

# Lithostratigraphy and sedimentary petrography of the Oligocene sediments from the Harre borehole, Denmark.

HENRIK FRIIS

Friis, H., 1994: Lithostratigraphy and sedimentary petrography of the Oligocene sediments from the Harre borehole, Denmark. *Aarhus Geoscience*, Vol. 1, pp. 35-43, Aarhus, 1994.

## ABSTRACT

In the Harre borehole the Oligocene sediments are referred to the Viborg Formation (Lower Oligocene), the Branden Formation (Upper Oligocene) and the Vejle Fjord Formation (Upper Oligocene). They represent one of the most complete sections in Jylland. The Viborg Formation and the Branden Formation are both very homogeneous with respect to textural and mineralogical characteristics. They are finegrained, silty clays with a high proportion of smectite, slightly more in the Viborg Formation than in the Branden Formation. Well sorted silt laminae represent an input of coarser clastic material which becomes increasingly important towards the end of the Oligocene. Thick intervals of glauconitic clays may represent periods of reduced sedimentation and reworking of older sediments. The Vejle Fjord Formation represents a change in sediment input resulting in coarse clastic sediments at the end of the Oligocene. This change is associated with a mineralogical change, representing the input of heavily weathered material with kaolinite as the dominating clay mineral and gibbsite persistently present. A high content of organic matter is the result of much terrestrial organic matter being supplied and a high depositional rate.

*H. Friis, Department of Earth Sciences, Aarhus University, DK-8000 Aarhus C, Denmark.*

## INTRODUCTION

The borehole at Harre (Fig. 1 in the introductory chapter, this volume) was drilled in 1980 as part of a geothermal research project. It produced an almost complete series of high quality cores through the Tertiary sequence which at Harre comprises 250 m of Paleocene through Oligocene clays (Fig. 2, Nielsen *et al.*, 1994, this volume). The general descriptions and lithological subdivision have been presented by Nielsen *et al.* (1993). Oligocene deposits have been known for many years in the area and are described in a number of papers (Ravn, 1896, 1906a, 1906b, 1907, 1909, 1924; Beyer, 1987; Ulleberg, 1988; Schnetler and Beyer, 1990). They have informally been subdivided into the Branden Formation (after the nearby locality at Branden Brickworks) and the Cilleborg Clay (after a locality at Mariager Fjord). Later Christensen and Ulleberg (1974) made a new formal subdivision of the Oligocene deposits. Mainly based on the Viborg-1 well they established the Viborg Formation which comprises lower Oligocene (Rupelian) clays, and they restricted the Branden Formation to comprise the upper Oligocene (Chattian) clays. They proposed the formal lithostratigraphic unit Sofienlund Formation for the more sandy Oligocene deposits, which at the Sofienlund

Brickworks (Ulstrup, Fig. 1 in the introductory chapter) are younger than the *Asterigerina* subzone. This formation is probably equivalent to the Vejle Fjord Formation as defined by Larsen and Dinesen (1959). In the present paper the subdivision proposed by Christensen and Ulleberg (1974) is followed for the Viborg and Branden Formations, whereas the deposits younger than the Branden Formation are referred to the Vejle Fjord Formation of Larsen and Dinesen (1959).

## SEDIMENTARY PETROGRAPHY

Samples were selected from the recovered cores to represent the various lithologies and are especially densely picked at lithological boundaries. The analyzed samples are listed in Table 1. A standard analytical routine was applied to obtain XRD bulk mineralogy, clay mineralogy, grain size distribution and chemical data. The chemical analyses were mainly used for calibration of the mineralogical quantification from XRD (for details see Nielsen, 1993). The analytical data are presented in Table 1 and Fig. 1.

Thin sections were prepared from two cemented samples to reveal textural relations.

