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HELLEFISK-1
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KANGAMIUT-1
NUKIK-1

Dinoflagellate cyst stratigraphy of the Upper Cretaceous to Paleogene strata from the Hellefisk-1, Ikermiut-1, Kangamiut-1 and Nukik-1 wells, offshore central West Greenland

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GEUS

Copenhagen

03/06-1998

DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 1998/54

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Abstract

The present biostratigraphic study of dinoflagellate cyst from the Kangâmiut-1, Ikermiut-1, Hellefisk-1 and Nukik-1 wells offshore West Greenland is based on 321 older samples of which 177 are reprocessed. The study has changed the previously dated ages considerably, especially in the upper part of the wells, which are all shown to be of an older stratigraphic age than previously suggested. These results have moved the base of dinoflagellate Zone D9 (base Middle Eocene) approximately 700 and 400 m upward in Hellefisk-1 and in Ikermiut-1, respectively.

Sediments younger than Late Eocene/?Early Oligocene have only been recognised by the dinoflagellate cyst assemblages in the Nukik-1 well, where Miocene sediments may be present.

A major hiatus spanning the uppermost Cretaceous to the Lower Paleocene has been recorded from both the Ikermiut-1 and Kangâmiut-1 wells, and a hiatus spanning the Upper Paleocene to Lower Eocene has been recorded from the Nukik-1 well and may also be present in the Hellefisk-1 well. A middle Lower Eocene hiatus is present in the Ikermiut-1 well. A upper Lower Eocene to lower/?middle Middle Eocene hiatus is present in both the Hellefisk-1 and Ikermiut-1 wells and one or more hiati are most likely present in the middle to upper Middle Eocene in all wells.

Contents

Introduction

During 1976 and 1977 five dry exploration wells (Hellefisk-1, Ikermiut-1, Kangâmiut-1, Nukik-1 and Nukik-2) were drilled through Tertiary and Upper Cretaceous sediments (on the shelf) offshore central West Greenland between 65° N and 68° N (Fig. 1). Rolle (1985) described the lithostratigraphy, sedimentary evolution and petroleum potential of the five wells. The ages of Rolle's (1985) lithostratigraphic formations were based on palynological datings by Croxton (1981a, b, c, d & e) and Costa (1982). Later, Toxwenius (1986) compiled the Upper Cretaceous–Tertiary biostratigraphical data and correlated the five wells.

Renewed geophysical interpretation of both older and newly acquired seismic data offshore West Greenland prompted the need for a reinvestigation of the biostratigraphy of the previously drilled wells as major problems correlating seismic sequences to the wells were encountered.

Palynological samples and methods

A palynostratigraphical correlation of the five wells has previously been presented by Toxwenius (1986; Fig. 3) who compiled data from studies by Croxton (1981a, b, c, d & e; approximately 1000 samples), Hansen (1978; 10 samples), Costa (1982; 46 reprocessed samples) and Toxwenius (1986; 177 samples).

Dinoflagellate cysts are regularly occurring in the Upper Cretaceous and in the Paleogene. Planktonic foraminifera are the most important fossil group in the Neogene, where the density and diversity of dinoflagellate cysts are low or absent Toxwenius (1986).

To describe the palynostratigraphy of the wells Toxwenius (1986) used the dinoflagellate cyst D zonation, later suggested by Costa & Manum (1988).

The dinoflagellate cysts stratigraphy presented here is also based on the D zonation of Costa & Manum (1988). When possible, the D zonation has been compared and correlated with the zonations in the North Sea region described by Bujak *et al.* (1980), Heilmann-Clausen (1985, 1994), Powell (1992), Powell *et al.* (1996), Bujak & Mudge (1994) and Mudge & Bujak (1996a, b; Fig. 2).

It should, however, be noted that the calibration of Costa & Manum's (1988) D zones to nannoplankton zones (NP zones) has changed. Toxwenius (1986) followed the callibration as later suggested by Costa & Manum (1988). In this study the calibration to NP zones follows Powell (1992; Fig. 2).

To simplify the comparison between the zonation suggested by Toxwenius (1986) and the zonation proposed in the present study (Fig. 3) the ages of the D zones identified by Toxwenius (1986) are also calibrated to the ages for the D zones given by Powell (1992; Fig.3). To illustrate the difference between the two correlations Zone D9 was dated as Early Eocene by Toxwenius (1986) based on the calibration of Zone D9 with NP 13 (pars) and NP 14 (pars) by Costa & Manum (1988). In the present study, however, Zone D9 is referred to as early Middle Eocene following Powell (1992) who calibrated Zone D9 with NP 14 (pars) to NP 16 (pars).

The old palynological slides for these studies were mainly produced from organic acid residues sieved on 10μm filters. The present study is based on 321 samples including organic residues from 164 samples processed during the 70s and 80s (Toxwenius, 1986) which have been sieved on 20μm nylon meshes and reoxidised with concentrated nitric acid, followed by washing with a weak potassium hydroxide solution. The reprocessing has improved the quality remarkably. In addition, 13 extra samples have been washed and processed from the cutting material housed at the Geological Survey of Denmark and Greenland (GEUS).

From Kangâmiut-1 45 previously processed samples and 8 new processed samples have been examined (Enclosure 1).

From Ikermiut-1 155 previously processed samples and 5 new processed samples have been studied (Enclosure 2); of these 106 have been re-sieved on 20μm nylon meshes and re-oxidised.

From Hellefisk-1 77 samples have been examined (Enclosure 3); of these 58 have been re-sieved on 20μm nylon meshes and re-oxidised.

From Nukik-1 31 samples have been examined (Enclosure 4).

Enclosures 1, 2, 3 and 4 illustrate the ranges and the LAD (Last Appearance Datum) of the recorded species.

Recording of material

The palynological slides were studied with transmitted light using a Leitz Dialux 22 microscope (512 742/057691).

Palynomorphs were recorded from the sieved, oxidised or gravitation-separated slides. Counting of specimens was carried out on those of the 321 samples that revealed dinoflagellate cysts (Enclosures 1–4). Approximately 100 specimens were counted when possible.

Laser video recordings (LVR) of 214 dinoflagellate cyst specimens are stored in the Survey's Micro Image (MI) database. A selection of important biostratigraphic marker species are illustrated on Plates 1–8. The systematics of Lentin & Williams (1993) are followed. The material is stored at GEUS.

Palynological results

The present study has revealed dinoflagellate cyst species of stratigraphic value from several samples that previously have been reported as poor or barren of dinoflagellate cysts by Toxwenius (1986). The new observations have changed the previous biostratigraphic dating of the sedimentary succession recorded in the Hellefisk-1, Ikermiut-1, Kangâmiut-1 and Nukik-1 radically, especially in the upper parts of the wells, where the base of D9 (base middle Eocene) has been moved upward approximately 700 m and 400 m in Hellefisk-1 and Ikermiut-1, respectively (Fig. 3).

The dinoflagellate cyst zonation and correlation of the four wells show that sediments younger than ?Early Oligocene/ Late Eocene only occur in the Nukik-1 well, where Miocene sediments may be present (Fig. 4).

The most complete Middle Eocene to middle Lower Eocene zonation occurs in the Kangâmiut-1 well, and the most complete middle Lower Eocene to Upper Paleocene and Upper Cretaceous zonation are represented in the Ikermiut-1 well.

A major hiatus spanning the uppermost Cretaceous to the Lower Paleocene has been recorded from both the Ikermiut-1 and Kangâmiut-1 wells, and a hiatus spanning the Upper Paleocene to Lower Eocene has been recorded from the Nukik-1 well and may also be present in the Hellefisk-1 well. A middle Lower Eocene hiatus is present in the Ikermiut-1 well. A upper Lower Eocene to lower/?middle Middle Eocene hiatus is present in both the Hellefisk-1 and Ikermiut-1 wells and one or more hiati are most likely present in the middle to upper Middle Eocene in all wells (Fig. 4).

Caved specimens occurs in large numbers in the Upper Paleocene in the Ikermiut-1, Kangâmiut-1 and Nukik-1 wells (Enclosures 2–4) and in the Upper Cretaceous in the Ikermiut-1 and Kangâmiut-1 wells (Enclosures 2, 3). Caved specimens occur in ditch cutting samples, where they are recognised by being less thermally mature and stratigraphically younger than the main assemblage.

Reworked specimens occur scattered at all levels in all the wells (Enclosures 1–4), but are never dominant. Reworked specimens are recognised by being more thermally mature and stratigraphical older than the main assemblage.

Hellefisk-1

Technical data

Hellefisk-1 was drilled in 1977 by Arco Greenland Inc. at 67° 52' 41" N and 56° 44' 21" W (Fig.1). The water depth was 163 m (536 ft). The rotary table was 12 m (38 ft) above sea level, and the total depth was 3201 m (10502 ft) below rotary table where the well reached ?Paleocene basalts (Rolle 1985). All sample depths are measured from rotary table datum.

Sample depth interval 723–1025 m (?lowermost Oligocene–Upper Eocene)

Definition of interval. The body of strata between the LAD (Last Appearance Datum) of *Areosphaeridium arcuatum* and the LAD of *Rhombodinium longimanum* (Enclosure 1).

Zonation and age. Dinoflagellate Zone D12, (Late Eocene to ?earliest Oligocene, Figs 2 & 3).

Diagnostic events. LAD of *Areosphaeridium arcuatum* and *Cribroperidinium* cf. *giuseppei* at 723 m (SWC, sidewall core sample), LAD of *Charlesdowniea coleothrypta* at 849 m (SWC), LAD of *Corrudinium incompositum* and *Lentinia* cf. *serrata* at 857 m (SWC) and LAD of *Apectodinium homomorphum* at 868 m (SWC).

Common species within the interval. Fragments and opercula of *C.* cf. *giuseppei* at 857 m (SWC). Saccate pollen and spores dominate the interval from 910 to 1025 m.

Reworked species. *Chatangiella* spp., *Nyktericysta* cf. *davisii*, *Palaeoperidinium pyrophorum* and *Wetzeliella astra* (723–751 m). *Deflandrea* spp. at 884 m. One specimen of *Wetzeliella spinula* at 1025 m.

Caved species. A single *Chiropteridium* specimen (723 m). Very hyaline specimens of *Deflandrea phosphoritica* occur together with other palynomorphs of higher thermal maturity at 857 m (SWC). *Svalbardella* cf. *cooksoniae* at 862 m (SWC).

Discussion. The presence of *Areosphaeridium arcuatum* and *Apectodinium homomorphum* suggest an age not younger than earliest Oligocene (top D12), correlating with the

Rhombodinium perforatum (Rpe) Interval Biozone of Powell (1992; Fig. 2). *Cribroperidinium giuseppei* has been recorded from the London Clay (Zone LC-3) to the Barton Beds (Zone Bar-5, Fig. 2) by Bujak *et al.* (1980), correlating with the base of D8 to the top of D11 (Powell, 1992). Brinkhuis and Biffi (1993) recorded *C. giuseppei* up to the lowermost Oligocene (NP21, Fig. 2) in Italy.

Corrudinium incompositum and *Lentinia serrata* have been recorded from the Barton Beds (Zone Bar-1– Zone Bar-5) by Bujak *et al.* (1980) which according to Powell (1992) correlate with the upper part of D10 to the top of D11. *Corrudinium incompositum* was originally described by Drugg (1970) from Oligocene sediments of the Gulf Coast, USA. Williams *et al.* (1993) reported a Lower Oligocene (Rupelian) to Middle Eocene (Bartonian) range for the species in the northern hemisphere, whereas Brinkhuis & Biffi (1993) recorded *C. incompositum* from the lowermost Oligocene (NP21) in Italy. *Lentinia serrata* was described from the upper Barton Beds by Bujak (1980) and Williams *et al.* (1993) recorded the LAD of *L. serrata* from the middle Priabonian (D12; Fig. 2).

The records from the present interval indicate no unambiguous age, however, the presence of *A. arcuatum*, *A. homomorphum*, *C. incompositum* and *L. serrata* in SWC suggest an earliest Oligocene or Middle Eocene age (D12), which allows correlation with the *Rhombodinium perforatum* (Rpe) Interval Biozone of Powell (1992; Fig. 2).

Previous dating. Toxwenius (1986; Fig. 3) mentioned that the latest occurrence of *Operculodinium centrocarpum* at 750 m possibly identified the early Late Miocene dinoflagellate Zone D19, and suggested a Middle to?Late Miocene age (U D17–D18, ?D19) for the interval 780–862 m. Toxwenius (1986) referred the interval 862–1010 m to Early Miocene (D16–D17) based on the latest occurrence of *Cordosphaeridium cantharellus* at 862 m (SWC); this species has not been identified at 862 m in the present study; however, two large chorate cysts have been observed. Toxwenius (1986) recorded samples from 1025 and 1033 m as barren of dinoflagellate cysts, but suggested an Early Oligocene (D13)/Early Miocene (D16) hiatus at 1010 m.

Sample depth interval 1045–1155 m (Middle Eocene)

Definition of interval. The body of strata between the LAD of *Rhombodinium longimanum* and the FAD (First Appearance Datum) of *Glaphyrocysta texta*.

Zonation and age. Upper part of dinoflagellate Zone D11 (Middle Eocene), correlating with the *Wetzeliella simplex* (Wsi) Interval Biozone (Fig. 2; Powell 1992).

Diagnostic events. The LAD of *Areosphaeridium fenestratum*, *Cordosphaeridium* cf. *fibrospinosum*, *Glaphyrocysta texta*, *Rhombodinium longimanum*, *Phthanoperidinium echinatum*, *P. geminatum* and *P. multispinum* at 1045 m (SWC). LAD of *Areosphaeridium* sp. 1 at 1095 m (SWC), LAD of *Rhombodinium draco* and *Wetzeliella spinula* at 1142 m (SWC) and FAD of *Glaphyrocysta texta* at 1155 m (SWC).

Common species within the interval. *Glaphyrocysta texta* (1045–1095 m), *Lingulodinium machaerophorum*, *W. spinula* (1142–1155 m) and *P. echinatum* (1152 m).

Discussion. According to Costa & Manum's (1988) definition of the D11 Zone, *Glaphyrocysta texta* becomes extinct at the top of the Zone. Powell (1992) correlated Zone D11 with the two Interval Biozones: *Wetzeliella simplex* (Wsi) and *Rhombodinium porosum* (Rpo) and he correlated the higher Zone (Wsi) with the Bar-4 and Bar-5 zones of Bujak *et al.* (1980; Fig. 2). The base of Zone Bar-4 is defined by the first occurrence of *W. spinula* among other species, whereas the top of Zone Bar-5 is defined by the last occurrence of *G. texta*, *R. longimanum* and *W. spinula* among others (Bujak *et al.*; 1980). Powell (1992) reported the LAD of *C. fibrospinosum* from the Middle Eocene (D9, Aar) in the North Sea region, whereas Williams *et al.* (1993) reported the LAD from the Lower Oligocene in the northern hemisphere. The observations from the interval 1045–1155 m in Hellefisk-1 suggest a correlation with the *W. simplex* (Wsi) interval Zone of Bujak (1979), Powell (1992) and E7b of Bujak & Mudge (1994).

Previous dating. Toxwenius (1986) suggested the presence of a late Early Oligocene to Late Oligocene (L D14–D15) hiatus in all the offshore wells and placed it in an interval barren of microfossils. Toxwenius (1986) referred the interval 1010–1140 m to lowermost Oligocene (D13 to lower part of D14) based on the LAD of *P. amoenum* (1045 m, SWC), the LAD and FAD of *Wetzeliella symmetrica* (1052–1086 m, 1095 m, SWC, 1125 m) and the LAD of *Deflandrea phosphoritica* (1145 m, SWC). Toxwenius (1986) referred the interval 1140–1801 m as Late Eocene (D12) based on the LAD of *P. echinatum* (1152 m, DCS).

Sample depth interval 1155–1234 m (Middle–?Lower Eocene)

Definition of interval. The body of strata between the FAD of *Glaphyrocysta texta* and the LAD of *Deflandrea oebisfeldensis*.

Zonation and age. Upper part of D8 to lower part of dinoflagellate Zone D11 (?latest Early Eocene to Middle Eocene).

Diagnostic events. The interval includes only two samples (1180 and 1234 m), both ditch cutting samples (DCS). *Phthanoperidinium echinatum* occurs in both samples. A single specimen of *Alterbidinium* aff. *bicellulum* occurs at 1180 m and single specimens of both *Rhombodinium draco* and *Wetzeliella spinula* have been recorded from 1234 m.

Common species within the interval. Dinoflagellate cysts are sparce but saccate pollen are very abundant at 1234 m.

Caved species. *Wetzeliella spinula* and possibly *Rhombodinium draco.*

Discussion. *Phthanoperidinium echinatum* is represented by five and six specimens in the two samples, and according to Powell (1992) the species ranges from the lower part of D8 (Ccl, Lower Eocene) to D12 (Rpe, Upper Eocene; Fig. 2). *Alterbidinium bicellulum* has previously only been recorded by Islam (1983) who described the species and its range from the Bracklesham Beds B-3 and B-4 in England. These beds correlate with dinoflagellate Zone D 9 (Fig. 2; Powell 1992). If not caved the presence of *A.* aff. *bicellulum* at 1180 m may suggest a hiatus spanning Zone D 10 between the samples at 1155 m and at 1180 m.

The presence of *Rhombodinium draco,* in the sample at 1234 m suggests a dinoflagellate zone not lower than D10 (Powell 1992) and is thus probably caved.

The present interval gives no unambiguous dinoflagellate cyst indication of age. The lack of stratigraphic marker species of the zones D8 to D10 suggests that hiati may be present within the interval. This may also be suggested by the relatively thin body of strata which according to the intervals above and below represent a long time span.

Previous dating. Toxwenius (1986) referred the interval 1140–1801 m to Late Eocene (D12) based on the LAD of *P. echinatum* (1152 m, DCS).

Sample depth 1357 m (middle, Lower Eocene)

Definition of interval. The body of strata between the LAD of *Deflandrea oebisfeldensis* and the LAD of *Dracodinium* cf. *simile*.

Zonation and age. Lowermost part of dinoflagellate Zone D8 (middle part of Early Eocene), correlating with the lower part of the *Charlesdowniea coleothrypta* (Ccl) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Deflandrea oebisfeldensis*, *Muratodinium fimbriatum*, FAD of single specimens of *Areosphaeridium* cf. *diktyoplokus*, *Charlesdowniea tenuivirgula* and *Dracodinium politum*.

Common species within the interval. *Alterbidinium* sp. and *Deflandrea oebisfeldensis*.

Discussion. According to Powell (1992) *D. oebisfeldensis* and *M. fimbriatum* have their LAD at the lower part of *Charlesdowniea coleothrypta* (Ccl) Interval Biozone, whereas the same author reported the FAD of *C. tenuivirgula*, and *D. condylos* from the base of Ccl, and the FAD of *A. diktyoplokus* from the younger dinocyst Interval Biozone (Pla). The presence *D. oebisfeldensis* and *M. fimbriatum* in the present sample may suggest that most of, the upper part of Ccl is missing in Hellefisk-1, and that the SWC from 1357 m represents the lowermost part of Ccl Interval Biozone (Powell 1992).

Previous dating. As for the interval above.

Sample depth interval 1425–1909 m (lower middle part of Lower Eocene)

Definition of interval. The body of strata between the LAD of *Dracodinium* cf. *simile* and the LAD of *Fibrocysta bipolaris*.

Zonation and age. Dinoflagellate Subzones D7a and D7b (early middle part of Early Eocene), correlating with the *Dracodinium simile* (Dsi) and the *Dracodinium varielongitudum* (Dva) Interval Biozones of Powell (1992), and maybe the uppermost part of D6b (Fig. 2).

Diagnostic events. *Wetzeliella lunaris* has a LAD at 1425 m (SWC) and FAD at 1754 m (SWC), while *Dracodinium* cf. *simile* and *Homotryblium tenuispinosum* only occur at 1425 m (SWC). *Paralecaniella indentata* has a LAD at 1588 m (SWC) and FAD at 1774 m (SWC). *Heteraulacacysta leptalea* has a LAD at 1634 m (DCS) and FAD at 1754 m (SWC). *Dracodinium* aff. *solidum* only occurs at 1754 m (SWC). The LAD of *Alisocysta* sp. 2 Heilmann-Clausen 1985 occurs at 1754 m (SWC) and the LAD of *Apectodinium paniculatum* is at 1862 m (SWC).

Common species within the interval. *Glaphyrocysta* spp. common throughout the most of the interval. *Spiniferites* aff. *pseudofurcatus* dominant at 1734 m (SWC), *Spiniferites* spp. common at 1806 m, (SWC), *Areoligera* spp. common at 1754 m and 1806 m (both SWC) and *Apectodinium homomorphum* common at 1862 m (SWC)

Reworked species. *Cerodinium* spp. (1725 m, DCS). *Palaeocystodinium bulliforme*, (1734 m, DCS),

Caved species. A single *Diphyes ficusoides* specimen (1425 m, SWC).

Discussion. According to Powell (1992) *Dracodinium simile* range from the base of the *Dracodinium simile* Interval Biozone (Dsi, base D7a) to the *Charlesdowniea coleothrypta* Interval Biozone (Ccl, lower D8). *Alisocysta* sp. 2 Heilmann-Clausen 1985 has its LAD in the upper part of the *Dracodinium varielongitudum* (Dva) Interval Biozone (upper D7b), and *Dracodinium. solidum*, *Homotryblium tenuispinosum* and *Wetzeliella lunaris* have their FAD in the *Dracodinium simile* (Dsi) Interval Biozone (lowermost D7a). *Heteraulacacysta leptalea* has its FAD in the Ccl Interval Biozone (lower D8) according to Powell (1992). This allows tentatively correlation of the lower boundary of the interval with the base of the Zone D7. However, the LAD of *Apectodinium paniculatum* at 1862 m (SWC) may suggest that the lower part of the interval represent the upper part of dinoflagellate Zone D6b according to Powell (1992).

Previous dating. Toxwenius (1986) referred the interval 1140–1801 m to Late Eocene (D12) based on a LAD of *Phthanoperidinium echinatum* (1152 m, DCS), the interval 1801–1862 m to Middle Eocene (D11) based on a LAD of *Apectodinium homomorphum* at 1806 m, the interval 1862–1915 m to D10 based on a LAD of *Glaphyrocysta ordinata* at 1862 m and the interval 1915–1935 m to middle and upper D9.

Sample depth interval 1928 m–1999 m (lower part of Lower Eocene)

Definition of interval. The body of strata between the LAD and FAD of *Fibrocysta bipolaris*.

Zonation and age. Dinoflagellate Subzone D6b (early part of Early Eocene), corresponding to the *Wetzeliella meckelfeldensis* (Wme) Interval Biozone of Powell (1992).

Diagnostic events. *Fibrocysta bipolaris* has a LAD at 1928 m (SWC) and FAD at 1999 m (DCS), *Wetzeliella meckelfeldensis* only occur at 1928 m (SWC); LAD of *Spiniferites septatus* at 1975 m (SWC).

Common species within the interval. *Fibrocysta bipolaris* at 1928 m, (SWC), at 1952 m (SWC) and at 1975 m (SWC) and *Operculodinium centrocarpum* at 1975 m (SWC).

Reworked species. *Palaeocystodinium bulliforme* (1928 m, SWC).

Discussion. Wilson (1988) recorded the range of *F. bipolaris* from the middle Paleocene to lowermost part of Lower Eocene and Powell *et al.* (1996) noted that *F. bipolaris* has its FAD within the *Glphyrocysta ordinata* (Gor) Interval Biozone (lowermost Eocene), however, no LAD for the species was reported by Powell *et al.* (1996). Powell (1992) reported the range of *W. meckelfeldensis* from the base of D6b to the top at D8 and the range of *S. septatus* from the top of D7b.

Previous dating. Toxwenius (1986) referred the interval 1935 m to 1982 m to early to middle D9 based on a LAD of *Hystrichosphaeridium tubiferum*, *F. bipolaris* at 1952 m (SWC).

Sample depth interval 1999–2315 m (lowermost Eocene–Upper Paleocene)

Definition of interval. The body of strata between the FAD of *Fibrocysta bipolaris* and the LAD of *Alisocysta margarita*.

Zonation and age. Dinoflagellate Subzone ?D5a (Late Paleocene), correlating with the *Apectodinium augustum* (Aau) to dinoflagellate Subzone ?D6a (earliest part of Early Eocene) correlating with the *Wetzeliella astra* (Was) Interval Biozones Interval Biozone (Powell 1992).

Diagnostic events. This interval shows no diagnostic events.

Reworked species. A single specimen of *Alisocysta* cf. sp. 1 Heilmann-Clausen 1985 at 2075 m (SWC).

Caved species. Possible *Fibrocysta bipolaris* (2113, 2249 m both DCS).

Discussion. Only a few specimens and no LAD of stratigraphic significant species have been recorded in the, which makes it impossible to date the interval. However, it is suggested to represent the lowermost part of Lower Eocene (Subzone ?D6a) to Upper Paleocene (?Upper part of Zone D4) based on the records above and below the interval.

The absence of abundant *Apectodinium* spp., which characterises the Subzone D5a in the Ikermiut-1 well and Kangâmiut-1 well, may suggest that lowermost Eocene and uppermost Paleocene strata are not represented in the Hellefisk-1 well, indicating that a hiatus occur within or at the base of the interval.

