

# Late Miocene dinoflagellate cysts and calcareous nanoplankton from the eastern North Sea Basin margin: biostratigraphy and palaeoenvironmental interpretation (Breklum research borehole, Germany)

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**Abstract** Dinoflagellate cysts and calcareous nanoplankton were studied from sediments of the Upper Mica Clay Member of the Breklum research well in northern Germany. The investigated section is of Late Miocene age (dinoflagellate cyst biozones DN8 and ?DN9 of Köthe, 2003). This age assignment is supported by calcareous nanoplankton biostratigraphy (zones NN6–NN11 of Martini, 1971; Middle to Late Miocene) in the middle part of the section. The calcareous nanoplankton biozone assignment is based on the presence of *Helicosphaera stalis*, which was used as an additional marker.

As in other southern North Sea Basin countries, the diversity, preservation and number of dinoflagellate cysts are good. Neogene records of calcareous nanoplankton in marginal North Sea Basin areas are known to be poor, but at Breklum an almost continuous section was found, with a higher diversity than expected. The calcareous nanoplankton possibly benefited from a slightly stronger marine influence at this site, compared to currently known onshore localities. Dinoflagellate cysts generally indicate a neritic environment, at least occasionally swept by oceanic waters.

**Keywords** Late Miocene, biostratigraphy, North Sea Basin, dinoflagellate cysts, calcareous nanoplankton

## 1. Introduction

Studies on Late Miocene dinoflagellate cysts, and on calcareous nanoplankton in particular, of the marginal North Sea Basin are sparse. The scarcity of calcareous nanoplankton in often non-calcareous sediments increases from the Early to the Late Miocene and, therefore, discourages investigation of this group. However, calcareous nanoplankton are one of the most important microfossil groups for worldwide correlation and, therefore, any dating they provide for Neogene sediments from the marginal North Sea is valuable. A combined study of both groups enables results and interpretations to be validated. The aim of this study was to improve the understanding of Late Miocene biostratigraphy by correlating dinoflagellate cysts and calcareous nanoplankton, and evaluating their palaeoenvironmental potential.

## 2. Material and methods

The Breklum borehole is located in northern Germany on the west coast of Schleswig-Holstein (TK25 1319 Bredstedt, Re: 3499968, H: 6053953; Figure 1). The section comprises two boreholes drilled at the same location by the Landesamt für Natur und Umwelt (LANU) of Schleswig-Holstein. The Breklum 2/96 borehole was drilled dry with an auger bit in 1996 to a total depth of 40m. In 2001, the Breklum 2001 borehole was flushed down to 40m and cored from 40–112m. As the boreholes lie in the vicinity of the terminal moraine of the Saalian Glacial Stage, Pleistocene faulting and disturbance of the sediments cannot be excluded. The boreholes (see Figure 2) were lithologically described and

sampled by K. Gürs (pers. comm., 2004). The sediments consist of micaceous clays and silts of the 'Oberer Glimmerton' (Upper Mica Clay Member). Forty-two samples (13 ditch-cuttings and 29 core samples) were investigated. In general, the samples were taken every three metres. More closely spaced samples were taken in some cases when the lithology changed. The results from Breklum were compared with previously investigated sections (Figure 3).



Figure 1: Location of the Breklum borehole

### 2.1 Dinoflagellate cysts

All samples were processed using standard palynological techniques (HCl, HF, KOH, ultrasonic sieving using a 10µm nylon screen) and mounted in glycerine jelly. All slides were examined using a Leitz (Aristoplan) light-microscope with interference contrast at 250x and 400x magnification. Two hundred dinoflagellate cyst

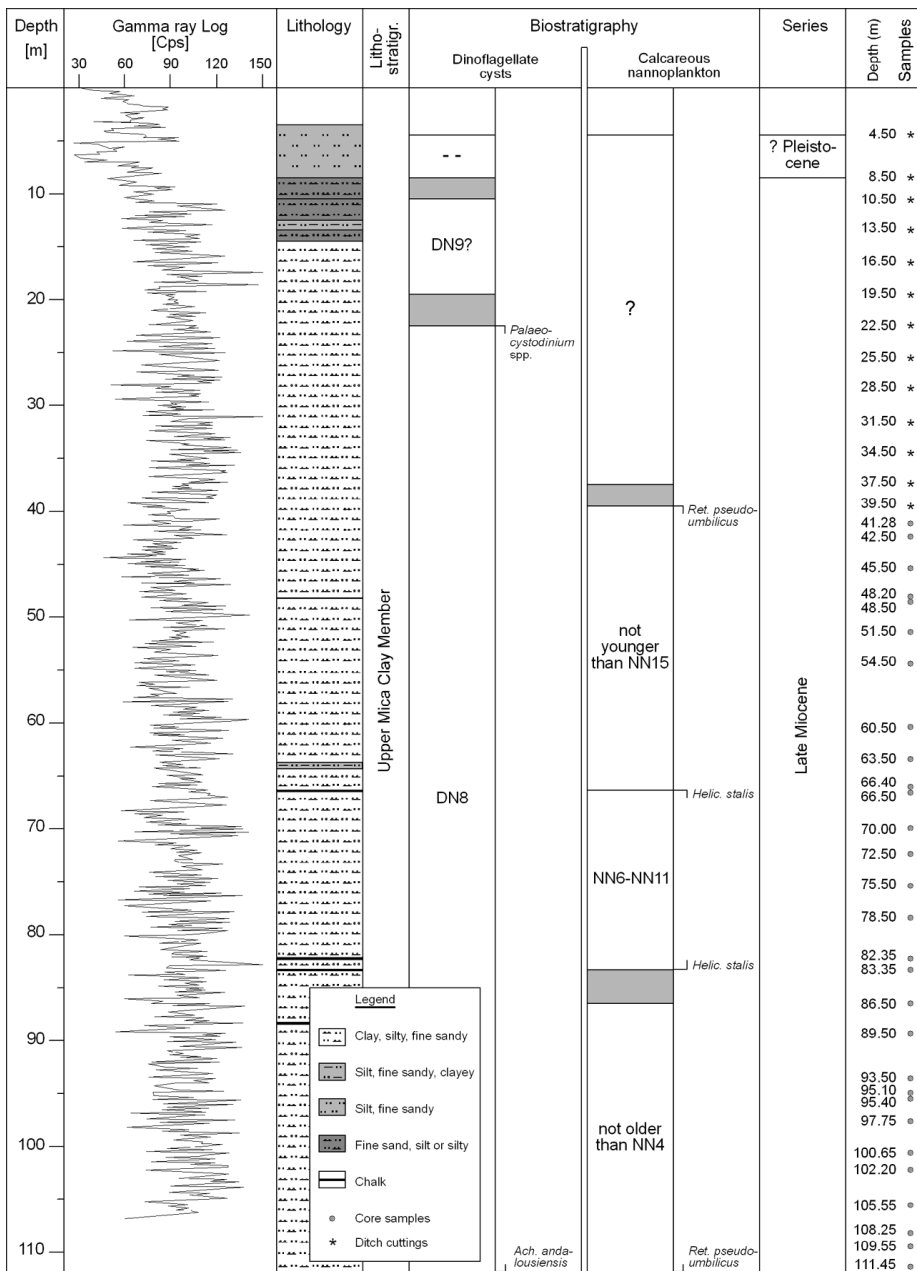


Figure 2: Gamma-ray log, lithology and biostratigraphy of the Breklum borehole

specimens per sample were counted. The total abundances of dinoflagellate cysts were defined as specimens per traverse (0.228cm<sup>2</sup>) of the slide, and relative abundances were grouped into four classes (Table 1).

