

Fehmarn Belt Fixed Link Pre-Quaternary Biostratigraphy

– a mid-term status report for Rambøll/-Arup JV

Emma Sheldon & Henrik Nøhr-Hansen



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Strategy

The results from a multidisciplinary biostratigraphic analysis of selected samples from 24 wells from onshore Fehmarn, onshore Rødbyhavn and the Fehmarn Belt is presented. The wells have been drilled both to investigate the character of the Quaternary deposits and the nature of the Palaeogene strata and chalk (where encountered) underlying the Quaternary deposits in preparation for construction of the Fehmarn Belt Fixed Link. The biostratigraphic analysis is carried out to supplement and constrain the geological model based on sedimentological and seismic data obtained by Rambøll/Arup JV & Fugro Engineers BV. Emma Sheldon carried out nannofossil and microfossil analysis and Henrik Nøhr-Hansen carried out palynological analysis.

Methods

This mid-term status report presents the results of a multidisciplinary biostratigraphic study of selected samples from 24 wells drilled in 2009 in the Fehmarn region. The 24 wells were drilled to a total depth (TD) of between 50 and ca. 100 m. All wells were totally cored in the pre-Quaternary deposits; the use of core material, rather than ditch cuttings samples, is important as it reduces errors in dating caused by caving. 1-10 core samples from each well were chosen by John Kjærgaard Frederiksen, Rambøll/Arup JV for biostratigraphic analysis. Biostratigraphic dating using calcareous nannofossils was carried out on all samples. Based on these results, further analyses were carried out using microfossils and dinoflagellate cysts if required.

For this study, 96 samples were analysed using calcareous nannofossils. 72 were analysed for their microfossil content and palynological analysis was carried out on 59 samples. 2 samples from the 09.A.019 well (from February 2010) are included in this report. Nannofossils are particularly useful for dating in chalk and clay lithologies, microfossils in chalk, sand and clay, and palynomorphs in clay lithologies. This multidisciplinary biostratigraphic approach allowed rapid yet reliable dating of the samples to be performed. One chalk sample, 46.2 m - 46.25 m from well 09.A.006 required particular analysis as it had a black amorphous material associated with it, it was analysed for both lithologies as described in the results section. Reworked material is denoted using 'RW'. If a biostratigraphic discipline has not been used to date a sample, 'n/a' is used and if a formation cannot be identified, this is also noted.

The Palaeogene zonation schemes primarily used in the study are applicable to the North Sea area: the calcareous nannofossil zonation scheme of Varol (1998), the planktonic and benthic microfossil schemes of King (1989) and the dinoflagellate cyst schemes of Heilmann-Clausen (1985, 1988); Bujak & Mudge (1994) and Mudge & Bujak (1996). These are correlated against additional, standard zonation schemes, chronostratigraphy and lithostratigraphy in Figure 1 which is adapted from Schiøler *et al.* 2007. The Upper Cretaceous chalk samples were dated using the Boreal region nannofossil zonation of Burnett (1998), the microfossil zonation scheme of King *et al.* (1989), and the palynological schemes of Schiøler and Wilson (1993), Schmitz *et al.* (1996) and Slimani (2001).

Studied samples

From south to north, the wells (with their terminal depth - TD) and selected samples examined in this project were:

Onshore Fehmarn

09.A.607: 5.20-5.25 m, 17.95-18.00 m, 31.20-31.25 m, TD 32.10 m.

09.A.601: 37.90-37.95 m, 77.30-77.35 m, TD 42.00 m.

09.A.604: 8.30-8.35 m, 11.7-11.75 m, 18.75-18.80 m, 23.20-23.25 m, 35.30-35.35 m, 50.15-50.20 m, TD 50.70 m.

09.A.606: 46.15-46.20 m, TD 50.60 m.

09.A.603: 36.70-36.75 m, 39.15-39.25 m, 42.15-42.20 m, 48.35-48.40 m, 57.00-57.10 m, 75.10-75.15 m, 89.30-89.35 m, 101.70-101.80 m, TD 102.20 m.

09.A.602: 9.60-9.65 m, 14.20-14.25 m, 19.45-19.50 m, 20.90-20.95 m, 38.15-38.20 m, 49.50-49.55 m, TD 51.00 m.

Offshore Fehmarn Belt

09.A.001: 11.90-11.95 m, 15.05-15.10 m, 29.00-29.05 m, 38.45-38.50 m, 48.85-48.90 m, TD 50.40 m.

