New dinocyst taxa from the Eocene of the North Sea

J. P. BUJAK
The Lexis Group, 9 Albion Avenue, Blackpool, Lancashire FY3 8NA, UK.

ABSTRACT - Dinoflagellate cysts (dinocysts) are abundant in the Eocene of the North Sea and provide a high-resolution biostratigraphic zonation. Twelve species are erected to accommodate zonal markers that have not been previously described. These are Areosphaeridiurn ebdonii, Areosphaeridiurn michoudii, Cerebrocysta magna, Diphyes brevispinurn, Diphyes pseudospiculoides, Hystrichosphaeropsis costae, Hystrichostrogonio clausenii, Membranilarnacia compressa, Phthanoperidinium clithridium, Phthanoperidinium distinctum, Phthanoperidinium powellii and Phthanoperidinium regalis. J. Micropalaeontol. 13(2): 119-131, December 1994.

INTRODUCTION
Bujak & Mudge (1994) defined eight dinocyst zones and 23 subzones for the Eocene of the North Sea based on last occurrence or abundance events (Fig. 1), which were observed in more than 150 wells examined from Quadrant 3 in the north to Quadrants 21 and 22 in the south. Many of the zonal markers also occur in northwest European stratotypes and reference sections, permitting correlation with standard nannoplankton (NP) zonal assignments made for these sections, of significance because few Eocene NP index species occur in North Sea wells.

Mudge & Bujak (1994) defined five North Sea Eocene stratigraphic sequences and eight subevents bounded by high gamma log peaks, based on the examination of over 750 released wells from Quadrant 3 to Quadrants 21 and 22. They demonstrated that each sequence and subsequence boundary consistently falls within the same dinocyst subzone, giving a high degree of confidence that these boundaries represent time lines.

Twelve dinocyst taxa used to define the zones and subzones erected by Bujak & Mudge (1994) have not been previously described, although some have been informally illustrated from northwest Germany, Belgium and Denmark. The purpose of this paper is to formally describe these taxa in order to provide the taxonomic framework needed for the North Sea Eocene dinocyst scheme proposed by Bujak & Mudge (1994).

MATERIAL
All of the illustrated material is from ditch cuttings, sidewall core or conventional core samples recovered from North Sea wells operated by various companies. Palynological slides containing the type material from the UK22/9-1, UK22/14-1 and UK22/16-1 wells are curated at the British Geological Survey, Keyworth. Palynological slides containing the type material from the UK15/13-2 and UK16/1a-1 wells are curated at BP Operating Company, Aberdeen. Palynological slides containing the type material from the UK21/28a-4, UK21/28a-5 and UK21/28a-6 wells are curated at Simon Petroleum Technology Limited, Llandudno. Palynological slides from all other wells were donated for curation at the Natural History Museum, London, by Chevron UK Limited, Conoco (UK) Limited, Oryx UK Energy, Shell UK Exploration and Production, Sun International Exploration and Production, Total Oil Marine plc, and Unocal UK Limited.

SYSTEMATICS
Division Dinoflagellata (Bütschli) Fensome et al., 1993
Class Dinophyceae Pascher, 1914
Order Gonyaulacales Taylor, 1980
Family Gonyaulacaceae Lindemann, 1928
Genus Areosphaeridiurn Eaton, 1971

Remarks. Stover & Williams (in press) reviewed the morphology of species that had been assigned to Areosphaeridiurn and emended its diagnosis, placing particular emphasis on the number and distribution of processes on the hypocyst. They distinguished two groups of species previously assigned to Areosphaeridiurn based on the hypocystal paratabulation. The hypocyst on Areosphaeridiurn dityiaplopus (Klump) Eaton and Areosphaeridiurn fenestraturn Bujak typically has seven processes on paraplates 5", 1p and 1"", arranged in the standard sexiform pattern. Stover & Williams retained these species in Areosphaeridiurn, which has a confirmed stratigraphic range of late Ypresian to Priabonian, according to Stover & Williams (in press).

Stover & Williams (in press) erected the genus Enneadocysta to accommodate the second group of species, previously assigned to Areosphaeridiurn, which have a partiform hypocyst configuration, with processes on paraplates 6", 2" and 1 ps. They designated Enneadocysta pectiniformis (Gerlach) Stover & Williams as the types species. Enneadocysta has a confirmed stratigraphic range of early Lutetian to Rupelian, according to Stover & Williams (in press).

Areosphaeridiurn ebdonii sp. nov.
(Plate 2, figs 8–9)

Derivation of name. Named after the palynologist Christopher Ebdon.

