New species of dinoflagellate cysts from Maastrichtian-Danian chalks of the Danish North Sea

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ABSTRACT
A palynological study of Danian-Maastrichtian chalks from the Dan oilfield (Danish North Sea) has revealed the presence of nine new species and subspecies of dinoflagellate cysts: Achmosphaera antleriformis sp. nov., Cassiculosphaeridia? tocheri sp. nov., Chlamydophorella? multiforma sp. nov., Isabelidinium majae sp. nov., Hystrichosphaeropsis perforata sp. nov., Hystrichostrogylon borisii sp. nov., Leberidocysta? flagellicnia sp. nov., Spiniferites foveolatus sp. nov. and Spiniferites pseudofurcatus granulosus ssp. nov. Seven of the taxa are considered important biostratigraphic markers in the area.

INTRODUCTION
The Geological Survey of Denmark is, in cooperation with Maersk Olie og Gas AS, carrying out a multidisciplinary geological research project (the Dan Field Project), on improved mapping and characterization of chalk reservoirs and seal properties in the Dan oilfield in the North Sea. The Dan Field produces oil from Maastrichtian and Danian chalks, which form part of the Chalk Group (Deegan and Scull, 1977). An overview of the exploration and production geology of the Danish chalk play is presented in Andersen and Doyle (1990). The structure, stratigraphy and development history of the Dan Field is treated comprehensively in Jorgensen (1993). The Dan Field Project integrates seismic forward modelling and interpretation with sedimentology and biostratigraphy. The project includes the establishment of a high resolution bio-stratigraphical zonation in the reservoir chalks, based on dinoflagellate cysts (Schiøler and Wilson, 1992, 1993). During the study several previously undescribed dinoflagellate taxa were encountered, nine of which are described here.

MATERIALS AND METHODS
The dinoflagellate cysts were recovered from core samples from the following six wells (well name is followed by platform coordinates): M-1x (UTM 31 E 634889.8m N 6149249.0m), ME-6 (UTM 31 E 638633.0m N 6150532.5m), MFA-4 (UTM 31 E 633336.9m N 6150421.0m), MFB-7 (UTM 31 E 633273.9m N 6150312.0m), M-9x (UTM 31 E 631842.0 N 6149710.5m) and M-lox (UTM 31 E 631842.0 N 6149710.5m). The locations of the wells are shown in Fig. 1. The samples were prepared using normal initial procedures for palynological preparation of chalk samples (cf. Wilson, 1971), except for oil-bearing chalks, which were prepared according to the method described in Nørgaard et al. (1991). Hydrofluoric acid treatment followed the maceration tank-method described by Poulsen et al. (1991). The material was sieved through 18 µm filter cloth; oxidation with nitric acid as well as heavy liquid separation with ZnCl2 was carried out whenever needed. Treatment with potassium hydroxide was not undertaken as this preparation step may alterate the morphologic appearance of the peridinioid dino-flagellates.

Fig. 1 Top Chalk Structure map of the Dan Field showing the locations of the wells studied herein.

(Schrank, 1988). The slides were mounted in glycerin jelly. Specimens were photographed with a Zeiss photomicroscope, located at the Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand.

The abundance of dinoflagellate cysts in the chalks is low, between 5 and 200 specimens per gram pure chalk. A higher abundance is found in stylolite-bearing chalks: 8 - 300 specimens per gram. Consequently stylolite-rich intervals were preferred during sampling of the cores. As the cysts are inert to most diagenetic processes, their relative enrichment in stylolites is thought to reflect concentration during the stylolite formation.

BIOSTRATIGRAPHY OF THE WELLS
The chalk intervals in the wells M-1x, M-9x, M-10x and MFA-4 have previously been dated using calcareous microfossils (unpublished service company reports by: Bailey, 1980, 1983; Bailey and Jutson, 1983; Bagnall et al., 1971; Charnock et al., 1985). No biostratigraphical data are available from the wells...
boundary was placed between 1996.8m (core) and 1998.0m. Bailey (1980) reported the biostratigraphy of the well based on presence of other characteristic forms. The presence of Pseudotextularia elegans, Racemiguembelina fructícosa, Gavelinella bullata, Bagnall et al. (1971) reported Danian strata in the interval 1798.3m (core) - 1838.3m (core). They dated the interval 1845.0m - 2066.6m (core and cuttings) as Maastrichtian, based on the occurrence of Bolivinoides draco draco, Reissella cristata, Globotruncanæa contusa as well as the presence of other characteristic forms. The presence of G. contusa was held to suggest a relatively complete Maastrichtian succession, although the absence of the latest Maastrichtian species Pseudotextularia elegans was noted (Bagnall et al., 1971, p. 7). In-house information (Stouge, 1990) suggests that the boundary between the Late and Early Maastrichtian is positioned at 1928.5m, and that the stratigraphic interval down to 2003.8m includes most of the Early Maastrichtian. The interval covered by the present study thus represents strata of Danian to Maastrichtian age, including at least some Early Maastrichtian.

Well M-9x (studied core interval: 1967.8m - 2060.8m)
Bailey (1980) reported the biostratigraphy of the well based on foraminiferæ: Globigerina daubjergensis, the Early Danian zonal marker of Bang (in Rasmussen, 1978), was encountered at 1972.4m (side wall core). The Maas-trichtian/Danian boundary was placed between 1996.8m (core) and 1998.0m (core), based on the first downhole appearance of the planctonic foraminiferid association of Globotruncanæa contusa, Pseudotextularia elegans and Racemiguembelina fructícosa. The boundary between the latest and early Late Maastrichtian was placed between 2018.7m (side wall core) and 2021.5m (side wall core), based on the lowest in situ occurrence of Pseudotextularia elegans at 2018.7m associated with the highest occurrence of Neoflabellina reticulata at 2021.5m, following the zonation of Koch (1977). The boundary between the Early and Late Maastrichtian was established by the present author using dinoflagellate cysts, and positioned at 2063.5m (cuttings), based on the common downhole occurrence of Stensiöellina pommerana from this depth and following Koch (1977) (in Bailey, 1980). The interval studied in the present paper thus ranges from the Late Danian to approximately 9 feet above the boundary between the Late and Early Maastrichtian.

