DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2016/14

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Contents

Summary

This report presents the results of a biostratigraphic analysis of the Miocene succession in the borehole Schillsdorf based on fossil dinoflagellate cysts (dinocysts). The borehole is located southeast of the village Schillsdorf, east of Neumünster, Germany (Fig. 1) and was drilled in 2015 using the “straight flush”-drilling method.

In previous studies from 2010 and 2015, respectively, 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 in Dybkjær & Rasmussen (2010). In Dybkjær (2015) a borehole at Schulensee were likewise dated and correlated with the Danish Miocene succession and with the Westerlangstedt borehole.

The purpose with the present study is to date the Miocene part of the drilled succession in the Schillsdorf borehole, to refer the succession to the dinocyst zonation of Dybkjær & Piasecki (2010), and to subdivide the succession into lithostratigraphic units. Unfortunately, only the lower part of the supposed Miocene succession (from 114 m and downwards) was sampled, as the interval from 78 m and down to approxiamtely 110 m previously was interpreted as being part of the Quaternary.

The sampled Miocene part of the studied succession (187 m - 114 m) is subdivided into the dinocyst zonation defined by Dybkjær & Piasecki (2010). Based on the dinocyst stratigraphy combined with the lithology and the gamma ray log pattern, the succession was further subdivided into the lithostratigraphic units of Rasmussen et al. (2010) and correlated with the succession in the Schulensee borehole, the Westerlangstedt borehole and with the Danish Miocene succession. The Miocene succession unconformably overlies Rupelian to lower Chattian clay, referred to dinocyst zone D14 of Köthe (1990; 2003). Minor reworking of Jurassic and especially Palaeogene palynomorphs was found throughout the studied succession. In addition, a few caved dinocysts were recorded.

The following dinocyst zones were found:
204 m - 187 m: D14
187 m - 181 m: The *Homotryblium* spp. Zone
181 m - 175 m: The *Caligodinium amiculum* Zone
175 m - 172 m: The *Thalassiphora pelagica* Zone
172 m - 114 m: The *Sumatradinium hamulatum* Zone

The Miocene succession thus comprises the interval from the lower Aquitanian to the lower Burdigalian, Lower 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) 187 m - 181 m: The Vejle Fjord Formation (=”Unterer Glimmerton”)

2) 181 m - 150 m: The Klintinghoved Formation (= “Unterer Glimmerton”)
3) 150 m - 145 m: The Bastrup Formation (= “Unterer Braunkohlensande”)
4) 145 m - 134 m: The Klintinghoved Formation (= “Unterer Glimmerton”)
5) 134 m - 120 m: The Bastrup Formation (= “Unterer Braunkohlensande”)
6) 120 m - 105 m: The Klintinghoved Formation (= “Unterer Glimmerton”)
7) 105 m - 100 m: The Stauning Member of the Odderup Formation (= “Obere Braunkohlensande”)
8) 100 m - 78 m: The Odderup Formation (= “Obere Braunkohlensande”)

The Miocene succession is unconformably overlain by Quaternary deposits.

Introduction

Two previous studies, Dybkjær (2010) (the Westerlangstedt borehole) and Dybkjær (2015) (the Schulensee borehole), respectively, proves that the dinocyst zonation of Dybkjær & Piasecki (2010), defined for the Danish Miocene succession, is applicable to the Miocene succession in the Schleswig-Holstein area.

The present report is based on cuttings samples from the Schillsdorf borehole, located southeast of the village Schillsdorf, east of Neumünster, Germany. The location of the borehole is shown in Figure 1. The borehole was drilled in 2015 using the “straight flush”-drilling method.

Figure 1: Location of the Schillsdorf borehole, 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 boreholes; Westerlangstedt and Schulensee, 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).

