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TNO report

TNO 2020 R11381

The palynological results of the Paleogene and Neogene successions in wells PNA-GT-01 and PNA-GT-04

Date	August 2020
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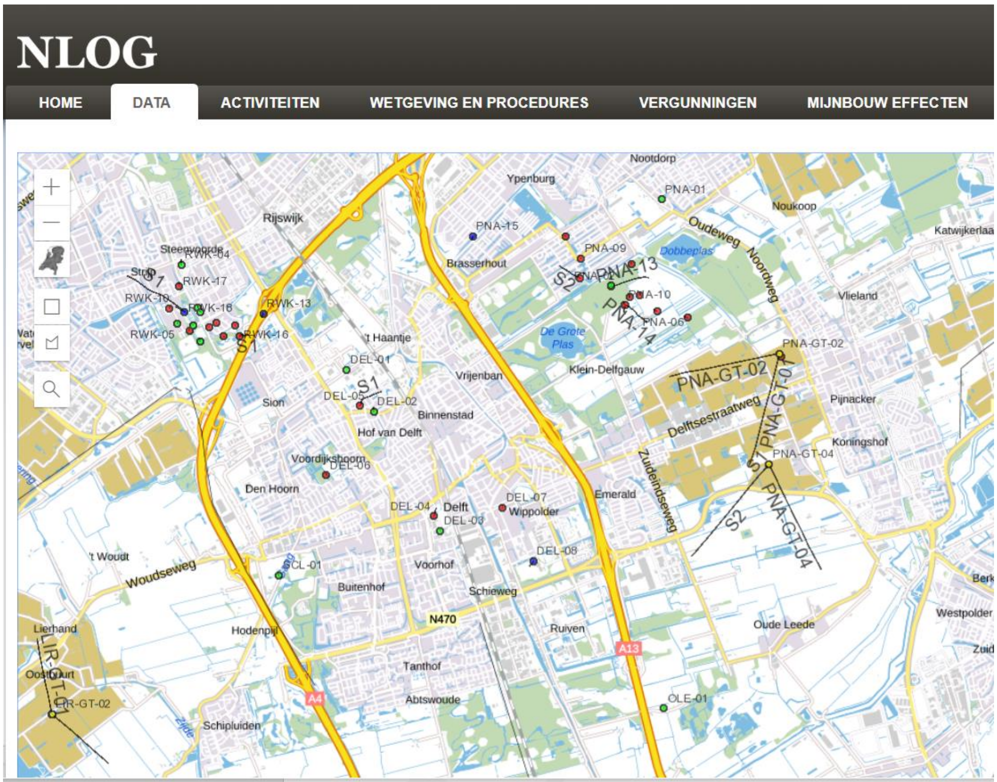
Number of pages	27
Number of appendices	4
Customer	TU-DELFT
Order nr. TU Delft	P2012020583
Project number	060.43561/01.02.01

Contents

1 Introduction

In this report to TU-Delft, the results of a palynological study on the Paleogene and Neogene successions from 2 wells in the West Netherlands Basin are presented. The respective wells are PNA-GT-01, interval 400-500 m and PNA-GT-04, interval 415-460 m (see Fig. 1).

Figure 1: Location map (NLOG, 18-08-2020)



The present palynological study contributes to the study “Preparing coring Paleogene clays within the frame of DAPwell at ~400 m depth by improved stratigraphic constraints using cutting palynology” written by Hemmo Abels, Department of Geosciences and Engineering, TU-Delft.

The Rupel and Landen Clay Members are the key units being considered for long-term storage of nuclear waste. Several research projects addressed the mechanical, chemical, and permeability and porosity behaviour of these units. Since core material is typically lacking from depths greater than 200 meters, direct measurements on the clays from greater depths are absent.

The thickness of the Rupel Clay and Landen Clay Members in the Delft subsurface is relatively uncertain (Fig. 2). Several subsurface tectonic lows and highs have caused variable deposition during the time period. On seismic cross-sections, faults show movements alongside these lows and highs. In between the highs, concentric seismic lines indicate thicker Landen and Rupel Clay Members (Fig. 3), but also sands assigned to the Berg Member, in the centre of the synclines, blanketing the

Cretaceous and early Paleogene Chalk Formation. On top, the Breda Member of the North Sea Group follows and is seemingly well visible on the seismics (Fig. 4).

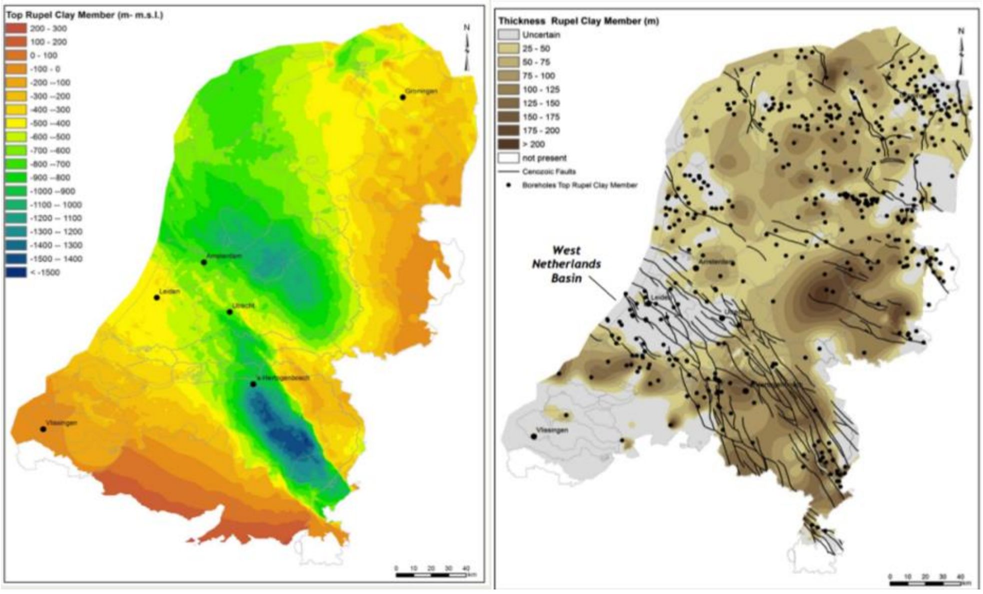


Figure 2 Estimated top of Rupel Clay Member in the Dutch and Belgian subsurface (panel A) and estimated thickness of the Rupel Clay Member (panel B) (source: TNO-GDN).

