DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2004/69

Stratigraphic analysis of ditch cuttings samples from the DGE-02 well in Lund, Sweden

Stefan Piasecki & Jan Audun Rasmussen

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF THE ENVIRONMENT

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GEUS

Contents

Introduction

The DGE-02 well was drilled in the summer 2004 near the city Lund in southern Sweden. This was the second well in a geothermal programme with the purpose of finding sand bodies with good reservoir potential for hot water. The well was drilled at the margin of the Hölviken Graben in the Rommelåsen Faultzone.

GEUS was requested to date selected successions by biostratigraphical analysis of ditch cuttings samples, and both micropalaeotological and palynological analyses were applied. The present report documents the results of these analyses.

Conclusions

The overall nannoflora characteristics indicate that the 815 m – 854 m interval is Cretaceous in age, probably older than Coniacian.

The palynoflora recorded in the sample at 830 m in the DGE-02 well indicate a Late Triassic, Rhaetian, age of the palynoflora.
The presence of lenticular and sculptured chitinozoans in samples 1148 – 1152 m suggests a Late Ordovician or Silurian age.
An Early to Middle Jurassic, Sinemurian – Pliensbachian – Toarcian/Aaalenian? age is indicated for samples from 1298 – 1556 m on the basis of the pollen and spore assemblages and the locally abundant dinoflagellates. This succession is apparently inverted as the strata become successively younger down-wards. This is well documented by the biostratigrahy.
An Early Cretaceous, late Ryazanian – early Valanginian, age is recorded from the lowermost succession at 1697 – 1907 m. A typical dinoflagellate assemblage previously recorded in the Jydegård Formation, Bornholm, characterises these strata. The sample at 1697 m is different with a poor marine flora probably also of Early Cretaceous age.

Methods

Preparation for microfossils

Three microfossil samples were prepared by wet-sieving of the 63–500 μm sediment fraction followed by drying. Fifty grams of sediment from each sample were washed. Subsequently the 63–500 μm fraction was gravity-separated in heavy liquid (δ = 1.8 g/cm3) by standard procedures to reduce the amount of sediment to be analysed.
The nannofossil sample was prepared using the smear slide method. A small amount of sediment was placed on a glass slide and a drop of distilled water added to make a sediment suspension. The suspension was smeared back and forth over the slide until a uniform rippled effect was obtained. Three drops of optical adhesive were added to a coverslip and this was placed face down on the glass slide.

Preparation for palynomorphs

The sample material comprises washed cuttings of several different lithologies in each sample varying from black, grey and reddish mudstone, white calcareous mudstone to sand and gravel of crystalline basement. However, from sample 1152 m one lithology was sorted out for preparation. Sediment grains from 1 to 4 millimetres were used for analysis in order to minimise the content of caved material and mud contamination.
The samples have been prepared with standard palynological techniques. Hydrochloric and hydrofluoric acids removed mineral matter, and the organic content was oxidised with concentrated nitric acid and washed with potassiumhydroxide to remove humic material. The standard preparation process was followed by specific treatment of each sample such as filtering with 11 or 20 micron mesh size, ultrasonic bath, swirling or heavy liquid separation. Four to five slides of different steps in the preparation were prepared for the analysis. The first slides were used mainly for evaluating the composition of the organic content and thermal maturity but all slides from each sample were scanned for stratigraphic significant taxa, which then were recorded on a record-sheet. Taxa of secondary importance were not recorded.

Litterature

The nannofossil biostratigraphy is based mainly on the zonations published by K. Perch-Nielsen (1985) and J. A. Burnett (1998).

The applied Lower Cretaceous dinoflagellate stratigraphy is based mainly on the dinoflagellate zonation described by R. J. Davey for the North Sea region (Davey 1979; Davey 1982) and more locally on Bornholm by S. Piasecki (Piasecki 1984).

