DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2016/45

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GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
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Contents

Summary

This report presents the results of a biostratigraphic analysis of the Miocene succession in the cored borehole Kasseburg based on fossil dinoflagellate cysts (dinocysts). The borehole was located near the village Trittau, east of Hamburg, Germany (Fig. 1) and was drilled in 1971.

In previous studies from 2010 and 2015 and 2016, 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) and in Dybkjær & Rasmussen (2016) the Schulensee borehole and the Schillsdorf borehole, respectively, 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 Kasseburg borehole, to refer the succession to the dinocyst zonation of Dybkjær & Piasecki (2010) and to subdivide the succession into lithostratigraphic units.

The sampled Miocene part of the Kasseburg core (243 m - 45 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 successions in the Schillsdorf, Schulensee and Westerlangstedt boreholes, 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 - lowermost Cretaceous and Palaeogene palynomorphs was found in some intervals (see below).

The following dinocyst zones were found:
308 m - 243 m: The D14 Zone
243 m - 235 m: The *Thalassiphora pelagica* Zone
235 m - 113 m: The *Sumatradinium hamulatum/Cordosphaeridium cantharellus* Zone
113 m - 112 m: The *Exochosphaeridium insigne*/*Cousteaudinium aubryae* Zone/lower *Labyrinthodinium truncatum* Zone
112 m - 47 m: The *Labyrinthodinium truncatum*/*Unipontodinium aquaductum* Zone
47 m - 46 m: The *Achomosphaera andalousiense* Zone

The Miocene succession thus comprises the interval from the lower Burdigalian (Lower Miocene) to the lower Serravallian (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) 243 m - 196 m: The Klintinghoved Formation (=”Unterer Glimmerton”)

2) 196 m - 114 m: The Bastrup Formation (= “Unterer Braunkohlensande”)
3) 114 m - 104 m: The Arnum Formation (= Hamburg Formation”)
4) 104 m - 58 m: The Odderup Formation (= “Obere Braunkohlensande”)
5) 58 m – 47 m: The Hodde Formation (= ”Obere Glimmerton”)
6) 47 m – 46 m: The Ørnhøj Formation (=”Obere Glimmerton”)

The Miocene succession is unconformably overlain by Quaternary deposits.

Introduction

Three previous studies, Dybkjær & Rasmussen (2010) (the Westerlangstedt borehole), Dybkjær (2015) (the Schulensee borehole), and Dybkjær & Rasmussen (2016) (the Schillsdorf 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 core samples from the Kasseburg borehole, located near the village Trittau, east of Hamburg, Germany. The borehole was drilled in 1971 and the location is shown in Figure 1.

