Revision of the Neogene stratigraphy of Belgium

Formalised by the NCS on 01/09/2023

Editors

Katrien De Nil and Jasper Verhaegen

The compiling authors of the Lithostratigraphic Information Sheets are, in alphabetical order:

Adriaens Rieko, Berwouts Isaac, Bogemans Frieda, Deckers Jef, Demoulin Alain, Dusar Michiel, Everaert Stijn, Goolaerts Stijn, Houthuys Rik, Laga Piet, Lanckacker Timothy, Louwye Stephen, Matthijs Johan, Vandenberghe Noël, Verhaegen Jasper, Vos Koen, Wesselingh Frank, Walstra Jan

National Commission for Stratigraphy of Belgium
Subcommission for Paleogene and Neogene Stratigraphy

Content

1 Preface

This proposal document is compiled by the Subcommission for Paleogene and Neogene Stratigraphy of Belgium. It provides the present status of the Lithostratigraphic Information Sheets (LIS) for the different Neogene lithostratigraphic units (chapters 3-64, formal, informal and obsolete units) as identified and discussed within this subcommission. This publication compiles the update of the formal division of Neogene lithostratigraphy in Belgium. Units at the transition of the Oligocene to the Miocene are also included because of the discussed correlations. Each sheet is compiled by several authors with expertise in the specific unit. The scientific background for these sheets is Vandenberghe & Louwye (2020).

According to the NCS-procedures, as from the 10th of May 2022 a provisional version of this document and the stratigraphic tables have been published on the website of the National Commission for Stratigraphy of Belgium as discussion document, together with the stratigraphic tables (Vandenberghe and Louwye, 2022) available at https://ncs.naturalsciences.be/paleogene-neogene . On the 19th of May 2022 an open one-day seminar 'Towards a revised Neogene stratigraphy of Belgium' was organised by the Subcommission in the Royal Belgian Institute of Natural Sciences in Brussels. The results of the stratigraphical review were presented. Special attention was given to the cross-border integration and the correlation of the Miocene and Pliocene deposits. During an excursion on the 20th of May 2022 relevant borehole samples were discussed in the Geotheek, the repository of the Flanders Government in Vilvoorde, and the Neogene deposits were discussed in some (temporary) outcrops of northern Belgium. The excursion guide is available on the DOV website (Verhaegen et al., 2023).

Comments on the published discussion document and tables, submitted to the president or the secretary of the Subcommission for Neogene and Paleogene stratigraphy, were processed.

This proposal document includes the accompanying revised stratigraphic tables of the Neogene of Belgium, edition 2023, compiled by Noël Vandenberghe & Stephen Louwye.

This document compiles the final status of the formalisation of the lithostratigraphy of the discussed Neogene units within the Subcommission and is submitted to the NCS secretary to accept this proposition medio 2023.

2 Stratigraphic tables of the Neogene units

The set of four stratigraphic tables of Vandenberghe and Louwye (2020; fig.1, fig. 2, fig. 3 and fig. 4) are compiled by Noël Vandenberghe and Stephen Louwye in two stratigraphic tables, available on the website of the National Commission of Stratigraphy as from the 10th of May 2022 for comments and discussions. As a result, a location map (Figure 2-1) and two stratigraphic tables in this document, Figure 2-2 and Figure 2-3 compiled by Noël Vandenberghe and Stephen Louwye, provide the state-of-the art of the Neogene stratigraphy in Belgium, based on the Lithostratigraphic Information Sheets of the individual units in this document. All units are ranked as accurate as possible according to their chronostratigraphical age. Uncertainties remain and are inherent to compiling the tables.

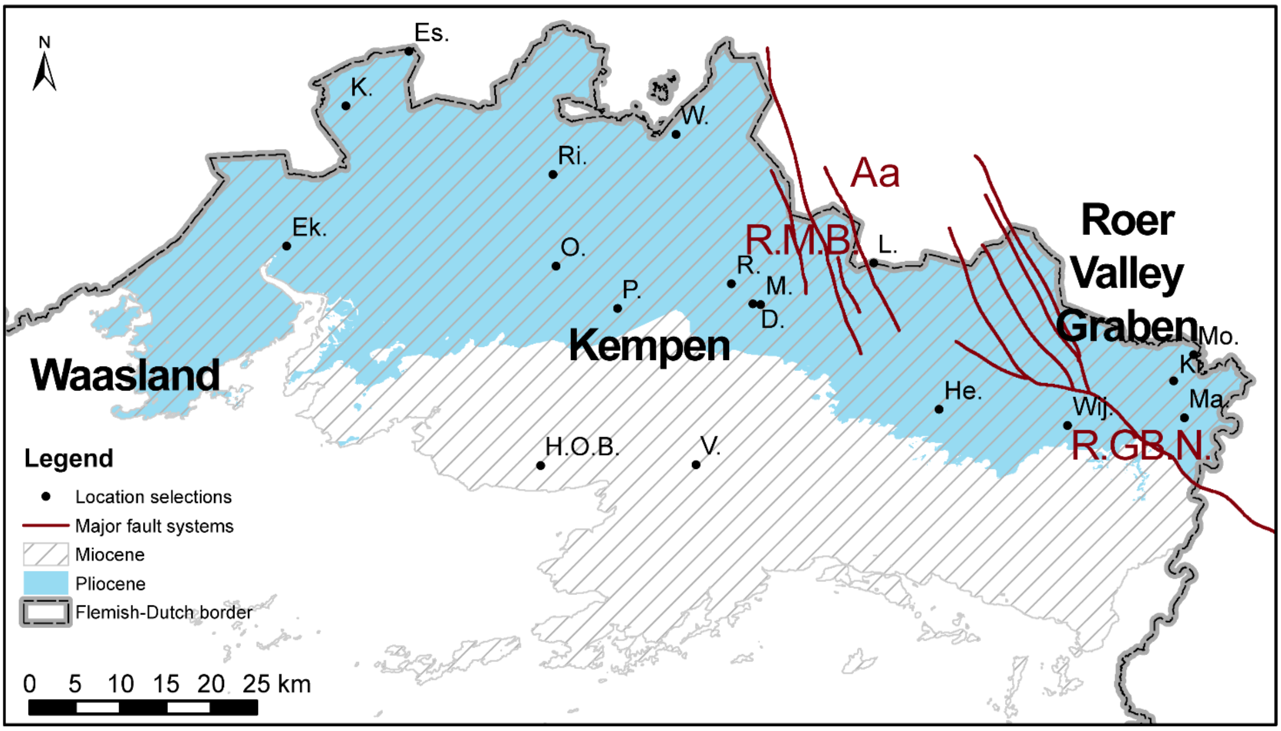


Figure 2-1: Map with the most important locations for the Neogene stratigraphy in Belgium, fault zones and occurrence of the Miocene and Pliocene units in the subsurface. Ek.: Ekeren (015W0142), Es.: Essen (001E0042), H.O.B.: Heist-op-den-Berg, He.: Hechtel (047E0192), K.: Kalmthout (006E110), Ki.: Kinrooi (049W0230), L.: Lommel-2 (032W0409), M.: Mol (031W0221), Ma.: Maaseik (049W0220), Mo.: Molenbeersel (049W0226), O.: Oostmalle (029E0249), P.: Poederlee (030W300), R.: Retie (031W0243), Ri.: Rijkevorsel (016E0153), V.: Veerle (060E0215), W.: Weelde (008E0159), Wij.: Wijshagen (048W0180), R.M.B.: Rijen - Mol - Beringen Fault Zone, R.GB.N.: Reppel - Grote Brogel - Neeroeteren Fault Zone, Aa: Aa Fault Zone (adjusted from Vandenberghe and Louwye, 2022).

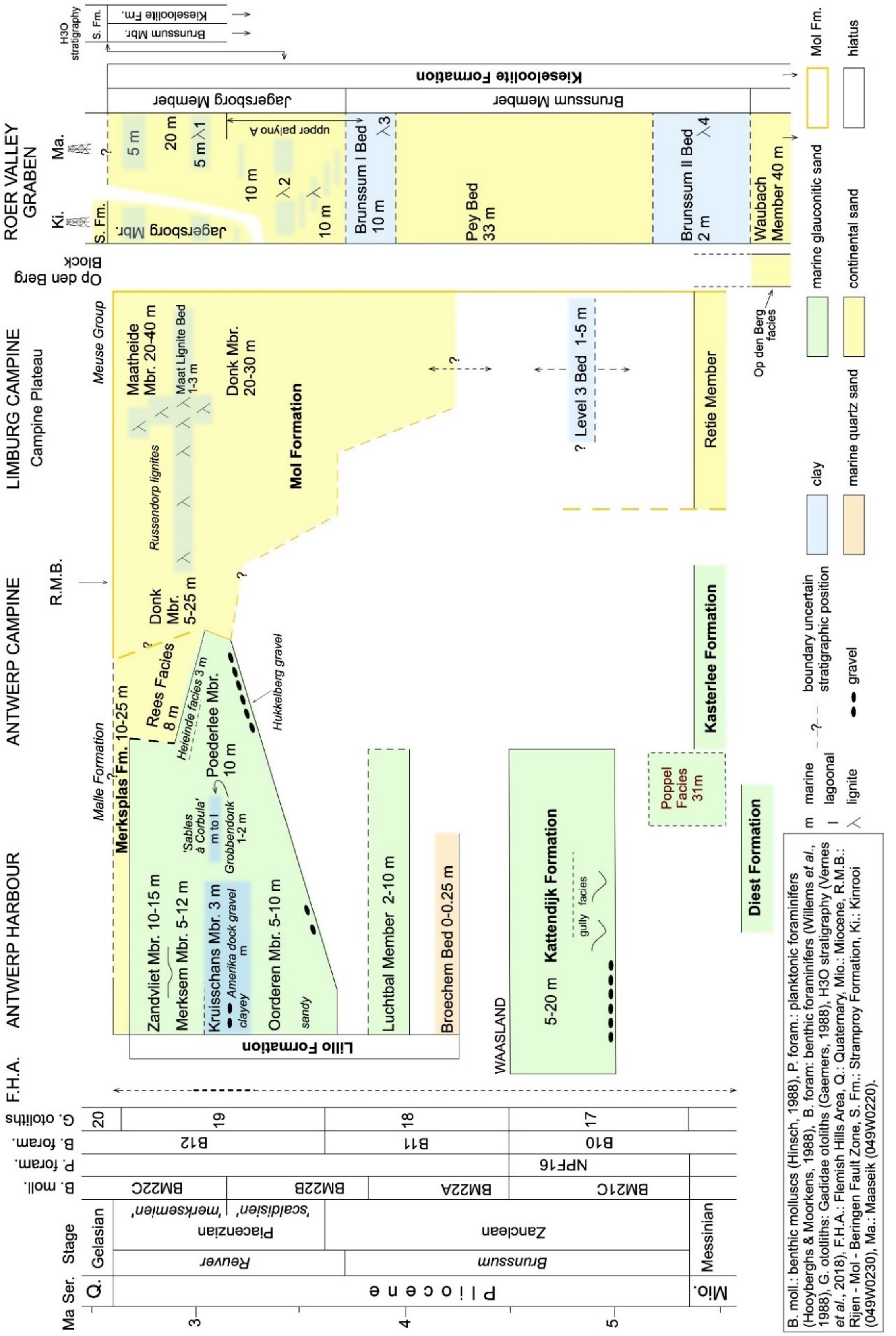


Figure 2-2: Stratigraphic table of the Pliocene units and units at the transition of the Miocene to Pliocene in Belgium. For the documentation, see the Lithostratigraphic Information Sheets of the individual units (authors: Vandenberghe N. and Louwye S.).

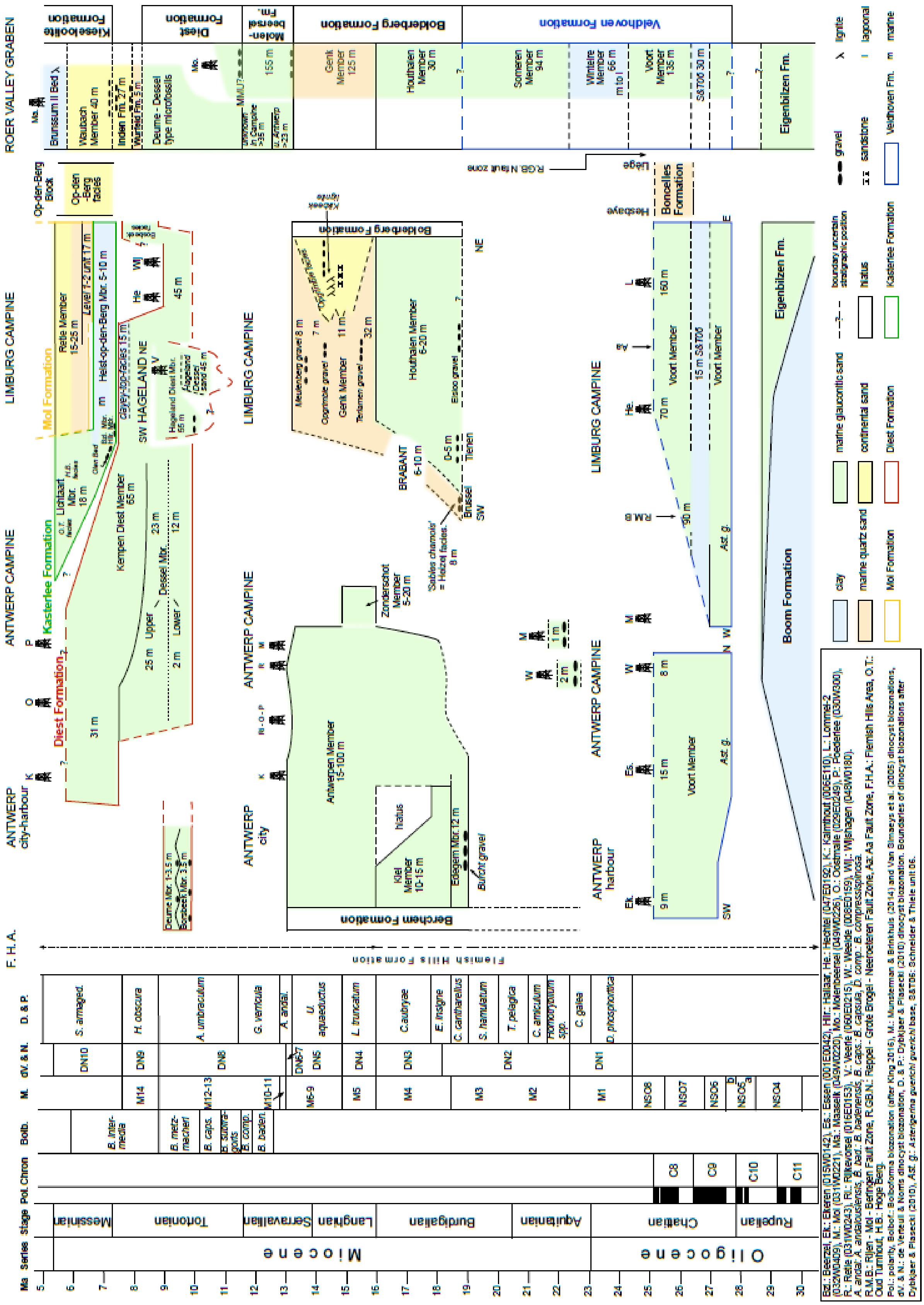


Figure 2-3: Stratigraphic table of the Miocene units and units at the transition of the Oligocene in Belgium. For the documentation, see the Lithostratigraphic Information Sheets of the individual units (authors: Vandenberghe N. and Louwye S.).

3 Veldhoven Formation

Unit name: Veldhoven Formation
Hierarchical unit name:
Type: Formation
Code: Vd
Author(s):
- Compiled by: Dusar Michiel and Vandenberghe Noël
Alternative names: Voort Formation. Former Veldhoven Member is renamed to Wintelre Member.
Origine of the name: -
Status: Formal
Date: 01/05/2022
How to refer: Dusar, M. & Vandenberghe, N., 2023. The Veldhoven Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Velhoven-Formation

3.1 Characterizing description

The Veldhoven Formation consists of fine grained glauconitic mollusc-bearing sand (Voort and Someren members) containing in some locations rich mollusc beds near its base (Voort Member in Campine coalfield) and with a clay unit in its middle part (Wintelre Member) . Other clayey intercalations can occur in the sand.

3.2 Type section, type locality, type borehole, or type geophysical borehole

Belgian parastratotype borehole Molenbeersel, drilled 1988 till final depth of 1773 m; GeoDoc 049W0226, ground level +33 m; Lambert coordinates x 247660, y 207752, Voort Formation 680 – 975 m below ground level.

Someren Member	680-774 m	S&T 2 to 4
Wintelre, ex-Veldhoven Member	774-840 m	S&T 1
Voort Member above gamma-ray peak	840-920 m	S&T 07 to 09
Voort Member gamma-ray peak interval	920-940 m	S&T 06
Voort Member below gamma-ray peak	940-975 m	S&T 05

Lithostratigraphic subdivision of the Veldhoven Formation in the Molenbeersel borehole, with depth range and corresponding Schneider and Thiele (1965) hydrostratigraphic codes of the Lower Rhine Basin and Chattian age assignments based on correlation with type sections in the Lower Rhine coal and salt districts. Table 1 in Dusar & Vandenberghe, 2020 (cf. Matthijs et al., 2016).

3.3 Description upper boundary

The Veldhoven Formation is fully developed only in the Roer Valley Graben. In the Belgian part of the graben the covering strata are assigned to the more greenish clayey Houthalen Sand, with high gamma ray reading at the base of the Bolderberg Formation. Across the Belgian – Dutch boundary the corresponding overlying strata are assigned to the Groote Heide Formation (Munsterman et al., 2019).

In the eastern Limburg Campine the Veldhoven Formation, represented by the Voort Member only, is also covered by the Houthalen Member of the Bolderberg Formation, with similar characteristics as in the graben.

The Veldhoven Formation in the western Antwerp Campine, also represented by the Voort Member only in the Mol area and by residual deposits further west, is covered by the Berchem Formation, characterised by black glauconitic sand with gamma-ray peak.

3.4 Description lower boundary

In rotary drilled boreholes the Veldhoven Formation passes rather inconspicuously in the Eigenbilzen Formation. Distinction between both units can be based on a higher glauconite content and more grey-green colour and consequently higher gamma-ray readings for the lower part of the Veldhoven Formation i.e. the Voort Member, which also contains more molluscs. Resistivities are nevertheless lower in the Voort Member compared to the underlying Eigenbilzen Formation because of a lower clay content. However, the contact between Voort Member and Eigenbilzen Formation corresponds to an unconformable contact due to different dip related to reactivation of the graben (Eigenbilzen dipping to the north, Voort to the north east).

Due to an increasing hiatus towards the west, the Veldhoven Formation – or at least its residual remnants – rest on Boom Clay in the Antwerp harbour area (provided there is biostratigraphic control, otherwise they will remain unnoticed).

3.5 Thickness

The thickness is 295 m in borehole Molenbeersel, in the Roer Valley Graben where the Veldhoven Formation is fully developed. Outside the graben the Veldhoven Formation is gradually wedging out.

3.6 Occurrence

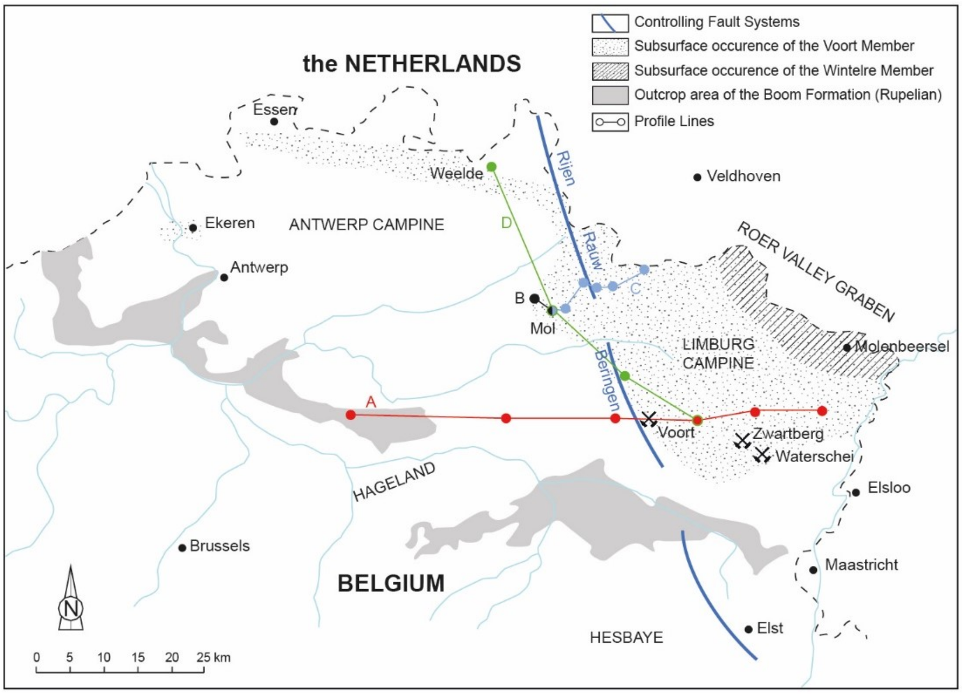


Figure 3-1 Subcrop map of Veldhoven Formation (Fig. 1 in Dusar & Vandenberghe, 2020).

The Veldhoven Formation is the youngest of the Paleogene stratigraphic units in Belgium, but it is also the first formation whose depositional area and thickness is controlled by active subsidence of the Roer Valley Graben. Hence, the Veldhoven Formation is subcropping in the Roer Valley Graben and adjoining part of the Campine Basin (Figure 3-1). As this formation is only accessible from boreholes, initial information came from the Campine coal mining district. There, only the lower part of the formation is encountered, named Voort Sand, after the locality name where the shafts of colliery Zolder were sunk (Van Straelen, 1923). This became the original type section of the Voort Formation, but is now considered as the type section for the Voort Member of the Veldhoven Formation.

3.7 Regional correlations

The Veldhoven Formation is put in equivalence with seismostratigraphic units V-VI (after NITG, 2001 and Verbeek et al., 2002), whereby unit V encompasses the Eigenbilzen Formation and the Veldhoven Formation up to the Wintelre Member, and unit VI the Someren Member. Each member of the Veldhoven Formation has a different seismic character: prograding for the lower Voort Member, more continuous reflectors on the clay-sand alternation in the middle Wintelre Member (building the top of seismostratigaphic unit V) and more transparent for the upper Someren Member (characteristic for seismostratigraphic unit VI) (Matthijs et al., 2016).

In the Lower Rhine Graben the Köln Formation is the lateral equivalent to the Belgian Veldhoven Formation and consists of cycles of marginal marine sand, minor fluvial sand, lagoonal or lacustrine clay and lignite layers (Schäfer and Utescher, 2014, fig. 3 and Hager et al., 1998, fig. 3). Schäfer and Utescher (2014) also show the Schneider and Thiele (1965) hydrostratigraphic codes in the Köln Formation; these codes are used in the Hager et al. (1998) sections and profiles. Because of their persistent character they could represent glacio-tectonic cycles as already postulated by Hager et al. (1998) and correlate with sand – clay alternances in the Veldhoven Formation in Belgium.

The Veldhoven Formation has been defined in the Netherlands for describing the strata covering the Rupel Formation (Boom – Eigenbilzen Formations in Belgium), with rapidly increasing in thickness towards the Roer Valley Graben and cut by the Mid Miocene Unconformity. Hence, biostratigraphic control of the deposits became essential for a good understanding.

In Belgium the process of distinguishing this formation, which is nowhere outcropping neither, was initialised by the discovery of Chattian faunas. This led to the definition of the Voort Formation (now Voort Member of Veldhoven Formation) in the Limburg Campine and its recognition on a more limited scale in the Antwerp Campine (Buffel et al., 2002). Subdivision of the more complete section in the Belgian part of the Roer Valley Graben led to the acceptance of the Dutch lithostratigraphical subdivision, thereby replacing Voort by Veldhoven as the formation name (it should be noted that no biostratigraphical or sedimentological studies are available for the graben deposits).

Towards the southeastern part of the Limburg Campine and across the Meuse river into Dutch South Limburg the Veldhoven Formation is in hiatus but the Elsloo gravel, occurring at the base of the overlying Miocene Bolderberg Formation, contains Chattian fossils derived from an eroded Voort Member.

The Boncelles sand unit of the Tertiary sand outliers in Hesbaye and Condroz regions is probably of Chattian age and corresponding to the Voort Member of the Campine, although precise age correlations are lacking. Boncelles Sands overlying sand is assigned to the Sint-Huibrechts-Hern Formation in the Hesbaye and to Sart-Tilman sand in the Condroz, equally correlated to the 'Tongrian' Sint-Huibrechts-Hern Formation. The Boncelles Sand is covered by coarse to gravelly sand loosely assigned to the Miocene in the Condroz / Ardennes and to the Bolderberg Formation in Hesbaye.

Residual Chattian deposits in the Antwerp harbour area corresponding to the Voort Member are covered by the Edegem Member of the Berchem Formation. However, these residual Chattian deposits could only be positively identified based on by micropaleontological dating. It is likely that similar, yet undated deposits elsewhere in the Antwerp harbour area remain included in the Edegem Member of the Berchem Formation.

Current stratigraphic subdivision places the Berchem Formation above the Veldhoven Formation. In the Netherlands, the Groote Heide Formation, which is stratigraphically covering the Veldhoven Formation, is correlated to the Antwerp Member of the Berchem Formation only.

3.8 Age

Van Simaeys (2004) and De Man et al. (2010) have described two gravel layers in the Veldhoven Formation from Weelde and Mol-1 boreholes in the Antwerp Campine, which subdivide the Chattian deposits in three parts corresponding to changes in the dinoflagellate cyst zonation. They are parallel to the boundaries between dinocyst zones NSO-6 - NSO-7 and NSO-7 - NSO-8 respectively.

Munsterman & Deckers (2020) confirmed the presence of Aquitanian sediments above the Chattian sediments, underneath the black sand of the Berchem Formation (equivalent to the Groote Heide Formation in the Netherlands) in the Weelde borehole, suggesting that residual deposits of the same age as the Wintelre or Someren members are occurring outside the graben.

There exists a discrepancy in interpretation between the former and the latter authors. Munsterman & Deckers (2020) place the Veldhoven (named Voort) – Berchem Formation boundary below the gravel layers in the Weelde borehole, which Van Simaeys (2004) and De Man et al. (2010) consider as a intra-Chattian boundary, in line with the Chattian as described in Hager et al. (1998).

3.9 Dataset

Data in this LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets , more specifically in the datasubset NCS_Neogene 2020_Dusar and Vandenberghe, 2020.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Belgian parastratotype borehole Molenbeersel	049w0226	kb18d49w-B226	https://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0226.txt	https://www.dov.vlaanderen.be/data/boring/1987-042705
Mol-1 borehole	031w0314	ON-MOL-1	https://collections.naturalsciences.be/ssh-geology-archives/arch/031w/031w0314.txt	https://www.dov.vlaanderen.be/data/boring/1997-160115
Weelde borehole	008e0159	kb8d8e-B161	https://collections.naturalsciences.be/ssh-geology-archives/arch/008e/008e0159.txt	https://www.dov.vlaanderen.be/data/boring/1996-098751

3.10 References:

Van Adrichem Boogaert, H.A. & Kouwe, W.F.P., 1993. Stratigraphic Nomenclature of the Netherlands, revision and update by RGD and NOGEPA, Med. RGD, nr. 50.

Buffel, Ph. , Van Barel, L. & Gullentops, F., 2002. Geologische kaart van België, Vlaams Gewest: Turnhout-Meerle, kaartblad 8-2. 1/50 000. Belgische Geologische Dienst en Afdeling Natuurlijke Rijkdommen en Energie, Brussel. https://www.vlaanderen.be/publicaties/tertiairgeologische-kaart-van-belgie-kaartblad-2-8-meerle-turnhout de Heinzelin, J. & Glibert, M., 1957. Lexique Stratigraphique International. Vol. I. Europe, Fasc. 4a: France, Belgique, Pays-Bas, Luxembourg. Fasc. 4a VII: Tertiaire. 217 p., 15 maps. Congrès Géologique International - Commission de Stratigraphie, Mexico, 1956. Centre National de la Recherche Scientifique, Paris, VIIe, 1957.

de Lang, F.D., 2003. Beschrijving lithostratigrafische eenheid: Veldhoven Formatie. NITG-TNO.

De Man, E., Van Simaeys, S., Vandenberghe, N., Harris, W.B. & Wampler, J.M., 2010. On the nature and chronostratigraphic position of the Rupelian and Chattian stratotypes in the southern North Sea basin. Episodes, 33/1, 3–14. https://doi.org/10.18814/epiiugs/2010/v33i1/002

Dusar, M. & Vandenberghe, N., 2020. Upper Oligocene lithostratigraphic units and the transition to the Miocene in North Belgium. Geologica Belgica 23/3-4 - The Neogene stratigraphy of northern Belgium: 113-125 URL : https://popups.uliege.be/1374-8505/index.php?id=6836.

Hager, H., Vandenberghe, N., van den Bosch, M., Abraham, M., von der Hocht, F., Rescher, K., Laga, P., Nickel, E., Verstraelen, A., Leroi, S. & van Leeuwen, R.J.W., 1998. The geometry of the Rupelian and Chattian depositional bodies in the Lower Rhine district and its border area: implications for Oligocene lithostratigraphy. Bulletin of the Geological Society of Denmark 45: 53-62.

Matthijs, J., Deckers, J., Broothaers M. & De Koninck, R., 2016. A new lithostratigraphic and seismostratigraphic interpretation of the Cenozoic strata for the Molenbeersel well (049W0226) in the Roer Valley Graben, NE Belgium. In: J.M. Baele, S. Papier, X. Devleeschauwer, N. Dupont, P. Goderniaux, M. Hennebert & O. Kaufmann, eds. 5th International Geologica Belgica 2016 Congress. Mons, 26-29 January 2016. Geologica Belgica Conference Proceedings, vol. 2, p. 257. https://popups.uliege.be/2593-6670/index.php?id=116.

Munsterman, D.K. & Deckers, J., 2020. The Oligocene/Miocene boundary in the ON-Mol-1 and Weelde boreholes along the southern margin of the North Sea Basin, Belgium. Geologica Belgica, 23/3-4. https://doi.org/10.20341/gb.2020.007

Munsterman, D.K., ten Veen, J.H., Menkovic, A., Deckers, J., Witmans, N., Verhaegen, J., Kerstholt-Boegehold, S.J., van de Ven, T. & Busschers, F.S., 2019. An updated and revised stratigraphic framework for the Miocene and earliest Pliocene strata of the RVG and adjacent blocks. Netherlands Journal of Geosciences, 98, e8. https://doi.org/10.1017/njg.2019.10

NAM & RGD, 1980. Stratigraphic nomenclature of the Netherlands –Verh. Kon. Ned. Geol. Mijnbouwk. Gen., 32: 1-77.

Schäfer, A. & Utescher, T., 2014. Origin, sediment fill, and sequence stratigraphy of the Cenozoic Lower Rhine Basin (Germany) interpreted from well logs. German J. Geoscience 165 p 287-314.

Schneider, H. & Thiele S., 1965. Geohydrologie des Erftgebietes. Ministerium für Ernährung, Landwirtschaft und Forsten Land Nordrhein-Westfalen, Düsseldorf, pp. 185.

TNO-GDN (2021). Veldhoven Formation. In: Stratigraphic Nomenclature of the Netherlands, TNO – Geological Survey of the Netherlands. Accessed on 13-12-2021 from https://www.dinoloket.nl/stratigrafische-nomenclator/formatie-van-veldhoven.

Van Simaeys, S., 2004. The Rupelian-Chattian boundary in the North Sea Basin and its calibration to the international time-scale. Netherlands Journal of Geosciences / Geologie en Mijnbouw, 83/3, 241–248. https://doi.org/10.1017/S0016774600023532

Van Straelen, V., 1923. Observations sur le Néogène et l'Oligocène en profondeur dans la Campine Limbourgeoise.Bulletin de la Société belge de Géologie 33: 58-65.

Vandenberghe, N., 2017. Ernest Van den Broeck medallist lecture 2016. Tectonic and climatic signals in the Oligocene sediments of the Southern North-Sea Basin. Geologica Belgica, 20/3-4, 105–123. http://dx.doi.org/10.20341/gb.2017.007

Verbeek, J.W., de Leeuw, C.S., Parkern N. & Wong, Th.E., 2002. Characterisation and correlation of Tertiary seismostratigraphic units in the Roer Valley Graben. Netherlands Journal of Geosciences / Geologie en Mijnbouw, 81, 159–166. https://doi.org/10.1017/S0016774600022393.

4 Voort Member (Veldhoven Formation)

Unit name: Voort Member

Hierarchical unit name: Veldhoven Formation

Type: Member

Code: VdVo

Author(s):

- Compiled by: Dusar Michiel and Vandenberghe Noël

Alternative names: Voort Formation, HCOVv2 hydrostratigraphic code (operated by VMM (2019)) for the Voort Member (named Voort zand 1): A0255.

Origine of the name: -

Status: Formal

Date: 01/05/2022

How to refer: Dusar, M. & Vandenberghe, N., 2023. The Voort Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Voort-Member

4.1 Characterizing description

Fine-grained and clayey, green glauconitic sands, often rich in macrofossils. The Geological Survey of Belgium holds a rich collection of predominantly molluscs from the coal mine shaft digging at Voort locality (062W 0226).

4.2 Type section, type locality, type borehole, or type geophysical borehole

Original type section of Voort Formation (now Voort Member of Veldhoven Formation): Coal mine shaft at Voort-Zolder (062W0226); reference section from -21 m to -45 m (Van Straelen, 1923; de Heinzelin & Glibert, 1957, p. 202); geological map 25/3-4 (Beringen-Houthalen). Co-ordinates: X = 217.330, Y = 192.725, Z = + 48,5 m.

Belgian parastratotype borehole Molenbeersel; GeoDoc 049W0226, ground level +33 m; Lambert coordinates x 247660, y 207752, Voort Member 840 – 975 m below ground level.

A further threefold subdivision of the Voort member can be made, based on a clayey marker horizon in the middle of the member:

Voort Member above gamma-ray peak	840-920 m	S&T 07 to 09
Voort Member gamma-ray peak interval	920-940 m	S&T 06
Voort Member below gamma-ray peak	940-975 m	S&T 05

Lithostratigraphic subdivision of the Veldhoven Formation in the Molenbeersel borehole, with depth range and corresponding Schneider and Thiele hydrostratigraphic codes of the Lower Rhine Basin and Chattian age assignments based on correlation with type sections in the Lower Rhine coal and salt districts. Table 1 in Dusar & Vandenberghe, 2020 (cf. Matthijs et al., 2016).

4.3 Description upper boundary

In the Roer Valley Graben where the Veldhoven Formation is fully developed, the Voort Member is succeeded by the Wintelre Member. The boundary is characterised by a steadfast increase in gamma-ray from Voort sands to Wintelre clays.

Outside the graben the younger Wintelre and Someren members are absent and the top of the Voort Member is progressively deeper eroded towards the edges of the subcrop area.

In the eastern Limburg Campine the Veldhoven Formation, represented by the Voort Member only, is covered by the more greenish clayey Houthalen Sand Member, with high gamma ray reading at the base of the Bolderberg Formation. The contact between both units coincides with a gravel layer (known as the Elsloo gravel).

The Veldhoven Formation in the western Antwerp Campine, also represented by the Voort Member only in the Mol area, is covered by the Berchem Formation, characterised by dark green to black glauconitic sands with gamma-ray peak, which correspond to the Groote Heide Formation across the boundary in the Netherlands (Buffel et al., 2002). Residual deposits consisting of Chattian age sediments occur as far west as the Antwerp harbour area (Ekeren borehole). However, the boundary criteria between the Veldhoven and Berchem Formations are matter for debate.

4.4 Description lower boundary

The Voort Member covers the Eigenbilzen Formation without noticeable erosional phase (absence of gravels or reworked deposits). The boundary can be recognised by a change in colour of grey to green (due to a higher glauconite content), a lower clay content and a slightly greater grain size and the occurrence of shell beds (or their fragments in destructive boreholes).

4.5 Thickness

The Voort Member reaches a thickness of 135 m in Molenbeersel borehole in the Roer Valley Graben. In the eastern Limburg Campine its maximum observed thickness is 75 m, gradually thinning towards the erosive edges of the subcrop area. This thinning is partly due to gradually diminishing accommodation space around the strongly subsiding Roer Valley Graben, rather than to internal hiatuses, as shown by the regular occurrence of the S&T 06 marker bed.

4.6 Occurrence

The Voort Member has the widest geographical extension of all units of the Veldhoven Formation and is the only recognizable member of the Veldhoven Formation outside the Roer Valley Graben. Current subcrop boundaries are of erosive nature, making discovery of additional outliers plausible, e.g. in the Antwerp harbour area.

The Voort Member probably correlates with the Boncelles Sands on Tertiary sand outliers in the Hesbaye and Condroz areas.

4.7 Regional correlations

A clayey unit persistently identified within the Voort member (e.g. 906-945 m interval in borehole Molenbeersel), is tentatively correlated with Schneider & Thiele (1965) hydrostratigraphic code S&T 06, defined in the Lower Rhine Graben. The gamma-ray peak associated with this level serves as a marker horizon for regional correlations.

This clayey marker horizon within the Voort Member, for convenience associated with its Lower Rhine counterpart S&T 06, occurs at a rather constant distance of about 15 to 30 m above the base of the Veldhoven Formation. In the eastern Limburg Campine, where it is thickest it has been misinterpreted in the past for the

Wintelre Member, previously described as Veldhoven clay in that area. In the Antwerp Campine (Mol area) progressive thinning/erosion of the Veldhoven Formation underneath the black sands of the Berchem Formation brings this S&T 06 gamma ray peak ever closer to the gamma ray peak on the black sands of the Berchem Formation till both peaks are confounded and the S&T 06 peak will disappear.

4.8 Age

Chattian ages established for the Veldhoven Formation in Belgium all refer to the Voort Member. No dating is available inside the Belgian Roer Valley Graben.

In the Antwerp Campine the age of the deposits above the gravel layers encountered in the Weelde and Mol boreholes (or more in general between the gamma ray peaks of the Chattian S&T 06 and the Burdigalian Berchem black sand) is controversial: Chattian for Van Simaeys (2004) and De Man et al. (2010), hence assigned to the Veldhoven Formation vs Aquitanian to Burdigalian for Munsterman & Deckers (2020), hence assigned to the Berchem Formation and corresponding to the Edegem (and possibly Kiel) Member(s) of the Berchem Formation.

4.9 Dataset

Data in this LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets, more specifically in the data subset NCS_Neogene 2020_Dusar and Vandenberghe, 2020.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Belgian parastratotype borehole Molenbeersel	049w0226	kb18d49w-B226	https://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0226.txt	https://www.dov.vlaanderen.be/data/boring/1987-042705
Mol-1 borehole	031w0314	ON-MOL-1	https://collections.naturalsciences.be/ssh-geology-archives/arch/031w/031w0314.txt	https://www.dov.vlaanderen.be/data/boring/1997-160115
Weelde borehole	008e0159	kb8d8e-B161	https://collections.naturalsciences.be/ssh-geology-archives/arch/008e/008e0159.txt	https://www.dov.vlaanderen.be/data/boring/1996-098751
Voort shaft	062W 0226	kb25d62w-B228	https://collections.naturalsciences.be/ssh-geology-archives/arch/062w/062w0226.txt	https://www.dov.vlaanderen.be/data/boring/2016-124351

4.10 References:

Buffel, Ph., Van Barel, L. & Gullentops, F., 2002. Geologische kaart van België, Vlaams Gewest: Turnhout-Meerle, kaartblad 8-2. 1/50 000. Belgische Geologische Dienst en Afdeling Natuurlijke Rijkdommen en Energie, Brussel. https://www.vlaanderen.be/publicaties/tertiairgeologische-kaart-van-belgie-kaartblad-2-8-meerle-turnhout.

de Heinzelin, J. & Glibert, M., 1957. Lexique Stratigraphique International. Vol. I. Europe, Fasc. 4a: France, Belgique, Pays-Bas, Luxembourg. Fasc. 4a VII: Tertiaire. 217 p., 15 maps. Congrès Géologique International - Commission de Stratigraphie, Mexico, 1956. Centre National de la Recherche Scientifique, Paris, VIIe, 1957.

De Man, E., Van Simaeys, S., Vandenberghe, N., Harris, W.B. & Wampler, J.M., 2010. On the nature and chronostratigraphic position of the Rupelian and Chattian stratotypes in the southern North Sea basin. Episodes, 33/1, 3–14. https://doi.org/10.18814/epiiugs/2010/v33i1/002

Dusar, M. & Vandenberghe, N., 2020. Upper Oligocene lithostratigraphic units and the transition to the Miocene in North Belgium. Geologica Belgica 23/3-4 - The Neogene stratigraphy of northern Belgium: 113-125 URL : https://popups.uliege.be/1374-8505/index.php?id=6836.

Matthijs, J., Deckers, J., Broothaers M. & De Koninck, R., 2016. A new lithostratigraphic and seismostratigraphic interpretation of the Cenozoic strata for the Molenbeersel well (049W0226) in the Roer Valley Graben, NE Belgium. In: J.M. Baele, S. Papier, X. Devleeschauwer, N. Dupont, P. Goderniaux, M. Hennebert & O. Kaufmann, eds. 5th International Geologica Belgica 2016 Congress. Mons, 26-29 January 2016. Geologica Belgica Conference Proceedings, vol. 2, p. 257. https://popups.uliege.be/2593-6670/index.php?id=116.

Munsterman, D.K. & Deckers, J., 2020. The Oligocene/Miocene boundary in the ON-Mol-1 and Weelde boreholes along the southern margin of the North Sea Basin, Belgium. Geologica Belgica, 23/3-4. https://doi.org/10.20341/gb.2020.007

Schneider, H. & Thiele S., 1965. Geohydrologie des Erftgebietes. Ministerium für Ernährung, Landwirtschaft und Forsten Land Nordrhein-Westfalen, Düsseldorf, pp. 185.

Van Simaeys, S., 2004. The Rupelian-Chattian boundary in the North Sea Basin and its calibration to the international time-scale. Netherlands Journal of Geosciences / Geologie en Mijnbouw, 83/3, 241–248. https://doi.org/10.1017/S0016774600023532

Van Straelen, V., 1923. Observations sur le Néogène et l'Oligocène en profondeur dans la Campine Limbourgeoise.Bulletin de la Société belge de Géologie 33: 58-65.

VMM, 2019. HCOV coding, https://www.dov.vlaanderen.be/page/hydrogeologische-codering-van-vlaanderen-hcov-versie-2, accessed 13/12/2021.

5 Wintelre Member (Veldhoven Formation)

Unit name: Wintelre Member

Hierarchical unit name: Veldhoven Formation

Type: Member

Code: VdWi

Author(s):

- Compiled by: Dusar Michiel and Vandenberghe Noël

Alternative names: Veldhoven Member: Veldhoven Clay Member was the original name of this unit but subsequently became the name of the entire formation. In order to avoid confusion the name of the member was modified into Wintelre (de Lang, 2003).

HCOVv2 hydrostratigraphic code (operated by VMM (2019)) for the Wintelre Member (named Voort klei): A0256.

Origin of the name: -

Date: 01/05/2022

How to refer: Dusar, M. & Vandenberghe, N., 2023. The Wintelre Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Wintelre-Member

5.1 Characterizing description

The Wintelre Member predominantly consists of grey-green to dark green clay, alternating with clayey sand.

5.2 Type section, type locality, type borehole, or type geophysical borehole

The reference section in the Dutch well Veldhoven-1 (NAM-RGD, 1980, p. 51, encl. 32) in Veldhoven can be used as a stratotype: Wintelre Clay Member (interval 935 – 1047 m). [TNO-GDN (2022), http://www.dinoloket.nl/veldhoven-formation-nmvf].

Belgian parastratotype: borehole Molenbeersel; GeoDoc 049W0226, ground level +33 m; Lambert coordinates x 247660, y 207752, Wintelre Member: 774 – 840 m below ground level.

5.3 Description upper boundary

The clayey deposits of the Wintelre Member grade into the sandy deposits of the Someren Member. This is characterised by a transition in gamma ray readings from a higher level on the Wintelre Clays to a lower level on the Someren Sand.

5.4 Description lower boundary

The Voort Sand grade into the Wintelre Clays. This is characterised by a transition in gamma ray readings from a lower level on the Voort Sand to a higher level on the Wintelre Clays. However, a more clayey marker horizon in the middle of the Voort Sand Member (S&T 06) has been confounded for the Wintelre Member (named Veldhoven Clay Member in the past).

5.5 Thickness

The thickness of the Wintelre Member is 66 m in borehole Molenbeersel, according to Table 1 in Dusar & Vandenberghe, 2020 (cf. Matthijs et al., 2016). The member is absent outside the Roer Valley Graben.

5.6 Occurrence

The Wintelre Member does not crop out, and appears to be only recorded in the subsurface north of the Grote-Brogel - Heerlerheide faults.

5.7 Regional correlations

The clay unit corresponding to the Schneider and Thiele (1965) hydrostratigraphic code S&T1 in the Lower Rhine Graben (Hager et al., 1998) can be regarded as the Veldhoven Member sensu Van Adrichem Boogaert & Kouwe (1993) and Wintelre Member sensu de Lang (2003).

5.8 Age

No datation is available in Belgium. The age is possibly still Chattian but certainly ranging into the Aquitanian.

5.9 Dataset

Data in this LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets, more specifically in the datasubset NCS_Neogene 2020_Dusar and Vandenberghe, 2020.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Belgian parastratotype borehole Molenbeersel	049w0226	kb18d49w-B226	https://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0226.txt	https://www.dov.vlaanderen.be/data/boring/1987-042705

- Dutch boreholes DINOloket:
    - B51D0127 (Veldhoven-01)
    - B52C0142 (Asten-01)

5.10 References

de Lang, F.D., 2003. Beschrijving lithostratigrafische eenheid: Veldhoven Formatie. NITG-TNO.

Dusar, M. & Vandenberghe, N., 2020. Upper Oligocene lithostratigraphic units and the transition to the Miocene in North Belgium. Geologica Belgica 23/3-4 - The Neogene stratigraphy of northern Belgium: 113-125 URL : https://popups.uliege.be/1374-8505/index.php?id=6836.

Hager, H., Vandenberghe, N., van den Bosch, M., Abraham, M., von der Hocht, F., Rescher, K., Laga, P., Nickel, E., Verstraelen, A., Leroi, S. & van Leeuwen, R.J.W., 1998. The geometry of the Rupelian and Chattian depositional bodies in the Lower Rhine district and its border area: implications for Oligocene lithostratigraphy. Bulletin of the Geological Society of Denmark 45: 53-62.

Matthijs, J., Deckers, J., Broothaers M. & De Koninck, R., 2016. A new lithostratigraphic and seismostratigraphic interpretation of the Cenozoic strata for the Molenbeersel well (049W0226) in the Roer Valley Graben, NE Belgium. In: J.M. Baele, S. Papier, X. Devleeschauwer, N. Dupont, P. Goderniaux, M. Hennebert & O. Kaufmann, eds. 5th International Geologica Belgica 2016 Congress. Mons, 26-29 January 2016. Geologica Belgica Conference Proceedings, vol. 2, p. 257. https://popups.uliege.be/2593-6670/index.php?id=116.

Schneider, H. & Thiele S., 1965. Geohydrologie des Erftgebietes. Ministerium für Ernährung, Landwirtschaft und Forsten Land Nordrhein-Westfalen, Düsseldorf, pp. 185.

TNO-GDN (2022). Formatie van Veldhoven. In: Stratigrafische Nomenclator van Nederland, TNO – Geologische Dienst Nederland. Geraadpleegd op 19-04-2022 op http://www.dinoloket.nl/stratigrafische-nomenclator/formatie-van-veldhoven.

Van Adrichem Boogaert, H.A. & Kouwe, W.F.P., 1993. Stratigraphic Nomenclature of the Netherlands, revision and update by RGD and NOGEPA, Med. RGD, nr. 50.

VMM, 2019. HCOV coding, https://www.dov.vlaanderen.be/page/hydrogeologische-codering-van-vlaanderen-hcov-versie-2, accessed 13/12/2021.

6 Someren Member (Veldhoven Formation)

Unit name: Someren Member

Hierarchical unit name: Veldhoven Formation

Type: Member

Code: VdSo

Author(s):

- Compiled by: Dusar Michiel and Vandenberghe Noël

Alternative names: HCOVv2 hydrostratigraphic code (operated by VMM (2019)) for the Someren Member (named Voort zand 2): A0257.

Origine of the name: -

Status: Formal

Date: 01/05/2022

How to refer: Dusar, M. & Vandenberghe, N., 2023. The Someren Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Someren-Member

6.1 Characterizing description

Light grey to green fine to very fine glauconiferous mollusc-bearing sand is characteristic for the Someren Member.

6.2 Type section, type locality, type borehole, or type geophysical borehole

Borehole Veldhoven-1 (NAM) in Veldhoven (NL), [TNO-GDN (2021), http://www.dinoloket.nl/veldhoven-formation-nmve]. 860-935 m is the stratotype for the Veldhoven Formation. Parastratotype: Borehole Asten-1 (NAM) in Asten (NL), is also the stratotype for the Someren Sand Member (interval 867 – 952 m).

Name derived from Someren, commune in Noord-Brabant, in proximity to location of the parastratotype borehole Asten-1.

Additional Belgian parastratotype borehole Molenbeersel, drilled 1988 till final depth of 1773 m; GeoDoc 049W0226, ground level +33 m; Lambert coordinates x 247660, y 207752, Someren Member: 680 – 774 m from ground level.

6.3 Description upper boundary

In the Molenbeersel well the Someren Member is covered by the Bolderberg Formation, at the base of which occur the more greenish, clayey Houthalen Sand, with slightly higher gamma-ray readings. In the Dutch part of the Roer Valley Graben the Groote Heide Formation is the overlying unit, which is also equivalent to the Antwerp Member of Berchem Formation (Munsterman et al., 2019).

Erroneous interpretations have been made in the past. Before the Someren Sand member was formally recognised this sand has been incorporated in the overlying Miocene Bolderberg or Breda formations.

6.4 Description lower boundary

The Someren Member is conformably overlying the Wintelre Member, from which it can be distinguished by the presence of clay layers in the latter. The transition is marked by a gradual drop in gamma-ray readings.

6.5 Thickness

There is only one site in Belgium where the Someren Member has been positively identified in a borehole, at Molenbeersel, borehole Molenbeersel, designated as new Belgian parastratotype for the Veldhoven Formation. The Someren Member attains a thickness of 94 m in this well, for a total thickness of 295 m of the entire formation, according to Table 1 in Dusar & Vandenberghe, 2020 (cf. Matthijs et al., 2016).

6.6 Occurrence

The upper unit or Someren Member is only known from the deepest parts of the Roer Valley Graben in Belgium and extends over adjoining tectonic blocks in The Netherlands.

6.7 Regional correlations

The Someren Member can be time-equivalent to the part of the Berchem Formation underlying the black sand of its Antwerp Member.

6.8 Age

No datation in Belgium is available. The age is Aquitanian to Burdigalian, based on datation in the Netherlands.

6.9 Dataset

Data in this LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets, more specifically in the datasubset NCS_Neogene 2020_Dusar and Vandenberghe, 2020.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Belgian parastratotype borehole Molenbeersel	049w0226	kb18d49w-B226	https://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0226.txt	https://www.dov.vlaanderen.be/data/boring/1987-042705

- Dutch boreholes DINOloket:
  - B51D0127 (Veldhoven-01)
  - B52C0142 (Asten-01)

6.10 References

Dusar, M. & Vandenberghe, N., 2020. Upper Oligocene lithostratigraphic units and the transition to the Miocene in North Belgium. Geologica Belgica 23/3-4 - The Neogene stratigraphy of northern Belgium: 113-125 URL : https://popups.uliege.be/1374-8505/index.php?id=6836.

Matthijs, J., Deckers, J., Broothaers M. & De Koninck, R., 2016. A new lithostratigraphic and seismostratigraphic interpretation of the Cenozoic strata for the Molenbeersel well (049W0226) in the Roer Valley Graben, NE Belgium. In: J.M. Baele, S. Papier, X. Devleeschauwer, N. Dupont, P. Goderniaux, M. Hennebert & O. Kaufmann, eds. 5th International Geologica Belgica 2016 Congress. Mons, 26-29 January 2016. Geologica Belgica Conference Proceedings, vol. 2, p. 257. https://popups.uliege.be/2593-6670/index.php?id=116.

Munsterman, D.K., ten Veen, J.H., Menkovic, A., Deckers, J., Witmans, N., Verhaegen, J., Kerstholt-Boegehold, S.J., van de Ven, T. & Busschers, F.S., 2019. An updated and revised stratigraphic framework for the Miocene and earliest Pliocene strata of the RVG and adjacent blocks. Netherlands Journal of Geosciences, 98, e8. https://doi.org/10.1017/njg.2019.10

TNO-GDN, 2021, Veldhoven Formation, In: Stratigraphic Nomenclature of the Netherlands, TNO – Geological Survey of the Netherlands. Accessed on 13-12-2021 from http://www.dinoloket.nl/veldhoven- formation-nmve.

VMM, 2019. HCOV coding, https://www.dov.vlaanderen.be/page/hydrogeologische-codering-van-vlaanderen-hcov-versie-2, accessed 13/12/2021.

7 Boncelles Formation

Unit name: Boncelles Formation

Hierarchical unit name: Rocourt Group (informal unit at the time of composing this LIS-file*) for the deposits on the eastern Hesbaye plateau, consisting from top to base of the Liège Formation, the Boncelles Formation and the Sint-Huibrechts-Hern Formation (proposal by Marion et al., 2018)

Type: Formation

Code: Bn

This LIS file takes into account the latest revision of the stratigraphy in the type area by Marion et al. (2018) and Delcambre (2018), who incorporated the Boncelles Formation in the proposed Rocourt Group, but gave it a different meaning depending on the geographical context. Here we consider in particular the upper 'Chattian' part of the Oligocene sand, following the subdivision by Fourmarier (1934).

Author(s):

- Compiled by: Dusar Michiel, Vandenberghe Noël & Demoulin Alain

Alternative names: Abbreviation 'BCL' on the geological maps of the Walloon region. Formerly part of 'sables oligocènes indifférenciés' or 'Om (dépôts inférieurs marins (Tongrien?) du système oligocène)' on the old 1/40.000 geological maps (e.g. Forir & Mourlon, 1897).

Status: Formal

Date: 01/05/2022

How to refer: Dusar, M., Vandenberghe, N. & Demoulin, A., 2023. The Boncelles Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Boncelles-Formation

*Note: This LIS file takes into account the latest revision of the stratigraphy in the type area by Marion et al. (2018) and Delcambre (2018), who incorporated the Boncelles Formation in the proposed Rocourt Group, but gave it a different meaning depending on the geographical context. Here we consider in particular the upper 'Chattian' part of the Oligocene sand, following the subdivision by Fourmarier (1934).

7.1 Characterising description

The Boncelles Formation forms the fine-grained upper part of remnant Oligocene sand deposits on the eastern Hesbaye and Condroz plateaus, up to the Hautes Fagnes region (= Boncelles Formation sensu stricto, restricted to the 'Chattian').

In the Boncelles type area (Figure 7-1) this lithostratigraphical unit consists of rather homogeneous well-sorted fine grained pale yellow sand, containing decalcified mollusc layers in some locations (= sables supérieurs on Figure 7-2). The top is weathered and rubified, a feature shared with the overlying Graviers liégeois (Liège Formation) (= limons et graviers on Figure 7-2). The base is formed by a thin double layer of red-stained glauconiferous coarse-grained sand with rounded quartz pebbles, overlying more heterogeneous coarser grained sand which is bleached white in colour (= sables moyens et inférieurs on Figure 7-2), resting on a residual flint deposit at the contact with the Palaeozoic bedrock (= silex on Figure 7-2).

However, according to the latest revision of the Wallonian geological map, the Boncelles Formation in the Boncelles type area on the Condroz plateau south of Liège (Figure 7-1) contains the entire sand sequence, corresponding to the Om unit of the old geological map (Forir & Mourlon, 1897). This Boncelles Formation sensu lato thus includes both 'Chattian' and 'Tongrian' parts, cf.7.8 Age).

The upper or 'Chattian' part of the Boncelles Formation sensu lato in the Condruzian type locality (= Boncelles Formation sensu stricto) is displaying a rhythmic succession in sets of 30 to 50 cm thickness, consisting of finely stratified sand with cross-bedding at their base and bioturbations at their top, exception made for the rubified top of the section. The sedimentary environment is open marine outside tidal influence, whereas the underlying 'Tongrian' sand has been deposited in tidal environments. The boundary between both units marks a hiatus with reorganisation of the sedimentary environment (Macar, 1934; Sierakowski, 1970).

No sedimentary features were described from other occurrences.

According to the proposal by Marion et al. (2018) the Boncelles Formation on the eastern Hesbaye plateau is restricted to the 'Chattian' part of the eponymous formation occurring on the Condroz plateau south of Liège, the 'Tongrian' part being assigned to the Sint-Huibrechts-Hern Formation. The Hesbayan Boncelles Formation has similar characteristics as the upper, Chattian part of the Condruzian Boncelles Formation, consisting of homogeneous yellow fine grained to silty sand, occasionally containing poorly preserved decalcified molluscs. The contact with the underlying Sint-Huibrechts-Hern Formation is sharp and marked by a horizon with quartz and flint pebbles. The Sint-Huibrechts-Hern Formation can be distinguished by its whitish-grey colour, coarser grain size and slight glauconite content.

The Oligocene sand on the Hautes Fagnes plateau is well-sorted, fine to medium and typically shiny and polished as beach deposits; its colour varies from yellow to bleached white or rubified. It is equally divided in two parts, the lower unit is medium-grained and had its coastline along the northern rim of the Hautes Fagnes plateau, the upper unit is fine-grained and had its coastline further south. Compared to the Boncelles type locality both Hautes Fagnes sand units display more beach sand features, a difference explained by the more proximal coastal setting on the Hautes Fagnes plateau compared to the more distal open marine environment in the Boncelles type area (Demoulin, 1986, 1987, 1989).

Based on this exclusively petrographical data, these units are proposed to correlate with the upper 'Chattian' and lower 'Tongrian' units at the Boncelles type locality and on the eastern Hesbaye plateau. Furthermore, all similar 'Tertiary' marine sand deposits preserved in N Eifel east of the Hautes Fagnes area are assigned to the Chattian 'Kölner Schichten' by German authors (Schäfer & Utescher, 2014)

7.2 Type section, type locality

The former Sart-Haguet sand pit in Boncelles forms the type section (134W0011); the former Gonhis (or Les Gonhirs in older documents) sand pit where Rutot (1907) first recorded a Chattian fauna (named Aquitanian by Rutot) can be considered as an auxiliary stratotype (134W0010). The entire 'lambeau de sables oligocènes' at Boncelles forms the type locality (Rutot, 1908; Fraipont, 1908; Destinez, 1909; Fourmarier, 1931, 1934; Ancion & Van Leckwijck, 1947; Calembert, 1954; Sierakowski, 1970; Juvigné et al., 2021a, b) – see Figure 7-1, Figure 7-2 from Sierakowski (1970) and the sand pit profiles by Rutot (1907) on Figure 7-3.

7.3 Description upper boundary

The Condruzian Boncelles Formation is unconformably covered by whitish clayey gravel deposits of fluviatile origin, formerly mapped as 'Onx' on the old geological maps (Forir & Mourlon, 1897), currently named the Liège gravels and assigned to the Liège Formation, which predate the incised Meuse river terraces (Juvigné et al, 2021b).

On the eastern Hesbaye plateau (provinces of Liège and Limburg) the Boncelles Formation is either overlain by the Quaternary loam cover or by the gravel of the Liège Formation. However, in the northern Hesbaye ('Vochtig Haspengouw') with more contiguous Paleogene – Neogene deposits, the older 'Tongrian' Sint-Huibrechts-Hern Formation of Lower Oligocene age is covered by the Mid-Miocene Bolderberg Formation; the intervening Boncelles Formation is either absent/eroded or has remained undetected.

On the Hautes Fagnes plateau and the Ardenne – Eifel transition the Oligocene sand is overlain by peat or mostly colluvial gravel.

7.4 Description lower boundary

On the Condroz plateau south of Liège – containing the type area - the base of the Boncelles Formation sensu lato consists of a residual clay-with-flint alteration unit, marked 'Sx' for 'Conglomérat à silex' on the old geological maps (Forir & Mourlon, 1897), covering Lower Devonian formations. The detailed topography seems to depend on the degree of weathering of the underlying Lower Devonian siliciclastics (Figure 7-2). However, the Boncelles Formation there has another content than on the Hesbaye plateau: the Condruzian Boncelles Formation sensu lato is encompassing both 'Chattian' and 'Tongrian' strata, the latter being excluded from the Boncelles Formation on the Hesbaye plateau sensu Marion et al. (2018). Hence, the fine-grained 'Chattian' upper part of the Boncelles Formation, corresponding to the Boncelles Formation sensu stricto as defined north of the Meuse, is overlying the coarser-grained and more whitish 'Tongrian' lower part of the Condruzian Boncelles Formation, equivalent to the Sint-Huibrechts-Hern Formation.

Fourmarier (1934) distinguished in this area a 'Chattian' Boncelles Formation from the underlying 'Tongrian' Sart-Tilman Formation. The Fourmarier nomenclature would provide the same meaning to the Boncelles Formation north and south of the Meuse. Nevertheless, this subdivision has not been applied by later authors.

On the Hesbaye plateau the Boncelles Formation is overlying coarser-grained and more whitish strata belonging to the 'Tongrian' Sint-Huibrechts-Hern Formation, assigned to the Lower Oligocene.

On the Hautes Fagnes plateau the fine-grained upper 'Chattian' unit may overlain the lower medium-grained 'Tongrian' unit or directly cover Cambrian bedrock south of the presumed Tongrian coast line (Figure 7-4)

7.5 Thickness

The thickness of the Boncelles Formation is 7 -11 m in Sart-Haguet sand pit type locality in Boncelles, for the Boncelles Formation sensu stricto, corresponding to the upper or 'Chattian' part of the formation (cf. Figure 7-2, Figure 7-3). The Boncelles Formation sensu lato (including the underlying sand correlated to the Sint-Huibrechts-Hern Formation) reaches about 20 m in thickness, similar to the maximal thickness reached on the eastern Hesbaye plateau by the Boncelles and Sint-Huibrechts-Hern formations combined (ca 25 m).

On the Hautes Fagnes plateau thickness of both the upper and lower units of the Oligocene sand is limited to 2 to max 5 m.

Due to post-Oligocene erosion the remaining thickness may be more reduced, resulting in limited conservation of the Boncelles Formation sensu stricto.

7.6 Occurrence

Geological mapping did not differentiate between the Oligocene sand. Hence, the Boncelles Formation is included either in the Sint-Huibrechts-Hern Formation (e.g. at Maurissen sand pit in Elst) on the Flemish geological maps (Claes et al., 2001) or in 'undifferentiated Oligocene sand' of the geological maps of Wallonia, except for Marion et al., 2018 and Delcambre, 2018 (unpublished), who include the Boncelles Formation in the proposed Rocourt Group on the Hesbaye plateau.

