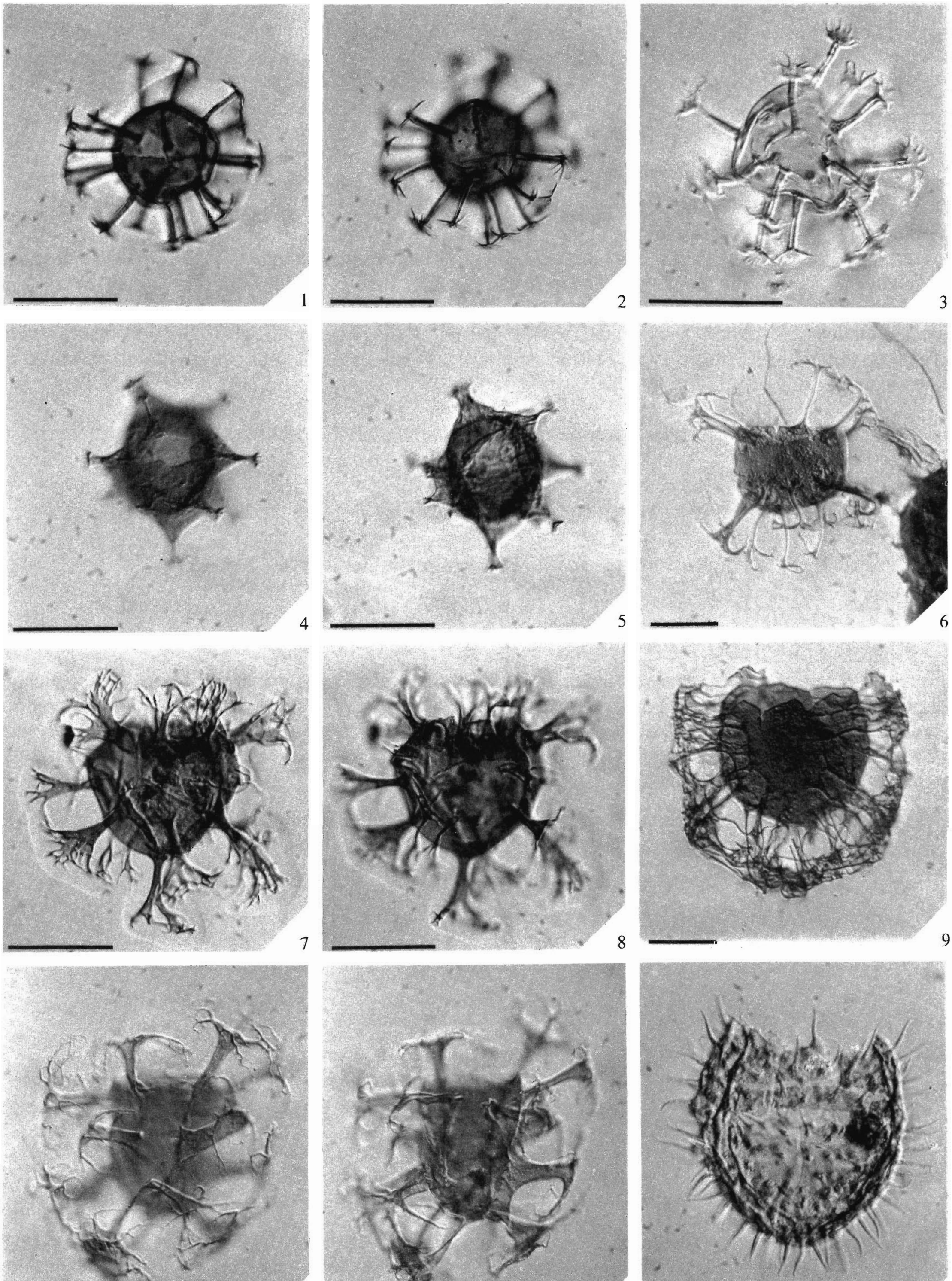
Fig. 6. *Areosphaeridium arcuatum* Eaton. Holotype, Bracklesham Beds, Whitecliff Bay, V57756(2) Q28/4.

Figs. 7–8. *Perisseiasphaeridium pannosum* Davey and Williams. Holotype, London Clay, Whitecliff Bay, V51743(1) S8/1. 7. Dorsal surface. 8. Ventral surface.

Fig. 9. *Cyclonephelium exuberans* Deflandre and Cookson. Bracklesham Beds, Whitecliff Bay. Upper, ventral surface.

Figs. 10–11. *Distatodinium craterum* Eaton. Holotype, Bracklesham Beds, Alum Bay, V57792 M61/4. 10. Upper surface. 11. Lower surface.

Fig. 12. *Eocladopyxis peniculatum* Morgenroth. Bracklesham Beds, Whitecliff Bay. Specimen with delineation of cingular and precingular paraplates and an apical archaeopyle.



BUJAK *et al.*, Dinoflagellate cysts

but are never joined along their entire lengths. Process formula when evident is 4′, 6″, 6c, 5–6‴, 1p, 1⁗, xs (including one posterior sulcal). Paraplates 1p, 1⁗, and p.s. are approximately equal in size, with their centres forming an equilateral triangle as in *Heteraulacus* Diesing, 1850, and *Pyrodinium* Plate, 1906. Periphragm smooth, granulate, or echinate. Endophragm smooth. Archaeopyle epicystal, type $A + \overline{3A} + 6P$. Opercular pieces may be partially or completely detached.

Type species. Polysphaeridium subtile Davey and Williams, 1966.

Discussion. Polysphaeridium was originally defined by Davey and Williams (1966) as having an apical archaeopyle. *P. subtile* was selected as the type species. Re-examination of the holotype and topotype material by Eaton (1976, p. 280) and Bujak (pers. obs.) has confirmed that this species has an epicystal archaeopyle. The genus *Hemicystodinium* Wall, 1967, p. 110, is therefore considered to be a junior synonym of *Polysphaeridium*. The diagnosis of *Polysphaeridium* is accordingly emended and the three species below are herein transferred to the genus. *Polysphaeridium* also includes species with archaeopyles of uncertain type. These species are retained in *Polysphaeridium* pending re-examination.

Polysphaeridium congregatum (Stover, 1977) comb. nov.

Plate 20, figs. 1–3

1977 *Hemicystodinium congregatum* Stover, p. 79, pl. 3, figs. 39–44. Middle Oligocene.

Polysphaeridium subtile Davey and Williams, 1966, emend.

Plate 3, figs. 9, 12

1966 *Polysphaeridium subtile* Davey and Williams, p. 92, pl. 11, fig. 1.

Emended diagnosis. Chorate cysts with a subspherical to subrectangular central body. Endophragm extremely thin and smooth; periphragm thin and granulate. Processes numerous (exceeding 60), slender, hollow, open distally with a serrate margin. Average process length is one-fifth to one-third of the central body diameter. Archaeopyle epicystal, type $A + \overline{3A} + 6P$. Opercular pieces may be partially or completely detached.

Discussion. The diagnosis is emended to include reference to the epicystal archaeopyle.

Polysphaeridium zoharyi (Rossignol, 1962) comb. nov.

1962 *Hystrichosphaeridium zoharyi* Rossignol, p. 132, pl. 2, fig. 10. Pleistocene.

EXPLANATION OF PLATE 3

Dinoflagellate cysts from the London Clay and Bracklesham Beds. Bar on all figures equals 30 μm.

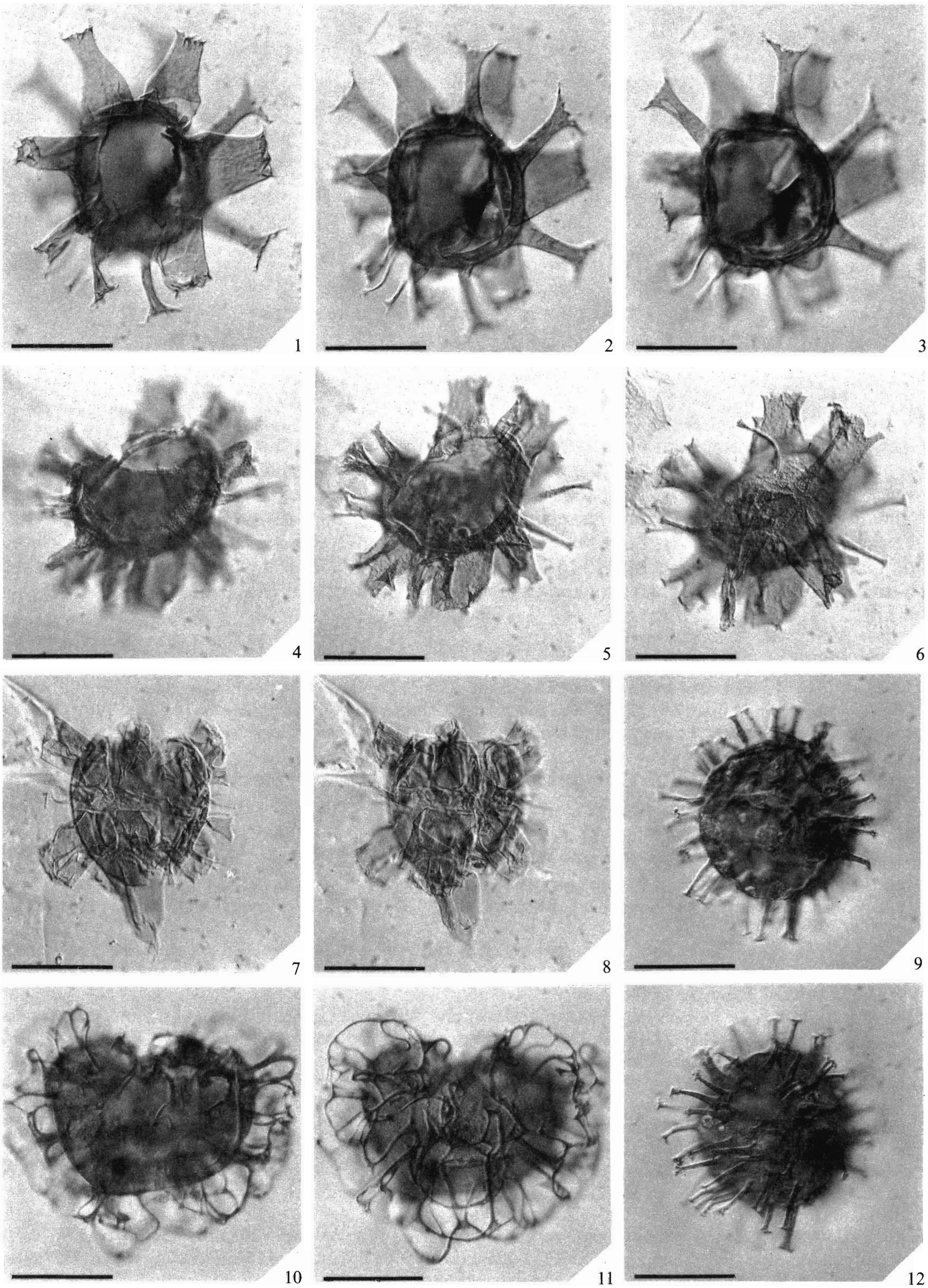
Figs. 1–3. *Hystrichokolpoma unispina* Williams and Downie. Holotype, London Clay, Whitecliff Bay, V51961(1) H36/1. 1. Upper surface focused on the archaeopyle margin and the precingular processes. 2–3. Optical section of the cingular processes.

Figs. 4–6. *Hystrichokolpoma granulata* Eaton. Holotype, Bracklesham Beds, Alum Bay, V57781(6) M34/2. 4. Lower surface showing the archaeopyle. 5. Optical section. 6. Upper surface.

Figs. 7–8. *Hystrichokolpoma salacia* Eaton. Holotype, Bracklesham Beds, Whitecliff Bay, V57757(6) G29/0. 7. Upper surface. 8. Lower surface.

Figs. 9, 12. *Polysphaeridium subtile* Davey and Williams. Holotype, London Clay, Sheppey, V51752(1) R20/2. 9. Upper surface showing partial separation of the epicystal paraplates along accessory archaeopyle sutures. 12. Lower surface.

Figs. 10–11. *Adnatosphaeridium multispinosum* Williams and Downie. London Clay, Whitecliff Bay.



BUJAK *et al.*, Dinoflagellate cysts

Genus THALASSIPHORA Eisenack and Gocht, 1960

Thalassiphora patula (Williams and Downie, 1966*b*) comb. nov.

1966*b* ?*Adnatosphaeridium patulum* Williams and Downie, p. 217, pl. 24, figs. 1–2, text-fig. 58. Early Eocene.

Discussion. Williams and Downie (1966*b*, p. 218) stated that '?*Adnatosphaeridium patulum* has a quadrate archaeopyle resulting from the loss of a single plate'. The present study has demonstrated that the archaeopyle results from the loss of paraplate 3″. This species is herein transferred to *Thalassiphora.*

V. DINOFLAGELLATE CYSTS AND ACRITARCHS FROM THE EOCENE BARTON BEDS OF SOUTHERN ENGLAND

by J. P. BUJAK

Introduction

One hundred indigenous dinoflagellate species occur in the Barton Beds of southern England. The fifty-nine species which also occur in the London Clay or Bracklesham Beds were described in Davey *et al.* (1966) and Eaton (1976). Species that are present only in the Barton Beds are listed in the following systematic section and illustrated in Plates 13 to 22. Type material is curated in the British Museum of Natural History, London. Locations of type material included in the systematic section and plates are given by the B.M.(N.H.) slide number (e.g. V59978) followed by the England Finder co-ordinates (e.g. J47/2). When England Finder co-ordinates are not given, the slide is a single grain mount.

Terminology

The definitions of previously defined terms used in the systematic section are outlined in Bujak (1979), Downie and Sarjeant (1966), Williams *et al.* (1973), Lentin and Williams (1976), and Evitt *et al.* (1977). Terms that are newly defined in the present paper or that relate to the dimensions of specimens are discussed below.

EXPLANATION OF PLATE 4

Dinoflagellate cysts from the London Clay. Bar on all figures equals 30 μm.

Figs. 1–2. *Spiniferites ramosus* (Ehrenberg) Loeblich and Loeblich subsp. *gracilis* (Davey and Williams) Lentin and Williams. Holotype, London Clay, Sheppey, V51757(1) X39/0. 1. Optical section. 2. Upper, dorsal surface.

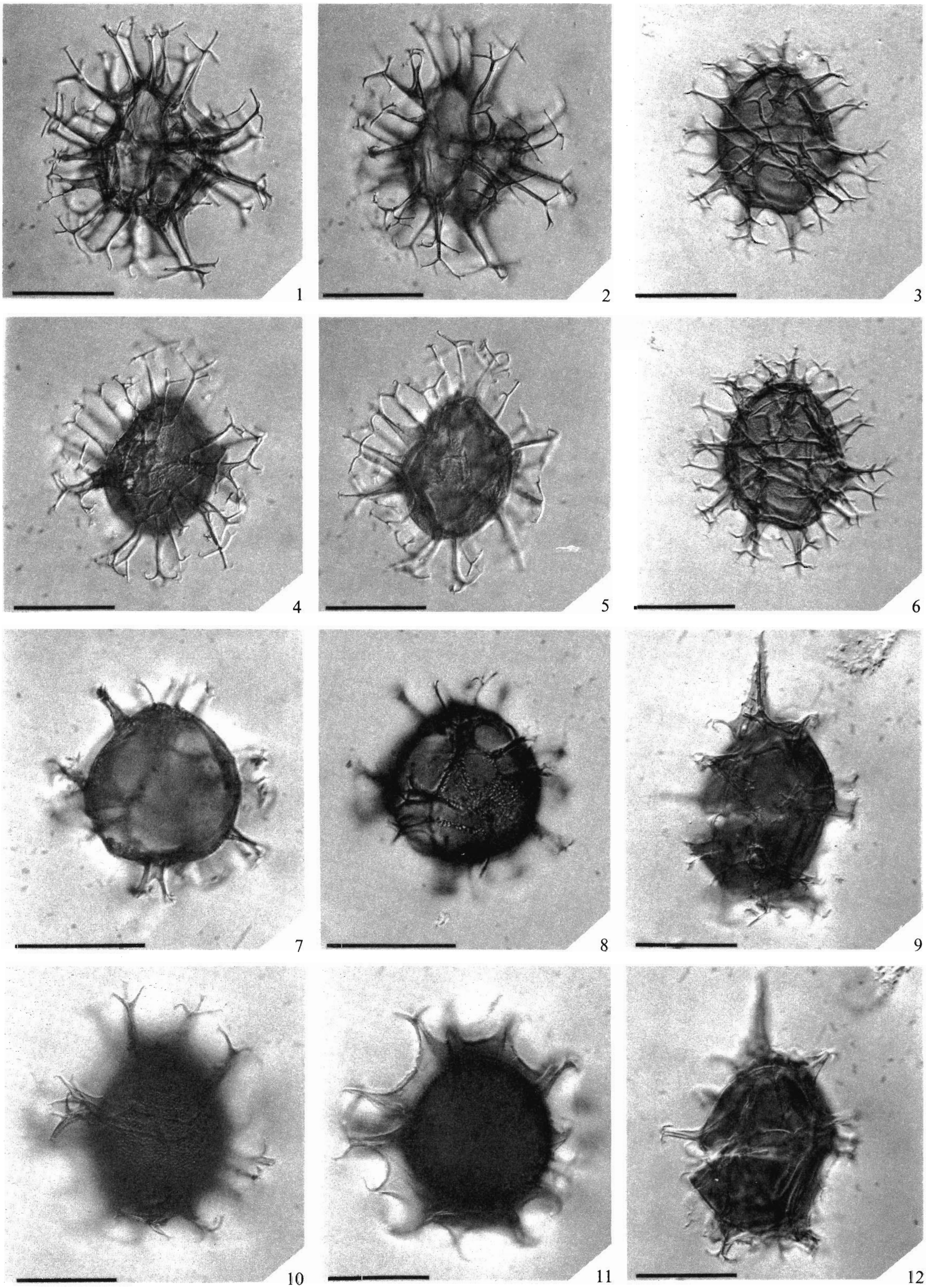
Figs. 3, 6. *Spiniferites ramosus* subsp. *multibrevis* (Davey and Williams) Lentin and Williams. Holotype, London Clay, Enborne, V59206(1) X35/0 (not V51759(1) and V51981(1) as published in Davey and Williams, 1966). 3. Upper surface. 6. Lower surface.

Figs. 4–5. *Spiniferites ramosus* subsp. *granosus* (Davey and Williams) Lentin and Williams. Holotype, London Clay, Sheppey, V51752(2) Q45/2. 4. Upper, dorsal surface. 5. Optical section.

Figs. 7–8. *Spiniferites monilis* (Davey and Williams) Sarjeant. Holotype, London Clay, Sheppey, V59210(1) K46/3 (not V51763(1) and V51986(1) as published in Davey and Williams, 1966). 7. Optical section. 8. Upper, ventral surface, showing that the beading noted by Davey and Williams (1966) is irregularly developed and probably the result of preservation.

Figs. 9, 12. *Spiniferites cornutus* (Gerlach) Sarjeant subsp. *laevimurus* (Davey and Williams) Lentin and Williams. Holotype, London Clay, Sheppey, V51752(3) W18/2. Considered by Cookson and Eisenack (1974) to be a junior synonym of *S. cornutus* subsp. *cornutus* (Gerlach) Sarjeant. 9. Upper, ventral surface. 12. Lower, dorsal surface.

Figs. 10–11. *Spiniferites ramosus* subsp. *granomembranaceus* (Davey and Williams) Lentin and Williams. Holotype, London Clay, Sheppey, V59207(1) Q23/1 (not V51982(1) and V51759(1) as published in Davey and Williams, 1966). 10. Upper surface. 11. Optical section.



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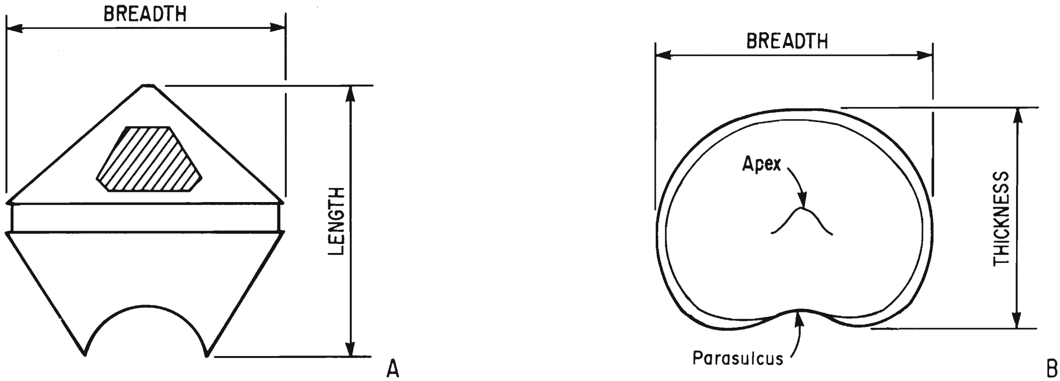
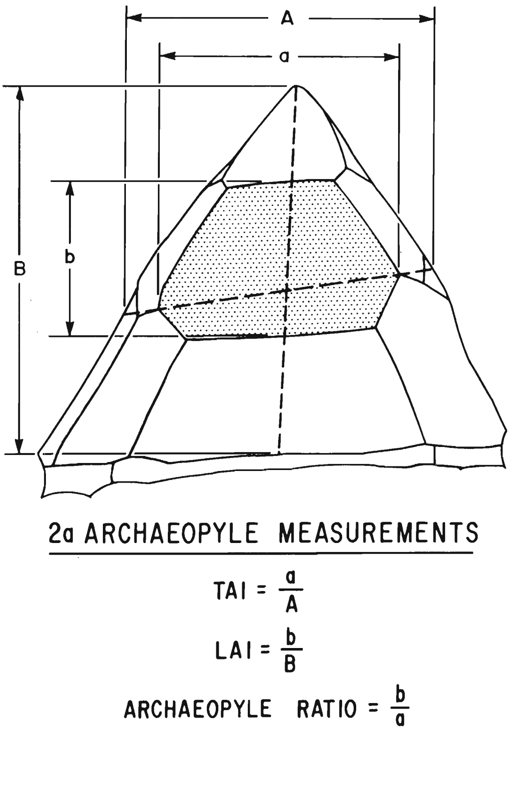


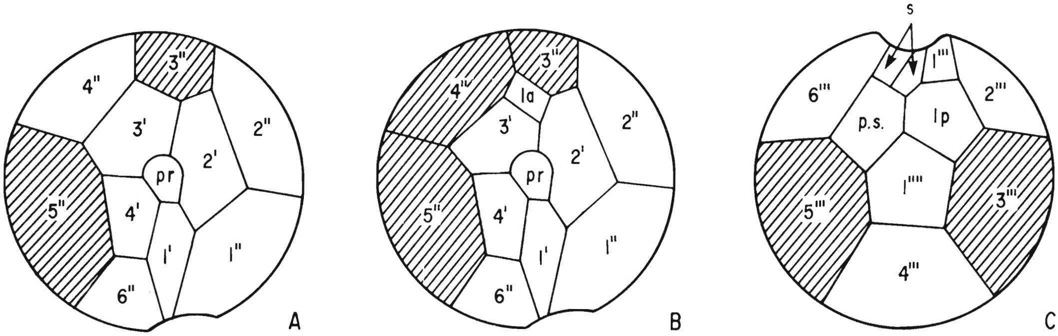
TEXT-FIG. 8. A, length and breadth of a peridiniacean cyst seen in dorsal view. B, breadth and thickness of a cyst seen in apical view.

The length, breadth, and thickness of a cyst are illustrated in text-fig. 8. The *breadth* of a cyst refers to the maximum cross-measurement in dorsal or ventral orientation (Sarjeant 1974) and the *thickness* denotes 'the distance between the dorsal and ventral extremities of the cyst when viewed apically, antapically, or laterally' (Bujak and Fisher 1976).

The size, shape, position, and symmetry of the archaeopyle is critical to the taxonomy of peridiniacean cysts. The relative size of the second intercalary paraplate within the dorsal epicyst is particularly important, since the size and shape of this paraplate determine the size, shape, and relationships of all the other dorsal epicystal paraplates. Lentin and Williams (1976) thus defined the *Transverse Archaeopyle Index* (TAI) for hexa 2a archaeopyles as the breadth of the archaeopyle at its broadest point in ambital view divided by the epicyst breadth in the same plane (text-fig. 9). Two other terms are defined in the present paper. The *Longitudinal*



TEXT-FIG. 9. Measurement of intercalary 2a archaeopyles. TAI = Transverse Archaeopyle Index. LAI = Longitudinal Archaeopyle Index.

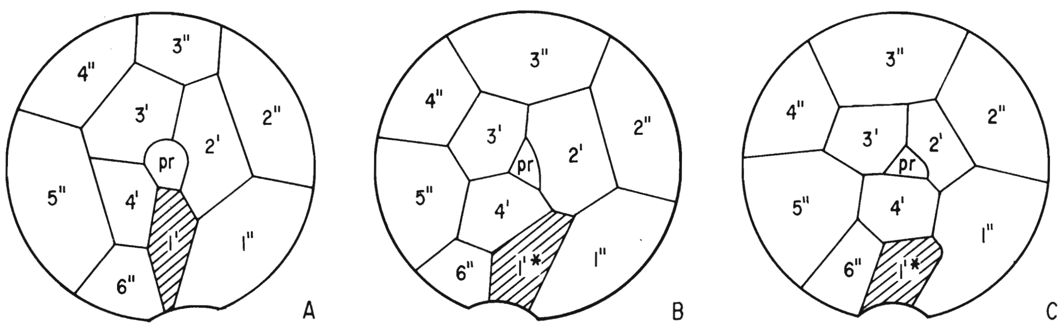


TEXT-FIG. 10. Precingular and postcingular (para)plate shapes in gonyaulacacean thecae and cysts. A, epitheca without intercalaries, showing the camerate precingulars 3″ and 5″ and the planate precingulars 2″ and 4″; 1″ and 6″ are considered to be planate. B, epitheca with one intercalary, showing the camerate precingulars 3″, 4″, and 5″ and the planate precingulars 1″, 2″, and 6″. C, hypotheca showing the camerate postcingulars 3‴ and 5‴ and the planate postcingulars 1‴, 2‴, 4‴, and 6‴. The tabulation patterns are from Taylor (1976). The Kofoidian notation is from Taylor (1976) and the present paper.

Archaeopyle Index (LAI) is the maximum archaeopyle length divided by the maximum epicyst length seen in ambital view. The *Archaeopyle Ratio* (R) is the maximum archaeopyle length divided by the maximum archaeopyle breadth. All these terms can be applied to either the periarchaeopyle or endoarchaeopyle.

Precingular plates vary in shape depending on the number of epithecal plates that they contact (text-fig. 10). When the precingular plate contacts three epithecal plates, it has a straight anterior margin and is herein termed *planate*. When the precingular plate contacts four epithecal plates, it has an anterior peak and is herein termed *camerate*. The postcingular plates can similarly be designated as planate or camerate. These terms can also be applied to the equivalent paraplates in cysts.

Strict adherence to Kofoidian notation may obscure the homologous relationship of thecate plates or cyst paraplates. This is evident when the modern genera *Gonyaulax* Diesing, 1866, *Heteraulacus* Diesing, 1850, and *Pyrodinium* Plate, 1906, or the fossil genera *Gonyaulacysta* Deflandre, 1964 ex Norris and Sarjeant, 1965, and *Heteraulacacysta* Drugg and Loeblich, 1967, are compared. Although the shaded plate (or paraplate) in text-fig. 11 is the first apical in *Gonyaulax*, it cannot be designated apical in *Heteraulacus* or *Pyrodinium* because it does not 'border the apical pore' (Kofoid 1909). Designation of this plate as a precingular or anterior sulcal plate is unsatisfactory, because of the reasons outlined in the present paper under the genus *Heteraulacacysta*. The term *homologue* is therefore suggested to replace plate or paraplate where homology can be demonstrated. The shaded plate of *Heteraulacus* and *Pyrodinium* in text-fig. 11 is then designated the first apical homologue and is

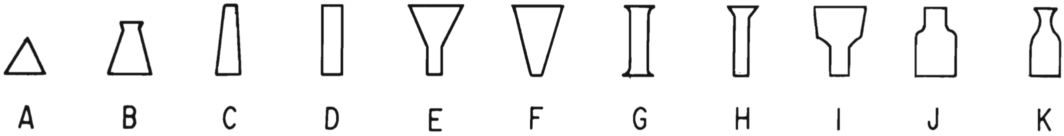


TEXT-FIG. 11. Epithecal tabulation of A, *Gonyaulax*; B, *Pyrodinium*; C, *Heteraulacus*. The shaded plate (1′*) of *Heteraulacus* and *Pyrodinium* is the homologue of the first apical plate (1′) of *Gonyaulax*. The tabulation patterns are from Taylor (1976), with Kofoidian notation inserted by the present author (J. P. B.).

denoted by an asterisk (1′*). The three (remaining) apical plates are numbered 2′, 3′, and 4′, and the precingular plates are numbered 1″ to 6″, as in *Gonyaulax*.

Downie and Sarjeant (1966) defined an epicystal archaeopyle as one formed 'by breakage parallel, and immediately anterior to, the cingulum (equivalent to epithecal archaeopyles of Norris 1965)'. In *Dinopterygium* Deflandre, 1935, and *Heteraulacacysta* Drugg and Loeblich, 1967, the archaeopyle is formed by separation of the cyst between the anterior and posterior cingular parasutures, and the operculum may be attached along the 1′/a.s. parasuture. When the cingular parasutures are represented by membranous crests, as in *Dinopterygium* and *Heteraulacacysta*, both parts of the cyst retain one paracingular crest after archaeopyle formation. This archaeopyle type is herein named *hemicystal.*

Downie and Sarjeant (1966) illustrated several process shapes including the distally expanded types buccinate, flared, and infundibular. The new term *caliculate* (Latin, *caliculus*, chalice) is proposed for processes that have a relatively thin proximal stem and are distally flared into a chalice or goblet shape (text-fig. 12).



TEXT-FIG. 12. Process shapes of dinoflagellate cysts. A, conical; B, subconical; C, tapering; D, cylindrical, E, infundibular; F, flared; G, tubiform; H, buccinate; I, caliculate; J, lagenate; K, bulbose. A–H, J–K are from Davey *et al.* (1966).