Previous dating. Toxwenius (1986) referred the interval 1915–2206 m to Early Eocene (D7 to lower D9) based on a LAD of *Hystrichosphaeridium tubiferum* and *F. bipolaris* at 1952 m (SWC), and the interval 2206–2324 m to latest Paleocene to Early Eocene (D5–D6) based on a LAD of *Cerodinium speciosum* whitin the interval 2206–2212 m.

Sample depth interval 2335–2481 m (Upper Paleocene)

Definition of interval. The body of strata below the FAD of *Alisocysta margarita*.

Zonation and age. Middle part of dinoflagellate Zone D4 (Late Paleocene) correlating with the *Alisocysta margarita* (Ama) Interval Biozone of Powell (1992). The middle part of D4 is subdivided into an upper and a lower part. The upper part (2335–2466 m) is characterised by the presence of *A. margarita* as the only *Alisocysta* species, whereas the lower part (2481–2637 m) is characterised by the co-occurrence of *A. margarita* and *A.* cf. sp. 1 Heilmann-Clausen 1985. The proposed subdivision can also be recognised in the Ikermiut-1 well (2462–2690 m) (Fig. 4).

According to log interpreted by Rolle (1985) the top of the Paleocene basalts occurs at 2500 m. Total depth is at 3201 m.

Diagnostic events. The LAD of *Alisocysta margarita* occurs at 2335 m (DCS), LAD of *Areoligera gippingensis* at 2396 m (DCS), LAD of *Thalassiphora delicata* at 2435 m (DCS), LAD of *Cerodinium medcalfii* at 2438 m (SWC), and LAD of *Alisocysta* cf. sp. 1 Heilmann Clausen 1985 at 2481 m (DCS).

Common species within the interval. *Alisocysta margarita* is common at 2481 m (DCS), *Cerodinium medcalfii*, *Deflandrea oebisfeldensis* are abundant at 2438 m (SWC) and *A. gippingensis* is abundant in the lower part of the interval.

Caved species. Probably all specimens recorded from samples in the Paleocene basalts bellow 2500 m, but for sure *Wetzeliella meckelfeldensis* at 2664 m (DCS).

Discussion. The presence of *Alisocysta margarita* throughout the interval, and the abundance of *A. gippingensis* in the lower part of the interval allows correlation with Zone 4 of Heilmann-Clausen (1985; Fig. 2) which, according to Powell (1992), is equivalent to the Ama Interval Biozone. The LAD of *A.* cf. sp. 1 Heilmann-Clausen 1985 is stratigraphically higher in the Hellefisk-1 well than the LAD for *A.* sp. 1 Heilmann-Clausen 1985 which was recorded from the top of Zone 3 (Heilmann-Clausen 1985). Powell (1992) correlated Zone 3 with the *Palaeoperidinium pyrophorum* (Ppy) Interval Biozone (lower part of Zone D4). The species *Alisocysta* cf. sp. 1 Heilmann-Clausen 1985 from Hellefisk-1 well differs from *A.* sp. 1 Heilmann-Clausen 1985 by having a slightly less pronounced reticulum composed of large and small luminae and by its low (less than 5µm) penitabular membranes.

Previous dating. Toxwenius (1986) referred the interval 2324–2535 m to Late Paleocene (D4) based on the LAD of a species reported as *Eisenackia* cf. *crassitabulata*. In the present study, the species most probably reported as *E.* cf. *crassitabulata* is identified as *Alisocysta* cf. sp. 1 Heilmann-Clausen 1985. Toxwenius (1986) also mentioned the abundant occurrence of *Areoligera senonensis*, the FAD of *Alisocysta margarita* and the LAD of *A. circumtabulata* (which is not identified in the present study) to be characteristic of Zone D4.

Ikermiut-1

Technical data

Ikermiut-1 was drilled in 1997 by Chevron Petroleum Co. of Greenland at 66° 56' 12" N and 56° 35' 26" W (Fig.1). The water depth was 447 m (1468 ft). The rotary table was 12 m (41 ft) above sea level, and the total depth was 3619 m (11874 ft) below rotary table where the well reached ?Campanian shale (Rolle 1985). All sample depths are measured from rotary table datum.

Sample depth 1049 m (Middle Eocene)

Definition of interval. The body of strata between the LAD of *Cerebrocysta bartonensis*, *Phthanoperidinium geminatum* and the LAD of *Glaphyrocysta vicina* (Enclosure 2).

Zonation and age. Upper part of Zone D10 (Middle Eocene), correlating with the *Rhombodinium draco* (Rdr) Interval Biozone of Powell (1992; Fig. 2).

Diagnostic events. The species *Glaphyrocysta semitecta*, *Heteraulacacysta porosa*, and *Phthanoperidinium geminatum* are only recorded at 1049 m (SWC). Diagnostic species with LAD at 1049 m are *Cerebrocysta bartonensis, Lentinia serrata*, *Phthanoperidinium echinatum* and *P. comatum*.

Common species within the sample. *Glaphyrocysta semitecta* common, *Operculodinium centrocarpum* abundant, *P. geminatum* common and *Spiniferites* spp. abundant.

Discussion. According to Bujak *et al.* (1980) and Powell (1992) *H. porosa* is only recorded from Zone D10 and the lower part of Zone D11. However, Bujak and Mudge (1994) extended the range for *H. porosa* in the North Sea upwards to the top of their Subzone E7b correlating with the top of Zone D11 (Fig. 2). Bujak (1980) described *G. semitecta*, *L. serrata* and *P. geminatum* from the Barton Beds in southern England (Zone Bar-1 to Zone Bar-5, corresponding to upper D10 and D11; Fig. 2). Brinkhuis & Biffi (1993) recorded the uppermost occurrence of *G. semitecta* and *L. serrata* in central Italy from the Lower Oligocene, corresponding to the upper part of Zone D12. The presence of *C. bartonensis* suggests a level not higher than Zone D11 (Bujak *et al.* 1980; Powell 1992) or not higher than

Subzone E7a (Bujak 1994; Bujak & Mudge 1994) correlating with upper part of Zone D10 (Fig. 2).

The presence of *H. porosa* together with *G. semitecta*, *L. serrata* and *P. geminatum* suggests that the sample belongs to the Zone D10 or D11; however, the absence of *G. texta*, *R. longimanum* and *W. spinula* which among others were recorded from Zone D11 in the Hellefisk-1 well (Enclosure 1) may suggest that the sample belongs to the uppermost part of Zone D10, which correlates with the *Rhombodinium draco* (Rdr) Interval Biozone (Fig. 2; Powell 1992).

Previous dating. Toxwenius, (1986) previously dated the interval as Middle Miocene (D18) (Fig. 3) based on a LAD of *Palaeocystodinium golzowense*, *Systematophora ancyrea* and *S. placacantha*. Whereas *Eatonicysta ursulae* and cf.*Phthanoperidinium amoenum* were regarded as reworked (Toxwenius, 1986). The present study suggests that the specimens previously identified as *E. ursulae* in fact are *G. semitecta,* and specimens identified as cf. *P. amoenum* are *P. geminatum*.

The Miocene indicator *Hystrichosphaeropsis obscura* reported by Toxwenius (1986) has not been found by the present author.

Sample depth interval 1130–1155 m (Middle Eocene)

Definition of interval. The body of strata between the LAD of *Glaphyrocysta vicina* and the LAD of *Glaphyrocysta* cf. *spineta*.

Zonation and age. Probably lower part of dinoflagellate Zone D10 (Middle Eocene), although the middle to upper part of D 9 cannot be excluded. The lower part of D10 correlates with the *Glaphyrocysta intricata* (Gin) Interval Biozone (Fig. 2; Powell 1992).

Diagnostic events. LAD of *Cribroperidinium giuseppei* and *Phthanoperidinium* aff. *distinctum* at 1130 m (DCS). LAD of *Areosphaeridium arcuatum*, *Deflandrea* sp. 1 and *Glaphyrocysta vicina* at 1155 m (SWC) and FAD of *Phthanoperidinium geminatum* at 1155 m (SWC).

Common species within the interval. *Deflandrea* sp. 1 abundant at 1155 m (SWC).

Reworked species. *Areoligera senonensis* at 1155 m (SWC).

Discussion. According to Bujak *et al.* (1980) and Powell (1992) *G. vicina* has its LAD and *P. geminatum* has its FAD in the lower part of Zone D10. Powell (1992) reported the LAD of the *A. senonensis* group from the middle part of Zone D9. Bujak & Mudge (1994) reported *Phthanoperidinium distinctum* from their North Sea Subzones E6a and E6b, which correlate with the upper part of the Middle Eocene Zone D9 (Fig. 2). *Cribroperidinium giuseppei* has been recorded from the London Clay (Zone LC-3) to Barton Beds (Zone Bar-5) by Bujak *et al.* (1980) which, according to Powell (1992), correlate with the base of Zone D8 to the top of Zone D11 (Fig. 2). Brinkhuis & Biffi (1993) recorded *C. giuseppei* up to the Lower Oligocene in Italy.

The record from the present interval gives no unambiguous age; however, it is suggested that the interval allows correlation with the lower part of Zone D10 based on the LAD of *G. vicina* (3 specimens).

Previous dating. Toxwenius, (1986) referred the interval 1070–1310 m to be Early Miocene (D16–D17; Fig. 3) based on the LAD of *Cordosphaeridium cantharellus* and *Homotryblium floripes*. These taxa have not been identified in the interval in the present study.

Sample depth interval 1170–1230 m (Middle Eocene)

Definition of interval. The body of strata between the LAD of *Glaphyrocysta* cf. *spineta* and the FAD of *Phthanoperidinium* aff. *distinctum.*

Zonation and age. Upper part of dinoflagellate Zone D9 (Middle Eocene) correlating with the upper part of the *Areosphaeridium arcuatum* (Aar) or the lower part of the *Glaphyrocysta intricata* (Gin) Interval Biozones of Powell (1992).

Diagnostic events. *Glaphyrocysta* cf. *spineta* only occurs at 1170 m (DCS). The FAD of *Phthanoperidinium* aff. *distinctum* at 1230 m (DCS).

Common species within the interval. *Glaphyrocysta* cf. *spineta* (1170 m, DCS), *Systematophora placacantha* (1230 m, DCS)

Discussion. Bujak *et al.* (1980) recorded the LAD of *G. spineta* from the lower part of the Bracklesham Beds (Zone B-5) which according to Powell (1992) correlate with the lowermost part of D10 (Fig. 2). Heilmann-Clausen & Costa (1989) recorded the LAD of *G. spineta* from the uppermost part of Zone D9 in north-west Germany. Bujak & Mudge (1994) reported the range of *P. distinctum* from their North Sea Subzones E6a and E6b, and an acme of *Systematophora placacantha* in their E6b Subzone which correlates with the upper part of the Zone D9 (Fig. 2).

Previous dating. As for the interval above.

Sample depth interval 1230–1470 m (Middle Eocene)

Definition of interval. The body of strata between the FAD of *Phthanoperidinium* aff. *distinctum* and the FAD of *Phthanoperidinium comatum.*

Zonation and age. Middle to lower part of dinoflagellate Zone D9 (Middle Eocene), correlating with the *Areosphaeridium arcuatum* (Aar) Interval Biozone (Powell, 1992).

Diagnostic events. *Microdinium reticulatum* only occurs at 1324 m (SWC), FAD of *Areosphaeridium arcuatum* at 1360 m (SWC) and FAD of *Phthanoperidinium comatum* at 1470 m (DCS).

Common species within the interval. The interval 1360 m to 1470 m is only represented by four almost barren samples (Enclosure 2).

Discussion. Powell (1992) reported the FAD of *A. arcuatum* from the lower part of Zone D9 and the FAD of *P. comatum* from the base of Zone D9. *Microdinium reticulatum* was originally described by Vozzhennikova (1967) from the Eocene of Western Siberia.

The sparse stratigraphic information recorded from this interval suggests that it may correspond to the middle and lower part of Zone D9.

Previous dating. Toxwenius (1986) referred the interval 1310–1400 m to Early Oligocene (D13–D14; Fig. 3) based on the LAD and FAD of *Phthanoperidinium amoenum*; this identification has not been confirmed by the present author, who has identified the species as *Microdinium reticulatum* based on an apical archeopyle with an often attached operculum.

Toxwenius (1986) interpreted the interval 1400–1560 m as Middle to Upper Eocene (upper D10–12) based on the LAD of *Apectodinium homomorphum* and *G. ordinata*.

Toxwenius (1986, p. 17) suggested that the uppermost part of Zone D9 and lower part of Zone D10 is missing in all of the wells, contrary to the present authors interpretation (Fig. 3).

Sample depth interval 1470–1573.5 m (Lower Eocene)

Definition of interval. The body of strata between the FAD of *Phthanoperidinium comatum* and the LAD of *Fibrocysta bipolaris.*

Zonation and age. Middle to lower part of dinoflagellate Zone D8 (Early Eocene), correlating with the lower part of the *Pentadinium laticinctum* (Pla) Interval Biozone of Powell (1992; Fig. 2).

Diagnostic events. LAD of *Glaphyrocysta ordinata* at 1558 m (DCS). LAD of *Glaphyrocysta* aff. *pastielsii* at 1566 m (SWC), LAD of *Areoligera medusettiformis* and *Turbiosphaera galatea* at 1573.5 m (SWC).

Abundance within the interval. *Areoligera medusettiformis Glaphyrocysta* aff. *pastielsii*, *G. ordinata* and *Glaphyrocysta* spp. common at 1573.5 m (SWC),

Discussion. A possible hiatus may occur in the interval between the samples at 1470 m and at 1558 m (Figs 3–4, Enclosure 2). This is suggested by the absence of *Eatonicysta ursulae*, which occurs within the upper and middle parts of Zone D8 in the Kangâmiut-1 well. The hiatus probably span upper part of Zone D8 (upper part of the *Pentadinium laticinctum* (Pla) Interval Biozone of Powell 1992) and the ?lowermost part of dinoflagellate Zone D9 (Fig. 2; *Phthanoperidinium comatum* (Pco) Interval Biozone of Powell 1992).

Bujak & Mudge (1994) described the the *Areoligera medusettiformis* acme from their Subzone E2c and the LAD of frequent *Areoligera medusettiformis* from the top of their upper Lower Eocene North Sea dinocyst Subzone E3a (Fig. 2). According to Bujak *et al.* (1980) *T. galatea* is only reported from the Bracklesham Beds (Zone B2 and lower part of Zone B-3) which correlate with the upper to lower part of Zone D8 and the lowermost part of Zone D9 (Fig. 2; Powell 1992).

Glaphyrocysta pastielsii is recorded from the lowermost Eocene (Gocht 1969) and the middle part of Zone D8 (LAD) (Köthe 1990) in Germany. Eaton (1976) reported occurrences from the Lower Eocene in Belgium and France. Heilmann-Clausen (1985) and Heilmann-

Clausen & Costa (1989) recorded the LAD for *G. pastielsii* from Zone D7a in Denmark and Germany (Fig. 2).

The stratigraphic information obtained from this interval suggests correlation with the middle to lower part of Zone D8.

Previous dating. Toxwenius (1986) referred the interval 1560–1920 m to Early Eocene (D9) based on the LAD of *Eatonicysta ursulae* (not recorded by the present author), *Wetzeliella articulata* and *W. meckelfeldensis.*

Sample depth interval 1590–1680 m (Lower Eocene)

Definition of interval. The body of strata between the LAD and FAD of *Fibrocysta bipolaris.*

Zonation and age. Dinoflagellate Subzone D6b (Early Eocene), corresponding to the *Wetzeliella meckelfeldensis* (Wme) Interval Biozone of Powell (1992; Fig. 2).

Abundance within the interval. *Cordosphaeridium* spp. common at 1620 m (DCS), *Spiniferites* spp. common at 1632 m (SWC).

Diagnostic events. LAD of *Fibrocysta bipolaris* at 1590 m (DCS) and FAD at 1680 m (DCS), LAD of *Apectodinium homomorphum* at 1590 (DCS), *Wetzeliella lunaris* only occurs at 1590 m. LAD of *Wetzeliella meckelfeldensis* at 1590 m (DCS) and FAD at 1650 m (DCS). LAD of *Carpatella* sp. at 1620 m (DCS) and FAD at 1650 m (DCS). FAD of *Muratodinium fimbriatum* and one specimen which may be identified as *Spiniferites septatus* at 1632 m (SWC). The FAD of *Alisocysta* sp. 2 Heilmann-Clausen 1985, *Apectodinium quinquelatum* and *Deflandrea oebisfeldensis* at 1650 m (DCS) may be reworked.

Reworked species. *Palaeocystodinium australinum* (1620 m, 1650 m both DCS) .

Discussion. A hiatus or a condensed section may occur in the strata between the samples at 1573.5 m and at 1590 m (Fig. 3, Enclosure 2). This is suggested by the absence of the characteristic species *Dracodinium condylos*, *D. simile* and *D. solidum*, which have been recorded from the lower part of dinoflagellate Zone D8 in the Kangâmiut-1 and Nukik-1 wells (Enclosures 3, 4).

Wilson (1988) recorded the range of *F. bipolaris* from the middle Paleocene to lowermost Eocene in New Zealand and Powell *et al.* (1996) noted that in the North Sea region *F. bipolaris* has its FAD within the Gor Interval Biozone. Powell (1992) reported the range of *W. lunaris* from the lower part of Subzone D7a to the lower part of Zone D9, the range of *W. meckelfeldensis* from the base of Subzone D6b to the top at Zone D8 and LAD of *S. septatus* from the top of Subzone D7b. The top of the interval is characterised by the co-occurrence of *F. bipolaris* and *W. meckelfeldensis* and the base of the interval is characterised by the FAD of *F. bipolaris*. The interval can be correlated to similar intervals in the Hellefisk-1, Kangâmiut-1 and Nukik-1 wells (Fig. 4).

Previous dating. Toxwenius (1986) interpreted the interval 1560–1920 m as D9 based on the LAD of *Eatonicysta ursulae* (not recorded by the present author), *Wetzeliella articulata* and *W. meckelfeldensis*.

Sample depth interval 1680–1980 m (Lower Eocene)

Definition of interval. The body of strata between the FAD of *Fibrocysta bipolaris* and the LAD of *Apectodinium parvum* and of a *Deflandrea oebisfeldensis* acme.

Zonation and age. Lower part of Subzone D6a to ?D6b (Early Eocene), correlating with the *Wetzeliella astra* (Was) and *Wetzeliella meckelfeldensis* (Wme) Interval Biozones of Powell (1992).

Diagnostic events. LAD of *Spiniferites septatus* at 1800 m (DCS) and one specimen of *Alisocysta* cf. sp. 2 Heilmann-Clausen 1985 is recorded from 1890 m. (DCS).

Common species within the interval. *Spiniferites* spp. common at 1919 m (SWC).

Reworked species. *Cerodinium striatum* at 1800 m (DCS).

Discussion. The upper part of the interval (1680–1770 m) contain no significant stratigraphical signals. According to Powell (1992) *S. septatus* and *Alisocysta* sp. 2 Heilmann-Clausen 1985 have their LAD in dinoflagellate Subzone D7b.

Previous dating. Toxwenius (1986) referred the interval 1560–1920 m as belonging to the Zone D9, see interval above, and 1944.5–2135 m as Zone D8 based on the LAD of *Apectodinium hyperacanthum* (2131 m).

Sample depth interval 1992–2070.5 m (lowermost Eocene–uppermost Paleocene)

Definition of interval. The body of strata between the LAD of *Apectodinium parvum* and of a *Deflandrea oebisfeldensis* acme and the LAD of consistent *Apectodinium* spp.

Zonation and age. Dinoflagellate Subzone D5b (earliest Eocene), correlating with the *Glaphyrocysta ordinata* (Gor) Interval Biozone of Powell (1992; Fig. 2). Powell *et al.* (1996) referred the Gor Interval Biozone to the latest Paleocene to earliest Eocene.

Diagnostic events. LAD of *Apectodinium paniculatum*, *A. parvum*, ?*A. summissum*, and *Spinidinium* aff. *sagittula* at 1992 m (DCS). LAD of *Apectodinium augustum* at 2010 m (DCS), a single specimen.

Common species within the interval. *Areoligera senonensis*, *Deflandrea oebisfeldensis*, *Cerodinium* spp. and *Spinidinium* aff. *sagittula* are common at 1992 m (DCS) .

Reworked species. *Chatangiella granulifera* at 1992 m (DCS), *Odontochitina costata* at 2040 m (DCS) and *Cerodinium striatum* at 2070 m (DCS).

Discussion. According to Powell (1992) *A. paniculatum* and *A. parvum* have their LAD in the Zone D6, whereas *A. summissum* has its LAD in the top of the Subzone D5b (upper part of Gor). Powell (1992) reported the LAD of *Apectodinium augustum* from the lowermost part of the Subzone D5b (lowermost Gor, which he referred to the lowermost Eocene). Later Powell *et al.* (1996) referred the lowermost part of Gor to uppermost Paleocene and suggested that the LAD of *A. augustum* occurs in the uppermost Paleocene, which is also suggested by Bujak & Mudge (1994) and Mudge & Bujak (1996 a, b).

Drugg (1970) described *Spinidinium sagittula* from the Lower Eocene from the Gulf Coast of USA.

In the definition of the *Deflandrea oebisfeldensis* Zone (lowermost Eocene) Powell (1988) mentioned that in addition to the common occurrence of *D. oebisfeldensis*, a suite of deflandreoid dinoflagellate cysts are also characteristic of this Biozone, and calibrated the Zone to NP10 (Powell, 1988, 1992). According to Costa & Manum (1988) their uppermost Paleocene dinoflagellate cyst Subzone D5b is characterised by an acme of *D. oebisfeldensis* and they calibrated D5b with NP9. Ioakim (1979), Heilmann-Clausen (1985), Heilmann-Clausen & Costa (1989) and Bujak & Mudge (1994) all have recorded a *D. oebisfeldensis* acme at the Paleocene/Eocene transition.

In the present study the assignment of, the *D. oebisfeldensis* acme to the lowermost Eocene of Powell (1988, 1992), and Bujak & Mudge (1994) has been followed. The LAD of *Apectodinium augustum* has been assigned to the uppermost Paleocene as proposed by Powell *et al.* (1996), Bujak & Mudge (1994) and Mudge & Bujak (1996 a,b).

Previous dating. As for the interval above.

Sample depth interval 2097.5–2340 m (uppermost Paleocene)

Definition of interval. The body of strata between the LAD of consistent *Apectodinium* spp. and the LAD of *Areoligera gippingensis*.

Zonation and age. Dinoflagellate Subzone D5a (latest Paleocene), correlating with the *Apectodinium augustum* (Aau) Interval Biozone of Powell, 1992).

Diagnostic events. The LAD of consistent *Apectodinium homomorphum* at 2097.5 m (SWC). Continuous occurrence of *Apectodinium augustum* from 2190 m (DCS) to 2370 m (DCS). FAD of *A. homomorphum*, *A. parvum* and *Muratodinium fimbriatum* at 2340 m (SWC), LAD of *Lejeunecysta hyalina* at 2116 m (DCS). *Spinidinium* sp. 2 has a range from 2190 m (DCS) to 2340 m (DCS). LAD of *Phthanoperidinium crenulatum* at 2340 (DCS, SWC).

Common species within the interval. *Apectodinium* spp. common to abundant from 2097.5 m (SWC) to 2340 m (SWC). *Apectodinium homomorphum* abundant from 2097.5 m (SWC) to 2340 m (SWC), *Pediastrum* spp. common at 2190 m (DCS) to 2340 m (SWC), *Adnatosphaeridium robustum* common at 2276 m (SWC), *Spiniferites* spp. are very abundant from 2190 m (DCS) to 2340 m (DCS).

Reworked species. *Chatangiella ditissima* (2161–2310 m, both DCS), *Chatangiella spectabilis* and *Surculosphaeridium longifurcatum*? (2340 m, DCS) and *Isabelidinium* spp. (2340 m SWC). *Aquilapollenites* spp. at 2070,5 m (SWC).

Caved species. *Lentinia serrata*? (2340 m, DCS).

Discussion. Heilmann-Clausen (1985) recorded the LAD for *Apectodinium augustum* from the lowermost part of Zone 7 and the acme of the species from Zone 6 (Fig. 2); according to Powell (1992) these datum levels correlate with the lowermost part of *Glaphyrocysta ordinata* (Gor, D5b) and all of his *Apectodinium augustum* (Aau, D5a) Interval Biozones, respectively. Costa & Manum (1988) without any published evidence, recorded the LAD of *A. augustum* from the top of the Subzone D5b. Bujak & Mudge (1994) defined the top of their uppermost Paleocene P6 *A. augustum* Biozone by the last occurrence of *A. augustum* and correlated it to the *A. augustum* Interval Biozone of Powell (1988). Bujak & Mudge (1994) mentioned that in most North Sea sections the LAD of *A. augustum* is either coincident with or just above the acme of *A. augustum*. Powell (1992) changed the definition of his *A. augustum* Interval Biozone (1988), to include the body of strata between the FAD of *A. augustum* and the FAD of *Phelodinium magnificum*, and correlated it with Zone 6 of Heilmann-Clausen (1985). *Phelodinium magnificum* has not been recorded in the present study. Heilmann-Clausen (1994) indicated that the FAD of *P. magnificum* may not be reliable and suggested that the top of the *A. augustum* Zone in the North Sea is better characterised by the top of the acme of *Apectodinium* spp.

