



Additional new organic-walled dinoflagellate cysts from two onshore UK Chalk boreholes

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Abstract. Beautifully preserved dinoflagellate cysts continue to be discovered in UK Cretaceous chalks and provide important new biostratigraphic information. Five new species – *Conosphaeridium norfolkense* sp. nov., *Glaphyrocysta coniacia* sp. nov., *Impletosphaeridium banterwickense* sp. nov., *Sentusidinium devonense* sp. nov., *Sentusidinium spinosum* sp. nov. and the new subspecies *Spiniferites ramosus* subsp. *ginakrogiae* subsp. nov. – are described from Upper Cretaceous strata of the British Geological Survey (BGS) Banterwick Barn and Trunch boreholes (onshore UK). An emended diagnosis for *Odontochitina diducta* Pearce is also provided to broaden the morphological variability in the type material.

1 Introduction

Cretaceous chalks from onshore UK boreholes have recently yielded beautifully preserved dinoflagellate cysts (Prince et al., 1999, 2008; Pearce et al., 2003, 2011; Pearce, 2010) but many undescribed forms continue to be found. The sample material is exceptional in its $\delta^{13}\text{C}$ chemostratigraphic correlation to outcrop sections with macrobiostratigraphic age control (see Jarvis et al., 2006). This paper describes five new species and one new subspecies from the British Geological Survey (BGS) Banterwick Barn (Berkshire; northern Anglo-Paris Basin) and BGS Trunch borehole (Norfolk, southern North Sea Basin; Fig. 1).

2 Materials and methods

The Banterwick Barn borehole (Berkshire; UK national grid reference SU 5134 7750; 51°29'39" N, 1°15'43" W) was cored in 1996 by the BGS as part of a Chalk aquifer study yielding ~97 m of Upper and Middle Chalk. Jarvis et al. (2006) used $\delta^{13}\text{C}$ isotope stratigraphy to determine an age range of Lower Turonian to Middle Coniacian. Pearce et al. (2003) demonstrated a significant attenuation/unconformity spanning much of the Middle and Upper Turonian. The Trunch borehole (Norfolk; UK national grid reference TG 2933 3455; 52°51'34" N, 01°24'19" E), was continuously cored in 1975 by the BGS (then the Institute of

Geological Sciences) to sample the Chalk at its most complete development in Britain. The 10 in. (25.4 cm) diameter core recovered a thick Quaternary cover and 468 m of Cenomanian–lower Maastrichtian Chalk (Wood et al., 1994), including 246 m of Campanian strata. The chalk samples from the borehole were taken from composite bags of 10 cm intervals, no cut round of core was preserved. Palynological processing techniques follow that of Pearce et al. (2003). All slides are lodged at the British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham, UK. England Finder (EF) coordinates are provided for type and reference specimens. Please note that the slide label must be placed on the right-hand side.

3 Systematic descriptions

Division **Dinoflagellata** (Bütschli, 1885) Fensome et al., 1993.
Subdivision **Dinokaryota** Fensome et al., 1993.
Class **Dinophyceae** Pascher, 1914.
Subclass **Peridiniphyceae** Fensome et al., 1993.
Order **Gonyaulacales** Taylor, 1980.
Suborder **Ceratiineae** Fensome et al., 1993.
Family **Ceratiaceae** Willey and Hickson, 1909.
Genus *Odontochitina* Deflandre, 1937.

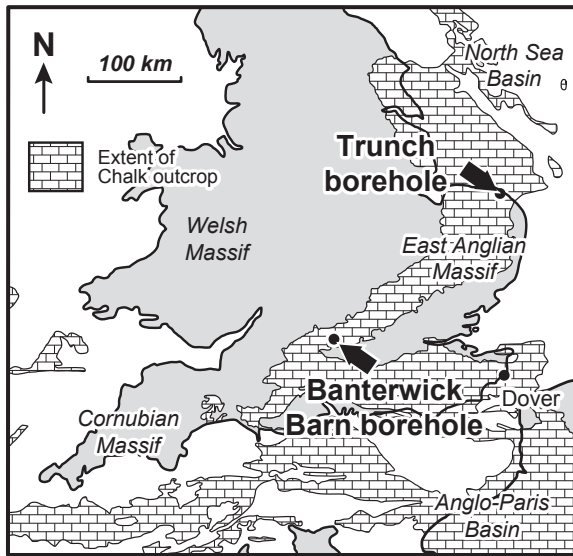


Figure 1. Location map of the BGS Banterwick Barn and Trunch boreholes (modified from Rawson, 1992).

Type. *Odontochitina operculata* (Wetzel, 1933) Deflandre and Cookson, 1955.

Odontochitina diducta Pearce, 2010 emend. nov.
(Pl. 1, figs. 1–3)

1967 *Odontochitina costata* Alberti, 1961; Clarke and Verdier: pl. 13, fig. 4 only.

1968 *Odontochitina* sp. Cookson and Eisenack: 112, pl. 2, fig. D.

1991 *Odontochitina operculata* (Wetzel, 1933) Deflandre and Cookson, 1955; Heine: pl. 27, fig. 15.

1992 *Odontochitina* sp. Costa and Davey: pl. 3.13, fig. 5.

1997 *Odontochitina operculata* (Wetzel, 1933) Deflandre and Cookson, 1955; Roncaglia and Corradini: pl. 2, fig. 5.

Emended diagnosis. A cornucavate to hypocavate species of *Odontochitina* with a widely divergent antapical and lateral horn separated by an angle equal to or greater than 80°.

Emended description. Large ceratioid, cavate dinoflagellate cyst with one apical, antapical and lateral horn of comparable length. The wall is two-layered, comprising a smooth endophragm and smooth, incompletely and faintly striate or distally perforate (although this may be due to corrosion) periphragm. The periphragm and endophragm are appressed in the precingular region with the lateral and antapical horns being either cornucavate or connected by a hypocavation. The endocyst is sub-spherical, lacking obvious projections into the pericoel. The antapical and lateral horns are separated by an angle of greater than 80°.

The paracingulum may be indicated by faint ridges on the periphragm. The archaeopyle is apical Type (tA) and the operculum is detached.

Remarks. In the original description of *O. diducta*, Pearce (2010:62) described the species as having “a well-developed cavation connecting the lateral and antapical horns”. However, this feature seems to be gradational to specimens from the same material that are cornucavate, and the diagnosis and description are emended here to account for this fact. The specimens referred to as *Odontochitina* sp. by Cookson and Eisenack (1968) and Costa and Davey (1992) are thus now considered synonymous with *O. diducta*.

Suborder **Gonyaulacineae** (autonym).

Family **Areoligeraceae** Evitt, 1963.

Genus *Glaphyrocysta* Stover and Evitt, 1978.

Type. *Glaphyrocysta retiintexta* (Cookson, 1965) Stover and Evitt, 1978.

Glaphyrocysta coniacia sp. nov.

(Pl. 1, figs. 4–11)

2003 *Glaphyrocysta* sp. A Pearce et al.: pl. 1, fig. 8.