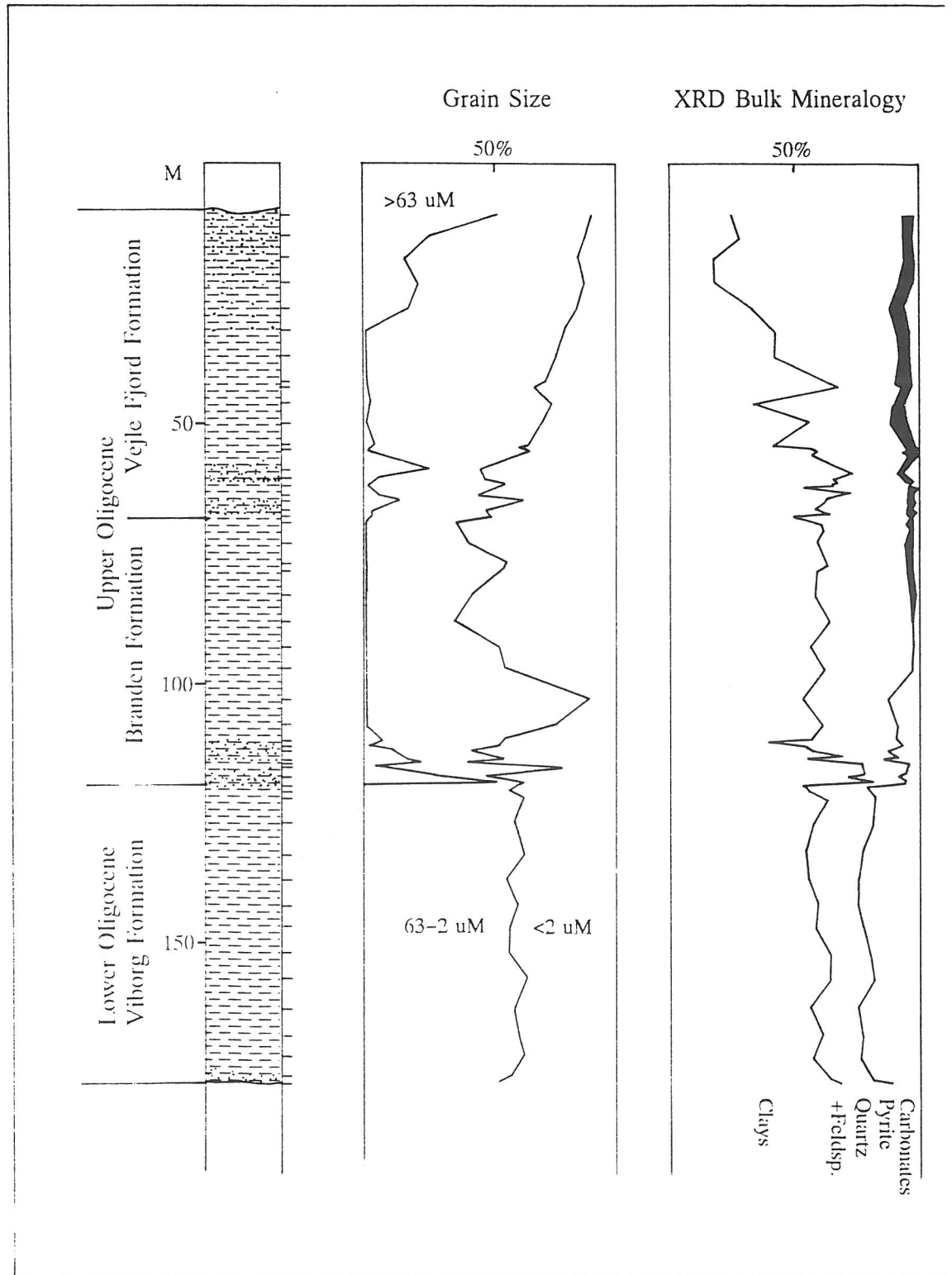


Fig. 1.