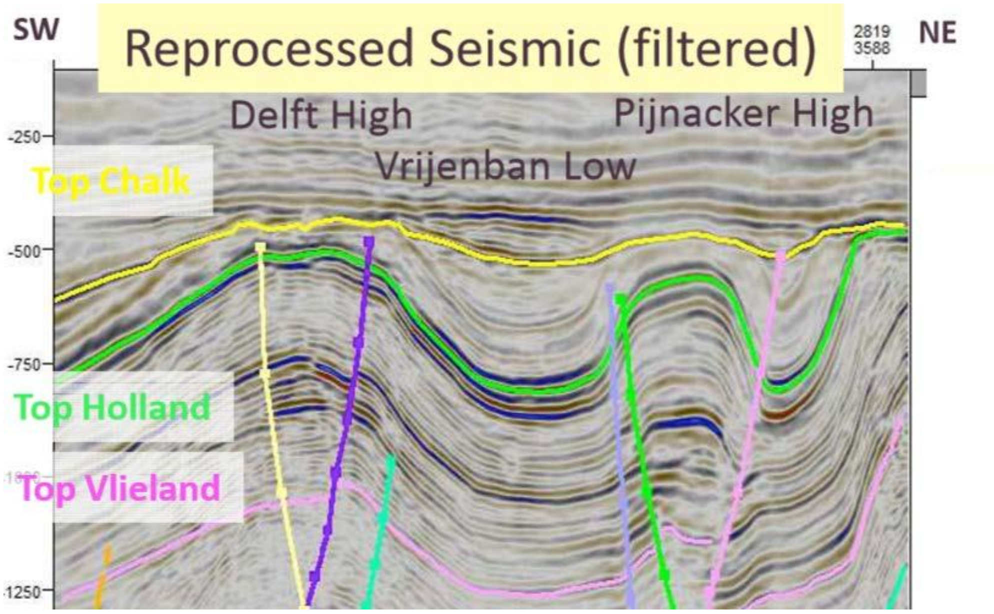


Figure 3. Reprocessed seismic line 2819 from SW to NE roughly through the area where DAPwell is planned between the Delft High and the Vrijenban Low. Several geothermal doublets are placed in the Vrijenban low towards the Pijnacker High. The line shows the interpreted Top Chalk in yellow above which the Paleogene clays should be deposited. (source: Panterra / TU Delft report).

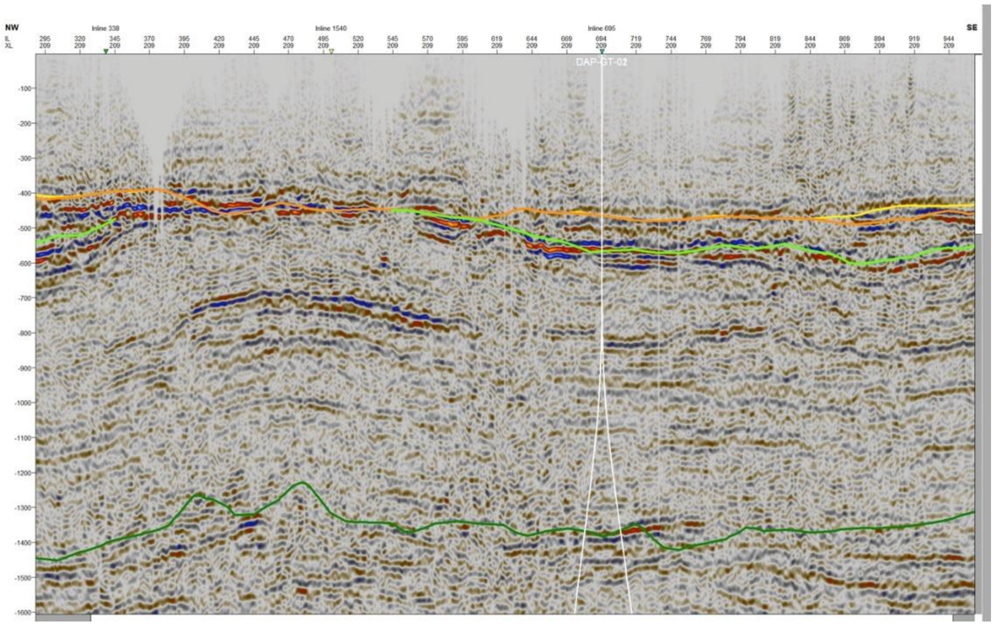


Figure 4. Reprocessed seismic line (also 2819?) by Geert-Jan Vis (TNO) showing the top Chalk in green and in orange the “inferred erosive base of the Miocene” / Neogene. The location of DAPwell is indicated to be not far NW of the point where Paleogene clays where not deposited or eroded. A move further north of the coring location would enhance the chance of thicker and undisturbed Paleogene clays.

The PNA-GT-01 to 04 wells are located structurally deeper in Vrijenban Low. There is, however, still significant lithostratigraphic variability within these interpreted structural units, while the overall thickness of the clay packages is relatively stable. In the DAPwell, one may therefore expect a succession of the Landen and Rupel Clay Members, possibly separated by thinner sandy intervals. The expected thickness for the clayey sequence is uncertain, with estimates ranging between 5 and 50 meters.

In order to prepare accurate planning of the DAPwell(s) with respect to the Paleogene clays, we here study the PNA-GT-01 and PNA-GT-04 wells. Key is the construction of robust biostratigraphic interpretation, that aid to resolve whether the suggested lithostratigraphic interpretation provided on nlog.nl are indeed correct.

Dirk Munsterman is responsible for the palynological analysis, interpretation and report. The results of the analysis are described in chapters 3 and 4. Discussion and conclusions are recorded in chapter 5. The references are listed in chapter 6.

2 Material and methods

2.1 Abbreviations

Standard abbreviations in use by TNO-GSN are listed in Table 1.

Table 1 Abbreviations used in this report

CO	Core sample
SC	Sidewall core sample
CU	Cuttings sample
m	Meter
MD	Measured depth
Ft	Feet
LOD	Last Occurrence Datum
FOD	First Occurrence Datum
LCOD	Last Common Occurrence Datum
FCOD	First Common Occurrence Datum

2.2 Samples

Twenty cuttings samples were taken from the TNO-Geological Survey of the Netherlands repository at Zeist. The samples prepared and analysed are listed in Table 2 and Table 3.

Table 2 Sample list of well PNA-GT-01

Depth (m - MD)	**Type**
415	CU
420	CU
425	CU
430	CU
435	CU
440	CU
445	CU
450	CU
455	CU
460	CU

Table 3 Sample list of well PNA-GT-04

Depth (m - MD)	**Type**
400	CU
410	CU
420	CU

430	CU
440	CU
450	CU
460	CU
470	CU
490*	CU
500	CU

*cuttings sample at depth 480 m was absent.

2.3 Sample processing

The samples were processed at the Palynological Laboratory Services (PLS - UK) by Malcolm Jones using the standard sample processing procedures, which involves HCl and HF treatment, and sieving over a 18 µm mesh sieve.

2.4 Palynological analysis

The microscopy analysis was done according to standard procedures. The associations on the microscope slides are counted until a total of ca 200 sporomorphs and dinoflagellate cysts (palynomorphs) is reached. The miscellaneous categories (*Botryococcus*, inner chambers of foraminifers, Tasmanaceae, etc.) are also calculated, but kept outside the total sum of palynomorphs. The remainder of the slide is thereafter scanned for any (rare) dinocyst species which are simply noted as “present” (+ symbol on the distribution chart).
Diagnostic species are discussed in the report, a complete distribution chart including all species found is given as appendix.

2.5 Taxonomy

For the dinoflagellate cyst taxonomy the so-called “Lentin and Williams” index is followed (Fensome et al., 2019).

2.6 Age interpretation

The age interpretation is based on the LOD’s and FOD’s of dinoflagellate cysts.

Palynological interpretation is based on key-references concerning the palynostratigraphy of Paleogene to Neogene from the North Sea region such as: Bujak & Mudge (1994), De Schepper and Head (2009), De Schepper et al. (2015), Dybkjaer & Piasecki (2010), Heilmann-Clausen (1985), Köthe (2003), Kuhlmann et al. (2006), Louwye (2005), Louwye et al. (2010), Munsterman & Brinkhuis (2004), Munsterman et al., 2019, Powell (1992) and Van Simaeys, Munsterman & Brinkhuis (2005). For the Miocene the dinocyst zonation scheme of Munsterman and Brinkhuis (2004), is used, recalibrated to Geological Time Scale (GTS) 2016 of Ogg et al. (2016) in Munsterman et al. (2019). In the Oligocene the dinocyst zonation of Van Simaeys et al (2005) is followed and for the Eocene-late Paleocene (Thanetian) the zonation of Bujak & Mudge (1994) is applied.