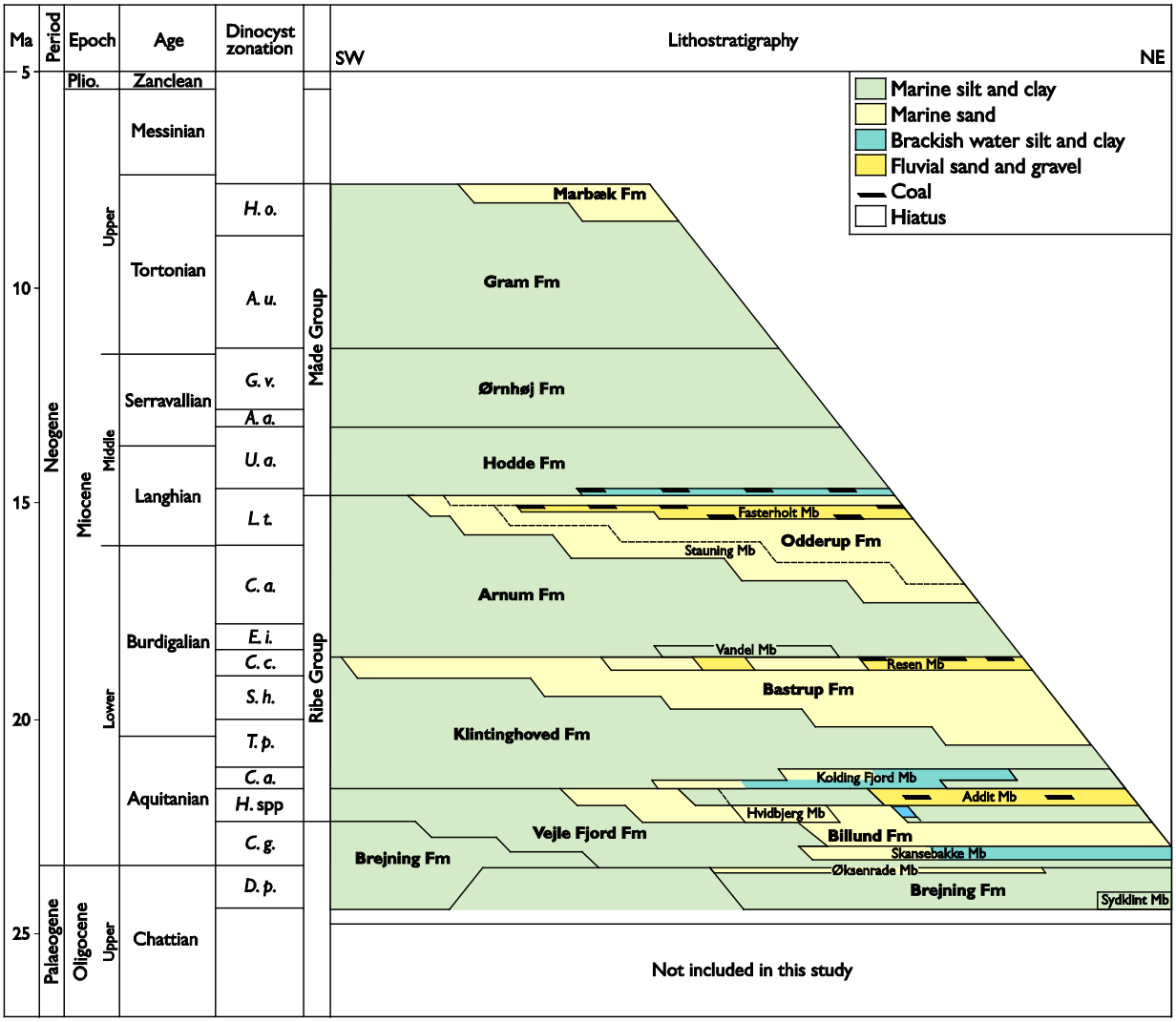

Fig. 2. Lithostratigraphy of the Danish Miocene (Rasmussen *et al.*, 2010).

Material and methods

The present report is based on cuttings samples from the German Schillsdorf borehole (Fig. 1). The borehole was drilled in 2015 using the “straight-flush”-drilling method. A total of 25 samples in the interval from 204 m (TD) and up to 114 m were selected for the present palynological study. Each sample represents an interval of 1.5 m, except for the sample at 144 - 147 m, which represents an interval of 3 m. 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, also the rare ones. 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 Schillsdorf borehole, is presented in Figure 6 in order to illustrate the suggested 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 D14 Zone, 204 m - 187 m

Dinocyst zonation

Based on the occurrence of *Chiropteridium galea* in the lowermost sample at 204 m - 202.5 m combined with the occurrences of *Chiropteridium lobospinosum* and *Wetzeliella gochtii* in the sample at 189 m - 187.5 m, the interval from 204 m - 187 m are referred to the dinocyst zone D14 of Köthe (1990; 2003). This is supported by the last occurrence of *Rhombodinium draco* in the sample at 192 m - 190.5 m.