The Rhaetian to Lower Jurassic palyno-stratigraphy in the Danish region is well documented by J. J. Lund (Lund 1977) and more recently by K. Dybkjær (Dybkjær 1988; Dybkjær 1991) and E. B. Koppelhus (Koppelhus & Nielsen 1994; Koppelhus & Batten 1996). In Scania, most recently palyno-stratigraphic studies on this part of the succession are published by D. Guy-Ohlson (Guy-Ohlson 1981; Guy-Ohlson & Malmquist 1985; Guy-Ohlson 1990). The NW-European, Jurassic dinoflagellate stratigraphy was summarized recently (Poulsen & Riding 2003). The spore-pollen and dinoflagellate cyst zonations are well elaborated and work well as biostratigraphic tools.

The Lower Palaeozoic stratigraphy was not worked out in details in this report but estimated from the general Chitinozoan palaeontology (Jansonius & Jenkins 1978).

Results

Micro- and nannofossil analysis

815 – 855 m: Cretaceous

The overall characteristics of the very limited nannoflora indicate that the 815 m – 854 m interval is Cretaceous in age, probably older than Coniacian. This is in contrast to the Late Triassic, Rhaetian age, at 830 m based on palynomorphs.
Microfossils: The light fraction ($\delta < 1.8$ g/cm3) of the three samples was barren in foraminifera, diatoms and radiolaria but coal fragments occur sporadically. Bisaccate pollen were observed in two samples. The nannofossil flora is very sparse in the investigated interval. Stellate nannoliths of the family Polycyclolithaceae, however, are more common than elliptical forms. The preservation is poor to moderate.
The very sparse and often poorly preserved nannofloral assemblages of the 815 m, 830 m and 854 m samples are clearly different from those of the Early Santonian and/or Late Coniacian interval of the DGE-01 well (Rasmussen, 2004). The investigated DGE-02 samples are dominated by stellate nannoliths of the family Polycyclolithaceae, while the DGE-01 samples in contrast contained abundant ellipsoidal heterococcoliths. The mostly poor preservation and general lack of useful zonal indices in the studied DGE-02 samples, however, prevents a precise age determination, as well as the low number of specimens makes it difficult to judge if certain specimens may be caved, reworked or *in situ*.

DCS 815 m

Microfossils: No microfossils but sparse coal fragments.
Nannofossils: The sample contained a very sparse and badly preserved nannofossil flora.

?*Braarudsphaera regularis*	1 (?Portland.–Turon.)
Uniplanarius aff. *gothicus* (four elements per cycle)	2 (*U. gothicus*: Sant.–Maast.)
Lithastrinus spp. (six elements per cycle)	1

Age: ?Late Cretaceous, Santonian – Maastrictian

DCS 830 m

Microfossils: Sparse coal fragments and a single specimen of a bisaccate pollen.
Nannofossils: Barren
Age: Unknown

DCS 845 m

Microfossils: Sparse coal fragments and a single specimen of bisaccate pollen.
Nannofossils: The sample contained a very sparse and badly preserved nannofossil flora.

Watznaueria barnesae	1 (Bajoc.–Maast.)
Eprolithus floralis	1 (Cenoman.–Sant.)
?*Eprolithus* sp. 2 Perch-Nielsen, 1985 (eight elements per cycle)	3 (Cenoman.–Turon.)

Comments: ?*Eprolithus* sp. 2 is also very similar to an informal but well-known species from the Valanginian of the North Sea named "*Octopet* sp. 2a".
Age: Cretaceous, pre-Coniacian.

Palynological analysis

830 m: Upper Triassic, Rhaetian

DCS 830 m

Organic matter: Very poor organic content of strongly degraded terrestrial matter. Sporomorphs form a small but significant fraction of the organic matter.
Palynomorphs: The terrestrial assemblage is poor and restricted. Spores dominate and pollen is present. Small trilete spores are abundant and comprise >50% of the assemblage. Marine palynomorphs are rare.
Dinoflagellate cysts: *Rhaetogonyaulax rhaetica*.
Acritarchs: None.
Spores and pollen: Small, smooth or scultured trilete spores are most common e.g. *Deltoidospora* spp. and *Apiculatisporites ovalis. Limbosporites lundbladii* are frequent and *Ricciisporites tuberculatus* are common where as *Corollina* spp. are rare. Saccate pollen e.g. *Pinuspollenites minimus* and *Ovalipollis ovalis* are also rare.
Depositional environment: Marginal marine.
Age: Rhaetian, Late Triassic.
Biozone: Spores and pollen: *Ricciisporites-Polypodiisporites* Zone Lund 1977. Dinoflagellate cysts: *Rhaetogonyaulax rhaetica* Zone Woollam & Riding 1983.
Comments: The frequent occurrence of *Limbosporites lundbladii* and common occurrence of *Ricciisporites tuberculatus* combined with the rarity of *Corollina* spp. suggest affinity to the *Ricciisporites–Polypodiisporites* Zone Lund 1977 but some of the characteristic species are not recorded.
1148 – 1158 m: Lower Palaeozoic, Upper Ordovician – Silurian