Derivation of name. Named after the Coniacian Stage from which the type material was obtained.

Diagnosis. A species of *Glaphyrocysta* with a microreticulate endophragm and a weakly fibrous periphragm forming processes of highly variable width, united into linear, arcuate, soleate or annulate complexes that unite distally into wide, perforate, recurved and irregular membranes.

Holotype. MPK 14626, EF coordinates: M40, Pl. 1, figs. 4–5.

Paratypes. Paratype 1, MPK 14627, EF coordinates: K46/1, Pl. 1, fig. 6; paratype 2, MPK 14628, EF coordinates: Q21/2, Pl. 1, fig. 7; paratype 3, MPK 14629, EF coordinates: K19, Pl. 1, fig. 8; paratype 4, MPK 14630, EF coordinates: J11, Pl. 1, fig. 9; paratype 5, MPK 14631, EF coordinates: L22/1, Pl. 1, figs. 10–11.

Type locality and horizon. BGS Banterwick Barn borehole, Berkshire; 1.48–1.55 m, Upper Chalk Formation (Broadstairs Chalk Member), *Micraster coranguinum* Zone (Middle Coniacian).

Description. Medium to large chorate dinoflagellate cyst with a lenticular, dorso-ventrally compressed, central

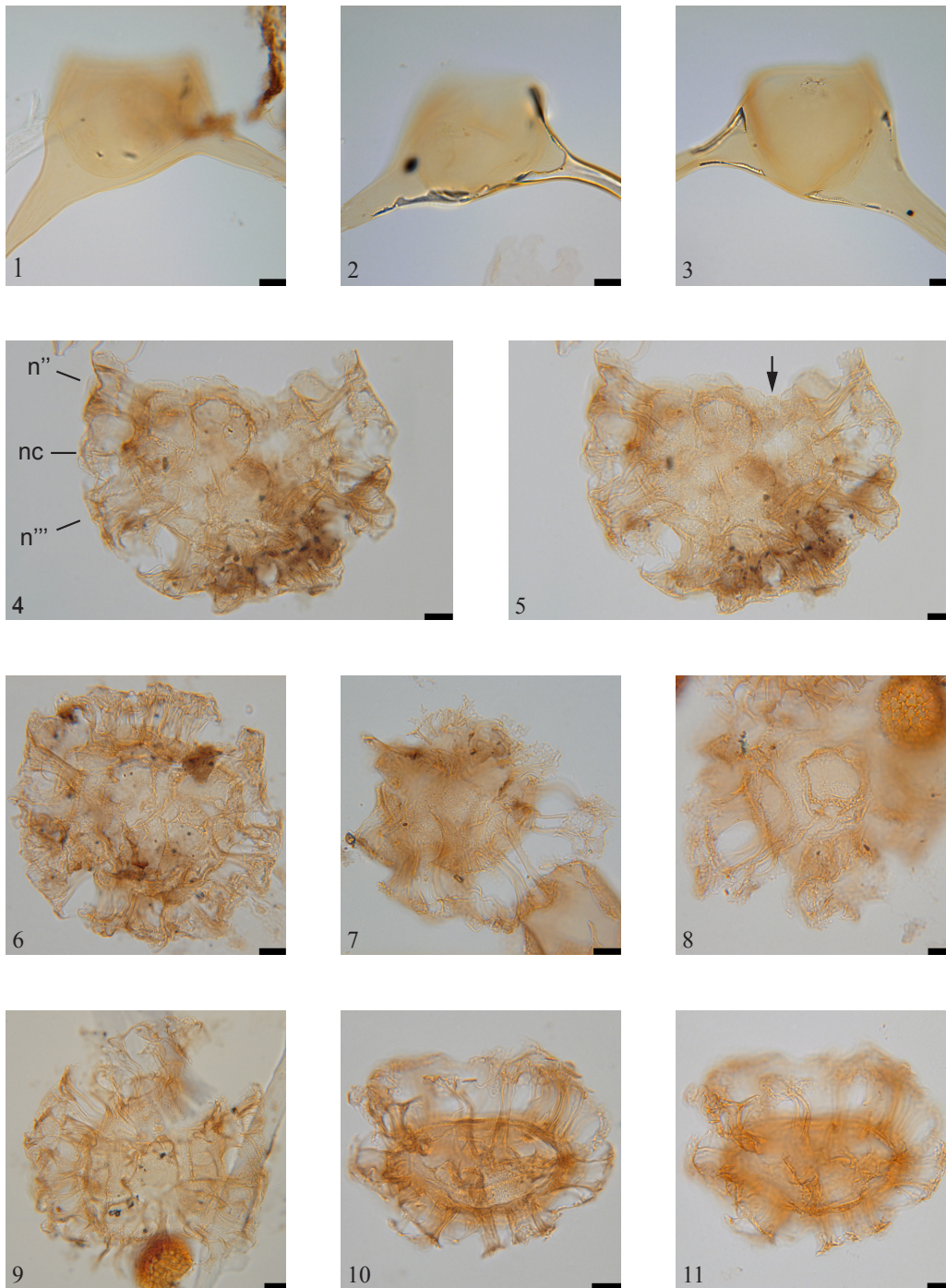


Plate 1. (1–3) *Odontochitina diducta* Pearce 2010, emend. nov.: (1) showing a very narrow hypopericoel connecting the lateral and antapical horns; (2–3) separate cornucave specimens. (4–5) *Glaphyrocysta coniacia* sp. nov. (holotype), MPK 14626, EF coordinates: M40: (4) internal (reversed) dorsal view, showing a precingular arcuate complex – n'', nc and n''' indicate the precingular, cingular and postcingular series, respectively; (5) external ventral view, with the arrow pointing to the offset sulcal notch. (6) *Glaphyrocysta coniacia* sp. nov. (paratype 1), MPK 14627, EF coordinates: K46/1: internal (reversed) ventral? view of a complete specimen showing the widely variable process widths. (7) *Glaphyrocysta coniacia* sp. nov. (paratype 2), MPK 14628, EF coordinates: Q21/2: external view showing the fenestrated distal platforms. (8) *Glaphyrocysta coniacia* sp. nov. (paratype 3), MPK 14629, EF coordinates: K19: external view showing a dorsal? annulate process. (9) *Glaphyrocysta coniacia* sp. nov. (paratype 4), MPK 14630, EF coordinates: J11: external dorsal view, showing a partially attached operculum. (10–11) *Glaphyrocysta coniacia* sp. nov. (paratype 5), MPK 14631, EF coordinates: L22/1: external antapical view showing the dorso-ventral compression. Scale bar represents 10 μ m.

body and an offset sulcal notch. Two weak antapical bulges may be present. Wall two-layered, comprising a micro-reticulate endophragm and a slightly fibrous periphragm that separate in the formation of processes. The processes are tabular, apparently solid, and are well developed around the ambitus of the central body, poorly developed on the mid-dorsal area and typically absent on the mid-ventral area. The marginal processes are of variable width but similar length on individual specimens and appear to be clustered into linear groups that are connected distally and may be connected at the base. The mid-dorsal processes may develop into shorter arcuate, soleate or annulate complexes. Distally, the processes widen into perforated platforms that are irregular in shape and typically recurved. The sulcal notch is offset to the left; the cingulum is represented by slender processes at margins of the central body. The archaeopyle is apical, Type tA, typically with a detached operculum.