Dinocyst assemblage

The dinocyst assemblage is dominated by *Dapsilidinium pseudocolligerum* and *Spiniferites* spp., while *Hystrichokolpoma rigaudiae*, *Operculodinium centrocarpum* and *Lingulodinium machaerophorum* are common.

Age

Rupelian to earliest Chattian.

Depositional environment

The dinocyst assemblage is abundant and diverse. Bisaccate pollen are common, while wood fragments are sporadic. Freshwater algae, non-saccate pollen and acritarchs occur very sporadic. Together this indicates a fully marine depositional environment with a large distance to freshwater influx.

Lithostratigraphy

The D14 dinocyst zone of Köthe (1990; 2003) correlates with the Danish Hvorslev Clay (D14na) and Branden Clay (D14nb) (Sliwinska et al. 2012). These lithostratigraphic units correlates with the German Rupel Clay and Chatt silt (Doornenbal & Stevenson 2010).

The *Homotryblium* spp. Zone, 187 m - 181 m

Dinocyst zonation

Based on the abundance of *Homotryblium* spp., the interval from 187 m up to 183 m is referred to the *Homotryblium* spp. Zone. This is supported by the last occurrence of *Caligodinium amiculum* in the sample at 177 m.

Dinocyst assemblage

The dinocyst assemblage is dominated by *Homotryblium plectilum* and *Spiniferites* spp., while *Apteodinium* cf. *australiense*, *Cleistosphaeridium placacanthum*, *Cordosphaeridium cantharellus*, *Dapsilidinium pseudocolligerum*, *Hystrichokolpoma rigaudiae*, *Operculodinium centrocarpum*, *Lingulodinium machaerophorum* and *Polysphaeridium zoharyi* are common (Enclosure 2).

Age
Early Aquitanian (Early Miocene) (Fig. 3).

Depositional environment
The dinocyst assemblage is less abundant and less diverse than in the samples below. The dominance of *Homotryblium* spp. within the dinocyst assemblage indicates a low-salinity depositional environment (Brinkhuis 1994; Dybkjær 2004). This is supported by the presence of the fresh- to brackish water algae, *Botryococcus*. The presence of the acritarch taxa *Paralecaniella indentata* and *Cyclopsiella granosa* indicate a shallow marine setting.
Non-saccate pollen and wood particles are common, while freshwater algae are very sporadic. These data indicate a marine, low-salinity depositional environment with some distance to freshwater influx (river mouths), but less than for the interval below.

Lithostratigraphy
Based on a combination of the dinocyst stratigraphy, the geophysical log pattern and the lithology of the samples, this interval (from 187 m – 181 m) is correlated with the Danish Vejle Fjord Formation (Figs. 2, 4 and 5).

The *Caligodinium amiculum* Zone, 181 m - 175 m

Dinocyst zonation

Based on the last occurrence of *Caligodinium amiculum* in the sample at 177 m - 175.5 m combined with only sporadic occurrences of *Homotryblium* spp., the interval from 181 m - 175 m is referred to the *Caligodinium amiculum* Zone. This is supported by the last occurrence of *Thalassiphora pelagica* in the sample at 174 m - 172.5 m.

Dinocyst assemblage
The dinocyst assemblage is dominated by *Dapsilidinium pseudocolligerum*, *Operculodinium centrocarpum* and *Spiniferites* spp., while *Apteodinium australiense*, *Hystrichokolpoma rigaudiae* and *Impletosphaeridium insolitum* are common (Enclosure 2).
The occurrence of a single specimen of *Cousteaudinium aubryae* (indicating deposits of late Burdigalian age) is interpreted as being the result of caving (contamination of samples with younger sediments falling downhole during the drilling process), but is important as it indicates the presence of the Arnum Formation/Odderup Formation in the un-sampled upper parts of the drilled succession, as also indicated by the log-patterns, see further the discussion.

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

Depositional environment
The dinocyst assemblage is relatively low-diverse. Non-saccate and bisaccate pollen and wood particles are common. *Botryococcus* occur frequently while the freshwater algae *Mouteotia latevirens*, *Pediastrum* and *Pseudokomwewuia* aff. g*ranulata* occur sporadically. Fungae spores and hyphae were also recorded sporadically. These observations indicate a coast-near marine depositional environment with a high influx of freshwater.

Lithostratigraphy
Based on a combination of the dinocyst stratigraphy, the geophysical log pattern and the lithology of the samples, this interval (from 181 m – 175 m) is correlated with the lowermost part of the Klintinghoved Formation (Figs. 2, 4 and 5).