DCS 1148 m

Organic matter: Poor organic content dominated by black, angular to rounded grains.

Palynomorphs: Black to dark brown *in situ* palynomorphs, thermally and chemically degraded with abundant imprints of pyrite.
Dinoflagellate cysts: None.
Acritarchs: Sphaeromorph acritarchs, acanthomorph acritarchs and *Leiofusa*? sp.
Spores and pollen: No *in situ* flora.
Others: Chitinozoans and fragments presumably of graptolithes.
Depositional environment: Marine.
Age: Early Palaeozoic, not older than Late Ordovician.
Biozone: Unknown.
Comments: The presence of lenticular and sculptured Chitinozoans suggests a Late Ordovician to Silurian age (Jansonius & Jenkins 1978). Chitinozoans disappear in the Devonian.
Contamination from caved cuttings and drilling mud/surface water? *Pinuspollenites minimus*, *Limbosporites lundbladii* and *Ricciisporites tuberculatus* represent a flora of orange to yellow spores and pollen presumably caved from higher Upper Triassic – Lower Jurassic strata.
Colourless bisaccate pollen, porate pollen and sphaeromorph algae with cytoplasma content occasional preserved represent contamination of Recent floras presumably from surface water.

DCS 1152 m (one lithology)

Organic matter: Very poor organic content.
Palynomorphs: Black, angular to rounded grains, which are thermally and physically degraded. No woody material is present.
Dinoflagellate cysts: None.
Acritarchs: Few, black sculptured acritarchs (acanthomorphs and sphaeromorphs).
Spores and pollen: No *in situ* spores or pollen.
Others: Chitinozoans.
Depositional environment: Marine.
Age: Early Palaeozoic, not older than Late Ordovician.
Biozone: No zonation.
Comments: The presence of lenticular and sculptured chitinozoans suggests a Late Ordovician to Silurian age. Chitinozoans becomes extinct during the Devonian (Jansonius & Jenkins 1978). The absence of woody material supports an Early Palaeozoic age.
Very little contamination of Recent algae, spores and pollen from surface water/drilling mud.

Casing 1250 m

1298–1556 m: Early – Middle? Jurassic, Sinemurian–Pliensbachian–Toarcian–Aalenian?

Discussion: The dinoflagellate flora of abundant *Liasidium variabile* in 1298 m strongly indicates a Sinemurian age. The associated pollen and spore flora also indicate a Sinemurian–

Pliensbachian age. The rich *L. variabile* flora caves into the next samples below, however *Mendicodinium* spp. occurs in these samples, 1352 and 1442 m suggesting a Pliensbachian age. The zonal species of the *Luehndea spinosa* Zone is not recorded but a corresponding Pliensbachian succession is represented in 1469 m. Successively younger strata of upper Pliensbachian – Toarcian/Aalenian age is recorded downwards in 1514 – 1556 m. Consequently, the succession must be upside-down!