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

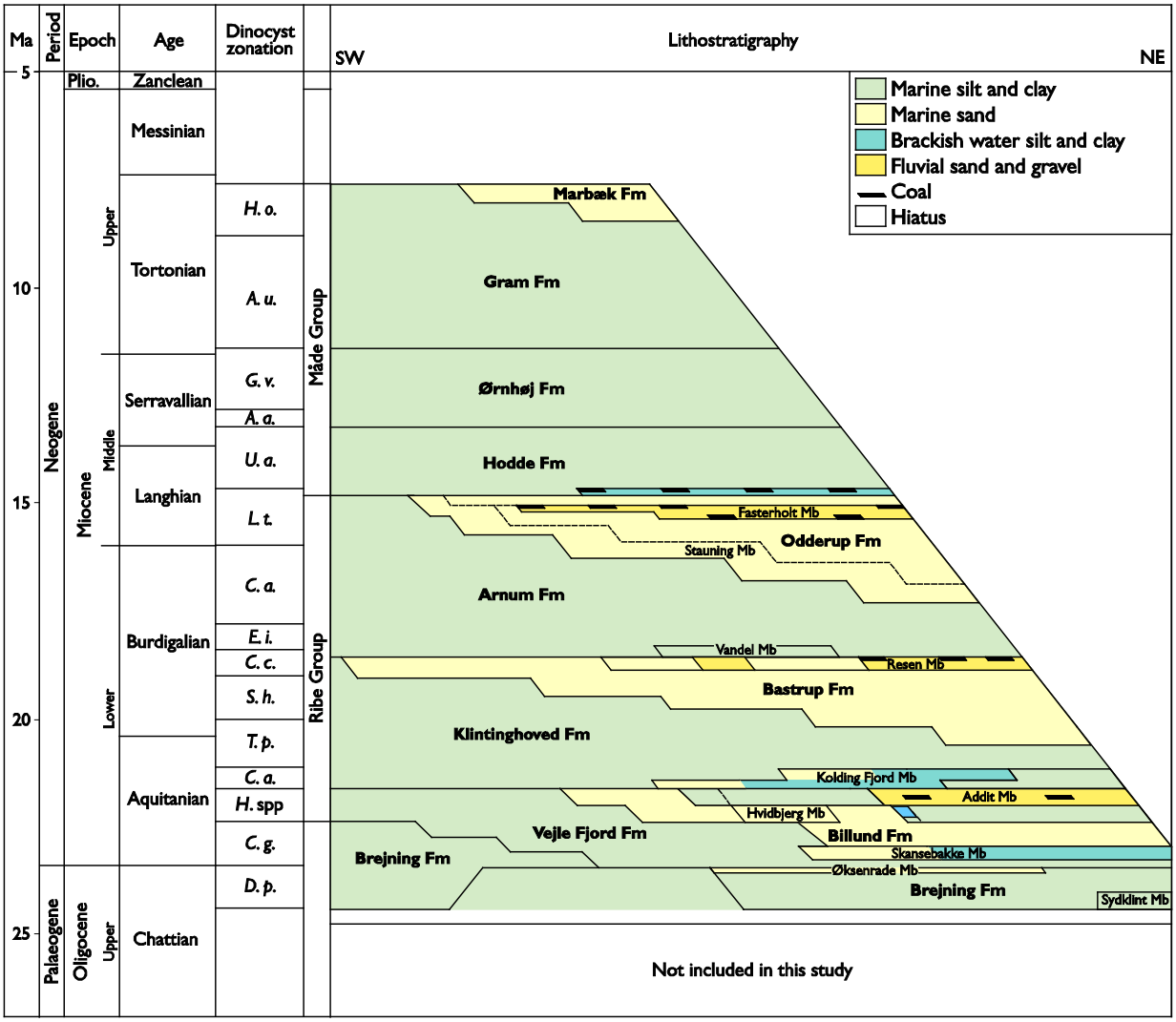

Fig. 2. Lithostratigraphy of the Danish Miocene (Rasmussen *et al.*, 2010).

Material and methods

The present report is based on core samples from the German Kasseburg borehole (Fig. 1), kindly provided by the late Carl Gürss in 2005. The borehole was drilled in 1971. A total of 20 samples in the interval from 308 m and up to 46 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 semi-quantitative analysis consisting of counting at least 200 dinocysts from each sample, were performed. All 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 “The Lentin & Williams Index” (Fensome et al. 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 and *in situ* acritarchs and freshwater algae 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 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 the 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 Kasseburg 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, 308 m - 243 m

Dinocyst zonation
Based on the occurrence of *Chiropteridium* spp. in the lowermost sample at 307-308 m combined with the occurrence of *Wetzeliella gochtii* in the sample at 243-244 m, the interval from 308 m - 243 m are referred to the dinocyst zone D14 of Köthe (1990; 2003).

Dinocyst assemblage
The dinocyst assemblage is dominated by *Apteodinium australiense*, *Cleistosphaeridium placacanthum*, *Dapsilidinium pseudocolligerum*, *Distatodinium paradoxum*, *Homotryblium plectilum*, *H. tenuispinosum*, *Impletosphaeridium insolitum*, *Operculodinium centrocarpum* and *Spiniferites* spp., while *Hystrichokolpoma rigaudiae*, and *Lingulodinium machaerophorum* are common. Reworked Jurassic and Lower Cretaceous dinocysts occur sporadically.

Age
Rupelian to earliest Chattian.

Depositional environment
The dinocyst assemblage is abundant and diverse. Bisaccate pollen and acritarchs are common, while non-saccate pollen and wood fragments are sporadic. Freshwater algae 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 *Thalassiphora pelagica* Zone, 243 m - 235 m

Dinocyst zonation
Based on the last occurrence of *Thalassiphora pelagica* in the sample at 235-236 m combined with the absence of both *Homotryblium* spp. and *Caligodinium amiculum,* the interval from 243 m - 235 m is referred to the *Thalassiphora pelagica* Zone.

Dinocyst assemblage
The dinocyst assemblage is dominated by *Cleistosphaeridium placacantha*, *Hystrichokolpoma rigaudiae*, *Operculodinium centrocarpum* and *Spiniferites* spp., while *Apteodinium tectatum*, *Impletosphaeridium insolitum* and *Lingulodinium machaerophorum* are common (Enclosure 2). Reworked Paleogene dinocysts occur sporadically.

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

Depositional environment
The organic sedimentary particles in this interval are dominated by bisaccate and non-saccate pollen and wood particles. Freshwater algae and dinocysts are common and the dinocyst assemblage is diverse. *Pseudokomewuia* aff. g*ranulata* occur abundantly in the sample at 242-243 m. In the samples above, both *Botryococcus* spp., *Pediastrum* spp. and *Pseudokomewuia* aff. g*ranulata* occur frequently while *Lecaniella* spp. and *Mougeotia latevirens* occur sporadically. Acritarchs occur sporadically. These observations indicate a fully marine depositional environment with a high influx of freshwater – especially in the sample at 242-243 m.

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).

The *Sumatradinium hamulatum* Zone/*Cordosphaeridium cantharellus* Zone, 235 m - 113 m

Dinocyst zonation
Based on the last occurrence of *Thalassiphora pelagica* in the sample at 235-236 m and the last occurrence of *Cordosphaeridium cantharellus* in the sample at 112-113 m, this interval is referred to the *Sumatradinium hamulatum* Zone and/or the *Cordosphaeridium cantharellus* Zone. The big gap in sampling from 227 m to 113 m precludes a more precise biostratigraphic subdivision of this interval.