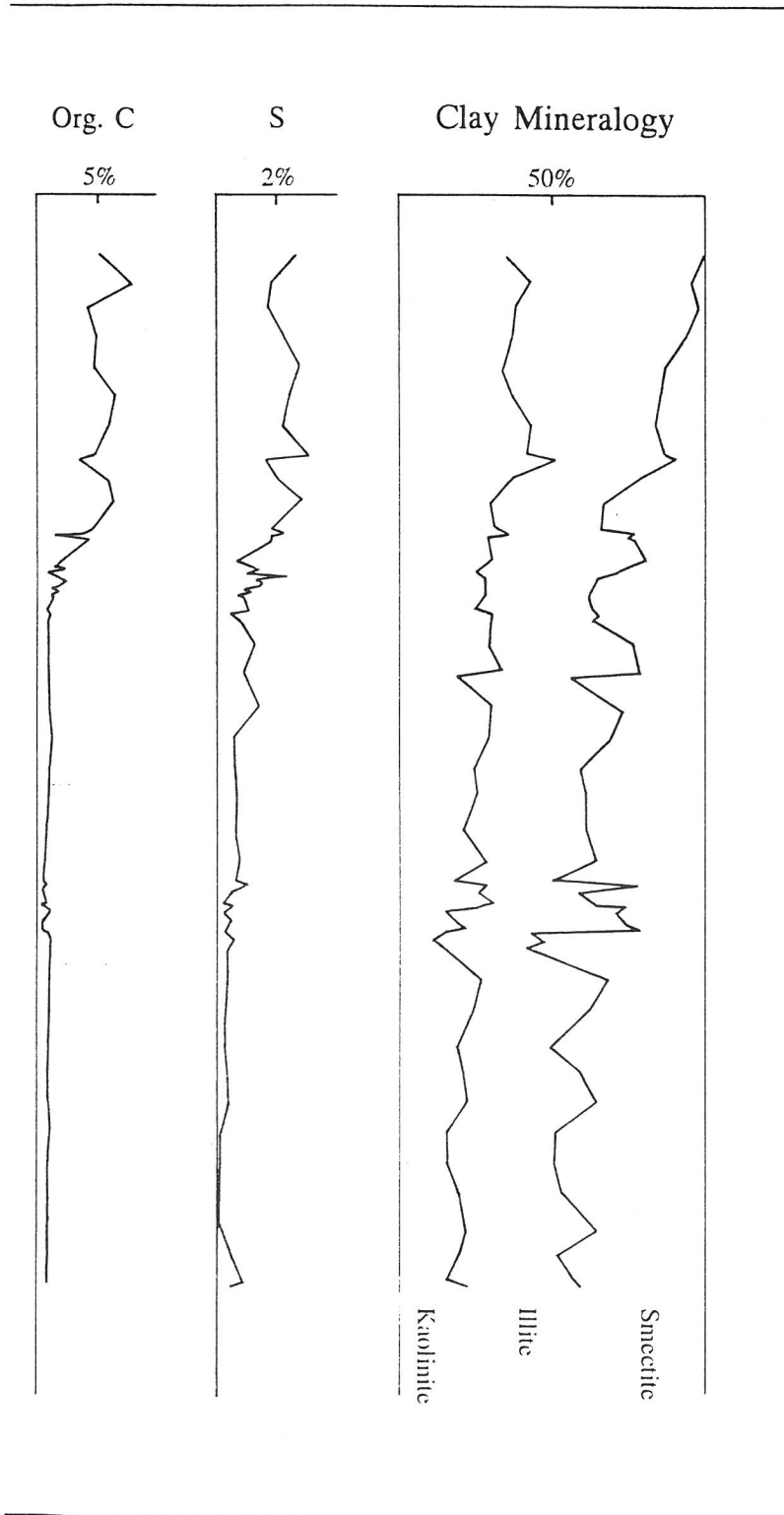


Fig. 1. (continued)

## MINERALOGY

The mineralogical variation (XRD bulk and clay mineralogy) within the Oligocene/Miocene sequence (177.0-9.75 m below surface (m.b.s.)) is partly controlled by grain-size (Fig. 1). The upwards increase in grain-size is paralleled by an increasing quartz and feldspar content, and kaolinite becomes increasingly important among the clay minerals. The content of organic carbon and sulphur is almost constant at low values in the Viborg Formation (1% organic C, less than 1/2% S) and the Branden Formation (1% organic C, less than 1% S) but gradually increasing to higher values in the Vejle Fjord Formation (up to 8% organic C, up to 3% S). Besides, there are some conspicuous variations in mineralogical composition that need to be commented on.

### Clay minerals.

Although there is an overall upwards change in clay mineralogy from a smectitic to an illitic/kaolinitic association, with smectite almost absent in the upper 10 meters, this is not strictly linked to the upwards increase in grain size. The transition from Viborg Formation to Branden Formation is marked by a strong increase in illite at the expense of smectite, whereas the kaolinite content does not change. After the first few meters, the clay mineral association is stabilized, with slightly lower smectite values than in the Viborg Formation, although the grain size distribution of the Branden Formation is as fine grained as in the Viborg Formation, although more variable. The abrupt change in clay mineralogy is probably related to transformation of smectite into glauconite, which is strongly dominating the bottom part of the Branden Formation (also affecting the grain size distribution). The glauconite is registered as illite in the clay mineral analyses. The glauconitic transition from the Branden Formation to the Vejle Fjord Formation is also characterized by a temporary increase in illite at the expense of smectite. So, except for the massive formation of glauconite in certain intervals, the general features of clay mineral distribution are a uniform composition in Viborg and Branden Formations with higher smectite values in the Viborg Formation, and gradually decreasing smectite content in the Vejle Fjord Formation, here closely related to the upwards increase in grain size, and eventually elimination of smectite in the uppermost samples.

### Gibbsite.

The occurrence of gibbsite is restricted to the uppermost part of the sequence, which is rich in organic matter, pyrite and kaolinite. No effort has been made to estimate the relative amount of gibbsite, but it is very scarce to absent in the interval from 60.25 to 55.10 m.b.s. and consistently present above. There is an apparent correlation between the content of kaolinite and gibbsite. Gibbsite has not been identified below 60.25 m.b.s. Gibbsite is known from a number of other Danish exposures of Upper Oligocene age, as discussed by Andreassen (1985).