Systematic Palaeontology

Division PYRRHOPHYTA Pascher, 1914
Class DINOPHYCEAE Fritsch, 1929
Order PERIDINIALES Haeckel, 1894

Genus AREOSPHAERIDIUM Eaton, 1971*a*

Areosphaeridium fenestratum Bujak, 1976

Plate 13, figs. 1–2

1976 *Areosphaeridium fenestratum* Bujak, p. 107, pl. 2, figs. 9–12; pl. 3, figs. 1–4, text-figs. 3D–F.

EXPLANATION OF PLATE 5

Dinoflagellate cysts from the London Clay and Bracklesham Beds. Bar on all figures equals 30 μm.

Fig. 1. *Achomosphaera ramulifera* (Deflandre) Evitt subsp. *perforata* (Davey and Williams) Lentin and Williams. Holotype, London Clay, Whitecliff Bay, V59211(1) O40/2 (not V51764(1) as published in Davey and Williams, 1966). Upper, ?ventral surface.

Figs. 2–3. *Spiniferites perforatus* (Davey and Williams) Sarjeant. Holotype, London Clay, Sheppey, V59208(1) T56/4 (not V51983(1) and V51760(1) as published in Davey and Williams, 1966). 2. Optical section. 3. Upper, ventral surface.

Fig. 4. *Impletosphaeridium cracens* Eaton. Holotype. Bracklesham Beds, Whitecliff Bay, V57745(1) E28/3.

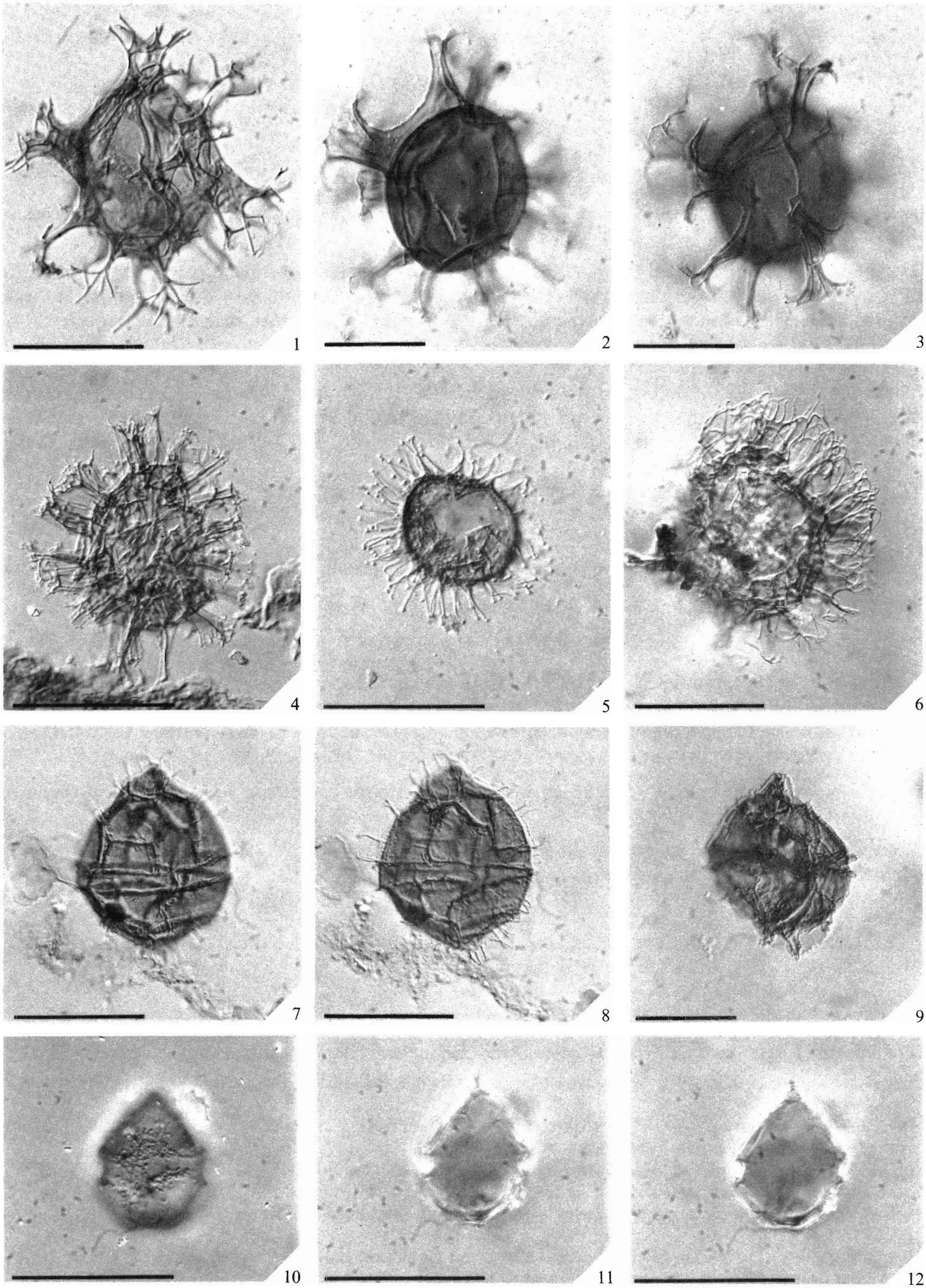
Fig. 5. *Impletosphaeridium insolitum* Eaton. Holotype, Bracklesham Beds, Whitecliff Bay, V57759(13) T32/0. Archaeopyle in focus.

Fig. 6. *Impletosphaeridium luxurium* Eaton. Holotype, Bracklesham Beds, Alum Bay, V57791(12) R45/1.

Figs. 7–8. '*Phthanoperidinium tritonium*' Eaton. Holotype, Bracklesham Beds, Whitecliff Bay, V57756(14) O50/0. Herein considered to be a junior synonym of *P. comatum* (Morgenroth) Eisenack and Kjellström. 7. Lower, dorsal surface. 8. Upper, ventral surface.

Fig. 9. *Phthanoperidinium alectrolophum* Eaton. Holotype, Bracklesham Beds, Alum Bay, V57791(13) W28/1. Upper, ?ventral surface.

Figs. 10–12. *Phthanoperidinium echinatum* Eaton. Holotype, Bracklesham Beds, Whitecliff Bay, V57755(4) P46/3. 10. Upper, ventral surface. 11. Detail of the 2a intercalary archaeopyle. 12. Optical section.



BUJAK *et al.*, Dinoflagellate cysts

Holotype. V59978 J47/2. Middle Barton Beds, Whitecliff Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V59829 O35/2; V59895 G13/3, G30/3; V59903 Q41/1, S39/0; V59910 Q26/4; V59954 P34/1.

Dimensions. Central body length (without operculum) = 28–42 μm, breadth = 30–46 μm. Process length = 14–23 μm. Number of specimens measured = 20.

Genus CEREBROCYSTA Bujak, gen. nov.

Derivation of name. Latin, *cerebrum*, brain, and Greek, *kystis*, bladder, sac, cell, with reference to the appearance of the cyst.

Diagnosis. Autocyst spherical to ovoidal, without apical, antapical, or other projections, except for an apparently random ornament of low crests. The crests occasionally suggest a paratabular arrangement. The archaeopyle is formed by the loss of one (3″) or more precingular paraplates.

Type species. *Cerebrocysta bartonensis* sp. nov. Late Eocene.

Discussion. *Cerebrocysta* differs from *Tectatodinium* Wall, 1967, and *Tapeinosphaeridium* Ioannides *et al.*, 1977, in possessing crests, from *Lingulodinium* Wall, 1967, in lacking processes, and from *Leptodinium* Klement, 1960, in lacking paratabulation.

Cerebrocysta bartonensis Bujak, sp. nov.

Plate 13, figs. 4–11

Derivation of name. Named for Barton, Hampshire, southern England.

Holotype. V59946 J31/0. Middle Barton Beds, Alum Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V59885 V26/0; V59925 V26/0; V59933 Q41/2; V59970 K42/2; V59994 P33/0.

Diagnosis. Autocyst spherical to ovoidal, without apical, antapical, or other projections, except for an ornament of low crests which give the cyst a cerebral appearance. The crests are mostly random, but occasionally suggest a paratabular arrangement. The archaeopyle is formed by the loss of between one and three precingular paraplates. Archaeopyle formula is P to 3P (3″ to 2″–4″).

Dimensions. Autocyst diameter = 24 × 24 μm to 28 × 28 μm. Height of crests to 2 μm. Number of specimens measured = 25.

Discussion. *Leptodinium incompositum* (Drugg, 1970) Lentin and Williams, 1973, differs from *C. bartonensis* in having paratabulation.

EXPLANATION OF PLATE 6

Dinoflagellate cysts from the London Clay and Bracklesham Beds. Bar on all figures equals 30 μm.

Figs. 1–2. *Turbiosphaera galatea* Eaton. Holotype, Bracklesham Beds, Alum Bay, V57783(4). 1. Upper surface. 2. Lower surface.

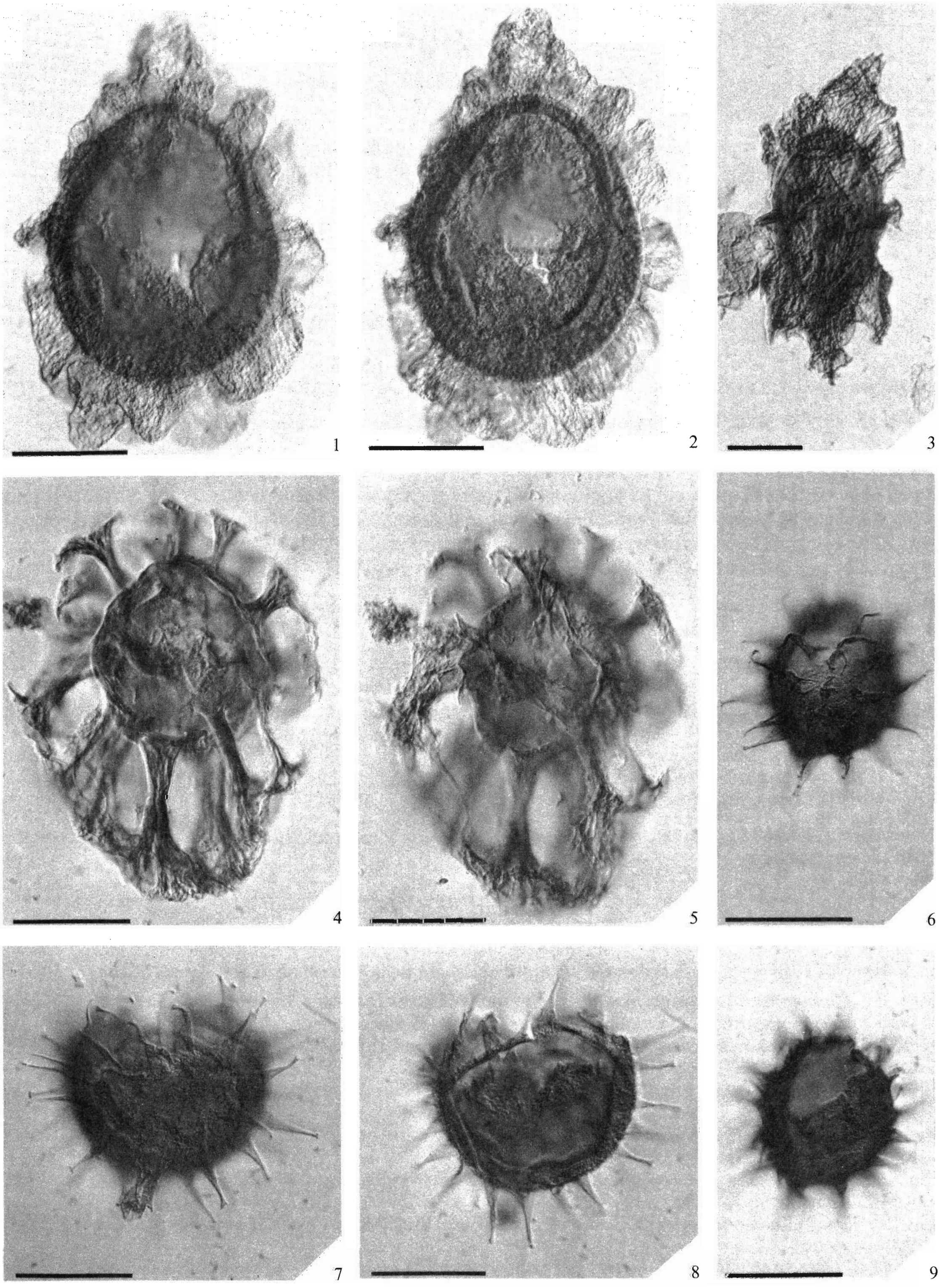
Fig. 3. *Turbiosphaera magnifica* Eaton. Holotype, Bracklesham Beds, Whitecliff Bay, V57756(7) H50/4, showing the precingular archaeopyle at top right.

Figs. 4–5. *Araneosphaera araneosa* Eaton. Holotype, Bracklesham Beds, Whitecliff Bay, V57765(2) T29/1. 4. Lower surface. 5. Upper surface.

Figs. 6, 9. *Dapsilidinium pastielsii* (Davey and Williams) comb. nov. Holotype, London Clay, Sheppey, V51753(1) V52/1.

Figs. 7–8. *Diphyes colligerum* (Deflandre and Cookson) Cookson. London Clay, Enborne. 7. Upper surface showing the broad antapical process. 8. Lower surface.

PLATE 6



BUJAK *et al.*, Dinoflagellate cysts

Genus CHIROPTERIDIUM Gocht, 1960

Chiropteridium aspinatum (Gerlach, 1961) Brosius, 1963

Plate 13, fig. 12

1961 *Membraniphoridium aspinatum* Gerlach, p. 199, pl. 29, fig. 7.
1963 *Chiropteridium aspinatum* (Gerlach) Brosius, p. 48, pl. 1, fig. 1.

Dimensions. Central body length (without operculum) = 45–63 μm, breadth = 47–72 μm. Maximum membrane height = 6–12 μm. Number of specimens measured = 40.

Genus CHYTROEISPHAERIDIA (Sarjeant, 1962) Downie and Sarjeant, 1965

Chytroeisphaeridia explanata Bujak, sp. nov.

Plate 13, figs. 13–14

Derivation of name. Latin, *explanatus*, make clear, elucidate, with reference to the archaeopyle.

Holotype. V59930 S45/2. Lower Barton Beds, Alum Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V59978 W24/0; V60012.

Diagnosis. Autocyst spherical to ovoidal. Autophragm smooth to chagrinate, without indication of paracingulum or parasulcus. Paratabulation absent except near the archaeopyle margin. Archaeopyle apical, tetratabular, with well-developed accessory archaeopyle sutures that delimit the lateral margins of paraplates 1″–6″ and a.s. The operculum is detached.

Dimensions. Autocyst length (without operculum) = 44–66 μm, breadth = 48–70 μm. Number of specimens measured = 10.

Genus CORDOSPHAERIDIUM Eisenack, 1963

Cordosphaeridium cantharellum (Brosius, 1963) Gocht, 1969

Plate 13, fig. 15

1963 *Hystrichosphaeridium cantharellum* Brosius, p. 40, pl. 16, fig. 1, text-figs. 2 (11*a–c*).
1969 *Cordosphaeridium cantharellum* (Brosius) Gocht, p. 45, pl. 5, figs. 11–13; pl. 6, figs. 10–11.

Dimensions. Central body diameter = 35 × 36 μm to 46 × 48 μm. Maximum process length = 13–29 μm. Number of specimens measured = 20.

EXPLANATION OF PLATE 7

Dinoflagellate cysts from the London Clay and Bracklesham Beds. Bar on all figures equals 30 μm.

Figs. 1–2. *Cordosphaeridium multispinosum* Davey and Williams. Holotype, London Clay, Sheppey, V51751(1) W22/2. 1. Upper surface. 2. Detail of the 3″ precingular archaeopyle.

Figs. 3, 6. *Cordosphaeridium fibrospinosum* Davey and Williams. Holotype, London Clay, Enborne, V51747(1) O50/3. 3. Optical section. 6. Upper, ?dorsal surface.

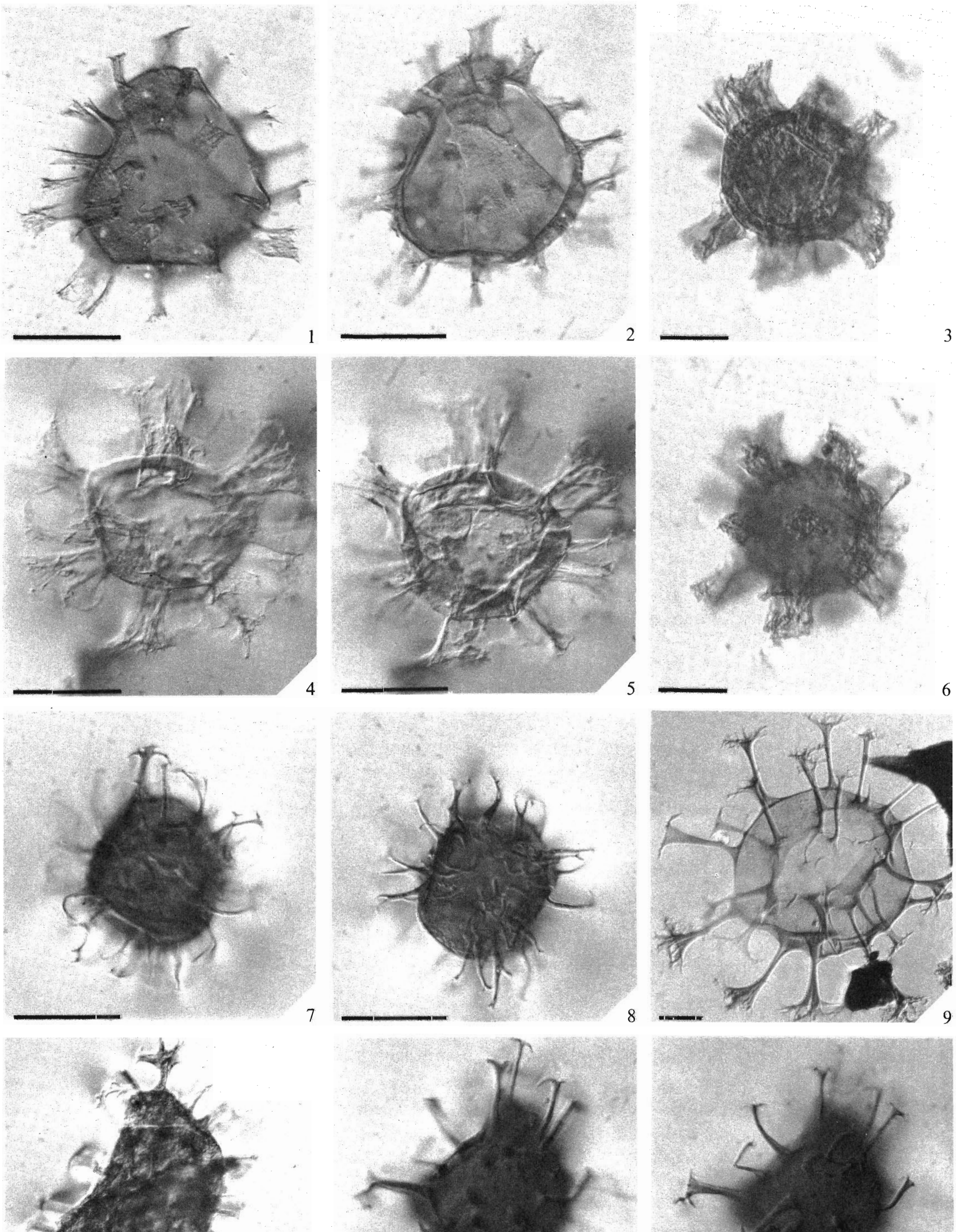
Figs. 4–5. *Cordosphaeridium exilimurum* Davey and Williams. Holotype, London Clay, Whitecliff Bay, V51749(1) M43/0. 4. Upper surface. 5. Optical section.

Figs. 7–8. *Cleistosphaeridium diversispinosum* Davey *et al.* Holotype, London Clay, Whitecliff Bay, V51750(1) K55/3. 7. Lower surface. 8. Upper surface.

Fig. 9. *Cordosphaeridium cracenospinosum* Davey and Williams. Holotype, London Clay, Enborne, V51748(1) K34/2. Archaeopyle in focus.

Fig. 10. *Lanternosphaeridium vectense* Eaton. Holotype, Bracklesham Beds, Alum Bay, V57797(2) Q39/0. Optical section.

Figs. 11–12. *Cordosphaeridium divergens* (Eisenack) Eisenack. London Clay, Whitecliff Bay. 11. Optical section. 12. Upper surface.



BUJAK *et al.*, Dinoflagellate cysts

Cordosphaeridium funiculatum Morgenroth, 1966*a*

Plate 13, figs. 16–17

?1954 *Hystrichosphaeridium inodes gracile* Eisenack *forma areolata* Eisenack, p. 67, pl. 12, fig. 21.
1966*a* *Cordosphaeridium funiculatum* Morgenroth, p. 22, pl. 6, figs. 2–3.

Dimensions. Central body length = 50–80 μm, breadth = 42–66 μm. Maximum process length = 16–33 μm. Number of specimens measured = 25.

Discussion. Some specimens described as *C. divergens* (Eisenack, 1954) Eisenack, 1963, have a periphragm structure that is identical to that of *C. funiculatum* (Eisenack 1954, pl. 9, fig. 16; Weyns 1970, pl. 3, fig. 32). These specimens may be synonymous with *C. funiculatum*.

Genus CYCLONEPHELIUM Deflandre and Cookson, 1955

Cyclonephelium microfenestratum Bujak, 1976

Plate 14, fig. 1

1976 *Cyclonephelium microfenestratum* Bujak, p. 112, pl. 3, fig. 12; pl. 4, figs. 1–7, text-fig. 3I.

Holotype. V60017. Upper Barton Beds, Whitecliff Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V59994 C48/2, D52/0, L43/2, Q23/4.

Dimensions. Central body length (with operculum) = 64–70 μm, length (without operculum) = 45–67 μm, breadth = 54–72 μm. Process length = 15–35 μm. Number of specimens measured = 14.

?*Cyclonephelium semitectum* Bujak, sp. nov.

Plate 14, figs. 2–9; text-fig. 13

1970 *Cyclonephelium exuberans* Deflandre and Cookson '*ellipsoidale*' Weyns, p. 254, pl. 1, figs. 4–5.
1972 *Cyclonephelium* cf. *pastielsii* Deflandre and Cookson; Benedek (*pars*) p. 8, pl. 1, fig. 6.

Derivation of name. Latin, *semi*, half, plus Latin, *tectus*, cover, with reference to the nature of the enveloping membrane.

Holotype. V60019. Middle Barton Beds, Alum Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V59894 K33/1; V59936 O37/1; V59881 Q34/0; V59930 S45/2; V60018.

EXPLANATION OF PLATE 8

Dinoflagellate cysts from the London Clay. Bar on all figures equals 30 μm.

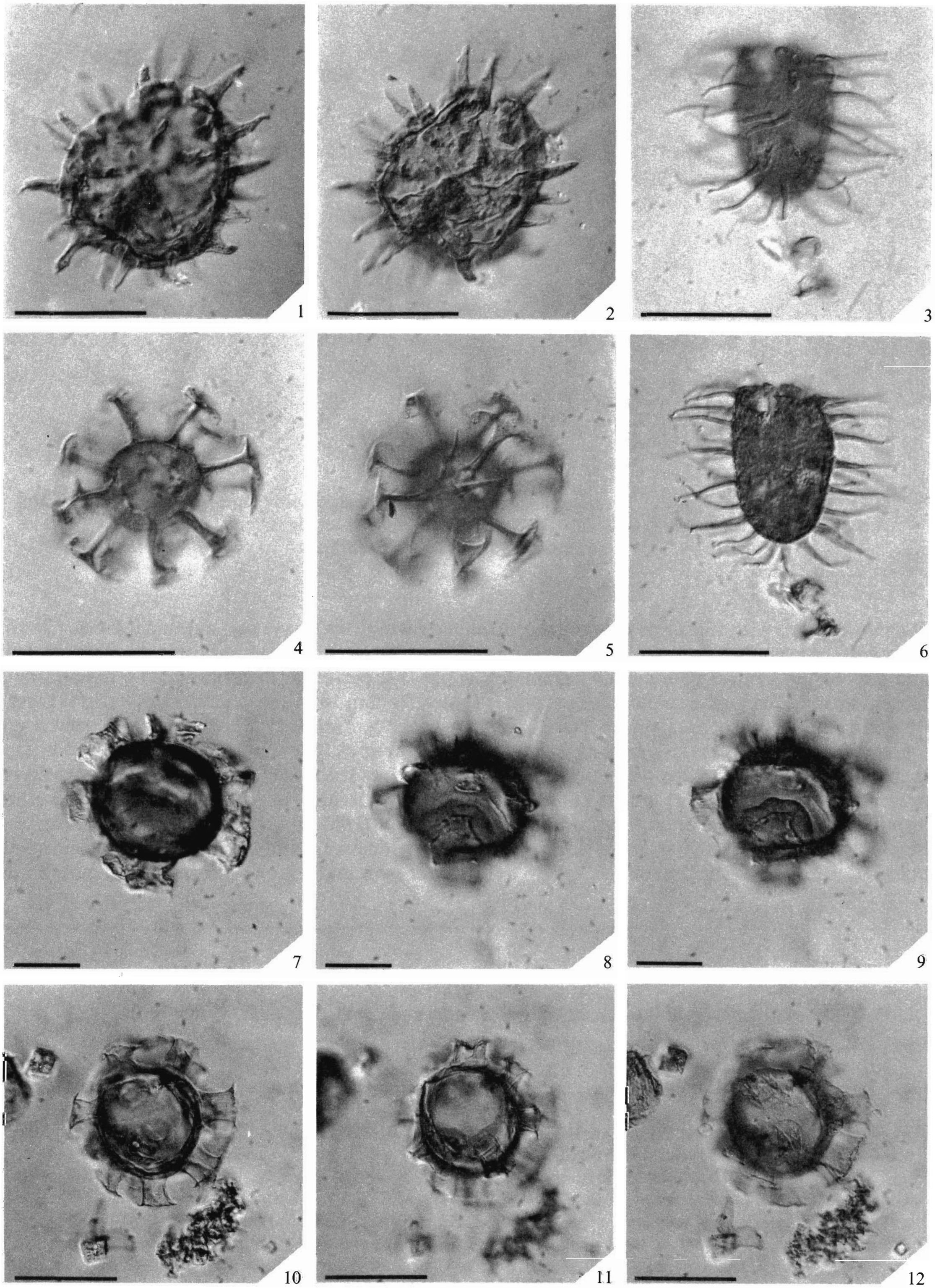
Figs. 1–2. '*Cleistosphaeridium disjunctum*' Davey *et al.* Holotype, London Clay, Whitecliff Bay, V51739(2) U64/4. Considered to be a junior synonym of *Lingulodinium machaerophorum* (Deflandre and Cookson) Wall by Reid (1974). 1. Lower surface. 2. Upper surface with displaced opercular paraplates.

Figs. 3, 6. *Tanyosphaeridium regulare* Davey and Williams. Holotype, London Clay, Whitecliff Bay, V51755(1) O39/2. 3. Upper surface. 6. Optical section.

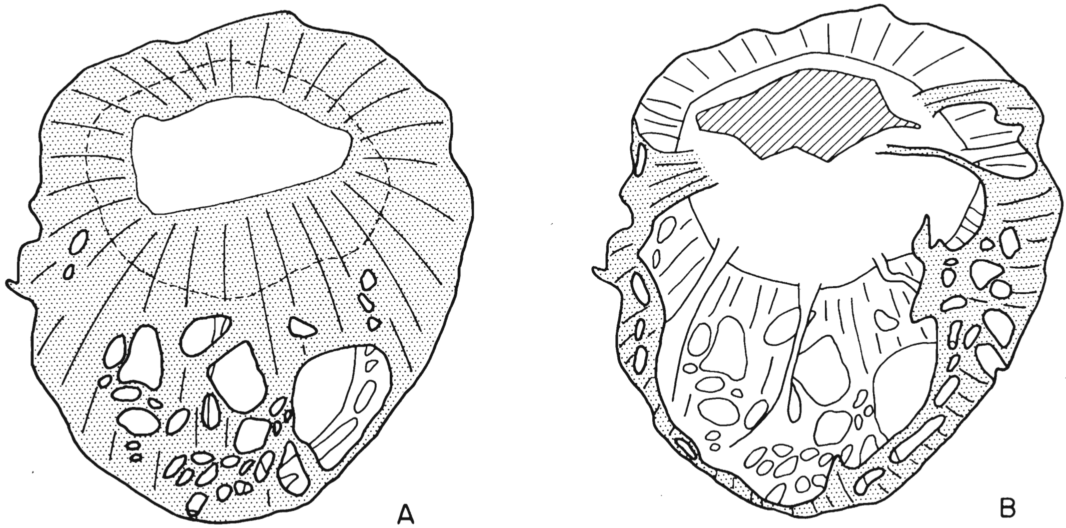
Figs. 4–5. ?*Hystrichosphaeridium latirictum* Davey and Williams. Holotype, London Clay, Enborne, V51740(1) X24/1. 4. Optical section. 5. Upper surface.

Figs. 7–9. *Achilleodinium latispinosum* (Davey and Williams) comb. nov. Holotype, London Clay, Sheppey. 7. Optical section. 8. Upper surface. 9. Upper surface focused on the displaced operculum (3″).

Figs. 10–12. *Hystrichosphaeridium tubiferum* (Ehrenberg) Deflandre subsp. *brevispinum* (Davey and Williams) Lentin and Williams. Holotype, London Clay, Enborne, V51738(1) T24/2. 10. Optical section. 11. Apex with archaeopyle. 12. Antapex.



BUJAK *et al.*, Dinoflagellate cysts



TEXT-FIG. 13. Morphology of ?*Cyclonephelium semitectum* Bujak, sp. nov. A, dorsal surface; B, ventral surface of the same specimen by transparency. Position of archaeopyle is hachured. Stippling indicates the external surface of the membrane.

