DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2015/69

Dinocyst zonation and lithostratigraphy of the Miocene succession in the Schulensee borehole, Kiel, Germany

Karen Dybkjær

GEUS

DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2015/69

Dinocyst zonation and lithostratigraphy of the Miocene succession in the Schulensee borehole, Kiel, Germany

Karen Dybkjær

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
DANISH MINISTRY OF ENERGY,UTILITIES AND CLIMATE

GEUS

Contents

Summary

This report presents the results of a biostratigraphic analysis of the Miocene succession in the borehole Schulensee based on fossil dinoflagellate cysts (dinocysts). The borehole is located in Schulensee, south of Kiel, Germany (Fig. 1) and was drilled in 2015 using the "straight flush"-drilling method.

In a previous study from 2010, it was proven that the dinocyst zonation of Dybkjær & Piasecki (2010), defined for the Danish Miocene succession, could be applied to the Miocene succession in the Schleswig-Holstein area. A detailed and well-documented correlation between the Miocene succession in the German Westerlangstedt borehole and the succession in the southern part of Jylland, Denmark was presented.

The present study is focussed on the Miocene part of the drilled succession (221 m - 98 m) in the Schulensee borehole, and the purpose is to date the Miocene succession in more detail, to refer the succession to the dinocyst zonation of Dybkjær & Piasecki (2010), and to subdivide the succession into lithostratigraphic units.

Massive reworking of Jurassic and especially Palaeogene palynomorphs was found throughout the studied succession. In addition, a few caved dinocysts was recorded.

In spite of problems with reworking, it was possible to subdivide the studied succession into the dinocyst zonation defined by Dybkjær & Piasecki (2010). Based on the dinocyst stratigraphy, the succession was further subdivided into the lithostratigraphic units of Rasmussen et al. (2010) and correlated with the succession in the Westerlangstedt borehole and with the Danish Miocene succession.

The following dinocyst zones were found:
221 m - 173 m: The *Thalassiphora pelagica* Zone (?) - the *Sumatradinium hamulatum* Zone (uppermost Aquitanian – lower Burdigalian, Lower Miocene).
173 m - 158 m: The *Cordosphaeridium cantharellus* Zone - the *Exochosphaeridium insigne* Zone (lower to mid Burdigalian, Lower Miocene).
158 m - 152 m: The *Cousteaudinium aubryae* Zone (upper Burdigalian, Lower Miocene).
152 m - 98 m: The *Labyrinthodinium truncatum* Zone (lower Langhian, Middle Miocene).

Based on a combination of the dinocyst stratigraphy, the lithology of the samples and the geophysical log-pattern, the studied succession was subdivided into the Miocene lithostratigraphic units defined in the Danish area (Rasmussen *et al.*, 2010) (the corresponding German lithostratigraphic units are mentioned in paranthese);
1) 221 m (TD) - 200 m: The Klintinghoved Formation (= "Unterer Glimmerton")
2) 200 m - 162 m: The Bastrup Formation (= "Unterer Braunkohlensande")
3) 162 m - 151 m: The Arnum Formation (= "Frörup Horizont")
4) 151 m - 98 m: The Odderup Formation (= "Obere Braunkohlensande")

The Miocene succession is unconformably overlain by Quaternary deposits.

Introduction

In a previous study from 2010, it was proven that the dinocyst zonation of Dybkjær & Piasecki (2010), defined for the Danish Miocene succession, could be applied to the Miocene succession in the Schleswig-Holstein area. A detailed and well-documented correlation between the Miocene succession in the German Westerlangstedt borehole and the succession in the southern part of Jylland, Denmark, was presented.

The present report is based on cuttings samples from the Schulensee borehole, located in Schulensee, south of Kiel, in Germany (Fig. 1). The location of the well is shown in Figure 1.

Figure 1: Location of the Schulensee borehole, the Westerlangstedt borehole and of the Danish boreholes included in the log-correlation panel in Figure 6.

The purpose of the study was to apply the dinocyst zonation defined in the Danish area (Dybkjær & Piasecki, 2010) to the drilled Miocene succession and, based on that, to date the succession, to subdivide the succession into lithostratigraphic units and to correlate the succession with the Miocene succession in the German Westerlangstedt borehole and with the Danish Miocene succession. The results of the study are presented within the frame of the lithostratigraphy of Rasmussen *et al.* (2010) (Fig. 2) and the dinocyst zonation of Dybkjær & Piasecki (2010) (Fig. 3).