Gibbsite is a common mineral under extreme weathering conditions but only occasionally reported as a diagenetic mineral. The formation of gibbsite requires high concentrations of dissolved  $Al^{3+}$  and low concentration of other dissolved cations. It is therefore unlikely that the gibbsite formed in situ in a marine sediment. The sudden occurrence in the Vejle Fjord Formation probably represents the introduction of detritus from a source area which had experienced lateritic weathering. Such conditions have not been reported from the sub-Late Oligocene discontinuity surface in Denmark or from the surrounding Fennoscandian Shield, which was the main source area according to heavy-mineral analyses by Larsen and Dinesen (1959). It is likely that the hot, humid climate prevailing in the Eocene (Spjeldnæs, 1975) caused lateritic weathering in the Fennoscandian shield. Supply from a heavily weathered source area is also indicated by the occurrence of oolitic ironstones in the basal part of the Vejle Fjord Formation from Horsens Fjord as reported by Mikkelsen (1983). The age of the weathering cannot be established on the present evidence. The first appearance of gibbsite in the Late Oligocene might be related to the general introduction of coarser clastics at that time (Sorgenfrei, 1949), but also the correlation with the kaolinite content and the grain-size effect should be considered. It is possible that the gibbsite follows the coarse fraction of clay minerals and was differentially settled close to the shore line. This would probably explain the main features of the distribution of gibbsite, but not its total absence in the Viborg and Branden Formations. Thus the supply of gibbsite would be the result of a source area expansion. A late Oligocene lateritic weathering is not considered likely since the climate in late Oligocene was rather cold (Bucharadt, 1978).

Table 1: Composition in % of Oligocene sediments from the Harre borehole. Depth in m.b.s. A-H: XRD-bulk mineralogy. A: Clay minerals. B: Quartz. C: Alkalifeldspar. D: Plagioclase. E: Calcite. F: Mixed calcites. G: Siderite. H: Pyrite. I-L: XRD-clay mineralogy. I: Smectite. J: Illite. K: Kaolinite. L: Chlorite. +: Present. -: Absent. (+): Probably present. na: Not analysed.

DEPTH	A	B	C	D	E	F	G	H	I	J	K	L
9,75	16	70	5	3	0	1	0	5	0	64	36	+
14,25	29	56	8	2	1	1	0	4	4	52	44	+
18,25	19	67	6	2	1	0	0	4	2	59	39	+
22,75	19	64	4	6	1	1	0	5	6	56	38	+
27,75	34	49	2	5	1	4	0	6	13	52	35	+
32,25	44	40	7	3	2	1	0	5	14	49	37	+
37,25	43	48	2	2	3	0	0	4	16	40	44	+
42,25	66	22	1	2	1	1	0	7	13	44	43	+
42,75	69	22	1	1	1	1	0	4	10	39	51	+
46,25	35	44	6	4	5	0	0	5	21	42	37	+
49,75	56	29	1	1	3	1	0	7	32	37	31	(+)
54,25	42	47	5	2	1	0	0	4	33	35	32	+
54,75	58	35	1	2	0	0	0	4	23	41	36	-
55,11	60	30	1	1	0	2	1	4	24	46	30	-
55,75	58	31	3	4	0	0	0	4	22	48	30	-
59,25	74	17	0	0	6	0	0	2	19	50	31	-
60,75	67	24	1	3	1	1	0	3	28	46	26	-
62,25	55	36	2	3	0	0	0	3	34	37	29	-
64,25	64	29	1	1	1	1	0	2	na	na	na	na
65,25	65	29	1	5	0	1	1	2	37	34	29	-
67,25	65	28	1	2	0	1	0	3	36	38	26	-
67,75	51	39	3	4	1	1	0	1	34	35	31	-
69,25	62	29	1	2	1	1	0	2	36	33	31	-
72,75	60	30	2	2	1	1	0	3	23	47	30	(+)
77,25	64	27	2	2	0	2	1	2	21	45	34	-
78,25	61	30	1	3	1	1	0	2	43	37	20	-
82,75	59	29	6	2	0	1	0	2	30	40	30	(+)
87,75	65	29	1	2	0	2	0	1	30	40	30	(+)
92,75	57	37	2	1	0	1	1	1	40	35	25	+
97,25	63	30	2	2	0	1	0	1	38	36	26	+
102,75	54	31	1	1	10	1	0	1	38	40	22	+
107,75	62	28	0	1	7	1	0	1	35	36	29	+
111,25	40	20	0	9	31	0	0	0	49	32	19	-
111,75	55	23	3	10	6	0	0	2	22	49	29	-
112,75	59	19	1	4	12	0	2	1	40	33	27	(+)
114,75	55	18	8	4	5	0	10	1	35	43	22	+
115,25	78	16	1	1	1	1	0	1	26	47	27	+
116,25	44	7	2	1	0	0	46	0	28	56	16	-
117,75	71	20	3	1	1	1	3	1	26	54	20	+
119,25	82	10	1	1	3	0	1	1	21	57	22	+
119,75	54	20	2	2	15	0	6	1	56	29	15	+
120,75	56	19	2	2	17	0	2	1	52	37	11	-
122,25	64	16	1	0	15	0	2	1	57	28	15	-
127,25	58	18	2	2	17	0	1	1	31	42	27	+
132,75	53	18	2	2	20	0	2	0	37	38	25	+
137,75	56	15	2	1	21	0	3	0	50	30	20	+
142,75	60	13	1	1	21	0	3	0	40	39	21	+
147,25	59	15	2	2	21	0	1	0	35	42	23	+
152,25	65	12	1	1	18	0	1	0	48	36	16	+
157,25	65	14	1	1	17	0	1	0	49	35	16	+
162,75	57	16	1	1	22	0	2	0	46	34	20	+
167,75	62	13	1	1	21	0	1	0	35	43	22	+
172,25	58	12	2	2	21	0	2	1	47	33	20	+
176,25	65	13	1	1	16	0	2	2	42	42	16	+
176,75	69	15	2	2	9	0	1	2	40	38	22	+