The *Thalassiphora pelagica* Zone, 175 m - 172 m

Dinocyst zonation
Based on the last occurrence of *Caligodinium amiculum* in the sample at 177 m - 175.5 m and the last occurrence of *Thalassiphora pelagica* in the sample at 174 m – 172.5 m, the interval from 175 m - 172 m is referred to the *Thalassiphora pelagica* Zone.

Dinocyst assemblage
The rather sparse dinocyst assemblage is dominated by *Apteodinium australiense*, *Operculodinium centrocarpum* and *Spiniferites* spp., while *Dapsilidinium pseudo-colligerum*, *Hystrichokolpoma rigaudiae* and *Impletosphaeridium insolitum* are common (Enclosure 2).

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

Depositional environment
The dinocyst assemblage is relatively low-diverse. Non-saccate and bisaccate pollen and wood particles are common and microspores are frequent. *Botryococcus* and *Pseudokomwewuia* aff. g*ranulata* occur frequently while *Mouteotia latevirens* and *Pediastrum* occur sporadically. Fungal spores and -hyphae were also recorded sporadically. These observations indicate a coast-near marine depositional environment with a high influx of freshwater.

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 lower part of the Danish Klintinghoved Formation (Figs. 2, 4 and 5).

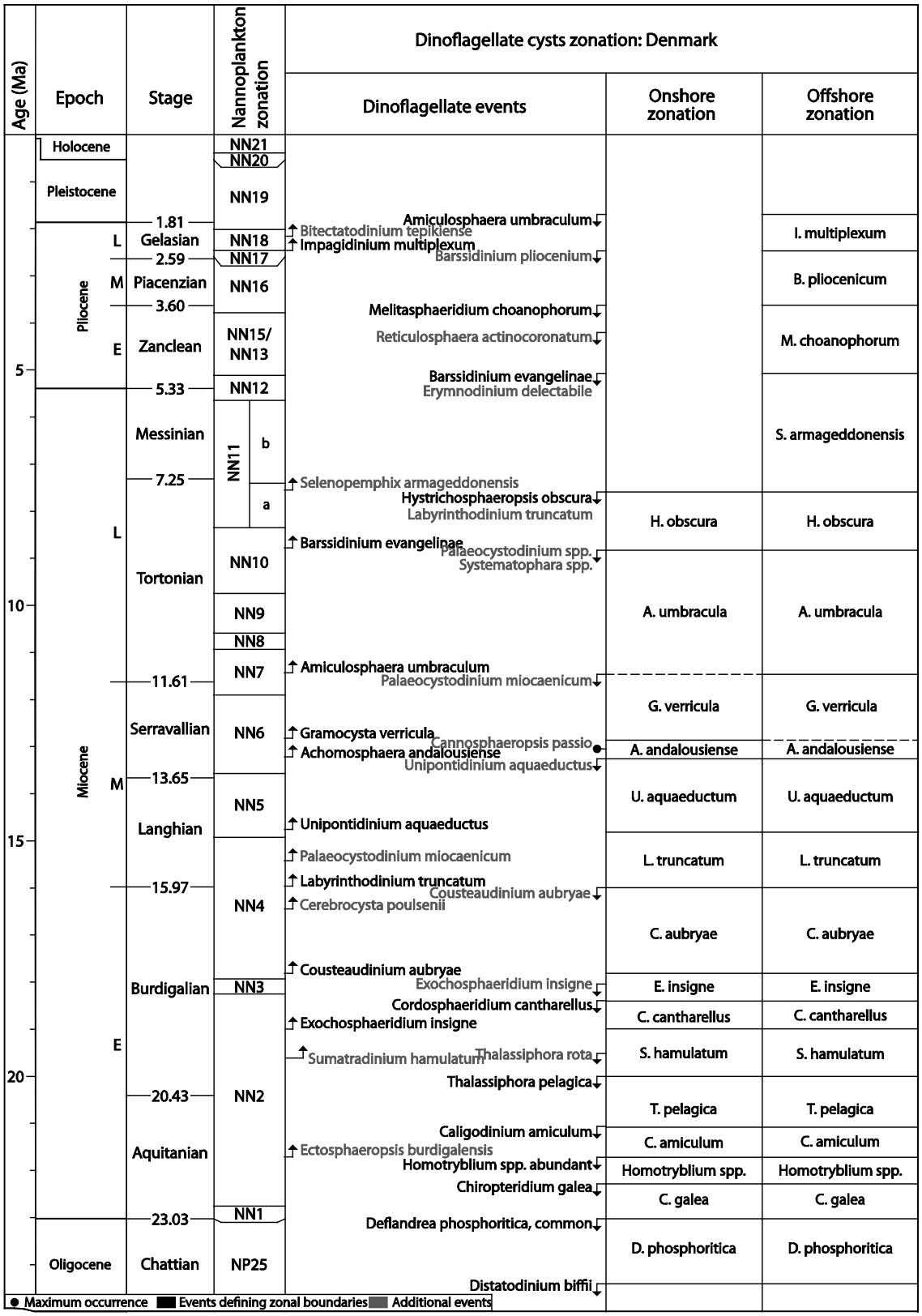

Figure 3: Dinocyst zonation (Dybkjær & Piasecki 2010). The species names shown in black marks the events (first or last occurrences, or abundance occurrences) defining the zonal boundaries. The species names shown in grey are additional stratigraphically usefull events.

The *Sumatradinium hamulatum* Zone, 172 m - 114 m

Dinocyst zonation