Dinocyst assemblage
The dinocyst assemblages in three samples from 233 m to 227 m are dominated by *Apteodinium australiense*, *Cleistosphaeridium placacantha*, *Dapsilidinium pseudocolligerum*, *Distatodinium paradoxum*, *Operculodinium centrocarpum* and *Spiniferites* spp., while *Cordosphaeridium cantharellus*, *Heteraulacacysta campanula*, *Hystrichokolpoma rigaudiae*, *Impletosphaeridium insolitum, Lingulodinium machaerophorum*, Mini dino 1 KD and *Spiniferites crassivariabilis* are common (Enclosure 2). No reworked dinocysts were recorded from these samples.

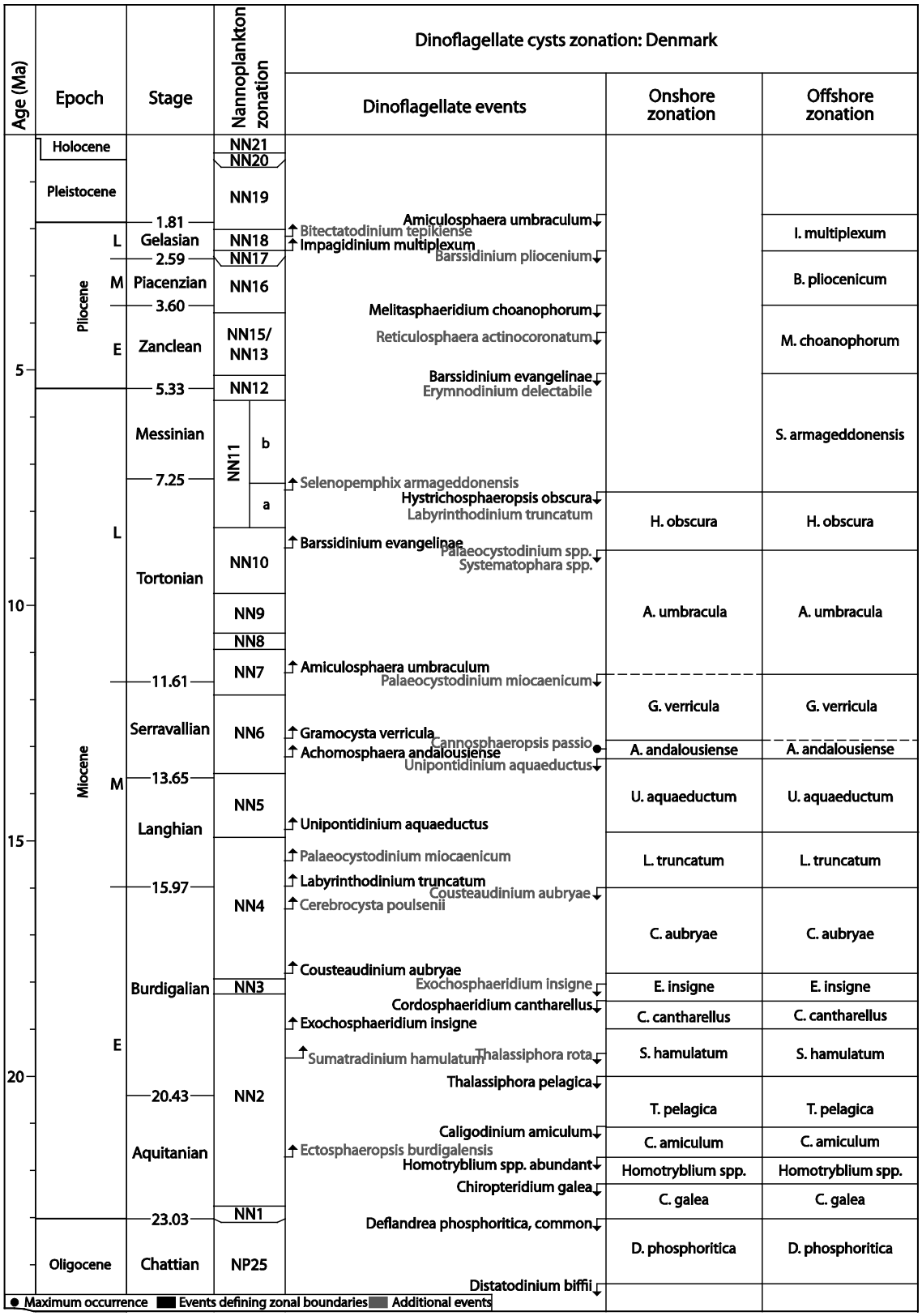

Figure 3: Dinocyst zonation (Dybkjær & Piasecki 2010). The species names shown in black mark the events (first or last occurrences, or abundance occurrences) defining the zonal boundaries. The species names shown in grey are additional stratigraphically usefull events.

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, acritarchs and freshwater algae (mainly *Pediastrum* and *Botryococcus*) occur sporadically (Enclosure 1).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, the interval from 235 m - 196 m is correlated with the Danish Klintinghoved Formation, while the interval from 196 m – 113 m is correlated with the Bastrup Formation (Figs. 2, 4 and 5).