Dimensions. Holotype, central body $w/l = 74 \times 61 \mu\text{m}$, maximum process length = $35 \mu\text{m}$; paratype 1, central body $w/l = 71 \times 62 \mu\text{m}$, maximum process length = $27 \mu\text{m}$; paratype 2, central body $w/l = 59 \times 53 \mu\text{m}$, maximum process length = $30 \mu\text{m}$; paratype 3, central body $w/l = 60 \times 60 \mu\text{m}$, maximum process length = $30 \mu\text{m}$; paratype 4, central body $w/l = 70 \times 53 \mu\text{m}$, maximum process length = $25 \mu\text{m}$; paratype 5, maximum process length = $36 \mu\text{m}$. Range, central body $w/l = 46(60)74 \times 42(55)64 \mu\text{m}$, maximum process length = $12(29)36 \mu\text{m}$. Sixteen specimens measured.

Stratigraphic range. Upper Chalk Formation, Broadstairs Chalk Member, *Micraster coranguinum* Zone (Middle Coniacian), above the White Fall Event in the Banterwick Barn borehole to an unconfirmed upper limit (Fig. 2).

Comparison. The closest species to *Glaphyrocysta coniacia* sp. nov. are *G. exuberans* (Deflandre and Cookson, 1955 ex Eaton, 1976) Stover and Evitt, 1978, *G. intricata* (Eaton, 1971) Stover and Evitt, 1978 and *G. texta* (Bujak, 1976) Stover and Evitt, 1978. Despite being described from the Palaeogene and therefore being significantly younger, *Glaphyrocysta exuberans* differs with processes that ramify elaborately halfway along their length, while *G. intricata* and *G. texta* show much less variability in process width. *Glaphyrocysta intricata* also differs in having processes that bifurcate distally to a variable length and width.

Family **Gonyaulacaceae** Lindemann, 1928.

Subfamily **Gonyaulacoideae** (autonym).

Genus *Spiniferites* Mantell, 1850.

Type. *Spiniferites ramosus* (Ehrenberg, 1837) Mantell, 1854.

Spiniferites ramosus subsp. *ginakrogiae* subsp. nov.

(Pl. 2, figs. 1–6, 7 (left), 8)

Derivation of name. After the Norwegian Gina Krog and oil field (in the Norwegian North Sea) of the same name, where the species has also been recognised.

Diagnosis. A large subspecies of *Spiniferites ramosus* with a smooth wall, narrow sutural crests and intergonal processes on some of the larger plate boundaries.

Holotype. MPK 14639, EF coordinates: T46, Pl. 2, figs. 1–3.

Paratypes. Paratype 1, MPK 14640, EF coordinates: V19/2, Pl. 2, fig. 4; paratype 2, MPK 14641, EF coordinates: V26/4, Pl. 2, fig. 3.

Type locality and horizon. BGS Trunch borehole, Norfolk; 451.0 m, Upper Chalk (Burnham Chalk Formation), *Sternotaxis plana* Zone (Upper Turonian).

Description. Large, spiniferate, chorate dinoflagellate cyst with a sub-spherical central body. The wall is two-layered with a thick ($\sim 2 \mu\text{m}$) and smooth endophragm and a thin ($\sim 0.5 \mu\text{m}$) periphragm, the latter of which develops solid processes. Distally trifurcating gonal and bifurcating intergonal processes (on the boundaries between the larger precingular, cingular and postcingular plates) are typically less than one-third the central body diameter, with the furcation occurring from 50% (on shorter processes) to 25% (on longer processes) from the distal end. Narrow sutural crests line the processes, often to the distal extremity, occasionally rendering the bi- and trifurcations relatively wide, and define a clear standard gonyaulacacean tabulation. The cingulum is weakly laevorotatory, typically by one cingulum width; the parasulcus lacks clearly developed sutures. The archaeopyle is precingular, Type P₃'', operculum detached.

Dimensions. Holotype: central body w/l : $74 \times 75 \mu\text{m}$, maximum process length = $22 \mu\text{m}$, paratype 1: central body w/l : $71 \times 76 \mu\text{m}$, maximum process length = $29 \mu\text{m}$, paratype 2: central body w/l : $91 \times 80 \mu\text{m}$, maximum process length = $19 \mu\text{m}$. Range central body $w/l = 54(69)91 \mu\text{m} \times 50(69)84 \mu\text{m}$, maximum process length, $15(21)30 \mu\text{m}$. Twenty specimens measured.

Stratigraphic range. Ferriby Chalk Formation, *Mantelliceras mantellii* Zone (Lower Cenomanian; questionably between the Lower Cenomanian Event I and the Virgatus Beds Event) to the Burnham–Flamborough Chalk Formation (undifferentiated), *Goniot euthis quadrata* Zone (Lower Campanian) in the Trunch borehole (Fig. 2).