Based on the last occurrence of *Thalassiphora pelagica* in the sample at 174 m - 172.5 m, the occurrence of *Cordosphaeridium cantharellus* in all samples within the interval (including the uppermost of the studied samples) and the absence of *Exochosphaeridium insigne*, this interval is referred to the *Sumatradinium hamulatum* Zone. The absence of *Sumatradinium hamulatum* may indicate that only the lower part of the zone is represented by the studied samples.

Dinocyst assemblage

The rather sparse dinocyst assemblage is dominated by *Apteodinium australiense*, *Dapsilidinium pseudocolligerum*, *Hystrichokolpoma rigaudiae*, *Operculodinium centrocarpum* and *Spiniferites* spp., while *Cordosphaeridium cantharellus*, *Impletosphaeridium insolitum* and *Spiniferites crassivariabilis* are common (Enclosure 2).
A slightly increase in reworked Palaeogene dinocysts were seen in the samples representing the interval from 120 m - 114 m.

Age

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

Depositional environment

The organic particles from this interval are dominated by non-saccate and bisaccate pollen and wood particles. Dinocysts, partly degraded vitrinite and freshwater algae (mainly *Pediastrum* and *Botryococcus*) occur sporadically (Enclosure 1). A few pieces of cuticle and a few fungal spore and hyphae were recorded. In the two uppermost samples it was not possible to count 200 dinocysts. These observations indicate a nearshore marine depositional environment with a high influx of freshwater, probably close to Taxodium swamp areas.

Lithostratigraphy

Based on a combination of the dinocyst stratigraphy, the geophysical log pattern and the lithology of the samples, the interval from 172 m - 114 m is correlated with the Danish Klintinghoved Formation, interrupted by two sand intervals, 150 m - 145 m and 134 m - 120 m, which are referred to the Bastrup Formation (Figs. 2, 4 and 5).

