

General discussions and conclusions, the Harre borehole.

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O. B. Nielsen and H. Friis, Department of Earth Sciences, Aarhus University, DK-8000 Århus C, Denmark

In this chapter some general remarks about the sediments and the analyses of them are given.

The borehole is located in the Danish Subbasin of the Tertiary North Sea Basin close to the Fennoscandian Border Zone and with 4 salt structures located within a distance of approximately 25 kms from the site.

Lithostratigraphy

The following lithostratigraphic units, all marine clays, of Tertiary age have been identified: Vejle Fjord Formation from 9.75-67.5 m.b.s. (meters below surface), the Branden Formation from 67.5-119.45 m.b.s., the Viborg Formation from 119.45-177.5 m.b.s., the Lillebælt Clay Formation, from 177.5-186 m.b.s., the Røsnæs Clay Formation from 186-190.88 m.b.s., the Ølst and Fur Formations from 190.88-222 m.b.s., the Holmehus Formation from 222-229.9 m.b.s., the "grey slightly to non-calcareous clay" from 229.9-244.5 m.b.s. and the Kerteminde Marl from 244.5-256.9 m.b.s.. Below 256.9 m.b.s. Danian Limestone is found. There are distinct stratigraphic gaps between the Røsnæs- and Lillebælt Clay Formations and between the Lillebælt Clay Formation and the Viborg Formation. The Fur- and Ølst Formations are here demonstrated to be interfingering, with gradual transition between the two different but contemporaneous formations.

Palaeoenvironments

The waterdepths during deposition have not been so great that sea level fluctuations and tectonic events were unable to influence the deposition. There are, however, no indications of subaerial weathering of any of the formations present. The gaps in the stratigraphic record are thus, either the result of periods of non-deposition, or submarine erosion or combinations of these. Intervals with substantial amounts of glauco-

nite probably represent these events. In Paleocene formations very few lateral variations occur. The sediments consist of very fine-grained smectite-dominated terrestrial material mixed with biogenic components, indicating a relatively limited but stable supply from the surrounding landmasses. In the Eocene some formations at other localities receive greater quantities of terrestrial supply, demonstrated by thicker sequences and a more kaolinite-dominated composition of the terrestrial input in these regions. The Oligocene environments are dominated by a significantly greater subsidence and supply of more coarse-grained terrestrial components. Sea-level falls are believed to play an important role in the presence of periods with limited accumulation rates.

Only in the Ølst/Fur Formations periods of anoxic sedimentation were present. The diatoms of these two formations indicate that they were deposited in a neritic environment, far enough away from the coast not to have received benthic diatoms. The productivity was high, but not so high as in the region west and northwest of the Harre borehole. The thickness of the formations is thus only half of that known in the western Limfjord area.

Reworking

The biostratigraphic analyses have demonstrated several intervals with presence of reworked microfossils.

In the Paleocene reworked Maastrichtian nannofossils dominate in the Kerteminde Marl, but no reworking is proved for the remaining part of the Paleocene. Eocene deposits have generally no reworked fossils. In the Vejle Fjord Formation Cretaceous fossils comprise the main part of reworked fossils while Paleocene and Eocene ones are subordinate. In the Branden Formation Paleocene and Eocene reworked fossils are more frequent than the Cretaceous ones, and in the Viborg Formation Eocene reworked fossils dominate

over Upper Cretaceous ones.

Uplifted Maastrichtian sediments in the inversion zone in Kattegat in Late Cretaceous to Early Paleocene is the possible source area for the reworked nannofossils in the Kerteminde Marl. It should be considered in more detail whether compressional tectonics due to a relatively northwards movement of the African plate as compared to the Eurasian plate has any genetic relation to the inversion phenomenon. The sea-level fall probably also played an important role for bringing Maastrichtian Chalks into an erosional position in Kerteminde Marl time.

No major tectonic events seem to have influenced the sediments in the remaining Paleocene or in Eocene. Sea level fluctuations have elsewhere in Denmark been demonstrated to influence the presence of reworked material and location of hiatus. The existence of a hiatus between nannoplankton zones NP 17 and 19 in the Late Eocene and the abrupt increase of smectite and the presence of zeolites in Bed L5 are examples of this. The very incomplete Eocene sediments in the Harre cores might be caused by local uplift of salt in the area.

The persistent presence of reworked material in the Oligocene sediments is most likely related to the general uplift of Scandinavia, which initiated in the earliest Oligocene or latest Eocene. The very complete Oligocene sediments might be related to peripheral sinks to one or more of the surrounding salt structures. The tendency for reworked fossils to be progressively older as the age of the host sediment becomes younger might be caused by successive erosion of older, mainly Mesozoic, sediments to the northeast, as the uplift of Scandinavia develops. The same tendency is observed elsewhere in Denmark, and for the moment this problem is under further investigation.

Age of the formations

Generally the stratigraphic investigations support the normally accepted ages for the identified formations. The age of the Ølst/Fur Formations have for many years been subject to many discussions, mainly caused by the absence of nannofossils and other indicative microfossils. Correlation of the diatoms with DSDP and ODP Sites from the Atlantic- and Indian Oceans indicate that at least the sequence from ash layer -30 to +30 was deposited in the Early Eocene in the Calcareous Nannofossil Zone CP9a.

Correlation of different stratigraphic tools

The magnetostratigraphic interpretations have proved

to be difficult to correlate with other stratigraphic results. One of the reasons is that there is no generally accepted calibration scheme established, and that, especially the Eocene section is so incomplete, leaving several possibilities open for the correlation.

The Holmehus Formation is tentatively referred by Abrahamsen to marine magnetic anomaly 28-29, but these zones are normally placed in the Danian, which definitely is too old.

Ulleberg uses a 3-fold division of the Oligocene in contrast to the other contributors, who use only 2 subdivisions. No Early Oligocene sediments were found by Ulleberg, so his Middle and Late Oligocene sediments correlate to Early and Late Oligocene respectively of contributors using a 2-fold division of the Oligocene.

The Vejle Fjord Formation is more fine-grained than elsewhere, and Ulleberg has found some similarities to a Klintingehoved Fm. foraminiferal fauna (Early Miocene), indicating that at least part of the unit might be slightly younger than elsewhere. The nannofossil stratigraphy of von Salis Perch-Nielsen does not exclude this interpretation.

All stratigraphic tools place the Viborg Fm. within the Rupelian.

The lower part of the Branden Fm. contains foraminifers partly similar to a zone, the *Globigerina* zone, defined by Ulleberg elsewhere in Jylland, characterized by planktonic foraminifers. This zone might be a special depositional event, but there are no distinct lithologic characteristics justifying a special lithostratigraphic identity.