Although the occurrence of the Boncelles Formation sensu stricto (meaning the deposits correlated with the Chattian) is poorly constrained and its known occurrences are limited to within the preservation area of the underlying sand correlated to the Sint-Huibrechts-Hern Formation, its conservation and the Hesbaye plateau is probably linked to dissolution of the underlying Cretaceous. Moreover, its depositional area will not far exceed the western boundary of the Roer Valley Graben Shoulder (Rauw, Beringen and Mal faults, cf. Dusar & Vandenberghe, 2020), along a limit extending further south towards the Liège region. Identified occurrences of the Chattian Boncelles Formation thus seem to be in geographical continuation with the Voort Member of the Veldhoven Formation (see LIS Veldhoven Formation) further north in the Campine. This means that assignment to the Chattian of the Rond Péry mollusc fauna on the adjoining mapsheet Jehay-Bodegnée – Saint-Georges indeed could be questioned (Delcambre, 2018, unpublished).

Linking the Boncelles Formation sensu stricto to the Voort Member of the Veldhoven Formation means also linking to the Köln Formation of the Lower Rhine Graben (Hager, 1980), despite the assumed absence of equivalent Chattian deposits in the Netherlands South Limburg and on the Herve plateau (Demoulin, 1989). Yet, the Oligocene sand deposits on the Hautes Fagnes plateau can equally be subdivided in two units. Although both units represent coastal barrier sand the upper one is consistently finer grained and more deprived of heavy minerals (Demoulin, 1986, 1987). Moreover, its occurrences extend across the Hautes Fagnes culmination up to the Weisser Stein, whereas the lower unit had its coastline along the Spa – Solwaster ridge along the northern flank of the Hautes Fagnes plateau (Figure 7-4). This means that the upper unit represents the latest Oligocene transgression, separate from the previous one which is associated with the Lower Oligocene 'Tongrian' transgression, and that this upper unit may be linked to the upper 'Chattian' part in the Boncelles type area (Demoulin, 1989). It also would mean that Miocene erosion has removed most of the easily erodible Chattian Boncelles Formation.

7.7 Regional correlations

The original succession described by Rutot (1907, 1908) for the Sart-Haguet and Gonhis sand pits (Figure 7-3) remains the basis for the stratigraphic subdivision, but was reviewed by Ancion & Van Leckwijck (1947), Ancion & Van Leckwijck, 1947) presented an overview, based on the Sart-Haguet and more northerly Bois St.-Jean sandpits, resulting in different thicknesses for the successive units already recognised by Rutot, from top to bottom:

a Stony loam with peaty layers (1.50 m, units A-B of Rutot)

b Rubified clayey sand with cross-bedding, loaded with pebbles and block of quartz and ardennian rock, eroding the underlying unit (2.50 m, unit C of Rutot)

c yellow fossiliferous sand with limonitic layers and concretions (7 to 10 m, units D to H of Rutot)

d rubified glauconific sand with quartz pebbles, often doubled (0.02 – 0.20 m, unit I of Rutot)

e white and salmon-coloured sand with thin pebble layers (3.50 to 5 m, unit J of Rutot)

f alternating white to yellow-brown sand (6 m, units J to L by Rutot), with black manganiferous nodules (level m – n of Rutot); at 1.50 m above the base horizon with small quartz pebbles et large weathered flint blocks (unit k of Rutot)

g bed of loose flint blocks (>0.30 m, unit M of Rutot).

Units a to b represent the Onx of Liège Formation, units c to d represent the 'Chattian' or the Boncelles Formation sensu stricto, units e to f represent the 'Tongrian' part of the Boncelles Formation sensu lato, unit g represents the clay-with-flints alteration unit but is incorporated in the Boncelles Formation because of its limited thickness.

Sierakowski (1970) adopted the subdivision made by Ancion & Van Leckwijck (1947) and attributed the 'Chattian' part to the upper sand unit and the 'Tongrian' part to the lower and middle sand units of the Oligocene sand deposit (on Figure 7-2), thereby following an informal classification already established by Calembert for internal reports.

The 'Chattian' – 'Tongrian' boundary, approximately in the middle of the Oligocene sand in the Boncelles type locality, originally observed by Rutot (1907, 1908, his horizon I), corresponding to level d of Ancion & Van Leckwijck 1947) has retained the attention in particular of Fourmarier (1931), Macar (1934) and Sierakowski (1970) as a high-energy level, separating the depositional environment of the Oligocene sand between more proximal and more distal.

The Boncelles Formation sensu stricto correlates with the Köln Formation (Kölner Schichten) in the Lower Rhine Graben (Schäfer and Utescher, 2014) and with the Veldhoven Formation in the Campine basin and adjacent Netherlands, more particularly with its lower Voort Member, mainly because of similarity in the Chattian mollusc faunas and the fact that the Voort Sand Member has the widest extent towards the south (Dusar & Vandenberghe, 2020).

Despite the poor dating, the twofold subdivision of the Oligocene sand, either on the eastern Hesbaye plateau or on the Condruzian promontory between Meuse and Ourthe south of Liège and even on the Hautes Fagnes plateau, and their rather constant thicknesses and facies are remarkable features. This suggests the prevalence of the early Savian unconformity, separating the Chattian from the older Oligocene and the effect of the Chattian sea level rise resulting in additional accommodation space (Vandenberghe, 2017; Munsterman & Deckers, 2022). Late Savian tectonics led to a marine regression towards the late Chattian (Munsterman & Deckers, 2022) and coverage by residual gravels of the Liège Formation, probably deposited when the area was still in lowland position (Juvigné et al., 2021b). Uplift of the Ardenno – Rhenish Massif removed most traces of the easily erodible Chattian sand (Demoulin, 1989; Juvigné et al., 2021ab) , except for their actual occurrences where the Oligocene sand is rather completely preserved due to deep weathering of the Cretaceous.

7.8 Age

A mollusc fauna occurring in the Boncelles Formation of the type area, first described by Rutot (1907) is characterised by the presence of Meretrix (Callista) beyrichi, considered as a guide fossil for the Chattian. Although some doubts have been raised about this datation because of the poor quality of the fauna and its value for detailed correlations (discussion in Demoulin, 1989) similar faunas have been recorded from the Voort Member of the Veldhoven Formation in the Campine, and cannot be assigned to any other lithostratigraphical unit of different age.

The stratigraphical assignment of the Boncelles Formation to the Oligocene is based on general palaeogeographical assumptions, supported by its heavy mineral association (Thibeau, 1960; Sierakowski, 1970; Demoulin, 1986, 1987, 1989; Juvigné et al., 2021a). In this way it is not dissociated from the underlying 'Tongrian' Oligocene sand, which is by all authors correlated to the Lower Oligocene Sint-Huibrechts-Hern Formation. Sierakowski (1970), thereby following Macar (1934) insisted on the twofold subdivision of the Oligocene sand in the Boncelles type area, whereas Demoulin (1986, 1987) also recognised two transgressive phases in the Oligocene sand on the Hautes Fagnes plateau and linked these to the subdivision already observed in the Boncelles type area.

No firm Upper Oligocene, Chattian age can be established for the upper unit in the Oligocene sand of the Hautes Fagnes plateau but its link to the Boncelles type area and via this to the eastern Hesbaye plateau makes the attribution to the latest Oligocene transgressive phase and possible connection to the Chattian transgression in the Lower Rhine Graben more plausible, as already postulated by Hager (1980). Whatever more precise datation may reveal, it can be stated that the sediments attributed to the Boncelles Formation sensu stricto - as described in this LIS file - unequivocally represent the latest Oligocene transgression in eastern Belgium.

7.9 Dataset

The former sand pit Maurissen in Elst (Millen, commune of Riemst, Fig. 5 in Dusar & Vandenberghe, 2020) is the single site included in the DOV-Neogene data collection, based on its links to the GSB data sheets, more specifically in the datasubset NCS_Neogene 2020_Dusar and Vandenberghe., 2020.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
sand pit Maurissen	107W0304	BGD107W0304	https://collections.naturalsciences.be/ssh-geology-archives/arch/107w/107W0304.pdf	https://www.dov.vlaanderen.be/data/boring/2008-170593

Extra data in this LIS:
The former Sart-Haguet sand pit stratotype for the Boncelles Formation by Rutot (1907) is 134W0011; the different sections in this sand pit described by Ancion & Van Leckwijck (1947) are 134W0312 to 316, 134W0334. The auxiliary stratotype of Les Gonhir by Rutot (1907) is 134W0010 in the GSB data archive.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Sart-Haguet sand pit	134W0011, 0312 to 0316	-	https://collections.naturalsciences.be/ssh-geology-archives/arch/134w/134w0011.txt , 0312.txt to 0316.txt	-
Les Gonhis sand pit	134W0010	-	https://collections.naturalsciences.be/ssh-geology-archives/arch/134w/134w0010.txt	-

7.10 References:

Ancion, Ch. & Van Leckwijck, W., 1947. Les sables de la région de Liège. Centenaire de l'Association des Ingénieurs sortis de l'Ecole de Liège (A.I.Lg.). Congrès 1947. Section Géologie: 187-191.

Calembert, L., 1954. Prodrôme d'une description géologique de la Belgique. L'Oligocène. Les Formations tertiaries de la Haute Belgique. Société Géologique de Belgique : 510-532.

Claes, S., Frederickx, E., Gullentops, F. & Felder, W., 2001. Toelichtingen bij de geologische kaart van België – Vlaams Gewest. Kaartblad (34) Tongeren. BGD – ANRE / ALBON: 1-55.

Delcambre, B., 2018. Carte géologique de la Wallonie, Jehay-Bodegnée – Saint-Georges 41/7-8. Notice explicative. SPW, Agriculture, Ressources naturelles et Environnement. Unpublished.

Demoulin, A., 1986. Nouvelles observations sur les sables oligocènes des Hautes Fagnes (Belgique). Annales de la Société géologique de Belgique, 109: 473-480.

Demoulin, A., 1987. Les sables oligocènes du plateau des Hautes Fagnes: une synthèse. Bulletin de la Société belge de Géologie, 96: 81-90.

Demoulin, A., 1989. Les trangressions oligocènes sur le Massif Ardenne-Eifel. Annales de la Société géologique de Belgique, 112: 215-224.

Destinez, p., 1909. Comparaison de la faune des sables de Boncelles avec celle de l'Oligocène supérieur de Westphalie. Annales de la Société géologique de Belgique, 36: M47-50.

Dusar, M. & Vandenberghe, N., 2020. Upper Oligocene lithostratigraphic units and the transition to the Miocene in North Belgium. Geologica Belgica 23/3-4 - The Neogene stratigraphy of northern Belgium: 113-125 URL : https://popups.uliege.be/1374-8505/index.php?id=6836.

Forir, H. & Mourlon, M., 1897. Carte géologique de la Belgique, dressée par ordre du gouvernement. Seraing - Chenée. N° 134 (planchettes 5-6 de la feuille XLII de la carte topographique). Commission géologique de la Belgique.

Fourmarier, P., 1931. Observations sur l'âge des dépots Onx de la carte géologique au 40000e dans la région de Liège. Annales de la Société géologique de Belgique, 54: 274-287.

Fourmarier, P., 1934. Observations nouvelles sur les dépôts tertiaires des environs de Liège. Annales de la Société géologique de Belgique, 57: 178-189.

Fraipont, C., 1908. Les sablières de Sart Tilman - lez-Liège. Annales de la Société géologique de Belgique, 35: 226-230.

Hager, H., 1980. Tertiär. In: Knapp, G., Erläuterungen zur Geologischen Karte der nördlichen Eifel 1:100 000. Fortschritte in der Geologie von Rheinland und Westfalen: 89-97.

Juvigné, E., Houbrechts, G. & Van Campenhout, J., 2021a. De l'Ourthe primitive à la Meuse primitive en Basse-Meuse liégeoise. Partie 1: Généralités et données. Bulletin de la Société royale des Sciences de Liège, 90: 249-287.

Juvigné, E., Houbrechts, G. & Van Campenhout, J., 2021b. De l'Ourthe primitive à la Meuse primitive en Basse-Meuse liégeoise. Partie 2: Modèle et discussion. Bulletin de la Société royale des Sciences de Liège, 90: 288-316.

Macar, P., 1934. Analyses granulométriques de sables tertiaires des environs de Liège. Annales de la Société géologique de Belgique, 58: 22-38.

Marion, J.-M., Mottequin, B. & Delcambre, B., 2018. Carte géologique de la Wallonie, Chenée – Seraing 42/5-6. Notice explicative. SPW, Agriculture, Ressources naturelles et Environnement. Unpublished.

Munsterman, D.K. & Deckers, J., 2022. Biostratigraphic ages and depositional environments of the upper Oligocene to lower Miocene Veldhoven Formation in the central Roer Valley Rift System (SE Netherlands - NE Belgium). Netherlands Journal of Geosciences / Geologie en Mijnbouw, 101: 10.1017/njg.2022.3 (16 p.)

Rutot, A., 1907. Un grave problème. Une industrie humaine datant de l'époque oligocène - comparaison avec les outils tasmaniens actuels. Bulletin de la Société belge de Géologie, 21: M439-482.

Rutot, A., 1908. Sur l'age des dépôts connus sous les noms de sable de Moll, d'argile de la Campine, de cailloux de quartz blanc, d'Ardenne et de sable à facies marin noté Om dans la légende de la Carte géologique de la Belgique au 40.000e. Académie royale de Belgique, Mémoires de la Classe des Sciences, in-4° 2° Série 2: 47 p.

Schäfer, A. & Utescher, T., 2014. Origin, sediment fill, and sequence stratigraphy of the Cenozoic Lower Rhine Basin (Germany) interpreted from well logs. German Journal of Geoscience, 165: 287-314.

Sierakowski, C., 1970. Etude sédimentologique des sables tertiaires de Boncelles (Liège). Annales de la Société géologique de Belgique, 93: 491-508.

Thibeau, M., 1960. Contribution nouvelle à l'étude géologique des lambeaux tertiaires de la région de Boncelles. Université de Liège, Faculté des Sciences Appliquées, travail de fin d'étude: 44 p.

Vandenberghe, N., 2017. Ernest Van den Broeck medallist lecture 2016. Tectonic and climatic signals in the Oligocene sediments of the Southern North-Sea Basin. Geologica Belgica, 20/3-4: 105–123. http://dx.doi.org/10.20341/gb.2017.007

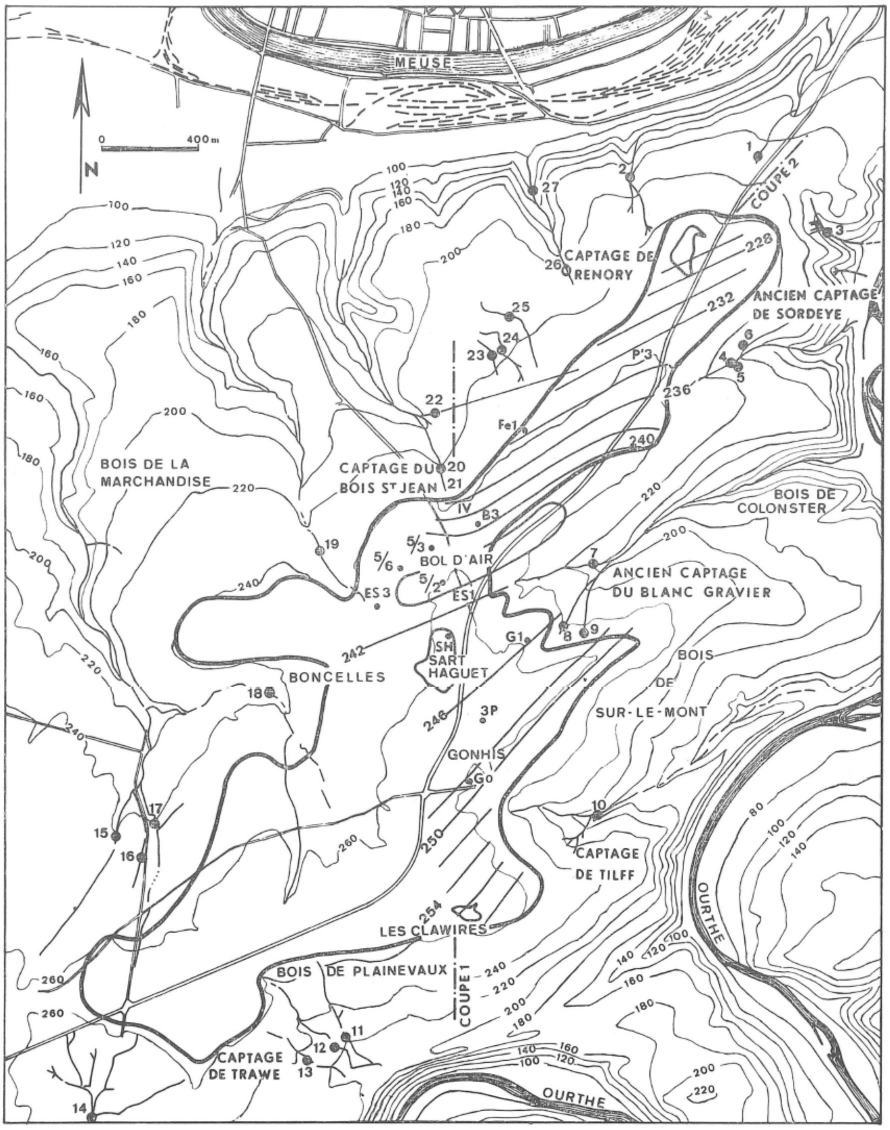


Figure 7-1: Type locality of the Condrusian Boncelles Formation showing the extent of Boncelles Sand on the watershed between Meuse and Ourthe rivers, south of Liège, extending 6 km in N-S direction and 0.3 tot 2.5 km in E-W direction, with location of former Sart-Haguet and Gonhis

sand pits (Sierakowski, 1970).

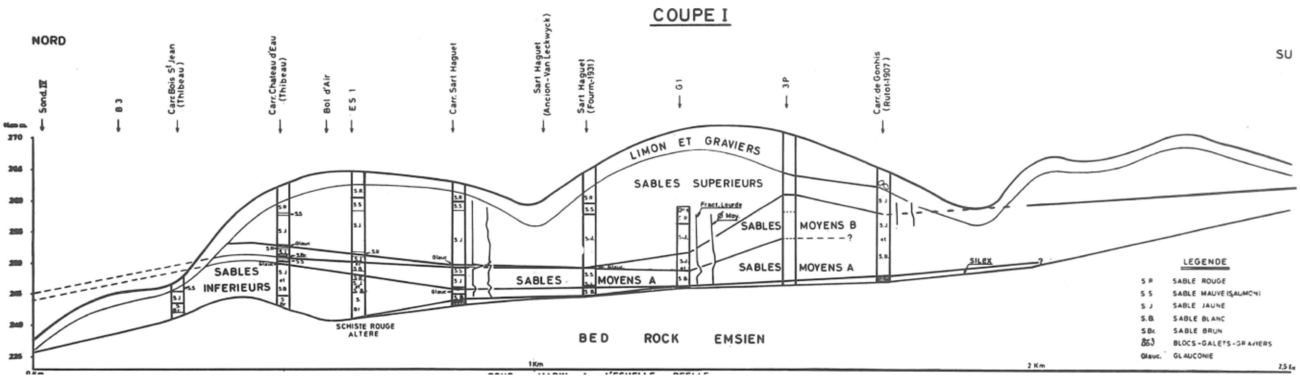


Figure 7-2: North-South cross section across the ‘lambeau à sables tertiaries de Boncelles’ type locality. The ‘sables supérieurs’ represent the deposits correlated to the Chattian or the Boncelles Formation sensu stricto, whereas the ‘sables moyens et inférieurs’ represent its Tongrian part, also included in the Boncelles Formation sensu lato (Sierakowski, 1970).

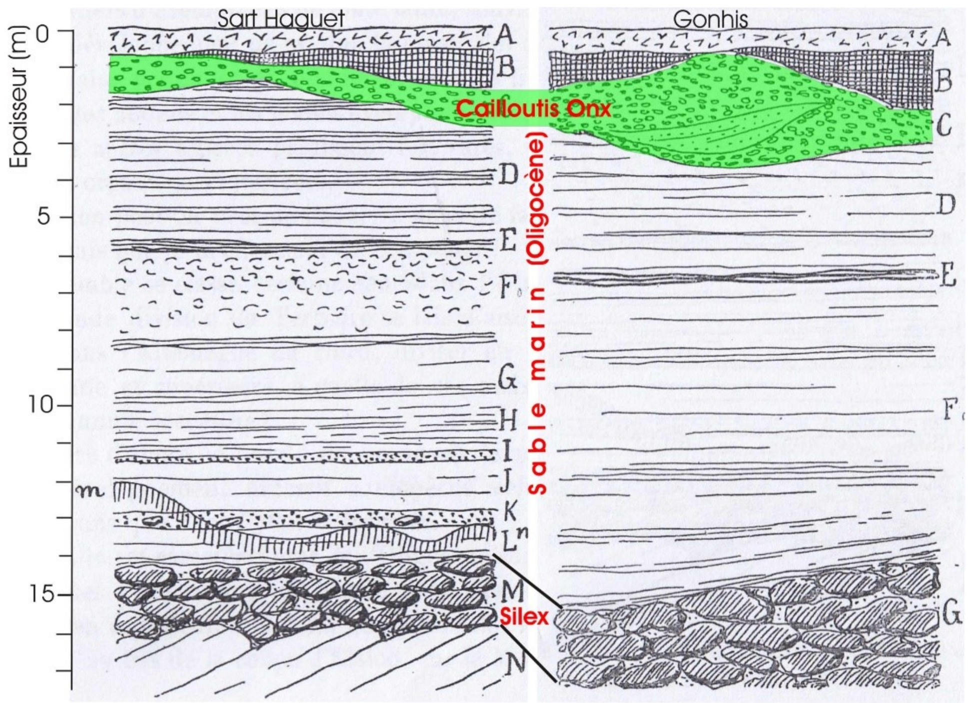


Figure 7-3: Sart-Haguet (134W0011) and Gonhis (Les Gonhir for Rutot, 134W0010) sand pits in the Boncelles type area, 500 m distant in NNW-SSE direction (location on Fig. 1), as surveyed by Rutot (1907, 1908), resumed by Marion et al. (2018). Legend according to Rutot (1907):

A. Actual stony soil (0.40 m)
B. Green water-saturated clay (0 – 1 m)
C. Gravel bed composed of quartz and ardennian siliciclastic rocks, interstratified with red clays and clayey sand (1 – 3 m, marked Cailloutis Onx)
D. Rubified finely-stratified sand with more clayey laminae (3 – 4 m)
E. Limonitised sand around clay layer (0.15 – 0.20 m)
F. Yellow, red-stained fine-grained micaceous stratified sand with decalcified shells (mainly ‘Pectunculus’ type), abundant in Sart-Haguet (1 to 1.50 m) and rare in Gonhis (10 m)
G. Yellow fine-grained micaceous stratified sand (3 – 4 m in Sart-Haguet, included in F in Gonhis)

H. Fine-grained micaceous well-stratified sand with alternating white and red lauers (2 m in Sart-Haguet, included in F in Gonhis)
I. Thin gravel bed with quartzitic pebbles (0.10 m in Sart-Haguet)
J. Well-stratified sand with 'salmon' colour (2 m in Sart-Haguet)
K. Gravel bed with quartzitic pebbles and large weathered flint (0.20 m in Sart-Haguet)
L. Red-stained greenish sand, bleached towards the base (0.50 m in Sart-Haguet)
M. Large blocks of flint embedded in compacted clayey sand, topped by well-rounded flattened flint pebbles (0.60 to 1 m in Sart-Haguet, unit G at least 1 m thick in Gonhis)
N. Unconformity on Lower Devonian bedrock

m- n weathering front marked by black-stained 'Manganese oxide' above the flint bed.

Units A – C represent the Liège Formation with weathered top, whereby unit C represents the Liège Formation sensu stricto. Units D to L represent the marine Oligocene / undifferentiated sand, grouped in the Condruzian Boncelles Formation, whereby units D – I represent the 'Chattian' part or the Boncelles Formation sensu stricto, and units J to L its 'Tongrian' part. Unit M in Sart-Haguet or G in Gonhis represents the Clay-with-flint alteration unit, overlain by the typical Tongrian basal flint and embedded in stiff clay of variegated colour (marked 'Ona, glaises plastiques diversement colorées' for les Gonhirs on the old geological map (Forir & Mourlon, 1897).

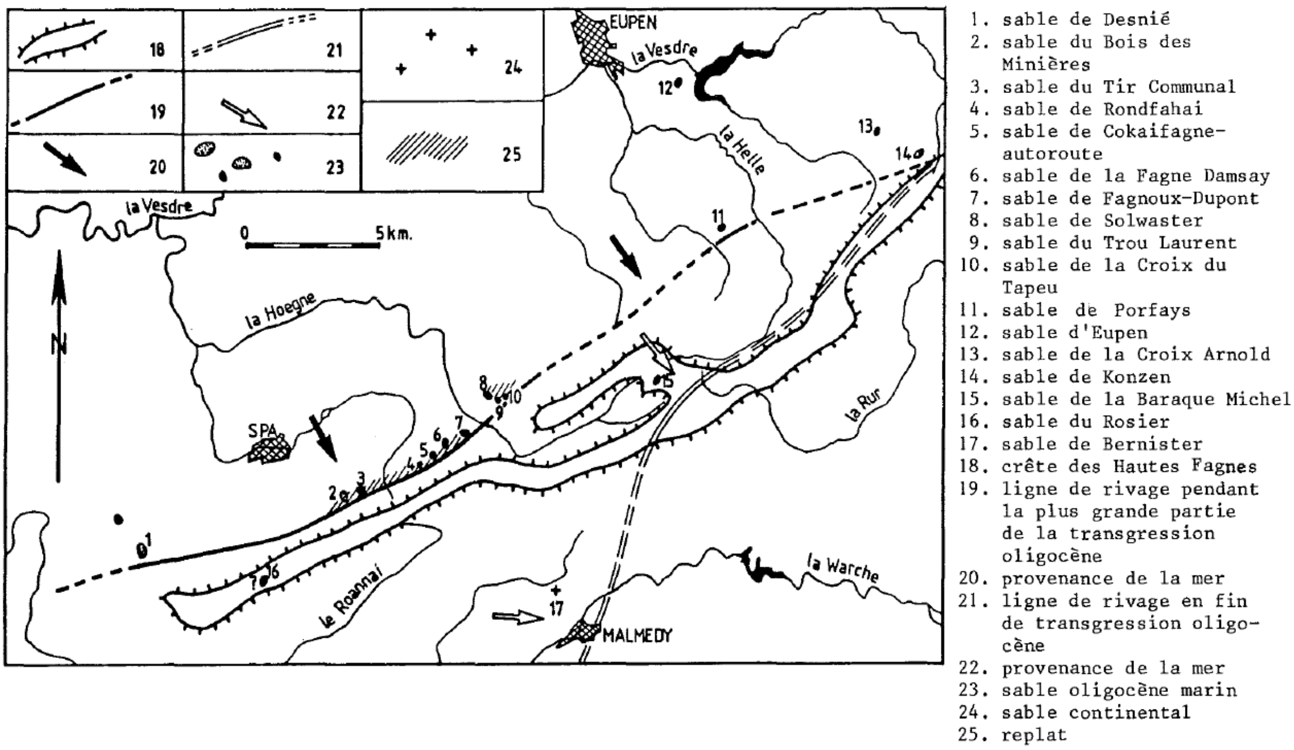


Figure 7-4: Occurrence of Oligocene sand on the Hautes Fagnes plateau. 19: presumed coast line during the deposition of the lower 'Tongrian' sand; 21: presumed coast line during the latest transgression, during deposition of the upper sand unit, correlated to the Chattian (Demoulin, 1987). The latter coast line must have been farther east to include the Weisser Stein massif (following Demoulin, 1989).

8 Berchem Formation

Unit name: Berchem

Hierarchical unit name: /

Type: Formation

Code: Bc

Author(s):

- Compiled by Louwye Stephen, Deckers Jef.
- Modified after De Meuter & Laga (1976)

Alternative names: /

Origin of the name: The origin of the name of the unit is discussed in De Meuter & Laga (1976) and Louwye et al. (2020).

Status: Formal

Date: 01/05/2022

How to refer: Louwye, S. & Deckers, J., 2023. The Berchem Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Berchem-Formation

8.1 Characterizing description

The Berchem Formation was redescribed in detail by Louwye et al. (2020). The Berchem Formation is a green to blackish, fine to medium-grained unit, often very glauconitic and with a minor clay content (Louwye et al., 2020). Smectite is the dominant clay mineral (Adriaens, 2015). The mode of the grain size within the formation varies between c. 130 µm and c. 330 µm (Verhaegen, 2020). The Berchem Formation holds a significant amount of epidote, amphiboles and garnet, making up on average more than 50% of the transparant heavy minerals (Verhaegen, 2020). Shells are abundantly present, dispersed or concentrated in massive layers. Parts of the formation, such as the Kiel Member, are locally decalcified. The Berchem Formation is on wireline log data typified by high gamma ray and moderate resistivity values (Deckers et al., 2019). A distinct gravel bed of dark, rounded flint pebbles is present at the base.

The Berchem Formation holds four members: the Edegem Member, Kiel Member, Antwerpen Member and Zonderschot Member.

8.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The type locality is Berchem, as defined by De Meuter & Laga, 1976. No single type section for the entire formation is available. The temporary outcrops for the construction of the highway around the city of Antwerp can be considered as a composite type section. The Edegem Member, Kiel Member and Antwerpen Member occur in the type locality in following temporary outcrops of the composite type section:

Antwerpen – Zuidstation III AR , I AR, IV AR, V AR, AR (De Meuter et al., 1976)

Antwerpen – Montignystraat AM (De Meuter et al., 1976)

Antwerpen – Van Rijswijcklaan AV (De Meuter et al., 1976)

Antwerpen – Nachtegalenpark AN (De Meuter et al., 1976)

Antwerpen – Berchem Station AM (De Meuter et al., 1976)

Antwerpen – Borbeeksepoort II BP (De Meuter et al., 1976)

Antwerpen – Kievitstraat II, V, VI AK (De Meuter et al., 1976), revised by Everaert et al. (2020)

Berchem – Grote Steenweg AG (De Meuter et al., 1976)

Borgerhout – Stenen Brug I SB (De Meuter et al., 1976), revised by Deckers and Everaert (2022)

Borgerhout – Rivierenhof XI BR (De Meuter et al., 1976) correlated to CPT GEO-07/154-S11 by Deckers and Everaert (2022)

Posthofbrug (Louwye et al., 2010) correlated to CPT GEO-68/101-SVII by Deckers and Everaert (2022)

Posthofbrug 2-3 (Hoedemakers & Dufraing, 2018)

Tweelingenstraat (Everaert et al., 2020)

Argenta (Everaert et al., 2020)

Post X (Everaert et al., 2020)

Wilrijk – Ter Weyde (Hooyberghs, 1996 & Hoedemakers & Dufraing, 2021)

Wilrijk – Revalidatiecentrum (Hoedemakers & Dufraing, 2021)

The type section of the Zonderschot Member is located about 30 km southeast of Antwerp and was described by Huyghebaert & Nolf (1979).

8.3 Description upper boundary

The formation is unconformably covered by the Diest Formation (upper Miocene), the Pliocene Kattendijk and/or Lillo formations, reworked Pliocene deposits or the Quaternary (De Meuter et al., 1976).

8.4 Description lower boundary

The formation rests unconformably on the lower Oligocene Boom Formation in the Antwerp area and the upper Oligocene Voort Formation in the Campine area. The formation thins towards the south.

8.5 Thickness

The Berchem Formation has a thickness of about 30 m in the Antwerp area to over 100 m in the east in the Campine area (Louwye et al., 2020).

8.6 Occurrence

The Berchem Formation occurs in northern Belgium between Antwerp in the west and Lommel in the east (see Figure 8-1 and Figure 8-2 in annex).

8.7 Regional correlations

The Berchem Formation can largely be correlated with the Bolderberg Formation which occurs in the eastern part of northern Belgium.

8.8 Age

Dinoflagellate cyst analysis positions the Berchem Formation in the type area between the mid-Burdigalian and late Serravallian (Louwye et al., 2020). Deposits of the Berchem Formation of Aquitanian age, based on dinoflagellate analysis, have been recorded at the base of the Weelde and Mol boreholes (Munsterman & Deckers, 2020).

8.9 Dataset

- Data in this LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.
- Extra data:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
CPT near Borgerhout – Rivierenhof XI BR outcrop		GEO-07/154-S11		https://www.dov.vlaanderen.be/data/sondering/2007-051813
CPT near Posthofbrug outcrop		GEO-68/101-SVII		https://www.dov.vlaanderen.be/data/sondering/1968-038916

8.10 References

Adriaens, R., 2015. Neogene and Quaternary clay minerals in the southern North Sea. Unpublished Ph.D. Thesis, KU Leuven, Leuven, 272 p.

Deckers, J., De Koninck, R., Bos, S., Broothaers, M., Dirix, K., Hambsch, L., Lagrou, D., Lanckacker, T., Matthijs, J., Rombaut, B., Van Baelen, K. &Van Haren, T., 2019. Geologisch (G3Dv3) en hydrogeologisch (H3D) 3D-lagenmodel van Vlaanderen. Studie uitgevoerd in opdracht van het Vlaams Planbureau voor Omgeving, departement Omgeving en de Vlaamse Milieumaatschappij. VITO, Mol, VITO-rapport 2018/RMA/R/1569. https://archief-algemeen.omgeving.vlaanderen.be/xmlui/handle/acd/251494

Deckers, J. & Everaert, S., 2022. Distinguishing the Miocene Kiel and Antwerpen Members (Berchem Formation) and their characteristic horizons using Cone Penetration Tests in Antwerp (northern Belgium). Geological Journal. https://doi.org/10.1002/gj.4384

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic foraminifera of the Neogene deposits in Northern Belgium. Bulletin Belgische Vereniging voor Geologie/Bulletin de la Société belge de Géologie, 85, 133–152.

De Meuter, F., Wouters, K. & Ringele, A., 1976. Lithostratigraphy from temporary outcrops in the Antwerpen City area. Professional Paper of the Geological Survey of Belgium, 3, 1–19.

Everaert, S., Munsterman, D., De Schutter, P., Bosselaers, M., Van Boeckel, J., Cleemput, G. & Bor, T., 2020. Stratigraphy and palaeontology of the lower Miocene Kiel Sand Member (Berchem Formation) in temporary exposures in Antwerp (northern Belgium). Geologica Belgica, 23/3-4, 167-198. https://doi.org/10.20341/gb.2020.025

Hoedemakers, K. & Dufraing, L., 2018. Een profiel bij Posthofbrug (Antwerpen). Afzettingen WTKG 39, 3, 65-80.

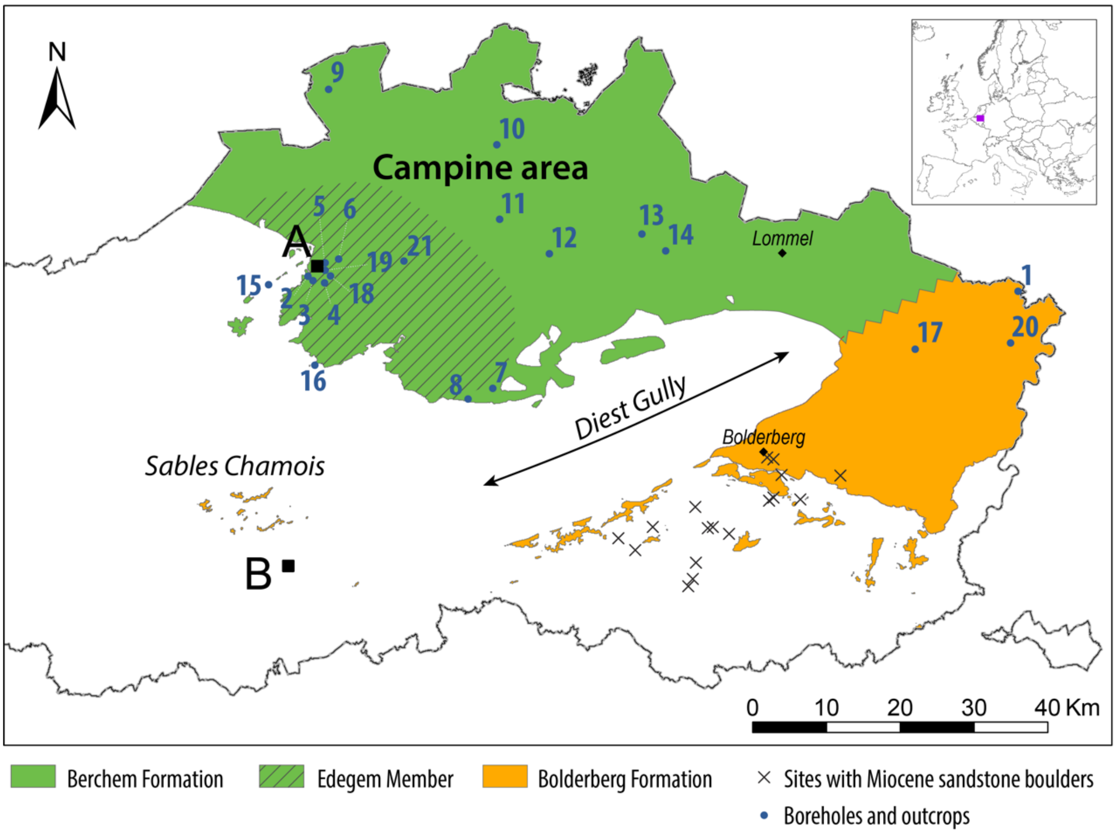
Hooyberghs, H.J.F., 1996. The stratigraphical position of the Edegem Sands Member (Berchem Formation, Miocene) in its type area at Wilrijk (N Belgium), based on planktonic foraminifera. – Geologie en Mijnbouw 75: 33-42.

Louwye, S., Marquet, R., Bosselaers, M. & Lambert, O., 2010. Stratigraphy of an Early-Middle Miocene sequence near Antwerp in northern Belgium (southern North Sea basin). Geologica Belgica, 13/3, 269-284.

Munsterman, D. & Deckers, J. ,2020. The Oligocene/Miocene boundary in the ON-Mol-1 and Weelde boreholes along the southern margin of the North Sea Basin, Belgium. Geologica Belgica, 13/3, 127-135.

Verhaegen, J., 2020. Stratigraphic discriminatory potential of heavy mineral analysis for the Neogene sediments of Belgium. Geologica Belgica, 23/3-4, 379-398. https://doi.org/10.20341/gb.2020.003

8.11 Annexes



Name	Code BGD	Code DOV	Nr
Molenbeersel	049W0225	kb18d49w-B225	1
Antwerp - Montignystraat	028W0394	kb15d28w-B448	2
Antwerp - Van Rijwijcklaan	028W0395	kb15d28w-B449	3
Berchem - Grote Steenweg	028W0397	kb15d28w-B451	4
Antwerp - Kievitstraat outcrop	028W0399	kb15d28w-B453	5
Borgerhout - Rivierenhof	028E0499	kb15d28e-B580	6
Zonderschoot		TO-19720101	7
Heist-op-den-Berg		kb24d59e-B180	8
Kalmthout	006E0110	kb7d6e-B239	9
Rijkevorsel	016E0153	kb8d16e-B36	10

Name	Code BGD	Code DOV	Nr
Oostmalle	029E0249	kb16d29e-B276	11
Poederlee	030W0300	kb16d30w-B315	12
Retie	031W0243	kb17d31w-B228	13
Mol	031W0221	kb17d31w-B212	14
Burcht outcrop		TO-20050101A	15
Terhagen outcrop		TO-20050101B	16
Wijshagen	048W0180	kb18d48w-B181	17
Berchem		TO-20150701	18
Antwerp		TO-20190417	19
Maaseik	049W0220	kb18d49w-B220	20
Oelegem	029W0378	kb16d29w-B401	21

Figure 8-1: Geographical distribution of the Berchem Formation in northern Belgium with locations of research boreholes and outcrops (Louwye et al., 2020).

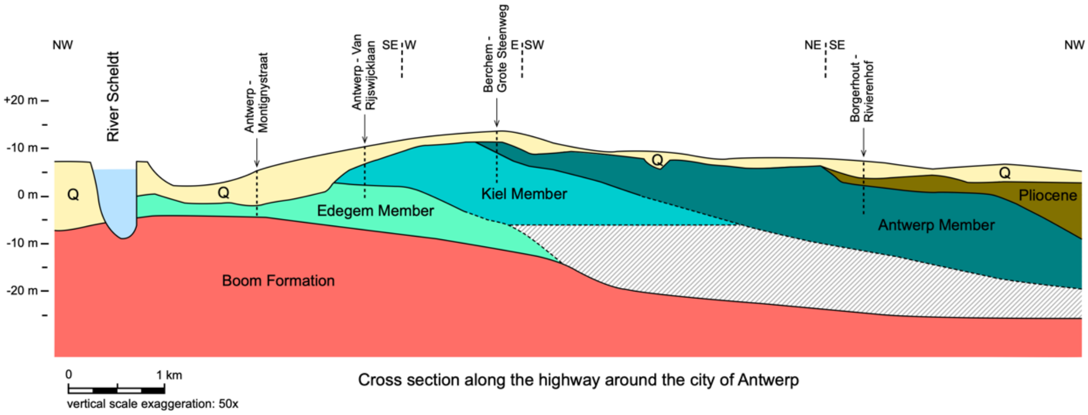


Figure 8-2: Geological cross-section of the Berchem Formation in the type area. See Louwye et al. (2020) for more information.

9 Edegem Member (Berchem Formation)

Unit name: Edegem Member

Hierarchical unit name: Berchem Formation

Type: Member

Code: BcEd

Author(s):

- Compiled by: Louwye Stephen, Adriaens Rieko, Deckers Jef, Everaert Stijn, Vandenberghe Noël, Verhaegen Jasper

- Modification of: De Meuter & Laga (1976)

Alternative names: This unit includes the Burcht gravel at its base.

Origin of the name: The origin of the name of the unit is discussed in De Meuter & Laga (1976) and Louwye et al. (2020).

Status: Formal

Date: 01/05/2022

How to refer: Louwye, S., Adriaens, R., Deckers, J., Everaert, S., Vandenberghe, N. & Verhaegen, J., 2023. The Edegem Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Edegem-Member

9.1 Characterizing description

The Edegem Member consists of green to greyish-green fine-grained, clayey and glauconitic sand (mode 190 µm ± 38 µm). The clay content is 4.7 ± 3.2% and the D90 of the grain size distribution is 284 ± 97 µm (De Meuter & Laga, 1976; Verhaegen, 2020). Large numbers of mollusks (Lucinoma borealis, Panopea meynardi, Pseudamussium lilli etc.) are dispersed throughout the sediment.

The granulometry of the Edegem Member displays an upwards coarsening signature as observed in two locations in the Antwerp area (Bastin, 1966), corroborated by the log-interpretation of the Edegem Member in borehole Oelegem. The grain-size distribution curves of glauconite are similar to the quartz grain size distribution curve. This indicates that the glauconites of the Edegem Member are reworked and were transported together with the quartz grains (Adriaens, 2015; Adriaens & Vandenberghe, 2020). The glauconite content of the Edegem Member is smaller than in the Antwerpen Member (Adriaens, 2015), which explains the paler color of sediments of the former compared to the latter.

9.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The name is derived from the type locality Edegem, a village circa 5 km south of Antwerp. According to De Meuter & Laga (1976), a type section was designated by Nyst (1861) in the (now disappeared) submerged Pauwels brickyard near Fortification VI at Wilrijk, south of Antwerp. No permanent outcropping type section for the member exists. The lithology of the member was described in following temporary outcrops in the Antwerpen area (see Figure 9-1 for a synthetic overview):

Antwerpen – Zuidstation III AR (De Meuter et al., 1976)

Antwerpen – Zuidstation VI AR (De Meuter et al., 1976)

Antwerpen – Zuidstation IV AR (De Meuter et al., 1976)

Antwerpen – Zuidstation V AR (De Meuter et al., 1976)

Antwerpen – Zuidstation AR (De Meuter et al., 1976)

Antwerpen – Montignystraat AM (De Meuter et al., 1976)

Antwerpen – Van Rijswijcklaan AV (De Meuter et al., 1976)

Antwerpen – Nachtegalenpark AN (De Meuter et al., 1976)

Wilrijk – Ter Weyde (Hooyberghs, 1996 & Hoedemakers & Dufraing, 2021)

Wilrijk – Revalidatiecentrum (Hoedemakers & Dufraing, 2021)

9.3 Description upper boundary

The Edegem Member is overlain by the Kiel Member of the Berchem Formation. This boundary coincides with an upwards decrease in shell and clay content, coarsening of the grain-size and generally with darkening of the sediment colour.

9.4 Description lower boundary

The base of the Edegem Member is formed by the Burcht gravel consisting of dark rounded flint pebbles, shell fragments, shark teeth and bone fragments. Reworked foraminifers, septaria and glauconite provide evidence for substantial reworking of sediment from the underlying lower Oligocene Boom Formation (Vandenberghe et al., 1998). Afterwards, the reworked septaria have been frequently drilled by Martesia rugosa (Janssen, 1964; Van der Mark, 1965).The Burcht gravel rests unconformably on the lower Oligocene Boom Formation.

9.5 Thickness

The Edegem Member reaches its maximum thickness of about 12 m just east of the city of Antwerp (Deckers et al., 2019).

9.6 Occurrence

According to De Meuter & Laga (1976), the Edegem Member crops out at the southern border of the province of Antwerp and is recorded in cores more to the north (the Antwerp Campine area).

9.7 Regional correlations

/

9.8 Age

The member holds the mid-Burdigalian NN3 Zone of Martini (1971) (Martini & Müller (1973), while Verbeek et al. (1988) propose a correlation with the Discoaster druggii NN2 Zone and the Sphenolithus belemnos NN3 Zone, indicative for an Aquitanian to Burdigalian age. Hooyberghs & Moorkens (1988) propose a correlation with the planktonic foraminifera NPF11 Globigerinoides primordius Zone defined by Spiegler et al. (1988), indicative of an Aquitanian age. According to Doppert et al. (1979), the benthic foraminifers from the Edegem Member point to the lower Miocene BFN1 Trifarina gracilis rugulosa – Elphidium ungeri Zone. Louwye et al. (2000) propose a late Aquitanian – early Burdigalian age (Cordosphaeridium cantharellus biozone) based on dinoflagellate cyst analysis (Figure 9-2). Radiometric dating was carried out on glauconite grains from the Edegem Member (Odin & Kreuzer, 1988). The glauconites in the Edegem Member are considered reworked and provide an erroneous age (K-Ar ages between 21.3 Ma and 26.6 Ma, i.e. an Aquitanian – Chattian age).

9.9 Dataset

Data in this LIS are part of the [DOV-Neogene data collection](), including links to the GSB-collection data sheets.

Subset of the lower and middle Miocene: https://www.dov.vlaanderen.be/data/opdracht/2020-022192

9.10 References

Adriaens, R., 2015. Neogene and Quaternary clay minerals in the southern North Sea. Unpublished Ph.D. Thesis, KU Leuven, Leuven, 272 p.

Adriaens, R. & Vandenberghe, N., 2020. Quantitative clay mineralogy as a tool for lithostratigraphy of Neogene Formations in Belgium: a reconnaissance study. Geologica Belgica 23/3-4: 365-378. https://doi.org/10.20341/gb.2020.018

Bastin, A., 1966. Sedimentpetrologie van de Zanden van Edegem en de Zanden van Antwerpen. Het Ingenieursblad, 35, 50.

Deckers, J., De Koninck, R., Bos, S., Broothaers, M., Dirix, K., Hambsch, L., Lagrou, D., Lanckacker, T., Matthijs, J., Rombaut, B., Van Baelen, K. & Van Haren, T., 2019. Geologisch (G3Dv3) en hydrogeologisch (H3D) 3D-lagenmodel van Vlaanderen. Studie uitgevoerd in opdracht van het Vlaams Planbureau voor Omgeving, departement Omgeving en de Vlaamse Milieumaatschappij. VITO, Mol, VITO- rapport 2018/RMA/R/1569.

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic foraminifera of the Neogene deposits in Northern Belgium. Bulletin Belgische Vereniging voor Geologie/Bulletin de la Société belge de Géologie, 85, 133–152.

De Meuter, F., Wouters, K. & Ringele, A., 1976. Lithostratigraphy from temporary outcrops in the Antwerpen City area. Professional Paper of the Geological Survey of Belgium, 3, 1–19.

Doppert, J.W.C., Laga, P. & De Meuter, F., 1979. Correlation of the biostratigraphy of marine Neogene deposits, based on benthonic foraminifera, established in Belgium and The Netherlands. Mededelingen Rijks Geologische Dienst, 31, 1–8.

Hoedemakers, K. & Dufraing, L., 2021. Elasmobranchii uit het Zand van Edegem (Mioceen van België). Afzettingen WTKG, 42, 2, 48-61.

Hooyberghs, H. & Moorkens, T., 1988. Planktonic foraminifera - Belgium. In Vinken, R. (ed.), The Northwest European Tertiary Basin. Geologisches Jahrbuch, Reihe A, 100, 190–198.

Hooyberghs, H.J.F., 1996. The stratigraphical position of the Edegem Sands Member (Berchem Formation, Miocene) in its type area at Wilrijk (N Belgium), based on planktonic foraminifera. – Geologie en Mijnbouw 75: 33-42.

Janssen, A.W., 1964. De E3 Scheldetunnel. Mededelingen van de Werkgroep voor Tertiaire en Kwartaire Geologie, 1, 50-54.

Louwye, S., De Coninck, J. & Verniers, J., 2000. Shallow marine Lower and Middle Miocene deposits at the southern margin of the North Sea Basin (northern Belgium): dinoflagellate cyst biostratigraphy and depositional history. Geological Magazine, 137, 381–393. https://doi.org/10.1017/s0016756800004258

Louwye, S., Deckers, J., Verhaegen, J., Adriaens, R. & Vandenberghe N., 2020. A review of the lower and middle Miocene of northern Belgium. Geologica Belgica, 23/3-4, 137-156. https://doi.org/10.20341/gb.2020.010

Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. In Farinacci, A. (ed.), Proceedings of the Second Planktonic Conference Roma 1970, 2 (ed. A.). Tecnoscienza, Roma, 739–785.

Martini, E. & Müller, C., 1973. Nannoplankton-Gemeinschaften im Miozän und Pliozän des Nordseebeckens. Neues Jahrbuch für Geologie und Paläontologie, Monatshefte, 9, 555–564.

Nyst, H., 1861. Notice sur un nouveau gîte de fossiles se rapportant aux espèces faluniennes du Midi de l'Europe, découvert à Edeghem, près d'Anvers. Bulletins de l'Académie royale des Sciences, des Lettres et des Beaux-Arts de Belgique, 2e série, 12, 29–53.

Odin, G.S. & Kreuzer, H., 1988. Geochronology: some geochronological calibrations points for lithostratigraphic units. In Vinken, R. (ed.), The Northwest European Tertiary Basin. Geologisches Jahrbuch, Reihe A, 100, 403–410.

Spiegler, D., Gramann, F. & Von Daniels, C.H., 1988. Planktonic foraminifera the description of the interregional zonation (NPF zones). In Vinken, R. (ed.), The Northwest European Tertiary Basin. Geologisches Jahrbuch, Reihe A, 100, 152–160.

Vandenberghe, N., Laga, P., Steurbaut, E., Hardenbol, J. & Vail, P. R., 1998. Tertiary sequence stratigraphy at the southern border of the North Sea Basin in Belgium. In de Graciansky, P.-C., Hardenbol, J., Jacquin, T. & Vail, P.R. (eds), Mesozoic and Cenozoic Sequence Stratigraphy of European Basins. SEPM Special Publication, 60, 119–154. https://doi.org/10.2110/pec.98.02.0119

Van der Mark, D., 1965. De samenstelling en het ontstaan van de Zanden van Edegem bij de E3 – tunnel te Antwerpen, in het bijzonder van de onderste lagen. Mededelingen van de Werkgroep voor Tertiaire en Kwartaire Geologie, 2, 47–61.

Verhaegen, J., 2020. Stratigraphic discriminatory potential of heavy mineral analysis for the Neogene sediments of Belgium. Geologica Belgica, 23/3-4, 379-398. https://doi.org/10.20341/gb.2020.003

Verbeek, J., Steurbaut, E. & Moorkens, T., 1988. Nannoplankton - Belgium. In Vinken, R. (ed.), The Northwest European Tertiary Basin. Geologisches Jahrbuch, Reihe A, 100, 267–273.

9.11 Annexes

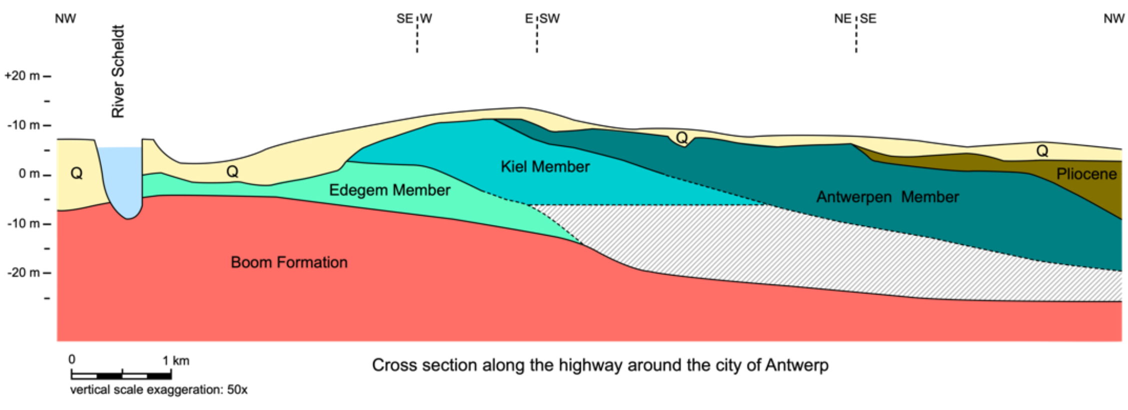


Figure 9-1. Geological cross-section of the Berchem Formation in the type area. See Louwye et al. (2020) for more information.

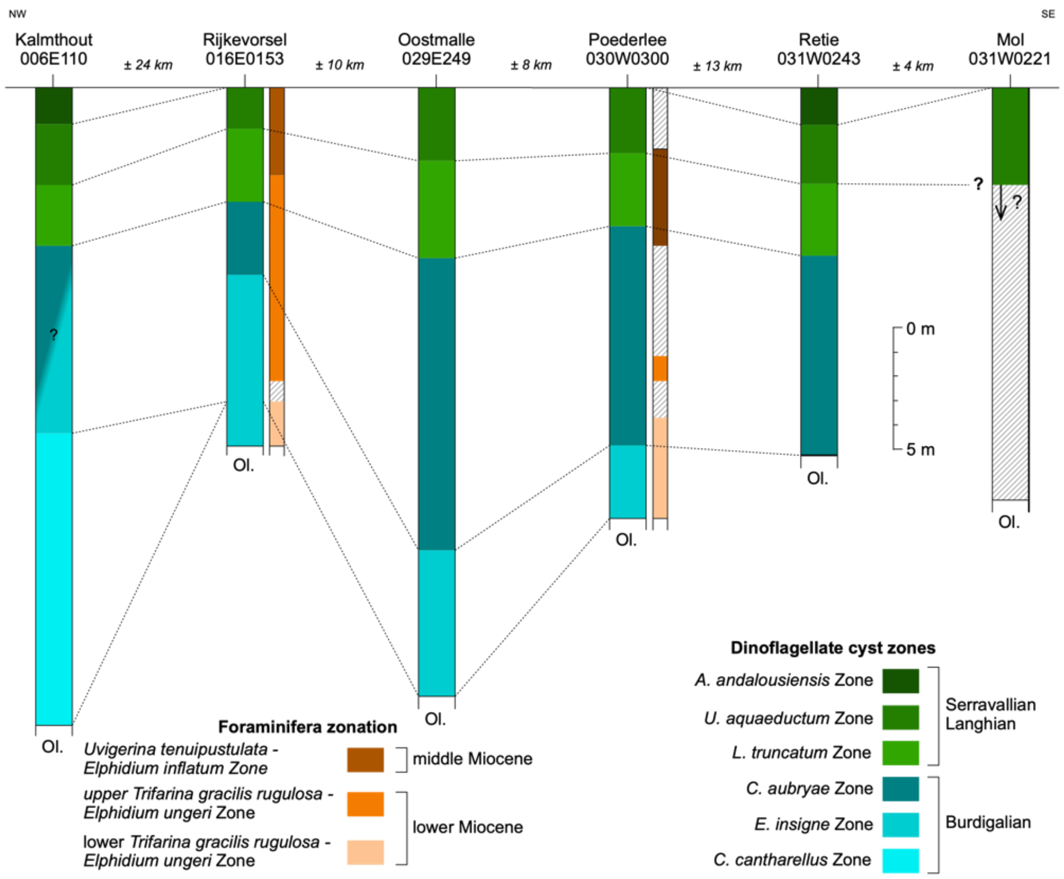


Figure 9-2. Distribution of lower and middle Miocene deposits in the Antwerp Campine area. See Louwye et al. (2020) for more information

10 Kiel Member (Berchem Formation)

Unit name: Kiel Member

Hierarchical unit name: Berchem Formation

Type: Member

Code: BcKi

Author(s):

- Compiled by: Louwye Stephen, Adriaens Rieko, Deckers Jef, Everaert Stijn, Vandenberghe Noël, Verhaegen Jasper

- Modification of: De Meuter & Laga (1976)

Alternative names: /

Origin of the name: The origin of the name of the unit is discussed in De Meuter & Laga (1976) and Louwye et al. (2020).

Status: Formal

Date: 01/05/2022

How to refer: Louwye, S., Adriaens, R., Deckers, J., Everaert, S., Vandenberghe, N. & Verhaegen, J., 2023. The Kiel Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Kiel-Member

10.1 Characterizing description

The Kiel Member was originally described as a non-fossiliferous (i.e. decalcified), grey-green medium fine-grained to coarse-grained sand (mode 248 µm ± 51 µm), very rich in glauconite, sometimes concentrated in patches, with rare clay streaks and sandstones. The clay content is 2.5 ± 1.3% and the D90 of the grain size distribution of 404 ± 108 µm, making the Kiel Member less clayey and with a larger coarse fraction compared to the underlying Edegem Member and overlying Antwerpen Member (De Meuter & Laga, 1976; Verhaegen, 2020). This facies occurs in the south and central part of the city of Antwerp (De Meuter & Laga, 1976). To the north and east of Antwerp this member becomes fossiliferous (Everaert et al., 2020). Everaert et al. (2020) studied several temporary outcrops of the Kiel Member in Antwerp and could distinguish the fossiliferous Kiel and Antwerpen members by a slight but marked color difference (greyish versus blackish) due to a somewhat lower clay and glauconite content and a coarser sand fraction in the Kiel Member. The glauconite content ranges from 28% to 54% and is on average 38% (Adriaens, 2015). The Kiel Member is characterized by a different ichnofacies, with the almost continuous presence of bioturbation. Everaert et al. (2020) described furthermore in great detail sandstone layers and shell layers (Glycymeris, Cordiopsis, Cyrtodaria), intercalated between several metres of loose grey sand, seemingly devoid of calcareous fossils. In contrast to the Antwerpen Member, the recorded molluscs are worn and very fragile due to heavy decalcification.

10.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

De Meuter & Laga (1976) mentioned Kiel, suburb of the city of Antwerp, as the type locality. No permanent outcropping type section for the member exists. The lithology of the member was described in following temporary outcrops in the Antwerpen area (see Figure 10-2 for a synthetic overview):

Antwerpen – Van Rijswijcklaan AV (De Meuter et al., 1976)

Antwerpen – Nachtegalenpark AN (De Meuter et al., 1976)

Berchem – Grote Steenweg AG (De Meuter et al., 1976)

Tweelingenstraat (Everaert et al., 2020)

Argenta (Everaert et al., 2020)

Post X (Everaert et al., 2020)

10.3 Description upper boundary

To the north and east, the Kiel Member is unconformably overlain by the Antwerpen Member of the Berchem Formation, locally characterized by load casts in the basal part of the Antwerpen Member. Biostratigraphic analysis with dinoflagellate cysts indicates that the hiatus between the Kiel Member and the Antwerpen Member increases in a northern direction (Everaert et al., 2020; Louwye et al., 2000), and probably corresponds to the Early Miocene Unconformity (EMU) (Munsterman et al, 2019). A sharp boundary between the Kiel and Antwerp members is also continuously found in the CPTs across the city of Antwerp, with higher qc values in the Kiel Member (12-14 MPa) compared to the Antwerpen Member (circa 8 MPa) (Deckers & Everaert, 2022).

10.4 Description lower boundary

The member rests on the Edegem Member of the Berchem Formation. Thin layers of coarser sand grains are occasionally present at the base of the unit (De Meuter & Laga, 1976) and a thin pebble layer was observed only in one outcrop (Vandenberghe et al., 1998).

10.5 Thickness

Based on the outcrop drawings by De Meuter et al. (1976) and CPTs, the Kiel Member has an approximate thickness of 10 m in the type area.

10.6 Occurrence

Deposits coeval with the Kiel Member are recorded in several boreholes north and east of the type area (Antwerp Campine area, Figure 10-2) reaching a thickness of circa 20 m (Louwye et al., 2020).

10.7 Regional correlations

/

10.8 Age

The radiometric dating of glauconites show diverging K-Ar ages (23 to 25.3 Ma; Chattian) and Rb-Sr ages (30 Ma; Rupelian) (Odin et al., 1974; Odin & Kreuzer, 1988, Vandenberghe et al., 2014) indicative of presumed reworking. This is underscored by the grain-size distribution curves (Adriaens, 2015). The Kiel Member holds the dinoflagellate cyst zones Exochosphaeridium insigne and Cousteaudinium aubryae, inferring a middle to late Burdigalian age (Louwye et al., 2000). An analysis of the dinoflagellate cysts of the Kiel Member by Everaert et al. (2020) indicates a similar age for the deposits, apart from a sample at the very base of a studied outcrop that yielded a deviating age (late Aquitanian) that needs further elucidation.

10.9 Dataset

Data in this LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the lower and middle Miocene: https://www.dov.vlaanderen.be/data/opdracht/2020-022192

10.10 References

Adriaens, R., 2015. Neogene and Quaternary clay minerals in the southern North Sea. Unpublished Ph.D. Thesis, KU Leuven, Leuven, 272 p.

Deckers, J. & Everaert, S., 2022. Distinguishing the Miocene Kiel and Antwerpen Members (Berchem Formation) and their characteristic horizons using Cone Penetration Tests in Antwerp (northern Belgium). Geological Journal. https://doi.org/10.1002/gj.4384

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic foraminifera of the Neogene deposits in Northern Belgium. Bulletin Belgische Vereniging voor Geologie/Bulletin de la Société belge de Géologie, 85, 133–152.

De Meuter, F., Wouters, K. & Ringele, A., 1976. Lithostratigraphy from temporary outcrops in the Antwerpen City area. Professional Paper of the Geological Survey of Belgium, 3, 1–19.