Well M-10x (studied core interval: 1944.6m - 2029.4m) Bailey and Jutson (1983) examined two core samples just below the contact between the Palaeocene clay and the underlying Chalk Group, and encountered nanofossils indicating the Subzone D10 of Perch-Nielsen (1979) at the depth 1932.26m. Bailey (1983) examined 12 core samples from the depth interval 1956.8m - 1990.4m, and dated the interval 1956.8m - 1962.9m as Danian, based on the total range of Globorotalia pseudoduboloides and other significant taxa. The interval dated 1966.0m - 1984.3m represents the Late Maastrichtian based on the occurrence of Pseudotextularia elegans. The interval 1987.3m - 1990.4m was, with some reservation, dated as Early Maastrichtian based on the common occurrence of calcsphaeres in the sample at 1987.3m. Four core samples from around the K/T boundary (1962.17m - 1963.84m) were investigated for calcareous microfossils by Chamock et al. (1985). The results show that an unconformity probably occurs between the Early Palaeocene and the latest Maastrichtian in the well (Charnock et al., 1985). The interval below 1990.4m has not been investigated for calcareous microfossils. In summary the interval studied herein spans the Danian and Late Maastrichtian, and probably Early Maastrichtian.

Well MFA-4 (studied core interval: 2366.2m - 2414.7m)
Charnock et al. (1985) investigated core samples from the interval 2366.2m - 2408.3m. The interval 2366.2m - 2400.0m is dated as Early Palaeocene based on the presence of several calcareous nanofossil and foraminiferid taxa; the presence of specimens of Globorotalia pseudoduboloides, although questionable to the authors, provides some evidence for the presence of uppermost Maastrichtian strata from 2402.7m (Charnock et al., 1985). Age diagnostic foraminiferæ were not recovered from deeper samples. Based on the occurrence of large Arkhangelskiella cymbiformis down to 2408.3m, uppermost Maastrichtian strata are indicated at least to this level (Charnock et al., 1985). The interval studied herein thus covers the Early Palaeocene to at least the latest Maastrichtian.

Wells ME-6 and MFB-7 (studied core intervals: ME-6: 2073.9m - 2083.6m, MFB-7: 2246.7m - 2436.9m)
The studied sequences from these wells have been correlated with the four other wells and with chronostratigraphical units by the present author using dinoflagellate cysts. Only two samples yielded dinoflagellate cysts in well ME-6. Both contain abundant Palynomium grallator, and consequently belong to the Palynomium grallator Zone of Hansen (1977),

Dinoflagellate cysts from the Dan Field, Danish North Sea. All figures to scale. Scale bar = 20μm.

Fig. 1 Isabelidinium majae sp. nov. DGU Cat. no. 1992-PS-1. Holotype. Ventral surface up, sectional focus.
Fig. 2 Isabelidinium majae sp. nov. DGU Cat. no. 1992-PS-2. Paratype. Dorsal surface up, sectional focus.
Fig. 3 Isabelidinium majae sp. nov. DGU Cat. no. 1992-PS-3. Paratype. Dorsal surface up, sectional focus.
Fig. 4 Isabelidinium majae sp. nov. DGU Cat. no. 1992-PS-4. Paratype. Ventral surface up, low focus.
Fig. 5 Isabelidinium majae sp. nov. DGU Cat. no. 1992-PS-5. Paratype. Ventral surface up, sectional focus. Specimen with folded periphragm.
Fig. 6 Isabelidinium majae sp. nov. DGU Cat. no. 1992-PS-6. Paratype. Ventral surface up, sectional focus.
Fig. 7 Hystrichosoglygon borisi sp. nov. DGU Cat. no. 1992-PS-7. Holotype. Lateral view, sectional focus.
Fig. 8 Hystrichosoglygon borisi sp. nov. DGU Cat. no. 1992-PS-8. Paratype. Dorsal surface up, sectional focus.
Fig. 9 Hystrichosoglygon borisi sp. nov. DGU Cat. no. 1992-PS-9. Paratype. Lateral view, sectional focus.

Explanation of Plate 1.
representing the latest Maastrichtian in Denmark. The studied interval from the MFB-7 well was correlated with the five other wells by the present author using qualitative and quantitative stratigraphic techniques, and is considered to be of Danian to late Early Maastrichtian age.

SYSTEMATIC PALYNOLOGY

Dinoflagellate cyst taxa described prior to 1989 and mentioned below are fully referenced in Lentin and Williams (1989). All other taxa are referenced herein. All type specimens and other figured specimens are lodged in the palynological collection of the Geological Survey of Denmark (DGU), and have been assigned DGU catalogue numbers. The inferred chronostratigraphical distribution of the new taxa is summarized in Fig. 2.

Division Pyrrophyta Pascher, 1914
Class Dinophyceae Fritsch, 1929
Order Peridiniales Haeckel, 1894
Genus Achomosphaera Evitt 1963
Achomosphaera antleriformis sp. nov.
(Pl. 3, Figs 1-6, text-fig. 2)

Derivation of name. After the robust process terminations, sometimes resembling the antlers of a deer.