Apectodinium augustum does not occur in high numbers in the present study; however as recorded by Heilmann-Clausen (1985, 1994), Costa & Manum (1988), Powell (1988, 1992) and Bujak & Mudge (1994) *A. augustum* co-occurs with high numbers of *Apectodinium* spp. A reliable FAD of *Apectodinium* spp. has been recorded at 2340 m (SWC).

According to Powell (1992) *A. parvum* has its FAD at the base of Subzone D5a, whereas the FAD of *M. fimbriatum* is in the lower part of Subzone D5a.

The range of *Phthanoperidinium crenulatum* defined Zone 5 by Heilmann-Clausen (1985), Zone 5 correllate with the uppermost part of Zone D4 and the *Apectodinium hyperacanthum* (Ahy) Interval Biozone of Powell (1992; Fig. 2). Later Nielsen *et al.* (1986) recorded of the LAD of *P. crenulatum* together with the FAD of *A. augustum* from the lowermost sample in Zone 6 of Heilmann-Clausen (1985).

The present interval is correlated with the Subzone D5a/Aua Interval Biozone of Powell (1992) which Powell *et al.* (1996) correlated with the range of the *Apectodinium* acme.

Previous dating. Toxwenius (1986) referred the interval 2161–2285 m to Zone D7 based on the LAD of *A. parvum* (2250 m) and the interval 2307–2340 m as Zone D6 (Fig. 3) based on the FAD of *Deflandrea phosphoritica* (2307 m) and on the LAD of *Cerodinium speciosum* (2340 m).

Sample depth interval 2370–2447 m (Upper Paleocene)

Definition of interval. The body of strata between the LAD of *Areoligera gippingensis* and the LAD of *Alisocysta margarita*.

Zonation and age. Upper part of dinoflagellate Zone D4 (Late Paleocene), corresponding to the *Apectodinium hyperacanthum* (Ahy) Interval Biozone of Powell (1992).

Diagnostic events. LAD of the *Areoligera gippingensis* acme at 2400 m (DCS) and LAD of *Cerodinium speciosum* subsp. *glabrum* at 2400 m (DCS).

Common species within the interval. *Areoligera gippingensis* abundant (2400–2447 m), *Deflandrea oebisfeldensis* common at 2429 m (DCS), *Cerodinium speciosum* subsp. *glabrum*, *Spinidinium* aff. *sagittula* and *Spiniferites* spp. abundant at 2447 m (DCS).

Reworked species. *Circulodinium distinctum* and *Xenascus* spp. at 2374,5 m (SWC), *Surculosphaeridium longifurcatum* at 2400 m (DCS), *Isabelidinium cooksoniae* and *Dinogymnium sibiricum* at 2447 m (DCS).

Caved species. *Muratodinium fimbriatum* (2374,5 m, DCS, 2400 m DCS), common to abundant *Apectodinium* spp. in the entire interval.

Discussion. The absence of *Alisocysta margarita*, the abundance of *A. gippingensis* (*A* cf. *senonensis* Heilmann-Clausen 1985) and the presence of *C. speciosum* subsp. *glabrum* and *D. oebisfeldensis* correlate well with Zone 5 of Heilmann-Clausen (1985) which, according to Powell (1992) is entirely equivalent to his *Apectodinium hyperacanthum* (Ahy) Interval Biozone (Fig. 2). The Ahy Interval Biozone is defined as the body of strata between the FAD of *A. homomorphum* and the FAD of *A. augustum* (Powell 1992). *Apectodinium homomorphum* as well as an abundance of other *Apectodinium* species have been recorded from the present interval (2370 - 2447 m); however, these may be regarded as caved as they only occur in ditch cutting samples.

Previous dating. Toxwenius (1986) referred the interval 2353–2411 m to D5 based on the occurrence of abundant *Apectodinium* spp. concurrent with the FAD of abundant *Apectodinium summissum*, *A. parvum*, *A. hyperacanthum* and the FAD of *Homotryblium tenuispinosum*. Toxwenius (1986) referred the interval 2429–2700 m to D4 based on occurrence of abundant *Areoligera senonensis*, and *Cerodinium dartmoorium* (LAD, 2447 m, DCS) together with the LAD of *Alisocysta* cf. *circumtabulata* at 2444 m (DCS). In the present study *C. dartmoorium* from 2447 m has been identified as either *D. oebisfeldensis* or *C. speciosum* subsp. *glabrum*. The sample from 2444 m with *A.* cf. *circumtabulata* has not been at disposal for the present study.

Sample depth interval 2462–2690 m (Upper Paleocene)

Definition of interval. The body of strata between the LAD of *Alisocysta margarita* and the LAD of *Cerodinium striatum*.

Zonation and age. Middle part of dinoflagellate Zone D4 (Late Paleocene), correlating with the *Alisocysta margarita* (Ama) Interval Biozone of Powell (1992). A subdivision of the interval has been proposed by the present author. The upper part (2462–2612 m) is characterised by the presence of *A. margarita* as the only *Alisocysta* species, whereas the lower part (2627–2690 m) is characterised by the co-occurrence of *A. margarita* and *A.* cf. sp. 1 Heilmann-Clausen 1985.

Diagnostic events. LAD of *Alisocysta margarita* at 2462 m (DCS). LAD of *Alisocysta* cf. sp. 1 Heilmann Clausen 1985 and *Thalassiphora inflata* at 2627 m (SWC).

Common species within the interval. *Alisocysta margarita* is common at 2627 m (SWC), *Areoligera gippingensis* is common to dominant throughout the interval, *Spiniferites* spp. are common and *Tenua* aff. *hystrix* is common at 2496 m (SWC).

Reworked species. *Chlamydophorella* spp. and *Circulodinium distinctum* (2462 m, DCS). The single *Aquilapollenites* specimen recorded from 2492 m (DCS) may be reworked. The single *Cerodinium striatum* specimen recorded from 2579 m (DCS) is most likely reworked.

Caved species. *Deflandrea oebisfeldensis* in the upper part of the interval, and common to abundant *Apectodinium* spp. in the entire interval.

Discussion. The LAD of *Alisocysta margarita* at the top, the presence of this species in SWC's throughout the interval and the abundance of *A. gippingensis* in the entire interval allows correlation with Zone 4 of Heilmann-Clausen (1985; Fig. 2), which is entirely equivalent to the Ama Interval Biozone of Powell (1992). The species *Alisocysta* cf. sp. 1 Heilmann-Clausen 1985 from Ikermiut-1 well differs from *A.* sp. 1 Heilmann-Clausen 1985 by having a slightly less pronounced reticulum composed of large and small luminae and by its low (less than 5µm) penitabular membranes. The LAD in the Ikermiut-1 well of *Alisocysta* cf. sp. 1 Heilmann-Clausen 1985 is stratigraphically higher than the LAD of *A.* sp. 1 which Heilmann-Clausen (1985) recorded from the top of Zone 3 (lower part of dinoflagellate Zone D4), which correlates with the *Palaeoperidinium pyrophorum* (Ppy) Interval Biozone of Powell (1992; Fig. 2). A few poorly preserved specimens identified as *Thalassiphora inflata* have been recorded from 2627 m (SWC) and 2670 m (DCS). The LAD of *T. inflata* was reported from the lower part of the Ppy Interval Biozone by Powell (1992).

Previous dating. See above. In the present study the species most probably reported as *Eisenackia* cf. *crassitabulata* by Toxwenius (1986) is identified as *Alisocysta* cf. sp. 1 Heilmann-Clausen 1985.

Sample depth interval 2724–2754 m (Upper Paleocene)

Definition of interval. The body of strata between the LAD of *Cerodinium striatum* and the LAD of *Heterosphaeridium difficile* and *Laciniadinium arcticum*.

Zonation and age. Lower part of dinoflagellate Zone D4 (Late Paleocene), correlating with the *Palaeoperidinium pyrophorum* (Ppy) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Cerodinium striatum* and *Palaeocystodinium bulliforme* at 2724 m (DCS), *Cerodinium speciosum* and *Palaeoperidinium pyrophorum* first become common down hole at 2724 m (DCS). LAD of *Cerodinium diebelii* at 2730 m (DCS). *Alisocysta margarita* and *A.* cf. sp. 1 Heilmann-Clausen 1985 are present throughout the interval.

Common species within the interval. *Areoligera senonensis*, *Cerodinium speciosum*, *C. striatum*, *Spiniferites* spp. and *Thalassiphora delicata* common. *Palaeoperidinium. pyrophorum* abundant in the lower part (2736–2748 m).

Caved species. Few *Apectodinium* spp. and abundant *Areoligera gippingensis* occur in DCS from the upper part of the interval. A single *Wetzeliella* sp. and a single *Rhombodinium* sp. has been recorded from 2736 m (DCS).

Discussion. The presence of *A. margarita* and *A.* cf. sp. 1 Heilmann Clausen 1985 in SWC throughout the interval, the LAD of *C. striatum* at the top of the interval together with common *C. speciosum* and *P. pyrophorum* from 2724 m (DCS) downwards suggest a correlation with Zone 3 of Heilmann-Clausen (1985). Zone 3 correlate with the lower part of dinoflagellate Zone D4 and the *Palaeoperidinium pyrophorum* (Ppy) Interval Biozone of Powell (1992; Fig. 2). The absence of *Isabelidinium? viborgense*, an important marker species for the upper D3/lowermost D4 dinoflagellate Zones, may suggest that the present interval correlate with the upper part of the Ppy Interval Biozone. *Isabelidinium? viborgense* has previously been recorded from the youngest Paleocene sediments on Nuussuaq (Nøhr-Hansen 1996, 1997b; Fig. 1). The common presence of *Thalassiphora delicata* in the SWC at 2740 m suggests an age not older than middle Selandian (upper D3).

Previous dating. Toxwenius (1986) referred the interval 2736–2740 m to ?D2–?D1 based on the presence of *Alisocysta reticulata* at 2736 m (DCS), which in the present study has been identified as *A.* cf. sp. 1 Heilmann-Clausen 1985.

Sample depth interval 2755–2805 m (Upper Santonian)

Definition of interval. The body of strata between the LAD of *Heterosphaeridium difficile* and the LAD of *Surculosphaeridium longifurcatum*.

Age. Late Santonian.

Diagnostic events. LAD of *Chatangiella ditissima*, *Chatangiella* spp., *Heterosphaeridium difficile*, *Isabelidinium* spp. and *Laciniadinium arcticum* at 2755 m (SWC). LAD of *Dorocysta litotes* at 2780 m (SWC). Few specimens of *Pediastrum* spp. and *Lejeunecysta* aff. *hyalina* present throughout the interval.

Common species within the interval. *Palaeoperidinium pyrophorum* common, but probably caved.

Caved species. *Areoligera* spp., *A. margarita*, *C. striatum* and *Glaphyrocysta* spp.

Discussion. A major hiatus spanning the Campanian to lower Paleocene occurs in the interval between sample at 2754 m and the sample at 2755 m (Figs 3, 4).

Costa & Davey (1992) reported the LAD of *Heterosphaeridium difficile* from the uppermost Santonian the LAD of *Chatangiella ditissima* from the upper Campanian in the North Sea region. *Dorocysta litotes* has been recorded from the Lower Coniacian in West Greenland (Nøhr-Hansen 1997a), however, it may range up to lower Campanian in western Canada (D.J. McIntyre personal communication 1990).

Previous dating. Toxwenius (1986) referred the interval 2755–2814 m to Maastrichtian based on the presence of *Palynodinium gralator*, which not has been identified in the present study.

Sample depth interval 2811–3120 m (Lower Santonian–Turonian)

Definition of interval. The strata between the LAD of *Surculosphaeridium longifurcatum* and the LAD of *Fromea amphora* and *Gardodinium trabeculosum.*

Age. Turonian to Early Santonian.

Diagnostic events. LAD of *Surculosphaeridium longifurcatum* at 2811 (DCS) and *Raphidodinium fucatum* at 2871 (DCS).

Common species within the interval. *Pediastrum* spp. and *Lejeunecysta* aff. *hyalina* present to common throughout the interval.

Caved species. *Apectodinium* spp., *Areoligera gippingensis*, *Cerodinium striatum* and *Thalassiphora delicata* present to common throughout the interval.

Discussion. Costa & Davey (1992) reported the LAD of *Surculosphaeridium longifurcatum* from the middle Lower Santonian in the North Sea region.

Previous dating. Toxwenius (1986) referred the interval 2814–3616 m to Campanian based on the LAD of *Chatangiella victoriensis* at 2814 m (DCS)

Sample depth interval 3138–3616 m (?Cenomanian)

Definition of interval. The strata below the LAD of *Fromea amphora* and the LAD of *Gardodinium trabeculosum.*

Age. ? Cenomanian.

Diagnostic events. LAD of *Gardodinium trabeculosum*, *Fromea amphora* at 3138 m (DCS), *Batioladinium jaegeri* at 3141 m (DCS) and FAD of *Chatangiella ditissima* at 3410 m (DCS).

Discussion. Costa & Davey (1992) reported the LAD of *Batioladinium jaegeri* from the middle Cenomanian and the LAD of *Fromea amphora* from the uppermost Cenomanian and the FAD of *Chatangiella ditissima* from the base of the Turonian in the North Sea region. The interval has questionably been dated as Cenomanian, as no other unambiguous Cenomanian marker species have been recorded below 3141 m. This may suggest that the Cenomanian species are reworked.

Previous dating. As for the interval above.

Kangâmiut-1

Technical data

Kangâmiut-1 was drilled in 1976 by Total Grønland Olie A/S. The position of the well was 66° 09' 01" N and 56° 11' 24" W (Fig.1). The water depth was 180 m (590 ft). The rotary table was 12 m (41 ft) above sea leavel, and the total depth was 3874 m (12710 ft) below rotary table where it reached Precambrian basement (Rolle, 1985). All sample depths given in this paper are measured from rotary table datum.

Sample depth interval 1556–1638 m (lowermost Oligocene–uppermost Middle Eocene)

Definition of interval. The strata between the LAD of *Charlesdowniea coleothrypta* and the LAD of *Cerebrocysta bartonensis*, *Phthanoperidinium geminatum* (Enclosure 3).

Zonation and age. Lower part of dinoflagellate Zone D11 (latest Middle Eocene) to the top of ?D13 (earliest Oligocene; Fig. 2).

Diagnostic events. Very few specimens have been recorded from the present interval, however the LAD of *C. coleothrypta* at 1622 m (SWC), is noteworthy.

Discussion. According to Powell (1992) the LAD of *C. coleothrypta* at 1622 m (SWC) indicates an age not younger than Early Oligocene, ?top of dinoflagellate Zone D13.

Previous dating. Toxwenius (1986) referred the interval 1300–1670 m to Early Miocene (D16–D17, Fig. 3) based on the uppermost occurrence of *Cordosphaeridium cantharellus* at 1390 m (DCS).

Sample depth interval 1725–1818 m (upper Middle Eocene)

Definition of interval. The strata between the LAD of *Cerebrocysta bartonensis*, *Phthanoperidinium geminatum* and the LAD of *Leptodinium membranigerum*.

Zonation and age. Lower to upper part of dinoflagellate Zone D10 (late Middle Eocene), which correlates with the upper part of the *Glaphyrocysta intricata* (Gin) and the *Rhombodinium draco* (Rdr) Interval Biozones of Powell (1992; Fig. 2).

Diagnostic events. LAD of *Cerebrocysta bartonensis*, *Glaphyrocysta* cf. *vicina* (a single specimen), *Membranophoridium* aff. *aspinatum*, *Phthanoperidinium geminatum* *P. multispinum* (a single specimen), *P. echinatum* at 1725 m (DCS) and LAD of *Glaphyrocysta semitecta* (a single specimen) at 1747 m (SWC).

Common species within the interval. *Deflandrea phosphoritica* common at 1725 m and at 1818 m (both DCS) and *M.* aff. *aspinatum* common at 1725 m. Plant tissues and tracheidal phytoclasts dominate the organic matter at 1785 m (DCS).

Discussion. The LAD of *Cerebrocysta bartonensis*, *Glaphyrocysta semitecta*, *G.* cf. *vicina*, *Membranophoridium* aff. *aspinatum*, *Phthanoperidinium echinatum*, *P. geminatum* and *P. multispinum* all indicate the presence of zones D10 and D11 (Bujak *et al.* 1980; Powell 1992; Fig. 2). The co-occurrence of *G.* cf. *vicina* and *M.* aff. *aspinatum* may suggest uppermost B-5/lowermost Bar-1 (Bujak *et al.* 1980) which correlate with the middle part of Zone D10 and the boundary between Gin and Rdr of Powell (1992).

The absence of *G. texta*, *R. longimanum* and *W. spinula* which among others was recorded from the Zone D11 in the Hellefisk-1 well (Enclosure 1) may suggest that the present interval belongs to Zone D10. The sparse assemblage recorded from the SWC's in the lower part of the interval shows no signals whether they represent the Rdr or the underlying *Glaphyrocysta intricata* (Gin) Interval Biozone.

Previous dating. Toxwenius (1986) interpreted the interval 1670–1960 m as Early Oligocene (D13–D14) based on the uppermost occurrence of *Phthanoperidinium amoenum* at 1725 m (DCS) and based on the LAD of *Charlesdowniea coleothrypta* and *Thalassiphora pelagica* at 1871 m (DCS).

Sample depth interval 1871–2004 m (Middle Eocene)

Definition of interval. The strata between the LAD of *Leptodinium membranigerum* and the FAD of *Areosphaeridium pectiniforme* and *Phthanoperidinium geminatum*.

Zonation and age. Uppermost part of Zone D9 to lower part of dinoflagellate Zone D10 (Middle Eocene), which correlates with the *Glaphyrocysta intricata* (Gin) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Areosphaeridium arcuatum*, *Areosphaeridium* sp. 1, *Leptodinium membranigerum*, *Rottnestia borussica* and *Wilsonidium* cf. *echinosuturatum* at 1871 m (SWC). FAD of *Areosphaeridium pectiniforme*, *L. membranigerum*, *Phthanoperidinium geminatum* and *W.* cf. *echinosuturatum* at 2004 m (DCS).

Common species within the interval. *Leptodinium membranigerum* and *Spiniferites* spp. present to common at 1871 m (SWC).

Discussion. According to Powell (1992) *Areosphaeridium arcuatum* has its FAD at the base of Zone D9 and *A. pectiniforme* and *P. geminatum* have their FAD at the base of Zone D10. Eaton (1976) recorded *Leptodinium membranigerum* from the Brackelsham Beds correlating with D8 to D10 (Fig. 2) in southern England, whereas Gerlach (1961) described the species from the Upper Oligocene and ?Middle Miocene in northern Germany. Wilson (1967, 1988) recorded *Wilsonidium echinosuturatum* from the Middle Eocene Porangan Stage in New Zealand and Heilmann-Clausen & Costa (1989) recorded it from the upper part of D9 and ?D10 (Middle Eocene) in Germany. *Areosphaeridium* sp. 1 was first recorded from the upper part of the upper Middle Eocene Zone D11 in the Hellefisk-1 well (Enclosure 1). The recorded species gives no unambiguous age, and the age of the interval is partly based on the recorded species and partly on the ages of the intervals above and below.

Previous dating. Toxwenius (1986) referred the interval 1670–1960 m to Early Oligocene (D13–D14), see above. Toxwenius (1986) interpreted the interval 1960–2520 m as Middle to Late Eocene (upper part of D10–D12) based on the LAD of *Areosphaeridium multicornutum* (now *A. pectiniforme*) at 2004 m (DCS) and suggested Zone D12 for 1960–2410 m.

Sample depth interval 2004–2604 m (lower Middle Eocene)

Definition of interval. The strata between the FAD of *Areosphaeridium pectiniforme* and *Phthanoperidinium geminatum* and the LAD of *Eatonicysta ursulae*.

Zonation and age. Lower to upper part of dinoflagellate Zone D9 (early Middle Eocene), which correlates with the *Areosphaeridium arcuatum* (Aar) Interval Biozone of Powell (1992).

Diagnostic events. FAD of *P. comatum* at 2159 m (SWC) and the LAD of *Wetzeliella meckelfeldensis* at 2604 m (SWC). Dinoflagellate cysts is very rare in this interval.

Discussion. According to Powell (1992) *Phthanoperidinium comatum* have its FAD at the base of Zone D9. *Wetzeliella meckelfeldensis* has its LAD in the middle part of Zone D9 correlating with the middle part of the *Areosphaeridium arcuatum* (Aar) Interval Biozone of Powell (1992). Seven almost barren samples represent the interval which make it difficult to date; however, the interval is referred to the upper to lower part of dinoflagellate Zone D9.

Previous dating. Toxwenius (1986) interpreted the interval 1960–2520 m as Middle to Late Eocene (upper part of D10–D12) based on the LAD of *Areosphaeridium multicornutum* (now *A. pectiniforme*) at 2004 m (DCS) and suggested Zone D12 for the interval1960–2410 m. The LAD of *Apectodinium homomorphum, Wetzeliella articulata* and *W. ovalis* from 2427 m (DCS) were interpreted as Zone D11. The palynological slides that have been at disposal for this study from depth 2427 m only contained a badly preserved specimen of *Systematophora placacantha*. The LAD record of *Glaphyrocysta ordinata* at 2447 m (DCS) was interpreted as upper part of Zone D10 for 2442–2520 m. Toxwenius (1986) referred the interval 2520–2606 m as Early Eocene (upper part of D9) based on the LAD of *Wetzeliella meckelfeldensis* at 2604 m (SWC).

Sample depth interval 2640–2725 m (lower Middle Eocene)

Definition of interval. The strata between the LAD of *Eatonicysta ursulae* and the LAD of *Charlesdowniea columna* and *Diphyes brevispinum.*

Zonation and age. Lowermost part of dinoflagellate Zone D9 (early Middle Eocene), which correlates with the lower part of the *Phthanoperidinium comatum* (Pco) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Charlesdowniea edwardsii, Cerebrocysta magna, Eatonicysta ursulae, Hystrichosphaeropsis costae* and *Wilsonidium* cf. *lineidentatum* at 2640 m (DCS). LAD of *Cerodinium depressum* and *Diphyes ficusoides* at 2700 m (DCS).

Common species within the interval. *Deflandrea phosphoritica* and *Palaeocystodinium golzowense* common at 2700 m (DCS). *Homotryblium tenuispinosum* abundant and *D. phosphoritica* common at 2721 m (SWC). *Spiniferites* spp. and *Wetzeliella* spp. common at 2725 m (SWC).

Discussion. According to Bujak *et al.* (1980) and Powell (1992) the LAD of *Eatonicysta ursulae* occurs in the middle part of the *Areosphaeridium arcuatum* (Aar) Interval Biozone (correlating with the middle part of NP15). However, Bujak & Mudge (1994) strongly indicate that *E. ursulae* has its LAD in their E3d Subzone (correlating with NP14), which correlates with the Pco Interval Biozone of Powell (1992). Bujak & Mudge (1994) described the LAD of the species *Cerebrocysta magna*, *Diphyes ficusoides* and *Hystrichosphaeropsis costae* from their North Sea dinocyst Subzones E4d and E4c (correlating with the lower to middle part of NP15; Fig. 2). Bujak & Mudge (1994) recorded abundant *Homotryblium tenuispinosum* from their E4c Subzone down to their E3b Subzone and superabundant in their underlying E3a Subzone (mid NP14; Fig. 2). Powell (1992) recorded the LAD of *Cerodinium depressum* from the upper part of his Pco Interval Biozone (NP14), whereas Bujak & Mudge (1994) described a LAD from their E4d Subzone (mid NP15).

Following Powell (1992), the present interval allows correlation with the lower part of his Aar Interval Biozone (NP15) or with his Pco Interval Biozone (NP14). According to the zonation of Bujak & Mudge (1994) the interval allows correlation with their Subzone E3d (mid NP14) and their Subzone E3c (upper NP13 to lower NP14) corresponding to the lower part Pco and the upper part of *Pentadinium laticinctum* (Pla) Interval Biozones of Powell (1992).

Previous dating. Toxwenius (1986) referred the interval 2631–2910 m as Zone D9 based on the LAD of *Charlesdowniea edwardsii*, *Eatonicysta ursulae* and the FAD of *Phthanoperidinium comatum* at 2640 m (DCS).

Sample depth interval 2770–2931 m (upper Lower Eocene)

Definition of interval. The strata between the LAD of *Charlesdowniea columna* and *Diphyes brevispinum* and the LAD of *Areoligera medusettiformis*.

Zonation and age. Middle and upper part of dinoflagellate Zone D8 (late Early Eocene), which correlates with the *Pentadinium laticinctum* (Pla) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Charlesdowniea columna, Diphyes brevispinum, Dracodinium* cf. *varielongitudum, Eatonicysta sequestra, Spiniferites cornutus* at 2770 m (DCS). LAD of several *Hystrichokolpoma* species, *Hystrichostrogylon membraniphorum* and possible *Wetzeliella lunaris* at 2871 m (DCS).

Common species within the interval. *Deflandrea phosphoritica, Homotryblium tenuispinosum, Thalassiphora pelagica* and *Wetzeliella* spp. common at 2770 m (DCS). *Charlesdowniea columna, H. tenuispinosum, Spiniferites* spp. *T. pelagica* and *Wetzeliella* spp. common at 2871 m (DCS).