### Calcite.

The content of calcite is low but variable in the uppermost part of the interval. It relates to the occurrence of macrofossils and minor concretions. Below 119.45 m.b.s. (in the Viborg Formation) the calcite content is fairly constant at approximately 20%, estimated both from XRD and from chemical analyses. The Viborg Formation has a high content of microfossils (foraminifera and calcareous nannofossils).

### Siderite.

Siderite is a major constituent of a few scattered concretions, mainly in the Branden Formation. The large proportion of siderite in the sample from 116.25 m below surface indicates an early cementation.

### Pyrite.

Pyrite is associated with organic carbon. In the Viborg Formation and in the lower half of the Branden Formation there are only trace amounts of pyrite and very low values of organic carbon. In the upper part of the Branden Formation there is a gradual increase in pyrite, whereas the content of organic carbon remains constant. In the Vejle Fjord formation the content of pyrite and organic carbon is at a higher level and increasing upwards, even if the grain size is also increasing.

## CONCRETIONS

A limited number of concretions were found in the cores from the Vejle Fjord Formation and from the Viborg Formation. Thin sections were prepared from two concretions, one at 41.25 m.b.s. in the Vejle Fjord Formation, one at 169.2 m.b.s. in the Viborg Formation.

The concretion in the Vejle Fjord Formation clearly demonstrates a sediment entirely consisting of muddy pellets with a high content of organic matter and pyrite. Among the pellets are a few foraminifera which are partly filled with calcite cement, and partly filled with pyrite. In small areas, the pellets are entirely cemented by pyrite, leaving the impression of an originally porous sediment of sandsized pellets. In other parts of the thin section the interpellet space is occupied by mud and calcite cement, but the mud

density is much lower than in neighbouring pellets. This may indicate, that also in these portions of the sediment, the original texture was a well sorted, porous pellet sand.

There are several possible explanations of this facies. One possibility is, that open burrows in the sediment were filled by faecal pellets leaving only these parts of the sediment as porous sediments. They were later cemented because they were the porous passways through the sediment. Another possibility is, that the sediment was in general deposited as pellets, that there was a fairly good sorting because of some stream competency of bottom currents, that were able to prevent fine suspended matter from settling. Later compaction has destroyed the pelleted appearance of the sediment and only left the evidence in early cemented parts (concretions), where the pellets are evidently uncompacted. From other parts of the Limfjord area (Beyer, 1987) several cemented blocks of Oligocene sediments are found on the shores. Many of these blocks show the same phenomena, indicating that the brownish-black Upper Oligocene silty clays may in fact be compacted, well sorted silt and pellet sands, in some cases strongly homogenized by bioturbation. This proves, that even if the content of organic matter is extremely high, and high proportions of pyrite has formed after deposition, the depositional environment was dominated by weak currents and was well oxygenated.

The concretion from the Viborg Formation is a very homogeneous carbonate mud with abundant small foraminifera. Quartz is present as single scattered detrital silt grains in the size of 10-20 microns. The thin section demonstrates no lamination, no occurrence of pellets and no large cement crystals.