Diagnosis. A skolochorate gonyaulacoid cyst which lacks indications of sutures between the processes. The processes are gonal, long-stemmed and straight, with wide, robust bi- or trifurcations which give rise to secondary furcations that are truncated terminally.

Holotype. DGU Cat. no. 1992-PS-19 (Pl. 3, fig. 2, text-fig. 2a,b).
Well M-1x, depth 1936.1m, Dan Field, Danish North Sea.
Paratype. DGU Cat. No. 1992-PS-18 (Pl. 3, figs 1,4)  
DGU Cat. No. 1992-PS-20 (Pl. 3, fig. 3)
DGU Cat. No. 1992-PS-21 (Pl. 3, fig. 5)

Stratigraphic occurrence: ME-6: 2082.1m - 2083.6m, MFA-4: 2404.0m - 2414.7m, MFB-7: 2281.5m - 2436.9m, M-1x: 1846.5m - 2003.8m, M-9x: 2001.6m - 2436.9m, M-lx: 1846.5m - 2060.8m, M-10x: 1964.8m - 2029.4m. Maastrichtian in the Dan Field, Danish North Sea. Common.

Description. Large skolochorate cyst. Periphragm and endophragm appressed between processes. The cyst body is ovoidal to subspherical. The periphragm and endophragm are smooth. The processes are gonal, hollow and closed; process length approximately equals the radius of the endocyst. The stems of the apical processes are sometimes connected by septa of variable height, forming a single polar process complex with four trifurcate terminations (Pl. 3, figs 2,5, text-fig. 2). Arkhachopyle type P(3), operculum free. Paracingulum and parasulcus not visible. Paratabulation gonyaulacoid, suggested by the position of the processes.

Dimensions (in μm): holotype range
overall length 107 - 101 (111) 130
overall width 93 - 87 (100) 110
length of endocyst 61 - 58 (61) 78
width of endocyst 49 - 44 (54) 78
process length 23 - 29 - 20 - 32

Specimens measured. 7

Remarks. Achomosphaera antleriformis sp. nov. is separated from the subspecies of Achomosphaera ramulifera (Deflandre 1937) Evitt 1963 by its more robust and truncated process terminations. A. antleriformis sp. nov. furthermore has narrower process stems than Achomosphaera ramulifera (Deflandre 1937) Evitt 1963, and twice as long processes as Achomosphaera ramulifera gabonensis (Boltenhagen 1977) Lentin and Williams 1981. Achomosphaera ramulifera perforata (Davey and Williams 1966) Lentin & Williams 1973 is separated from the new species by its fenestrate processes. Achomosphaera fenestrata Kirsch 1991 differs from the new species in having open processes with striate process stems and a perforated

Explanation of Plate 2

Dinoflagellate cysts from the Dan Field, Danish North Sea. Scale bars = 20 μm.
Fig. 1 Hystrichosphaeridion perforata sp. nov. DGU Cat. no. 1992-PS-10. Lateral view, sectional focus.
Fig. 2 Hystrichosphaeridion perorata sp. nov. DGU Cat. no. 1992-PS-11. Lateral view, sectional focus. Same scale as 1.
Fig. 3 Hystrichosphaeridion perorata sp. nov. DGU Cat. no. 1992-PS-12. Paratype. Lateral view, sectional focus. Same scale as 1.
Fig. 4 Hystrichosphaeridion perorata sp. nov. DGU Cat. no. 1992-PS-13. Holotype. Dorso lateral view, sectional focus.
Fig. 5 Hystrichosphaeridion perorata sp. nov. DGU Cat. no. 1992-PS-14. Paratype. Dorso lateral view, sectional focus. Same scale as 4.
Fig. 6 Hystrichosphaeridion perorata sp. nov. DGU Cat. no. 1992-PS-15. Paratype. Ventral surface up, sectional focus. Same scale as 4.
Fig. 7 Hystrichosphaeridion perorata sp. nov. DGU Cat. no. 1992-PS-16. Ventral surface up, sectional focus.
Fig. 8 Hystrichosphaeridion perorata sp. nov. DGU Cat. no. 1992-PS-17. Close-up of antapical part of pericyst. Notice coarse perforations of the free part of the periphragm.
membrane connecting the distal furcations of each process. *Achomosphaera alicornu* (Eisenack 1954) Davey & Williams 1966 differs in having open processes which terminate trifurcating and funnel-shaped. Hansen (1977, fig. 17f) illustrated a specimen of the latter species from the Danian of Denmark which has a superficial resemblance to the new species; his specimen can be differentiated by the lack of distinct branching of the process terminations and the presence of faint sutures between the process bases.

Genus *Cassiculosphaeridia* Davey 1969
*Cassiculosphaeridia? tocheri* sp. nov. (Pl. 4, Figs 4-12)

**Derivation of name.** In honour of the palynologist Dr. Bruce A. Tocher, University of Aberystwyth, who has worked extensively on Late Cretaceous dinoflagellate cysts.

**Diagnosis.** A large spherical to subspherical autocyst in which the phragm is ornamented with a thick-walled reticulum enclosing large subspherical lumina.