Reworked species. ?*Muratodinium fimbriatum* at 2844 m (DCS).

Discussion. Bujak & Mudge (1994) described the LAD of *Charlesdowniea columna* and *Diphyes brevispinum* from the top of their North Sea dinocyst Subzone E3b and the FAD from E3a (correlating with NP13 and the middle part of the Pla Interval Biozone, Fig. 2). The abundance of *H. tenuispinosum* recorded by Bujak & Mudge (1994) from Subzone E4c down to Subzone E3a (Fig. 2) mentioned above supports a late Early Eocene age.

Eatonicysta sequestra has its LAD in lower Lutetian (lower Middle Eocene) in England and may range down to the Ypresian (Lower Eocene) in Denmark (Stover & Williams 1995).

Previous dating. Interval 2631–2910 m as for the interval above. Toxwenius (1986) referred the interval 2910–3040 as Early Eocene (D8) based on the LAD of *Apectodinium hyperacanthum* at 2961 m. According to Powell (1992) *A. hyperacanthum* has a LAD in Subzone D5a in the North Sea region.

Sample depth 2961 m (middle Lower Eocene)

Definition of interval. The strata between the LAD of *Areoligera medusettiformis* and the LAD of *Dracodinium condylos.*

Zonation and age. Middle part of dinoflagellate Zone D8 (middle Early Eocene), which correlates with the lower part of the *Pentadinium laticinctum* (Pla) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Areoligera medusettiformis.*

Common species within the interval. *Areoligera medusettiformis* and *Areoligera* spp common at 2961 m (DCS).

Reworked species. Possibly *Muratodinium fimbriatum* and *Alisocysta* spp..

Discussion. Bujak & Mudge (1994) described the LAD of *Areoligera medusettiformis* from the dinocyst Subzone E3a and the LAD of the *A. medusettiformis* acme from their Subzone E2c (Fig. 2). The common *A. medusettiformis* in the sample at 2961 m supports a late Early Eocene age.

Previous dating. Interval 2631–2910 m as for the interval above. Toxwenius (1986) referred the interval 2910–3040 m as Early Eocene (D8) based on the LAD of *Apectodinium hyperacanthum* at 2961 m. According to Powell (1992) *A. hyperacanthum* has a LAD in the Subzone D5a in the North Sea region.

Sample depth interval 2991–3080 m (middle Lower Eocene)

Definition of interval. The strata between the LAD of *Dracodinium condylos* and the LAD of *Spiniferites septatus* and *Deflandrea oebisfeldensis.*

Zonation and age. Lower part of dinoflagellate Zone D8 (middle Early Eocene), which correlates with the *Charlesdowniea coleothrypta* (Ccl) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Dracodinium condylos, D. politum* and *Muratodinium fimbriatum* at 2991 m (DCS), LAD of *Apectodinium homomorphum* and a single questionable specimen of *D. solidum* at 3080 m (DCS).

Abundance within the interval. *Charlesdowniea columna* common at 2991 m (DCS). *Charlesdowniea coleothrypta* and *Cordosphaeridium* spp. common at 2991, 3080 m (both DCS's). *Deflandrea phosphoritica* abundant at 2991 m and common at 3080 m.

Reworked species. *Laciniadinium arcticum* at 3080 m (DCS).

Discussion. According to Powell (1992) *Dracodinium condylos* has its LAD at the top the Ccl Interval Biozone and its FAD at the base of the same zone correlating with the base of Zone

D8. *Dracodinium politum* has its highest consistent occurrence at the top of Ccl, whereas Powell (1992) recorded the LAD of *Muratodinium fimbriatum* from the lower part of Ccl. The presence of *M. fimbriatum* throughout the interval may suggest that the entire interval can be referred to the lower part of Ccl Interval Biozones of Powell (1992) correlating with Subzone E2b of Bujak & Mudge (1994).

Previous dating. Interval 2910–3040 m as for the interval above. Toxwenius (1986) referred the interval 3040–3170 m as Early Eocene (D7) based on the FAD of *Dracodinium condylos, D. solidum* and *Eatonicysta ursulae* within his interval.

Sample depth 3110 m (middle Lower Eocene)

Definition of interval. The strata between the LAD of *Deflandrea oebisfeldensis*, *Spiniferites septatus* and the LAD of *Fibrocysta bipolaris*.

Zonation and age. Dinoflagellate Subzone D7a–D7b (middle Early Eocene), which correlates with the *Dracodinium simile* (Dsi) and the *Dracodinium varielongitudum* (Dva) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Deflandrea oebisfeldensis* and *Spiniferites septatus* at 3110 m (DCS).

Common species within the sample. *Charlesdowniea coleothrypta* common at 3110 m.

Discussion. According to Powell (1992) *Deflandrea oebisfeldensis* has its LAD within the lowermost part of dinoflagellate Zone D8 (Ccl) and *Spiniferites septatus* has its LAD within the uppermost part of dinoflagellate Subzone D7b (Dva). Bujak & Mudge (1994) recorded *Deflandrea oebisfeldensis* consistently from the top of their Subzone E2a, which correlates with NP11/top D7b (Fig. 2).

Previous dating. As for the interval above.

Sample depth interval 3170–3183 m (lower part of Lower Eocene)

Definition of interval. The strata between the LAD of *Fibrocysta bipolaris* and the LAD of *Apectodinium paniculatum* and the top of the *Wetzeliella astra* acme.

Zonation and age. Dinoflagellate Subzone D6b (early part of Early Eocene), corresponding to the *Wetzeliella meckelfeldensis* (Wme) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Wetzeliella astra*, *Fibrocysta bipolaris* and *Hystrichosphaeridium tubiferum* at 3170 m (DCS).

Common species within the interval. *Cordosphaeridium* spp., *Glaphyrocysta* spp. and *Spiniferites* spp. common 3183 m (DCS).

Caved species. *Dracodinium condylos* at 3170 m.

Discussion. Powell (1992) reported the LAD of *Wetzeliella astra* from the lower part of Wme and FAD at the base of *Wetzeliella astra* (Was) Interval Biozone (lower part of Subzone D6b to the base of Subzone D6a; Fig. 2). Wilson (1988) recorded the range of *F. bipolaris* from the lower part of the Lower Eocene to the middle Paleocene in New Zealand. Bujak & Mudge (1994) defined the top of their Subzone E1c by the last occurrence of frequent *Hystrichosphaeridium tubiferum* and the top of their Subzone E1b by the last occurrence of frequent *Deflandrea oebisfeldensis* and common *Glaphyrocysta ordinata*. The subzones were correlated to the upper and middle part of NP10 which correspond to the Wme Interval Biozone of Powell (1992; Fig. 2).

Previous dating. Toxwenius (1986) referred the interval 3170–3220 m to latest Paleocene (D6) based on the LAD of *Cerodinium speciosum* (3174 m, DCS).

Sample depth interval 3210–3231 m (lower part of Lower Eocene)

Definition of interval. The strata between the LAD of *Apectodinium paniculatum*, the top of the *Wetzeliella astra* acme and the top of the *Apectodinium* species acme.

Zonation and age. Dinoflagellate Subzones D5b to D6a (early part of Early Eocene), corresponding to the *Glaphyrocysta ordinata* (Gor) and the *Wetzeliella astra* (Was) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Apectodinium paniculatum* at 3210 m (DCS), LAD of *Charlesdowniea crassiramosa* and FAD of *Wetzeliella meckelfeldensis* at 3231 m(DCS).

Common species within the sample. *Wetzeliella astra* abundant at 3210 m and *Cordosphaeridium* spp., *Glaphyrocysta* spp., *Spiniferites* spp. and *Wetzeliella* spp. common to abundant at 3231 m.

Caved species. *Homotryblium abbreviatum* and *Deflandrea phosphoritica* at 3231 m.

Discussion. Powell (1992) reported the LAD of *Wetzeliella astra* from the lower part of *Wetzeliella meckelfeldensis* (Wme) Interval Biozone and FAD at the base of Was (lower part of D6b to the base of D6a, Fig. 2). *Charlesdowniea crassiramosa* has only been recorded from the lower part of Wme (Powell, 1992). Powell (1992) reported common *Glaphyrocysta ordinata* from the *Glaphyrocysta ordinata* (Gor) Interval Biozone (D5b; Fig.2).

Previous dating. Toxwenius (1986) referred the interval 3220–3306 m to earliest Eocene (D5) Based on the LAD of *Palaeoperidinium pyrophorum* (3231 m, DCS).

Sample depth interval 3243–3270 m (lowermost Lower Eocene–uppermost Paleocene)

Definition of interval. The strata between the top of the *Apectodinium* species acme and the top of the *Areoligera gippingensis* acme.

Zonation and age. Upper part of Dinoflagellate Zone D4 to Subzone D5a (earliest Early Eocene and latest Paleocene) corresponding to the *Apectodinium hyperacanthum* (Ahy) and the *Apectodinium augustum* (Aau) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Apectodinium* at 3255 m (DCS).

Common species within the interval. *Apectodinium* spp and *Spiniferites* spp. abundant at 3243 m and at 3255 m (both DCS).

Caved species. *Dracodinium politum* and *Wetzeliella meckelfeldensis* at 3243 m.

Reworked species. The few recorded specimens of *Areoligera gippingensis* at 3243 m and at 3255 m may be reworked.

Discussion. Powell (1992) and Powell *et al.* (1996) defined the Aau Interval Biozone by the *Apectodinium* complex acme whereas the *Apectodinium* complex is less dominant in the Ahy Interval Biozone. Following this, the samples from 3243 m and 3255 m may represent Aau and the sample from 3270 m represent the Ahy.

Previous dating. Toxwenius (1986) referred the interval 3220–3306 m to earliest Eocene (D5) based on the LAD of *Palaeoperidinium pyrophorum* (3231 m, DCS).

Sample depth interval 3297–3370 m (Upper Paleocene)

Definition of interval. The strata between the top of the *Areoligera gippingensis* acme and the LAD of *Cerodinium striatum.*

Zonation and age. Middle part of dinoflagellate Zone D4 (Late Paleocene), corresponding to the *Alisocysta margarita* (Ama) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Alisocysta margarita* at 3306 m (DCS).

Common species within the interval. *Areoligera gippingensis* is common at 3297 m, 3306 m, dominant at 3370 m (all DCS).

Reworked species. *Odontochitina operculata* and *Chatangiella* spp. at 3370 m, and possibly a few specimens of *Palaeoperidinium pyrophorum* at 3306 and 3370 m (both DCS).

Caved species. *Apectodinium* spp. at 3306 and 3370 m (both DCS).

Discussion. Powell (1992) reported the LAD of *Alisocysta margarita* from the upper part of the Ama Interval Biozone, corresponding to the middle part of Zone D4. Later Powell *et al.* (1996) reported the LAD of *Areoligera gippingensis* from the upper part of the Ama Interval Biozone of Powell (1992), above the LAD of *Alisocysta margarita*, whereas the *Areoligera gippingensis* acme was reported from the lower part of the Ama, corresponding to the record of the species in Kangâmiut-1 well (Enclosure 3).

Previous dating. Toxwenius (1986) referred the interval 3306–3621 m to latest middle to early Late Paleocene (D4) based on the LAD of *Alisocysta circumtabulata* (3306 m, DCS) and abundant *Areoligera* spp. within the interval.

Sample depth interval 3441–3651 m (Upper Paleocene)

Definition of interval. The strata between the LAD of *Cerodinium striatum* and the LAD of *Heterosphaeridium difficile*, *Surculosphaeridium longifurcatum* and *Tanyosphaeridium variecalamus*.

Zonation and age. Lower part of dinoflagellate Zone D4 (Late Paleocene), corresponding to the *Palaeoperidinium pyrophorum* (Ppy) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Cerodinium striatum* and *C. speciosum* at 3441 m (DCS) and LAD of *Palaeoperidinium pyrophorum* at 3591 m (DCS).

Common species within the interval. *Pediastrum* spp. present to common within the interval.

Reworked species. *Chatangiella* spp., *Isabelidinium* spp, *Laciniadinium arcticum* and *Odontochitina operculata*.

Caved species. *Apectodinium* spp. and *Areoligera gippingensis*.

Discussion. Powell (1992) reported the LAD of *Cerodinium striatum* and *C. speciosum* from the top of the Ppy Interval Biozone.

Previous dating. Toxwenius (1986) referred the interval 3306–3621 m to latest middle to early Late Paleocene (D4) based on the LAD of *Alisocysta circumtabulata* (3306 m, DCS) and abundant *Areoligera* spp. within the interval. Toxwenius (1986) referred the interval 3621–3687 m to middle Paleocene (D3) based on the LAD of *Cerodinium striatum* at 3621 m and abundant *Palaeoperidinium pyrophorum* at 3621 m (DCS) and at 3672 m (SWC),

Sample depth interval 3687–3696 m (Lower Santonian or older)

Definition of interval. The strata between the LAD of *Heterosphaeridium difficile*, *Surculosphaeridium longifurcatum* and *Tanyosphaeridium variecalamus* and the basement at 3700 m.

Age. Early Santonian or older.

Diagnostic events. LAD of *Chatangiella* spp, *Heterosphaeridium difficile*, *Isabelidinium* spp, *Laciniadinium arcticum*, *Surculosphaeridium longifurcatum* and *Tanyosphaeridium variecalamus*.

Abundance within the sample. *Pediastrum* spp. present to common within the interval.

Reworked species. *Leptodinium* aff. *cancellatum* at 3696 m (DCS).

Caved species. *Apectodinium* spp., *Cerodinium striatum Thalassiphora delicata* and common *Areoligera gippingensis*.

Discussion. Costa & Davey (1992) reported the LAD of *Surculosphaeridium longifurcatum* from the middle Lower Santonian and the LAD of *Heterosphaeridium difficile* and *Tanyosphaeridium variecalamus* from the uppermost Santonian in the North Sea region.

Previous dating. Toxwenius (1986) referred the interval 3687–3696 m to Campanian based on the LAD of *Chatangiella ditissima* and *Palaeohystrichophora infusorioides* at 3687 m.

Nukik-1

Technical data

Nukik-1 was drilled in 1977 by Mobil Exploration Greenland Inc. The position of the well was 65º 31' 36" N and 54º 45' 38" W (Fig. 1). The water depth was 104 m (342 ft) The rotary table was 24 m (80 ft) above sea leavel, and the total depth was 2363 m (7754 ft) below rotary table where it reached Precambrian basement (Rolle, 1985). All sample depth given in this paper are measured from rotary table datum.

Sample depth interval 1554–1626 m (?Middle Miocene)

Definition of interval. The strata between the LAD of *Deflandrea phosphoritica* and the LAD and FAD of *Cerebrocysta poulsenii* (Enclosure 4).

Zonation and age. Dinoflagellate Zones ?D18–?D17, Middle Miocene or less likely Early Miocene to Late Oligocene (Powell 1992)

Diagnostic events. LAD of *Deflandrea phosphoritica* at 1554 m (SWC) and the FAD and LAD of *Cerebrocysta poulsenii* at 1626 m (SWC). Dinoflagellate cysts are rare in the present interval, except for SWC at 1626 m.

Common species within the interval. *Tectatodinium pellitum* abundant and *Cordosphaeridium* spp. common at 1626 m (SWC).

Discussion. According to De Verteuil & Norris (1996) *Cerebrocysta poulsenii* ranges from the upper Lower Miocene to upper Middle Miocene, whereas they reported the LAD of *Deflandrea phosphoritica* from the lowermost Miocene. According to Powell (1992) *Deflandrea phosphoritica* has its LAD in the Upper Oligocene (upper part of NP14).

The presence of a single specimen of *Deflandrea phosphoritica* at 1554 m (SWC) above the LAD of *Cerebrocysta poulsenii* may suggest reworking of *D. phosphoritica* into Middle Miocene sediments.

Previous dating. Toxwenius (1986) dated the interval from 1439–1619 m as Early Oligocene (D13) based on the LAD *Deflandrea phosphoritica* and *Charlesdowniea coleothrypta* at 1554 m and the interval from 1626–1829 m as Late Eocene (D12?).

Sample depth interval 1768–1927 m (?Lower Miocene–?Middle Eocene)

Definition of interval. Dinoflagellate cysts are very rare in the interval, no stratigraphically important species have been recognised and the dating has been based on the intervals above and below.

Zonation and age. Dinoflagellate Zones ?D16–?D10, ?Late Oligocene/Early Miocene to ?Middle Eocene.

Previous dating. Toxwenius (1986) dated the interval from 1626–1829 m as Late Eocene (D12?) and the interval from 1829–1927 m as Middle Eocene (upper D10 to D11)

Sample depth interval 1950–1951 m (lower Middle Eocene)

Definition of interval. The strata between the LAD of *Diphyes pseudoficusoides* and *Eatonicysta ursulae* and the LAD of *Diphyes ficusoides* and abundant *Homotryblium tenuispinosum*.

Zonation and age. Lower part of dinoflagellate Zone D9 (early Middle Eocene), which correlates with the lower part of the *Phthanoperidinium comatum* (Pco) and the *Areosphaeridium arcuatum* (Aar) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Diphyes pseudoficusoides* and *Eatonicysta ursulae* at 1951 m (DCS).

Common species within the interval. *Spiniferites* spp., *Thalassiphora pelagica* and *Wetzeliella articulata* common at 1951 m (SWC).

Discussion. Bujak & Mudge (1994) describe the LAD of *Diphyes pseudoficusoides* from their North Sea dinocyst Subzone E6a (correlating with the upper part of NP15, Fig. 2) and

Eatonicysta ursulae has its LAD in the middle part of the Aar Zone (correlating with the middle part of NP15; Bujak *et al.* 1980; Powell 1992). However, Bujak & Mudge (1994) indicate that *E. ursulae* has its LAD in their Subzone E3d (correlating with the middle part of NP14), which correlate with the Pco Interval Biozone of Powell (1992). Following Powell (1992), the interval allows correlation with the middle part of his Aar Interval Biozone (NP15) or with his Pco Interval Biozone (NP14). According to the zonation of Bujak & Mudge (1994) the interval allows correlation with their Subzone E3d (mid NP14) and their E3c Subzone (upper NP13 to lower NP14) corresponding to the upper part of Pla and the lower part Pco (Powell, 1992).

Previous dating. Based on the LAD of *Eatonicysta ursulae* at 1551 m (SWC) and the FAD of *Phthaoperidinium comatum* at 2115 m (DCS) Toxwenius (1986) referred the interval 1950–2120 m to D9.

Sample depth interval 1971–2001 m (lower Middle–upper Lower Eocene)

Definition of interval. The strata between the LAD of *Diphyes ficusoides* and abundant *Homotryblium tenuispinosum* and the LAD of *Dracodinium condylos* and *D. solidum*.

Zonation and age. Upper part of dinoflagellate Zone D8 to Lower part of Zone D9 (late Early to early Middle Eocene), which correlates with the upper part of the *Pentadinium laticinctum* (Pla) and the *Phthanoperidinium comatum* (Pco) Interval Biozones of Powell (1992).

Diagnostic events. LAD of *Cerebrocysta bartonensis*, *Diphyes ficusoides, Homotryblium abbreviatum*, *H. tenuispinosum* and *Hystrichosphaeropsis* aff. *costae* from 1971 m (SWC), and *Cerebrocysta magna* and *Dracodinium politum* from 1978 m (DCS).

Common species within the interval. *Homotryblium abbreviatum*, *H. tenuispinosum* common and fungal abundant at 1971 m (SWC) and *Thalassiphora pelagica* common at 1978 m (DCS).

Discussion. Bujak & Mudge (1994) describe the LAD of the species *C. magna*, *D. ficusoides* and *H. costae* from their North Sea dinocyst Subzones E4d and E4c (correlating with middle to lower part of NP15; Fig. 2). Bujak & Mudge (1994) recorded abundant *Homotryblium tenuispinosum* from E4c down to E3b and superabundant in the E3a and E2c Subzones (middle NP14 to upper NP12; Fig. 2). Powell (1992) recorded the LAD of *Dracodinium politum* from the Pco Interval Biozone (lower D9, correlating with upper NP14). The dinoflagellate cyst assemblage suggests not ages younger than early Middle Eocene (base D9) and not older than late Early Eocene (top D8).

Previous dating. As for the interval above.

Sample depth interval 2014–2042 m (upper–middle Lower Eocene)

Definition of interval. The strata between the LAD of *Dracodinium condylos* and *D. solidum* and the LAD of *Fibrocysta bipolaris* and *Carpatella* spp.

Zonation and age. Dinoflagellate Zone D7 to lower part of Zone D8 (middle to late Early Eocene), which correlates with the *Dracodinium simile* (Dsi), *Dracodinium varielongitudum* (Dva) and the *Charlesdowniea coleothrypta* (Ccl) Interval Biozones of Powell (1992).

Diagnostic events. LAD of *Dracodinium solidum* and *D.* aff. *varielongitudum* at 2014m (SWC) and LAD of *Dracodinium condylos* at 2015 m (DCS).

Discussion. According to Powell (1992) *Dracodinium condylos* has its LAD at the top of the Ccl Interval Biozone and its FAD at the base of the same Zone which correlates with the base of Zone D8 (Fig. 2).

Previous dating. As for the interval above.

Sample depth 2079 m (lower part of Lower Eocene)

Definition of interval. The strata between the LAD of *Fibrocysta bipolaris*, *Carpatella* spp. and the LAD of *Deflandrea oebisfeldensis*, *Wetzeliella astra*.

Zonation and age. Dinoflagellate Subzone D6b (early part of Early Eocene) corresponding to the *Wetzeliella meckelfeldensis* (Wme) Interval Biozones of Powell (1992).

Diagnostic events. LAD of *Fibrocysta bipolaris* and *Carpatella* spp. at 2079 m (SWC).

Common species within the interval. *Fibrocysta bipolaris common and Fibrocysta* spp. abundant at 2079 m.

Discussion. Wilson (1988) recorded the range of *F. bipolaris* from the lowermost part of the Lower Eocene to the middle Paleocene in New Zealand and Powell *et al.* (1996) noted that *F. bipolaris* has its FAD within the Gor Interval Biozone in the North Sea region.

Previous dating. Toxwenius (1986) referred the interval 1950–2120 m to Zone D9 and the interval 2120–2200 m to Zone D8.

Sample depth interval 2161–2238 m (lower part of Lower Eocene)

Definition of interval. The strata between the LAD of *Deflandrea oebisfeldensis* and *Wetzeliella astra* and the LAD of *Areoligera gippingensis*.

Zonation and age. Dinoflagellate Subzones D6a and D6b (early part of Early Eocene), corresponding to the *Wetzeliella astra* (Was) and the *Wetzeliella meckelfeldensis* (Wme) Interval Biozones of Powell (1992).

Diagnostic events. LAD of *Deflandrea oebisfeldensis* at 2161 m (DCS), LAD of *Paralecaniella indentata* at 2195 m (SWC) and LAD of *Wetzeliella astra* at 2198 m (DCS).

Common species within the interval. *Paralecaniella indentata* common at the lower part of the interval.

Discussion. Powell (1992) reported the LAD of *Wetzeliella astra* from the lower part of Wme and FAD at the base of Was (lower part of Subzone D6b to the base of Subzone D6a; Fig. 2).

Previous dating. Toxwenius (1986) referred the interval 1950–2120 m as D9, the interval 2120–2200 m as D8 and 2200–2280 m as D7.

Sample depth interval 2252–2363 m (Upper Paleocene)

Comments. The interval from 2342–2363 m is Precambrian basement according to Rolle (1985) and Toxwenius (1986).

Definition of interval. The strata below the LAD of *Areoligera gippingensis.*

Zonation and age. Middle part of dinoflagellate Zone D4 (Late Paleocene), corresponding to the *Alisocysta margarita* (Ama) Interval Biozone of Powell (1992).

Diagnostic events. LAD of *Areoligera gippingensis* at 2252 m (DCS) and LAD of *Alisocysta margarita* at 2344 m (DCS).

Common species within the sample. *Areoligera gippingensis* common in the interval.

Caved species. *Deflandrea phosphoritica*, *Eatonicysta ursulae* and *Wetzeliella* spp.

Discussion. The absence of *Apectodinium* spp. in the interval above suggests that the entire Zone D5 and the upper part of Zone D4 (Ahy Interval Biozone of Powell (1992)) are missing in the present well. The absence of an *Apectodinium* spp. acme which normally indicate these zones suggest a hiatus between the samples at 2238 m (SWC) and 2252 m (DCS). However the *Apectodinium* spp. acme may in the Nukik-1 well have been displaced by common *Paralecaniella indentata* (depth 2195 m (SWC) to 2225 m (DCS)). According to Brinkhuis & Schiøler (1996) may abundant *Paralecaniella* spp. indicate marginal marine to restricted marine influence or increased transport from such settings.

Powell (1992) reported the LAD of *Alisocysta margarita* from the upper part of Ama Interval Biozone, corresponding to the middle part of Zone D4. Later Powell *et al.* (1996) reported the LAD of *Areoligera gippingensis* from the upper part of the Ama Interval Biozone of Powell (1992), above the LAD of *Alisocysta margarita*, whereas the *Areoligera gippingensis* acme was reported from the lower part of the Ama.

Previous dating. Toxwenius (1986) referred the interval 2200–2280 m to D7, the interval 2280–2307 m to D6, the interval 2307–2335 m to D5 and the interval 2335–2342 m to D4.