Diagnosis. Cysts skolochorate with subspherical bodies comprising an autophragm. Body typically with 17 intratabular processes, ten on the epicyst and seven on the
| Time (Ma) | Series | Stage | Nanoo Biozone | Program Biozone | North Sea Dinocyst Zonation of Bujak & Mudge (in press) | Last Occurrence Events |
|----------|--------|-------|---------------|----------------|-------------------------------------------------------|-----------------------|
| 35       | L.Olig | RUP   | NP22          | P18            | not defined                                           | A. diktypoklos         |
| 40       | U.Eocene | Pr Eoc | NP21          | P17            | A. diktypoklos (E8)                                   | A. michoudii           |
| 45       | U.Eocene | Pr Eoc | NP19          | P16            | E8a                                                   | H. porosa, R. porosum  |
|          |        |       |               |                |                                                       | R. borussica           |
|          |        |       | NP18          | P15            | E8b                                                   | A. sentosa, A. tauloma |
| 50       | M.Lutet | Barton | NP17          | P14            | E7b                                                   | consistent D. colligerum, R. rhomboideum |
|          |        |       |               |                |                                                       | P. distinctum, P. powelli, S. placacantha O |
|          |        |       | NP16          | P13            | E7a                                                   | D. pseudoficusoides     |
|          |        |       |               |                |                                                       | S. placacantha          |
|          |        |       | NP15          | P12            | E6c                                                   | A. ebdoni, P. clithridium, P. regalis |
|          |        |       |               |                |                                                       | consistent C. depressum, D. ficusoides, G. exuberans, consistent T. delicta |
|          |        |       | NP14          | P11            | E6b                                                   | A. vittatum, S. placacantha |
|          |        |       |               |                |                                                       | A. polypetellum, C. magna, G. ordinata |
|          |        |       |               |                |                                                       | H. tubiferum, H. costae |
|          |        |       |               |                |                                                       | H. clausenii            |
|          |        |       |               |                |                                                       | W. articulata brevicornuta |
|          |        |       |               |                |                                                       | D. pachydermum          |
|          |        |       |               |                |                                                       | E. ursulae, D. pachydermum |
|          |        |       |               |                |                                                       | E. ursulae, M. glabra   |
|          |        |       |               |                |                                                       | C. columna D. brevispinum |
|          |        |       |               |                |                                                       | M. compressa, M. glabra, H. tenispinosum |
|          |        |       |               |                |                                                       | M. furesins, A. medusettiformis |
|          |        |       |               |                |                                                       | A. medusettiformis, consistent D. variolongitudum |
|          |        |       |               |                |                                                       | consistent D. condylus, consistent D. politum, D. similis, D. variolongitudum O |
|          |        |       |               |                |                                                       | D. similis, D. solidum, consistent D. eobifeldensis |
|          |        |       |               |                |                                                       | E1c: H. tubiferum       |
|          |        |       |               |                |                                                       | E1b: consistent C. wardense, D. eobifeldensis, G. ordinata O |
|          |        |       |               |                |                                                       | C. wardense             |
|          |        |       |               |                |                                                       | C. dartmoorum, C. speciosum, P. magnificum |
|          |        |       |               |                |                                                       | A. augustum             |

Fig. 1. The North Sea Eocene dinocyst zonation of Bujak & Mudge (1994)

hypocyst; areas between process bases smooth, or indistinctly ornamented, or finely and irregularly granulate. Processes less than 15 μm in length. Process stems solid, with proximal fibrous ends expanded slightly and merging smoothly with the autophagm surface. Process stems expanded distally into vasiform or infundibular, fenestrate to reticulate process platforms with irregular to circular outlines. On some specimens the vasiform or infundibular distal terminations have irregular or entire margins. The processes reflect a paratabulation of 4', 6'', 0c, 5", 1"", 0s, with the hypocyst paratabulation following the standard sexiform pattern. Paracingulum typically expressed by the absence of processes, but one or two narrow paracingular processes may be present. Parasulcal processes absent although a medial parasutural notch is frequently discernible. Archeopyle apical; operculum tetraplocoid, contiguous.

Type locality and stratum. Locality: North Sea, UK22/14-1
well. Stratum: section at 8020 ft, Early Eocene (Ypresian).

**Holotype.** UK22/14-1, 8020 ft (ditch cuttings), England Finder coordinates D44/4, illustrated in Plate 2, figs 8–9, curated at the British Geological Survey, Keyworth, slide number MPK 9725.

**Paratype.** UK22/14-1, 8020 ft (ditch cuttings), England Finder coordinates U49/3, curated at the British Geological Survey, Keyworth, slide number MPK 9726.

**Dimensions.** Central body length (without operculum) 47–53 μm, breadth 40–48 μm, maximum process length 10–12 μm.

**Observed stratigraphic range.** North Sea dinocyst zones: E3c to E5a of Bujak & Mudge (1994) (Early to Middle Eocene: Ypresian to Lutetian).

**Remarks.** *A. ebdonii* is distinguished from other species of *Aresophysidium* by its short processes.

*Aresophysidium michoudii* sp. nov.

(Plate 1, figs 1–3)

**Derivation of name.** Named after the palynologist Daniel Michoux.

**Diagnosis.** Cysts skolochorate with subspherical bodies comprising an autophragm. Central body diameter typically greater than 50 μm. Body typically with 17 intratabular processes, ten on the epicyst and seven on the hypocyst: areas between process bases smooth, or indistinctly ornamented, or finely and irregularly granulate. Process stems solid, with proximal fibrous ends expanded slightly and merging smoothly with the autophragm surface. Process stems expanded distally, and forming recurved or straight distal bifurcations. The distal margin of the bifurcations are digitate or bear completely or partially developed fenestrations which are restricted to a band lying along the bifurcations. The processes reflect a paratabulation of 4°, 6°, 0°, 5°, 1°, 1°, 0°, with the hypocyst paratabulation following the standard sexiform pattern. Paracircularly typically expressed by the absence of processes. Parasulcal processes absent although a medial parasutural notch is frequently discernible. Archeopyle apical; opital processes absent although a paraplate 5°, lp, l°°, Os, with the hypocyst paratabulation following the standard sexiform pattern. Paraplate 3°.

**Type locality and stratum.** Locality: North Sea, UK21/28a-7 well. Stratum: section at 3900 ft, Middle Eocene (Lutetian).

**Holotype.** UK21/28a-7, 3900 ft (ditch cuttings), England Finder coordinates X17/0, illustrated in Plate 1, figs 1–2, curated at The Natural History Museum, London, slide number FD 513(1).

**Paratypes.** UK21/28a-7, 3900 ft (ditch cuttings), England Finder coordinates V30/3, curated at The Natural History Museum, London, slide number FD 513(3); UK16/16b-4, 6040 ft (ditch cuttings), England Finder coordinates U39/3, curated at The Natural History Museum, London, slide number FD 524(1).

**Dimensions.** Central body length (without operculum) 50–58 μm, breadth 56–63 μm, maximum process length 35–40 μm.

**Observed stratigraphic range.** North Sea dinocyst zones: E2c to E4c of Bujak & Mudge (1994) (Early to Late Eocene: Ypresian to Priabonian).