09.A.002: 09.30-09.35 m, 13.40-13.45 m, 21.35-21.40 m, 32.90-32.95 m, 42.30-42.35 m, 50.20-50.25 m, 59.35-59.40 m, 66.55-66.6 m, 79.65-79.70 m, 96.5-96.55 m, TD 100.10 m.

09.A.009: 16.55-16.60 m, 28.80-28.85 m, 40.15-40.20 m, 50.30-50.35 m, TD 50.60 m.

09.A.003: 19.60-19.65 m, 32.65-32.7 m, 49.25-49.3 m, 49.25-49.30 m, TD 50.00 m.

09.A.015: 28.85-28.90 m, 35.60-35.65 m, TD 35.80 m.

09.A.015A: 46.80-46.85 m, 61.65-61.70 m, 74.15-74.20 m, 86.15-86.20 m, TD 100.50 m.

09.A.010: 15.25-15.45 m, 28.90-29.05 m, 44.55-44.65 m, TD 50.20 m.

09.A.006: 45.70-45.75 m, 46.20-46.25 m, 46.20-46.25 m, 95.35 m (grey chalk)
95.35 m (white chalk), TD 99.90 m.

09.A.007: 21.50-21.55 m, TD 50.10 m.

09.A.008: 25.60-25.65 m, 66.00-66.05 m, 99.90-99.95 m, TD 100.60 m.

09.A.019: 61.55 m, 86.75 m, TD 104.00 m.

09.A.013: 78.05-78.10 m, 82.65-82.70 m, 97.25-97.30 m, 99.25-99.30 m, TD
101.30 m.

09.A.014: 66.25-66.40 m, 72.25-73.30 m, TD 75.20 m.

09.A.018: 59.80-59.85 m, 66.33 m, 70.20 m, TD 70.30 m.

Onshore Rødbyhavn

09.A.701: 27.55-27.60 m, 40.00-40.05 m, 56.65-56.70 m, 63.95-64.00 m, 73.40-
73.50 m, 89.85-89.90 m, TD 100.20 m.

09.A.702: 59.20-59.25 m, 71.05-71.15 m, 88.35-88.40 m, TD 88.40 m.

09.A.704: 25.30-25.35 m, 38.35-38.45 m, 48.70-48.75 m, TD 50.90 m.

09.A.703: 17.85-17.90 m, 30.85-30.90 m, 44.65-44.70 m, TD 50.90 m.

Results

Detailed study of amorphous black material

Sample 46.2 m - 46.25 m from well 09.A.006 was analysed both for chalk and a 'greasy' black material. The chalk proved to be upper Maastrichtian in age, but the black material proved more puzzling. The black material was apparently not found in wells from an earlier drilling campaign (in 1996) which also encountered chalk, but appears 'perhaps smeared' into fractures in the chalk in the 2009 wells. It was initially suggested that the black material could have resulted from lubricant used during drilling but this has been refuted by Fugro Engineers BV. The material was tested for traces of hydrocarbons at the GEUS sourcerock laboratory, but none were found. Palynological analysis indicates that the material is Selandian Æbelø Formation clay. Analysis of further samples of the black material from supplementary wells, in addition to re-examination of the 1996 campaign chalk wells is required for further interpretation.

Biostratigraphic results

A south to north correlation of the examined wells and samples from onshore Fehmarn to onshore Rødbyhavn can be seen on Enclosure 1. The raw biostratigraphic data are provided on Tables 1a and b. A summary of the nannofossil, microfossil and palynological data is listed below for each sample, along with the formation the sample is attributed to, and its age.

Onshore Fehmarn

09.A.607

5.20-5.25 m

Nannofossils: barren

Microfossils: sparse, long ranging

Palynology: middle part of Zone D9 = *Areosphaeridium diktyoplokus* Zone, middle to upper part of E3a

Formation: upper part of the R6 bed of the Røsnæs Clay Formation and maybe part of the beds L1 and L2 of the Lillebælt Clay Formation

Age: upper Ypresian

17.95-18.00 m

Nannofossils: barren

Microfossils: sparse, long ranging

Palynology: lower to middle part of Zone D9 = *Areosphaeridium diktyoplokus* Zone, lower to middle part of E3a

Formation: upper part of the R6 bed of the Røsnæs Clay Formation and maybe part of the beds L1 and L2 of the Lillebælt Clay Formation

Age: upper Ypresian

31.20-31.25 m

Nannofossils: barren

Microfossils: NSB3, RW late Paleocene & Late Cretaceous (Campanian-Maastrichtian)