Acknowledgements

The author's work was financed by the Danish Ministry of Environment and Energy as part of the project 'Bassin modellering Vestgrønland' (Grant No. EFP 1313/91-0014).

Special thanks go to Jens M. Lyck and Stefan Piasecki. The author is grateful to Yvonne Desezar, Kim Villadsen and Henrik Lund who prepared the samples, to Jette Halskov, Stefan Sølberg and Carsten Thuesen who produced the figures and to Martin Sønderholm who reviewed the report, all staff at GEUS.

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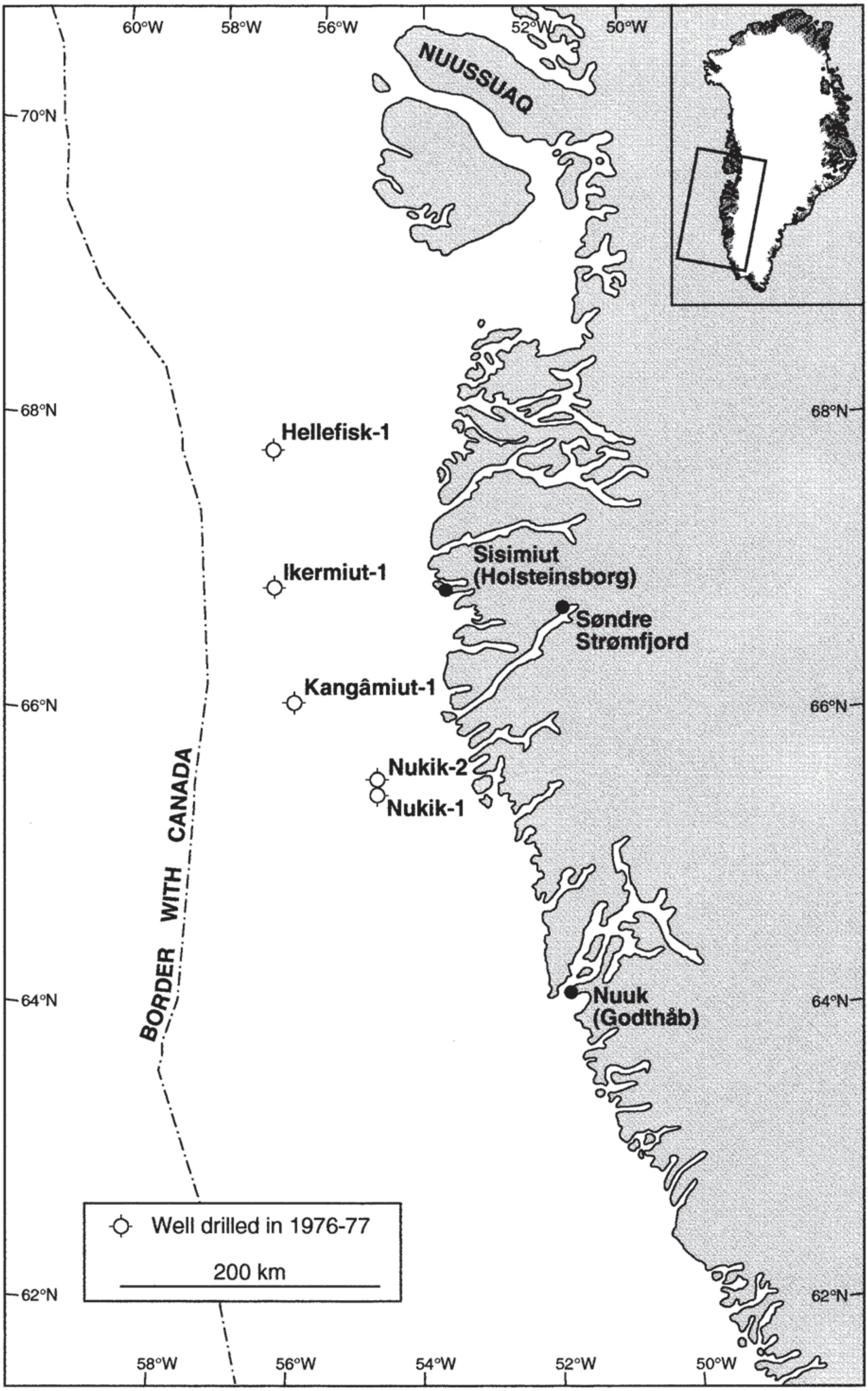

Fig. 1 Location of the offshore Greenland wells

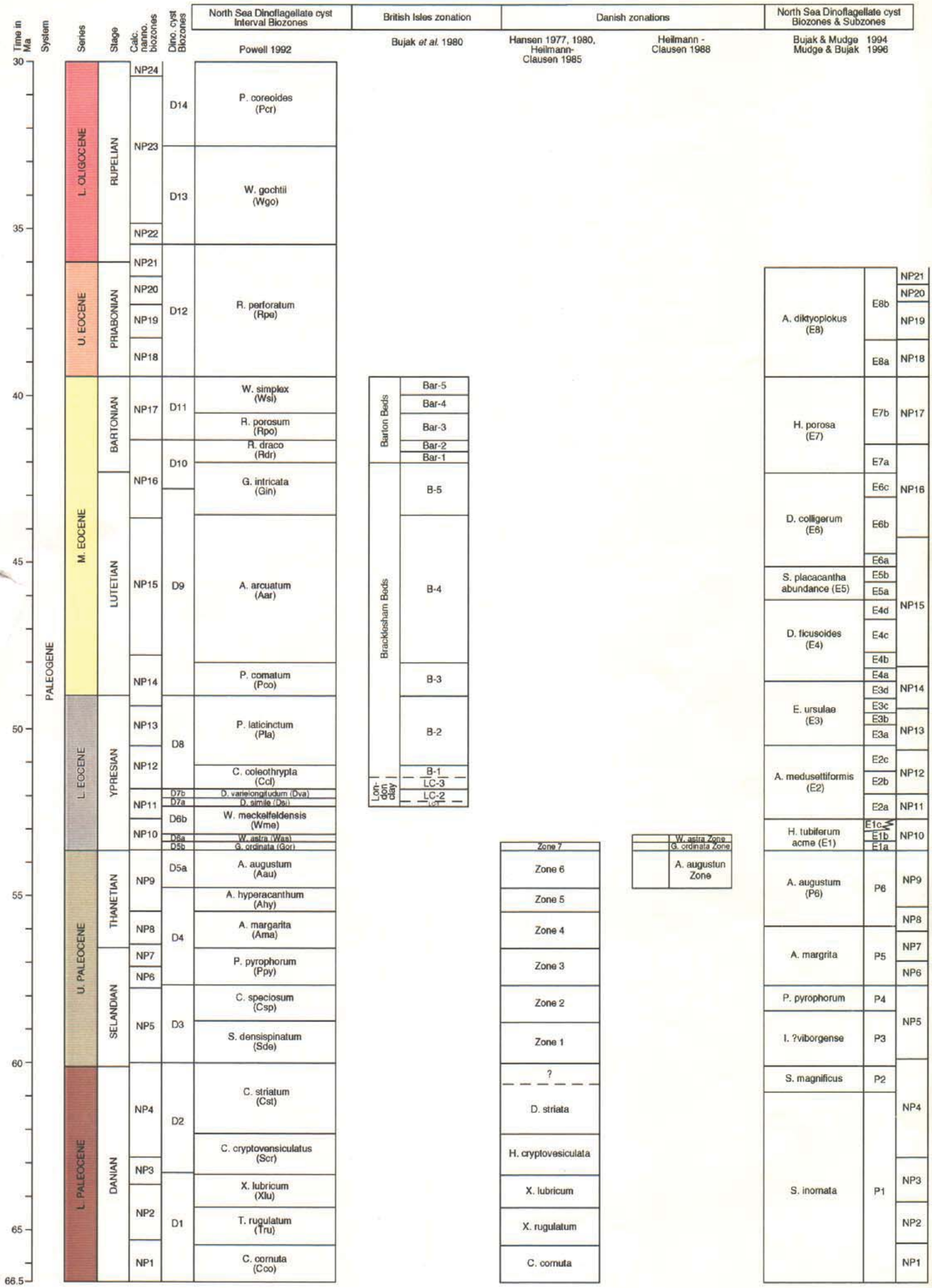

Fig. 2
Dinoflagellate cyst stratigraphy of this study compared with the dinoflagellate cyst stratigraphy og Toxwenius (1986)

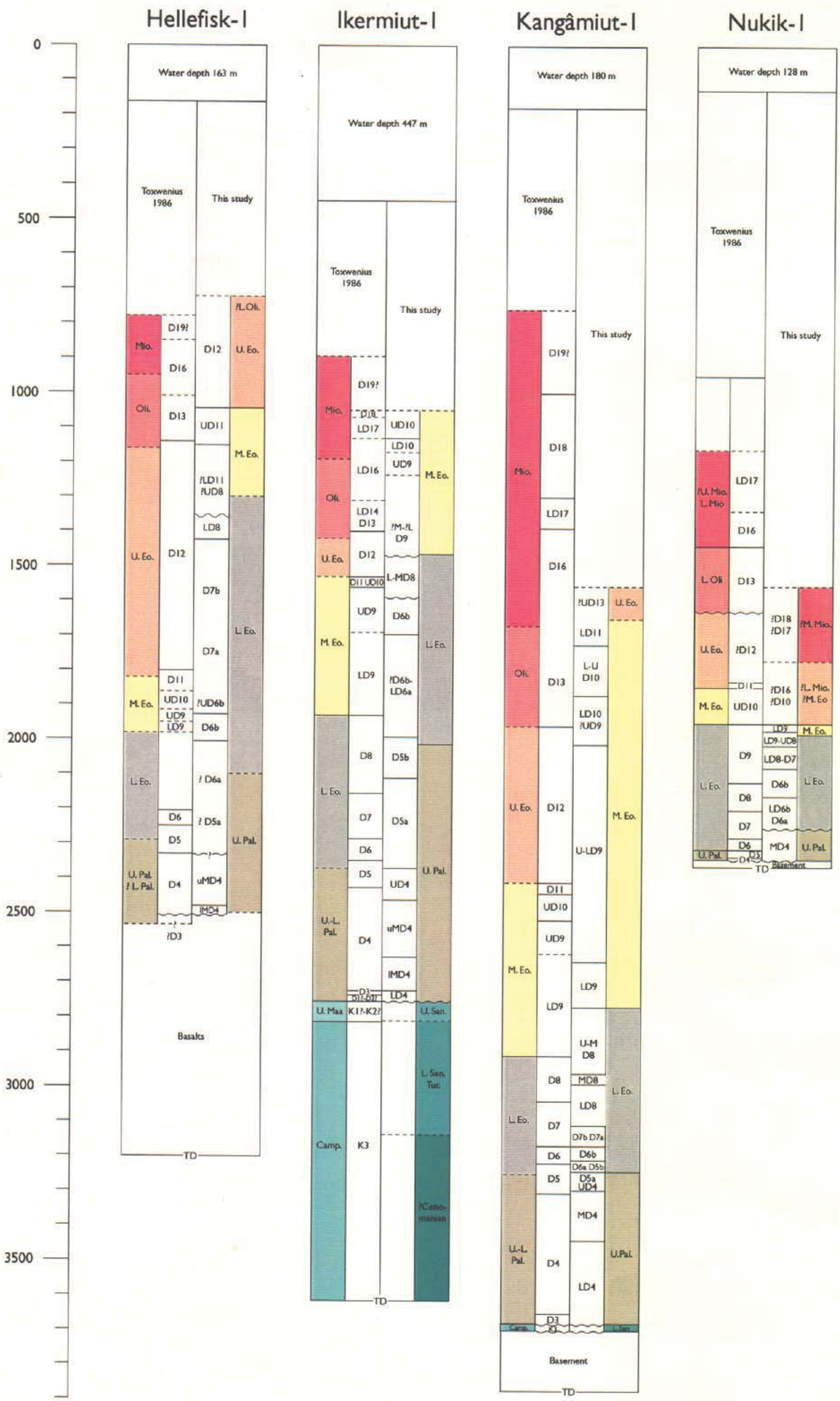

Fig. 3
Dinoflagellate cyst stratigraphy of this study compared with the dinoflagellate cyst stratigraphy of Toxwenius (1986)

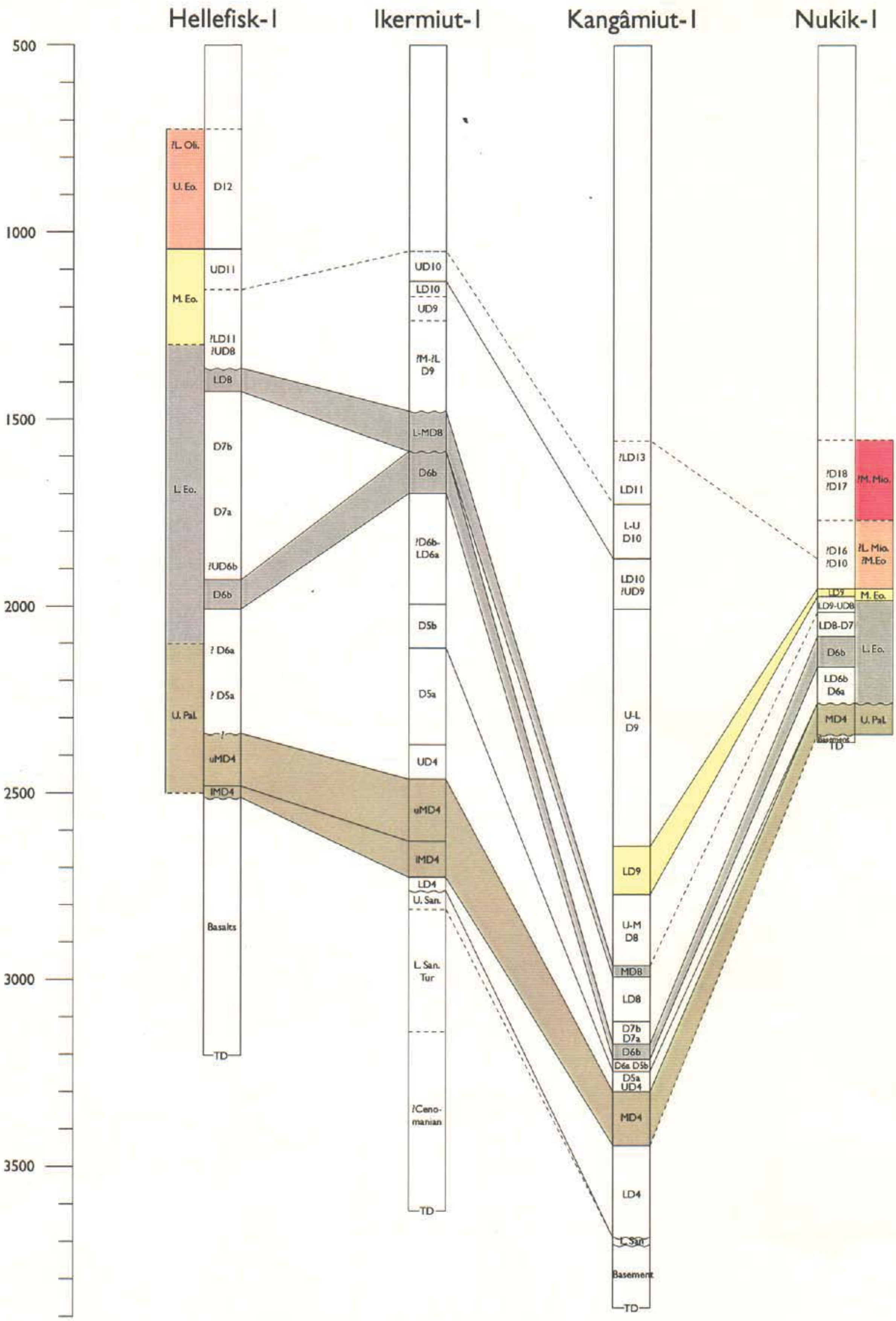

Fig. 4
Correlation of the Hellefisk-1, Ikermiut-1, Kangâmiut-1, and Nukik-1 wells based on the results from this study

Plate 1, Palynomorphs from Dinoflagellate cyst Zone D12 and D11

Figure 1. *Cribroperidinium giusseppei*, Ikerrmiut-1, 04B2035, 1130 m CC1, 38.0–95.8; LVR 1.6375; MI 4767.

Figure 2. *Lentinia* cf. *serrata*, Hellefisk-1, Arco 2812 ", 857 m SWC, 27.4–111.7; LVR 1.6386; MI 4771.

Figure 3. *Corrudinium incompositum*, Hellefisk-1, Arco 2812 ", 857 m SWC, 24.2–105.5; LVR 1.6388; MI 4774.

Figure 4. *Phthanoperidinium* aff. *distinctum,* Ikermiut-1, 04B2035, 1130 m CC1, 33.3–97.5; LVR 1.6379; MI 4768.

Figure 5. *Glaphyrocysta texta*, Hellefisk-1, 02E6517, 1045 m SWC, 55.9–98.5; LVR 1.6418; MI 4788.

Figure 6. *Rhombodinium longimanum*, Hellefisk-1, 02E6517-3, 1045 m SWC, 35.7–109.1; LVR 1.9554; MI 4795.

Figure 7. *Phthanoperidinium multispinum*, Hellefisk-1, 02E6517-1, 1045 m SWC, 42.9–107.2; LVR 1.6457; MI 4808.

Figure 8. *Phthanoperidinium geminatum*, Hellefisk-1, 02E6517-2, 1045 m SWC, 20.7–96.1; LVR 1.6461; MI 4810.

Figure 9. *Areosphaeridium* sp. 1, Hellefisk-1, 02E6519-3, 1095 m SWC, 30.8–109.5; LVR 1.6471 MI 4815.

Figure 10. *Areosphaeridium fenestratum*, Hellefisk-1, 02E6517-3, 1045 m SWC, 25.0–110.0; LVR 1.6446; MI 4801.

Figure 11. *Areoligera* aff. *tauloma*, Hellefisk-1, 02E6517, 1045 m SWC, 23.8–97.8; LVR 1.6422; MI 4789.

Figure 12. *Wetzeliella spinula*, Hellefisk-1, 02E6622-1, 1155 m SWC, 46.6–111.5; LVR 1.5298; MI 3992.

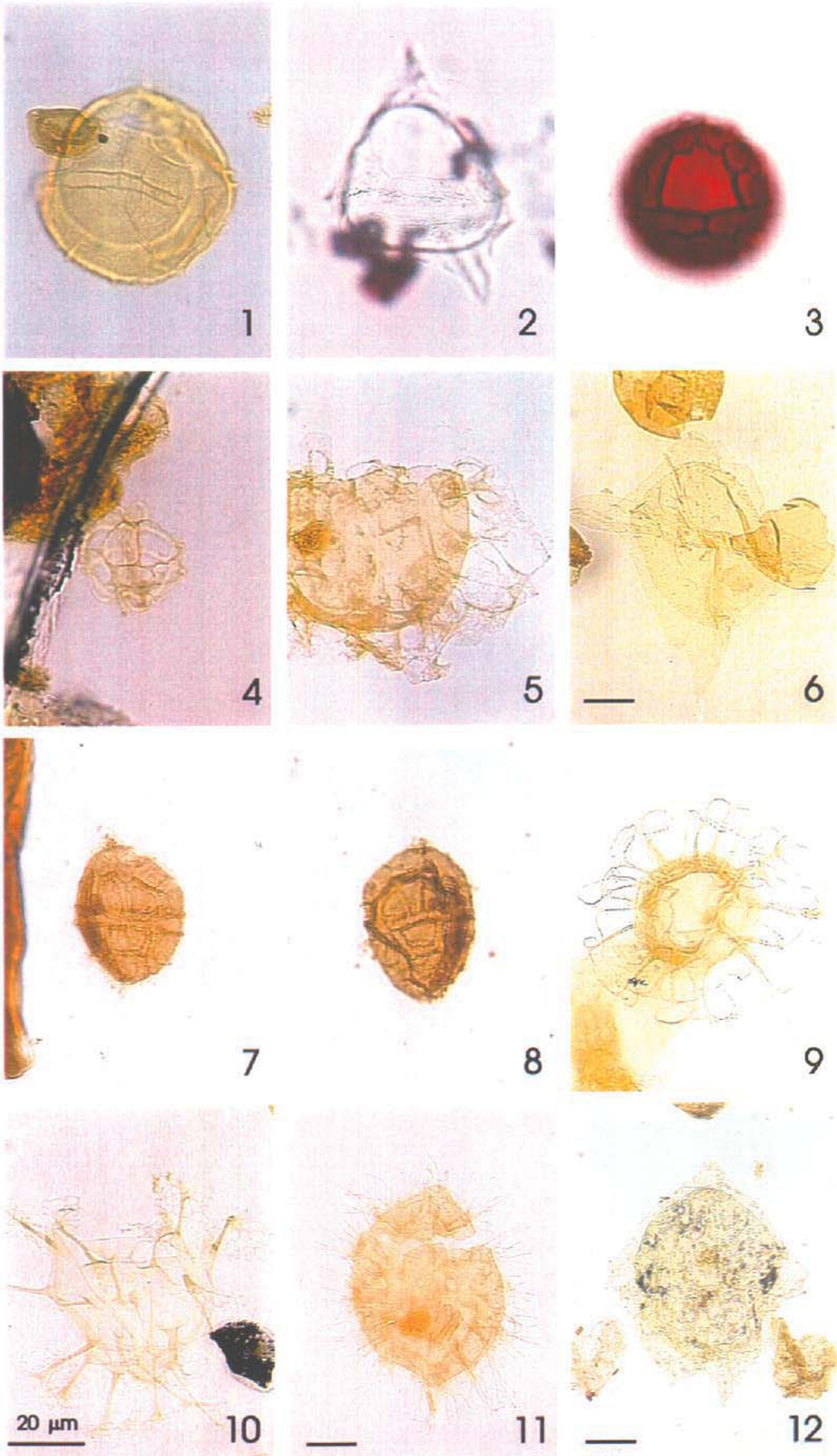
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Plate 2, Palynomorphs from Dinoflagellate cyst Zone UD10

Figure 1. *Cerebrocysta bartonensis*, Ikerrmiut-1, 04E6501-2, 1049 m SWC, 34.2–112.8; LVR 1.7489; MI 5483.

Figure 2. *Cerebrocysta bartonensis*, Ikerrmiut-1, 04E6501-2, 1049 m SWC, 30.1–103.2; LVR 1.7493; MI 5485.

Figure 3. *Heteraulacacysta porosa*, Ikerrmiut-1, 04E6501-2, 1049 m SWC, 27.8–97.2; LVR 1.7505; MI 5491.

Figure 4. *Glaphyrocysta semitectata*, Ikerrmiut-1, 04E6501-2, 1049 m SWC, 30.6–97.6; LVR 1.7503; MI 5489.

Figure 5 & 6. *Glaphyrocysta semitectata*, Ikerrmiut-1, 04E6501-1, 1049 m SWC, 43.7–93.0; LVR 1.7494–5; MI 5487.

Figure 7 & 10. *Lentinia serrata*, Ikerrmiut-1, 04E6501-3, 1049 m SWC, 36.4–105.2; LVR 1.7507–8; MI 5492.

Figure 8. *Phthanoperidinium echinatum*, Ikerrmiut-1, 04E6501-1, 1049 m SWC, 30.4–113.9; LVR 1.7511; MI 5493.

Figure 9. *Phthanoperidinium comatum*, Ikerrmiut-1, 04E6501-1, 1049 m SWC, 39.0–106.2; LVR 1.7515; MI 5495.

Figure 11. *Membranophoridium* aff. *aspinatum*, Kangâmiut-1, 01B0117-2, 1725 m, 36.3–102.0; LVR 1.6641; MI 4936.

Figure 12. *Membranophoridium* aff. *aspinatum*, specimen without processes.Kangâmiut-1, 01B0117-2, 1725 m, 33.–98.2; LVR 1.6705; MI 4971.