Everaert, S., Munsterman, D., De Schutter, P., Bosselaers, M., Van Boeckel, J., Cleemput, G. & Bor, T., 2020. Stratigraphy and palaeontology of the lower Miocene Kiel Sand Member (Berchem Formation) in temporary exposures in Antwerp (northern Belgium). Geologica Belgica, 23/3-4, 167-198. https://doi.org/10.20341/gb.2020.025

Louwye, S., De Coninck, J. & Verniers, J., 2000. Shallow marine Lower and Middle Miocene deposits at the southern margin of the North Sea Basin (northern Belgium): dinoflagellate cyst biostratigraphy and depositional history. Geological Magazine, 137, 381–393. https://doi.org/10.1017/s0016756800004258

Louwye, S., Deckers, J., Verhaegen, J., Adriaens, R. & Vandenberghe N., 2020. A review of the lower and middle Miocene of northern Belgium. Geologica Belgica, 23/3-4, 137-156. https://doi.org/10.20341/gb.2020.010

Munsterman, D.K., ten Veen, J.H., Menkovic, A., Deckers, J., Witmans, N., Verhaegen, J., Kerstholt-Boegehold, S.J., van de Ven, T. & Busschers, F.S., 2019. An updated and revised stratigraphic framework for the Miocene and earliest Pliocene strata of the Roer Valley Graben and adjacent blocks. Netherlands Journal of Geosciences, 98, e8. https://doi.org/10.1017/njg.2019.10

Odin, G.S. & Kreuzer, H., 1988. Geochronology: some geochronological calibrations points for lithostratigraphic units. In Vinken, R. (ed.), The Northwest European Tertiary Basin. Geologisches Jahrbuch, Reihe A, 100, 403–410.

Odin, G.S., Hunziker, J.C., Keppens, E., Laga P. & Pasteels, P., 1974. Analyse radiométrique de glauconies par les méthodes au strontium et à l'argon; l'Oligo-Miocène de Belgique. Bulletin de la Société belge de Géologie, 83, 35–48.

Vandenberghe, N., Laga, P., Steurbaut, E., Hardenbol, J. & Vail, P. R., 1998. Tertiary sequence stratigraphy at the southern border of the North Sea Basin in Belgium. In de Graciansky, P.-C., Hardenbol, J., Jacquin, T. & Vail, P.R. (eds), Mesozoic and Cenozoic Sequence Stratigraphy of European Basins. SEPM Special Publication, 60, 119–154. https://doi.org/10.2110/pec.98.02.0119

Vandenberghe, N., Harris, W.B., Wampler, J.M., Houthuys, R., Louwye, S., Adriaens, R., Vos, K., Lanckacker, T., Matthijs, J., Deckers, J., Verhaegen, J., Laga, P., Westerhoff, W. & Munsterman, D., 2014. The implications of K-Ar glauconite dating of the Diest Formation on the paleogeography of the Upper Miocene in Belgium. Geologica Belgica, 17, 161–174.

Verhaegen, J., 2020. Stratigraphic discriminatory potential of heavy mineral analysis for the Neogene sediments of Belgium. Geologica Belgica, 23/3-4, 379-398. https://doi.org/10.20341/gb.2020.003

10.11 Annexes

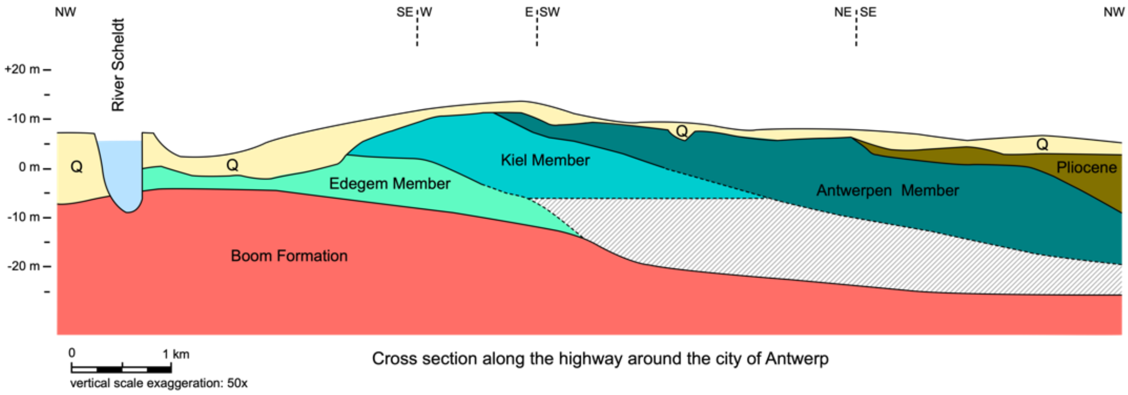


Figure 10-1 Geological cross-section of the Berchem Formation in the type area. See Louwye et al. (2020) for more information.

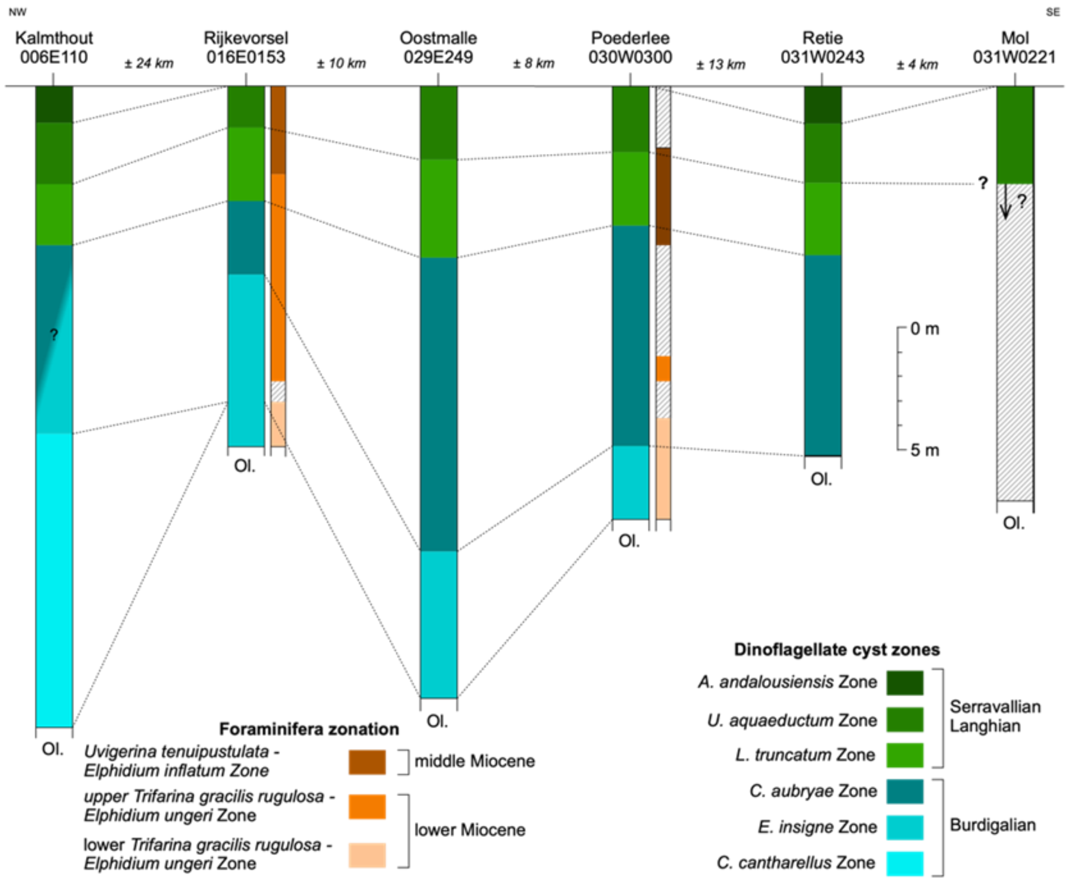


Figure 10-2: Distribution of lower and middle Miocene deposits in the Antwerp Campine area. See Louwye et al. (2020) for more information

11 Antwerpen Member (Berchem Formation)

Unit name: Antwerpen Member

Hierarchical unit name: Berchem Formation

Type: Member

Code: BcAn

Author(s):

- Compiled by: Louwye Stephen, Adriaens Rieko, Deckers Jef, Everaert Stijn, Vandenberghe Noël, Verhaegen Jasper

- Modification of: De Meuter & Laga (1976)

Alternative names: /

Origin of the name: The origin of the name of the unit is discussed in De Meuter & Laga (1976) and Louwye et al. (2020).

Status: Formal

Date: 01/05/2022

How to refer: Louwye, S., Adriaens, R., Deckers, J., Everaert, S., Vandenberghe, N. & Verhaegen, J., 2023. The Antwerpen Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Antwerpen-Member

11.1 Characterizing description

The Antwerpen Member consists of dark green to blackish, medium fine-grained, slightly clayey and very glauconitic sand with a mode of 219 µm ± 61 µm. The dispersed clay content is 3.7 ± 2.3% and the D90 of the grain size distribution is 352 ± 102 µm (De Meuter & Laga, 1976; Verhaegen, 2020). Characteristic are shell layers strongly dominated by Glycymeris baldii with a varying thickness. Some of these shell beds can be traced continuously across the entire type area (Deckers & Everaert, 2022). Layers with phosphatic concretions, friable sandstones, bones and shark teeth are present towards the base of the member. No clear basal gravel is present. The glauconite content ranges from 28% to locally as high as 85% and is on average 47%, which is the highest amount in any unit in the Campine Basin (Adriaens, 2015; Adriaens & Vandenberghe, 2020). The Antwerpen Member contains mostly authigenic glauconite (Vandenberghe et al., 2014; Odin & Kreuzer, 1988).

11.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

According to De Meuter & Laga (1976), the type locality of the member is the city centre of Antwerp. The original, and now disappeared, type section of the member was described during the excavations works for a fort at Antwerp (Nyst, 1845). Nowadays no permanent outcropping type section for the member exist. The lithology of the member was described in following temporary outcrops in the Antwerpen area (see Figure 11-1 for a synthetic overview):

Antwerpen – Berchem Station AM (De Meuter et al., 1976)

Antwerpen – Borbeeksepoort II BP (De Meuter et al., 1976)

Borgerhout – Stenen Brug I SB (De Meuter et al., 1976), revised by Deckers and Everaert (2022)

Borgerhout – Rivierenhof XI BR (De Meuter et al., 1976) correlated to CPT GEO-07/154-S11 by Deckers and Everaert (2022)

Antwerpen – Kievitstraat II, V, VI AK (De Meuter et al., 1976), revised by Everaert et al. (2020)

Posthofbrug (Louwye et al., 2010) correlated to CPT GEO-68/101-SVII by Deckers and Everaert (2022)

Posthofbrug 2-3 (Hoedemakers & Dufraing, 2018)

Tweelingenstraat (Everaert et al., 2020)

Argenta (Everaert et al., 2020)

Post X (Everaert et al., 2020)

11.3 Description upper boundary

In the greater Antwerp area, the member is unconformably covered by the Deurne/Borsbeek members of the Diest Formation (upper Miocene), the Pliocene Kattendijk and/or Lillo formations, reworked Pliocene deposits or the Quaternary (De Meuter et al., 1976). Often, a succession of compact Glycymeris shell beds forms the top of the Antwerpen Member (S3 in Deckers & Everaert, 2022), probably due to its stronger resistance against erosion.

11.4 Description lower boundary

The Antwerpen Member rests unconformably on the Kiel Member in the Antwerp area. This boundary displays the geometry of an unconformity, as the upper part of the Kiel Member disappears to the north of Antwerp (Louwye et al., 2000; Everaert et al., 2020). The basal part of the Antwerpen Member has a denser texture due to its finer admixture, with a slightly higher clay and silt content, in contrast to the Kiel Member. This locally gave rise to the development of load casting structures in the base of the Antwerpen Member. Locally, large lithified Ophiomorpha burrows are concentrated just below the base of the Antwerpen Member.

11.5 Thickness

Based on (sometimes lithostratigraphically revised) outcrop drawings by De Meuter et al. (1976) and correlations with nearby CPTs, the Antwerpen Member has an approximate thickness of 7 m in the type area.

11.6 Occurrence

Deposits coeval with the Antwerpen Member are recorded in several boreholes north (Antwerp Campine area) and east (Campine area) of the type area reaching a maximum thickness of c. 5 to 10 m (Louwye et al., 2020).

11.7 Regional correlations

/

11.8 Age

The planktonic foraminifers from the Antwerpen Member indicate the presence of the NPF12 Globogineroides trilobus Zone to the NPF13 Globorotalia praescitula Zone defined by Spiegler et al. (1988), and point towards a late Burdigalian to Langhian age. The benthic foraminifera from the Antwerpen Member are indicative for the mid-Miocene Uvigerina tenuipustulata – Elphidium inflatum Assemblage Zone (De Meuter & Laga, 1976), while the calcareous nannoplanton proposes a correlation with the late Burdigalian to Langhian NN4 Zone (Martini & Müller, 1973). Dinoflagellate cyst analysis demonstrates the presence of the Labyrinthodinium truncatum Zone, the Unipontidinium aquaeductus Zone and the Achomosphaera andalousiensis Zone and suggests deposition between 15.97 Ma and 12.8 Ma (Langhian – mid-Serravallian) (Louwye et al., 2000) (Figure 11-2). The radiometric datings of glauconites from the Antwerpen Member give a K-Ar age of 20 Ma and a Rb-Sr age of 18.5 Ma to 21.5 Ma (Odin & Kreuzer, 1988), i.e. a latest Aquitanian to mid-Burdigalian age.

Vandenberghe et al. (2014) and Adriaens (2015) attribute the diverging age assessment to the presence of reworked glauconite pellets.

11.9 Dataset

Data in this LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the lower and middle Miocene: https://www.dov.vlaanderen.be/data/opdracht/2020-022192

11.10 References

Adriaens, R., 2015. Neogene and Quaternary clay minerals in the southern North Sea. Unpublished Ph.D. Thesis, KU Leuven, Leuven, 272 p.

Adriaens, R. & Vandenberghe, N., 2020. Quantitative clay mineralogy as a tool for lithostratigraphy of Neogene Formations in Belgium: a reconnaissance study. Geologica Belgica 23/3-4, 365-378. https://doi.org/10.20341/gb.2020.018

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic foraminifera of the Neogene deposits in Northern Belgium. Bulletin Belgische Vereniging voor Geologie/Bulletin de la Société belge de Géologie, 85, 133–152.

De Meuter, F., Wouters, K. & Ringele, A., 1976. Lithostratigraphy from temporary outcrops in the Antwerpen City area. Professional Paper of the Geological Survey of Belgium, 3, 1–19.

Deckers, J. & Everaert, S., 2022. Distinguishing the Miocene Kiel and Antwerpen Members (Berchem Formation) and their characteristic horizons using Cone Penetration Tests in Antwerp (northern Belgium). Geological Journal. https://doi.org/10.1002/gj.4384

Everaert, S., Munsterman, D., De Schutter, P., Bosselaers, M., Van Boeckel, J., Cleemput, G. & Bor, T., 2020. Stratigraphy and palaeontology of the lower Miocene Kiel Sand Member (Berchem Formation) in temporary exposures in Antwerp (northern Belgium). Geologica Belgica, 23/3-4, 167-198. https://doi.org/10.20341/gb.2020.025

Hoedemakers, K. & Dufraing, L., 2018. Een profiel bij Posthofbrug (Antwerpen). Afzettingen WTKG 39, 3, 65-80.

Louwye, S., De Coninck, J. & Verniers, J., 2000. Shallow marine Lower and Middle Miocene deposits at the southern margin of the North Sea Basin (northern Belgium): dinoflagellate cyst biostratigraphy and depositional history. Geological Magazine, 137, 381–393. https://doi.org/10.1017/s0016756800004258

Louwye, S., Deckers, J., Verhaegen, J., Adriaens, R. & Vandenberghe N., 2020. A review of the lower and middle Miocene of northern Belgium. Geologica Belgica, 23/3-4: 137-156. https://doi.org/10.20341/gb.2020.010

Louwye, S., Marquet, R., Bosselaers, M. & Lambert, O., 2010. Stratigraphy of an Early-Middle Miocene sequence near Antwerp in northern Belgium (southern North Sea basin). Geologica Belgica, 13/3, 269-284.

Martini, E. & Müller, C., 1973. Nannoplankton-Gemeinschaften im Miozän und Pliozän des Nordseebeckens. Neues Jahrbuch für Geologie und Paläontologie, Monatshefte, 9, 555–564.

Nyst, P.-H., 1845. Description des coquilles et des polypiers fossiles des terrains tertiaires de la Belgique. Mémoires couronnés et mémoires des savants étrangers de l'Académie royale des Sciences et Belles-Lettres de Bruxelles, 17, 1–697.

Odin, G.S. & Kreuzer, H., 1988. Geochronology: some geochronological calibrations points for lithostratigraphic units. In Vinken, R. (ed.), The Northwest European Tertiary Basin. Geologisches Jahrbuch, Reihe A, 100, 403–410.

Spiegler, D., Gramann, F. & Von Daniels, C.H., 1988. Planktonic foraminifera the description of the interregional zonation (NPF zones). In Vinken, R. (ed.), The Northwest European Tertiary Basin. Geologisches Jahrbuch, Reihe A, 100, 152–160.

Vandenberghe, N., Harris, W.B., Wampler, J.M., Houthuys, R., Louwye, S., Adriaens, R., Vos, K., Lanckacker, T., Matthijs, J., Deckers, J., Verhaegen, J., Laga, P., Westerhoff, W. & Munsterman, D., 2014. The implications of K-Ar glauconite dating of the Diest Formation on the paleogeography of the Upper Miocene in Belgium. Geologica Belgica, 17, 161–174.

Verhaegen, J., 2020. Stratigraphic discriminatory potential of heavy mineral analysis for the Neogene sediments of Belgium. Geologica Belgica, 23/3-4, 379-398. https://doi.org/10.20341/gb.2020.003

11.11 Annexes

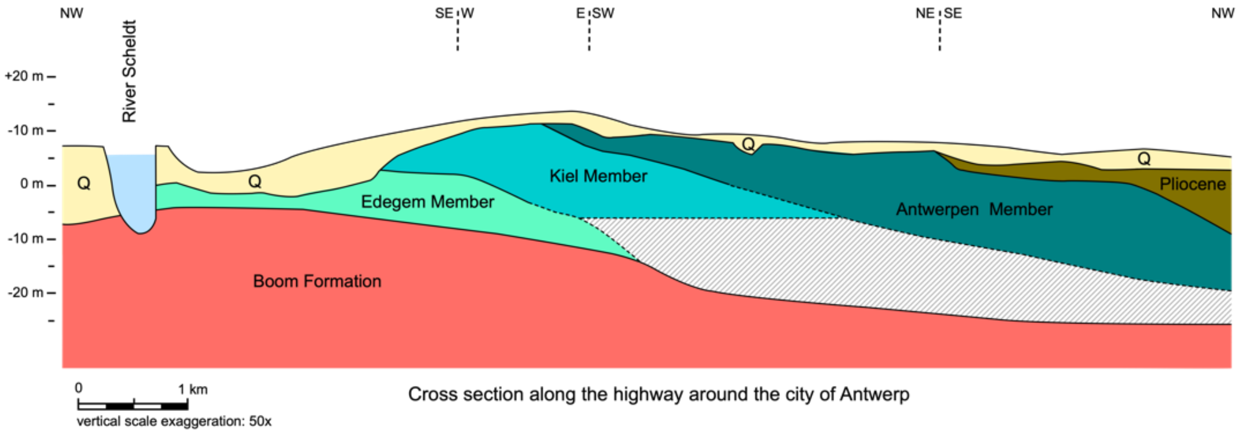


Figure 11-1. Geological cross-section of the Berchem formation in the type area. See Louwye et al. (2020) for more information.

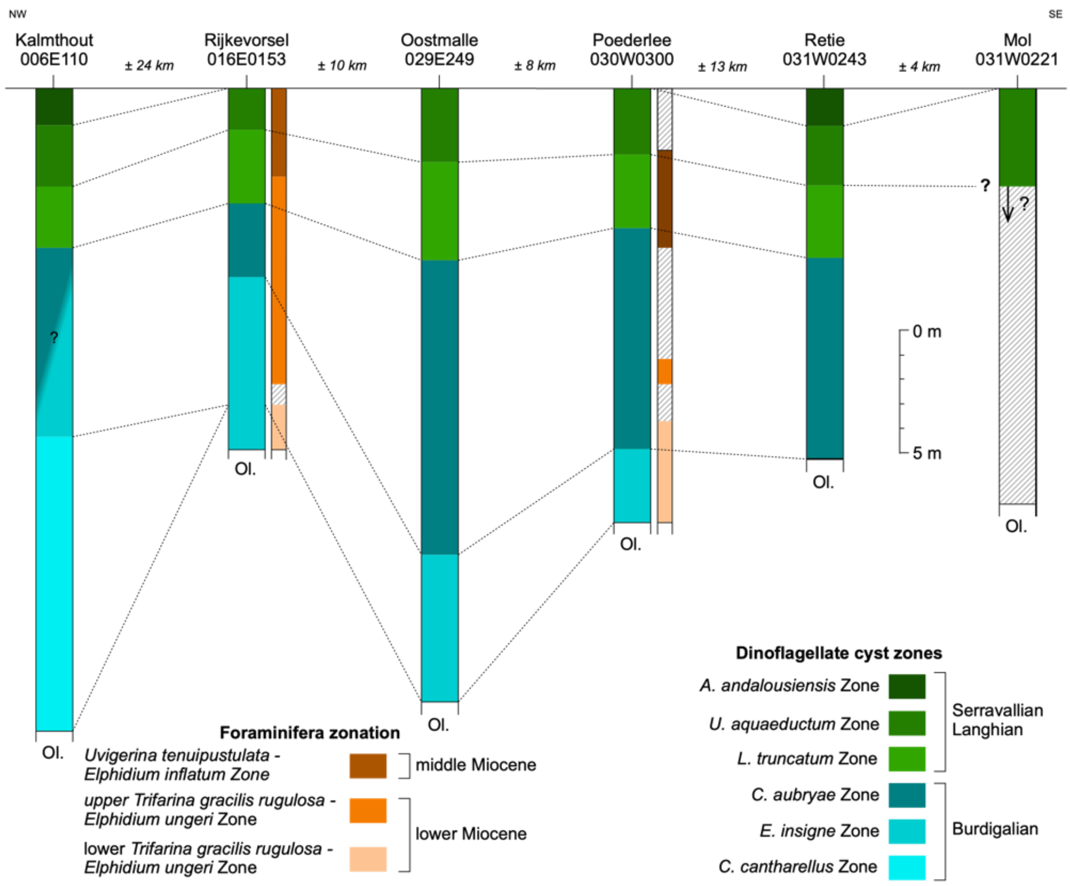


Figure 11-2 Distribution of lower and middle Miocene deposits in the Antwerp Campine area. See Louwye et al. (2020) for more information.

12 Zonderschot Member (Berchem Formation)

Unit name: Zonderschot Member

Hierarchical unit name: Berchem Formation

Type: Member

Code: BcZo

Authors:

- Compiled by: Louwye Stephen, Adriaens Rieko, Deckers Jef, Everaert Stijn, Vandenberghe Noël, Verhaegen Jasper

- Modification of: De Meuter & Laga (1976)

Alternative names: /

Origin of the name: The origin of the name of the unit is discussed in De Meuter & Laga (1976) and Louwye et al. (2020).

Status: Formal

Date: 01/05/2022

How to refer: Louwye, S., Adriaens, R., Deckers, J., Everaert, S., Vandenberghe, N. & Verhaegen, J., 2023. The Zonderschot Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Zonderschot-Member

12.1 Characterizing description

The member was formally described for the first time by De Meuter & Laga (1976) as a dark green, rather fine-grained, clayey, slightly ligniferous, very glauconitic sand, with a mode between 125 µm and 177 µm (Louwye et al., 2020; after Huyghebaert & Nolf, 1979). The micaceous sediment is very rich in homogeneously dispersed shells. The Zonderschot Member is finer grained than the other members of the Berchem Formation and has a higher clay content of approximately 12% (Huyghebaert & Nolf, 1979).

12.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The unit was described in detail in a 7 km long pipeline trench by Huyghebaert & Nolf (1979). The type locality is Zonderschot, a hamlet of Heist-op-den-Berg circa 30 km southeast of the Antwerpen. The location of the type section is given in Huyghebaert & Nolf (1979).

12.3 Description upper boundary

In the type area, the member is covered by Quaternary deposits and to the northeast and east by the upper Miocene Diest Formation.

12.4 Description lower boundary

The Zonderschot Member rest unconformably on the lower Oligocene Boom Formation. The member wedges out towards the south.

12.5 Thickness

Huyghebaert & Nolf (1979) noted a maximum thickness of 5 m in the type section.

12.6 Occurrence

The geographical distribution of the Zonderschot Member is not well known and is probably restricted because of the lack of outcrops and cored drillings.

12.7 Regional correlations

The Zonderschot Member is coeval with the lower part of the Antwerpen Member of the Berchem Formation (Louwye, 2000), and differs lithologically by the presence of mica and lignite.

12.8 Age

The planktonic foraminifers belong to the Globigerinoides trilobus trilobus/Globigerinoides altiaperturus Biozone (Blow, 1969) or the Biozone N6 or Biozone N7 (Hooyberghs, 1996), which indicates at least a Burdigalian age. The Zonderschot Member holds the benthic foraminifers of the middle Miocene Uvigerina tenuipustulata – Elphidium inflatum BFN2 Zone (De Meuter & Laga, 1976; Doppert et al., 1979; De Meuter, 1980). The calcareous nannoplankton from the Zonderschot Member indicates the presence of the NN4 Zone, and a late Burdigalian to early Langhian age is inferred (Verbeek et al., 1988). The dinoflagellate cysts indicate the presence of the early Langhian Labyrinthodinium truncatum Zone by Dybkjær & Piasecki (2010).

12.9 Dataset

Data in this LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the lower and middle Miocene: https://www.dov.vlaanderen.be/data/opdracht/2020-022192

12.10 References

Blow, W., 1969. Late middle Eocene to Recent planktonic foraminiferal biostratigraphy. In Bronnimann, P. & Renz, H. (eds), Proceedings of the First International Conference on Planktonic Microfossils, Geneva. Brill, Leiden, 199–421.

De Meuter, F., 1980. Benthonic foraminifera from the Miocene of Belgium. Aardkundige Mededelingen, 1, 78–170.

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic foraminifera of the Neogene deposits in Northern Belgium. Bulletin Belgische Vereniging voor Geologie/Bulletin de la Société belge de Géologie, 85, 133–152.

Doppert, J.W.C., Laga, P. & De Meuter, F., 1979. Correlation of the biostratigraphy of marine Neogene deposits, based on benthonic foraminifera, established in Belgium and The Netherlands. Mededelingen Rijks Geologische Dienst, 31, 1–8.

Dybkjær, K. & Piasecki, S., 2010. Neogene dinocyst zonation for the eastern North Sea Basin, Denmark. Review of Palaeobotany and Palynology, 161, 1–29. https://doi.org/10.1016/j.revpalbo.2010.02.005

Hooyberghs, H., 1996. Planktonic foraminifera from the Zonderschot Sands Member of the Berchem Formation (Miocene) at Zonderschot, Belgium. Tertiary Research, 17, 15–25.

Huyghebaert, B., 1978. Teleostei-otolieten en stratigrafie van de Zanden van Zonderschot (Midden Mioceen van Belgie). Unpublished Master Thesis, Universiteit Gent, Gent, 67 p.

Huyghebaert, B. & Nolf, D., 1979. Otolithes de Téléostéens et biostratigraphie des Sables de Zonderschot (Miocène Moyen de la Belgique). Mededelingen van de Werkgroep voor Tertiaire en Kwartaire Geologie, 16/2, 59–100.

Louwye, S. (2000). Dinoflagellate cysts and acritarchs form the Miocene Zonderschot Sands, northern Belgium: stratigraphic significance and correlation with contiguous areas. Geologica Belgica, 3/1, 55-65.

Louwye, S., Deckers, J., Verhaegen, J., Adriaens, R. & Vandenberghe N., 2020. A review of the lower and middle Miocene of northern Belgium. Geologica Belgica, 23/3-4, 137-156. https://doi.org/10.20341/gb.2020.010

Verbeek, J., Steurbaut, E. & Moorkens, T., 1988. Nannoplankton - Belgium. In Vinken, R. (ed.), The Northwest European Tertiary Basin. Geologisches Jahrbuch, Reihe A, 100, 267–273.

13 Bolderberg Formation

Unit name: Bolderberg Formation

Hierarchical unit name: /

Type: Formation

Code: Bb

Author(s):

- Compiled by: Deckers Jef & Louwye Stephen

Alternative names: /

Origin of the name: The origin of the unit name is discussed in De Meuter & Laga (1976).

Status: Formal

Date: 01/05/2022

How to refer: Deckers, J. & Louwye, S., 2023. The Bolderberg Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Bolderberg-Formation

13.1 Characterizing description

The lithology of the Bolderberg Formation consists in the eastern part of northern Belgium at the base of dark green, often clayey, medium fine-grained sandy unit, micaceous, slightly ligniferous and glauconitic (i.e. the Houhalen Member), grading into fine-grained to fairly coarse-grained sand with lignite and gravel layers (i.e. the Genk Member) (Louwye et al. 2020). The boundary between both facies is not sharp but gradual. The basal gravel layer (the Elsloo gravel) consists of rounded pebbles and shark teeth. A third lithofacies is encountered in the very eastern part of the Limburg Province, namely a medium-grained, white sandy unit holding a lignite seam (the Kikbeek lignite) and a quartzite layer, called the Opgrimbie Facies) (Gullentops, 1963, 1972-1973; Matthijs, 1999). The isolated Heizel Facies occurs west of Brussels and consists of yellow-brown, micaceous, fine-grained sand with thin clay layers (Gulinck, 1956, 1959)

13.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The type locality is the village of Bolderberg, about 10 km north of Hasselt (Limburg province). The type sections of the formation are the now disappeared outcrops (road cuttings) on the Bolderberg hill.

The Gruitrode borehole (DOV kb18d48w-B186; GSB 048W0185) is a type geophysical borehole with the Bolderberg Formation between 92 m and 178 m depth on top of the Voort Formation and below the Diest Formation, according to Louwye et al. (2020).

13.3 Description upper boundary

The Bolderberg Formation is covered unconformably by the basal gravel of the Diest Formation, the Molenbeersel Formation near the Roer Valley graben or Quaternary deposits.

13.4 Description lower boundary

The Bolderberg Formation rests unconformably on the upper Oligocene deposits.

13.5 Thickness

The thickness generally increases in northeastern direction across the Campine area and reaches around 80 m just to the west or in the footwall of the border fault system of the Roer Valley Graben (Deckers et al., 2019).

The thickness further increases into the Roer Valley Graben where it reaches its maximum of 155 m in the Molenbeersel borehole (DOV kb18d49w-B225; GSB 049W0225; Figure 13-2).

13.6 Occurrence

The Bolderberg Formation occurs in the eastern part of northern Belgium, in exposures in the hills around and to the south of Diest (Brabant province), and in the top of the hills west of Brussels (see Figure 13-1).

13.7 Regional correlations

The Bolderberg Formation can largely be correlated with the Berchem Formation which occurs in the eastern part of northern Belgium.

13.8 Age

The Bolderberg Formation has a confirmed late Burdigalian to early Serravallian age through dinoflagellate cyst analysis (Deckers & Louwye, 2017).

13.9 Dataset

Data in this LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Molenbeersel borehole	049W0225	kb18d49w-B225	http://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0225.txt	https://www.dov.vlaanderen.be/data/boring/1985-082429
Gruitrode borehole	048W0185	kb18d48w-B186	http://collections.naturalsciences.be/ssh-geology-archives/arch/048w/048w0185.txt	https://www.dov.vlaanderen.be/data/boring/1984-024471

13.10 References

Deckers, J., De Koninck, R., Bos, S., Broothaers, M., Dirix, K., Hambsch, L., Lagrou, D., Lanckacker, T., Matthijs, J., Rombaut, B., Van Baelen, K. & Van Haren, T., 2019. Geologisch (G3Dv3) en hydrogeologisch (H3D) 3D-lagenmodel van Vlaanderen. Studie uitgevoerd in opdracht van het Vlaams Planbureau voor Omgeving, departement Omgeving en de Vlaamse Milieumaatschappij. VITO, Mol, VITO-rapport 2018/RMA/R/1569. https://archief-algemeen.omgeving.vlaanderen.be/xmlui/handle/acd/251494

Deckers, J. & Louwye, S., 2017. A reinterpretation of the ages and depositional environments of the lower and middle Miocene stratigraphic records in a key area along the southern margin of the North Sea Basin. Geological Magazine, 156, 525–532. https://doi.org/10.1017/s0016756817000991

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic foraminifera of the Neogene deposits in Northern Belgium. Bulletin Belgische Vereniging voor Geologie/Bulletin de la Société belge de Géologie, 85, 133–152.

Gulinck, M., 1956. Note sur la formation des ‘Sables Chamois’ (Néogène) de la région du Heysel. Bulletin de la Société belge de Géologie, de Paléontologie et d’Hydrologie, 65, 227–229.

Gulinck, M., 1959. Sur l’extension, en Campine, des “Sables Chamois” du Heysel. Bulletin de la Société belge de Géologie, 68, 371-372.

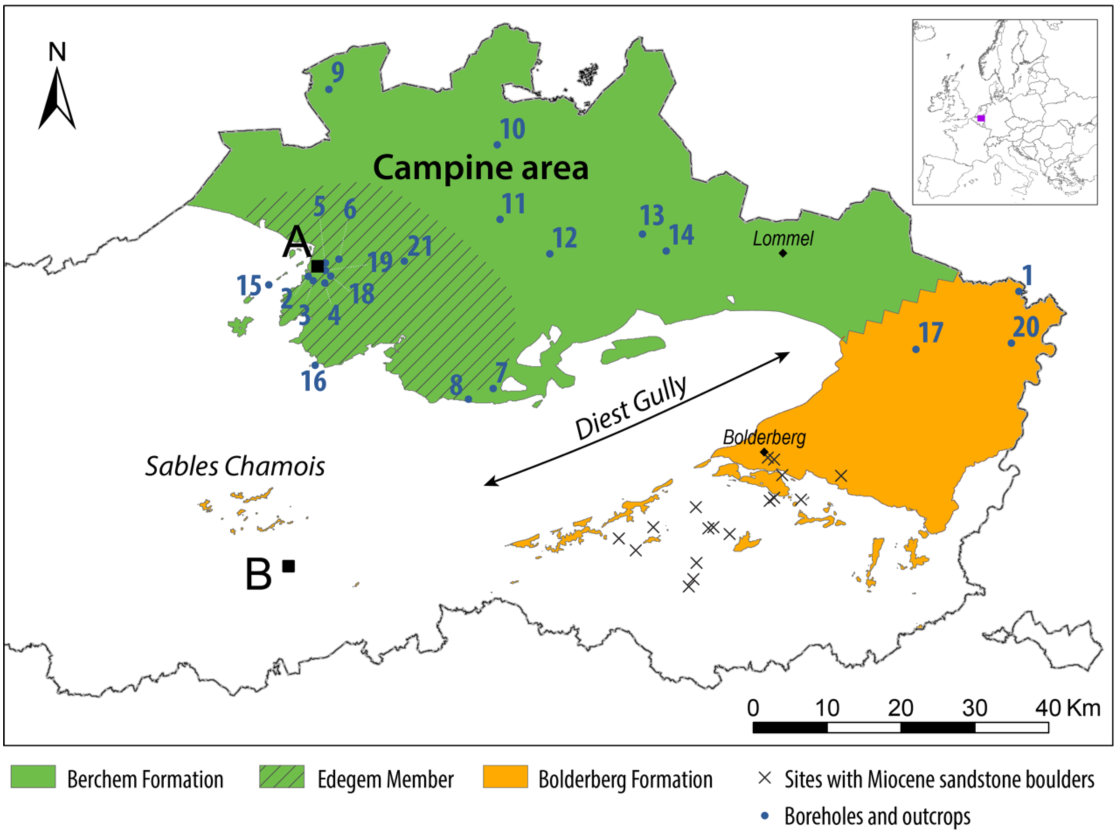
Gullentops, F., 1963. Etude de divers faciès quaternaires et tertiaires dans le Nord et l’Est de la Belgique. 6e Congrès International de Sédimentologie, Belgique et Pays-Bas, 20 p.

Gullentops, F., 1972-1973. Grainsize and mineralogy of Miocene glass- sands of Maasmechelen, Belgian Limburg. Mededelingen Rijks Geologische Dienst, 23, 25–34.

Louwye, S., Deckers, J., Verhaegen, J., Adriaens, R. & Vandenberghe N., 2020. A review of the lower and middle Miocene of northern Belgium. Geologica Belgica, 23/3-4, 137-156. https://doi.org/10.20341/gb.2020.010

Matthijs J., 1999. Toelichtingen bij de geologische kaart van België, Vlaams Gewest: kaartblad 25, Hasselt [1/50 000]. Belgische Geologische Dienst en Ministerie van de Vlaamse Gemeenschap, Afdeling Natuurlijke Rijkdommen en Energie, Brussel, 104 p.

13.11 Annexes



Name	Code BGD	Code DOV	Nr
Molenbeersel	049W0225	kb18d49w-B225	1
Antwerp - Montignystraat	028W0394	kb15d28w-B448	2
Antwerp - Van Rijwijcklaan	028W0395	kb15d28w-B449	3
Berchem - Grote Steenweg	028W0397	kb15d28w-B451	4
Antwerp - Kievitstraat outcrop	028W0399	kb15d28w-B453	5
Borgerhout - Rivierenhof	028E0499	kb15d28e-B580	6
Zonderschoot		TO-19720101	7
Heist-op-den-Berg		kb24d59e-B180	8
Kalmthout	006E0110	kb7d6e-B239	9
Rijkevorsel	016E0153	kb8d16e-B36	10

Name	Code BGD	Code DOV	Nr
Oostmalle	029E0249	kb16d29e-B276	11
Poederlee	030W0300	kb16d30w-B315	12
Retie	031W0243	kb17d31w-B228	13
Mol	031W0221	kb17d31w-B212	14
Burcht outcrop		TO-20050101A	15
Terhagen outcrop		TO-20050101B	16
Wijshagen	048W0180	kb18d48w-B181	17
Berchem		TO-20150701	18
Antwerp		TO-20190417	19
Maaseik	049W0220	kb18d49w-B220	20
Oelegem	029W0378	kb16d29w-B401	21

Figure 13-1: Geographical distributionof the Berchem Formation in northern Belgium with locations of research boreholes and outcrops (Louwye et al., 2020).

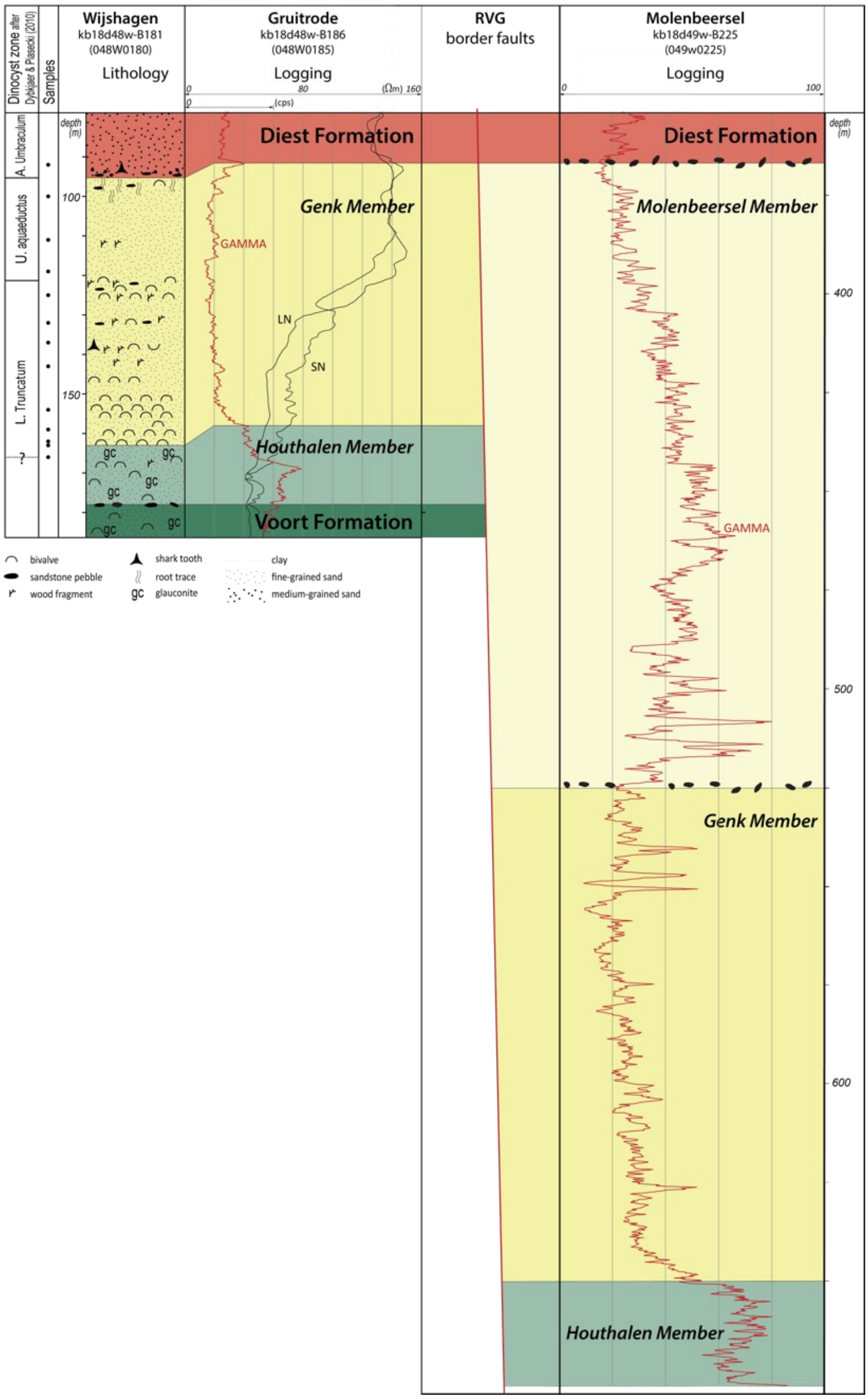


Figure 13-2: The Bolderberg Formation in the Wijshagen, Gruitrode and Molenbeersel wells. See Louwye et al. (2020) for further information.

14 Houthalen Member (Bolderberg Formation)

Unit name: Houthalen Member

Hierarchical unit name: Bolderberg Formation

Type: Member

Code: BbHo

Author(s):

- Compiled by: Louwye Stephen, Adriaens Rieko, Deckers Jef, Vandenberghe Noël, Verhaegen Jasper

- Modification of: Tavernier & De Heinzelin (1963); revised by De Meuter & Laga (1976)

Alternative names: This unit includes the Elsloo gravel at its base.

Origin of the name: The origin of the name of the unit is discussed in De Meuter & Laga (1976) and Louwye et al. (2020).

Status: Formal

Date: 01/05/2022

How to refer: Louwye, S., Adriaens, R., Deckers, J. Vandenberghe, N. & Verhaegen, J., 2023. The Houthalen Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Houthalen-Member

14.1 Characterizing description

The Houthalen Member is a dark green, often clayey, medium fine-grained sandy unit, micaceous, slightly ligniferous and glauconitic. Dispersed and concentrated mollusks occur which are also reworked in the basal gravel of the superjacent Diest Formation (De Meuter & Laga, 1976). The Houthalen Member has an average glauconite content of 17% (Adriaens, 2015). The Elsloo gravel at the base of the Houthalen Member consists of reworked Oligocene components, dark blue, egg-shaped, indented phosphate pebbles and shark teeth (Vandenberghe et al., 1998).

14.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The type locality is Houthalen (north of Hasselt). The type section is the mine shaft “Puits no. 1)” of the Houthalen coal mine (De Meuter & Laga, 1976; after Glibert, 1945). The Houthalen Member in the Wijshagen borehole (DOV kb18d48w-B181; GSB 048W0180; depth 162 m to probably 178 m) is an alternative type section. The Houthalen borehole (DOV kb25d62e-B274; GSB 062E0270) is a type geophysical borehole with the Houthalen Member expressed by high gamma-ray and low resistivity values between 90 m and 101 m depth.

14.3 Description upper boundary

The boundary with the superjacent Genk Member is gradual and not easily discerned, and coincides with an upwards decrease in glauconite content and therefore change towards paler colours. On borehole logs, this boundary is expressed by a strong upwards decrease in gamma-ray values and increase in resistivity values.

14.4 Description lower boundary

The Houthalen Member rests with the basal Elsloo Gravel unconformably on the Oligocene Voort Formation. The lower boundary is geophysically not easily detected but coincides regularly with an upward increase of the gamma ray values and a decrease of the resistivity values (Deckers et al. 2019).

14.5 Thickness

11 m in the Houthalen borehole (DOV kb25d62e-B274; GSB 062E0270), 16 m in the Wijshagen borehole (DOV kb18d48w-B181; GSB 048W0180) and reaches a maximum of 30 m in the Molenbeersel boreholes (DOV kb18d49w-B225 and kb18d49w-B226; GSB 049W0225 and 049W0226) in the differentially subsiding Roer Valley Graben.

14.6 Occurrence

The Houthalen Member occurs in the subsoil of the type area and outcrops in the hills near Bolderberg, Waanrode (south of the city of Diest) and Lubbeek (De Meuter & Laga, 1976).

14.7 Regional correlations

Louwye et al. (2020) consider the greater part of the Houthalen Member coeval with the Edegem and Kiel members, while the topmost part probably correlates with the lower part of the Antwerp and Zonderschot members. It correlates with the Kakert Member of the Groote Heide Formation in the Netherlands (Deckers & Munsterman, 2020).

14.8 Age

The benthic foraminifers from the Houthalen Member were extensively studied by De Meuter (1980), De Meuter & Laga (1976) and Willems et al. (1988) and indicated deposition during early Miocene times. The analysis of the planktonic foraminifera (Hooyberghs & De Meuter, 1972; Hooyberghs, 1983; Hooyberghs & Moorkens, 1988) indicates deposition during the Burdigalian. Nannoplankton studies (Martini & Müller, 1973; Verbeek et al., 1988) point towards a lower Miocene age. Wouters (1978) recognised the lower Miocene U2 Ostracoda Zone, while Gaemers (1988) reports the presence of the late Burdigalian to Langhian otolith Zones 12/13.

14.9 Dataset

Data in this LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the lower and middle Miocene: https://www.dov.vlaanderen.be/data/opdracht/2020-022192

14.10 References

Adriaens, R., 2015. Neogene and Quaternary clay minerals in the southern North Sea. Unpublished Ph.D. Thesis, KU Leuven, Leuven, 272 p.

Deckers, J., De Koninck, R., Bos, S., Broothaers, M., Dirix, K., Hambsch, L., Lagrou, D., Lanckacker, T., Matthijs, J., Rombaut, B., Van Baelen, K. & Van Haren, T., 2019. Geologisch (G3Dv3) en hydrogeologisch (H3D) 3D-lagenmodel van Vlaanderen. Studie uitgevoerd in opdracht van het Vlaams Planbureau voor Omgeving, departement Omgeving en de Vlaamse Milieumaatschappij. VITO, Mol, VITO- rapport 2018/RMA/R/1569.

Deckers, J. & Louwye, S., 2019. Late Miocene increase in sediment accommodation rates in the southern North Sea Basin. Geological Journal, 55, 728–736. https://doi.org/10.1002/gj.3438

Deckers, J., & Munsterman, D., 2020. Middle Miocene depositional evolution of the central Roer Valley Rift System. Geological Journal, 1–10, https://doi.org/10. 1002/gj.3799

De Meuter, F., 1980. Benthonic foraminifera from the Miocene of Belgium. Aardkundige Mededelingen, 1, 78–170.

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic foraminifera of the Neogene deposits in Northern Belgium. Bulletin Belgische Vereniging voor Geologie/Bulletin de la Société belge de Géologie, 85, 133–152.

Gaemers, P.A.M., 1988. The regional distribution of otolith assemblages; correlation of the interregional zonation with the regional lithostratigraphic formations. In Vinken, R. (ed.), The Northwest European Tertiary Basin. Geologisches Jahrbuch, Reihe A, 100, 379–389.

Glibert, M., 1945. Faune malacologique du Miocène de la Belgique. I. Pélécypodes. Mémoires de l'Institut Royal des Sciences naturelles de Belgique, 103, 1–263.

Hooyberghs, H. & De Meuter, F., 1972. Biostratigraphy and interregional correlation of the Miocene deposits of Northern Belgium based on planktonic foraminifera; the Oligocene-Miocene boundary on the southern edge of the North Sea Basin. Mededelingen van de Koninklijke Academie voor Wetenschappen, Letteren en Schone Kunsten van België, Klasse der Wetenschappen, 34, 3, 1–47.

Hooyberghs, H., 1983. Contribution to the study of planktonic foraminifera in the Belgian Tertiary. Aardkundige Mededelingen, 2, 1–131.

Hooyberghs, H. & Moorkens, T., 1988. Planktonic foraminifera - Belgium. In Vinken, R. (ed.), The Northwest European Tertiary Basin. Geologisches Jahrbuch, Reihe A, 100, 190–198.

Louwye, S., Deckers, J., Verhaegen, J., Adriaens, R. & Vandenberghe N., 2020. A review of the lower and middle Miocene of northern Belgium. Geologica Belgica, 23/3-4, 137-156. https://doi.org/10.20341/gb.2020.010

Martini, E. & Müller, C., 1973. Nannoplankton-Gemeinschaften im Miozän und Pliozän des Nordseebeckens. Neues Jahrbuch für Geologie und Paläontologie, Monatshefte, 9, 555–564.

Tavernier, R. & de Heinzelin, J., 1963. Introduction au Néogène de la Belgique. Mémoires de la Société belge de Géologie, de Paléontologie et d'Hydrologie, série in-8°, 6, 7–30.

Vandenberghe, N., Laga, P., Steurbaut, E., Hardenbol, J. & Vail, P. R., 1998. Tertiary sequence stratigraphy at the southern border of the North Sea Basin in Belgium. In de Graciansky, P.-C., Hardenbol, J., Jacquin, T. & Vail, P.R. (eds), Mesozoic and Cenozoic Sequence Stratigraphy of European Basins. SEPM Special Publication, 60, 119–154. https://doi.org/10.2110/pec.98.02.0119

Verbeek, J., Steurbaut, E. & Moorkens, T., 1988. Nannoplankton - Belgium. In Vinken, R. (ed.), The Northwest European Tertiary Basin. Geologisches Jahrbuch, Reihe A, 100, 267–273.

Willems, W., Laga, P. & Moorkens, T., 1988. Benthic foraminifera - Belgium. In Vinken, R. (ed.), The Northwest European Tertiary Basin. Geologisches Jahrbuch, Reihe A, 100, 179–188.

Wouters, K. 1978. Een systematische, biostratigrafische en paleobiologische studie van de Ostracoda uit de Miocene afzettingen in Noord-België. Unpublished Ph.D. Thesis, KU Leuven, Leuven, 3 vol.

15 Genk Member (Bolderberg Formation)

Unit name: Genk Member

Hierarchical unit name: Bolderberg Formation

Type: Member

Code: BbGe

Author(s):

- Compiled by: Louwye Stephen, Adriaens Rieko, Deckers Jef, Vandenberghe Noël, Verhaegen Jasper

- Modification of: de Heinzelin & Glibert (1956); revised by De Meuter & Laga (1976)

Alternative names: /

Origin of the name: The origin of the name of the unit is discussed in De Meuter & Laga (1976) and Louwye et al. (2020).

Status: Formal

Date: 01/05/2022

How to refer: Louwye, S., Adriaens, R., Deckers, J. Vandenberghe, N. & Verhaegen, J., 2023. The Genk Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Genk-Member

15.1 Characterizing description

Fine-grained to fairly coarse-grained sand with lignite and gravel layers (De Meuter & Laga, 1976; Louwye et al., 2020). Lignite is generally dispersed, but can locally form about 3 m thick complexes as observed in the Sibelco sand pit in Opgrimbie (Gullentops, 1963, 1972-1973). Molluscs are generally lacking, but become apparent in the northernmost parts of occurrences, such as the Wijshagen and Molenbeersel boreholes (Deckers & Louwye, 2017). The Genk Member has a modal grain size of 172 ± 12 µm, a clay content of 2.1 ± 0.7% and a D90 of 411 ± 274 µm, based on a small amount of samples (Verhaegen, 2020). One of those samples has a second coarse mode of 623 µm explaining also the large variation in D90. The colour of the sand is yellowish in the east Brabant area, brownish to yellowish in the subsurface in the Hasselt area and becomes white in the easternmost part of Limburg (Opgrimbie Facies).

15.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The type locality is Genk. The first type section defined was in a now disappeared sand quarry near the railway station of Genk (De Meuter & Laga, 1976, after Mourlon, 1898). The Genk Member in the Wijshagen borehole (DOV kb18d48w-B181; GSB 048W0180; depth 94 m and 162 m) is an alternative type section. The Gruitrode borehole (DOV kb18d48w-B186; GSB 048W0185) is a type geophysical borehole (located near the Wijshagen borehole) with the Genk Member expressed by low gamma-ray and high resistivity values between 92 m and 159 m depth.

15.3 Description upper boundary

The Genk Member is unconformably covered by the basal gravel of the Diest Formation or by the Molenbeersel Formation in the easternmost part of the Limburg province (Molenbeersel wells DOV kb18d49w-B225 and kb18d49w-B226; GSB 049W0225 and 049W0226, Roer Valley Graben).

15.4 Description lower boundary

The boundary with the subjacent Houthalen Member is gradual and characterized by a downward increase in glauconite.

15.5 Thickness

The thickness of the Genk Member is 68 m in the Wijshagen borehole (DOV kb18d48w-B181; GSB 048W0180) and reaches a maximum of 128 m in the Molenbeersel boreholes (DOV kb18d49w-B225 and kb18d49w-B226; GSB 049W0225 and 049W0226) in the differentially subsiding Roer Valley Graben.

15.6 Occurrence

The Genk member is present in the central and eastern part of the Limburg province.

15.7 Regional correlations

The Genk Member is coeval with the greater part of the Antwerpen Member and the Zonderschot Member of the Berchem Formation (Louwye et al., 2020). It largely correlates with the Heksenberg Member of the Groote Heide Formation in the Netherlands (Deckers & Munsterman, 2020; Munsterman et al. 2019).

15.8 Age

Palynological analysis with dinoflagellate cysts from the Wijshagen borehole indicate deposition during Langhian – earliest Serravallian interval (Deckers & Louwye, 2017; Louwye & Laga, 2008).

15.9 Dataset

Data in this LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the lower and middle Miocene: https://www.dov.vlaanderen.be/data/opdracht/2020-022192

15.10 References

Deckers, J. & Louwye, S., 2017. A reinterpretation of the ages and depositional environments of the lower and middle Miocene stratigraphic records in a key area along the southern margin of the North Sea Basin. Geological Magazine, 156, 525–532. https://doi.org/10.1017/s0016756817000991

Deckers, J., & Munsterman, D., 2020. Middle Miocene depositional evolution of the central Roer Valley Rift System. Geological Journal, 55, 6188-6197. https://doi.org/10.1002/gj.3799

de Heinzelin, J. & Glibert, M., 1956. Lexique Stratigraphique International, Vol. 1, Europe. Fascicule 4a, France, Belgique, Pays- Bas, Luxembourg; 7, Tertiaire. Centre National de la Recherche Scientifique, Paris, 1–45.

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic foraminifera of the Neogene deposits in Northern Belgium. Bulletin Belgische Vereniging voor Geologie/Bulletin de la Société belge de Géologie, 85, 133–152.

Gullentops, F., 1963. Etude de divers faciès quaternaires et tertiaires dans le Nord et l’Est de la Belgique. 6e Congrès International de Sédimentologie, Belgique et Pays-Bas, 20 p.

Gullentops, F., 1972-1973. Grainsize and mineralogy of Miocene glass-sands of Maasmechelen, Belgian Limburg. Mededelingen Rijks Geologische Dienst, 23, 25–34.

Louwye, S., Deckers, J., Verhaegen, J., Adriaens, R. & Vandenberghe N., 2020. A review of the lower and middle Miocene of northern Belgium. Geologica Belgica, 23/3-4, 137-156. https://doi.org/10.20341/gb.2020.010

Louwye, S. & Laga, P., 2008. Dinoflagellate cyst stratigraphy and palaeoenvironment of the marginal marine Middle and Upper Miocene of the eastern Campine area, northern Belgium (southern North Sea Basin). Geological Journal, 43, 75–94. https://doi.org/10.1002/gj.1103

Mourlon, M. (1898). Sur les dépôts tertiaires de la Campine limbourgeoise à l'Ouest de la Meuse. Bulletin de la Société belge de Géologie, 12, 45-58.

Munsterman, D., ten Veen, J., Menkovic, A., Deckers, J., Witmans, N., Verhaegen, J., Kerstholt-Boegehold, S., van de Ven, T., & Busschers, F., 2019. An updated and revised stratigraphic framework for the Miocene and earliest Pliocene strata of the Roer Valley Graben and adjacent blocks. Netherlands Journal of Geosciences, Volume 98, e8. https://doi.org/10.1017/njg.2019.10

Verhaegen, J., 2020. Stratigraphic discriminatory potential of heavy mineral analysis for the Neogene sediments of Belgium. Geologica Belgica, 23/3-4, 379-398. https://doi.org/10.20341/gb.2020.003

15.11 Annexes

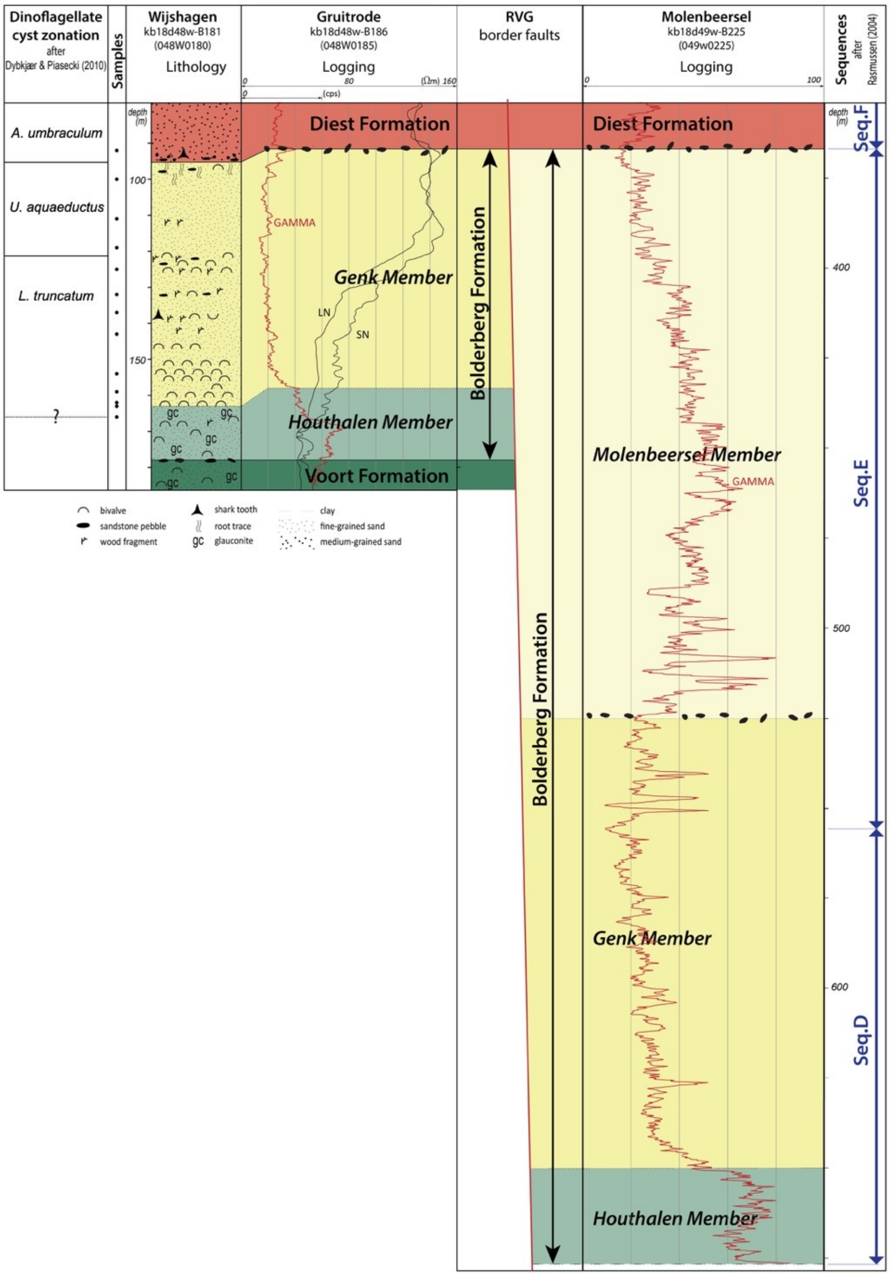


Figure 15-1. The Bolderberg Formation in the Wijshagen, Gruitrode and Molenbeersel wells. See Louwye et al. (2020) for further information.

16 Opgrimbie Facies (Genk Member)

Unit name: Opgrimbie Facies

Hierarchical unit name: Genk Member

Type: Facies

Code: BbOg

Author(s):

- Compiled by: Louwye Stephen, Adriaens Rieko, Deckers Jef, Vandenberghe Noël, Verhaegen Jasper

Alternative names: Miocene glass sand of Maasmechelen (Gullentops, 1972-1973); Maasmechelen Silver Sands (Sels et al., 2001; Buffel et al., 2001), 'Mechelen aan de Maas sand' (Laga, 1973). This unit includes the Terlamen gravel at its base. It is topped by the Opgrimbie gravel.

Origin of the name: The origin of the name of the unit is discussed in Louwye et al. (2020).

Status: Formal

Date: 01/05/2022

How to refer: Louwye, S., Adriaens, R., Deckers, J. Vandenberghe, N. & Verhaegen, J., 2023. The Opgrimbie Facies, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Opgrimbie-Facies

16.1 Characterizing description

A medium-grained, white sandy unit holding a lignite seam (Kikbeek Lignite) and a quartzite layer (a silcrete cemented by originally opal bioliths) (Gullentops, 1963, 1972-1973; Matthijs, 1999). The white sand of the Opgrimbie Facies has in the type locality (Opgrimbie quarry) a modal grain size of approximately 215 µm. A sample from this facies in the Wijshagen borehole has a modal grain size of 296 µm, a clay content of only 0.7 % and a D90 of 433 µm. (Gullentops, 1963, 1973; see also Adriaens, 2015).

16.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

Sibelco sand pit at Opgrimbie in eastern part of the Limburg province (Gulinck, 1961; Wouters & Vandenberghe, 1994; Van Loon, 2009).

16.3 Description upper boundary

The Opgrimbie Facies is topped by the undulating Opgrimbie gravel consisting of well-rounded blue flint pebbles (Matthijs, 1999).

16.4 Description lower boundary

The Terlamen gravel occurs at the base of the Opgrimbie Facies, resting on a sandy unit representing a transition from the underlying marine, glauconitic Houthalen Member (Matthijs, 1999).