Diagnosis. Cysts with spherical to ovoidal central body which may have two antapical lobes. Central body surface granulate or reticulate. Simple fibrous processes arising from the central body periphery and two of the ventral precingular paraplates, support a perforate membrane. The membrane is present around the dorsal side of the cyst and is absent from most of the ventral side. It arises from a subquadrate middorsal area, where it is in contact with the central body. The height of the membrane is greatest antapically and lessens progressively towards the apex. The ventral border of the membrane is entire and occurs near the processes. The membrane rises from the anterior border of the dorsal zone of contact and forms a striate flange which extends anteriorly beyond the archaeopyle suture, terminating in a straight or undulating entire margin. Additional small simple ventral processes may be present and are distally free. No dorsal precingular processes were observed. The archaeopyle is apical, tetratabular. The operculum has up to four processes and a high perforate distal membrane.

EXPLANATION OF PLATE 9

Dinoflagellate cysts from the Bracklesham Beds. Bar on all figures equals 30 μm.

Figs. 1–2. *Areoligera tauloma* Eaton. Holotype, Bracklesham Beds, Whitecliff Bay, V57768(3) U38/0. 1. Ventral surface. 2. Dorsal surface.

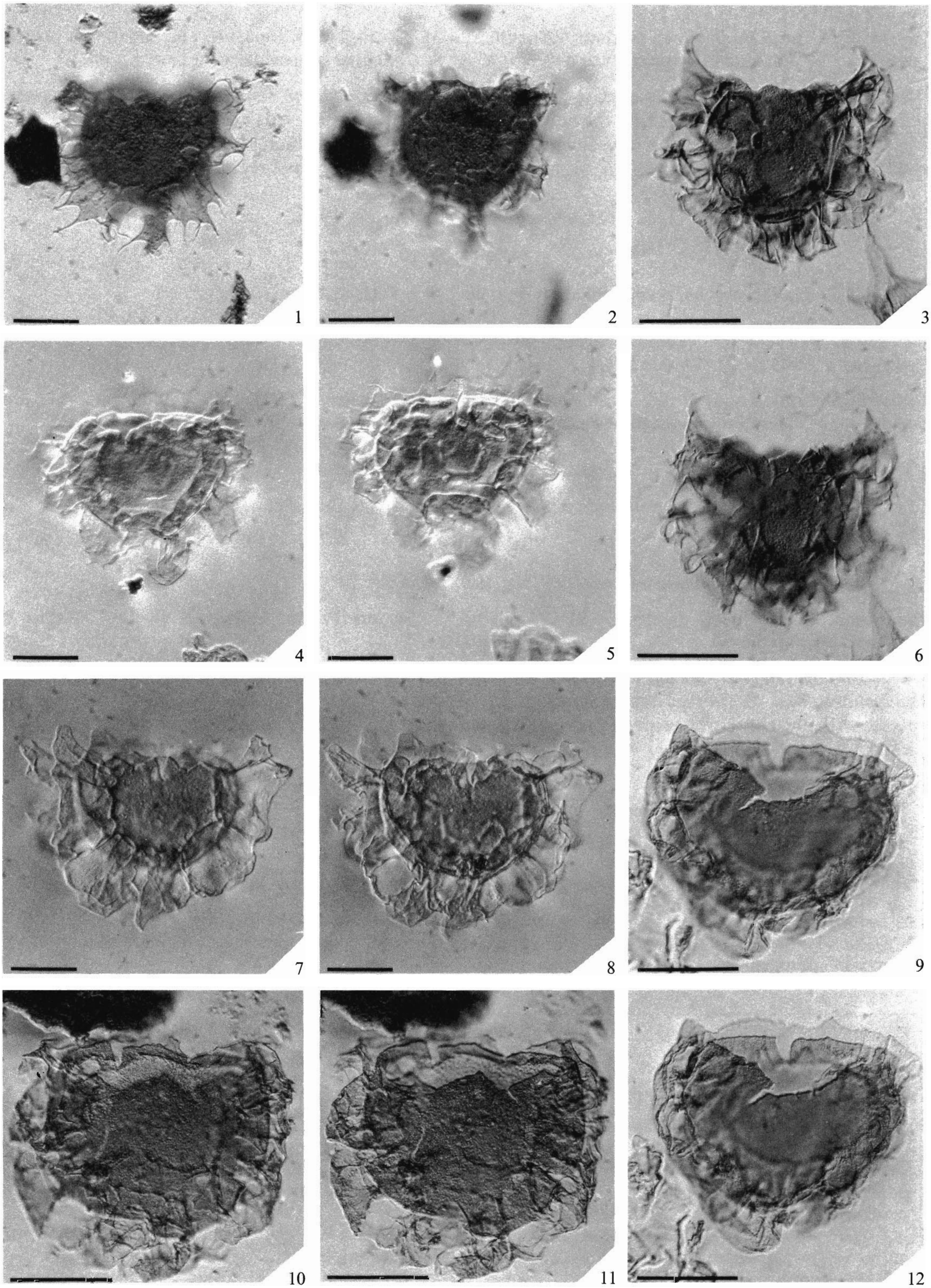
Figs. 3, 6. *Cyclonephelium laciniiforme* Gerlach. Bracklesham Beds, Alum Bay. 3. Lower, ventral surface. 4. Upper, dorsal surface.

Figs. 4–5. *Areoligera sentosa* Eaton. Holotype, Bracklesham Beds. Alum Bay, V57794(5) V32/1. 4. Upper, ventral surface. 5. Lower, dorsal surface.

Figs. 7–8. *Areoligera undulata* Eaton. Holotype, Bracklesham Beds, Alum Bay, V57802(3) M36/3. 7. Upper, ventral surface. 8. Lower, dorsal surface.

Figs. 9, 12. *Cyclonephelium vicinum* Eaton. Holotype, Bracklesham Beds, Whitecliff Bay, V57744. 9. Lower, ?ventral surface. 12. Upper, ?dorsal surface, focused on the archaeopyle margin.

Figs. 10–11. *Cyclonephelium spinetum* Eaton. Holotype, Bracklesham Beds, Whitecliff Bay, V57742 L54/0. 10. Lower, dorsal surface. 11. Upper, ventral surface.



BUJAK *et al.*, Dinoflagellate cysts

Dimensions. Central body length (without operculum) = 33–52 μm, breadth = 45–60 μm. Maximum process length = 15–37 μm, maximum membrane height = 25–46 μm. Number of specimens measured = 40.

Discussion. Weyns (1970) figured a specimen of *Cyclonephelium semitectum* as *C. exuberans* '*ellipsoidale*', but did not describe the subspecies or refer it to a previous author.

C. semitectum is characterized by the high perforate membrane which covers the dorsal side of the cyst, other than the middorsal area, and is absent from the midventral region.

Cyclonephelium textum Bujak, 1976

Plate 14, fig. 10

1976 *Cyclonephelium textum* Bujak, p. 110, pl. 3, figs. 6–11, text-figs. 3G–H.

Holotype. V59986 N25/2. Middle Barton Beds, Whitecliff Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V59905 F43/4; V59974 P44/4, R46/4; V59976 G52/0; V59983 F37/3.

Dimensions. Central body length (with operculum) = 38–45 μm, length (without operculum) = 29–42 μm, breadth = 32–50 μm. Process length = 9–22 μm. Number of specimens measured = 30.

Genus DAPSILIDINIUM Bujak *et al.*

Dapsilidinium simplex (White, 1842) Bujak *et al.*

Plate 14, figs. 11–12

1842 *Xanthidium tubiferum simplex* White, p. 38, pl. 4, fig. 10.

Dimensions. Central body diameter = 20 × 23 μm to 33 × 36 μm. Process length = 9–17 μm. Number of specimens measured = 60.

Discussion. Bujak *et al.* in Part IV of the present paper demonstrated that the type species of the genus *Polysphaeridium*, *P. subtile*, has an epicystal archaeopyle. They erected the genus *Dapsilidinium* for species with an apical archaeopyle previously assigned to *Polysphaeridium*. These include *D. simplex*.

Genus DEFLANDREA Eisenack, 1938

Deflandrea cf. *D. heterophlycta* Deflandre and Cookson, 1955, *sensu* Gocht, 1969

Plate 15, fig. 1

1969 *Deflandrea* cf. *heterophlycta* Deflandre and Cookson; Gocht, p. 11, text-fig. 4.

Dimensions. Pericyst length = 140–160 μm, breadth = 90–105 μm. Endocyst length = 70–90 μm, breadth = 60–70 μm. Maximum tubercle height on endophragm = 3·5 μm. Maximum spine length on periphragm = 3 μm. Number of specimens measured = 10.

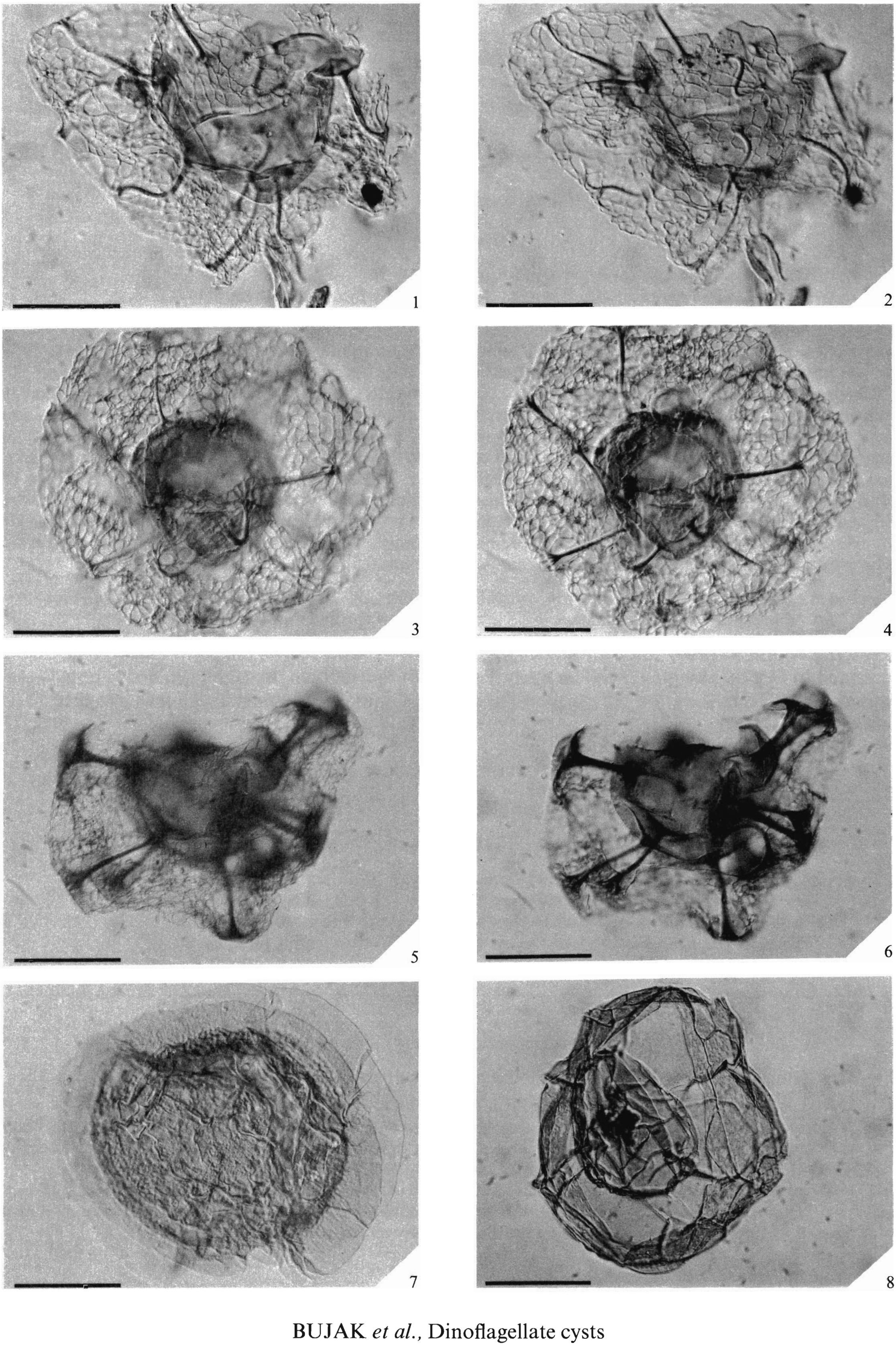
EXPLANATION OF PLATE 10

Dinoflagellate cysts from the London Clay and Bracklesham Beds. Bar on all figures equals 30 μm.

Figs. 1–6. *Membranilarnacia ursulae* (Morgenroth) De Coninck. 1–2. Bracklesham Beds, Alum Bay. 1. Lower surface. 2. Upper surface. 3–4. Holotype of '*Membranilarnacia reticulata*' Williams and Downie from the London Clay, Sheppey, V51959(2) W26/0, considered to be a junior synonym of *M. ursulae* by Gocht (1969). 3. Upper surface. 4. Lower surface. 5–6. London Clay, Sheppey. Specimen showing the absence of cingular processes. 5. Upper surface. 6. Lower surface.

Fig. 7. *Heteraulacacysta leptalea* Eaton. Holotype, Bracklesham Beds, Whitecliff Bay, V57766(8) K24/1. Upper surface showing the partial development of perforations in the periphragm.

Fig. 8. *Thalassiphora delicata* Williams and Downie. Holotype, London Clay, Enborne, V51756(3) S46/1.



BUJAK *et al.*, Dinoflagellate cysts

Discussion. Deflandre and Cookson (1955) described the periphragm of *D. heterophlycta* as finely and sparsely punctate, and the endophragm as ornamented with irregularly dispersed, solid tubercles. Specimens from the Barton Beds are identical to those described by Gocht (1969) as *Deflandrea* cf. *heterophlycta*. They differ from the Australian type material in possessing short, slender spines that cover all of the periphragm other than the pandasutural areas. Forms with small tubercles on the endophragm intergrade into specimens assigned to *D. spinulosa* Alberti, 1959, from the Barton Beds.

Deflandrea spinulosa Alberti, 1959

Plate 15, figs. 2–3

1959 *Deflandrea spinulosa* Alberti, p. 95, pl. 8, figs. 8–9.
1960 *Deflandrea phosphoritica* Eisenack; Manum, p. 18, figs. 4–8, text-fig. 1.
1963 *Deflandrea phosphoritica* Eisenack; Brosius, p. 36, pl. 5, fig. 1.

Description. D. spinulosa from the Barton Beds falls within the morphological variation defined by Alberti (1959) for the species. The following additional observations are made for specimens from the Barton Beds.

The surface of the periphragm is differentiated into laevigate to granulate pandasutural areas and denticulate to spinate penitabular areas. Broader denticles are aligned along the paracingular and parasulcal margins, and the other paraplate borders are defined by extremely low, narrow crests. The ornament on the periphragm denotes a paratabulation of 4′, 3a, 7″, 5‴, 2⁗. Low parasutural crests delimit individual cingular paraplates, but their number has not been determined. The endophragm is granulate and may have small tubercles on the ambital periphery. The periarchaeopyle is broad hexa, resulting from the detachment of paraplate 2a. Paraplates 1a and 3a, which are long, narrow, and pentagonal, are not involved in the archaeopyle formation. The transverse archaeopyle index is 0·8, the longitudinal archaeopyle index is 0·4, and the archaeopyle ratio is 0·6. The endoarchaeopyle results from the detachment of a subapical portion of the endocyst.

Dimensions. Pericyst length = 90–120 μm, breadth = 75–105 μm. Endocyst length = 55–70 μm, breadth = 55–80 μm. Maximum height of ornament = 2·5 μm. Number of specimens measured = 20.

Remarks. Manum (1960) noted granules and echinae of variable size on the periphragm of specimens assigned to *D. phosphoritica* from the Early Tertiary of Spitsbergen. Brosius (1963) also noted small spines (up to 2 μm long) on the periphragm of Late Oligocene German specimens assigned to *D. phosphoritica.*

Genus DIACROCANTHIDIUM Deflandre and Foucher, 1967

Diacrocanthidium echinulatum (Deflandre, 1937) Loeblich and Loeblich, 1970

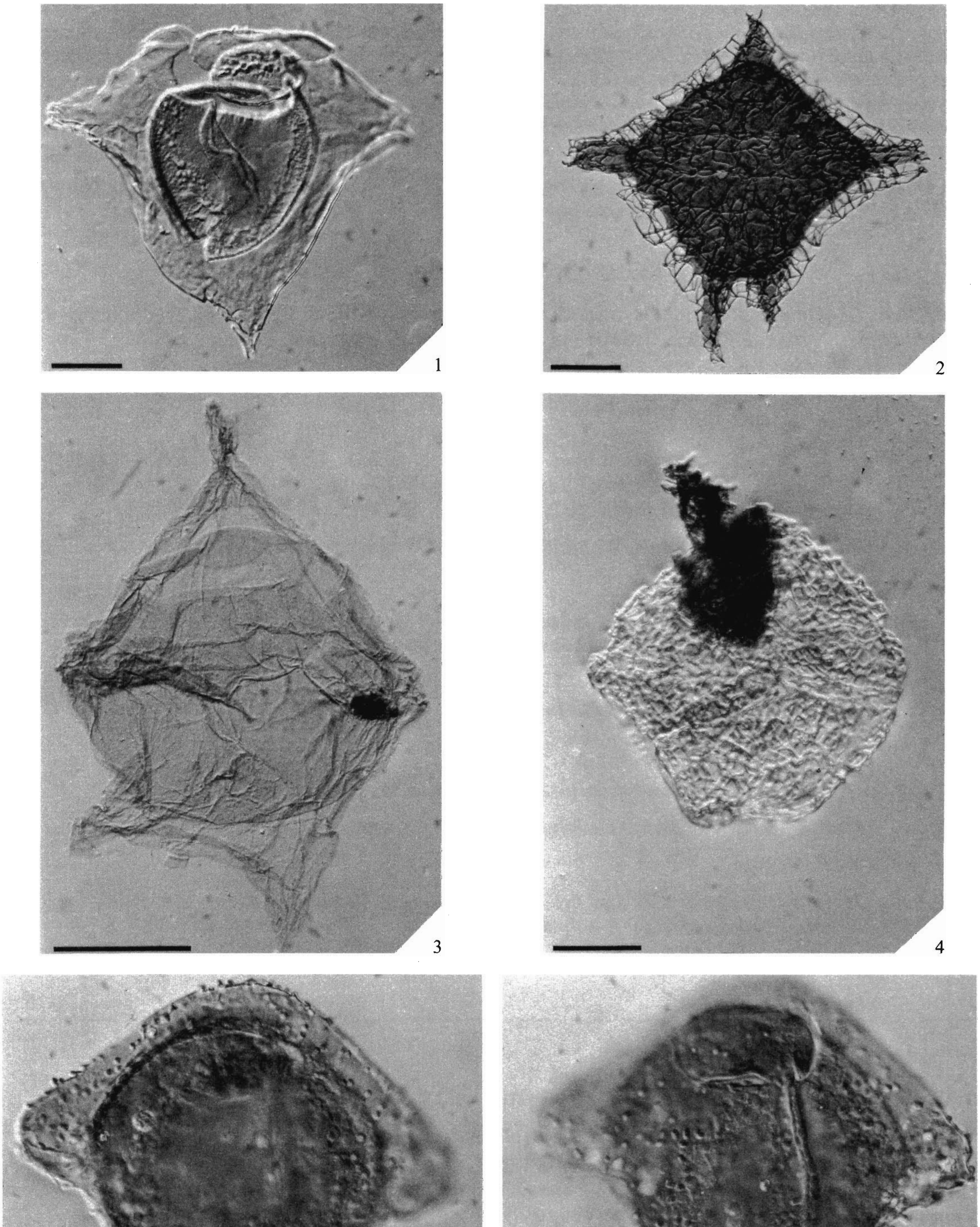
Plate 15, fig. 4

1937 *Palaeostomocystis echinulatum* Deflandre, p. 55, pl. 11, fig. 9.
1969 ?*Cleistosphaeridium parvum* Davey, p. 157, pl. 7, figs. 11–12.
1970 *Diacrocanthidium echinulatum* (Deflandre) Loeblich and Loeblich, p. 200.
1971 ?*Cleistosphaeridium parvum* Davey; Davey and Verdier, p. 15, pl. 2, fig. 3.

EXPLANATION OF PLATE 11

Dinoflagellate cysts from the London Clay and Bracklesham Beds. Bar on all figures equals 30 μm.

Fig. 1. *Dracodinium politum* sp. nov. Bracklesham Beds, Whitecliff Bay. Lower, dorsal surface.
Fig. 2. *Kisselovia tenuivirgula* (Williams and Downie) Lentin and Williams. Bracklesham Beds, Whitecliff Bay.
Fig. 3. *Ceratiopsis wardenensis* (Williams and Downie) comb. nov. Holotype, London Clay, Sheppey, V51980(1). Endoarchaeopyle in focus, formed by the displacement of three intercalary paraplates.
Fig. 4. *Kisselovia insolens* Eaton. Holotype, Bracklesham Beds, Alum Bay, V57774(4) O41/4. Upper surface.
Figs. 5–6. ?*Dracodinium condylos* (Williams and Downie) comb. nov. London Clay, Enborne. 5. Lower, ventral surface. 6. Upper, dorsal surface showing the displaced operculum attached anteriorly.



BUJAK *et al.*, Dinoflagellate cysts

Description. Specimens of *D. echinulatum* from the Barton Beds have smooth, thin-walled, elongate central bodies with an equatorial constriction. The spines, which are absent from the equatorial zone, occur in a postcingular row about 2 μm from the end of the body opposite an opening, and a precingular row which borders a circular opening present on all recorded specimens. Each row contains six to nine spines. In addition to these two rows of spines, other more randomly positioned spines may be present. The spines are solid and generally taper to a simple ending, although bifurcations may occur.

Dimensions. Central body length (without operculum) = 8–10 μm, breadth = 7–8 μm. Maximum spine length = 5–10 μm. Number of specimens measured = 16.

Genus GOCHTODINIUM Bujak, 1979

Discussion. Morphological details and the relationships between species of *Gochtodinium* and *Rhombodinium* from the Barton Beds are given in Bujak (1979).

Gochtodinium simplex Bujak, 1979

Plate 15, fig. 5

1977*b* *Wetzeliella* sp. A Williams and Bujak, pl. 3, figs. 3–4.
1979 *Gochtodinium simplex* Bujak, pl. 2, fig. 10; pl. 3, figs. 1–12, text-figs. 4B, 8F.

Holotype. V60004. Upper Barton Beds, Whitecliff Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V60005; V60006; V60010.

Dimensions. Pericyst length = 95–125 μm, breadth = 105–140 μm. Endocyst length = 75–95 μm, breadth = 75–100 μm. Maximum process length = 7–12 μm. Number of specimens measured = 15.

Gochtodinium spinulum Bujak, 1979

Plate 15, fig. 6

1979 *Gochtodinium spinulum* Bujak, pl. 2, figs. 3–9, text-fig. 8E.

Holotype. V60008. Upper Barton Beds, Alum Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V60007; V60016.

Dimensions. Pericyst length = 90–120 μm, breadth = 95–130 μm. Endocyst length = 75–95 μm, breadth = 75–100 μm. Maximum process length is less than 5 μm. Number of specimens measured = 10.

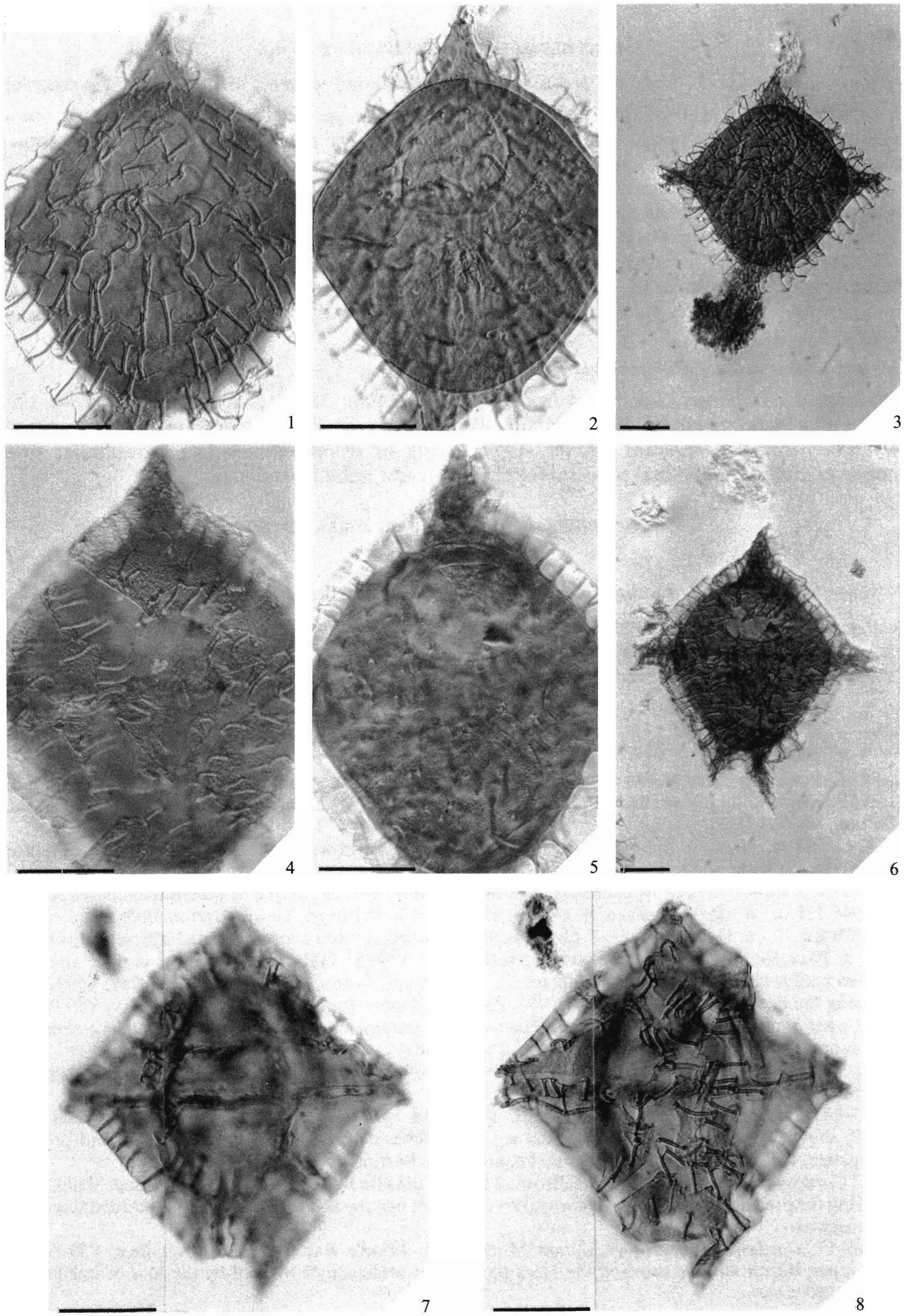
EXPLANATION OF PLATE 12

Dinoflagellate cysts from the London Clay. Bar on all figures equals 30 μm.

Figs. 1–3. *Kisselovia tenuivirgula* (Williams and Downie) Lentin and Williams. London Clay, Sheppey. 1. Upper, dorsal surface focused on the processes. 2. Dorsal surface/optical section showing the periarchaeopyle and displaced perioperculum. 3. General morphology.

Figs. 4–6. *Kisselovia reticulata* (Williams and Downie) Lentin and Williams. London Clay, Sheppey. 4. Upper, ventral surface focused on the distal process platforms. 5. Dorsal surface/optical section showing the periarchaeopyle. 6. General morphology.

Figs. 7–8. *Kisselovia coleothrypta* (Williams and Downie) Lentin and Williams. Holotype, London Clay, Sheppey, V51753(3) R47/0. 7. Lower, dorsal surface. The distal process ornament is restricted to lists. 8. Upper, ventral surface. The distal process ornament overlies most of the area above each paraplate.



BUJAK *et al.*, Dinoflagellate cysts

Genus HEMISPHAERIDIUM Bujak, gen. nov.

Derivation of name. Greek, *hemi*, half, plus Greek, *sphaera*, ball, with reference to the nature of the archaeopyle.

Diagnosis. Chorate cysts with a spherical, ovoidal, or ellipsoidal central body and a smooth, granulate, or reticulate periphragm. Numerous processes are arranged in intratabular complexes. Processes slender, tubiform, and open distally. Process complexes annulate or soleate on the apical, precingular, postcingular, antapical, posterior intercalary, and posterior sulcal paraplates; additional processes are sometimes present within the complexes. The paracingular process complexes are arcuate or linear. The processes forming a process complex are united distally by a membrane or trabeculate network. Processes of adjacent complexes are occasionally connected by distal trabeculae or membranes. Paratabulation 4′, 6″, 6c, 6‴, 1p. 1⁗, 1p.s. Process complexes may be absent from some paraplates. Archaeopyle epicystal, formed by the detachment of the apical and precingular paraplates.

Type species. Hemisphaeridium fenestratum sp. nov. Late Eocene.

Discussion. Hemisphaeridium differs from *Polysphaeridium* Davey and Williams, 1966, in having intratabular process complexes, each of which bears a distal membrane or is trabeculate. *Polysphaeridium congregatum* (Stover, 1977) Bujak *et al.* sometimes has intratabular process complexes, but the individual processes are typically not united distally.

Hemisphaeridium fenestratum Bujak, sp. nov.

Plate 15, figs. 7–9

Derivation of name. Latin, *fenestratus*, windowed, with reference to the distal process platforms.

Holotype. V59994 O30/2. Upper Barton Beds, Whitecliff Bay, Isle of Wight, southern England. Late Eocene.

EXPLANATION OF PLATE 13

Dinoflagellate cysts from the Barton Beds. Bar on all figures equals 30 μm.

Figs. 1–2. *Areosphaeridium fenestratum* Bujak, showing the difference in distal process platform development. 1. Holotype, Middle Barton Beds, Whitecliff Bay, V59978 J47/2. 2. Paratype, Middle Barton Beds, Barton Section, V59903 Q41/1.

Fig. 3. *Ceratiopsis depressa* (Morgenroth) Lentin and Williams, Lower Barton Beds, Whitecliff Bay, V59970 S41/0. Archaeopyle and striations in focus.