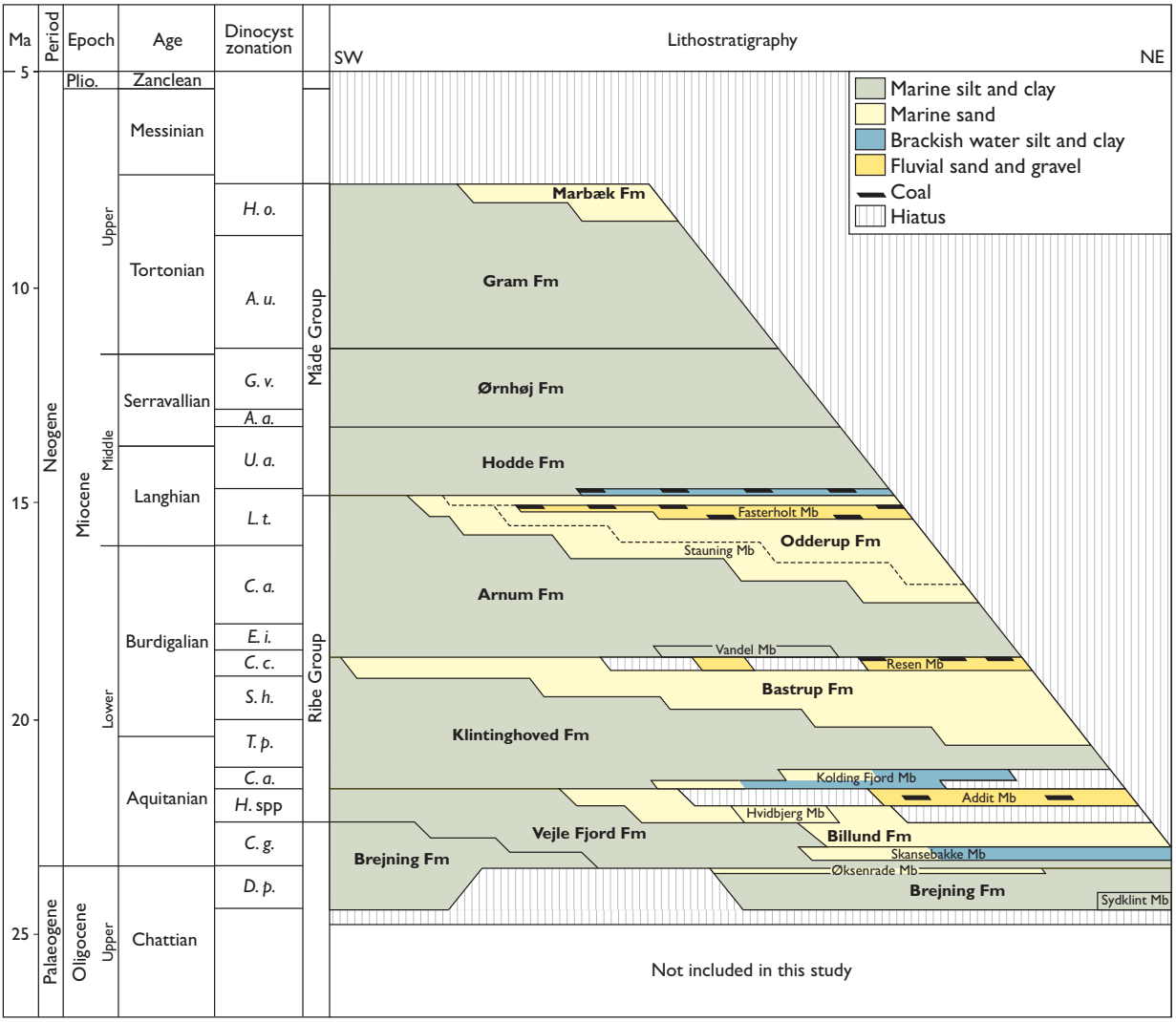

Fig. 2. Lithostratigraphy of the Danish Miocene (Rasmussen *et al.*, 2010).

Material and methods

The present report is based on cuttings samples from the German Schulensee borehole (Fig. 1). The borehole was drilled in 2015 using the “straight-flush”-drilling method. A total of 25 samples in the interval from 221 m (TD) and up to 98 m, each representing an interval of 3 m, were selected for the present palynological study. The samples were processed following standard palynological preparation methods, including treatment with HCl, HF, heavy liquid separation and brief oxygenation with HNO_3. Following sieving on 20 µm filters the organic residue was mounted on glass slides using a glycerine jelly medium. The dinoflagellate cyst (dinocyst) content was analysed using a normal light microscope. A semiquantitative analysis consisting of counting at least 200 dinocysts from each sample, were performed where possible (in some samples there were to few dinocysts). All other marine algae, acritarchs and freshwater algae observed while counting the 200 dinocysts, were registered in order to assess the abundance of dinocysts relative to these other palynomorph groups. The qualitative analysis consisted of a thorough study of two palynological slides per sample in order to register all dinocyst species occurring in each sample. The taxonomy used herein follows “The Lentin & Williams Index” (Fensome & Williams, 2008).

The results of the palynological study are presented in Enclosure 1 and 2. In Enclosure 1 the absolute abundances of *in situ* dinocysts, reworked dinocysts, reworked (Jurassic) spores and pollen, freshwater algae, acritarchs (AC), other marine algae (OM) and fungi are shown. The variations in these assemblages reflect partly stratigraphic changes and partly changes in the depositional environment, e.g. in salinity, nutrient availability and sea water temperature. Dinocyst taxa interpreted as a result of caving (downfall of material from younger strata during the drilling process) are marked with a ”C”. Occurrences marked with a ”?” indicate that the identification to species or genus level is questionable. Variations in the relative abundances within the presumed “*in situ*” dinocyst group are presented in Enclocure 2.

Based on first- and last occurrences of stratigraphically important species (”events”) the studied succession is subdivided into the dinocyst zonation defined by Dybkjær & Piasecki (2010) (Figs. 3, 4; Enclosures 1, 2). Furthermore, the succession is correlated with the Danish Miocene lithostratigraphic units (Rasmussen *et al.*, 2010) (Figs. 2, 5). A log-correlation panel running north-south, from the Danish Rødding borehole to the Kiel, WW Schulensee - GWM 63 borehole, is presented in Figure 6 in order to illustrate the straight forward correlation.

In the text, dinocyst taxa which comprise more than 10% of the total number of dinocysts are ”dominant”, 5-10% are ”common”, 2-4% are frequent and an occurrence of less than 2% are ”sporadic” or ”consistent”, depending on whether the taxa in question occurs only in a few of the samples representing the described interval, or if it occurs in most of the samples.

Palynology/biostratigraphy

The results of the palynological analysis are presented in Figure 4 and in Enclosures 1 and 2 and are discussed below.

The *Thalassiphora pelagica* Zone? - *Sumatradinium hamulatum* Zone, 221 m - 173 m

Dinocyst zonation

Based on the only sporadic occurrences of *Homotryblium* spp. and the absence of *Caligodinium amiculum* in the lower part of the studied succession, combined with the first occurrence of *Exochosphaeridium insigne* at 173 m, the interval from 221 m (TD) up to 173 m is referred to the *Thalassiphora pelagica* Zone and/or the *Sumatradinium hamulatum* Zone. This is supported by the dominance of *Impletosphaeridium insolitum* (see Dybkjær & Piasecki 2010). Due to the massive reworking, it is not possible to subdivide this interval into each of these two zones, or to decide if they are both present.

Thalassiphora pelagica, defining the upper boundary of the *T. pelagica* Zone, is present in low numbers up through most of the studied succession. Although it in the range charts (Enclosure 1 and 2) is indicated as having its last occurrence at 203 m with the occurrences above being due to reworking, the occurrences below 206 m may also be a result of reworking. It is thus not possible to decide if the *T. pelagica* Zone is present or not. Neither is the first occurrence of *Sumatradinium hamulatum* of any use. Due to a very sporadic occurrence, it appears at 158 m, at the base of the *Cousteaudinium aubryae* Zone, which is far too high.