DCS 1298 m

Organic matter: Relatively low organic content. Angular, brown and black woody material dominates. Spores, pollen and dinoflagellates are frequent.
Palynomorphs: Bisaccte pollen, trilete spores and dinoflagellates are equally frequent.
Dinoflagellate cysts: A monotypic assemblage of abundant *Liasidium variabile*.
Acritarchs: Acanthomorph acritarchs are present.
Spores and pollen: *Cerebrocysta macroverrucosus*, *Chasmatosporites apertus*, *C. hians*, *Quadraeculina anellaeformis*. Reworked? *Heliosporites altmarkensis*.
Depositional environment: Marine.
Age: Early Jurassic, Sinemurian.
Biozone: Dinoflagellate zonation; *Liasidinium variabile* Zone (Woollam & Riding 1983; Dybkjær 1991). Pollen and spore zonation; *Cerebropollenites macroverrucosus* Zone (Lund 1977; Dybkjær 1991).
Comments: The *Liasidium variabile* Zone (Woollam & Riding 1983; Dybkjær 1991) is restricted to the Sinemurian, Lower Jurassic, and is characterised by a monotypic marine flora of this species. The *Cerebropollenites macroverrucosus* Zone (Lund 1977; Dybkjær 1991) comprised Sinemurian and Plienbachian. The *Chasmatosporites* Zone (Koppelhus & Nielsen 1994) was defined later for the Plienbachian part of the *Cerebropollenites macroverrucosus* Zone based on a more abundant occurrence of e.g. *Cerebropollenites*, *Chasmatosporites* and *Corollina*. The spore–pollen flora alone is too limited to distinguish Sinemurian from Plienbachian in this sample but supports the result from the dinoflagellate flora.

DCS 1352 m

Organic matter: Relatively low organic content. Angular, brown and black woody material dominates.
Palynomorphs: Spores, pollen and dinoflagellates are frequent.
Dinoflagellate cysts: An assemblage dominated of abundant *Liasidium variabile*. Rare, possible *Mendicodinium* spp. are present.
Acritarchs: Acanthomorph acritarchs are present.
Spores and pollen: *Alisporites robustus*, *Cerebrocysta macroverrucosus*, *Chasmatosporites apertus*, *C. hians*, *C. major*, *Corollina* spp., *Deltoispora toralis*, *Perinopollenites elatoides* and *Quadraeculina anellaeformis* are common.
Depositional environment: Marine / marginal marine.
Age: Early Jurassic, Pliensbachian.
Biozone: Dinoflagellate zonation; *Mendicodinium reticulatum* Zone. Pollen and spore zonation; *Chasmatosporites* Zone (Koppelhus & Nielsen 1994).

Comments: The slightly higher abundance of *Cerebropollenites* spp. and *Chasmatosporites* spp. in this sample favours the identification of the *Chasmatosporites* Zone of Pliensbachian age. The appearance of *Mendicodinium* spp. indicates correlation to the lower Pliensbacian *M. reticulata* Zone.

DCS 1442 m

Organic matter: Angular, brown and black woody material dominates. Spores, pollen and dinoflagellates are frequent.
Palynomorphs: Bisaccate pollen dominates.
Dinoflagellate cysts: A monotypic assemblage of common *Liasidium variabile*. Few *Beaumontella*? sp. are also recorded.
Acritarchs: Acanthomorph acritarchs are common.
Spores and pollen: *Cerebrocysta macroverrucosus*, *Chasmatosporites apertus*, *C. hians*, *Corollina* spp., *Deltoispora toralis*, *Ovallipollis ovalis*, *Pinuspollenites minimus*, *Perinopollenites elatoides*, *Stereisporites punctus*, cf. *Striatella seebergensis*, *Quadraeculina anellaeformis*.
Depositional environment: Marine / marginal marine.
Age: Early Jurassic, Pliensbachian.
Biozone: Pollen and spore zonation; *Chasmatosporites* Zone (Koppelhus & Nielsen 1994).
Comments: The slightly higher abundance of *Cerebropollenites* spp. and *Chasmatosporites* spp. in this sample favours the identification of the *Chasmatosporites* Zone?