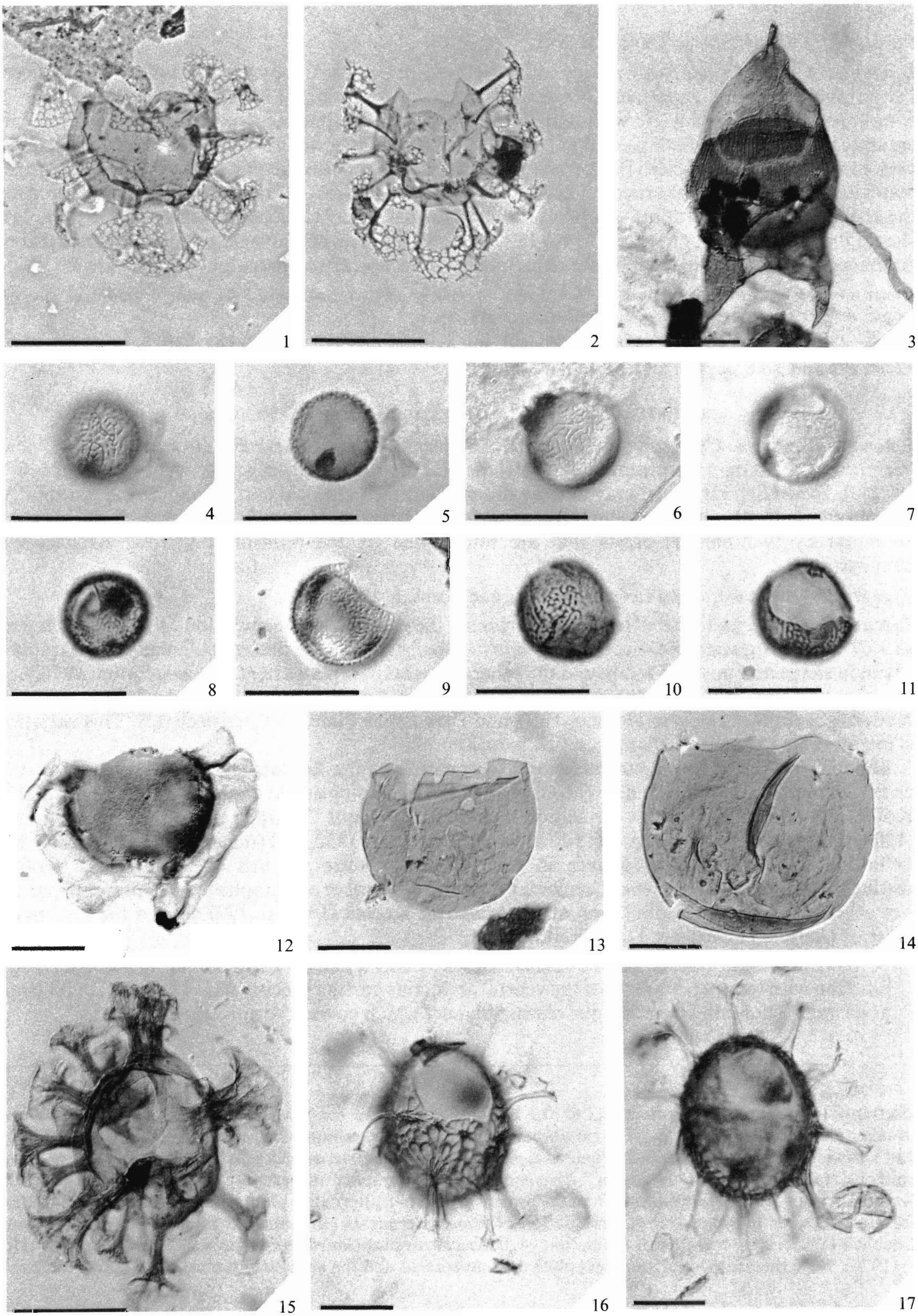
Figs. 4–11. *Cerebrocysta bartonensis* Bujak, gen. nov., sp. nov. 4–5. Holotype, Middle Barton Beds, Alum Bay, V59946 J31/0. 4. Upper surface. 5. Optical section. 6–7. Paratype, Lower Barton Beds, Whitecliff Bay, V59970 K42/2. 6. Upper surface. 7. Lower surface showing the archaeopyle formed by the loss of paraplate 3″. 8. Paratype, Upper Barton Beds, Whitecliff Bay, V59933 Q41/2, lower, apical surface showing the archaeopyle formed by the loss of paraplate 3″. 9. Paratype, Lower Barton Beds, Alum Bay, V59925 V26/0, showing the precingular archaeopyle. 10–11. Paratype, Upper Barton Beds, Whitecliff Bay, V59994 P33/0. 10. Upper surface showing the partial delineation of paraplates. 11. Lower, dorsal surface showing the archaeopyle formed by the loss of paraplates 2″, 3″, and 4″.

Fig. 12. *Chiropteridium aspinatum* (Gerlach) Brosius. Lower Barton Beds, Barton Section, V59891 F27/3, ventral surface.

Figs. 13–14. *Chytroeisphaeridia explanata* Bujak, sp. nov. 13. Holotype, Lower Barton Beds, Alum Bay, V59930 S45/2, showing the apical archaeopyle and sutural notches delineating the anterior sulcal and precingular paraplates. 14. Paratype, Bracklesham Bed equivalents, Barton section, V60012.

Fig. 15. *Cordosphaeridium cantharellum* (Brosius) Gocht. Middle Barton Beds, Whitecliff Bay, V59930 O53/3, showing the precingular archaeopyle formed by the loss of one paraplate, and the occasional distal connection of processes.

Figs. 16–17. *Cordosphaeridium funiculatum* Morgenroth. Middle Barton Beds, Alum Bay, V59951 S12/2. 16. Upper, dorsal surface showing the large precingular archaeopyle formed by the loss of one paraplate. 17. Optical section.



BUJAK *et al.*, Dinoflagellate cysts

Paratypes. V59983 E21/1; V59992 R47/3.

Diagnosis. Chorate cysts with an ovoidal to ellipsoidal central body that is longer than broad. Periphragm smooth to chagrinate. Numerous processes are arranged in process complexes. Process complexes annulate or soleate with four to nine processes on the apical, precingular, postcingular, antapical, posterior intercalary, and posterior sulcal paraplates; additional processes are sometimes present within the complexes. The paracingular process complexes are linear, with two or three processes in each complex. The processes are slender, tubiform and distally open, expanded, and aculeate, the aculei of processes within a complex joining to form a reticulate network reflecting the paraplate shape. Paratabulation 4′, 6″, 6c, 6‴, 1p, 1⁗, 1p.s., with process complexes on all of the paraplates. Archaeopyle epicystal, formed by the detachment of the apical and precingular paraplates.

Dimensions. Central body length = 45–47 μm (4 specimens), breadth = 27–41 μm. Maximum process length = 11–19 μm. Number of specimens measured = 25.

Discussion. *H. fenestratum* is distinguished by having process complexes with distal reticulate networks and an epicystal archaeopyle.

Genus HETERAULACACYSTA Drugg and Loeblich, 1967, emend.

Emended diagnosis. Cyst spherical, ovoidal, or discoidal, approximately circular in polar view. Periphragm forming parasutural crests which delimit a paratabulation of 1pr, 1′*, 3′, 6″, xc, 5–6‴, 1p, 1⁗, 1p.s. The first apical may or may not contact the preapical and second apical paraplates. Periphragm smooth, chagrinate, granulate, perforate, or echinate; never tuberculate. Paracingulum delimited by two parallel crests that are interrupted by the parasulcal furrow. Archaeopyle hemicystal.

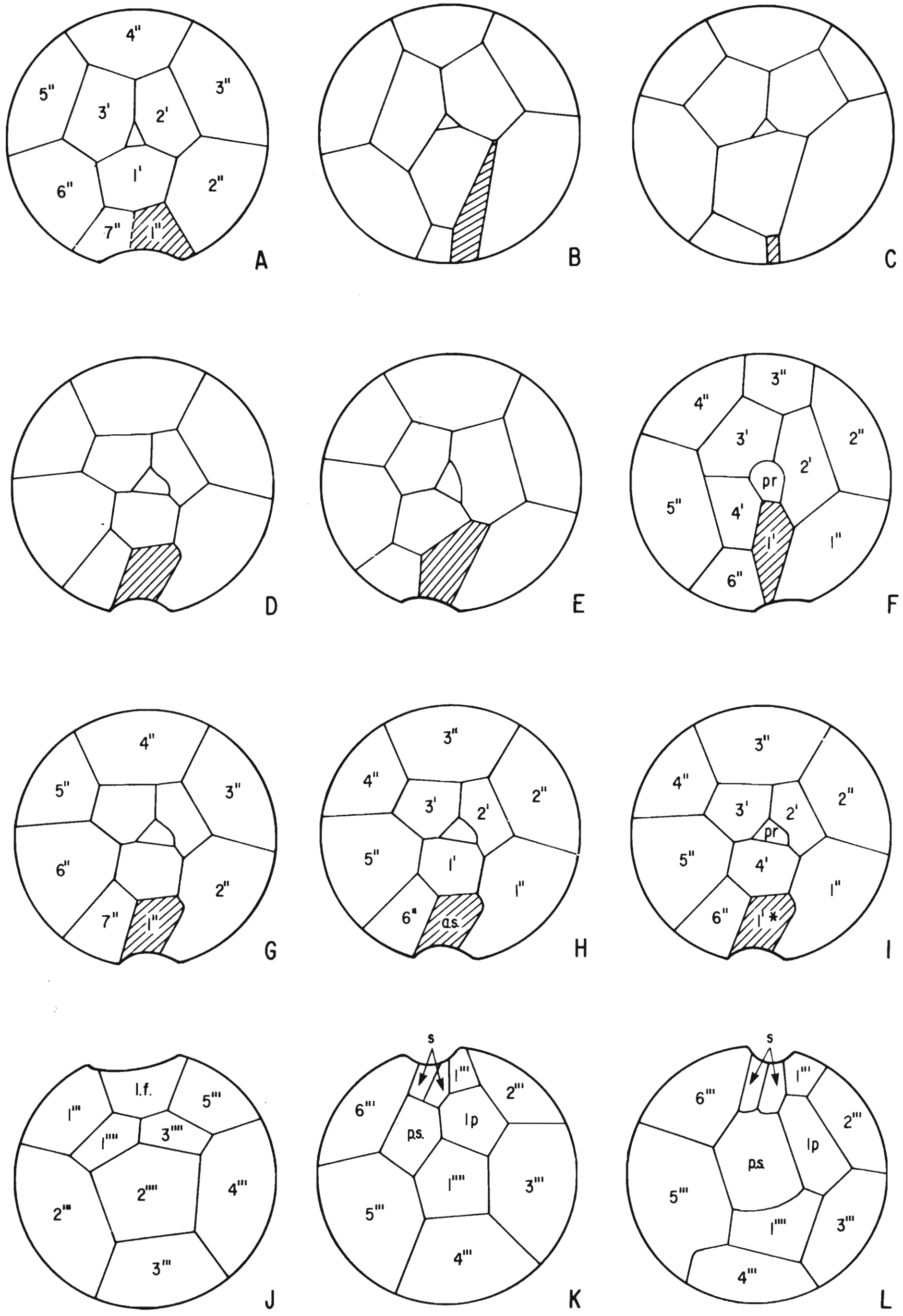
Type species. *Heteraulacacysta campanula* Drugg and Loeblich, 1967.

Discussion. Drugg and Loeblich (1967) interpreted the epicystal paratabulation of *Heteraulacacysta* as 3′, 7″ and designated the shaded paraplate in text-fig. 14A as the first precingular. This paraplate varies in shape and position relative to the other epicystal paraplates in *H. leptalea* Eaton, 1976, and *H. porosa* sp. nov. It can border either one or two of the apical paraplates (text-fig. 14B–E), as in the modern genera *Heteraulacus* Diesing, 1850, and *Pyrodinium* Plate, 1906, respectively. This variation is intraspecific in both *H. leptalea* and *H. porosa*.

Labelling of the shaded (para)plate and designation of the first apical (1′) in text-fig. 14A–E is critical since it determines the numbering of all of the remaining apical and precingular (para)plates. Kofoid (1907) first applied his tabulation scheme to the genus *Ceratium* Schrank, 1793, and later (1909, 1911) extended his notation to *Peridinium* Ehrenberg, 1832, and *Gonyaulax* Diesing, 1866. His definition of the tabulation pattern in *Gonyaulax* is relevant to this discussion since Kofoid distinguished *Heteraulacus* from *Gonyaulax* only by the number of antapical plates present, and did not otherwise discuss the tabulation of *Heteraulacus*. Kofoid (1911, p. 197) defined the first apical plate of *Gonyaulax* (text-fig. 14F) as follows.

> 'The midventral plate (1′) of the apical series is usually a narrow plate extending posteriorly to a junction with the anterior plate of the ventral area, thus parting precingulars 1″ and 6″. . . . It bears at its apex a delicate extension, the closing platelet which covers the apical region.'

TEXT-FIG. 14. Different interpretations of the Kofoidian notation for *Gonyaulax, Heteraulacacysta, Heteraulacus*, and *Pyrodinium*. A, epicystal paratabulation of *Heteraulacacysta campanula* as interpreted by Drugg and Loeblich (1967). B–C, variation in epicystal paratabulation of *Heteraulacacysta leptalea* and *H. porosa*. D–F, epithecal tabulation of *Heteraulacus, Pyrodinium,* and *Gonyaulax* respectively, from Taylor (1976); the Kofoidian notation for *Gonyaulax* is from the present paper. G–I, alternative plate notations discussed in the text for *Heteraulacus*. J, hypocystal paratabulation of *Heteraulacacysta campanula* as interpreted by Drugg and Loeblich (1967). K–L, hypothecal tabulation of *Heteraulacus* and *Gonyaulax* respectively, partly from Taylor (1976). Note the pentagonal antapical plate in *Heteraulacus* and the arcuate antapical plate in *Gonyaulax*.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Examination of the tabulation of *Heteraulacacysta*, *Heteraulacus*, and *Pyrodinium* (text-fig. 14A–E) shows that none of the plates can be designated the first apical using Kofoid's definition, since none extends from the apex to the anterior sulcal plate (a.s.), designation of the shaded plate as the anterior sulcal being incorrect (text-fig. 14H). Kofoid (1911, p. 194) was emphatic in his restriction of the longitudinal furrow 'to that part of the thecal wall in which the flagellum is found extending posteriorly between the two ends of the girdle'. Furthermore, the shaded plate cannot be assigned to the precingular series (text-fig. 14G), since none of the three apical plates could then be designated the first apical, or to the anterior intercalaries, since the shaded plate does not 'lie between the apical and precingular series' (Kofoid 1911, p. 195).

It is thus evident that this plate cannot be assigned to any of the plate series originally defined by Kofoid. In such cases the concept of plate homology facilitates plate numbering. Comparison of the plate patterns in *Heteraulacus*, *Heteraulacacysta*, *Pyrodinium*, and *Gonyaulax* (text-fig. 14B–F) indicates that the shaded plate of the first three genera is the homologue of the first apical of *Gonyaulax*. This plate is thus designated the first apical homologue (1′*) in *Heteraulacus*, *Heteraulacacysta*, and *Pyrodinium*, and the six precingular plates are routinely numbered 1″–6″ (text-fig. 14I). The three remaining apical plates (2′, 3′, 4′) are numbered by comparing their relationship with the precingular plates as seen on *Gonyaulax*; the third precingular (3″) is camerate and contacts apical plates 2′ and 3′, while precingular plates 2″ and 4″ are planate and contact only one apical plate each (2′ and 3′ respectively). This gives a tabulation of 1pr, 1′*, 3′, 6″ (also written as 1pr, 1′*, 2′–4′, 1″–6″) for *Heteraulacus*, *Heteraulacacysta*, and *Pyrodinium*.

Drugg and Loeblich (1967) interpreted the hypocystal paratabulation of *Heteraulacacysta* as 5‴, 3⁗ (text-fig. 14J). Specimens of *H. leptalea* and *H. porosa* sometimes possess a small first postcingular paraplate which is similar in size and position to that of the modern genera *Heteraulacus* and *Gonyaulax* (text-fig. 14K–L). The presence of this paraplate on *Heteraulacacysta* indicates that the postcingular series should be numbered as in text-fig. 14K, with paraplate 4‴ being planate and contacting the first antapical as in *Gonyaulax*. Specimens of *H. leptalea* and *H. porosa* in which one postcingular is absent have paraplates 2‴–6‴ present. The remaining two hypocystal paraplates are designated the posterior sulcal (p.s.) and the posterior intercalary (1p) as in *Gonyaulax*, *Heteraulacus*, and *Pyrodinium* (Taylor 1976).

Heteraulacacysta leptalea Eaton, 1976

1976 *Heteraulacacysta ?leptalea* Eaton, p. 305, pl. 21, figs. 1–2.

Discussion. Eaton (1976) tentatively assigned this species to *Heteraulacacysta* because he was not able to determine the full paratabulation and mode of archaeopyle formation from his material. Specimens from the Barton Beds demonstrate that these features conform with the diagnosis of *Heteraulacacysta* as emended in the present paper.

EXPLANATION OF PLATE 14

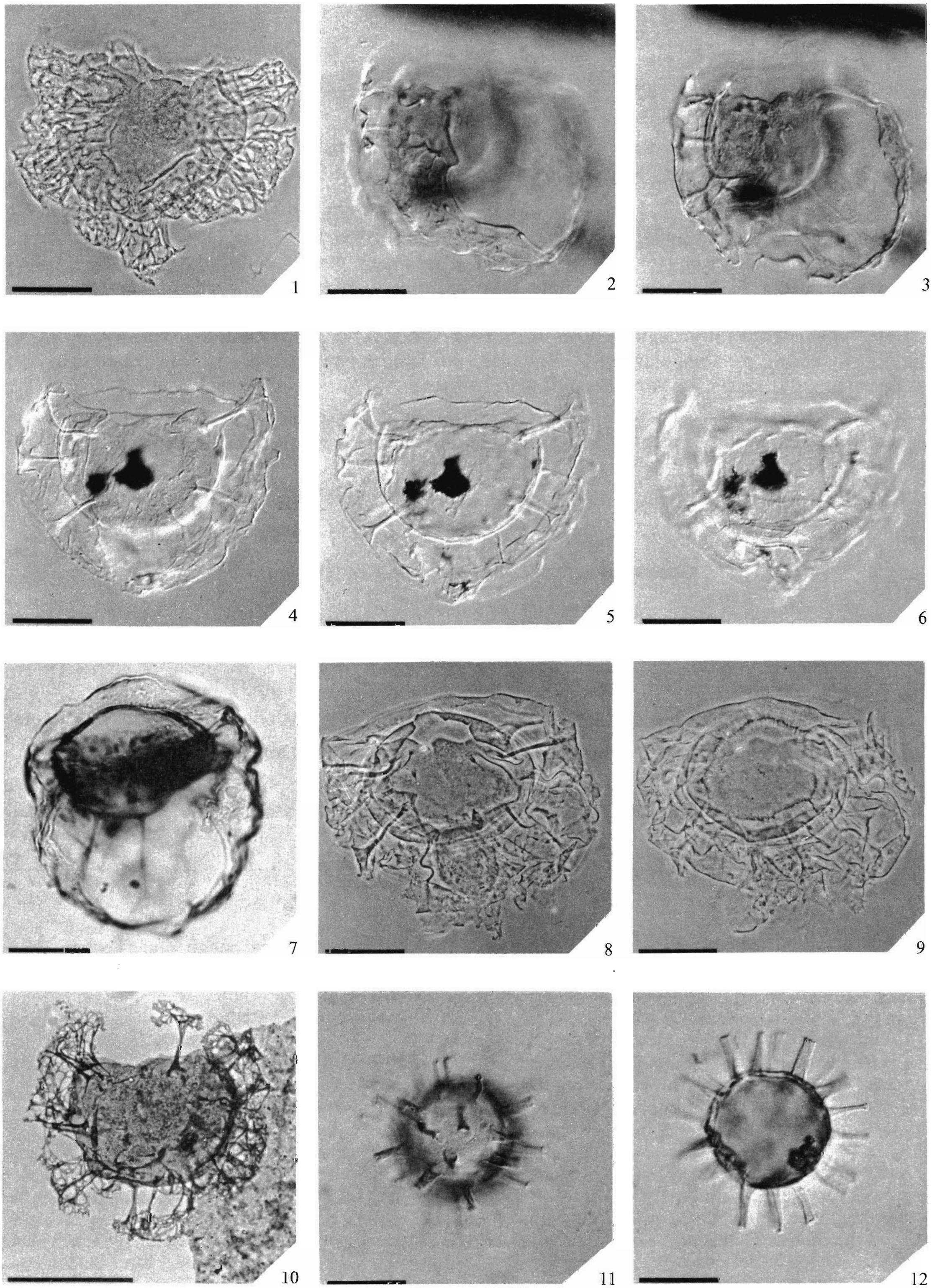
Dinoflagellate cysts from the Barton Beds. Bar on all figures equals 30 μm.

Fig. 1. *Cyclonephelium microfenestratum* Bujak. Holotype, Upper Barton Beds, Whitecliff Bay, V60017, ventral surface.

Figs. 2–9. ?*Cyclonephelium semitectum* Bujak, sp. nov. 2–3. Paratype, Lower Barton Beds, Alum Bay, V59930 S45/2, showing the ventral extremity of the distal process membrane. 4–6. Holotype, Lower Barton Beds, Alum Bay, V60019. 4. Upper, ventral surface showing the extremity of the distal process membrane on the right of the photograph. 5. Showing the anterior extremity of the membrane on the dorsal surface of the cyst. 6. Showing the circum-middorsal zone of contact of the membrane with the central body. 7. Paratype, Middle Barton Beds, Alum Bay, V59936 O37/1, showing the ventral extremity of the distal process membrane. 8–9. Paratype, Lower Barton Beds, Alum Bay, V60018. 8. Ventral surface. 9. Dorsal surface showing the circum-middorsal zone of contact of the membrane with the central body.

Fig. 10. *Cyclonephelium textum* Bujak. Paratype, Middle Barton Beds, Whitecliff Bay, V59974 P44/4.

Figs. 11–12. *Dapsilidinium simplex* (White) comb. nov. Lower Barton Beds, Alum Bay, V59930 R26/3.



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Heteraulacacysta porosa Bujak, sp. nov.

Plate 15, figs. 10–13; text-fig. 14B–C

Derivation of name. Latin, *porosus*, full of holes, with reference to the periphragm.

Holotype. V59888 S23/0. Lower Barton Beds, Barton, Hampshire, England. Late Eocene.

Paratypes. V59885 O27/4, T21/4, X48/1; V59887 T25/0; V59888 L42/0; V59889 U41/0; V59930 L34/1; V60013.

Diagnosis. Cyst discoidal with polar compression, approximately circular in polar view. Periphragm forming parasutural crests which delimit a paratabulation of 1pr, 1′*, 3′, 6″, xc, 5?‴–6‴, 1p, 1⁗, p.s. The first apical homologue (1′*) does not touch the preapical. It may contact 2′, 4′ and 1″ or only 4′ and 1″. The first postcingular paraplate may be absent. Paracingulum defined by two broad membranous crests. The periphragm, including the paracingular crests, is perforate over its entire surface. The perforations are uniform over the central body, but are arranged in concentric rings on the distally entire, paracingular crests. Radiating striae occur near the junction of the central body and paracingular crests. The archaeopyle is hemicystal.

Dimensions. Over-all diameter in polar view = 66×75 μm to 100×110 μm. Central body diameter in polar view = 50×52 μm to 70×80 μm. Maximum height of paracingular crests = 15–23 μm. Number of specimens measured = 18.

Discussion. H. porosa is distinguished from all other described species of *Heteraulacacysta* by its perforate periphragm.

Genus HOMOTRYBLIUM Davey and Williams, 1966

Homotryblium caliculum Bujak, sp. nov.

Plate 16, fig. 1

Derivation of name. Latin, *caliculus*, chalice, with reference to the process shape.

Holotype. V59983 O20/0. Middle Barton Beds, Whitecliff Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V59903 F15/2; V59907 G26/4, N37/3; V59986 P35/2; V59994 M26/4.

Diagnosis. Chorate cysts with a subspherical to ovoidal central body. Periphragm smooth to chagrinate, forming intratabular processes, one per paraplate. Processes caliculate and open distally

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EXPLANATION OF PLATE 15

Dinoflagellate cysts from the Barton Beds. Bar on figures 1–3, 5–13 equals 30 μm; bar on figure 4 equals 10 μm.

Fig. 1. *Deflandrea* cf. *D. heterophlycta* Deflandre and Cookson *sensu* Gocht, 1969, Lower Barton Beds, Alum Bay, V60020.

Figs. 2–3. *Deflandrea spinulosa* Alberti. 2. Lower Barton Beds, Alum Bay, V60023. 3. Lower Barton Beds, Barton section, V60024.

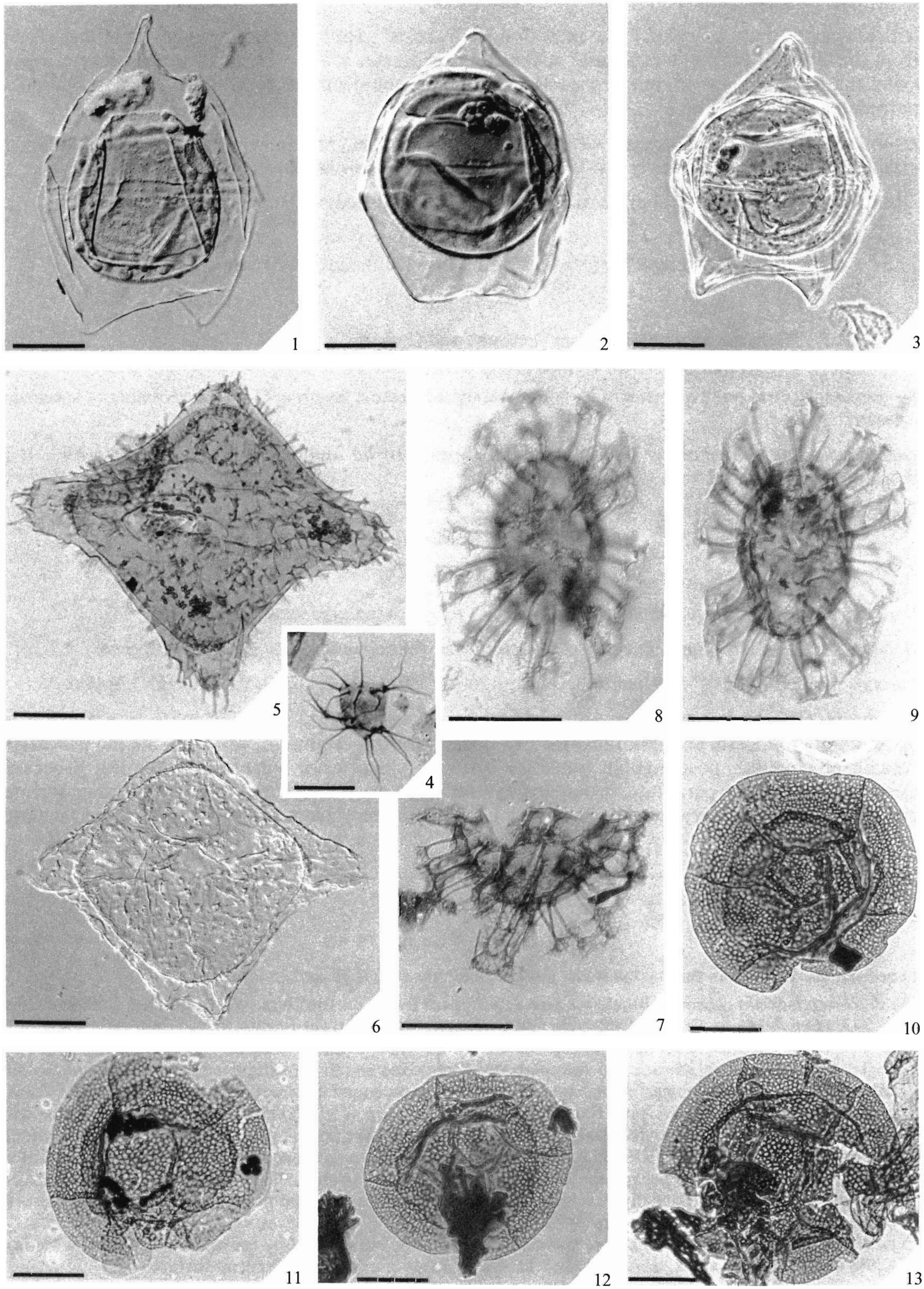
Fig. 4. *Diacrocanthidium echinulatum* (Deflandre) Loeblich and Loeblich, Middle Barton Beds, Whitecliff Bay, V59975 R26/4. Specimen with apex removed.

Fig. 5. *Gochtodinium simplex* Bujak. Holotype, Upper Barton Beds, Whitecliff Bay, V60004.

Fig. 6. *Gochtodinium spinulum* Bujak. Holotype, Upper Barton Beds, Alum Bay, V60008.

Figs. 7–9. *Hemisphaeridium fenestratum* Bujak, gen. nov., sp. nov. 7. Holotype, Upper Barton Beds, Whitecliff Bay, V59994 O30/2, showing the epicystal archaeopyle and fenestrate networks distally connecting paraplate process complexes. 8–9. Paratype, Middle Barton Beds, Whitecliff Bay, V59983 E21/1. 8. Upper surface showing the fenestrate distal process platforms. 9. Optical section.

Figs. 10–13. *Heteraulacacysta porosa* Bujak, sp. nov. 10. Holotype, Lower Barton Beds, Barton section, V59888 S23/0. 11. Paratype, Lower Barton Beds, Barton section, V59885 X48/1. 12. Paratype, Lower Barton Beds, Barton section, V59888 L42/0. 13. Paratype, Lower Barton Beds, Barton section, V59887 T25/0.



BUJAK *et al.*, Dinoflagellate cysts

with entire or serrate margins. Paratabulation 4′, 6″, xc, 6‴, 1p, 1⁗, p.s. Processes sometimes absent from the cingular paraplates. Slender adventitious processes are occasionally present. Archaeopyle epicystal; archaeopyle margin characterized by an anterior sulcal projection. All opercular paraplates are detached.