Dinocyst assemblage

The rather limited *in situ* dinocyst assemblage is dominated by *Hystrichokolpoma rigaudiae*, *Impletosphaeridium insolitum*, *Operculodinium centrocarpum* and *Spiniferites* spp., while *Apteodinium australiense*, *Cordosphaeridium cantharellus*, *Dapsilidinium pseudo-colligerum*, and *Lingulodiniumpiniferites machaerophorum* are common (Enclosure 2). In the lowermost sample (221-218 m), *Dapsilidinium pseudocolligerum* are dominant.

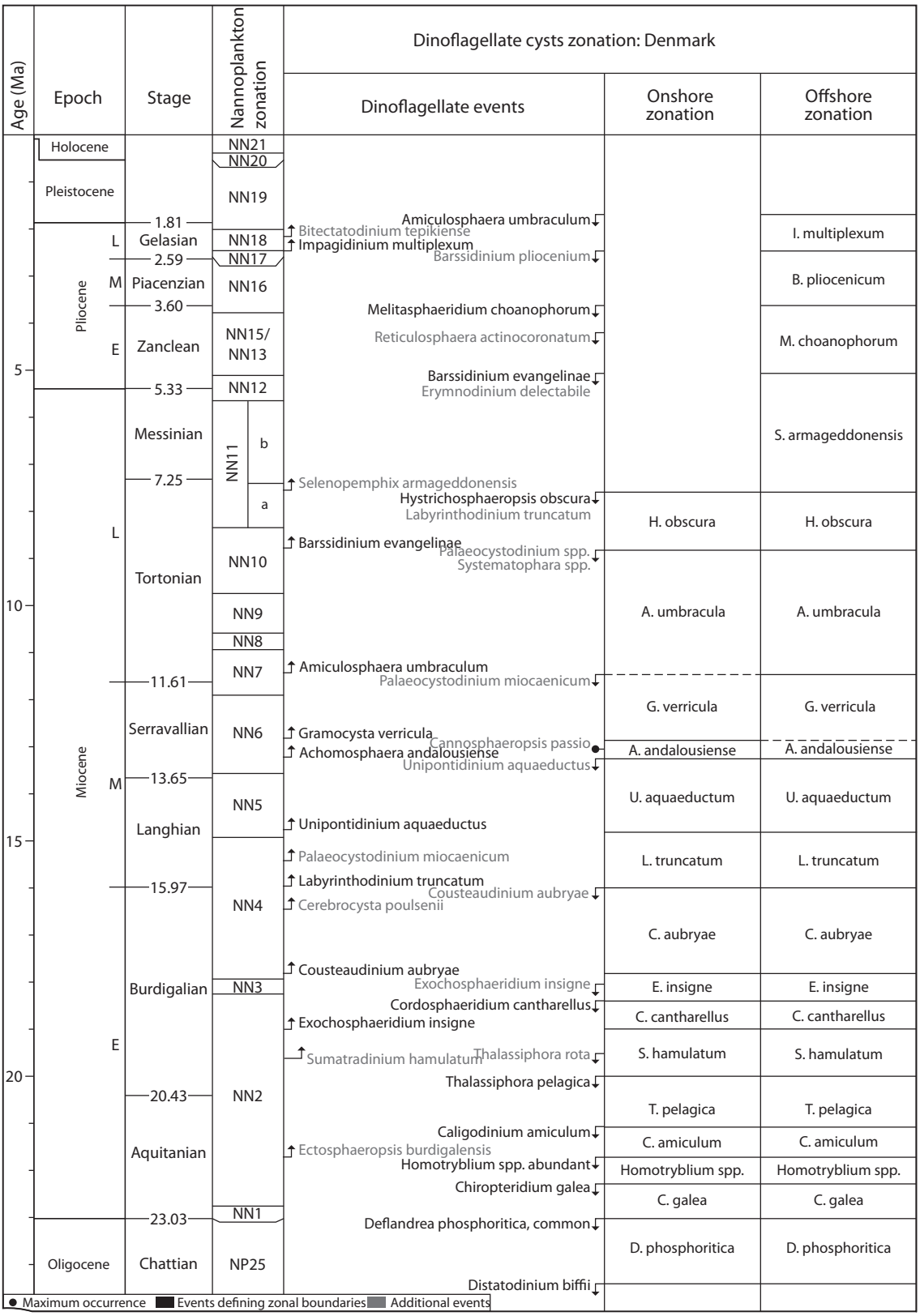

Figure 3: Dinocyst zonation (Dybkjær & Piasecki 2010). The species names shown in black marks the events (first or last occurrences, or abundance occurrences) defining the zonal boundaries. The species names shown in grey are additional stratigraphically usefull events.

Reworking of palaeogene deposits is indicated by the presence of e.g. *Apectodinium augustum*, *Areoligera gippingensis*, *Eatonicysta ursulae*, *Deflandrea* spp., *Diphyes* spp. and *Wetzeliella* spp. Reworking of Jurassic deposits are indicated by the presence of e.g. *Chasmatosporites hians* and *Corollina torosus*, see further Enclosure 1. Caving during the drilling process is indicated by the presence of e.g. *Cousteaudinium aubryae*, *Habibacysta tectata* and *Labyrinthodinium truncatum*.

Age
Latest Aquitanian? – early Burdigalian (Early Miocene) (Fig. 3).

Depositional environment
The somewhat limited *in situ* dinocyst assemblage combined with abundant reworked dinocysts and a very high abundance of freshwater algae (especially *Pediastrum*) indicate a shallow marine depositional environment with a very high influx of freshwater from nearby rivermouths and/or land areas. This is supported by abundant terrestrial plant remains, i.e. wood-particles, cuticles and non-saccate and bisaccate pollen in the samples.

Lithostratigraphy
Based on a combination of the dinocyst stratigraphy, the geophysical log pattern and the lithology of the samples, the lower part of this interval (from TD at 221 m up to approximately 200 m) is correlated with the Danish Klintinghoved Formation, while the upper part (200 m - 173 m) is correlated with the Bastrup Formation (Figs. 2, 4 and 5).