**Remarks.** *A. michoudii* is distinguished from all other species of *Aresophysidium* by its distally bifid processes which lack fenestrate or reticulate process platforms. The process terminations on *A. michoudii* are similar to those on several species of *Enneadocysta*, including *E. arcuata* (Eaton) Stover & Williams and *E. multicornuta* (Eaton) Stover & Williams which are common in the North Sea. *A. michoudii* differs from all species of *Enneadocysta* in having a sexiform hypocyst paratabulation reflected by a processes on paraplates 5°, 1° and 1°. Species of *Enneadocysta* have a partiform hypocyst paratabulation reflected by processes on paraplates 6°, 2° and ps.

Genus *Cerebrocysta* Bujak in Bujak et al., 1980

*Cerebrocysta magna* sp. nov.

(Plate 2, figs 10–11)

**Derivation of name.** Latin, *magnus*, large, with reference to the large cyst size.

**Diagnosis.** Autocyst spherical to ovoidal, without apical, antapical or other projections, except for an apparently random ornament of low crests which give the cyst a cerebral appearance. The crests occasionally suggest a paratabular arrangement. Cyst diameter always exceeding 40 μm. Archeopyle formed by the loss of precingular paraplate 3°.

**Type locality and stratum.** Locality: North Sea, UK21/28a-5 well. Stratum: section at 4619 ft, Middle Eocene (Lutetian).

**Holotype.** UK21/28a-5, 4619 ft (conventional core), England Finder coordinates V38/2, illustrated in Plate 2, fig. 10, curated at Simon Petroleum Technology Limited, Llandudno.

**Paratypes.** UK16/17-3, 6830 ft (ditch cuttings), England Finder coordinates N47/0, curated at The Natural History Museum, London, slide number FD 514(1); UK16/26-2, 7030 ft (ditch cuttings), England Finder coordinates F27/3, illustrated in Plate 2, fig. 11, curated at The Natural History Museum, London, slide number FD 515(1).

**Dimensions.** Cyst length 49–59 μm, breadth 46–63 μm.

**Observed stratigraphic range.** North Sea dinocyst zones: E2c to E4c of Bujak & Mudge (1994) (Early to Middle Eocene: Ypresian to Lutetian).

**Remarks.** The genus *Cerebrocysta* was erected by Bujak (1980) for specimens present in the Barton Beds of the Hampshire Basin, with the type species, *C. bartonensis* Bujak, having a cyst diameter ranging from 24–28 μm (Plate 2, fig. 12). *C. bartonensis* is persistently present in fairly low numbers in the North Sea where it has its highest occurrence in Bartonian Subzone E7a of Bujak & Mudge (1994). *C. magna* is identical to *C. bartonensis* in all respects except for its larger size, and there is no indication that the two species intergrade. *C. magna* has a more restricted stratigraphic range in the North Sea, having its highest occurrence at the top of Lutetian Subzone E4c of Bujak & Mudge (1994).

Genus *Diphyes* Cookson, 1965

*Diphyes brevispinum* sp. nov.

(Plate 2, figs 4–6)
Plate 1
New dinocyst taxa

Derivation of name. Latin, brevis, short, plus spina, thorn, with reference to the short processes.

Diagnosis. Cyst subspherical, skolochorate and biphragmal, endophragm and periphragm adpressed except beneath the processes. Periphragm smooth to chagrinate, forming numerous nontabular processes. Processes other than the antapical process less than 5 μm in length, tubular, tapering from broader circular bases to narrow, open or closed terminations. Antapical process large, inflated, ovoidal to subspherical, with a closed circular base, and a constricted distal opening. Archeopyle apical; operculum tetraplacoid, contiguous.

Type locality and stratum. Locality: North Sea, UK21/28a-4 well. Stratum: section at 4580 ft, Early Eocene (Ypresian).

Holotype. UK21/28a-4, 4580 ft (sidewall core), England Finder coordinates R46/3, illustrated in Plate 2, figs 4–5, curated at Simon Petroleum Technology Ltd, Llandudno.

Paratypes. UK21/28a-4, 4567 ft (sidewall core), England Finder coordinates K38/0, illustrated in Plate 2, fig. 6, curated at Simon Petroleum Technology Limited, Llandudno; UK21/28a-4, 4567 ft (sidewall core), England Finder coordinates M47/3, curated at Simon Petroleum Technology Limited, Llandudno.

Dimensions. Central body length (without operculum) 22–28 μm, breadth 27–31 μm, antapical process length 17–20 μm, breadth 15–25 μm, maximum process length (excluding the antapical process) 2.5–4 μm.

Observed stratigraphic range. North Sea dinocyst zones: E3a to E3b of Bujak & Mudge (1994) (Early Eocene: Ypresian).

Remarks. D. brevispinum is intermediate in morphology between D. ficusoides Islam and Duosphaeridiurn nudum (Cookson) Loeblich & Loeblich. D. nudum does not possess processes except for the large antapical process, whereas D. ficusoides has processes that typically vary in length between 11–15 μm. D. brevispinum has a more restricted North Sea stratigraphic range than D. ficusoides which ranges up into Lutetian Subzone E4d of Bujak & Mudge (1994). D. nudum is rare in North Sea wells (Bujak, pers. obs.), and has approximately the same stratigraphic range as D. brevispinum.

Diphyes pseudoficusoides sp. nov.
(Plate 2, figs 2–3)

Derivation of name. Greek, pseudos, false, plus ficusoides, with reference to the similarity to, but distinction from Diphyes ficusoides.

Diagnosis. Cyst subspherical, skolochorate and biphragmal, endophragm and periphragm adpressed except beneath the processes. Periphragm smooth to chagrinate, forming numerous nontabular processes. Processes greater than 10 μm in length; processes other than the antapical process tubular, tapering from broad circular bases to narrow necks before ending in expanded, distally aculate or entire terminations. Antapical process expanded, having a maximum breadth of between 10 μm and 15 μm, and tapering distally to a constricted termination that is typically open. Archeopyle apical; operculum tetraplacoid, contiguous.