All slides are stored in the dinoflagellate cyst collection of the Federal Institute for Geosciences and Natural Resources, Hannover (BGR). The biostratigraphic zonation (DN zones) follows Köthe (2003; see Figure 4). The biozonation proposed by Munsterman & Brinkhuis (2004) could not be applied, because the chronological order of their index-markers contradicts observations from Germany (Köthe, 2000; Strauss *et al.*, 2001). The taxonomy follows Williams *et al.* (1998), where full citations of the identified species

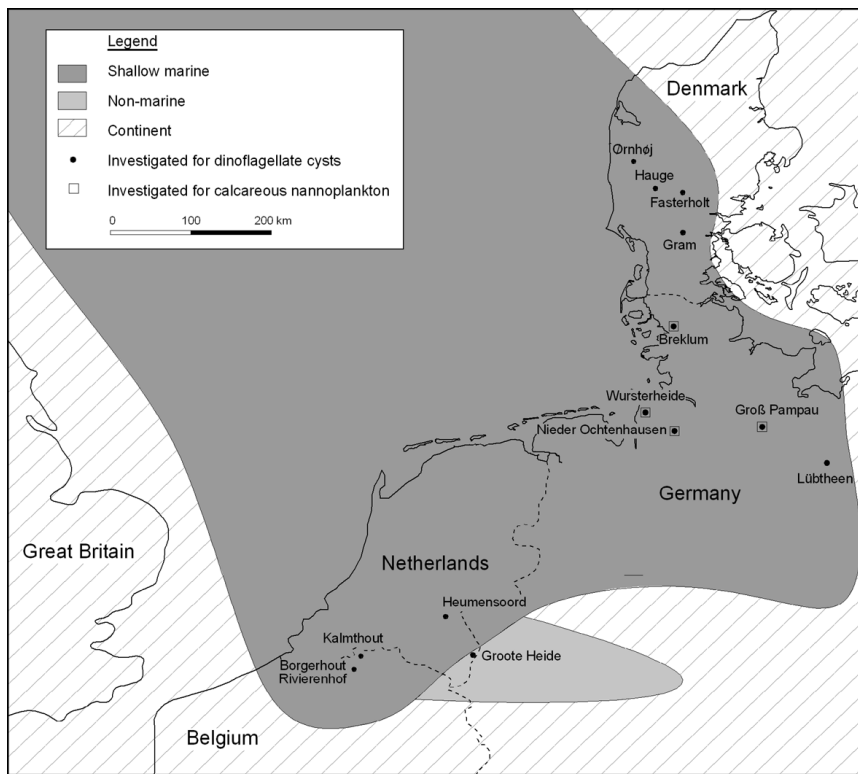
can be found.

## 2.2 Calcareous nannoplankton

Sample preparation followed standard settling techniques (Hay, 1977; Bown & Young, 1998). To avoid dissolution during preparation, use was made of demineralised water saturated with calcium carbonate and buffered with ammonia (Andruleit *et al.*, 2000). All slides were examined with a Zeiss Axioplan 2 light-microscope at 1000x magnification. All slides are stored in the BGR calcareous nannoplankton collection. Total abundances of the calcareous nannoplankton were defined as specimens per field of view (Table 2). Relative abundances were grouped into classes (Table 2). The standard Neogene calcareous nannoplankton biozonation, as described by Martini (1971: NN zones), was used as a basis for this study (Figure 4). Additionally, the biostratigraphy and taxonomy presented by Young (1998) was used. Full citations of the identified species can be found in Bown (1998).

## 3. Palaeogeography of the study area

After extensive transgression in the Middle Miocene, the Late Miocene indicates a period of regression (Gramann & Kockel, 1988, p.439; Balson, 1999; Huuse, 2002). The sediments reflect deposition during long-term climatic cooling and eustatic sea-level fall (Huuse, 2002). The extent of the southern North Sea was similar to that of today, but it is unlikely that there was a connection to the Bay of Biscay via the English Channel (Figure 3; Balson, 1999). Therefore, the southern North Sea was probably a semi-enclosed embayment. The main depocentre lay along the axis of the subsiding Rhine Graben (Balson, 1999). Progressive filling of the eastern and central North Sea Basin by large deltas continued. During the Late Miocene, rivers were fed from the Baltic region. The Baltic River System formed a westward prograding delta, which deposited



**Figure 3:** Palaeogeography of the marginal North Sea Basin in the late Middle Miocene (after Popov *et al.*, 2004). Known locations analysed for dinoflagellate cysts and calcareous nannoplankton, covering the same time-interval as the Breklum research well, are depicted. The palaeogeographic map and the investigated sections differ slightly in age

huge amounts of sediment in northern Germany (Huuse, 2002). In the Lower Rhine Embayment, isochronous coastal-deltaic and continental-fluvial beds comprise sands, clays and several thick lignite horizons (Herngreen, 1987) of economic importance. Apart from seismic surveys, most publications covering the Late Miocene in the southern North Sea Basin concern onshore locations. The sediments consist of near-shore, shallow marine sediments, swept only occasionally by oceanic waters.

## 4. Results

Taxa used for biozonation are shown on Figure 2.

### 4.1 Dinoflagellate cysts

All samples contain common to abundant dinoflagellate cyst assemblages, except for the uppermost five samples that yield fewer specimens. The two uppermost samples are almost barren. Preservation is good.

The identified dinoflagellate cysts are shown in Table 1. Based on the co-occurrence of *Achomosphaera andalousiensis* (Pl.1, figs 1–3) and *Palaeocystodinium* spp. (Pl.1, figs 6,

7), the interval from 111.45m to 22.50m is of early to middle Late Miocene age (zone DN8). Because specimens of *Palaeocystodinium* are very rare, identification of DN9 (middle to late Late Miocene), from 19.50m to 10.50m, remains questionable.

The assemblages are dominated by *Achomosphaera* and *Spiniferites*. Almost continuously present and common are *Lingulodinium machaerophorum*, *Nematosphaeropsis? crassimuratus?* and *Operculodinium israelianum* (Plate 2). *Spiniferites pseudofurcatus*, *Hystriocholpoma salacia* and *Homostryblum tenuispinosum* (Plate 3) are not continuously present but are very abundant in some samples. The genera *Impagidinium*, *Selenopemphix* and *Sumatradinium* are only sporadically present and occur in low numbers (Plate 4).

Dybkjær (2004) notes that, in north-western Europe, the last occurrence of *H. tenuispinosum* is distinctly younger than the 23.67Ma (around the Oligocene/Miocene boundary) suggested by Hardenbol *et al.* (1998, chart 3). The presence of *H. tenuispinosum* in the Late Miocene in Breklum supports Dybkjær (2004).

Reworked specimens of Paleogene and Lower Miocene strata are regularly distributed in the sequence, but they do not exceed 2% of the total dinoflagellate cyst

Time (Ma)	Series	International stages	Dinoflagellate cysts		Calcareous nannoplankton	
			Zones	Marker	Zones	Marker
10	LATE MIOCENE	MESSINIAN	DN10	<i>Erymodinium defleabile</i>	5.6 NN12	<i>Discoaster quinqueramus</i>
					NN11	
		7.25				
		TORTONIAN	7.6	<i>Hystriochosphaeropsis obscura</i> ; <i>Dapsilodinium pseudocolligerum</i> , <i>Habibacysta tectata</i> , <i>Labyrinthodinium truncatum</i>	8.3	<i>Discoaster quinqueramus</i>
			8.8	<i>Palaeocystodinium golzowense</i> ; <i>Palaeocystodinium</i> spp.	NN10	
			DN8	<i>Habibacysta tectata</i>	9.7	<i>Discoaster hamatus</i>
					NN9	<i>Discoaster hamatus</i>
					10.55	<i>Discoaster hamatus</i>
					10.9	<i>Catinaster coalitus</i>
			(11.2)	<i>Achomosphaera andalousiensis</i>	NN8	
			DN7	<i>Cannosphaera passio</i>	NN7	
		11.6			11.85	<i>Discoaster kugleri</i>

**Figure 4:** Correlation between dinoflagellate cysts and calcareous nannoplankton zones (modified after Köthe, 2005) and their markers in the Late Miocene. The time-scale follows Gradstein *et al.* (2004)