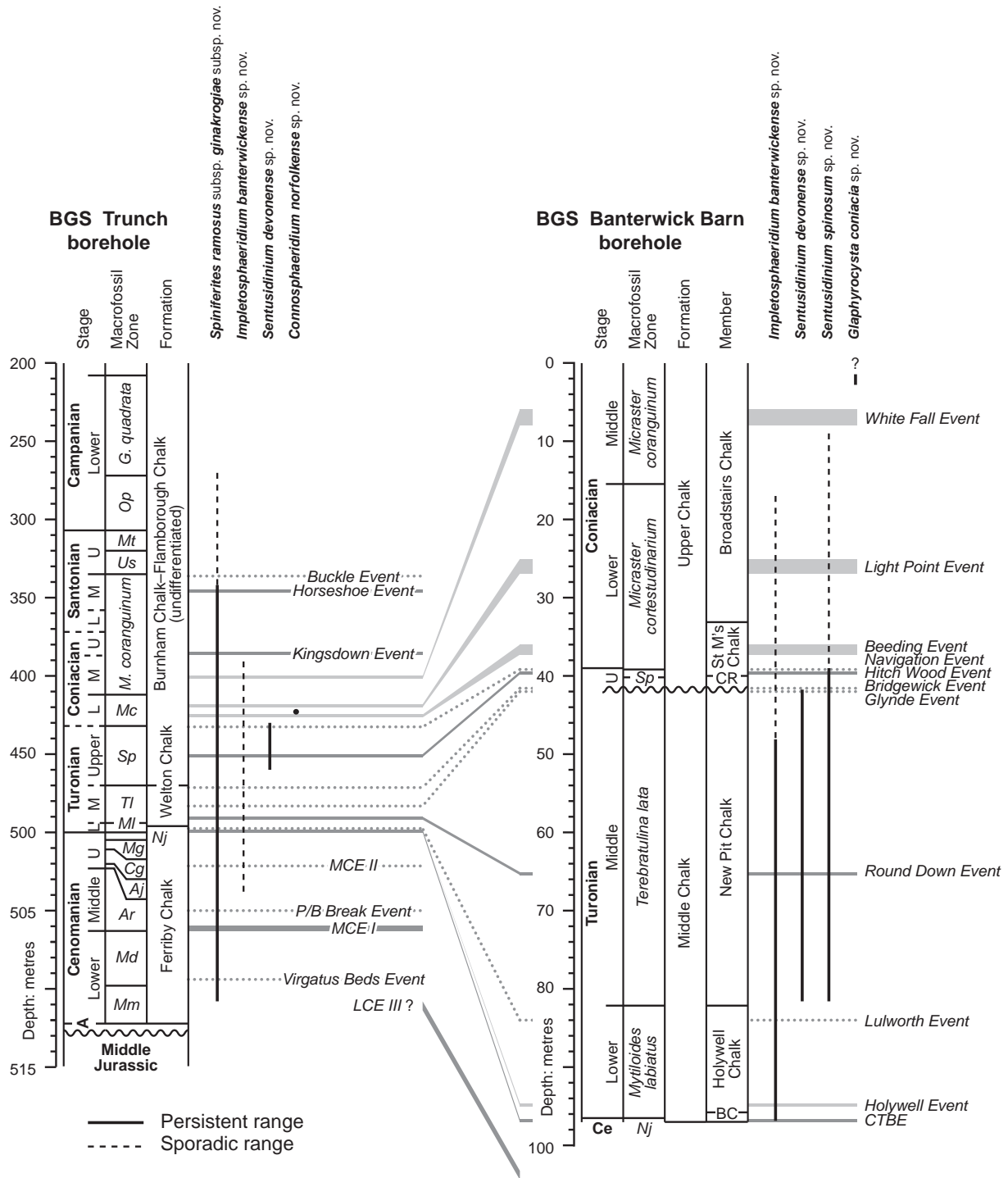


Figure 2. Stratigraphic distribution of the new species from the BGS Banterwick Barn and Trunch boreholes, calibrated by the isotopic events of Jarvis et al. (2006). Abbreviations: A, Albian; Aj, *Acanthoceras jukesbrownei*; BC, Ballard Cliff Member; Ce, Cenomanian; Cg, *Calycoceras guerangeri*; CTBE, Cenomanian–Turonian Boundary Event; CR, Chalk Rock; G. quadrata, *Goniotooth quadrata*; L, lower; LCE III, Lower Cenomanian Event III; M, middle; M. coranguinum, *Micraster coranguinum*; Mc, *Micraster cortestudinarium*; MCE I, Middle Cenomanian Event I; MCE II, Middle Cenomanian Event II; Md, *Mantelliceras dixonii*; Mg, *Metoicoceras geslinianum*; MI, *Mytiloides labiatus*; Mm, *Mantelliceras mantelli*; Mt, *Marsupites testudinarius*; Nj, *Neocardioceras juddii*; Op, *Offaster pilula*; Sp, *Sternotaxis plana*; St M’s Chalk, St Margaret’s Chalk; TI, *Terebratulina lata*; U, upper; Us, *Uintacrinus socialis*. Modified from Jarvis et al. (2006).

