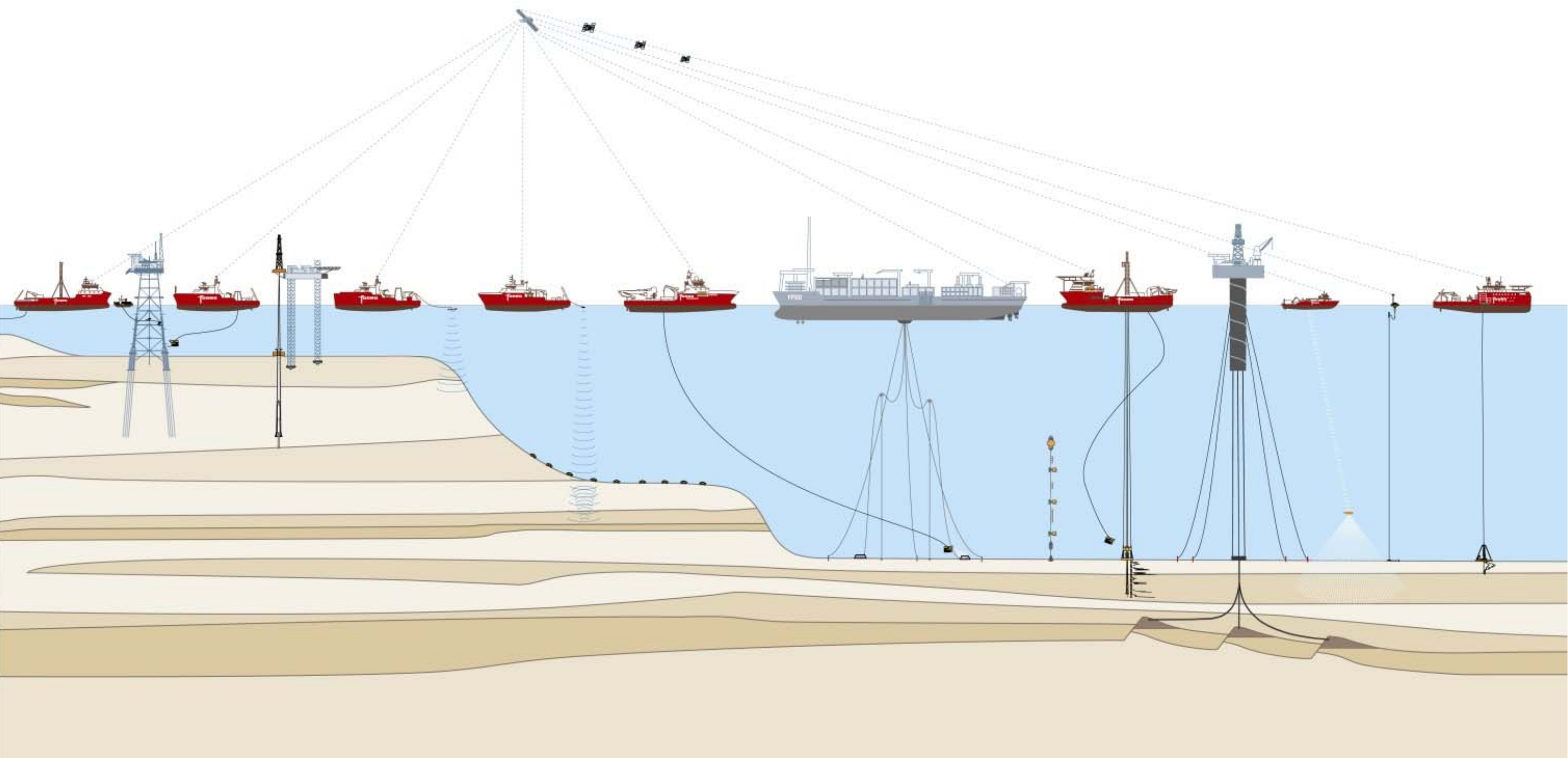
Biostratigraphic Analyses
Wind Farm Sites I to IV
Borssele Wind Farm Zone
Dutch Sector, North Sea

Client Reference WOZ1500010
Fugro Reference N6083/09 (2)

Rijksdienst voor Ondernemend Nederland (RVO)



Technical Note Biostratigraphic Analyses Wind Farm Sites I to IV Borssele Wind Farm Zone Dutch Sector, North Sea	
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1. PURPOSE AND SCOPE

This technical note presents results of biostratigraphic analyses carried out on selected samples from locations at Wind Farm Sites (WFS) I to IV that are part of the Borssele Wind Farm Zone (BWFZ). Samples tested were collected during two geotechnical site investigations at the BWFZ. Results of the geotechnical site investigations can be found in Fugro (2015a & 2015b) and Fugro (2016a & 2016b).

This technical note is a revision of the document dated 15 April 2016.

Results of the biostratigraphic analyses can be used for verification of the stratigraphic framework used for development of the geological ground model (Fugro, 2015c to 2015f). This technical note includes a paragraph discussing results of the biostratigraphic analyses in comparison to the stratigraphic framework used for the BWFZ.

Information presented in this report includes:

- Results of the biostratigraphic analyses performed on 27 samples from five borehole locations;
- Evaluation of test results and comparison with the stratigraphic framework adopted for the BWFZ (Fugro, 2015c to 2015f).

2. STUDY OVERVIEW

2.1 Test Programme and Sample Selection

To verify the stratigraphic framework developed for the BWFZ, an age dating programme was performed. The age dating focussed predominantly on soils believed to be of Tertiary age. Two samples from Quaternary formations were analysed. Age dating used biostratigraphic assessments by means of palynological analyses.

Ideally, age dating analyses are performed on samples from a location where a complete sequence of the various formations is present. However, due to the dipping nature of formations across the BFWZ, no single location included a complete profile within the investigated depth. Five locations from across the BWFZ were selected, which together include the complete stratigraphy; refer to Plate 1 and Table 2.1 for details. Where possible, selected locations included common formations to allow cross-correlation.

A total of 27 samples were selected for palynology analyses. Selection considered the different formations and soil types. Selected samples were predominantly fine-grained. Such soils (clay and silt) or silty/clayey sands are considered most suitable to be used for palynology testing as these soils are generally deposited in a low energetic depositional environment and as such have a better preservation potential of pollen and spores. Sands typically characterise a higher energy depositional environment were reworking is more significant. Therefore, Tertiary Unit E4 was not considered for age dating due to the expected lack of fines in these soils.

Samples were selected above or below key seismic horizons, allowing correlation between investigation points in order to estimate minimum and maximum ages. Samples from boreholes in the northern part of the BWFZ (BH-WFS4-7 and BH-WFS1-5A) mainly cover Unit C1 through Unit E3. Samples from borehole BH-WFS2-7 in the south of the BWFZ cover Unit E5b through Unit F3. Samples from borehole BH-SubStatB-1 in the centre of the BWFZ cover Unit E3 through Unit F1a and thereby provide an overlap between the northern and southern stratigraphic profiles; refer to Table 2.1 and Plate 1 for a spatial overview.

In borehole BH-WFS2-2A, a thin layer of clay is present in Unit B at the base of a scour hollow. From this clay layer, two samples were used for age dating as well, which brings the total quantity of samples to 27.

Table 2.1: Overview of Analysed Units and Borehole Locations

Geotechnical Unit (Geological Formation)	Borehole Location				
	BH-WFS4-7	BH-WFS1-5A	BH-SubStatB-1	BH-WFS2-7	BH-WFS2-2A
B (Eem/Kreftenheye)					2
C1 (Westkapelle Ground)	1				
C2 (Westkapelle Ground)	1	1			
D (Rupel)	2	1			
E1 (Tongeren)	2				
E2 (Tongeren)	1				
E3 (Tongeren)	2		2		
E5a (Tongeren)			2		
E5b (Tongeren)			2	1	
F1a (Dongen)			1	1	
F1b (Dongen)				1	
F1c (Dongen)				1	
F2 (Dongen)				1	
F3 (Dongen)				2	

Note:
- Number indicates quantity of samples used per unit and per borehole

2.2 Sample Handling

Important stages in sample handling included:

- Selection of bag samples from sample storage facility of Fugro geotechnical laboratory in Wallingford, United Kingdom (UK);
- Sample transport in labelled shipping containers to PetroStrat biostratigraphic laboratory in Conwy (UK);

- Palynology analyses on selected samples;
- Packaging and labelling of left-over sample material for disturbed preservation;
- Transport of left-over material in labelled shipping containers to the Fugro geotechnical laboratory in Wallingford (UK).

2.3 Analysis Method

Palynological analyses involved a pre-treatment of samples followed by various count methods which are explained in detail in Appendix 2. This appendix also includes results of the palynological analyses.

Interpretation of the palynological analyses and correlation with the Geological Ground Model for WFS I to IV (Fugro, 2015c to 2015f) is provided in Appendix 1. In this appendix, for each borehole a biostratigraphic analysis has been performed, including:

- Chronostratigraphic succession;
- Palynological zonation;
- Biostratigraphic examination with listing of primary age diagnostic events together with selected additional events;
- Stratigraphic discussion.

3. DISCUSSION

In general, the biostratigraphic interpretations presented in Appendix 1 support the Fugro geological model presented in Fugro (2015c to 2015f). A number of samples of Units C1, C2, E3, E5a, E5b and F3 returned ages which are at variance with those proposed by Fugro (units indicated in orange in Table 3.1). It should be noted that the units are defined on the basis of their geotechnical and geophysical properties and characteristics. The lithostratigraphy and geological ages of these units are based on matching characteristics and descriptions with lithostratigraphic formations in the Dutch nomenclature. Therefore, the ages of the unit boundaries (as used by Fugro and interpreted from the biostratigraphic analyses) are not as fixed and unambiguous as may be suggested by the various biostratigraphic tables in Appendices 1 and 2.

The reported variances may be attributable to (a combination of) the following reasons:

- Samples taken from sandy lithologies may contain large quantities of reworked material. Reworking can have a ‘blurring’ effect on the biostratigraphic record;
- Samples selected close to lithostratigraphic boundaries may have been imprecisely picked;
- Various (literature) sources may have differing opinions about the stratigraphic significance of certain species for age determination. This could result in the scenario that multiple ages are possible for a certain unit, depending on which source/species is given more importance;
- Palynology analyses have been performed on a limited number of samples. Further sampling and palynology analyses may be required to confirm results of the analyses presented in this document, to clarify dating variances, and to improve resolution;
- The stratigraphic framework used in Fugro (2015c to 2015f) is based on two sources (Rijsdijk et al., 2005; TNO, 2013a to 2013c). Biostratigraphic analyses used in these two sources may have been influenced by the same factors as mentioned here.

Assigning a different age to a geotechnical unit does not influence the geotechnical properties of the unit. Geotechnical unit boundaries as interpreted by Fugro based on results of geophysical and geotechnical site investigations do not require amendments based on the current results of the palynology analyses.

Table 3.1: Chronostratigraphy of Analysed Units

<table>
<tr><th>Geotechnical Unit (Geological Formation)</th><th>Epoch (Age)[1)]</th><th>Epoch (Age)[2)]</th><th>Details biostratigraphic analyses[3)]</th></tr>
<tr><td>B (Eem/Kreftenheye)</td><td>Pleistocene</td><td>Pleistocene</td><td>-</td></tr>
<tr><td>C1
(Westkapelle Ground)</td><td>Late Pliocene</td><td>Early Pleistocene (Gelasian)</td><td>The in situ component of a sample from BH-WFS4-7 provides good age control as it shows very good evidence for the Netherlands Early Pleistocene (Gelasian) ‘Tiglian B’ pollen stage (Kuhlman et al., 2006).</td></tr>
<tr><td>C2
(Westkapelle Ground)</td><td>Early Pliocene (Zanclean)</td><td>Early Pleistocene (Gelasian)/ Early Pliocene (Zanclean)</td><td>An analysed sample from BH-WFS1-5A suggests that the material is most likely from the Praetiglian pollen stage (Kuhlman et al., 2006), dated as Early Pleistocene (Gelasian).

A sample from BH-WFS4-7 shows a mixture of two different ages: a strong component of typical Early Pliocene (Zanclean) markers together with presumably reworked Early Oligocene (Rupelian) markers.</td></tr>
<tr><td>D (Rupel)</td><td rowspan="4">Early Oligocene (Rupelian)</td><td rowspan="3">Early Oligocene (Rupelian)</td><td rowspan="3">-</td></tr>
<tr><td>E1 (Tongeren)</td></tr>
<tr><td>E2 (Tongeren)</td></tr>
<tr><td>E3 (Tongeren)</td><td>Late Eocene (Priabonian)</td><td>Analysed sample material from BH-SubStatB-1 provides good evidence for a Late Eocene (Priabonian) age.</td></tr>
<tr><td>E5a (Tongeren)</td><td rowspan="2">Late Eocene (Priabonian)</td><td rowspan="2">Late Eocene (Priabonian)/ Middle Eocene (Bartonian)</td><td rowspan="2">Sample material from BH-SubStatB-1 shows indicators for an ‘earliest’ Late Eocene (Priabonian) age for Units E5a/b. Other sources (refer to Appendix 1 and 2 for details) however use these species to indicate a Middle Eocene (Bartonian) age for these units.

Analysed material from another sample from BH-SubStatB-1 strongly suggests a Middle Eocene (Bartonian) age for Unit E5b.

A sample from BH-WFS2-7 contains material which suggests an earliest Priabonian to Bartonian age for Unit E5b. Alternatively, the Bartonian markers may have been reworked into earliest Priabonian sediments.</td></tr>
<tr><td>E5b (Tongeren)</td></tr>
<tr><td>F1a (Dongen)</td><td rowspan="4">Middle Eocene (Bartonian)</td><td rowspan="5">Middle Eocene (Bartonian)</td><td rowspan="4">-</td></tr>
<tr><td>F1b (Dongen)</td></tr>
<tr><td>F1c (Dongen)</td></tr>
<tr><td>F2 (Dongen)</td></tr>
<tr><td>F3 (Dongen)</td><td>Early Eocene (Lutetian)</td><td>No Lutetian markers were seen in sample material from BH-WFS2-7 indicating that Unit F3 is Bartonian in age.</td></tr>
<tr><td colspan="4">Notes:
1) Age of geotechnical unit as used for the BWFZ lithostratigraphic framework (Fugro, 2015c to 2015f)
2) Age of geotechnical unit as determined from biostratigraphic analyses (Appendices 1 and 2 to this report)
3) Refer to Appendix 1 for details</td></tr>
</table>

4. REFERENCES

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Deep, 2015b. *Geophysical Site Investigation Survey – Borssele Wind Farm Development Zone – Wind Farm Site 2.* Final Report (Rev 02), 3 April 2015. Amsterdam: Deep B.V. Hydrography & Geophysics.