The *Cordosphaeridium cantharellus* Zone – *Exochosphaeridium insigne* Zone, 173 m - 158 m

Dinocyst zonation
The lower part of this interval is referred to the *Cordosphaeridium cantharellus* Zone (Dybkjær & Piasecki 2010) due to the first occurrence of *Exochosphaeridium insigne* in the sample at 173-170 m. The upper part, up to the first presumed *in situ* occurrence of *Cousteaudinium aubryae* in the sample at 158-155 m, is referred to the *Exochosphaeridium insigne* Zone. *Cordosphaeridium cantharellus* is the marker species separating these two zones, but as *Cordospaheridium cantharellus*, due to reworking, occur up through all of the studied succession (Enclosure 1), it is not possible to use this last occurrence and thus to locate the boundary between the two zones. In the range charts the last *in situ* occurrence of *Cordosphaeridium cantharellus* is arbitrarily indicated at 173 m, while the occurrences recorded above 173 m are to be found in the panel with reworked specimens.

Dinocyst assemblage
The dinocyst assemblage is very sporadic, and it was not possible to count 200 *in situ* specimens in any of the samples in this interval. The assemblage is dominated by *Hystrichokolpoma rigaudiae*, *Operculodinium centrocarpum* and *Spiniferites* spp. *Dapsilidinium pseudocolligerum/pastielsii* and *Melitasphaeridium choanophorum* are common (Enclosure 2).

Reworking of Palaeogene deposits is indicated by the presence of e.g. *Apectodinium* spp.*, Areoligera gippingensis, Deflandrea* spp., *Glaphyrocysta pastielsii* and *Wetzeliella gochtii* (Enclosure 1). No reworked Jurassic palynomorphs were recorded from this interval.
Caving is indicated by the presence of *Habibacysta tectata* in the sample at 161-158 m.

Age
Early to mid Burdigalian (Early Miocene) (Fig. 3).

Depositional environment
The organic particles from this interval are strongly dominated by wood particles, partly degraded vitrinite, cuticle and fungi spores and hyphae. Only a very limited *in situ* dinocyst assemblage was found, while the fresh- to brackish water algae *Botryococcus* and the freshwater algae *Pediastrum* occur in high numbers (Enclosure 1). These observations indicate a nearshore marine depositional environment, probably close to Taxodium swamp areas, and strongly influenced by freshwater run-off from land.

Lithostratigraphy
Based on a combination of the dinocyst stratigraphy, the geophysical log pattern and the lithology of the samples, the lower part of this interval (up to 162 m) is correlated with the Danish Bastrup Formation, while the upper part (162 m-158 m) is correlated with the Arnum Formation (Figs. 2, 4 and 5).

The *Cousteaudinium aubryae* Zone, 158 m - 152 m

Dinocyst zonation
This interval is referred to the C*ousteaudinium aubryae* Zone (Dybkjær & Piasecki 2010) due to the combined last occurrence of *E. insigne* and first occurrence of *Cousteaudinium aubryae* in the sample at 158-155 m and the first occurrence of *Labyrinthodinium truncatum* in the sample at 152-149 m (Enclosure 1). This is further supported by the first occurrence of *Cerebrocysts poulsenii* in the sample at 155-152 m.

Dinocyst assemblage
The abundance and diversity of dinocysts are clearly higher than in the interval below. The assemblage is dominated by *Operculodinium centrocarpum* and *Spiniferites* spp., while *Apteodinium australiense, Dapsilidinium pseudocolligerum* and *Hystrichokolpoma rigaudiae* are common (Enclosure 2).

Massive reworking of Palaeogene deposits is indicated by the high numbers of e.g. *Apectodinium* spp., *Areoligera gippingensis*, *Diphyes ficusoides*, *Deflandrea* spp., *Hystrisphaeridium tubiferum* and *Wetzeliella* spp. (Enclosure 1).

Age
Late Burdigalian (Early Miocene) (Fig. 3).

Depositional environment
This interval is characterised by a relatively rich dinocyst assemblage combined with relatively sparse occurrences of freshwater algae. In addition, high abundances of wood

particles, partly degraded vitrinite and some cuticle were observed. The interval is interpreted as representing a nearshore marine depositional setting with less freshwater influx than the intervals below.

Lithostratigraphy

Based on a combination of the dinocyst stratigraphy, the geophysical log pattern and the lithology of the samples, this interval is correlated with the Danish Arnum Formation (Figs. 2, 4 and 5).