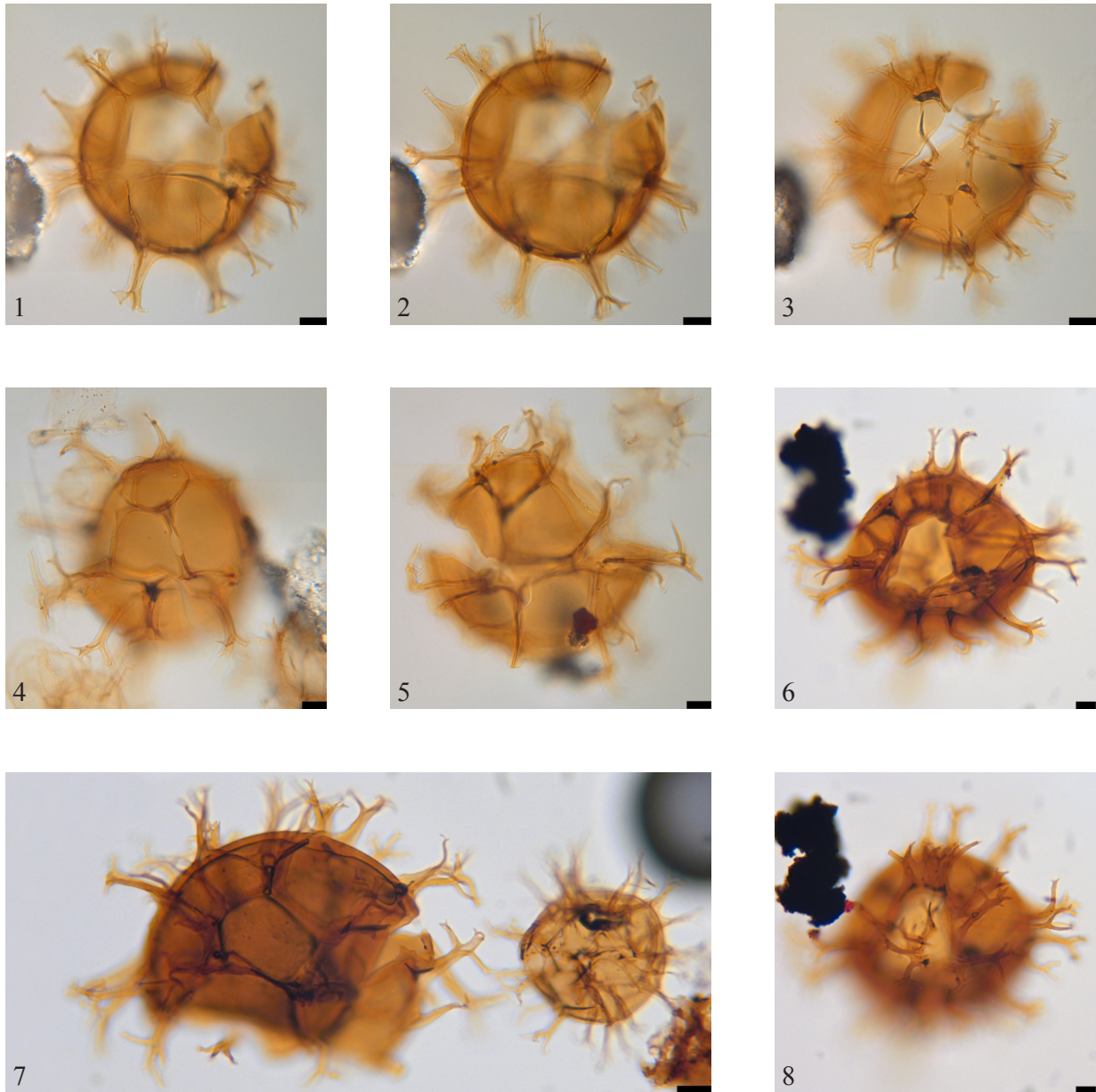


Plate 2. (1–3) *Spiniferites ramosus* subsp. *ginakrogiiae* subsp. nov. (holotype), MPK 14639, EF coordinates: T46: (1) internal (reversed) dorsal view; (2) ambital view; (3) external ventral view. (4) *Spiniferites ramosus* subsp. *ginakrogiiae* subsp. nov. (paratype 1), MPK 14640, EF coordinates: V19/2: external (right) lateral view. (5) *Spiniferites ramosus* subsp. *ginakrogiiae* subsp. nov. (paratype 2), MPK 14641, EF coordinates: V26/4: external (left) lateral view. (6, 8) *Spiniferites ramosus* subsp. *ginakrogiiae* subsp. nov., specimen from the Gina Krog Field, Norwegian North Sea; (7) *Spiniferites ramosus* subsp. *ginakrogiiae* subsp. nov. (left) and *S. ramosus* subsp. *ramosus* (right), size comparison. Scale bar represents 10 μm .

Remarks. This species appears to be morphologically intermediate between *Spiniferites ramosus* subsp. *gracilis* (by possessing intergonal processes) and *Spiniferites porosus* (in size). The central body diameter of *Spiniferites porosus* ranges from 66 to 69 μm (the holotype is 66 \times 75 μm), with process lengths ranging from 17 to 36 μm (holotype 17–23 μm) long.

Comparison. Differs from other subspecies of *Spiniferites ramosus* by its conspicuously large size.

Subfamily **Leptodinioidae** Fensome et al., 1993.

Genus *Conosphaeridium* Cookson and Eisenack, 1969.

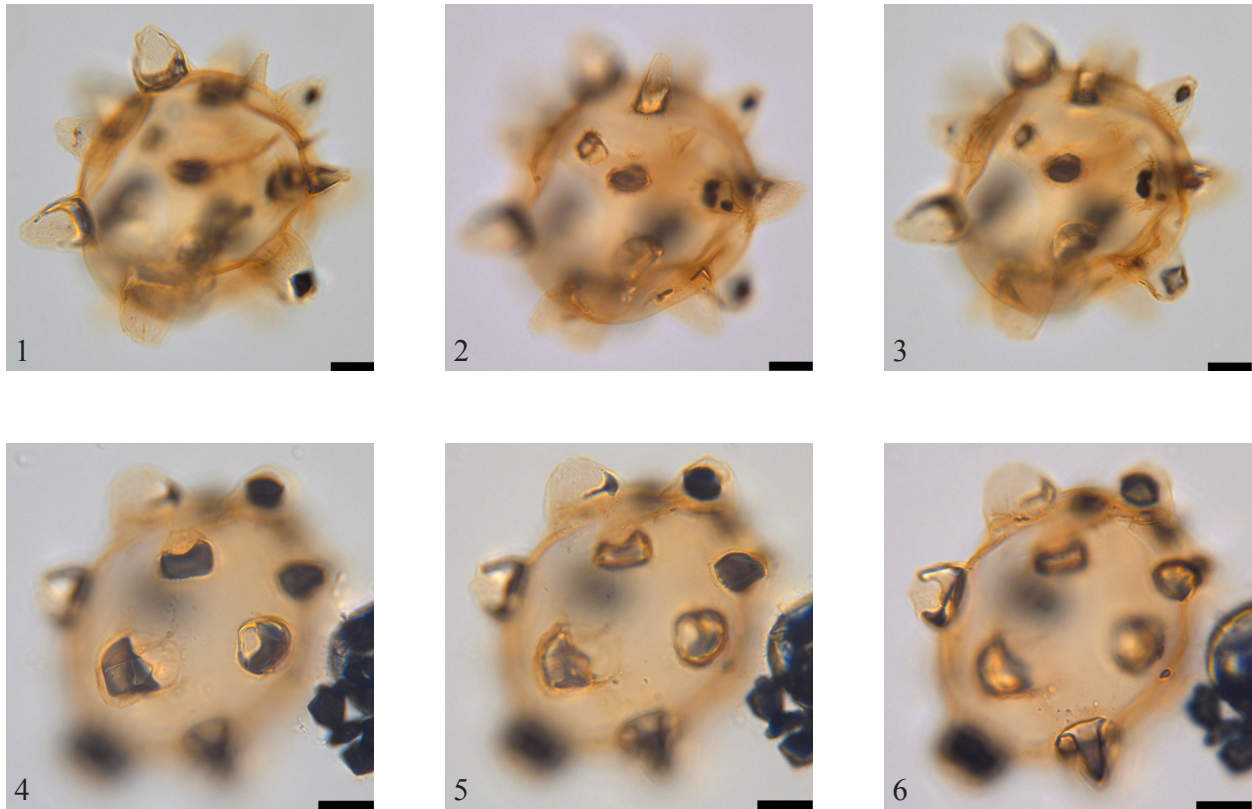


Plate 3. (1–3) *Conosphaeridium norfolkense* sp. nov. (holotype), MPK 14624, EF coordinates: K37/1: internal (reversed) view of the precingular archaeopyle; precise orientation not determined. (4–6) *Conosphaeridium norfolkense* sp. nov. (paratype), MPK 14625, EF coordinates: V26/1: external view; precise orientation not determined. Scale bar represents 10 μm .

Type. *Conosphaeridium striatoconum* (Deflandre and Cookson, 1955) Cookson and Eisenack, 1969.

Conosphaeridium norfolkense sp. nov.
(Pl. 3, figs. 1–6)

1976 *Conosphaeridium* cf. *striatoconum* of Benson: pl. 1, figs. 4–5.

Derivation of name. Named after the English county of Norfolk, from where the type material was obtained.

Diagnosis. A species of *Conosphaeridium* with a smooth to only very weakly striate periphragm.

Holotype. MPK 14624, EF coordinates: K37/1, Pl. 3, figs. 1–3.

Paratype. MPK 14625, EF coordinates: V26/1, Pl. 3, figs. 4–6.

Type locality and horizon. BGS Trunch borehole, Norfolk; 423.0 m, Upper Chalk (Burnham Chalk Formation), *Micraster cortestudinarium* Zone (Lower Coniacian).

Description. Medium-sized proximochorate dinoflagellate with a globular sub-spherical central body. The wall is two-layered, comprised of a thin, smooth endophragm and smooth to very weakly striate periphragm that forms hollow intratabular processes. The processes are relatively squat, rounded-lagenate and typically open distally. The archaeopyle is precingular, Type P_{3'}, the operculum may be attached, but more usually detached.

Dimensions. Holotype, central body diameter = 60 μm , maximum processes length = 17 μm . Paratype, central body diameter = 51 μm , maximum processes length = 12 μm . Range, central body diameter = 44(54)65 μm , maximum processes length = 8(12)17 μm . Six specimens measured.