Palynology: n/a

Formation: not identified

Age: middle Ypresian

09.A.601

37.90-37.95 m

Nannofossils: sparse, long ranging

Microfossils: NSB3b

Palynology: n/a

Formation: Røsnæs Clay Formation

Age: middle Ypresian

09.A.604

8.30-8.35 m

Nannofossils: barren

Microfossils: sparse, long ranging

Palynology: lower part of Zone D9 = *Areosphaeridium diktyoplokus* Zone, lower part of E3a

Formation: upper part of the R6 bed of the Røsnæs Clay Formation and maybe part of the beds L1 and L2 of the Lillebælt Clay Formation

Age: upper Ypresian

11.7-11.75 m

Nannofossils: barren

Microfossils: sparse, long ranging

Palynology: lower part of Zone D9 = *Areosphaeridium diktyoplokus* Zone, lower part of E3a

Formation: upper part of the R6 bed of the Røsnæs Clay Formation and maybe part of the beds L1 and L2 of the Lillebælt Clay Formation

Age: upper Ypresian

18.75-18.80 m

Nannofossils: NNTe1D-2

Microfossils: n/a

Palynology: upper part of Zone D8 = *Charlesdowniea coleothrypta* Zone, ?lower part of E2c/E2b

Formation: upper part of the bed R5 and lower part of bed R6 of the Røsnæs Clay Formation

Age: middle Ypresian

23.20-23.25 m

Nannofossils: NNTe2

Microfossils: n/a

Palynology: n/a

Formation: lower Røsnæs Clay Formation

Age: middle Ypresian

35.30-35.35 m

Nannofossils: barren

Microfossils: NSB3b

Palynology: lower part of D8 = *Charlesdowniea coleothrypta*, to upper subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: upper bed R5 & lower bed R6, and middle part of the red facies i.e. of the R 4/R 5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

50.15-50.20 m

Nannofossils: NNTe1D-2

Microfossils: n/a

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4 / R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

09.A.606

46.15-46.20 m

Nannofossils: barren

Microfossils: sparse, long ranging

Palynology: lower part of Zone D9 = *Areosphaeridium diktyoplokus* Zone, lower part of E3a

Formation: upper part of the R6 bed of the Røsnæs Clay Formation and maybe part of the beds L1 and L2 of the Lillebælt Clay Formation

Age: upper Ypresian

09.A.603

36.70-36.75 m

Nannofossils: NNTe1D-NNTe2

Microfossils: n/a

Palynology: n/a

Formation: lower Røsnæs Clay Formation

Age: middle Ypresian

39.15-39.25 m

Nannofossils: barren

Microfossils: NSB3 with RW from NSB1b

Palynology: n/a

Formation: Røsnæs Clay Formation

Age: middle Ypresian

42.15-42.20 m

Nannofossils: ?NNTe1C-2

Microfossils: NSB3

Palynology: n/a

Formation: lower Røsnæs Clay Formation

Age: middle Ypresian

48.35-48.40 m

Nannofossils: NNTe1B-?2

Microfossils: NSB3 with RW from NSB1b

Palynology: n/a

Formation: lower Røsnæs Clay Formation

Age: middle Ypresian

57.00-57.10 m

Nannofossils: NNTe1D-2

Microfossils: n/a

Palynology: n/a

Formation: lower Røsnæs Clay Formation

Age: middle Ypresian

75.10-75.15 m

Nannofossils: NNTe1D-2

Microfossils: n/a

Palynology: n/a

Formation: lower Røsnæs Clay Formation

Age: middle Ypresian

77.30-77.35 m

Nannofossils: NNTe1D

Microfossils: n/a

Palynology: n/a

Formation: base Røsnæs Clay Formation

Age: middle Ypresian

89.30-89.35 m

Nannofossils: long ranging

Microfossils: NSB3 with RW from NSB1b

Palynology: n/a

Formation: Røsnæs Clay Formation

Age: middle Ypresian

101.70-101.80 m

Nannofossils: NNTe1C-NNTe2

Microfossils: NSB3 with RW from NSB1b

Palynology: n/a

Formation: lower Røsnæs Clay Formation

Age: middle Ypresian

09.A.602

9.60-9.65 m

Nannofossils: UC20d, NNTp2G-?, NNTe3-5

Microfossils: Coniacian-Maastrichtian, NSB1b, NSB3

Palynology: n/a

Formation: not identified

Age: uppermost Maastrichtian, Danian, Ypresian

14.20-14.25 m

Nannofossils: barren

Microfossils: ?late Paleocene

Palynology: lower part of Zone D9 = *Areosphaeridium diktyoplokus* Zone, lower part of E3a