Figure 5: Miocene dinozonation sensu Munsterman & Brinkhuis (2004), recalibrated to the GTS sensu Ogg et al. (2016) in Munsterman et al. (2019).

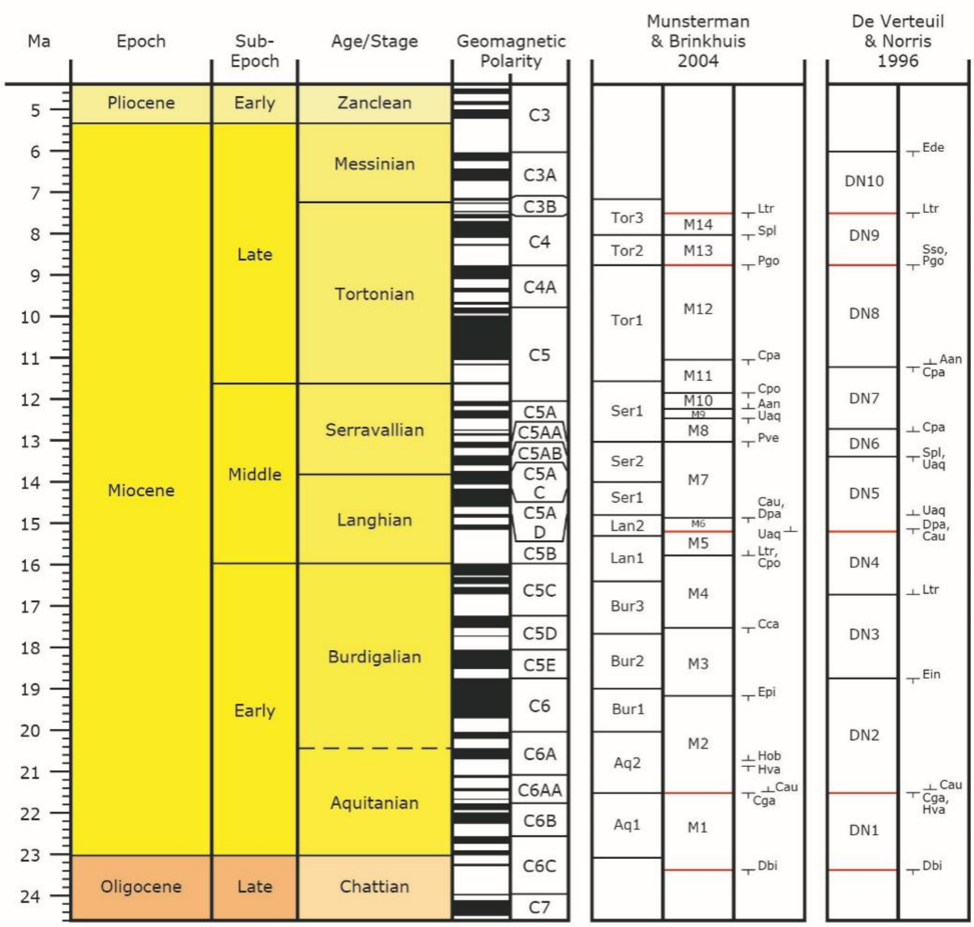


Figure 6: Oligocene zonation scheme sensu Van Simaeys, Munsterman & Brinkhuis (2005).

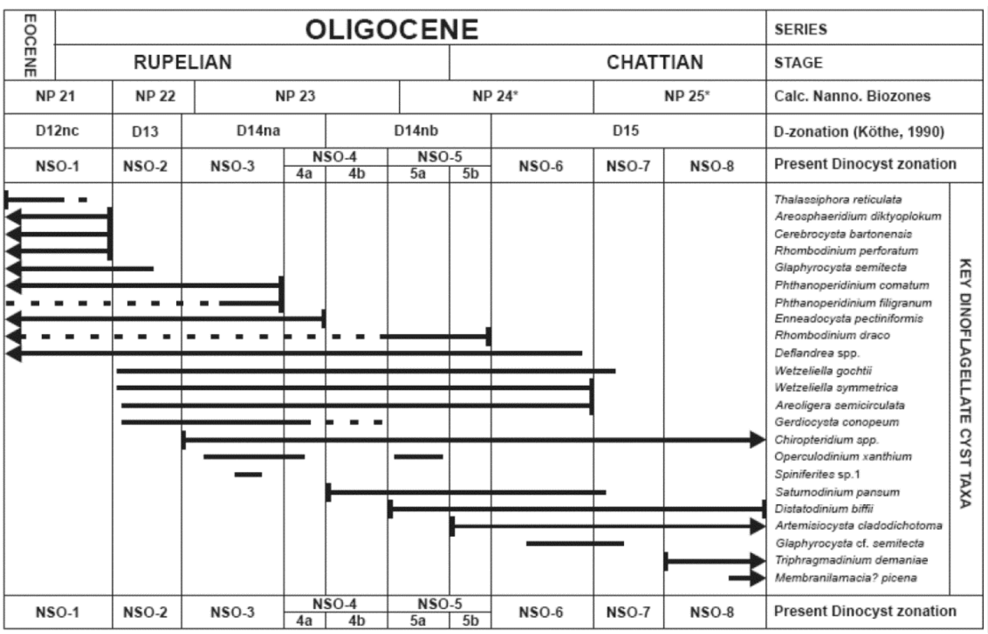
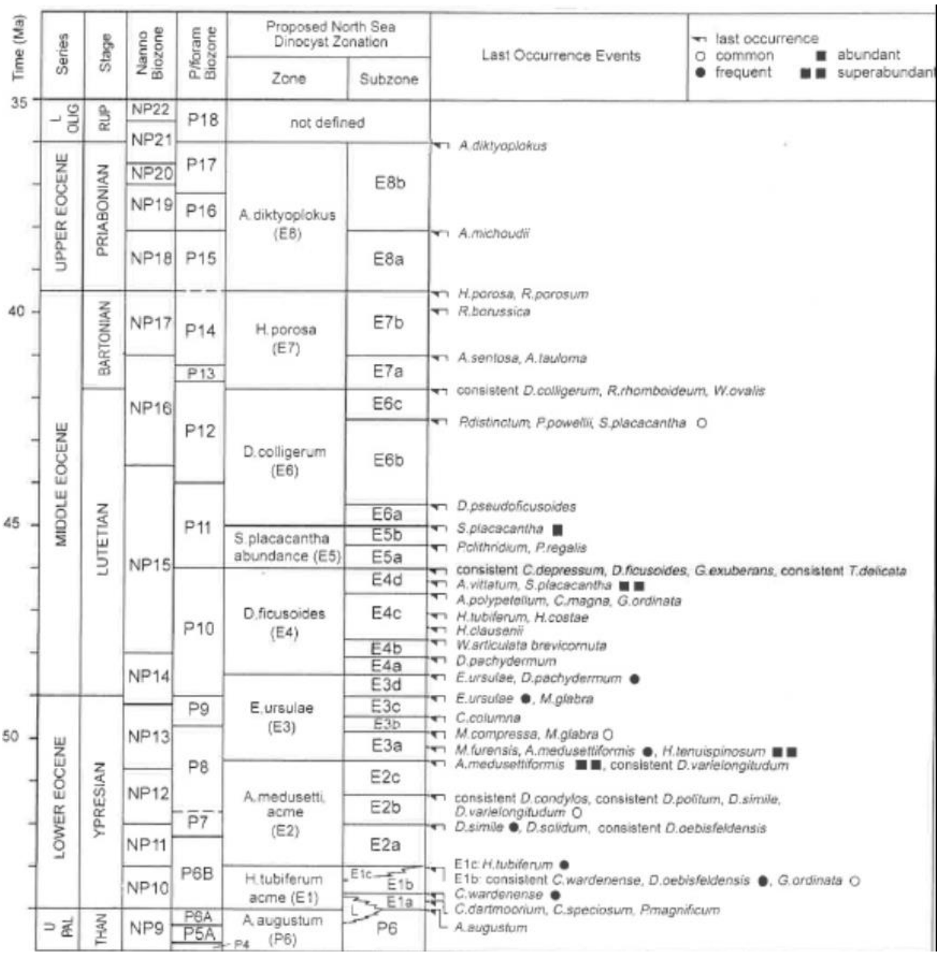