Stratigraphic range. Only observed from the sample containing the holotype, between the Beeding and Light Point events (Fig. 2).

Comparison. Both *Conosphaeridium abbreviatum* Wilson, 1984 and *C. striatoconum* (Deflandre and Cookson, 1955) Cookson and Eisenack, 1969 differ by possessing strong ribs on the processes; the former also has a much larger central body size (holotype body diameter 95 \times 81 μm). Brideaux

and McIntyre (1975, pl. 7, figs. 17–18) figured a specimen as *Conosphaeridium* sp. A from the Middle Albian of northern Canada that is similar to *C. norfolkense* in possessing a very weakly striate periphragm, but which differs in the shape of the processes that are tubular and narrow distally with a truncated distal margin. The specimen figured as *Conosphaeridium* cf. *striatoconus* by Benson (1976) from the undifferentiated Upper Cretaceous of Maryland, USA, is considered here synonymous with *C. norfolkense* sp. nov.

Subfamily uncertain

Genus *Sentusidinium* Sarjeant and Stover, 1978.

Type. *Sentusidinium rioultii* (Sarjeant, 1968) Sarjeant and Stover, 1978.

Remarks. As stated by Wood et al. (2016) in their emendation of the genus, the operculum of *Sentusidinium* is normally detached (implying that attached operculae are permitted), and deep accessory archaeopyle sutures are typically present.

Sentusidinium devonense sp. nov.

(Pl. 4, figs. 1–12)

1987 *Sentusidinium* sp. B in Tocher and Jarvis: pl. 9.3, figs. 7–9.

1995 *Canningia* sp. B FitzPatrick: fig. 9n.

Derivation of name. From the English county of Devon, from where the species was originally recorded.

Diagnosis. A species of *Sentusidinium* with an even covering of short, flexuous and acuminate spines.

Holotype. MPK 14634, EF coordinates: O17, Pl. 4, figs. 1–3.

Paratypes. Paratype 1, MPK 14635, EF coordinates: F37/3, Pl. 4, figs. 4–6; paratype 2, MPK 14636, EF coordinates: D50/4, Pl. 4, figs. 7–9; paratype 3, MPK 14637, EF coordinates: L16, Pl. 4, figs. 10–12.

Type locality and horizon. BGS Banterwick Barn borehole, Berkshire; 48.06–48.09 m, Middle Chalk Formation, New Pit Chalk Member, *Terebratulina lata* Zone (Middle Coniacian).

Description. A medium-sized proximate dinoflagellate cyst with a sub-rounded body. The wall is composed of a finely granular autophragm that possesses short (~2 µm), evenly distributed and apparently solid, simple flexuous spines with acuminate tips. No expression of the cingulum or sulcus is present. The archaeopyle is apical, Type tA, with a zig-zag margin and clear accessory sutures. The operculum may be attached but more usually detached.

Dimensions. Holotype, central body *w/l* (excluding operculum) = 66 × 43 µm, maximum process length 2 µm; paratype 1, central body *w/l* (excluding operculum) = 65 × 48 µm, maximum process length 2 µm; paratype 2, central body *w/l* = 68 × 50 µm, maximum process length 2 µm; paratype 3, central body *w/l* = 60 × 50 µm, maximum process length 3 µm. Range, central body *w/l* (excluding operculum) = 40(61)76 × 40(48)60 µm, maximum process length = 2(2)3 µm. Seventeen specimens measured.

Stratigraphic range. Middle Chalk Formation, Holywell Chalk Member, *Mytiloides labiatus/Terebratulina lata* boundary (Middle Turonian; between the Lulworth and Round Down events in the Banterwick Barn borehole) to the Burnham–Flamborough Chalk Formation (undifferentiated), *Micraster cortestudinarium* Zone (Lower Coniacian; between the Navigation and Beeding events in the Trunch borehole; Fig. 2).

Remarks. FitzPatrick (1995) described the informal species *Canningia* sp. B from the Turonian of Southern England. She considered the generic attribution based on the subspherical outline, non-tabular spinose ornament and apical archaeopyle; however, she also mentioned the lack of an offset sulcal notch. These observations suggest that the species is not an areoligeracean, and that it has a greater affinity with *Sentusidinium*, and it is here considered synonymous with *S. devonense* sp. nov.

Comparison. For such a simple genus of dinoflagellate cyst, there are a number of comparable species, but which all differ in the shape of the central body and/or the morphology of the processes. *Sentusidinium aptiense* (Burger, 1980a) Burger, 1980b possesses hollow tubular spines and *S. capillatum* (Davey, 1975) Lentin and Williams, 1981, *S. echinatum* (Gitmez and Sarjeant, 1972) Sarjeant and Stover, 1978 and *S? millepedii* (Jain and Milleped, 1975) Islam, 1993 possesses much more densely distributed ornament. *Sentusidinium capitatum* (Cookson and Eisenack, 1960) Wood et al., 2016 may possess short spines with acuminate tips but the body is distinctly elongate, while *S. minus* (Jiabo, 1978) He et al. in He et al., 1989 is significantly smaller. *Sentusidinium myriatricum* Fensome, 1979 possesses significantly shorter and denser ornament and *S. perforoconum* (Yun Hyesu, 1981) Islam, 1993 has a densely perforate periphragm. *Sentusidinium pilosum* (Ehrenberg, 1854) Sarjeant and Stover, 1978 has a denser cover of short processes with variable tips that are also variable in *S. rioultii* Sarjeant, 1968, *S. sahii* (Khanna and Singh, 1981) Wood et al., 2016, *S. sparsibarbatum* Erkmen and Sarjeant, 1980 and *S. villersense* (Sarjeant, 1968) Sarjeant and Stover, 1978. *Sentusidinium separatum* (McIntyre and Brideaux, 1980) Lentin and Williams, 1981 has bifid and branched process tips.