Dimensions. Central body diameter = 31 × 36 μm to 42 × 48 μm. Maximum process length = 10–15 μm, maximum process breadth distally = 9–15 μm. Number of specimens measured = 18.

Discussion. H. caliculum is characterized by its caliculate processes.

Homotryblium floripes (Deflandre and Cookson, 1955) Stover, 1975

Plate 16, figs. 2–3

1955 *Hystrichosphaeridium floripes* Deflandre and Cookson, p. 276, pl. 7, figs. 1–2, 7.
1967 *Homotryblium plectilum* Drugg and Loeblich, p. 184, pl. 2, figs. 1–9, text-fig. 3.

Dimensions. Central body diameter = 33–60μm. Maximum process length = 15–27 μm. Number of specimens measured = 30.

Discussion. The morphology of *H. plectilum* appears to be identical to that of *H. floripes*. It is therefore synonymized with the latter species.

Homotryblium variabile Bujak, sp. nov.

Plate 16, figs. 4–9

Derivation of name. Latin, *variabilis*, changeable, with reference to the process number.

Holotype. V59908 B8/1. Upper Barton Beds, Barton, Hampshire, southern England. Late Eocene.

Paratypes. V59910 T32/0; V59915 K19/0, O20/1, R26/1; V59983 L35/2, O27/3; V59986 O53/3, R41/0.

Diagnosis. Chorate cysts with a subspherical to ovoidal central body, a coarsely granulate or occasionally reticulate endophragm and a thinner, smooth periphragm which forms the processes. Apical, precingular, postcingular, posterior intercalary, posterior sulcal and antapical processes intratabular, one per paraplate, broad and cylindrical, tapering or flared, distally entire or serrate, and either closed or with a restricted opening. Cingular processes mostly slender, sometimes taeniate.

EXPLANATION OF PLATE 16

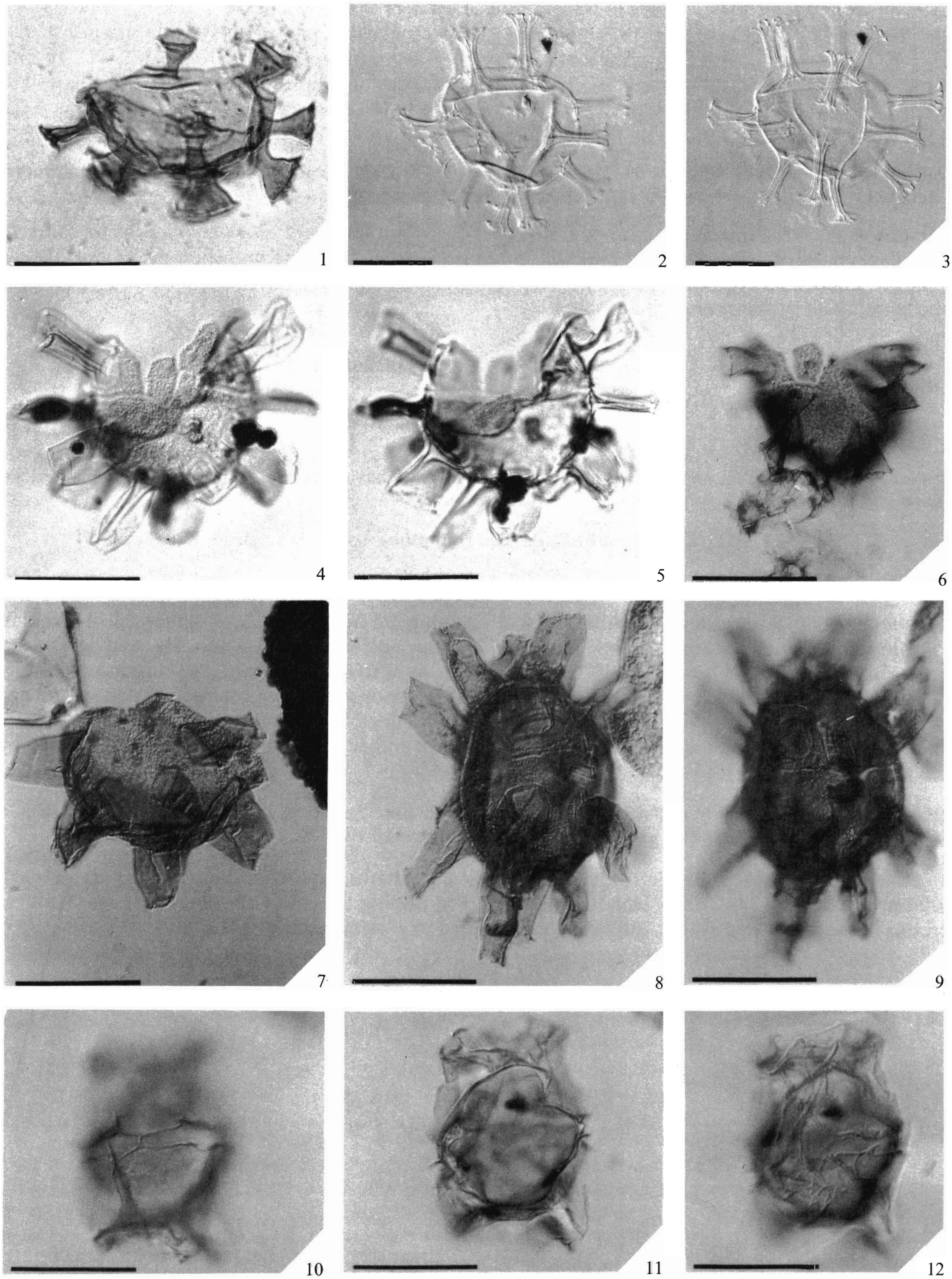
Dinoflagellate cysts from the Barton Beds. Bar on all figures equals 30 μm.

Fig. 1. *Homotryblium caliculum* Bujak, sp. nov. Holotype, Middle Barton Beds, Whitecliff Bay, V59983 O20/0.

Figs. 2–3. *Homotryblium floripes* (Deflandre and Cookson) Stover. Lower Barton Beds, Alum Bay, V60021.

Figs. 4–9. *Homotryblium variabile* Bujak, sp. nov. 4–5. Holotype, Upper Barton Beds, Barton section, V59908 B8/1. 4. Upper, ventral surface with paraplates 2′–4′ removed and the precingular and first apical paraplates adhering to the cyst. 5. Lower, dorsal surface with all the precingular paraplates adhering and some folded inside the cyst. 6. Paratype, Upper Barton Beds, Barton section, V59915 O20/1, upper, ventral surface with paraplates 1′–4′ and 3″ removed. Paraplates 1″–2″ and 4″–6″ are adhering to the cyst. 7. Paratype, Middle Barton Beds, Whitecliff Bay, V59983 L35/2, upper, ventral surface, archaeopyle formed by the removal of all the apical and precingular paraplates. 8–9. Paratype, Middle Barton Beds, Whitecliff Bay, V59983 O27/3, complete specimen with partially developed sutures between the epicystal paraplates. Note the variation in cingular process development in figs. 4–9.

Figs. 10–12. ?*Hystrichosphaeropsis rectangularis* Bujak, sp. nov. Holotype, Lower Barton Beds, Barton section, V59891 G40/4. 10. Lower, dorsal surface. 11. Optical section. 12. Upper, ventral surface.



BUJAK *et al.*, Dinoflagellate cysts

Small acuminate spines are often present on the cingular and sulcal paraplates. Paratabulation 4′, 6″, 6c, 6‴, 1p, 1⁗, p.s., with processes sometimes absent from paraplates 1′, 3″, 6″, 3‴, 6‴, 1p and some or all of the cingular paraplates. The shapes and relationships of the epicystal paraplates are consistent with those of *Homotryblium*, as illustrated by Evitt (1967, pl. 9, figs. 7–14, as Forma AC). Archaeopyle epicystal, formed by the detachment of paraplates 1′–4′ and 1″–6″.

Dimensions. Central body length = 39–55 μm, breadth = 35–50 μm, thickness = 24–26 μm. Maximum process length = 11–24 μm, breadth = 9–20 μm. Number of specimens measured = 45.

Discussion. *H. variabile* is distinguished from other described species of *Homotryblium* by its coarsely granulate endophragm and predominantly broad processes of distinct morphology. *H. variabile* is also characterized by the variation in process distribution on paraplates 1′, 3″, 6″, 3‴, 6‴, 1p, p.s., and some or all of the cingular paraplates.

Genus HYSTRICHOSPHAEROPSIS Deflandre, 1935

?*Hystrichosphaeropsis rectangularis* Bujak, sp. nov.

Plate 16, figs. 10–12; text-fig. 15

Derivation of name. Latin, *rectus*, straight, and Latin *angularis*, having angles, with reference to the pericyst shape.

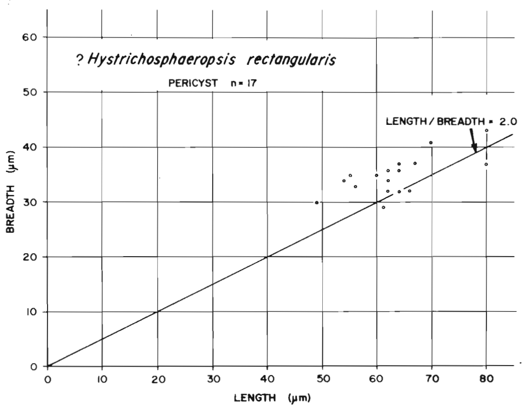
Holotype. V59891 G40/4. Lower Barton Beds, Barton, Hampshire, southern England. Late Eocene.

Paratype. V59961 M20/2.

Diagnosis. Pericyst rectangular, without apical or antapical horns. Endocyst spherical to ovoidal. Periphragm forming sutural crests that are highest apically and antapically and delimit a paratabulation of ?4′, 6″, 6c, ?6‴, 1⁗. Endophragm smooth to chagrinate. Pericingulum strongly helicoid, delimited by low crests with short simple bifurcate or trifurcate processes. Processes are not present elsewhere on the pericyst. A long perisulcus is defined by low crests and is slightly arcuate. Individual sulcal paraplates have not been observed. The archaeopyle is precingular, being formed by the loss of paraplate 3″.

Dimensions. Pericyst length = 49–80 μm, breadth = 26–42 μm. Endocyst length = 30–46 μm, breadth = 26–42 μm. Process length up to 6 μm. Number of specimens measured = 20.

Discussion. It was not possible to determine optically whether apical and antapical pericoels are present in ?*H. rectangularis*. A wall was not observed uniting the distal margins of the parasutural crests. ?*H. rectangularis* is thus questionably assigned to *Hystrichosphaeropsis*.



TEXT-FIG. 15. Pericyst length and breadth of ?*Hystrichosphaeropsis rectangularis* Bujak, sp. nov. from the Barton Beds.

Genus KISSELOVIA Vozzhennikova, 1963

Kisselovia variabilis Bujak, sp. nov.

Plate 17, figs. 1–6; text-fig. 16

Derivation of name. Latin, *variabilis*, changeable, with reference to the distal process ornament.

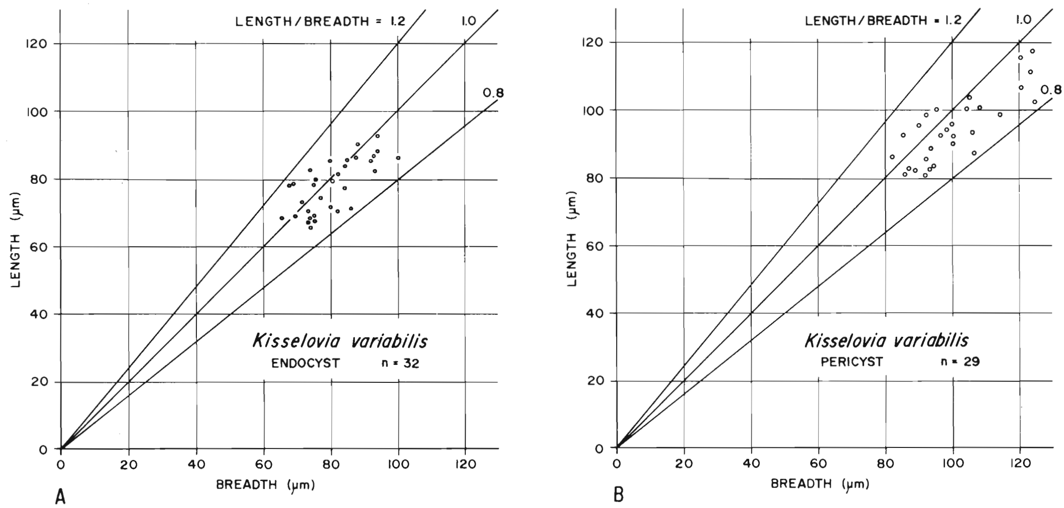
Holotype. V60001. Lower Barton Beds, Barton, Hampshire, southern England. Late Eocene.

Paratypes. V60002; V60003; V60009.

Diagnosis. Pericyst ambitus rhomboidal. Epicyst commonly shorter than the hypocyst. Apical horn indistinct, poorly developed, sometimes with a distal tubercle. Pericingular horns poorly to well developed, causing fluctuations in length : breadth ratio of 1:0·8 to 1:1·1. Antapex prolonged into a small left horn, the right being absent or reduced to a slight swelling of the pericyst. Endocyst ambitus circular, oval, or rounded rhomboidal with a length : breadth ratio of 1:0·8 to 1:1·2. Cornucavate pericoels are connected by a narrow ambital pericoel. The processes are arranged in simulate complexes and within the complexes are united distally by a trabeculate network of variable interconnection and complexity. The networks may be single trabeculae between processes of a simulate complex or a complexly interconnected network of trabeculae uniting all the processes of a paraplate. All morphological intergradations may be present on individual specimens. Endophragm surface smooth, may be granulate near the horns. Process complexes reflect a paratabulation of 4′, 3a, 7″, xc, 5‴, 2⁗, xs, with paraplate 4″ being extremely broad relative to 2a. Pericingulum and perisulcus delineated by process complexes. Periarchaeopyle quadra intercalary, formed by the detachment of paraplate 2a. Perioperculum free. Endoarchaeopyle adjacent to the periarchaeopyle and of the same size and shape. Endoperculum detached.

Dimensions. Pericyst length = 80–117 μm, breadth = 82–124 μm. Endocyst length = 65–92 μm, breadth = 66–100 μm. Process length up to 10 μm. Number of specimens = 39.

Discussion. *K. variabilis* differs from *K. tenuivirgula* (Williams and Downie, 1966*a*) Lentin and Williams, 1976, and *Kisselovia reticulata* (Williams and Downie, 1966*a*) Lentin and Williams, 1976, in possessing shorter horns and a variable distal process ornament that is not as complex as that of *K. reticulata*, but is more complex than that of *K. tenuivirgula*.



TEXT-FIG. 16. Dimensions of *Kisselovia variabilis* Bujak, sp. nov. from the Barton Beds. A, endocyst dimensions. B, pericyst dimensions.

Genus LEJEUNIA Gerlach, 1961, emend. Bujak

Emended diagnosis. Autocyst peridinioid with dorsoventral compression and a pentagonal ambitus. The epicyst and hypocyst lengths are approximately equal. The apex is rounded or prolonged into a small distinct boss. The antapex has two approximately equal, symmetrically located horns which are small, pointed, and solid. Autophragm laevigate to chagrinate. Paratabulation is only indicated near the archaeopyle and paracingulum. A planar or very slightly helicoidal paracingulum is delimited by two folds and a shallow indentation. The folds are distally entire and may be continuous or partite. When partite, the paracingulum is separated into seven anterior and five posterior divisions. The parasulcus is marked by a shallow depression. The archaeopyle is intercalary 2a and is symmetrically located on the middorsal line. It extends almost to the paracingulum. The operculum is free or remains attached along the posterior margin. Transverse archaeopyle index = 0·34–0·51, longitudinal archaeopyle index = 0·59–0·63, archaeopyle ratio = 0·72–0·94.

Type species. Lejeunia hyalina Gerlach, 1961.

Discussion. The genus *Lejeunia* differs from *Selenopemphix* Benedek, 1972, in having an intercalary archaeopyle that is symmetrically located on the middorsal line.

Lejeunia cinctoria Bujak, sp. nov.

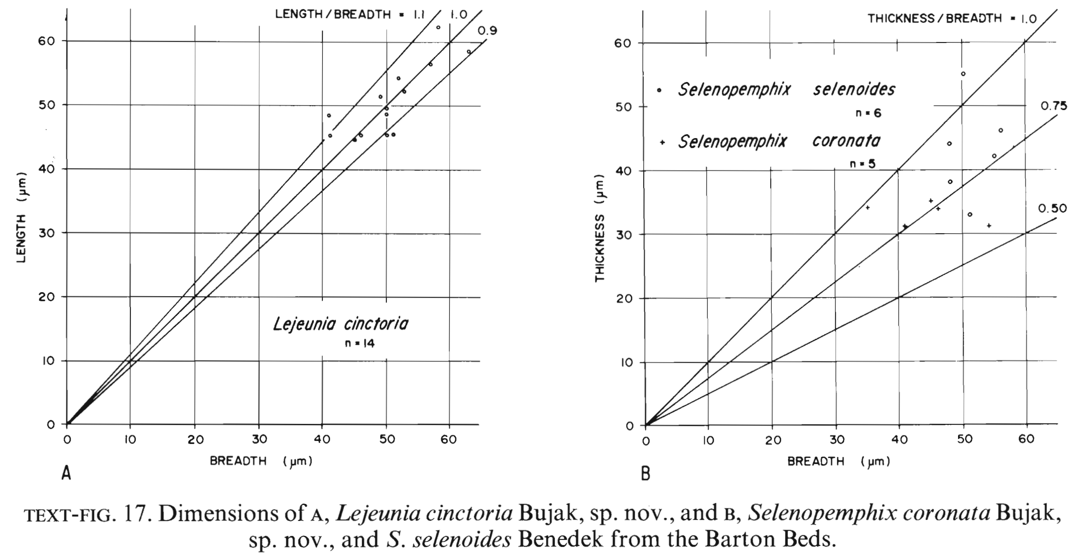
Plate 18, figs. 1–4; text-fig. 17

Derivation of name. Latin, *cinctorium*, sword-belt, with reference to the ornament.

Holotype. V59983 C35/0. Middle Barton Beds, Whitecliff Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V59983 O46/2; V59978 G50/4.

Diagnosis. Autocyst peridinioid with dorsoventral compression and a pentagonal ambitus. The epicyst and hypocyst lengths are approximately equal. The apex is rounded, truncated, or has a small distinct boss. Two approximately equal, symmetrically located antapical horns are present or absent. When present, the horns are pointed and solid. Autophragm laevigate to chagrinate. Spines are always present on the paracingular margins. They may also be present at the apex, ambital periphery,



TEXT-FIG. 17. Dimensions of A, *Lejeunia cinctoria* Bujak, sp. nov., and B, *Selenopemphix coronata* Bujak, sp. nov., and *S. selenoides* Benedek from the Barton Beds.

and often form a curved row between the antapical horns. The spines are solid, short, proximally expanded, simple or bifid, and often vary in size and shape on a single specimen. Paratabulation is only indicated near the archaeopyle and paracingulum. The planar or slightly helicoidal paracingulum is delimited by two folds and a shallow indentation. The folds are distally spinate and may be continuous or partite. When partite, the paracingulum is separated into seven anterior and five posterior divisions. The parasulcus is marked by a shallow depression. The archaeopyle is intercalary 2a and is symmetrically located on the middorsal line. It extends almost to the paracingulum. The operculum is free or remains attached along the posterior margin. Transverse archaeopyle index = 0·37–0·42, longitudinal archaeopyle index = 0·68–0·78, archaeopyle ratio = 0·9–1·2.

Dimensions. Autocyst length = 44–62 μm, breadth = 41–63 μm, maximum spine length = 3–4 μm. Number of specimens measured = 14.

Discussion. L. cinctoria differs from *L. paratenella* Benedek, 1972, in having spines on both the anterior and posterior paracingular margins.

Genus LENTINIA Bujak, gen. nov.

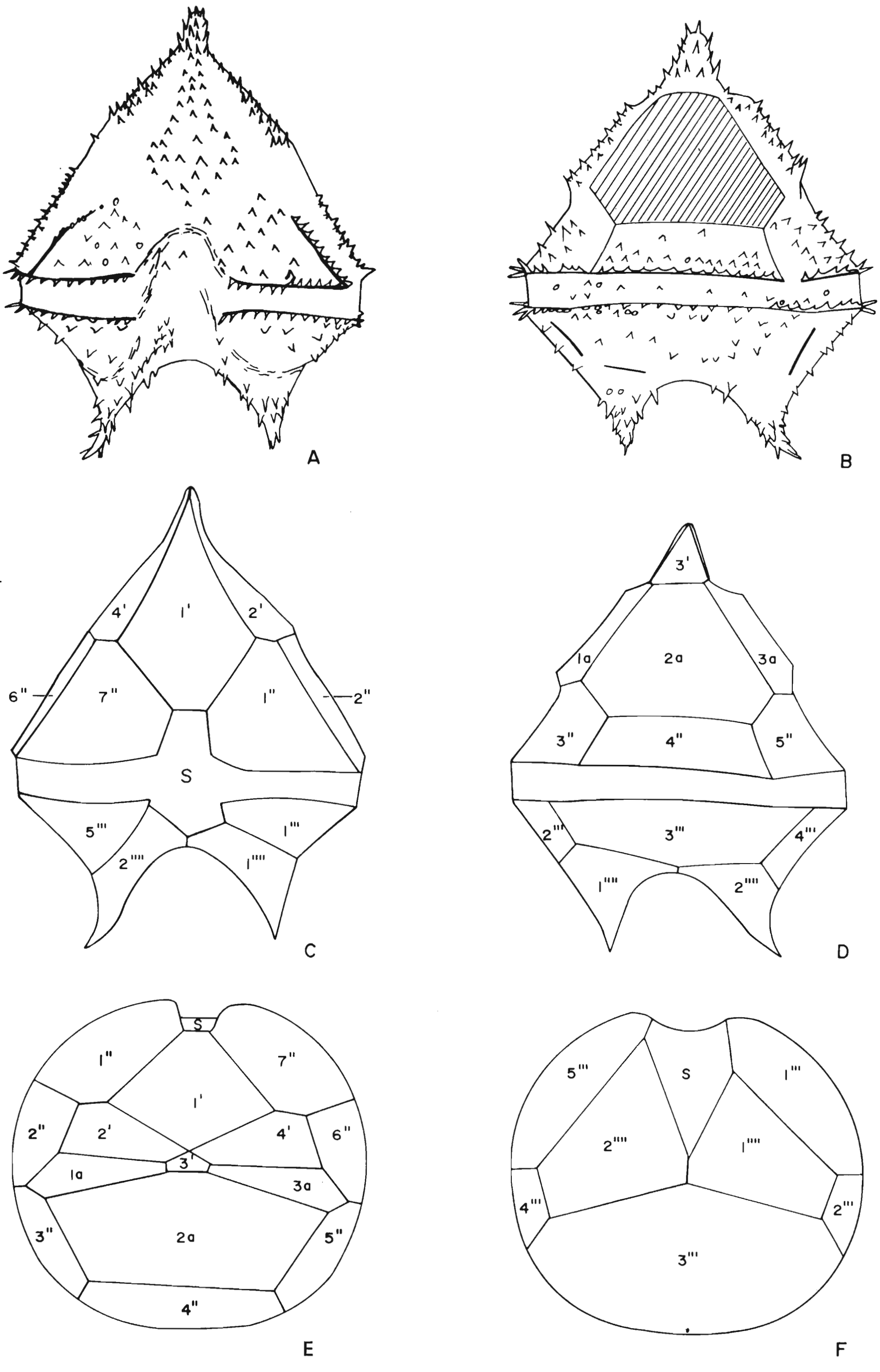
Derivation of name. Named for Dr. J. K. Lentin.

Diagnosis. Pericyst ambitus peridinioid, prolonged into one apical and two, more or less equal, symmetrically located antapical horns. Endocyst ambitus ovoidal to peridinioid, usually in contact with the pericyst in the precingular, cingular, and postcingular regions. Pericoels may be present or absent, but when present are cornucavate. Periphragm laevigate, chagrinate, granulate, denticulate, or rugulate; always denticulate along the paracingular margins. Endophragm laevigate or scabrate, never verrucate or tuberculate. Penitabular denticles or parasutural crests denote a paratabulation of 4′, 3a, 7″, 5‴, 2⁗. Paraplate 1′ is pentagonal and elongated anterio-posteriorly, 2′ and 4′ are narrower and shorter. Paraplate 3′ is considerably shorter than the other apicals. Anterior intercalary paraplate 2a is hexagonal, occupies much of the dorsal epipericyst, and is broader than paraplate 4″. Paraplates 1a and 3a are considerably narrower than 2a. All the precingular paraplates are pentagonal except for 4″ which is four-sided, broad, and short. Paraplate 3‴ is the largest postcingular and is pentagonal, with the remaining postcingulars being four-sided. The antapical paraplates 1⁗ and 2⁗ are of approximately equal size and shape. A pericingulum is always present and is commonly indented. It is planar or very slightly helicoidal. The pericingular margins are always marked by denticulate crests. The perisulcus is indented with margins that may be delimited by crests or rows of denticles. Paratabulation has not been observed on the endocyst. The periarchaeopyle is broad hexa intercalary, resulting from the loss or displacement of paraplate 2a. Transverse archaeopyle index = 0·8, longitudinal archaeopyle index = 0·5, archaeopyle ratio = 0·7 (measurements based on type species only). The endoarchaeopyle underlies the periarchaeopyle. Archaeopyle formula = I/I (2a/2a).

Type species. Lentinia serrata sp. nov. Late Eocene.

Discussion. The genus *Lentinia* differs from *Deflandrea* Eisenack, 1938, in possessing the following combination of features:

1. Pericoels absent or restricted to horns, may be rarely present around an extremely narrow peripheral ambital zone.
2. Ornament on endophragm lacking; scabrate at most, usually laevigate.
3. Ornament on periphragm always includes denticles although these may be restricted to the paracingular margins.
4. The periarchaeopyle occupies most of the dorsal epipericyst, resulting in paraplates 3′ and 4″ being of greatly reduced length, and paraplates 1a and 3a being of greatly reduced breadth.
5. The endoarchaeopyle is adjacent to the periarchaeopyle and has the same size and shape.



TEXT-FIG. 18. Morphology and paratabulation of the holotype of *Lentinia serrata* Bujak, gen. nov., sp. nov. A, ventral view; B, dorsal view; C–F, inferred tabulation; C, ventral; D, dorsal; E, apical; F, antapical.

Lentinia serrata Bujak, sp. nov.

Plate 18, figs. 7–12; text-figs. 18–19

Derivation of name. Latin, *serratus*, with reference to the ornament.

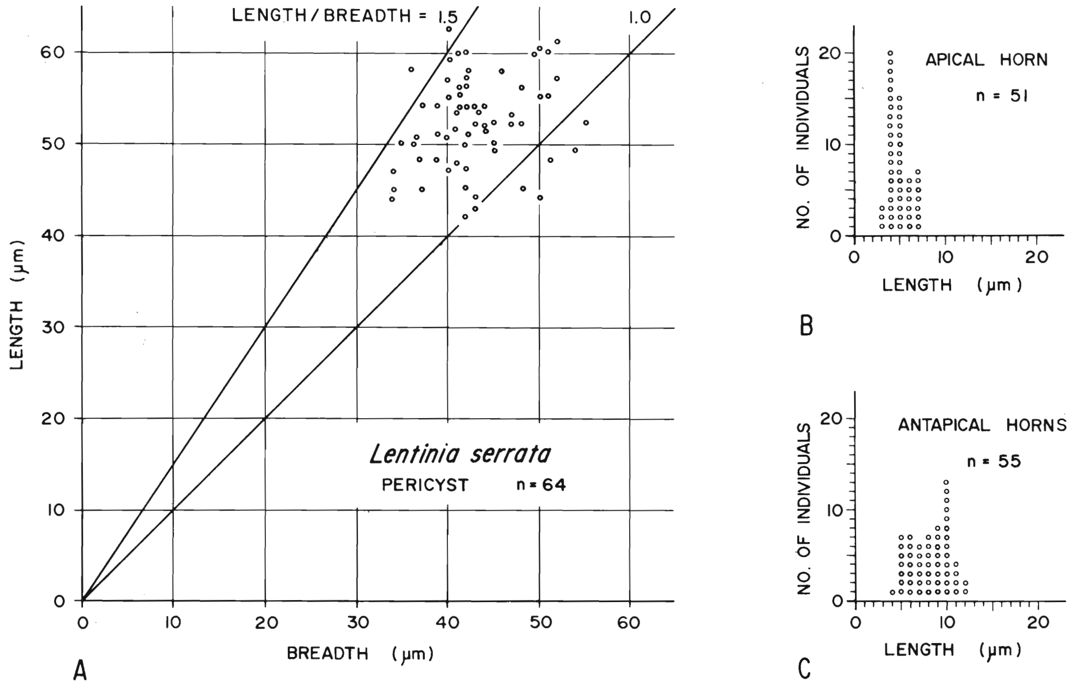
Holotype. V59907 J27/1. Upper Barton Beds, Barton, Hampshire, southern England. Late Eocene.

Paratypes. V59885 F31/2; V59891 O8/2; V59892 P27/0; V59901 N4/1; V59907 N4/1; V59938 T37/0; V59983 P44/2.

Diagnosis. Pericyst peridinioid. Apical horn smaller than the antapical horns, but distinct from the remaining epipericyst. Right antapical horn often slightly smaller than the left. Endocyst rounded peridinioid. Pericoels cornucavate when present. Periphragm laevigate to chagrinate, always denticulate along the pericingular margins, variably denticulate elsewhere on the periphragm surface and strongly denticulate on the horns. A peritabulation of 4′, 3a, 7″, 5‴, 2⁗ may be delimited by the denticles. Pericingulum planar or slightly helicoidal. Perisulcus marked by an indentation that is broad on the hypocyst, narrowing anteriorly on the epicyst. Periarchaeopyle broad hexa intercalary, resulting from the loss of paraplate 2a. Transverse archaeopyle index = 0·8. Longitudinal archaeopyle index = 0·5. Archaeopyle ratio = 0·7. The endoarchaeopyle is adjacent to the periarchaeopyle and has the same size and shape.