Type locality and stratum. Locality: North Sea, UK15/30-4 well. Stratum: section at 5760 ft, Middle Eocene (Lutetian).

Holotype. UK15/30-4, 5760 ft (ditch cuttings), England Finder coordinates R46/3, illustrated in Plate 2, fig. 3, curated at The Natural History Museum, London, slide number FD 526(1).

Paratypes. UK15/30-2, 6080 ft (ditch cuttings), England Finder coordinates L47/2, illustrated in Plate 2, fig. 2, curated at The Natural History Museum, London, slide number FD 525(1); UK22/14-1, 7780 ft (ditch cuttings), England Finder coordinates H39/0, curated at the British Geological Survey, Keyworth, slide number MPK 9718.

Dimensions. Central body length (without operculum) 29–34 μm, breadth 27–40 μm, antapical process length 13–21 μm, breadth 10–15 μm, maximum process length (excluding the antapical process) 12–17 μm.

Observed stratigraphic range. North Sea dinocyst zones: E2b to E6a of Bujak & Mudge (1994) (Early to Middle Eocene: Ypresian to Lutetian).

Remarks. D. pseudoficusoides is distinguished from other species of Diphyes by its antapical process, which is intermediate in morphology between that on D. colligerum and D. ficusoides. The antapical process on D. colligerum typically varies in breadth between 6–8 μm, whereas that on D. ficusoides varies in breadth between 18–28 μm.

D. colligerum, D. pseudoficusoides and D. ficusoides have different stratigraphic ranges in the North Sea, where their last occurrences are zonal markers within the Eocene (Bujak & Mudge, 1994). D. colligerum has a last consistent occurrence at the top of Subzone E6c of Bujak & Mudge (1994), near the Lutetian–Bartonian boundary, but ranges up sporadically in the North Sea into the late Priabonian. D. pseudoficusoides has its last occurrence at the top of Lutetian Subzone E6a of Bujak & Mudge (1994), and D. ficusoides has its last occurrence at the top of Lutetian

Explanation of Plate 1

Magnification bar represents 20 μm for all specimens. Figs 1–3. Areospheeridiurn michoudii sp. nov. Figs 1-2. Holotype. UK21/28b-7, 3900 ft, showing the sexiform hypostomal process arrangement: fig. 1, lower dorsal surface; fig. 2, upper ventral surface. Fig. 3. Isolated operculum. UK21/28b-7, 3900 ft. Figs 4–6. HystrichostrogyIon clauseni sp. nov. Holotype. UK21/28b-7, 3900 ft: fig. 4, lower dorsal surface, showing the archepyle formed by the loss of two precingular paraplates; fig. 5, optical section, showing the claustrum developed on the left cingular-postcingular side of the periphragm; fig. 6, upper ventral surface.
Subzone E4d of Bujak & Mudge (1994). D. ficsoides and 
D. pseudoficusoides have their first North Sea occurrences in 
the early Ypresian, whereas D. colligerum ranges down in 
the Palaeocene in the North Sea Basin.

Genus Hystrichosphaeropsis Deflandre, 1935

Hystrichosphaeropsis costae sp. nov.

(Plate 3, figs 1–4)

1989 Hystrichosphaeropsis sp. 1 Heilmann-Clausen & Costa: 
467, pl. 17, figs 1–4, 6–8.

1993 Hystrichosphaeropsis sp. Heilmann-Clausen: 98, 
text-figs 5C–D.

Derivation of name. Named after the palynologist Lucy 
Costa.

Diagnosis. A species of Hystrichosphaeropsis with a 
weakly developed apical horn, and without antapical horns 
but with a well-developed antapical pericoel. Endophragm 
and periphragm smooth to chagrinate. Low, perforate or 
unperforate parasutural crests variably and incompletely 
developed, and typically absent from the paracingular 
region. Low, simple or bifid gonal processes may be 
present near the antapex in the postcingular periphragm. 
Archeopyle precingular, formed by the loss of paraplate 
3°.

Type locality and stratum. Locality: North Sea, UK22/14-1 
well. Stratum: section at 8020 ft, Early Eocene (Ypresian).

Holotype. UK22/14-1, 8020 ft (ditch cuttings), England 
Finder coordinates P36/2, illustrated in Plate 3, figs 1–3, 
curated at the British Geological Survey, Keyworth, slide 
number MPK 9719.

Paratypes. UK22/14-1, 8020 ft (ditch cuttings), England 
Finder coordinates L50/1, illustrated in Plate 3, fig. 4; 
UK22/14-1, 8020 ft (ditch cuttings), England Finder 
coordinates R64/3; UK22/14-1, 8020 ft (ditch cuttings), 
England Finder coordinates M35/2; UK22/14-1, 8020 ft 
(ditch cuttings), England Finder coordinates J47/4. All 
paratypes curated at the British Geological Survey, 
Keyworth, slide numbers MPK 9720 to 9723.

Dimensions. Percyst length 56–75 μm, breadth 40–55 μm, 
edocyst length 32–49 μm, breadth 36–51 μm, maximum 
process length 3–5 μm.

Observed stratigraphic range. North Sea dinocyst zones: 
E3a to E4c of Bujak & Mudge (1994) (Early to Middle 
Eocene: Ypresian to Lutetian).

Remarks. H. costae is distinguished from Rottnestia 
borussica (Eisenack) in possessing poorly developed 
parasutural crests, and in having processes that are absent 
or restricted to the paracingular region and which are 
much shorter than those on R. borussica (typical process 
length on R. borussica is greater than 10 μm). H. costae 
differs from Hystrichosphaeropsis? rectangularis Bujak in 
having less well-developed parasutural crests.