The *Exochosphaeridium insigne*/*Cousteaudinium aubryael* lower *Labyrinthodinium truncatum* Zone, 113 m - 112 m

Dinocyst zonation
The combination of the last occurrence of *Cordosphaeridium cantharellus* and the first occurrences of both *Exochosphaeridium insigne*, *Cousteaudinium aubryae*, *Labyrinthodinium truncatum* and *Palaeocystodinium miocaenicum* in the sample at 112-113 m, indicates that the sample interval represents both the *Exochosphaeridium insigne* Zone, the *Cousteaudinium aubryae* Zone and the lower part of the *Labyrinthodinium truncatum* Zone.

Dinocyst assemblage
The low-diverse dinocyst assemblage in the sample from 112-113 m is dominated by *Cleistosphaeridium placacantha*, *Lingulodinium machaerophorum*, *Operculodinium centrocarpum* and *Spiniferites* spp. while *Dapsilidinium pseudocolligerum*/*pastielsii*, *Distatodinium paradoxum*, *Hystrichokolpoma rigaudiae*, *Polysphaeridium zoharyi* and *Spiniferites pseudofurcatus* are common (Enclosure 2). No reworked dinocysts were recorded from this sample.

Age
Burdigalian to earliest Langhian (Early Miocene to earliest Middle Miocene) (Fig. 3).

Depositional environment
The organic particles from this interval are dominated by non-saccate and bisaccate pollen and wood particles. Dinocysts are common while freshwater algae (mainly *Pediastrum* and *Botryococcus*) and acritarchs occur sporadically (Enclosure 1). A few pieces of cuticle were recorded. These observations indicate a 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, the interval from 112 m - 113 m is correlated with the Danish Arnum Formation (Figs. 2, 4 and 5).

The *Labyrinthodinium truncatum* Zone/*Unipontodinium aquaductum* Zone, 112 m - 47 m

Dinocyst zonation
The first occurrence of *Labyrinthodinium truncatum* in the sample at 112-113 m, combined with the first occurrence of *Cannosphaeropsis passio* in the sample at 46-47 m indicates that interval from 112 - 47 m should be referred to the *Labyrinthodinium truncatum* Zone and the *Unipontodinium aquaductum* Zone. This is supported by the last occurrences of both *Cousteaudinium aubryae* and *Distatodinium paradoxum* in the sample at 67-68 m. The absence of *Unipontodinium aquaductum* may be explained either by a missing recording of *U. aquaductum* within the zone (it often occur rather sporadically), or that the *U. aquaductum* Zone is located within the interval between the sample at 67-68 m and the uppermost sample at 46-47 m.

Dinocyst assemblage
The rather low-diverse dinocyst assemblages in this interval are dominated by *Cleistosphaeridium placacantha*, *Lingulodinium machaerophorum*, *Operculodinium centrocarpum*, *Palaeocystodinium miocaenicum*/*minor* and *Spiniferites* spp. while *Dapsilidinium pseudocolligerum*/*pastielsii*, *Distatodinium paradoxum*, *Hystrichokolpoma rigaudiae*, *Melitasphaeridium choanophorum* and *Spiniferites pseudofurcatus* are common (Enclosure 2). Furthermore, *Polysphaeridium zoharyi* are common in the sample at 102-103 m and occur abundantly in the sample at 67-68 m (Enclosure 2). Reworked Paleogene dinocysts occur sporadically.

Age
Langhian to ?earliest Serravallian (Middle Miocene) (Fig. 3).

Depositional environment
The assemblage of organic particles from this interval consists of approximately equal amounts of non-saccate and bisaccate pollen, dinocysts and wood particles. The dinocyst diversity is rather low. Freshwater algae (mainly *Pediastrum* and *Botryococcus*) and acritarchs occur sporadically (Enclosure 1). These observations indicate a coast-near marine depositional environment with a high influx of freshwater. The abundant occurrence of *Polysphaeridium zoharyi* in the sample at 67-68 m indicates a coastal to shallow marine environment (Dale 1996).

Lithostratigraphy
Based on a combination of the dinocyst stratigraphy, the geophysical log pattern and the lithology of the samples, the interval from 112 m - 47 m is correlated with the Danish Arnum, Odderup and Hodde Formations (Figs. 2, 4 and 5).

The *Achomosphaera andalousiense* Zone, 47 m - 46 m

Dinocyst zonation

A minor increase in the number of the nominate species, combined with the occurrence of *Cannosphaeropsis passio* in the sample at 46-47 m indicate that the sample represents the *Achomosphaera andalousiense* Zone.

Dinocyst assemblage

The rich and diverse dinocyst assemblage in this sample is dominated by *Bitectatodinium arborichiarum, Dapsilidinium pseudocolligerum*/*pastielsii*, *Labyrinthodinium truncatum*, *Operculodinium centrocarpum* and *Spiniferites* spp., while *Lingulodinium machaerophorum* Mini dino 1 KD, and *Spiniferites pseudofurcatus* are common (Enclosure 2). One reworked Jurassic to lowermost Cretaceous dinocyst and one reworked Paleogene dinocyst were recorded.

Age

Serravallian (Middle Miocene) (Fig. 3).

Depositional environment

The organic particles from this interval are dominated by dinocysts. Bi-saccate and non-saccate pollen and wood particles are common while acritarchs occur sporadically. No freshwater algae were recorded from this interval (Enclosure 1). These observations indicate a fully marine depositional environment with a minor influx of freshwater.