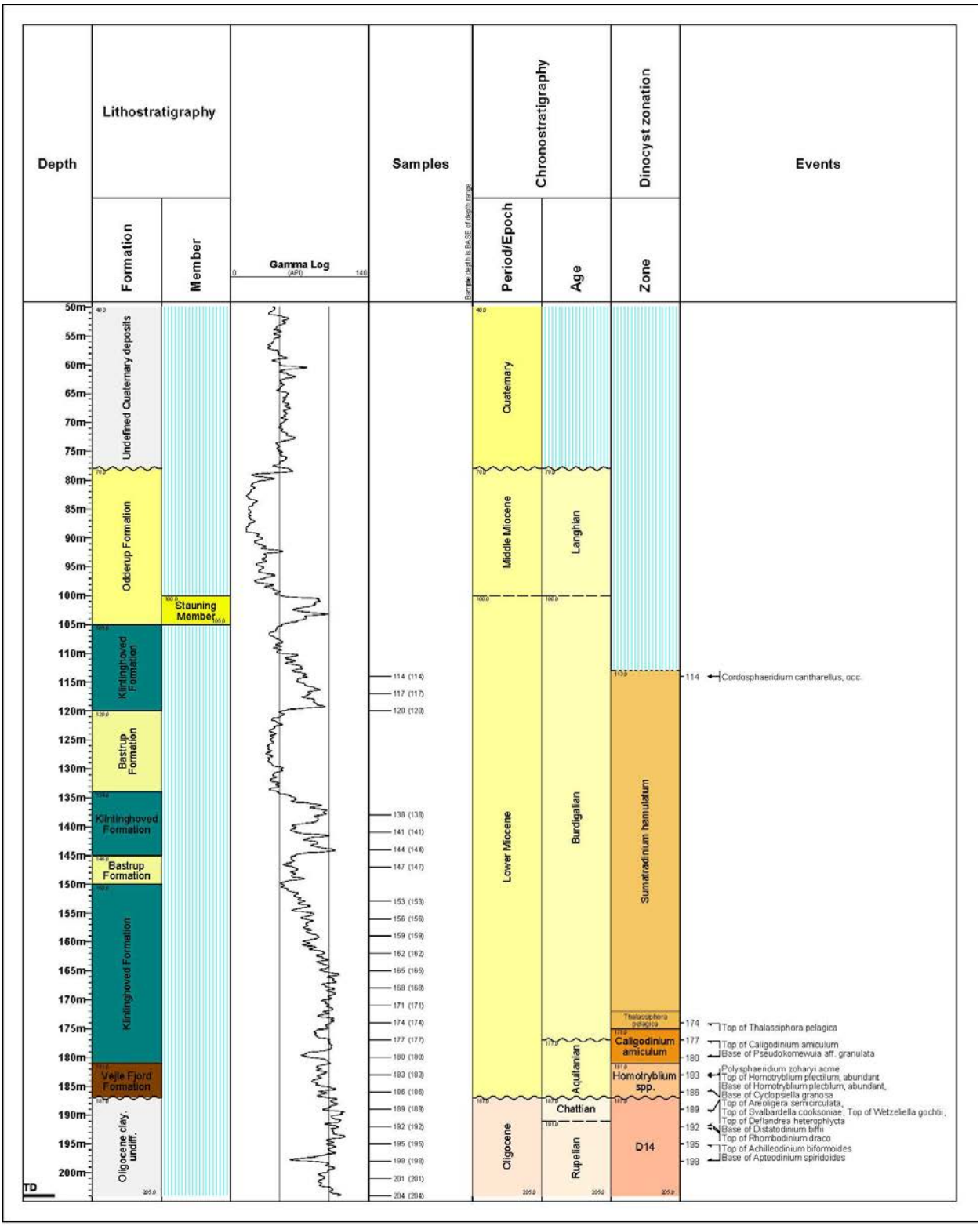

Figure 4: Stratigraphic summary for the Schillsdorf borehole.

Discussion

Although no samples were available from the interval above 114 m, the interval from 114 m – 105 m are tentatively referred to the upper part of the Danish Klintinghoved Formation, the interval from 105 m -100 m are referred to the Stauning Member of the Odderup Formation and the interval from 105 m -78 m are referred to the Odderup Formation (Figs. 2, 4 and 5). This interpretation is based partly on the geophysical log-pattern and partly on the lithology descriptions. The presence of the Odderup Formation is further supported by the recordance of one specimen of the dinocyst species *Cousteaudinium aubryae* in the sample at 177 m - 175.5 m (referred to the lowermost Klintinghoved Formation). As *C. aubryae* only is known from the late Burdigalian *Cousteaudinium aubryae* Zone, which correlate with either the Arnum Formation or the Odderup Formation (see fig. 2), this occurrence is interpreted as being the result of caving from one of these formations. If this should be possible, at least one of these formations has to be present in the drilled overlying succession.

The high gamma log readings in the interval from 105 m – 100 m are interpreted as due to the presence of heavy minerals, as no clay was recorded according to the lithological descriptions provided by Landesamt für Landwirtschaft, Umwelt und ländliche Räume Schleswig-Holstein. Heavy minerals are well-known from the Stauning Member.