**Holotype.** DGU Cat. no. 1992-PS-31 (Pl. 4, figs 4,5). Well M-9x, depth 2031.2m, Dan Field, Danish North Sea.

**Paratypes.**
- DGU Cat. No. 1992-PS-32 (Pl. 4, fig. 6)
- DGU Cat. No. 1992-PS-33 (Pl. 4, fig. 7)
- DGU Cat. No. 1992-PS-37 (Pl. 4, fig. 11)
- DGU Cat. No. 1992-PS-38 (Pl. 4, fig. 12)

**Stratigraphic occurrence.** ME-6: 2082.1m - 2083.6m, MFA-4: 2403.1m - 2414.7m, MFB-7: 2319.2m - 2394.8m. Late Maastrichtian samples examined during the present study, spores and pollen as well as acritarchs are very rare. The occasional presence of features that point to an apical archaeopyle on the new species (see Pl. 4, figs 4,6,9,11), is currently taken as sufficient evidence by the present author for the location of the taxon in Class Dinophyceae. Alternatively the taxon could be a spore, a pollen grain, or an acritarch; however, in all the Maastrichtian samples examined during the present study, spores and pollen as well as acritarchs are very rare. The occasional presence of features that point to an apical archaeopyle on the new species (see Pl. 4, figs 4,6,9,11), is currently taken as sufficient evidence by the present author for the location of the taxon in Class Dinophyceae. The new species differs from all other species of *Cassiculosphaeridia* in having a high and thick-walled reticulum.

Genus *Chlamydophorella* Cookson and Eisenack 1958 emend. Duxbury 1983
*Chlamydophorella? multifibrata* sp. nov. (Pl. 5, Figs 7-12)

**Derivation of name.** After the numerous strands bearing the ectophragm.

**Diagnosis.** A subspherical differentiated autocyst with apical archaeopyle. The ectophragm is connected to the autocyst by a densely fibrous mat, formed by numerous hairlike strands.

**Holotype.** DGU Cat. no. 1992-PS-47 (Pl. 5, fig. 9). Well M-9x, depth 2001.6m, Dan Field, Danish North Sea.

**Paratypes.**
- DGU Cat. No. 1992-PS-45 (Pl. 5, fig. 7)
- DGU Cat. No. 1992-PS-46 (Pl. 5, fig. 8)
- DGU Cat. No. 1992-PS-48 (Pl. 5, fig. 10)
- DGU Cat. no. 1992-PS-50 (Pl. 5, fig. 12)

**Stratigraphic occurrence.** MFA-4: 2403.1m - 2404.9m, MFB-7: 2281.5m - 2289.6m, M-1x: 1846.5m - 1869.1m, M-9x: 2001.6m - 2060.8m, M-10x: 1997.7m - 2083.6m, M-9x: 2001.6m - 2050.1m, M-10x: 1964.8m - 2001.0m. Maastrichtian in the Dan Field, Danish North Sea. Frequent.

**Description.** A differentiated autocyst with a subcircular outline. The wall of the autophagm is thick, the ectophragm is very thin. The autophagm and the ectophragm are connected by a densely fibrous mat of very thin strands (<0.25 μm in thickness). Length of strands 4 - 11 pm.

**Explanation of Plate 3.**

| DIMENSIONS | HOLOTYPE | RANGE |
|------------|----------|-------|
| TOTAL DIAMETER | 92 | 78 (89) 96 |
| HEIGHT OF ECTOPHRAGM | 9 | 6 (9) 12 |

**Specimens measured.** 13

**Remarks.** As archaeopyle relationship is somewhat problematic in this species and paratabulation is absent, it is with some hesitation that the new taxon is established in Class Dinophyceae. Alternatively the taxon could be a spore, a pollen grain, or an acritarch; however, in all the Maastrichtian samples examined during the present study, spores and pollen as well as acritarchs are very rare. The occasional presence of features that point to an apical archaeopyle on the new species (see Pl. 4, figs 4,6,9,11), is currently taken as sufficient evidence by the present author for the location of the taxon in Class Dinophyceae. The new species differs from all other species of *Cassiculosphaeridia* in having a high and thick-walled reticulum.

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Dinoflagellate cysts from the Dan Field, Danish North Sea. Scale bars = 20 μm, except 14.

Fig. 1 *Achomosphaera antleriformis* sp. nov. DGU Cat. no. 1992-PS-18. Paratype. Dorsolateral view, sectional focus. Artificially stained specimen.

Fig. 2 *Achomosphaera antleriformis* sp. nov. Holotype. DGU Cat. no. 1992-PS-19. Ventrolateral view, sectional focus. Same scale as 1.

Fig. 3 *Achomosphaera antleriformis* sp. nov. DGU Cat. no. 1992-PS-20. Paratype. Lateral view, sectional focus. Fig. 4 *Achomosphaera antleriformis* sp. nov. DGU Cat. no. 1992-PS-18. Same specimen and scale as 1. High focus.

Fig. 5 *Achomosphaera antleriformis* sp. nov. DGU Cat. no. 1992-PS-21. Paratype. Lateral view, sectional focus. Same scale as 1. Fig. 6 *Achomosphaera antleriformis* sp. nov. DGU Cat. no. 1992-PS-22. Lateral view, low focus. Same scale as 1. Fig. 7 *Leberidocysta? flagellichnia* sp. nov. DGU Cat. no. 1992-PS-23. Holotype. Ventral surface up, high focus.

Fig. 8 *Leberidocysta? flagellichnia* sp. nov. Same specimen and scale as 7. Sectional focus. Fig. 9 *Leberidocysta? flagellichnia* sp. nov. DGU Cat. no. 1992-PS-24. Paratype. Ventral side up, high focus. Same scale as 7.

Fig. 10 *Leberidocysta? flagellichnia* sp. nov. Same specimen as 9, same scale as 7. Sectional focus. Fig. 11 *Leberidocysta? flagellichnia* sp. nov. DGU Cat. no. 1992-PS-25. Paratype. Oblique ventrolateral view, high focus. Same scale as 7. Fig. 12 *Leberidocysta? flagellichnia* sp. nov. DGU Cat. no. 1992-PS-26. Paratype. Ventral surface up, high focus. Same scale as 7.