Lithostratigraphy

Based on a combination of the dinocyst stratigraphy, the geophysical log pattern and the lithology of the samples, the interval from 46-47 m is correlated with the Danish Ørnhøj Formation (Figs. 2, 4 and 5). The Ørnhøj Formation is characterised by the presence of glaucony. This was not mentioned in the lithological description for the Kasseburg borehole. However, as the content of glaucony in the Danish Ørnhøj formation is variable and as the log-pattern and the dinocyst stratigraphy indicates a correlation with this formation, the sample from 46-47 m is here referred to the Ørnhøj Formation.

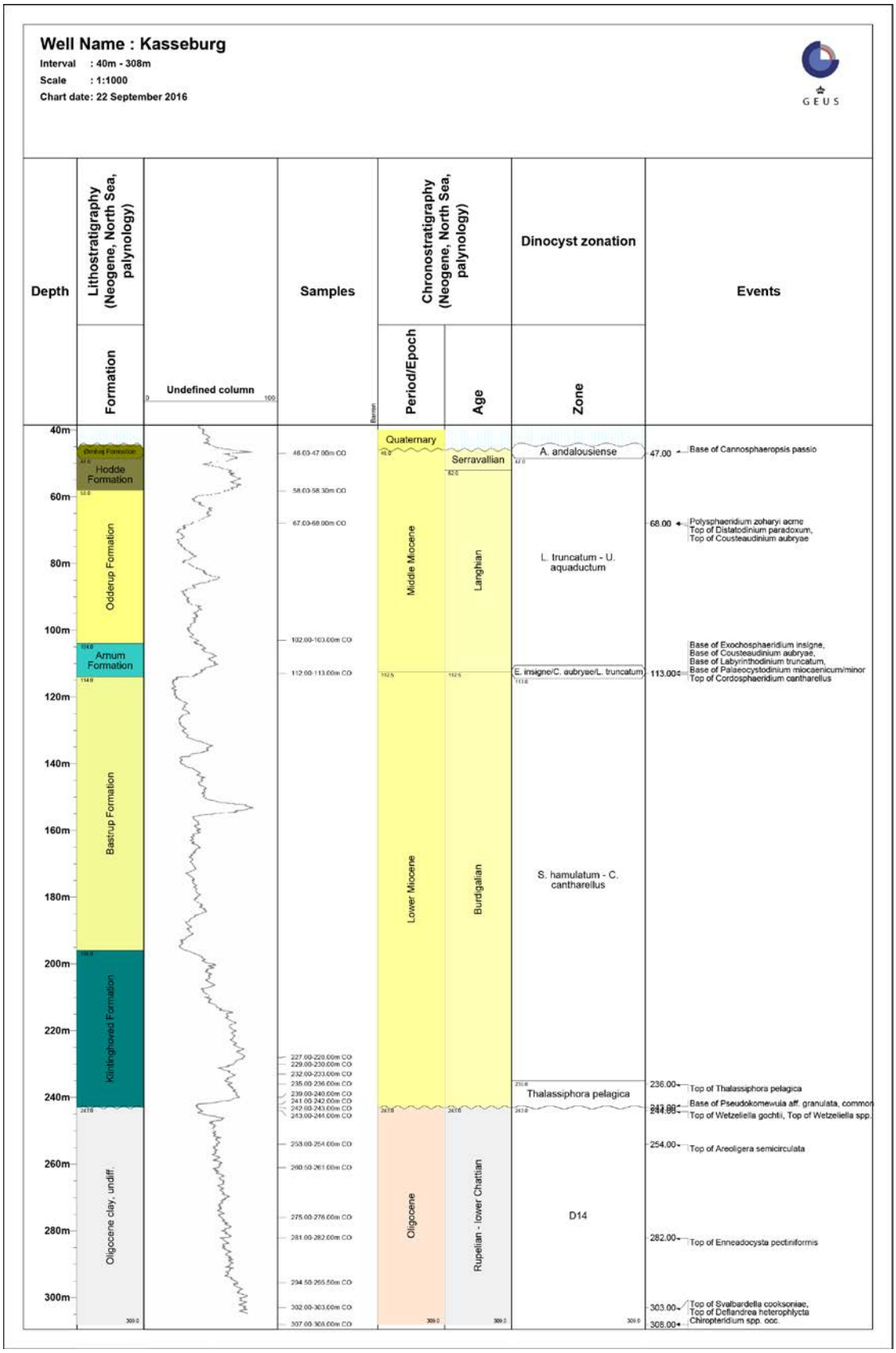

Figure 4: Stratigraphic summary for the Kasseburg borehole.

Discussion

In spite of the large gaps between the samples, especially from 227-113 m, it has been possible to subdivide the studied succession into dinocyst zones, to date the succession and to refer it to the Danish lithostratigraphic units.