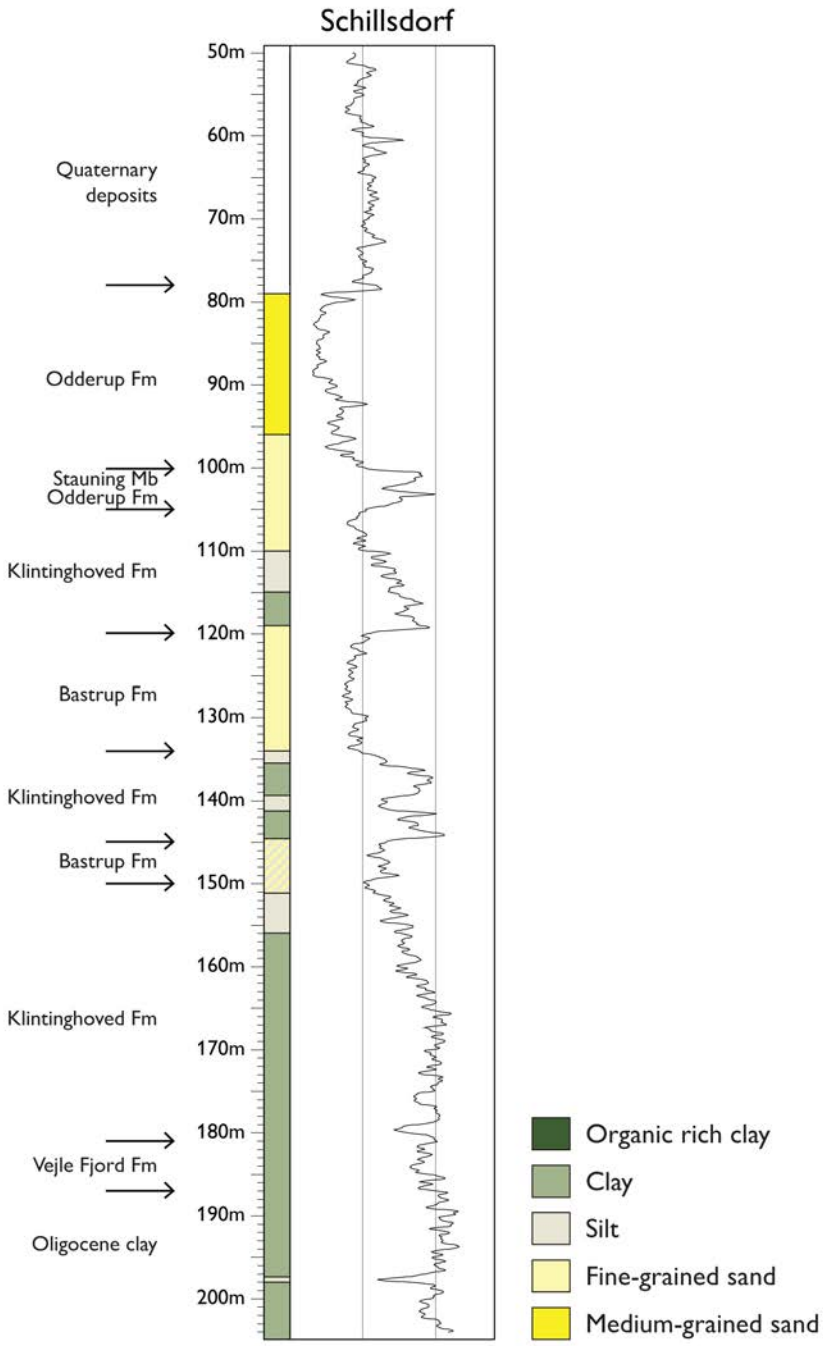

Figure 5: Correlation between the Miocene succession in the Schillsdorf borehole and the Danish lithostratigraphy of Rasmussen *et al.* (2010).

Conclusion

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

204 m - 187 m: D14
187 m - 181 m: The *Homotryblium* spp. Zone
181 m - 175 m: The *Caligodinium amiculum* Zone
175 m - 172 m: The *Thalassiphora pelagica* Zone
172 m - 114 m: The *Sumatradinium hamulatum* Zone

The Miocene succession thus comprises the interval from the lower Aquitanian to the lower Burdigalian, Lower 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) 187 m - 181 m: The Vejle Fjord Formation (=”Unterer Glimmerton”)
2) 181 m - 150 m: The Klintinghoved Formation (= “Unterer Glimmerton”)
3) 150 m - 145 m: The Bastrup Formation (= “Unterer Braunkohlensande”)
4) 145 m - 134 m: The Klintinghoved Formation (= “Unterer Glimmerton”)
5) 134 m - 120 m: The Bastrup Formation (= “Unterer Braunkohlensande”)
6) 120 m - 105 m: The Klintinghoved Formation (= “Unterer Glimmerton”)
7) 105 m - 100 m: The Stauning Member of the Odderup Formation (= “Obere Braunkohlensande”)
8) 100 m - 78 m: The Odderup Formation (= “Obere Braunkohlensande”)

The studied succession was inserted in a log-correlation panel striking north-south, from the Danish Rødding borehole to the Schillsdorf 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 Schillsdorf borehole are comparable and the correlation is straight forward.