Fig. 13 *Leberidocysta? flagellichnia* sp. nov. DGU Cat. no. 1992-PS-27. Paratype. Ventral side up, high focus. Same scale as 7. Fig. 14 *Leberidocysta? flagellichnia* sp. nov. Same specimen as 13. Close-up of flagellar scar. Scale bar = 10 μm.
μm. The archaeopyle is apical (TA), the operculum is free. The precingular plate series consists of six plates, and is expressed by accessory archaeopyle sutures. No other indications of paratabulation are present on the cyst.

**Dimensions (in μm):**
- holotype range
  - overall diameter: 61 - 60 (63) - 70
  - length of fibrous strands: 6-8 - 4 (7) - 11

**Remarks.** The new species superficially resembles species of *Cometodinium* Deflandre and Courtville 1939 in having numerous closely spaced processes, but differs in the development of an ectophragm enclosing the processes and in the presence of a conspicuous archaeopyle. It is with some hesitation that the new species is placed in *Chlamydophorella* as its lacks the bifid or expanded process terminations typical for that genus. The new species may belong to a new genus. The development of a densely fibrous mat between autocyst and ectophragm separates *Chlamydophorella? multifibrata* sp. nov. from all other species in the genus.

Genus *Hystrichosphaeropsis* Deflandre 1935 emend.

**Hystrichosphaeropsis perforata** sp. nov.

(Pl. 2, Figs 4-8, text-fig. 3)

**Derivation of name.** After the perforate periphragm.

**Diagnosis.** An elongate bicavate gonyaulacoid cyst with perforate to fenestrate periphragm. The epi- and hypocoeal are large and of approximately the same size; the epicyst has acute apex, the hypocyst has rounded to flat termination.

**Holotype.** DGU Cat. no. 1992-PS-13 (Pl. 2, fig. 4, text-fig. 3). Well MFA-4, depth 2414.7m, Dan Field, Danish North Sea.

**Paratypes.**
- DGU Cat. no. 1992-PS-14 (Pl. 2, fig. 5)
- DGU Cat. no. 1992-PS-15 (Pl. 2, fig. 6)

**Stratigraphic occurrence.** MFA-4: 2353.7m, MFB-7: 2362.0m: early Late Maastrichtian in the Dan Field, Danish North Sea. Rare in a narrow stratigraphic interval.

**Description.** An elongated bicavate cyst. The peri- and endophragm are smooth and appressed equatorially. The epi- and hypophragm tape to a blunted horn. The hypophragm terminates rounded to flat. The free part of the periphragm is perforated by large, generally axially elongated protrosions (3-10 μm). Sometimes the perforations are very closely spaced, giving the periphragm a fenestrate appearance (Pl. 2, fig. 8). The archaeopyle type is P(3); the peri- and endoperculum are free. The position of the paracingulum is indicated by 4 - 5 low and axially elongated protrosions of the periphragm (length of protrosions c. 3-5μm). Three of the protrosions on the holotype are indicated on text-fig. 3. The paracingulum is only faintly indicated. The paratabulation is partially indicated by folds or ridges on the periphragm: 4',6''?,c,s,6'',7p,1'''.

**Dimensions (in μm):**
- holotype range
  - length of pericyst: 96 - 87 (97) - 104
  - width of pericyst: 58 - 55 (60) - 67
  - length of endocyst: 38 - 35 (41) - 44
  - width of endocyst: 38 - 35 (41) - 44

**Remarks.** The new species differs from all other species of *Hystrichosphaeropsis* in having a perforate periphragm.

Genus *Hystrichostrogon* Agelopoulos 1964 emend.

**Hystrichostrogon borisii** sp. nov.

(Pl. 1, figs 7-9, Pl. 2, figs 1-3)

**Derivation of name.** Named after my son Boris.

**Diagnosis.** A camocavate gonyaulacoid cyst in which the periphragm and endophragm are appressed on the dorsal surface. The archaeopyle type is P(3); the peri- and endoperculum are free. The position of the paracingulum is indicated by 4 - 5 low and axially elongated protrosions of the periphragm (length of protrosions c. 3-5μm). Three of the protrosions on the holotype are indicated on text-fig. 3. The paracingulum is only faintly indicated. The paratabulation is partially indicated by folds or ridges on the periphragm: 4',6''?,c,s,6'',7p,1'''.

**Dimensions (in μm):**
- holotype range
  - length of pericyst: 96 - 87 (97) - 104
  - width of pericyst: 58 - 55 (60) - 67
  - length of endocyst: 38 - 35 (41) - 44
  - width of endocyst: 38 - 35 (41) - 44

**Remarks.** The new species differs from all other species of *Hystrichosphaeropsis* in having a perforate periphragm.

Genus *Hystrichosphaeropsis* Deflandre 1935 emend.

**Hystrichosphaeropsis perforata** sp. nov.

(Pl. 2, Figs 4-8, text-fig. 3)

**Derivation of name.** After the perforate periphragm.

**Diagnosis.** An elongate bicavate gonyaulacoid cyst with perforate to fenestrate periphragm. The epi- and hypocoeal are large and of approximately the same size; the epicyst has acute apex, the hypocyst has rounded to flat termination.

**Holotype.** DGU Cat. no. 1992-PS-13 (Pl. 2, fig. 4, text-fig. 3). Well MFA-4, depth 2414.7m, Dan Field, Danish North Sea.