The interval from 243 m – 196 m are referred to the upper part of the Danish Klintinghoved Formation, the interval from 196 m – 114 m are referred to the Bastrup Formation, the interval from 114 m - 104 m are referred to the Arnum Formation, the interval from 104 m – 58 m are referred to the Odderup Formation, the interval from 58 m - 47 m are referred to the Hodde Formation (Figs. 2, 4 and 5) and the interval from 47 m - 46 m are referred to the Ørnhøj Formation. The Miocene succession is unconformably overlain by Quaternary deposits. This interpretation is based partly on the dinocyst stratigraphy, partly on the geophysical log-pattern and partly on the lithology descriptions.

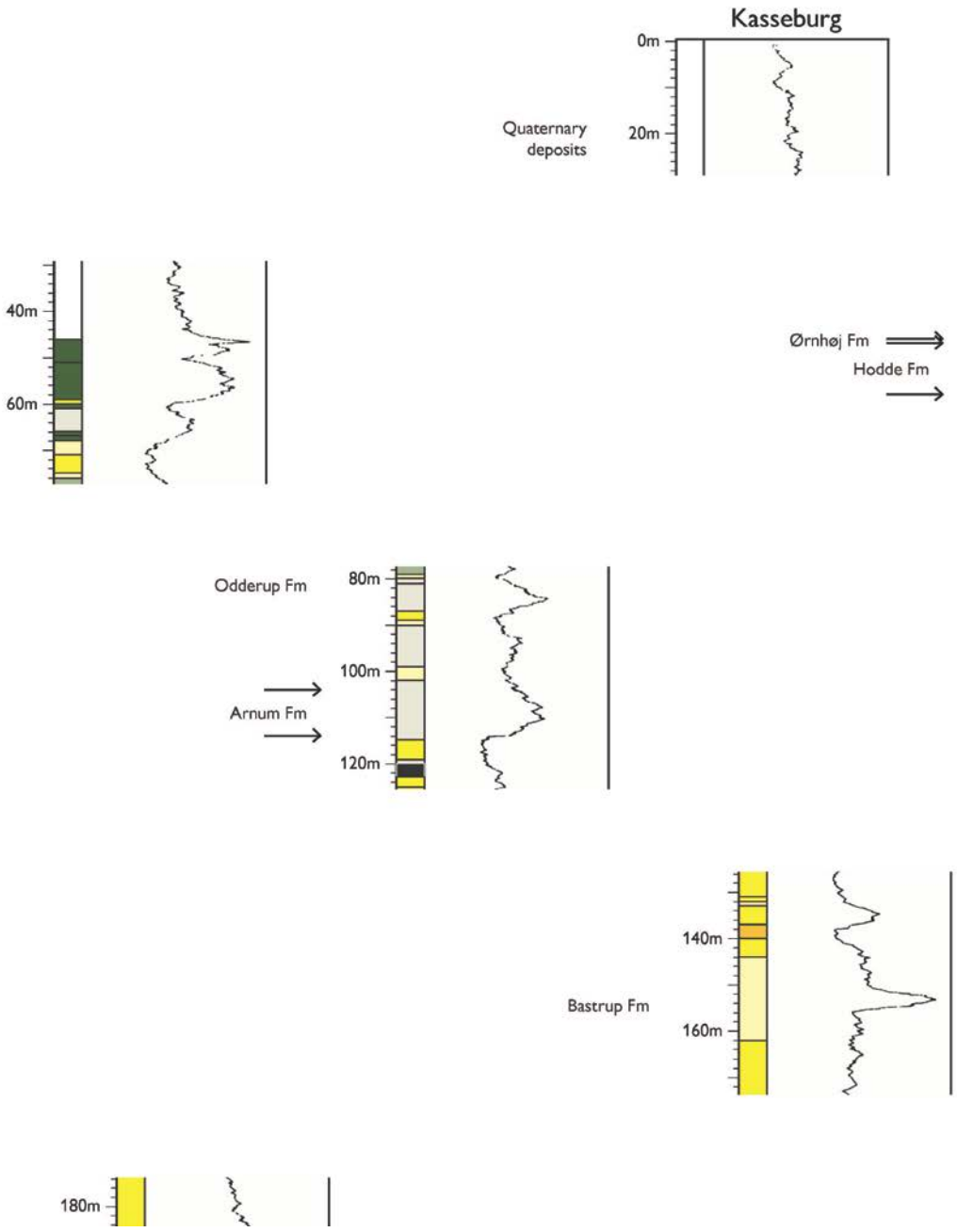

Figure 5: Correlation between the Miocene succession in the Kasseburg borehole and the Danish lithostratigraphy of Rasmussen *et al.* (2010).

Conclusion

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

308 m - 243 m: The D14 Zone
243 m - 235 m: The *Thalassiphora pelagica* Zone
235 m - 113 m: The *Sumatradinium hamulatum*/*Cordosphaeridium cantharellus* Zone
113 m - 112 m: The *Exochosphaeridium insigne*/*Cousteaudinium aubryae*/
lower *Labyrinthodinium truncatum* Zone
112 m - 47 m: The *Labyrinthodinium truncatum*/*Unipontodinium aquaductum* Zone
47 m – 46 m: The *Achomosphaera andalousiense* Zone

The Miocene succession thus comprises the interval from the lowermost Burdigalian (Lower Miocene) to the Serravallian (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) 243 m - 196 m: The Klintinghoved Formation (=”Unterer Glimmerton”)
2) 196 m - 114 m: The Bastrup Formation (= “Unterer Braunkohlensande”)
3) 114 m - 104 m: The Arnum Formation (= “Hamburg Formation”)
4) 104 m - 58 m: The Odderup Formation (= “Obere Braunkohlensande”)
5) 58 m – 47 m: The Hodde Formation (= ”Obere Glimmerton”)
6) 47 m – 46 m: The Ørnhøj Formation (= “Obere Glimmerton”)

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 Kasseburg 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 Kasseburg borehole are comparable and the correlation is straight forward.