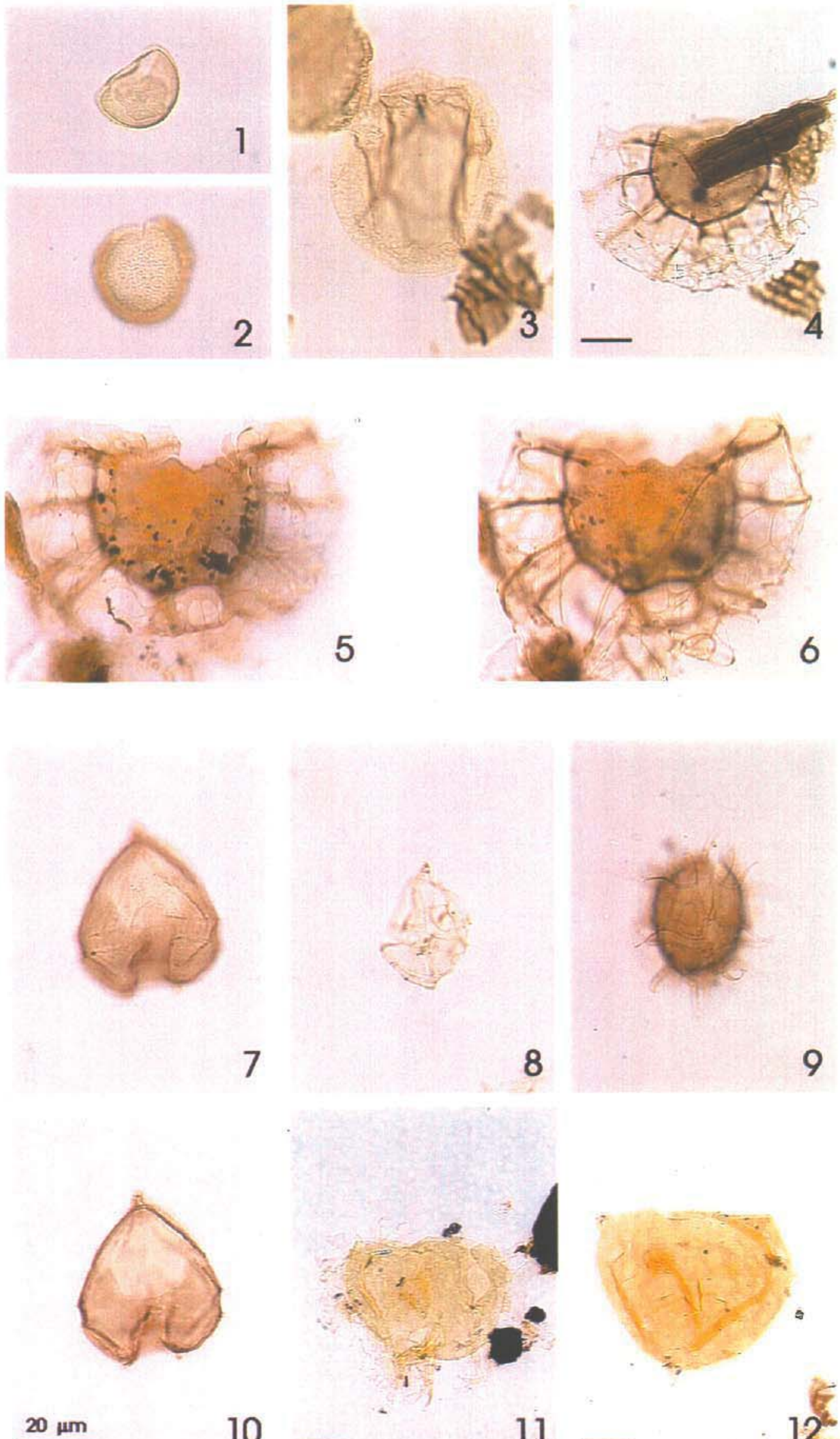
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Plate 3, Palynomorphs from Dinoflagellate cyst Zone LD10–LD9

Figure 1. *Deflandrea*? sp. 1, Ikerrmiut-1, 04E6503-3, 1155 m SWC, 33.0–112.8; LVR 1.7521; MI 5497.

Figure 2. *Deflandrea*? sp. 1, Ikerrmiut-1, 04E6503-3, 1155 m SWC, 41.0–113.5; LVR 1.7524; MI 5498.

Figure 3. *Deflandrea*? sp. 1, Ikerrmiut-1, 04E6504-2, 1155 m SWC, 36.0–97.1; LVR 1.7526; MI 5499.

Figure 4. *Glaphyrocysta vicina*, Ikerrmiut-1, 04E6503-3, 1155 m SWC, 29.5–113.2; LVR 1.7518; MI 5496.

Figure 5. *Glaphyrocysta* cf. *spineta*, Ikerrmiut-1, 04B2039, 1170 m DCS, 26.6–102.0; LVR 1.7528; MI 5500.

Figure 6. *Systemaophora placacantha*, Ikerrmiut-1, 04B2045, 1230 m DCS, 23.7–112.2; LVR 1.77540; MI 5506.

Figure 7. *Microdinium reticulatum*, Ikerrmiut-1, 04E6507-3, 1324 m SWC, 37.9–101.9; LVR 1.7544; MI 5508.

Figure 8. *Cerebrocysta magna*, Kangâmiut-1, 01C1010-9, 2640 m DCS, 45.3–108.2; LVR 1.6785; MI 5011.

Figure 9. *Wilsonidium* cf. *lineidentatum*, Kangâmiut-1, 01C1010-3, 2640 m DCS, 31.3–108.9; LVR 1.6795; MI 5017.

Figure 10. *Hystrichosphaeropsis costae*, Kangâmiut-1, 01C1010-7, 2640 m DCS, 41.4–103.8; LVR 1.6780; MI 5009.

Figure 11. *Eatonicysta ursulae*, Kangâmiut-1, 01C1016-9, 2700 m DCS, 38.8–102.6; LVR 1.7553; MI 5511.

Figure 12. *Diphyes ficusoides*, Kangâmiut-1, 01C1016-6, 2700 m DCS, 34.9–112.2; LVR 1.7555; MI 5512.

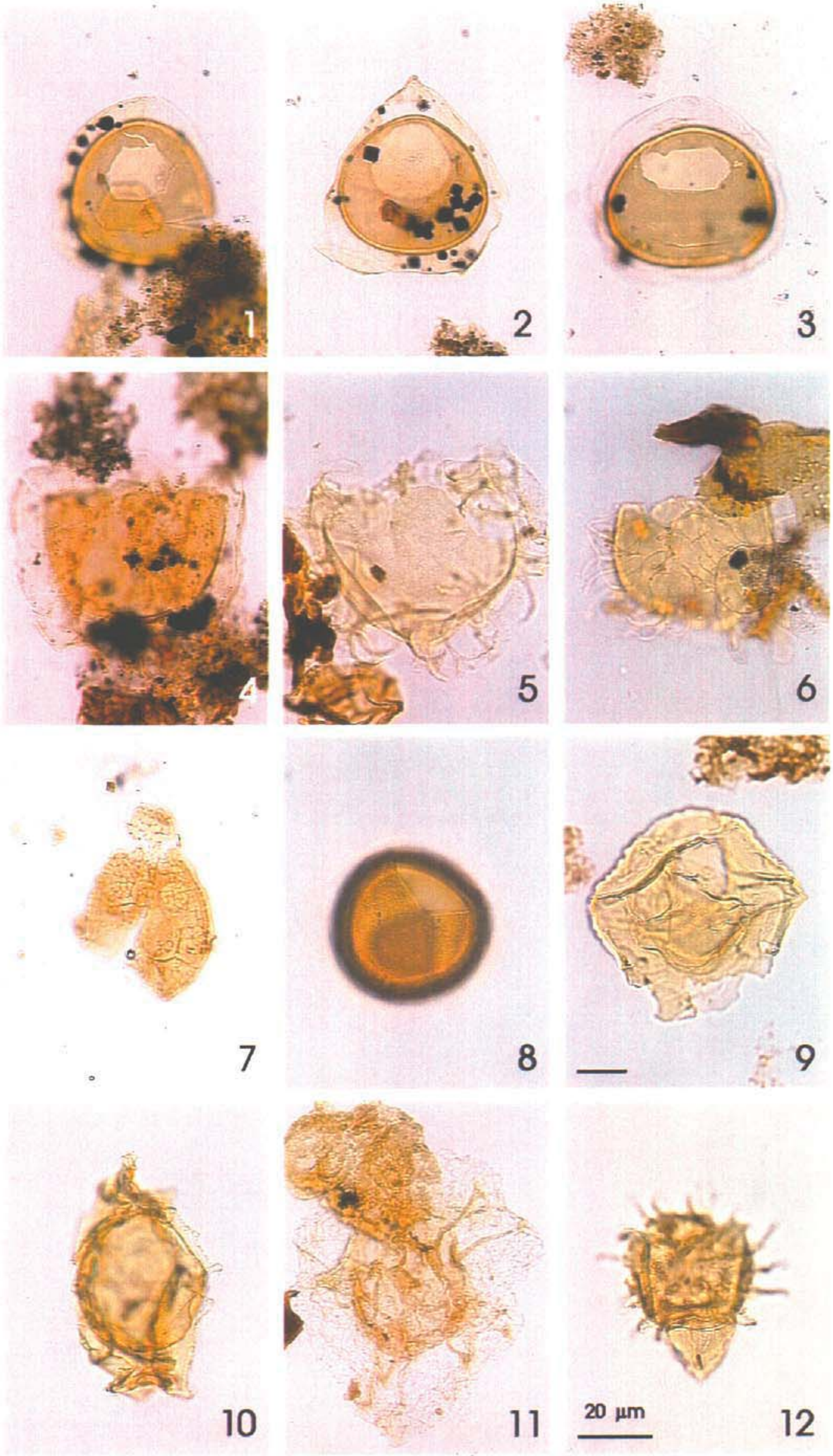
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Plate 4, Palynomorphs from Dinoflagellate cyst Zone U–LD8

Figure 1. *Diphyes brevispinum*, Kangâmiut-1, 01C2559-6, 2871 m DCS, 47.6–113.6; LVR 1.6837; MI 5041.

Figure 2. *Spiniferites cornutus*, Kangâmiut-1, 01C1022-5, 2770 m DCS, 36.4–105.9; LVR 1.7557; MI 5513.

Figure 3. *Charlesdowniea columna*, Kangâmiut-1, 01C2559-3, 2871 m DCS, 29.9–98.1; LVR 1.7572; MI 5522.

Figure 4. *Hystrichostrogylon membraniphorum*, Kangâmiut-1, 01C2559-3, 2871 m DCS, 36.0–108.5; LVR 1.7569; MI 5520.

Figure 5. *Wetzeliella lunaris*, Kangâmiut-1, 01C2559-3, 2871 m DCS, 45.5–103.7; LVR 1.7570; MI 5521.

Figure 6. *Eatonicysta sequestra*, Kangâmiut-1, 01C1022-10, 2770 m DCS, 28.3–111.3; LVR 1.7565; MI 5517.

Figure 7. *Dracodinium* cf. *varielongitudum*, Kangâmiut-1, 01C2559-7, 2871 m DCS, 54.2–95.9; LVR 1.7567; MI 5519.

Figure 8. *Dracodinium politum*, Kangâmiut-1, 01C2597-3, 2991 m DCS, 21.3–107.8; LVR 1.6840; MI 5042.

Figure 9. *Dracodinium condylos*, Kangâmiut-1, 01C1047-7, 3080 m DCS, 32.1–109.2; LVR 1.7585; MI 5529.

Figure 10. *Muratodinium fimbriatum*, Kangâmiut-1, 01C2597-3, 2991 m DCS, 35.5–103.2; LVR 1.7576; MI 5525.

Figure 11. *Rottnestia borussica*, Kangâmiut-1, 01C1047-3, 3080 m DCS, 28.2–98.2; LVR 1.7580; MI 5526.

Figure 12. *Dracodinium solidum*, Kangâmiut-1, 01C1056-10, 3170 m DCS, 42.0–96.0; LVR 1.7592; MI 5532.

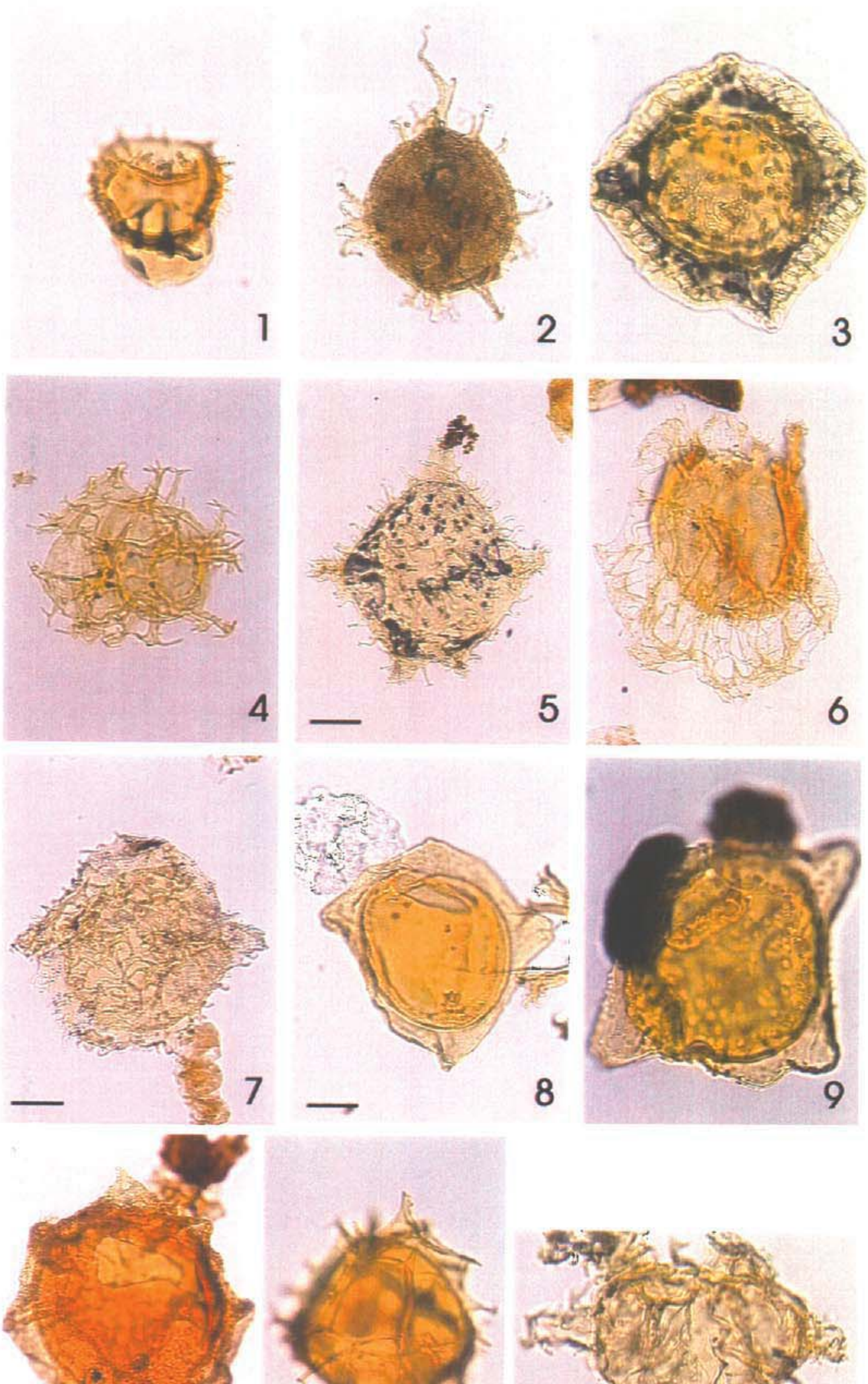
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Plate 5, Palynomorphs from Dinoflagellate cyst Subzone D7b–D6a

Figure 1. *Dracodinium* cf. *simile*, Hellefisk-1, 02E6527-1, 1425 m SWC, 48.3–108.7; LVR 1.7598; MI 5534.

Figure 2. *Wetzeliella lunaris*, Hellefisk-1, 02E6527-2, 1425 m SWC, 43.0–112.8; LVR 1.7600; MI 5535.

Figure 3. *Paralecaniella indentata*, Hellefisk-1, 02E6529-3, 1588 m SWC, 30.5–106.3; LVR 1.7602; MI 5537.

Figure 4. *Homotryblium tenuispinosum*, Hellefisk-1, 02E6527-2, 1425 m SWC, 32.5–95.4; LVR 1.7601; MI 5536.

Figure 5. *Heteraulacacysta leptalea*, Hellefisk-1, 02B2130, 1634 m DCS, 27.3–94.4; LVR 1.7604; MI 5538.

Figure 6. *Spiniferites* aff. *pseudofurcatus*, Hellefisk-1, 02E6533-3, 1734 m SWC, 19.4–94.7; LVR 1.7605; MI 5540.

Figure 7. *Areoligera* spp., Hellefisk-1, 02E6535-2, 1754 m SWC, 27.0–104.7; LVR 1.7609; MI 5544.

Figure 8. *Wetzeliella meckelfeldensis*, Ikermiut-1, 04E6515-1, 1600 m SWC, 48.1–104.1; LVR 1.7613; MI 5547.

Figure 9. *Fibrocysta bipolaris*, Ikermiut-1, 04B2106-2, 1590 m DCS, 26.8–108.9; LVR 1.7615; MI 5548.

Figure 10. *Carpatella* sp., Ikermiut-1, 04B2115-3, 1620 m DCS, 45.4–109.6; LVR 1.7619; MI 5549.

Figure 11. *Spiniferites septatus*, Kangâmiut-1, 01C1056-7, 3170 m DCS, 31.2–95.7; LVR 1.7594; MI 5533.

Figure 12. *Apectodinium quinquelatum*, Ikermiut-1, 04B2203-3, 1992 m DCS, 32.2–105.7; LVR 1.7626; MI 5552.

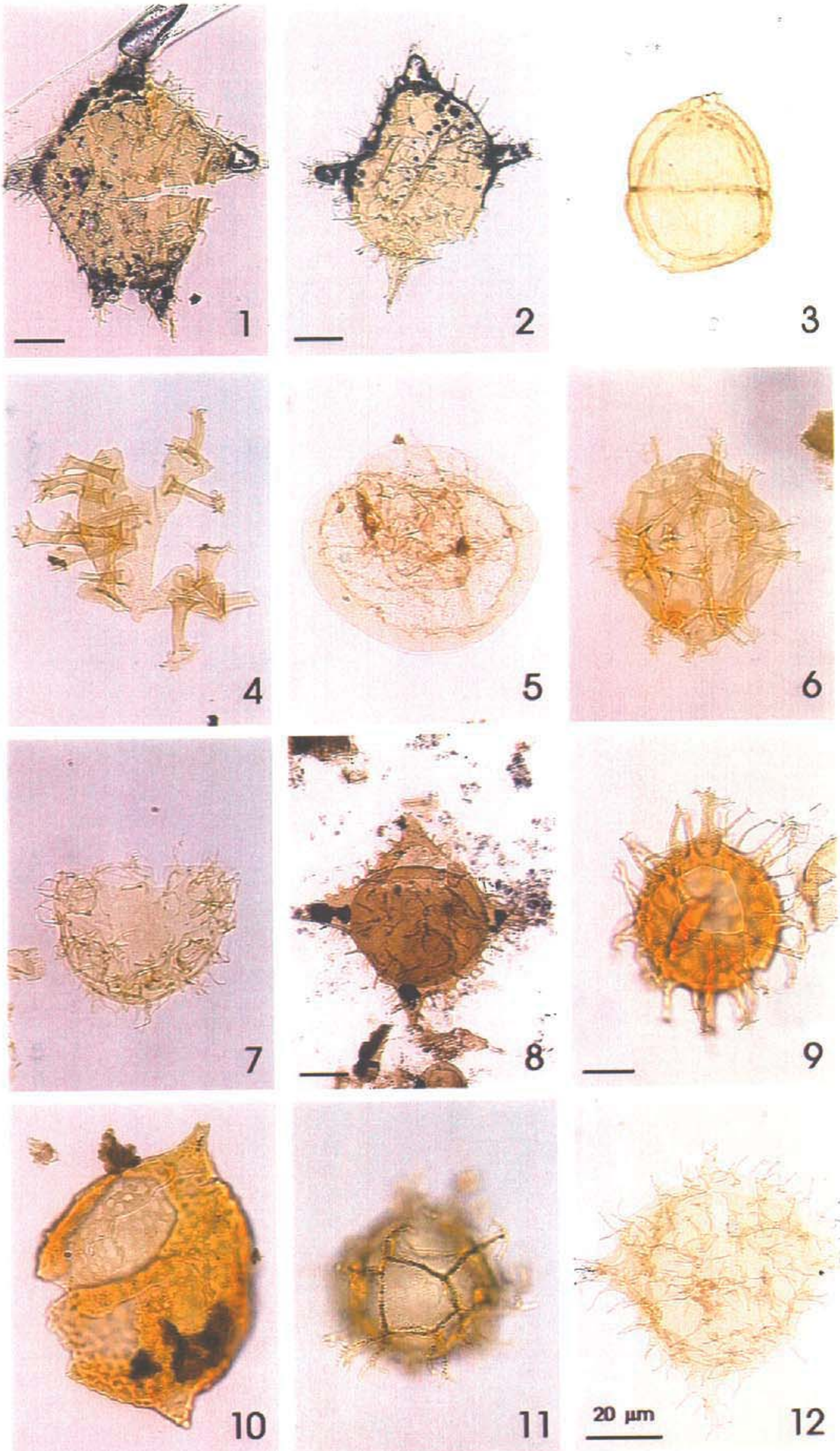
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Plate 6, Palynomorphs from Dinoflagellate cyst Subzone D6a–D5a

Figure 1. *Apectodinium paniculatum*, Ikermiut-1, 04B2203-3, 1992 m DCS, 47.9–98.6; LVR 1.7630; MI 5557.

Figure 2. *Apectodinium parvum*, Ikermiut-1, 04B2203-3, 1992 m DCS, 30.6–115.7; LVR 1.7628; MI 5555.

Figure 3. *Areoligera gippingensis*, Ikermiut-1, 04E6543-2, 2529 m SWC, 44.6–100.0; LVR 1.9556; MI 6899.

Figure 4. *Pediastrum* sp., Ikermiut-1, 04B2203-3, 1992 m DCS, 25.5–99.4; LVR 1.7632; MI 5558.

Figure 5. *Spinidinium* aff. *sagittula*, Ikermiut-1, 04B2203-3, 1992 m DCS, 22.8–104.3; LVR 1.7635; MI 5561.

Figure 6. *Deflandrea oebisfeldensis*, Ikermiut-1, 04B2203-3, 1992 m DCS, 53.3–94.8; LVR 1.7638; MI 5564.

Figure 7. *Apectodinium augustum*, Ikermiut-1, 04B2264-3, 2220 m DCS, 49.2–112.4; LVR 1.7649; MI 5573.

Figure 8. *Adnatosphaeridium robustum*, Ikermiut-1, 04B2277-2, 2280 m DCS, 34.0–96.2; LVR 1.7652; MI 5575.

Figure 9. *Lejeunecysta hyalina*, Ikermiut-1, 04B2252-2, 2161 m DCS, 16.6–112.5; LVR 1.7643; MI 5568.

Figure 10. *Spinidinium* sp. 2, Ikermiut-1, 04B2277-2, 2280 m DCS, 29.0–97.4; LVR 1.7651; MI 5574.

Figure 11. *Phthanoperidinium crenulatum,* Ikermiut-1, 04E6537-2, 2340 m SWC, 44.0–99.3; LVR 1.7667; MI 5582.

Figure 12. *Aquilapollenites* sp., Ikermiut-1, 04E6530-2, 2070.5 m SWC, 43.0–105.5; LVR 1.7670; MI 5584.

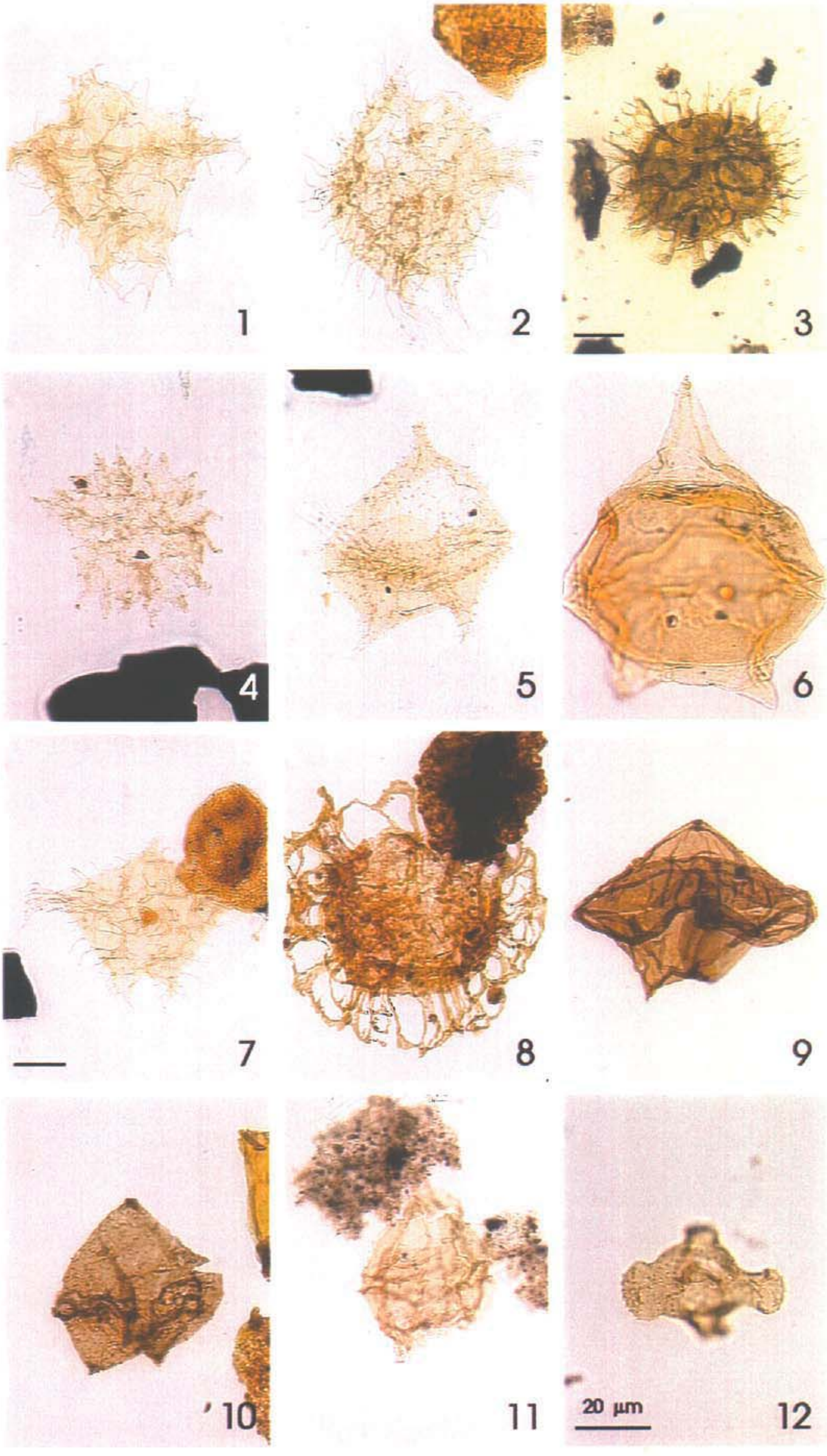
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Plate 7, Palynomorphs from Dinoflagellate cyst Zone D4

Figure 1. *Cerodinium speciosum* subsp. *glabrum*, Ikermiut-1, 04B2318-3, 2447 m DCS, 18.0–105.2; LVR 1.7683; MI 5592.