## THE FORMATIONS

### The Viborg Formation.

The Viborg Formation has been defined by Christensen and Ulleberg (1973) to comprise the interval from 169.5 m to 255.3 m below ground surface in Viborg 1 (Geological Survey of Denmark file no. 66.318). This section has been described by Flagler (1940), who divided it into three units of which the lowermost is a calcareous, sticky clay. Following the descriptions of Flagler (1940), at least the upper sandy unit in Viborg 1 is not found in the Harre

borehole. This corresponds well to the observation that the arenaceous unit is thinning northwards from Viborg 1 to Viborg 5. Unfortunately Flagler (1940) gave no indication of thickness of his units, and Christensen and Ulleberg (1973) did not comment on the original subdivision of Flagler in their description of the Viborg Formation (Christensen & Ulleberg, 1973) nor in their paper on the regional evolution of the Viborg Formation (Christensen & Ulleberg, 1974).

In the Harre borehole a very uniform deposit of greenish grey clay is correlated with the Viborg Clay Member. It includes a thin (25 cm) glauconitic bed at the base, which has elsewhere been established as a separate member of the Viborg Formation (the Grundfær Clay Member sensu Christensen & Ulleberg, 1974). The grain size distribution of the Viborg Clay Member as well as the mineralogical composition is almost identical throughout the entire section, and only the occurrence of thin silt laminae modifies this picture. Also at other known locations the Viborg Formation has a very uniform appearance (cf. Christensen and Ulleberg, 1973, 1974). Only the uppermost part is known to become more sandy at some locations (i.a. Flagler, 1940). Christensen and Ulleberg (1973) suggested an outer shelf depositional environment for the Viborg Formation. This is strongly supported by the uniform character of the sediment. A low content of organic carbon (Fig. 1) as well as the rich fauna of benthic foraminifera reported by Ulleberg (1994, this volume) indicate that bottom conditions were generally oxic although bioturbation is generally not visible in the core samples. The depositional site was often reached by slightly more coarsegrained detritus, either as distal storm silt or as windborn dust. There are no descriptions from other locations which might indicate a gradient in thickness or grain size of these laminae, and their origin is consequently uncertain. Von Salis Perch-Nielsen (1994, this volume) found a high content of reworked Eocene nannofossils in the basal part of the formation, indicating that also a large proportion of the sediment, maybe including the glauconite, could be reworked older Tertiary clays.

#### The Branden Formation.

The upper limit of the Viborg Formation is at 119.45 m.b.s. Here is a sharp lithological change from greenish grey clay to darker, strongly glauconitic clay. The boundary is accentuated by a 1 cm thick

light coloured clay layer without glauconite. Bioturbation across the boundary was not observed.

Between 119.45 m.b.s. and 111.0 m.b.s. the sediment is strongly variable but generally rich in glauconite. At 114.85 m.b.s. there is a prominent change in colour from dark greenish grey and lighter colours above to olive grey and olive black below. Immediately below 114.85 m.b.s. there is a decreasing content of glauconite in a 70 cm thick interval. Below, the sediment is again strongly glauconitic. This boundary coincides with a mineralogical change. The sediment above the boundary has a lower illite/kaolinite ratio and a relatively high content of calcite whereas calcite is negligible below. In his study of foraminiferal zones Ulleberg (1994, this volume) noted a special fauna within the lowermost samples from this interval. The fauna shares some characteristics with a planctonic fauna, the *Globigerina*-fauna, which he concluded to represent a short period with more open marine conditions (Ulleberg, 1987). This lower part is by Ulleberg (1994, this volume) considered to be of Rupelian age and probably separated from the upper part by a hiatus. He refers it to the Hvorslev Clay Member of the Viborg Formation (informally defined by Ulleberg 1987). Consequently, the lower boundary of the Branden Formation might be placed at 114.85 m below surface at the base of the second glauconite sand. The interval between 119.45 m.b.s. and 114.85 m.b.s. cannot readily be included in the Viborg Formation or the Branden Formation and for practical reasons the entire glauconitic unit is here included in the basal part of the Branden Formation. The areal distribution of the Branden Formation is limited (Ulleberg, 1987) and there are no available sedimentological analyses from other parts of the formation. It differs from the Viborg Formation mainly by having a very low content of calcite and a higher content of pyrite, but benthic foraminifera were present throughout and the depositional environment was probably largely identical to that of the Viborg Formation.