Formation: upper part of the R6 bed of the Røsnæs Clay Formation and maybe part of the beds L1 and L2 of the Lillebælt Clay Formation

Age: upper Ypresian

19.45-19.50 m

Nannofossils: barren

Microfossils: ?NSB3-5a

Palynology: lower part of Zone D9 = *Areosphaeridium diktyoplokus* Zone, lower part of E3a

Formation: upper part of the R6 bed of the Røsnæs Clay Formation and maybe part of the beds L1 and L2 of the Lillebælt Clay Formation

Age: upper Ypresian

20.90-20.95 m

Nannofossils: barren

Microfossils: ?late Paleocene

Palynology: lower part of Zone D9 = *Areosphaeridium diktyoplokus* Zone, lower part of E3a

Formation: upper part of the R6 bed of the Røsnæs Clay Formation and maybe part of the beds L1 and L2 of the Lillebælt Clay Formation

Age: upper Ypresian

38.15-38.20 m

Nannofossils: barren

Microfossils: long ranging

Palynology: lower part of Zone D9 = *Areosphaeridium diktyoplokus* Zone, lower part of E3a

Formation: upper part of the R6 bed of the Røsnæs Clay Formation and maybe part of the beds L1 and L2 of the Lillebælt Clay Formation

Age: upper Ypresian

49.50-49.55 m

Nannofossils: NNTe3

Microfossils: n/a

Palynology: n/a

Formation: middle Røsnæs Clay Formation

Age: middle Ypresian

Offshore Fehmarn Belt

09.A.001

11.9-11.95 m

Nannofossils: NNTe2-3

Microfossils: n/a

Palynology: n/a

Formation: lower-middle part of Røsnæs Clay Formation

Age: middle Ypresian

15.05-15.10 m

Nannofossils: NNTe3

Microfossils: n/a

Palynology: n/a

Formation: middle part of Røsnæs Clay Formation

Age: middle Ypresian

29.00-29.05 m

Nannofossils: NNTe3

Microfossils: n/a

Palynology: n/a

Formation: middle part of Røsnæs Clay Formation

Age: middle Ypresian

38.45-38.50 m

Nannofossils: ?NNTe3-NNTe6

Microfossils: NSB3b with RW from NSB1b

Palynology: n/a

Formation: middle part of Røsnæs Clay Formation with RW from mid Paleocene

Age: middle Ypresian

48.85-48.9 m

Nannofossils: NNTe1C-NNTe5

Microfossils: NSB3b with RW from NSB1b

Palynology: n/a

Formation: middle part of Røsnæs Clay Formation with RW from mid Paleocene

Age: middle Ypresian

09.A.002

09.30-09.35 m

Nannofossils: NNTe2-3

Microfossils: middle NSB3 (+ RW from late Paleocene)

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

13.40-13.45 m

Nannofossils: barren

Microfossils: barren

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

21.35-21.40 m

Nannofossils: NNTe2-5

Microfossils: middle NSB3 (+ RW from late Paleocene)

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

32.90-32.95 m

Nannofossils: NNTe1D-2

Microfossils: middle NSB3 (+ RW from late Paleocene), probably NSB3a

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

42.30-42.35 m

Nannofossils: NNTe2

Microfossils: middle NSB3 (+ RW from late Paleocene), probably NSB3a

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

50.20-50.25 m

Nannofossils: NNTe2

Microfossils: middle NSB3 (+ RW from late Paleocene), probably NSB3a

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

59.35-59.40 m

Nannofossils: NNTe1C-D

Microfossils: middle NSB3 (+ RW from late Paleocene), probably NSB3a

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

66.55-66.60 m

Nannofossils: NNTe1D-2

Microfossils: n/a

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

79.65-79.70 m

Nannofossils: barren

Microfossils: NSB3/NSP5

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

96.5-96.55 m

Nannofossils: NNTe1C

Microfossils: n/a

Palynology: subzone D7a = *Eatonicysta ursulae* Zone and *Dracodinium solidum* Zone, E2a

Formation: upper part of the Knudshoved Member and Bed R1 (Røsnæs Clay Formation) and lower part of the red Røsnæs Clay facies i.e. in the lower part of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