Figure 7: Eocene zonation of Bujak & Mudge, 1994.



2.7 Composite well log and lithostratigraphy (NLOG August 2020)

Table 4: Lithostratigraphy of well PNA-GT-01 cf. NLOG (18-08-2020)

Boorgatnaam	PIJNACKER-GT-01
Diepte in meter t.o.v.	Drill Floor
Einddiepte (m)	2869
Lithostratigrafie	
Datum interpretatie	2018-11-06
Bron	KARTERING DIEP 2018 (WNB_SCHIELAND)
Conform Adrichem Boogaert & Kouwe (1993) en Munsterman et al (2012)	

Diepte stratigrafische eenheden (gemeten langs het boorgat)

Stratigrafische eenheid	Bovenkant van interval	Onderkant van interval
Upper North Sea Group	0	110
Maassluis Formation	110	295
Oosterhout Formation	295	390
Breda Formation	390	430
Rupel Clay Member	430	465
Landen Clay Member	465	470
Ommelanden Formation	470	595

Figure 8: Composite well log of well PNA-GT-01 (NLOG 18-08-2020); caliper log in red and gamma-ray log in black (last column)

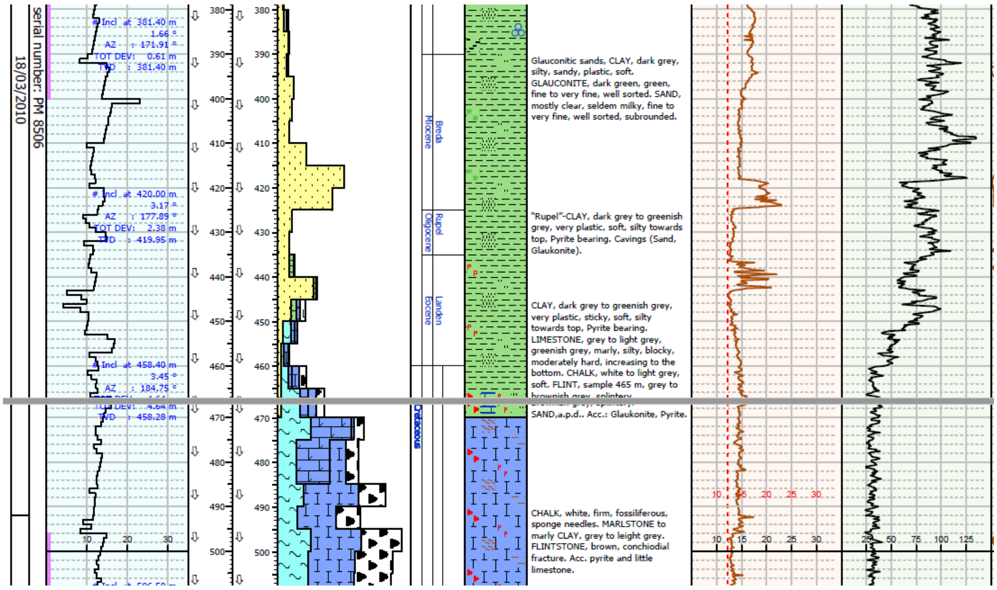


Table 5: Lithostratigraphy of well PNA-GT-04 cf. NLOG (18-08-2020)

Boorgatnaam	PIJNACKER-GT-04
Diepte in meter t.o.v.	Drill Floor
Einddiepte (m)	2957
Lithostratigrafie	
Datum interpretatie	2018-11-07
Bron	KARTERING DIEP 2018 (WNB_SCHIELAND)
Conform Adrichem Boogaert & Kouwe (1993) en Munsterman et al (2012)	

Diepte stratigrafische eenheden (gemeten langs het boorgat)

Stratigrafische eenheid	Bovenkant van interval	Onderkant van interval
Oosterhout Formation	0	130
Maassluis Formation	130	330
Oosterhout Formation	330	400
Breda Formation	400	450
Rupel Clay Member	450	481
Rupel Formation	481	500
Ommelanden Formation	500	910

Figure 9: Composite well log of well PNA-GT-04 (NLOG 18-08-2020)

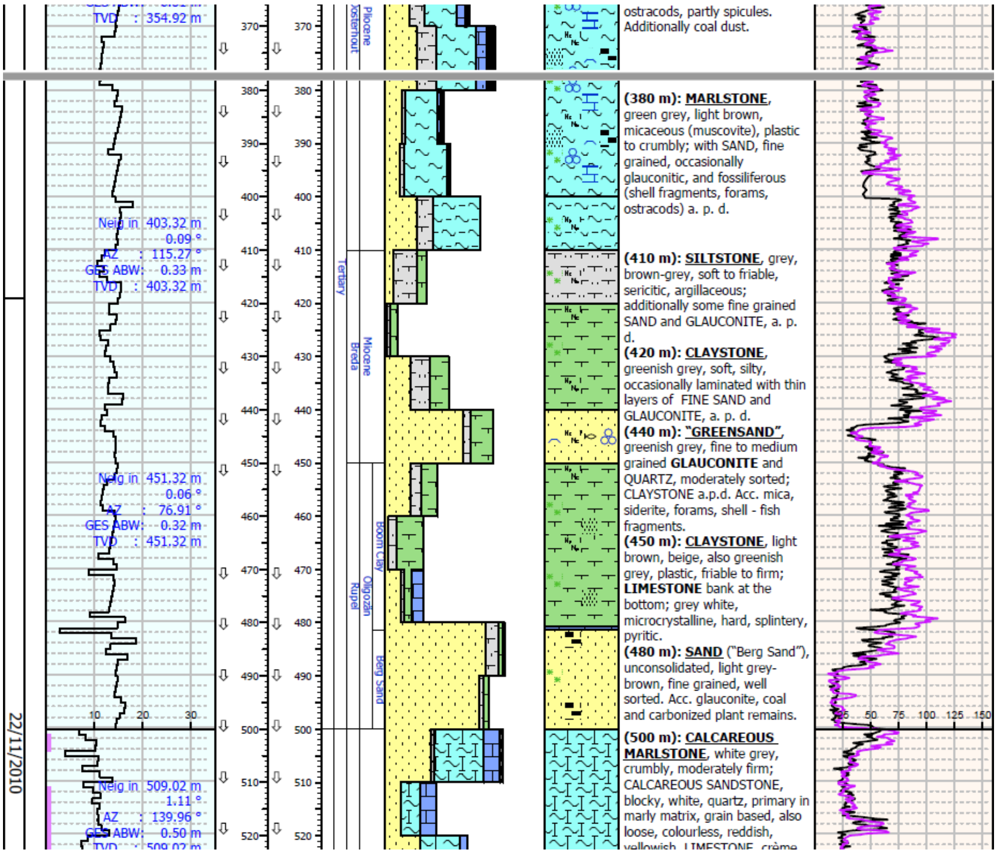


Table 6: Old and new lithostratigraphic names used.