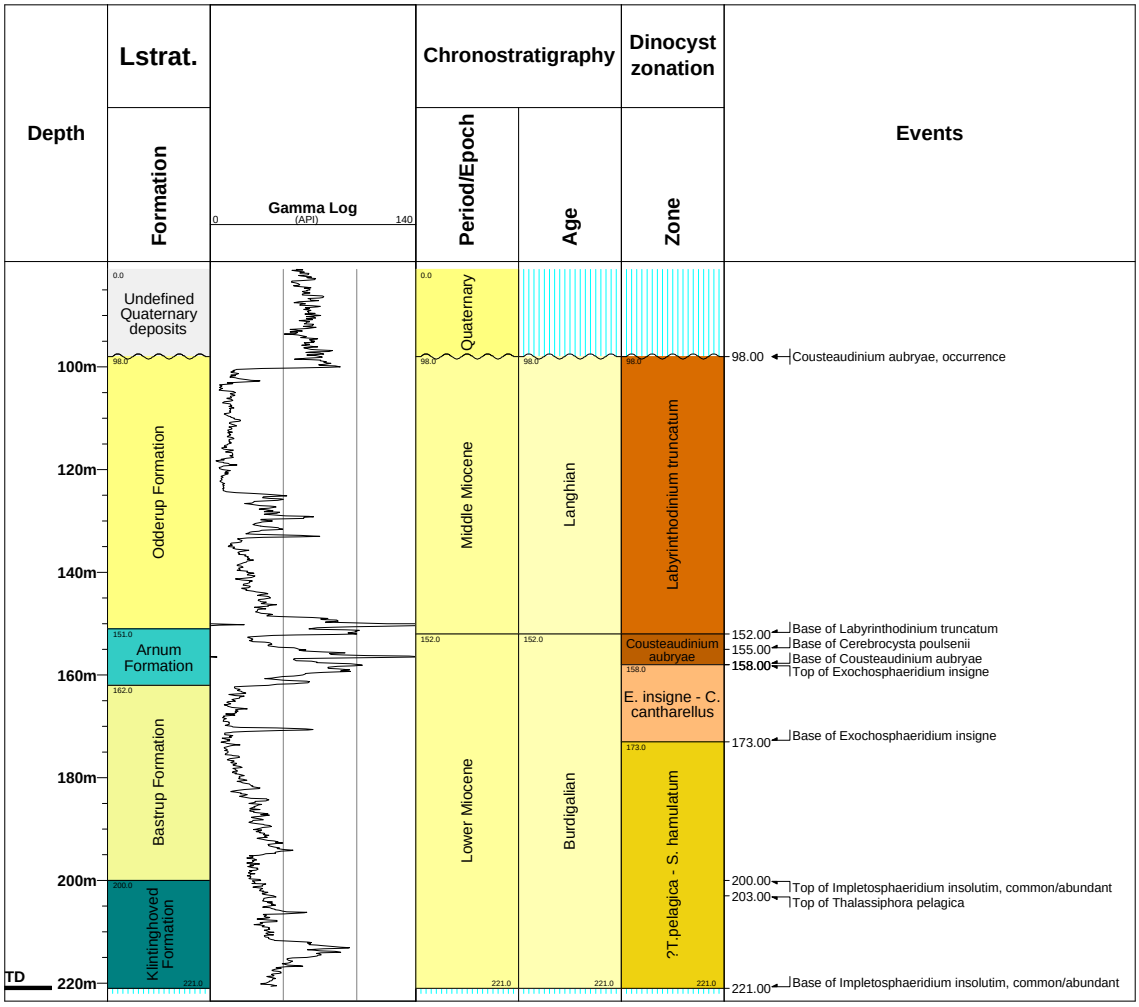

Figure 4: Stratigraphic summary for the Schulensee borehole.

The *Labyrinthodinium truncatum* Zone, 152 m - 98 m

Dinocyst zonation

This interval is referred to the *Labyrinthodinium truncatum* Zone (Dybkjær & Piasecki 2010) due to the first presumed *in situ* occurrence of *Labyrinthodinium truncatum* in the sample at 152-149 m combined with the presence of *Cousteaudinium aubryae* up through the whole interval (Enclosure 1).

Dinocyst assemblage

The abundance and diversity of dinocysts varies within the interval with very sporadic dinocyst recordings in the samples at 125-122 m and 122-119 m. The *in situ* assemblage is dominated by *Operculodinium centrocarpum* and *Spiniferites* spp., while *Apteodinium australiense*, *Dapsilidinium pseudocolligerum*, *Hystrichokolpoma rigaudiae* and *Polysphaeridium zoharyi* are common (Enclosure 2).

Massive reworking of Palaeogene deposits is, also in this interval, indicated by high numbers of e.g. *Apectodinium* spp., *Areoligera gippingensis*, *Diphyes ficusoides*, *Deflandrea* spp., *Hystrisphaeridium tubiferum* and *Wetzeliella* spp. In addition, reworked specimens referred to *Cordosphaeridium cantharellus*,is common in the uppermost part of this interval (Enclosure 1).

Reworking of Jurassic deposits is indicated by the recording of a single specimen of *Callialasporites dampieri* in the sample at 113-110 m.

Age

Early Langhian (Middle Miocene) (Fig. 3).

Depositional environment

The abundances of *in situ* dinocysts within this interval are variable, with very low numbers in the samples at 125-122 m and 122-119 m, especially in the latter. In contrast, fungi and *Botryococcus* are abundant in these two samples. The interval is interpreted as representing a nearshore marine depositional setting with a high freshwater influx, especially in the interval from 125 m - 119 m. This is supported by high abundances of wood particles, partly degraded vitrinite and cuticle.

Lithostratigraphy

Based on a combination of the dinocyst stratigraphy, the geophysical log pattern and the lithology of the samples, this interval is correlated with the Danish Odderup Formation (Figs. 2, 4 and 5).