H. costae is considered to be conspecific with Hystrichosphaeropsis sp. 1, which Heilmann-Clausen & 
Costa (1989) described from the Wursterheide research well, 
northwest Germany, within the Glinde Formation, assigned 
to NP14 in their table 1. This informal species was also 
described from both the German Wursterheide research 
well and the Hinge section in Denmark as Hystrichosphaeropsis sp. by Heilmann-Clausen (1993). 
Heilmann-Clausen documented a morphological series from 
R. borussica to Hystrichosphaeropsis sp. and suggested that 
Hystrichosphaeropsis sp. was descended from R. borussica.

Genus Hystrichostrogylon Agelopoulos, 1964

Hystrichostrogylon clausenii sp. nov.

(Plate 1, figs 4–6)

1989 Hystrichostrogylon sp. 1 Heilmann-Clausen & Costa: 
468, pl. 18, figs 5, 6, 8, 9.

Derivation of name. Named after the palynologist Claus 
Heilmann-Clausen.

Diagnosis. Endocyst smooth with a circular outline. 
Periphragm smooth to chagrinate, compressed dorso-
ventrally, forming a high membrane surrounding the 
ambital periphery of the cyst, except in the mid-dorsal and 
mid-ventral regions where the periphragm and endophragm 
are in contact. Trifurcate and occasional bifurcate 
processes extend a short distance above the periphragm, 
except on the right lateral side of the cyst where the 
height of the periphragm is reduced and the length of the 
processes extending beyond the membrane is increased. 
A claustrum is typically developed on the left cingular-
postcingular side of the periphragm. Archeopyle precingular, 
formed by the loss of paraplate 3° and sometimes also 
paraplates 2° and/or 4°.

Type locality and stratum. Locality: North Sea, UK21/28b-
7 well. Stratum: section at 3900 ft, Middle Eocene 
(Lutetian).

Holotype. UK21/28b-7, 3900 ft (ditch cuttings), England 
Finder coordinates G23/0, illustrated in Plate 1, figs 4–6, 
curated at The Natural History Museum, London, slide 
number FD 513(2).

Paratype. UK21/28a-6, 4320 ft (ditch cuttings), England

---

**Explanation of Plate 2**

Magnification bar represents 20 μm for all specimens. **Fig. 1.** Diphys ficsoides Islam. Holotype shown for comparison with Diphys pseudoficusoides and Diphys brevispinum. **Figs 2-5.** Diphys pseudoficusoides sp. nov.: fig. 2, paratype. UK15/30-2, 6080 ft; fig. 3, holotype. UK15/30-4, 5760 ft. **Figs 6-11.** Diphys brevispinum sp. nov.: figs 4–5 Holotype. UK21/28a-4, 4580 ft; fig. 4, lower, oblique antapical view; fig. 5, upper, oblique apical view; fig. 6, paratype. UK21/28a-4, 4567 ft. **Fig. 7.** Diphys colligerum (Deflandre & Cookson) Cookson. UK21/28b-7, 3676 ft. Shown for comparison with Diphys pseudoficusoides. **Figs 8–9.** Areosphaeridiurn ebdoni sp. nov. Holotype. UK22/14-1, 8020 ft; fig. 8, lower surface; fig. 9, upper surface. **Figs 10–11.** Cerebrocysta magna sp. nov.: fig. 10, holotype, lower dorsal surface. UK21/28a-5, 4619 ft, fig. 11, paratype, upper surface. UK16/26-2, 7030 ft. **Fig. 12.** Cerebrocysta bartonensis Bujak. UK21/28b-7, 3960 ft. Shown for comparison with Cerebrocysta magna.
New dinocyst taxa

Finder coordinates Q32/3, curated at Simon Petroleum Technology Limited, Llandudno.

**Dimensions.** Pericyst length 63–73 µm, breadth 63–75 µm, endocyst length 32–41 µm, breadth 31–40 µm.

**Observed stratigraphic range.** North Sea dinocyst zones: E3c to E4c of Bujak & Mudge (1994) (Early to Middle Eocene: Ypresian to Lutetian).

**Remarks.** H. clauseni is considered to be conspecific with *Hystrichosphaeropsis* sp. 1, which Heilmann-Clausen & Costa (1989) described from the Wursterheide research well, northwest Germany, within the Glinde Formation, assigned to NP14 in their table 1.

**Genus Membranilarnacia** Eisenack, 1963

**Membranilarnacia compressa** sp. nov. (Plate 3, figs 5–6)

1975 *Membranilarnacia* sp. A De Coninck 1975: 94, pl. 16, figs 17–19; pl. 17, fig 1.

1989 *Membranilarnacia* sp. A Heilmann-Clausen & Costa 1989: pl. 11, figs 4, 8, 9.

**Derivation of name.** Latin, compressus, compressed, with reference to the compressed nature of the cyst resulting from the short processes.

**Diagnosis.** Endocyst subspherical to ovoidal; periphragm smooth to chagrinate, in contact with the endophragm except beneath the processes. Processes intratabular, solid or hollow, proximally and distally expanded, less than 15 µm in length. Processes supporting a continuous, smooth, entire, but rare specimens have been observed in the North Sea with a perforate ectophragm. These have the same stratigraphic range as specimens with an entire ectophragm, and they are included in *M. compressa*.

*M. compressa* has shorter processes than those on *Membranilarnacia glabra* Agelopoulos, which are typically 15–21 µm in length *M. glabra* last occurs in the North Sea at the top of Ypresian Subzone E3c of Bujak & Mudge (1994), whereas *M. compressa* last occurs at the top of Ypresian Subzone E3a of Bujak & Mudge (1994). Species of *Eatonicysta* Stover & Evitt differ from *M. compressa* in possessing an ectophragm that is reticulate, fenestrate or irregularly net-like.