Old lithostratigraphic names (Van Adrichem Boogaert & Kouwe, 1993-1997)	New lithostratigraphic names (Stratigraphic Nomenclator online, 24-07-2020 & Munsterman et al., 2019)
Breda Formation	Diessen
	Groote Heide
Veldhoven Clay Member	Wintelre Member
Rupel Clay Member	Boom Member
Basal Dongen Sand Member	Oosteind Member
Landen Clay Member	Liessel Member

3 Palynological results of well PNA-GT-01

The associations are all rich in palynomorphs. The marine dinoflagellate cysts dominate the palynomorph (dinoflagellate cysts, spores and pollen) spectrum. The open-marine genus *Spiniferites* is present very common. The bisaccate pollen (gymnosperms) are the most abundant category among the sporomorphs. Bisacccate pollen have a high buoyancy in both air and water and can be transported over large distances (and provide a distal signal from the coast). Caving from overlying successions can be common due to the drill technique used (resulting in cuttings samples). Reworking is often present, but in low number. The preservation is fair to good.

Sample/Interval 415-420 m: middle Miocene, mid-Langhian, Zone SNSM6

The dating is based on:
- LOD *Cousteaudinium aubryae* at 415 m
- LOD *Distatodinium paradoxum* at 420 m

Remarks: Chronostratigraphic important species fitting in this interpretation are *Apteodinium tectatum, Labyrintodinium truncatum modicum*, *Labyrintodinium truncatum truncatum, Sumatradinium druggii,* and common *Systematophora placacantha. Classopollis* spp. and *Callialasporites dampieri* are considered as reworking from the Mesozoic and *Wetzeliella symmetrica* from the Oligocene.

Sample/Interval 425 m: early Oligocene, Rupelian, Zone NSO-3

The dating is based on:
- LOD *Enneadocysta pectiniformis*
- LOD *Gerdiocysta conopeum*
- LOD *Glaphyrocysta* cf. *semitecta*
- LOD *Phthanoperidinium comatum*
- LOD *Wetzeliella symmetrica*

Remarks: Dinoflagellate cysts confirming the age are *Chiroperidium galea, Chiropteridium* sp., *Cordosphaeridium funiculatum, Deflandrea phosphoritica, Hystrichokolpoma cinctum, Hystrichokolpoma pseudooceanicum,* and *Operculodinium tiara.*

Sample/Interval 430 m: early Oligocene, Rupelian, Zone NSO-2

The dating is based on:
- LOD *Glaphyrocysta semitecta*

Remarks: Caving is common in this slide showing beautifully preserved e.g. *Amiculosphaera umbracula* and *Cannosphaeropsis passio.* Although using FOD’s of taxa is highly uncertain in case of cuttings samples due to (possible) caving, here we recorded several taxa with a first occurrence in the early Rupelian, Zone NSO-2, such as *Areoligera semicirculata, Wetzeliella gochtii* and *Wetzeliella symmetrica.* Minor reworking from the late Thanetian-Ypesian is recorded by the presence of *Alisocysta* sp. 2 in Heilmann-Causen (1985), *Apectodinium* spp., and *Areoligera gippingensis.*

Sample/Interval 435 m: early Eocene, mid Ypresian, Zone E2b

The dating is based on:
- LOD *Deflandrea oebisfeldensis*
- LOD *Dracodinium simile*
- LOD *Dracodinium* aff. *condylos*
- LOD *Dracodinium varielongitudum*

Remarks: *Glaphyrocysta ordinata* fits with the age assessment. A lot of caving is present.

Sample/Interval 440-445 m: early Eocene, early-mid Ypresian

The dating is based on:
- LCOD *Apectodinium* spp.
- LOD *Dracodinium politum*
- Superposition

Remarks: Minor reworking is recorded from the Carboniferous (*Densosporites*), Jurassic-Cretaceous (*Cicatricosisporites* and *Classopollis*) and Paleocene (*Alisocysta circumtabulata*).

Sample/Interval 450 m: earliest Eocene, earliest Ypresian, Zone P6

The dating is based on:
- LOD *Apectodinium augustum*
- Acme *Apectodinium* spp.

Remarks: The Paleocene–Eocene Thermal Maximum (PETM), alternatively "Eocene Thermal Maximum 1" (ETM1) is reached. This climate event occurred at approximately the Paleocene/Eocene boundary. The exact age and duration of the event is uncertain, but it is estimated to have occurred around 55.5 million years ago. *Odontochitina operculata* is reworked from the Cretaceous.

Sample/Interval 455-460 m: late Paleocene, Thanetian, Zone P5

The dating is based on:
- LOD *Alisocysta margarita* at 455 m
- LCOD *Areoligera gippingensis* at 455 m

Remarks: This Zone P5 correlates with Zone *Ama* of Powell (1992) and Zone 4 in Heilmann-Clausen (1985). Reworking is rarely shown: *Callialasporites dampieri* and *Densoisporites* indicate a Jurassic-Early Cretaceous origin.

4 Palynological results of well PNA-GT-04

The assemblages are rich in palynomorphs (dinoflagellate cysts, spores and pollen). Dinoflagellate cysts dominate the microflora in all cuttings samples, except at depth 410 m, where the most substantial category comprises bisaccate pollen (gymnosperms). Within the sporomorphs (pollen and spores) the bisaccates are most abundant. The open-marine genus *Spiniferites* attains the highest values among the dinoflagellate cysts. Downhole contamination (caving from rocks above the sample interval) does occur in the current cutting samples and can be in high concentrations. Also reworking from older strata occasionally plays an important role. The preservation is fair to good, with the exception of the cuttings sample at depth 500 m, which shows a poor preservation.

Sample/Interval 400 m: late Pliocene, Piazencian, or Early Pleistocene

The dating is based on:
- LOD *Invertocysta tabulata*

Remarks: *Amiculosphaera umbracula* and *Operculodinium eirikianum* fit in the age assessment, but taxa both have a LOD in the Early Pleistocene. Remarkable high is the amount of reworking in this cuttings sample. *Cerebrocysta, Classopollis, Couperisporites jurassicus* and *Gonyaulacysta* have an origin in the Late Jurassic-Early Cretaceous. *Areoligera gippingensis* and *Apectodinium* (10 specimens) can be interpreted around the Paleocene/Eocene boundary. *Areoligera, Deflandrea*, and *Wetzeliella* have a LOD in the early Chattian and start in Paleocene/Eocene. *Distatodinium paradoxum* has a range from mid Eocene to mid Miocene. The large concentration of reworking is well-known in the Early Pleistocene and younger successions, but occurs less frequent in the Pliocene. Hence the in-situ occurrence of *Invertocysta tabulata* could also be doubted here. An alternative (second) interpretation of age may be Early Pleistocene.