DCS 1469 m

Organic matter: Angular, black woody material dominates associated with abundant degraded terrestrial plant material.
Palynomorphs: Bisaccate pollen and spores dominate. Dinoflagellates and acritarchs are common.
Dinoflagellate cysts: *Beaumontella langii*, *Beaumontella* sp., *Liasidium variabile*, *Mendicodinium reticulatum*, *Mendicodinium* spp., *Parvocysta* sp., *Valveodinium stipulatum*, *Waneria* sp. (very small).
Acritarchs: Acanthomorph acritarchs are common, e.g. *Micrhystridium* spp. and *Veryhachium* spp. *Pterospermella* sp. is present.
Others: Foraminifera, inner linings.
Spores and pollen: *Alisporites robustus*, *Cerebropollenites macroverrucatus*, *Corollina* spp., *Chasmatosporites hians*, *Chasmatosporites major*, *Cingutriletes infrapunctus*, *Ovalipollis ovalis*?, *Perinopollenites elatoides*, *Semirhaetisporites gothae*?, *Quadraecullina anellaeformis*.
Depositional environment: Marine.
Age: Early Jurassic, early Pliensbachian.
Biozone: Dinoflagellate zonation; *Mendicodinium reticulatum* Zone (Koppelhus & Nielsen 1994). Pollen and spore zonation: *Chasmatosporites* Zone (Koppelhus & Nielsen 1994).
Comments: *B. langii* has range top in Pliensbachian (Riding & Thomas 1992). A Pliensbachian range for *Valveodinium stipulatum* has been reported from Øresund (Poulsen 1996). *Mendicodinium reticulatum* appears in the basal Pliensbachian (Poulsen & Riding 2003)

Further studies may recover more dinoflagellate taxa.

DCS 1514 m

Organic matter: Dominated of strongly degraded, partly structured, terrestrial plant material in association with black woody material.
Palynomorphs: Bisaccate pollen dominate, trilete spores are common and marine flora is present.
Dinoflagellate cysts: *Liasidium variabile* and specimens of the *Nannoceratopsis gracilis* complex (e.g. *N. gracilis*, *N. senex* and *N. triangulata*) are common in association with less frequent *Mendicodinium reticulatum*, *Mendicodinium* sp. and *Pareodinia* sp.
Acritarchs: A variety of morphotypes are present in low numbers, most of which can be classified as *Baltisphaeridium* spp., *Micrhystridium* spp. and *Veryhaccium* spp.
Spores and pollen: The assemblage is dominated by relatively frequent *Cerebropollenites macroverrucosus*, *Corollina* spp., *Deltoidospora toralis* and *Chasmatosporites* spp. (e.g. *C. apertus*, *C. elegans* and *C. major*). The bisaccate pollen *Alisporites robustus* and *Pinuspollenites minimus* are present together with *Cerebropollenites thiergartii*, *Leptolepidites* sp. tetrade, *Lycopodiumsporites* spp., *Quadraeculina anellaeformis*, *Uvaesporites argentaeformis*.
Others: *Botryococcus* spp. and *Lecaniella* spp.
Depositional environment: Marine.
Age: Early Jurassic, upper Pliensbachian.
Biozone: Dinoflagellate zonation: *Luhenda spinosa* Zone *sensu* (Riding & Thomas 1992)(zonal species not recorded); Spore/pollen zonation: *Chasmatosporites* Zone (Koppelhus & Nielsen 1994).
Comments: *Liasidium variabile* much less abundant than above and is probably caved. *Mendicodinium reticulatum* appears in basal Pliensbachian and *Nannoceratopsis* spp. appears in mid – upper Pliensbachian (Poulsen & Riding 2003). The *Chasmatosporites* Zone is of Pliensbachian age (Koppelhus & Nielsen 1994).

DCS 1556 m

Organic matter: Dominated of degraded terrestrial matter in association with black woody material and few palynomorphs.
Palynomorphs: Totally dominated of smooth, trilete spores.
Dinoflagellate cysts: None.
Acritarchs: None.
Other algae: None.
Spores and pollen: The assemblage is dominated of abundant smooth, trilete spores such as *Deltoidosporites toralis*, *D. minor* and *Cibotiumspora juriensis* together with few granulate and bacculate trilete spores. *Cerebropollenites macroverrucosus* and *Callialasporites* spp. (*C. damperii*, *C. trilobatus* and *C. turbatus*), *Eucomiidites troedsonii*, *Leptolepidites major* and *Perinopollenites elatoides* are common. Bisaccate pollen are rare. *Quadraeculina anellaeformis* is present.
Depositional environment: Terrestrial.
Age: Latest Early Jurassic to Middle Jurassic, Toarcian–Aalenian or younger?

Biozone: Most probably *Callialasporites-Perinopollenites* Zone (Dybkjær 1991; Koppelhus & Nielsen 1994).
Comments: The content of abundant *Callialasporites* spp., especially *C. turbatus*, frequent *Eucomiidites troedsonii* and *Leptolepidites major* indicate an age of Toarcian or younger. The presence of *Quadraeculina anellaeformis* suggests an age no youger than Bajocian. The age of the *Callialasporites-Perinopollenites* Zone is suggested to be Aalenian but with some uncertainty.