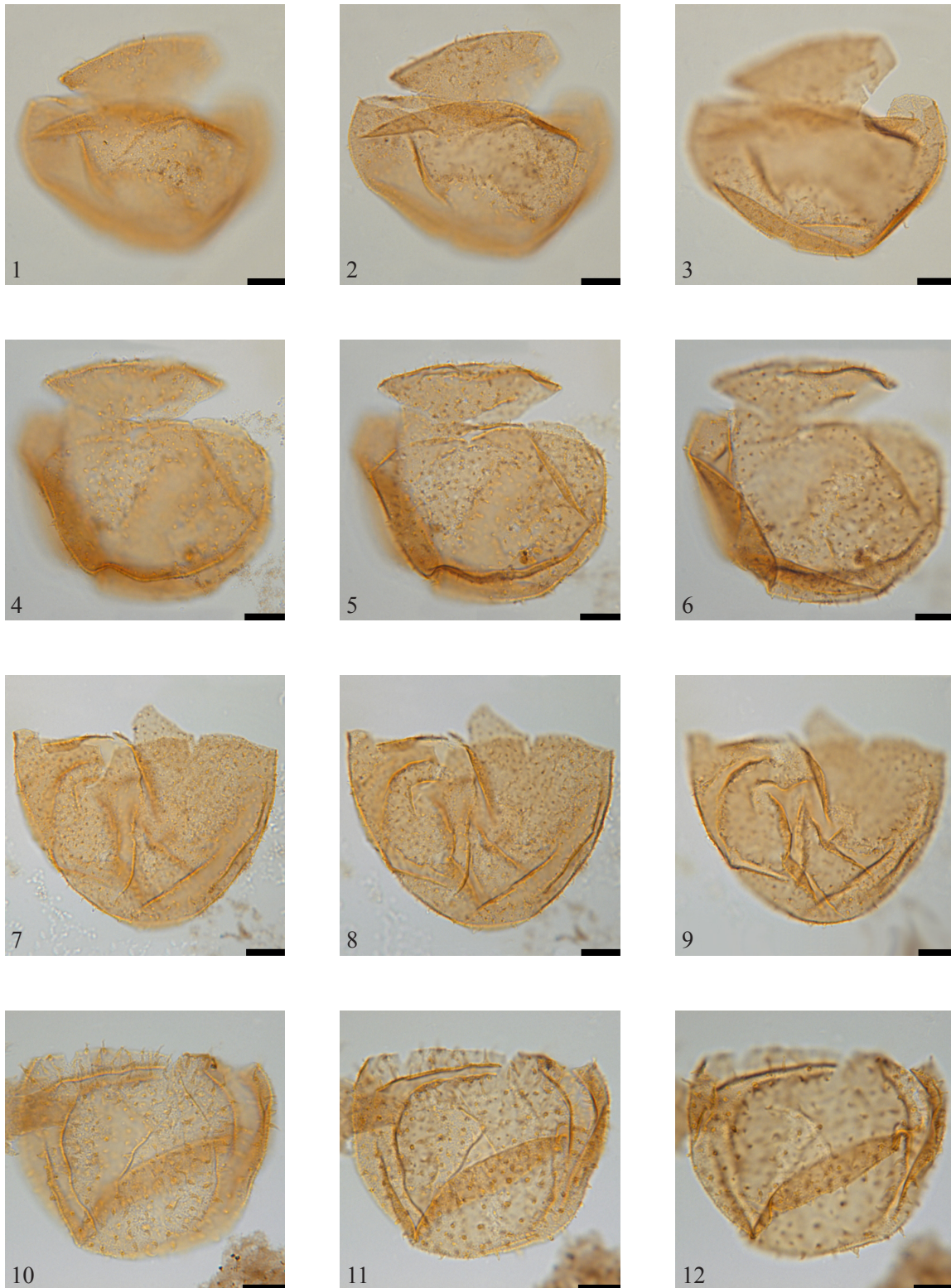


Plate 4. (1–3) *Sentusidinium devonense* sp. nov. (holotype), MPK 14634, EF coordinates: O17: (1) external view; (3) internal (reversed) view. (4–6) *Sentusidinium devonense* sp. nov. (paratype 1), MPK 14635, EF coordinates: F37/3: (4) external view; (6) internal (reversed) view. (7–9) *Sentusidinium devonense* sp. nov. (paratype 2), MPK 14636, EF coordinates: D50/4: (7) external view; (9) internal (reversed) view. (10–12) *Sentusidinium devonense* sp. nov. (paratype 3), MPK 14637, EF coordinates: L16: (10) external view; (12) internal (reversed) view. Scale bar represents 10 μ m.

Sentusidinium spinosum sp. nov.

(Pl. 5, figs. 1–6)

Derivation of name. From the Latin *spinosum*, meaning spiny.

Diagnosis. A species of *Sentusidinium* with an even covering of relatively long, flexuous and acuminate spines.

Holotype. MPK 14638, EF coordinates: S13/4, Pl. 5, figs. 1–6.

Type locality and horizon. BGS Banterwick Barn borehole, Berkshire; 39.55–39.59 m, Upper Chalk Formation, St. Margaret's Chalk Member, *Sternotaxis plana* Zone (Middle Turonian).

Description. A medium-sized proximate dinoflagellate cyst with a sub-rounded body. The wall is composed of a micro-reticulate autophragm that possesses relatively long (4–16 µm), evenly distributed, hollow spines with simple acuminate tips. No expression of the cingulum or sulcus is present. The archaeopyle is apical, Type tA, with a zig-zag margin and clear accessory sutures. The operculum may be attached but more usually detached.

Dimensions. Holotype, central body $w/l = 61 \times 48$ µm, maximum process length = 11 µm. Range, central body $w/l = 46(56)72 \times 30(46)56$ µm, maximum processes length = 4(6)16 µm. Twenty specimens measured.

Stratigraphic range. Middle Chalk Formation, Holywell Chalk Member, *Mytiloides labiatus/Terebratulina lata* boundary (Middle Turonian; between the Lulworth and Round Down events) to the Upper Chalk Formation, Broadstairs Chalk Member, *Micraster coranguinum* Zone (Middle Coniacian; below the White Fall Event) in the Banterwick Barn borehole (Fig. 2).

Comparison. *Sentusidinium aptiense* (Burger, 1980a) Burger, 1980b also possesses hollow spines but which differ from *S. spinosum* sp. nov. in their relatively shorter length of 3–4 µm. These species also have mutually exclusive ranges, being Callovian to Aptian for *S. aptiense* (Wood et al., 2015) and Turonian for *S. spinosum* sp. nov. *Sentusidinium densicomatum* (Maier, 1959) Sarjeant, 1983 differs in possessing more densely distributed hair-like projections. The processes are also much more numerous on *S. pilosum* (Ehrenberg, 1854) Sarjeant and Stover, 1978 and which also have variable tips. Spine length is comparable on *S. sahi* (Khanna and Singh, 1981) Wood et al., 2016 and *S. seperatum* (McIntyre and Brideaux, 1980) Lentin and Williams, 1981 but which also have variable tips in the former and bifid and branched tips in the latter.

Suborder **uncertain**

Family **uncertain**

Genus *Impletosphaeridium* Morgenroth, 1966.

Type. *Impletosphaeridium transfodum* Morgenroth, 1966.

Impletosphaeridium banterwickense sp. nov.

(Pl. 5, figs. 7–12)

Derivation of name. Named after Banterwick Barn, the borehole from where the species is described.

Diagnosis. A species of *Impletosphaeridium* possessing spines that terminate distally into a simple bifurcation with endings of equal length.

Holotype. MPK 14632, EF coordinates: Q35/2, Pl. 5, figs. 7–9.

Paratype. MPK 14633, EF coordinates: K6/3, Pl. 5, figs. 10–12.

Type locality and horizon. BGS Banterwick Barn borehole, Berkshire; 79.51–79.53 m, Middle Chalk Formation, New Pit Chalk Member, *Terebratulina lata* Zone (Middle Turonian).