Sample/Interval 410 m: early Pliocene, early Zanclean, ca 4.5 Ma, or older

The dating is based on:
- LOD *Reticulatosphaerea actinocoronata*
- Presence of *Operculodinium tegillatum*

Remarks: Reworking is very rare: the presence of *Densosporites* sp. indicates an origin in the Carboniferous.

Sample/Interval 420 m: late Miocene, mid-late Tortonian, Zone SNSM13

The dating is based on:
- LOD *Labyrintodinium truncatum*
- LOD *Systematophora placacantha*

Remarks: Minor reworking from the Jurassic-Early Cretaceous is shown by the occurrence of the genera *Gonyaulacysta* and *Pareodinia.* Two fragments of *Cannosphaeropsis passio* (small fragments are not counted in the total sum palynomorphs) are also considered as reworking. The dating is considered as post Mid-Miocene Unconformity (MMU).

Sample/Interval 430 m: mid(-late Miocene), late Serravallian(-early Tortonian), Zone SNSM11

The dating is based on:
- LOD *Cannosphaeropsis passio* (fairly frequent)
- LCOD *Systematophora placacantha* (fairly frequent)

Remarks: Because both taxa mentioned above are fairly frequent the stratigraphic interpretation is considered as pre-MMU. Reworking however is also noted in substantial amounts: *Densosporites* and *Lycospora* (Carboniferous), *Kraeuselisporites reissingeri* tetrad (Triassic), *Callialasporites dampieri, Callialasporites trilobatus* and *Gonyaulacysta* sp.(Jurassic-Early Cretaceous) and *Wetzeliella symmetrica* (Oligocene).

Sample/Interval 440 m: late Oligocene, early Chattian, Zone NSO-6, or older

The dating is based on:
- LOD *Areoligera semicirculata*
- LOD *Deflandrea heterophlycta*
- LOD *Spiniferella cornuta*
- LOD *Wetzeliella symmetrica*

Remarks: Also recorded in the assemblages are *Distatodinium paradoxum* (LOD mid-Langhian) and *Thalassiphora pelagica* (LOD early Burdigalian). A few percent reworking refers to the (Late) Jurassic-Early Cretaceous (by the presence of *Callialasporites dampieri, Cerebropollenites* sp., and *Cicatricosisporites* spp.).

Sample/Interval 450 m: early Oligocene, Rupelian, Zone NSO-3, or older

The dating is based on:
- LOD *Enneadocysta pectiniformis*
- LOD *Phthanoperidinium filigranum*
- LOD *Phthanoperidinium comatum*
- LOD *Charlesdowniea* spp.
- LOD *Operculodinium tiara*

Remarks: Reworking is very rare. *Odontochitina operculata* is known from the Cretaceous.

Sample/Interval 460 m: early Oligocene, Rupelian, Zone NSO-2

The dating is based on:
- LOD *Glaphyrocysta semitecta*

Remarks: Taxa with a first occurrence in the early Rupelian, Zone NSO-2, occur like *Wetzeliella gochtii* and *Wetzeliella symmetrica.* The association is largely similar to that of the overlying cuttings sample. The (considered) reworking however is mainly from the Early Eocene, Ypresian (*Apectodinium* sp., *Dracodinium* sp. and several *Eatonicysta ursulae*).

Sample/Interval 470-490 m: early Eocene, early-mid Ypresian, Zone E2b or older

The dating is based on:

- LOD *Deflandrea oebisfeldensis* at 470 m
- LOD *Alisocysta* sp.2 sensu Heilmann-Clausen (1985) at 470 m
- LOD (consistent and frequent) *Apectodinium* spp. at 470 m
- LOD *Dracodinium varielongitudum* at 470 m
- LOD *Dracodinium condylos* at 490 m

Remarks: Also present are *Diphyes pseudoficusoides, Dracodinium varielongitudum, Glaphyrocysta exuberans, Hystrichosphaeridium tubiferum, Thalassiphora delicata,* and *Wetzeliella articulata brevicornuta.* Minor reworking is noted: *Densosporites* (Carboniferous), *Callialasporites trilobatus, Classopollis, Pareodinia,* and *Plicatella* (Jurassic-Early Cretaceous).

Sample/Interval 500 m: Not diagnostic

Remarks: The palynological yielding shows a stratigraphic indifferent assemblage of palynomorphs with a undiagnostic age. Again dinoflagellate cysts, in particular the open-marine genus *Spiniferites,* dominate the association. Bisaccates are very common among the sporomorphs (pollen and spores). The microflora shows less variety, no new occurrences of palynomorphs, a lot of caving from in particular Neogene or younger strata. Reworking from the Jurassic- Early Cretaceous is also present by the occurrences of *Cicatricosisporites, Gonyaulacysta* and *Pareodinia.*

5 Discussion and conclusion

The palynostratigraphic results of well PNA-GT-01 and PNA-GT-04 are respectively tabulated below:

Table 7: Overview age-assessments of well PNA-GT-01

Depth (m - MD)	**Age, Zone**
415-420	middle Miocene, mid-Langhian, Zone SNSM6
ca. 420.1	~~~~~~~ (Savian phase + EMU)
425	early Oligocene, Rupelian, Zone NSO-3
430	early Oligocene, Rupelian, Zone NSO-2
ca. 431	~~~~~~~ (Pyrenean phase)
435	early Eocene, mid Ypresian, Zone E2b
440-445	early Eocene, early-mid Ypresian
450	earliest Eocene, earliest Ypresian, Zone P6 (PETM)
455-460	late Paleocene, Thanetian, Zone P5

Table 8: Overview age-assessments of well PNA-GT-04

Depth (m - MD)	**Age, Zone**
400	late Pliocene, Piazencian (or Early Pleistocene)
410	early Pliocene, early Zanclean, ca 4.5 Ma, or older
ca. 410	~~~~~~~ (LMU)
420	late Miocene, mid-late Tortonian, Zone SNSM13
ca. 426	~~~~~~~ (MMU)
430	middle Miocene, late Serravallian Zone, SNSM11
ca. 436	~~~~~~~ (Savian phase + EMU)
440	late Oligocene, early Chattian, Zone NSO-6, or older
ca. 450	~~~~~~~
450	early Oligocene, Rupelian, Zone NSO-3
460	early Oligocene, Rupelian, Zone NSO-2
ca. 463	~~~~~~~ (Pyrenean phase)
470-490	early Eocene, early-mid Ypresian, Zone E2b or older
500	Not Diagnostic

Table 9: Updated and revised lithostratigraphy of well PNA-GT-01

Depth (m)	**New lithostratigraphy**	**Depth (m)**	**Old lithostratigraphy cf. NLOG, Aug. 2020**
(415)-420.1	Groote Heide Fm	390-430	Breda Fm
420.1-431	Rupel Fm	430-465	Rupel Clay Mb
420.1-425	Boom Mb		
425-431	Berg Mb		
431-445.5	Ieper Clay Mb		

445.5-451	Oosteind Mb		
451-460	Liessel Mb		
460-470	Indiff. Landen Fm	465-470	Landen Clay Mb

Table 10: Updated and revised lithostratigraphy of well PNA-GT-04

Depth (m)	**New lithostratigraphy**	**Depth (m)**	**Old lithostratigraphy cf. NLOG Aug. 2020**
-410	Oosterhout Fm	330-400	Oosterhout Fm
410-426	Diessen Fm	400-450	Breda Fm
426-436	Groote Heide Fm		
436-450	Veldhoven Fm		
436-443	Wintelre Mb		
443-450	Voort Mb		
450-463	Rupel Fm, Boom Mb	450-500	Rupel Fm
463-488	Ieper Clay Mb	450-481	Rupel Clay Mb
488-500	Oosteind Mb		