16.5 Thickness

The thickness of the Opgrimbie Facies ranges between 10 and 15 m. The lignite seam has a thickness of about 3 m. The precise lateral and vertical limits of this facies remain to be determined (Louwye et al., 2020).

16.6 Occurrence

The Opgrimbie Facies occurs in the eastern part of the Limburg province.

16.7 Regional correlations

The Kikbeek Lignite can be correlated with the Frimmersdorf Lignite Seam (Lower Rhine Graben) (Louwye et al., 2020), while the quartzite is correlated with the Braunkohlen Quartzit (Gullentops, 1963) or the Nivelstein Sandstone (van Loon, 2009). The Opgrimbie Sand is correlated with the Heksenberg Member of the Groote Heide Formation (Deckers & Munsterman, 2020; Munsterman et al., 2019; van Loon, 2009).

16.8 Age

No precise absolute or relative dating of the Opgrimbie Facies is available. The Genk Member has been relatively dated through biostratigraphy as Langhian to early Serravallian (Louwye et al., 2020).

16.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the lower and middle Miocene: https://www.dov.vlaanderen.be/data/opdracht/2020-022192

16.10 References

Adriaens, R., 2015. Neogene and Quaternary clay minerals in the southern North Sea. Unpublished Ph.D. Thesis, KU Leuven, Leuven, 272 p.

Buffel, P., Claes, S. & Gullentops, F., 2001. Toelichtingen bij de geologische kaart van België, Vlaams Gewest: kaartblad 26, Rekem [1/50 000]. Belgische Geologische Dienst en Ministerie van de Vlaamse Gemeenschap, Afdeling Natuurlijke Rijkdommen en Energie, Brussel, 56 p.

Deckers, J., & Munsterman, D., 2020. Middle Miocene depositional evolution of the central Roer Valley Rift System. Geological Journal, 55, 6188-6197. https://doi.org/10.1002/gj.3799

Gulinck, M., 1961. Note sur le Boldérien d'Opgrimbie (Campine) et remarques sur les grès 'erratiques' du Limbourg. Bulletin de la Société belge de Géologie, de Paléontologie et d'Hydrologie, 70, 297–301.

Gullentops, F., 1963. Etude de divers faciès quaternaires et tertiaires dans le Nord et l'Est de la Belgique. 6e Congrès International de Sédimentologie, Belgique et Pays-Bas, 20 p.

Gullentops, F., 1972-1973. Grainsize and mineralogy of Miocene glass- sands of Maasmechelen, Belgian Limburg. Mededelingen Rijks Geologische Dienst, 23, 25–34.

Laga, P., 1973. The Neogene deposits of Belgium. Guidebook for the Field Meeting of the Geologists' Association London, 31 March–3 April, 1973. Geological Survey of Belgium, Brussels, 31 p.

Louwye, S., Deckers, J., Verhaegen, J., Adriaens, R. & Vandenberghe N., 2020. A review of the lower and middle Miocene of northern Belgium. Geologica Belgica, 23/3-4, 137-156. https://doi.org/10.20341/gb.2020.010

Matthijs J., 1999. Toelichtingen bij de geologische kaart van België, Vlaams Gewest: kaartblad 25, Hasselt [1/50 000]. Belgische Geologische Dienst en Ministerie van de Vlaamse Gemeenschap, Afdeling Natuurlijke Rijkdommen en Energie, Brussel, 104 p.

Munsterman, D., ten Veen, J., Menkovic, A., Deckers, J., Witmans, N., Verhaegen, J., Kerstholt-Boegehold, S., van de Ven, T., & Busschers, F., 2019. An updated and revised stratigraphic framework for the Miocene and earliest Pliocene strata of the Roer Valley Graben and adjacent blocks. Netherlands Journal of Geosciences, Volume 98, e8. https://doi.org/10.1017/njg.2019.10

Sels, O., Claes, S. & Gullentops, F., 2001. Toelichtingen bij de geologische kaart van België, Vlaams Gewest: kaartblad 18 - 10, Maaseik - Beverbeek [1/50 000]. Belgische Geologische Dienst en Ministerie van de Vlaamse Gemeenschap, Afdeling Natuurlijke Rijkdommen en Energie, Brussel, 50 p.

van Loon, A.J., 2009. Unravelling the enigmas of the 'silver sands' in the Dutch/German/Belgian border area. Netherlands Journal of Geosciences, 88, 133–145. https://doi.org/10.1017/s0016774600000858

Wouters L. & Vandenberghe, N., 1994. Geologie van de Kempen. ONDRAF-NIRAS, Brussel, NIROND-94, 208 p.

17 Heizel Facies (Bolderberg Formation)

Unit name: Heizel Facies

Hierarchical unit name: Bolderberg Formation

Type: Facies

Code: BbHe

Author(s):

- Compiled by: Louwye Stephen, Adriaens Rieko, Deckers Jef, Vandenberghe Noël, Verhaegen Jasper

- Modification of: Le Hon (1862), revised by De Meuter & Laga (1976)

Alternative names: Sables Chamois

Origin of the name: The origin of the name of the unit is discussed in Louwye et al. (2020).

Status: Formal

Date: 01/05/2022

How to refer: Louwye, S., Adriaens, R., Deckers, J. Vandenberghe, N. & Verhaegen, J., 2023. The Heizel Facies, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Heizel-Facies

17.1 Characterizing description

Yellow-brown, micaceous, fine-grained sand. Thin clay layers are present (Gulinck, 1956, 1959). A gravel layer consisting of flint pebbles, marine mammal bone fragments and plant fragments is present at the base of the unit.

17.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

Top of the hills west of Brussels near the village Jette. No precise section nor location is given.

17.3 Description upper boundary

The Heizel Facies is covered by Quaternary deposits, occasionally by isolated patches of the upper Miocene Diest Formation (Gulinck, 1956, 1959).

17.4 Description lower boundary

The unit rests on Bartonian deposits (Gulinck, 1956, 1959).

17.5 Thickness

Gulinck (1956; 1959) mentions a thickness of 1.5 m for the Heizel Facies.

17.6 Occurrence

The Heizel Facies occurs in the top of the hills west of Brussels.

17.7 Regional correlations

The gravel layer at the base of the Heizel Facies has been correlated with the Elsoo Gravel at the base of the Bolderberg Formation (De Heinzelin, 1963).

17.8 Age

No precise absolute or relative dating is available for the Heizel Facies.

17.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the lower and middle Miocene: https://www.dov.vlaanderen.be/data/opdracht/2020-022192

17.10 References

de Heinzelin, J., 1963. Heisel-Wemmel. Compte-rendu des excursions. Point 4 de la carte-itinéraire. In Symposium sur la stratigraphie du Néogène nordique, Gand 1961. Société belge de Géologie, de Paléontologie et d'Hydrologie, Mémoires in-8°, 6, 195–197.

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic foraminifera of the Neogene deposits in Northern Belgium. Bulletin Belgische Vereniging voor Geologie/Bulletin de la Société belge de Géologie, 85, 133–152.

Gulinck, M., 1956. Note sur la formation des 'Sables Chamois' (Néogène) de la région du Heysel. Bulletin de la Société belge de Géologie, de Paléontologie et d'Hydrologie, 65, 227–229.

Gulinck, M., 1959. Sur l'extension, en Campine, des "Sables Chamois" du Heysel. Bulletin de la Société belge de Géologie, 68, 371-372.

Le Hon, H., 1862. Terrains tertiaires de Bruxelles, leur composition, leur classement, leur faune et leur flore. Bulletin de la Société géologique de France, 2e série, 19, 804–831.

Leriche, M., 1934. Les "sables chamois". Un gîte fossilifère nouveau à la base de "sables chamois" du Petit-Brabant. Annales de la Société Géologique de la Belgique, 58, 76-82.

Louwye, S., Deckers, J., Verhaegen, J., Adriaens, R. & Vandenberghe N., 2020. A review of the lower and middle Miocene of northern Belgium. Geologica Belgica, 23/3-4, 137-156. https://doi.org/10.20341/gb.2020.010

18 Molenbeersel Formation

Unit name: Molenbeersel Formation

Hierarchical unit name: /

Type: Formation

Code: Mn

Author(s): Louwye Stephen & Deckers Jef

Alternative names: /

Origin of the name: Borehole near the village of Molenbeersel

Status: Formal

Date: 01/05/2022

How to refer: Louwye, S. & Deckers, J., 2023. The Molenbeersel Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Molenbeersel-Formation

18.1 Characterizing description

The unit consists of brown-grey to grey-green, clay- and shell-bearing silt and fine-grained sand. The unit holds glauconite and lignite fragments. The central part of the formation is richest in glauconite and is also micaceous. Lignite fragments are distinctly present in the upper part.

18.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The type locality is Molenbeersel in the easternmost part of the Limburg province. The type section is between 369 m and 525 m depth in the Molenbeersel borehole (DOV kb18d49w-B225; GSB 049W0225). The gamma ray values in the Molenbeersel Formation interval increase from a basal gravel towards a maximum in the central part (Figure 18-1), which is richest in glauconite and shells (including Glycymeris) and is also micaceous. From this maximum, a decrease takes place in the gamma-ray values towards the top section (Figure 18-1), which coincides with an increase in lignite.

18.3 Description upper boundary

The Molenbeersel Formation is capped by the basal gravel of the Diest Formation. On borehole logs, this boundary coincides with an upwards increase in gamma-ray values (Figure 18-1).

18.4 Description lower boundary

The Molenbeersel Formation rests upon the Genk Member of the Bolderberg Formation. At the contact, some small gravel (up to 1 cm) was described. Compared to the underlying Genk Member, the unit is characterized by a markedly higher gamma-ray values (Figure 18-1).

18.5 Thickness

The Molenbeersel Formation has a thickness of c. 156 m in the Molenbeersel borehole (DOV kb18d49w-B225; GSB 049W0225; Figure 18-1).

18.6 Occurrence

The Molenbeersel Formation is restricted to the differentially subsiding Roer Valley Graben in the eastern part of the Limburg province.

18.7 Regional correlations

Deckers & Munsterman (2020) propose a correlation with the Vrijherenberg Sand of the Groote Heide Formation (Figure 18-1).

18.8 Age

No absolute or relative dating is available for the Molenbeersel Formation. Based on the geophysical correlation with the Vrijherenberg Sand, Deckers & Munsterman (2020) infer a Serravallian age (Figure 18-1).

18.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection

Subset of the lower and middle Miocene: https://www.dov.vlaanderen.be/data/opdracht/2020-022192

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Molenbeersel borehole	049W0225	kb18d49w-B225	http://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0225.txt	https://www.dov.vlaanderen.be/data/boring/1985-082429

18.10 References

Deckers, J. & Munsterman, D., 2020. Middle Miocene depositional evolution of the central Roer Valley Rift System. Geological Journal, 55, 6188-6197. https://doi.org/10.1002/gj.3799

Louwye, S., Deckers, J., Verhaegen, J., Adriaens, R. & Vandenberghe N., 2020. A review of the lower and middle Miocene of northern Belgium. Geologica Belgica, 23/3-4, 137-156. https://doi.org/10.20341/gb.2020.010

18.11 Annexes

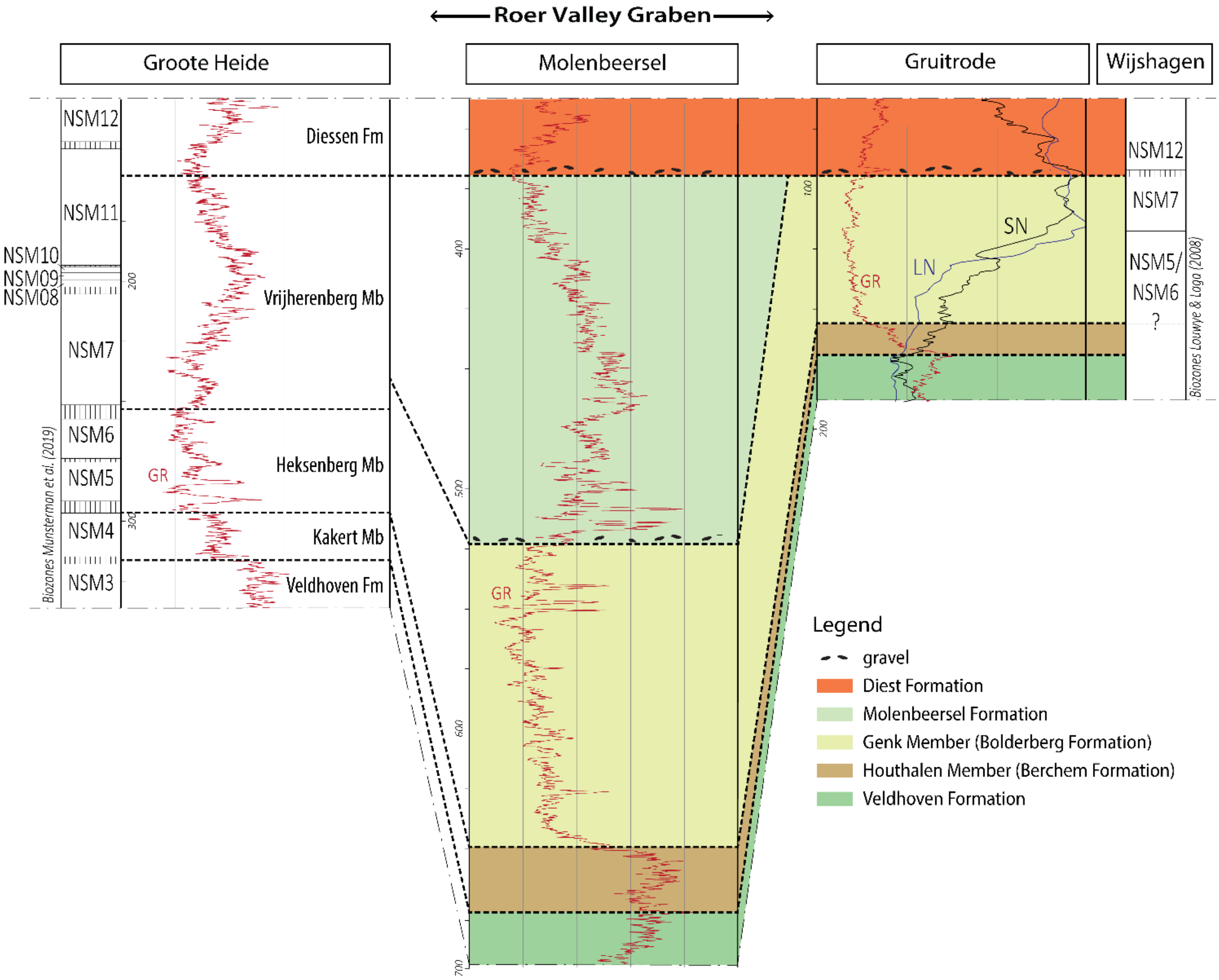


Figure 18-1. The Molenbeersel Formation in the Molenbeersel borehole in the Roer Valley Graben and its correlation with the Vrijherenberg Member of the Groote Heide Formation in the Groote Heide borehole in the Netherlands. Also the correlation with the Gruitrode/Wijshagen boreholes in the Campine area, where the Molenbeersel Formation is absent, is shown. The panel is flattened on the base of the Diest Formation. See Deckers & Munsterman (2020) for further information.

19 Diest Formation

Unit name: Diest Formation

Hierarchical unit name: /

Type: Formation

Code: Di

Author(s):

- Compiled by: Houthuys Rik, Adriaens Rieko, Goolaerts Stijn, Laga Piet, Louwye Stephen, Matthijs Johan, Vandenberghe Noël & Verhaegen Jasper

- Modification of: De Meuter & Laga (1976), after Dumont (1839)

Alternative names: disused names: Sables et grès de Diest à Terebratula perforata, Sable diestien, Diestiaanzand

Origin of the name: see Houthuys et al. (2020) for an extensive overview

Status: Formal

Date: 01/05/2022

How to refer: Houthuys, R., Adriaens, R., Goolaerts, S., Laga, P., Louwye, S., Matthijs, J., Vandenberghe, N. & Verhaegen, J., 2023. The Diest Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Diest-Formation

19.1 Characterizing description

The Diest Formation consists of grey green to brownish, poorly sorted, fine to medium to coarse very glauconiferous sand, locally cemented by variable amounts of iron (hydr)oxide into ironstone, in particular in the outcrop areas of Hageland and Zuiderkempen. Glauconite content varies from 25% to 60%. The coarse beds often contain a subpopulation of 0.5 to 2 mm (sub)angular quartz grains. In the vertical direction, grain size is either constant or coarsening upwards. The sand shows various primary structures: large and small-scale cross-bedding, massive sand, spaced planar lamination, displaying varying intensities of bioturbation. The cross-bedded facies may also contain isolated or bundled clay laminae. In the outcrop area, macrofossils are only known from a small number of localities, and they exist solely in the form of casts. In the shallow and deeper subsurface of the Antwerp and the Antwerp Campine areas, calcareous macro- and microfossils are locally abundant.

The subdivision of the Diest Formation into members still necessitates further study (Houthuys et al. 2020; Goolaerts et al., 2020). The present views lead to maintaining the Dessel Member and Deurne Member and introducing the Hageland Diest Member, Kempen Diest Member and the Borsbeek Member.

The local facies "clayey Diest" and "Bosbeek/Opoeteren" (see location in Vandenberghe & Louwye, 2020, Fig. 3, added in annex 2) need better descriptions of extent, correlations and depositional structures. Therefore, no formal members inside the Diest Formation are proposed for these facies now.

19.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The type locality is Diest, where exposures were available at the former town fortress. In the wide neighbourhood of Diest, exposures are temporarily offered at construction sites. The exposures represent only the Hageland Diest Member. A key permanent outcrop is present at the Kesselberg in Leuven.

No type borehole has been selected. The variation in available descriptions and geophysical log signatures reflects the geographical variation inherent of this formation.

19.3 Description upper boundary

The upper boundary is, in the outcrop area (see Annex 1), a near-planar truncation surface, either uncovered or covered by Quaternary continental deposits, and often strongly incised by the present-day topography. In its subcrop area (Annex 1), the upper boundary is a near-planar truncation surface, covered by the Kasterlee Formation, the formation that stratigraphically follows the Diest Formation (Annex 2). Locally, inside the Roer Valley Graben, the overlying deposit is the Inden Formation (Louwye & Vandenberghe, 2020; Annex 3). At the city of Antwerpen, the overlying deposit is the Kattendijk Formation, which west of Antwerpen truncates the Diest Formation (Deckers & Louwye, 2020).

19.4 Description lower boundary

The lower boundary is erosive, locally, and in particular in the Hageland and Zuiderkempen areas, deeply incising into older Neogene and Paleogene strata. A lag deposit draping the base is present in many localities (Houthuys et al., 2020; Goolaerts et al., 2020). The directly underlying unit, if not removed by the strong erosion at the base of the Diest Formation, is the Berchem Formation in the Antwerpen and Kempen area and the Bolderberg Formation in Vlaams-Brabant and Limburg. Also when these formations have been preserved, there is an important hiatus below the Diest Formation (Annex 2).

19.5 Thickness

General evolution from less than 10 m in the west and southwest of its extent to almost 200 m in NE Belgium inside the Roer Valley Graben. Important thickness variations in Hageland and Zuiderkempen are related to the incised nature of the formation base. The thickness reaches more than 100 m in the centre of some of those incisions.

19.6 Occurrence

See Annex 1. Outcrop area from Brussels to Leuven and Hageland in Vlaams-Brabant, from Antwerpen to Zuiderkempen in the province of Antwerpen, neighbouring area in western Limburg. Subcrop area to north and northeast of the outcrop area and continuing into SE-Netherlands.

19.7 Regional correlations

The Diest Formation can be correlated with the Diessen Formation in the Netherlands to the north, which is bounded by the Mid Miocene Unconformity at its base and the Late Miocene Unconformity at its top (Munsterman et al., 2019). In the Roer Valley Graben, the Diest Formation is partly equivalent to the Inden Formation.

19.8 Age

Late Miocene: Tortonian (top part of DN8 biozone) - early Messinian (at least base of DN10 biozone) (Annex 2).

19.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets: https://www.dov.vlaanderen.be/data/opdracht/2020-021774.

Subset of the Diest Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021774

19.10 References

Deckers, J. & Louwye, S., 2020. The architecture of the Kattendijk Formation and the implications on the early Pliocene depositional evolution of the southern margin of the North Sea Basin. Geologica Belgica, 23/3-4, 323-331. https://doi.org/10.20341/gb.2020.017

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic foraminifera of the Neogene deposits in Northern Belgium. Bulletin Belgische Vereniging voor Geologie/Bulletin de la Société belge de Géologie, 85, 133–152.

Dumont, A., 1839. Rapport sur les travaux de la carte géologique pendant l'année 1839. Bulletins de l'Académie royale des Sciences et Belles-Lettres de Bruxelles, 6/2, 464–485.

Goolaerts, S., De Ceuster, J., Mollen, F.H., Gijsen, B., Bosselaers, M., Lambert, O., Uchman, A., Van Herck, M., Adriaens, R., Houthuys, R., Louwye, S., Bruneel, Y., Elsen, J. & Hoedemakers, K., 2020. The upper Miocene Deurne Member of the Diest Formation revisited: unexpected results from the study of a large temporary outcrop near Antwerpen International Airport, Belgium. Geologica Belgica, 23/3-4, 219-252. https://doi.org/10.20341/gb.2020.011

Houthuys, R., Adriaens, R., Goolaerts, S., Laga, P., Louwye, S., Matthijs, J., Vandenberghe, N. & Verhaegen, J., 2020. The Diest Formation: a review of insights from the last decades. Geologica Belgica, 23/3-4, 199-218. https://doi.org/10.20341/gb.2020.012

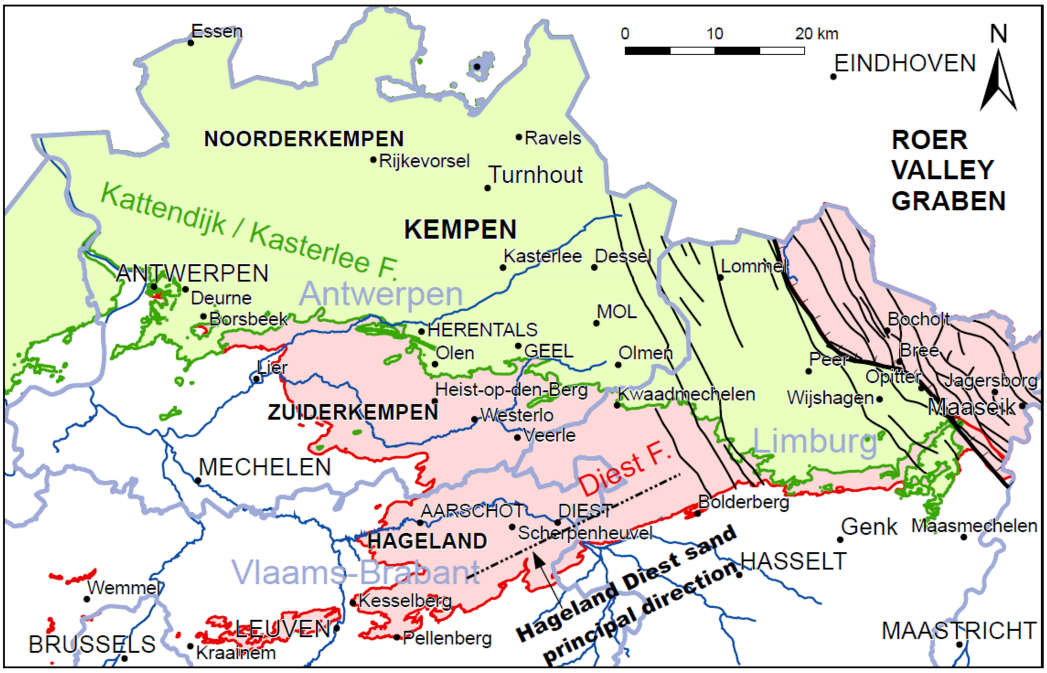
Louwye, S. & Vandenberghe, N., 2020. A reappraisal of the dinoflagellate cyst biostratigraphy of the upper Miocene in the Maaseik well 49W0220. Geologica Belgica, 23/3-4, 289-295. https://doi.org/10.20341/gb.2020.013

Munsterman, D.K., ten Veen, J.H., Menkovic, A., Deckers, J., Witmans, N., Verhaegen, J., Kerstholt-Boegehold, S.J., van de Ven, T., & Busschers, F.S., 2020. An updated and revised stratigraphic framework for the Miocene and earliest Pliocene strata of the Roer Valley Graben and adjacent blocks. Netherlands Journal of Geosciences, 98, e8. https://doi.org/10.1017/njg.2019.10

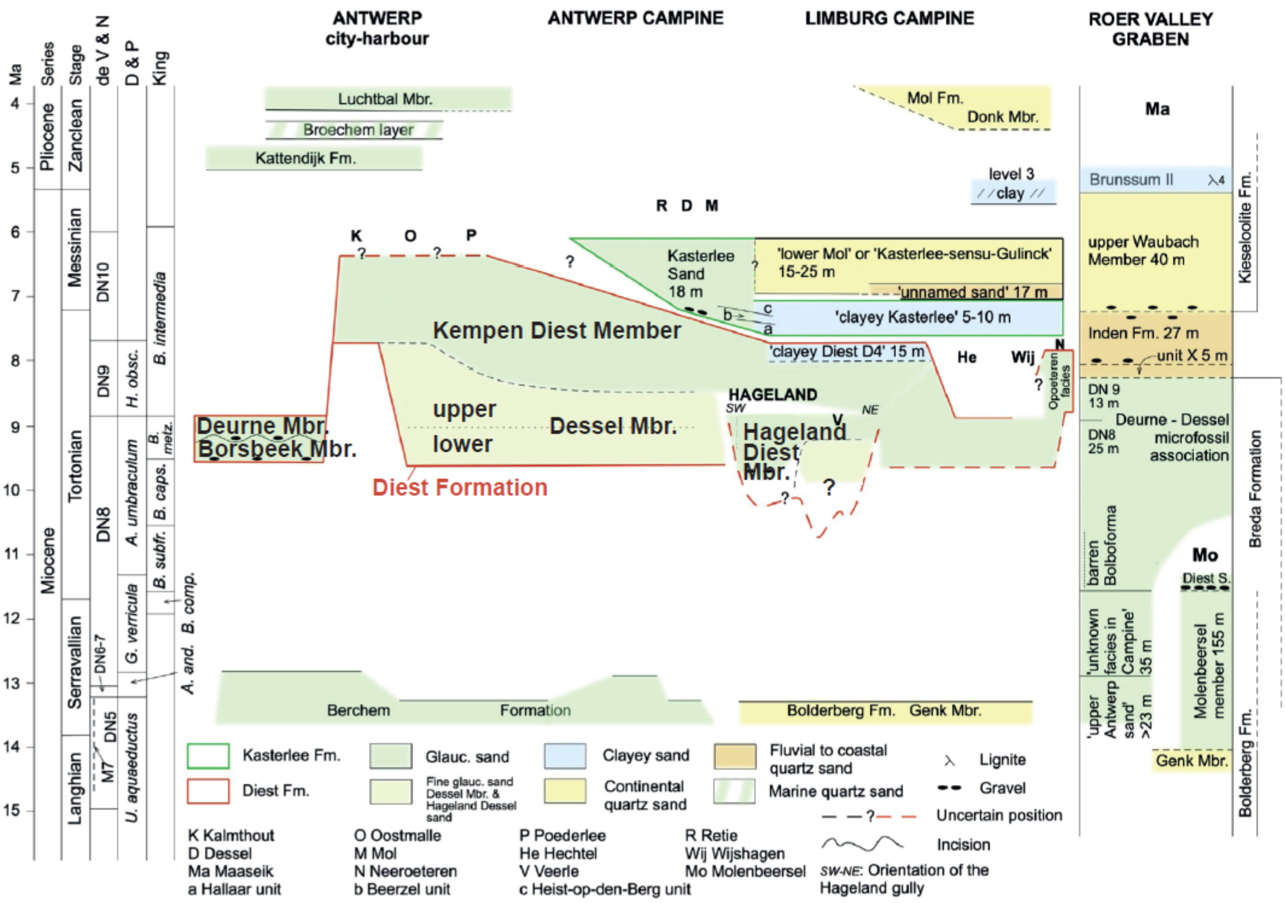
Vandenberghe, N. & Louwye, S., 2020. An introduction to the Neogene stratigraphy of northern Belgium: present status. Geologica Belgica, 23/3-4, 97-112. https://doi.org/10.20341/gb.2020.008

19.11 Annexes

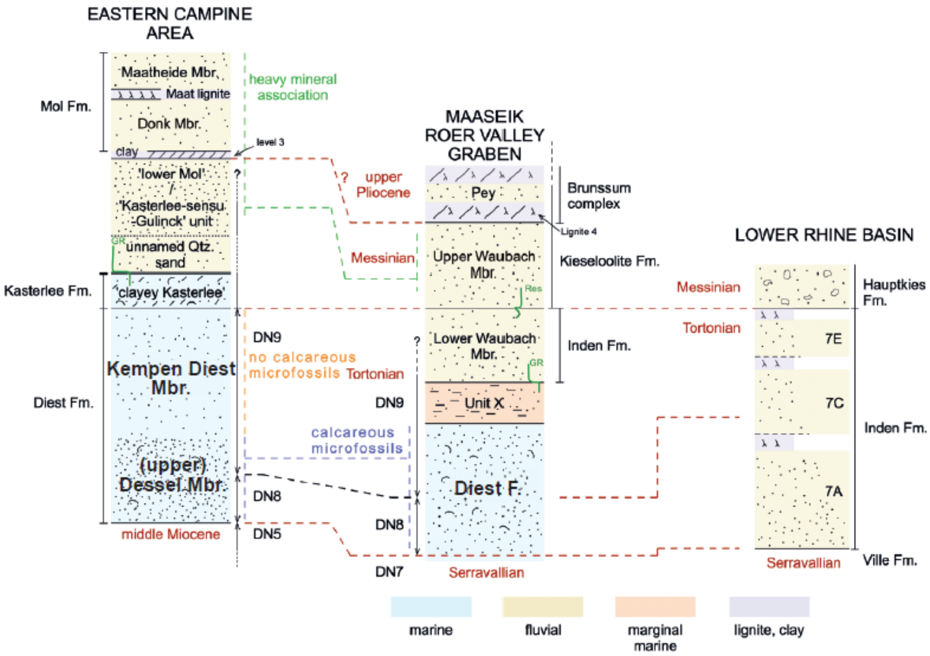
Annex 1: Fig. 1B of Houthuys et al. (2020):



Annex 2: Fig. 3 of Vandenberghe & Louwye (2020), with member names highlighted:



Annex 3: Fig. 3 of Louwye & Vandenberghe (2020), with member names highlighted:



20 Borsbeek Member (Diest Formation)

Unit name: Borsbeek Member

Hierarchical unit name: Diest Formation

Type: Member

Code: DiBo

Author(s): Goolaerts Stijn

Alternative names: /

Origin of the name: Town of Borsbeek, east of the city of Antwerp

Status: Formal

Date: 01/05/2022

How to refer: Goolaerts, S., 2023. The Borsbeek Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Borsbeek-Member

20.1 Characterizing description

The Borsbeek Member as introduced by Goolaerts et al. (2020) is characterised by greenish-coloured, intensely bioturbated, heterogenous glauconiferous, fine-grained sand with an important clay-silt-very fine sand fraction (<125 µm) (28–46%, 62% at base) and variable amounts of median and coarse sand (>250 mm, high and variable (11–36%) in the lower half, small and stable (7-8%) in the upper half). It has a glauconite content of 30% throughout, except for a much higher content (45–60%) in the basal part. A basal gravel with reworked phosphorites and different types of flint and flint pebbles residing in the sandy matrix occurs in the lowermost meter. Large-scale sedimentary structures are absent, except for horizontal bedding. The sediment may have a mottled appearance on mechanically dug vertical walls. An anomalously high concentration of marine mammal fossils may occur both in the lower and the upper half of the deposit. The invertebrate fauna is relatively poorly diverse, with pycnodontids and pectinids occurring in beds, while disciniscid (lower part) and lingulid (upper part) brachiopods are generally found dispersed. Terebratulid brachiopods are locally abundant.

20.2 Type section, type locality, type borehole, or type geophysical borehole

Temporary excavations near Antwerp International Airport (AIA), section LP1-A as described by Goolaerts et al. (2020).

20.3 Description upper boundary

The Borsbeek Member is erosively overlain by the Deurne Member, and may locally be completely eroded and reduced to a lag deposit at the base of the overlying Deurne Member.

20.4 Description lower boundary

The Borsbeek Member is the lowest member of the Diest Formation in the Antwerp area. Its lower boundary is an erosive contact with the Berchem Formation. In all yet documented sites, the Borsbeek Member overlays the Antwerpen Member of the Berchem Formation.

20.5 Thickness

The Borsbeek Member has an observed maximal thickness of 4.5-5 m. Due to the erosive nature of the base with the overlying Deurne Member, the member may be locally reduced to zero.

20.6 Occurrence

The Borsbeek Member is currently identified in a small number of temporary outcrops in the Antwerp area, located to the S and SE of Antwerp city, mostly in the municipalities of Borsbeek, Mortsel and Deurne. In many localities, it may have been partially or even completely removed by erosion with only a lag deposit with reworked bones, pebbles and sandstone remaining at the base of the overlying Deurne Member (e.g. Rivierenhof gravel).

20.7 Regional correlations

The Borsbeek Member is thought to be a lateral and more nearshore equivalent of the (lower part of the) Dessel Member.

20.8 Age

The age of the Borsbeek Member is middle Tortonian (upper Miocene). Dinoflagellates indicate the Amiculosphaera umbraculum Zone of Dybkjær & Piasecki (2010) and the DN8 Zone of de Verteuil & Norris (1996). Most probably, the base falls also within the Bolboforma metzmacheri Zone, which allows to situate it in the time interval between 9.54 and 8.8 Ma (Goolaerts et al., 2020).

20.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets: https://www.dov.vlaanderen.be/data/opdracht/2020-023222

Subset of the Diest Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021774

20.10 References

de Verteuil, L. & Norris, G., 1996. Miocene dinoflagellate stratigraphy and systematics of Maryland and Virginia. Micropaleontology, 42, Supplement, 1–172. https://doi.org/10.2307/1485926

Dybkjær, K. & Piasecki, S., 2010. Neogene dinocyst zonation for the eastern North Sea Basin, Denmark. Review of Palaeobotany and Palynology, 161/1-2, 1–29. https://doi.org/10.1016/j.revpalbo.2010.02.005

Goolaerts, S., De Ceuster, J., Mollen, F., Gijsen, B., Bosselaers, M., Lambert, O., Uchman, A., Adriaens, R., Van Herck, M., Houthuys, R., Louwye, S., Bruneel, Y., Elsen, J., Hoedemaekers, K., 2020. The Upper Miocene Deurne Member of the Diest Formation revisited: unexpected results from the study of a large temporary outcrop near Antwerp International Airport, Belgium. Geologica Belgica, 23/3-4, 219-252. https://doi.org/10.20341/gb.2020.011

20.11 Annexes

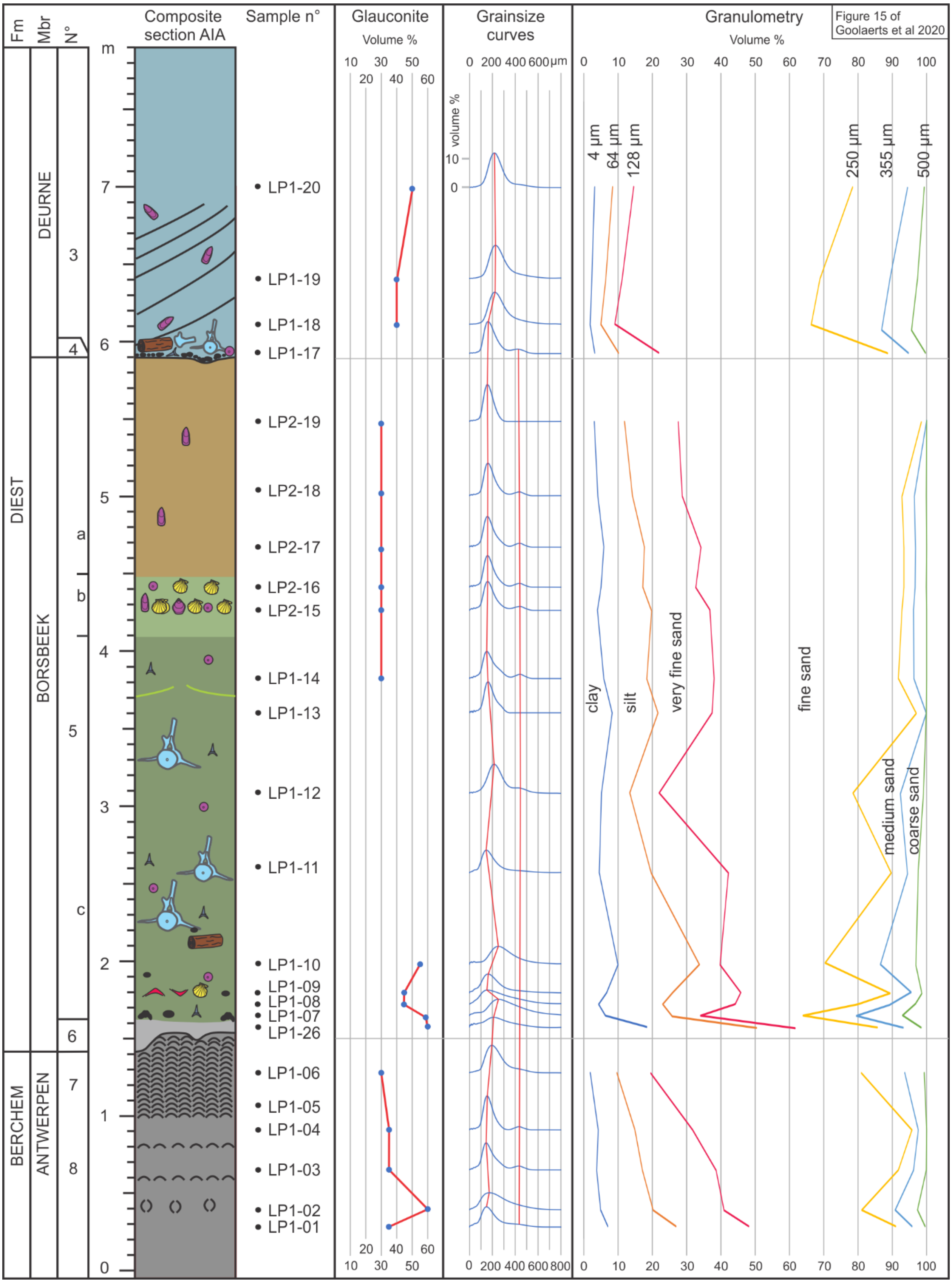


Figure 20-1. Glauconite content, grain-size frequency distribution curves and granulometry plotted against a (hypothetical) Antwerp International Airport composite. (from Goolaerts et al., 2020)

21 Deurne Member (Diest Formation)

Unit name: Deurne Member

Hierarchical unit name: Diest Formation

Type: Member

Code: DiDn

Author(s):

- Compiled by: Goolaerts Stijn

- Modification of: De Meuter & Laga (1976), after Glibert & de Heinzelin de Braucourt (1955a,b)

Alternative names: /

Origin of the name: temporary exposures in Deurne, Antwerp

Status: Formal

Date: 01/05/2022

How to refer: Goolaerts, S., 2023. The Deurne Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Deurne-Member

21.1 Characterizing description

The Deurne Sand Member, originally introduced by De Meuter & Laga (1976) revising the 'Sables de Deurne' of Glibert & de Heinzelin de Braucourt (1955a, b) is according to the revised description of Goolaerts et al. (2020) to be characterised as a complex of facies deposited in trough-shaped structures with intensely bioturbated foresets and remnants of bryozoan reefs in the lower part. The sediment consists of heterogenous glauconiferous fine-grained sand with a much lower number of fines (<125µm 15%), a larger amount of coarse grains (>250 µm 21–33%) and glauconite (39–49%) than that of the underlying Borsbeek Member. The color ranges from bluish-green to whitish-grey, depending on the amount of carbonate particles originating from the abrasion of the remains of the inhabitants of the bryozoan reefs that are incorporated in the sediment. Locally, the sediment is very fossiliferous, especially in the lower part. The macrofauna is generally small-sized, with bryozoans, serpulids (e.g. Ditrupa), decapod and cirripede crustaceans, bivalves and gastropods, echinoids and brachiopods. Terebratulids are locally abundant in the lower part and can be found both loose in the sediment as well as encased in sandstone. These terebratulids can also be encrusted by bryozoans. The brachiopod Cryptopora nysti is locally abundant. Shell fragments of lingulid brachiopods (Glottidia dumortieri) occur throughout. Trace fossils Macaronichnus segregatis, M. s. degiberti and Scolicia occur abundantly, and allow to ascribe the member to the Cruziana ichnofacies. Yellowish- to orange-colored clayey-limestone concretions and light-colored calcareous sandstone with bryozoans, terebratulids and small-sized mollusks in mold preservation are locally abundant above the basal gravel. The basal gravel generally contains small quartz and flint pebbles, reworked elasmobranch teeth, fish bones and fragments of marine mammal bones, and sometimes also larger sized concretions and bones that are reworked from the Borsbeek Member.

21.2 Type section, type locality, type borehole, or type geophysical borehole

De Meuter & Laga (1976) only named 'Deurne' and 'temporary exposures of shallow excavations at Deurne' as the type section, while Glibert & de Heinzelin de Braucourt (1955a) only gave a composite section based on the observations of Mourlon (1876) at four outcrops at Deurne and Borgerhout. Bosselaers et al. (2004)

identified VII BR Borgerhout Rivierenhof described by De Meuter et al. (1967, fig. 2, Section A), De Meuter & Laga (1970, text-fig. 1) and De Meuter et al. (1976, fig. 17) as the most relevant of all the studied sections, and designated it as the stratotype. However, as discussed by Goolaerts et al. (2020), this proposed stratotype presents several shortcomings and the Middelares section of Bosselaers et al. (2004) could be a better stratotype section, but additional documentation for its microfossil content, namely dinoflagellates and Bolboforma is necessary.

21.3 Description upper boundary

The Deurne Member is erosively overlain by Pliocene deposits. Rather frequently, sandstone reworked from the Deurne Member is incorporated into the base of these Pliocene deposits.

21.4 Description lower boundary

The Deurne Member is the upper member of the Diest Formation in the Antwerp area. Its lower boundary is an erosive contact with the Borsbeek Member, locally scouring through and fully removing the Borsbeek Member. In these cases, the Deurne Member directly overlays Berchem Formation deposits.

21.5 Thickness

The Deurne Member has a fairly limited thickness; in many of the documented sites it has a thickness well below 1 m. Locally, when it scours deep into the underlying Borsbeek Member, it may reach up to more than 5.5 m. The presence of reworked sandstones from the Deurne Member at the base of overlying Pliocene deposits implies that an unknown interval of the Deurne Member was eroded prior to the deposition of these Pliocene deposits.

21.6 Occurrence

The Deurne Member occurs in the shallow subsurface of the Antwerp area. Its possible extension towards the Campine needs further study.

21.7 Regional correlations

Its possible occurrence and correlation with Diest Formation deposits outside the Antwerp area still needs to be resolved. It is possibly correlative to the coarse-grained Diest Sand of the Hageland and southern Campine areas (Goolaerts et al., 2020; Houthuys et al., 2020).

21.8 Age

The age of the Deurne Member is middle Tortonian (upper Miocene). Dinoflagellates indicate Amiculosphaera umbraculum Zone of Dybkjær & Piasecki (2010) and the upper part of the DN8 Zone of de Verteuil & Norris (1996) (Goolaerts et al., 2020). According to King (2016), and based on De Meuter & Laga (1970), De Meuter (1974, 1980), King (1983) and Hooyberghs & Moorkens (2005), the presence of the Foraminifera Elphidium dopperti (Elphidium antoninum), Uvigerina pygmaea and Uvigerina venusta (hosiusi) deurnensis, together with the common presence of dextral Neogloboquadrina atlantica ('Globigerina pachyderma') are indicative of Zone NS40 of King (2016). The presence of Bolboforma metzmacheri, indicative of the Bolboforma metzmacheri Zone (De Meuter, 1974; Willems, 1976; Spiegler, 2001), allows to refine the latter positioning to King (2016)'s Subzone NS40b and to date it in the interval between 9.54 and 8.8 Ma (Goolaerts et al., 2020).

21.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets: https://www.dov.vlaanderen.be/data/opdracht/2020-023222

Subset of the Diest Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021774

21.10 References

Bosselaers, M., Herman, J., Hoedemakers, K., Lambert, O., Marquet, R. & Wouters, K., 2004. Geology and palaeontology of a temporary exposure of the Late Miocene Deurne Sand Member in Antwerpen (N. Belgium). Geologica Belgica, 7/1-2, 27–39.

De Meuter, F., 1974. Bijdrage tot de systematiek en de paleoecologie van de benthonische foraminiferen uit het Mioceen van België. Unpublished Ph.D. Thesis, Katholieke Universiteit Leuven, Leuven, Part I, 30 p.

De Meuter, F., 1980. Benthonic Foraminifera from the Miocene of Belgium. Aardkundige Mededelingen, 1, 78–169.

De Meuter, F.J.C. & Laga, P.G.H., 1970. Coiling ratios and other variations of Globigerina pachyderma (Ehrenberg, 1861) and the stratigraphic significance in the Neogene deposits of the Antwerpen area, Belgium. Bulletin de la Société belge de Géologie, de Paléontologie et d'Hydrologie, 79/2, 175–184.

De Meuter, F.J. & Laga, P.G., 1976. Lithostratigraphy and biostratigraphy based on benthonic foraminifera of the Neogene deposits of Northern Belgium. Bulletin de la Société belge de Géologie, 85/4, 133–152.

De Meuter, F.J., Laga, P.G., Ringelé, A. & Roose, V., 1967. Compte rendu de l'excursion du samedi 29 octobre 1966, faite à Deurne, près d'Anvers. Bulletin de la Société belge de Géologie, de Paléontologie et d'Hydrologie, 75, 392–394.

De Meuter, F., Wouters, K. & Ringelé, D., 1976. Lithostratigraphy of Miocene sediments from temporary outcrops in the Antwerp city area: Pl. Antwerpen 28 W, Pl. Borgerhout 28 E. Service Géologique de Belgique, Professional Paper, 1976/3, 19 p.

de Verteuil, L. & Norris, G., 1996. Miocene dinoflagellate stratigraphy and systematics of Maryland and Virginia. Micropaleontology, 42, Supplement, 1–172. https://doi.org/10.2307/1485926

Dybkjær, K. & Piasecki, S., 2010. Neogene dinocyst zonation for the eastern North Sea Basin, Denmark. Review of Palaeobotany and Palynology, 161/1-2, 1–29. https://doi.org/10.1016/j.revpalbo.2010.02.005

Glibert, M. & de Heinzelin de Braucourt, J., 1955a. La faune et l'âge Miocène supérieur des Sables de Deurne : I. Descriptions. Bulletin de l'Institut royal des Sciences naturelles de Belgique, 30/71, 1–27.

Glibert, M. & de Heinzelin de Braucourt, J., 1955b. La faune et l'âge Miocène supérieur des Sables de Deurne : II. Conclusions. Bulletin de l'Institut royal des Sciences naturelles de Belgique, 31/72, 1–12.

Goolaerts, S., De Ceuster, J., Mollen, F., Gijsen, B., Bosselaers, M., Lambert, O., Uchman, A., Adriaens, R., Van Herck, M., Houthuys, R., Louwye, S., Bruneel, Y., Elsen, J., Hoedemaekers, K., 2020. The Upper Miocene Deurne Member of the Diest Formation revisited: unexpected results from the study of a large temporary outcrop near Antwerp International Airport, Belgium. Geologica Belgica, 23/3-4, 219-252. https://doi.org/10.20341/gb.2020.011

Hooyberghs, H.J.F. & Moorkens, T.L.A., 2005. Biostratigraphic study of the "Middelares Hospital" outcrop section in the Deurne Sand Member (Upper Miocene, Belgium) as based on foraminifera. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 237/1, 5–28. https://doi.org/10.1127/njgpa/237/2005/5

Houthuys, R., Adriaens, R., Goolaerts, S., Laga, P., Louwye, S., Matthijs, J., Vandenberghe, N. & Verhaegen, J., 2020. The Diest Formation: a review of insights from the last decades. Geologica Belgica, 23/3-4, 199-218. https://doi.org/10.20341/gb.2020.012

King, C., 1983. Cainozoic Micropalaeontological Biostratigraphy of the North Sea. Report of the Institute of Geological Sciences, 82/7, 40 p.

King, C., 2016. A revised correlation of Tertiary rocks in the British Isles and adjacent areas of NW Europe. Gale, A.S. & Barry, T.L. (eds). Geological Society, London, Special Reports, 27, 1–719. https://doi.org/10.1144/SR27

Mourlon, M., 1876. Sur les dépôts qui, aux environs d'Anvers, séparent les sables noirs miocènes des couches pliocènes scaldisiennes. Bulletin de l'Académie royale des Sciences, des Lettres et des Beaux-Arts de Belgique, 2e série, 42, 760–790.

Spiegler, D., 2001. Bolboforma biostratigraphy in the Neogene glauconitic sands of Belgium. In Vandenberghe, N. (ed.), Contributions to the Paleogene and Neogene stratigraphy of the North Sea Basin. Aardkundige Mededelingen, 11, 61–68.

Willems, W., 1976. The genus Bolboforma Von Daniels & Spiegler in the Upper Miocene of northern Belgium. Bulletin de la Société belge de Géologie, 85/1, 31–38.

22 Dessel Member (Diest Formation)

Unit name: Dessel Member

Hierarchical unit name: Diest Formation

Type: Member

Code: DiDe

Author(s):

- Compiled by: Houthuys Rik, Adriaens Rieko, Goolaerts Stijn, Laga Piet, Louwye Stephen, Matthijs Johan, Vandenberghe Noël & Verhaegen Jasper

Alternative names: sables fins du Diestien (Gulinck et al., 1963)

Origin of the name: Dessel in the east of the province of Antwerpen.

Status: Formal

Date: 01/05/2022

How to refer: Houthuys, R., Adriaens, R., Goolaerts, S., Laga, P., Louwye, S., Matthijs, J., Vandenberghe, N. & Verhaegen, J., 2023. The Dessel Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Dessel-Member

22.1 Characterizing description

The member contains the fine-grained, glauconiferous, greyish green sand that is found near the base of the Diest Formation only in subcrop in boreholes in the central and northern part of the Kempen and in northern Limburg (Houthuys et al., 2020). Glauconite content averages 25%. In the vertical direction, grain size is either constant or coarsening upwards. The sand is most often homogenized by bioturbation. In cores, white burrow traces devoid of glauconite can be seen. No primary lamination is found in this member. The member was originally defined as the lowest part of the Diest Formation in the Kempen containing foraminifera and organic-walled microfossils (Laga & De Meuter, 1972). In practice however, the member has primarily been identified based on the grain-size criterion "modal grain size smaller than 200 µm". This implies that also overlying fine-grained sand without carbonates is included in the member. The lowest, carbonaceous part is referred to as "lower Dessel Member" and the overlying, fine-grained sand without carbonates as "upper Dessel Member" (see annex 2 to Diest Formation sheet). The lower Dessel Member is not found systematically over the area of the Dessel Member.

22.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

To be defined. A preferred candidate would be one of the cored boreholes from Dessel or Mol preserved in the collections of the Royal Belgian Institute of Natural Sciences.

22.3 Description upper boundary

The upper boundary is a gradual upwards transition to the Kempen Diest Member. For practical reasons, the modal grain size of 200 µm is used to separate it from the Kempen Diest Member. In the SE part of the extent, the member underlies the Hageland Diest Member, as observed in the Veerle borehole (060E0215) and referred to "Hageland Dessel sand" in Vandenberghe & Louwye (2020, fig. 3 p. 106).

22.4 Description lower boundary

Where it occurs, the Dessel Member is at the base of the Diest Formation. A gravel occurs at the base; but it is only a thin layer of coarse grains and it is not found systematically in all boreholes.

22.5 Thickness

The thickness is difficult to establish as the upper boundary is not well defined. The thickness is often between 10 and 30 m. If there is a lower calciferous part, it is only about 10 m thick. In the Veerle borehole, the "Hageland Dessel sand" is 45 m thick.

22.6 Occurrence

The member occurs in the Kempen region below the Kempen Diest Member. The western border is a few km east of the city of Antwerpen and the southern border is approximately along a line Lier – Veerle – southwest border fault of the Roer Valley Graben. Both borders are poorly defined.

22.7 Regional correlations

The member boundaries are not (yet) well defined. The lower part of the Dessel Member may biostratigraphically correlate to the Hageland Diest Member, the Borsbeek Member and possibly also the Deurne Member. The upper Dessel Member may constitute the bottomset part of the prograding marine delta of the Kempen Diest Member. Near Maaseik in the Roer Valley Graben, a fine grained glauconite sand from biochron DN9 may be a lateral biostratigraphic correlate (Louwye & Vandenberghe, 2020).

22.8 Age

Late Miocene: last part of the early to middle Tortonian biochron DN8 for the lower, often calcareous, part of the Dessel Member (Vandenberghe & Louwye, 2020; Goolaerts et al., 2020); late Tortonian to earliest Messinian, biochron DN9 for the upper, often non-calcareous, part of the Dessel Member (Vandenberghe & Louwye, 2020).

22.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets: https://www.dov.vlaanderen.be/data/opdracht/2020-021774.

Subset of the Diest Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021774

22.10 References

Goolaerts, S., De Ceuster, J., Mollen, F.H., Gijsen, B., Bosselaers, M., Lambert, O., Uchman, A., Van Herck, M., Adriaens, R., Houthuys, R., Louwye, S., Bruneel, Y., Elsen, J. & Hoedemakers, K., 2020. The upper Miocene Deurne Member of the Diest Formation revisited: unexpected results from the study of a large temporary outcrop near Antwerpen International Airport, Belgium. Geologica Belgica, 23/3-4, 219-252. https://doi.org/10.20341/gb.2020.011

Gulinck, M., Geets, S. & Van Voorthuysen, J.H., 1963. Note sur les sondages du Centre Nucléaire à Mol. Bulletin de la Société belge de Géologie, 72, 283–294

Houthuys, R., Adriaens, R., Goolaerts, S., Laga, P., Louwye, S., Matthijs, J., Vandenberghe, N. & Verhaegen, J., 2020. The Diest Formation: a review of insights from the last decades. Geologica Belgica, 23/3-4, 199-218. https://doi.org/10.20341/gb.2020.012

Laga, P. & De Meuter, F., 1972. A foraminiferal fauna found in the lower Member of the Diest Formation of borings in the Antwerp Kempen (NE-Belgium). Bulletin de la Société belge de Géologie, 81, 211–220

Louwye, S. & Vandenberghe, N., 2020. A reappraisal of the dinoflagellate cyst biostratigraphy of the upper Miocene in the Maaseik well 49W0220. Geologica Belgica, 23/3-4, 289-295. https://doi.org/10.20341/gb.2020.013

Vandenberghe, N. & Louwye, S., 2020. An introduction to the Neogene stratigraphy of northern Belgium: present status. Geologica Belgica, 23/3-4, 97-112. https://doi.org/10.20341/gb.2020.008

23 Hageland Diest Member (Diest Formation)

Unit name: Hageland Diest Member

Hierarchical unit name: Diest Formation

Type: Member

Code: DiHa

Author(s): Houthuys Rik, Adriaens Rieko, Goolaerts Stijn, Laga Piet, Louwye Stephen, Matthijs Johan, Vandenberghe Noël & Verhaegen Jasper

Alternative names: in the past, Diest Formation (De Meuter & Laga, 1976; after Dumont, 1839) was often used for only this member

Origin of the name: Hageland region in Vlaams-Brabant.

Status: Formal

Date: 01/05/2022

How to refer: Houthuys, R., Adriaens, R., Goolaerts, S., Laga, P., Louwye, S., Matthijs, J., Vandenberghe, N. & Verhaegen, J., 2023. The Hageland Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Hageland-Member

23.1 Characterizing description

The member is created to accommodate the poorly sorted medium to coarse, very glauconiferous, grey green to brownish, Diest Sand that crops out in between Brussels and Leuven, in Hageland, Zuiderkempen and western-central Limburg (Houthuys et al., 2020). In the outcrop area, the sand is often loosely or firmly limonite-cemented. Hageland ironstone has been used as iron ore and as building stones.

Glauconite content varies from 25% to 60%. The coarse beds often contain a subpopulation of 0.5 to 2 mm (sub)angular quartz grains. In the vertical direction, grain size is either constant or coarsening upwards. The sand shows various primary structures: large and small-scale cross-bedding, massive sand, spaced planar lamination, all of which can display scarce to abundant biogenic burrows, and homogenization by bioturbation. The cross-bedded facies may contain isolated or bundled clay laminae. The sand is non-calcareous and only occasionally contains limonite fossil prints.

23.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The type locality is Diest, where exposures were available at the former town fortress. Hageland and Zuiderkempen can be considered as the type area. Numerous small and larger outcrops are found in the sunken roads. The Kesselberg geosite 2 km NE of Leuven and disused quarries 0.5 km NE of Wezemaal are well-known exposures. Additional exposures are temporarily offered at construction sites.

23.3 Description upper boundary

The upper boundary is, in the outcrop area, a near-planar truncation surface, either uncovered or covered by Quaternary continental deposits, and often strongly incised by the present topography. In its subcrop area, the upper boundary is not well-confined. Houthuys et al. (2020) argue the Kempen Diest Member covers the Hageland Diest Member.

23.4 Description lower boundary

Erosive lower boundary, well expressed in outcrop and core. Locally associated with a well-developed base gravel of rounded flint pebbles, especially in the area where deep local incisions at the base cut through underlying Neogene and Paleogene strata. The depositional unit stratigraphically underlying the Diest Formation is the Berchem Formation at the northern reaches of the Zuiderkempen area and the Bolderberg Formation in Hageland and central Limburg. The lower boundary surface of the Diest Formation incises by variable amounts, often by several 10s of metres, into the underlying units, especially in Hageland and Zuiderkempen, possibly also in north Limburg. At these locations, any older Neogene, Oligocene or upper to middle Eocene deposit that occurs in NE Belgium may underlie the Diest Formation.

23.5 Thickness

General evolution from less than 10 m near the south and west margins of its extent to several 10s of metres in the centre of its extent. Important thickness variations in Hageland and Zuiderkempen are related to the incised nature of the member base. The thickness reaches more than 100 m in the centre of some incisions.

23.6 Occurrence

Outcrop area between Brussels, Leuven, Diest, Heusden-Zolder, Geel and Heist-op-den-Berg (Hageland and Zuiderkempen), Subcrop area to the northeast of the outcrop area, in central and possibly into north-Limburg and continuing into SE-Netherlands.

23.7 Regional correlations

The Hageland Diest Member is the only member of the Diest Formation that occurs in the outcrop area of Hageland and Zuiderkempen. It represents the bulk of the deposits of the first sedimentary cycle inside the Diest Formation (Houthuys et al., 2020; Vandenberghe et al., 2014). The cycle is interpreted as the fill of an incised large tidal inlet of the southern North Sea bight, which was at that time situated in the Lower Rhine embayment. It may be age-equivalent to the Borsbeek, Deurne and lower Dessel members as well as to part of the fine-grained and bioturbated Diest Sand found in north-Limburg.

23.8 Age

There is no direct proof of the age of the member, except its relative position in the lithostratigraphy of the area. Awaiting further proof, the age is assumed to be late Miocene: Tortonian, biochron DN8.

23.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets: https://www.dov.vlaanderen.be/data/opdracht/2020-021774.

Subset of the Diest Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021774

23.10 References

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic foraminifera of the Neogene deposits in Northern Belgium. Bulletin Belgische Vereniging voor Geologie/Bulletin de la Société belge de Géologie, 85, 133–152.

Dumont, A., 1839. Rapport sur les travaux de la carte géologique pendant l'année 1839. Bulletins de l'Académie royale des Sciences et Belles-Lettres de Bruxelles, 6/2, 464–485.

Houthuys, R., Adriaens, R., Goolaerts, S., Laga, P., Louwye, S., Matthijs, J., Vandenberghe, N. & Verhaegen, J., 2020. The Diest Formation: a review of insights from the last decades. Geologica Belgica, 23/3-4, 199-218. https://doi.org/10.20341/gb.2020.012

Vandenberghe, N., Harris, W.B., Wampler, J.M., Houthuys, R., Louwye, S., Adriaens, R., Vos, K., Lanckacker, T., Matthijs, J., Deckers, J., Verhaegen, J., Laga, P., Westerhoff, W. & Munsterman, D., 2014. The implications of

K-Ar glauconite dating of the Diest Formation on the paleogeography of the Upper Miocene in Belgium. Geologica Belgica, 17, 161–174.

24 Kempen Diest Member (Diest Formation)

Unit name: Kempen Diest Member

Hierarchical unit name: Diest Formation

Type: Member

Code: DiKe

Author(s): Houthuys Rik, Adriaens Rieko, Goolaerts Stijn, Laga Piet, Louwye Stephen, Matthijs Johan, Vandenberghe Noël & Verhaegen Jasper

Alternative names: formerly part of the at the time not yet subdivided Diest Formation sensu De Meuter and Laga (1976) after Dumont (1839)

Origin of the name: Kempen region in Antwerp and Limburg provinces.

Status: Formal

Date: 01/05/2022

How to refer: Houthuys, R., Adriaens, R., Goolaerts, S., Laga, P., Louwye, S., Matthijs, J., Vandenberghe, N. & Verhaegen, J., 2023. The Kempen Diest Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Kempen-Diest-Member

24.1 Characterizing description

The member is created to accommodate the poorly sorted medium to coarse, very glauconiferous, greyish green Diest sand that is mostly found in subcrop in boreholes in the northern part of the Kempen and in northern Limburg (Houthuys et al., 2020). Glauconite content varies from 25% to 60%. The coarse beds often contain a subpopulation of 0.5 to 2 mm (sub)angular quartz grains. In the vertical direction, grain size is either constant or coarsening upwards. The sand is most often homogenized by bioturbation. In cores, white burrow traces devoid of glauconite can be seen. No clear primary lamination has been reported in this member. The sand of this member has a loose packing. The sand is often non-calcareous.

On seismic profiles, this member shows large-scale clinoforms with low slope angles (usually around 2%, locally in north Limburg up to 8%), prograding to NW. In north-Limburg, also stacking of aggrading beds is observed (De Batist & Versteeg, 1998). The clinoforms are interpreted as the slope deposits of a prograding marine delta.

24.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

A cored borehole in Mol or Dessel, e.g. from the 'ON' series of boreholes drilled by NIRAS such as ON-Dessel-2 or ON-Dessel-5, can be proposed as type section (remains to be done).

24.3 Description upper boundary

The upper boundary is a near-planar truncation surface, covered by the Kasterlee Formation, the formation that stratigraphically follows the Diest Formation. Locally, inside the Roer Valley Graben, the overlying deposit is the Inden Formation (Louwye & Vandenberghe, 2020). Near Antwerpen, the overlying deposit is the Kattendijk Formation.