## autochthonous dinoflagellate cysts

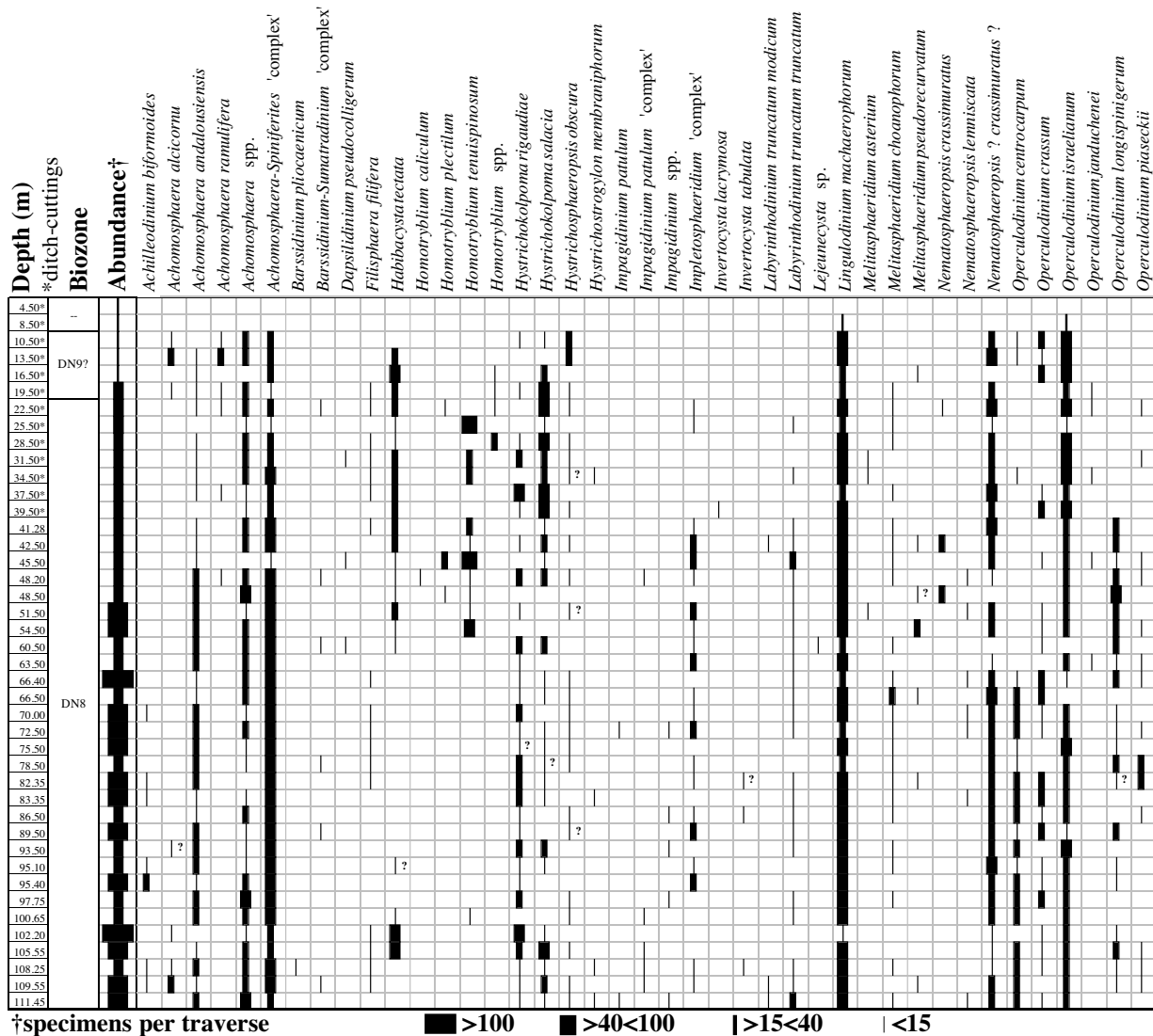


Table 1: Range-chart of dinoflagellate cysts, Breklum borehole

counts (Pl.5, figs 7, 9). The presence of the fresh-water alga *Pediastrum kawraiskyi*, at 4.50m and 8.50m, might indicate a Pleistocene age, as this alga is only known from this period in Germany. The presence of *P. kawraiskyi* in the core samples at 41.28m, 48.20m and, questionably, at 60.50m might indicate caving or Pleistocene faulting and disturbance of the sediments. No other observations support this interpretation.

#### 4.2 Calcareous nannoplankton

The majority of samples yield at least sparse nannofloras, but 15 were barren, and none of the samples contained very abundant calcareous nannoplankton. The autochthonous nannoplankton (Plate 6) generally show species richness of a maximum of 12 species (Sample 66.50m), but usually no more than five species are found. The most ubiquitous species is *Coccolithus pelagicus*, followed by species of the genus *Reticulofenestra*. Other

species are generally rare and occur only sporadically. Most samples contain reworked calcareous nannoplankton, mainly of Late Cretaceous age (Plate 7). Preservation is generally moderate to poor, especially when abundances are low.

The investigated interval can be subdivided using nannoplankton (Table 2). The lowermost section, from 111.45m to 86.50m, is no older than Early Miocene (zone NN4), due to the presence of *Reticulofenestra pseudumbilicus*. The occurrence of *Helicosphaera stalis* indicates a Middle to Late Miocene age (NN6 to NN11) for the section from 83.35m to 66.50m. From core-depths 66.40m to 39.50m, the section is no younger than Pliocene (NN15), due to the presence of *R. pseudumbilicus*. Further age determination using nannoplankton cannot be given for the uppermost part of the section.

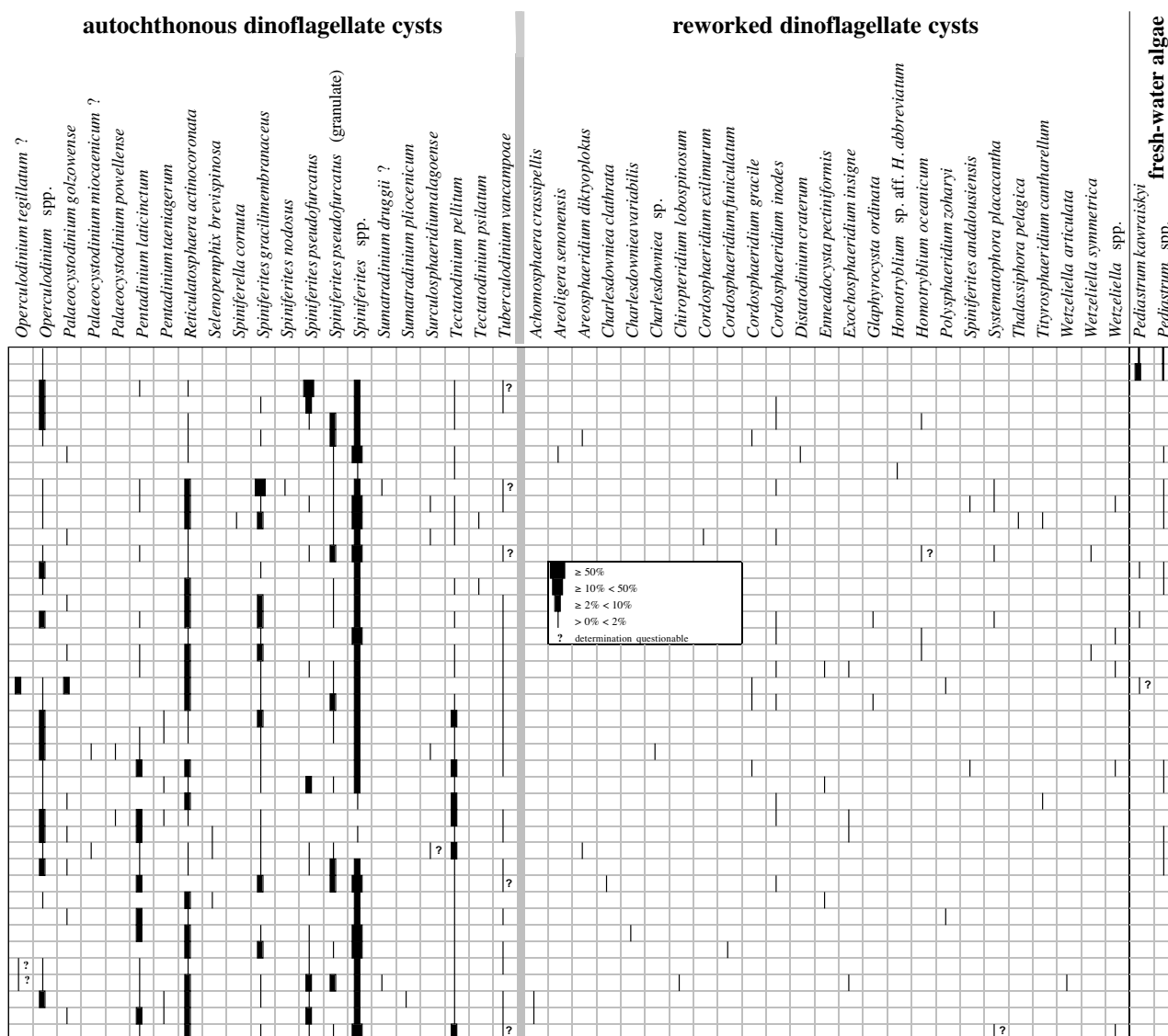


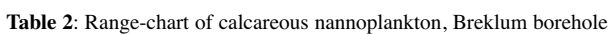
Table 1 cont'd: Range-chart of dinoflagellate cysts, Breklum borehole