Figure 2. *Alisocysta margarita*, Ikermiut-1, 04B2333-2, 2447 m DCS, 40.8–94.1; LVR 1.7684; MI 5594.

Figure 3. *Alisocysta margarita*, Ikermiut-1, 04E6343-2, 2627 m SWC, 39.6–108.8; LVR 1.7693; MI 5598.

Figure 4. *Alisocysta* cf. sp. 1 Heilmann-Clausen 1985, Ikermiut-1, 04B2387-3, 2670 m DCS, 32.1–94.6; LVR 1.7699; MI 5601.

Figure 5. *Alisocysta* cf. sp. 1 Heilmann-Clausen 1985, Ikermiut-1, 04E6343-3, 2627 m SWC, 36.2–93.5; LVR 1.7689; MI 5593.

Figure 6. *Alisocysta* cf. sp. 1 Heilmann-Clausen 1985, Ikermiut-1, 04E6343-3, 2627 m SWC, 42.6–97.2; LVR 1.7691; MI 5597.

Figure 7. *Alisocysta* cf. sp. 1 Heilmann-Clausen 1985, Ikermiut-1, 04B2387-4, LC, 2670 m DCS, 59.0–94.8; LVR 1.7717 MI 5609.

Figure 8. *Tenua* aff. *hystrix*, Ikermiut-1, 04E6342-2, 2696 m SWC, 39.2–97.8; LVR 1.7688; MI 5596.

Figure 9. *Thalassiphora inflata*, Ikermiut-1, 04E6343-2, 2627 m SWC, 33.8–98.0; LVR 1.7696; MI 5599.

Figure 10. *Cerodinium striatum*, Ikermiut-1, 04B2637-3, 2760 m DCS, 52.6–107.0; LVR 1.7723; MI 5612.

Figure 11. *Cerodinium speciosum*, Ikermiut-1, 04B2627-3, 2730 m DCS, 30.0–109.0; LVR 1.7721; MI 5611.

Figure 12. *Thalassiphora delicata*, Ikermiut-1, 04B2404-4, 2724 m DCS, 32.3–102.0; LVR 1.7720; MI 5610.

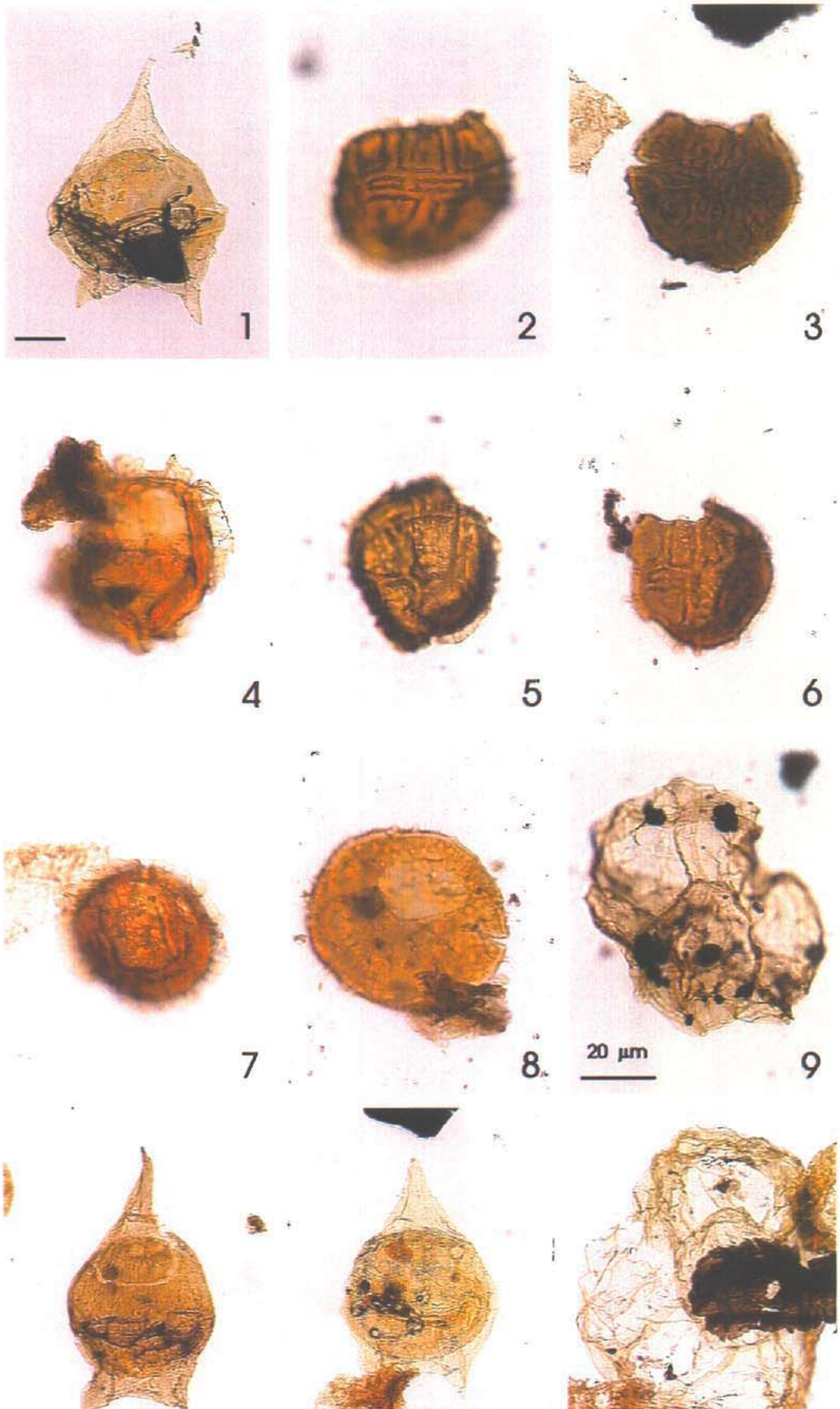
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Plate 8, Palynomorphs from Upper Cretaceous

Figure 1. *Heterosphaeridium difficile*, Ikermiut-1, 04E6551-2, 2755 m SWC, 45.9-102.1; LVR 1.9559; MI 6900.

Figure 2. *Heterosphaeridium difficile*, Ikermiut-1, 04E6551-2, 2755 m SWC, 42.0-103.0; LVR 1.9560; MI 6901.

Figure 3. *Lejeunecysta* aff. *hyalina*, Ikermiut-1, 04B2637-3, 2760 m DCS, 52.8-104.0; LVR 1.9564; MI 6905.

Figure 4. *Laciniadiniun arcticum*, Ikermiut-1, 04B2637-3, 2760 m DCS, 25.3-109.7; LVR 1.9562; MI 6903.

Figure 5. *Chatangiella ditissima*, Ikermiut-1, 04B2637-3, 2760 m DCS, 37.6-98.5; LVR 1.9563; MI 6904.

Figure 6. *Surculosphaeridium longifurcatum*, Ikermiut-1, 04B2653-1, 2811 m DCS, 23.4-103.8; LVR 1.9565; MI 6906.

Figure 7. *Palaeohystrichophora infusorioides*, Ikermiut-1, 04B2653-2, 2811 m DCS, 49.8-97.0 LVR 1.9569; MI 6910.

Figure 8. *Dorocysta litotes*, Ikermiut-1, 04B2662-2, 2841 m DCS, 48.7-108.3 LVR 1.9571; MI 6912.

Figure 9. *Raphidodinium fucatum*, Ikermiut-1, 04B2678-4, 2889 m DCS, 25.8-94.0 LVR 1.9572; MI 6913.

Figure 10. *Dinogumnium* aff. *sibiricum*, Ikermiut-1, 04B2653-1, 2811 m DCS, 40.2-105.4 LVR 1.9566; MI 6907.

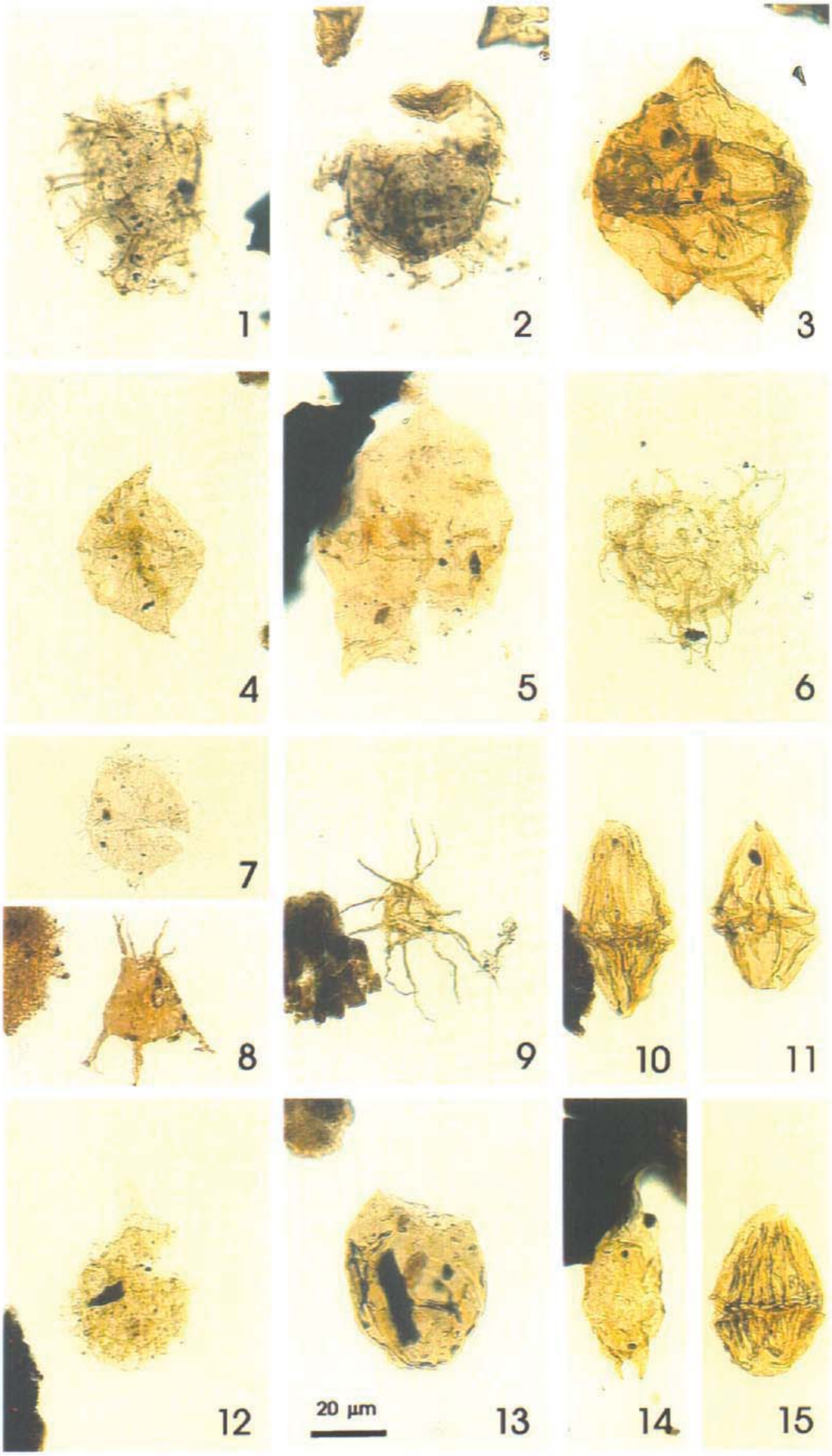
Figure 11. *Dinogumnium* sp., Ikermiut-1, 04B2653-2, 2811 m DCS, 27.2-110.5 LVR 1.9567; MI 6908.

Figure 12. *Gardodinium trabeculosum*, Ikermiut-1, 04B2469-2, 3138 m DCS, 53.3–98.7; LVR 1.9575; MI 6916.

Figure 13. *Fromea amphora*, Ikermiut-1, 04B2469-2, 3138 m DCS, 54.0–101.6; LVR 1.9576; MI 6917.

Figure 14. *Batioladinium jaegeri*, Ikermiut-1, 04B2470-2, 3140 m DCS, 25.1–110.0; LVR 1.9577; MI 6918.

Figure 15. *Dinogumnium* sp., Ikermiut-1, 04B2469-2, 3138 m DCS, 22.0–197.4 LVR 1.9574; MI 6915.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ENCLOSURE 1 | SHEET: 1 | SCALE: 1: 4000 | Groups: A D S P E | Complete spp. set | GEUS

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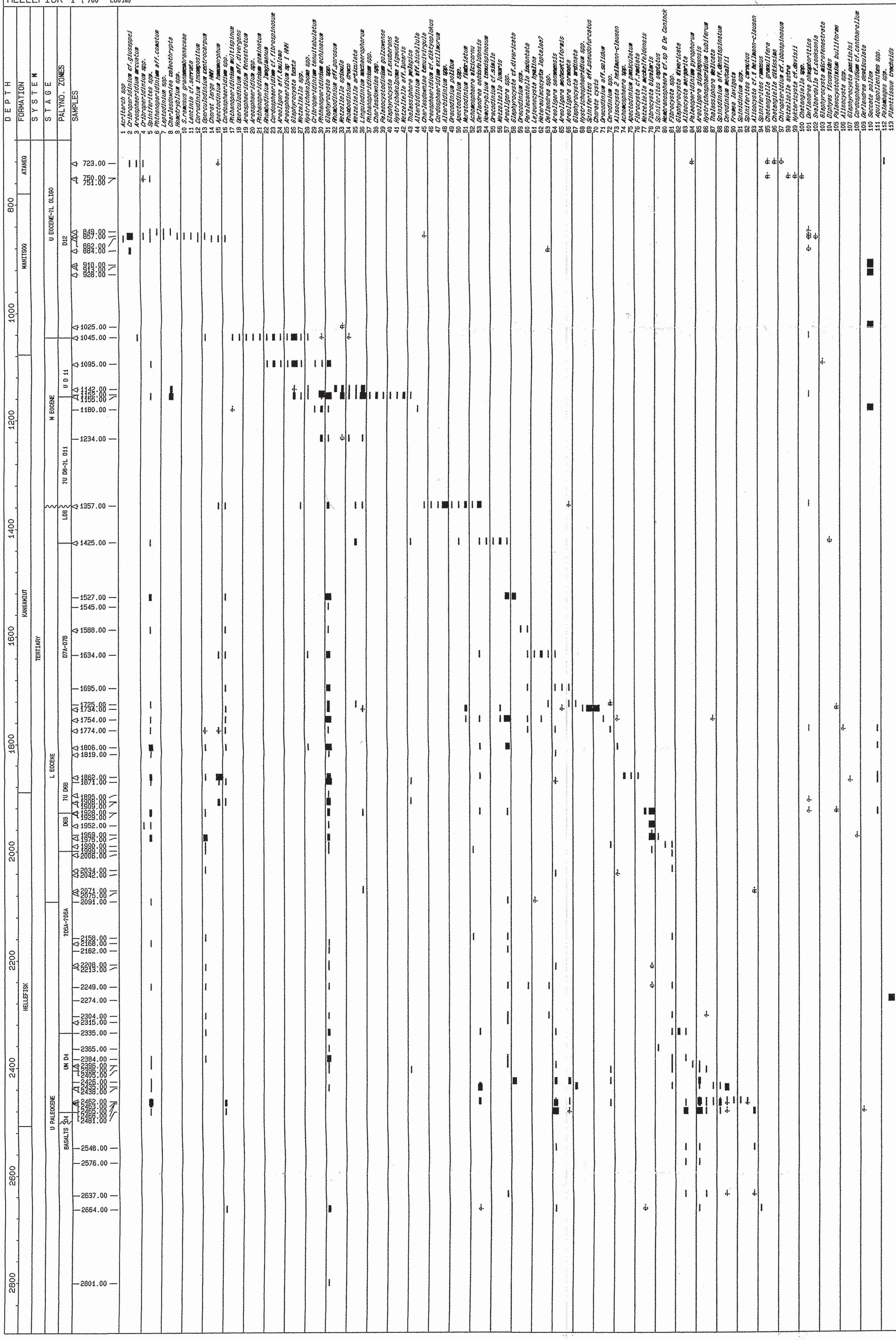


ALPHABETICAL SPECIES LIST

62 Achomosphaera alcicornu
74 Achomosphaera spp.
1 Acritarch spp
73 Alisocysta 2 heilmann-clausen
93 Alisocysta cf.1 heilmann-clausen
83 Alisocysta margarita
106 Alisocysta spp.
44 Alterbidinium aff.bicellula
48 Alterbidinium spp.
15 Apectodinium homomorphum
75 Apectodinium paniculatum
50 Apectodinium spp.
111 Aquilapollenites spp.
24 Areoligera aff.tauloma
68 Areoligera coronata
85 Areoligera gippingensis
65 Areoligera medusettiformis
64 Areoligera senonensis
57 Areoligera spp.
3 Areosphaeridium arcuatum
46 Areosphaeridium cf.diktyoplokus
19 Areosphaeridium fenestratum
25 Areosphaeridium sp 1 HNH
20 Areosphaeridium spp.
89 Cerodinium medcalfii
72 Cerodinium spp.
8 Charlesdowniea coleothrypta
38 Charlesdowniea spp.
45 Charlesdowniea tenuivirgula
96 Chatangiella ditissima
95 Chatangiella granulifera
100 Chatangiella spp.
97 Chiropteridium cf.lobospinosum
14 Chorat large HNH
70 Chorate cysts
108 Cordosphaeridium cf.cantharellum
23 Cordosphaeridium cf.fibrospinosum
47 Cordosphaeridium exilimurum
16 Cordosphaeridium spp.
12 Corrudinium incompositum
2 Cribroperidinium cf.giuseppei
4 Cribroperidinium spp.
29 Cribroperidinium tenuitabulatum
109 Deflandrea denticulata
53 Deflandrea oebisfeldensis
101 Deflandrea phosphoritica
63 Deflandrea spp.
104 Diphyes ficusoides
71 Dracodinium aff.solidum
55 Dracodinium cf.simile
49 Dracodinium politum
59 Dracodinium spp.
78 Fibrocysta bipolaris
76 Fibrocysta cf.radiata
81 Fibrocysta spp.
90 Fromea lavigata
58 Glaphyrocysta cf.divaricata
40 Glaphyrocysta cf.exuberans
82 Glaphyrocysta divaricata
103 Glaphyrocysta microfenestrata
67 Glaphyrocysta ordinata
107 Glaphyrocysta pastielsi
31 Glaphyrocysta spp.
26 Glaphyrocysta texta
62 Heteraulacacysta leptalea?
9 Homotryblium spp.
54 Homotryblium tenuispinosum
41 Hystrichokolpoma rigaudiae
28 Hystrichokolpoma spp.
68 Hystrichosphaeridium spp.
86 Hystrichosphaeridium tubiferum
61 Lejeunecysta hyalina
11 Lentinia cf.serrata
7 Leptodinium spp.
36 Lingulodinium machaerophorum
80 Membranosphaera cf.sp B De Coninck
51 Muratodinium fimbriatum
99 Nyktericysta cf.davisii
18 Operculodinium aff.divergens
13 Operculodinium centrocarpum
105 Palaeocystodinium bulliforme
39 Palaeocystodinium golzowense
84 Palaeoperidinium pyrophorum
112 Palambages spp.
60 Paralecaniella indentata
6 Phthanoperidinium aff.comatum
30 Phthanoperidinium echinatum
21 Phthanoperidinium geminatum
17 Phthanoperidinium multispinum
37 Phthanoperidinium spp.
113 Planttissue tracheids
32 Rhombodinium aff.porosum
34 Rhombodinium draco
22 Rhombodinium longimanum
10 S.ramosus granomembranaceae
110 Saccate pollen
88 Spinidinium aff.densispinatum
91 Spinidinium spp.
69 Spiniferites aff.pseudofurcatus
92 Spiniferites cornutus
94 Spiniferites ramosus
79 Spiniferites septatus
5 Spiniferites spp.
102 Svalbardella cf.cooksonia
87 Thalassiphora delicata
43 Thalassiphora pelagica
42 Wetzeliella aff.lunaris
35 Wetzeliella articulata
98 Wetzeliella astra
56 Wetzeliella lunaris
77 Wetzeliella meckelfeldensis
33 Wetzeliella spinula
27 Wetzeliella spp.