Description. A small chorate dinoflagellate cyst with a sub-rounded body. The wall is composed of a finely granular autophragm from which arises evenly distributed, non-tabular solid spines, which terminate in a short bifurcation. No expression of the cingulum or sulcus is present. The archaeopyle is apical, Type tA, with a zig-zag margin and accessory sutures. The operculum may be attached but more usually detached.

Dimensions. Holotype, central body $w/l = 46 \times 39$ µm, maximum process length = 12 µm. Paratype, central body $w/l = 46 \times 39$ µm, maximum process length = 14 µm. Range, central body $w/l = 35(41)47 \times 29(36)43$ µm, maximum process length = 10(13)16 µm. Twenty specimens measured.

Stratigraphic range. Middle Chalk Formation, Ballard Cliff Member (uppermost Cenomanian; upper Cenomanian–Turonian Boundary Event) in the Banterwick Barn borehole to the Burnham–Flamborough Chalk Formation (undifferentiated), *Micraster coranguinum* Zone (Middle Coniacian; between the White Fall and Kingsdown events) in the Trunch borehole (Fig. 2).

Comparison. *Impletosphaeridium furcillatum* (Prössl, 1990 ex Prössl, 1992) Williams et al., 1998 differs in possessing thicker bifurcate to multifurcate processes, while

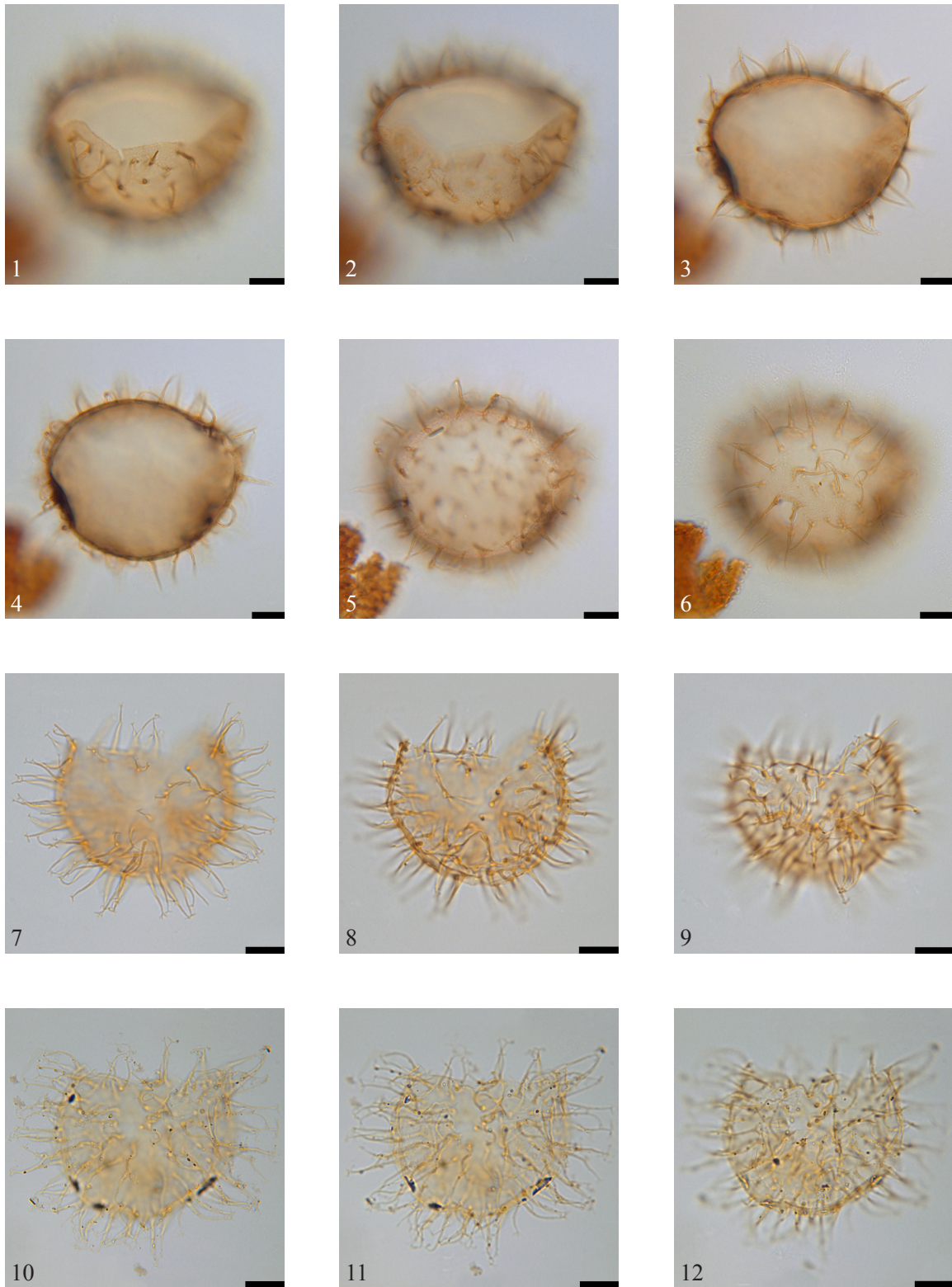


Plate 5. (1–6) *Sentusidinium spinosum* sp. nov. (holotype), MPK 14638, EF coordinates: S13/4: (1) internal (reversed) view, showing the archaeopyle margin; (6) external view of the antapical region. (7–9) *Impletosphaeridium banterwickense* sp. nov. (holotype), MPK 14632, EF coordinates: Q35/3: (7) external view; (9) internal (reversed) view. (9–12) *Impletosphaeridium banterwickense* sp. nov. (paratype), MPK 14633, EF coordinates: K6/3: (10) external view; (12) internal (reversed) view. Scale bar represents 10 μ m.

I. ligospinosum (de Coninck, 1969) Islam, 1983 differs in possessing bifurcations of unequal length. In *I. varispinosum* (Sarjeant, 1959) Islam, 1993, the spines are more numerous and differ in being occasionally simple but more frequently bifurcate, clavate or “hammer-headed”. The only similar species of comparable age is *I. williamsii* (Boltenhagen, 1977) Islam, 1993; although it possesses acuminate to bifurcate processes, many of the latter style more closely resemble flared process endings than bifurcating spines. Species of *Downiesphaeridium* differ in possessing hollow (and distally closed) processes, the closest species of which is *D. aciculare* (Davey, 1969) Islam, 1993, which differs further by possessing wider (although relatively thin), blade-like processes. According to Davey (1969), the processes of *Downiesphaeridium aciculare* are always pointed distally and occasionally bear small subsidiary spines near their extremities. In *I. banterwickense* sp. nov., the subsidiary spines occur at the extremity and are significantly longer.

Data availability. All slides are lodged at the British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham, UK. England Finder (EF) coordinates are provided for type and reference specimens.

Competing interests. The author declares that he has no conflict of interest.

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