**Paratypes.**
- DGU Cat. no. 1992-PS-14 (Pl. 2, fig. 5)
- DGU Cat. no. 1992-PS-15 (Pl. 2, fig. 6)

**Stratigraphic occurrence.** MFA-4: 2353.7m, MFB-7: 2362.0m: early Late Maastrichtian in the Dan Field, Danish North Sea. Rare in a narrow stratigraphic interval.

**Description.** An elongated bicavate cyst. The peri- and endophragm are smooth and appressed equatorially. The epi- and hypophragm tape to a blunted horn. The hypophragm terminates rounded to flat. The free part of the periphragm is perforated by large, generally axially elongated protrosions (3-10 μm). Sometimes the perforations are very closely spaced, giving the periphragm a fenestrate appearance (Pl. 2, fig. 8). The archaeopyle type is P(3); the peri- and endoperculum are free. The position of the paracingulum is indicated by 4 - 5 low and axially elongated protrosions of the periphragm (length of protrosions c. 3-5μm). Three of the protrosions on the holotype are indicated on text-fig. 3. The paracingulum is only faintly indicated. The paratabulation is partially indicated by folds or ridges on the periphragm: 4',6''?,c,s,6'',7p,1'''.

**Dimensions (in μm):**
- holotype range
  - length of pericyst: 96 - 87 (97) - 104
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  - width of endocyst: 38 - 35 (41) - 44

**Remarks.** The new species differs from all other species of *Hystrichosphaeropsis* in having a perforate periphragm.

Genus *Hystrichostrogon* Agelopoulos 1964 emend.

**Hystrichostrogon borisii** sp. nov.

(Pl. 1, figs 7-9, Pl. 2, figs 1-3)

**Derivation of name.** Named after my son Boris.

**Diagnosis.** A camocavate gonyaulacoid cyst in which the periphragm and endophragm are appressed on the dorsal surface. The archaeopyle type is P(3); the peri- and endoperculum are free. The position of the paracingulum is indicated by 4 - 5 low and axially elongated protrosions of the periphragm (length of protrosions c. 3-5μm). Three of the protrosions on the holotype are indicated on text-fig. 3. The paracingulum is only faintly indicated. The paratabulation is partially indicated by folds or ridges on the periphragm: 4',6''?,c,s,6'',7p,1'''.
Maastrichtian-Danian dinoflagellate from the Danish North Sea
hemisphere. The ventral pericoel opens to the exterior through a large rounded midventral claustrum which approximately equals the radius of the endophragm in diameter. The periphagm is smooth, the endophragm is ornamented with granulae, verrucae or vermiculae.

**Holotype.** DGU Cat. no. 1992-PS-7 (Pl. 1, fig. 7). Well M-10x, depth 1966.6m, Dan Field, Danish North Sea.

**Paratypes.**
- DGU Cat. no. 1992-PS-8 (Pl. 1, fig. 8)
- DGU Cat. no. 1992-PS-9 (Pl. 1, fig. 9)
- DGU Cat. no. 1992-PS-12 (Pl. 2, fig. 3)

**Stratigraphic occurrence.** ME-6: 2082.1m - 2083.6m, MFB-7: 2264.7m - 2283.0m, M-1x: 1837.7m, M-9x: 1973.3m - 2004.4m, M-10x: 1950.7 - 2001.0m. Latest Maastrichtian to Early Danian in the Dan Field, Danish North Sea.

**Description.** Camocavate cyst. The periphagm and endophragm are subspherical; the periphragm is appressed vermiculate (height of ornamentation: 0.5 - 1.5 µm). The size and type of the ornament are constant within a sample, but vary from one group of samples to another. The archaeopyle type is P(3) and the opeculum is free. The paracingulum is often indicated by equatorial folds on the periphagm and by the presence of low septa between the longer processes. A parasulcus is not observed. Apart from paracingulum and archaeopyle the paratabulation is not clearly expressed.

**Dimensions (in µm):**
- holotype range and mean
  - overall length of pericyst: 73 (74) 84
  - overall width of pericyst (lat.): 81 (78) 87
  - length of endocyst: 44 (40) 46
  - width of endocyst: 38 (32) 44
  - length of processes: 4 - 14: 4 - 20

**Specimens measured.** 12

**Remarks.** *Hystrichostrogon coninckii* Heilmann-Clausen 1985 in having a conspicuously ornamented endophragm. Together with *H. coninckii*, *H. borisii* sp. nov. differs from all other species of *Hystrichostrogon* in having a large rounded midventral claustrum in the periphagm.

**Genus Isabelaedium** Lentin and Williams 1977

**Isabelaedium majae** sp. nov.

**Paratypes.** DGU Cat. no. 1992-PS41. Lateral view, sectional focus. Same scale as 7.

**Derivation of name:** Named after my daughter Maja.

**Diagnosis.** A cavate peridinioid cyst with a smooth endo- and periphagm without indications of paracingulum. The ambitus shows overall axial symmetry. The periarcheopyle is lami-deltaform.

**Holotype.** DGU Cat. no. 1992-PS-1 (Pl. 1, fig. 1, text-fig. 4a).

**Paratypes**
- DGU Cat. no. 1992-PS-2 (Pl. 1, fig. 2, text Fig 4d)
- DGU Cat. no. 1992-PS-3 (Pl. 1, fig. 3, text Fig 4f)
- DGU Cat. no. 1992-PS-4 (Pl. 1, fig. 4, text Fig 4c)
- DGU Cat. no. 1992-PS-5 (Pl. 1, fig. 5, text Fig 4e)
- DGU Cat. no. 1992-PS-6 (Pl. 1, fig. 6, text Fig 4g)

**Stratigraphic occurrence.** ME-6: 2082.1m - 2083.6m, MFB-7: 2283.0m - 2283.6m, M-10x: 1973.0m. Latest Maastrichtian in the Dan Field, Danish North Sea. Common in a narrow stratigraphic interval.