BIOSTRATIGRAPHICAL EVENTS

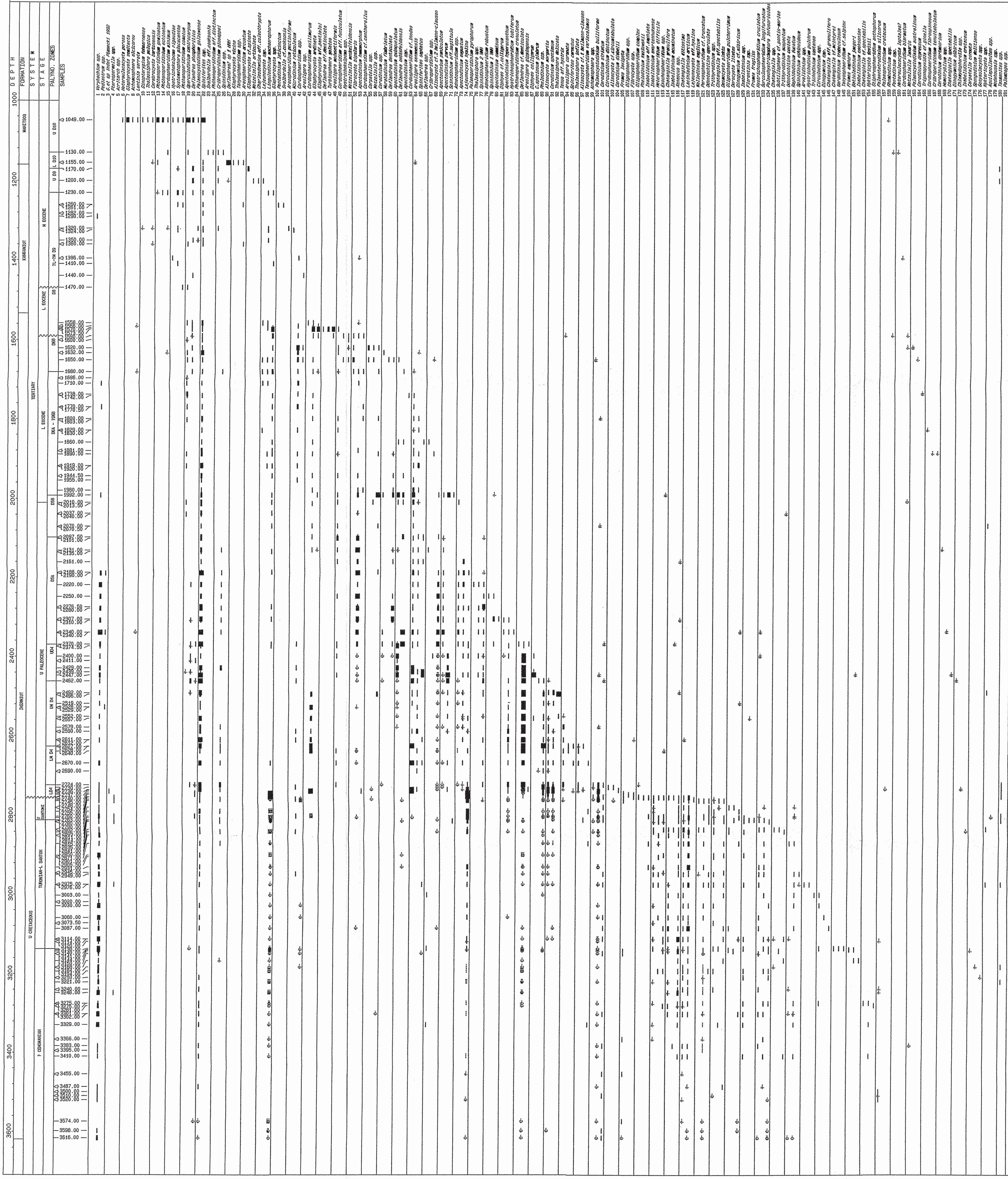
T: top M: max B: base I: influx
+ 5-9 ++10-24 +++25-59 ++++ >59

Areosphaeridium arcuatum	T
Apectodinium homomorphum	T
Areosphaeridium arcuatum	B
Glaphyrocysta texta	TM+++
Rhombodinium longimanum	T
Rhombodinium longimanum	B
Wetzeliella spinula	T+
Glaphyrocysta texta	B+
Wetzeliella spinula	MB++
Charlesdowniea tenuivirgula	TB
Deflandrea oebisfeldensis	T++
Dracodinium politum	TB
Muratodinium fimbriatum	TM+
Dracodinium cf.simile	TB
Wetzeliella lunaris	TM+
Paralecaniella indentata	T
Dracodinium aff.solidum	TB
Muratodinium fimbriatum	B
Wetzeliella lunaris	B
Apectodinium homomorphum	M++++
Apectodinium paniculatum	TB
Apectodinium homomorphum	B+
Fibrocysta bipolaris	T+++
Wetzeliella meckelfeldensis	TMB+
Fibrocysta bipolaris	M++++
Fibrocysta bipolaris	B
Paralecaniella indentata	B
Alisocysta margarita	T
Areoligera gippingensis	T
Deflandrea oebisfeldensis	M++
Deflandrea oebisfeldensis	B+
Alisocysta cf.1 heilmann-clausen	TM+
Alisocysta margarita	M++
Areoligera gippingensis	M+++
Alisocysta cf.1 heilmann-clausen	B
Alisocysta margarita	B
Areoligera gippingensis	B

ENCLOSURE 2 | SHEET: 1 | Groups: A D S P E
SCALE: 1: 4000 | Complete spp. set

GEUS

IKERMIUT 1 (1000 - 3619m)



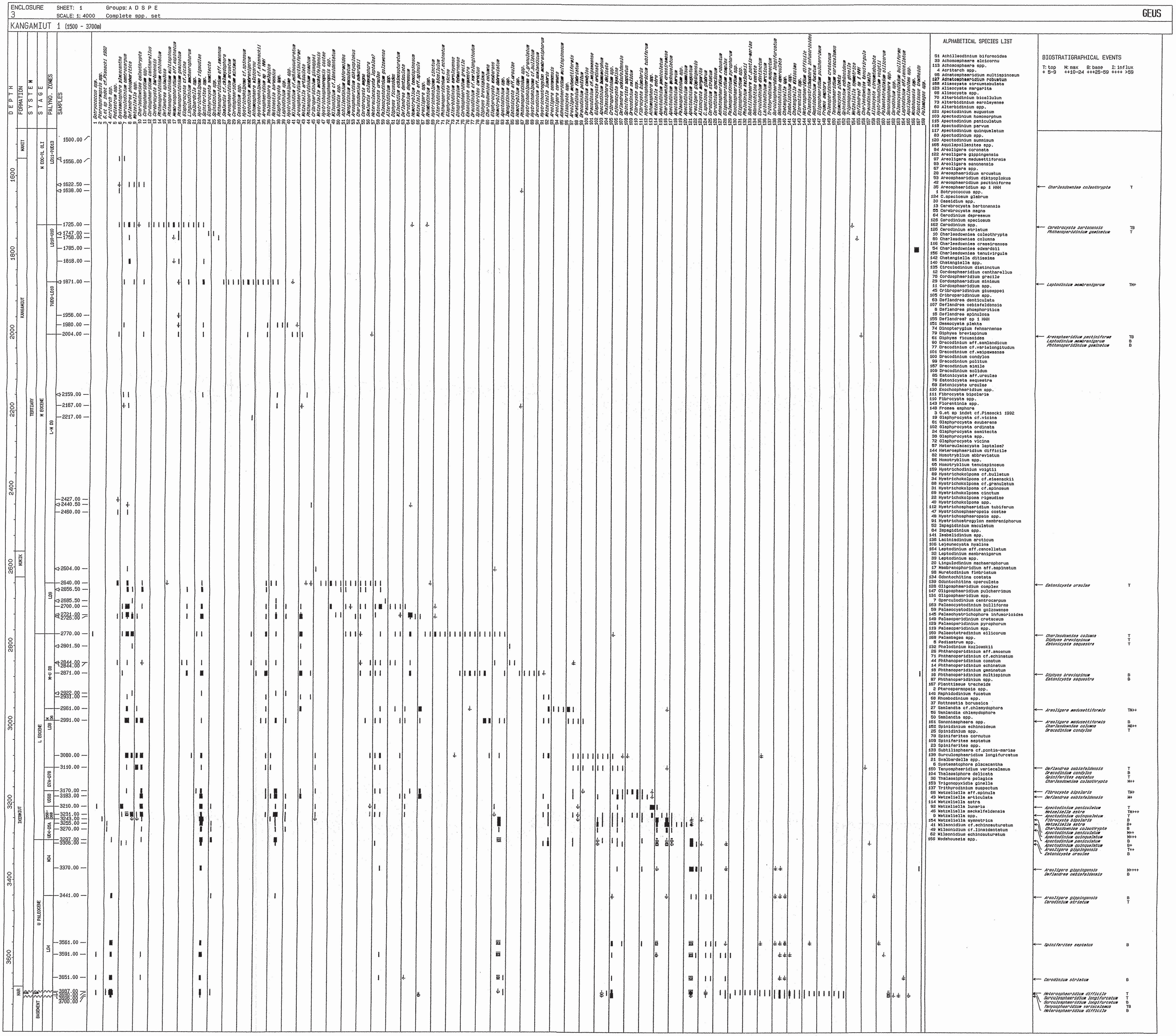
ALPHABETICAL SPECIES LIST

8 Achomosphaera alcicornu
99 Achomosphaera spp.
5 Acritarch spp.
78 Adnatosphaeridium robustum
72 Adnatosphaeridium spp.
97 Alisocysta cf.1 heilmann-clausen
88 Alisocysta cf.2 heilmann-clausen
103 Alisocysta cf.circumtabulata
90 Alisocysta margarita
73 Apectodinium augustum
53 Apectodinium homomorphum
82 Apectodinium hyperacanthum
69 Apectodinium paniculatum
70 Apectodinium parvum
60 Apectodinium quinquelatum
62 Apectodinium spp.
80 Apectodinium summissum
178 Aquilapollenites spp.
94 Areoligera coronata
65 Areoligera gippingensis
48 Areoligera medusettiformis
64 Areoligera senonensis
42 Areoligera spp.
30 Areosphaeridium arcuatum
39 Areosphaeridium pectiniforme
141 Arvalidinium spp.
151 Batioladinium jaegeri
88 C.speciosum glabrum
174 Carpatella cornuta
55 Carpatella spp.
12 Cerebrocysta bartonensis
168 Cerodinium dartmoorium
164 Cerodinium depressum
104 Cerodinium diebelii
91 Cerodinium speciosum
57 Cerodinium spp.
101 Cerodinium striatum
33 Charlesdowniea aff.coleothrypta
146 Chatangiella aff.granulifera
124 Chatangiella aff.spectabilis
147 Chatangiella cf.mcintyrei
153 Chatangiella cf.spectabilis
117 Chatangiella ditissima
114 Chatangiella granulifera
170 Chatangiella spectabilis
135 Chatangiella spp.
172 Chlamydophorella spp.
102 Circulodinium distinctum
144 Circulodinium spp.
49 Cordosphaeridium aff.funiculatum
161 Cordosphaeridium biarmatum
54 Cordosphaeridium cf.cantharellus
63 Cordosphaeridium cf.inodes
43 Cordosphaeridium exilimurum
166 Cordosphaeridium fibrospinosum
15 Cordosphaeridium minimum
41 Cordosphaeridium spp.
25 Cribroperidinium giuseppei
87 Cribroperidinium spp.
167 Cribroperidinium tenuitabulatum
46 Deflandrea aff.denticulata
85 Deflandrea cf.denticulata
59 Deflandrea denticulata
61 Deflandrea oebisfeldensis
20 Deflandrea phosphoritica
66 Deflandrea spp.
27 Deflandrea? sp 1 HNH
125 Desmocysta plekta
128 Dinogymnium cf.sibiricum
171 Dinogymnium sibiricum
145 Dinogymnium spp.
10 Dinopterygium fehmarnense
81 Diphyes cf.colligerum
87 Diphyes colligerum
127 Dorocysta litotes
113 Exochosphaeridium spp.
52 Fibrocysta bipolaris
107 Fibrocysta spp.
130 Florentinia spp.
150 Fromea amphora
131 Fromea fragilis
105 Fromea laevigata
3 G.et sp indet Piasecki 1992
148 Gardodinium trabeculosum
45 Glaphyrocysta aff.pastielsi
31 Glaphyrocysta cf.spineta
44 Glaphyrocysta ordinata
7 Glaphyrocysta semitecta
36 Glaphyrocysta spp.
28 Glaphyrocysta vicina
176 Gonyaulacysta spp.
160 Heteraulacacysta leptalea?
6 Heteraulacacysta porosa
112 Heterosphaeridium difficile
169 Homotryblium spp.
142 Hystrichodinium pulchrum
16 Hystrichokolpoma rigaudiae
50 Hystrichokolpoma spp.
132 Hystrichosphaeridium cruciatum
83 Hystrichosphaeridium tubiferum
115 Isabelidinium acuminatum
110 Isabelidinium aff.amphiata
152 Isabelidinium cooksoniae
173 Isabelidinium cretaceum
129 Isabelidinium spp.
111 Isabelidinium svartenhukense
118 Laciniadinium arcticum
119 Lejeunecysta aff.hyalina
74 Lejeunecysta hyalina
34 Lejeunecysta spp.
9 Lentinia serrata
35 Lingulodinium machaerophorum
40 Microdinium reticulatum
58 Muratodinium fimbriatum
154 Nyktericysta davisii
177 Nyktericysta spp.
138 Odontochitina costata
122 Odontochitina operculata
108 Oligosphaeridium complex
126 Oligosphaeridium pulcherrimum
106 Oligosphaeridium spp.
19 Operculodinium centrocarpum
163 Palaeocystodinium australinum
100 Palaeocystodinium bulliforme
21 Palaeocystodinium golzowense
134 Palaeohystrichophora infusorioides
157 Palaeoperidinium cretaceum
76 Palaeoperidinium pyrophorum
156 Palaeotetradinium silicorum
181 Palambages spp.
2 Pediastrum spp.
37 Pentadinium laticinctum
159 Pentadinium spp.
121 Pervosphaeridium cf.truncatum
109 Phelodinium kozlowskii
89 Phelodinium spp.
24 Phthanoperidinium aff.distinctum
18 Phthanoperidinium comatum
84 Phthanoperidinium crenulatum
14 Phthanoperidinium echinatum
13 Phthanoperidinium geminatum
4 Pterospermella spp.
139 Raphidodinium fucatum
158 Rhombodinium spp.
79 Spinidinium 1 HNH
77 Spinidinium 2 HNH
71 Spinidinium aff.sagittula
140 Spinidinium echinoideum
26 Spinidinium spp.
95 Spiniferites cornutus
85 Spiniferites septatus
22 Spiniferites spp.
175 Spongodinium delitiense
155 Stiphrosphaeridium anthophorum
136 Subtilisphaera cf.pontis-mariae
133 Surculosphaeridium longifurcatum
23 Svalbardella aff.cooksonia
38 Svalbardella cf.cooksonia
17 Systematophora placacantha
149 Tanyosphaeridium cf.salpinx
29 Tanyosphaeridium spp.
98 Tanyosphaeridium variecalamus
180 Tasmanites spp.
93 Tenua aff.hystrix
92 Thalassiphora delicata
96 Thalassiphora inflata
11 Thalassiphora pelagica
76 Thalassiphora spp.
143 Trichodinium castanea
165 Trigonopyxidia cf.ginella
123 Trithyrodinium spp.
137 Trithyrodinium suspectum
47 Turbiosphaera galatea
1 Veryhachium spp.
120 Wallodinium anglicum
32 Wetzeliella articulata
162 Wetzeliella lunaris
51 Wetzeliella meckelfeldensis
56 Wetzeliella spp.
179 Wodehouseia spp.
116 Xenascus spp.

BIOSTRATIGRAPHICAL EVENTS

T: top | M: max | B: base | I: influx
+ 5-9 | ++10-24 | +++25-59 | ++++ >59

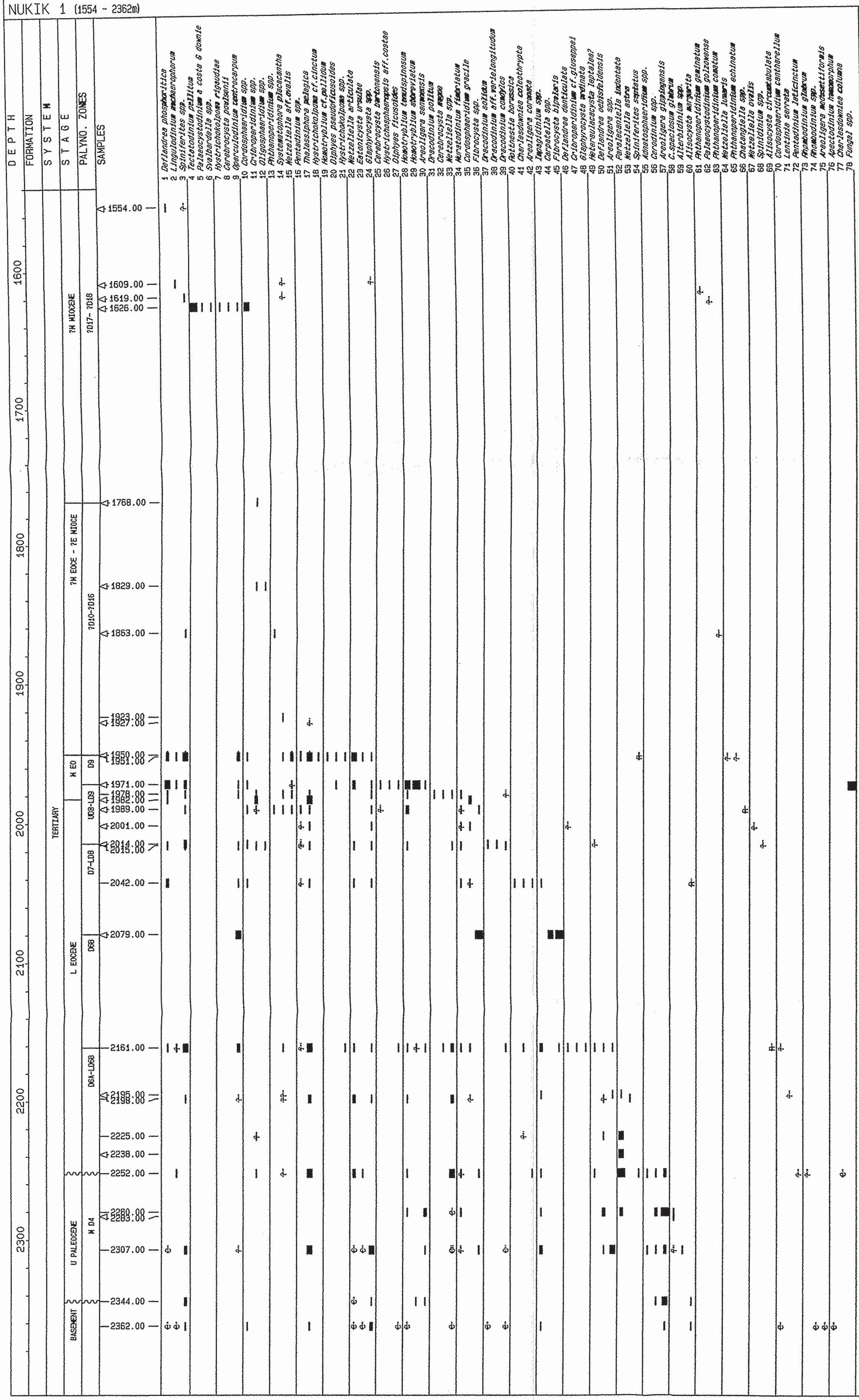
Cerebrocysta bartonensis	TB
Heteraulacacysta porosa	TB
Phthanoperidinium comatum	T
Phthanoperidinium geminatum	TM++
Systematophora placacantha	T
Phthanoperidinium aff.distinctum	T
Glaphyrocysta vicina	TB
Phthanoperidinium geminatum	B
Glaphyrocysta cf.spineta	TMB+
Phthanoperidinium aff.distinctum	B
Systematophora placacantha	M+
Systematophora placacantha	B
Phthanoperidinium comatum	B
Areoligera medusettiformis	TM++
Turbiosphaera galatea	TMB+
Areoligera medusettiformis	B
Fibrocysta bipolaris	T
Wetzeliella meckelfeldensis	T
Deflandrea oebisfeldensis	T
Fibrocysta bipolaris	M+
Wetzeliella meckelfeldensis	B
Fibrocysta bipolaris	B
Apectodinium paniculatum	T
Apectodinium parvum	T
Deflandrea oebisfeldensis	M++
Apectodinium augustum	T
Apectodinium augustum	M+
Apectodinium paniculatum	M++
Apectodinium parvum	M++
Apectodinium augustum	B
Apectodinium paniculatum	B++
Apectodinium parvum	B
Areoligera gippingensis	T
Areoligera gippingensis	M++++
Deflandrea oebisfeldensis	B++
Alisocysta margarita	T
Alisocysta cf.1 heilmann-clausen	T
Alisocysta margarita	M+++
Areoligera gippingensis	B++++
Cerodinium striatum	T+
Alisocysta cf.1 heilmann-clausen	B
Cerodinium striatum	M++
Alisocysta margarita	B+
Cerodinium striatum	B+
Heterosphaeridium difficile	T
Laciniadinium arcticum	T
Surculosphaeridium longifurcatum	T
Laciniadinium arcticum	M+
Fromea amphora	TB
Gardodinium trabeculosum	TB
Heterosphaeridium difficile	B
Batioladinium jaegeri	TB
Surculosphaeridium longifurcatum	B
Laciniadinium arcticum	B


ENCLOSURE 3
SHEET: 1
SCALE: 1: 4000
Groups: A D S P E
Complete spp. set
GEUS
KANGAMIUT 1 (1500 - 3700m)
DEPTH
FORMATION
SYSTEM
STAGE
PALYNO. ZONES
SAMPLES
ALPHABETICAL SPECIES LIST
BIOSTRATIGRAPHICAL EVENTS
T: top M: max B: base I: influx
+ 5-9 ++10-24 +++25-59 ++++ >59
Charlesdowniea coleothrypta T
Cerebrocysta bartonensis TB
Phthanoperidinium geminatum
Leptodinium membranigerum TN+
Areosphaeridium pectiniforme TB
Leptodinium membranigerum B
Phthanoperidinium geminatum B
Eatonicysta ursulae T
Charlesdowniea columna T
Diphyes brevispinum T
Eatonicysta saquestra T
Diphyes brevispinum B
Eatonicysta saquestra B
Areoligera medusettiformis TM++
Areoligera medusettiformis B
Charlesdowniea columna MB++
Dracodinium condylos T
Deflandrea oebisfeldensis T
Dracodinium condylos B
Spiniferites septatus T
Charlesdowniea coleothrypta M++
Fibrocysta bipolaris TM+
Deflandrea oebisfeldensis M+
Apectodinium paniculatum T
Wetzeliella astra TM+++
Apectodinium quinquelatum T
Fibrocysta bipolaris B
Wetzeliella astra B+
Charlesdowniea coleothrypta B
Apectodinium paniculatum M++
Apectodinium quinquelatum M+++
Apectodinium paniculatum B
Apectodinium quinquelatum B+
Areoligera gippingensis T++
Eatonicysta ursulae B
Areoligera gippingensis M++++
Deflandrea oebisfeldensis B
Areoligera gippingensis B
Cerodinium striatum T
Spiniferites septatus B
Cerodinium striatum B
Heterosphaeridium difficile T
Surculosphaeridium longifurcatum T
Surculosphaeridium longifurcatum B
Tanyosphaeridium variecalamus TB
Heterosphaeridium difficile B

GEUS

ENCLOSURE 4 — SHEET: 1 — SCALE: 1:2000 — Groups: A D S P E — Complete spp. set

NUKIK 1 (1554 - 2362m)



ALPHABETICAL SPECIES LIST

55 Adnatosphaeridium spp.
69 Alisocysta circumtabulata
60 Alisocysta margarita
59 Alterbidinium spp.
76 Apectodinium homomorphum
42 Areoligera coronata
57 Areoligera gippingensis
75 Areoligera medusettiformis
30 Areoligera senonensis
51 Areoligera spp.
58 C.speciosum glabrum
44 Carpatella spp.
25 Cerebrocysta bartonensis
32 Cerebrocysta magna
8 Cerebrocysta poulsenii
56 Cerodinium spp.
41 Charlesdowniea coleothrypta
77 Charlesdowniea columna
66 Chatangiella spp.
70 Cordosphaeridium cantharellum
35 Cordosphaeridium gracile
10 Cordosphaeridium spp.
47 Cribroperidinium cf.giuseppei
11 Cribroperidinium spp.
46 Deflandrea denticulata
50 Deflandrea oebisfeldensis
1 Deflandrea phosphoritica
27 Diphyes ficusoides
20 Diphyes pseudoficusoides
38 Dracodinium aff.varielongitudum
39 Dracodinium condylos
31 Dracodinium politum
37 Dracodinium solidum
23 Eatonicysta ursulae
45 Fibrocysta bipolaris
36 Fibrocysta spp.
78 Fungal spp.
48 Glaphyrocysta ordinata
24 Glaphyrocysta spp.
49 Heteraulacacysta leptalea?
29 Homotryblium abbreviatum
19 Homotryblium cf.pallidum
28 Homotryblium tenuispinosum
18 Hystrichokolpoma cf.cinctum
7 Hystrichokolpoma rigaudiae
21 Hystrichokolpoma spp.
26 Hystrichosphaeropsis aff.costae
43 Impagidinium spp.
71 Lentinia serrata
2 Lingulodinium machaerophorum
34 Muratodinium fimbriatum
12 Oligosphaeridium spp.
9 Operculodinium centrocarpum
5 Palaeocystodinium a costa & downie
62 Palaeocystodinium golzowense
52 Paralecaniella indentata
72 Pentadinium laticinctum
16 Pentadinium spp.
63 Phthanoperidinium comatum
65 Phthanoperidinium echinatum
61 Phthanoperidinium geminatum
13 Phthanoperidinium spp.
73 Rhombodinium glabrum
74 Rhombodinium spp.
40 Rottnestia borussica
68 Spinidinium spp.
54 Spiniferites septatus
3 Spiniferites spp.
6 Svalbardella spp.
14 Systematophora placacantha
4 Tectatodinium pellitum
17 Thalassiphora pelagica
15 Wetzeliella aff.ovalis
22 Wetzeliella articulata
53 Wetzeliella astra
64 Wetzeliella lunaris
67 Wetzeliella ovalis
33 Wetzeliella spp.

BIOSTRATIGRAPHICAL EVENTS

T: top — M: max — B: base — I: influx
+ 5-9 — ++10-24 — +++25-59 — ++++ >59

Deflandrea phosphoritica	T
Cerebrocysta poulsenii	TB
Palaeocystodinium a costa & downie	TB
Tectatodinium pellitum	TMB+++
Systematophora placacantha	T
Thalassiphora pelagica	T
Homotryblium cf.pallidum	TB
Diphyes pseudoficusoides	T
Eatonicysta ursulae	T
Wetzeliella articulata	TM++
Hystrichosphaeropsis aff.costae	TB
Cerebrocysta bartonensis	TB
Deflandrea phosphoritica	M++
Diphyes ficusoides	T
Diphyes pseudoficusoides	B
Homotryblium abbreviatum	TM+++
Homotryblium tenuispinosum	TM++
Cerebrocysta magna	T
Dracodinium politum	TB
Muratodinium fimbriatum	T
Dracodinium aff.varielongitudum	TB
Dracodinium solidum	TB
Dracodinium condylos	T
Rottnestia borussica	TB
Carpatella spp.	TMB++
Fibrocysta bipolaris	TM+++
Cerebrocysta magna	B
Deflandrea oebisfeldensis	T
Deflandrea phosphoritica	B
Diphyes ficusoides	B
Dracodinium condylos	B
Fibrocysta bipolaris	B
Heteraulacacysta leptalea?	T
Systematophora placacantha	B
Thalassiphora pelagica	M++
Paralecaniella indentata	T
Areoligera gippingensis	T+
Eatonicysta ursulae	B
Heteraulacacysta leptalea?	B
Paralecaniella indentata	M+++
Spiniferites septatus	TB
Wetzeliella articulata	B+
Areoligera gippingensis	M+++
C.speciosum glabrum	T
Deflandrea oebisfeldensis	M+
Homotryblium tenuispinosum	B
Muratodinium fimbriatum	B
Paralecaniella indentata	B+
C.speciosum glabrum	B
Deflandrea oebisfeldensis	B
Alisocysta margarita	T
Homotryblium abbreviatum	B
Alisocysta margarita	B
Areoligera gippingensis	B
Thalassiphora pelagica	B