24.4 Description lower boundary

The lower boundary is not yet well-defined. There is a gradual downwards transition to the Dessel Member. For practical reasons, the modal grain size of 200 µm is used to separate it from the Dessel Member. Possibly, in the SE part of the extent, the member overlies the Hageland Diest member.

24.5 Thickness

The thickness is difficult to establish as the lower boundary is not well defined. The thickness is several 10s of metres and reaches more than 100 m in the Roer Valley Graben and near the Dutch border.

24.6 Occurrence

The member occurs in the central and north Kempen region. The western border is a few km east of the city of Antwerpen and the southern border is approximately along a line Lier – Herentals – Olmen – southwest border fault of the Roer Valley Graben. However, awaiting a clear description of the transition to the Hageland Diest and Borsbeek/Deurne members, the borders are at present poorly defined.

24.7 Regional correlations

The member boundaries are not (yet) well defined. The Kempen Diest Member is lateral to the Hageland Diest Member, yet was deposited in a lateral depositional phase (Vandenberghe et al., 2014).

24.8 Age

Late Miocene: late Tortonian to earliest Messinian, biochron DN9. North of Antwerpen, biochron DN10.

24.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets: https://www.dov.vlaanderen.be/data/opdracht/2020-021774.

Subset of the Diest Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021774

24.10 References

De Batist, M. & Versteeg, W.H., 1998. Seismic stratigraphy of the Mesozoic and Cenozoic in northern Belgium: main results of a high-resolution reflection seismic survey along rivers and canals. Geologie en Mijnbouw, 77, 17–37. https://doi.org/10.1023/A:1003446611678

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic foraminifera of the Neogene deposits in Northern Belgium. Bulletin Belgische Vereniging voor Geologie/Bulletin de la Société belge de Géologie, 85, 133–152.

Dumont, A., 1839. Rapport sur les travaux de la carte géologique pendant l'année 1839. Bulletins de l'Académie royale des Sciences et Belles-Lettres de Bruxelles, 6/2, 464–485.

Houthuys, R., Adriaens, R., Goolaerts, S., Laga, P., Louwye, S., Matthijs, J., Vandenberghe, N. & Verhaegen, J., 2020. The Diest Formation: a review of insights from the last decades. Geologica Belgica, 23/3-4, 199-218. https://doi.org/10.20341/gb.2020.012

Louwye, S. & Vandenberghe, N., 2020. A reappraisal of the dinoflagellate cyst biostratigraphy of the upper Miocene in the Maaseik well 49W0220. Geologica Belgica, 23/3-4, 289-295. https://doi.org/10.20341/gb.2020.013

Vandenberghe, N., Harris, W.B., Wampler, J.M., Houthuys, R., Louwye, S., Adriaens, R., Vos, K., Lanckacker, T., Matthijs, J., Deckers, J., Verhaegen, J., Laga, P., Westerhoff, W. & Munsterman, D., 2014. The implications of K-Ar glauconite dating of the Diest Formation on the paleogeography of the Upper Miocene in Belgium. Geologica Belgica, 17, 161–174.

25 Clayey-top-facies (Diest Formation)

Unit name: clayey-top-facies

Hierarchical unit name: Diest Formation

Type: Facies

Code: DiCl

Author(s):

- Compiled by: Adriaens Rieko, Houthuys Rik, Vandenberghe Noël

Alternative names: Diest D4 facies in Adriaens (2015)

Origin of the name: The origin of the name of the unit is discussed in Wouters and Schiltz (2011), Adriaens & Vandenberghe (2020)

Status: Informal

Date: 01/05/2022

How to refer: Adriaens, R. & Houthuys, R., 2023. The Clayey-top-facies, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Clayey-top-facies

25.1 Characterizing description

The clayey-top-facies consist of a glauconite-rich, poorly-sorted clayey sand with a characteristic higher clay content compared to the coarse Kempen Diest Member below. The size distribution mode typically ranges between 170 µm and 250 µm. The clay content (dispersed, <2µm) typically ranges between 1% and 10%. The pelletal glauconite content ranges between 26% and 67% and is on average 32.9% (Adriaens, 2015).

The mineralogical and clay mineralogical composition of the clayey-top-facies is very specific and differs from the rest of the Diest Formation. The clay mineralogy consists of a significant amount of expandable clay minerals: dioctahedral smectite but also, and more distinctly, trioctahedral Fe-rich vermiculite (see Adriaens & Vandenberghe, 2020 for details). This type of vermiculite is rare in the stratigraphic column, and is assumed to be related to a glauconitic soil environment. Most likely, it was not formed in-situ but originates from a remote source area where a soil developed on glauconitic sediment in very specific, yet poorly understood, conditions.

Apart from the distinct vermiculite, the clayey-top-facies is also relatively enriched in siderite, apatite and sporadically vivianite and chlorite but the relatively high clay content and the presence of Fe-vermiculite are the distinctive criteria for the clayey-top-facies.

This facies needs better descriptions of extent, correlations and depositional structures. Therefore, it is defined as a facies and not as a formal member inside the Diest Formation.

25.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The name clayey-top-facies was first proposed by Wouters and Schiltz (2011) in their description of the ONDRAF/NIRAS boreholes in the central Campine in region Kasterlee - Mol - Dessel. For now, the occurrence of the facies is also confined to this area. The type localities are the ON-Dessel-2 and ON-Dessel-3 boreholes. At present, the facies has not been recognized in outcrops. The facies was recognized in following boreholes:

ON-Dessel-2 (031W0338/ kb17d31w-B299)

ON-Dessel-3 (031W0354/ ON Dessel-3)

Mol (031E0435/ B/1-96196)

Rees (017E0399/kb8d17e-B495)

25.3 Description upper boundary

The Diest clayey-top-facies is overlain by the Kasterlee Formation, more specific the Hallaar and Heist-op-den-Berg members. The boundary is defined in the type area based on the appearance of a fraction >500µm in the top of the Diest Formation often accompanied by a decrease in the gamma ray signal. In the first 2m above the contact, Fe-vermiculite still occurs in lower quantities as the sediment above the contact is reworked. Above the contact, the dispersed clay content (<2µm) increases to 10-20%. Clay lenses are rare in the clayey-top-facies whereas cm-thick brown to purple clay occurs frequently above the contact.

25.4 Description lower boundary

The base of the clayey-top-facies covers the Kempen Diest Member which is clearly coarser-sized and does not contain the distinct Fe-vermiculite tracer of the clayey-top-facies. The clay content (<2µm) of the clayey-top-facies typically is 1% to 10%, whereas the Kempen Diest Member has a clay content <0.5% and a loose appearance.

25.5 Thickness

The clayey-top-facies reaches its largest thickness of about 12 m in the ON-Dessel-2 and ON-Dessel-3 boreholes.

25.6 Occurrence

The occurrence of the clayey-top-facies is confined to the central Campine area in and around the villages Mol and Dessel. The unit is not recognized in the outcrops more to the western (Kasterlee) and southern (Olen, Heist-op-den-berg) part of the Campine and is also absent in the Hageland area. The extension of the facies in the eastern part of the Campine is not investigated although the occurrence of organic-rich clay lenses at the top of the Diest Formation reported at several locations in Limburg (Helchteren kb25d62e-B272/ 62E261, Peer, Wijshagen kb18d48w-B181/ 48W 180) by Gulinck suggests a possible relation with the clayey-top-facies in the central Campine.

25.7 Regional correlations

/

25.8 Age

Dinoflagellate cyst biozone DN9 was identified in the clayey top facies attributing a late Tortonian to Messinian Miocene age to this facies (Louwye et al., 2007). Additional data are required.

25.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the Diest Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021774

25.10 References

Adriaens, R., 2015. Neogene and Quaternary clay minerals in the southern North Sea. Unpublished Ph.D. Thesis, KU Leuven, Leuven, 272 p.

Adriaens, R. & Vandenberghe, N., 2020. Quantitative clay mineralogy as a tool for lithostratigraphy of Neogene Formations in Belgium: a reconnaissance study. Geologica Belgica 23/3-4, 365-378. https://doi.org/10.20341/gb.2020.018

Louwye, S., De Schepper, S., Laga, P., & Vandenberghe, N., 2007. The Upper Miocene of the southern North Sea Basin (northern Belgium): a palaeoenvironmental and stratigraphical reconstruction using dinoflagellate cysts. Geological Magazine, 144/1, 33–52. https://doi.org/10.1017/S0016756806002627

Wouters, L. & Schiltz, M., 2012. Overview of the field investigations in and around the nuclear site of Mol Dessel. ONDRAF/NIRAS NIROND-TR report 2011–42 E, 100 p.

26 Bosbeek facies (Diest Formation)

Unit name: Bosbeek facies

Hierarchical unit name: Diest Formation

Type: Facies

Code: DiBs

Author(s): Houthuys Rik, Vandenberghe Noël, Matthijs Johan

Alternative names: Opoeteren Sand used by Gulinck in borehole description GSB 064W0234/DOV kb26d64w-B242 to refer to the Diest Formation outcrop in the Bosbeek valley a few km south of the borehole.

Origin of the name: newly introduced name to refer to the outcrops of the Diest Formation in the Bosbeek valley

Status: informal

Date: 01/05/2022

How to refer: Houthuys, R., Vandenberghe, N. & Matthijs, J., 2023. The Bosbeek facies, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Bosbeek-facies

26.1 Characterizing description

The Bosbeek facies is the local expression of the Diest Formation in the northern part of the Kempen Plateau, such as found in outcrop in the flanks of the Bosbeek Valley (Figure 26-1). It consists of fine, poorly sorted, glauconiferous sand. The sand is bioturbated and has a subhorizontal stratification. It contains thin subhorizontal clay layers. It contains no carbonates or fossils. The outcrops are rare. They show a weathered facies.

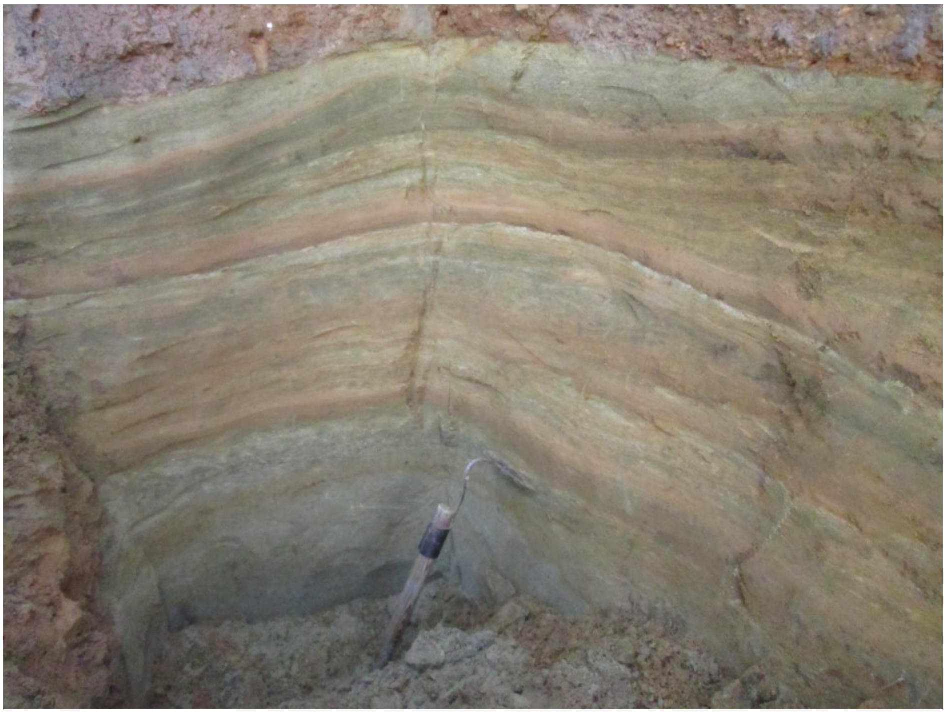


Figure 26-1. Outcrop at Opoeteren-Dorne, Dornerstationsstraat 6, in 2017.

In the present state of understanding, it is assumed that the "facies of Opoeteren" described by Gulinck (1964) between 6 and 22 m in the Neeroeteren borehole (http://collections.naturalsciences.be/ssh-geology-archives/arch/064w/064w0234.txt, accessed 14/01/2022) as fine, glauconiferous sand with pale burrows, sporadic clay lenses and some coarse quartz is at least in part comparable to the Bosbeek facies identified in outcrops. The uncertainty in the correlation of this borehole interval and the Bosbeek valley outcrops is due to the presence between both of the Rotem and Neeroeteren Faults.

26.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

Outcrops are scarce. The disused sandpit at Opoeteren, Dorperberg, Eggestraat (Lambert72 X 239965, Y 195400) could be refreshed and re-examined.

26.3 Description upper boundary

Unknown. In the outcrop area, the facies is covered by Pleistocene gravel (Zutendaal Formation).

26.4 Description lower boundary

Unknown. In the outcrop area, the facies covers the Genk Member of the Bolderberg Formation.

26.5 Thickness

15-20 m, to be verified.

26.6 Occurrence

The Bosbeek facies is found in outcrop in North-Limburg, in Opoeteren, Dorne and Opglabbeek in the flanks of the Bosbeek valley; possibly in the Maas Valley left flank near Bergerven and probably in the Neeroeteren subsurface. Mapping the extent and the correlation to the other Diest Formation members requires new observations.

26.7 Regional correlations

Not clear. This facies may be a local representation of the Hageland Diest Member: the Wijshagen borehole, 8 km to WNW, contains biozone DN8 for the level interpreted there as the Diest Formation (Louwye & Laga, 2008). However, the Opoeteren facies in the Neeroeteren borehole (GSB 064W0234/DOV kb26d64w-B242) and according to Gulinck correlated to the Bosbeek facies contains biozone DN9 (Louwye et al., 1999).

26.8 Age

Middle to late Tortonian. Biozones DN8 and/or DN9. Remains to be established.

26.9 Dataset

/

26.10 References

Louwye, S., De Coninck, J. & Verniers, J., 1999. Dinoflagellate cyst stratigraphy and depositional history of Miocene and Lower Pliocene formations in northern Belgium (southern North Sea Basin). Geologie en Mijnbouw 78: 31-46

Louwye, S. & Laga, P., 2008. Dinoflagellate cyst stratigraphy and palaeoenvironment of the marginal marine Middle and Upper Miocene of the eastern Campine area, northern Belgium (southern North Sea Basin). Geological Journal, 43, 75–94. https://doi.org/10.1002/gj.1103

27 Flemish Hills Formation

Unit name: Flemish Hills Formation / Formatie van de Vlaamse Heuvels / Formation des Collines Flamandes

Hierarchical unit name: -

Type: Formation

Code: Vh

Author(s): Houthuys Rik

Alternative names: Diestien des Collines de Flandre (disused) / including the poudingue de Renaix, de Cassel

Origin of the name: New name. The Flemish Hills are outlier hills situated in historic Flanders but presently on the linguistic Flemish-French border. Therefore, an exception to the linguistic rules is proposed and an English name is also proposed.

Status: Formal

Date: 01/05/2022

How to refer: Houthuys, R., 2023. The Flemish Hills Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Flemish-Hills-Formation

27.1 Characterizing description

The Flemish Hills Formation consists of poorly to very poorly sorted, fine to coarse sand. The grain size coarsens upwards. Though the description of the vertical build-up was made in the Ronse area, it is believed to be valid for the North French and southern West-Vlaanderen area (Houthuys, 2014). Small to coarse (up to 15 cm) flint pebbles occur throughout the vertical profile, dispersed in the sand or in inclined or channel-like beds. Towards the top, there is an increasing admixture of coarse, often angular grains. Glauconite varies from almost none at the base to locally 20% near the top. The lower part of the sand deposit is bioturbated. The central part shows besides bioturbated beds also inclined beds and shallow channels partially filled by low-angle parallel lamination. The content of pebbles is highest in this middle part. The top part shows subhorizontal and inclined parallel lamination, and hummocky and swaley cross stratification. The successive parts show gradual transitions, and can interdigitate. The formation is devoid of carbonates and fossils. The formation is affected by limonite cementation in various, often capricious shapes and in various degrees of solidness. Thick cemented beds may be found in the top of the formation. Locally, the ironstone has been used for building stone (poudingue de Renaix, de Cassel: pudding stone, named after the dark brown cemented sand matrix containing pale flint pebbles). In the central part, rare thin, pale to salmon coloured, clay layers occur; they are rich in kaolinite (Adriaens, 2015). Houthuys (2014) presented an up-to-date interpretation of the sedimentary environment.

27.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

Disused sandpit and dump site at Lumen, municipality of Flobecq, just south of Brakelbos. The site is private-owned and the owner doesn't allow access. Other outcrops are the sunken lane between Pottelberg and Queneau at Flobecq and the disused sandpit north of Muziekbosstraat at Ronse.

27.3 Description upper boundary

The Flemish Hills Formation is in the Flemish Hills area the topmost deposit. The flat hill tops suggest the top surface was also flat. It is unknown which Paleogene or Neogene deposits may have covered the formation before denudation.

27.4 Description lower boundary

Probably subhorizontal truncation surface, covered by a flint pebble gravel. The gravel is thin to a few decimetres thick. The pebbles are well rounded, and dark-coloured (unweathered). The underlying unit is the Asse Member, possibly also the Ursel Member, of the Maldegem Formation. The other members of that formation are lacking. The preserved clay is truncated by the lower surface of the Flemish Hills Formation.

27.5 Thickness

The Flemish Hills Formation is maximally 29 m thick (Cassel, France) and 25 m (Pottelberg near Flobecq). The thickness is less where the outlier hills have tops that don't reach 25 m above the subhorizontal base surface.

27.6 Occurrence

The Flemish Hills Formation occurs in the top part of each of the outlier hills that constitute the row of Flemish Hills, from West to East: Cassel, Mont des Récollets, Mont des Cats, Mont de Boeschepe, Mont Noir/Zwarteberg, Rodeberg, Scherpenberg, Kemmelberg, Kluisberg/Mont de l'Enclus, Hotondberg, Muziekberg, Pottelberg, Bois de la Louvière/Livierenbos (Fig. 1 in Houthuys, 2014). It remains to be confirmed if the formation is also found west of Cassel (e.g. Noires Mottes west of Calais). It was observed in reworked remnants in borehole GSB 101W079 on Kesterheide (Gooik). There is a possible eastern outlier between Kraainem and Tervuren (awaiting new evidence, Houthuys et al., 2020).

27.7 Regional correlations

Houthuys (2014) and Houthuys et al. (2020) give an overview of correlations suggested by various authors. Additional data is required to elaborate on the precise correlations.

27.8 Age

Any age between latest Eocene and late Pliocene. Remains to be established.

27.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Outcrop Pottelberg sunken lane		TO-20140501B		https://www.dov.vlaanderen.be/data/boring/2019-164501
Muziekberg old sandpit		TO-20140501		https://www.dov.vlaanderen.be/data/boring/2019-164498

Extra data:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Pottelberg well	099W1474	kb30d99w-B1474	https://collections.naturalsciences.be/ssh-geology-archives/arch/099w/099w1474.txt	https://www.dov.vlaanderen.be/data/boring/1968-069737
Kesterberg well	101W079	kb31d101w-B79	https://collections.naturalsciences.be/ssh-geology-archives/arch/101w/101w0079.txt	https://www.dov.vlaanderen.be/data/boring/1989-090836

27.10 References

Adriaens, R., 2015. Neogene and Quaternary clay minerals in the southern North Sea. Published Ph.D. Thesis, KU Leuven, Leuven, 272 p. https://limo.libis.be/primo-explore/fulldisplay?docid=LIRIAS1930587&context=L&vid=Lirias&search_scope=Lirias&tab=default_tab&lang=en_US

Houthuys, R., 2014. A reinterpretation of the Neogene emersion of central Belgium based on the sedimentary environment of the Diest Formation and the origin of the drainage pattern. Geologica Belgica, 17/3-4, 211-235. https://popups.uliege.be/1374-8505/index.php?id=4602.

Houthuys, R., Adriaens, R., Goolaerts, S., Laga, P., Louwye, S., Matthijs, J., Vandenberghe, N. & Verhaegen, J., 2020. The Diest Formation: a review of insights from the last decades. Geologica Belgica, 23/3-4: 199-218. https://doi.org/10.20341/gb.2020.012

28 Kasterlee Formation

Unit name: Kasterlee Formation

Hierarchical unit name: /

Type: Formation

Code: Kl

Author(s):

- Compiled by: Verhaegen Jasper & Vandenberghe Noël

- Modification of: De Meuter & Laga (1976) after Dumont (1882)

Alternative names: /

Origin of the name: The outcrops along the Lichtaart-Kasterlee hill ridge. The meaning of the Kasterlee Formation is extended compared to the definition by De Meuter & Laga (1976) after Dumont (1882) in Lithostratigraphic scale of Belgium (Laga et al., 2001).

Status: Formal

Date: 01/05/2022

How to refer: Verhaegen, J. & Vandenberghe, N., 2023. The Kasterlee Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Kasterlee-Formation

28.1 Characterizing description

The main properties allowing to identify the classical Kasterlee Formation in its type area are undoubtedly the fine sand grain-size compared to the medium sand grain-size of the underlying Diest Formation and a moderate to low glauconite content giving the sand a colour from grey to green depending on the content. No grain-size contrast with the overlying Poederlee Sand exists but the boundary is marked by the characteristic Hukkelberg Gravel layer at the base of the latter. Where the Kasterlee Formation is almost devoid of glauconite grains and overlain or laterally bordered by Mol Sand, the boundary can be debatable. The Kasterlee Formation contains no carbonate and calcareous fossils are absent. Dinoflagellate cysts do occur. Muscovite flakes are common. A basal flint gravel is only observed at southern locations while otherwise no basal gravel is present.

Recent comprehensive studies of the Kasterlee Formation since the earlier review by Laga et al. (2001) have justified the subdivision into members. A thin basal part with reworked coarser Diest Formation sand, containing a larger amount of glauconite pellets and a bimodal grain-size distribution, is generally recognised and named the Hallaar Member. A clayey facies occurs in the east and south of the formation, named the Heist-op-den-Berg Member; it is characterized by an alternation of cm- to dm-scale fine sand and grey clay layers. A fine sand unit with low glauconite content named the Beerzel Member only occurs locally between the Hallaar and Heist-op-den-Berg members. In the east of the formation distribution area, a pale grey quartz sand practically without glauconite pellets occurs systematically above the Heist-op-den-Berg Member. In the archives of the Geological Survey of Belgium this facies was incorporated into the Kasterlee Formation although its colour and quartz composition relate it lithostratigraphically to the Mol Sand. The difference with the classical Mol Sand can be made by the presence of a coarser size fraction in the latter. The name of Retie Member is proposed for this pale grey facies which for geometrical, paleogeographical reasons, and for stratigraphical nomenclature continuity, could be grouped in the Kasterlee Formation. However it is chosen to rank the Retie Member as a lithostratigraphic member of the Mol Sand Formation because of its pale grey colour and its quartz composition (for a discussion see Vandenberghe et al., 2020). In this subdivision of the Kasterlee Formation, the classical fine-grained and pale green sand type of the previous Kasterlee Formation definitions, in the northwest of the formation occurrence area, needs to be defined as a member within the formation and the name Lichtaart Member is proposed for it.

28.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The type section of the Kasterlee Formation selected in the Lithostratigraphic scale of Belgium (2001) are occasional outcrops in the flanks of the hills between Herentals, Lichtaart and Kasterlee on the right bank of the Kleine Nete valley. In this stratotype area the Lichtaart Member is observed and overlain by Hukkelberg Gravel at the base of the Poederlee Sand. The base of the formation cannot be observed in these outcrops. However, a CPT on the hill near Kasterlee (10-CPTE-138) shows the base of the Lichtaart Member at +4.25 m TAW and the base of the formation at -2 m TAW.

As the other members occur laterally of the classical Lichtaart Member, type sections for these are also relevant and discussed in these member descriptions. For the Hallaar, Beerzel and Heist-op-den-Berg members the sunken lane in Heist-op-den-Berg is proposed (TO-20140919 / TO-20190617).

28.3 Description upper boundary

In the northwest, the formation can be overlain by the Poederlee Sand in which case the characteristic Hukkelberg Gravel occurs at the latter's base just above the top of the Kasterlee Formation. In the eastern area where the top of the Kasterlee Formation is made up by the clayey Heist-op-den-Berg Member, it is overlain by the pale grey fine quartz sand of the Retie Member (Mol Formation)

28.4 Description lower boundary

The Kasterlee Formation is always underlain by the Diest Formation. The Diest Formation has a coarser grain size. When the top of the Diest Formation is also enriched in clay or contains clay laminae, as is the case in the Mol-Dessel area, the boundary between both formations can be uncertain. However in the area east of Kasterlee, the appearance of a fraction >500 µm in the top of the Diest Formation often accompanied by a decrease in the gamma ray signal allows to mark the boundary between both formations. This boundary is consistent with a correlative signal change in CPT measurements. It has been observed that the base of the Kasterlee Formation contains reworked Diest Formation sand up to 2-3 m above the contact (Hallaar Member) influencing also the gamma ray signal.

A disperse basal gravel, the Olen Gravel Bed, has been found only in the Beerzel, Heist-op-den-Berg and Olen outcrops, in the south of the formation occurrence area. The gravel consists of somewhat flattened flint pebbles with a characteristic spotted patina. The top of the Diest Formation in this area is much coarser, though with a larger clay fraction, less well sorted and has a higher glauconite content compared to the base of the Kasterlee Formation. Further northwards, only a somewhat coarser sand level occasionally occurs at the base of the Kasterlee Formation.

28.5 Thickness

In the type area Herentals-Lichtaart-Kasterlee a thickness of about 15 m is interpreted in sections drafted by Laga and Gulinck and confirmed by a CPT log interpretation (10-CPTE-138). In the boreholes Gierle (017W0158/kb8d17w-B14) and Rees (017E0399/kb8d17e-B495), in which only the Lichtaart Member occurs underlying the Poederlee Formation, thickness is reduced to 8 to 10 m. East of Kasterlee, with the Hallaar and Heist-op-den-Berg members, thicknesses between 5 and 10 m are interpreted in boreholes. In the Beerzel and Heist-op-den-Berg outcrops the thickness is 8 m and in the Olen outcrop 5 m; in both outcrops the Kasterlee Formation is overlain by Quaternary sediments.

28.6 Occurrence

The paleogeographical map shows the distribution of the Kasterlee Formation and its Lichtaart (open marine), Beerzel (barrier sand) and Heist-op-den-Berg (clayey facies) members (Figure 28-1). The Hallaar Member with marked reworking of underlying Diest Formation sand occurs where the latter is most strongly eroded, namely in the coastal marine realm. The Retie Member distribution is similar to that of the Heist-op-den-Berg Member.

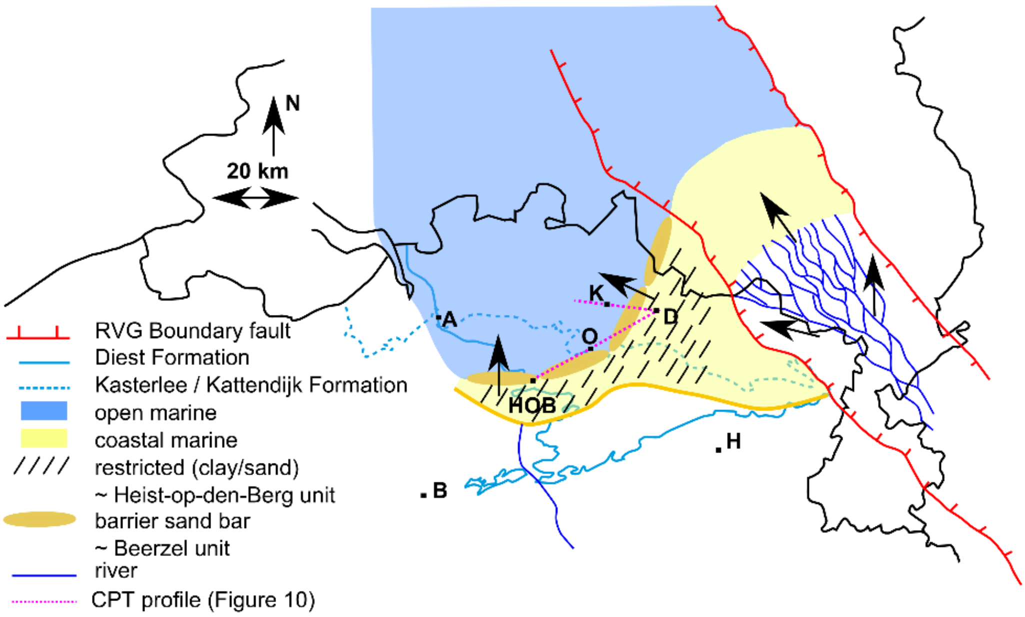


Figure 28-1. Paleogeographical map of the Kasterlee Formation (Verhaegen et al., 2020).

28.7 Regional correlations

As no calcareous microfossils occur in the Kasterlee Formation, its lateral geometry with the fossiliferous Kattendijk Formation was used to consider both formations as each other's lateral equivalent. However dinoflagellate cyst biozone DN10 identified in the Lichtaart Member (Rees borehole, 017E0399; kb8d17e-B495) and in the Heist-op-den-Berg Member (ON-Dessel-2 borehole 031W0338 / kb17d31w-B299) attributes a late Tortonian to Messinian Miocene age to the Kasterlee Formation compared to the early Zanclean Pliocene age of the Kattendijk Formation. The difficulty to distinguish between the Kattendijk and Kasterlee formations in the subsurface of the Antwerp province is apparent in several profiles of Laga and Gulinck (Laga, 1976) and probably also explains the possibly 40 m thickness for the Kasterlee Formation in the northeast of the Antwerp province cited in the Lithostratigraphic scale of Belgium (2001). Based on the DN10 biozonation, the Kasterlee Formation is laterally equivalent to the top of the Diest Formation to the west. In the east, the Kasterlee Formation partly underlies (Heist-op-den-Berg Member) and is partly lateral to (Lichtaart Member) the base of the Mol Formation (Retie Member).

28.8 Age

Dinoflagellate cyst biozone DN10 was identified in the Lichtaart Member (Rees borehole, 017E0399; kb8d17e-B495) and in the Heist-op-den-Berg Member (ON-Dessel-2 borehole 031W0338 / kb17d31w-B299), attributing a late Tortonian to Messinian Miocene age to the Kasterlee Formation.

28.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the Kasterlee Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021580

28.10 References

Buffel, P., Vandenberghe, N., Goolaerts, S. & Laga, P., 2001. The Pliocene sediments in 4 boreholes in the Turnhout area (North-Belgium): the relationship with the Lillo and Mol Formations. Aardkundige Mededelingen, 11, 1–8.

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/4, 133–152.

Dumont, A., 1882. Mémoires sur les terrains crétacé et tertiaires préparés par feu A. Dumont pour servir à la description de la carte géologique de Belgique, 2 éd. par Mourlon, M. IV Terrains tertiaires, partie 3, 1–702.

Fobe, B., 1995. Lithologie en lithostratigrafie van de Formatie van Kasterlee (Plioceen van de Kempen). Natuurwetenschappelijk Tijdschrift, 75, 35–45.

Gullentops, F. & Huyghebaert, L., 1999. A profile through the Pliocene of Northern Kempen, Belgium. Aardkundige Mededelingen, 9, 191–202.

Laga, P., 1976. Geologische Doorsneden. Archieven Belgische Geologische Dienst. http://collections.naturalsciences.be/ssh-geology/geology/profiles-neogeen2020, accessed 15/03/2020.

Laga, P., Louwye, S. & Geets, S., 2001. Paleogene and Neogene lithostratigraphic units (Belgium). In Bultynck, P. & Dejonghe, L., (eds), Guide to a revised lithostratigraphic scale of Belgium. Geologica Belgica, 4/1-2, 135–152. https://doi.org/10.20341/gb.2014.050

Louwye, S., De Schepper, S., Laga, P. & Vandenberghe, N., 2007. The Upper Miocene of the southern North Sea Basin (northern Belgium): a paleoenvironmental and stratigraphical reconstruction using dinoflagellate cysts. Geological Magazine, 144, 33–52. https://doi.org/10.1017/S0016756806002627

Schiltz, M., 2020. On the use of CPT's in stratigraphy; recent observations and some illustrative cases. Geologica Belgica, 23/3-4, 399-411. https://doi.org/10.20341/gb.2020.019

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, R., Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica, 23/3-4, 265-287. https://doi.org/10.20341/gb.2020.014

Verhaegen, J., Adriaens, R., Louwye, S., Vandenberghe, N. & Vos, K., 2014. Sediment-petrological study supporting the presence of the Kasterlee Formation in the Heist-op-den-Berg and Beerzel hills, southern Antwerp Campine, Belgium. Geologica Belgica, 17, 323–332.

Verhaegen, J., Frederickx, L. & Schiltz, M., 2020. New insights into the stratigraphy and paleogeography of the Messinian Kasterlee Formation from the analysis of a temporary outcrop. Geologica Belgica, 23/3-4, 253-263. https://doi.org/10.20341/gb.2020.015

29 Hallaar Member (Kasterlee Formation)

Unit name: Hallaar Member

Hierarchical unit name: Kasterlee Formation

Type: Member

Code: KlHa

Author(s): Verhaegen Jasper & Vandenberghe Noël

Alternative names: formerly part of the at the time not yet subdivided Kasterlee Formation sensu De Meuter and Laga (1976) and Laga et al. (2001).

Origin of the name: Description of the Kasterlee Formation at Heist-op-den-Berg and Beerzel by Fobe (1995)

Status: Formal

Date: 01/05/2022

How to refer: Verhaegen, J. & Vandenberghe, N., 2023. The Hallaar Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Hallaar-Member

29.1 Characterizing description

In its type area around the hills of Heist-op-den-Berg and Beerzel up to Olen more the north, a disperse gravel of flattened and partly weathered flint pebbles, the Olen Gravel Bed, is present at the base of the Hallaar Member, together with coarse quartz grains and white weathered silex, described in detail in Verhaegen et al. (2014). The Hallaar Member has transitional characteristics between the Diest Formation and Kasterlee Formation. Glauconite content is significantly lower than in the Diest Formation but concentrations of >10% (glauconite/quartz ratio of 0.20–0.68) are still present (Verhaegen et al., 2020). The grain size distribution is bimodal. The coarser mode is similar to the modal grain size of the underlying Diest Sand and can be attributed to reworking of sediment from the Diest Formation. Another finer modal grain size is also present (< 200 µm) which is more typical of the Kasterlee Formation. The sediment has a large fine fraction, with 50% of grains <85 µm. The Hallaar Member has a similar content of dioctahedral 2:1 Al-rich layer silicates (11–15%, 2:1 Al-clay/quartz ratio of 0.22–0.23) to the Diest Formation, yet higher than the overlying Beerzel Member and the sandy parts of the Heist-op-den-Berg Member. Feldspar content (4–5%, feldspar/quartz ratio of 0.06–0.09) is significantly higher compared to the Diest Formation and similar to the overlying Beerzel and Heist-op-den-Berg members. In outcrops or cores, the Hallaar Member may be recognized by its brownish-green weathered color if oxidized above the groundwater table, significant glauconite and clay content, and a mottled appearance due to the presence of green-greyish clay-enriched patches of sediment (Verhaegen et al., 2020).

The Hallaar Member, with its reworking of the underlying Diest Formation sand, appears to be present across most of the occurrence area of the Kasterlee Formation, based on CPT profiles and core observations. On CPT's there is a drop in qc value from the Diest Formation to the Hallaar Member (Vandenberghe et al., 2020). North of Olen no basal gravel is present. In this area, the Hallaar Member is distinguished based on its transitional characteristics between the Diest and Kasterlee formations.

29.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The proposed type section of the lower three members of the Kasterlee Formation, including the Hallaar Member, is the sunken lane atop the hill of Heist-op-den-Berg (DOV TO-20140919 and TO-20190617). The type section is described in detail in Verhaegen et al. (2014) and Verhaegen et al. (2020), and was originally proposed by Fobe (1995).

29.3 Description upper boundary

In the southern area of Beerzel, Heist-op-den-Berg and Olen, the Hallaar Member is always overlain by Beerzel Member sand. This is a transitional boundary which can be identified based on a shift from the brown-green colour of the Hallaar Member to the yellow-white colour of the Beerzel Member, due to a strong decrease in glauconite and goethite content in the Beerzel Member. The Beerzel Member is a better sorted fine sand with a lower clay content compared to the Hallaar Member.

Towards the north, the Beerzel Member is not always present and the Halllaar Member is often directly overlain by the Heist-op-den-Berg Member. This is a sharper boundary which can be placed at the first cm- to dm-scale clay layer at the base of the Heist-op-den-Berg Member, followed by a sand-clay alternation within the Heist-op-den-Berg Member.

29.4 Description lower boundary

The Hallaar Member is always underlain by the Diest Formation, which has a coarser modal grain size and a higher glauconite content. In the type area to the south, the lower boundary is marked by the occurrence of the Olen Gravel Bed, a disperse gravel of flattened flint pebbles with a spotted patina, together with a very coarse quartz fraction (>1 mm) and white weathered silex fragments.

Towards the north, the basal gravel is no longer present making the boundary harder to identify as the Hallaar Member contains reworked Diest Sand, leading to transitional characteristics between the Diest and Kasterlee formations. This may be further complicated in cases where the top of the Diest Formation is also enriched in clay laminae. However in the area east of Kasterlee, the appearance of a fraction >500 µm in the top of the Diest Formation often accompanied by a decrease in the gamma ray signal allows to mark the boundary between both formations. This boundary is consistent with a correlative signal change in CPT measurements. The reworked Diest Sand in the Hallaar Member also influences the gamma ray signal.

29.5 Thickness

The Hallaar Member comprises the lower couple of meters of the Kasterlee Formation, in which reworking of the underlying Diest Formation is apparent. In the type section, the thickness is approximately 3 m and this appears rather consistent throughout the occurrence area to the north, with a thickness of 2-3 m.

29.6 Occurrence

The Hallaar Member appears as a transitional basal unit of the Kasterlee Formation throughout most of its occurrence area. Only in the northwest such a transitional unit cannot always be observed and the Diest Formation is directly overlain by the Lichtaart Member.

29.7 Regional correlations

The base of the Hallaar Member represents a wave-ravinement surface formed due to a rapid transgressional phase, leading also to the reworking of the underlying Diest Sand. As such, the member has mostly developed in the more proximal environments towards the south and east, while it may not be recognized in the northwest (northwest of Kasterlee village), where only the shallow open marine Lichtaart Member is identified. The Hallaar Member is laterally equivalent with the base of the Lichtaart Member in the northwest, where no significant reworking of the Diest Sand is recorded.

29.8 Age

No age data are available for the Hallaar Member, yet it is underlain by the late Tortonian to Messinian Campine Diest Sand and overlain by the Heist-op-den-Berg Member in which dinoflagellate cyst biozone DN10 of late Tortonian to Messinian Miocene age was identified.

29.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the Kasterlee Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021580

Subset of the Heist-op-den-Berg type section: https://www.dov.vlaanderen.be/data/opdracht/2020-022424

29.10 References

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/4, 133–152.

Fobe, B., 1995. Lithologie en lithostratigrafie van de Formatie van Kasterlee (Plioceen van de Kempen). Natuurwetenschappelijk Tijdschrift, 75, 35–45.

Laga, P., Louwye, S. & Geets, S., 2001. Paleogene and Neogene lithostratigraphic units (Belgium). In Bultynck, P. & Dejonghe, L., (eds), Guide to a revised lithostratigraphic scale of Belgium. Geologica Belgica, 4/1-2, 135–152. https://doi.org/10.20341/gb.2014.050

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, R., Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica, 23/3-4, 265-287. https://doi.org/10.20341/gb.2020.014

Verhaegen, J., Adriaens, R., Louwye, S., Vandenberghe, N. & Vos, K., 2014. Sediment-petrological study supporting the presence of the Kasterlee Formation in the Heist-op-den-Berg and Beerzel hills, southern Antwerp Campine, Belgium. Geologica Belgica, 17, 323–332.

Verhaegen, J., Frederickx, L. & Schiltz, M., 2020. New insights into the stratigraphy and paleogeography of the Messinian Kasterlee Formation from the analysis of a temporary outcrop. Geologica Belgica, 23/3-4, 253-263. https://doi.org/10.20341/gb.2020.015

30 Olen Gravel Bed (Hallaar Member)

Unit name: Olen Gravel Bed

Hierarchical unit name: Hallaar Member

Type: Bed

Code: KlOl

Author(s): Verhaegen Jasper & Vandenberghe Noël

Alternative names: formerly part of the at the time not yet subdivided Kasterlee Formation sensu De Meuter and Laga (1976) and Laga et al. (2001).

Origin of the name: This gravel bed was first described in the 1972 temporary outcrop for construction of the Olen sluice along the Albert Canal (Louwye et al., 2007)

Status: Formal

Date: 01/05/2022

How to refer: Verhaegen, J. & Vandenberghe, N., 2023. The Olen Gravel Bed, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Olen-Gravel-Bed

30.1 Characterizing description

The Olen Gravel Bed is a disperse gravel which occurs at the base of the Kasterlee Formation in the type area of the Hallaar Member, from Olen down to the hills of Heist-op-den-Berg and Beerzel. The gravel was first observed during the construction works for an additional sluice on the Albert Canal at Olen, in 1972. It was briefly mentioned in Louwye et al. (2007) as "the presence of coarser quartz grains, occasional round stones and even a silicified shell fragment". It was later also identified to the south in the Beerzel and Heist-op-den-Berg Hills and described in detail by Verhaegen et al. (2014). The gravel occurs diffusely in the sediment of the Hallaar Member and can be best recognized by sieving a sample over a 1 mm screen. Flattened and elongated flint pebbles with a length up to 4 cm occur. The pebbles have a characteristic spotted patina. Many coarse (> 1 mm) quartz grains occur, which are mostly angular but larger rounded grains are present as well. A third component are white powdery fragments of weathered silex, which are markedly larger (> 1 cm) in the Olen outcrop. Lastly, iron crust fragments up to 1.5 cm with rounded edges occur as well.

30.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The proposed type section of the lower three members of the Kasterlee Formation, including the Hallaar Member and Olen Gravel Bed, is the sunken lane atop the hill of Heist-op-den-Berg (DOV TO-20140919 and TO-20190617). The type section is described in detail in Verhaegen et al. (2014) and Verhaegen et al. (2020).

30.3 Description upper boundary

The Olen Gravel Bed occurs diffusely in the lower part of the Hallaar Member and gradually disappears towards the top of this member.

30.4 Description lower boundary

The Olen Gravel Bed occurs diffusely in the lower part of the Hallaar Member and is underlain by the coarse green glauconite rich sand of the Diest Formation.

30.5 Thickness

The Olen Gravel Bed occurs diffusely in the lower part of the Hallaar Member, which has a thickness of about 3 m in the type area, and gradually disappears towards the top of this member.

30.6 Occurrence

The Olen Gravel Bed occurs in the type area of the Hallaar Member, which is located in the southern reach of the Kasterlee Formation occurrence area, from Olen to the hills of Heist-op-den-Berg and Beerzel. North of this area, a distinct gravel is no longer present yet the boundary between the Kasterlee Formation and Diest Formation may still be delineated by the occurrence of a coarse (> 500 µm) fraction of quartz grains.

30.7 Regional correlations

-

30.8 Age

No age data are available for the Hallaar Member which contains the Olen Gravel Bed, yet it is underlain by the late Tortonian to Messinian Campine Diest Sand and overlain by the Heist-op-den-Berg Member in which dinoflagellate cyst biozone DN10 of late Tortonian to Messinian Miocene age was identified.

30.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the Kasterlee Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021580

Subset of the Heist-op-den-Berg type section: https://www.dov.vlaanderen.be/data/opdracht/2020-022424

30.10 References

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/4, 133–152.

Fobe, B., 1995. Lithologie en lithostratigrafie van de Formatie van Kasterlee (Plioceen van de Kempen). Natuurwetenschappelijk Tijdschrift, 75, 35–45.

Laga, P., Louwye, S. & Geets, S., 2001. Paleogene and Neogene lithostratigraphic units (Belgium). In Bultynck, P. & Dejonghe, L., (eds), Guide to a revised lithostratigraphic scale of Belgium. Geologica Belgica, 4/1-2, 135–152. https://doi.org/10.20341/gb.2014.050

Louwye, S., De Schepper, S., Laga, P. & Vandenberghe, N., 2007. The Upper Miocene of the southern North Sea Basin (northern Belgium): a paleoenvironmental and stratigraphical reconstruction using dinoflagellate cysts. Geological Magazine, 144, 33–52. https://doi.org/10.1017/S0016756806002627

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, R., Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica, 23/3-4, 265-287. https://doi.org/10.20341/gb.2020.014

Verhaegen, J., Adriaens, R., Louwye, S., Vandenberghe, N. & Vos, K., 2014. Sediment-petrological study supporting the presence of the Kasterlee Formation in the Heist-op-den-Berg and Beerzel hills, southern Antwerp Campine, Belgium. Geologica Belgica, 17, 323–332.

Verhaegen, J., Frederickx, L. & Schiltz, M., 2020. New insights into the stratigraphy and paleogeography of the Messinian Kasterlee Formation from the analysis of a temporary outcrop. Geologica Belgica, 23/3-4, 253-263. https://doi.org/10.20341/gb.2020.015

31 Beerzel Member (Kasterlee Formation)

Unit name: Beerzel Member

Hierarchical unit name: Kasterlee Formation

Type: Member

Code: KlBe

Author(s): Verhaegen Jasper & Vandenberghe Noël

Alternative names: formerly part of the at the time not yet subdivided Kasterlee Formation sensu De Meuter and Laga (1976) and Laga et al. (2001).

Origin of the name: Description of the Kasterlee Formation at Heist-op-den-Berg and Beerzel by Fobe (1995)

Status: Formal

Date: 01/05/2022

How to refer: Verhaegen, J. & Vandenberghe, N., 2023. The Beerzel Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Beerzel-Member

31.1 Characterizing description

The Beerzel Member in the type area can be recognized by its yellow to white colour and low glauconite and clay content, and is consistently underlain by a more glauconite-rich unit – the Hallaar Member, and overlain by a unit with clay-sand alternations – the Heist-op-den-Berg Member. It has a homogeneous appearance, except for possible irregular brownish intercalations due to oxidation above the groundwater table, linked to groundwater fluctuations. Glauconite content is significantly lower in the Beerzel Member compared to the underlying Hallaar Member (2–6%, glauconite/quartz ratio of 0.02–0.08). The grain size distribution curves show a very well sorted sediment with a modal grain size between 185 and 204 µm and only a small amount of material outside of the 100 to 300 µm range. The content of dioctahedral 2:1 Al-rich layer silicates (3–9%, 2:1 Al-clay/quartz ratio of 0.03–0.11) is lower than in the Hallaar Member and similar to the sandy layers of the overlying Heist-op-den-Berg Member, and there is an overall decrease to the top. Feldspar content remains largely constant within the member (4–6%, feldspar/quartz ratio of 0.05– 0.08).

On CPT's, the Beerzel Member can be identified based on an interval with constant qc values, a bit higher than in the underlying and overlying members. Based on CPT profiles, the Beerzel Member also occurs further north, such as near Kasterlee, though not consistently (Vandenberghe et al., 2020).

31.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The proposed type section of the lower three members of the Kasterlee Formation, including the Beerzel Member, is the sunken lane atop the hill of Heist-op-den-Berg (DOV TO-20140919 and TO-20190617). The type section is described in detail in Verhaegen et al. (2014) and Verhaegen et al. (2020). The member name was originally proposed after a study of this section by Fobe (1995).

31.3 Description upper boundary

The Beerzel Member is overlain by the Heist-op-den-Berg Member. In type area in the south, the boundary is placed at the occurrence of the first dm-scale purple clay layer at the base of the Heist-op-den-Berg Member (Verhaegen et al., 2020). The overlying Heist-op-den-Berg Member can be easily distinguished based on the alternation of fine sand and clay layers, in contrast to the homogenous fine sand of the Beerzel Member.

Towards the north, the Beerzel Member is often absent. Where it is present, it can be recognized by the constant CPT signal or gamma-ray signalcompared to the strongly fluctuating signal of the overlying Heist-op-den-Berg Member (e.g. ON-Kasterlee-1; Verhaegen et al., 2020, Fig. 10). In cores as well, the boundary between both members occurs where the alternation of clay and sand layers starts (Vandenberghe et al., 2020).

31.4 Description lower boundary

The Beerzel Member is always underlain by the Hallaar Member. This is a transitional boundary which can be identified based on a shift from the brown-green colour of the Hallaar Member to the yellow-white colour of the Beerzel Member, due to a strong decrease in glauconite and goethite content in the Beerzel Member (Verhaegen et al., 2020). The Beerzel Member is a more well sorted fine sand with a lower clay content compared to the Hallaar Member. The CPT and gamma-ray signal of the Beerzel Member is more constant, due to its homogenous character, compared to the Hallaar Member.

31.5 Thickness

In the type section, the Beerzel Member has a thickness of 4 m. Where the Beerzel Member occurs towards the north, the thickness fluctuates but is generally less than 4 m.

31.6 Occurrence

The Beerzel Member occurs consistently in the southern occurrence area of the Kasterlee Formation, in the area Beerzel – Heist-op-den-Berg – Olen. Towards the northeast, in the area Geel-Kasterlee-Retie, the member occurs locally. It appears to be absent in the area Mol-Dessel and further to the east, as well as in the northwestern occurrence area of the Kasterlee Formation.

31.7 Regional correlations

The Beerzel Member and overlying Heist-op-den-Berg Member are part of a progradational coastal barrier and back-barrier lagoon system, in which the Beerzel Member represents the coastal barrier sand. As such, the Beerzel Member is laterally equivalent with the Heist-op-den-Berg Member deposited contemporaneously more to the southeast, and with a lower part of the shallow open marine Lichtaart Member deposited to the west.

31.8 Age

No age data are available for the Beerzel Member, yet it is underlain by the late Tortonian to Messinian Campine Diest Sand and overlain by the Heist-op-den-Berg Member in which dinoflagellate cyst biozone DN10 of late Tortonian to Messinian Miocene age was identified.

31.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the Kasterlee Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021580

Subset of the Heist-op-den-Berg type section: https://www.dov.vlaanderen.be/data/opdracht/2020-022424

31.10 References

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/4, 133–152.

Fobe, B., 1995. Lithologie en lithostratigrafie van de Formatie van Kasterlee (Plioceen van de Kempen). Natuurwetenschappelijk Tijdschrift, 75, 35–45.

Laga, P., Louwye, S. & Geets, S., 2001. Paleogene and Neogene lithostratigraphic units (Belgium). In Bultynck, P. & Dejonghe, L., (eds), Guide to a revised lithostratigraphic scale of Belgium. Geologica Belgica, 4/1-2, 135–152. https://doi.org/10.20341/gb.2014.050

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, R., Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica, 23/3-4, 265-287. https://doi.org/10.20341/gb.2020.014

Verhaegen, J., Adriaens, R., Louwye, S., Vandenberghe, N. & Vos, K., 2014. Sediment-petrological study supporting the presence of the Kasterlee Formation in the Heist-op-den-Berg and Beerzel hills, southern Antwerp Campine, Belgium. Geologica Belgica, 17, 323–332.

Verhaegen, J., Frederickx, L. & Schiltz, M., 2020. New insights into the stratigraphy and paleogeography of the Messinian Kasterlee Formation from the analysis of a temporary outcrop. Geologica Belgica, 23/3-4, 253-263. https://doi.org/10.20341/gb.2020.015

32 Heist-op-den-Berg Member (Kasterlee Formation)

Unit name: Heist-op-den-Berg Member

Hierarchical unit name: Kasterlee Formation

Type: Member

Code: KlHe

Author(s): Verhaegen Jasper & Vandenberghe Noël

Alternative names: 'clayey Kasterlee' unit (Vandenberghe et al., 2020), formerly part of the at the time not yet subdivided Kasterlee Formation sensu De Meuter and Laga (1976) and Laga et al. (2001).

Origin of the name: Description of the Kasterlee Formation at Heist-op-den-Berg and Beerzel by Fobe (1995)

Status: Formal

Date: 01/05/2022

How to refer: Verhaegen, J. & Vandenberghe, N., 2023. The Heist-op-den-Berg Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Heist-op-den-Berg-Member

32.1 Characterizing description

In its type area around the hills of Heist-op-den-Berg and Beerzel up to Olen more to the north, the Heist-op-den-Berg Member can be easily recognized by the yellow-brownish, due to oxidation, well-sorted fine-grained sand with a very low glauconite content and the occurrence of thin grey and thick purple clay intercalations. The base of the member can be placed at the base of the first thick purple clay layer (>10 cm). The glauconite content of the sandy layers in the Heist-op-den-Berg Member is similar to the underlying Beerzel Member sand (2–4%, glauconite/quartz ratio of 0.03–0.05). Also the grain size distribution of the sandy intercalations is very similar to the Beerzel Member, well sorted with a mode at ~185 µm, though with a slightly larger fine fraction. Both feldspar content (5–6%, feldspar/quartz ratio of 0.07–0.08) and content of dioctahedral 2:1 Al-rich layer silicates (7–9%, 2:1 Al-clay/quartz ratio of 0.09–0.12) are similar to the Beerzel Member. In contrast to the Beerzel Member, The Heist-op-den-Berg Member sand layers contain more kaolinite (5–7%, kaolinite/2:1 Al-clay ratio of 0.6–1.0) indicating an increased component of continental sediment supply. The clay layers are mainly composed of 2:1 Al-clays (32– 44%, 2:1 Al-clay/quartz ratio of 0.9–2.3) and kaolinite (20–25%, kaolinite/2:1 Al-clay ratio of 0.5–0.6), and a considerable amount of goethite is present as well (2–4%, goethite/glauconite ratio of 0.3–0.7).

The Heist-op-den-Berg Member also occurs consistently north and northeast of its type area, where it is buried deeper under younger Neogene and Quaternary sediments and can only be sampled in cores. There as well, the member is characterized by an alternation of fine sand and grey clay layers. In contrast to the type area, the sandy intercalations have a green colour due to an increased glauconite content (Vandenberghe et al., 2020). Both on CPT's and borehole logs the sand-clay alternation can be easily recognized based on the fluctuating qc and gamma-ray signals.

32.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The proposed type section of the lower three members of the Kasterlee Formation, including the Heist-op-den-Berg Member, is the sunken lane atop the hill of Heist-op-den-Berg (DOV TO-20140919 and TO-

20190617). The type section is described in detail in Verhaegen et al. (2014) and Verhaegen et al. (2020). The member name was originally proposed after a study of this section by Fobe (1995).

32.3 Description upper boundary

In the southern area near the type section, the Heist-op-den-Berg Member is generally covered by a thin Quaternary cover. Towards the northeast, the Heist-op-den-Berg Member is covered by the Retie Member of the Mol Formation. A rather sharp boundary can be observed from the green sand and grey clay alternations in the Heist-op-den-Berg Member to the fine grey quartz sand of the Retie Member (Vandenberghe et al., 2020, Plate 1). In borehole logs, this boundary represents a sharp drop in gamma-ray signal, while a strong increase in qc value is observed on CPT's. Towards the northwest, near Kasterlee village, the Heist-op-den-Berg Member is locally overlain by the Lichtaart Member. This boundary has only been observed in CPT's and is also characterized by a sharp increase in qc value (Verhaegen et al., 2020, Fig. 10).

32.4 Description lower boundary

In the type section, the Heist-op-den-Berg Member is underlain by the Beerzel Member. The boundary is placed at the occurrence of the first dm-scale purple clay layer (Verhaegen et al., 2020). The Heist-op-den-Berg Member can be easily distinguished based on the alternation of fine sand and clay layers, in contrast to the homogenous fine sand of the underlying Beerzel Member.

Towards the north, the Beerzel Member is often absent. Where it is present, it can be recognized by the constant CPT signal or gamma-ray signal (e.g. ON-Kasterlee-1; Verhaegen et al., 2020, Fig. 10), compared to the strongly fluctuating signal of the overlying Heist-op-den-Berg Member. In cores as well, the boundary between both members occurs where the alternation of clay and sand layers starts (Vandenberghe et al., 2020). Where the Beerzel Member is absent, the Heist-op-den-Berg Member lies directly on top of the basal Hallaar Member of the Kasterlee Formation. The boundary can again be placed at the first cm- to dm-scale clay layer at the base of the Heist-op-den-Berg Member, followed by a sand-clay alternation within the Heist-op-den-Berg Member.

32.5 Thickness

In the type section, the Heist-op-den-Berg Member is cut off by a Quaternary cover and does not represent the initial thickness. Based on CPT's near the type section, approximately 4 m of Heist-op-den-Berg Member is present on top of the hills (Verhaegen et al., 2020). Towards the north, the thickness fluctuates between 2 and 5 m, with an apparent general decrease towards the northeast where the overlying Retie Member strongly increases in thickness.

32.6 Occurrence

The Heist-op-den-Berg Member occurs consistently in the southern, northern and northeastern sections of the Kasterlee Formation occurrence area. Only in the northwestern area, west of Kasterlee, the member is absent.

32.7 Regional correlations

The Heist-op-den-Berg Member and underlying Beerzel Member are part of a progradational coastal barrier and back-barrier lagoon system, in which the Heist-op-den-Berg Member represents the lagoonal sand-clay alternation. As such, the Heist-op-den-Berg Member is laterally time equivalent with the Beerzel Member deposited more to the northwest, and with a lower part of the shallow open marine Lichtaart Member deposited in the northwest of the Kasterlee Formation occurrence zone.

32.8 Age

Dinoflagellate cyst biozone DN10 was identified in the Heist-op-den-Berg Member (ON-Dessel-2 borehole 031W0338 / kb17d31w-B299), attributing a late Tortonian to Messinian Miocene age to this member.

32.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the Kasterlee Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021580

Subset of the Heist-op-den-Berg type section: https://www.dov.vlaanderen.be/data/opdracht/2020-022424

32.10 References

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/4, 133–152.

Fobe, B., 1995. Lithologie en lithostratigrafie van de Formatie van Kasterlee (Plioceen van de Kempen). Natuurwetenschappelijk Tijdschrift, 75, 35–45.

Laga, P., Louwye, S. & Geets, S., 2001. Paleogene and Neogene lithostratigraphic units (Belgium). In Bultynck, P. & Dejonghe, L., (eds), Guide to a revised lithostratigraphic scale of Belgium. Geologica Belgica, 4/1-2, 135–152. https://doi.org/10.20341/gb.2014.050

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, R., Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica, 23/3-4, 265-287. https://doi.org/10.20341/gb.2020.014

Verhaegen, J., Adriaens, R., Louwye, S., Vandenberghe, N. & Vos, K., 2014. Sediment-petrological study supporting the presence of the Kasterlee Formation in the Heist-op-den-Berg and Beerzel hills, southern Antwerp Campine, Belgium. Geologica Belgica, 17, 323–332.

Verhaegen, J., Frederickx, L. & Schiltz, M., 2020. New insights into the stratigraphy and paleogeography of the Messinian Kasterlee Formation from the analysis of a temporary outcrop. Geologica Belgica, 23/3-4, 253-263. https://doi.org/10.20341/gb.2020.015

33 Lichtaart Member (Kasterlee Formation)

Unit name: Lichtaart Member

Hierarchical unit name: Kasterlee Formation

Type: Member

Code: KlLi

Author(s):

- Compiled by: Verhaegen Jasper & Vandenberghe Noël

- Modification of: De Meuter & Laga (1976) after Dumont (1882)

Alternative names: type Kasterlee Sand (Vandenberghe et al., 2020), formerly part of the at the time not yet subdivided Kasterlee Formation sensu De Meuter and Laga (1976) and Laga et al. (2001).

Origin of the name: before the Kasterlee Formation was subdivided in members, the presently defined Lichtaart Member was meant to be the Kasterlee Formation in its type area (the Lichtaart-Kasterlee hill)

Status: Formal

Date: 01/05/2022

How to refer: Verhaegen, J. & Vandenberghe, N., 2023. The Lichtaart Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Lichtraart-Member

33.1 Characterizing description

The Lichtaart Member consists of pale green fine sand with a moderate glauconite content. Reported modal grain size varies between 125 and 170 µm and a <62 µm fraction of about 10 to 15% is present. The sand fraction is very well sorted. The colour varies from pale to darker green depending on the glauconite content; sparse glauconite grains can give the sand a speckled outlook. Glauconite pellet content can range from around 4% in the Lichtaart –Kasterlee hill outcrops, called the Hoge Berg Facies, up to 30% in boreholes north of the hill ridge, called the Oud-Turnhout Facies. Muscovite flakes are common. An exceptionally high content of hornblende in the heavy mineral fraction (55%) is reported in Lichtaart (TO-19990101B). The Lichtaart Sand Member contains neither calcareous fossils nor carbonates in general.

33.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The occasional outcrops in the flanks of the hills between Herentals, Lichtaart and Kasterlee on the right bank of the Kleine Nete valley always expose the top part of the Kasterlee Formation. Therefore these outcrops are always part of the Lichtaart Member. They were selected as the type section for the Kasterlee Formation in the Lithostratigraphic scale of Belgium (2001) although the lower part of the formation was never exposed in the hill ridge. These outcrops in fact show the southern glauconite-poor Hoge Berg Facies.

Several boreholes in the Turnhout area contain reference data on the Lichtaart Member, where the northern glauconite-rich Oud-Turnhout Facies is present. The reference section selected for the Lichtaart Member is in the Rees borehole (017E0399; kb8d17e-B495). The full section described as Kasterlee Formation between 25 and 33,5 m is interpreted as the Lichtaart Member. Cores, sediment analyses and dinoflagellate cyst analyses are available in this interval (Buffel et al., 2001; Vandenberghe et al., 2020). The Kasterlee Formation in the Gierle borehole (017W0158 ; Kb8d17w-B14) between 26 and 34 m is also identified as the Lichtaart Member and has detailed grain-size analyses (Gullentops and Huyghebaert, 1999). Although the base of the Lichtaart

Member is not reached in the Oud-Turnhout borehole (017E 0401;kb817e-B497), a section of about 11 m of the Lichtaart Member between 39 and 50 m with sediment analyses is juxtaposed to a gamma-ray log of the similar interval in the nearby Turnhout borehole (017E0398; kb8d17e-B294) in Louwye et al. (2020 fig. 4).

33.3 Description upper boundary

In the reference areas of the Lichtaart–Kasterlee hill ridge and the Turnhout area boreholes, the Lichtaart Member is overlain by the characteristic Hukkelberg Gravel at the base of the Poederlee Sand (Louwye et al., 2020). The grain size of the Poederlee Formation is almost indistinguishable from the Lichtaart Member sand.

33.4 Description lower boundary

The lower boundary of the Lichtaart Member is not exposed. It is only known from boreholes. In the Turnhout area the boundary with the underlying Diest Sand Formation is located where the fine grain size of the Lichtaart Member abruptly changes to coarser sand in the Diest Formation. Under the Lichtaart-Kasterlee hill ridge a CPT (10-CPTE-138) log suggests that the clay-enriched Heist-op-den-Berg Member could be present underlying the Lichtaart Member with a sharp contact at + 4.25 m TAW (Schiltz, 2020; Vandenberghe et al., 2020; Verhaegen et al., 2020).

33.5 Thickness

In the type area Herentals-Lichtaart-Kasterlee a thickness of about 15 m is interpreted in sections drafted by Laga and Gulinck (Laga, 1976) and confirmed by a CPT log interpretation (10-CPTE-138).