## 5. Discussion

### 5.1 Comparison with previous investigations

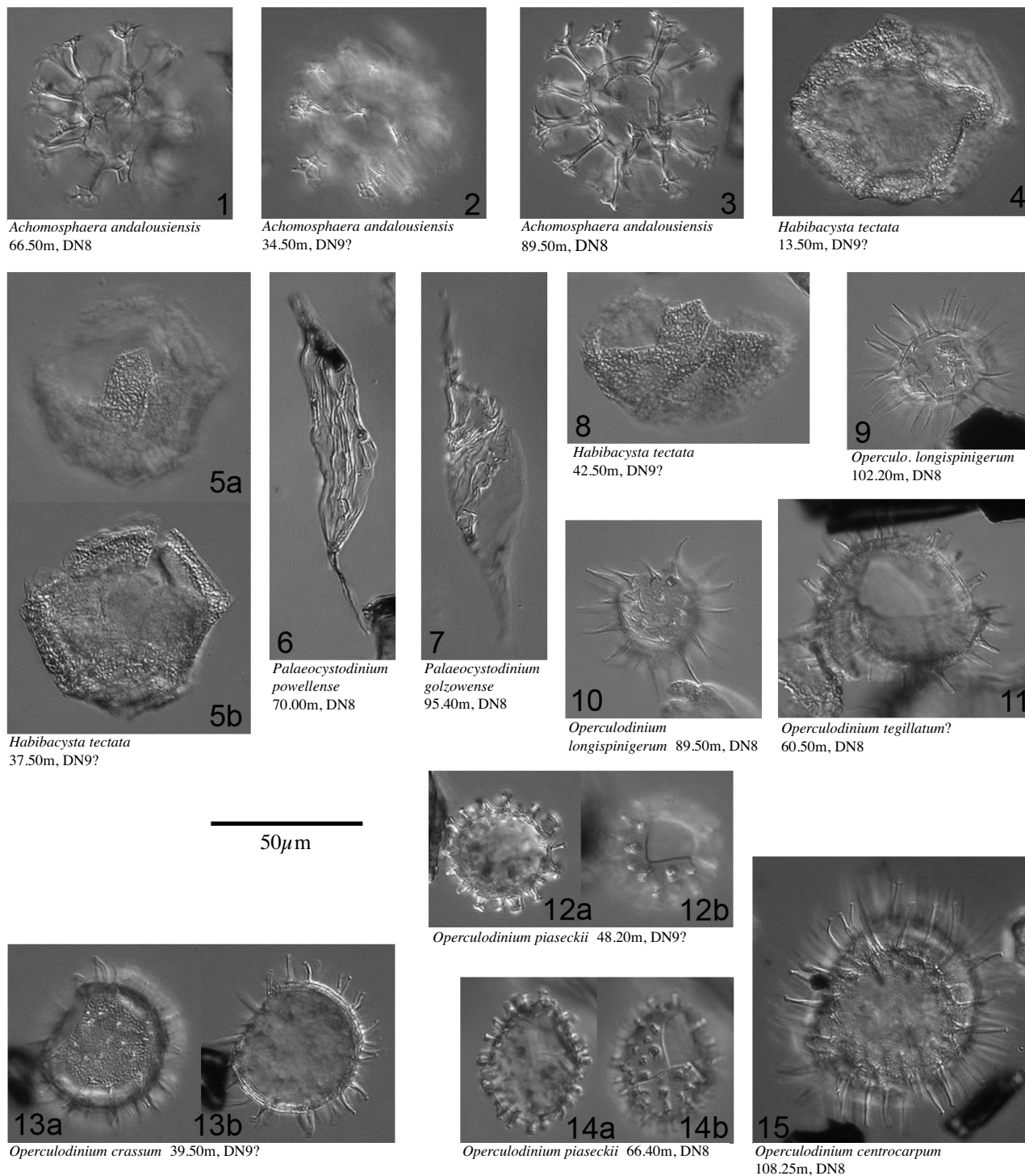
Few published data from the southern North Sea Basin concern Late Miocene dinoflagellate cysts, and even fewer deal with calcareous nannoplankton (Figure 3). In Denmark, dinoflagellate cysts of the isochronous Gram Formation were studied by Piasecki (1980). According to the first occurrence of *Achomosphaera andalousiensis*, the base of the Gram Formation can be dated as DN8 and the upper part of the Gram Formation as DN9, based on the last occurrence of *Palaeocystodinium golzowense* (*sensu* Köthe, 2003). The Gram Formation yields rich dinoflagellate cyst assemblages, dominated by *Homotryblum* cf. *H. plectilum* and *Gramocysta verricula*. Neither species are encountered at Breklum. Although Breklum lies close to the Danish border (Figure 3), the dinoflagellate cyst assemblages differ considerably.

In Germany, the boreholes at Wursterheide (Cepek, 1989; Lund & Heilmann-Clausen, 1999), Nieder Ochtenhausen (Martini, 2001; Strauss *et al.*, 2001) and Groß Pampau (Lund & Lund-Christensen *in* Daniels *et al.*, 1990; Martini, 2001) were investigated, looking at both fossil groups. Their positions are shown on Figure 3. Zones DN8 and DN9 are present in the Nieder Ochtenhausen borehole and DN9 in the Wursterheide borehole (Köthe, 2005). In Nieder Ochtenhausen, the dinoflagellate cysts *Lingulodinium machaerophorum* and the genus *Spiniferites* are abundant, although few specimens of *Gramocysta verricula* were identified. Zone DN8 (*sensu* Köthe, 2003) is also present in the Groß Pampau clay pit, dominated by *G. verricula* (lower sample only) and *Spiniferites* (Lund & Lund-Christensen *in* Daniels *et al.*, 1990). Dating by calcareous nannoplankton was not possible in these three localities due to the scarcity of this group. The Upper Pritzler Beds



## Plate 1

Figs 1–8: dinoflagellate cyst index and secondary markers  
Figs 9–15: dinoflagellate species of the genus *Operculodinium*

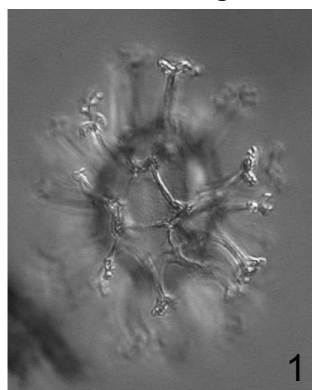


in the Lübtheen 27/82 borehole (Figure 3) yield rich dinoflagellate cyst assemblages of zones DN8 and DN9, which are dominated by species of the *Achomosphaera-Spiniferites* complex, *Habibacysta tectata*, *Hystrichokolpoma rigaudiae* and *L. machaerophorum* (Köthe, 2000).