Dimensions. Pericyst length = 42–63 μm, breadth = 32–55 μm, thickness = 24–35 μm. Apical horn length = 3–7 μm, antapical horn length = 4–12 μm. Length of denticles up to 2 μm. Number of specimens measured = 63 in side view, 23 in polar view.

Discussion. *L. serrata* differs from *L. wetzelii* in pericyst shape. The pericyst of *L. serrata* is broadest at the pericingulum, so that the pericyst ambitus tapers strongly from the pericingulum to the apical and antapical horns. In *L. wetzelii* the pericyst has similar breadth in the precingular, cingular, and



TEXT-FIG. 19. Dimensions of *Lentinia serrata* Bujak, gen. nov., sp. nov. from the Barton Beds.

postcingular regions. Pericoel development also differs in the two species, being greater in *L. wetzelii* than in *L. serrata*. This is particularly noticeable beneath the apical horn, as *L. serrata* usually has no apical pericoel.

Lentinia wetzelii (Morgenroth, 1966*a*) Bujak, comb. nov.

1966*a* *Deflandrea wetzelii* Morgenroth, p. 9, pl. 1, figs. 4–5. Early Eocene.

Discussion. This species is herein transferred to *Lentinia* because of the nature of the archaeopyle, periphragm ornament, and cornucavate pericoels. *L. wetzelii* was not observed in the Barton Beds.

Genus LEPTODINIUM Klement, 1960

Leptodinium incompositum (Drugg, 1970) Lentin and Williams, 1973

Plate 19, figs. 1–2

1970 *Gonyaulacysta incomposita* Drugg, pp. 810–811, figs. 1E–O, 2A.
1973 *Leptodinium incompositum* (Drugg) Lentin and Williams, p. 87.

Dimensions. Pericyst length = 27–32 μm, breadth = 23–31 μm. Number of specimens measured = 6.

Genus PHTHANOPERIDINIUM Drugg and Loeblich, 1967

Phthanoperidinium comatum (Morgenroth, 1966*b*) Eisenack and Kjellström, 1971

Plate 19, figs. 5–6; text-figs. 20B, 21

1966*b* *Peridinium comatum* Morgenroth, p. 1, pl. 1, figs. 1–2.
1971 *Phthanoperidinium comatum* (Morgenroth) Eisenack and Kjellström, p. 907.
1976 *Phthanoperidinium tritonium* Eaton, p. 299, pl. 17, figs. 2–3, 6–7, text-figs. 23C, 24.

Dimensions. Pericyst length (without spines) = 27–57 μm, breadth = 25–46 μm. Maximum spine length = 7–16 μm. Number of specimens measured = 25.

Discussion. *P. tritonium* Eaton, 1976, is placed in synonymy with *P. comatum*. Eaton (1976, p. 300) distinguished the two species by the consistently longer spines on *P. comatum*. Specimens from the Barton Beds possess spines whose lengths overlap that of both species.

Phthanoperidinium geminatum Bujak, sp. nov.

Plate 19, figs. 8–12; text-figs. 20D, 22A

Derivation of name. Latin, *geminatus*, double, with reference to the two zones of ornament.

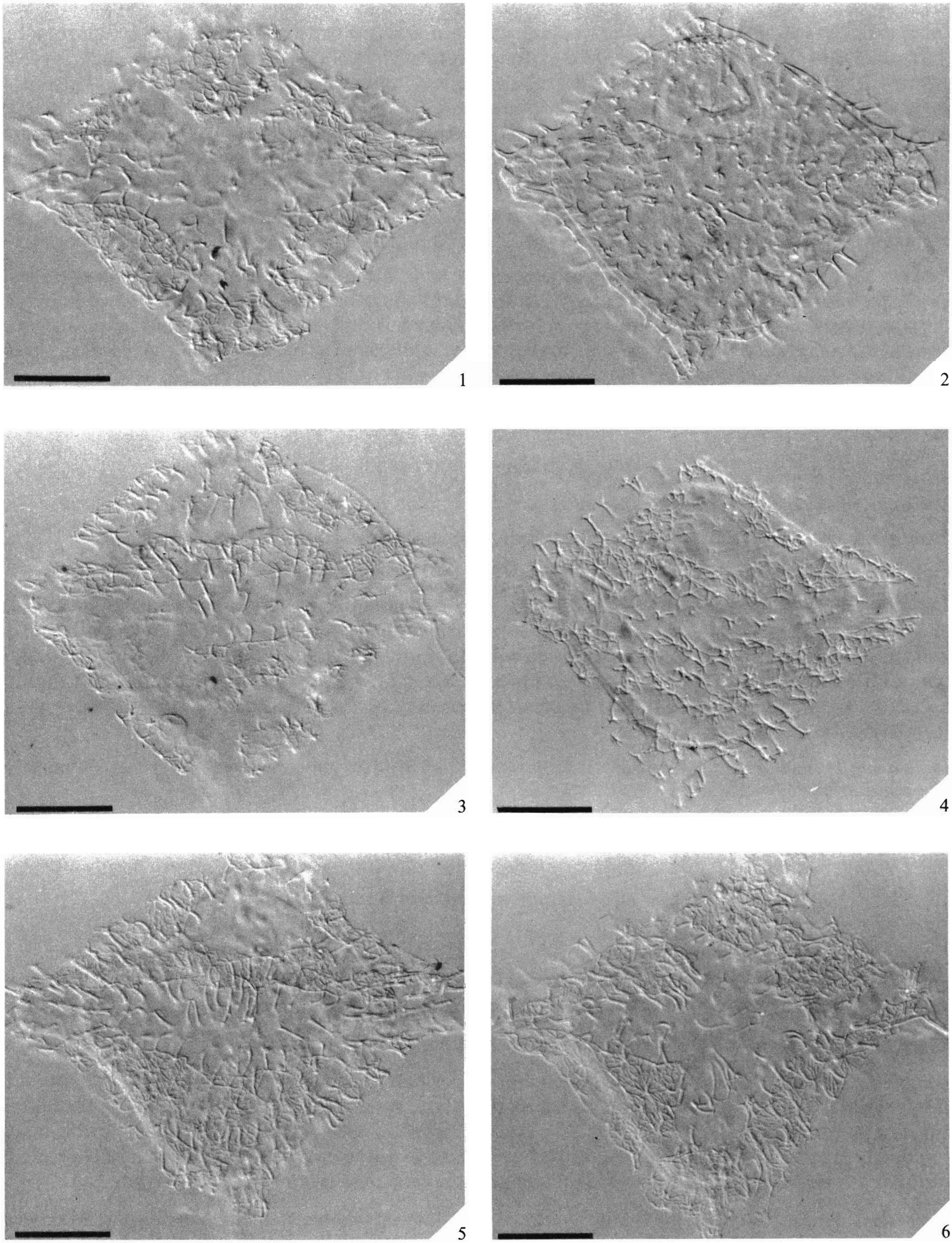
Holotype. V59946 T36/2. Middle Barton Beds, Alum Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V59883 S26/0; V59885 T12/0; V59994 R36/4.

EXPLANATION OF PLATE 17

Dinoflagellate cysts from the Barton Beds. Bar on all figures equals 30 μm.

Figs. 1–6. *Kisselovia variabilis* Bujak, sp. nov. 1–3. Holotype, Bracklesham Bed equivalents, Barton section, V60001. 1. Ventral surface. 2. Optical section showing the poorly developed apical and antapical horns. 3. Dorsal surface. 4. Paratype, Bracklesham Bed equivalents, Barton section, V60002, dorsal surface showing the irregularly developed distal process ornament. 5–6. Paratype, Bracklesham Bed equivalents, Barton section, V60009. 5. Dorsal surface. 6. Ventral surface, showing the well-developed distal process platforms.



BUJAK *et al.*, Dinoflagellate cysts

Diagnosis. Pericyst ovoidal with one small apical horn and one or two unequal antapical horns, the right always being strongly reduced. An endocyst is rarely visible. The periphragm is chagrinate to granulate with parasutural rows of granules, short spines, or low crests. These delimit a paratabulation of 4′, 3a, 7″, xc, 5‴, 2⁗. Simulate rows or zones of similar ornament are always present and lie 1 μm to 3 μm inside the parasutures, except for those bordering the paracingulum on the precingular and postcingular paraplates. These typically merge with the cingular parasutures. An archaeopyle is formed by the loss of paraplate 2a.

Dimensions. Pericyst length = 32–60 μm, breadth = 30–46 μm. Maximum ornament height = 1–4 μm. Number of specimens measured = 25.

Discussion. Species of *Phthanoperidinium* often have simulate zones of ornament (usually granules). On *P. geminatum* these are more strongly developed than in other species and often exceed in height the parasutural ornament. *P. geminatum* is further characterized by the absence of parasutural crests, present in species such as *P. levimurum* Bujak, sp. nov., and spines as in *P. alectrolophum* Eaton, 1976, *P. comatum*, and *P. multispinum* Bujak, sp. nov.

Phthanoperidinium levimurum Bujak, sp. nov.

Plate 19, figs. 13–16; text-figs. 20E, 22B

Derivation of name. Latin, *levis*, smooth, and Latin, *murus*, wall, with reference to the parasutural crests.

Holotype. V59992 W49/2. Lower Barton Beds, Barton, Hampshire, southern England. Late Eocene.

Paratypes. V59880 T38/0; V59974 P24/2; V59983 U36/4; V59986 U28/0; V60022.

Diagnosis. Pericyst compressed dorsoventrally with an oval ambitus. One small conical apical horn and one or two unequal small antapical horns are present. An endocyst is rarely visible. The periphragm is granulate to sparsely verrucate with thin, smooth or undulating crests which delimit a paratabulation of 4′, 3a, 7″, xc, 5‴, 2⁗. Spines are absent from the crests. A deep, narrow, slightly helicoidal paracingulum is delimited by crests which may be finely denticulate. The archaeopyle is formed by the loss of paraplate 2a.

Dimensions. Pericyst length = 44–62 μm, breadth = 40–59 μm. Maximum crest height = 4–10 μm. Number of specimens measured = 25.

Discussion. Palaeoperidinium basilium (Drugg, 1967) Drugg, 1970, from the Danian of the U.S.A. differs in its larger size (about 122 μm × 106 μm) and in usually having a less distinct paratabulation.

Phthanoperidinium multispinum Bujak, sp. nov.

Plate 19, figs. 17–19; text-fig. 20F

Derivation of name. Latin, *multus*, much, many, and Latin, *spina*, thorn, with reference to the parasutural crests.

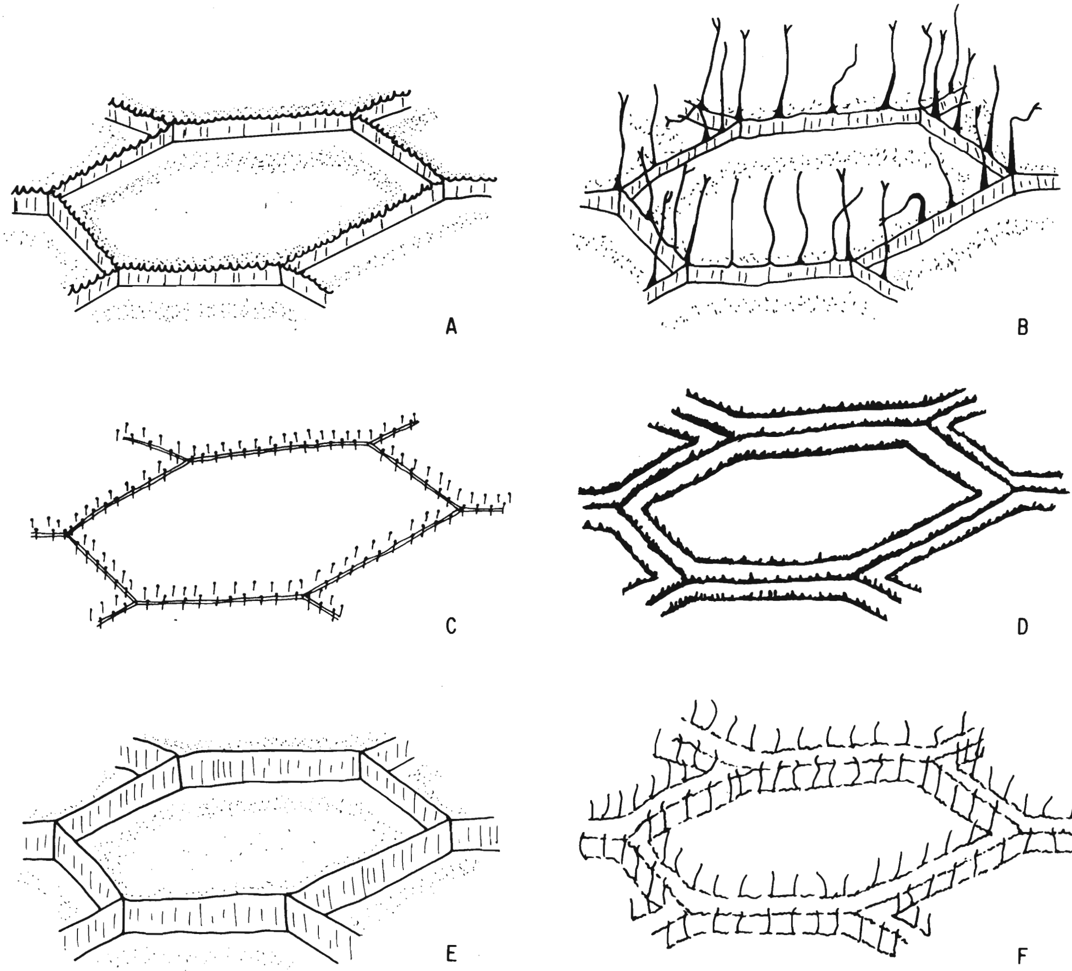
Holotype. V59978 O23/2. Middle Barton Beds, Whitecliff Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V59885 P45/1; V59895 R17/4; V59978 N25/1.

Diagnosis. Pericyst ovoidal with one apical and one or two unequal antapical horns. An endocyst is rarely visible. The periphragm is chagrinate to granulate, with low membranous crests which delimit a paratabulation of 4′, 3a, 7″, xc, 5‴, 2⁗. The crests bear closely spaced, solid, simple or bifurcate spines that are up to 6 μm long. Concentration of coarse granules on the periphragm may result in simulate rings within the paraplates. The archaeopyle is formed by the loss of paraplate 2a.

Dimensions. Pericyst length = 35–45 μm, breadth = 30–37 μm. Maximum crest height = 2–4 μm. Maximum spine height = 4–6 μm. Number of specimens measured = 6.

Discussion. P. multispinum is distinguished from *P. alectrolophum* Eaton, 1976, in having longer spines. However, they are not as long as in *P. comatum*.



TEXT-FIG. 20. Ornament of *Phthanoperidinium* species from the Barton Beds. A, *P. alectrolophum* Eaton; B, *P. comatum* (Morgenroth) Eisenack and Kjellström; C, *P. echinatum* Eaton and ?*P. pseudoechinatum* Bujak, sp. nov.; D, *P. geminatum* Bujak, sp. nov.; E, *P. levimurum* Bujak, sp. nov.; F, *P. multispinum* Bujak, sp. nov.

?*Phthanoperidinium pseudoechinatum* Bujak, sp. nov.

Plate 19, fig. 20; text-fig. 20C

Derivation of name. Greek, *pseudes*, false, and Latin, *echinatus*, prickly, spiny, with reference to the superficial resemblance of this species to *Phthanoperidinium echinatum* Eaton, 1976.

Holotype. V59898 V34/3. Middle Barton Beds, Barton, Hampshire, southern England. Late Eocene.

Paratype. V59881 H50/1.

Diagnosis. Pericyst ovoidal with one short, solid apical horn and one or two unequal antapical horns; one or both are often strongly reduced. The endocyst is rarely visible. The periphragm is laevigate to chagrinate, with low crests delimiting a paratabulation of 4′, 3a, 7″, xc, 5‴, 2⁗. A row of unconnected, short, distally spherical spines is located along both sides of each parasutural crest.

Archaeopyle formation involves a variable number of paraplates, with 2a and 4″ always being lost and maximum development involving paraplates 1a–3a and 3″–5″. The operculum separates into individual paraplates. Archaeopyle formula I + P to 3I + 3P (2a + 4″ to 1a–3a + 3″–5″).

Dimensions. Pericyst length = 30–45 μm, breadth = 26–36 μm. Maximum spine length = 1–3 μm. Number of specimens measured = 20.

Discussion. ?*P. pseudoechinatum* differs from *P. echinatum* Eaton, 1976, in the mode of archaeopyle formation. The archaeopyle in *P. echinatum* is formed by the loss of paraplate 2a, with accessory archaeopyle sutures often occurring between paraplates 3″ and 4″ and 4″ and 5″. The archaeopyle in ?*P. pseudoechinatum* always involves paraplates 2a and 4″ and also may include 1a, 3a, 3″, and 5″. ?*P. pseudoechinatum* is provisionally assigned to the genus *Phthanoperidinium* because of its archaeopyle. ?*P. pseudoechinatum* is abundant in sample M77 (Upper Barton Beds, Barton section), where it is associated with marginal marine to non-marine sediments.

Genus POLYSPHAERIDIUM Davey and Williams, 1966

Polysphaeridium congregatum (Stover, 1977) Bujak *et al.*

Plate 20, figs. 1–3

1977 *Hemicystodinium congregatum* Stover, p. 79, pl. 3, figs. 39–44.

Dimensions. Central body diameter = 30 × 30 μm to 36 × 38 μm. Process length = 11–15 μm. Number of specimens measured = 5.

Discussion. Bujak *et al.* transferred *Hemicystodinium congregatum* to *Polysphaeridium* in Part IV of the present paper because they considered *Hemicystodinium* to be a junior synonym of *Polysphaeridium*.

Genus PSALIGONYAULAX Sarjeant, 1966*a*

Psaligonyaulax simplicia (Cookson and Eisenack, 1961) Sarjeant, 1969

Plate 20, figs. 4–5

1961 *Rottnestia simplicia* Cookson and Eisenack, p. 42, pl. 2, figs. 3–4, text-fig. 1*e–f*.
1969 *Psaligonyaulax simplicia* (Cookson and Eisenack) Sarjeant, p. 15.

Dimensions. Pericyst length = 51–54 μm, breadth = 35–45 μm. Endocyst length = 40–43 μm, breadth = 33–43 μm. Number of specimens measured = 5.

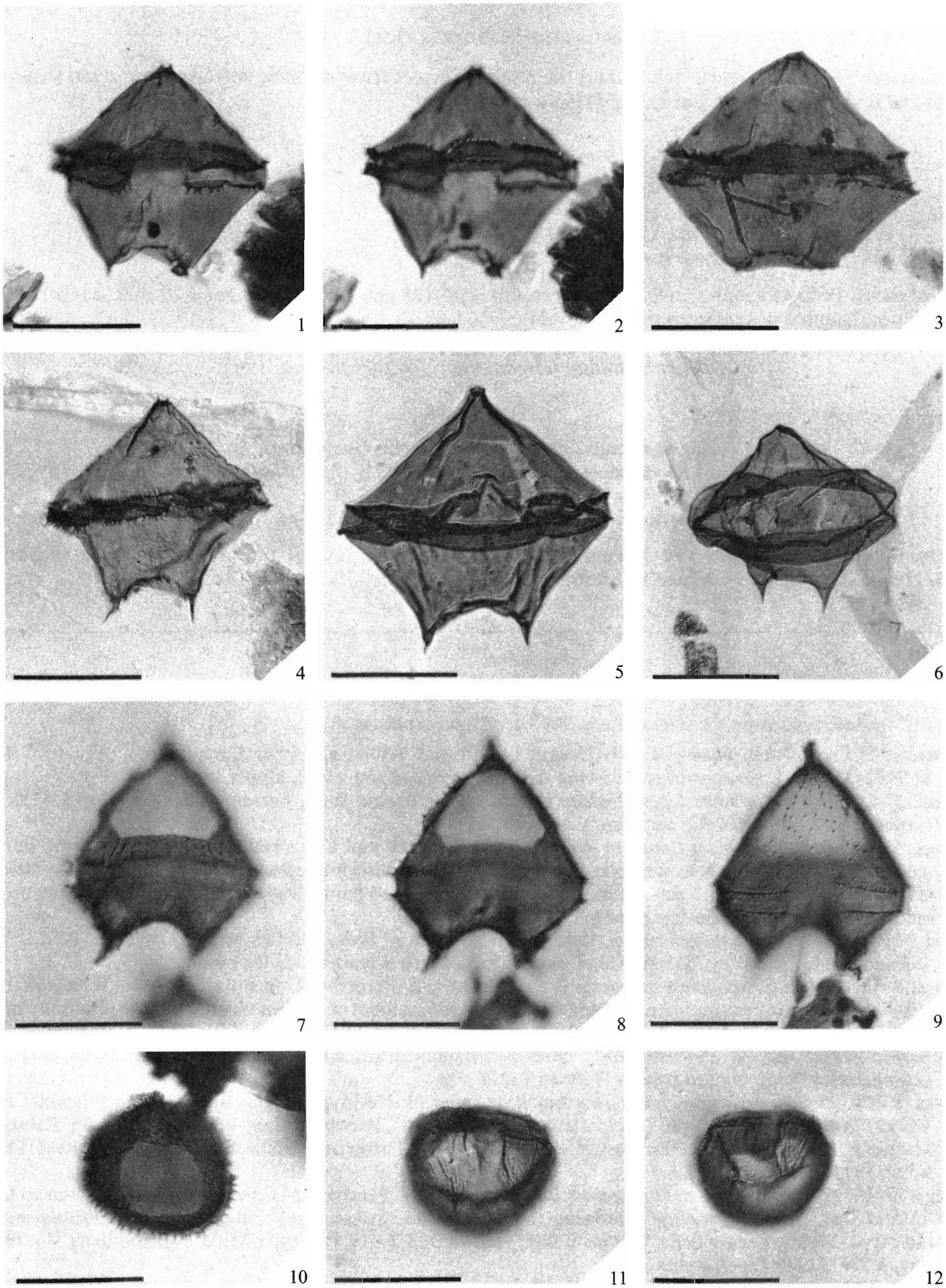
EXPLANATION OF PLATE 18

Dinoflagellate cysts from the Barton Beds. Bar on all figures equals 30 μm.

Figs. 1–4. *Lejeunia cinctoria* Bujak, sp. nov. 1–2. Holotype, Middle Barton Beds, Whitecliff Bay, V59983 C35/0. 1. Ventral paracingulum and archaeopyle in focus. 2. Partite dorsal paracingulum in focus. 3. Paratype, Middle Barton Beds, Whitecliff Bay, V59983 O46/2, showing the archaeopyle and poorly developed antapical horns. 4. Paratype, Middle Barton Beds, Whitecliff Bay, V59978 G50/4.

Figs. 5–6. *Lejeunia hyalina* Gerlach. 5. Middle Barton Beds, Whitecliff Bay, V59976 D53/0. 6. Middle Barton Beds, Whitecliff Bay, V59978 O30/0.

Figs. 7–12. *Lentinia serrata* Bujak, gen. nov., sp. nov. 7–9. Holotype, Upper Barton Beds, Barton section, V59907 J27/1. 7. Dorsal surface showing the large archaeopyle formed by the loss of paraplate 2a. Note the short, broad paraplate 4″. 8. Optical section showing the long, narrow paraplates 1a and 3a, and the absence of pericoels. 9. Ventral surface showing intratabular spines delineating paraplates 1′, 1″ and 7″. 10. Paratype, Middle Barton Beds, Whitecliff Bay, V59983 P44/2, apical surface. 11. Paratype, Middle Barton Beds, Barton section, V59901 N4/1, antapical-ventral surface showing the deep parasulcus. 12. Paratype, Upper Barton Beds, Barton section, V59907 D4/1, antapical surface.



BUJAK *et al.*, Dinoflagellate cysts

Genus RHOMBODINIUM Gocht, 1955

Discussion. Morphological details and the relationships between species of *Rhombodinium* from the Barton Beds are discussed in Bujak (1979).

Rhombodinium draco Gocht, 1955

Plate 20, fig. 6

1952 *Wetzeliella* sp. ind. Gocht, p. 315, pl. 2, fig. 41.
1955 *Rhombodinium draco* Gocht, p. 85, text-fig. 1.

Dimensions. Pericyst length = 100–135 μm, breadth = 90–125 μm. Endocyst length = 70–100 μm, breadth = 75–90 μm. Number of specimens measured = 11.

Rhombodinium longimanum Vozzhennikova, 1967

Plate 20, fig. 7

1967 *Wetzeliella* (*Rhombodinium*) *draco* (Gocht) Gocht; Gocht (*pars*), pl. 13, figs. 4, 6.
1967 *Rhombodinium longimanum* Vozzhennikova, p. 171, pl. 92, figs. 1–3; pl. 93, figs. 1–6; pl. 94, figs. 1–3.
1969 *Wetzeliella* (*Rhombodinium*) *draco* (Gocht) Gocht; Gocht (*pars*), pl. 9, fig. 1.

Dimensions. Pericyst length = 90–150 μm, breadth = 120–175 μm. Endocyst length = 80–115 μm, breadth = 80–120 μm. Number of specimens measured = 10.

EXPLANATION OF PLATE 19

Dinoflagellate cysts from the Barton Beds. Bar on all figures equals 30 μm.

Figs. 1–2. *Leptodinium incompositum* (Drugg) Lentin and Williams, Upper Barton Beds, Whitecliff Bay, V59992 O33/0. 1. Lower surface showing the archaeopyle at top left. 2. Upper surface.

Figs. 3–4. *Phthanoperidinium alectrolophum* Eaton, Lower Barton Beds, Barton section, V59889 U41/0. 3. Lower, dorsal surface. 4. Upper, ventral surface.

Figs. 5–6. *Phthanoperidinium comatum* (Morgenroth) Eisenack and Kjellström, Upper Barton Beds, Barton section, V59915 G25/1. 5. Lower, dorsal surface showing the hexa intercalary archaeopyle (sutural spines not in focus). 6. Upper, ventral surface showing the well-delineated parasulcus and simulate granulation on the apical, precingular, and postcingular paraplates.

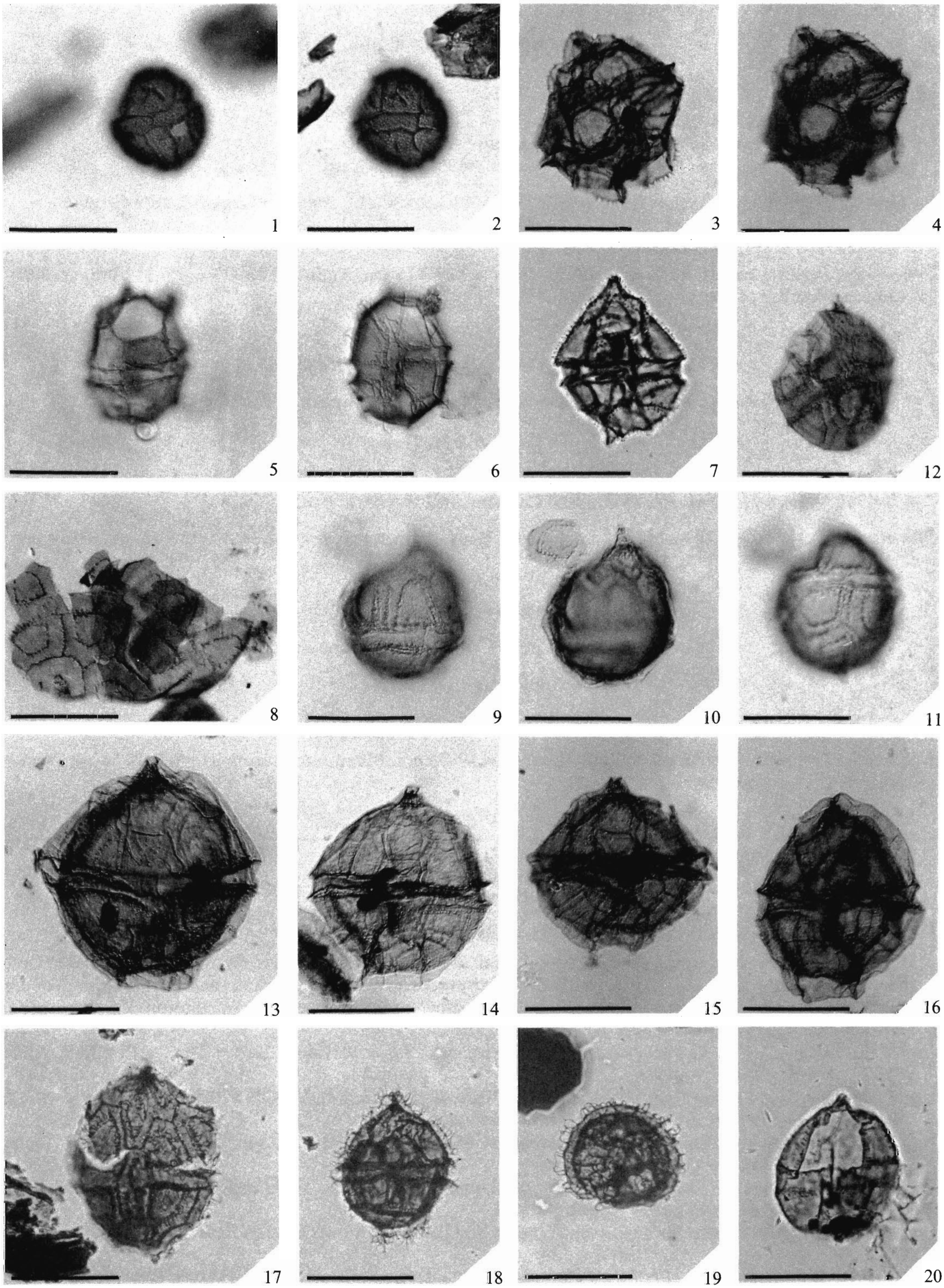
Fig. 7. *Phthanoperidinium echinatum* Eaton, Lower Barton Beds, Barton section, V59882 B37/3. The archaeopyle is formed by the removal of paraplate 2a which is lying inside the cyst.