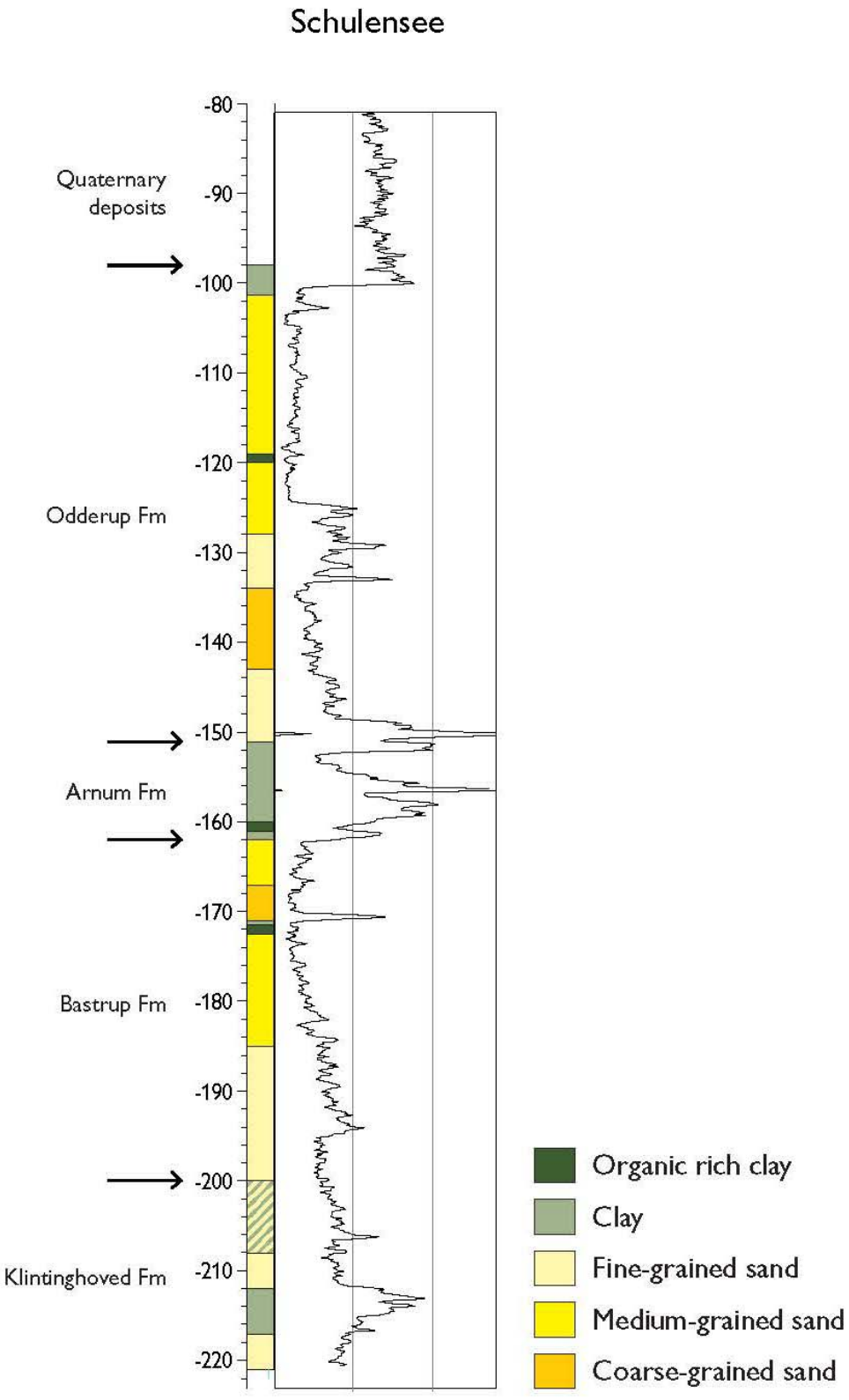

Figure 5: Correlation between the Miocene succession in the Schulensee borehole and the Danish lithostratigraphy of Rasmussen *et al.* (2010).

Conclusion

The dinocyst zonation of Dybkjær & Piasecki (2010), developed for the Danish Miocene succession was successfully applied to the studied succession from the Schulensee borehole. The following dinocyst zones were found:

221 m - 173 m: The *Thalassiphora pelagica* Zone (?) - the *Sumatradinium hamulatum* Zone (uppermost Aquitanian – lower Burdigalian, Lower Miocene).
173 m - 158 m: The *Cordosphaeridium cantharellus* Zone - the *Exochosphaeridium insigne* Zone (lower to mid Burdigalian, Lower Miocene).
158 m - 152 m: The *Cousteaudinium aubryae* Zone (upper Burdigalian, Lower Miocene).
152 m - 98 m: The *Labyrinthodinium truncatum* Zone (lower Langhian, Middle Miocene).

Massive reworking of especially Palaeogene palynomorphs was observed up through all of the studied succession. Minor caving of upper Burdigalian and Middle Miocene deposits was observed in the lower (uppermost Aquitanian – lower Burdigalian) part of the succession.

Based on a combination of the dinocyst stratigraphy, the lithology of the samples and the geophysical log-pattern, the studied succession can be subdivided into the following Miocene lithostratigraphic units, following the lithostratigraphy defined in the Danish area (Rasmussen *et al.*, 2010) (the corresponding German lithostratigraphic unit is mentioned in paranthese);

1) 221 m (TD) - 200 m: The Klintinghoved Formation (= “Unterer Glimmerton”)
2) 200 m - 162 m: The Bastrup Formation (= “Unterer Braunkohlensande”)
3) 162 m - 151 m: The Arnum Formation (= “Frörup Horizont”)
4) 151 m - 98 m: The Odderup Formation (= “Obere Braunkohlensande”)

The Miocene succession is unconformably overlain by Quaternary deposits.

The studied succession was inserted in a log-correlation panel striking north-south, from the Danish Rødding borehole to the Schulensee borehole (Fig. 6). Except for the distinctly thicker succession in the Tinglev borehole, located within the Tønder Graben, the thicknesses of the Miocene formations in the Danish boreholes and the Schulensee borehole are comparable and the correlation is straight forward.