On request, the sample has been thoroughly searched for any marine or terrestrial flora of another age than the Jurassic mentioned above, but without results.
Lower Cretaceous 1697 – 1907 m
Discussion: The Lower Cretacous succession could well be upside-down as the overlying Jurassic succession is. The stratigraphy of sample 1697 m with a poor flora is crucial for this consideration. However, the flora is too limited and uncharacteristic to justify interpretation of its stratigraphic position above or below the ”Jydegård Fm. assemblage”. More work may solve this problem.

DCS 1697 m

Organic matter: Finely disseminated organic matter with black woody material and palynomorphs.
Palynomorphs: Abundance of pollen and spores associated with few dinoflagellates.
Dinoflagellate cysts: A low diverse and low abundance flora of *Cribroperidinium granuligerum* and *Hystrichodinium* aff. *pulchrum*. The presence of *Liasidium variabile* and *Nannoceratopsis gracilis* is considered due to caving from higher strata in the well.
Acritarchs: *Micrhystridium* spp.
Other algae: *Botryococcus* spp. and *Schizosporis reticulatus*.
Spores and pollen: The assemblage is totally dominated by Jurassic spores and pollen which presumably are caved from the strata above; e.g. *Callialasporites trilobatus*, *Cerebropollenites macroverrucosus*, *Chasmatosporites* spp., *Corollina* spp. *Deltoidospora* spp. and *Quadraeculina anellaeformis*.
Depositional environment: Restricted marine.
Age: Cretaceous, most probably Early Cretaceous.
Biozone: Insufficiently data.
Comments: The species *Cribroperidinium granuligerum* and *Hystrichodinium* aff. *pulchrum* were also recorded in Lower Cretaceous strata of the DGE #1 well in a typical “Jydegård Fm. assemblage”. Here in DGE #2, they occur separately in strata above the typical “Jydegård Fm. assemblage” in samples 1811, 1877 and 1907 m. In the Danish Basin, *C. granuligerum* is reported (Poulsen 1996) to reach from the Jurassic into the Ryazanian, uppermost *Gochteodinia villosa* Zone (Davey 1979). In the Jydegård Formation, *C. granuligerum* reaches further into the *P. pelliferum* Zone (Piasecki 1984). *H. pulchrum* has a long range in the Jurassic and Cretaceous. Sample 1697 m is most probable of Early Cretaceous age and associated with the succession below. The accompanying pollen and spore assemblage is definitively Jurassic and very different from the Lower Cretaceous assemblage recorded below. Similarly, the colour of sporomorphs and the organic matter in general reflect higher thermal degradation (TAI $2–2^+$; orange) as in the Jurassic above.

The presence of the dinoflagellates *Nannoceratopsis gracilis* and *Liasidium variabile* is in conflict with both a Late Jurassic or Early Cretaceous age and they are considered caved. This indicate, that also the Jurassic sporomorph flora is caved and further supports that the age of these strata is Early Cretaceous rather that Late Jurassic. The record of one *Schizosporis reticulatus* supports a Cretaceous age of these strata (Pierce 1976; Piasecki 1984).

DCS 1811 m

Organic matter: Finely disseminated- to large lumps of amorphous kerogene dominate the organic content totally. Black, woody material and palynomorphs occur subordinate (< 1%).
Palynomorphs: Dinoflagellates are abundant. Terrestrial palynomorphs are present.
Dinoflagellate cysts: A poorly preserved, low diverse flora which is dominated by *Muderongia simplex* and *Sentusidinium pelionense*. *Cantulodinium speciosum*, *Hurlandsia rugarum* and *Pseudoceratium pelliferum* are present.
Acritarchs: *Pterospermella* sp. and *Veryhaccium* sp.
Other algae: Colonies of *Botryococcus* spp. are common.
Spores and pollen: Spores and pollen are present but not identified. Caved, Jurassic spores and pollen do occur e.g. *Leptolepidites* spp.
Depositional environment: Marine.
Age: Early Cretaceous, late Ryazanian – early Valanginian.
Biozone: *Pseudoceratium pelliferum* Zone (Davey 1979).
Comments: This dinoflagellate assemblage corresponds to the assemblage reported from the Jydegård Formation on Bornholm (Piasecki 1984).
No thermal degradation recognised (TAI 1–$^{-}$2). Few orange spores (TAI 2–2$^{+)}$ may be caved from higher Jurassic strata.