**Description.** Cavate peridinioid cyst. Cyst outline is almost bilateral symmetric in ambital view. The periphagm is smooth and has a broad-based rounded to acute apical horn and two acute to broad rounded antapical horns. The epicyst lacks shoulders, and has a concave margin. The area between the antapical horns has a moderately concave curvature. The endophragm is smooth and subcircular to oval in ambital view. The peri- and endophragm are often in contact laterally. The archaeopyle type is I(2) and is lami-deltaform with Transversal Archaeopyle Index (TAI) c. 0.70. The paracingulum is not indicated. The parasulcus is often indicated by a longitudinal fold in the periphagm. Apart from the archaeopyle and the parasulcus no other paratabulation is present.

**Dimensions (in µm):**
- holotype range and mean
  - length of pericyst: 96 (95) 104
  - width of pericyst: 61 (61) 73
  - length of endophragm: 55 (58) 61
  - width of endophragm: 55 (52) 64

**Specimens measured.** 12

**Explanation of Plate 5**

Dinoflagellate cysts from the Dan Field, Danish North Sea. Scale bars = 20µm.

Fig. 1 Spiniferites foveolatus sp. nov. DGU Cat. no. 1992-PS-39. Paratype. Lateral view, high focus. Fig. 2 Spiniferites foveolatus sp. nov. DGU Cat. no. 1992-PS-40. Holotype. Dorsalateral view, high focus. Same scale as 1. Fig. 3 Spiniferites foveolatus sp. nov. DGU Cat. no. 1992-PS-41. Lateral view, high focus. Same scale as 1. Fig. 4 Spiniferites foveolatus sp. nov. DGU Cat. no. 1992-PS-42. Lateral view, low focus. Same scale as 1. Fig. 5 Spiniferites foveolatus sp. nov. DGU Cat. no. 1992-PS-43. Paratype. Dorsalateral view, high focus. Same scale as 1. Fig. 6 Spiniferites foveolatus sp. nov. DGU Cat. no. 1992-PS-44. Paratype. Dorsal surface up, high focus. Same scale as 1. Fig. 7 Chlamydohorea? multifibra sp. nov. DGU Cat. no. 1992-PS-45. Paratype. Unknown orientation. Fig. 8 Chlamydohorea? multifibra sp. nov. DGU Cat. no. 1992-PS-46. Paratype. Lateral view, sectional focus. Same scale as 7. Fig. 9 Chlamydohorea? multifibra sp. nov. DGU Cat. no. 1992-PS-47. Holotype. Apical view, high focus. Same scale as 7. Fig. 10 Chlamydohorea? multifibra sp. nov. DGU Cat. no. 1992-PS-48. Paratype. Lateral view, sectional focus. Same scale as 7. Fig. 11 Chlamydohorea? multifibra sp. nov. DGU Cat. no. 1992-PS-49. Lateral view, sectional focus. Same scale as 7. Fig. 12 Chlamydohorea? multifibra sp. nov. DGU Cat. no. 1992-PS-50. Paratype. Ventral surface up, high focus. Same scale as 7.
Maastrichtian-Danian dinoflagellate from the Danish North Sea
Genus *Leberidocysta* Stover and Evitt 1978

*Leberidocysta? flagellichnia* sp. nov.

(Pl. 3, figs 7-14, text-fig. 5)

**Derivation of name.** After the flagellar scar on the endophragm.

**Diagnosis.** A small holocavate oval cyst with a narrow pericoel. The periphragm is smooth, and occasionally has folds which indicate parts of the paratabulation. The endophragm is granulate and has a small, kidney-shaped scar in the sulcal area. The archaeopyle is apical and the operculum is usually attached.

**Holotype.** DGU Cat. no. 1992-PS-23 (Pl. 3, figs 7-8, text-fig. 5). Well M-9X, depth 2004.4m, Dan Field, Danish North Sea.

**Paratypes.**
- DGU Cat. no. 1992-PS-24 (Pl. 3, figs 9-10)
- DGU Cat. no. 1992-PS-25 (Pl. 3, fig. 11)
- DGU Cat. no. 1992-PS-26 (Pl. 3, fig. 12)
- DGU Cat. no. 1992-PS-27 (Pl. 3, figs 13-14)

**Stratigraphic occurrence.** ME-6: 2082.1m - 2083.6m, MFA-4: 2403.1m - 2414.7m, MFB-7: 2281.5m - 2436.9m, M-1x: 1846.5m - 2003.8m, M-9x: 1979.4m - 2060.8m, M-10x: 1964.8m - 2032.4m. Maastrichtian to Early Danian in the Dan Field, Danish North Sea; common.

**Description.** Oval holocavate cyst. The periphragm is thin and smooth, and is separated from the endophragm by a narrow (1-3μm) pericoel (Pl. 3, figs 8, 10, 13). The endophragm is relatively thick-walled and granulate to verrucilate. A conspicuous kidney-shaped ornament with low relief is always present ventrally on the endophragm beneath the point of operculum attachment (Pl. 3, figs 7, 9, 12, 13, 14, Text-fig 5). Archaeopyle apical (IA). The peri- and endoperculum usually are attached. The paracingulum is occasionally indicated by folds in the periphragm (Pl. 3, figs 11, 12). The position of the parasulcus is indicated by a kidney-shaped ornament on the endophragm, and sometimes by a longitudinal fold in the periphragm (Pl. 3, fig. 12). The larger adcingular paraplates occasionally are indicated by folds in the periphragm (Pl. 3, fig. 12). The paratabulation occurs inconsistently and has not been determined.