In the boreholes of the Turnhout area, Gierle (017W0158/kb8d17w-B14), Rees (017E0399/kb8d17e-B495), Oud-Turnhout (017E 0401;kb817e-B497) and Turnhout (017E0398; kb8d17e-B294), the Lichtaart Member occurs underneath the Poederlee Sand and thickness is reduced to 8 to 11 m.

Towards the border with the Netherlands in the north of the Antwerp province, the Kasterlee Formation, probably the Lichtaart Member, is suggested to thicken in the profiles drafted by Laga (1976).

33.6 Occurrence

The Lichtaart Member occurs west of an approximate line Olen–Kasterlee. Due to the northwards dip of the Kasterlee Formation, south of Olen only the Hallaar, Beerzel and Heist-op-den-Berg members occur. East of this Olen-Kasterlee line the Lichtaart Member is geometrically replaced by the Retie Member of the Mol Formation (Schiltz, 2020; Vandenberghe et al., 2020; Verhaegen et al., 2020). West and northwest of an approximate Grobbendonk–Merksplas-Weelde zone, the Lichtaart Member wedges out, probably as a consequence of end-Miocene to earliest Pliocene erosion.

33.7 Regional correlations

Regional correlations need to respect the presence of the Messinian DN10 dinocyst biozone of de Verteuil & Norris in the Lichtaart Member in the Oud-Turnhout and Rees boreholes (Louwye & De Schepper, 2010; Vandenberghe et al., 2020). The limited available biostratigraphy of the Retie Member also contains the same DN10 dinocyst biozone suggesting that Lichtaart and Retie members are contemporaneous (Vandenberghe et al. 2020). The Lichtaart Member can be the more marine facies lateral from the other lagoonal to near-shore members of the Kasterlee Formation. The transition to the Breda Formation in the Netherlands is not clear.

It is therefore probable that a transition area exists between the Lichtaart Member and the Retie Member, expressed by the loss of glauconite pellet content towards the Retie Member. West of an approximate Grobbendonk-Merkpslas-Weelde zone, the Lichtaart Member is geometrically replaced by the younger Kattendijk Formation.

33.8 Age

Dinoflagellate cyst biozone DN10 was identified in the Lichtaart Member (Rees borehole, 017E0399; kb8d17e-B495), attributing a late Tortonian to Messinian Miocene age to this member.

33.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the Kasterlee Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021580

33.10 References

Buffel, P., Vandenberghe, N., Goolaerts, S. & Laga, P., 2001. The Pliocene sediments in 4 boreholes in the Turnhout area (North-Belgium): the relationship with the Lillo and Mol Formations. Aardkundige Mededelingen, 11, 1–8.

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/4, 133–152.

Gullentops, F. & Huyghebaert, L., 1999. A profile through the Pliocene of Northern Kempen, Belgium. Aardkundige Mededelingen, 9, 191–202.

Laga, P., 1976. Geologische Doorsneden. Archieven Belgische Geologische Dienst. http://collections.naturalsciences.be/ssh-geology/geology/profiles-neogeen2020, accessed 15/03/2020.

Laga, P., Louwye, S. & Geets, S., 2001. Paleogene and Neogene lithostratigraphic units (Belgium). In Bultynck, P. & Dejonghe, L., (eds), Guide to a revised lithostratigraphic scale of Belgium. Geologica Belgica, 4/1-2, 135–152. https://doi.org/10.20341/gb.2014.050

Louwye, S. & De Schepper, S., 2010. The Miocene-Pliocene hiatus in the southern North Sea Basin (northern Belgium) revealed by dinoflagellate cysts. Geological Magazine, 147/5, 760–776. https://doi.org/10.1017/S0016756810000191

Louwye, S., Deckers, J. & Vandenberghe, N., 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica, 23/3-4, 297-313. https://doi.org/10.20341/gb.2020.016

Schiltz, M., 2020. On the use of CPT's in stratigraphy; recent observations and some illustrative cases. Geologica Belgica, 23/3-4, 399-411. https://doi.org/10.20341/gb.2020.019

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, R., Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica, 23/3-4, 265-287. https://doi.org/10.20341/gb.2020.014

Verhaegen, J., Frederickx, L. & Schiltz, M., 2020. New insights into the stratigraphy and paleogeography of the Messinian Kasterlee Formation from the analysis of a temporary outcrop. Geologica Belgica, 23/3-4, 253-263. https://doi.org/10.20341/gb.2020.015

34 Oud-Turnhout Facies (Lichtaart Member)

Unit name: Oud-Turnhout Facies

Hierarchical unit name: Lichtaart Member

Type: Facies

Code: KlOu

Author(s): Verhaegen Jasper & Vandenberghe Noël

Alternative names: formerly part of the at the time not yet subdivided Kasterlee Formation sensu De Meuter and Laga (1976) and Laga et al. (2001).

Origin of the name: Named after a key borehole in which this facies was observed

Status: Formal

Date: 01/05/2022

How to refer: Verhaegen, J. & Vandenberghe, N., 2023. The Oud-Turnhout Facies, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Oud-Turnhout-Facies

34.1 Characterizing description

The Oud-Turnhout Facies is a glauconite-rich facies of the Lichtaart Member (Kasterlee Formation). It's high glauconite content (30%) makes it distinct from the Hoge Berg Facies (4-5% glauconite). Other sedimentological characteristics of both facies are similar.

34.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

Several boreholes in the Turnhout area contain reference data on the Lichtaart Member, where the northern glauconite-rich Oud-Turnhout Facies is present. The reference section selected for the Lichtaart Member is in the Rees borehole (017E0399; kb8d17e-B495). The full section described as Kasterlee Formation between 25 and 33,5 m is interpreted as the Lichtaart Member. Cores, sediment analyses and dinoflagellate cyst analyses are available in this interval (Buffel et al., 2001; Vandenberghe et al., 2020). The Kasterlee Formation in the Gierle borehole (017W0158 ; Kb8d17w-B14) between 26 and 34 m is also identified as the Lichtaart Member and has detailed grain-size analyses (Gullentops and Huyghebaert, 1999). Although the base of the Lichtaart Member is not reached in the Oud-Turnhout borehole (017E 0401;kb817e-B497), a section of about 11 m of the Lichtaart Member between 39 and 50 m with sediment analyses is juxtaposed to a gamma-ray log of the similar interval in the nearby Turnhout borehole (017E0398; kb8d17e-B294) in Louwye et al. (2020 fig. 4).

34.3 Description upper boundary

In the reference area of the Turnhout area boreholes, the Oud-Turnhout Facies is overlain by the characteristic Hukkelberg Gravel at the base of the Poederlee Sand (Louwye et al., 2020). The grain size of the Poederlee Sand is almost indistinguishable from the Lichtaart Member sand.

34.4 Description lower boundary

The lower boundary of the Lichtaart Member is not exposed. It is only known from boreholes. In the Turnhout area the boundary of the Oud-Turnhout Facies with the underlying Diest Sand Formation is located where the fine grain size of the Lichtaart Member abruptly changes to coarser sand in the Diest Formation.

34.5 Thickness

In the boreholes of the Turnhout area, Gierle (017W0158/kb8d17w-B14), Rees (017E0399/kb8d17e-B495), Oud-Turnhout (017E 0401;kb817e-B497) and Turnhout (017E0398; kb8d17e-B294), the Oud-Turnhout Facies of the Lichtaart Member occurs underneath the Poederlee Sand and the thickness is 8 to 11 m.

34.6 Occurrence

The Oud-Turnhout Facies is known from boreholes in the Turnhout area and occurs north of the Hoge Berg Facies in the Lichtaart-Kasterlee hill ridge.

34.7 Regional correlations

Regional correlations need to respect the presence of the Messinian DN10 dinocyst biozone of de Verteuil & Norris in the Oud-Turnhout Facies of the Lichtaart Member in the Oud-Turnhout and Rees boreholes (Louwye & De Schepper, 2010; Vandenberghe et al., 2020). The limited available biostratigraphy of the Retie Member also contains the same DN10 dinocyst biozone suggesting that Lichtaart and Retie members are contemporaneous (Vandenberghe et al. 2020). The Lichtaart Member can be the more marine facies lateral from the other lagoonal to near-shore members of the Kasterlee Formation . The transition to the Breda Formation in the Netherlands is not clear. Towards the south, the glauconite-rich Oud-Turnhout Facies is replaced by the glauconite-poor Hoge Berg Facies.

34.8 Age

Dinoflagellate cyst biozone DN10 was identified in the Oud-Turnhout Facies (Rees borehole, 017E0399; kb8d17e-B495), attributing a late Tortonian to Messinian Miocene age to this facies.

34.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the Kasterlee Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021580

34.10 References

Buffel, P., Vandenberghe, N., Goolaerts, S. & Laga, P., 2001. The Pliocene sediments in 4 boreholes in the Turnhout area (North-Belgium): the relationship with the Lillo and Mol Formations. Aardkundige Mededelingen, 11, 1–8.

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/4, 133–152.

Gullentops, F. & Huyghebaert, L., 1999. A profile through the Pliocene of Northern Kempen, Belgium. Aardkundige Mededelingen, 9, 191–202.

Laga, P., Louwye, S. & Geets, S., 2001. Paleogene and Neogene lithostratigraphic units (Belgium). In Bultynck, P. & Dejonghe, L., (eds), Guide to a revised lithostratigraphic scale of Belgium. Geologica Belgica, 4/1-2, 135–152. https://doi.org/10.20341/gb.2014.050

Louwye, S. & De Schepper, S., 2010. The Miocene-Pliocene hiatus in the southern North Sea Basin (northern Belgium) revealed by dinoflagellate cysts. Geological Magazine, 147/5, 760–776. https://doi.org/10.1017/S0016756810000191

Louwye, S., Deckers, J. & Vandenberghe, N., 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica, 23/3-4, 297-313. https://doi.org/10.20341/gb.2020.016

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, R., Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica, 23/3-4, 265-287. https://doi.org/10.20341/gb.2020.014

35 Hoge Berg Facies (Lichtaart Member)

Unit name: Hoge Berg Facies

Hierarchical unit name: Lichtaart Member

Type: Facies

Code: KlHo

Author(s): Verhaegen Jasper & Vandenberghe Noël

Alternative names: formerly part of the at the time not yet subdivided Kasterlee Formation sensu De Meuter and Laga (1976) and Laga et al. (2001).

Origin of the name: Named after the locality near Lichtaart where this facies can be observed

Status: Formal

Date: 01/05/2022

How to refer: Verhaegen, J. & Vandenberghe, N., 2023. The Hoge Berg Facies, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Hoge-Berg-Facies

35.1 Characterizing description

The Hoge Berg Facies is a glauconite-poor facies of the Lichtaart Member (Kasterlee Formation). Its low glauconite content (4-5%) makes it distinct from the Oud-Turnhout Facies (30% glauconite). Also, an exceptional high content of hornblende in the heavy mineral fraction (55%) is reported in Lichtaart (TO-19990101B) (Gullentops & Huyghebaert, 1999). Other sedimentological characteristics of both facies are similar.

35.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The occasional outcrops in the flanks of the hills between Herentals, Lichtaart and Kasterlee on the right bank of the Kleine Nete valley always expose the top part of the Kasterlee Formation. Therefore these outcrops are always part of the Hoge Berg Facies of the Lichtaart Member. They were selected as the type for the Kasterlee Formation in the Lithostratigraphic scale of Belgium (2001) although the lower part of the Formation was never exposed in the hill ridge.

35.3 Description upper boundary

The Hoge Berg Facies in the Lichtaart-Kasterlee hill rigde is overlain by the characteristic Hukkelberg Gravel at the base of the Poederlee Sand (Louwye et al., 2020). The grain size of the Poederlee Sand is almost indistinguishable from the Lichtaart Member sand.

35.4 Description lower boundary

Under the Lichtaart-Kasterlee hill ridge a CPT (10-CPTE-138) log suggests that the clay-enriched Heist-op-den-Berg Member could be present underlying the Lichtaart Member with a sharp contact at + 4.25 m TAW (Schiltz, 2020; Vandenberghe et al., 2020; Verhaegen et al., 2020).

35.5 Thickness

In the type area Herentals-Lichtaart-Kasterlee a thickness of about 15 m is interpreted in sections drafted by Laga and Gulinck (Laga, 1976) and confirmed by a CPT log interpretation (10-CPTE-138).

35.6 Occurrence

The Hoge Berg Facies of the Lichtaart Member is found in the outcrop area of the Kasterlee Formation in the Lichtaart-Kasterlee hill ridge.

35.7 Regional correlations

It is probable that a transition area exists between the Lichtaart Member in the Lichtaart-Kasterlee hill ridge and the Retie Member of the Mol Formation to the east, expressed by the loss of glauconite pellet content towards the Retie Member. Towards the north the glauconite content increases towards the Oud-Turnhout Facies of the Lichtaart Member.

35.8 Age

Dinoflagellate cyst biozone DN10 was identified in the Lichtaart Member, in the lateral Oud-Turnhout Facies (Rees borehole, 017E0399; kb8d17e-B495), attributing a late Tortonian to Messinian Miocene age to this member and its facies.

35.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the Kasterlee Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021580

35.10 References

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/4, 133–152.

Gullentops, F. & Huyghebaert, L., 1999. A profile through the Pliocene of Northern Kempen, Belgium. Aardkundige Mededelingen, 9, 191–202.

Laga, P., 1976. Geologische Doorsneden. Archieven Belgische Geologische Dienst. http://collections.naturalsciences.be/ssh-geology/geology/profiles-neogeen2020, accessed 15/03/2020.

Laga, P., Louwye, S. & Geets, S., 2001. Paleogene and Neogene lithostratigraphic units (Belgium). In Bultynck, P. & Dejonghe, L., (eds), Guide to a revised lithostratigraphic scale of Belgium. Geologica Belgica, 4/1-2, 135–152. https://doi.org/10.20341/gb.2014.050

Louwye, S., De Schepper, S., Laga, P. & Vandenberghe, N., 2007. The Upper Miocene of the southern North Sea Basin (northern Belgium): a paleoenvironmental and stratigraphical reconstruction using dinoflagellate cysts. Geological Magazine, 144, 33–52. https://doi.org/10.1017/S0016756806002627

Schiltz, M., 2020. On the use of CPT's in stratigraphy; recent observations and some illustrative cases. Geologica Belgica, 23/3-4, 399-411. https://doi.org/10.20341/gb.2020.019

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, R., Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica, 23/3-4, 265-287. https://doi.org/10.20341/gb.2020.014

Verhaegen, J., Frederickx, L. & Schiltz, M., 2020. New insights into the stratigraphy and paleogeography of the Messinian Kasterlee Formation from the analysis of a temporary outcrop. Geologica Belgica, 23, 3-4, this volume. https://doi.org/10.20341/gb.2020.015

36 Poppel Facies

Unit name: Poppel Facies

Hierarchical unit name: uncertain stratigraphic position

Type: Facies

Code: Po

Author(s):

- Compiled by: Verhaegen Jasper, Vandenberghe Noël & Walstra Jan

Alternative names: /

Origin of the name: Named after the area in the north of the Antwerp province where this facies is present. It was previously considered as an informal unit of the underlying Diest Formation.

Status: Formal

Date: 31/01/2023

How to refer: Verhaegen, J., Vandenberghe, N. & Walstra, J., 2023. The Poppel Facies, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Poppel-Facies

36.1 Characterizing description

The Poppel sand has been described in a flushed borehole Weelde (BGD 008E0133; DOV kb8d8e-B26) by Laga & Notebaert (1981). An interval of 31 m between 102 and 133 m deep is described as poorly glauconitic fine clayey and also carbonate containing homogeneous sand. This sand interval has a characteristic gamma-ray profile: a cyclic evolution with a middle very low gamma-ray signal; the resistivity values increase upwards but above the middle part of the interval resistivities remain high in two lobes. (Figure 36-1).

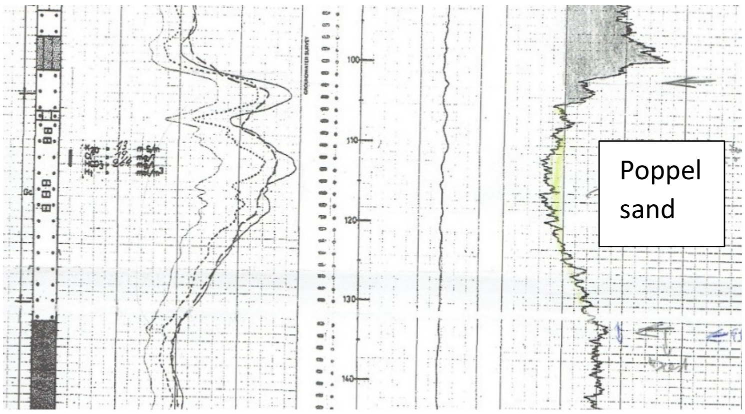


Figure 36-1. Log signature of the Poppel Facies in the Weelde borehole

The stratigraphic interpretation is unsure. Laga & Notebaert (1981) have opted to consider the sand as a glauconite poor part of the underlying Diest Formation. The sand above was interpreted by these authors as the Kattendijk Formation. However on regional profiles drawn in the mid and late 1970s by Laga for the Groundwater Commission of the Province of Antwerp (Archives of the Geological Survey of Belgium), the Poppel Facies obviously is not yet indicated as it was not yet described, but on the profiles PGL/76/106/3 (Poppel-Ravels-Turnhout) and PGL 76/106/2 (Poppel-Ravels-Dessel) (Laga, 1976), this Poppel Facies would geometrically have been included in about 45 m of fine glauconitic sand interpreted as Kasterlee Formation sand below the Lillo Formation with shell debris and overlying the Diest Formation (Vandenberghe et al. , 2020 figs 7a&b). Nevertheless, the presence of carbonates in the sand is not in line with either the classical Kasterlee Formation or the Diest Formation. Another complicating factor is that the geometrical relay of Kattendijk Sand in the west by Kasterlee Sand in the east is shown to occur in the Weelde area on profile PGL/74/105 (Laga, 1976). Given the carbonate content of the Poppel Facies a lateral correlation of this unit with the carbonate containing Kattendijk Formation is plausible. Based on log correlations between Belgium and the Netherlands in the northwestern Campine area (Vernes et al., 2023), the Poppel Facies may be correlated with the Goirle Member of the Oosterhout Formation (see Fig. 35.2). The overlying Kattendijk Formation is the lateral equivalent of the Tilburg Member of the Oosterhout Formation, while the underlying Diest Formation can be correlated with the Diessen Formation. Based on this correlation, a position of the Poppel Facies as a basal unit of the Kattendijk Formation in the Voorkempen area may be proposed. More data are required before the interval can be given its definitive stratigraphic position.

36.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The borehole Weelde (BGD 008E0133; DOV kb8d8e-B26) between 102-133 m.

36.3 Description upper boundary

The Poppel Sand Facies is delineated at its top by a marked gamma-ray signal increase, attributed by Laga & Notebaert (1981) to the base of the Kattendijk Formation.

36.4 Description lower boundary

The Poppel Sand Facies is delineated at its base by the change in gamma-ray signal from an increasing downward trend in the Poppel Facies into a stable signal in the underlying Diest Sand, and analogously by the change from a decreasing RES log signature trend in the Poppel Facies to a stable low resistivity signal in the Diest Sand.

36.5 Thickness

A thickness of 31 m is interpreted in the Weelde borehole (BGD 008E0133).

36.6 Occurrence

Although the Poppel Facies was only described in the Weelde (BGD 008E0133) borehole, a more recent drilling at Weelde-vlieghaven (DOV kb8d8e-B161) shows a comparable borehole log interval but no further analyses in the interval of concern are available.

36.7 Regional correlations

-

36.8 Age

The Poppel Facies has a late Miocene to early Pliocene age, based on its stratigraphic position in between the underlying Diest Formation and overlying Kattendijk Formation.

36.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Subset of the Kasterlee Formation: https://www.dov.vlaanderen.be/data/opdracht/2020-021580

36.10 References

Archives of the Geological Survey of Belgium, Brussels. Information at: GSB@naturalsciences.be.

Laga, P., 1976. Geologische Doorsneden. Archieven Belgische Geologische Dienst. http://collections.naturalsciences.be/ssh-geology/geology/profiles-neogeen2020, accessed 15/03/2020.

Laga, P. & Notebaert, K., 1981. Description of the borehole Weelde - GSB 008E0133. Archieven Belgische Geologische Dienst, http://collections.naturalsciences.be/ssh-geology-archives/arch/008e/008e0133.txt accessed 05 06 2021

Munsterman, D.K., ten Veen, J.H., Menkovic, A., Deckers, J., Witmans, N., Verhaegen, J., Kerstholt-Boegehold, S.J., van de Ven, T. & Busschers, F.S., 2019. An updated and revised stratigraphic framework for the Miocene and earliest Pliocene strata of the Roer Valley Graben and adjacent blocks. Netherlands Journal of Geosciences, 98, e8. https://doi.org/10.1017/njg.2019.10

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, R., Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica, 23/3-4, 265-287. https://doi.org/10.20341/gb.2020.014

Vernes R.W., Walstra J., Deckers J., Kruisselbrink A.F., Menkovic A., Bogemans F., De Ceukelaire M., Dirix K., Dusar M., Hummelman H.J., Maes R., Meyvis B., Munsterman D.K., Reindersma R., Rombaut B., Van Baelen K., Van de Ven T.J.M., Van Haren T. & Welkenhuysen K., 2023. Geologisch en hydrogeologisch 3D model van het Cenozoïcum van de Belgisch-Nederlandse grensstreek van De Noorderkempen/West-Brabant (H3O-De Voorkempen). TNO, VITO & BGD-rapport.

36.11 Annexes

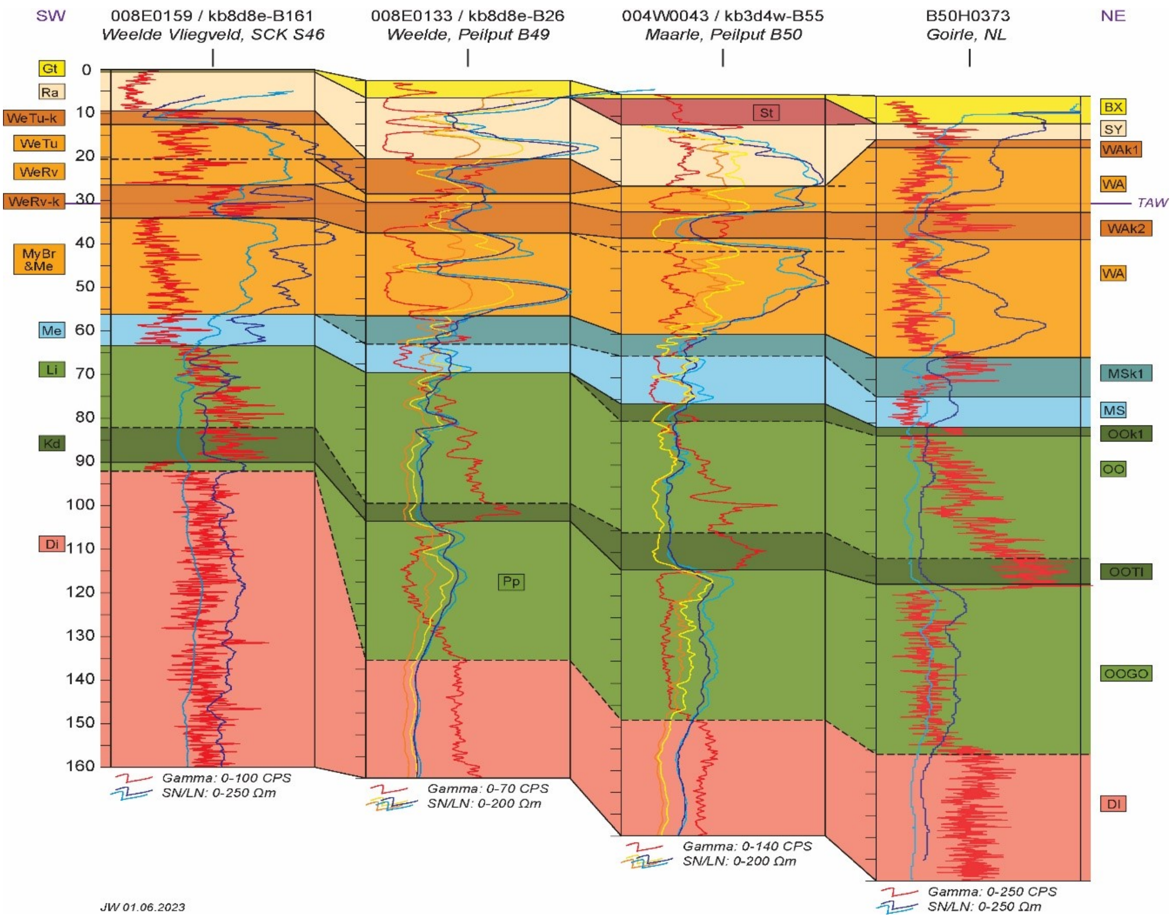


Figure 36-2: Correlation of geophysical well logs with interpretation of the Poppel Facies. Interpretations and correlations based on H3O-De Kempen project in black lines (Vernes et al., 2018); the dashed lines are interpretations based on Vernes et al. (2023) and Munsterman (2019).

37 Wurfeld Formation

Unit name: Wurfeld Formation

Hierarchical unit name: For the time being this quartz-enriched unit is considered independent. Not to be incorporated in the Kasterlee Formation with which it shares a marked gamma ray signature, nor with the underlying Diest Formation because of the latter's glauconite content, and nor with the Inden Formation or Kieseloolite Formation, two other quartz-enriched stratigraphic units in the Neogene stratigraphic realm of the Roer Valley Graben.

Type: Formation

Code: Wu

Authors:

- Compiled by: Vandenberghe Noël and Dusar Michiel

Alternative names: unit X : This name has been used in literature since the unit was first described by Vandenberghe et al. (2005) and in the review of its stratigraphic position by Louwye & Vandenberghe (2020).

Origin of the name: Wurfeld is the name of an old hamlet closeby

For the time being this unit is considered independent of other stratigraphic units and therefore it is ranked as a formation. However its thickness is smaller than usual for a formation and its extension is poorly known.

Status: formal

Date: 01/05/2022

How to refer: Vandenberghe, N., & Dusar, M., 2023. The Wurfeld Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Wurfeld-Formation

37.1 Characterizing description

In the Maaseik borehole (049W0220), quartz-enriched pale coloured sand occurs above green glauconite enriched sand. Above the latter, the basal part of the pale-colored sand between 192.7 m and 198 m depth is singled out because of its finer grain size - modal size between 128 and 174 µm-, high mica content, faint lamination, a few percentages of glauconite pellets (1.7 -3.5 %) and as an interval with a more elevated natural gamma ray (GR) signature. The basal part of this pale-colored sand above 198 m was interpreted as a shallow marine deposit.

37.2 Type section, type locality, type borehole, or type geophysical borehole

Until now the Wurfeld Formation has only been positively identified in the Maaseik borehole (049W0220) between 192.7 m and 198 m, consequently making this borehole the reference.(Vandenberghe et al., 2005 ; Louwye & Vandenberghe, 2020).

37.3 Description upper boundary

The upper boundary is best recognised by a jump to higher gamma-ray values, probably caused by the higher mica content compared to the quartz-enriched sand with lignitic fragments above and interpreted as the Inden Formation.

37.4 Description lower boundary

The lower base is marked by the occurrence of green glauconite sand below of the Diest Formation. On the gamma ray log the signal becomes sharply reduced at the top of this underlying glauconite sand. The lithology of the base of the Wurfeld Formation has the characteristics of a reworked deposit: greenish clay, pieces of peat and some gravel.

37.5 Thickness

The thickness is 5,3 m in the Maaseik reference borehole .

Because of its limited thickness and its high gamma-ray signature the unit was included in the underlying Diest Formation in the H30-project (Vernes et al., 2018).

37.6 Occurrence:

Until now the Wurfeld Formation has only been described in cores of the Maaseik borehole (049W0220). However, based on the gamma ray signal, it is suspected that the formation can be more generally present in the Belgian part of the Roer Valley Graben (see logs in Vandenberghe et al., 2005, fig.10).

It should be noted however that the use of the jump to higher gamma ray values needs to be interpreted with caution as in the Maaseik well within the RVG its lithological significance is different compared to the area Dessel-Mol where the top of this gamma-ray signal corresponds to the clayey glauconite sand of the Heist-op-den-Berg Member of the Kasterlee Formation (‘clayey Kasterlee’ in the Geologica Belgica ,2020 Neogene volume).

37.7 Regional correlations

The proposed correlation scheme below (Figure 37-1) between the Belgian part of the Roer Valley Graben, the Eastern Campine west of the Reppel-Heerlerheide main bordering RVG faults, and between the Lower Rhine Basin (Vandenberghe & Louwye , 2020) is based on dinoflagellate cysts (DN biozones) in the Wurfeld Formation, unit X as reported in Louwye & Vandenberghe (2020).

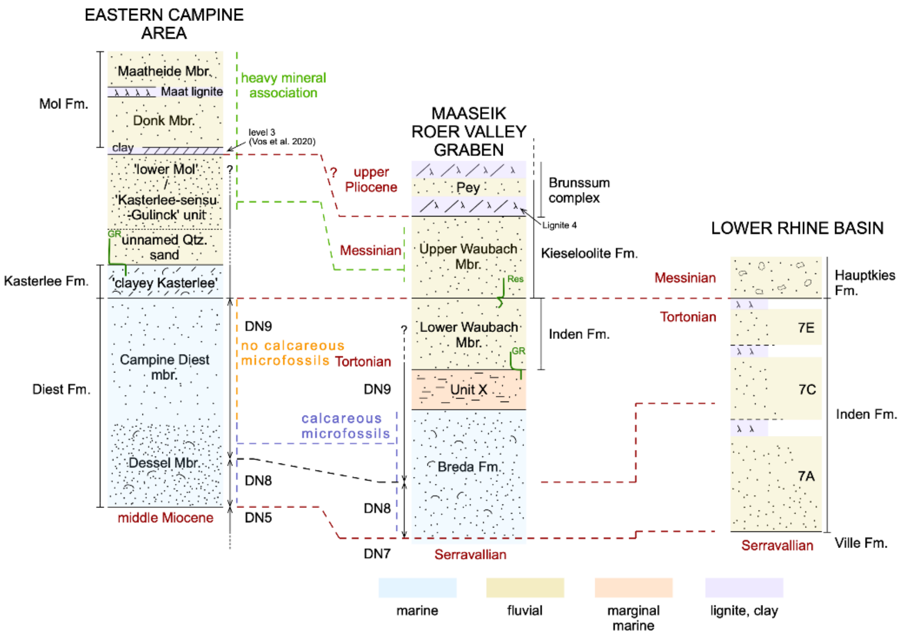


Figure 37-1 Correlation scheme for the Wurfeld Formation (formerly unit X), based on dinoflagellate cysts as reported in Louwye & Vandenberghe (2020).

37.8 Age

Dinoflagellate cysts biostratigraphy shows all samples of the Wurfeld Formation hold the H. obscura Zone, age calibrated between 7.6 and 8.8 Ma indicating a mid-late Tortonian age (7.246 to 11.63 Ma) (Louwye & Vandenberghe, 2020).

37.9 Dataset

Data in the LIS are part of NCS_Neogene 2020_Louwye and Vandenberghe, 2020., including links to the GSB-collection data sheets.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Maaseik borehole	049W0220	kb18d49w-B220	https://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0220.txt	https://www.dov.vlaanderen.be/data/boring/1980-025921

37.10 References

Louwye, S. & Vandenberghe, N. «A reappraisal of the stratigraphy of the upper Miocene unit X in the Maaseik core, eastern Campine area (northern Belgium)», Geologica Belgica [En ligne], Volume 23 (2020), number 3-4 - The Neogene stratigraphy of northern Belgium, 289-295 URL : https://popups.uliege.be/1374-8505/index.php?id=6680.

Vandenberghe, N., Laga, P., Louwye, S., Vanhoorne, R., Marquet, R., De Meuter, F., Wouters, K. & Hagemann, H.W., 2005. Stratigraphic interpretation of the Neogene marine-continental record in the Maaseik well (49W0220) in the Roer valley Graben, NE Belgium. Memoirs of the Geological Survey of Belgium, 52, 39 p.

Vernes, R.W., Deckers, J., Bakker, M.A.J., Bogemans, F., De Ceukelaire, M., Doornenbal, J.C., den Dulk, M., Dusar, M., Van Haren, T.F.M., Heyvaert, V.M.A., Kiden, P., Kruisselbrink, A.F., Lanckacker, T., Menkovic, A., Meyvis, B., Munsterman, D.K., Reindersma, R., Rombaut, B., ten Veen, J.H., van de Ven, T.J.M., Walstra, J. & Witmans, N., 2018. Geologisch en hydrogeologisch 3D model van het Cenozoïcum van de Belgisch-Nederlandse grensstreek van Midden-Brabant / De Kempen (H3O – De Kempen). TNO-rapport TNO 2017 R11261 – VITO 2017/RMA/R/1348, 109 p.

38 Inden Formation

Unit name: Inden Formation

Hierarchical unit name :

Type: Formation

Code: In

Author(s):

- Compiled by: Vandenberghe Noël & Michiel Dusar

Alternative names : in older literature the Inden Formation sand was included in the 'Waubach sand and gravel unit'.

Origin of the name: -

Status: Formal

Date: 01/05/2022

How to refer: Vandenberghe, N., & Dusar, M., 2023. The Inden Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Inden-Formation

38.1 Characterizing description

A pale grey to white coarse sand, which can be darker grey coloured due to mobile organic matter content, containing particularly in the coarsest horizons small wood fragments and clay clasts. Some thin clayey horizons occur near the base of the sand. The sand contains a pollen assemblage. No carbonates occur. Dinoflagellate cysts are absent except for the very base of the unit. The resistivity signal increases upwards.

38.2 Type section, type locality, type borehole, or type geophysical borehole

The reference for the Inden Formation in Belgium is the166-192,5 m interval in the Maaseik (049W0220/ Kb18d49w-B220) borehole; cores, SP, Res and GR geophysical logs of the interval are available in Vandenberghe et al. (2005).

38.3 Description upper boundary

A sudden increase in the spontaneous potential signal and a marked short drop in resistivity signal, are characterising the upper boundary. It probably corresponds to a thin level with lignite and clay fragments in otherwise coarse sand.

38.4 Description lower boundary

A marked sudden gamma ray signal increase characterises the transition to fine yellow and mica-rich sand (unit X in borehole Maaseik) or to greenish glauconite-bearing sand of the Diest Formation.

38.5 Thickness

In the Belgian part of the Roer Valley Graben (RVG), boreholes with the Inden Formation identified show a thickness of the formation in the same order of magnitude as the 26,5 m in the Maaseik reference well.

38.6 Occurrence

The Inden Formation as defined in the Maaseik reference borehole occurs in the Belgian part of the RVG east of the main bordering faults of Neeroeteren and Reppel as suggested by borehole correlations to Jagersborg (049W0236/ Kb18d49w-B235), Kinrooi (049W0230/ Kb18d49w-B230) and St.-Huibrechts-Lille (033W0139/Kb18d33w-B142) boreholes in fig.6 in Vandenberghe et al. (2020).

38.7 Regional correlations

In the Netherlands the Inden Formation was formally introduced in the nomenclature by Menkovic & Westerhoff (2010) and has been duly considered in the recent stratigraphic scheme of Munsterman et al. (2019, fig. 8 and TNO-GDN (2022)). Consequently the Kieseloolite Formation only starts at the base of the upper Waubach unit.

In Belgium, since the study of the Maaseik core stratigraphy by Dusar et al. (2012, p. 18), the lower part of the Waubach sand and gravel unit, the lower Waubach unit, is interpreted as the Inden Formation. The correlation with the Netherlands can easily be done through the Roosteren borehole (B60A0325) near the Belgian border (see Vandenberghe et al., 2020, fig.6). Also in the more recent geological-hydrological study of the Belgian-Dutch border area the lower part of the Waubach unit in the Maaseik borehole was interpreted as the Inden Formation (Vernes et al., 2018 , annex D fig. 7.3)

The reference for the Inden Formation is in the brown coal pits in Nordrhein-Westfalen and the unit has systematically been used in the stratigraphic studies of the German Lower Rhine area by e.g. Schäfer and Utescher (2014) and Utescher et al. (2021). In the Maaseik borehole only the very base of the Inden Formation is constrained biostratigraphically, namely an upper Tortonian dinoflagellate cyst assemblage. A correlation scheme of the Maaseik area in the RVG with the Lower Rhine stratigraphy in the east and the Campine area in the west is shown in Figure 38-1 below from Louwye and Vandenberghe (2020).

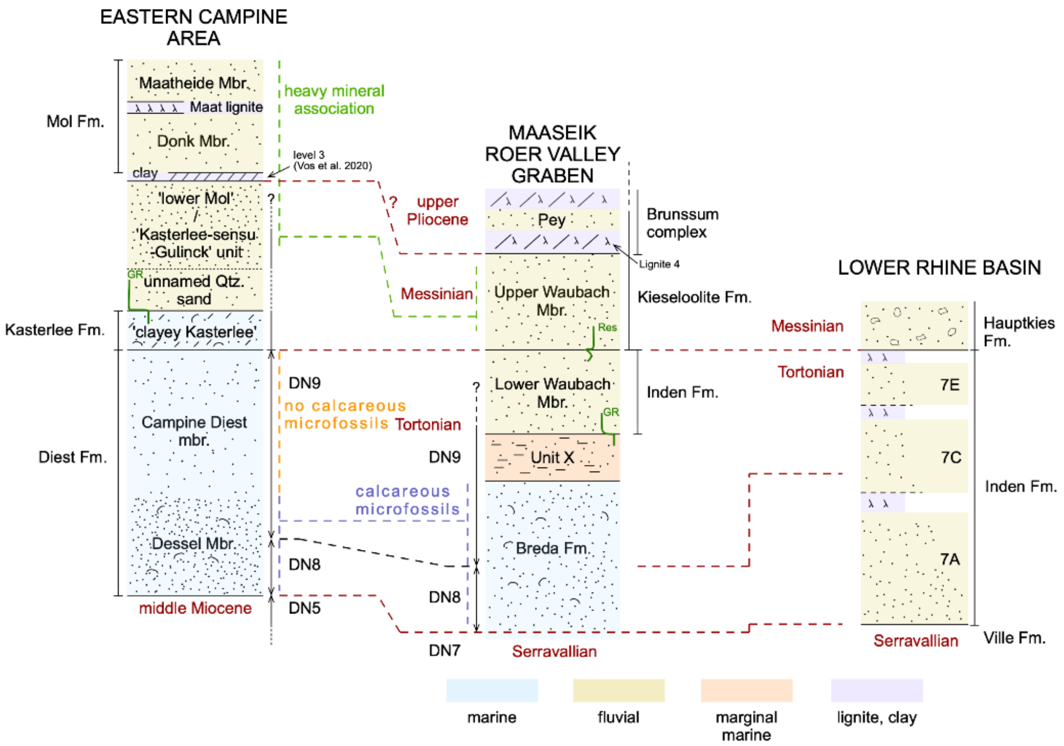


Figure 38-1 Correlation scheme of the Maaseik area in the RVG with the Lower Rhine stratigraphy in the east and the Campine area in the west; note that the Inden Formation as defined in the present LIS corresponds to the former and now disused lower Waubach unit (from Louwye and Vandenberghe, 2020).

38.8 Age

The Inden Formation identified in the Belgian RVG corresponds to the latest part of the Inden Formation in the Lower Rhine Basin Inden Formation. Based on dinoflagellate content it is considered end Tortonian as discussed in Louwye & Vandenberghe (2020).

38.9 Dataset

Data in the LIS are part of the [DOV-Neogene data collection, including links to the GSB-collection data sheets]

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Maaseik borehole	049W0220	kb18d49w-B220	https://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0220.txt	https://www.dov.vlaanderen.be/data/boring/1980-025921
Jagersborg borehole	049W0236	kb18d49w-B235	https://collections.naturalsciences.be/ssh-geology-archives/arch/059e/059e0140.txt	https://www.dov.vlaanderen.be/data/boring/1989-042715
Kinrooi borehole	049W0230	kb18d49w-B230	https://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0230.txt	https://www.dov.vlaanderen.be/data/boring/1995-102445

St.-Huibrechts-Lille borehole	033W0139	kb18d33w-B142	https://collections.naturalsciences.be/ssh-geology-archives/arch/033w/033w0139.txt	https://www.dov.vlaanderen.be/data/boring/1984-082391
Roosteren borehole (DINOloket B60A0325)	-	B60A0325	-	https://www.dov.vlaanderen.be/data/boring/1977-165105

38.10 References

Dusar, M., De Ceukelaire, M., Walstra, J., 2012. Stratigrafische interpretatie en correlatie van het Quartair en continentale Neogeen. Koninklijk Belgisch Instituut voor Natuurwetenschappen - Belgische Geologische Dienst, 81 p. Unpublished report.

Louwye, S. & Vandenberghe, N., 2020. A reappraisal of the stratigraphy of the upper Miocene unit X in the Maaseik core, eastern Campine area (northern Belgium).In: Vandenberghe, N. & Louwye, S., The Neogene stratigraphy of northern Belgium. Geologica Belgica, Volume 23 , number 3-4, 289-295 URL : https://popups.uliege.be/1374-8505/index.php?id=6680.

Menkovic, A. & Westerhoff, W., 2010. Formatie van Inden. In: Lithostratigrafische Nomenclator van de Ondiepe Ondergrond. Retrieved May 25, 2020. from https://www.dinoloket.nl/formatie-van-inden

Munsterman, D.K., ten Veen, J.H., Menkovic, A, Deckers, J, Witmans, N, Verhaegen, J, Kerstholt-Boegehold, S.J., van de Ven, T. & Busschers, F.S., 2019. An updated and revised stratigraphic framework for the Miocene and earliest Pliocene strata of the Roer Valley Graben and adjacent blocks. Netherlands Journal of Geosciences, 98, e8. https://doi.org/10.1017/njg.2019.10

Schäfer, A., & Utescher, T., 2014. Origin, sediment fill, and sequence stratigraphy of the Cenozoic lower Rhine Basin (Germany) interpreted from well logs. Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, 165(2), 287–314.

TNO-GDN (2022). Formatie van Inden. In: Stratigrafische Nomenclator van Nederland, TNO – Geologische Dienst Nederland. Geraadpleegd op 19-04-2022 op http://www.dinoloket.nl/stratigrafische-nomenclator/formatie-van-inden.

Utescher, T., Ashraf, A., Kern, A.K. & Mosbrugger, V., 2021. Diversity patterns in microfloras recovered from Miocene brown coals of the lower Rhine Basin reveal distinct coupling of the structure of the peat-forming vegetation and continental climate variability. Geological Journal, 56:768–785. https://doi.org/10.1002/gj.3801

Vandenberghe, N., Laga, P., Louwye, S., Vanhoorne, R., Marquet, R., De Meuter F., Wouters, K., Hagemann, H.W., 2005. Stratigraphic interpretation of the Neogene marine-continental record in the Maaseik well (49W0220) in the Roer valley Graben, NE Belgium. Memoirs of the Geological Survey of Belgium 52, 39 p.

Vandenberghe, N.; Wouters, L.; Schiltz, M.; Beerten, K.; Berwouts, I.; Vos, K.; Houthuys, R.; Deckers, J.; Louwye, S.; Laga, P.; Verhaegen, J.; Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. In: Vandenberghe, N. & Louwye, S., The Neogene stratigraphy of northern Belgium. Geologica Belgica , Volume 23, number 3-4, 265-287 URL : https://popups.uliege.be/1374-8505/index.php?id=6530.

Vernes, R.W., Deckers, J., Bakker, M.A.J., Bogemans, F., De Ceukelaire, M., Doornenbal, J.C., den Dulk, M., Dusar, M., Van Haren, T.F.M., Heyvaert, V.M.A., Kiden, P., Kruisselbrink, A.F., Lanckacker, T., Menkovic, A., Meyvis, B., Munsterman, D.K., Reindersma, R., Rombaut, B., ten Veen, J.H., van de Ven, T.J.M., Walstra, J. & Witmans, N., 2018. Geologisch en hydrogeologisch 3D model van het Cenozoïcum van de Belgisch-Nederlandse grensstreek van Midden-Brabant / De Kempen (H3O – De Kempen). TNO-rapport TNO 2017 R11261 – VITO 2017/RMA/R/1348. 109 p.

39 Kieseloolite Formation

Unit name: Kieseloolite Formation

Hierarchical unit name : A group name for the white, pale grey quartz-enriched sand units of the Pliocene, eventually transitional to Pleistocene, including a.o. Kieseloolite, Mol, Merksplas …formations can be considered if sufficient sedimentological and mineralogical data become available to characterise individual formations, differentiating them from each other and at the same time showing their degree of relationship. At present no name is proposed for such an eventual group of white to pale-grey sand.

Type: Formation

Code: Kz

Authors:

- Compiled by: Vandenberghe Noël & Dusar Michiel

Alternative names: See note on the orthography below

Origin of the name:

Status: Formal

Date: 01/05/2022

How to refer: Vandenberghe, N., & Dusar, M., 2023. The Kieseloolite Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Kieseloolite-Formation

Note on orthography:
Several ways to spell the name of this unit occur in literature in different languages:

- Kieseloolite (in Westerhoff , 2009),
- Kiezeloolith (in Vandenberghe et al. , 2020 & Vandenberghe et al., 2005)),
- Kiezeloöliet (H3O projects Flanders-the Netherlands (Vernes et al., 2009), in Laga et al. ,2001),
- Kieseloolith (German stratigraphic table www.stratigraphie.de),
- les Kiezeloolithes (Gulinck ,1960)).

In the Neogene 2020 Geologica Belgica Volume the Westerhoff (2009) spelling is mostly used and is also followed in the present LIS.

Preliminary explanatory note on the Belgian and the Dutch stratigraphic practices with regard to the Kieseloolite Formation sensu lato in the Roer Valley Graben (RVG).

- Belgian Neogene stratigraphy practice in borehole studies in the RVG is based on Van der Sluys (2000), followed in the mapping of the Maaseik-Beverbeek sheet 18-10 (Sels et al. , 2001) and as also applied in the Maaseik (049W 0220) reference well by Vandenberghe et al. (2005). This practice is described in the Synthesis by Louwye et al. (2020).
- In the Belgian-Dutch transboundary H3O-project, the results of which are reported by Vernes et al. (2018), the Dutch stratigraphic practice has been the guiding principle. Consequently this has led in this project report to the introduction in Belgian borehole descriptions and profiles of subdivisions and nomenclature different from the Synthesis published by Louwye et al. (2020).

- As the present LIS Kieseloolite Formation is intended by the NCS-Subcommission Paleogene-Neogene to define the stratigraphy in the Belgian part of the RVG, in a first part of the present LIS the Belgian practice is used as a basis for nomenclature and definitions.
- Because the hydrostratigraphic model elaborated in the H3O-project (Vernes et al., 2018) has led to a lithostratigraphic classification and definitions amending what is applied in the Belgian practice, these implications are discussed separately in a second part which is based on Dusar et al. (2014).

I. The traditional Belgian Neogene stratigraphy practice in the RVG (Van der Sluys, 2000; Sels et al., 2001; Vandenberghe et al., 2005; Louwye et al., 2020).

39.1 Characterizing description

The Kieseloolite Formation in Belgium is limited to the Belgian part of the Roer Valley Graben (Laga et al., 2001). The main lithology in the formation is a white quartz-enriched sand. The grain-size varies from fine to coarse, in particular in the lower part of the formation. The marked difference in log resistivities measured at different current penetration depths points to a permeable sand. The sand contains small lignitic fragments and ripped up clay clasts.

Lignite, clay and lignitic clay horizons varying in thickness from a few cm to 2 to 4 m in thickness occur in the sand. Subdivisions in the formation are based on the presence of some of the thicker lignite and clay beds which could be aquitards at least at local scale.

The subdivisions identified from bottom to top are: the Waubach sand, Brunssum II clay, Pey sand , Brunssum I clay and Schinveld/Jagersborg sand. Except for Jagersborg , these subdivisions and their nomenclature in the Belgian part of the RVG are based on the stratigraphy in the Dutch RVG published a.o. by Wong et al. (2007, fig. 13) as illustrated below (Figure 39-1):

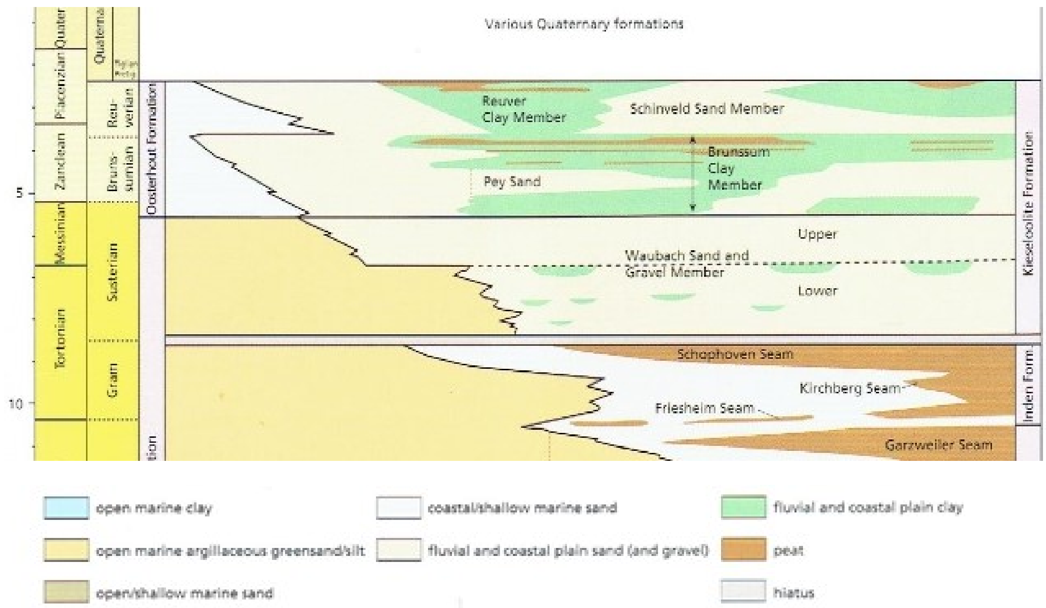


Figure 39-1: Stratigraphic scheme of the Kieseloolite Formation in the southern Netherlands from Wong et al., (2007), after Van Adrichem Boogaert & Kouwe (1997).

39.2 Type section, type locality, type borehole, or type geophysical borehole

The reference borehole for the Kieseloolite Formation in the Belgian Roer Valley Graben is the cored and geophysically logged Maaseik borehole (049W0220) between 22 and 166 m, studied by Vandenberghe et al. (2005) and revised by Louwye & Vandenberghe (2020).

It should be noted that the coarse sand below 166 m was originally considered as part of the Kieseloolite Formation but is now identified as the Inden Formation as discussed in Louwye & Vandenberghe (2020).

39.3 Description upper boundary

The upper boundary of the Kieseloolite Formation in the reference Maaseik borehole is marked by the appearance above it at 22 m depth of Pleistocene river gravels. At greater distance from the Meuse river, the upper boundary is marked by the appearance of the Sterksel Formation.

39.4 Description lower boundary

In the reference Maaseik borehole a sudden drop in the spontaneous potential signal and a marked short drop in resistivity signal at 164 m depth, are characterising the lower boundary. It probably corresponds to a thin level with lignite and clay fragments in otherwise coarse sand. This level marks the top of the underlying Inden Formation following the description by Menkovic & Westerhoff (2010) in the Dutch RVG.

39.5 Thickness

In the Maaseik borehole the thickness is 144 m. Van der Sluys (2000) reports a fairly constant thickness between 130 and 160 m of the Kieseloolite Formation including the now recognized Inden Formation (formerly also described as lower Waubach unit) but strongly varying thicknesses for its members (see also Vandenberghe et al., 2020, fig. 6).

39.6 Occurrence

By definition the Kieseloolite Formation in the Belgian RVG is limited to the RVG east of the Heerlerheide-Reppel boundary faults.

39.7 Regional correlations

a) age

The base of the Kieseloolite Formation is correlated with the Messinian Hauptkies Formation in the German Lower Rhine area (Louwye & Vandenberghe, 2020). The palynology in the reference borehole by Vanhoorne in Vandenberghe et al. (2005) suggests a late Pliocene age for the top of the formation although Praetiglian is not excluded. However the palynological stratigraphy needs to be used with caution (see Donders et al., 2007).

b) oolite occurrence

The name Kieseloolite Formation refers to the presence in the sand of small silicified oolite pebbles (Kieseloolite) as also found in the Neeroeteren sand, the Mol Formation and the Hukkelberg gravel. Some of these pebbles are even found as a lag deposit on the hill tops in a curve from Brugge to Kasterlee and are considered to mark a major Pliocene shoreline (Gullentops & Huyghebaert, 1999, p. 193). Similar oolitic pebble gravels also occur in the oldest river terrace along the Meuse between Namur and Huy (e.g., Rixhon & Demoulin, 2018).

c) correlation of the RVG Kieseloolite Formation with the Campine and Antwerp harbour area.

Unfortunately no sediment, mineral nor biostratigraphical data are available of the sediments below the Maat lignite in the eastern Campine area (west of the RVG) . Louwye & Vandenberghe (2020, fig.3) have discussed a possible chronostratigraphic correlation scheme of the lower part of the Kieseloolite Formation and the underlying Inden Formation in the Maaseik reference borehole for the Belgian RVG with the eastern Campine west of the Heerlerheide-Reppel boundary faults and with the Lower Rhine Basin (see Figure 39-2). This correlation assumes no major hiatuses in the RVG section – due to the very high subsidence rates in the tectonically active graben - and is based on limited heavy mineral data, on dinoflagellate cyst biostratigraphy and on palynology; the upper part of the Kieseloolite Formation, above the upper Brunssum complex has a palynology comparable to the Maat lignite in the eastern Campine while the palynology of the section above may grade into the Praetiglian (data by Vanhoorne in Vandenberghe et al. , 2005 p 13-14). It is possible that in the eastern Campine area (west of the RVG) hiatuses exist below the Mol Formation (see Vandenberghe and Louwye, 2020).

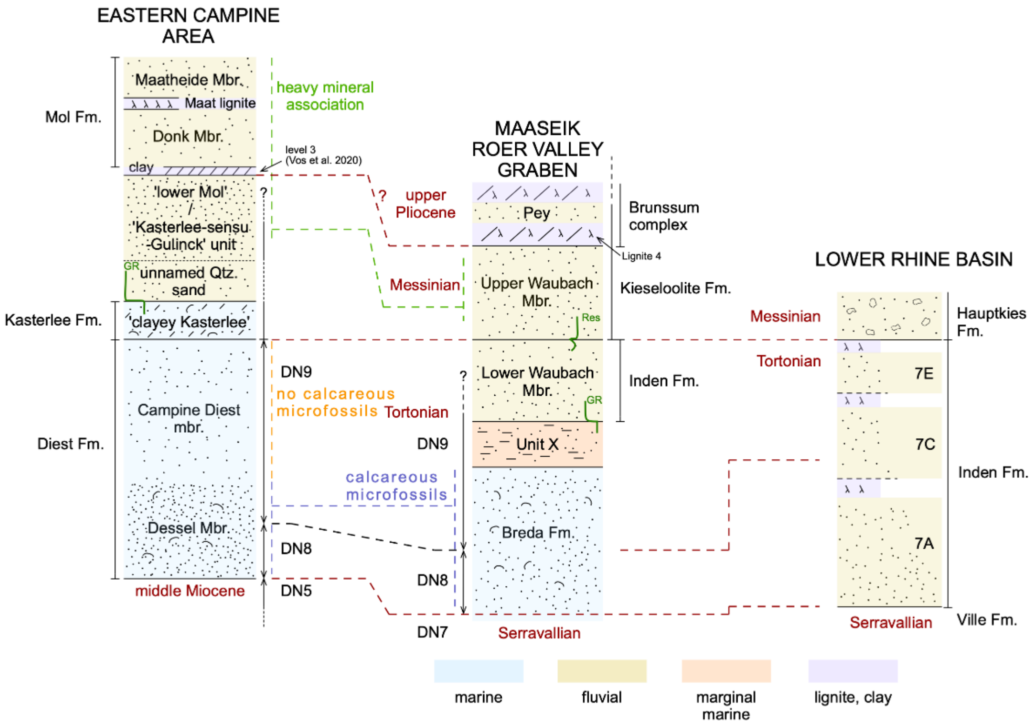


Figure 39-2 Stratigraphic position of the Kieseloolite Formation in the RVG with respect to the Eastern Campine area and the Lower Rhine Basin according to Louwye & Vandenberghe (2020)

II. Implications of the H3O-hydrogeological model for the Belgian lithostratigraphy in the RVG.

The Dutch stratigraphic practice has been the guiding principle in the hydrostratigraphic model elaborated in the H3O-project (Vernes et al. , 2018). This principle has led to the introduction in this report of subdivisions and nomenclature different from the Synthesis published by Louwye et al. (2020) in Belgian borehole descriptions and profiles (this LIS part I). These implications are discussed separately in this second part, based on Dusar et al. (2014) and Vernes et al. (2018).

Given below (

Figure 39-3) is an extract of the correlation table between the H3O geological and hydrogeological model units, the lithostratigraphic units in the Belgian part of the RVG discussed in part I above and in the Neogene-2020 volume, and the Flemish hydro-stratigraphic units (HCOV), presented as Table 1 in Dusar et al. (2014). In addition the Kieseloolite Formation is lithostratigraphically subdivided in two members ('laagpakketten'), a lower Waubach Member, equivalent to the Waubach sand, encompassing the hydrostratigraphic unit Kl-z-4 and beyond (only Kl-z-4 in Maaseik borehole), and an upper Brunssum Member, equivalent to Jagersborg inf, Brunssum I clay, Pey sand, Brunssum II clay, encompassing the hydrostratigraphic units Kl-k-1 to Kl-k-3:

H3O Geologisch model	H3O Hydrogeologisch model	Vlaamse stratigrafische eenheid (formatie - lid)	Vlaamse hydrogeologische eenheid (HCOV kartering)			
		Zutendaal - Winterslag	0200			
Sterksel	ST-z-1	Sterksel - Lommel	0200		0171	Afzettingen Hoofdterras
	ST-k-1	Sterksel - Hamont				
	ST-z-2	Sterksel - Bocholt				
Stramproy	SY-z-1	Kiezeloöliet - Jagersborg sup.	0200	0210		
	SY-k-1					
	SY-z-2				0211	Zand boven Brunssum I-klei
	SY-k-2					
	SY-z-3					
	SY-k-3					
	SY-z-4					
Kiezeloöliet	KI-z-1	Kiezeloöliet - Jagersborg inf.	0200	0210		
	KI-k-1					
	KI-z-2					
	KI-k-2	Kiezeloöliet - Brunssum I			0212	Brunssum I-klei
	KI-z-3	Kiezeloöliet - Pey			0213	Zand van Pey
	KI-k-3	Kiezeloöliet - Brunssum II			0214	Brunssum II-klei
	KI-z-4	Kiezeloöliet - Waubach			0215	Zand van Waubach
	KI-k-4					
	KI-z-5					
Inden	IE-z-1	Inden (+ herwerkt Breda)	0200	0210/0230	0234/0215	Zand van Poederlee en/of top Kasterlee of Zand van Waubach
	IE-k-1					
	IE-z-2					
	IE-k-2					
	IE-z-3					

Figure 39-3: Comparison of the RVG lithostratigraphic and hydrostratigraphic nomenclatures in use in Flanders and used in the H30 reporting (Dusar et al., 2014).

1. On the presence of the Stramproy Formation and the disuse of Jagersborg/Schinveld sand unit.

   The Jagersborg Sand unit as used in Belgium is split up (inf. and sup.) and the upper part included in the Stramproy Formation (TNO-GSN 2021). The Stramproy Formation is consequently used in a more broader sense than in the Belgian practice and also previously in the Netherlands. In Belgian practice, the very low GR values are the determining characteristic of the Stramproy Sand (see e.g. Fig. 10 in Vandenberghe et al., 2005). In the hydrostratigraphic H3O-project practice a more clayey interval is included near the base of the Stramproy Formation. Although not yet formally defined on the NCS website , the Belgian practice considers the Stramproy Formation as a Pleistocene unit and hence it was not discussed in the Neogene stratigraphic nomenclature reviews.
   The lower part of the Jagersborg unit is included in the Kieseloolite Formation and the Jagersborg unit is no longer used in the H3O stratigraphy. Schinveld sand, considered equivalent with Jagersborg sand in Belgium, is also taken out of the Dutch DINOloket database.

2. The identification of additional clay layers and the labelling of the clay beds illustrated by the H3O interpretation of the Maaseik (049W0220) and Bocholt (033W0153) boreholes.

In the hydrogeological model a leading principle is the identification of aquitard clay layers between porous sand layers.

In the interpretation of the Maaseik (049W0220) borehole in the H3O project report, a separate clay unit around 50 m is individualised and labelled SY-k-3 as part of the Stramproy Formation (Sy). In the interpretation by Vandenberghe et al. (2005) and discussed above this interval was not individualised and it was included in the Jagersborg sand (see further in Stramproy unit). The same clay level is interpreted in the H3O report to occur between about 91 and 101 m in the Bocholt (033W0153) borehole described by Van der Sluys (2000).

The Brunssum I (upper) and II (lower) clay units (see LIS Brunssum beds) identified in the Belgian practice as discussed above are labelled respectively Kl-k-2 and Kl-k-3 (Kl for Kieseloolite) in the H3O hydrogeological model.

Besides the Brunssum I (upper) and II (lower) clay units (see Brunssum beds), in the hydrogeological model an additional clay unit labelled Kl-k-1 is identified closely above the Brunssum I = Kl-k-2. In the Maaseik (049W0220) borehole it occurs at a level with thinner clay layers and a lignite bed (lignite 2 in the section described in Vandenberghe et al., 2005) between 63,2 and 73,6 m. However, this unit should not be present everywhere nor possess aquitard properties. In the Bocholt (033W0153) borehole this clay layer is not present; it is suggested in the H3O-project report that is eroded by the overlying sand unit.

Van der Sluys (2000), with the information available at that time, interpreted the sand above the upper Brunssum I clay unit in this Bocholt borehole as Kedichem Formation or a sand unit transitional to the Kieseloolite Formation.