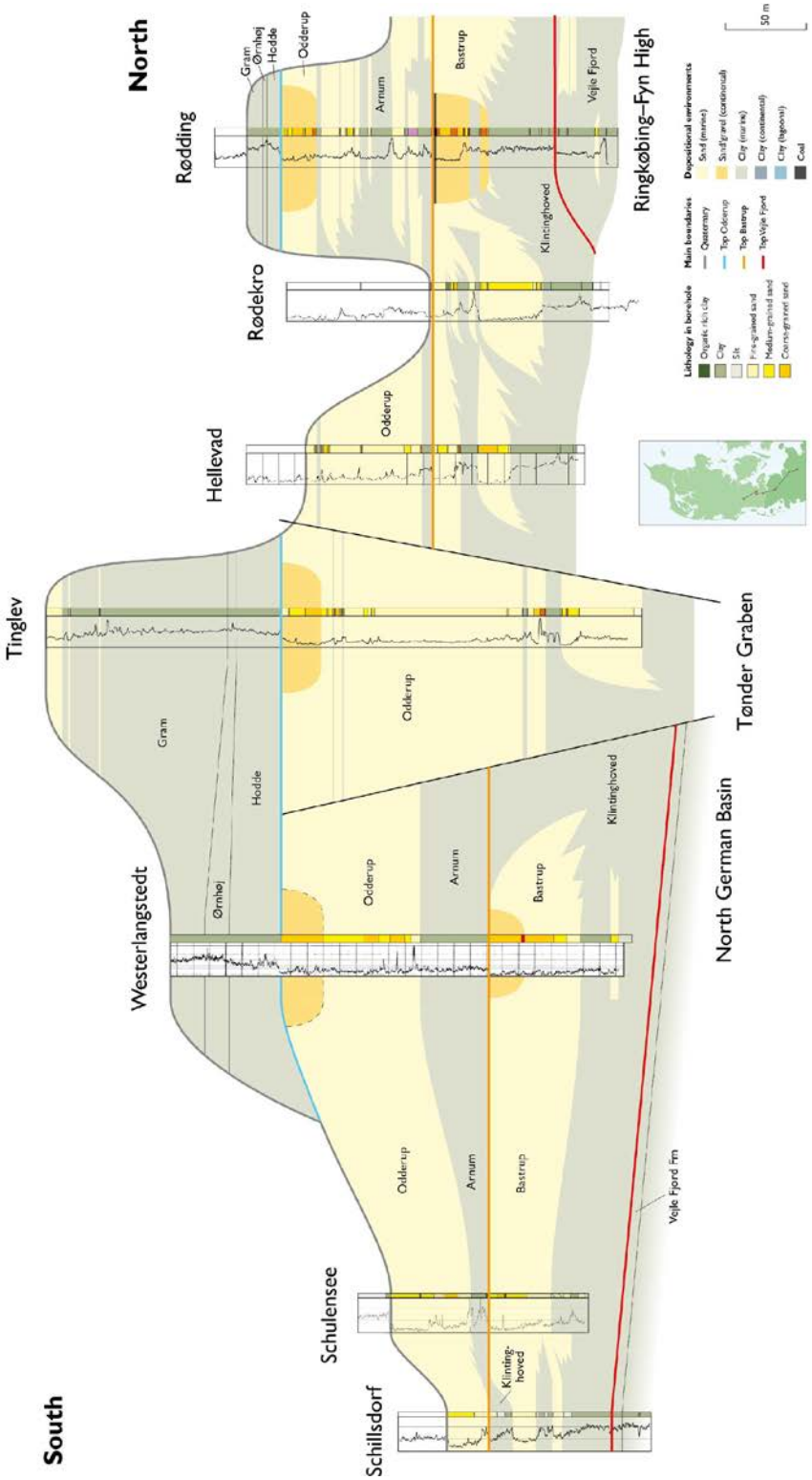

Figure 6: Log-correlation panel showing the Miocene succession in the boreholes; Rødding, Rødekro, Hellevad, Tinglev, Westerlangstedt, Schulensee and Schillsdorf. Notice how the Tønder Graben results in a distinct thickening of the Odderup Formation in the Tinglev borehole.

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Enclosures

Enclosure 1: Rangechart for the Schillsdorf 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 Schillsdorf 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.