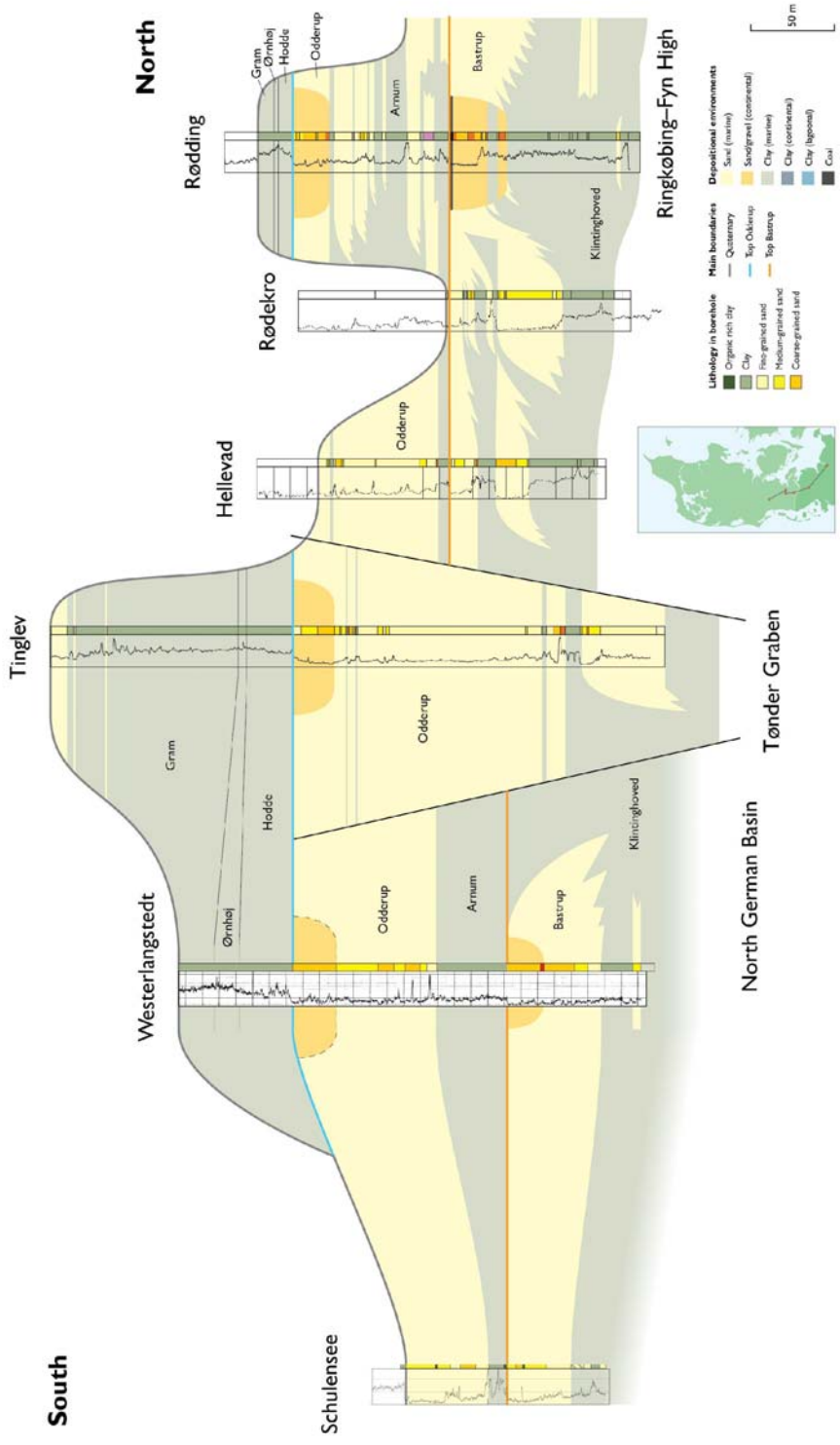

Figure 6: Log-correlation panel showing the Miocene succession in the boreholes; Rødding, Rødekro, Hellevad, Tinglev, Westerlangstedt and Schulensee. Notice how the Tønder Graben results in a distinct thickening of the Odderup Formation in the Tinglev borehole.

References

Dybkjær, K. & Piasecki, S., 2010: Neogene dinocyst zonation for the eastern North Sea Basin, Denmark. Review of Palaeobotany and Palynology **161**, 1–29.

Rasmussen, E.S., Dybkjær, K. & Piasecki, S., 2010: Lithostratigraphy of the Upper Oligocene – Miocene succession in Denmark. Geological Survey of Denmark and Greenland Bulletin **22**, 92pp.

Enclosures

Enclosure 1: Rangechart for the Schulensee borehole. The chart presents; the lithostratigraphic subdivision (based on the Danish lithostratigraphy by Rasmussen et al., 2010), the chronostratigraphy, the dinocyst zonation (Dybkjær & Piasecki, 2010), the dinocyst events, the absolute abundances of the recorded *in situ* and caved dinocyst species, the presumed reworked dinocysts, the presumed reworked Jurassic spores and pollen, the freshwater algae, acritarchs (AC), other marine algae (OM) and fungi. Occurrences marked by a ”C” means that it is interpreted as being the result of caving. Occurrences marked by a ”?” means that the indentification of the specimen to species or genus is questionable.

Enclosure 2: Rangechart for the Schulensee borehole. The chart presents; the lithostratigraphic subdivision (based on the Danish lithostratigraphy by Rasmussen et al., 2010), the chronostratigraphy, the dinocyst zonation (Dybkjær & Piasecki, 2010), the dinocyst events and the relative abundances of the recorded *in situ* and caved dinocyst species. Occurrences marked by a ”C” means that it is interpreted as being the result of caving. Occurrences marked by a ”?” means that the indentification of the specimen to species or genus is questionable.

Well Name : Schulensee

Interval : 81m - 222m
Scale : 1:1000
Chart date: 30 September 2015 **Karen Dybkjær**

GEUS

Enclosure 1

Depth | Lithostratigraphy: Formation | Gamma Log (API) | Chronostratigraphy: Period/Epoch, Age | Dinocyst zonation: Zone | Events | Samples

Undefined Quaternary deposits
Odderup Formation
Arnum Formation
Bastrup Formation
Kristianstad Formation
TD 220m

Quaternary | Middle Miocene | Lower Miocene
Langhian | Burdigalian

Labyrinthodinium truncatum
Cousteaudinium aubryae
E. insigne - C. cantharellus
?? pelagica - S. hamulatum

98.00 ← Cousteaudinium aubryae, occurrence
152.00 ←/Base of Labyrinthodinium truncatum
155.00 ←/Base of Cerebrocysta poulsenii
158.00 ←/Top of Exochosphaeridium insigne
173.00 ←/Base of Exochosphaeridium insigne
200.00 ←/Top of Impletosphaeridium insolitum, common/abundant
203.00 ←/Top of Thalassiphora pelagica
221.00 ←/Base of Impletosphaeridium insolitum, common/abundant

Samples: 98-101, 101-104, 110-113, 119-122, 122-125, 125-128, 146-149, 149-152, 152-155, 155-158, 158-161, 161-164, 170-173, 185-188, 188-191, 191-194, 194-197, 197-200, 200-203, 203-206, 206-209, 209-212, 212-215, 215-218, 218-221

Dinoflaggellate Cysts

Absolute abundance (30mm=100 counts)
In-Situ,Caved,'f' occurrences

Achomosphaera alcicornu
Achomosphaera andalousiensis
Achomosphaera ramulifera
Apteodinium australiense
Apteodinium cf. australiense
Apteodinium spiridoides
Apteodinium tectatum
Batiacasphaera sphaera
Batiacasphaera subtilis
Cerebrocysta poulsenii
Cleistosphaeridium placacanthum
Cleistosphaeridium polypes
Cleistosphaeridium polypes/placacanthum
Cleistosphaeridium placacanthum
Cordosphaeridium cantharellus
Cordosphaeridium gracile
Cousteaudinium aubryae
Dapsilidinium pseudocolligerum/pastielsii
Deflandrea spp.
Exochosphaeridium insigne
Exochosphaeridium phosphoritica
Habibacysta tectata
Heteraulacacysta campanula
Homotryblium plectilum
Homotryblium tenuispinosum
Labyrinthodinium truncatum
Lingulodinium machaerophorum
Membranosphaeridium aspinatum
Operculodinium centrocarpum
Polysphaeridium zoharyi
Spiniferites pseudofurcatus
Spiniferites ramosus
Spiniferites spp.
Tectatodinium pellitum
Unidentifiable dinoflagellate cysts
Wetzeliella gochtii
Wetzeliella spp.