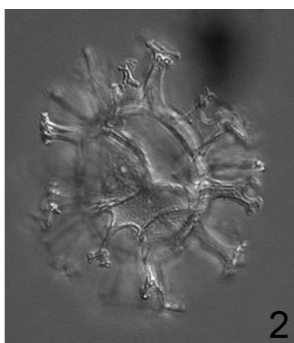
In The Netherlands, two boreholes close to the German border yield Late Miocene dinoflagellate cysts (Munsterman & Brinkhuis, 2004), but a range-chart is not provided. The determination of a Late Miocene age in the Cuyk and Broeksittard boreholes (Herngreen, 1987) is not proven, according to the zonation of Köthe (2003).

## Plate 2

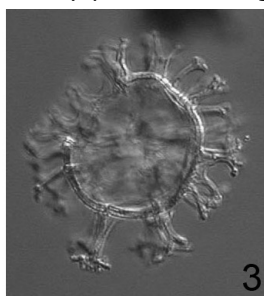
Dinoflagellate cysts which are almost continuously present throughout the borehole



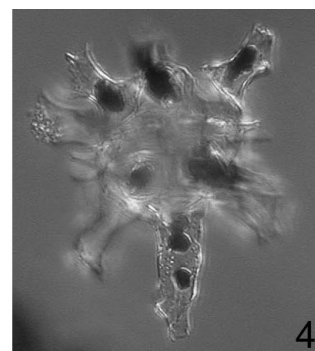
*Nematosphaeropsis? crassimuratus?*  
22.50m, DN9?



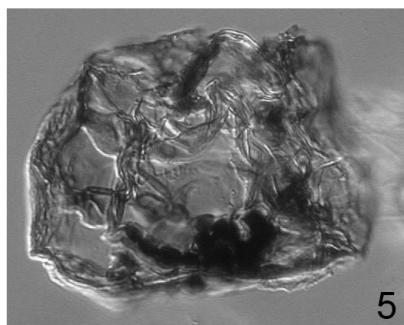
*Nematosphaeropsis? crassimuratus?*  
34.50m, DN9?



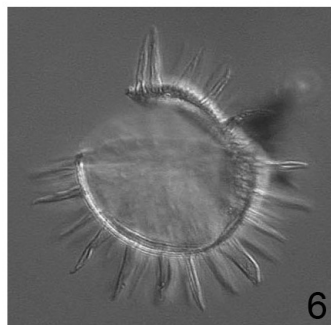
*Nematosphaeropsis? crassimuratus?*  
10.50m, DN9?



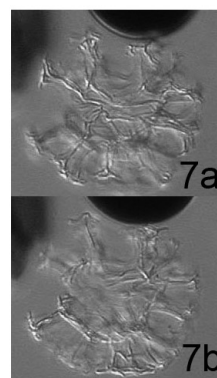
*Hystrichokolpoma rigaudiae*  
28.50m, DN9?



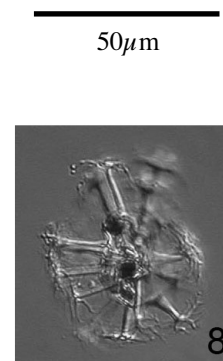
*Tuberculodinium vancampoae*  
102.20m, DN8



*Lingulodinium machaerophorum*  
111.45m, DN8



*Spiniferites*  
*gracilimembranaceus*  
72.50m, DN8



*Reticulosphaera*  
*actinocoronata*  
34.50m, DN9?

In Belgium, the Bolderberg Formation is dated as DN8 (Louwye *et al.*, 1999) and the Diest Formation as top DN9–DN10 (Louwye & Laga, 1998), that is, together comprising DN8, DN9 and DN10 (Louwye *et al.*, 1999). The Deurne Sands of the Diest Formation (DN8; Louwye, 2002) contain a diverse and well-preserved dinoflagellate cyst assemblage. *Selenopemphix brevispinosa* and *S. armageddonensis* are limited to the Diest Formation. *A. andalousiensis* and *Amiculosphaera umbracula* are present, whereas *P. golzowense* and *G. verricula* are missing. At Breklum, *S. brevispinosa* is restricted to the lower part of the studied section (DN8, 83.35m–95.10m). *G. verricula*, the index marker of the Middle to Late Miocene *G. verricula* Zone (Piasecki, 1980; Powell, 1992) was not recorded in Breklum. Both results correspond to the findings from the Diest Formation in Belgium.

Miocene sediments are not present onshore Great Britain, except for the Lenham Beds, which may be of Late Miocene age (Balson, 1999, p.240).

The dinoflagellate cyst assemblages at Breklum show affinities to those from other German and Belgian localities. All these are dominated by *Spiniferites* and were deposited in a shallow marine environment, whereas the Danish localities indicate a shallower, restricted marine environment, due to the dominance of *H. cf. H.*

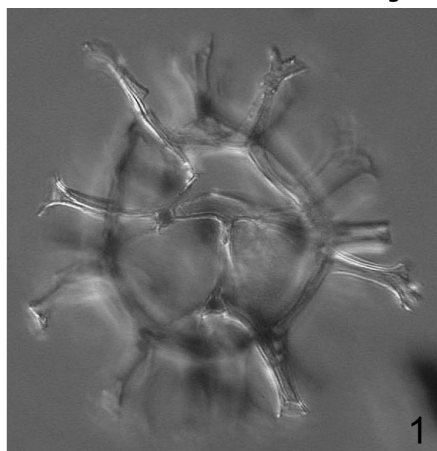
*plectilum*.

Based on dinoflagellate cysts, the studied section at Breklum is of Late Miocene age (DN8, ?DN9). This is in agreement with the biostratigraphy based on calcareous nannoplankton (not older than NN4, NN6–NN11, not younger than NN15), as DN8 is correlated internationally with NN9 and NN10, and DN9 with the lower part of NN11 (De Verteuil & Norris, 1996). The presence of *Helicosphaera stalis* in particular, which was not described until 1984, can be used as an additional marker. As in other southern North Sea countries, the number of dinoflagellate cysts in Breklum is high and the preservation good, whereas the calcareous nannoplankton were obviously affected by dissolution. Calcareous nannoplankton are generally very rare in Neogene sediments of North Germany and the North Sea Basin margin, and subdivision by means of calcareous nannoplankton was not thought to be possible (Köthe, 1988). Considering the entire North Sea Basin, the Neogene assemblages appear to be poor, basin-wide, and age determinations are generally vague (Gallagher, 1990). Sections younger than Middle Miocene are often barren of autochthonous calcareous nannoplankton or characterised by rare occurrences of long-ranging, and therefore stratigraphically insignificant, taxa (Cepek, 1989). Some Early and Middle Miocene north-western

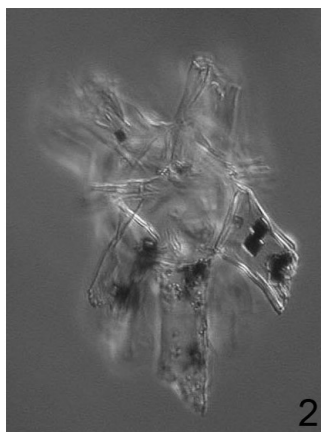


## Plate 3

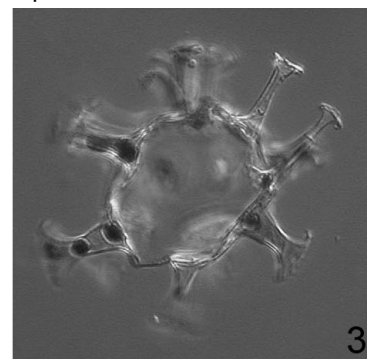
Dinoflagellate cysts that are abundant in some samples



*Spiniferites pseudofurcatus* 75.50m, DN8



*Hystriocholpoma salacia* 28.50m, DN9?



*Homotryblum tenuispinosum* 25.50m, DN9?

50µm

European local stages were dated by nannoplankton biostratigraphy (Martini & Müller, 1973; Müller *et al.*, 1979), but nannoplankton biozonations are not available for the local Late Miocene stages.

### 5.2 Environmental conditions during deposition

The results herein do not contradict the general impression of an unfavourable environment for calcareous nannoplankton in the North Sea Basin during the Late Miocene, but show that an almost continuous section, with a higher diversity than expected, can be found (Müller *et al.*, 1979). The calcareous nannoplankton may possibly have benefited from temporarily more offshore conditions at this site. Martini (2001) showed that abundances of autochthonous calcareous nannoplankton assemblages from the south-western North Sea area might be positively correlated to Neogene sea-level high-stands. However, the distorting influence of carbonate dissolution has to be considered when interpreting the autochthonous calcareous nannoplankton, especially since a number of samples are barren of autochthonous, as well as reworked, calcareous nannoplankton.