*M. compressa* is considered to be conspecific with *Membranilarnacia* sp. A, which De Coninck (1975) illustrated from the Argile de Merelbeke in the Kallo borehole, Belgium, assigned to NP13 by Verbeek (1988). Heilmann-Clausen & Costa (1989) also recorded *Membranilarnacia* sp. A sensu De Coninck (1975) from the Ypresian Heiligen-Hafen Formation of the Wursterheide research well, northwest Germany, between sections assigned to NP12 and NP14.

Family Deflandraceae Eisenack, 1954

**Genus Phthanoperidinium** Drugg & Loeblich, 1967

**Remarks.** Islam (1982) emended the diagnosis of *Phthanoperidinium* to include three major types of archeopyle: (1) intercalary archeopyles involving paraplate 2a; (2) combination precingular-intercalary archeopyles involving paraplates 4" and 2a; (3) combination precingular-intercalary archeopyles involving paraplates 2–4" and 1–3a.

**Phthanoperidinium clithridium** sp. nov. (Plate 4, figs 1–3)

**Derivation of name.** Greek, kleithridion, small key-hole, with reference to the shape of the archeopyle.

**Diagnosis.** Pericyst ovoidal with one small apical horn and one or two unequal antapical horns, the right always being strongly reduced. Endocyst ovoidal, and in contact with the periphragm except sometimes beneath the apical and antapical horns. Periphragm chagrinate to granulate with or without extremely low parasutural crests. When present these partially delimit a paratabulation of 4′, 3a, 7" , xc, 5″, 2″. An archeopyle is always formed by the loss of paraplates 2a and 4".

**Type locality and stratum.** Locality: North Sea, UK16/16b-4 well. Stratum: section at 5900 ft, Middle Eocene (Lutetian).

**Holotype.** UK16/16b-4, 5900 ft (ditch cuttings), England Finder coordinates K36/4, illustrated in Plate 4, figs 1–2, 4–6.

**Explanation of Plate 3**

Magnification bar represents 20 µm for all specimens. *Figs 1–4: Hystrichosphaeropsis costae* sp. nov. *Figs 1–3.* Holotype. UK22/14-1, 8020 ft; fig. 1, lower surface; fig. 2, optical section; fig. 3, upper surface. *Fig. 4.* Paratype. UK22/14-1, 8020 ft. *Figs 5–6.* *Membranilarnacia compressa* sp. nov. Holotype. UK21/28b-7, 3960 ft; fig. 5, lower surface; fig. 6, upper surface. *Figs 7–9.* *Phthanoperidinium powelli* sp. nov.: fig. 7, paratype. UK16/16b-4, 5200 ft; figs 8, holotype. UK16/26-2, 6280 ft; fig. 9, paratype. UK16/17-2A, 6010 ft.
New dinocyst taxa

curated at The Natural History Museum, London, slide number FD 518(1).

**Paratypes.** UK16/16b-4, 5900 ft (ditch cuttings), England Finder coordinates P35/2, illustrated in Plate 4, fig. 3, curated at The Natural History Museum, London, slide number FD 518(2); UK16/16b-4, 6040 ft (ditch cuttings), England Finder coordinates P41/0, curated at The Natural History Museum, London, slide number FD 525(1).

**Dimensions.** Pericyst length 32–44 μm, breadth 27–40 μm, apical horn length less than 2 μm.

**Observed stratigraphic range.** North Sea dinocyst zones: E4c to E5a of Bujak & Mudge (1994) (Middle Eocene: Lutetian).

**Remarks.** *P. clithridium* is distinguished from all other species of *Phthanoperidinium* except *P. regalis* by the formation of an archeopyle involving the loss of paraplates 2a and 4”. The mode of archeopyle formation is identical in *P. clithridium* and *P. regalis* which differ in their ornament. *P. clithridium* does not possess the penitabular ornament present on *P. regalis* and has less well-defined parasutural ornament. Rare specimens intergrade between these taxa, but the majority of specimens comprise distinct morphological populations, which have different palaeogeographic distributions in the North Sea (Bujak, pers. obs.). *P. clithridium* has not been recorded outside the North Sea region.

*Phthanoperidinium distinctum* sp. nov.  
(Plate 4, figs 7–12)

**Derivation of name.** Latin, distinctus, distinct, with reference to the distinctive morphology of the cyst.

**Diagnosis.** Pericyst subpolygonal peridinioid, with a small but distinct apical horn, without antapical horns or with a poorly developed left antapical horn. Endocyst ovoidal, thin and often corroded, sometimes absent due to preservation, exhibiting birefringence under phase contrast illumination. Periphragm thin and chagrinate, forming low but thick and robust parasutural crests that are distally smooth and delimit a paratabulation of 4’, 3a, 7”, 6c, 5”, 2”. Penitabular areas of the periphragm between the parasutural crests may be absent due to corrosion. Archeopyle formed by the loss of paraplate 2a.

**Type locality and stratum.** Locality: North Sea, UK16/16b-4 well. Stratum: section at 5624 ft, Middle Eocene (Lutetian).

**Holotype.** UK16/16b-4, 5624 ft (sidewall core), England Finder coordinates K24/3, illustrated in Plate 4, figs 7–8, curated at The Natural History Museum, London, slide number FD 519(1).

**Paratypes.** UK21/28a-5, 4460 ft (ditch cuttings), England Finder coordinates E39/2, illustrated in Plate 4, fig. 9, curated at Simon Petroleum Technology Limited, Llandudno; UK21/28b-7, 3740 ft (ditch cuttings), England Finder coordinates N35/2, curated at The Natural History Museum, London, slide number FD 520(1).

**Dimensions.** Pericyst length 37–50 μm, breadth 38–46 μm, apical horn length less than 2 μm.

**Observed stratigraphic range.** North Sea dinocyst zones: E6a to E6b of Bujak & Mudge (1994) (Middle Eocene: Lutetian).

**Remarks.** *P. distinctum* is characterized by its peridinioid shape, thin birefringent endocyst that may be corroded or absent, and the low but robust smooth parasutural crests. The periphragm between the crests is thin and may be absent, so that all that remains of the cyst in these extreme cases is a paratabular network of crests (Plate 4, figs 11–12).