09.A.009

16.55-16.60 m

Nannofossils: NNTe1D

Microfossils: n/a

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

28.80-28.85 m

Nannofossils: NNTe1A- top NNTe5

Microfossils: barren

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

40.15-40.20 m

Nannofossils: barren

Microfossils: NBS3

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

50.30-50.35 m

Nannofossils: barren

Microfossils: NSB3

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

09.A.003

19.60-19.65 m

Nannofossils: NNTe1C-D

Microfossils: NSB3 (+ RW from late Paleocene)

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

32.65-32.70 m

Nannofossils: NNTe1C-D

Microfossils: NSB3 (+ RW from late Paleocene)

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

49.25-49.30 m

Nannofossils: NNTe1C

Microfossils: NSB3a (+ RW from late Paleocene)

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, or ?subzone D7a = *Eatonicysta ursulae* Zone and *Dracodinium solidum* Zone, E2b or ?E2a

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation), or ?upper part of the Knudshoved Member and in Bed R1 (Røsnæs Clay Formation) lower part of the red Røsnæs Clay facies i.e. in the lower part of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

09.A.015

28.85-28.9 m

Nannofossils: barren

Microfossils: NSB2 / NSP4

Palynology: probably uppermost part of Zone D4 = upper part of Viborg Zone 5, P6a

Formation: base Balder Formation / top Sele Formation (microfossils), or older dark grey non-calcareous clay (palynology)

Age: upper Paleocene / early Eocene

35.6-35.65m

Nannofossils: barren

Microfossils: NSB2 / NSP4

Palynology: Viborg Zone 3, P4a

Formation: Balder Formation (microfossils), Æbelø Formation (palynology)

Age: early Eocene / upper Selandian

09.A.015A

46.80-46.85 m

Nannofossils: barren

Microfossils: ?NSB4

Palynology: ?early Middle Eocene, RW Lower Jurassic, Upper Cretaceous, upper Selandian

Formation: ?upper Lillebælt Clay Formation, or the ?lowermost part of the Søvind Marl Formation

61.65-61.70 m

Nannofossils: NNTe4/5 boundary (late Paleocene RW)

Microfossils: NSB3b (RW late Paleocene)

Palynology: upper part of D9 = *Dracodinium pachydermum* Zone, possibly RW material of Early Eocene age, E4a or E3d

Formation: ?lower to middle part of Lillebælt Clay Formation (palynology)

Age: Lutetian

74.15-74.20 m

Nannofossils: NNTe1D-NNTe3 (+ late Paleocene RW)

Microfossils: NSB3a (+ late Paleocene RW)

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone or middle part of D9 = middle part of the *Areosphaeridium diktyoplokus* Zone, possible RW material of middle Early Eocene age, E2b or E3c & 3d

Formation: lower part of Røsnæs Clay Formation (nannofossils & microfossils), lower or upper part of Røsnæs Clay Formation (palynology)

Age: Lutetian

86.15-86.20 m

Nannofossils: barren

Microfossils: NSB2 / NSP4

Palynology: subzone D5b *Deflandrea oebisfeldensis* Zone = Viborg Zone 7, E1b

Formation: upper Balder Formation (microfossils), upper part of Ølst Formation (palynology)

Age: lowermost Eocene

98.10-98.20 m

Nannofossils: barren

Microfossils: NSB2 / NSP4

Palynology: subzone D5a *Apectodinium augustum* or lower part of the *Deflandrea oebisfeldensis* Zone = Viborg Zone 6 or lower part of Viborg Zone 7, L or P6

Formation: Balder Formation (microfossils), lower part of Ølst Formation (palynology)

Age: lowermost Eocene / uppermost Paleocene

09.A.010

15.25-15.45 m

Nannofossils: barren

Microfossils: NSB2 / NSP4

Palynology: n/a

Formation: Balder Formation

Age: lower Ypresian

28.9-29.05 m

Nannofossils: barren

Microfossils: NSB2 / NSP4

Palynology: n/a

Formation: Balder Formation

Age: lower Ypresian

44.55-44.65 m

Nannofossils: NNTe1C-D

Microfossils: n/a

Palynology: n/a

Formation: base Røsnæs Clay Formation

Age: lower to middle Ypresian

09.A.006

45.7-45.75 m

Nannofossils: barren

Microfossils: long ranging

Palynology: uppermost part of Viborg Zone 3, P4b

Formation: probably the lower part of Holmehus Formation green and brown non-calcareous clay or the underlying dark grey, non-calcareous clay

Age: upper Selandian

46.2-46.25 m (chalk)

Nannofossils: UC20c

Microfossils: n/a

Palynology: Viborg Zone 3 or upper Maastrichtian, P4a or upper Maastrichtian

Formation: Tor Formation equivalent (nannofossils and palynology) with

?Æbelø Formation (palynology)

Age: upper, but not uppermost Maastrichtian chalk and upper Selandian clay

46.2-46.25 m (black amorphous material)

Nannofossils: NNTp4F (late Danian) and Maastrichtian

Microfossils: n/a

Palynology: Viborg Zone 3, upper Selandian, P4a

Formation: dark grey non-calcareous clay, Æbelø Formation?