**Dimensions (in μm):**
- length of pericyst: 35 (28) 41
- width of pericyst: 36 (32) 41
- length of endocyst: 32 (27) 36
- width of endocyst: 33 (30) 38

**Specimens measured.** 12

**Remarks.** Form X spp. 1 and 2 of Marheinecke (1992, p. 121, pl. 27, figs 11-13, 7-9) closely resemble the new species in general appearance and size; Form X sp. 2 apparently only differs from *Leberidocysta? flagellichnia* sp. nov. in having a larger antapical pericoel, and may be conspecific with the new species. Form X sp. 1 differs further in having an alveolate endophragm. "Hexagonifera verrucosa" of Wilson (1974) differs from *Leberidocysta? flagellichnia* sp. nov. in having a verrucate endophragm (and thereby resembling Form X sp. 1 of Marheinecke, 1992). The kidney-shaped sulcal ornament is interpreted as representing the relic of...
Maastrichtian-Danian dinoflagellate from the Danish North Sea

Fig. 5 Leberidocysta flagellicha sp. nov. DGU Cat. no. 1992-PS-23. Camera lucida drawing of the ventral surface of the holotype. Scale bar = 20 μm.

the flagella insertion point by the present author. It is with some hesitation that the new species is located in genus Leberidocysta as this genus is not thought to have attached opercula (Stover and Evitt, 1978 p. 60). However, the illustration of the type specimen of the genus, L. chlamydata, shows peri- and endoperculum in place (Cookson and Eisenack, 1962, Pl. 7, fig. 2). This fact is considered here to justify the generic location of the new species in Leberidocysta.

Genus Spiniferites Mantell 1850 emend. Sarjeant 1970
Spiniferites foveolatus sp. nov.
Pl. 5, Figs 1-6

Derivation of name. Named after its foveolate endophragm.

Diagnosis. A skolochorate gonyaulacoid cyst in which the endo- and periphragm are appressed between the processes. The processes occupy gonal positions and terminate trifurcate and bifurcate. Low to intermediate septal crests connect the processes. The periphragm is smooth, the endophragm is foveolate; the foveolation descends approximately half-way down the endophragm.

Holotype. DGU Catalogue no. 1992-PS-40 (Pl. 5, fig. 2) Well M-9x, depth 2055.0m, Dan Field, Danish North Sea.

Paratypes. DGU Cat. no. 1992-PS-39 (Pl. 5, fig. 1)
DGU Cat. no. 1992-PS-43 (Pl. 5, fig. 5)
DGU Cat. no. 1992-PS-44 (Pl. 5, fig. 6)

Stratigraphic occurrence. MFA-4: 2404.9m - 2411.0m, MFB-7: 2297.0m - 2433.5m, M-1x: 1846.5m - 1917.5m, M-9x: 2001.6m - 2060.7m, M-10x: 1964.8m - 2029.4m. Late Maastrichtian in the Dan Field, Danish North Sea. Rare to frequent.

Remarks. The new subspecies differs from the two other subspecies of Spiniferites pseudofurcatus only in having a granulate endophragm and a slightly striate periphragm.

Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970 emend. Sarjeant 1981
Spiniferites pseudofurcatus granulosus ssp. nov.
(Pl. 4, figs 1-3)

Derivation of name. After the ornament on the endophragm.

Diagnosis. A skolochorate gonyaulacoid cyst in which the endo- and periphragm are appressed between the processes. The processes occupy gonal positions and terminate bifurcate to tetrafurcate and never ramify. Low septal crests connect the processes. The periphragm is slightly striate, the endophragm is finely granulate.

Holotype. DGU Catalogue no. 1992-PS-29 (Pl. 4, fig. 2) Well M-9x, depth 2031.2m, Dan Field, Danish North Sea.

Paratypes. DGU Cat. no. 1992-PS-28 (Pl. 4, fig. 1)
DGU Cat. no. 1992-PS-30 (Pl. 4, fig. 3)

Stratigraphic occurrence. ME-6: 2082.1m - 2083.6m, MFA-4: 2403.1m - 2408.9m, MFB-7: 2297.0m - 2367.7m, M-1x: 1854.4m - 1997.7m, M-9x: 2004.4m - 2055.0m, M-10x: 1969.0m - 2029.4m. Maastrichtian in the Dan Field, Danish North Sea. Rare to frequent.

Remarks. The new subspecies differs from the two other subspecies of Spiniferites pseudofurcatus only in having a granulate endophragm and a slightly striate periphragm.

DINOFLAGELLATE STRATIGRAPHY
The stratigraphic distribution of the new taxa is summarised in Fig. 6. The restricted stratigraphic occurrence of Isabelidinium majae sp. nov. and Hystrichosphaeropsis perforata sp. nov. suggests that they are important marker species for narrow stratigraphic intervals in the Late Maastrichtian. The first appearance datum of Hystrichostrogyon borisii sp. nov. is considered an important stratigraphic marker for the latest Maastrichtian (Schioeler...
ACKNOWLEDGEMENTS

The Danish Research Academy is acknowledged for support during a research fellowship, supervised by F. Surylk, University of Copenhagen. The Danish ministry of Energy and Maersk Olie og Gas AS are acknowledged for supporting the Dan Field Project at the Geological Survey of Denmark, of which the present study forms a part. Graeme J. Wilson, Institute of Geological and Nuclear Sciences Ltd, Lower Hutt, New Zealand, is thanked for helpful suggestions and for critically reading the manuscript. Constructive criticism by an anonymous journal referee is gratefully acknowledged.

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