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5. USE OF THIS TECHNICAL NOTE

Fugro Engineers B.V. prepared this Technical Note according to a project specification determined by the Client.

Fugro understands that the presented information will be used for the purpose described above. That purpose was a significant factor in determining the scope and level of the services. If the purpose for which the presented information is used or the Client's proposed development or activity changes, this Technical Note may no longer be valid.

Document distribution is restricted to project participants approved by the Client.

This document has 8 pages, 1 plate and 2 appendices, the definitive versions of which are held in Fugro's information system.

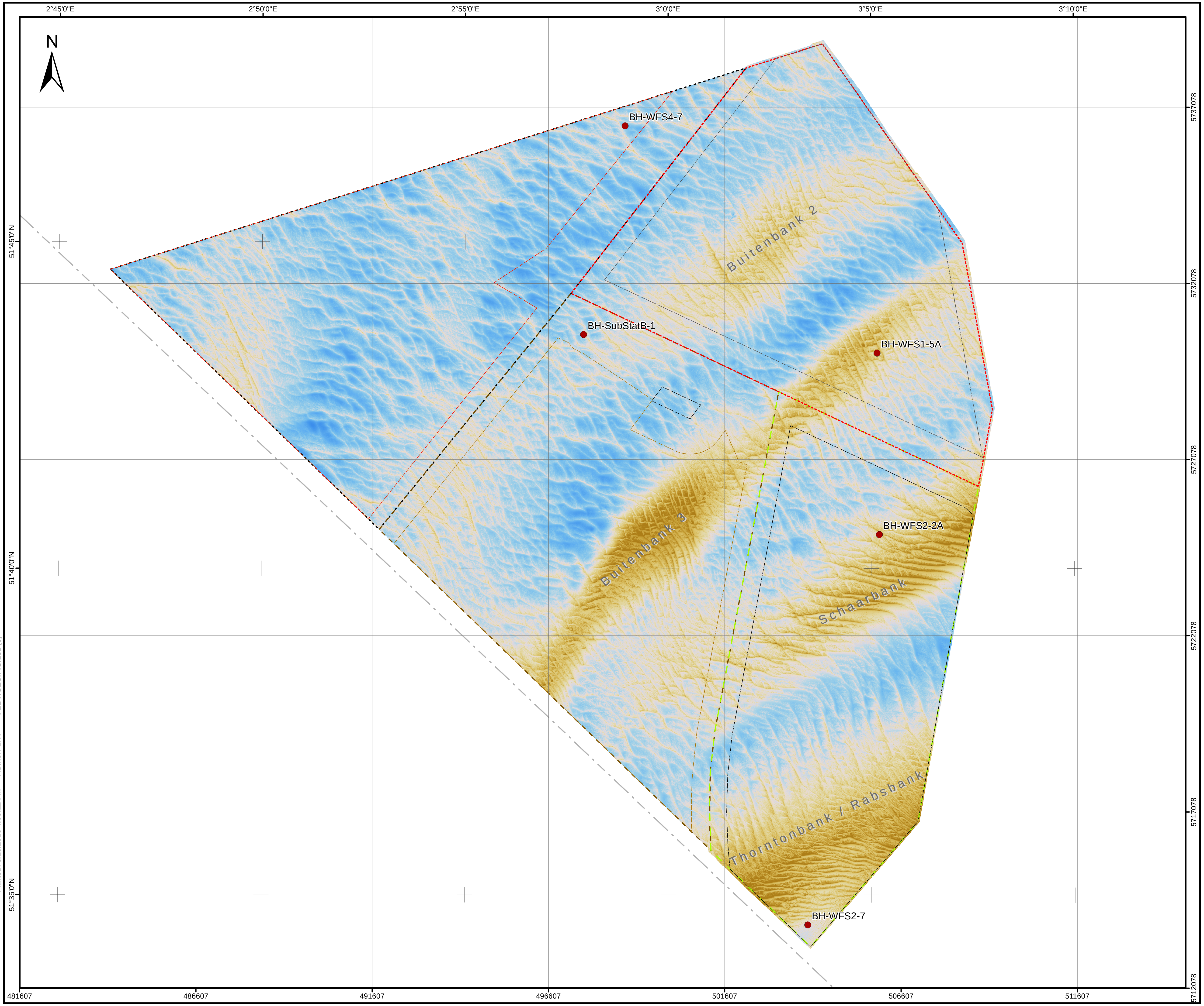
Document Check: B. Meijninger – Geologist
Document Review and Approval: M. Klein – Principal Engineer

Project Lead: signed

....

E. Schoute

Senior Project Engineer



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LEGEND:

- BH Locations
- Outline of WFS I
- Outline of WFS II
- Outline of WFS III
- Outline of WFS IV
- Outline of WFS V
- Outline of WFS IV
- Investigation Area I
- Investigation Area II
- Investigation Area III
- Investigation Area IV
- Maritime Boundary

Bathymetry [m below LAT]

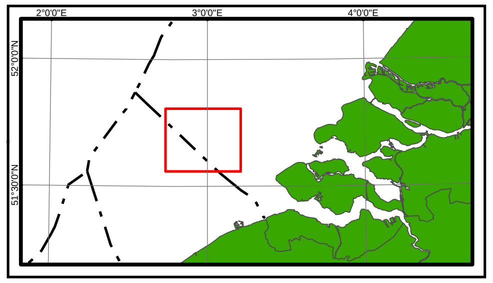
13, 17, 21, 25, 29, 33, 37, 41, 43

NOTES ON BATHYMETRY:

- Reproduced from Deep (2015a and 2015b) and Fugro (2015g and 2015h)
- Resolution cells 0.5 m x 0.5 m (for WFS III and IV)
- Resolution cells 1 m x 1 m (for WFS I and II)
- Data acquired by Multi-Beam Echo Sounder (MBES)

GEODETIC PARAMETERS:

DATUM	ETRS89
Ellipsoid	GRS80
Semi major axis	a = 6 378 137.000
Inverse flattening	1/f = 298.257222101
PROJECTION	UTM, Zone 31 North
Central Meridian (CM)	3° 00' 00" E
Latitude of Origin	0° 00' 00" N
False Easting	500 000 m
False Northing	000 000 m
Scale factor	0.9996
Units	metres/degrees



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Croeselaan 15, 3521 BJ, Utrecht - THE NETHERLANDS

Fugro

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DETAILED LOCATION PLAN

BORSSELE WIND FARM ZONE, WFS I-IV
DUTCH SECTOR, NORTH SEA

Scale 1:100,000
at original A3 page size

0 1,000 2,000 3,000 metres

Fugro Report No. N6083/09	Issue 2	Plate 1

APPENDIX 1: BIOSTRATIGRAPHY REPORT

CONTENTS Pages

StrataData

Biostratigraphic computing
Biostratigraphy
Geochronology

Report No: 02/16 (final) **31 March 2016**

Biostratigraphy of cores from the Borssele Wind Farm Zone, offshore The Netherlands

by

John Athersuch (coordinator)
Paul Cornick and Marcel Polling, PetroStrat (palynology)

for

Fugro Engineers B.V., Nootdorp

This report was written and compiled by **StrataData Ltd***, 17 Ottershaw Park, Chobham Road, Ottershaw, Surrey KT16 0QG*

Contents

page no.

1 – Executive summary

Biostratigraphic analysis of 27 core samples has provided age determinations for Geotechnical Units in the Borssele Wind Farm Zone.

Unit A: not sampled

Unit B: only analysed in borehole BH-WFS2-2A where it is present in a major scour hollow. The samples analysed yielded superabundant ‘earliest’ Oligocene (Rupelian) to ‘latest’ Eocene (Priabonian) palynomorphs with no younger material present although given the context of this borehole the assemblage is most probably reworked assemblage into a Pleistocene unit.

Unit C1: only seen in BH-WFS4-7 where it shows a very dominant reworked signal (glacial) and an *in-situ* assemblage that strongly indicates an Early Pleistocene (Gelasian) age.

Unit C2: at the top of unit C2 an Early Pleistocene (Gelasian) age was determined in BH-WFS1-5A while in borehole BH-WFS4-7 an Early Pliocene (Zanclean) age was interpreted at the very base of the unit.

Unit D/E1/E2: were all found to be entirely of Early Oligocene (Rupelian) age in borehole BH-WFS4-7 and BH-WFS1-5A. Several distinct assemblage changes make it possible to distinguish between these units.

Unit E3: seen in both BH-WFS4-7 and BH-SubStatB-1 where it is of a Late Eocene (Priabonian) age.

Unit E5a/b: unit E5a is most likely Late Eocene (Priabonian) in age in BH-SubStatB-1, while unit E5b may be Middle Eocene (Bartonian) in BH-SubStatB-1 and BH-WFS2-7 or Late Eocene (Priabonian) with reworked Middle Eocene material above a regional unconformity between the Bassevelde Sand and the underlying Onderdijke Clay (=unit F1a).

Unit F1 (a/b/c), F2, F3: these units are all dated as Middle Eocene (Bartonian) in boreholes BH-SubStatB-1 and BH-WFS2-7. Distinct assemblage changes make it possible to distinguish between units F1, F2 and F3. No Lutetian sediments were encountered.

These results have been compared with the prognosis and there are several instances where our conclusions are at variance with the assignments based on the current geological model. Possible reasons for these differences are discussed in the text. The main problem interval is clearly Priabonian (E5b)/Bartonian (F1a) boundary due to reworking of Bartonian material and the varying opinions about the exact stratigraphic range of some of the key marker species.

Palynology has, however, generally proved an excellent means of dating and differentiating geotechnical units in this area as the material extracted for analysis is abundant, diverse and extremely well preserved. Further sampling is recommended to confirm these results, clarify some dates and to improve resolution if required.

2 – Objectives

The main objective of the investigation was to date specific core samples to test the current geological model as part of an ongoing geotechnical site investigation of the Borssele Wind Farm Zone (WFZ), offshore The Netherlands.

Samples were selected to check the age assignments of each of the geotechnical units in the selected boreholes.

Figure 1 shows the location of the four wind farm blocks and the five borehole locations.

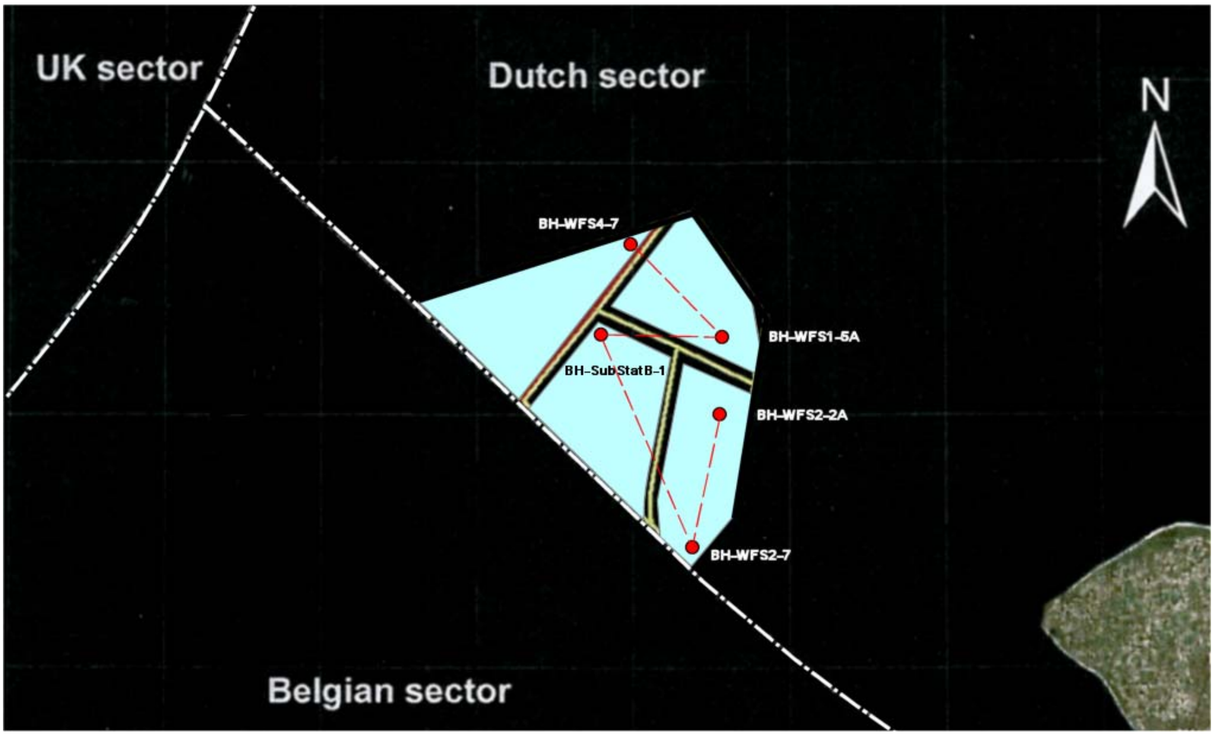


Figure 1: Locations of boreholes in this study (after Fugro BV). Transect shown in Appendix 2.

3 - Material

Twenty-seven core samples from five borehole locations in the Borssele Wind Farm Zone (WFS I-IV) were provided by Fugro Engineers B.V. for palynological analysis which was undertaken by specialists at PetroStrat Ltd.

Summary results for each location are displayed within the text. Detailed discussion of the palynology and biostratigraphic distribution charts are presented in a separate report by PetroStrat Ltd.