Age: upper Selandian clay

95.35 m (grey chalk)

Nannofossils: UC18

Microfossils: n/a

Palynology: n/a

Formation: Tor Formation equivalent

Age: lower Maastrichtian or older

95.35 m (white chalk)

Nannofossils: UC16d

Microfossils: n/a

Palynology: n/a

Formation: Tor Formation equivalent

Age: Campanian

09.A.007

21.50-21.55 m

Nannofossils: UC20d & NNTp5B

Microfossils: n/a

Palynology: P3, lower part of Viborg Zone 3, ?upper part of Viborg Zone 2

Formation: Selandian dark grey clay

Age: uppermost Maastrichtian and upper Danian, with middle Selandian clay

09.A.008

25.60-25.65 m

Nannofossils: NP10-11

Microfossils: NSB3/NSP5

Palynology: Viborg Zone 3, P4a

Formation: Røsnæs Formation (nannofossils), dark grey non-calcareous clay, Æbelø Formation (palynology)

Age: lower Ypresian clay or upper Selandian clay

66.00-66.05 m (chalk)

Nannofossils: ?UC19

Microfossils: FCS22b-23a

Palynology: *Alterbidinium acutulum* (*A. ac*) Interval Subzone

Formation: Tor Formation equivalent

Age: middle Maastrichtian (nannofossils & microfossils), uppermost lower Maastrichtian (palynology)

99.90-99.95 m (chalk)

Nannofossils: UC16c

Microfossils: FCS21b

Palynology: *Areoligera coronata* (*A. cor*) Zone

Formation: Tor Formation equivalent

Age: middle upper Campanian

09.A.019

61.50 m

Nannofossils: UC20c

Microfossils: n/a

Palynology: n/a

Formation: Tor Formation equivalent

Age: upper, though not uppermost, Maastrichtian

86.75 m

Nannofossils: ?UC19

Microfossils: n/a

Palynology: n/a

Formation: Tor Formation equivalent

Age: middle Maastrichtian

09.A.013

78.05-78.1 m

Nannofossils: barren

Microfossils: NSB3 / NSP5

Palynology: Viborg Zone 4 / ?lower part of Viborg Zone 5, P5b

Formation: Røsnæs Clay Formation (microfossils), ?Holmehus Formation (palynology)

Age: middle Ypresian (microfossils), upper Selandian (palynology)

82.65-82.70 m

Nannofossils: barren

Microfossils: NSB3 / NSP5

Palynology: Viborg Zone 4 / ?lower part of Viborg Zone 5, P5b

Formation: Røsnæs Clay Formation (microfossils), ?Holmehus Formation (palynology)

Age: middle Ypresian (microfossils), upper Selandian (palynology)

97.25-97.30 m

Nannofossils: barren

Microfossils: NSB1b/NSP1 (tentatively, based on very rare fauna)

Palynology: Viborg Zone 3, P4a

Formation: dark grey non-calcareous clay, ?Æbelø Formation

Age: upper Selandian

99.25-99.30 m

Nannofossils: barren

Microfossils: NSB2 / NSP4

Palynology: Viborg Zone 3, P4a

Formation: ?Balder/Sele Formation (nannofossils), dark grey non-calcareous clay, ?Æbelø Formation (palynology)

Age: lower Ypresian (microfossils), upper Selandian (palynology)

09.A.014

66.25-66.40 m

Nannofossils: barren

Microfossils: NSB3 / NSP5

Palynology: subzone D6b = *Wetzeliella meckelfeldensis* Zone, lower part of E2a or upper part of E1

Formation: lower part of the Knudshoved Member, Røsnæs Clay Formation

Age: lowermost Ypresian

72.25-73.30 m

Nannofossils: NP10-11

Microfossils: NSB2 / NSP4

Palynology: subzone D5b = *Deflandrea oebisfeldensis* Zone, corresponds to the later part of Viborg Zone 7, E1b

Formation: Fur and Ølst Formations from near ash layer -19b to the top of both formations

Age: lower Ypresian (nannofossils & microfossils), lowermost Ypresian/uppermost Thanetian (palynology)