The dominance of the dinoflagellate genera *Operculodinium*, *Homotryblum* and *Spiniferites* indicate neritic conditions (Pross *et al.*, 2004). The genera *Impagidinium* and *Nematosphaeropsis*, which indicate, even in very small numbers, the influence of oceanic waters (Dale, 1996), occur only sporadically at Breklum. *Impagidinium* is notably present between 72.50m and 111.45m, and *Nematosphaeropsis* (apart from *Nematosphaeropsis? crassimuratus?*) between 83.35m and 42.50m. There is no correlation between the presence of calcareous nannoplankton and the presence of oceanic dinoflagellate cysts.

The interpretation of the depositional environment of

the dinoflagellate genus *Homotryblum* has recently been demonstrated by Dybkjær (2004). According to her investigations, *Homotryblum tenuispinosum* is dominant and continuously present in the distal parts of the highstand systems tract (HST) of a brackish sequence. *H. tenuispinosum* is not continuously present in Breklum, but most abundant in Samples 45.50m (54%) and 25.50m (90%). The presence of autochthonous calcareous nannoplankton in Sample 45.50m also undermines the interpretation of a brackish environment, whereas in Sample 25.50m, calcareous nannoplankton are not present. Therefore, the interpretation of a brackish environment during the deposition of these two samples remains doubtful. The genus *Homotryblum* is very scarce in Wursterheide, Lübtheen and in Groß Pampau. In Nieder Ochtenhausen, it is common to abundant in the lower part of DN8.

In conclusion, the calcareous nannoplankton possibly benefited from a slightly stronger marine influence at this site, compared to currently known onshore localities. Dinoflagellate cysts generally indicate a neritic environment, at least occasionally swept by oceanic waters.

### Acknowledgements

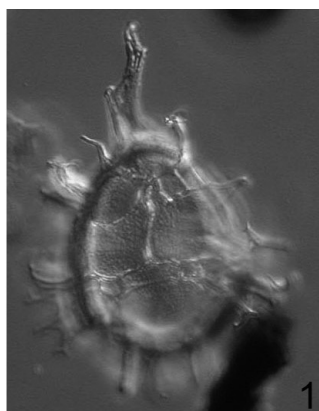
We are grateful to Dr. Karl Gürs (LANU) who kindly provided the samples and the log data. The technical support by Angelika Malik, Barbara Piesker and Sabine Stäger (BGR) is thankfully acknowledged. Drs Liam Gallagher, Keith Gueinn (Network Stratigraphic Consulting Limited, UK), and Emma Sheldon and Stefan Piasecki (Geological Survey of Denmark and Greenland, Denmark), improved the manuscript by constructive reviews.

### References

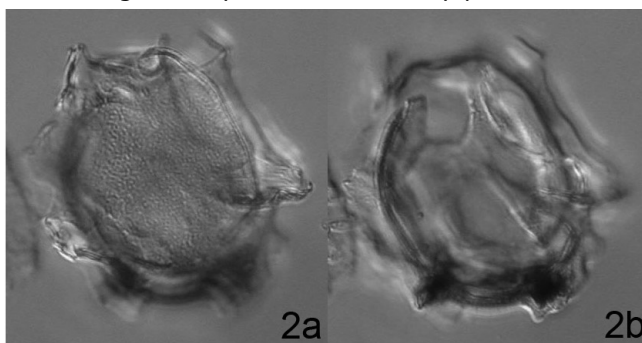
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## Plate 4

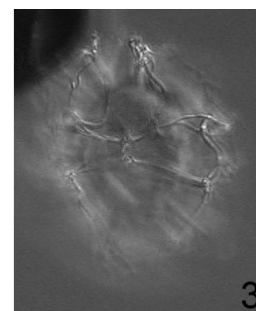
### Dinoflagellate cysts that are rarely present



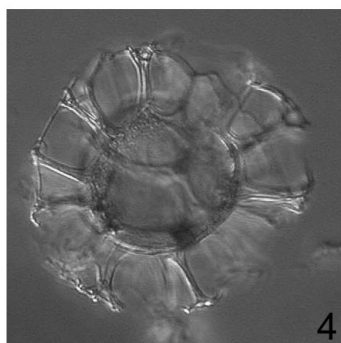
*Spiniferella cornuta* 34.50m, DN9?



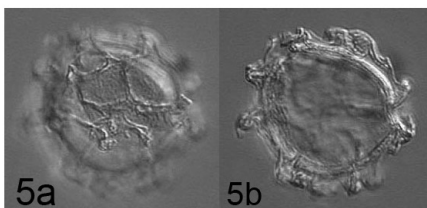
*Pentadinium taeniagerum* 108.25m, DN8



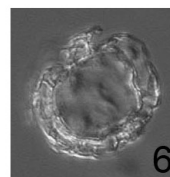
*Nematospaeropsis crassimuratus*  
42.50m, DN9?



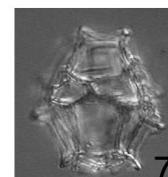
*Nematospaeropsis crassimuratus*  
42.50m, DN9?



*Spiniferites nodosus* 28.50m, DN9?

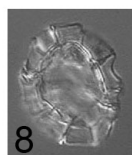


*Labyrinthodinium truncatum*  
*modicum* 111.45m, DN8

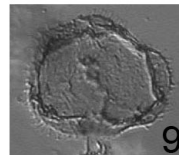


*Imp. patulum* 'complex'  
100.65m, DN8

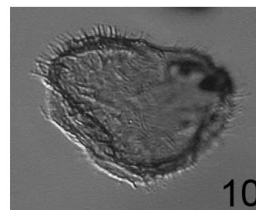
50µm



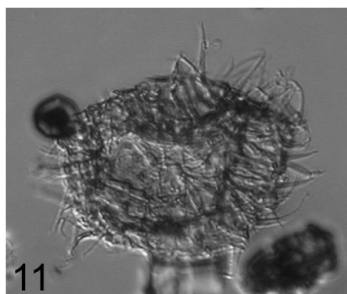
*Impagidinium patulum*  
72.50m, DN8



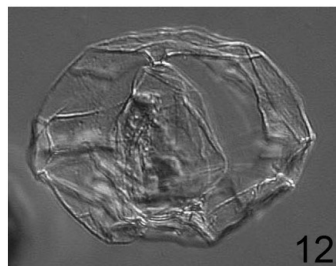
*Sel. brevispinosa*  
95.10m, DN8



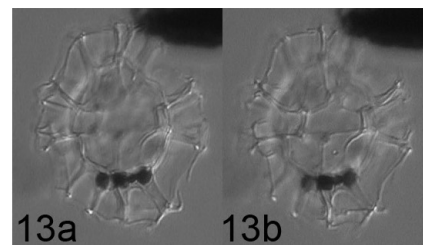
*Selenopemphix brevispinosa*  
86.50m, DN8



*Sumatradinium pliocenicum* 108.25m, DN8



*Invertocysta lacrymosa* 39.50m, DN9?

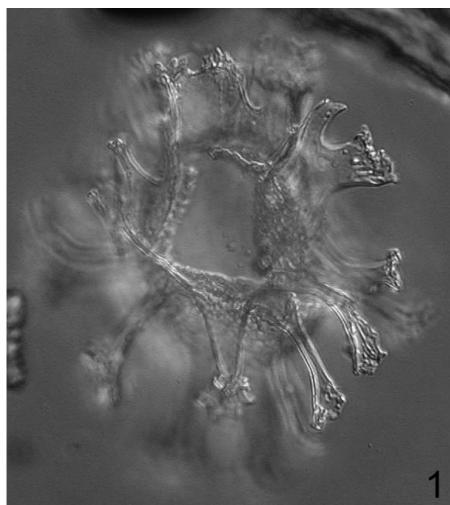


*Nematospaeropsis lemniscata* 48.20m, DN9?