Dinoflaggellate Cysts

Absolute abundance (30mm=100 counts)
Reworked,'r' occurrences

Achomosphaera andalousiensis
Achomosphaera ramulifera
Alisocysta spp.
Apectodinium augustum
Apectodinium spp.
Areoligera gippingensis
Areoligera cf. senonensis
Areoligera spp.
Caligodinium amiculum
Charlesdowniea spp.
Chiropteridium spp.
Cleistosphaeridium placacanthum
Cordosphaeridium cantharellus
Cordosphaeridium gracile
Cordosphaeridium spp.
Dapsilidinium spp.
Deflandrea heterophylyta
Deflandrea oebisfeldensis
Deflandrea spp.
Diphyes ficusoides
Diphyes spp.
Eatonicysta ursulae
Enneadocysta arcuata/pectiniformis Group
Exochosphaeridium insigne
Hystrichosphaeridium tubiferum
Spiniferites crassivariabilis
Spiniferites spp.
Thalassiphora pelagica
Impagidinium velorium
Nematosphaeropsis spp.
Palaeocystodinium golzowense
Palaeocystodinium minor
Palaeocystodinium spp.
Palaeoperidinium pyrophorum
Pyxidinopsis psilatum
Samlandinium hamulatum
Achomosphaera ramulifera
Homotryblium plectilum
Operculodinium spp.
Batiacasphaera sphaera
Batiacasphaera subtilis
Operculodinium sp. 3 de Vertuil & Norris 199
Cleistosphaeridium ancoriferum/placacanthum
Dinopterygium cladoides
Erichosphaeridium insigne
Heteraulacacysta campanula
Hystrichosphaeridium cf. tubiferum
Cordosphaeridium cantharellus
Spiniferites crassivariabilis
Impletosphaeridium insolitum
Nematosphaeropsis spp.
Palaeocystodinium golzowense
Palaeocystodinium minor
Apteodinium spiridoides
Pyxidinopsis psilatum
Distatodinium paradoxum
Thalassiphora pelagica
Impagidinium velorium

Spores And Pollen

*1
Caliaiasporites dampieri
Caliaiasporites tribolatus
Cerebropollenites macroverrucosus
Chasmatosporites hians
Cicatricosisporites sp.
Concavissimisporites sp.
Quadraecullina anellaeformis

Freshwater Algae

Absolute abundance (30mm=100 counts)
In-Situ,Caved,'f' occurrences

Botryococcus spp.
Lecaniella spp.
Mougeotia laeteverens
Oocystes spp.
Pediastrum spp.
Pseudoschizaea aff. granulata
Tetraporina spp.

AC: *2 *3
OM: *1 *3
Fungi: *1 In-Situ,Caved,'f' occurrences

Botryococcus spp.
Acritarch type 1, long granular process
Lecaniella spp.
Large spheres
Tasmanites spp.
Fungal spp.

Well Name : Schulensee

Interval : 81m - 222m

Scale : 1:1000

Chart date: 02 October 2015 Karen Dybkjær

GEUS

Enclosure 2

Depth

Lithostratigraphy

Formation

Gamma Log (API) 0 140

Chronostratigraphy

Period/Epoch

Age

Dinocyst zonation

Zone

Events

Samples

Dinoflagellate Cysts

% within panel (30mm=100%)
In-Situ; Caved; ? occurrences

Undefined Quaternary deposits

Odderup Formation

Arnum Formation

Bastrup Formation

Klintinghoved Formation

Quaternary

Middle Miocene

Lower Miocene

Langhian

Burdigalian

Labyrinthodinium truncatum

Cousteaudinium aubryae

E. insigne - C. cantharellus

?T.pelagica - S. hamulatum

98.00 Cousteaudinium aubryae, occurrence

152.00 Base of Labyrinthodinium truncatum

155.00 Base of Cerebrocysta poulsenii

158.00 Base of Cousteaudinium aubryae
Top of Exochosphaeridium insigne

173.00 Base of Exochosphaeridium insigne

200.00 Top of Impletosphaeridium insolutim, common/abundant

203.00 Top of Thalassiphora pelagica

221.00 Base of Impletosphaeridium insolutim, common/abundant

TD

1 Achomosphaera alcicornu
35 Achomosphaera ramulifera
2 Apteodinium australiense
3 Apteodinium cf. australiense
66 Apteodinium spindoides
4 Apteodinium tectatum
38 Barssidinium evangelineae
27 Batiacasphaera spp.
39 Bitectatodinium raedwaldii
5 Cerebrocysta poulsenii
42 Cleistosphaeridium ancorae/placacanthum
7 Cleistosphaeridium placacanthum
49 Cordosphaeridium cantharellus
8 Cousteaudinium aubryae
9 Dapsilidinium pseudocolligerum/pastielsii
44 Dinopterygium cladoides
74 Distatodinium paradoxum
45 Exochosphaeridium insigne
10 Habibacysta tectata
46 Heteraulacacysta campanula
36 Homotryblium plectilum
11 Homotryblium tenuispinosum
12 Hystrichokolpoma rigaudiae
13 Hystrichosphaeropsis obscura
47 Hystrichosphaeropsis cf. obscura
14 Impagidinium spp.
91 Impagidinium velorum
54 Impletosphaeridium insolitum
15 Invertocysta lacrymosa
16 Labyrinthodinium truncatum
17 Lingulodinium machaerophorum
18 Melitasphaeridium choanophorum
28 Mini dino spp.
29 Nematosphaeropsis labyrinthus
55 Nematosphaeropsis spp.
19 Operculodinium centrocarpum
30 Operculodinium piaseckii
40 Operculodinium sp. 3 de Verteuil & Norris 199
37 Operculodinium spp.
56 Palaeocystodinium golzowense
31 Palaeocystodinium minor
33 Palaeocystodinium spp.
62 Pentadinium laticinctum "minor"
32 Pentadinium laticinctum laticinctum
20 Polysphaeridium zoharyi
70 Pyxidinopsis psilatum
51 Spiniferites crassivariabilis
21 Spiniferites pseudofurcatus
22 Spiniferites solidago
23 Spiniferites spp.
24 Tectatodinium pellitum
75 Thalassiphora pelagica
26 Unidentifiable dinoflagellate cysts

Sample: depth is BASE of depth range