Log-based lithostratigraphic interpretation is challenging in the study area. The relatively indistinct lithological and wireline log results from condensed successions, occasionally make lithostratigraphic interpretation difficult, as shown by the studied wells. Biostratigraphic analysis based on ditch cuttings is affected by uncertainty due to the sample resolution and caving from overlying sections. Also, in particular in this area, by the occasional inclusion of reworking from older strata. This addresses the need once more for additional core samples (excluding caving). Nevertheless, the results of palynological interpretation provide interesting stratigraphic insights, pointing towards the need to revise the (18-08-2020) lithostratigraphic NLOG classification substantially and reaching a higher differentiation in lithostratigraphic units. Based on the palynological study of wells PNA-GT-01 and PNA-GT-04, the following conclusions are reached:

- The Groote Heide Formation interval (Munsterman et al., 2019) is thinner than previously recorded in this sub-basin.
- Instead of being the older part of the Breda Formation in well PNA-GT-04, the interval, 436-450 m, is interpreted as the Veldhoven Formation. This is based on the dating, late Oligocene, early Chattian, Zone NSO-6 at 440 m. The glauconitic sands (greensands), interval 443-450 m, typically belong to the Voort Member.
- Another (more important with reference to the current focus of this study) acquired insight is that the Rupel Clay section is thinner than earlier adopted (see tables 9 and 10).
- *New* in both wells is the occurrence of a basal part of the Dongen Formation, namely the Ieper Clay Member and Oosteind Member (see tables 8 and 9). Previously, the Dongen Formation was not discriminated, but classified as Rupel Formation.
- The Berg Sand Member (Vessem Sand cf. Van Adrichem Boogaert & Kouwe, 1993-1997) as part of the Rupel Formation in well PNA-GT-04, interval 481-500 m was misinterpreted on NLOG (18-08-2020). The Oosteind Member is established here.
- In well PNA-GT-01 the PETM event is convincingly recorded, including an acme of *Apectodinium* spp. and several specimens of *Apectodinium*

augustum. This PETM event is also recorded in the Oosteind Member of several other wells (like e.g. in well Rijsbergen-1 (RSB-01)).

- The Liessel Member in well PNA-GT-01 is confirmed by the palynological analysis, but also in a more limited interval, 451-460 m (see Table 9).

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7 Signature

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Lead author Research manager

Well Name : PNA-GT-01

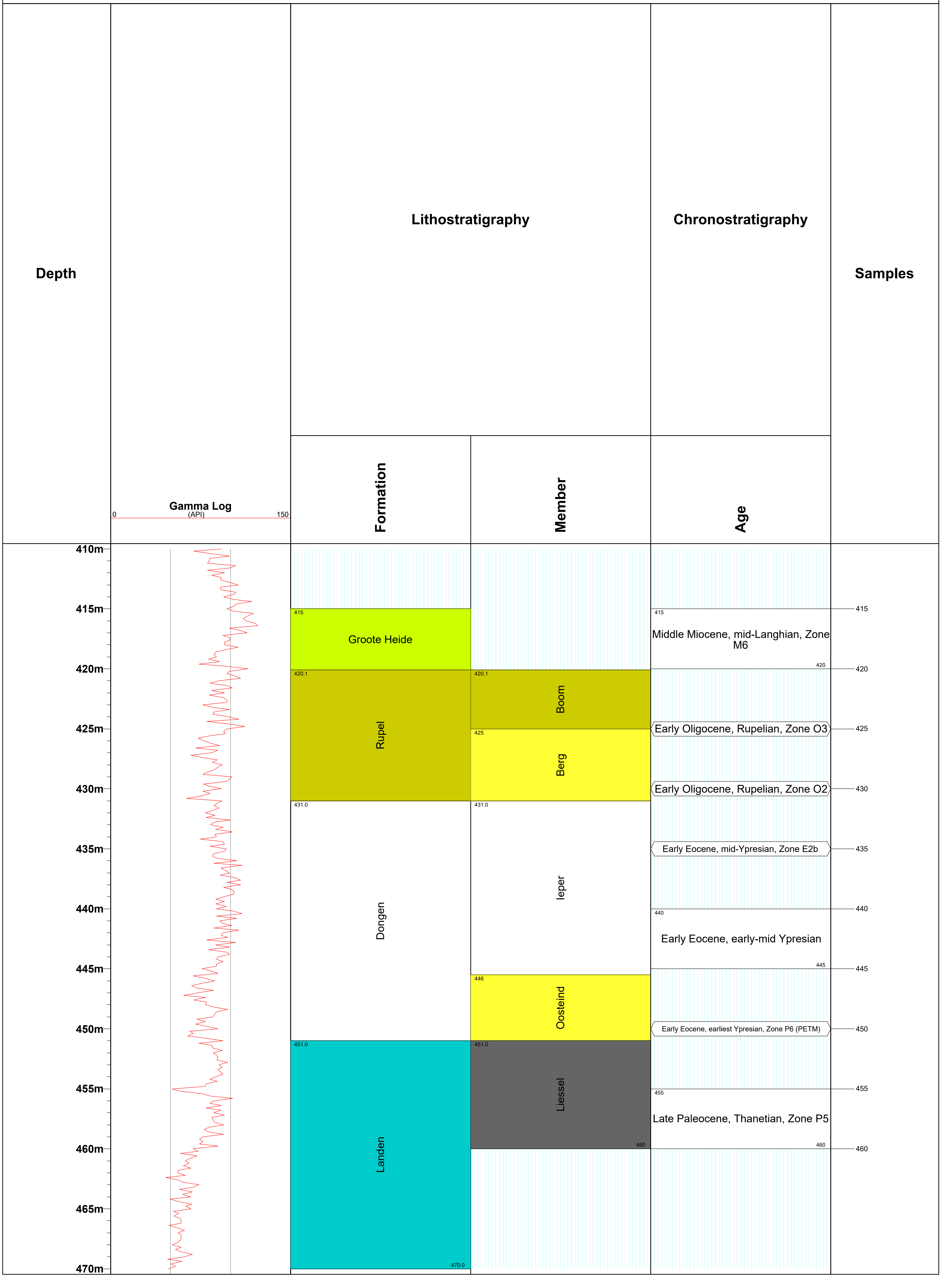
Interval : 410.00m - 470.00m
Scale : 1:300
Chart date: 21 August 2020