4 - Regional stratigraphy

The lithostratigraphic scheme selected by Fugro Engineers B.V. for use in this study is shown below in relationship to the geotechnical units and geological formations recognised in this area. Ages as used by Fugro in their Geological Ground Model are displayed alongside ages determined by palynological analysis in this study.

Geotechnical unit	Member	Formation	Age (geological model)		Age (herein)
A		Southern Bight	Holocene		not sampled
B		Kreftenheye/Eem	Pleistocene		Pleistocene
Regional unconformity					
C1		Westkapelle Ground	Pliocene*		Pleistocene (Gelasian)
C2					Gelasian - Zanclean
Regional unconformity					
D	Rupel Clay	Rupel	Early Oligocene	Rupelian	Rupelian
E1	Ruisbroek Sand	Tongeren			
E2	Watervliet Clay				
E3	Bassevelde 3 Sand		Late Eocene	Priabonian	Priabonian
E4	Bassevelde 2 Sand				
E5a	Bassevelde 1 Sand				Pria - Bart
E5b					
Regional unconformity					
F1a	Onderdijke	Dongen	Middle Eocene	Bartonian	Bartonian
F1b					
F1c					
F2	Buisputten				
F3	Zomergem		Early Eocene	Lutetian	

Figure 2: Geotechnical units displayed against regional lithostratigraphy and chronostratigraphy

(A Pleistocene age is also considered possible according to geological model)*

The Quaternary subdivisions are according to Rijsdijk *et al.* (2005) while the Tertiary scheme follows the Dutch onshore nomenclature of TNO (2013a – c).

Tertiary sediments of Eocene to Pliocene age dip gently NNE and are unconformably overlain by Pleistocene and a thin veneer of Holocene sediments on a very irregular erosional surface. As a consequence the age of the sub-cropping strata increases in a southwesterly direction. Samples for this study were selected from locations where boreholes penetrated sediments of different ages beneath the unconformity.

5- Summary of geotechnical stratigraphy

The following table illustrates the stratigraphic position of samples used in this study in relationship to the Geotechnical Unit scheme applied by Fugro. Unit "tops" are shown for each borehole with sampled units highlighted in grey.

Geotechnical unit	BH-WFS1-5A	BH-WFS2-2A	BH-WFS2-7	BH-SubStatB-1	BH-WFS4-7
A	0.0	0.0	0.0	0.0	0.0
B	6.4	4.0	1.9	1.4	1.4
Regional unconformity					
C1	16.1	–	–	–	6.1
C2	16.9	–	–	–	10.8
Regional unconformity					
D	24.9	–	–	–	13.8
E1	32.7	–	–	–	24.6
E2	46.0	–	–	–	32.0
E3	50.5	–	–	9.7	35.5 - 51.9 TD
E4	61.0 - 65.2 TD	–	–	22.7	
E5a		–	–	33.8	
E5b		53.0 - 59.1 TD	6.2	46.0	
Regional unconformity					
F1a			12.0	57.7	
F1b			18.8	65.0	
F1c			20.5	67.1	
F2			26.4	71.8	
F3			30.1 - 52.0 TD	78.6 - 80.8 TD	

Figure 3: Geotechnical unit "tops" in boreholes (TD = terminal depth of borehole)

(after Fugro Engineers B.V.; not to scale)

6 - Biostratigraphic results

The following text is a summary of the more detailed report provided by PetroStrat for this study (Polling, 2016). Age determinations highlighted in red differ from the prognosis and are discussed in further detail in Section 7 of this report.

Location: BH-WFS1-5A

Unit interval		Presumed geotechnical unit	Lithology	Sample		Ages from Geological model	Age determined by palynology (this study)
Top depth (m)	Base depth (m)			Top depth (m)	Base depth (m)		
16.9	24.9	C2	Sand	17.00	17.05	(E) Pliocene	E Pleistocene (Gelasian)
24.9	32.7	D	Clay	25.80	25.90	Rupelian	Rupelian

Sample 17.00-17.05 m (Geotechnical unit C2)
This sample is very similar to the sample at 9.50 m from borehole BH-WFS4-7 in that it yielded very abundant reworking (mainly Early Cretaceous/Late Jurassic, Tertiary) together with an *in-situ* component consisting of superabundant *Operculodinium israelianum* and superabundant *Bitectatodinium/Filisphaera* spp., and *Impagidinium multiplexum* which indicates that it is most likely from the Praetiglian pollen stage of Kuhlman *et al.* (2006), dated as Early Pleistocene (Gelasian).

Age: Early Pleistocene (Gelasian)

Sample 25.80-25.90 m (Geotechnical Unit D)
A very different assemblage is found at this depth, with a dominance of *Microdinium "granulatum"* (a different species of *Microdinium* than seen in Geotechnical unit D of BH-WFS4-7) together with an abundance of *Wetzeliella* spp. including *W. symmetrica*. Several marker species that were seen in unit D of BH-WFS4-7, such as *Achilleodinium biformoides* and *Phthanoperidinium comatum,* are absent in this sample. An increase in *Wetzeliella* spp. is used in the Central North Sea to indicate PetroStrat biozone PPg23, which is of a 'middle' Rupelian age.

This sample is thus slightly younger than the sample at 14.75 m and 12.80 m in BH-WFS4-7 indicating that the unconformity may have cut out less stratigraphy in the BH-WFS1-5A borehole than in BH-WFS4-7.

Age: Early Oligocene (Rupelian)

Location: BH-WFS2-2A

Unit interval		Presumed geotechnical unit	Lithology	Sample		Ages from Geological model	Age determined by palynology (this study)
Top depth (m)	Base depth (m)			Top depth (m)	Base depth (m)		
4.0	53.0	B	Sand	47.50	47.85	Pleistocene	?Pleistocene
		B	Clay	51.50	51.60		?Pleistocene

Sample 47.50-47.85 m (Geotechnical unit B)
The samples from this borehole were taken from Geotechnical unit B which is believed to fill a major Pleistocene scour hollow at this location. No Pleistocene species were identified but an assemblage that seems to be a mixture of material of various ages from within the Early Oligocene (Rupelian), the oldest of which indicates PetroStrat biozone PPg21a, was recovered. This assemblage is interpreted as representing reworking from Geotechnical units D, E1 and/or E2 (= Rupel Fm).

Age: ?Pleistocene

Sample 51.50-51.60 m (Geotechnical unit B)
A slightly different assemblage is seen in this sample with the appearance of some 'earliest' Rupelian taxa such as *Phthanoperidinium comatum* and typical Late Eocene (Priabonian) taxa such as *Areosphaeridium diktyoplokum* and *Rottnestia borussica*.

As in the sample at 47.50 m, no Pleistocene marker species were found but in the context of a scour hollow we assume that this sample is also Pleistocene in age. The reworking seems to be slightly older than at 47.50 m, most likely originating from the upper part of the Bassevelde Sand (= Geotechnical units E3/E4).

Age: ?Pleistocene

Location: BH-WFS2-7

Unit interval		Presumed geotechnical unit	Lithology	Sample		Ages from Geological model	Age determined by palynology (this study)
Top depth (m)	Base depth (m)			Top depth (m)	Base depth (m)		
6.2	12.0	E5b	Sand	7.35	7.75	Priabonian	Priabonian (- Bartonian)
12.0	18.9	F1a	Clay	13.00	13.15	Bartonian	Bartonian
18.9	20.5	F1b	Clay	19.45	19.65		
20.5	26.4	F1c	Clay	24.00	24.10		
26.4	30.1	F2	Clay	28.00	28.10		
30.1	52.0	F3	Clay	33.70	33.85	Lutetian	Bartonian
		F3	Clay	48.80	48.89		

Sample 7.35-7.75 m (Geotechnical unit E5b)
This sample contains *Areosphaeridium diktyoplokum* and *Heteraulacacysta porosa,* and also *Cerebrocysta bartonensis* and *Rhombodinium glabrum* which together suggest an earliest Priabonian to Bartonian age. Alternatively, the Bartonian markers may have been reworked into earliest Priabonian sediments.

Age: Late Eocene (earliest Priabonian) (- Middle Eocene (Bartonian))

Samples 13.00-13.15 m, 19.45-19.65 m, 24.00-24.10 m, 28.00-28.10 m, 33.70-33.85 m, 48.80-48.89 m (Geotechnical units F1a, F1b, F1c, F2, F3)
A downhole increase in *Homotryblium floripes/vallum* is recorded at 13.00 m which was also found at 57.00 m in BH-SubStatB-1 and provides evidence for a Middle Eocene, Bartonian age. *Rhombodinium glabrum* and *Araneosphaera araneosa* are also present, further supporting this interpretation. Furthermore, the last downhole occurrence (LDO) of *Rhombodinium glabrum* at 19.45m and subsequent LDO of *Rhombodinium porosum* at 24.00m both provide strong evidence for an intra-Bartonian age.

Samples are dated as Bartonian down to 48.80 m where some species such as *Enneadocysta arcuata* and *Heteraulacacysta porosa,* which have their earliest occurrences in the ‘earliest’ Bartonian, are present. No Lutetian markers were seen either in 33.70 m or 48.80 m indicating that geotechnical unit F3 is Bartonian in age. At 33.70 m (F3) there is a huge influx of siliceous fragments accompanied by superabundant *Wetzeliella* spp. and *Deflandrea* spp. which probably indicates a period of increased productivity and could help in differentiating unit F3 and F2.

Age: Middle Eocene (Bartonian)

Location: BH-SubStatB-1

Unit interval		Presumed geotechnical unit	Lithology	Sample		Ages from Geological model	Age determined by palynology (this study)
Top depth (m)	Base depth (m)			Top depth (m)	Base depth (m)		
9.7	22.7	E3	Sand	10.55	10.75	Priabonian	Priabonian
		E3	Sand	22.00	22.35		
33.8	46.0	E5a	Sand	34.50	34.80		
		E5a	Sand	41.00	41.30		Priabonian-Bartonian
46.0	57.7	E5b	Sand	49.25	49.40		
		E5b	Sand	57.00	57.35		Bartonian
57.7	65.0	F1a	Clay	61.35	61.40	Bartonian	Bartonian

Samples 10.55–10.75 m, 22.00-22.35 m and 34.50-34.80 m (Geotechnical units E3 and E5a)
Both samples from Geotechnical unit E3 (10.55 m and 22.00 m) provide good evidence for a Late Eocene (Priabonian) age. *Heteraulacacysta porosa* is present from 10.55 m to 57.00 m, and *Rhombodinium porosum* is seen between 22.00 m and 61.35 m. Vandenberghe *et al.* (2004) used the first downhole occurrences of both these species to identify the Early Priabonian Bassevelde 1 Sand but others (e.g. Williams *et al*., 2004) record them higher in the Priabonian. In view of this uncertainly a general Late Eocene, (Priabonian) age is assigned herein. The sample at 34.50-34.80 m (E5a) shows a similar assemblage to the samples above but also shows some minor reworking, most likely from the Lower Dongen Formation (= Early Eocene).

Age: Late Eocene (Priabonian)

Samples 41.00-41.30 m and 49.25-49.40 m (Geotechnical units E5a/b)
The sample at 41.00 m shows the first downhole occurrences of *Rhombodinium glabrum* and *Cerebrocysta bartonensis* which are both good indicators for an 'earliest' Late Eocene (Priabonian) age according to the PetroStrat Tertiary zonation scheme. Eldrett *et al.*, (2004) and others (e.g. Williams *et al.,* 2004) however, use these species to indicate a Middle Eocene, Bartonian age. Especially *Rhombodinium glabrum* is thought to be highly age-restricted to magnetochron C18n.2n, which is intra-Bartonian (Eldrett et al, 2004). Because of this controversy we have interpreted this section as straddling the Late/Middle Eocene (Priabonian/Bartonian) boundary. As there is an unconformity between the Onderdijke Clay and Bassevelde Sand (Vandenberghe *et al.,* 1998 use the term 'interburrowed omission surface') there is the possibility that the Bartonian marker species could have been reworked. However, the very persistent nature of these species down to the base of the borehole tends to refute this suggestion.

Age: Late to Middle Eocene (Priabonian – Bartonian)

Samples 57.00-57.35 m and 61.35-61.40 m (Geotechnical units E5b, F1a)
At 57.00 m the LDO of *Heteraulacacysta porosa* and increase in *Homotryblium floripes/vallum* grp. strongly suggests a Middle Eocene, Bartonian age. The FDO *Araneosphaera araneosa* and a strong increase in prasinophyte algae (= marginal marine) are also typical for this age. *Rhombodinium porosum* is also present, and following King *et al*. (2016) a 'late' Bartonian age is implied.

Age: Middle Eocene (Bartonian)

Location: BH-WFS4-7

Unit interval		Presumed geotechnical unit	Lithology	Sample		Ages from Geological model	Age determined by palynology (this study)
Top depth (m)	Base depth (m)			Top depth (m)	Base depth (m)		
6.1	10.8	C1	Clay	9.50	9.60	(L) Pliocene	E Pleistocene (Gelasian)
10.8	13.8	C2	Sand	12.80	13.30	(E) Pliocene	E Pliocene (Zanclean)
13.8	24.6	D	Clay	14.75	14.80	Rupelian	Rupelian
		D	Clay	23.00	23.10		
24.6	32.0	E1	Sand	27.35	27.65		
		E1	Sand	31.30	31.75		
32.0	35.5	E2	Clay	33.75	33.95		
35.5	51.9	E3	Sand	38.95	39.40	Priabonian	Priabonian
		E3	Sand	43.10	43.40		

Sample 9.50-9.60 m (Geotechnical unit C1)
This sample is strongly dominated by reworked palynomorphs consisting of a mixture of Early Eocene, Late Jurassic - Early Cretaceous and Carboniferous spores. The *in-situ* component of this sample provides good age control as the presence of superabundant *Operculodinium israelianum* in the absence of *Impagidinium multiplexum* provides very good evidence for the Netherlands Early Pleistocene (Gelasian) 'Tiglian B' pollen stage (*sensu* Kuhlman *et al.*, 2006).