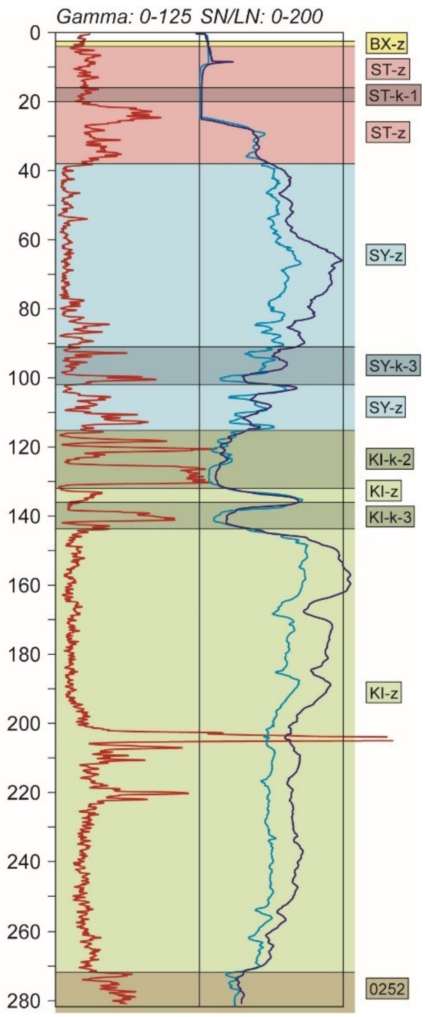


Figure 39-4: H3O interpretation of the Bocholt-Sluis (033W0153) borehole (courtesy Jan Walstra, Geological Survey of Belgium) to be compared with the interpretation given in Van der Sluys (2000). In the above figure the interpreted Stramproy Formation is coloured blue; the grey blue interval is the clay layer SY-k-3 between 91 and 101 m. The yellowish colour is the Kieseloolite Formation; the two upper dark yellow layers are the KI-k-1 and KI-k-2 (= Brunssum I). Note the small thickness of Kl-kz bed between the two Brunssum clay beds (Kl-k-2 en Kl-k-3) in the Maaseik borehole in Figure 5. The original interpretation by Van der Sluys (2000) : 2,5 -38,5 m Sterksel Fm-Lommel Sand , 38,5-115 m Kedichem Fm. The top of the Kieseloolite Fm is 115 m en Brunssum I Bed is between 115 and 133 m; Pey Sand 133-137,7 m ; Brunssum II bed 137,7-143,7 m. Below 143,7 -272 m is interpreted as Waubach Sand and deeper below occurs the Breda Fm. Van der Sluys (2000) also reports in Brunssum I clay the occurrence of moderately cold palynology comparable to Campine and Tegelen clay while in Brunssum II clay a palynology occurs comparable to Mol and Merkspslas deposits.

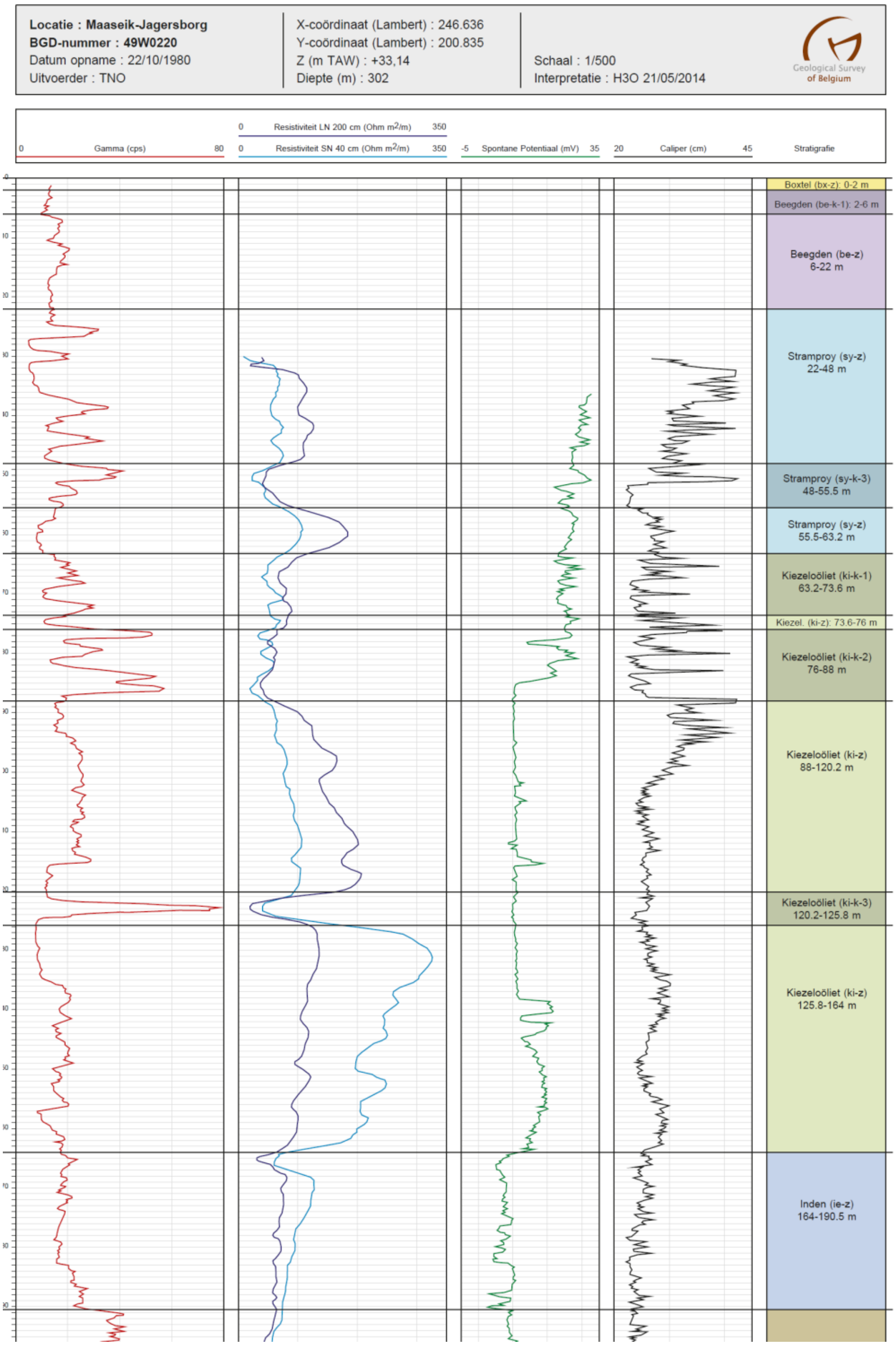


Figure 39-5: H3O interpretation of the Maaseik (049W0220) borehole to be compared with the interpretation in Vandenberghe et al. (2005) and discussed above in I (from Vernes et al., 2018, annex D fig.7.3).

3. Definition of the Kieseloolite Formation

In the hydrogeological model, the base of the Stramproy Formation defines the top of the Kieseloolite Formation. This base of the Stramproy Formation is defined at the point where the high RES value of the basal sand layer in the Stramproy unit sharply drops to marked lower values pointing to more clay in the underlying sediment. This top clayey unit in the Kieseloolite Formation is the newly introduced clay level Kl-k-1 in the Maaseik (049W0220) borehole or the upper Brunssum =Kl-k-2 clay level in the Bocholt (033W0153) borehole.

This implies that the Stramproy Formation includes the sandy part of the former Jagersborg unit (TNO-GSN DINOloket Stramproy, 2021) (Jagersborg sup in Dusar et al., 2018, Tabel 1) while the clayey basal part of the latter (Jagersborg inf in Dusar et al., 2014, Tabel 1) is now included in the top of the Kieseloolite Formation (Dusar et al. ,2014; Vernes et al., 2018, annex D fig.7.3).

4. Disused names

Schinveld and Jagersborg sand units are not defined in the Dutch DINOloket database.

The terminology Brunssum I and Brunssum II clays, Pey sand and Waubach sand is not formally used in the figures of appendix D in H3O report and these intervals are coded as Kl-z sand units in the hydrostratigraphic model. Pey Sand is labelled Kl-z-3 and Waubach Sand is labelled Kl-k-4 in Dusar et al. (2014, Tabel 1). However, the names Waubach and Brunssum are retained as members of the Kieseloolite Formation in the Dutch stratigraphy.

See also note on the

39.8 Age

Detailed chronostratigraphy of the Kieseloolite Formation is poorly documented. The age of the lowest lithostratigraphic unit of the Kieseloolite Formation, the Waubach Member, is latest Miocene while the Brunssum and Jagersborg members probably are continuously formed during the Pliocene. The transition to the Pleistocene is uncertain. The introduction of an alternative lithostratigraphic subdivision including the Stramproy Formation above the Kieseloolite Formation places the Kieseloolite definitely in the Pliocene and the Stramproy Formation in the early Pleistocene - Middle Pleistocene (Tiglian - early Cromerian) (TNO-GDN (2022)

39.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Maaseik borehole	049W0220	kb18d49w-B220	https://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0220.txt	https://www.dov.vlaanderen.be/data/boring/1980-025921
Bocholt borehole	033W0153	B/7-0356	https://collections.naturalsciences.be/ssh-geology-archives/arch/033w/033w0153.txt	https://www.dov.vlaanderen.be/data/boring/1995-025169

39.10 References

Donders, T.H., Kloosteroer-van Hoeve, M.L., Westerhoff, W., Verreussel R.M.C.H. & Lotter, A.F., 2007. Late Neogene continental stages in NW Europe revisited. Earth-Science reviews 85: 161-186.

Dusar, M., Deckers, J., Juhász-Holterman, Matthijs, J., Menkovic, A., Six, S., Walstra, J. & Westerhoff, W.E., 2014. De Roerdalslenk. in : Dassargues, A. & Walraevens, K. (eds), Watervoerende Lagen en Grondwater in België/Aquifères et Eaux Souterraines en Belgique, Gent, Academia Press, XXIV +455p, 47-57.

Gullentops, F. & Huyghebaert, L., 1999. A profile through the Pliocene of the Northern Kempen, Belgium. Aardkundige Mededelingen, 9, 191–202.

Gulinck, M. , 1960. Un gisement de kiezeloolithes à Lichtaart (Campine). Comparaison avec les cailloutis à kiezeloolithes des collines flamandes. Bulletin Société belge de Géologie, de Paléontologie et d' Hydrologie, 69, 191-210.

Laga, P., Louwye, S. & Geets, S., 2001. Paleogene and Neogene lithostratigraphic units (Belgium). Geologica Belgica, 4/1-2, 135–152. https://doi.org/10.20341/gb.2014.050

Louwye, S. & Vandenberghe, N., 2020. A reappraisal of the stratigraphy of the upper Miocene unit X in the Maaseik well, eastern Campine area (northern Belgium). Geologica Belgica, 23/3-4, this volume. https://doi.org/10.20341/gb.2020.013

Louwye, S., Deckers J. & Vandenberghe, N., 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a Synthesis, Geologica Belgica [En ligne], Volume 23 (2020), number 3-4 - The Neogene stratigraphy of northern Belgium, 297-313 URL : https://popups.uliege.be/1374-8505/index.php?id=6841.

Menkovic, A. & Westerhoff, W. , 2010 . Formatie van Inden. In: Lithostratigrafische Nomenclator van de Ondiepe Ondergrond. Retrieved May 25, 2020. from https://www.dinoloket.nl/formatie-van-inden

Rixhon, G. & Demoulin, A., 2018. The picturesque Ardennian Valleys: Plio-Quaternary incision of the drainage System in the uplifting Ardenne. In Demoulin, A. (ed.), Landscapes and Landforms of Belgium and Luxembourg. Springer, World Geomorphological Landscapes, 159–175. https://doi.org/10.1007/978-3-319-58239-9_10

Sels, O., Claes, S. & Gullentops, F., 2001. Toelichtingen bij de geologische kaart van België, Vlaams Gewest: kaartblad 18-10, Maaseik - Beverbeek [1/50 000]. Belgische Geologische Dienst en Ministerie van de Vlaamse Gemeenschap, Afdeling Natuurlijke Rijkdommen en Energie, Brussel, 50 p.

TNO-GSN, 2021. Stramproy Formation. In: Stratigraphic Nomenclature of the Netherlands, TNO – Geological Survey of the Netherlands. Accessed on 30-09-2021 from http://www.dinoloket.nl/en/stratigraphic-nomenclature/stramproy-formation.

Van Adrichem Boogaert, H.A. & Kouwe, W.F.P., 1997. Stratigraphic nomenclature of the Netherlands, revision and update by RGD and NOGEPA. Mededelingen Rijks Geologische Dienst 50, Section I. Tertiary: 39p.

Vandenberghe, N , & Louwye, S., 2020. An introduction to the Neogene stratigraphy of northern Belgium: present status, Geologica Belgica , Volume 23 , number 3-4 – 97 . 112 URL : https://popups.uliege.be/1374-8505/index.php?id=6843.

Vandenberghe, N., Laga, P., Louwye, S., Vanhoorne, R., Marquet, R., De Meuter F., Wouters, K. & Hagemann, H.W., 2005. Stratigraphic interpretation of the Neogene marine-continental record in the Maaseik well (49W0220) in the Roer valley Graben, NE Belgium. Memoirs of the Geological Survey of Belgium 52, 39 p.

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, R., Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica , 23, 3-4, https://doi.org/10.20341/gb.2020.014

Van der Sluys, J., 2000. Verkenningsboringen in het Belgische deel van de Roerdalslenk. Geological Survey of Belgium, Professional Paper 2000/3 n° 292, 92p.

Vernes, R.W., Deckers, J., Bakker, M.A.J., Bogemans, F., De Ceukelaire, M., Doornenbal, J.C., den Dulk, M., Dusar, M., Van Haren, T.F.M., Heyvaert, V.M.A., Klden, P., Kruisselbrink, A.F., Lanckacker, T., Menkovic, A., Meyvis, B., Munsterman, D.K., Reindersma, R., Rombaut, B., ten Veen, J.H., van de Ven, T.J.M., Walstra, J. & Witmans, N., 2018. Geologisch en hydrogeologisch 3D model van het Cenozoïcum van de Belgisch-Nederlandse grensstreek van Midden-Brabant / De Kempen (H3O – De Kempen). TNO-rapport TNO 2017 R11261 – VITO 2017/RMA/R/1348, 109 p.

Westerhoff, W., 2009. Stratigraphy and sedimentary evolution. The lower Rhine-Meuse System during the Late Pliocene and Early Pleistocene (southern North Sea basin). TNO Geological Survey of the Netherlands , 168 p.

Wong, Th.E., de Lugt, I.R., Kuhlmann, G. & Overeem, I., 2007. Tertiary. In: Th.E. Wong, D.A.J. Batjes & J. de Jager, Geology of the Netherlands. Royal Netherlands Academy of Arts and Sciences (KNAW): 151-171.

40 Waubach Member (Kieseloolite Formation)

Unit name: Waubach Member

Hierarchical unit name: Kieseloolite Formation

Type: Member

Code: KzWb

Author(s):

- Compiled by: Vandenberghe Noël & Dusar Michiel

Alternative names/ origin of the name: As it became clear that the originally described Waubach sand and gravel in the Belgian part of the Roer Valley Graben (RVG) as in Vandenberghe et al. (2005, fig.10) could be systematically split up in 2 parts based on geophysical logs signals (Vandenberghe et al. 2020 fig. 6), the terms Lower and Upper Waubach Member were used (Louwye & Vandenberghe, 2020, fig. 3); since it became clear that the lower part of Waubach sand and gravel could be identified as the Inden Formation, the name Waubach Member is now reserved for its former upper part, but without the prefix upper.

It is not clear how the upper and lower Waubach terms used above the Inden Formation in the scheme by Wong et al. (2007) in the adjacent Dutch RVG (Figure 40-1) correspond to parts of the Waubach Sand as described above. Probably the clay shown at the contact between the two parts on the scheme is related to the clay horizon labelled Ki-k-4 and underlain by a sand unit Ki-z-5 by Dusar et al. (2014) Ki-k-4 and Ki-z-5 are absent in the Belgian part of the RVG . The Waubach Sand Member present in the Belgian RVG is labelled Ki-z-4 by Dusar et al. (2014) (see Figure 39-3 in LIS Kieseloolite Formation).

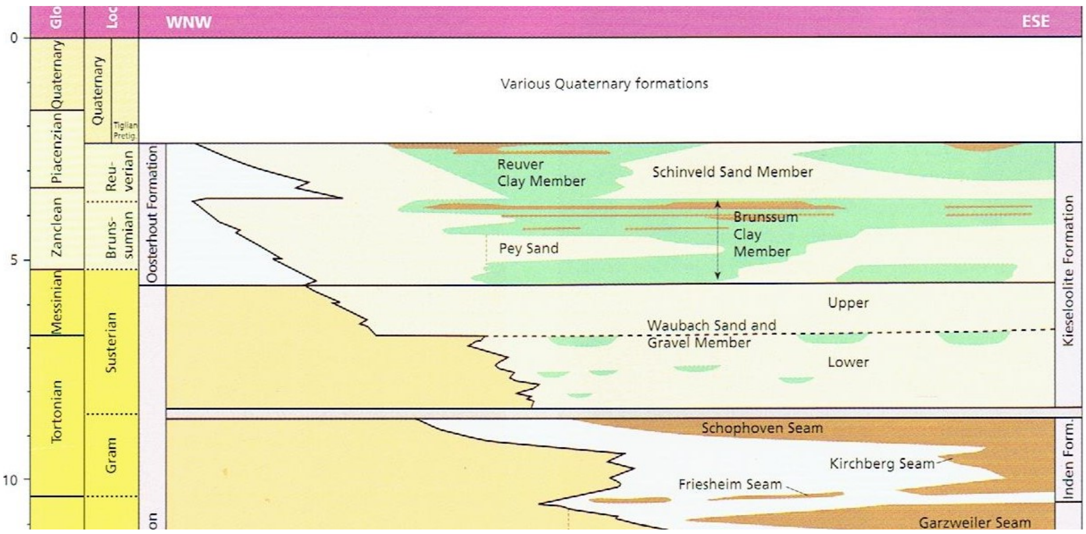


Figure 40-1 The stratigraphic position of the Waubach Sand and Gravel Member with respect to the Brunssum Clay and the Inden Formation in the southern Netherlands (Wong et al., 2007). Note also the subdivision into an lower and upper Waubach unit separated by discontinuous clay beds.

Status: Formal

Date: 01/05/2022

How to refer: Vandenberghe, N., & Dusar, M., 2023. The Waubach Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Waubach-Member

40.1 Characterizing description

The main lithology is pale grey to white quartz-enriched sand. The sand is fine to medium grained and becomes coarse to even gravelly, especially at the base of the member. Thin clay laminae, ripped up clasts and some lignitic particles may be present and organic colloids can stain parts of the sand purple. Van der Sluys (2000) notes that gravel is rare in the Belgian RVG and that from top to base, the resistivity decreases and the difference between short and deep resistivity values decreases as well as can also be observed on the resistivity logs of the Maaseik borehole (049W0220) (Vandenberghe et al., 2005, fig.2).

40.2 Type section, type locality, type borehole, or type geophysical borehole:

The 127- 166 m interval in the Maaseik borehole (049W0220) (Vandenberghe et al., 2005) is chosen as the reference section.

40.3 Description upper boundary

The top of the Waubach Member is the base of the overlying lignite and clay of the Brunssum II clay Bed, easily identified by a sharp change in the natural radioactivity and resistivity signals.

40.4 Description lower boundary

A sudden drop in the spontaneous potential signal and a marked short drop in resistivity signal, are characterising the lower boundary (see e.g. Louwye & Vandenberghe (2020, fig 2). It probably corresponds to a thin level with lignite and clay fragments in otherwise coarse sand. Below occurs the Inden Formation.

40.5 Thickness

The thickness is 25- 55 m, based on Vandenberghe et al. (2020, fig. 6).

40.6 Occurrence

The Waubach Member as defined in the Maaseik reference borehole occurs in the Belgian part of the RVG east of the main bordering faults of Heerlerheide and Reppel.

40.7 Regional correlations and age

Vandenberghe & Louwye (2020, fig. 3) and Louwye & Vandenberghe (2020, fig.3) (Figure 40-2) have integrated the available stratigraphic information of the upper Miocene units. They concluded that in the RVG the presently defined Waubach Member is probably a time equivalent facies of the clayey part of the Kasterlee Formation and of the overlying Retie Member of the Mol Formation (see LIS Mol Formation). This Retie Member is the now formalised 'lower Mol' or 'Kasterlee-sensu-Gulinck' lithostratigraphic unit described in the Neogene-2020 volume. The Retie Member is for lithological reasons ranked in the Mol Formation. The Waubach Member probably correlates with the Hauptkies in the Lower Rhine area however , detailed correlations between both areas remain hypothetical.

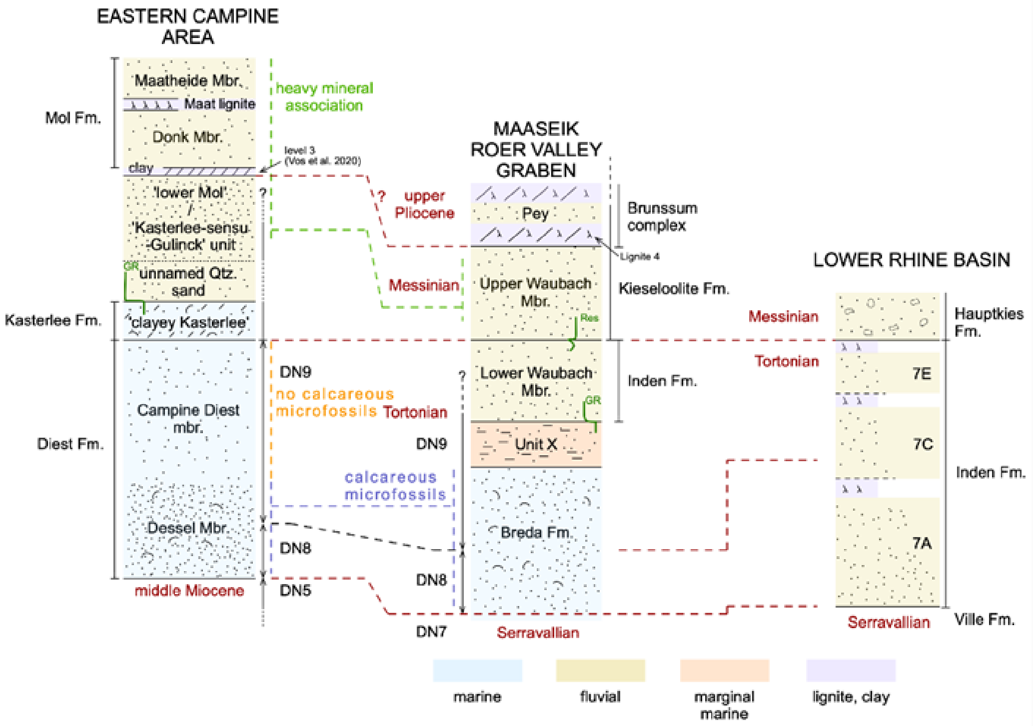


Figure 40-2 The Waubach Member as defined in the present LIS corresponds to the formerly used Upper Waubach Mbr figured in the Belgian RVG stratigraphy by Louwye and Vandenberghe (2020); note that the formerly used Lower Waubach Member in this scheme is in the present interpretation considered to be part of the Inden Formation defined in the Lower Rhine area. (Louwye and Vandenberghe, 2020)

40.8 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Maaseik borehole	049W0220	kb18d49w-B220	https://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0220.txt	https://www.dov.vlaanderen.be/data/boring/1980-025921

40.9 References

Dusar, M., Deckers, J., Juhász-Holterman, Matthijs, J., Menkovic, A., Six, S., Walstra, J. & Westerhoff, W.E., 2014. De Roerdalslenk. in : Dassargues,A. & Walraevens, K. (eds), Watervoerende Lagen en Grondwater in België/Aquifères et Eaux Souterraines en Belgique, Gent, Academia Press, XXIV +455p, 47-57.

Louwye, S. & Vandenberghe, N., 2020. A reappraisal of the stratigraphy of the upper Miocene unit X in the Maaseik well, eastern Campine area (northern Belgium). Geologica Belgica, 23/3-4, this volume. https://doi.org/10.20341/gb.2020.013

Vandenberghe, N , & Louwye, S., 2020. An introduction to the Neogene stratigraphy of northern Belgium: present status, Geologica Belgica , Volume 23 , number 3-4 – 97 . 112 URL : https://popups.uliege.be/1374-8505/index.php?id=6843.

Vandenberghe, N., Laga, P., Louwye, S., Vanhoorne, R., Marquet, R., De Meuter F., Wouters, K. & Hagemann, H.W., 2005. Stratigraphic interpretation of the Neogene marine-continental record in the Maaseik well (49W0220) in the Roer valley Graben, NE Belgium. Memoirs of the Geological Survey of Belgium 52, 39 p.

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, R., Deckers, J., Louwye, S., Laga, P.,Verhaegen, J.,Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica , 23, 3-4, https://doi.org/10.20341/gb.2020.014

Van der Sluys, J. 2000. Verkenningsboringen in het Belgische deel van de Roerdalslenk. Geological Survey of Belgium, Professional Papers 2000/3 n° 292, 92p.

Wong, T., de Lugt, I., Kuhlmann, G. & Overeem, I., 2007. Tertiary. In Wong, T., Batjes, D. & de Jager, J. (eds), Geology of the Netherlands. Royal Netherlands Academy of Arts and Sciences, Amsterdam, 151–171.

41 Op-den-Berg Facies (Kieseloolite Formation)

Unit name: Op-den-Berg Facies

Hierarchical unit name: Kieseloolite Formation

The ranking in the Kieseloolite Formation, and not in the Mol Formation as was cautiously suggested by Gullentops (1974) and Gulinck (1962), is justified by the location of the facies east of the Roer Valley Graben (RVG) border fault.

Type: Facies

Code: KzOp

Authors:

- Compiled by: Vandenberghe Noël & Dusar Michiel

Alternative names: Neeroeteren sand

Origin of the name: Original name was the Neeroeteren facies (Tavernier & de Heinzelin (1962), Gulinck (1962), Gullentops (1963)), but is changed because the name is already formally in use for the Neeroeteren Formation of the Carboniferous.

Status: Formal facies , exact stratigraphic position uncertain

Date: 01/05/2022

How to refer: Vandenberghe, N., & Dusar, M., 2023. The Op-den-Berg Facies, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Op-den-Berg-Facies

41.1 Characterizing description

A medium to coarse-grained even gravelly, poorly-sorted, grey to white quartz-enriched sand; quartz grains have angular outlines. Gully structures and oblique stratification occur in the sand. Among the gravels, which are mainly of Ardennes origin, a few ooliths occur.

41.2 Type section, type locality, type borehole, or type geophysical borehole

Tavernier & de Heinzelin (1962) define the Op-den-Berg, formerly Neeroeteren, sand as analogous to the Mol sand but situated at about + 80 m topographic height at the border of the Campine Plateau. They indicate on the geological map attached to their paper the sand pit Magge close to Neeroeteren-Berg. The Magge sand pit was first described by Hacquaert & Tavernier (1946).

The Op-den-Berg Facies is described, formerly as Neeroeteren facies, from the former sand quarry Neeroeteren-Berg (064W0211, kb26d64w-B217), by Gulinck (1962) and by Gullentops (1963) who made a sedimentological and mineralogical analysis of the sand pit, and by Sels et al. (2001, Stop 4 & Photo 2) who ranked the sand in the Waubach sand and Gravel unit. Geys (1972) has analysed in detail the grain size of the Magge sand pit in Neeroeteren and interpreted a fluviatile depositional environment with some beach horizons.

41.3 Description upper boundary

Not defined yet. On the slope towards the Campine Plateau, south of the sand pit and at a higher topographic level, the Zutendaal gravel is outcropping, with strong red weathering facies with black incrustation. Due to the tectonic deformation, the exact geometric relation between the Neeroeteren sand and Zutendaal gravel is not well known.

41.4 Description lower boundary

Not defined yet.

41.5 Thickness

A minimal thickness of 19 m, figured in the reference sandpit (Gullentops, 1963).

41.6 Occurrence

The reference sand pit is located just east of the fault zone bordering the deeper subsidence area of the Roer Valley Graben in east Belgium, in between the Feldbiss/Geleen and Heerlerheide Faults (Op den Berg fault block by Langenaeker, 1999). Therefore the Op-den-Berg Facies is included in the Kieseloolite Formation rather than in the Mol Formation.

41.7 Regional correlations

Tavernier & de Heinzelin (1962), Gulinck (1962) and Gullentops (1963) cautiously suggested that the Op-den-Berg Facies, formerly Neeroeteren facies, represents a lateral facies of the Mol Formation. Given its location in the RVG, the lithofacies and following the present stratigraphic practice regarding the occurrence of the Mol and Kieseloolite Formations, the Op-den-Berg Facies is better included in the Kieseloolite Formation.

On an idealised section, Gullentops (1974) related the gravel in the Op-den-Berg, formerly Neeroeteren, sand with a sparse gravel in the outcropping part of the Mol Formation and with the Hukkelberg gravel at the base of the Poederlee Formation. However in the legend of the 1:50 000 Geological Map 18-10 Maaseik-Beverbeek (Sels et al., 2001, Stop 4, p. 42, sand quarry Neeroeteren-Berg, named quarry Opitter in Gullentops (1963), BGD 064W0211, DOV kb26d64w-B217; Fig. 1, Table 1), this formerly Neeroeteren sand facies is considered as the lower part of the Kieseloolite Formation, namely the Waubach sand and gravel. Most probably this is because of the presence of gravel and the closeness to a natural outcrop also interpreted as Waubach sand and gravel (Sels et al., 2001, op.cit. photo 3) (Figure 41-1).

Figure 41-1 :Outcrop of poorly lithified and jointed Waubach Sand in Bergerven, in the prolongation of the Neeroeteren sand quarry towards the Meuse valley (photo M. Dusar).

41.8 Age

No biostratigraphic data are available.

41.9 Dataset

Neeroeteren-Berg (064W0211, kb26d64w-B217) is probably the Magge sand pit in Tavernier & de Heinzelin (1962) and Geys (1972) with coordinates in Geys (1972) x= 242.300 , y= 197.200 , z= +55m. This borehole is part of the DOV-Neogene data collection, including links to the GSB-collection data sheets:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Neeroeteren-Berg	064W0211	kb26d64w-B217	https://collections.naturalsciences.be/ssh-geology-archives/arch/064w/064w0211.txt	https://www.dov.vlaanderen.be/data/boring/1920-042751

41.10 References

Geys, J.F., 1972. Sedimentologie van de Zanden van Neeroeteren. Natuurwetenschappelijk Tijdschrift 54: 128-138.

Gulinck, M., 1962. Essai d'une carte géologique de la Campine. Etat de nos connaissances sur la nature des terrains néogènes recoupés par sondages. Mémoires de la Société belge de Géologie, de Paléontologie et d'Hydrologie, série in-8°, 6, 30–39.

Gullentops, F., 1963. Etude de divers faciès quaternaires et tertiaires dans le Nord et l'Est de la Belgique. Excursion O-P. 6e Congrès International de Sédimentologie, Belgique et Pays-Bas, 20 p.

Gullentops, F., 1974. Field trip notes 21-22 June 1975. Société belge de Géologie & Société géologique de Belgique.

Hacquaert, A. & Tavernier, R., 1946. Excursions géologiques en Campine. Extrait du Compte rendu de la Session Extraordinaire des Sociétés belges de Géologie (19-27 septembre 1946). Annexe au Bulletin Société belge de Géologie, Paléontologie et Hydrologie, t LV, fasc 2 & 3.

Langenaeker, V., 1999. Indications for a transpressional Late Cretaceous inversion in the Belgian part of the Roer Valley Graben. Aardkundige Mededelingen, 9: 139-142.

Sels, O., Claes, S. & Gullentops, F., 2001. Toelichtingen bij de geologische kaart van België, Vlaams Gewest: kaartblad 18-10, Maaseik - Beverbeek [1/50 000]. Belgische Geologische Dienst en Ministerie van de Vlaamse Gemeenschap, Afdeling Natuurlijke Rijkdommen en Energie, Brussel, 50 p.

Tavernier, R. & de Heinzelin, J., 1962. Introduction au Néogène de la Belgique. Mémoires de la Société belge de Géologie, de Paléontologie et d'Hydrologie, série in-8°, 6, 7-28.

42 Brunssum Member (Kieseloolite Formation)

Unit name: Brunssum Member

Hierarchical unit name: Kieseloolite Formation

Type: Member with Beds Brunssum I , II and Pey Sand Bed

Code: KzBr, KzB1, KzB2, and KzPe

Authors:

- Compiled by: Vandenberghe Noël & Dusar Michiel

Alternative names:

In the geological map sheet 18-10 Maaseik + Beverbeek (Sels et al., 2001) as in the Maaseik (049W0220) borehole interpretation (Vandenberghe et al., 2005), 2 levels with Brunssum Clay are identified and labelled I and II ; Van der Sluys (2001) labelled these two levels respectively upper and lower.

The Brunssum Member defined as a formal unit in the present LIS is the interval between the base of the Brunssum II Bed and the top of the Brunssum I Bed. The Pey Sand Bed occurs in between both Brunssum Beds and is discussed in a separate LIS.

In the hydrostratigraphy of the H30-project (Vernes et al., 2018 ; Dusar et al., 2014) the upper Brunssum I is labelled Ki-k-2 and the lower Brunssum II is labelled Ki-k-3. These authors have also introduced an additional uppermost clay level Ki-k-1 still included in the Kieseloolite Formation as defined by these authors (see LIS Kieseloolite Formation).

Origin of the name: -

Status: Formal

Date: 01/05/2022

How to refer: Vandenberghe, N., & Dusar, M., 2023. The Brunssum Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Brunssum-Member

42.1 Characterizing description:

The Brunssum Beds are layered dark lignitic clay and lignite horizons. Brunssum I can be more than 5 m in thickness and composed of several layers and contain larger wood fragments. Brunssum II is generally thinner and then consisting of a single clay layer. Root traces are visible in the clay. A few very thin sand layers can occur. The clayey intervals have marked gamma-ray signals. In between the 2 Brunssum Beds occurs a sand unit, the Pey Bed that can be a few meter to 30 m thick.

42.2 Type section, type locality, type borehole, or type geophysical borehole:

The Bocholt borehole (033W0153 / kb18d33w-B160) contains two intervals with Brunssum Member clay beds and lignite : 115,20 -133 m and 137,70-143,70 m. In between occurs the Pey Bed. The borehole is cored, sedimentological and mineralogical analyses are available as well as geophysical well logs and also palynological investigations are reported (Van der Sluys, 2000). The combination of marked high natural radioactivity and low resistivity signals allows a clear identification of the Brunssum Beds with respect to surrounding sand units.

Regional profiles suggest the consistent existence in the area of at least two Brunssum Beds , labelled I and II (Vandenberghe et al. , 2005; Vernes et al. , 2018 , annex D fig. 7.5 in which the same beds are labelled B1 and B2), while the profile presented by Dusar et al. (2014) shows also continuity of an additional uppermost clay bed labelled as Ki-k-1 indicating the incorporation of this bed in the Kieseloolite Formation.

42.3 Description upper and lower boundaries

The boundaries of the Brunssum beds with the overlying and underlying sand units is generally sharp and the boundaries can therefore be picked rather well on gamma and resistivity logs.

If thinner clay or lignite horizons occur in the overlying sand, the exact boundary can be subject for discussion. This is well illustrated by the interpretation of the Maaseik (049W0220) borehole in Vernes et al. (2018, annex D fig.7.3) that leads to the upwards extension of the Kieseloolite Formation top (see LIS Kieseloolite Formation). The Kl-k-2 Kieseloolite-clay, corresponding to the upper Brunssum I clay bed in Vandenberghe et al. (2005), is overlain by a thin 2,4 m sand layer (73,6-76 m) followed by a thicker clay zone (63,2 -73,6m) with a clearly lower natural gamma ray signal and higher resistivity signal than the Kl-k-2 Brunssum bed. This lower gamma ray signal clay zone is included in the overlying Jagersborg/Schinveld sand in the interpretation by Vandenberghe et al. (2005) but in Vernes et al. (2018, annex D fig.7.3) this thicker clay zone (63,2 -73,6m) is labelled as Kl-k-1 and interpreted to belong to the Kieseloolite Formation and marking the latter's top (in contact with overlying Stramproy Formation). The Kl-k-1 interval is described in the cores of the Maaseik (049W0220) borehole as fine sand with systematic presence of 5 to 10 cm thick clay layers some of which some are dark stained by lignite particles; also a 40 cm lignite layer occurs (Vandenberghe et al., 2005).

42.4 Thickness

In the reference borehole Bocholt the upper Brunssum I clay bed is almost 18 m and the lower Brunssum II clay bed 6 m. However thicknesses are variable as can be expected from the depositional conditions of the Brunssum clay in floodplain swamps and lakes and from its occurrence in an actively faulted block area in the west of the Roer Valley Graben (RVG). In the Maaseik borehole (049W0220) the upper Brunssum I bed is 12 m thick and the lower Brunssum II bed 5,6 m. Maximal thicknesses are observed in the Kinrooi (049W0230 /kb18d49w-B230) borehole: slightly more than 30 m for the lower clay unit and 20 m for the upper unit. The two Brunssum I and II clay beds can be separated 30 m apart by Pey Sand Bed (see Vandenberghe et al., 2005, fig. 10).

42.5 Occurrence

The Brunssum Member and the Brunssum Beds in Belgium are only recognised in the RVG area east of the Reppel-Heerlerheide faults.

42.6 Regional correlations

The Brunssum clay beds in Belgium are the lateral extension of the clays of the Brunssum Member (or Brunssum Laagpakket) in the Dutch RVG (TNO-GSN, 2021).

42.7 Age

In the Dutch part of the RVG, the Brunssum Member is considered Pliocene in age (Wong et al., 2007; TNO-GSN 2021).

Palynological interpretations of Vanhoorne in Vandenberghe et al. (2005) seem to confirm a Pliocene age. However palynology reported from the Bocholt borehole by Van der Sluys (2000, 2.1.5) compares the pollen in the upper Brunssum I bed with the early Pleistocene clays of the Weelde Formation in Belgium and the Tegelen Member in the Netherlands. Donders et al. (2007) have demonstrated that stratigraphic correlations based on palynology need caution.

42.8 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Maaseik borehole	049W0220	kb18d49w-B220	https://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0220.txt	https://www.dov.vlaanderen.be/data/boring/1980-025921
Bocholt borehole	033W0153	B/7-0356	https://collections.naturalsciences.be/ssh-geology-archives/arch/033w/033w0153.txt	https://www.dov.vlaanderen.be/data/boring/1995-025169
Kinrooi borehole	049W0230	kb18d49w-B230	https://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0230.txt	https://www.dov.vlaanderen.be/data/boring/1995-102445

42.9 References

Donders, T.H., Kloosteroer-van Hoeve, M.L., Westerhoff, W., Verreussel R.M.C.H. & Lotter, A.F., 2007. Late Neogene continental stages in NW Europe revisited. Earth-Science reviews 85: 161-186.

Dusar, M., Deckers, J., Juhász-Holterman, Matthijs, J., Menkovic, A., Six, S., Walstra, J. & Westerhoff, W.E., 2014. De Roerdalslenk. in : Dassargues,A. & Walraevens, K. (eds), Watervoerende Lagen en Grondwater in België/Aquifères et Eaux Souterraines en Belgique, Gent, Academia Press, XXIV +455p, 47-57.

Sels, O., Claes, S. & Gullentops, F., 2001. Toelichtingen bij de geologische kaart van België, Vlaams Gewest: kaartblad 18-10, Maaseik - Beverbeek [1/50 000]. Belgische Geologische Dienst en Ministerie van de Vlaamse Gemeenschap, Afdeling Natuurlijke Rijkdommen en Energie, Brussel, 50 p.

TNO-GSN (2021). Brunssum Member. In: Stratigraphic Nomenclature of the Netherlands, TNO – Geological Survey of the Netherlands. Accessed on 22-06-2021 from http://www.dinoloket.nl/en/stratigraphic-nomenclature/brunssum-member.

TNO-GDN (2021). Laagpakket van Brunssum. In: Stratigrafische Nomenclator van Nederland, TNO – Geologische Dienst Nederland. Geraadpleegd op 30-09-2021 op http://www.dinoloket.nl/stratigrafische-nomenclator/laagpakket-van-brunssum.

Vandenberghe, N., Laga, P., Louwye, S., Vanhoorne, R., Marquet, R., De Meuter F., Wouters, K. & Hagemann, H.W., 2005. Stratigraphic interpretation of the Neogene marine-continental record in the Maaseik well (49W0220) in the Roer valley Graben, NE Belgium. Memoirs of the Geological Survey of Belgium, 52, 39 p.

Van der Sluys, J. 2000. Verkenningsboringen in het Belgische deel van de Roerdalslenk. Geological Survey of Belgium, Professional Papers 2000/3 n° 292, 92p.

Vernes, R.W., Deckers, J., Bakker, M.A.J., Bogemans, F., De Ceukelaire, M., Doornenbal, J.C., den Dulk, M., Dusar, M., Van Haren, T.F.M., Heyvaert, V.M.A., Kiden, P., Kruisselbrink, A.F., Lanckacker, T., Menkovic, A., Meyvis, B., Munsterman, D.K., Reindersma, R., Rombaut, B., ten Veen, J.H., van de Ven, T.J.M., Walstra, J. & Witmans, N., 2018. Geologisch en hydrogeologisch 3D model van het Cenozoïcum van de Belgisch-

Nederlandse grensstreek van Midden-Brabant / De Kempen (H3O – De Kempen). TNO-rapport TNO 2017 R11261 – VITO 2017/RMA/R/1348, 109 p.

Wong, T., de Lugt, I., Kuhlmann, G. & Overeem, I., 2007. Tertiary. In Wong, T., Batjes, D. & de Jager, J. (eds), Geology of the Netherlands. Royal Netherlands Academy of Arts and Sciences, Amsterdam, 151–171.

43 Pey Bed (Brunssum Member)

Unit name: Pey Bed

Hierarchical unit name: Brunssum Member of the Kieseloolite Formation

Type: Bed

Code: KzPe

Authors:

- Compiled by: Vandenberghe Noël & Dusar Michiel

Alternative names: The sand unit named Pey sand in this LIS is unnamed in the H30-project but labelled as Ki-z-3 between Ki-k-2 and Ki-k-3 (Dusar et al., 2014) or just undifferentiated ki-z in Vernes et al. (2018).

Origin of the name:-

Status: Formal

Date: 01/05/2022

How to refer: Vandenberghe, N., & Dusar, M., 2023. The Pey Bed, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Pey-Bed

43.1 Characterizing description

A fine to medium sized pale grey to white sand intercalated between the two Brunssum clay Beds named upper or I and lower or II. Clay laminae, lignitic levels and clay clasts are present. A 2-3 m thick clay layer in the middle of the sand is reported in the explanatory notes of the geological map 18-10 Maaseik + Beverbeek (Sels et al., 2001). On the geophysical log pattern of the Maaseik (049W0220) the sediments are arranged in a few cycles (Vandenberghe et al., 2005, figs 2 & 10) but in general the log signatures in other boreholes can be quite different. Still the Pey Sand Bed is an important regional hydrogeological layer.

43.2 Type section, type locality, type borehole, or type geophysical borehole:

The Pey Bed sand reference is the interval 88-120,2 m in the Maaseik (049W0220) cored borehole where the bed has its thickest development in the Belgian part of the RVG and of which analyses and geophysical logs are available (Vandenberghe et al., 2005). Description upper and lower boundary:

As the definition of the Pey Bed requires its intercalation between two Brunssum Clay Beds, the upper and lower boundaries are marked by a transition from sand to clay and are easily picked on geophysical logs.

43.3 Description upper boundary

The upper boundary of the Pey Bed is a sharp drop in RES and sharp rise in GR log signals at the contact with the overlying clay of the Brunssum I Bed (Vandenberghe et al., 2005, fig.10).

43.4 Description lower boundary

The lower boundary of the Pey Bed is a sharp drop in RES and a sharp rise in GR log signals at the contact with the underlying clay of the Brunssum II Bed (Vandenberghe et al., 2005, fig.10).

43.5 Thickness

Thickness of the Pey Bed between 2 Brunssum Clay Member units varies between about 3 and 30 m (Vandenberghe et al., 2005, fig.10).

43.6 Occurrence

The Pey Bed can only be identified where 2 Brunssum Clay Beds can be distinguished in the Belgian part of the Roer Valley Graben (RVG).

43.7 Regional correlations

The Pey Bed is not listed by the Dutch TNO-GSN (TNO-GSN DINOloket 2021) but an earlier practice in the Netherlands, comparable to the occurrence between two Brunssum clay Beds as defined above, is conceptually illustrated in the figure below by Wong et al. (2007) (Figure 43-1)

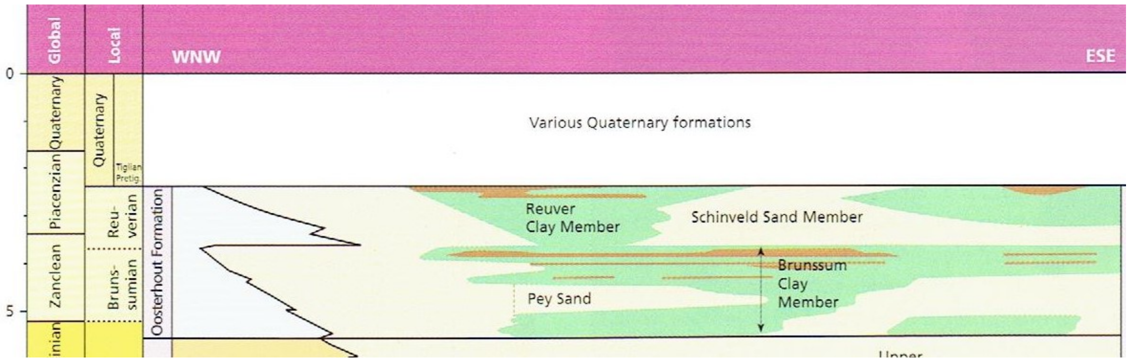


Figure 43-1: The occurrence of Pey Sand between a lower and an upper Brunssum Clay in the southern Netherlands as figured by Wong et al. (2007).

43.8 Age

The palynological interpretation by Vanhoorne reported in Vandenberghe et al. (2005) is not contradicting a Brunssumian age as given in Wong et al. (2007). Also in the Maaseik borehole according to Vanhoorne, the Brunssum Clay Bed I, just above the Pey Sand, and the about 20 m above it, have a pollen spectrum ('upper part of palynozone A') comparable to the spectrum in the Maat Lignite Bed of the Mol Formation.

43.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Maaseik borehole	049W0220	kb18d49w-B220	https://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0220.txt	https://www.dov.vlaanderen.be/data/boring/1980-025921

43.10 References

Dusar, M., Deckers, J., Juhász-Holterman, Matthijs, J., Menkovic, A., Six, S., Walstra, J. & Westerhoff, W.E., 2014. De Roerdalslenk. in : Dassargues, A. & Walraevens, K. (eds), Watervoerende Lagen en Grondwater in België/Aquifères et Eaux Souterraines en Belgique, Gent, Academia Press, XXIV +455p, 47-57.

Sels, O., Claes, S. & Gullentops, F., 2001. Toelichtingen bij de geologische kaart van België, Vlaams Gewest: kaartblad 18-10, Maaseik - Beverbeek [1/50 000]. Belgische Geologische Dienst en Ministerie van de Vlaamse Gemeenschap, Afdeling Natuurlijke Rijkdommen en Energie, Brussel, 50 p.

TNO-GSN (2021). Brunssum Member. In: Stratigraphic Nomenclature of the Netherlands, TNO – Geological Survey of the Netherlands. Accessed on 22-06-2021 from http://www.dinoloket.nl/en/stratigraphic-nomenclature/brunssum-member.

TNO-GSN (2021). Kiezeloolite Formation. In: Stratigraphic Nomenclature of the Netherlands, TNO – Geological Survey of the Netherlands. Accessed on 22-06-2021 from http://www.dinoloket.nl/en/stratigraphic-nomenclature/kiezeloolite-formation.

TNO-GSN (2021). Waubach Member. In: Stratigraphic Nomenclature of the Netherlands, TNO – Geological Survey of the Netherlands. Accessed on 23-06-2021 from http://www.dinoloket.nl/en/stratigraphic-nomenclature/waubach-member.

Vandenberghe, N., Laga, P., Louwye, S., Vanhoorne, R., Marquet, R., De Meuter F., Wouters, K. & Hagemann, H.W., 2005. Stratigraphic interpretation of the Neogene marine-continental record in the Maaseik well (49W0220) in the Roer valley Graben, NE Belgium. Memoirs of the Geological Survey of Belgium, 52, 39 p.

Vernes, R.W., Deckers, J., Bakker, M.A.J., Bogemans, F., De Ceukelaire, M., Doornenbal, J.C., den Dulk, M., Dusar, M., Van Haren, T.F.M., Heyvaert, V.M.A., Kiden, P., Kruisselbrink, A.F., Lanckacker, T., Menkovic, A., Meyvis, B., Munsterman, D.K., Reindersma, R., Rombaut, B., ten Veen, J.H., van de Ven, T.J.M., Walstra, J. & Witmans, N., 2018. Geologisch en hydrogeologisch 3D model van het Cenozoïcum van de Belgisch-Nederlandse grensstreek van Midden-Brabant / De Kempen (H3O – De Kempen). TNO-rapport TNO 2017 R11261 – VITO 2017/RMA/R/1348, 109 p.

Wong, T., de Lugt, I., Kuhlmann, G. & Overeem, I., 2007. Tertiary. In Wong, T., Batjes, D. & de Jager, J. (eds), Geology of the Netherlands. Royal Netherlands Academy of Arts and Sciences, Amsterdam, 151–171.

44 Jagersborg Member (Kieseloolite Formation)

Unit name: Jagersborg Member

Hierarchical unit name: Kieseloolite Formation

Type: Member

Code: KzJa

Authors:

- Compiled by: Vandenberghe Noël & Dusar Michiel

Alternative names: sometimes Jagersborg/Schinveld is used in literature to point out the at least partial correspondence of the Belgian Jagersborg Sand with the Dutch Schinveld Sand.

In the H30-project (Vernes et al., 2018, annex D section 7 fig. 7.3) the sandy part in the interval interpreted as Jagersborg Member in the published Maaseik borehole (Vandenberghe et al., 2005) is interpreted as Stramproy Formation; neither Jagersborg nor Schinveld sand are interpreted in this H30-project stratigraphy and at present neither of both terms is still described in the Dutch DINOloket.

Origin of the name:-

Status: Formal

Date: 01/05/2022

How to refer: Vandenberghe, N., & Dusar, M., 2023. The Jagersborg Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Jagersborg-Member

44.1 Characterizing description

Ash-grey to white sand, often stained by organics, laminated, fine to medium sized with a few coarse levels. Clay laminae of mm, cm and even dm scale occur. Erosive surfaces with clay and lignite clasts are common and laminae with concentrations of mica flakes sorted by currents occur. A 3,5 m thick lignite layer with preserved wood fragments is present. Towards the base more cm to dm clay layers and another 40 cm lignite occur.

In the H3O report a clay unit is identified within the Belgian Jagersborg Sand Member and labelled SY-k-3 (SY for Stramproy) (see further in Stramproy unit) (Dusar et al., 2014; Vernes et al., 2018, annex D fig. 7.3). According to this report the SY-k-3 clay bed occurs around 50 m in the Maaseik (049W0220) borehole and between about 91 and 101 m in the Bocholt (33W0153) borehole described by Van der Sluys (2000).

44.2 Type section, type locality, type borehole, or type geophysical borehole

The Jagersborg Sand is defined in a study by Vanhoorne et al. (1999) in the Kinrooi-Maaseik-Neeroeteren area. The Jagersborg Member is described in the 22 to 76 m interval of the reference Maaseik borehole (049W0220) , between overlying Pleistocene Meuse terrace gravels and the underlying upper Brunssum clay layer (Brunssum I) unit below.

Dusar et al (2014) have split the Jagersborg Member in an inferior and superior part, the lower part containing more clay than the upper sandy part. The boundary between the two subunits occurs at 63.2 m in the Maaseik borehole. In the H30 report (Vernes et al., 2018) the upper Jagersborg is part of the Stramproy Formation and the lower Jagersborg is part of the Kieseloolite Formation.

44.3 Description upper boundary

In the Maaseik area the Jagersborg Member is overlain by the Meuse terrace gravels (Vanhoorne et al. , 1999).

44.4 Description lower boundary

The top of the lignitic clay interval, the upper Brunssum (Brunssum I) , is defined as the base of the overlying Jagersborg member; it can be identified by a marked increase in the gamma-ray signal.

44.5 Thickness

The thickness varies between minimal 10 and about 50 m.

44.6 Occurrence

The Jagersborg Member is also reported in the regional review for the geological map 18-10 Maaseik + Beverbeek (Sels et al., 2001). On the map and the profiles accompanying the map, the sand unit above the Brunssum clay I unit is mapped as Jagersborg Member over the whole area east of the Reppel Roer Valley Graben bordering fault.

The name Jagersborg Sand has been introduced by Vanhoorne et al. (1999) for white quartz sand underlying the Meuse gravel in the area. Nevertheless, the map authors recognise that possibly part of the sand unit could be the Early Pleistocene fluviatile Kedichem Formation (nowadays included in the Waalre Formation (Westerhoff, 2009, p16) on top of the Jagersborg Sand as also interpreted by Van der Sluys (2000).

In a regional profile (Vandenberghe et al., 2005, fig.10) all except the Maaseik (049W0220) boreholes have the Stramproy Formation sand overlying the Jagersborg/Schinveld unit. The Stramproy Formation is deposited by rivers that drained the Belgian area in contrast to the about time-equivalent mixed Meuse-Rhine river deposits of the Waalre Formation; the former is characterised by dominantly stable heavy minerals and the latter by unstable heavy minerals (Westerhoff, 2009, p 16). In the present practice also more clayey layers are included and a gradual transition to the Kieseloolite Formation is reported (TNO-GDN, 2021) explaining why in the H3O report (Vernes et al., 2018) the Stramproy Formation is also interpreted in the Maaseik (049W0220) borehole between 22 and 63.2 m depth.

44.7 Regional correlations

Dusar et al. (2014, table 1) incorporate only the clayey lower part of the Jagersborg unit (Jagersborg inf.) in the Kieseloolite Formation while the main overlying sandy part of the Jagersborg unit (Jagersborg sup.) is considered as belonging to the Stramproy Formation.

44.8 Age

Seen the debatable nature of the lithostratigraphic units underlying the Meuse gravel in the Maaseik and surrounding area , the reported palynological data in the area need to be used cautiously (Donders et al., 2007). Palynology in the Maaseik (049W0220) borehole points to upper Pliocene, latest Reuver C for the upper part of the Jagersborg Member while the lower part of the Jagersborg Member (57,6-87,5 m)(base Stramproy Formation and top Kieseloolite Formation in H30 report interpretation) has a similar palynology as the Maat Lignite Bed in the Mol Formation (Vanhoorne in Vandenberghe et al., 2005). Vanhoorne et al. (1999) suggest that Jagersborg Member in the broader Maaseik-Kinrooi area could be Praetiglian.

44.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Maaseik borehole	049W0220	kb18d49w-B220	https://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0220.txt	https://www.dov.vlaanderen.be/data/boring/1980-025921

44.10 References

Donders, T.H., Kloosteroer-van Hoeve, M.L., Westerhoff, W., Verreussel R.M.C.H. & Lotter, A.F. , 2007. Late Neogene continental stages in NW Europe revisited. Earth-Science reviews 85: 161-186.

Dusar, M., Deckers, J., Juhász-Holterman, Matthijs, J., Menkovic, A.,Six, S., Walstra, J. & Westerhoff, W.E., 2014. De Roerdalslenk. in : Dassargues,A. & Walraevens, K. (eds), Watervoerende Lagen en Grondwater in België/Aquifères et Eaux Souterraines en Belgique, Gent, Academia Press, XXIV +455p, 47-57.

Sels, O., Claes, S. & Gullentops, F., 2001. Toelichtingen bij de geologische kaart van België, Vlaams Gewest: kaartblad 18-10, Maaseik - Beverbeek [1/50 000]. Belgische Geologische Dienst en Ministerie van de Vlaamse Gemeenschap, Afdeling Natuurlijke Rijkdommen en Energie, Brussel, 50 p.

TNO-GDN (2021). Stramproy Formation. In: Stratigraphic Nomenclature of the Netherlands, TNO – Geological Survey of the Netherlands. Accessed on 02-12-2021 from http://www.dinoloket.nl/en/stratigraphic-nomenclature/stramproy-formation.

Vandenberghe, N., Laga, P., Louwye, S., Vanhoorne, R., Marquet, R., De Meuter F., Wouters, K. & Hagemann, H.W., 2005. Stratigraphic interpretation of the Neogene marine-continental record in the Maaseik well (49W0220) in the Roer valley Graben, NE Belgium. Memoirs of the Geological Survey of Belgium, 52, 39 p.

Van der Sluys, J. 2000. Verkenningsboringen in het Belgische deel van de Roerdalslenk. Geological Survey of Belgium, Professional Papers 2000/3 n° 292, 92p.

Vanhoorne, R., Hammenecker, J. & Gullentops, F., 1999. Sedimentology and palynology of the Upper-Pliocene in the Rur Valley Graben near Maaseik, Belgium. Aardkundige Mededelingen, 9, 169-182.

Vernes, R.W., Deckers, J., Bakker, M.A.J., Bogemans, F., De Ceukelaire, M., Doornenbal, J.C., den Dulk, M., Dusar, M., Van Haren, T.F.M., Heyvaert, V.M.A., Kiden, P., Kruisselbrink, A.F., Lanckacker, T., Menkovic, A., Meyvis, B., Munsterman, D.K., Reindersma, R., Rombaut, B., ten Veen, J.H., van de Ven, T.J.M., Walstra, J. & Witmans, N., 2018. Geologisch en hydrogeologisch 3D model van het Cenozoïcum van de Belgisch-Nederlandse grensstreek van Midden-Brabant / De Kempen (H3O – De Kempen). TNO-rapport TNO 2017 R11261 – VITO 2017/RMA/R/1348, 109 p.

Westerhoff, W., 2009. Stratigraphy and sedimentary evolution. The lower Rhine-Meuse system during the Late Pliocene and Early Pleistocene (southern North Sea basin). TNO Geological Survey of the Netherlands , 168 p.

45 Mol Formation

Unit name: Mol Formation

Hierarchical unit name: The hierarchic position of the Mol unit in relation with other quartz sand units can be discussed

Type: Formation

Code: Ml

Author(s):

- Compiled by: Vandenberghe Noël, Berwouts Isaac, Vos Koen

Alternative names:

Origine of the name: -

Status: Formal

Date: 01/05/2022

How to refer: Vandenberghe, N., Berwouts, I. & Vos, K., 2023. The Mol Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Mol-Formation

45.1 Characterizing description

The Mol Formation is characterised by pale grey to white quartz sand. The exceptionally high quartz content and the chemical purity of the sand has led to its mining as silica sand in the Mol to Lommel area. Some rare thin clay laminae are reported from boreholes. No macrofossils are present. Lignite horizons, commonly enriched in clay, are present and at least one such horizon, the Maat lignite, can be correlated as a stratigraphic marker. Therefore it is attributed a bed status, the Maat Lignite Bed. Another younger lignite bed, the Russendorp lignite, once proposed as a stratigraphic marker, is too discontinuous to be reliably correlated.

The Maat Lignite Bed has been chosen to subdivide the Mol Formation into a Donk Member below the lignite and a Maatheide Member above the bed (Gullentops & Vandenberghe, 1995a). Occasionally the Maatheide Member might be dark stained by organics. The Donk Sand Member is finer grained than the Maatheide Sand Member with modal size respectively < 250 µm and > 250 µm. However the Donk Sand Member west of the Mol Rauw Fault in the Witgoor-Dessel area has a median grain size well above 250 µm, whilst further west in the Retie-Geel-Kasterlee area its median size is smaller than 200 µm (Vandenberghe et al., 2020, fig. 2).

Underneath the Donk Member, a finer-grained pale grey sand, with a median around 180 µm and trace amounts of dispersed glauconite pellets, occurs. This unit, the Retie Member, was provisionally described in Vandenberghe et al. (2020) as 'lower Mol' of 'Kasterlee-sensu-Gulinck' unit. Although there are also arguments to rank the Retie Member in the Kasterlee Formation, lithologically it certainly fits with the quartz-sand family of the Mol Formation. In boreholes, the Retie Member can hardly be distinguished by colour from Mol Formation sand. Drilling mud is reported to start colouring slightly green at the top of the Retie Member. Even in the Retie-Geel-Kasterlee area the grain size of the Retie Member and the Donk Member are very similar and only a notable fraction >250 µm in the Donk Member allows to detect the boundary between both. It is beyond doubt that the mention in the definition of the Mol Formation by Laga et al. (2001) of 'in the type region, lower part very slightly glauconiferous', a literal translation from the description of the Sables de Mol by Gulinck (1962), is referring to the sand of this Retie Member. The presence of the Retie Member type sand is also at the origin of the 'Mol inférieur' term, which does not correlate exactly with the Retie Member but refers to the same impurities of glauconite. Mol inférieur was never precisely defined but used in borehole descriptions of the Archives of the Geological Survey of Belgium. 'Mol supérieur' was used for the rest of the Mol Formation, above Mol inférieur.

In the Poppel-Mol Rauw Fault zone and east of it, a high natural gamma-ray signal occurs on top of the Retie Member and a clayey and lignitic horizon is documented in cores at that level in at least one borehole (MHL 03/01 Stevensvennen, 032W0460/GEO-03/071-B2). It is proposed to informally name this geophysically expressed horizon 'level 3 clay bed ' as in Vandenberghe et al. (2020), until more lithological information becomes available. The same authors also identify in the same area a probably coarsening downwards interval (between levels 1-2 of the authors) below the fine-grained Retie Member and with the same colour as the latter. It is labelled 'unnamed sand' in Vandenberghe and Louwye (2020) and now informally named 'level 1-2 sand unit' until more lithological information becomes available.

Northwest of Mol, the Mol Formation is mapped as far as north of the Lichtaart-Kasterlee hill ridge where the pale quartz Mol sand becomes very coarse particularly in its base (Buffel et al., 2001). On the geological map 8-2 Turnhout-Meerle, this coarse Rees sand, which is now considered as a separate formal unit (see LIS Rees Facies), is considered the most westward facies of the Mol Formation picking up some rare glauconite grains and muscovite. Further westwards, pale quartz sand evolves into olive grey to greenish grey sand with some glauconite, muscovite and thin clay lenses; these sand facies are ranked into the Brasschaat Formation as on the geological maps or in the Merksplas Formation as in Louwye et al. (2020) (see Merksplas Formation Lithostratigraphic Information Sheets).

45.2 Type section, type locality, type borehole, or type geophysical borehole

The exploitation pits for silica sand along the Campine Canal between Mol and Lommel are indicated as stratotype for the Mol Formation by Laga et al. (2001). The pits are named, from west to east, Donk, Pinken, Schans, Kanaalplas- De Maat, Rauw, Blauwe kei, Russendorp en Maatheide. Type gamma-ray logs, grain size data and glauconite contents from boreholes in that area are reported in Vandenberghe et al. (2020).

The geophysical log data and cores in the SCR-Sibelco N.V. borehole at Stevensvennen MHL03/01 (032W0460/GEO-03/071-B2), as interpreted in Vandenberghe et al. (2020) is a good reference for the Maatheide and Donk members and also for the Maat Lignite Bed.

A reference geophysical expression on the gamma-ray log for the informal 'level 3 clay bed' is the SCK 13/Postel2 borehole (032W0415 / kb17d32w-B385) between 62 and 69 m depth.

The reference for the Retie Member is the ONDRAF/NIRAS borehole ON-Retie-2 (031W0375) borehole between 8 and 19.5 m, with geophysical data, sediment analyses and CPT log in Vandenberghe et al. (2020). The SCK 13/Postel2 borehole (032W0415 / kb17d32w-B385) also serves as a reference for the informally named 'level 1-2 sand' unit between 92 and 107 m.