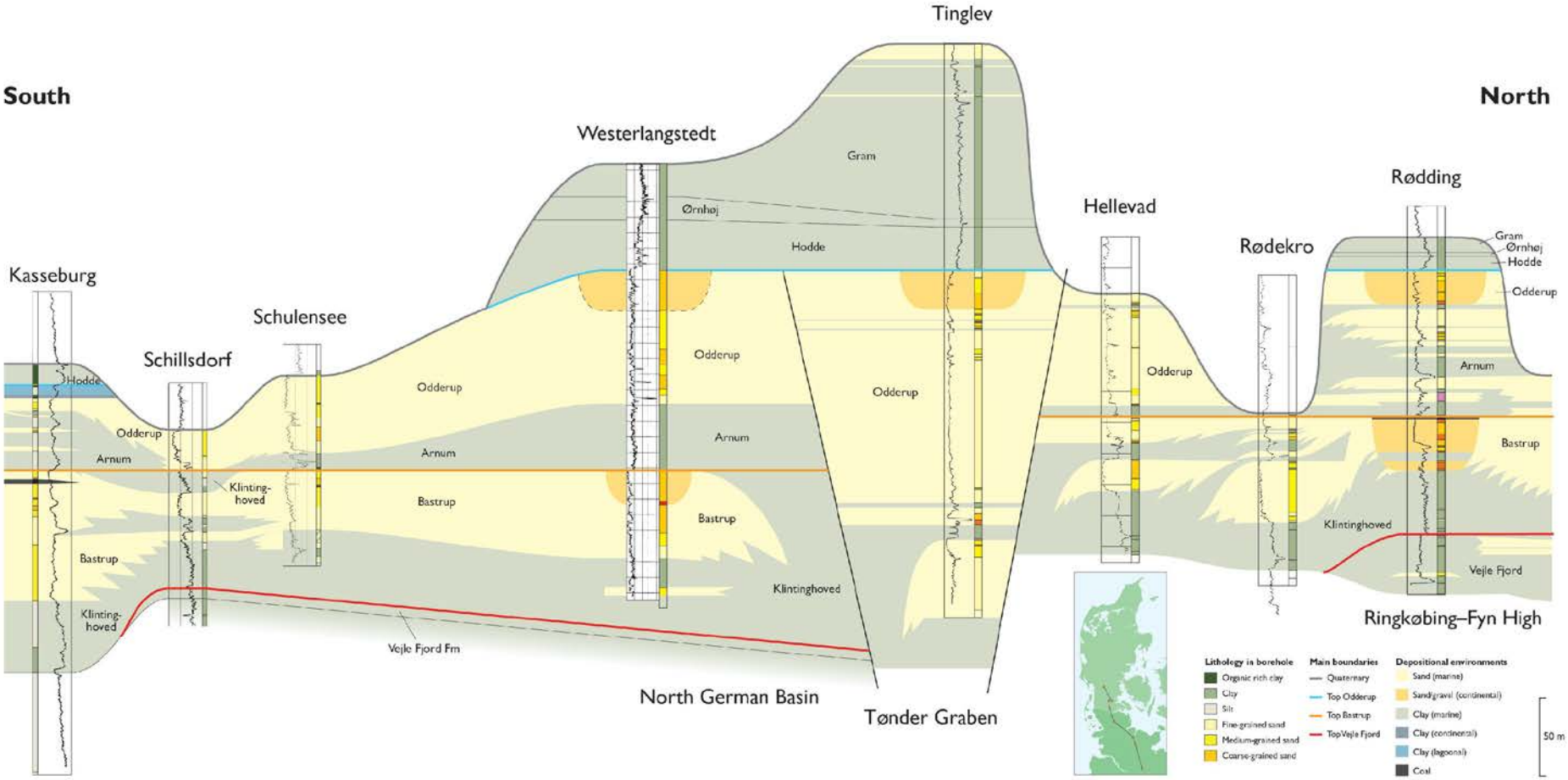
South
North
Kasseburg
Schillsdorf
Schulensee
Westerlangstedt
Tinglev
Hellevad
Rødekro
Rødding
Hodde
Odderup
Arnum
Bastrup
Klinting-hoved
Vejle Fjord Fm
Gram
Ørnhøj
Klintinghoved
North German Basin
Tønder Graben
Ringkøbing–Fyn High
Vejle Fjord
Lithology in borehole
Organic rich clay
Clay
Silt
Fine-grained sand
Medium-grained sand
Coarse-grained sand
Main boundaries
Quaternary
Top Odderup
Top Bastrup
Top Vejle Fjord
Depositional environments
Sand (marine)
Sand/gravel (continental)
Clay (marine)
Clay (continental)
Clay (lagoonal)
Coal
50 m

Figure 6: Log-correlation panel showing the Miocene succession in the boreholes; Rødding, Rødekro, Hellevad, Tinglev, Westerlangstedt, Schulensee, Schillsdorf and Kasseburg. 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 Kasseburg 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 studied samples, the absolute abundances of the recorded *in situ* and caved dinocyst species, the presumed reworked dinocysts, the freshwater algae and the acritarchs (AC). Occurrences marked by a ”?” means that the indentification of the specimen to species or genus is questionable.