Age: Early Pleistocene (Gelasian)

Sample 12.80-13.30 m (Geotechnical unit C2)
This sample shows a mixture of two different ages: a strong component of typical Early Pliocene (Zanclean) markers such as *Reticulatosphaera actinocoronata*, common *Amiculosphaera umbracula* and abundant *Operculodinium centrocarpum sensu* Wall & Dale, 1996 together with presumably reworked Early Oligocene (Rupelian) markers like *Achilleodinium biformoides*, *Samlandia chlamydophora* and *Phthanoperidinium comatum*.

Age: Early Pliocene (Zanclean)

Samples 14.75-80 m, 23.00-23.10 m, 27.35-27.65 m, 31.30-31.75 m, 33.75-33.95 m (Geotechnical units D, E1, E2)
These samples show the continuous presence of superabundant to common *Microdinium* sp. 1 *sensu* Chateauneuf (1980), *Achilleodinium biformoides* and *Phthanoperidinium comatum* which are typical constituents of PetroStrat biozone PPg21a of Early Oligocene (Rupelian) age. The first downhole occurrence of *Thalassiphora succincta* at 27.35 m suggests an 'earliest' Early Oligocene age.

Geotechnical unit D can be differentiated from the lower units E1 and E2 by the dominant presence of *Microdinium* sp. 1 *sensu* Chateauneuf, 1980 together with *Membranosphaera* spp. and its much more marine character (i.e. dinocyst dominated). Unit E2 can be differentiated from E1 by the dominance of marginal marine, lagoonal dinocyst species (*Homotryblium* spp.) and abundance of *Charlesdowniea coleothrypta*.

The *Rhombodinium porosum* specimen seen at 33.75 m most likely represents local reworking as the rest of the assemblage still strongly suggests an Early Oligocene, Rupelian age.

Age: Early Oligocene (Rupelian)

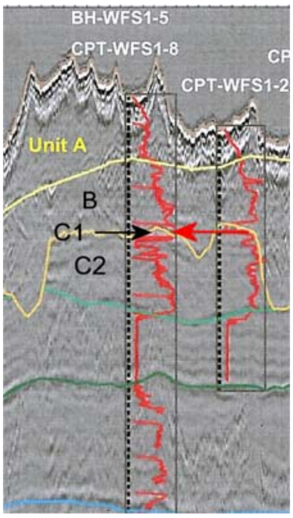
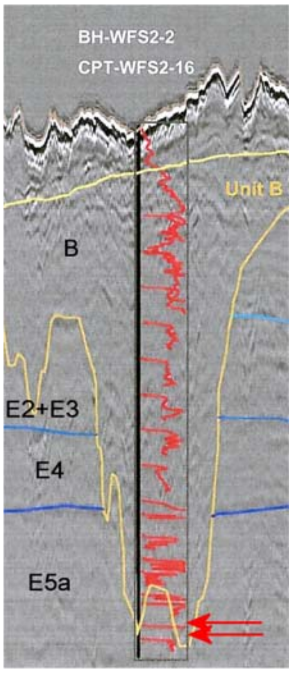
Interval 38.95-39.40 m and 43.10-43.40 m: (Geotechnical unit E3)
A distinct shift in assemblage is seen at 38.95 m with numerous typical Late Eocene (Priabonian) markers appearing such as (among others) *Areosphaeridium diktyoplokum*, *Areosphaeridium michoudii*, *Rottnestia borussica* and *Melitasphaeridium pseudorecurvatum*. *Rhombodinium glabrum (*intra-Bartonian) is also present in this sample but absent in the underlying sample (43.10 m) so probably represents reworking. These assemblages are very similar to those seen in Unit E3 samples at 10.55 m and 22.00 m in borehole BH-SubStatB-1.

Age: Late Eocene (Priabonian)

7 - Comparison of biostratigraphic results with prognosis

Generally, our biostratigraphic interpretations support the current proposed geological model. However, a number of samples returned ages which were at variance with those proposed by Fugro. Where they deviate from the prognosis the differences are mainly minor and often attributable merely to the opinions of different specialists about the stratigraphic significance of certain species. Another complication is the blurring effect on the biostratigraphic record of reworking; many of the samples were sand lithologies which by their very nature are expected to contain large amounts of reworked material. Furthermore many of the samples were picked close to lithostratigraphic boundaries which may have been imprecisely picked.

In the figures below and the next pages, biostratigraphic interpretations which differ from the prognosis are highlighted, and discussed in the table below where extracts from seismic sections have been annotated with red arrows to indicate the approximate depths from which these samples were taken.

BH-WFS1-5A **17.00-17.05 m, Unit C2** According to the lithostratigraphic scheme proposed Unit C2 is Early Pliocene in age. However, in this sample there is no palynological evidence for this. In fact the assemblage is very similar to an assemblage of *Impagidinium multiplexum* with an acme of *Bitectatodinium-Filisphaera* spp. all clearly pointing to an Early Pleistocene (Gelasian) age. This sample comes from an interval which appears to be difficult to resolve on the seismic and which is within 80 cm of the base of Unit B of proven Pleistocene age. This sample compares well with BH-WFS4-7 (9.50-9.60 m) which was also dated as Gelasian.	
BH-WFS2-2A **47.50-47.85 m and 51.50-51.60 m, Unit B** Both of these samples come from the base of a large scour hollow of presumed Pleistocene age. However, there is no palynological evidence of a Pleistocene age in these samples. In the upper of the two samples (47.50-47.85 m) only Oligocene palynomorphs were observed but the assemblage is an odd one and it is likely that it is the result of reworking. The deeper of the two samples (51.50-51.60 m) contains some Priabonian markers in addition. In conclusion, in consideration of the context of these samples they are probably Pleistocene with abundant Oligocene (and Priabonian) reworked assemblages.	

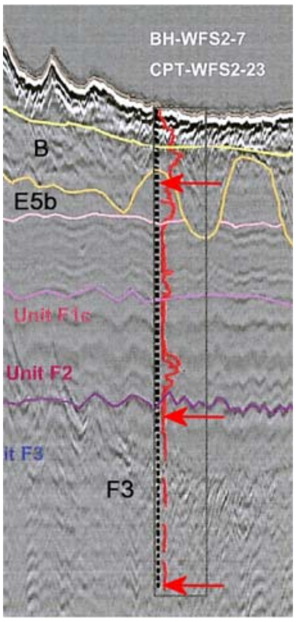
BH-WFS2-7

7.35-7.75 m, Unit E5b

The sample from 7.35-7.75 m contains earliest Priabonian index species and also some species which according to some authorities may range into the Bartonian. This suggests a position close to the Bartonian/Priabonian boundary or to reworking of Bartonian material into the Priabonian.

33.70-33.85 m and 48.00-48.89 m, Unit F3

The proposed age for Unit F3 is Eocene (Lutetian) but there is no palynological evidence for this in either of these samples (e.g. first downhole occurrence of *Phthanoperidinium distinctum*, superabundance of *S. placacantha* or *Diphyes ficusoides* none of which were observed). This suggests that either Unit F3 has not been penetrated or it is younger at this location.



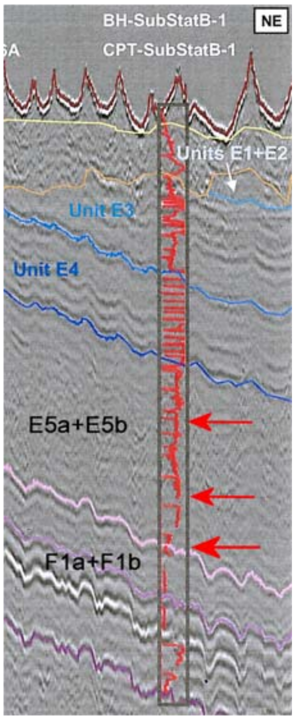
BH-SubstatB-1

41.00-41.30 m and 49.25-49.40 m, Units E5a and E5b

There is a difference of opinion amongst specialists as to the age significance (earliest Priabonian or Bartonian) of the indices in these samples and a Priabonian-Bartonian age is assigned.

57.00-57.35 m, Unit E5b

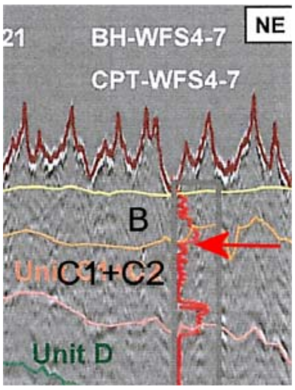
The Priabonian/Bartonian boundary is a problem in this area because the Onderdijke/Bassevelde contact is possibly unconformable and consequently reworking of Bartonian markers into basal Bassevelde sands is probable. This sample comes from the very base of Unit E5b where reworking of Bartonian sediments is most likely. However, the nature of the palynological assemblage does not support this. On the basis of this study we are not able to resolve this issue one way or the other and opt for a broad Bartonian/Priabonian assignment.



BH-WFS4-7

9.50-9.60 m, Unit C1

This sample comes from an interval shown on the available seismic section as undifferentiated units C1 and C2 and where the upper boundary with Unit B is not clearly resolved. The palynological assemblage is comparable with Netherlands Pollen stage 'Tiglian B' of early Pleistocene (Gelasian) age. This sample compares well with BH-WFS1-5a (17.00-17.05 m) which was also dated as Gelasian.



8 – Recommendations

Further sampling is recommended to confirm these results, clarify some dates and to improve resolution if required.

9 – References

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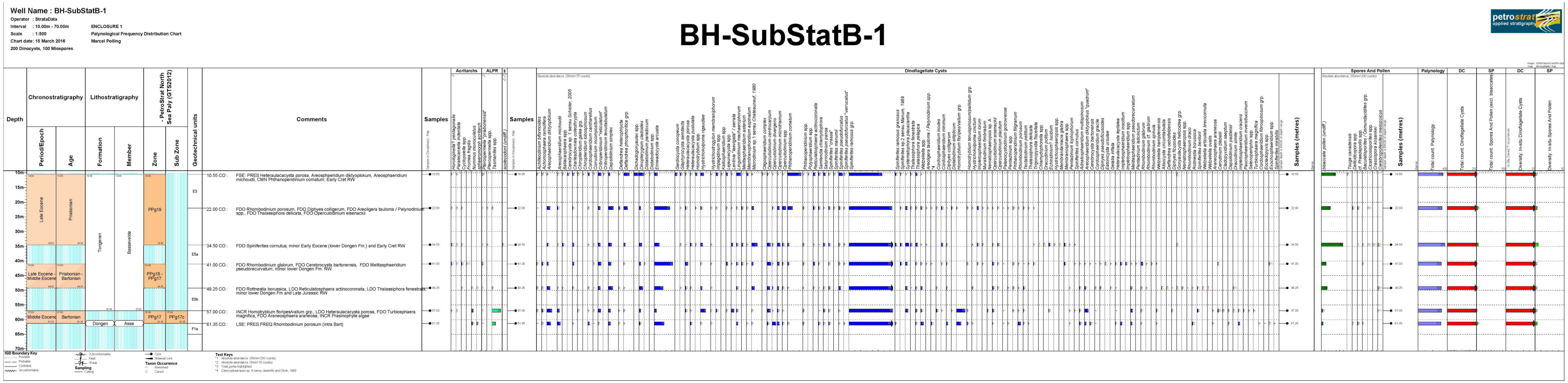
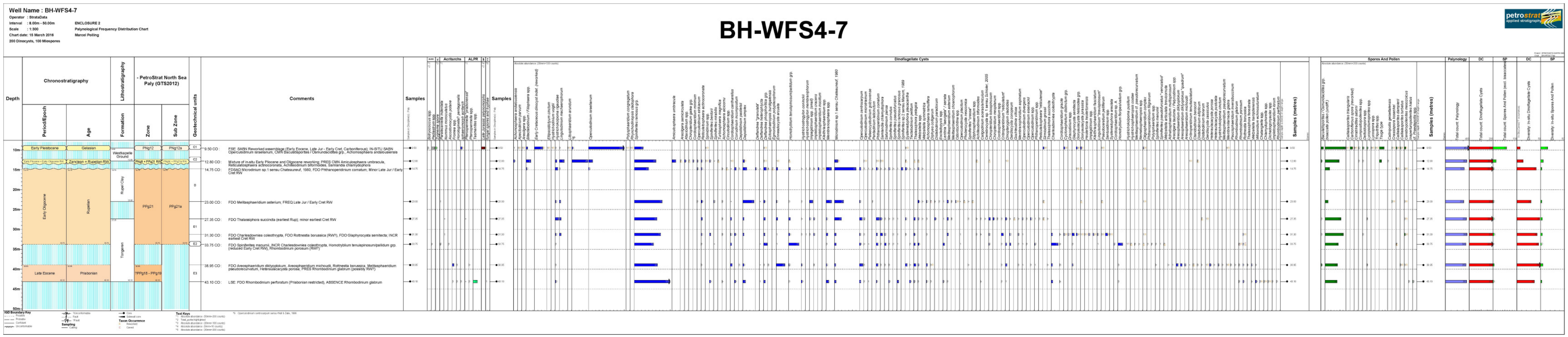
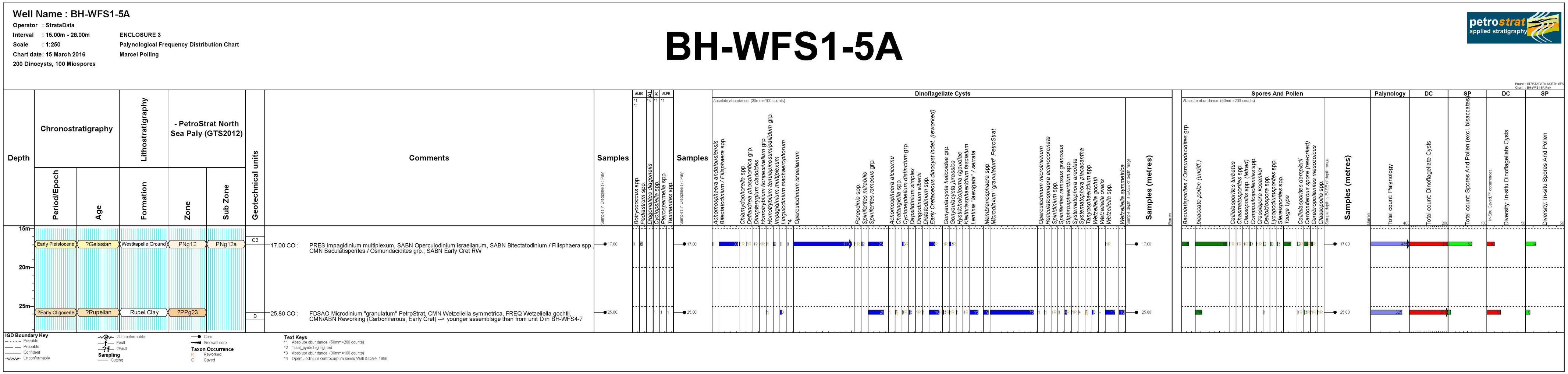
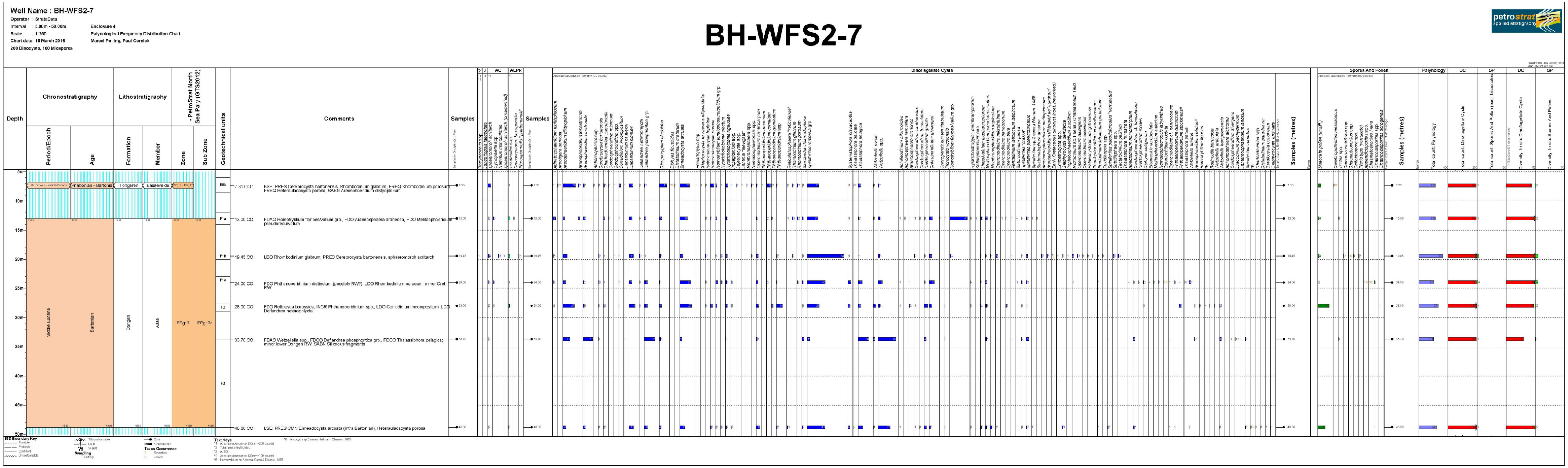
Appendix 1 – Biostratigraphic distribution charts