#### The Vejle Fjord Formation.

The upper limit of the Branden Formation is located at 67.5 m.b.s.. Above, the sediment becomes more silty and slightly darker, and glauconite becomes a major constituent. Glauconite is found up to 58.25 m.b.s. where it gradually becomes more scarce and eventually disappears. This upper part of the

glaucanitic zone is transitional to the typical dark brown, micaceous silt of the Vejle Fjord Formation. The glauconitic zone is divided into two by a less glauconitic to glauconite-free interval at 61.5- 63.3 m.b.s.. This interval is clearly marked by grain-size analyses, where the sand ratio is decreasing. According to Ulleberg (1994, this volume) the two glauconitic zones belong to two different foraminiferal zones, the lowermost of them with affinity to that of the Branden Formation, the uppermost with affinity to that of the Vejle Fjord Formation. However, in many locations in eastern and central Jutland, the basal glauconitic part of the Vejle Fjord Formation represents the initial deposition of a sequence which gradually becomes more and more sandy and represents the first introduction of detrital sands into this part of the basin. The basal glauconitic sediments seem to contain much higher amounts of reworked older Tertiary deposits and actually have been strongly undersupplied with coarser clastics, which were not available from older Tertiary deposits. Therefore, the lower boundary of the Vejle Fjord Formation is considered to be located at 67.5 m.b.s. although there is a change in the foraminiferal faunas a few m above the base. The introduction of gibbsite slightly above the base of the formation (60.75 m.b.s.) is considered to represent the gradually more important supply of Scandinavian detrital material.

Although the sediments of the Vejle Fjord Formation are generally rich in organic matter and pyrite, the depositional environment does not generally appear to have been anoxic, as burrows occur and benthic foraminifera and molluscs are generally present. Probably a high rate of deposition and a large supply of terrestrial organic matter resulted in a high preservation of the organic matter and a diagenetic increase in sulphides. The gradually increase in grainsize and change in mineralogy (Fig. 1) results from the retreat of the nearby coastline. Coastal sediments have been reported from neighbouring areas (Beyer, 1987; Schnetler and Beyer, 1990) but their specific age and relation to the sediments from the Harre berehole cannot be establish.

## SUMMARY

The Oligocene formations represent the increasingly important supply of clastic material from Fennoscandia, culminating in Late Oligocene and Miocene.

The Viborg and Branden Formation are strongly influenced by reworked older Tertiary sediments, being very finegrained and rich in smectite. The influx of coarser clastic material was still not prominent but silt admixture and well sorted silt laminae indicate the first supply from another source. In the Vejle Fjord Formation the grainsize gradually increases and the gradually increasing dominance of kaolinite in the clay mineral assemblage demonstrate together with the presence of gibbsite that sediment was now supplied from a strongly weathered source area which could supply sandy material.

## DANSK SAMMENDRAG

Harre boringen indeholder de tre oligocæne formationer Viborg Formationen (nedre oligocæn), Branden Formationen (øvre oligocæn) og Vejle Fjord Formationen (øvre oligocæn). Viborg Formationen og Branden Formationen er gældende formationsnavne for de pågældende sedimentære enheder og repræsenterer lithologiske enheder af et meget homogent udseende, der relativt nemt lader sig korrelere inden for de kendte udbredelsesområder, der er noget større for Viborg Formationen end for Branden Formationen. Vejle Fjord Formationen er oprindeligt defineret for kystnære sedimenter i Vejle Fjord området, og der har gennem tiden været brugt en række andre betegnelser og egentlige formationsnavne for sedimenter, der i det væsentlige svarer til Vejle Fjord Formationen i alder og i generel geologisk udvikling. Sedimenterne i Harre boringen repræsenterer en meget tyk, relativt finkornet sedimentserie, der ikke snævert kan korreleres med Vejle Fjord Formationen, men den synes at være del af en successiv udvikling, der ultimativt fører til aflejring af sedimenter, der tydeligere svarer til andre kendte forekomster. Derfor er sedimenterne henført til denne lithostratigrafiske enhed. Viborg og Branden Formationerne er meget ensartede med hensyn til kornstørrelse og mineralogisk sammensætning. Viborg Formationen er domineret af smectit i lerfraktionen, og har et konstant forholdsvis højt indhold af kalcit, medens Branden Formationen har et lidt lavere indhold af smectit og er stort set kalkfri. Tynde lameller af velsorteret silt demonstrerer den begyndende tilførsel af grovere klastisk materiale, der kommer til at præge det danske område fra det yngste oligocæn. Denne udvikling ses tydeligt i sedimenterne fra Vejle Fjord Formationen, der mod

toppen bliver mere og mere sandede. Samtidig ændres den mineralogiske sammensætning som resultat af, at der efterhånden tilføres materiale fra stærkt forvitrede områder (dominans af kaolinit i lerfraktionen og konstant tilstedeværelse af gibbsit).

#### ACKNOWLEDGEMENT

Ole Bjørnslev Nielsen is thanked for his continuous interest and for valuable comments and Chris King for correcting the English of this text.