TNO report
Palynological interpretation
D.K. Munsterman

PNA-GT-01

TNO-NITG
Utrecht

Enclosure 1



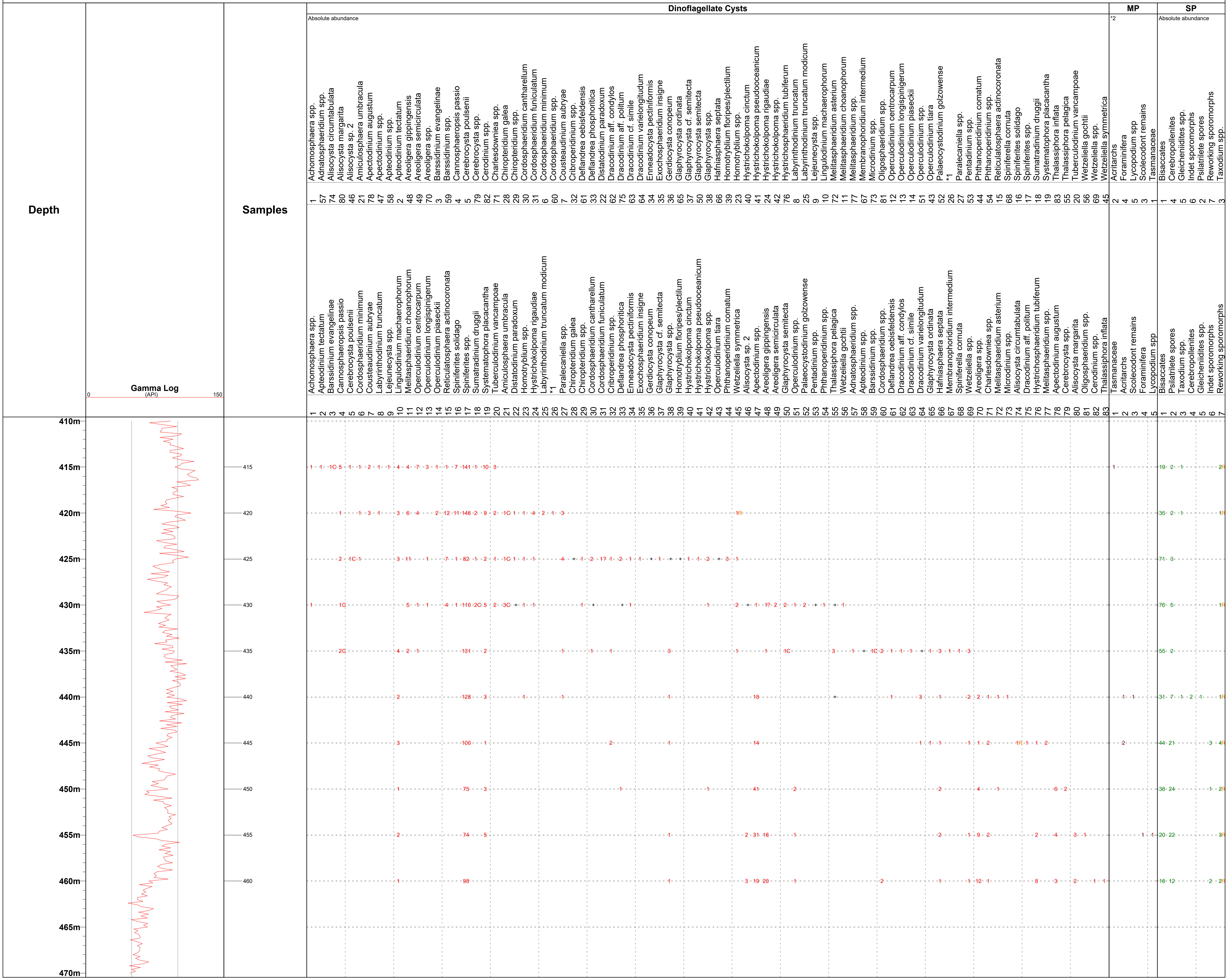
Well Name : PNA-GT-01

Interval : 410.00m - 470.00m — TNO report
Scale : 1:300 — Distribution chart
Chart date: 20 August 2020 — D.K. Munsterman

PNA-GT-01

TNO-NITG
Utrecht

Enclosure 2



Well Name : PNA-GT-04

Interval : 390m - 510m
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TNO report
Palynological interpretation
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PNA-GT-04

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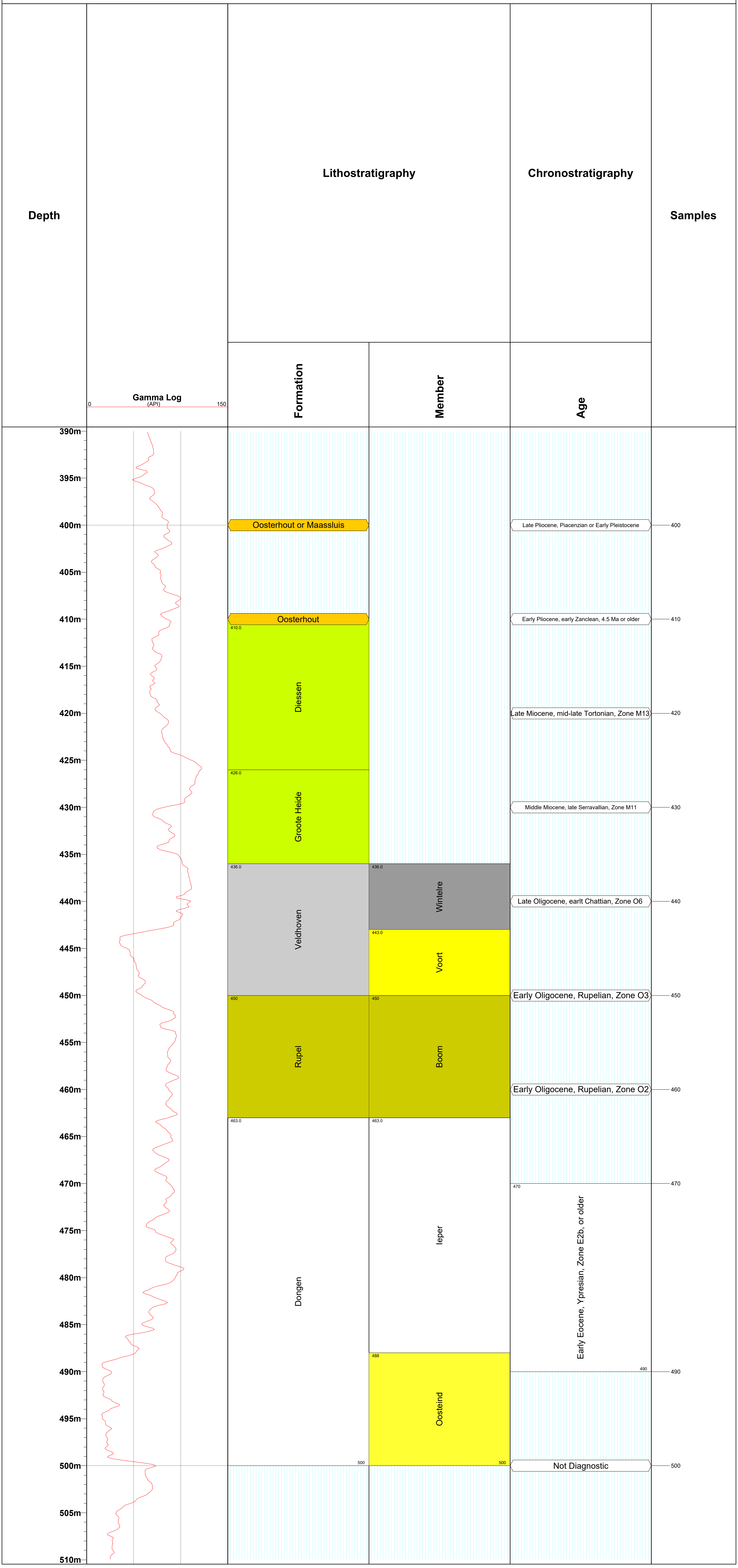
Enclosure 3



Well Name : PNA-GT-04

Interval : 390m - 510m

Scale : 1:300

Chart date: 20 August 2020

TNO report

Distribution chart

D.K.Munsterman

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Enclosure 4