09.A.018

59.80-59.85 m

Nannofossils: NP13

Microfossils: NSB3b / NSP5b

Palynology: subzone D7b = *Dracodinium varielongitudum* Zone, E2b

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

66.33 m

Nannofossils: barren

Microfossils: NSB3a / NSP5a

Palynology: subzone D7a = *Eatonicysta ursulae* Zone and *Dracodinium solidum* Zone, E2a

Formation: upper part of the Knudshoved Member and in Bed R1 (Røsnæs Clay Formation) lower part of the red Røsnæs Clay facies i.e. in the lower part of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

70.20 m

Nannofossils: barren

Microfossils: sparse and long ranging

Palynology: subzone D6a = *Wetzelilla astra* Zone, lower part of E2a

Formation: basal part of the Knudshoved Member (Røsnæs Clay Formation)

Age: lowermost Ypresian

Onshore Rødbyhavn

09.A.701

27.55-27.60 m

Nannofossils: barren

Microfossils: sparse and long ranging

Palynology: subzone D7b = *Dracodinium varielongitudum* or Subzone D7a = *Eatonicysta ursulae* Zone and *Dracodinium solidum* Zone, E2b or E2a

Formation: middle part of the red facies i.e. of the R4/R5 beds (Røsnæs Clay Formation)

Age: lower to middle Ypresian

40.0-40.05 m

Nannofossils: NNTe1D

Microfossils: n/a

Palynology: n/a

Formation: base Røsnæs Clay Formation

Age: lower to middle Ypresian

56.65-56.70 m

Nannofossils: barren

Microfossils: sparse and long ranging

Palynology: probably Viborg Zone 7, ?E1b

Formation: probably the upper part of the Ølst Formation

Age: lower Ypresian

63.95-64.00 m

Nannofossils: barren

Microfossils: mid-upper NSB2 / NSP4

Palynology: n/a

Formation: Balder Formation

Age: lower Ypresian

73.40-73.50 m

Nannofossils: barren

Microfossils: NSB2 / NSP4

Palynology: n/a

Formation: lower part of Balder Formation

Age: lower Ypresian

89.85-89.90 m

Nannofossils: barren
Microfossils: NSB1c
Palynology: n/a
Formation: Lista Formation
Age: Selandian-Thanetian

99.35-99.40 m

Nannofossils: barren
Microfossils: sparse, long ranging
Palynology: upper part of Viborg Zone 4, P5a
Formation: upper part of Holmehus Formation / or green and brown non-calcareous clay (Heilmann-Clausen 1985)
Age: upper Selandian

09.A.702

59.20-59.25 m

Nannofossils: NNTe2-5
Microfossils: NSB3
Palynology: n/a
Formation: Røsnæs Clay Formation
Age: middle Ypresian

71.05-71.15 m

Nannofossils: NNTe1C-2
Microfossils: NSB3
Palynology: n/a
Formation: lower Røsnæs Clay Formation
Age: middle Ypresian

88.35-88.40 m

Nannofossils: barren
Microfossils: upper NSB2 / NSP4
Palynology: n/a
Formation: Balder Formation
Age: lower Ypresian

09.A.704

25.30-25.35 m

Nannofossils: barren

Microfossils: NSB1c

Palynology: upper part of Viborg Zone 4, P5a

Formation: upper part of Holmehus Formation / green and brown non-calcareous clay

Age: upper Selandian

38.35-38.45 m

Nannofossils: Campanian, Maastrichtian, Danian & Eocene

Microfossils: Campanian, Maastrichtian, Danian & Eocene

Palynology: n/a

Formation: not identified

48.70-48.75 m

Nannofossils: barren

Microfossils: ?NSB2 / NSP4

Palynology: upper part of Viborg Zone 4 or lowermost part of Viborg Zone 5, P5a or lowermost part of P5b

Formation: upper part of Holmehus Formation / green and brown non-calcareous clay or lowermost part of dark grey non-calcareous clay

Age: upper Selandian

09.A.703

17.85-17.90 m

Nannofossils: barren

Microfossils: sparse, long ranging

Palynology: upper part of Viborg Zone 4, P5a

Formation: upper part of Holmehus Formation / green and brown non-calcareous clay or lowermost part of dark grey non-calcareous clay

Age: upper Selandian

30.85-30.90 m

Nannofossils: barren

Microfossils: sparse, long ranging

Palynology: middle to upper part of Viborg Zone 4, P5a

Formation: middle to upper part of Holmehus Formation / green and brown non-calcareous clay