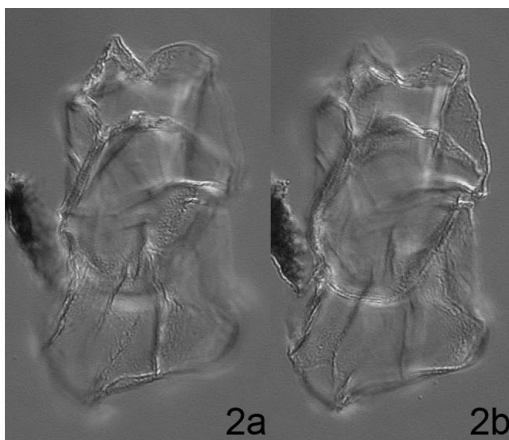
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## Plate 5

Figs 1-6, 8, 10, 11: autochthonous dinoflagellate cysts  
Figs 7, 9: reworked Paleogene dinoflagellate cysts

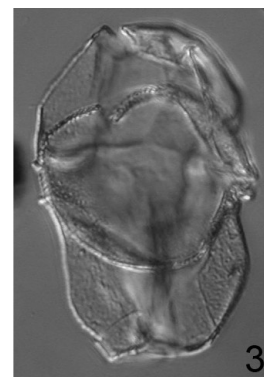


*Spiniferites pseudofurcatus* 'granulate' 16.50m, DN9?

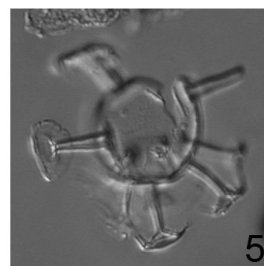


*Hystrichosphaeropsis obscura* 86.50m, DN8

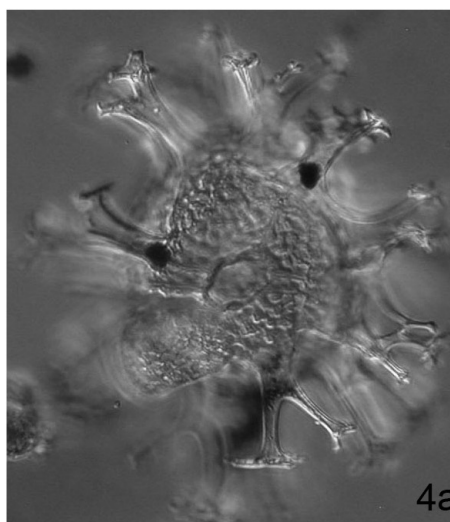
50µm



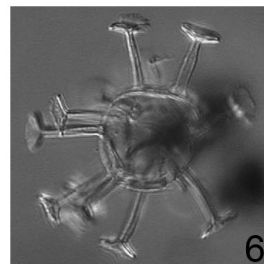
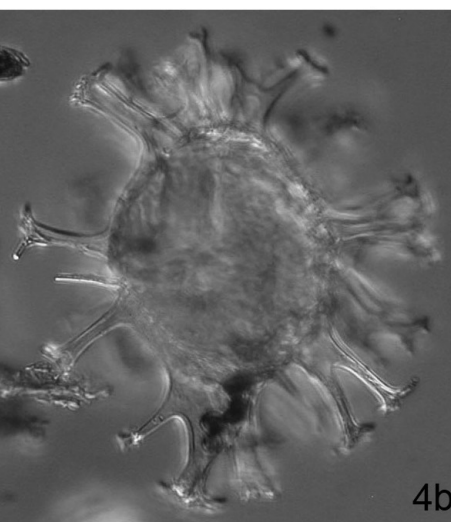
*Hystrichosphaeropsis obscura*  
66.50m, DN8



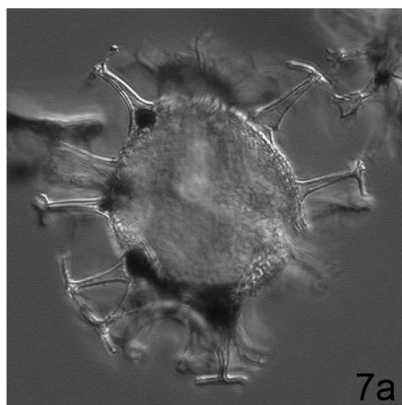
*Melitasphaeridium*  
*choanophorum* 60.50m, DN8



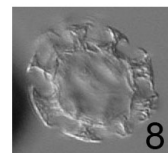
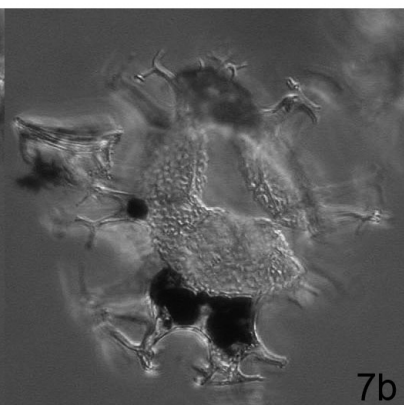
*Spiniferites pseudofurcatus* 'granulate' 19.50m, DN9?



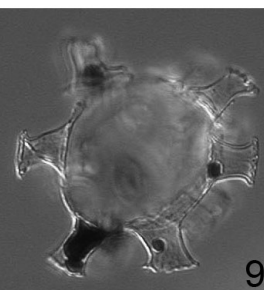
*Melitasphaeridium*  
*choanophorum* 25.50m, DN9?



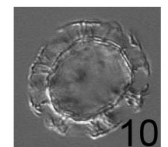
*Achomospaera crassipellis* 109.55m, DN8



*Labyrinthodinium*  
*truncatum truncatum*  
42.50m, DN9?



*Homotryblium* sp. aff. *H.*  
*abbreviatum* 25.50m, DN9?