Well Name : BH-WFS1-5A
Operator : StrataData
Interval : 15.00m - 28.00m
Scale : 1:250
Chart date: 15 March 2016
200 Dinocysts, 100 Miospores
ENCLOSURE 3
Palynological Frequency Distribution Chart
Marcel Polling
BH-WFS1-5A
petrostrat applied stratigraphy
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
- PetroStrat North Sea Paly (GTS2012)
Zone
Sub Zone
Geotechnical units
Comments
Samples
Dinoflagellate Cysts
Spores And Pollen
Palynology
DC
SP
Early Pleistocene
?Gelasian
Westkapelle Ground
PNg12
PNg12a
C2
17.00 CO : PRES Impagidinium multiplexum, SABN Operculodinium israelianum, SABN Bitectatodinium / Filisphaera spp., CMN Baculatisporites / Osmundacidites grp.; SABN Early Cret RW
?Early Oligocene
?Rupelian
Rupel Clay
?PPg23
D
25.80 CO : FDSAO Microdinium "granulatum" PetroStrat, CMN Wetzeliella symmetrica, FREQ Wetzeliella gochtii, CMN/ABN Reworking (Carboniferous, Early Cret) --> younger assemblage than from unit D in BH-WFS4-7
IGD Boundary Key
Sampling
Taxon Occurrence
Text Keys
*1 Absolute abundance (50mm=200 counts)
*2 Total_pyrite highlighted
*3 Absolute abundance (30mm=100 counts)
*4 Operculodinium centrocarpum sensu Wall & Dale, 1996


Well Name : BH-WFS2-7
Operator : StrataData
Interval : 5.00m - 50.00m
Scale : 1:250
Chart date: 15 March 2016
200 Dinocysts, 100 Miospores
Enclosure 4
Palynological Frequency Distribution Chart
Marcel Polling, Paul Cornick
BH-WFS2-7
petrostrat applied stratigraphy
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Member
- PetroStrat North Sea Paly (GTS2012)
Zone
Sub Zone
Geotechnical units
Comments
Samples
Dinoflagellate Cysts
Spores And Pollen
Palynology
DC
SP
E5b
7.35 CO : FSE: PRES Cerebrocysta bartonensis, Rhombodinium glabrum, FREQ Rhombodinium porosum, FREQ Heteraulacacysta porosa, SABN Areosphaeridium diktyoplokum
F1a
13.00 CO : FDAO Homotryblium floripes/vallum grp., FDO Araneosphaera araneosa, FDO Melitasphaeridium pseudorecurvatum
F1b
19.45 CO : LDO Rhombodinium glabrum; PRES Cerebrocysta bartonensis, sphaeromorph acritarch
F1c
24.00 CO : FDO Phthanoperidinium distinctum (possibly RW?), LDO Rhombodinium porosum; minor Cret RW
F2
28.00 CO : FDO Rottnestia borussica, INCR Phthanoperidinium spp., LDO Corrudinium incompositum, LDO Deflandrea heterophlycta
33.70 CO : FDAO Wetzeliella spp., FDCO Deflandrea phosphoritica grp., FDCO Thalassiphora pelagica; minor lower Dongen RW, SABN Siliceous fragments
F3
Middle Eocene
Bartonian
Dongen
Asse
PPg17
PPg17c
48.80 CO : LSE: PRES CMN Enneadocysta arcuata (intra Bartonian), Heteraulacacysta porosa
IGD Boundary Key
Sampling
Taxon Occurrence
Text Keys

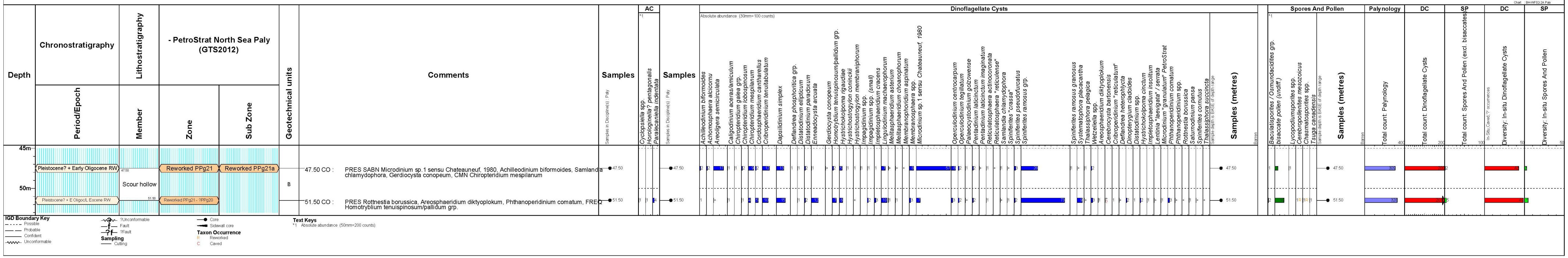
Well Name : BH-WSF2-2A

Operator : StrataData
Interval : 45.00m - 53.00m
Scale : 1:250
Chart date: 15 March 2016
200 Dinocysts, 100 Miospores

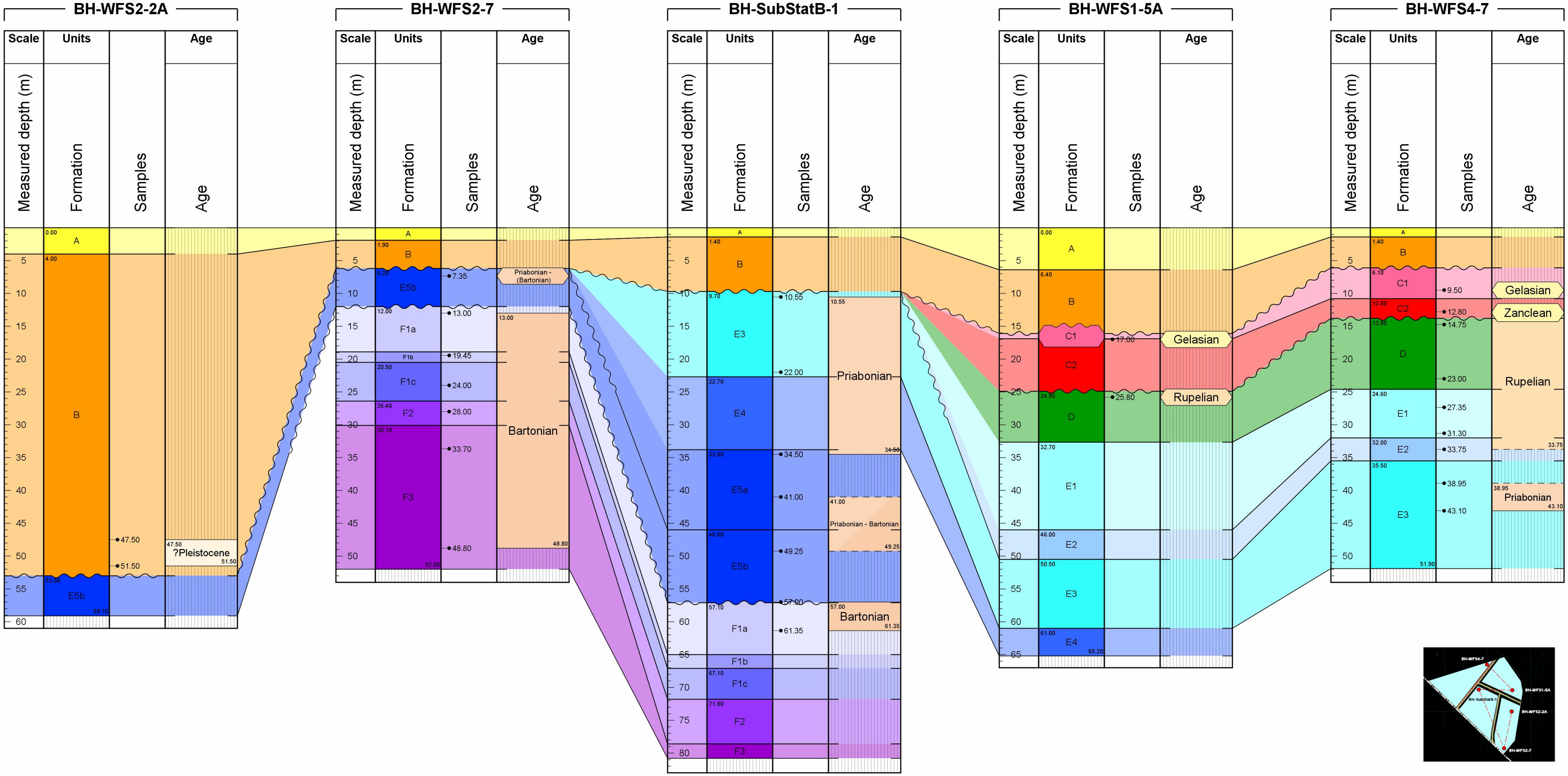
ENCLOSURE 5
Palynological Frequency Distribution Chart
Marcel Polling

BH-WSF2-2A

Project : STRATADATA NORTH SEA
Chart : BH-WFS2-2A Paly



Appendix 2 – Borehole correlation



Correlation of studied boreholes based on proposed Geotechnical Units and showing biostratigraphic ages determined in the study.

APPENDIX 2: PALYNOLOGY REPORT

CONTENTS Pages

Palynological analysis of 27 core samples from 5 boreholes in the Borssele Wind Farm Zone, Southern North Sea

Report No. **PS15-106**

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Proof Report Date: 10th March 2016

Final Report Date: 8th April 2016

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CONTENTS

1 SUMMARY

This report presents the results of an office-based palynological study conducted on 5 boreholes from the Southern North Sea, in the Borssele Wind Farm Zone (WFZ), the Netherlands. These boreholes were taken in the so-called Southern Bight (the area between the Netherlands, Belgium and the United Kingdom). The stratigraphic subdivision presented herein is based on palynological analyses on 27 core samples that encompass the Eem/Krefentheye, Westkapelle Ground, Rupel, Tongeren and Dongen Formations ranging in age from Early Pleistocene down to Middle Eocene. Recovery in the studied cores was exceptionally good and very rich and diverse palynomorph assemblages were recovered from all studied samples.

In the lithostratigraphic framework for the Borssele WFZ area, geotechnical units have been identified. In this summary the encountered geotechnical units will be briefly discussed in terms of age and results from the palynological analysis. For more in-depth information for each borehole please refer to stratigraphic discussion sections:

- Unit B: this unit is only analysed in borehole BH-WFS2-2A where it is present in a major scour hollow. The samples analysed originate from the ‘earliest’ Oligocene, Rupelian to ‘latest’ Eocene, Priabonian age with no younger material present. This probably represents the drowning out of *in-situ* fossils by superabundant reworked material in the scour hollow.

- Unit C1: only seen in BH-WFS4-7 where it shows a very dominant reworked signal (glacial) and an *in-situ* assemblage that strongly indicates an Early Pleistocene, Gelasian age probably from the Netherlands ‘Tiglian B’ pollen stage.