Age: upper Selandian

44.65-44.70 m

Nannofossils: barren

Microfossils: NSB1c

Palynology: n/a

Formation: Lista Formation

Age: Selandian-Thanetian

Figures

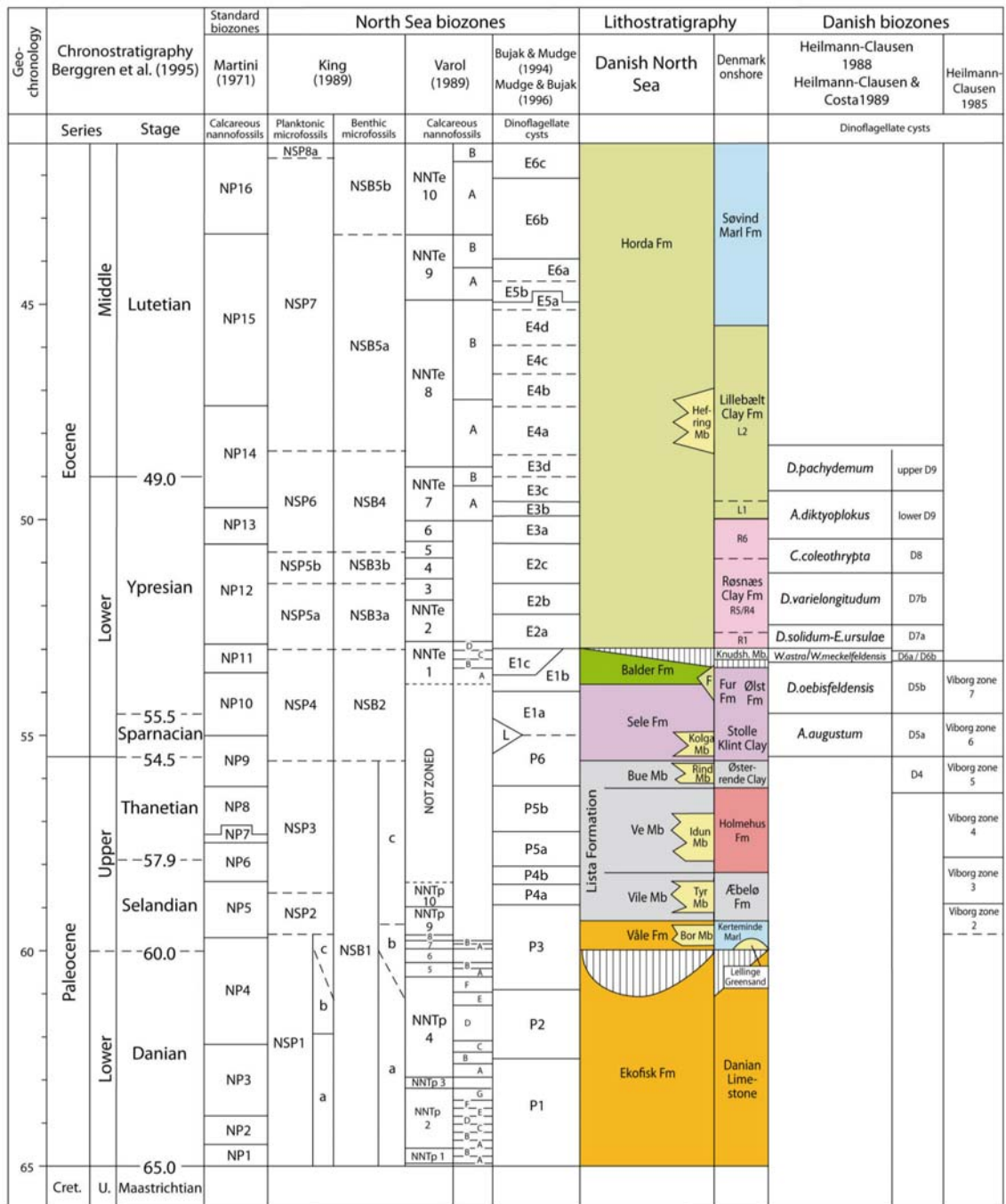


Figure 1: Chronostratigraphic, biostratigraphic and lithological correlation for onshore Denmark and the Danish Central Graben, North Sea. Adapted from Schiøler *et al.* (2007).

Enclosure 1: South to north correlation of 24 wells; Fehmarn-offshore Fehmarn Belt-Rødbyhavn

Table 1a: Biostratigraphic raw data

Table 1b: Biostratigraphic raw data (south-north)

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