*Labyrinthodinium truncatum*  
*truncatum* 93.50m, DN8

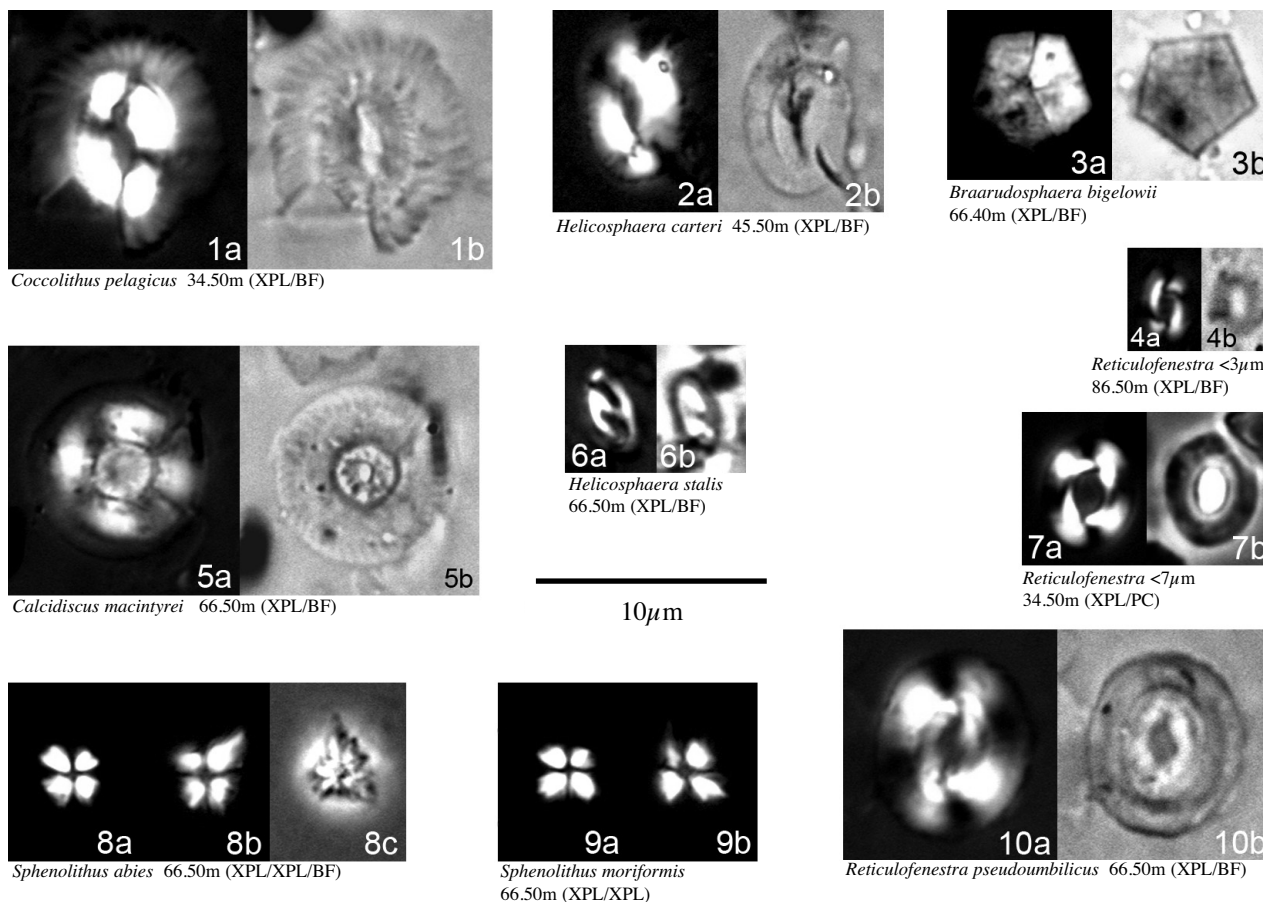


*Filisphaera filifera* 34.50m, DN9?

## Plate 6

### Autochthonous calcareous nannoplankton

BF = bright-field, PC = phase-contrast, XPL = cross-polarised light

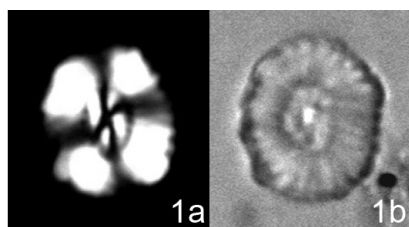


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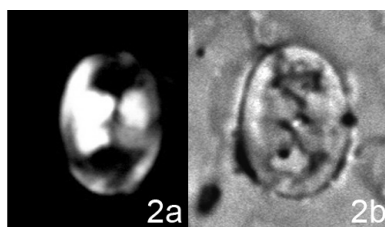
## Plate 7

Reworked calcareous nannoplankton

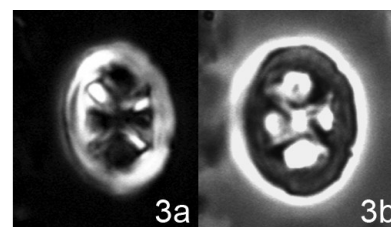
BF = bright-field, PC = phase-contrast, XPL = cross-polarised light



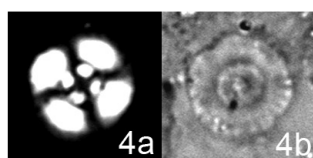
*Watznaueria barnesia* 86.50m (XPL/BF)



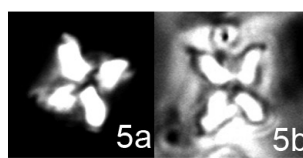
*Tranolitus orionatus* 86.50m (XPL/BF)



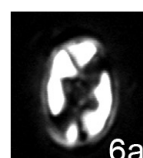
*Helicolithus anceps* 19.50m (XPL/PC).



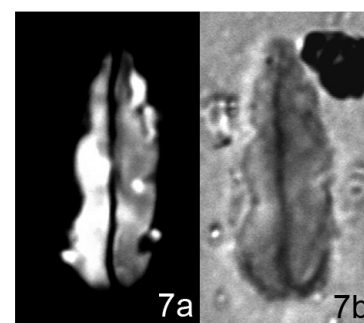
*Cyclagelosphaera margerelii*  
60.50m (XPL/BF)



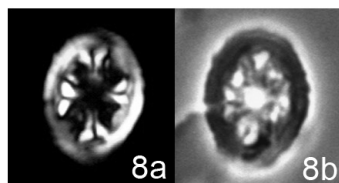
*Micula staurophora* 19.50m (XPL/PC)



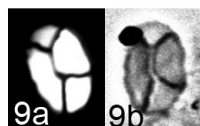
*Eifellithus gorkae*  
86.50m (XPL/BF)



*Lucianorhabdus cayeuxii* 34.50m (XPL/BF)

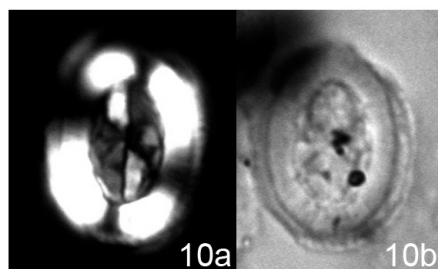


*Ahmuellerella octoradiata* 45.50m (XPL/PC)

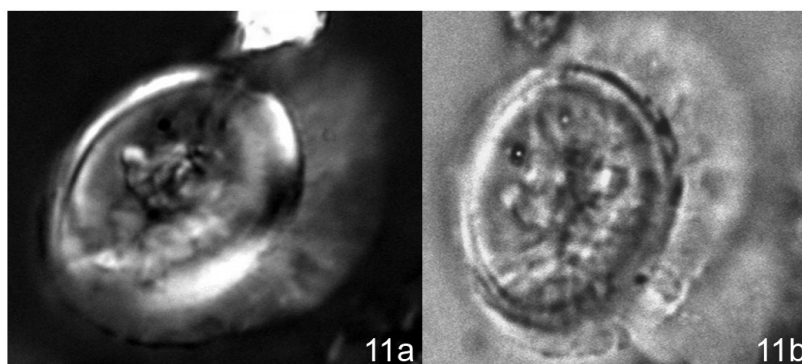


*Calculites obscurus* 63.50m (XPL/BF)

10µm



*Arkhangelskiella cymbiformis* 100.65m (XPL/BF)



*Kamptnerius magnificus* 66.50m (XPL/BF)

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- Spiniferites gracilimembranaceus* Strauss & Lund, 1992
- Spiniferites pseudofurcatus* (Klumpp, 1953) Sarjeant, 1970
- Spiniferites pseudofurcatus* ‘granulate’ (Klumpp, 1953) Sarjeant, 1970
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- Tuberculodinium vancampoe* (Rossignol, 1962) Wall, 1967

## Figured dinocyst taxa

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- Achomospaera crassipellis* (Deflandre & Cookson, 1955) Stover & Evitt, 1978
- Filisphaera filifera* Bujak, 1984
- Habibacysta tectata* Head *et al.*, 1989
- Homotryblium* sp. aff. *H. abbreviatum* Eaton, 1976
- Homotryblium tenuispinosum* Davey & Williams, 1966
- Hystrichokolpoma rigaudiae* Deflandre & Cookson, 1955
- Hystrichokolpoma salacia* Eaton, 1976
- Hystrichosphaeropsis obscura* Habib, 1972
- Impagidinium patulum* (Wall, 1967) Stover & Evitt, 1978
- Invertocysta lacrymosa* Edwards, 1984
- Labyrinthodinium truncatum modicum* DeVerteuil & Norris, 1996
- Labyrinthodinium truncatum truncatum* Piasecki, 1980
- Lingulodinium machaerophorum* (Deflandre & Cookson, 1955) Wall, 1967
- Melitasphaeridium choanophorum* (Deflandre & Cookson, 1955) Harland & Hill, 1979
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- Nematosphaeropsis lemniscata* Bujak, 1984
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- Operculodinium crassum* Harland, 1979
- Operculodinium longispinigerum* Matsuoka, 1983
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- Palaeocystodinium powellense* Strauss *et al.*, 2001
- Pentadinium taeniagerum* Gerlach, 1961
- Reticulatosphaera actinocoronata* (Benedek, 1972) Bujak & Matsuoka, 1986
- Selenopemphix brevispinosa* Head *et al.*, 1989
- Spiniferella cornuta* (Gerlach, 1961) Stover & Hardenbol,