DCS 1877 m

Organic matter: Amorphous kerogene dominates totally, either finely disseminated or in large lumps. Black, woody material is present mainly in small fragments but larger lath-shaped fragments are also present. Sporomorphs are rare.
Palynomorphs: Spores and pollen dominate but dinoflagellates are almost as frequent.
Dinoflagellate cysts: A relatively low-diverse but abundant assemblage dominated by *Sentusidinium pelionense* and with frequent *Cantulodinium speciosa* and *Hurlandsia rugara*. *Cribroperidinium* spp., *Muderongia simplex simplex* and *M. simplex microperforatum* are present together with *Batioladinium pomum*, *Canningia* sp., *Pseudoceratium pelliferum* and unidentified chorate cysts (*Systematophora* spp. / *Stiphosphaeridium* spp.). *Aldorfia* sp. A (Davey 1982), *Gochteodinia sp. 2* (Davey 1982) and *Oligosphaeridium asterigium/complex* are considered not *in situ*.
Acritarchs: Relatively common *Veryhachium* spp. compared to the samples below and above.
Other algae: Colonies of *Botryococcus* spp. are common.
Spores and pollen: Present but not identified; severely degraded.
Depositional environment: Marginal marine.
Age: Early Cretaceous, late Ryazanian – early Valanginian.

Biozone: *Pseudoceratium pelliferum* Zone (Davey 1979).
Comments: This dinoflagellate assemblage corresponds to the assemblage reported from the Jydegård Formation on Bornholm (Piasecki 1984).
The presence of a low number of Jurassic spores and pollen (e.g. *Quadraeculina anellaeformis*, *Corollina* spp. etc.) may be due to caving from the overlying Lower Jurassic succession. However, specimens of *Gochteodinium* sp. 2 (Davey 1982) and fragments of *Aldorfia* sp. A (Davey 1982) indicate reworking from older strata (latest Jurassic) and the presence of a single *O. asterigium/complex* suggests caving from sligthly younger strata (Early Cretaceous).
No thermal degradation recognised (TAI 1–$^{-}$2). Few orange spores (TAI 2–2$^{+)}$ may be caved from higher Jurassic strata.

DCS 1907 m

Organic matter: Amorphous kerogene dominates totally, either finely disseminated or in large lumps. Black, woody material and sporomorphs are present (< 1%).
Palynomorphs: Strongly degraded spores and pollen dominate but dinoflagellates are frequent.
Dinoflagellate cysts: Relatively low diverse assemblage dominated by *Sentusidinium pelionense*, together with common *Cantulodinium speciosum*, *Hurlandsia rugare* and *Muderongia simplex* (including subsp. *microperforatum*).
Batioladinium varigranosum, unidentified chorate cysts, *Oligosphaerium asterigium*/*complex*, *Pseudoceratium pelliferum* are recorded by one or more specimens.
Acritarchs: *Veryhachium* spp., *Micrhystridium* spp. and *Pterospermella* spp.
Other algae: *Botryococcus* spp.
Spores and pollen: The assemblage comprises mainly discrete, thin-walled bisaccate pollen and trilete spores.
Depositional environment: Marginal marine.
Age: Early Cretaceous, late Ryazanian – early Valanginian.
Biozone: *Pseudoceratium pelliferum* Zone (Davey 1979).
Comments: This dinoflagellate assemblage corresponds to the assemblage reported from the Jydegård Formation on Bornholm (Piasecki 1984).
The presence of one *O. asterigerum*/*complex* and one *B. varigranosum* indicate a younger Valanginian age according to (Davey 1982). However, these specimens may be caved from younger, Early Cretaceous strata?
No thermal degradation recognised (TAI 1–$^{-}$2). Few orange spores (TAI 2–2$^{+)}$ may be caved from higher Jurassic strata.

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