Figs. 8–12. *Phthanoperidinium geminatum* Bujak, sp. nov. 8. Paratype, Upper Barton Beds, Whitecliff Bay, V59994 R36/4. Broken specimen showing the distinctive ornament of *P. geminatum*. Note the proximity of the simulate and paracingular ornament on the precingular and postcingular paraplates. 9–11. Holotype, Middle Barton Beds, Alum Bay, V59946 T36/2. Note the partially attached operculum (paraplate 2a). 12. Paratype, Lower Barton Beds, Barton section, V59885 T12/0.

Figs. 13–16. *Phthanoperidinium levimurum* Bujak, sp. nov. 13. Holotype, Upper Barton Beds, Whitecliff Bay, V59992 W49/2. 14. Paratype, Bracklesham Bed equivalents, Barton section, V59880 T38/0. 15. Paratype, Middle Barton Beds, Whitecliff Bay, V59986 U28/2. 16. Paratype, Middle Barton Beds, Whitecliff Bay, V59983 U36/4.

Figs. 17–19. *Phthanoperidinium multispinum* Bujak, sp. nov. 17. Paratype, Middle Barton Beds, Barton section, V59895 R17/4, broken specimen showing the simulate and parasutural ornament of *P. multispinum*. 18. Holotype, Middle Barton Beds, Whitecliff Bay, V59978 O23/2. 19. Paratype, Middle Barton Beds, Whitecliff Bay, V59978 N25/1, polar view.

Fig. 20. ?*Phthanoperidinium pseudoechinatum* Bujak, sp. nov. Holotype, Middle Barton Beds, Barton section, V59898 V34/3, showing the simulate rows of spines and the combination anterior intercalary and precingular archaeopyle.



BUJAK *et al.*, Dinoflagellate cysts

Rhombodinium porosum Bujak, 1979

Plate 20, fig. 8

1961 *Dracodinium solidum* Gocht; Alberti, p. 11, pl. 1, fig. 9.
1977*a* *Rhombodinium* sp. A Williams and Bujak, pl. 1, fig. 2.
1979 *Rhombodinium porosum* Bujak, pl. 1, figs. 3, 5–8; pl. 2, fig. 11, text-fig. 8C.

Holotype. V59996. Upper Barton Beds, Whitecliff Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V59983 W36/2; V59992 D25/2; V59997; V59998; V59999.

Dimensions. Pericyst length = 105–150 μm, breadth = 115–175 μm. Endocyst length = 75–115 μm, breadth = 75–120 μm. Number of specimens measured = 20.

Genus ROTTNESTIA Cookson and Eisenack, 1961

Rottnestia borussica (Eisenack, 1954) Cookson and Eisenack, 1961

Plate 20, figs. 9–10

1954 *Hystrichosphaera* (*Hystrichosphaeropsis*) *borussica* Eisenack, p. 62, pl. 9, figs. 5–7.
1961 *Rottnestia borussica* (Eisenack) Cookson and Eisenack, p. 42.

Dimensions. Pericyst length = 48–76 μm. Central body diameter = 28 × 36 μm to 42 × 50 μm. Number of specimens measured = 15.

Genus SAMLANDIA Eisenack, 1954

Samlandia reticulifera Cookson and Eisenack, 1965

Plate 20, figs. 11–12

1965 *Samlandia reticulifera* Cookson and Eisenack, p. 126, pl. 15, figs. 10–15.

Dimensions. Over-all length = 63–104 μm, breadth = 59–76 μm. Maximum process length = 7–14 μm. Number of specimens measured = 20.

EXPLANATION OF PLATE 20

Dinoflagellate cysts from the Barton Beds. Bar on all figures equals 30 μm.

Figs. 1–3. *Polysphaeridium congregatum* (Stover) comb. nov. Upper Barton Beds, Barton section, V59915 L16/4, specimen with an epicystal archaeopyle. 1. Cingular processes in focus, showing their intratabular grouping. 2. Postcingular process groups in focus. 3. Antapex, showing the symmetrical distribution of process groups on paraplates 1p, 1'''', and p.s.

Figs. 4–5. *Psaligonyaulax simplicia* (Cookson and Eisenack) Sarjeant. Lower Barton Beds, Alum Bay, V59931 W53/1. 4. Epicyst. 5. Hypocyst.

Fig. 6. *Rhombodinium draco* Gocht. Lower Barton Beds, Barton section, V59889 P31/0. Specimen showing the soleiform archaeopyle characteristic of *Rhombodinium*.

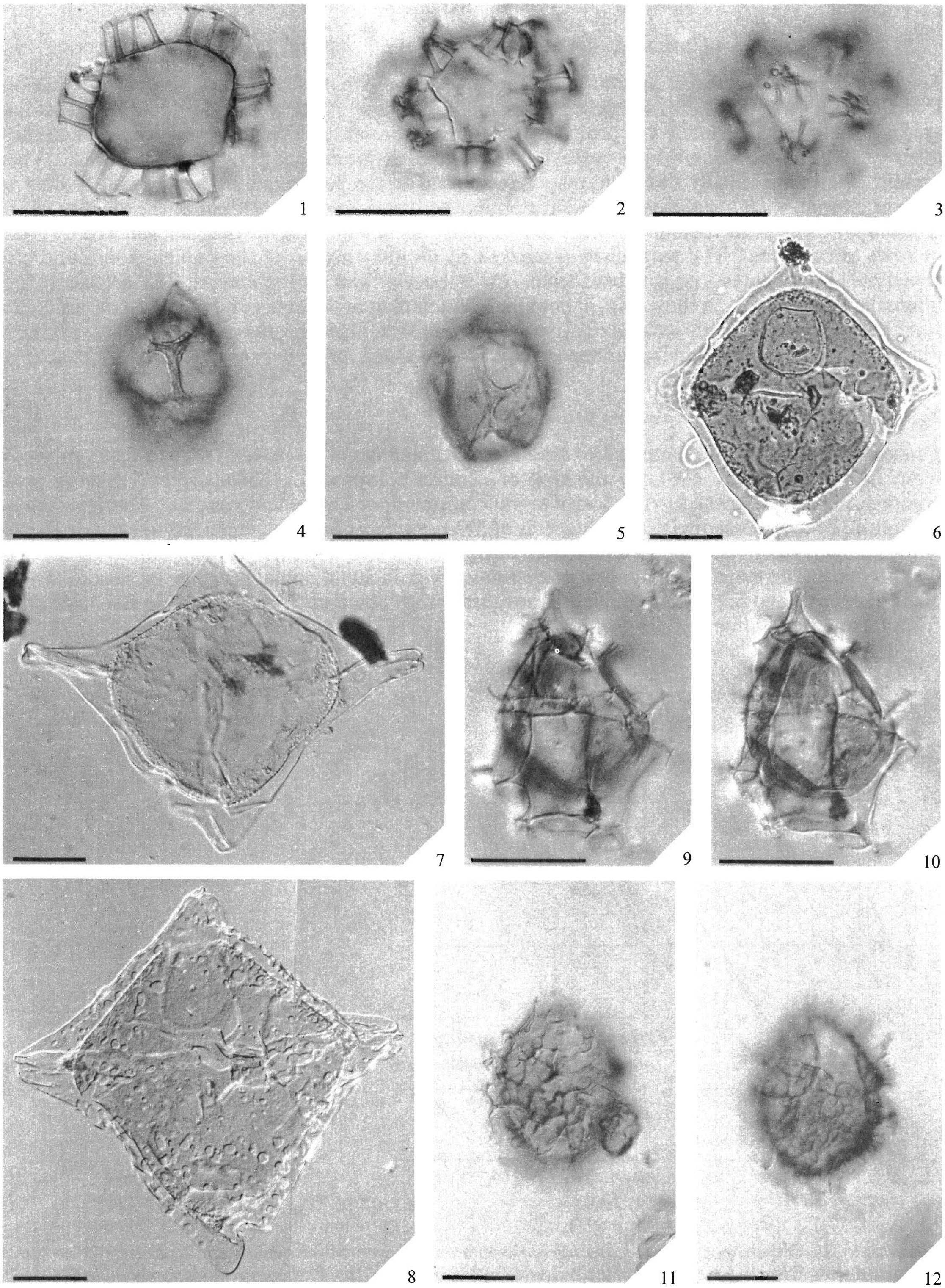
Fig. 7. *Rhombodinium longimanum* Vozzhennikova. Middle Barton Beds, Alum Bay, V59951 J5/2. Optical section showing the long pericingular horns.

Fig. 8. *Rhombodinium porosum* Bujak. Holotype, Upper Barton Beds, Whitecliff Bay, V59996, showing the soleiform archaeopyle and perforate periphragm.

Figs. 9–10. *Rottnestia borussica* (Eisenack) Cookson and Eisenack. Lower Barton Beds, Whitecliff Bay, V59968 A32/0. 9. Upper surface. 10. Optical section.

Figs. 11–12. *Samlandia reticulifera* Cookson and Eisenack. Lower Barton Beds, Alum Bay, V59930 L33/2. 11. Upper, ventral surface. 12. Lower, dorsal surface showing the precingular archaeopyle.

PLATE 20



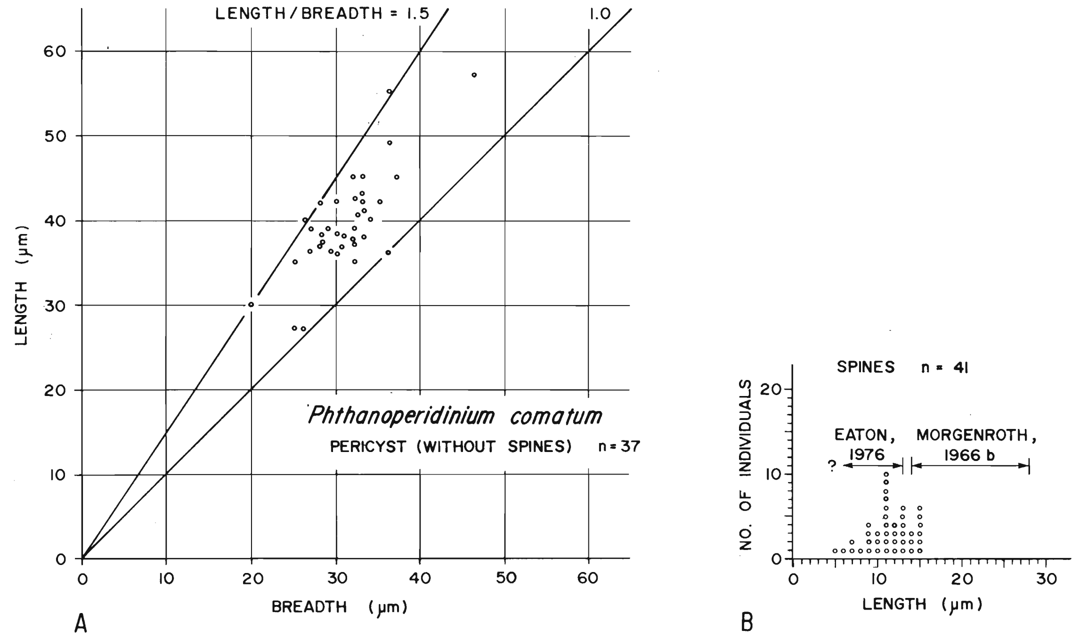
BUJAK *et al.*, Dinoflagellate cysts

Genus SELENOPEMPHIX Benedek, 1972, emend. Bujak

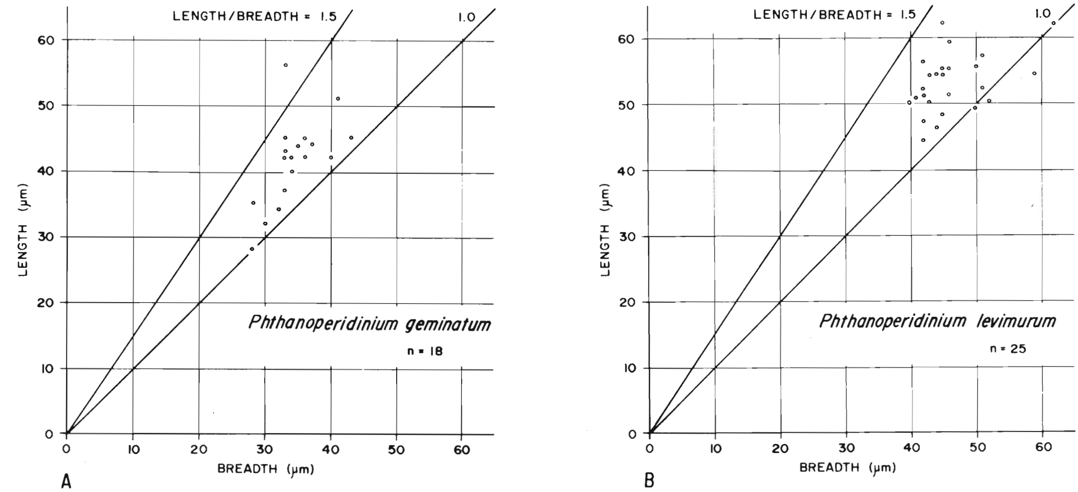
Emended diagnosis. Autocyst circular to oval in polar view, with or without a parasulcal indentation. Dorsoventral outline peridinioid, pentagonal, or rhomboidal. Apex rounded or prolonged into an apical horn. Antapex rounded or prolonged into two, more or less symmetrically located antapical lobes or horns. The autophragm is laevigate, chagrinate, granulate, perforate, or spinate. When present, spines are usually solid and may be restricted to the paracingulum and horns, or may be present over all the autophragm. The paratabulation is unknown other than in the vicinity of the archaeopyle. The paracingulum appears to be slightly helicoidal, with the margins denoted by crests or rows of ornament. The parasulcus is marked by an interruption of the paracingulum and also sometimes by a depression; it is broader on the hypocyst than on the epicyst. The archaeopyle is intercalary resulting from the partial or complete detachment of the anterior intercalary paraplate 2a. It is always asymmetrically located relative to the middorsal line, with the degree of offset varying in different species. Operculum free or remaining attached along the posterior parasuture. Archaeopyle formula I (2a).

Type species. Selenopemphix nephroides Benedek, 1972.

Discussion. Lentin and Williams (1976) expanded the diagnosis of *Selenopemphix* and distinguished it from *Lejeunia* Gerlach, 1961, by the type of pericyst compression, *Selenopemphix* having polar compression and *Lejeunia* having dorsoventral compression. The genera were not distinguished on the nature of the archaeopyle. The diagnosis of *Selenopemphix* is herein emended to exclude species with symmetrically located archaeopyles. Such species are assigned to *Lejeunia* regardless of compression. The emended diagnosis of *Selenopemphix* includes spinate species such as *S. armata* Bujak, sp. nov., and *S. coronata* Bujak, sp. nov., since they possess a 2a intercalary archaeopyle offset from the middorsal line.



TEXT-FIG. 21. Dimensions of *Phthanoperidinium comatum* (Morgenroth) Eisenack and Kjellström from the Barton Beds. The ranges in spine length recorded by Eaton (1976) for '*Phthanoperidinium tritonium*' Eaton (= jr. syn. of *P. comatum*), and by Morgenroth 1966*b* for *P. comatum* are also shown in 21B.



TEXT-FIG. 22. Dimensions of A, *Phthanoperidinium geminatum* Bujak, sp. nov., and B, *P. levimurum* Bujak, sp. nov. from the Barton Beds.

The genera *Multispinula* Bradford, 1975, and *Omanodinium* Bradford, 1975, are probably synonymous with either *Lejeunia* or *Selenopemphix*. It is not possible to determine the position of the archaeopyle in either of these genera from Bradford's (1975) descriptions or illustrations.

Selenopemphix armata Bujak, sp. nov.

Plate 21, figs. 1–3; text-figs. 23D, 24

Derivation of name. Latin, *armatus*, furnish with weapons, with reference to the spines.

Holotype. V59907 M45/0. Upper Barton Beds (*Chama* Beds), Barton, Hampshire, southern England. Late Eocene.

Paratypes. V59890 H31/2; V59992 K35/4; V60014.

Diagnosis. Autocyst compression polar. Apex rounded, sometimes prolonged into a small rounded horn. Antapex rounded or prolonged into two small rounded horns of approximately equal size. Autophragm laevigate to chagrinate, without perforations, may be faintly striate. Paracingular margins denoted by distally entire crests. Spines are present on the apical and antapical horns and on the paracingular ridges, but are absent from the precingular and postcingular zones. The spines are solid, curved, and distally acuminate or bulbous; they may be proximally branched particularly on the horns. The parasulcus may be defined by a shallow indentation. Archaeopyle intercalary, rounded and broad, resulting from the partial or complete detachment of the second anterior intercalary paraplate 2a. It is always asymmetrically located relative to the middorsal line. The operculum is free or remains attached along the posterior parasuture.

Dimensions. Autocyst thickness without spines = 26–43 µm, breadth without spines = 24–45 µm, spine length = 9–17 µm. Number of specimens measured = 34.

Discussion. Wall and Dale (1968) obtained six thecae of *Peridinium conicum* (Gran, 1900) Ostenfeld and Schmidt, 1902, by incubating cysts similar in morphology to *S. armata*. The cysts of *P. conicum* differ from *S. armata* in possessing precingular and postcingular spines and in having larger breadth and thickness. The 2a intercalary archaeopyle in *P. conicum* cysts is broad as in *S. armata* and also appears to be offset relative to the middorsal line.

Multispinula quanta, described by Bradford (1975) as synonymous with cysts of *P. conicum*, differs from *S. armata* in having precingular and postcingular spines. The dimensions of *M. quanta* and *S. armata* do not appear to differ significantly.

Wall and Dale (1968) incubated thecae of *P. ?nudum* Meunier, 1919, from cysts similar to *S. armata* in size and morphology other than the presence of precingular and postcingular spines. The cysts of *P. ?nudum* also differ in forming an archaeopyle that is narrower than that of *S. armata*.

S. elegantula (Williams, 1978) Bujak, comb. nov., described from subsurface strata dated as Eocene, Deep Sea Drilling Project Site 370, offshore West Africa, differs from *S. armata* in possessing precingular and postcingular spines and in having dorsoventral compression.

Selenopemphix coronata Bujak, sp. nov.

Plate 21, figs. 4–5; text-figs. 17B, 23C

Derivation of name. Latin, *coronatus*, crown, with reference to the ornament.

Holotype. V59983 S42/2. Middle Barton Beds, Whitecliff Bay, Isle of Wight, southern England. Late Eocene.

Paratype. V59994 B48/0.

Diagnosis. Autocyst compression polar. Apex prolonged into a small rounded horn. Antapex prolonged into two small rounded horns of approximately equal size. Autophragm laevigate to chagrinate, without perforations. Paracingular margins denoted by distally entire, spinate ridges. Spines closely spaced, about 4 μm long, slender, solid, tapering, distally bifurcate. The bifurcations are distally bulbous or connected to the nearest bifurcation of an adjacent spine. Spines are absent from the horns and precingular and postcingular zones. The parasulcus may be defined by a shallow indentation. Archaeopyle intercalary, rounded, resulting from the partial or complete detachment of the second anterior intercalary paraplate 2a. It is always asymmetrically located relative to the middorsal line. The operculum is free or remains attached along the posterior parasuture.

Dimensions. Autocyst thickness = 31–36 μm, breadth = 35–54 μm, spine length = $3\frac{1}{2}$–5 μm. Number of specimens measured = 5.

Discussion. *S. coronata* differs from other species of *Selenopemphix* in the distinctive spine morphology.

Selenopemphix elegantula (Williams, 1978) Bujak, comb. nov.

1978 ?*Vozzhennikovia elegantula* Williams, p. 797, pl. 7, figs. 7, 9

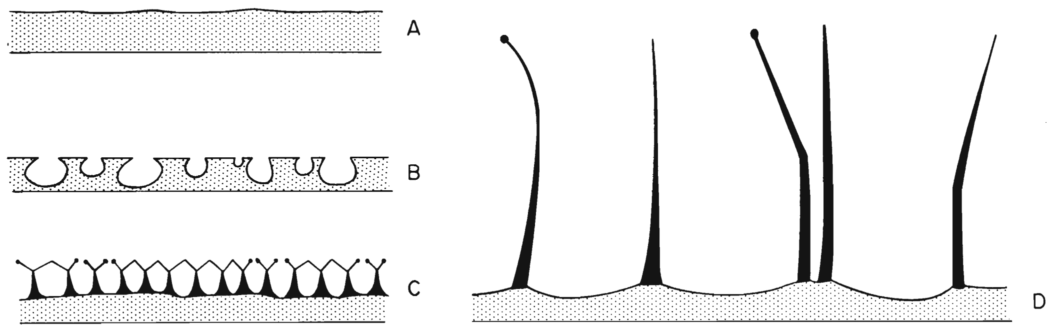
Discussion. This species is herein transferred to *Selenopemphix* because of the asymmetrical location of its archaeopyle. *S. elegantula* was not observed in the Barton Beds.

Selenopemphix nephroides Benedek 1972, emend. Bujak

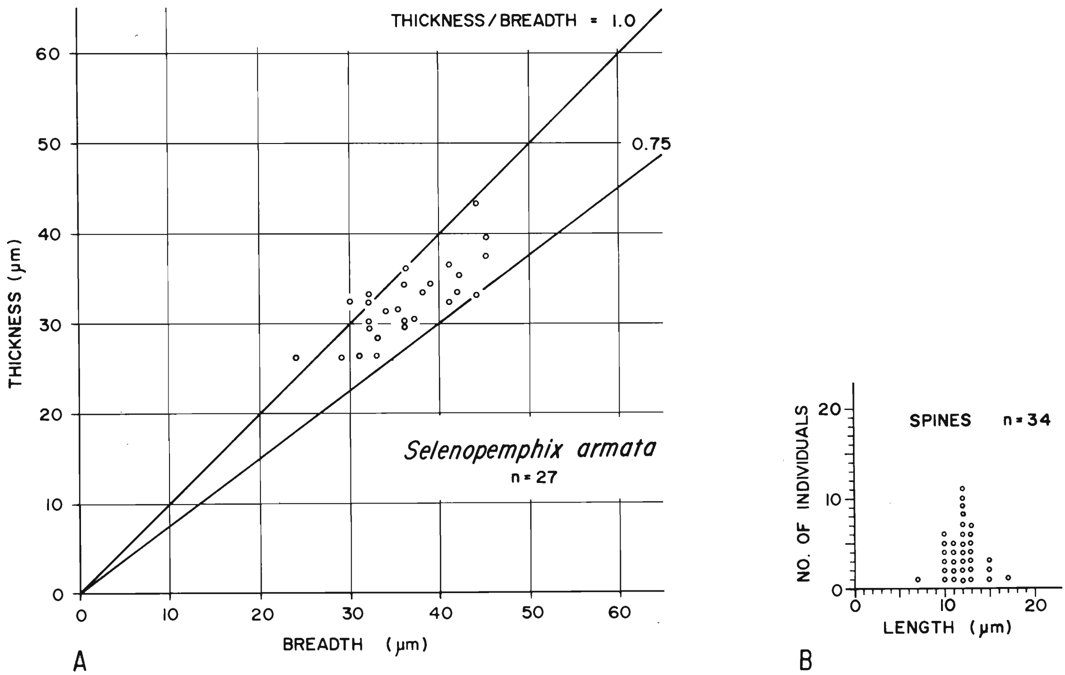
Plate 21, fig. 6; text-fig. 23A

1972 *Selenopemphix nephroides* Benedek, p. 47, pl. 11, fig. 13; pl. 16, figs. 1–4.

Emended diagnosis. Autocyst compression polar. Apex rounded, sometimes prolonged into a small rounded horn. Antapex rounded or prolonged into two small rounded horns of approximately equal size. Autophragm laevigate to chagrinate, without spines or perforations. Paracingular margins denoted by distally entire, raised ridges devoid of spines. Parasulcus may be defined by a shallow indentation. Archaeopyle intercalary, rounded, resulting from the partial or complete detachment of the second anterior intercalary paraplate 2a. It is always asymmetrically located relative to the middorsal line. The operculum is free or remains attached along the posterior parasuture.



TEXT-FIG. 23. Paracingular ornament on species of *Selenopemphix* from the Barton Beds. A, *S. nephroides* Benedek; B, *S. selenoides* Benedek; C, *S. coronata* Bujak, sp. nov.; D, *S. armata* Bujak, sp. nov.



TEXT-FIG. 24. Dimensions of *Selenopemphix armata* Bujak, sp. nov. from the Barton Beds.

Dimensions. Autocyst thickness = 28–56 μm, breadth = 36–56 μm. Number of specimens measured = 21.

Discussion. The diagnosis of *S. nephroides* is emended to specify its polar compression and the offset nature of the archaeopyle.

Selenopemphix selenoides Benedek 1972, emend. Bujak

Plate 21, figs. 7–8; text-figs. 17B, 23B

1972 *Selenopemphix selenoides* Benedek, p. 48, pl. 11, fig. 15; pl. 16, figs. 5–8, text-fig. 22.

Emended diagnosis. Autocyst compression polar, crescentic in polar view, always with a deeply incised parasulcus. Apex rounded or sometimes prolonged into a small rounded horn. Antapex rounded or prolonged into two small rounded horns of approximately equal size. Autophragm laevigate to chagrinate, often perforate. Paracingular margins denoted by perforate ridges. Parasulcus deep, delimited on the hypocyst by perforate ridges. Archaeopyle intercalary, rounded, resulting from the partial or complete detachment of the second anterior intercalary paraplate 2a. It is always asymmetrically located relative to the middorsal line. The operculum is free or remains attached along the posterior parasuture.

Dimensions. Autocyst thickness = 33–55 μm, breadth = 48–56 μm. Number of specimens measured = 6.

Discussion. The diagnosis of *S. selenoides* is emended to specify its polar compression and the offset nature of the archaeopyle.

Genus SPINIFERITES Mantell, 1850

Spiniferites mirabilis (Rossignol, 1963) Sarjeant, 1970

Plate 21, fig. 10

1963 *Hystrichosphaera mirabilis* Rossignol, pl. 2, figs. 16–21.
1970 *Spiniferites mirabilis* (Rossignol) Sarjeant, p. 76.

EXPLANATION OF PLATE 21

Dinoflagellate cysts from the Barton Beds. Bar on all figures equals 30 μm.

Figs. 1–3. *Selenopemphix armata* Bujak, sp. nov. 1. Holotype, Upper Barton Beds, Barton section, V59907 M45/0, polar view showing the two rows of paracingular spines, the two antapical spines and the asymmetrically located anterior intercalary archaeopyle. 2. Paratype, Lower Barton Beds, Barton section, V59890 H31/2, polar view. 3. Paratype, Upper Barton Beds, Whitecliff Bay, V59992 K35/4, dorsoventral view showing the strong polar compression and peridinioid outline.

Figs. 4–5. *Selenopemphix coronata* Bujak, sp. nov. 4. Holotype, Middle Barton Beds, Whitecliff Bay, V59983 S42/2, polar view showing the two rows of paracingular spines and the asymmetrically located anterior intercalary archaeopyle. 5. Paratype, Upper Barton Beds, Whitecliff Bay, V59994 B48/0, polar view.

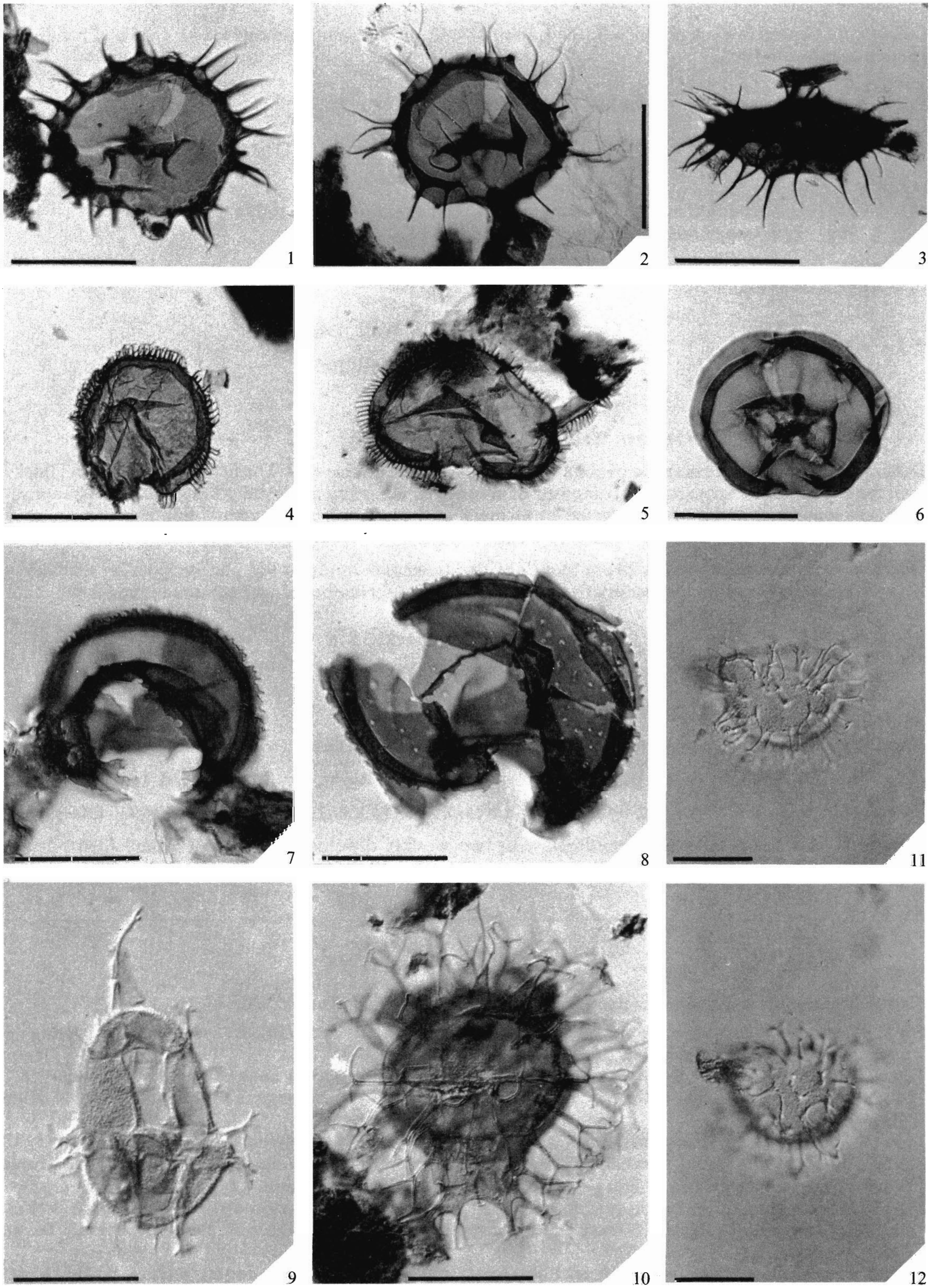
Fig. 6. *Selenopemphix nephroides* Benedek. Lower Barton Beds, Barton section, V59883 B5/0, polar view showing the asymmetrically located anterior intercalary archaeopyle.