*Phthanoperidinium powellii* sp. nov.  
(Plate 3, figs 7–9)

**Derivation of name.** Named after the palynologist A.J. Powell.

**Diagnosis.** Endocyst compressed dorso-ventrally, with an oval ambitus and one small conical apical horn; antapical horns absent or very poorly developed. Endophragm relatively thick, ovoidal and chagrinate to granulate. Pericyst ovoidal, sometimes with a small, solid apical horn. Periphragm thin and smooth to chagrinate, separated from the endocyst by a wide pericoel. Paratabulation indistinct or absent, sometimes poorly delimited by extremely low and indistinct parasutural crests on the periphragm. Paracingulum circular to weakly helicoidal, delimited by low crests. Parasulcus narrow and poorly defined. Archeopyle typically formed by the loss of paraplate 2a, or by the loss of paraplates 1a to 3a on rare specimens.

**Type locality and stratum.** Locality: North Sea, UK16/26-2 well. Stratum: section at 6280 ft, Middle Eocene (Lutetian).

**Holotype.** UK16/26-2, 6280 ft (ditch cuttings), England Finder coordinates P34/1, illustrated in Plate 3, fig. 8, curated at The Natural History Museum, London, slide number FD 521(1).

**Paratypes.** UK16/16b-4, 5200 ft (ditch cuttings), England Finder coordinates N28/0, illustrated in Plate 3, fig. 7, curated at The Natural History Museum, London, slide number FD 522(1); UK16/17-2A, 6010 ft, England Finder coordinates U36/3, illustrated in Plate 3, fig. 9, curated at The Natural History Museum, London, slide number FD 523(1).

**Explanation of Plate 4**

Magnification bar represents 20 μm for all specimens. Figs 1–3. *Phthanoperidinium clithridium* sp. nov. Figs. 1–2. Holotype. UK16/16b-4, 5900 ft; fig. 1, lower dorsal surface showing the archeopyle formed by the loss of paraplates 4” and 2a; fig. 2, upper ventral surface. Fig. 3. Paratype. UK16/16b-4, 5900 ft. Figs 4–6. *Phthanoperidinium regalis* sp. nov. Figs 4–5. Holotype. UK16/16b-4, 6040 ft; fig. 4, upper dorsal surface; fig. 5, optical section. Fig. 6. Paratype. 16/16a-3, 1689 m. Figs 7–12. *Phthanoperidinium distinctum* sp. nov. Figs 7–8. Holotype. UK16/16b-4, 5624 ft; fig. 8, phase contrast illumination showing the birefringent endocyst. Fig. 9. Paratype. UK21/28a-5, 4460 ft. Fig. 10. UK22/16-1, 8100 ft. Specimen with a corroded endophragm. Figs 11–12. UK21/28a-4, 4190 ft. Specimen without endophragm, and with the periphragm removed between the paratabular crests: fig. 11, lower dorsal surface; fig. 12, upper ventral surface.
Dimensions. Pericyst length 56–65 μm, breadth 51–65 μm, endocyst length 43–51 μm, breadth 34–44 μm, maximum pericoel height 7.5–14 μm, apical horn length on endocyst 3–5 μm.

Observed stratigraphic range. North Sea dinocyst zones: E6a to E6b of Bujak & Mudge (1994) (Middle Eocene: Lutetian).

Remarks. *P. powelli* is distinguished from all other species of *Phthanoperidinium* by the presence of a large pericoel.

---

**Phthanoperidinium regalis** sp. nov.

*(Plate 4, figs 4–6)*

**Derivation of name.** Latin, *regale*, royal.

**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, but is sometimes present beneath the apical horn. Periphragm chagrinate to granulate with parasutural rows of granules, short spines, or low, irregular crests. These delimit a paratabulation of 4', 3a, 7', 6c, 5', 2'''. Strongly developed penitabular rows or zones of similar ornament lie 1–3 μm inside the parasutures, except adjacent to the paracinulum where the parasutural and penitabular ornament merges. Archeopyle always formed by the loss of paraplates 2a and 4''.

**Type locality and stratum.** Locality: North Sea, UK16/16b-4 well. Stratum: section at 6040 ft, Middle Eocene (Lutetian).

**Holotype.** UK16/16b-4, 6040 ft (ditch cuttings), England Finder coordinates K26/4, illustrated in Plate 4, figs 4–5, curated at The Natural History Museum, London, slide number FD 525(2).

**Paratype.** UK16/16a-3, 1689 m (sidewall core), England Finder coordinates P37/1, illustrated in Plate 4, fig. 6, curated at BP Operating Company, Aberdeen.

**Dimensions.** Pericyst length 37–46 μm, breadth 33–37 μm, apical horn length 2–3 μm.

**Observed stratigraphic range.** North Sea dinocyst zones: E6a to E5b of Bujak & Mudge (1994) (Middle Eocene: Lutetian).

**Remarks.** *P. regalis* is identical to *P. geminatum* Bujak in all respects except for the mode of archeopyle formation which comprises the loss of paraplate 2a in *P. geminatum*, and the loss of paraplates 2a and 4'' in *P. regalis*. The stratigraphic ranges of the two taxa are also distinct. *P. regalis* has its last North Sea occurrence in Lutetian Subzone E5a of Bujak & Mudge (1994), whereas *P. geminatum* ranges up into the Bartonian.

The mode of archeopyle formation is identical in *P. regalis* and *P. clithridium* which differ in their ornament. *P. clithridium* does not possess the penitabular ornament present on *P. regalis* and has less well-defined parasutural crests. Rare specimens intergrade between these taxa, but the majority of specimens assigned to the two taxa comprise populations with distinct palaeogeographic distributions in the North Sea (Bujak, pers. obs.). *P. regalis* has not been recorded outside the North Sea region.