- Unit C2: at the top of unit C2 an ‘earliest’ Early Pleistocene, Gelasian age (‘Praetiglian’ pollen stage) was seen from BH-WFS1-5A while at the very base an Early Pliocene, Zanclean age was identified from BH-WFS4-7. The Westkapelle Ground Formation thus seems to range in age from Early Pliocene to at least ‘earliest’ Early Pleistocene.

- Unit D/E1/E2: are found to be entirely of an Early Oligocene, Rupelian age from BH-WFS4-7 and BH-WFS1-5A. Several distinct assemblage changes make it possible to distinguish between units D, E1 and E2.

- Unit E3: seen in both BH-WFS4-7 and BH-SubStatB-1 where it is of a Late Eocene, Priabonian age.

- Unit E5a/b: unit E5a is most likely still of a Late Eocene, Priabonian age while in unit E5b several typical Middle Eocene, Bartonian markers were seen both in BH-SubStatB-1 and BH-WFS2-7. It is possible however that these represent local reworking as an unconformity is probably present between the base of the Bassevelde Sand and the underlying Onderdijke Clay.

- Unit F1 (a/b/c), F2, F3: these units are all aged Middle Eocene, Bartonian as seen from BH-SubStatB-1 and BH-WFS2-7. Distinct assemblage changes make it possible to distinguish between unit F1, F2 and F3.

2 INTRODUCTION

2.1 PROJECT DATA

The following materials and data were provided by StrataData Ltd:

Sample Type	Borehole	Interval (meters)
Core	BH-SubStatB-1 BH-WFS4-7 BH-WFS1-5A BH-WFS2-7 BH-WFS2-2A	10.55 – 61.35 9.50 – 43.10 17.00 – 25.80 7.35 – 48.80 47.50 – 51.50

2.2 ANALYTICAL PROCEDURES

This report presents the results of the following analyses, conducted at PetroStrat Ltd. Office:

Analysis	Borehole	Number of samples
Palynology (quantitative):	BH-SubStatB-1	7
	BH-WFS4-7	9
	BH-WFS1-5A	2
	BH-WFS2-7	7
	BH-WFS2-2A	2

Quantitative palaeontological data are displayed in Enclosures 1 to 5 and a correlation panel is shown in Enclosure 6. All depths quoted in this report are top depths as provided by StrataData Ltd in the sample manifest.

Palynology – methodology

Samples for palynological analyses were subject to the standard palynological preparation technique which involves removal of all mineral material by hydrofluoric acid digestion and sieving to produce a residue of the 20 micron and above size fraction. A strew mount coverslip is prepared for the residue fraction for each sample.

Palynological analyses involved an initial count of 100 *in situ* palynomorph specimens, of all types. Any obviously reworked or caved specimens of any type were counted in addition to the 100 *in situ* specimens and were not included in the 100 count. When the initial 100 count of *in situ* specimens was completed, counting of reworked and caved taxa was stopped and the number of dinoflagellate cysts (dinocysts) present within this count is recorded as ‘Dinocysts (count 1)’ whereas the number of pollen and spores within this initial 100 count is recorded as ‘Pollen and Spores (count 1)’. Dinocysts are a marine indicator, whereas pollen and spores are terrestrially derived. The bisaccate pollen (undiff.) where also dropped from the count at this point. Counting of *in situ* dinocysts then continued until a count of 200 *in situ* specimens was achieved. Because of the extremely rich nature of the material, the rest of the coverslip was then scanned for rare palynomorph taxa present outside the count (recorded as "+" on the charts in Enclosure 1-5).

Abundance categories

The following standard abundance criteria have been used to qualify biostratigraphic events discussed herein and on the charts accompanying this report:

≤1% of total palynoflora	rare
2-5%	frequent
6-15%	common
16-25%	abundant
>26%	superabundant

2.3 BIOSTRATIGRAPHIC ZONATIONS

The zonation scheme used by PetroStrat for the Neogene and Paleogene is illustrated in Appendix 1. It is a widely used zonation scheme mainly focussed on the UKCS but proved to be very applicable in other relatively nearby areas such as the Southern North Sea as well.

2.4 CHRONOSTRATIGRAPHIC NOMENCLATURE

The chronostratigraphy follows the scheme of Gradstein et al. (2012). Age breakdowns based on biostratigraphic evidence are expressed in terms of chronostratigraphic units (Series, Stage), divided into formal Early, Middle and Late (Series) where applicable. Additionally, informal divisions such as 'earliest', 'middle' or 'latest' may be applied where differentiation of formal units is not possible on the available data.

Zalasiewicz *et al*., 2004 (Geological Society Stratigraphic Commission) recommended ending the long-held but often impractical distinction between time-rock units (chronostratigraphy) and geological time units (geochronology). They favoured blanket use of "Early" and "Late", rendering "Lower" and "Upper" redundant. We follow their recommendations.

Note that in Enclosures 1 to 5 chronostratigraphic units are listed under the headers Period/Epoch (= Series) and Age (= Stage), due to the StrataBugs™ default set-up.

2.5 LITHOSTRATIGRAPHIC NOMENCLATURE

The lithostratigraphic nomenclature used in this report follows Rijsdijk et al, (2005) for the Quaternary as it is believed to be more applicable to the Borssele WFZ area. The Tertiary lithostratigraphy is according to Dutch onshore nomenclature (TNO, see below).

Vandenberghe et al, (2003) and (2004) present a subdivision of the Bassevelde Member (Tongeren Formation) and Asse Member (Dongen Formation) based on micro-fauna in the Belgian lithostratigraphic scheme. Where possible, this subdivision will be applied although several noticeable differences make direct application to the Borssele WFZ area problematic (i.e. reworking or absence of important marker species).

<table>
<tr><th colspan="3">Lithostratigraphy</th><th colspan="3">Lithostratigraphy Onshore</th><th colspan="2">Lithostratigraphy Offshore</th><th colspan="3">Time Scale</th></tr>
<tr><th>Unit</th><th>Sub-Unit</th><th>Stratigraphy</th><th>Formation</th><th colspan="2">Member</th><th>Formation</th><th>Member</th><th>Age</th><th>Epoch</th><th>Period</th></tr>
<tr><td>D</td><td></td><td>Rupel Clay</td><td>Rupel</td><td colspan="2">Rupel Clay</td><td rowspan="3">Rupel</td><td>Rupel Clay</td><td rowspan="3">Rupelian</td><td rowspan="3">Oligocene</td><td rowspan="12">Tertiary</td></tr>
<tr><td>E1</td><td></td><td>Ruisbroek Sand</td><td rowspan="6">Tongeren</td><td rowspan="6">Zelzate</td><td>Ruisbroek</td><td rowspan="3">Vessem</td></tr>
<tr><td>E2</td><td></td><td>Watervliet Clay</td><td>Watervliet</td></tr>
<tr><td>E3</td><td></td><td>Bassevelde 3 Sand</td><td rowspan="4">Bassevelde</td><td rowspan="4">Undifferentiated</td><td rowspan="4">Priabonian</td><td rowspan="9">Eocene</td></tr>
<tr><td>E4</td><td></td><td>Bassevelde 2 Sand</td><td rowspan="3"></td></tr>
<tr><td rowspan="2">E5</td><td>E5a</td><td rowspan="2">Bassevelde 1 Sand</td></tr>
<tr><td>E5b</td></tr>
<tr><td rowspan="3">F1</td><td>F1a</td><td rowspan="3">Onderdijke</td><td rowspan="5">Dongen</td><td colspan="2" rowspan="5">Asse</td><td rowspan="5">Dongen</td><td rowspan="5">Asse</td><td rowspan="4">Bartonian</td></tr>
<tr><td>F1b</td></tr>
<tr><td>F1c</td></tr>
<tr><td>F2</td><td></td><td>Buisputten</td></tr>
<tr><td>F3</td><td></td><td>Zomergem</td><td>Lutonian</td></tr>
</table>

2.6 ABBREVIATIONS

The following abbreviations are used within this report:

(P)	Palynology
FSE	First sample examined
LSE	Last sample examined
PRES	Presence
FDO	First downhole occurrence (‘top’)
FDFO	First downhole frequent occurrence
FDCO	First downhole common occurrence
FDAO	First downhole abundant occurrence
FDSAO	First downhole superabundant occurrence
LDO	Last downhole occurrence (‘base’)
LDCO	Last downhole common occurrence
LDAO	Last downhole abundant occurrence
LDSAO	Last downhole superabundant occurrence
INCR	Increase in abundance
DECR	Decrease in abundance
REAPP	Reappearance
FREQ	Frequent
CMN	Common
ABN	Abundant
SABN	Superabundant
ACME	Highest abundance of a species
TD	Total Depth
CVD	Caved
RW	Reworked

2.7 PERSONNEL

The following personnel were involved in this study:

Project co-ordination:	Marcel Polling
Palynology:	Marcel Polling, Paul Cornick

We wish to acknowledge the help and support provided by StrataData Ltd staff during the course of this work, especially John Athersuch.

3 BIOSTRATIGRAPHY OF BH-SUBSTATB-1

3.1 CHRONOSTRATIGRAPHIC SUCCESSION

Series	Stage	Top Sample (m)	Base Sample (m)
Late Eocene	Priabonian	10.55 (FSE)	34.50
Late Eocene - Middle Eocene	Priabonian - Bartonian	41.00	49.25
Middle Eocene	Bartonian	57.00	61.35 (LSE)

3.2 BIOZONATION

Palynological Zonation

Zone	Subzone	Top Sample (m)	Base Sample (m)
PPg19		10.55 (FSE)	34.50
PPg18 – PPg17		41.00	49.25
PPg17	PPg17c	57.00	61.35 (LSE)

3.3 BIOSTRATIGRAPHIC EVENTS

Biostratigraphic examination of this well section commenced at 10.55m. Primary age diagnostic events are listed below together with selected additional events that may be locally correlative. Events are prefixed M, N or P within the "Disc." column (= Discipline) to denote Micropalaeontology, Nannopalaeontology or Palynology, respectively.

Depth (m)	Disc	Event/Comment
10.55	P	FSE: PRES *Heteraulacacysta porosa, Areosphaeridium diktyoplokum, Areosphaeridium michoudii,* CMN *Phthanoperidinium comatum*
22.00	P	FDO *Rhombodinium porosum*, FDO *Diphyes colligerum*, FDO *Areoligera tauloma / Palynodinium* spp., FDO *Thalassiphora delicata*, FDO *Operculodinium eisenackii*
34.50	P	FDO *Spiniferites cornutus*; minor Early Eocene RW (lower Dongen Fm.)
41.00	P	FDO *Rhombodinium glabrum*, FDO *Cerebrocysta bartonensis*, FDO *Melitasphaeridium pseudorecurvatum*; minor lower Dongen Fm. RW

49.25	P	FDO *Rottnestia borussica*, LDO *Reticulatosphaera actinocoronata*, LDO *Thalassiphora fenestrata*; minor lower Dongen Fm and Late Jurassic RW
57.00	P	INCR *Homotryblium floripes/vallum* grp., LDO *Heteraulacacysta porosa*, FDO *Turbiosphaera magnifica*, FDO *Araneosphaera araneosa*; INCR Prasinophyte algae
61.35	P	LSE: PRES FREQ *Rhombodinium porosum* (intra Bart)

3.4 STRATIGRAPHIC DISCUSSION

Interval 10.55 – 34.50m: Late Eocene – Priabonian (Geotechnical unit E3 and E5a)

Both samples from Geotechnical unit E3 (10.55 and 22.00m) provide good evidence for a Late Eocene, Priabonian age. *Heteraulacacysta porosa* is present from the first sample examined (FSE from now on) down to 57.00m and *Rhombodinium porosum* is seen from 22.00m down to 61.35m (LSE). Both species are used by Vandenberghe et al, (2004) to subdivide the Bassevelde Sand and their FDO's are used to define the lowermost sequence (i.e. Sequence Ba 1) - which is the oldest sequence just above the Priabonian/Bartonian boundary. In the Lithostratigraphic scheme for the Borssele WFZ (see chapter 2.5 in this report), the Bassevelde 1 Sand corresponds to this sequence which is seen in Geotechnical unit E5 (a and b). So following Vandenberghe et al, (2004) unit E3 would be of an 'early' Priabonian age but other references (e.g. Williams et al, 2004) cite that *Heteraulacacysta porosa* ranges well into the Priabonian. Following this uncertainty unit E3 is best assigned a general Late Eocene, Priabonian age.

The sample at 34.50m (E5a) shows a similar assemblage to the samples above but also shows some minor reworking, most likely from the Lower Dongen Formation (Early Eocene).

Interval 41.00 – 49.25m: Late Eocene / Middle Eocene – Priabonian / Bartonian (Geotechnical Unit E5a/b)

The sample at 41.00m shows the FDO's of *Rhombodinium glabrum* and *Cerebrocysta bartonensis* which are both good indicators for an 'earliest' Late Eocene, Priabonian age in the PetroStrat Tertiary zonation scheme. Eldrett et al, (2004) and others (e.g. Williams et al, 2004) however, use these species to indicate a Middle Eocene, Bartonian age. Especially *Rhombodinium glabrum* is thought to be highly age-restricted to magnetochron C18n.2n, which is intra-Bartonian (Eldrett et al, 2004). This could represent a degree of diachroneity in these events and we have therefore ranged this section as straddling the Late/Middle Eocene boundary (Priabonian/Bartonian).

An unconformity is present between the Onderdijke Clay and Bassevelde Sand (Vandenberghe et al, 1998 use the term ‘interburrowed omission surface’) and alternatively the Bartonian marker species could have been reworked. The very persistent nature of these species down to the base of the borehole though does not imply reworking.

Interval 57.00 – 61.35m: Middle Eocene, Bartonian (Geotechnical unit E5b, F1a)

At 57.00m the LDO of *Heteraulacacysta porosa* and increase in typical near-shore species *Homotryblium floripes/vallum* grp. strongly suggests a Middle Eocene, Bartonian age. The FDO *Araneosphaera araneosa* and a strong increase in prasinophyte algae (= marginal marine) are also typical for this age. *Rhombodinium porosum* is still present though and following King et al, (2016) this implies a ‘late’ Bartonian age.