Figs. 7–8. *Selenopemphix selenoides* Benedek. 7. Upper Barton Beds, Barton section, V59907 V26/1. Polar view of the hypocyst showing the deep parasulcus with perforated marginal crests, two rows of perforated paracingular crests and the asymmetrically located anterior intercalary archaeopyle (not in focus). 8. Upper Barton Beds, Barton section, V59908 P8/0, broken specimen showing the perforate autophragm, deep sulcus, and asymmetrically located archaeopyle (not in focus).

Fig. 9. *Spiniferites cornutus* (Gerlach) Sarjeant. Bracklesham Bed equivalents, Barton section, V60015, showing the dorsal surface, apical horn, and long, narrow precingular archaeopyle characteristic of *S. cornutus*.

Fig. 10. *Spiniferites mirabilis* (Rossignol) Sarjeant. Upper Barton Beds, Whitecliff Bay, V59992 U49/0, showing the slender processes and antapical membrane characteristic of *S. mirabilis*.

Figs. 11–12. *Systematophora placacantha* (Deflandre and Cookson) Davey *et al.* Middle Barton Beds, Alum Bay, V59948 W54/4.



BUJAK *et al.*, Dinoflagellate cysts

Dimensions. Central body diameter = 35 × 40 μm to 44 × 46 μm. Maximum process length = 23 μm. Number of specimens measured = 3.

Genus SYSTEMATOPHORA Klement, 1960

Systematophora placacantha (Deflandre and Cookson, 1955) Davey *et al*., 1969

Plate 21, figs. 11–12

1955 *Hystrichosphaeridium placacanthum* Deflandre and Cookson, p. 276, pl. 9, figs. 1–3.
1969 *Systematophora placacantha* Davey *et al*., p. 17.

Dimensions. Central body diameter = 36 × 38 μm to 49 × 53 μm. Maximum process length = 14–22 μm. Number of specimens measured = 20.

Genus TECTATODINIUM Wall, 1967

Tectatodinium pellitum Wall, 1967

Plate 22, fig. 1

1967 *Tectatodinium pellitum* Wall, p. 113, pl. 16, figs. 11–12.

Description. The cyst is spherical to ovoidal with a characteristic double wall. The periphragm is always thicker than the endophragm, appears to be composed of interwoven fibres and is generally 2–3 μm thick. However, its thickness sometimes varies on a specimen by as much as 4 μm. The endophragm is thin and appears to be homogeneous. The archaeopyle is formed by the detachment of paraplate 3″.

Dimensions. Cyst diameter = 27 × 28 μm to 40 × 41 μm. Inner wall thickness = 1 μm. Periphragm thickness = 1½–2 μm (rarely to 7 μm on specimens of varying wall thickness). Number of specimens measured = 40.

Genus TENUA Eisenack, 1958

Tenua microcysta Bujak, sp. nov.

Plate 22, figs. 2–5

Derivation of name. Greek, *mikros*, small, and *kystis*, sac, cell, with reference to the small size of the cyst.

Holotype. V59948 V56/0. Middle Barton Beds, Alum Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V59886 G33/0; V59942 R46/2; V59948 U15/0; V59952 X30/1; V59955 R13/0; V59986 E31/3.

Diagnosis. Autocyst ovoidal, sometimes with two weakly developed antapical lobes. Autophragm smooth to chagrinate with abundant processes. The processes are nontabular and are of constant

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EXPLANATION OF PLATE 22

Dinoflagellate cysts and acritarchs from the Barton Beds. Bar on all figures equals 30 μm.

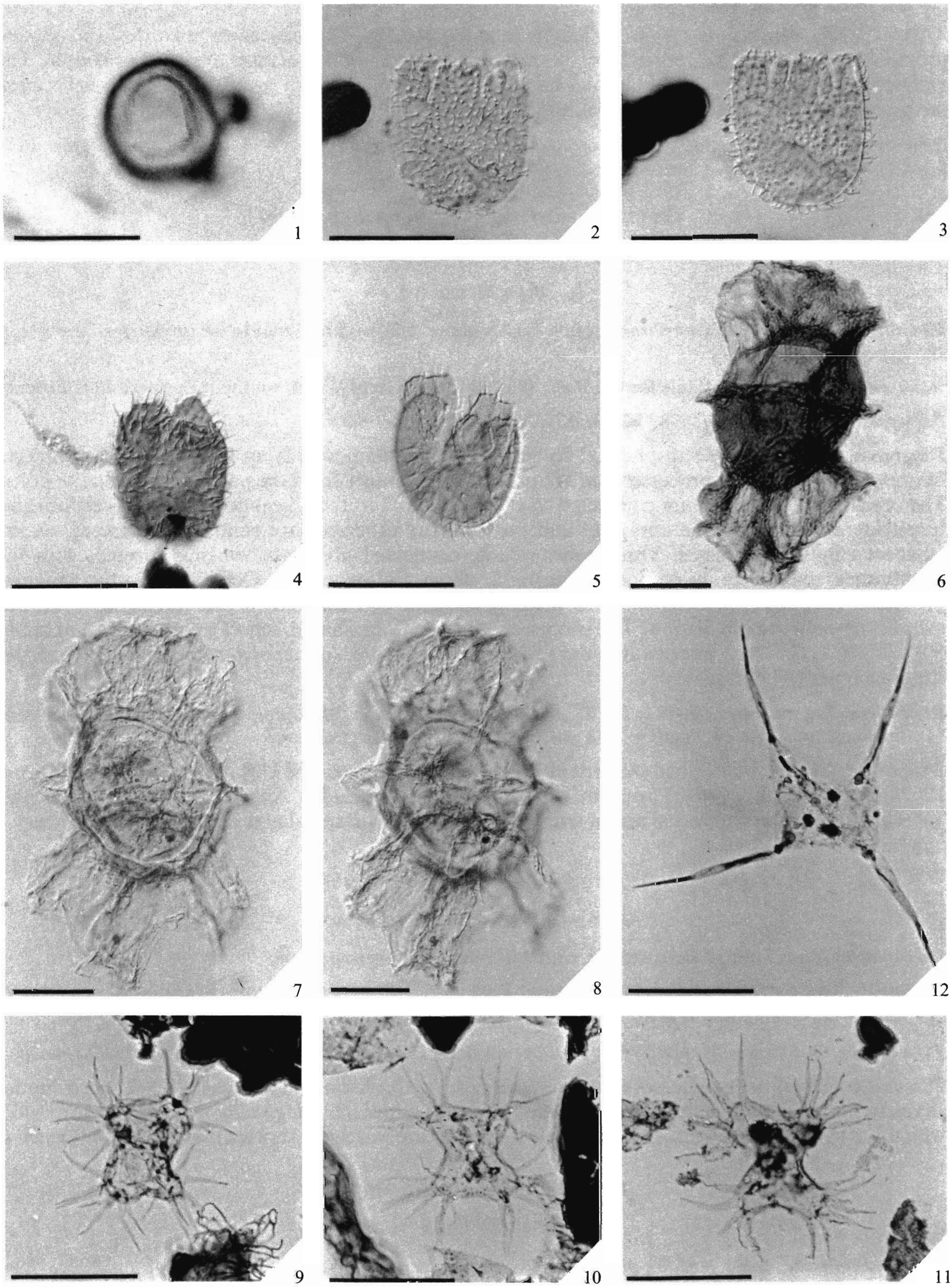
Fig. 1. *Tectatodinium pellitum* Wall. Middle Barton Beds, Alum Bay, V59956 S49/1, showing the precingular archaeopyle formed by the loss of paraplate 3″.

Figs. 2–5. *Tenua microcysta* Bujak, sp. nov. 2–3. Holotype, Middle Barton Beds, Alum Bay, V59948 V56/0. 4. Paratype, Lower Barton Beds, Barton section, V59886 G33/0. 5. Paratype, Middle Barton Beds, Alum Bay, V59942 R46/2.

Figs. 6–8. *Turbiosphaera symmetrica* Bujak, sp. nov. 6. Holotype, Middle Barton Beds, Whitecliff Bay, V59978 V52/4, showing the well-delineated pericingulum and the precingular archaeopyle. 7–8. Paratype, Middle Barton Beds, Whitecliff Bay, V60011. 7. Optical section. 8. Ventral surface.

Figs. 9–11. *Quadrina pallida* Bujak, gen. et., sp. nov. 9. Holotype, Lower Barton Beds, Barton section, V59885 O27/0. 10. Paratype, Middle Barton Beds, Whitecliff Bay, V59975 S41/0. 11. Paratype, Middle Barton Beds, Whitecliff Bay, V59977 O49/1.

Fig. 12. *Veryhachium disjunctum* Bujak, sp. nov. Holotype, Upper Barton Beds, Barton section, V59909 V34/3.



BUJAK *et al.*, Dinoflagellate cysts and Acritarchs length on a specimen, but vary in length intraspecifically. The processes are mostly expanded proximally, hollow, and are distally capitate or bifid. Occasional processes are solid or simple. The archaeopyle is apical, tetratabular, and has well-developed accessory archaeopyle sutures between the precingular paraplates. The operculum is detached.

Dimensions. Autocyst length (without operculum) = 28–36 μm, breadth = 24–34 μm. Process length is up to 6 μm. Number of specimens measured = 25.

Genus TURBIOSPHAERA Archangelsky, 1969*a*

Turbiosphaera symmetrica Bujak, sp. nov.

Plate 22, figs. 6–8

Derivation of name. Greek, *symmetros*, proportional, symmetrical, with reference to the similarity of the epicyst and hypocyst.

Holotype. V59978 V52/4. Middle Barton Beds, Whitecliff Bay, Isle of Wight, southern England. Late Eocene.

Paratypes. V59978 K42/0; V59989 B26/0, H37/0; V60011.

Diagnosis. Central body subspherical to ellipsoidal, sometimes with an apical boss. Periphragm fibrous, forming fibrous processes that are progressively longer from the paracingulum to the poles. The precingular processes are connected to each other and to the apical processes by erect fibrous, fenestrate membranes. The antapical and postcingular processes are similarly connected, as are adjacent cingular processes. Three zones of interconnected processes are thus formed, with the membranes sometimes being indistinguishable from the processes. Occasionally, the cingular processes may be connected to the precingular and postcingular processes by thin fibrous membranes, but remain distinct. The processes, when distinguishable, reflect a paratabulation of ?4′, 6″, xc, 5–?6‴, 1⁗, with one intratabular process per paraplate. Archaeopyle precingular, formed by the detachment of paraplate 3″.

Dimensions. Central body length = 59–70 μm, breadth = 53–67 μm. Maximum process length = 26–42 μm. Maximum cingular process length = 7–18 μm. Number of specimens measured = 15.

Discussion. Forma F described by Evitt (1961) from the Eocene of the U.S.A., and *T. filosa* (Wilson, 1967*a*) Archangelsky, 1969*a*, from the Lower Tertiary (?Eocene) of Antarctica differ from *T. symmetrica* in having unconnected apical and precingular, and antapical and postcingular processes.

Group ACRITARCHA Evitt, 1963

Genus QUADRINA Bujak, gen. nov.

Derivation of name. Latin, *quadra*, square, with reference to the over-all shape.

Diagnosis. Test flattened and rectangular with four rounded corners. A group of spines is present only at each corner of the test. A pylome has not been observed.

Type species. *Quadrina pallida* Bujak, sp. nov. Barton Beds, Hampshire, southern England. Late Eocene.

Discussion. The dinoflagellate cyst genus *Horologinella* Cookson and Eisenack, 1962, has a similar shape to that of *Quadrina*, but does not usually possess spines. *Horologinella spinosa* Cookson, 1965, which has spines, possesses an opening and the spines are relatively shorter than those of *Quadrina*.

Quadrina pallida Bujak, sp. nov.

Plate 22, figs. 9–11

Derivation of name. Latin, *pallidus*, pale, with reference to the wall.

Holotype. V59885 O27/0. Lower Barton Beds, Barton, Hampshire, southern England. Late Eocene.

Paratypes. V59975 S41/0; V59977 O49/1.

Diagnosis. Test flattened and rectangular with four rounded, often swollen, corners. The longer pair of opposite sides are constricted medially and the shorter pair of sides are less strongly constricted or are unconstricted. Wall thin, smooth to chagrinate, and pale. Between six and twelve spines occur at each corner of the test. The spines are flexuous and ribbon-like with acuminate or rounded terminations.

Dimensions. Test = 16×17 μm to 24×28 μm. Spine length up to 17 μm. Number of specimens measured = 15.

Genus VERYHACHIUM (Deunff, 1954) Deunff, 1958

Veryhachium disjunctum Bujak, sp. nov.

Plate 22, fig. 12

1972 *Lagerheimia* aff. *longiseta* (Lemmern) Printz; Benedek, p. 53, pl. 12, fig. 2.

Derivation of name. Latin, *disjunctus*, separate, with reference to the stratigraphical occurrence of this species.

Holotype. V59909 V34/3. Upper Barton Beds, Barton, Hampshire, southern England. Late Eocene.

Paratypes. V59892 V28/3; V59905 W25/2; V59935 V33/2; V59989 M42/1.

Diagnosis. Test compressed, smooth to chagrinate, with four relatively long spines in the plane of compression. The spines are hollow, sometimes distally solid and taper to pointed, rounded, or bifid endings. The spine bases are joined so that the central part of the test has two parallel sides and two opposite concave sides. A pylome has not been observed.

Dimensions. Central body diameter = 8×11 μm to 19×27 μm. Maximum spine length = 22 to 58 μm. Number of specimens measured = 35.

Discussion. *V. disjunctum* is characterized by its large size, central body shape, and relatively long spines. Unlike other species of *Veryhachium* found in the Barton Beds (*V. irregulare* Jekhowsky, 1961, and *V. rhomboideum* Downie, 1959), it is probably indigenous. *V. disjunctum* occurs in most marine samples from the Barton Beds. The present author therefore does not agree with Benedek (1972) who suggested a freshwater habitat for this species. Benedek observed that in his samples *V. disjunctum* was only found with *Pediastrum* Meyen, 1828. *V. disjunctum* occurs only in Benedek's two oldest samples which, although they contain *Pediastrum* (less than ten specimens in each sample), also have marine dinoflagellate species. *V. disjunctum* is absent from Benedek's younger samples which contain *Pediastrum*.

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VIII. APPENDIX

Species found during the present study in the Eocene of southern England are listed below in alphabetical order. Those shown with an asterisk are not included on the range charts. Plate and figure numbers are given for those species illustrated in the present paper.

Achilleodinium biformoides (Eisenack) Eaton
**Achilleodinium latispinosum* (Davey and Williams) comb. nov. Plate 8, figs. 7–9
**Achomosphaera alcicornu* (Eisenack) Davey and Williams
Achomosphaera membraniphora (Agelopoulos) Eaton
**Achomosphaera ramulifera* (Deflandre) Evitt
**Achomosphaera ramulifera* subsp. *perforata* (Davey and Williams) Lentin and Williams. Plate 5, fig. 1
**Achomosphaera sagena* Davey and Williams
Adnatosphaeridium multispinosum Williams and Downie. Plate 3, figs. 10–11
Adnatosphaeridium robustum (Morgenroth) De Coninck
Adnatosphaeridium vittatum Williams and Downie
Apectodinium homomorphum (Deflandre and Cookson) Lentin and Williams
**Apectodinium homomorphum* subsp. *quinquelatum* (Williams and Downie) Lentin and Williams
Araneosphaera araneosa Eaton. Plate 6, figs. 4–5
Areoligera coronata (O. Wetzel) Lejeune-Carpentier
Areoligera cf. *A. coronata* (O. Wetzel) Lejeune-Carpentier, *sensu* Williams and Downie, 1966*b*
Areoligera medusettiformis (O. Wetzel) Lejeune-Carpentier
Areoligera cf. *A. medusettiformis* (O. Wetzel) Lejeune-Carpentier, *sensu* Williams and Downie, 1966*b*
Areoligera senonensis Lejeune-Carpentier
Areoligera cf. *A. senonensis* Lejeune-Carpentier, *sensu* Williams and Downie, 1966*b*
Areoligera sentosa Eaton. Plate 9, figs. 4–5
Areoligera tauloma Eaton. Plate 9, figs. 1–2
Areoligera undulata Eaton. Plate 9, figs. 7–8
Areosphaeridium arcuatum Eaton. Plate 2, fig. 6
Areosphaeridium diktyoplokus (Klumpp) Eaton
Areosphaeridium fenestratum Bujak. Plate 13, figs. 1–2
Areosphaeridium multicornutum Eaton
Cannosphaeropsis reticulensis Pastiels, *sensu* Williams and Downie, 1966*b*
Ceratiopsis depressa (Morgenroth) Lentin and Williams. Plate 13, fig. 3
**Ceratiopsis wardenensis* (Williams and Downie) comb. nov. Plate 11, fig. 3
Cerebrocysta bartonensis Bujak, sp. nov. Plate 13, figs. 4–11
Chiropteridium aspinatum (Gerlach) Brosius. Plate 13, fig. 12
Chiropteridium cf. *C. dispersum* Gocht, *sensu* Eaton, 1976
Chytroeisphaeridia explanata Bujak, sp. nov. Plate 13, figs. 13–14
*'*Cleistosphaeridium disjunctum*' Davey *et al.* Plate 8, figs. 1–2
**Cleistosphaeridium diversispinosum* Davey *et al.* Plate 7, figs. 7–8
Cordosphaeridium cantharellum (Brosius) Gocht. Plate 13, fig. 15
Cordosphaeridium cracenospinosum Davey and Williams. Plate 7, fig. 9
**Cordosphaeridium divergens* (Eisenack) Eisenack. Plate 7, figs. 11–12
Cordosphaeridium exilimurum Davey and Williams. Plate 7, figs. 4–5
Cordosphaeridium fibrospinosum Davey and Williams. Plate 7, figs. 3, 6
Cordosphaeridium funiculatum Morgenroth. Plate 13, figs. 16–17
Cordosphaeridium gracile (Eisenack) Davey and Williams
Cordosphaeridium inodes (Klumpp) Eisenack
?*Cordosphaeridium minimum* (Morgenroth) Benedek
**Cordosphaeridium multispinosum* Davey and Williams. Plate 7, figs. 1–2
Cyclonephelium divaricatum Williams and Downie
Cyclonephelium exuberans Deflandre and Cookson. Plate 2, fig. 9
Cyclonephelium aff. *C. exuberans* Deflandre and Cookson, *sensu* Eaton, 1976
Cyclonephelium intricatum Eaton
Cyclonephelium laciniiforme Gerlach. Plate 9, figs. 3, 6
Cyclonephelium microfenestratum Bujak. Plate 14, fig. 1

Cyclonephelium ordinatum Williams and Downie
**Cyclonephelium pastielsii* Deflandre and Cookson
?*Cyclonephelium semitectum* Bujak, sp. nov. Plate 14, figs. 2–9
Cyclonephelium spinetum Eaton. Plate 9, figs. 10–11
Cyclonephelium textum Bujak. Plate 14, fig. 10
Cyclonephelium vicinum Eaton. Plate 9, figs. 9, 12
Dapsilidinium pastielsii (Davey and Williams) comb. nov. Plate 6, figs. 6, 9
Dapsilidinium simplex (White) comb. nov. Plate 14, figs. 11–12
Deflandrea denticulata Alberti
Deflandrea cf. *D. heterophlycta* Deflandre and Cookson, *sensu* Gocht, 1969. Plate 15, fig. 1
Deflandrea oebisfeldensis Alberti
Deflandrea phosphoritica Eisenack
**Deflandrea phosphoritica* subsp. *australis* Cookson and Eisenack
Deflandrea spinulosa Alberti. Plate 15, figs. 2–3
**Diacrocanthidium echinulatum* (Deflandre) Loeblich and Loeblich. Plate 15, fig. 4
Dinopterygium cladoides Deflandre, *sensu* Morgenroth, 1966*a*
Diphyes colligerum (Deflandre and Cookson) Cookson. Plate 6, figs. 7–8
Distatodinium craterum Eaton. Plate 2, figs. 10–11
Distatodinium ellipticum (Cookson) Eaton
Distatodinium paradoxum (Brosius) Eaton
?*Dracodinium condylos* (Williams and Downie) comb. nov. Plate 11, figs. 5–6
Dracodinium politum sp. nov. Plate 11, fig. 1
Eocladopyxis peniculatum Morgenroth. Plate 2, fig. 12
Gochtodinium simplex Bujak. Plate 15, fig. 5
Gochtodinium spinulum Bujak. Plate 15, fig. 6
Gonyaulacysta giuseppei (Morgenroth) Sarjeant
Hemisphaeridium fenestratum Bujak, sp. nov. Plate 15, figs. 7–9
Heteraulacacysta leptalea Eaton. Plate 10, fig. 7
Heteraulacacysta porosa Bujak, sp. nov. Plate 15, figs. 10–13
Homotryblium abbreviatum Eaton. Plate 1, figs. 7–9
Homotryblium caliculum Bujak, sp. nov. Plate 16, fig. 1
Homotryblium floripes (Deflandre and Cookson) Stover. Plate 16, figs. 2–3
Homotryblium oceanicum Eaton. Plate 1, figs. 10–12
Homotryblium pallidum Davey and Williams. Plate 1, figs. 1–3
Homotryblium tenuispinosum Davey and Williams. Plate 1, figs. 4–6
Homotryblium variabile Bujak, sp. nov. Plate 16, figs. 4–9
Hystrichokolpoma eisenackii Williams and Downie
**Hystrichokolpoma eisenackii* subsp. *turgida* (Williams and Downie) Lentin and Williams
Hystrichokolpoma granulata Eaton. Plate 3, figs. 4–6
Hystrichokolpoma rigaudiae Deflandre and Cookson
Hystrichokolpoma salacia Eaton. Plate 3, figs. 7–8
Hystrichokolpoma unispina Williams and Downie. Plate 3, figs. 1–3
?*Hystrichosphaeridium latirictum* Davey and Williams. Plate 8, figs. 4–5
Hystrichosphaeridium patulum Davey and Williams
Hystrichosphaeridium salpingophorum Deflandre
'*Hystrichosphaeridium sheppeyense*' Davey and Williams. Plate 2, figs. 1–2
Hystrichosphaeridium tubiferum (Ehrenberg) Deflandre
Hystrichosphaeridium tubiferum subsp. *brevispinum* (Davey and Williams) Lentin and Williams. Plate 8, figs. 10–12
?*Hystrichosphaeropsis rectangularis* Bujak, sp. nov. Plate 16, figs. 10–12
Impletosphaeridium cracens Eaton. Plate 5, fig. 4
Impletosphaeridium implicatum Morgenroth
Impletosphaeridium insolitum Eaton. Plate 5, fig. 5
Impletosphaeridium kroemmelbeinii Morgenroth
Impletosphaeridium luxurium Eaton. Plate 5, fig. 6
Impletosphaeridium rugosum Morgenroth
Kisselovia coleothrypta (Williams and Downie) Lentin and Williams. Plate 12, figs. 7–8

Kisselovia insolens Eaton. Plate 11, fig. 4
Kisselovia reticulata (Williams and Downie) Lentin and Williams. Plate 12, figs. 4–6
Kisselovia tenuivirgula (Williams and Downie) Lentin and Williams. Plate 11, fig. 2; Plate 12, figs. 1–3
**Kisselovia tenuivirgula* subsp. *crassoramosa* (Williams and Downie) Lentin and Williams
Kisselovia variabilis Bujak, sp. nov. Plate 17, figs. 1–6
Lanternosphaeridium axiale (Eisenack) Morgenroth
Lanternosphaeridium lanosum Morgenroth
Lanternosphaeridium radiatum Morgenroth
Lanternosphaeridium vectense Eaton. Plate 7, fig. 10
Lejeunia cinctoria Bujak, sp. nov. Plate 18, figs. 1–4
Lejeunia hyalina Gerlach. Plate 18, figs. 5–6
Lentinia serrata Bujak, sp. nov. Plate 18, figs. 7–12
Lentinia wetzelii (Morgenroth) Bujak, comb. nov.
Leptodinium incompositum (Drugg) Lentin and Williams. Plate 19, figs. 1–2
**Leptodinium membranigerum* Gerlach
Lingulodinium machaerophorum (Deflandre and Cookson) Wall
Melitasphaeridium asterium (Eaton) comb. nov. Plate 2, fig. 3
Melitasphaeridium pseudorecurvatum (Morgenroth) comb. nov. Plate 2, figs. 1–2
'*Membranilarnacia reticulata*' Williams and Downie. Plate 10, figs. 3–4
Membranilarnacia ursulae (Morgenroth) De Coninck. Plate 10, figs. 1–6
**Oligosphaeridium complex* (White) Davey and Williams
Operculodinium centrocarpum (Deflandre and Cookson) Wall
Palaeocystodinium golzowense Alberti
Paucisphaeridium inversibuccinum (Davey and Williams) comb. nov. Plate 2, figs. 4–5
Pentadinium laticinctum Gerlach
**Perisseiasphaeridium pannosum* Davey and Williams. Plate 2, figs. 7–8
Phthanoperidinium alectrolophum Eaton. Plate 5, fig. 9; Plate 19, figs. 3–4
Phthanoperidinium comatum (Morgenroth) Eisenack and Kjellström. Plate 5, figs. 7–8; Plate 19, figs. 5–6.
Phthanoperidinium echinatum Eaton. Plate 5, figs. 10–12; Plate 19, fig. 7
Phthanoperidinium geminatum Bujak, sp. nov. Plate 19, figs. 8–12
Phthanoperidinium levimurum Bujak, sp. nov. Plate 19, figs. 13–16
Phthanoperidinium multispinum Bujak, sp. nov. Plate 19, figs. 17–19
?*Phthanoperidinium pseudoechinatum* Bujak, sp. nov. Plate 19, fig. 20
'*Phthanoperidinium tritonium*' Eaton. Plate 5, figs. 7–8
Polysphaeridium congregatum (Stover) comb. nov. Plate 20, figs. 1–3
Polysphaeridium subtile Davey and Williams. Plate 3, figs. 9, 12
Psaligonyaulax simplicia (Cookson and Eisenack) Sarjeant. Plate 20, figs. 4–5
**Quadrina pallida* Bujak, sp. nov. Plate 22, figs. 9–11
Rhombodinium draco Gocht. Plate 20, fig. 6
Rhombodinium longimanum Vozzhennikova. Plate 20, fig. 7
Rhombodinium porosum Bujak. Plate 20, fig. 8
Rottnestia borussica (Eisenack) Cookson and Eisenack. Plate 20, figs. 9–10
Samlandia chlamydophora Eisenack
Samlandia reticulifera Cookson and Eisenack. Plate 20, figs. 11–12
Selenopemphix armata Bujak, sp. nov. Plate 21, figs. 1–3
Selenopemphix coronata Bujak, sp. nov. Plate 21, figs. 4–5
Selenopemphix nephroides Benedek. Plate 21, fig. 6
Selenopemphix selenoides Benedek. Plate 21, figs. 7–8
**Spiniferites cingulatus* (O. Wetzel) Sarjeant
Spiniferites cornutus (Gerlach) Sarjeant. Plate 4, figs. 9, 12; Plate 21, fig. 9
**Spiniferites crassipellis* (Deflandre and Cookson) Sarjeant
**Spiniferites membranaceus* (Rossignol) Sarjeant
**Spiniferites mirabilis* (Rossignol) Sarjeant. Plate 21, fig. 10
Spiniferites monilis (Davey and Williams) Sarjeant. Plate 4, figs. 7–8
**Spiniferites perforatus* (Davey and Williams) Sarjeant. Plate 5, figs. 2–3
Spiniferites pseudofurcatus (Klumpp) Sarjeant
**Spiniferites ramosus* subsp. *gracilis* (Davey and Williams) Lentin and Williams. Plate 4, figs. 1–2

**Spiniferites ramosus* subsp. *granomembranaceus* (Davey and Williams) Lentin and Williams. Plate 4, figs. 10–11
**Spiniferites ramosus* subsp. *granosus* (Davey and Williams) Lentin and Williams. Plate 4, figs. 4–5
**Spiniferites ramosus* subsp. *multibrevis* (Davey and Williams) Lentin and Williams. Plate 4, figs. 3, 6
**Spiniferites ramosus* subsp. *ramosus* (Ehrenberg) Loeblich and Loeblich
Systematophora placacantha (Deflandre and Cookson) Davey *et al.* Plate 21, figs. 11–12
Tanyosphaeridium regulare Davey and Williams. Plate 8, figs. 3, 6
Tectatodinium pellitum Wall. Plate 22, fig. 1
Tenua microcysta Bujak, sp. nov. Plate 22, figs. 2–5
Thalassiphora delicata Williams and Downie. Plate 10, fig. 8
**Thalassiphora patula* (Williams and Downie) comb. nov.
Thalassiphora pelagica (Eisenack) Eisenack and Gocht
**Thalassiphora velata* (Deflandre and Cookson) Eisenack and Gocht
Turbiosphaera galatea Eaton. Plate 6, figs. 1–2
Turbiosphaera magnifica Eaton. Plate 6, fig. 3
Turbiosphaera symmetrica Bujak, sp. nov. Plate 22, figs. 6–8
Veryhachium disjunctum Bujak, sp. nov. Plate 22, fig. 12
Wetzeliella articulata Eisenack
**Wetzeliella articulata* subsp. *conopia* (Williams and Downie) Lentin and Williams
Wetzeliella lunaris Gocht
Wetzeliella meckelfeldensis Gocht
Wetzeliella cf. *W. meckelfeldensis* Gocht
**Wetzeliella ovalis* Eisenack
Wetzeliella similis Eisenack
Wetzeliella symmetrica Weiler
**Wetzeliella symmetrica* subsp. *lobisca* (Williams and Downie) Lentin and Williams
**Wetzeliella varielongituda* Williams and Downie