Enclosure 2: Rangechart for the Kasseburg 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 studied sampes and the relative abundances of the recorded *in situ* dinocyst species. Occurrences marked by a ”?” means that the indentification of the specimen to species or genus is questionable.

Well Name : Kasseburg

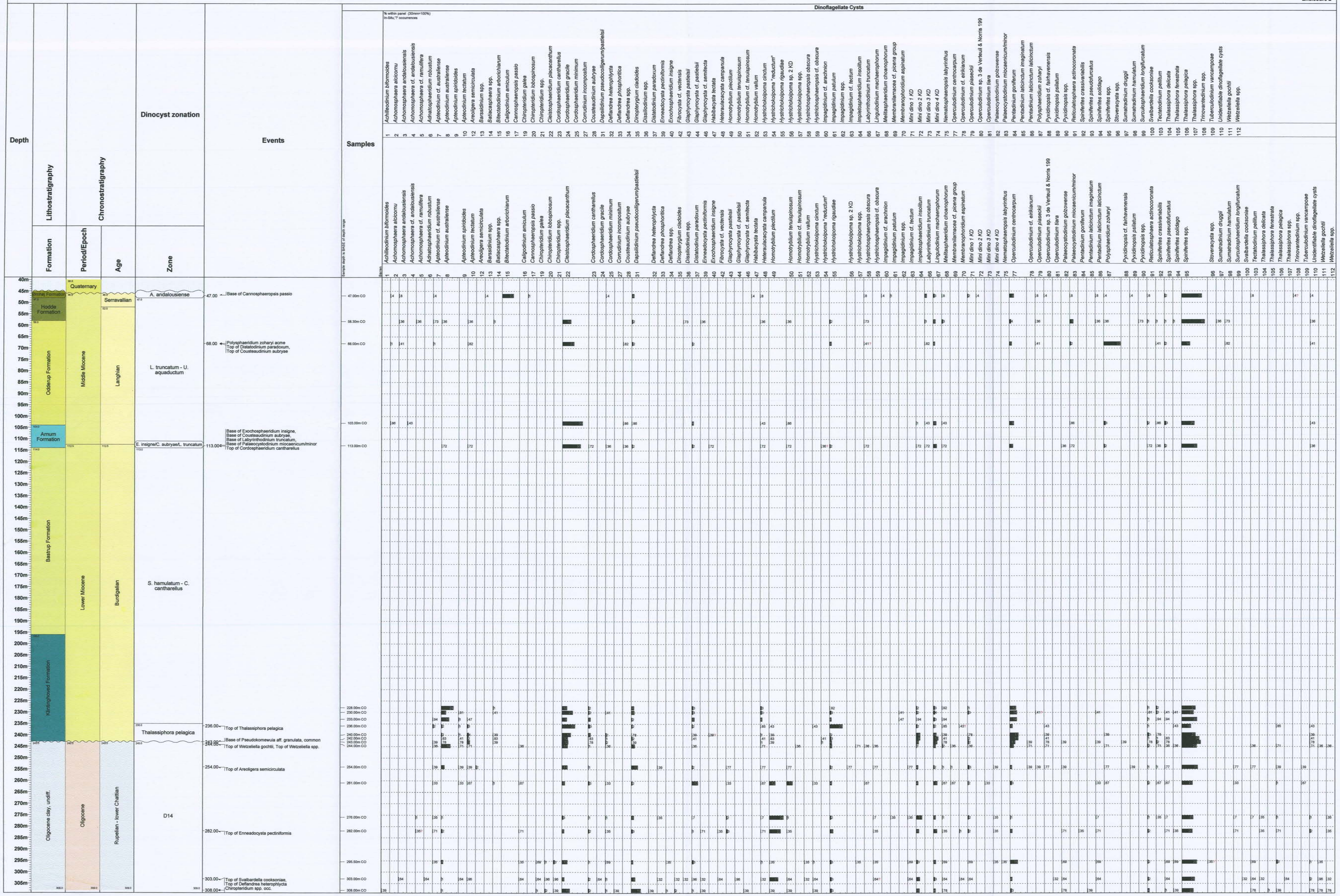
Interval : 40m - 308m

Scale : 1:750

Chart date: 05 October 2016 Karen Dybkjær

GEUS

Enclosure 2



Well Name : Kasseburg

Interval : 40m - 308m

Scale : 1:750

Chart date: 12 October 2016 Karen Dybkjær

GEUS

Enclosure 1

Depth

Lithostratigraphy (Neogene, North Sea, palynology)

Chronostratigraphy

Dinocyst zonation

Events

Samples

Dinoflagellate Cysts

Dinoflagellate Cysts

Freshwater Algae

Acritarchs