4 BIOSTRATIGRAPHY OF BH-WFS4-7

4.1 CHRONOSTRATIGRAPHIC SUCCESSION

Series	Stage	Top Sample (m)	Base Sample (m)
Early Pleistocene	Gelasian	9.50 (FSE)	9.50
Early Pliocene + Early Oligocene RW	Zanclean + Rupelian RW	12.80	12.80
Early Oligocene	Rupelian	14.75	33.75
Late Eocene	Priabonian	38.95	43.10 (LSE)

4.2 BIOZONATION

Palynological Zonation

Zone	Subzone	Top Sample (m)	Base Sample (m)
PNg12	PNg12a	9.50 (FSE)	9.50
PNg9 + PPg21 RW	PNg9c + PPg21a RW	12.80	12.80
PPg21	PPg21a	14.75	33.75
?PPg18 – PPg19		38.95	43.10 (LSE)

4.3 BIOSTRATIGRAPHIC EVENTS

Biostratigraphic examination of this well section commenced at 9.50m. Primary age diagnostic events are listed below together with selected additional events that may be locally correlative. Events are prefixed M, N or P within the "Disc." column (= Discipline) to denote Micropalaeontology, Nannopalaeontology or Palynology, respectively.

Depth (m)	Disc	Event/Comment
9.50	P	FSE: SABN Reworked assemblage (Early Eocene, Late Jur - Early Cret, Carboniferous); IN-SITU SABN *Operculodinium israelianum*, CMN *Baculatisporites / Osmundacidites* grp., *Achomosphaera andalousiensis*
12.80	P	Mixture of Early Pliocene and Oligocene; PRES CMN *Amiculosphaera umbracula*, *Reticulatosphaera actinocoronata*, *Achilleodinium biformoides*, *Samlandia chlamydophora*

14.75	P	FDSAO *Microdinium* sp.1 sensu Chateauneuf, 1980, FDO *Phthanoperidinium comatum*; Minor Late Jur / Early Cret RW
23.00	P	FDO *Melitasphaeridium asterium*; FREQ Late Jur / Early Cret RW
27.35	P	FDO *Thalassiphora succincta* (earliest Rup); minor earliest Cret RW
31.30	P	FDO *Charlesdowniea coleothrypta*, FDO *Rottnestia borussica* (RW?), FDO Glaphyrocysta semitecta; INCR earliest Cret RW
33.75	P	FDO Spiniferites manumii, INCR Charlesdowniea coleothrypta, Homotryblium tenuispinosum/pallidum grp. (reduced Early Cret RW), *Rhombodinium porosum* (RW?)
38.95	P	FDO *Areosphaeridium diktyoplokum*, *Areosphaeridium michoudii*, *Rottnestia borussica*, *Melitasphaeridium pseudorecurvatum*, *Heteraulacacysta porosa*; PRES *Rhombodinium glabrum* (possibly RW?)
43.10	P	LSE: FDO *Rhombodinium perforatum* (Priabonian restricted), ABSENCE *Rhombodinium glabrum*

4.4 STRATIGRAPHIC DISCUSSION

Sample 9.50m: Early Pleistocene, Gelasian (Geotechnical unit C1)

This sample is highly dominated by reworked palynomorphs consisting of a mixture of Early Eocene, Late Jurassic - Early Cretaceous and even Carboniferous spores. This is a good indication for the presence of glaciers around this time that scour the landscape and drop all sorts of material of different age in the sea.

The *in-situ* component of this sample though provides good age control as the presence of SABN *Operculodinium israelianum* in the absence of *Impagidinium multiplexum* provides very good evidence for the Netherlands Early Pleistocene 'Tiglian B' pollen stage (sensu Kuhlman et al, 2006). This stage is part of the Gelasian period of the Pleistocene (i.e. Early Pleistocene, ca 2.45 million years ago). This event is also recognized in the 'Thurnian' of East Anglia where it constitutes up to >85% of the assemblage (similar to what is seen in this sample). The 'Thurnian' corresponds to the 'Tiglian A' stage in the Netherlands so it is likely that these events are a similar age.

Sample 12.80m: Early Pliocene + Early Oligocene RW, Zanclean + Rupelian RW (Geotechnical Unit C2)

This sample shows a mixture of two different ages: a strong component of *in-situ* typical Early Pliocene markers such as *Reticulatosphaera actinocoronata*, CMN *Amiculosphaera umbracula* and ABN *Operculodinium centrocarpum* sensu Wall & Dale, 1996 which all indicate a Zanclean age (~4.5Ma; Anthonissen, 2009) is found together with abundant reworked Early Oligocene, Rupelian markers like *Achilleodinium biformoides*, *Samlandia chlamydophora* and *Phthanoperidinium comatum* (from 'middle' to 'early' Rupelian, PetroStrat biozone PPg21a). The mixture of these two assemblages indicates that Early Oligocene reworking from geotechnical units D,E1 and/or E2 was very prevalent during the Early Pliocene.

Interval 14.75 – 33.75m: Early Oligocene, Rupelian (Geotechnical unit D, E1, E2)

This interval shows the continuous presence of SABN – CMN *Microdinium* sp. 1 sensu Chateauneuf, 1980, *Achilleodinium biformoides* and *Phthanoperidinium comatum* which are typical constituents of Petrostrat biozone PPg21a of an Early Oligocene, Rupelian age. The FDO of *Thalassiphora succincta* at 27.35m suggests an 'earliest' Early Oligocene age.

Geotechnical unit D can be differentiated from the lower units E1 and E2 by the dominant presence of *Microdinium* sp. 1 sensu Chateauneuf, 1980 together with *Membranosphaera* spp. and the much more marine character (i.e. dinocyst dominated). Unit E2 can be differentiated from E1 by the dominance of marginal marine, lagoonal dinocyst species (*Homotryblium* spp.) and abundance of *Charlesdowniea coleothrypta*.

The *Rhombodinium porosum* specimen seen at 33.75m most likely represents local reworking as the rest of the assemblage still strongly suggests an Early Oligocene, Rupelian age.

Interval 38.95 – 43.10m: Late Eocene, Priabonian (Geotechnical unit E3)

A distinct shift in assemblage is seen at 38.95m with numerous typical Late Eocene, Priabonian markers appearing such as (among others): *Areosphaeridium diktyoplokum*, *Areosphaeridium michoudii*, *Rottnestia borussica* and *Melitasphaeridium pseudorecurvatum*. *Rhombodinium glabrum* is also present in this sample but absent in the following sample (43.10m) so potentially represents reworking. These samples show strong similarity in assemblage to the samples at 10.55 and 22.00m of BH-SubStatB-1.

5 BIOSTRATIGRAPHY OF BH-WFS1-5A

5.1 CHRONOSTRATIGRAPHIC SUCCESSION

Series	Stage	Top Sample (m)	Base Sample (m)
Early Pleistocene	Gelasian	17.00	17.00
?Early Oligocene	?Rupelian	25.80	25.80

5.2 BIOZONATION

Palynological Zonation

Zone	Subzone	Top Sample (m)	Base Sample (m)
PNg12	PNg12a	17.00	17.00
?PPg23	?PPg23	25.80	25.80

5.3 BIOSTRATIGRAPHIC EVENTS

Biostratigraphic examination of this well section commenced at 17.00m. Primary age diagnostic events are listed below together with selected additional events that may be locally correlative. Events are prefixed M, N or P within the "Disc." column (= Discipline) to denote Micropalaeontology, Nannopalaeontology or Palynology, respectively.

Depth (m)	Disc	Event/Comment
17.00	P	PRES *Impagidinium multiplexum*, SABN *Operculodinium israelianum*, SABN *Bitectatodinium / Filisphaera* spp., CMN *Baculatisporites / Osmundacidites* grp.; SABN Early Cret RW
25.80	P	FDSAO *Microdinium "granulatum"* PetroStrat, CMN *Wetzeliella symmetrica*, FREQ *Wetzeliella gochtii*, CMN/ABN Reworking (Carboniferous, Early Cret)

5.4 STRATIGRAPHIC DISCUSSION

Sample 17.00m: Early Pleistocene, Gelasian (Geotechnical unit C2)

This sample shows high similarity to the sample at 9.50m from BH-WFS4-7 with very abundant reworking (mainly Early Cretaceous/Late Jurassic, Tertiary) together with an *in-situ* component consisting of SABN *Operculodinium israelianum*. In this sample at BH-WFS1-5A though, *Impagidinium multiplexum* and SABN *Bitectatodinium/Filisphaera* spp. are also recorded which indicates that it is slightly older, most likely from the ‘Praetiglian’ pollen stage sensu Kuhlman et al, (2006) - which is of an ‘earliest’ Early Pleistocene, Gelasian age.

The sample at 12.80m of BH-WFS4-7 showed that some Early Pliocene, Zanclean is present in Geotechnical unit C2 which indicates that it has an age range of ‘earliest’ Early Pleistocene to Early Pliocene, Zanclean.

Sample 25.80m: ?Early Oligocene, ?Rupelian (Geotechnical Unit D)
A very different assemblage is found at this depth, with a dominance of *Microdinium “granulatum”* (a different species of *Microdinium* than seen in Geotechnical unit D of BH-WFS4-7) together with an abundance of *Wetzeliella* spp. including *W. symmetrica*. Several marker species that were seen in unit D of BH-WFS4-7 such as *Achilleodinium biformoides* and *Phthanoperidinium comatum* are absent in this sample. An increase in *Wetzeliella* spp. is used in the Central North Sea to indicate Petrostrat biozone PPg23, which is of a ‘middle’ Rupelian age.

This sample is thus slightly younger than the sample at 14.75m and even 12.80m of BH-WFS4-7 indicating that the unconformity may have cut down less stratigraphy in BH-WFS1-5A than in BH-WFS4-7.

6 BIOSTRATIGRAPHY OF BH-WFS2-7

6.1 CHRONOSTRATIGRAPHIC SUCCESSION

Series	Stage	Top Sample (m)	Base Sample (m)
Late Eocene – Middle Eocene	Priabonian - Bartonian	7.35 (FSE)	7.35 (FSE)
Middle Eocene	Bartonian	13.00	48.80 (LSE)

6.2 BIOZONATION

Palynological Zonation

Zone	Subzone	Top Sample (m)	Base Sample (m)
PPg18 – PPg17		7.35 (FSE)	7.35 (FSE)
PPg17	PPg17c	13.00	48.80 (LSE)

6.3 BIOSTRATIGRAPHIC EVENTS

Biostratigraphic examination of this well section commenced at 7.35m. Primary age diagnostic events are listed below together with selected additional events that may be locally correlative. Events are prefixed M, N or P within the "Disc." column (= Discipline) to denote Micropalaeontology, Nannopalaeontology or Palynology, respectively.

Depth (m)	Disc	Event/Comment
7.35	P	FSE: PRES *Cerebrocysta bartonensis*, *Rhombodinium glabrum*, FREQ *Rhombodinium porosum*, FREQ *Heteraulacacysta porosa*, SABN *Areosphaeridium diktyoplokum*
13.00	P	FDAO *Homotryblium floripes/vallum* grp., FDO *Araneosphaera araneosa*, FDO *Melitasphaeridium pseudorecurvatum*
19.45	P	LDO *Rhombodinium glabrum*; PRES *Cerebrocysta bartonensis*, sphaeromorph acritarch
24.00	P	FDO *Phthanoperidinium distinctum* (possibly RW?), LDO *Rhombodinium porosum*; minor Cret RW

28.00	P	FDO *Rottnestia borussica*, INCR *Phthanoperidinium* spp., LDO *Corrudinium incompositum*, LDO *Deflandrea heterophlycta*
33.70	P	FDAO *Wetzeliella* spp., FDCO *Deflandrea phosphoritica* grp., FDCO *Thalassiphora pelagica*; minor lower Dongen RW, SABN Siliceous fragments
48.80	P	LSE: PRES CMN *Enneadocysta arcuata* (intra Bartonian), *Heteraulacacysta porosa*

6.4 STRATIGRAPHIC DISCUSSION

Sample 7.35m: Late Eocene / Middle Eocene – Priabonian / Bartonian (Geotechnical unit E5b)

This sample contains typical Late Eocene marker species *Areosphaeridium diktyoplokum* and *Heteraulacacysta porosa* but also contains *Cerebrocysta bartonensis* and *Rhombodinium glabrum* that are also seen in borehole BH-SubStatB-1 in Geotechnical unit E5b and possibly indicate that this unit straddles the Priabonian/Bartonian boundary. Alternatively the Bartonian marker species have been reworked into the 'earliest' Priabonian.

Interval 13.00 – 48.80m: Middle Eocene – Bartonian (Geotechnical unit F1a, F1b, F1c, F2, F3)

An increase in *Homotryblium floripes/vallum* is recorded at 13.00m which was also found at 57.00m in BH-SubStatB-1 and provides evidence for a Middle Eocene, Bartonian age. *Rhombodinium glabrum* and *Araneosphaera araneosa* are also present, further supporting this interpretation. Furthermore, the LDO of *Rhombodinium glabrum* at 19.45m and subsequent LDO *Rhombodinium porosum* at 24.00m are both strong evidence for an intra-Bartonian age (~40Ma; Williams et al, 2004; Eldrett et al, 2004).

This Bartonian age is found down to the LSE at 48.80m where some species are still present that have their first occurrences (= LDO's) in the 'earliest' Bartonian such as *Enneadocysta arcuata* and *Heteraulacacysta porosa*. No Lutetian markers were seen either in 33.70m or 48.80m indicating that geotechnical unit F3 is all Bartonian in age, similar to overlying units F1 and F2. At 33.70m (F3) there is a huge influx of siliceous fragments accompanied by SABN *Wetzeliella* spp. and *Deflandrea* spp. which probably indicates a period of increased productivity and can help in differentiating F3 from overlying unit F2.