#### REFERENCES

- Andreasen, A.D., 1985:** En sedimentologisk undersøgelse af Ø. Oligocæn-N. Miocæn ved Bjerringbro og Ulstrup, Midtjylland. Unpubl. MSc.-thesis, Aarhus Universitet (in Danish):150 pp.
- Beyer, C., 1987:** Ø. oligocæn - n. miocæn i Nordvestjylland. Faciesanalyse og magnetostratigrafi. Unpubl. MSc.-thesis, Aarhus Universitet (in Danish): 164 pp.
- Buchardt, B., 1978:** Oxygen isotope palaeotemperatures from the Tertiary period in the North Sea area. *Nature*, 275, pp. 121-123.
- Christensen, L. and Ulleberg, K., 1973:** Sedimentology and micropalaeontology of the Middle Oligocene sequence at Sofienlund, Denmark. *Bull. geol. Soc. Denmark*, 22, pp. 283-305.
- Christensen, L. and Ulleberg, K., 1974:** Sediments and foraminifers of the Middle Oligocene Viborg Formation, Denmark. *Bull. geol. Soc. Denmark*, 23, pp. 109-117.
- Flagler, C.W., 1940:** Report on the Stratigraphy and Foraminifera of the Viborg Core Drill Profile, Mid-Jutland, Denmark. Danish American Prospecting Company, unpubl. rep. 36 pp.
- Larsen, G. and Dinesen, A., 1959:** Vejle Fjord Formationen ved Brejning. *Danmarks geol. Unders.*, 2,82, 114 pp.
- Mikkelsen, J., 1983:** En lithofaciesundersøgelse af Ungtertiæret omkring Vejle Fjord. Unpubl. MSc.-thesis, Aarhus Universitet (in Danish): 100 pp.
- Nielsen, O.B., 1994, this volume:** Lithostratigraphy and sedimentary petrography of the Paleocene and Eocene sediments from the Harre Borehole, Denmark. *Aarhus Geoscience*, Vol. 1, pp. 15-34
- Nielsen, O.B., Friis, H. and Korsbech, U., 1994, this volume:** Lithology and lithostratigraphy of the Harre borehole, Denmark. *Aarhus Geoscience*, Vol. 1, pp. 5-15.
- Ravn, J.P.N., 1897:** Nogle bemærkninger om danske tertiæraflejrings Alder. *Meddr. dansk geol. Foren.*, 4, pp. 1-16.
- Ravn, J.P.N., 1906a:** Om det såkaldte plastiske lers alder. *Meddr. dansk geol. Foren.*, 2,12, pp. 23-28.
- Ravn, J.P.N., 1906b:** Nogle bemærkninger om de oligocæne og miocæne aflejringer i Jylland. *Meddr. dansk geol. Foren.*, 2,12, pp. 1-6.
- Ravn, J.P.N., 1907:** Molluskfaunaen i Jyllands Tertiæraflejringer. *De kongelige danske Videnskabernes Selskabs Skrifter, 7. Række, Naturvidenskabelig og Mathematisk Afdeling III.2*
- Ravn, J.P.N., 1922:** Geologisk Kort over Danmark. Dybere liggende Dannelser. *Danm. geol. Unders.*, 3,22, 79 pp.
- von Salis Perch-Nielsen, K., 1994, this volume:** Neogene and Paleogene calcareous nannofossils from the Harre borehole, Denmark. *Aarhus Geoscience*, Vol. 1, pp. 45-52.
- Schnetler, K.I. and Beyer, C., 1987:** A Late Oligocene (Chattian B) mollusc fauna from the clay-pit of Galten Brickworks at Nørre Vissing, Jylland, Denmark. *Meded. Werkgr. Tert. Kwart. Geol.*, 24, pp. 193-224.
- Schnetler, K.I. and Beyer, C., 1990:** A Late Oligocene (Chattian B) molluscan fauna from the coastal cliff at Mogenstrup, North of Skive, Jutland, Denmark. *Contr. Tert. Quatern. Geol.*, 27, pp. 39-81.
- Sorgenfrei, Th., 1949:** Nye undersøgelser over Fyns undergrund. *Meddr. dansk geol. Foren.*, 11, pp. 490-493.
- Spjeldnæs, N., 1975:** Palaeogeography and facies distribution in the Tertiary of Denmark and surrounding area. *Norges geol. Unders.*, 316, pp. 289-311.
- Ulleberg, K., 1987:** Foraminiferal zonation of the Danish Oligocene sediments. *Bull. geol. Soc. Denmark*, 36, pp. 191-202.
- Ulleberg, K., 1994, this volume:** Oligocene foraminifera and stratigraphy from the Harre borehole, Denmark. *Aarhus Geoscience*, Vol. 1, pp. 81-84.