**ACKNOWLEDGEMENTS**

The author is grateful to H. Brinkhuis, J. De Coninck and C. Heilmann-Clausen for their constructive comments on the manuscript. Thanks are also due to the following for permission to use palynological slides as reference material for type specimens: the British Geological Survey, BP Operating Company, Chevron UK Limited, Conoco (UK) Limited, Mobil North Sea Limited, Oryx UK Energy Company, Shell UK Exploration and Production, Simon Petroleum Technology Limited, Sun International Exploration and Production, Total Oil Marine plc, and Unocal UK Limited.

**Manuscript received June 1993**

**Manuscript accepted December 1993**

**REFERENCES**

Agelopoulos, J. 1964. *Hystrichostrogon membraniphorum* n.g., n.sp. aus dem Heiligenhafener Kieselton (Eozän). Neues Jahrbuch für Geologie und Paläontologie, Monatshefte, 673–675.

Bujak, J. P. 1980. Dinoflagellate cysts and acritarchs from the Eocene Barton Beds of southern England. In Bujak, J. P., Downie, C., Eaton G. L. & Williams, G. L. (Eds) *Dinoflagellate cysts and acritarchs from the Eocene of southern England*, 36–91, The Palaeontological Association, Special Papers in Palaeontology, 24.

Bujak, J. P. Downie, C., Eaton G. L. & Williams, G. L. 1980. Dinoflagellate cysts and acritarchs from the Eocene of southern England. The Palaeontological Association, Special Papers in Palaeontology, 24.

Bujak, J. P. & Mudge, D. C. 1994. A high-resolution North Sea Eocene dinocyst zonation. *Journal of the Geological Society, London, 151*: 449–462.

Cookson, I. C. 1965. Microplankton from the Browns Creek Clays, SW Victoria. *Proceedings of the Royal Society of Victoria, 79*: 119–131.

De Coninck, J. 1975. Microfossiles à paroi organique de l’Épéisien du Bassin belge. Ministère des affaires économiques. Service Géologique de Belgique, Prof. Paper no. 12 (1975), 1–151.

Deflandre, G. 1935. Considérations biologiques sur les microorganismes d’origine planctonique conservés dans les silex de la craie. *Bulletin biologique de la France et de la Belgique, 69*: 213–244.

Drugg, W. S. & Loblich, A. R., Jr. 1967. Some Eocene and Oligocene photyplankton from the Gulf Coast, U.S.A. *Tulane Studies in Geology, 5*: 181–194.

Eaton, G. L. 1971. A morphogenetic series of dinoflagellate cysts from the Bracklesham Beds of the Isle of Wight, southern England. In Farinacci, A. (Ed.), *Proceedings of the Second Planktonic Conference Rome* 1970, 1: 355–379, Edizioni Tecnoscientia, Rome.

Eisenack, A. 1954. Mikrofossilien aus Phosphoriten des samländischen Unteroligozäns und über die Einheitlichkeit der Hystrichosphaerideen. *Palaeontographica, Abt. A*, 105: 49–95.

Eisenack, A. 1963. Zur *Membranilamnax*-Frage. Neues Jahrbuch für Geologie und Paläontologie, Monatshefte, 98–103.

Fensome, R. A., Taylor, F. J. R., Norris, G., Sarjeant, W. A. S., Wharton, D. I. & Williams, G. L. 1993. A classification of living and fossil dinoflagellates. Micropaleontology Press, Special Publication, 7, 1–351.

Heilmann-Clausen, C. 1993. Gradual morphological changes in some dinoflagellate cysts from the Eocene (Lower Tertiary) of the North Sea Basin. *Palynology, 17*: 91–100.

Heilmann-Clausen, C. & Costa, L. I. 1989. Dinoflagellate zonation of the uppermost Paleocene? to Lower Mioce in the Wursterheide research well, NW Germany. *Geologisches Jahrbuch, A111*: 431–521.
New dinocyst taxa

Islam, M. A. 1982. archaeopyle structure in the fossil dinoflagellate Phthanoperidinium. Review of Palaeobotany and Palynology, 36: 305–316.

Lejeune-Carpentier, M. 1938. L'étude microscopique des silex. Areoligeria: nouveau genre d'Hystichosphaeridée (Sixième note). Annales de la Société géologique de Belgique, 62: B163–B174.

Lindemann, E. 1928. Abteilung Peridineae (Dinoflagellatae). In Engler, A. & Prantl, K (Eds), Die natürlichen Pflanzenfamilien nebst ihren Gattungen und wichtigeren Arten insbesondere den Nutzpflanzen. Zweite stark vermehrte und verbesserte Auflage herausgegeben von A. Engler. 2 Band, 3–104. Wilhelm Engelmann, Leipzig.

Mudge, D. C. & Bujak, J. P. 1994. Eocene stratigraphy of the North Sea basin. Journal of Sedimentary and Petroleum Geology, 11: 166–181.

Pascher, A. 1914. Über Flagellaten und Algen. Deutsche Botanische Gesellschaft, Berichte, 32: 136–160.

Stover, L. E. & Evitt, W. R. 1978. Analyses of pre-Pleistocene organic-walled dinoflagellates. Stanford University Publications, Geological Sciences, 15.

Stover, L. E. & Williams, G. L. in press Morphology and stratigraphy of the Paleogene dinoflagellate genera Areosphaeridium Eaton 1971 and Eatonycsra Stover and Evitt 1978. Micropaleontology.

Taylor, F. J. R. 1980. On Dinoflagellate Evolution. Biosystems, 13: 65–108.

Verbeek, J. W. 1988 The regional distribution of nannoplankton assemblages; correlation of the interregional zonation with the regional lithostratigraphic formations. The Netherlands. In Verbeek, R. (Comp.), The Northwest European Tertiary Basin, 273–275. Results of the International Geological Correlation Programme, Project No. 124. Geologisches Jahrbuch, A, 100.