7 BIOSTRATIGRAPHY OF BH-WFS2-2A

7.1 CHRONOSTRATIGRAPHIC SUCCESSION

Series	Stage	Top Sample (m)	Base Sample (m)
Pleistocene + Early Oligocene RW		47.50	47.50
Pleistocene + E Oligocene/L Eocene RW		51.50	51.50

7.2 BIOZONATION

Palynological Zonation

Zone	Subzone	Top Sample (m)	Base Sample (m)
Reworked PPg21	Reworked PPg21a	47.50	47.50
Reworked PPg21 – ?PPg20		51.50	51.50

7.3 BIOSTRATIGRAPHIC EVENTS

Biostratigraphic examination of this well section commenced at 47.50m. Primary age diagnostic events are listed below together with selected additional events that may be locally correlative. Events are prefixed M, N or P within the "Disc." column (= Discipline) to denote Micropalaeontology, Nannopalaeontology or Palynology, respectively.

Depth (m)	Disc	Event/Comment
47.50	P	PRES SABN *Microdinium* sp.1 sensu Chateauneuf, 1980, *Achilleodinium biformoides*, *Samlandia chlamydophora*, *Gerdiocysta conopeum,* CMN *Chiropteridium mespilanum*
51.50	P	PRES *Rottnestia borussica*, *Areosphaeridium diktyoplokum*, *Phthanoperidinium comatum*, *Homotryblium tenuispinosum / pallidum* grp.

7.4 STRATIGRAPHIC DISCUSSION

Sample 47.50m: Pleistocene? + Reworked Early Oligocene, Rupelian (Geotechnical unit B)

The samples from this borehole were taken from Geotechnical unit B which is a major scour hollow supposedly of a Pleistocene age. No Pleistocene species were identified though, and instead an assemblage is seen that seems to be a mixture of Early Oligocene, Rupelian material – the oldest of which is from Petrostrat biozone PPg21a. The abundance of *Chiropteridium* species and *Cribroperidinium tenuitabulatum* originating from PPg23 (intra-Rupelian). Because the sample seems to be a mixture of Early Oligocene material it is likely to represent a strong reworked signal most probably originating from Geotechnical units D, E1 or E2 (Rupel Fm).

Sample 51.50m: Pleistocene? + Reworked Early Oligocene/?Late Eocene, Rupelian/?Priabonian (Geotechnical unit B)

A slightly different assemblage is seen in this sample with the appearance of some 'earliest' Rupelian such as *Phthanoperidinium comatum* and typical Late Eocene, Priabonian taxa such as *Areosphaeridium diktyoplokum* and *Rottnestia borussica*. According to van Simaeys et al, (2005) *Areosphaeridium diktyoplokum* ranges up into the 'earliest' Rupelian but since this species has always been used as a traditional marker for top Eocene (Priabonian) and still is in the most recent update of Tertiary North Sea zonations (King, 2016) we question this interpretation. None of the possibly Bartonian marker species (e.g. *Rhombodinium glabrum* or *Cerebrocysta bartonensis*) were seen.

As in the sample at 47.50m, no Pleistocene marker species were found possibly indicating that the amount of reworking is so great that is completely drowned out the *in-situ* component. The reworking seems to originate from slightly older rocks though at 51.50m, most likely originating from the upper part of the Bassevelde Sand (Geotechnical units E3/E4).

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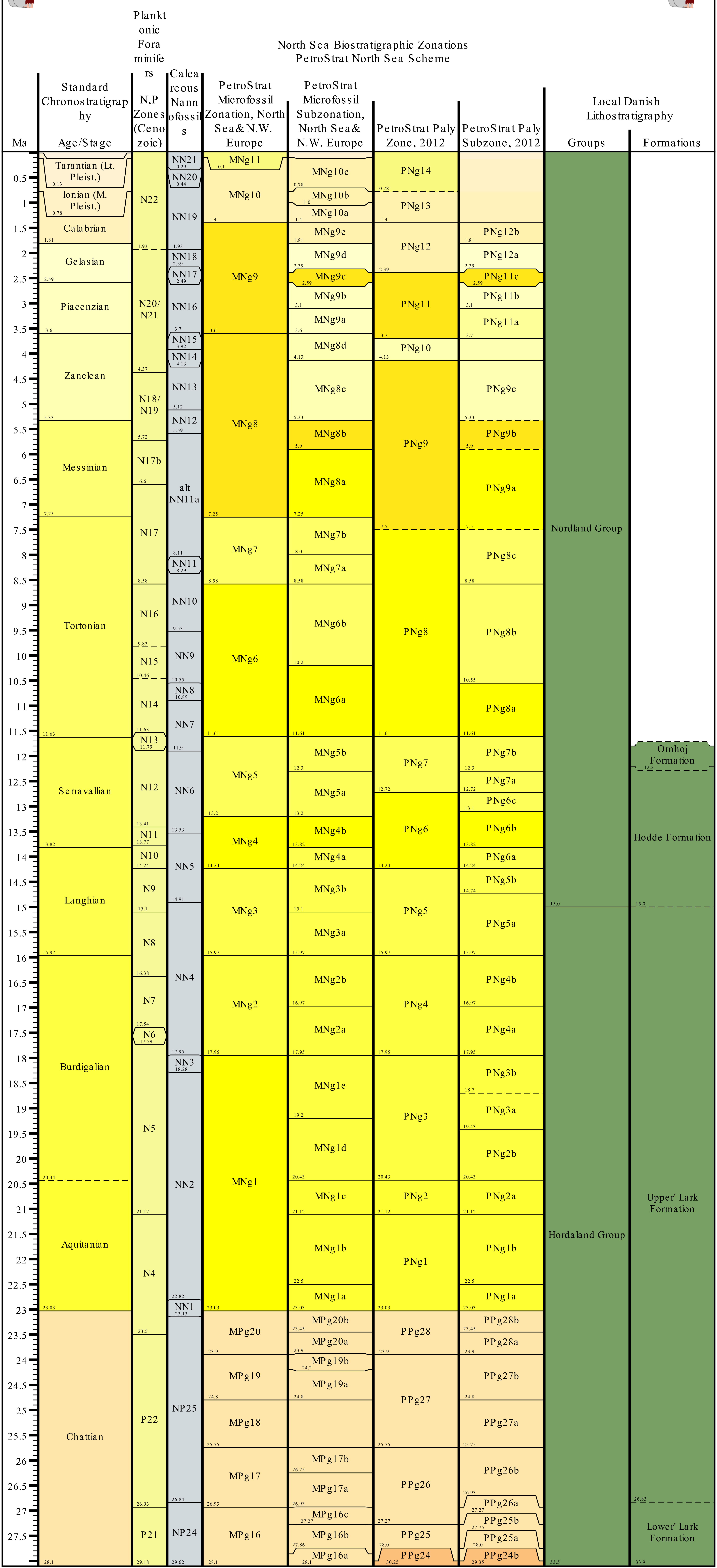
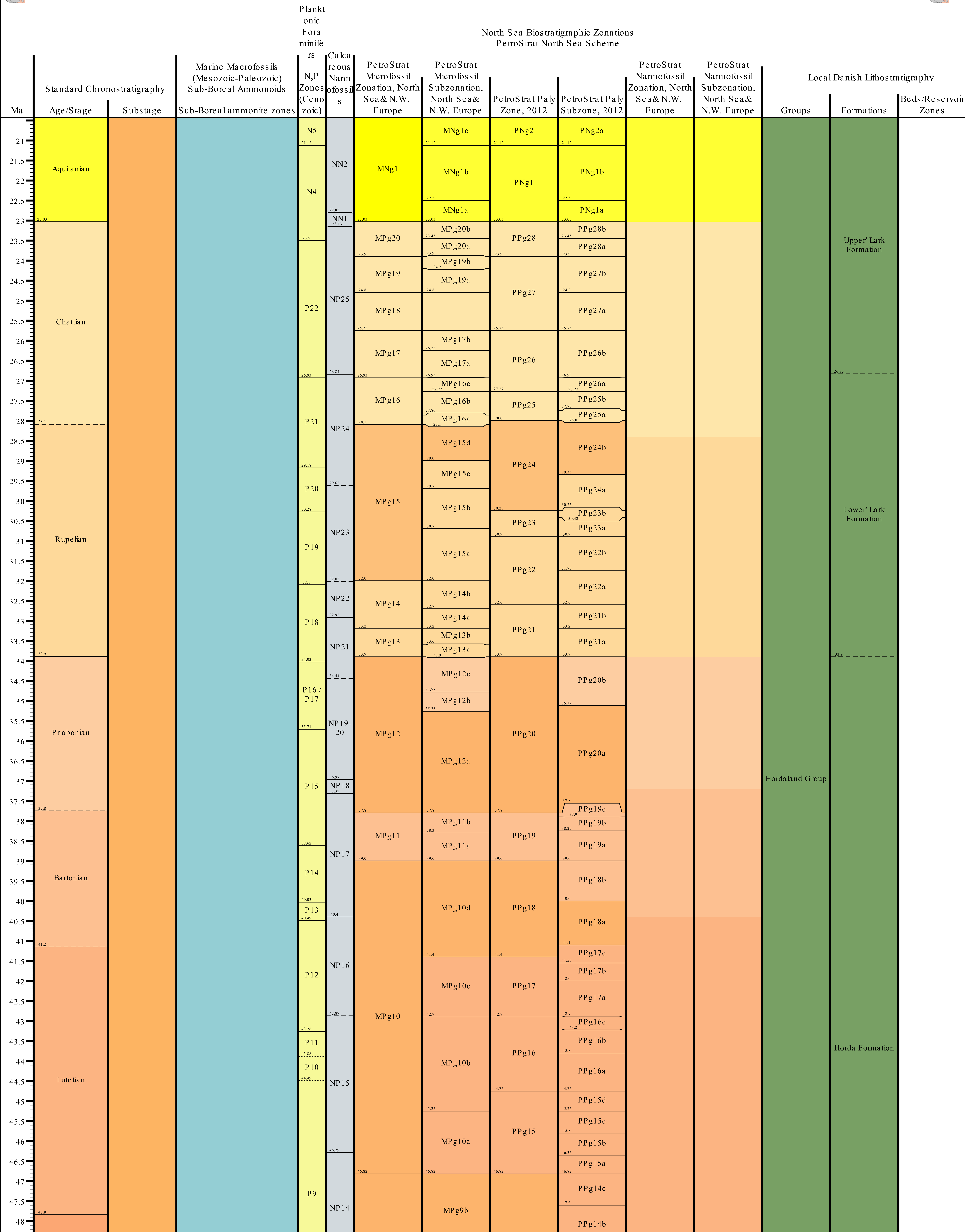
APPENDIX 1

PetroStrat North Sea Zonation and Calibration



APPENDIX 1

PetroStrat North Sea Zonation and Calibration



Well Name : BH-SubStatB-1

Operator : StrataData

Interval : 10.00m - 70.00m **ENCLOSURE 1**

Scale : 1:500 **Palynological Frequency Distribution Chart**

Chart date: 15 March 2016 **Marcel Polling**

200 Dinocysts, 100 Miospores

BH-SubStatB-1

IGD Boundary Key

- Possible
- Probable
- Confident
- Unconformable
- ?Unconformable
- Fault
- ?Fault

Sampling

- Cutting
- Core
- Sidewall core

Taxon Occurrence

- R Reworked
- C Caved

Text Keys

- *1 Absolute abundance (50mm=200 counts)
- *2 Absolute abundance (5mm=10 counts)
- *3 Total_pyrite highlighted
- *4 Cannosphaeropsis sp. A sensu Jaramillo and Oboh, 1999

Well Name : BH-WFS4-7

Operator : StrataData
Interval : 8.00m - 50.00m
Scale : 1:300
Chart date: 15 March 2016
200 Dinocysts, 100 Miospores

ENCLOSURE 2
Palynological Frequency Distribution Chart
Marcel Polling

BH-WFS4-7

petrostrat applied stratigraphy

Well Name : BH-WFS1-5A

Operator : StrataData
Interval : 15.00m - 28.00m
Scale : 1:250
Chart date: 15 March 2016
200 Dinocysts, 100 Miospores

ENCLOSURE 3
Palynological Frequency Distribution Chart
Marcel Polling

BH-WFS1-5A

IGD Boundary Key
- Possible
- Probable
- Confident
- Unconformable

- ?Unconformable
- Fault
- ?Fault

Sampling
- Cutting
- Core
- Sidewall core

Taxon Occurrence
- R Reworked
- C Caved

Text Keys
- *1 Absolute abundance (50mm=200 counts)
- *2 Total_pyrite highlighted
- *3 Absolute abundance (30mm=100 counts)
- *4 Operculodinium centrocarpum sensu Wall & Dale, 1996

Well Name : BH-WFS2-7

Operator : StrataData
Interval : 5.00m - 50.00m
Scale : 1:250
Chart date: 15 March 2016
200 Dinocysts, 100 Miospores

Enclosure 4
Palynological Frequency Distribution Chart
Marcel Polling, Paul Cornick

BH-WFS2-7

IGD Boundary Key
- Possible
- Probable
- Confident
- Unconformable
- ?Unconformable
- Fault
- ?Fault

Sampling
- Cutting
- Core
- Sidewall core

Taxon Occurrence
- R Reworked
- C Caved

Text Keys
- *1 Absolute abundance (50mm=200 counts)
- *2 Total_pyrite highlighted
- *3 ALBO
- *4 Absolute abundance (30mm=100 counts)
- *5 Homotryblium sp.A sensu Costa & Downie, 1975
- *6 Alisocysta sp.2 sensu Heilmann-Clausen, 1985

Well Name : BH-WSF2-2A

Operator : StrataData
Interval : 45.00m - 53.00m
Scale : 1:250
Chart date: 15 March 2016
200 Dinocysts, 100 Miospores

ENCLOSURE 5
Palynological Frequency Distribution Chart
Marcel Polling

BH-WSF2-2A

Project : STRATADATA NORTH SEA
Chart : BH-WSF2-2A Paly

IGD Boundary Key
Possible
Probable
Confident
Unconformable

?Unconformable
Fault
?Fault

Sampling
Cutting
Core
Sidewall core

Taxon Occurrence
R Reworked
C Caved

Text Keys
*1 Absolute abundance (50mm=200 counts)

Chart date: 15 March 2016   Marcel Polling

200 Dinocysts, 100 Miospores

Correlation panel