All members of the Mol Formation, as divided in these LIS files, are present in the SCK 13/Postel2 borehole (032W0415 / kb17d32w-B385) and are expressed on geophysical borehole logs, without samples however.

45.3 Description upper boundary

The overlying formations are Quaternary deposits. In the west overlies the Vosselaar Formation (Rees borehole 017E0399/kb8d17e-B495) which is finer grained than the Rees Facies. In the Antwerp province type area, diverse pale coloured quartz-enriched sand deposits occur which have higher chroma colours compared to the Mol Sand and are admixed with loam or organics; also base gravel may be present. In the Limburg Campine area overlies the coarser sandy and gravelly Sterksel Formation.

45.4 Description lower boundary

In the west the Mol Formation is underlain by the Poederlee Member or the Kasterlee Formation which are differentiated by a glauconite content and consequently a more olive grey to greenish grey colour. The top of the underlying Heist-op-den-Berg Member of the Kasterlee Formation is a marked increase of the gamma ray signal. The basal one to two meter of the Retie Member can contain a marked content of reworked greenish sediment from the underlying Kasterlee Formation. From the Poppel-Rauw Fault zone eastwards below the Retie Member occurs a coarser sand that is identified as a separate interval on geophysical borehole logs as the informally named 'level 1-2 sand' unit.

45.5 Thickness

The thickness of the formation increases from west to east. In the Kasterlee-Mol-Dessel area west of the Poppel-Rauw Fault zone, the combined thickness of the formation is between 12 and 28 meter with 5 to 10 m for the Donk Member and 7 to 22 m for the Retie Member. The Donk and Pinken sand pits closer to the Poppel- Rauw Fault zone show a marked increase in the Donk Member thickness up to 24 m. From this fault zone eastwards occur the Maatheide (up to almost 40 m), Donk (about 25 m) , Retie (about 25 m) members, the Maat Lignite Bed (about 3 m), the informal 'level 3' bed (7 m) and the coarser informal 'level 1-2 sand interval' (15 m) (Vandenberghe et al., 2020) below the Retie Member and above the marked increased gamma ray signal of the top of the Kasterlee Formation.

45.6 Occurrence

As the general dip of the strata is north-northeast, the southern occurrence of the Mol Formation is limited by its outcrop zone on the geological maps 8/2 Turnhout-Meerle (Buffel et al., 2002), 17/Mol (Gullentops & Vandenberghe, 1995b) and 18/10 Maaseik-Beverbeek (Sels et al., 1999); the formation outcrops along the Campine Canal near Mol-Dessel and further eastwards south of Lommel, Kleine and Grote Brogel and Bree. From the Poppel-Rauw Fault zone and east of it, the southern outcrop limit is affected by the occurrence of the RVG boundary faults (Geological Map 17 Mol (Gullentops & Vandenberghe, 1995b)). On the maps, the Mol Formation is conventionally limited in the east by the major RVG western boundary fault of Reppel, to the east of which occurs the quartz sand of the Kieseloolite Formation.

Laterally from the Rees Facies in the west occurs the Brasschaat Formation with the Schorvoort, Hemeldonk and Malle facies discussed in Buffel et al. (2001) and mapped as Brasschaat Formation on the 8/2 Turnhout Meerle geological map. In the subsurface to the north in the Antwerp province, the distinction of the Mol Formation with the Brasschaat Formation is not obvious (Laga, 1976 –profile PGL76/106/3) and geometrically the formation seems to transition into the relatively coarse Merksplas Formation (Laga, 1976 – profiles 76/106/2 and 75/104/1) [see also Lithostratigraphic Identification sheet of the Merksplas Formation (Note: in the Neogene Volume Louwye et al. (2020) and Vandenberghe and Louwye (2020) have named the Pliocene quartz sand in the west the Merksplas Formation and not Brasschaat Member as this name is reserved in the NCS for Pleistocene fine-sized sand.).

The Maat Lignite Bed, subdividing the Donk Member below from the Maatheide Member above, is outcropping along the Campine Canal in the Poppel-Rauw Fault zone west of Rauw 1 Fault and the outcrop of the Russendorp lignite is mapped west of the Reusel Fault (Geological Map 17 Mol). Both faults act as normal faults bordering the lignite and down dropping it at their eastern side.

The informal units ('level 3 clay' & 'level 1-2 sand') only occur in the subsurface from the Poppel-Rauw fault zone on and eastwards of it.

Figure 45-1 Sibelco exploitation pits of Mol Sand along the Campine Canal plotted on the geological map sheet 17 Mol, with orange: Brasschaat Formation, yellow: Mol Formation, green: Kasterlee Formation (Gullentops & Vandenberghe, 1995b). MHL & MHR Maatheide Links (Left) and Maatheide Rechts (Right). For a more recent mapping of the Brasschaat Member (now formally of the Malle Formation) see https://ncs.naturalsciences.be/paleogene-neogene/210-merksplas-formation.

45.7 Regional correlations

Based on geometry and on the common strongly quartz-enriched sand composition, a grouping of at least part of the Mol Formation with the Kieseloolite Formation in the east and with the Merksplas Formation in the west and northwest is obvious.

A major constraint for a full stratigraphic understanding is the absence of clear biostratigraphic control in such quartz sand. The limited data on the palynology of the lignitic horizons, as reviewed by Louwye et al. (2020), show a top Pliocene age for the upper part of the Mol Formation and support a correlation with at least parts of the Merksplas and Kieseloolite Formations.

Louwye et al. (2020) have proposed a correlation of the Mol Formation with the Kieseloolite Formation based on limited dinoflagellate data, palynology and heavy minerals. Based on dinoflagellates, the Retie Member is considered upper Miocene and can be correlated with at least parts of other upper Miocene deposits like the Waubach Member of the Kieseloolite Formation in the RVG and the Hauptkies in the Lower Rhine area. The palynology of the Brunssum I Bed and about 20 m of the overlying sediment in the Maaseik (049W0220) borehole allows to correlate the top part of the Kieseloolite Formation in the RVG with the Maat Lignite Bed in the Mol Formation. Consequently the Brunssum II Bed and the Pey Bed Sand below the Brunssum I Bed could be related to the Donk Member, the middle part of the Mol Formation.

In the H30-report (Vernes et al., 2018, annex D 7. Kiezeloöliet Formation / Onderverdeling) it is reported that the Kieseloolite Formation correlates with the Donk Member of the Mol Formation, while the Maatheide Member correlates with the Stramproy Formation. Taking into account the position of the Maat Lignite Bed between both parts of the Mol Formation and the palynological correlation of it with the Brunssum clay beds of the Kieseloolite Formation, this proposed correlation is reasonable. However the lower part of the Kieseloolite Formation, the Waubach Member, could be older than the Donk Member as discussed above and (partly) correlate with the Retie Member. It is expected that in the Belgian Campine a hiatus may occur below the Mol Formation (see e.g. Vandenberghe & Louwye, 2020 , figs. 3 & 4).

The Retie Member is a particular case. Lithologically it is related to the quartz-enriched sand of the Mol Formation. However geometry, CPT logs and the albeit limited biostratigraphic data suggest that sedimentologically the Retie Member is a lateral facies evolution of the Kasterlee Formation; therefore the member is also discussed in the Kasterlee Formation thereby honouring the tradition of borehole interpretation by the Geological Survey of Belgium (Vandenberghe et al.,2020)-. Data on the informal ‘level 3 clay’ bed at the top of the Retie Member and the informal ‘level 1-2 sand’ unit are very limited and tentative suggestions for correlation with the RVG stratigraphy are presented by Louwye and Vandenberghe (2020).

45.8 Age

Based on dinoflagellate cyst stratigraphy the newly defined oldest lithostratigraphic unit of the Mol Formation, the Retie Member, was formed during the end Miocene (Messinian); the age of the overlying informal Level 3 bed is uncertain and the main part of the Mol Formation (Donk Member, Maat Lignite Bed and Maatheide Member) is Piacenzian and probably already later Zanclean in the Limburg Campine area. Palynology situates the Maat Lignite Bed and also the former Russendorp lignite in the top of the formation in the later parts of the Reuver local stage. In the Antwerp Campine area the Plio-Pleistocene boundary becomes uncertain.

45.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
MHL 03/01 Stevensvennen	032W0460	GEO-03/071-B2	https://collections.naturalsciences.be/ssh-geology-archives/arch/032w/032w0460.txt	https://www.dov.vlaanderen.be/data/boring/2016-133443
SCK 13/Postel2 borehole	032W0415	kb17d32w-B385	https://collections.naturalsciences.be/ssh-geology-archives/arch/032w/032w0415.txt	https://www.dov.vlaanderen.be/data/boring/1982-022507
ON-Retie-2	031W0375	ON-Retie-2	https://collections.naturalsciences.be/ssh-geology-archives/arch/031w/031w0375.txt	https://www.dov.vlaanderen.be/data/boring/2008-160132
Rees borehole	017E0399	kb8d17e-B495	https://collections.naturalsciences.be/ssh-geology-archives/arch/017e/017e0399.txt	https://www.dov.vlaanderen.be/data/boring/1998-083222

45.10 References

Buffel, P., Vandenberghe, N., Goolaerts, S. & Laga, P., 2001. The Pliocene in four boreholes in the Turnhout area (North-Belgium): the relation with the Lillo and Mol Formations. Aardkundige Mededelingen 11, 1–9.

Buffel, Ph., Van Barel, L. & Gullentops, F., 2002. Geologische kaart van België, Vlaams Gewest: Turnhout - Meerle, kaartblad 8 - 2. 1/50 000. Belgische Geologische Dienst en Afdeling Natuurlijke Rijkdommen en Energie, Brussel.

Gulinck, M., 1962. Essai d'une carte géologique de la Campine. Etat de nos connaissances sur la nature des terrains néogènes recoupés par sondages. Mémoires de la Société belge de Géologie, de Paléontologie et d'Hydrologie, série in-8°, 6, 30–39.

Gullentops, F. & Vandenberghe, N., 1995a. Toelichtingen bij de geologische kaart van België, Vlaams Gewest: kaartblad 17, Mol [1/50 000]. Belgische Geologische Dienst en Ministerie van de Vlaamse Gemeenschap, Afdeling Natuurlijke Rijkdommen en Energie, Brussel, 65 p.

Gullentops, F. & Vandenberghe, N. , 1995b. Geologische kaart van België, Vlaams Gewest: Mol, kaartblad 17. 1/50 000. Belgische Geologische Dienst en Afdeling Natuurlijke Rijkdommen en Energie, Brussel.

Laga, P., 1976. Geologische Doorsneden. Archieven Belgische Geologische Diensthttp://collections.naturalsciences.be/ssh-geology/geology/profiles-neogeen2020, accessed 24/05/2021.

Laga, P., Louwye, S. & Geets, S., 2001. Paleogene and Neogene lithostratigraphic units (Belgium). In Bultynck, P. & Dejonghe, L., (eds), Guide to a revised lithostratigraphic scale of Belgium. Geologica Belgica, 4/1-2, 135–152. https://doi.org/10.20341/gb.2014.050

Louwye, S. & Vandenberghe, N., 2020. A reappraisal of the stratigraphy of the upper Miocene unit X in the Maaseik core, eastern Campine area (northern Belgium). Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 289-295 URL : https://popups.uliege.be/1374-8505/index.php?id=6680.

Louwye, S. , Deckers, J. & Vandenberghe, N. , 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 297-313 URL : https://popups.uliege.be/1374-8505/index.php?id=6841.

Sels, O., Claes, S. & Gullentops, F., 1999. Geologische kaart van België, Vlaams Gewest: Maaseik - Beverbeek, kaartblad 18 - 10. 1/50 000.

Vandenberghe, N. & Louwye, S., 2020. «An introduction to the Neogene stratigraphy of northern Belgium: present status», Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 97-112 URL : https://popups.uliege.be/1374-8505/index.php?id=6843.

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, H. Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 265-287 URL : . https://popups.uliege.be/1374-8505/index.php?id=6530

Vernes, R.W., Deckers, J., Bakker, M.A.J., Bogemans, F., De Ceukelaire, M., Doornenbal, J.C., den Dulk, M., Dusar, M., Van Haren, T.F.M., Heyvaert, V.M.A., Kiden, P., Kruisselbrink, A.F., Lanckacker, T., Menkovic, A., Meyvis, B., Munsterman, D.K., Reindersma, R., Rombaut, B., ten Veen, J.H., van de Ven, T.J.M., Walstra, J. & Witmans, N., 2018. Geologisch en hydrogeologisch 3D model van het Cenozoïcum van de Belgisch-Nederlandse grensstreek van Midden-Brabant / De Kempen (H3O – De Kempen). TNO-rapport TNO 2017 R11261 – VITO 2017/RMA/R/1348, 109 p.

46 Retie Member (Mol Formation)

Unit name: Retie Member

Hierarchical unit name: Mol Formation

Type: Member

Code: MlRt

Author(s):

- Compiled by: Vandenberghe Noël, Verhaegen Jasper, Berwouts Isaac, Vos Koen

Alternative names: 'lower Mol' or 'Kasterlee-sensu-Gulinck' unit / including Dorperberg sand as discussed in Vandenberghe et al. (2020)

Origine of the name: -

Status: Formal

Date: 01/05/2022

How to refer: Vandenberghe, N., Verhaegen, J., Berwouts, I. & Vos, K., 2023. The Retie Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Retie-Member

46.1 Characterizing description

The Retie Member is a fine-grained pale grey sand unit, with a median grain size around 180 µm and only trace amounts of dispersed glauconite pellets, that occurs underneath the Donk Sand Member of the Mol Formation.

At the top of the Retie Member drilling mud is reported to start colouring slightly green, obviously on the condition that at the start clear water is used to make up the drilling fluid. By colour, the Retie Member can hardly be distinguished in boreholes from the overlying Donk Member. In the Retie-Geel-Kasterlee area only a notable size fraction >250 µm in the Donk Formation allows to detect the boundary between both members. Eastwards, in the Mol-Dessel area the grain size of the the Donk Member becomes coarser and the boundary with the underlying Retie Member is clear (Vandenberghe et al., 2020, fig.2). In the Poppel-Rauw Fault area and eastwards of it, a relatively thin but marked high gamma-ray clayey bed occurs on top of the Retie Member sand that is named informally the 'level 3 clay' bed and on top of which the drilling mud starts to become green.

Below the Retie Member occurs the much more clayey Heist-op-den-Berg Member of the Kasterlee Formation in the Retie-Geel-Kasterlee-Dessel area and the boundary is marked by a clear gamma-ray signal increase in the top of the Heist-op-den-Berg Member. In the Poppel-Rauw Fault area and eastwards of it, occurs a slightly coarser unit, the informal 'level 1-2 sand' of the Mol Formation. The top of the latter is indicated by the start of a trend in gamma-ray and resistivity signals whereas in the Retie Member these signals are stable. Although the few grain-size data available in the top of the 'level 1-2 sand' suggest a coarser grain size compared to the Retie Member, the gamma ray signal of the 'level 1-2 sand' unit is higher (Vandenberghe et al. , 2020) requiring further data.

46.2 Type section, type locality, type borehole, or type geophysical borehole

The reference for the Retie Member is the section between 8 and 19,5 m in the ONDRAF-NIRAS ON-Retie-2 (031W0375) borehole, of which also geophysical data , sediment analyses and a CPT log are available (Vandenberghe et al., 2020). For the Retie Member occurring east of Kasterlee, gamma-ray logs are interpreted (ON-Retie-1; ON-Dessel-3; ON-Dessel-4; ON-Mol-2B).

An additional reference geophysical expression on the gamma-ray log of the Retie Member together with the informal 'level 3 clay bed' above it and the informal 'level 1-2 sand ' unit below it is the Postel SCK 13 borehole (032W0415 / kb17d32w-B385) between 69 and 92 m depth.

46.3 Description upper boundary

The upper boundary in the Kasterlee-Retie-Mol-Dessel area is the appearance of a notable >250 µm size fraction above it, or a notably increased >250 µm fraction above it in the Poppel-Rauw Fault area and eastwards of it.

In the Poppel-Rauw Fault area and eastwards of it, a relatively thin but marked high gamma-ray clayey bed occurs on top of the Retie Member sand that is informally named the 'level 3 clay' bed.

46.4 Description lower boundary

In the area between Kasterlee and Mol-Dessel the lower boundary is clearly marked by an increased gamma-ray signal at the top of the clayey Heist-op-den-Berg Member of the Kasterlee Formation. In the Poppel-Rauw Fault zone and eastwards of it the lower boundary of the Retie Member is marked by the start of a downwards increasing gamma ray signal of the 'level 1-2 sand' whereas in the Retie Member itself the gamma ray signal is more stable. In the Postel SCK 13 borehole (032W0415 / kb17d32w-B385) interpretation in Vandenberghe et al. (2020), the lower boundary of the Retie Member at level 2 occurs at 92 m depth.

46.5 Thickness

Between Kasterlee and Mol-Dessel the thickness varies between 7 and 22 m and from the Poppel-Rauw Fault zone and eastwards of it, the thickness is about 25 m.

46.6 Occurrence

The Retie Member occurs from the east of Kasterlee until the Reppel Fault in the east, across which the Kieseloolite Formation occurs (Buffel et al., 2001).

It is assumed that the 'Kasterliaan' as described in the Hechtel (kb17d47e-B186; 047E0192), Wijshagen (kb18d48w-B181; 48W 180), Helchteren (kb25d62e-B265; 62E 261) boreholes in the Archives of the Belgian Geological survey, as well as the so called Dorperberg sand in the Opitter Molen (GSB048e0151C) outcrop (geological map 26 Rekem) also belong to the Retie Member as discussed in Vandenberghe et al. (2020).

46.7 Regional correlations

Lithologically the Retie Member is related to the quartz-enriched sand of the Mol Formation and therefore it is ranked as member of the Mol Formation. At the same time geometry , CPT continuity with the type area Kasterlee Formation, and the albeit limited biostratigraphic data suggest that sedimentologically the Retie Member developed as a lateral facies of the Kasterlee Formation. In fact in the former tradition of borehole interpretation by the Geological Survey of Belgium, this unit was integrated within the Kasterlee Formation. This ambiguity was expressed in the provisional name 'lower Mol' or 'Kasterlee-sensu-Gulinck' unit used by Vandenberghe et al. (2020) in their analysis of this unit.

It is beyond doubt that the description 'in the type region, lower part very slightly glauconiferous' in the definition of the Mol Formation by Laga et al. (2001) is referring to the sand of what is now called the Retie

Member. It is also this type of sand that is at the origin of the 'Mol inférieur' term, never precisely defined but used in borehole descriptions in the Archives of the Geological Survey of Belgium.

46.8 Age

It is suggested that chronostratigraphically the Retie Member occurs in the same time interval as the Lichtaart Member of the Kasterlee Formation but that lithostratigraphically it fits in the younger Mol Formation due to the westward migration of the continental over the marine facies during the Neogene (Louwye et al., 2020). See also LIS file Mol Formation for information on the age of this member.

46.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
SCK 13/Postel2 borehole	032W0415	kb17d32w-B385	https://collections.naturalsciences.be/ssh-geology-archives/arch/032w/032w0415.txt	https://www.dov.vlaanderen.be/data/boring/1982-022507
ON-Retie-2	031W0375	ON-Retie-2	https://collections.naturalsciences.be/ssh-geology-archives/arch/031w/031w0375.txt	https://www.dov.vlaanderen.be/data/boring/2008-160132
ON-Retie-1	031w0362	ON-Retie-1	https://collections.naturalsciences.be/ssh-geology-archives/arch/031w/031w0362.txt	https://www.dov.vlaanderen.be/data/boring/2008-157939
ON-Dessel-3	031W0354	ON-Dessel-3	https://collections.naturalsciences.be/ssh-geology-archives/arch/031w/031w0354.txt	https://www.dov.vlaanderen.be/data/boring/2008-162468
ON-Dessel-4	031W0353/0376	ON-Dessel-4	https://collections.naturalsciences.be/ssh-geology-archives/arch/031w/031w0376.txt and 0376.txt	https://www.dov.vlaanderen.be/data/boring/2008-160128
ON-Mol-2B	031E0440	ON-Mol-2B	https://collections.naturalsciences.be/ssh-geology-archives/arch/031e/031e0440.txt	https://www.dov.vlaanderen.be/data/boring/2014-160122

46.10 References

Buffel, P., Claes, S. & Gullentops, F., 2001. Toelichtingen bij de geologische kaart van België, Vlaams Gewest: kaartblad 26, Rekem [1/50 000]. Belgische Geologische Dienst en Ministerie van de Vlaamse Gemeenschap, Afdeling Natuurlijke Rijkdommen en Energie, Brussel, 56 p.

Laga, P., Louwye, S. & Geets, S., 2001. Paleogene and Neogene lithostratigraphic units (Belgium). In Bultynck, P. & Dejonghe, L., (eds), Guide to a revised lithostratigraphic scale of Belgium. Geologica Belgica, 4/1-2, 135–152. https://doi.org/10.20341/ gb.2014.050

Louwye, S. , Deckers, J. & Vandenberghe, N. , 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 297-313 URL : https://popups.uliege.be/1374-8505/index.php?id=6841.

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, H. Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 265-287 URL : . https://popups.uliege.be/1374-8505/index.php?id=6530.

47 Donk Member (Mol Formation)

Unit name: Donk Member

Hierarchical unit name: Mol Formation

Type: Member

Code: MlDo

Author(s):

- Compiled by: Vandenberghe Noël, Berwouts Isaac, Vos Koen

Alternative names: -

Origin of the name: -

Status: Formal

Date: 01/05/2022

How to refer: Vandenberghe, N., Berwouts, I. & Vos, K., 2023. The Donk Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Donk-Member

47.1 Characterizing description

The Maat lignite Bed subdivides the Mol Formation into a Donk Member below the lignite and a Maatheide Member above the bed.

Both sand units are pale grey to white quartz sand with an exceptionally high quartz content. The Donk Sand Member is finer grained than the Maatheide Sand Member; the latter has a modal size generally above 250 µm (Gullentops & Vandenberghe, 1995). However the Donk Sand Member close to the Mol Rauw Fault in the Witgoor-Dessel area also has a median grain size well above 250 µm, whilst further west in the Retie-Geel-Kasterlee area its median size is smaller than 200 µm (Vandenberghe et al., 2020). In the Poppel-Rauw fault zone and eastwards of it the Donk Sand Member contains a substantial 250-355 µm size fraction. Compared to the underlying Retie Member, the Donk Member is characterized by a fraction > 250 µm; in addition during drilling the borehole mud starts to take an olive-green hue at the top of the Retie Member. Some rare thin clay laminae are reported in boreholes, as are some quartz and quartzite gravels at the base (Gullentops and Vandenberghe, 1995). No macrofossils are present.

47.2 Type section, type locality, type borehole, or type geophysical borehole

The area west of the Poppel-Rauw Fault as figured in a series of boreholes in Vandenberghe et al. (2020, fig. 2) is a reference area for the Donk Member. In particular the boreholes in the Dessel area are considered as reference: ON-Dessel-2 (031W0338/kb17d31w-B299), ON-Dessel-3 (031W0354) & ON-Dessel-4 (031W0353/0376). These boreholes by ONDRAF-NIRAS have cores, sediment and mineral analyses, CPT logs and resistivity and gamma-ray logs (references in Vandenberghe et al., 2020 and Schiltz , 2020). In the area of the Poppel-Rauw Fault zone and eastward of it, the Donk Member is observed only in the subsurface below the Maat lignite Bed as figured in the boreholes in fig. 5 in Vandenberghe et al. (2020).

47.3 Description upper boundary:

In the Antwerp province type area, diverse pale coloured quartz-enriched sand Quaternary deposits occur above the Donk Member; they have higher chroma colours compared to the Donk Member and are admixed with loam or organics; also base gravel may be present. The base of the Quaternary varies between 2,5 and 5 m depth. In the Poppel-Rauw Fault zone the Donk Member occurs below the Maat Lignite Bed.

47.4 Description lower boundary

In the Kasterlee-Mol-Dessel area west of the Poppel-Rauw Fault zone, the contact with underlying Retie Member in the reference boreholes occurs at 8 m depth in ON-Dessel-2, at 13,6 m in ON-Dessel-3 and at 14 m depth in ON-Dessel-4. The Donk Sand Member is differentiated from the Retie Member by the presence of a > 250 µm fraction in the former. In the area east of the Rauw Fault a clay bed (the informal level 3 clay bed) is present below the Donk Member and above the Retie Member as observed in the boreholes Stevensvennen MHL 03/01 (032W0460; GEO-03/071-B2) and SCK3/Postel 2 (032W/0415;kb17d32w-B385). Gravel can occur in the basal part of the Donk Member.

47.5 Thickness

In the Kasterlee-Mol-Dessel area west of the Poppel-Rauw Fault zone, the thickness of the Donk Member is between 5 and 10 m. The Donk (SIB-DON-02-03) and Pinken (SIB-PIN-03-03) sand pits closer to the Poppel-Rauw Fault zone show a marked increase in the Donk Member thickness up to 24 m. From this fault zone eastwards the Donk Member is about 25 m thick.

47.6 Occurrence

The Maat lignite Bed, subdividing the Donk Member below from the Maatheide Member above, is outcropping along the Campine Canal in the Poppel-Rauw Fault zone west of Rauw 1 Fault (Geological map 17 Mol, Gullentops & Vandenberghe (1995)). The faults are normal faults bordering the extent of the lignite and down dropping it at their eastern side. Therefore the Donk Member occurs near surface directly underlying the Quaternary only west of the Rauw 1 Fault. In the subsurface to the north in the Antwerp province the Mol Formation the distinction with the Brasschaat Formation is not obvious (Laga, 1976 –profile PGL76/106/3) and geometrically the formation seems to transition into the relatively coarse Merksplas Formation (Laga, 1976 – profiles 76/106/2 and 75/104/1) [see also Lithostratigraphic Identification sheets of the Merksplas Formation (Note: in the Neogene Volume Louwye et al. (2020) and Vandenberghe and Louwye (2020) have named the Pliocene quartz sand in the west the Merksplas Formation and not Brasschaat Member as this name is reserved in the NCS for Pleistocene fine-sized sand.).

East of the Rauw -1 Fault the Donk Member occurs in the subsurface below the Maatheide Member and Maat Lignite Bed. On the geological maps, the Mol Formation, including the Donk Member, is conventionally limited in the east by the major Roer Valley Graben (RVG) western boundary fault of Reppel to the east of which occurs the quartz sand of the Kieseloolite Formation.

47.7 Regional correlations

In the absence of solid biostratigraphic data , geometrical considerations alone allow to suggest a possible correlation with part of the Kieseloolite Formation in the RVG, the Rees Facies and the Merksplas Formation in the west (Louwye & Vandenberghe, 2020, fig. 3.

Gullentops and Vandenberghe (1995) have reported at the base of the Donk Member, the occurrence of a quartz gravel of the same type as the Hukkelberg gravel bed at the base of the Poederlee Member.

47.8 Age

See LIS file Mol Formation for information on the age of this member.

47.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
MHL 03/01 Stevensvennen	032W0460	GEO-03/071-B2	https://collections.naturalsciences.be/ssh-geology-archives/arch/032w/032w0460.txt	https://www.dov.vlaanderen.be/data/boring/2016-133443
SCK 13/Postel2 borehole	032W0415	kb17d32w-B385	https://collections.naturalsciences.be/ssh-geology-archives/arch/032w/032w0415.txt	https://www.dov.vlaanderen.be/data/boring/1982-022507
ON-Dessel-2	031W0338	kb17d31w-B299	https://collections.naturalsciences.be/ssh-geology-archives/arch/031w/031w0338.txt	https://www.dov.vlaanderen.be/data/boring/2002-096456
ON-Dessel-3	031W0354	ON-Dessel-3	https://collections.naturalsciences.be/ssh-geology-archives/arch/031w/031w0354.txt	https://www.dov.vlaanderen.be/data/boring/2008-162468
ON-Dessel-4	031W0353/0376	ON-Dessel-4	https://collections.naturalsciences.be/ssh-geology-archives/arch/031w/031w0376.txt and 0376.txt	https://www.dov.vlaanderen.be/data/boring/2008-160128
Donk pit borehole	-	SIB-DON-02-03	-	https://www.dov.vlaanderen.be/data/boring/2019-162348
Pink pit borehole	-	SIB-PIN-03-03	-	https://www.dov.vlaanderen.be/data/boring/2019-162349

47.10 References

Gullentops, F. & Vandenberghe, N. , 1995. Geologische kaart van België, Vlaams Gewest: Mol, kaartblad 17. 1/50 000. Belgische Geologische Dienst en Afdeling Natuurlijke Rijkdommen en Energie, Brussel.

Laga, P., 1976. Geologische Doorsneden. Archieven Belgische Geologische Dienst. http://collections.naturalsciences.be/ssh-geology/geology/profiles-neogeen2020, accessed 02/12/2020.

Louwye, S. , Deckers, J. & Vandenberghe, N. , 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 297-313 URL : https://popups.uliege.be/1374-8505/index.php?id=6841.

Louwye, S. & Vandenberghe, N., 2020. A reappraisal of the stratigraphy of the upper Miocene unit X in the Maaseik core, eastern Campine area (northern Belgium). Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 289-295 URL : https://popups.uliege.be/1374-8505/index.php?id=6680.

Schiltz, M., 2020. On the use of CPTs in stratigraphy: recent observations and some illustrative cases. Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 399-411 URL : https://popups.uliege.be/1374-8505/index.php?id=6668.

Vandenberghe, N. & Louwye, S., 2020. «An introduction to the Neogene stratigraphy of northern Belgium: present status», Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 97-112 URL : https://popups.uliege.be/1374-8505/index.php?id=6843.

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, H. Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 265-287 URL : . https://popups.uliege.be/1374-8505/index.php?id=6530

48 Maat Lignite Bed (Mol Formation)

Unit name: Maat Lignite Bed

Hierarchical unit name: Mol Formation

Type: Bed

Code: MlMa

Author(s):

- Compiled by: Vandenberghe Noël, Berwouts Isaac, Vos Koen

Alternative names:

Origine of the name: -

Status: Formal

Date: 01/05/2022

How to refer: Vandenberghe, N., Berwouts, I. & Vos, K., 2023. The Maat Lignite Bed, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Maat-Lignite-Bed

48.1 Characterizing description

The Maat Lignite Bed is a black lignite layer enriched in clay and of limited thickness. Original observations were made in former extraction sites of the lignite that was used as heating resource in the Mol area, and also in the now no longer exploited De Maat sand pit where the bed was 1-2,5 m thick. Wood fragments were stacked in the lignite bed and flattened tree stems of several meter length occurred in it (Gullentops and Vandenberghe, 1995a).

In the subsurface, the bed was mapped within the Mol sand by Gulinck (1962, fig.3). In geophysical borehole logs the bed is well expressed by an elevated gamma-ray signal.

The Maat Lignite Bed was chosen to subdivide within the Mol Formation the Maatheide Member above it and the Donk Member below it (Gullentops and Vandenberghe, 1995a).

48.2 Type section, type locality, type borehole, or type geophysical borehole

At present no outcrop of the Maat Lignite Bed is accessible. Therefore a reference is selected in the geophysically logged and cored borehole Stevensvennen MHL 03/01 (032W0460; GEO-3/071-B2) between 22,5 and 25,5 m in which the lithologies in the interval are described as brown sandy clay, lignitic clay, lignite, sandy clay (Vandenberghe et al., 2020).

48.3 Description upper boundary

The lignite bed is overlain by pale grey Maatheide Member.

48.4 Description lower boundary

The lignite bed is underlain by pale grey Donk Member.

48.5 Thickness

Reported thickness varies between 1 and 3 m.

48.6 Occurrence

At the surface, the Maat Lignite Bed occurs in the Poppel-Rauw Fault zone along both sides of the Campine Canal (Gullentops and Vandenberghe, 1995b). To the east of this fault zone the Maat Lignite Bed occurs in the subsurface till the Reppel Fault across which by convention the Kieseloolite Formation occurs.

48.7 Regional correlation

Geometrically the Maat Lignite Bed is related to the Kieseloolite Formation. The study of the palynomorphs in the Maaseik borehole (049W0220/ kb18d49w-B220) distinguishes in the upper part of a palynozone A, between 88–58 m depth, an association that also occurs in the lignite of the Mol Formation (Vanhoorne in Vandenberghe et al., 2005). In the Maaseik borehole this interval corresponds to the upper Brunssum clay and the lower part of the Jagersborg Sand (Vanhoorne 1973).

48.8 Age

See LIS file Mol Formation for information on the age of this bed.

48.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
MHL 03/01 Stevensvennen	032W0460	GEO-03/071-B2	https://collections.naturalsciences.be/ssh-geology-archives/arch/032w/032w0460.txt	https://www.dov.vlaanderen.be/data/boring/2016-133443
Maaseik borehole	049W0220	kb18d49w-B220	https://collections.naturalsciences.be/ssh-geology-archives/arch/049w/049w0220.txt	https://www.dov.vlaanderen.be/data/boring/1980-025921

48.10 References

Gulinck, M., 1962. Essai d'une carte géologique de la Campine. Etat de nos connaissances sur la nature des terrains néogènes recoupés par sondages. Mémoires de la Société belge de Géologie, de Paléontologie et d'Hydrologie, série in-8°, 6, 30–39.

Gullentops, F. & Vandenberghe, N., 1995a. Toelichtingen bij de geologische kaart van België, Vlaams Gewest: kaartblad 17, Mol [1/50 000]. Belgische Geologische Dienst en Ministerie van de Vlaamse Gemeenschap, Afdeling Natuurlijke Rijkdommen en Energie, Brussel, 65 p.

Gullentops, F. & Vandenberghe, N., 1995b. Geologische kaart van België, Vlaams Gewest: Mol, kaartblad 17. 1/50 000. Belgische Geologische Dienst en Afdeling Natuurlijke Rijkdommen en Energie, Brussel.

Louwye, S. , Deckers, J. & Vandenberghe, N. , 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 297-313 URL : https://popups.uliege.be/1374-8505/index.php?id=6841.

Vandenberghe, N., Laga, P., Louwye, S., Vanhoorne, R., Marquet, R., De Meuter F. & Wouters, K., Hagemann, H.W., 2005. Stratigraphic interpretation of the Neogene marine-continental record in the Maaseik well (49W0220) in the Roer valley Graben, NE Belgium. Memoirs of the Geological Survey of Belgium, 52, 39 p.

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, H. Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 265-287 URL : . https://popups.uliege.be/1374-8505/index.php?id=6530

Vanhoorne, R., 1973. The continental Pleistocene in Belgium. Proceedings of the III International palynological conference. Academy of Sciences of the USSR, Institute of Geography, Nauka, Moscow, 175–178.

49 Maatheide Member (Mol Formation)

Unit name: Maatheide Member

Hierarchical unit name: Mol Formation

Type: Member

Code: MlMh

Author(s):

- Compiled by: Vandenberghe Noël, Berwouts Isaac, Vos Koen

Alternative names: -

Origin of the name: -

Status: Formal

Date: 01/05/2022

How to refer: Vandenberghe, N., Berwouts, I. & Vos, K., 2023. The Maatheide Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Maatheide-Member

49.1 Characterizing description

The Maat Lignite Bed subdivides the Mol Formation into a Donk Member below the lignite and a Maatheide Member above the bed.

Both sand units are pale grey to white quartz sand with an exceptionally high quartz content. The Maatheide Sand Member can occasionally be stained dark due to finely dispersed lignite. The Maatheide Member has a modal size generally above 250 µm in contrast with the underlying Donk Member which is somewhat finer grained (Gullentops & Vandenberghe, 1995). The Maatheide Member has a substantial size fraction 250 to 355 µm. It can contain some clayey-lignitic horizons such as the Russendorp lignite mapped on the Geological Map 17 Mol, west of the Reusel Fault and north of the Campine Canal (Russendorp sand pit). No macrofossils are present.

49.2 Type section, type locality, type borehole, or type geophysical borehole

The 2 close to each other boreholes RUS 04/03 between 5 and 39 m and SCK3/Postel 2 (032W/0415;kb17d32w-B385) between 2 and 39 m depth, can be considered as reference boreholes for the Maatheide Member. RUS 04/03 is a continuously sampled pulsed borehole and has in addition gamma ray and resistivity logs and sediment analyses (Vandenberghe et al., 2020).

Also in the Stevensvennen MHL03/01 (032W0460/GEO-03/071-B2) borehole the Maatheide Member section between 3,5 and 22,5 m is documented by geophysical well logs, cores and sediment analyses.

49.3 Description upper boundary

The upper boundary is made up by the base of the Quaternary deposits.

49.4 Description lower boundary

The lower boundary is always at the top of the Maat Lignite Bed.

49.5 Thickness

Obviously the thickness depends on the depth of the Maat Lignite Bed, down warped by the normal faults. The thickness measured in the study by Vandenberghe et al. (2020) varies between 19 and 37 m.

49.6 Occurrence

The Maatheide Member occurs east of the Rauw -1 Fault above the down warped Maat lignite Bed. On the geological maps, the Mol Formation, including the Maatheide Member, is conventionally limited in the east by the major Roer Valley Graben (RVG) western boundary fault of Reppel to the east of which occurs the quartz sand of the Kieseloolite Formation.

49.7 Regional correlations

Only geometrical considerations suggest a possible correlation with part of the Kieseloolite Formation in the RVG, and possibly with the Merksplas Formation in the west (Louwye et al., 2020 fig. 5).

A limiting condition for correlations is the palynology of the underlying Maat Lignite Bed situating it in the late Pliocene (Reuverian) based on analyses by Vanhoorne (1962).

49.8 Age

See LIS file Mol Formation for information on the age of this member.

49.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
MHL 03/01 Stevensvennen	032W0460	GEO-03/071-B2	https://collections.naturalsciences.be/ssh-geology-archives/arch/032w/032w0460.txt	https://www.dov.vlaanderen.be/data/boring/2016-133443
SCK 13/Postel2 borehole	032W0415	kb17d32w-B385	https://collections.naturalsciences.be/ssh-geology-archives/arch/032w/032w0415.txt	https://www.dov.vlaanderen.be/data/boring/1982-022507
RUS 04/03	-	RUS04/03	-	https://www.dov.vlaanderen.be/data/boring/2018-158885

49.10 References

Gullentops, F. & Vandenberghe, N. , 1995. Geologische kaart van België, Vlaams Gewest: Mol, kaartblad 17. 1/50 000. Belgische Geologische Dienst en Afdeling Natuurlijke Rijkdommen en Energie, Brussel.

Louwye, S. , Deckers, J. & Vandenberghe, N. , 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 297-313 URL : https://popups.uliege.be/1374-8505/index.php?id=6841.

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, H. Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 265-287 URL : . https://popups.uliege.be/1374-8505/index.php?id=6530

Vanhoorne, R., 1962. La superposition des Sables de Mol et des Argiles de Campine. Mémoires de la Société belge de Géologie, de Paléontologie et d'Hydrologie, série in-8°, 6, 83–95.

50 informal level 1-2 sand unit (Mol Formation)

Unit name: informal level 1-2 sand unit

Hierarchical unit name: Mol Formation

Type: informal unit

Code: -

Author(s):

- Compiled by: Vandenberghe Noël, Berwouts Isaac, Vos Koen

Alternative names: -

Origine of the name: -

Status: Informal

Date: 01/05/2022

How to refer: Vandenberghe, N., Berwouts, I. & Vos, K., 2023. The informal level 1-2 sand unit, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/informal-level-1-2-sand-unit

50.1 Characterizing description

In the Poppel-Mol Rauw Fault zone and east of it a coarsening downwards interval is observed below or in the base of (?) the fine-grained Retie Member. It is situated between the levels 1-2 in Vandenberghe et al. (2020) and therefore labelled informally as 'level 1-2 sand unit' (see also Kasterlee Formation Lithostratigraphic Information Sheet).

Limited sediment information from the top of the unit in the boreholes ZEH08/05 and RUS04/03 shows this informal unit is sand, has the same colour as the Retie Member and is slightly coarser than the Retie Member. However the downwards increasing gamma-ray together with a decreasing resistivity signal as observed in the SCK13/Postel2 (032W0415 / kb17d32w-B385) logically would suggest a fining downwards.

50.2 Type section, type locality, type borehole, or type geophysical borehole

The Postel SCK 13 borehole (032W0415 / kb17d32w-B385) is suggested as a reference for the informally named 'level 1-2 sand' unit between 92 and 107 m.

50.3 Description upper boundary

The upper boundary is defined where the trend in gamma-ray signal starts to increase below the stable signal in the overlying Retie Member.

50.4 Description lower boundary

The lower boundary is defined by the sharp increase of the gamma ray signal at the top of the clayey Heist-op-den-Berg Member of the Kasterlee Formation.

50.5 Thickness

The thickness is about 15 m in the Postel SCK 13 borehole (032W0415 / kb17d32w-B385).

50.6 Occurrence

The informal 'level 1-2 sand unit' occurs in the subsurface of Poppel-Mol Rauw Fault zone and east of it; it is limited in the east by the Reppel Fault east of which occurs the Kieseloolite Formation.

50.7 Regional correlations

The informally 'level 1-2 sand unit' occurs between the Retie Member and the Heist-op-den-Berg Member.

50.8 Age

See LIS file Mol Formation for information on the age of the Mol Formation units.

50.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection , including links to the GSB-collection data sheets.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
SCK 13/Postel2 borehole	032W0415	kb17d32w-B385	https://collections.naturalsciences.be/ssh-geology-archives/arch/032w/032w0415.txt	https://www.dov.vlaanderen.be/data/boring/1982-022507
ZEH08/05	-	ZEH08/05	-	https://www.dov.vlaanderen.be/data/boring/2018-158884
RUS 04/03	-	RUS04/03	-	https://www.dov.vlaanderen.be/data/boring/2018-158885

50.10 References

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, H. Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 265-287 URL : . https://popups.uliege.be/1374-8505/index.php?id=6530

51 informal level 3 clay bed (Mol Formation)

Unit name: informal level 3 clay bed

Hierarchical unit name: Mol Formation

Type: bed

Code: -

Author(s):

- Compiled by: Vandenberghe Noël, Berwouts Isaac, Vos Koen

Alternative names:

Origine of the name: -

Status: Informal

Date: 01/05/2022

How to refer: Vandenberghe, N., Berwouts, I. & Vos, K., 2023. The informal level 3 clay bed, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/informal-level-3-clay-bed

51.1 Characterizing description

East of the Mol Rauw Fault zone a high natural gamma-ray signal is observed on top of the Retie Member. A clayey and lignitic horizon is documented at that level in borehole Stevensvennen MHL O3/01 (032W0460/GEO-03/071-B2). It is proposed to provisionally and informally name this geophysically expressed horizon **'level 3 clay bed '** as in Vandenberghe et al. (2020). It was observed in boreholes ZEH08/05 and RUS 04/03 that the colour of the drilling mud turned green at the top of the level 3 clay bed.

51.2 Type section, type locality, type borehole, or type geophysical borehole:

A reference geophysical expression on the gamma-ray log for the informal 'level 3 clay bed' is the Postel SCK 13 borehole (032W0415 / kb17d32w-B385) between 62 and 69 m depth.

In borehole Stevensvennen MHL O3/01 (032W0460/GEO-03/071-B2) the gamma ray signal is increased between 51 and 52,5 m depth and sharply increased between 52,5 and 53,5 m. The borehole cores however show only a limited presence of dark stained clay in that interval.

51.3 Description upper boundary

The top of the gamma-ray signal increase can be sharp but not on all logs.

51.4 Description lower boundary

The base of the gamma-ray signal increase can be sharp but not on all logs.

51.5 Thickness (min/max. m)

The thickness, based on the geophycical gamma-ray logs, is 1 to 7 m.

51.6 Occurrence

Only observed in the subsurface in the Poppel-Rauw Fault zone and eastwards of it.

51.7 Regional correlations

Occurs under the Donk Sand Member and above or in the top of the Retie Member.

51.8 Age

See LIS file Mol Formation for information on the age of the Mol Formation units.

51.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
MHL 03/01 Stevensvennen	032W0460	GEO-03/071-B2	https://collections.naturalsciences.be/ssh-geology-archives/arch/032w/032w0460.txt	https://www.dov.vlaanderen.be/data/boring/2016-133443
SCK 13/Postel2 borehole	032W0415	kb17d32w-B385	https://collections.naturalsciences.be/ssh-geology-archives/arch/032w/032w0415.txt	https://www.dov.vlaanderen.be/data/boring/1982-022507
ZEH08/05	-	ZEH08/05	-	https://www.dov.vlaanderen.be/data/boring/2018-158884
RUS 04/03	-	RUS04/03	-	https://www.dov.vlaanderen.be/data/boring/2018-158885

51.10 References

Vandenberghe, N. & Louwye, S., 2020. «An introduction to the Neogene stratigraphy of northern Belgium: present status», Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 97-112 URL : https://popups.uliege.be/1374-8505/index.php?id=6843.

52 Mol inférieur / Mol supérieur (abanbonned, Mol Formation)

Unit name: Mol inférieur / Mol supérieur (both abandoned)

Hierarchical unit name: Mol Formation

Type: Abandoned part of the Mol Formation

Code: -

Author(s) :

- Compiled by: Vandenberghe Noël , Berwouts Isaac, Vos Koen

Alternative names:

Origine of the name: -

Status: Abandoned

Date: 01/05/2022

How to refer: Vandenberghe, N., Berwouts, I. & Vos, K., 2023. The Mol inférieur / Mol supérieur, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Mol-inferieur-Mol-superieur

52.1 Characterizing description

In the archives of the Geological Survey of Belgium several borehole descriptions have used a subdivision of the pale grey to white Mol Sand into Mol supérieur and inférieur. The term Mol inférieur was introduced to describe the lower part of the Mol Formation where it picked up some glauconite pellets and mica flakes thereby changing the colour from white to rather grey. The mention in the definition of the Mol Formation by Laga et al. (2001) 'in the type region, lower part very slightly glauconiferous', seems to justify the practice of using a distinction between Mol inférieur and supérieur.

This mention however follows exactly part of the description of the Sables de Mol by Gulinck (1962) where this author referred to a debatable sand unit in the Mol area below coarser Mol sand; the sand unit was soon interpreted by this author as the lateral extension of the Kasterlee sand (Gulinck,1963) and he continued to do so afterwards (Gulinck and Laga , 1975). This debatable sand unit has been discussed in Vandenberghe et al. (2020) and these authors better defined this sand unit below the coarser sand of the Mol Formation and provisionally named it the 'lower Mol' or 'Kasterlee-sensu-Gulinck' unit. It is now formally defined as the Retie Member.

At the base of the Donk Member and of the Retie Member, some reworked sand from the underlying units can be present, but the less than 2 m thickness at maximum of such reworked base certainly does not require a separate ranking.

The term Mol inférieur has never been precisely defined and neither was the boundary with the companion term, the so called Mol supérieur which undoubtedly largely corresponds to the sand of the Donk and/or Maatheide Members. In addition, the term Mol inférieur was confused with the Kasterlee Sand sensu-Gulinck.

Therefore the division Mol supérieur–inférieur is obsolete and the term Mol inférieur should not be used any longer.

52.2 Type section, type locality, type borehole, or type geophysical borehole

not existing

52.3 Description upper boundary

not defined

52.4 Description lower boundary

not defined

52.5 Thickness

not defined

52.6 Occurrence

not defined

52.7 Regional correlations

not defined

52.8 Age

See LIS file Mol Formation for information on the age of the Mol Formation units.

52.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

52.10 References

Gulinck, M., 1962. Essai d'une carte géologique de la Campine. Etat de nos connaissances sur la nature des terrains néogènes recoupés par sondages. Mémoires de la Société belge de Géologie, de Paléontologie et d'Hydrologie, série in-8°, 6, 30–39.

Gulinck, M. & Laga, P., 1975. Boring SCK te Mol 31W-237. Geologische beschrijving door de Belgische Geologische Dienst. Archieven Belgische Geologische Dienst. http://gisel.naturalsciences.be/data/text/031W/031W0237.txt, accessed 15/03/2020.

Gulinck, M., Geets, S. & Van Voorthuyzen, J.H., 1963. Note sur les sondages du centre Nucléaire à Mol. Bulletin de la Société belge de Géologie, de Paléontologie et d'Hydrologie, 72, 283–394.

Laga, P., Louwye, S. & Geets, S., 2001. Paleogene and Neogene lithostratigraphic units (Belgium). In Bultynck, P. & Dejonghe, L., (eds), Guide to a revised lithostratigraphic scale of Belgium. Geologica Belgica, 4/1-2, 135–152. https://doi.org/10.20341/gb.2014.050

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, H. Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 265-287 URL : . https://popups.uliege.be/1374-8505/index.php?id=6530

53 Russendorp lignite bed (abandoned, Mol Formation)

Unit name: Russendorp lignite bed (abandoned)

Hierarchical unit name: Mol Formation

Type: Abandoned as formal stratigraphic term for the bed

Code: -

Author(s) :

- Compiled by: Vandenberghe Noël , Berwouts Isaac, Vos Koen

Alternative names:

Origine of the name: -

Status: Abandoned

Date: 01/05/2022

How to refer: Vandenberghe, N., Berwouts, I. & Vos, K., 2023. Russendorp lignite bed, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Russendorp-lignite-bed

53.1 Characterizing description

A thin lignitic-peaty layer occurring above or in the upper part of the Maatheide Member.

53.2 Type section, type locality, type borehole, or type geophysical borehole

The Russendorp lignite bed was studied for palynology in the top of the former 'Maatheide Links'(MHL) sand pit and correlated with a lignitic-peaty layer just north of the Campine Canal in the Russendorp locality (Gullentops and Vandenberghe, 1995a). On the Geological map 17 Mol the outcrop of the Russendorp lignite bed is mapped in a small area west of the Reusel Fault (Gullentops and Vandenberghe, 1995b).

In recent interpretations of boreholes near and to the east of the Rauw Fault zone, the Russendorp lignite bed was tentatively indicated in the top of the Maatheide Member based on an elevated gamma-ray signal (Vandenberghe et al., 2020, fig.5). However experience in the area shows that the Russendorp lignite bed is just one of more lignitic-clayey streaks that can occur occasionally in the Maatheide Member and that no systematic correlation is possible. Therefore it was concluded to abandon the Russendorp lignite bed as a formal lithostratigraphic unit (Vandenberghe et al., 2020).

53.3 Description upper boundary

The lignite bed occurs in the top of the Maatheide Member.

53.4 Description lower boundary

The lignite bed occurs in the top of the Maatheide Member.

53.5 Thickness

At maximum 1 m thick , based on gamma-ray signal.

53.6 Occurrence

The outcrop of the Russendorp lignite bed is mapped west of the Reusel Fault on the Geological map 17 Mol (Gullentops and Vandenberghe, 1995b). It may occur within the upper part of the Maatheide Member to the east of the outcrop zone although, it is not certain that always the same lignitic-peaty horizon is involved.

53.7 Regional correlations

According to palynological analysis by Dricot (reported in Gullentops and Vandenberghe, 1995a), the vegetation was different from the vegetation in the Maat Lignite Bed occurring deeper in the Mol Formation, although the palynological stratigraphy is still late Pliocene Reuver as is the Maat Lignite Bed.

53.8 Age

See LIS file Mol Formation for information on the age of the Mol Formation units.

53.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

53.10 References

Gullentops, F. & Vandenberghe, N., 1995a. Toelichtingen bij de geologische kaart van België, Vlaams Gewest: kaartblad 17, Mol [1/50 000]. Belgische Geologische Dienst en Ministerie van de Vlaamse Gemeenschap, Afdeling Natuurlijke Rijkdommen en Energie, Brussel, 65 p.

Gullentops, F. & Vandenberghe, N., 1995b. Geologische kaart van België, Vlaams Gewest: Mol, kaartblad 17. 1/50 000. Belgische Geologische Dienst en Afdeling Natuurlijke Rijkdommen en Energie, Brussel.

Vandenberghe, N., Wouters, L., Schiltz, M., Beerten, K., Berwouts, I., Vos, K., Houthuys, H. Deckers, J., Louwye, S., Laga, P., Verhaegen, J., Adriaens, R. & Dusar, M., 2020. The Kasterlee Formation and its relation with the Diest and Mol Formations in the Belgian Campine. Geologica Belgica [En ligne], Volume 23, number 3-4 - The Neogene stratigraphy of northern Belgium, 265-287 URL : . https://popups.uliege.be/1374-8505/index.php?id=6530

54 Kattendijk Formation

Unit name: Kattendijk Formation

Hierarchical unit name: /

Type: Formation

Code: Kd

Author(s):

- Compiled by: Deckers Jef, Louwye Stephen, Goolaerts Stijn & Everaert Stijn
- Modification of: De Meuter & Laga (1976) after de Heinzelin (1955c)

Alternative names: /

Origin of the name: Kattendijk, locality north of Antwerpen city centre, disappeared at the time of the construction of the dock and the sluice Kattendijk

Type: Formal

Date: 01/05/2022

How to refer: Deckers, J., Louwye, S., Goolaerts, S. & Everaert, S., 2023. The Kattendijk Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Kattendijk-Formation

54.1 Characterizing description

Dark grey to grey green, fine to medium fine, glauconiferous (around 20%) quartz sand, slightly clayey; sometimes intensely bioturbated, locally with an important amount of Ditrupa; shells mostly dispersed but sometimes concentrated in shell beds; large scale sedimentary structures limited to certain intervals, with throughs and sometimes intensely bioturbated foresets, basal gravel of rounded quartz and flint pebbles, together with shark teeth, sandstones, phosphatic nodules and rounded bones. The basal gravel may reach considerable (dm) thickness. Some typical molluscs for the Kattendijk Formation are Laevastarte omalii omalii, Pygocardia rustica tumida, Glycymeris obovata ringelei, Glossus humanus, Pecten grandis etc.

54.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The stratotype section of the Kattendijk Formation selected by De Meuter and Laga (1976) was the temporary outcrop of the Verbindingsdok (GSB 028W0539; DOV kb15d28w-B603, described in detail by Cogels (1874). From 2.5 m to 6.25 m depth or translating to -1.00 m TAW to - 4.75 m TAW. Here, the Kattendijk Formation is located in between the Lillo and Berchem Formations.

Three additional well-studied temporary outcrops are absolutely worth referring:

- The Tunnel Kanaaldok section of Laga (1972) (now named Tijsmanstunnel) (GSB 015W0304; DOV BGD015W0304; Kattendijk Formation between 23.5 m to 27 m depth or translating to -22 m TAW to -25.5 m TAW; Figure 54-1). The base of the Kattendijk Formation is not reached in the outcrop, but a nearby CPT (DOV GEO-20/034-S5) shows it at -27 m TAW, which is confirmed by nearby borehole (DOV GEO-61/2891-C).

- The Verrebroekdok section of Goolaerts (2000) (DOV TO-19990901; Kattendijk Formation between -11 m TAW to -18 m TAW; Figure 54-2). The base of the Kattendijk Formation is not reached, but a nearby CPT (DOV GEO-97/138-SM196) shows it at -23 m TAW.

- The Beverentunnel section of Janssen (1974) and Gaemers (1975) (DOV kb15d27e-B180; GSB 027e0176; Kattendijk Formation between 12.45 m to 21.3 m depth translating to -9.65 and -18.5 m TAW.

Type geophysical borehole is borehole Stabroek (GSB: 015W0216; DOV kb7d15w-B296) with the Kattendijk Formation from 36 m to 41 m depth (modified after Laga, 1979; Figure 54-3).

54.3 Description upper boundary

In its southernmost area, the formation is overlain by Quaternary strata, while further north, it is consistently overlain by the Lillo Formation, in particular by its Luchtbal and Oorderen members. This contact is erosional and overlain by a thick shell bed that causes load casts into the top of the formation. Generally, the transition from the Lillo Formation towards the Kattendijk Formation coincides with a strong decrease in shell content (from shell-rich towards shell-bearing), change in colour from grey or green-grey towards grey-green and an increase in glauconite content from roughly 10% in the Oorderen Member towards roughly 20% in the Kattendijk Formation. On geophysical borehole logs, this boundary coincides with an upwards decrease in gamma-ray values and increase in resistivity values (Figure 54-3).

54.4 Description lower boundary

The Kattendijk Formation seems to conformably cover the Diest Formation to the east of the City/Port of Antwerp area. Further west, the Kattendijk Formation truncates progressively older strata towards the west, with first the Diest Formation just to the east of the City/Port of Antwerp area, next the Berchem Formation in the City/Port of Antwerp area and finally, in the Waasland area, also the Boom Formation. A major dm thick basal gravel was observed in many temporary outcrops.

The transition towards the Diest Formation coincides with an increase in glauconite content, often coarsening of the grain size and disappearance of shells and shell grit. The transition towards the Berchem Formation also coincides with an increase in glauconite content and sediments getting darker green to black colours.

On borehole logs, the transition towards the Berchem Formation generally coincides with an increase in gamma-ray values, and the transition towards the Diest Formation with an increase in resistivity values (Figure 54-3).

54.5 Thickness

In the Campine area the thickness of this formation is rather uniform between 5 to 10 m (Deckers et al., 2019). In gully systems in the Port of Antwerp, it reaches maximum thicknesses of almost 15 m (Deckers & Louwye, 2020).

54.6 Occurrence

From the Waasland area in the west (Laga, 1971), across the City of Antwerp and Port of Antwerp areas into the western Campine area. It presumably covers the western Campine area up to roughly the SW-NE line between Beerse and Weelde in the east. Here, the boundary with the older, but lithologically similar Kasterlee Formation can be presumed, but remains rather difficult to pinpoint. The absence of the Kattendijk Formation in borehole Oud-Turnhout (GSB 017e0401, DOV kb8d17e-B497) to the east of Beerse is established by both litho- and biostratigraphic data (Buffel et al., 2001; Louwye & De Schepper, 2010).

54.7 Regional correlations

It correlates with the Tilburg Member of the Oosterhout Formation in the Netherlands (Munsterman et al., 2019).

54.8 Age

Early Pliocene. See Deckers and Louwye (2020) and references therein.

54.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Outcrop Tunnel Kanaaldok	015W0304	BGD015W0304	http://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0304.txt	https://www.dov.vlaanderen.be/data/boring/1999-161693
Borehole Tunnel Kanaaldok	015W0144	GEO-61/2891-C	http://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0144.txt	https://www.dov.vlaanderen.be/data/boring/1961-080825
Outcrop Verrebroekdok		TO-19990901		https://www.dov.vlaanderen.be/data/boring/1999-161693
CPT Verrebroekdok		GEO-97/138-SM196		https://www.dov.vlaanderen.be/data/sondering/1998-005094
Borehole Oud-Turnhout	017E0401	kb8d17e-B497	http://collections.naturalsciences.be/ssh-geology-archives/arch/017e/017e0401.txt	https://www.dov.vlaanderen.be/data/boring/1998-083226

Extra data:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Outcrop Verbindingsdok	028W0539	kb15d28w-B603	http://collections.naturalsciences.be/ssh-geology-archives/arch/028w/028w0539.txt	https://www.dov.vlaanderen.be/data/boring/1874-081520
CPT Tunnel Kanaaldok		GEO-20/034-S5		https://www.dov.vlaanderen.be/data/sondering/2020-079300
Outcrop Kallo (Beverentunnel)	027e0176	kb15d27e-B180	http://collections.naturalsciences.be/ssh-geology-archives/arch/027e/027e0176.txt	https://www.dov.vlaanderen.be/data/boring/1971-083850
Borehole Stabroek	015W0216	kb7d15w-B296	http://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0216.txt	https://www.dov.vlaanderen.be/data/boring/2016-147541

54.10 References

Buffel, P., Vandenberghe, N., Goolaerts, S. & Laga, P., 2001. The Pliocene in four boreholes in the Turnhout area (North-Belgium): the relation with the Lillo and Mol Formations. Aardkundige Mededelingen, 11, 1–9.

Cogels, P., 1874. Observations géologiques et paléontologiques sur les différents dépôts rencontrés à Anvers lors du creusement des nouveaux bassins. Annales de la Société malacologique de Belgique, 9, 7–32.

Deckers, J., De Koninck, R., Bos, S., Broothaers, M., Dirix, K., Hambsch, L., Lagrou, D., Lanckacker, T., Matthijs, J., Rombaut, B., Van Baelen, K. &Van Haren, T., 2019. Geologisch (G3Dv3) en hydrogeologisch (H3D) 3D-lagenmodel van Vlaanderen. Studie uitgevoerd in opdracht van het Vlaams Planbureau voor Omgeving, departement Omgeving en de Vlaamse Milieumaatschappij. VITO, Mol, VITO-rapport 2018/RMA/R/1569. https://archief-algemeen.omgeving.vlaanderen.be/xmlui/handle/acd/251494

Deckers, J. & Louwye, S., 2020. The architecture of the Kattendijk Formation and the implications on the early Pliocene depositional evolution of the southern margin of the North Sea Basin. Geologica Belgica, 23/3-4, 323-331. https://doi.org/10.20341/gb.2020.017

Deckers, J., Louwye, S. & Goolaerts, S., 2020. The internal division of the Pliocene Lillo Formation: correlation between Cone Penetration Tests and lithostratigraphic type sections. Geologica Belgica, 23/3-4, 333-343. https://doi.org/10.20341/gb.2020.027

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/3-4, 133–152.

Gaemers, P.A.M., 1975. Enkele paleo-ecologische opmerkingen over de pliocene afzettingen in de tunnelput nabij Kallo, België, provincie Oost-Vlaanderen, Deel I. Mededelingen van de Werkgroep voor Tertiaire en Kwartaire Geologie, Leiden, 12/1, 25–37.

Goolaerts, S., 2000. Sedimentologische, stratigrafische en paleoecologische studie van de Pliocene en Quartaire afzettingen aangetroffen in fase 2 van het Verrebroekdok, provincie Oost-Vlaanderen. Proefschrift Licentiaat Geologie (unpublished Master Thesis), KULeuven, Leuven, 133 p.

Janssen, A.W., 1974. Het profiel van de bouwput onder het eerste kanaaldok nabij Kallo, provincie Oost-Vlaanderen, België. Mededelingen van de Werkgroep voor Tertiaire en Kwartaire Geologie, 11/4, 173–185.

Laga, P., 1971. De Neogene afzettingen van het Waasland (kb Beveren-Waas). Belgische Geologische Dienst, Professional Paper, 1971/7, 11 p.

Laga, P., 1972. Stratigrafie van de mariene Plio-Pleistocene afzettingen uit de omgeving van Antwerpen met een bijzondere studie van de foraminiferen. Unpublished Ph.D. Thesis. Katholieke Universiteit Leuven - Faculteit Wetenschappen, Leuven. 3 vol., 252 p.

Laga, P., 1979. Borehole description Stabroek 015W0216. http://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0216.txt, accessed 01/12/2021.

Louwye, S. & De Schepper, S., 2010. The Miocene–Pliocene hiatus in the southern North Sea Basin (northern Belgium) revealed by dinoflagellate cysts. Geological Magazine, 147/5, 760–776. https://doi.org/10.1017/S0016756810000191

Munsterman, D.K., ten Veen, J.H., Menkovic, A., Deckers, J., Witmans, N., Verhaegen, J., Kerstholt-Boegehold, S.J., van de Ven, T. & Busschers, F.S., 2019. An updated and revised stratigraphic framework for the Miocene and earliest Pliocene strata of the Roer Valley Graben and adjacent blocks. Netherlands Journal of Geosciences, 98, e8. https://doi.org/10.1017/njg.2019.10

54.11 Annexes

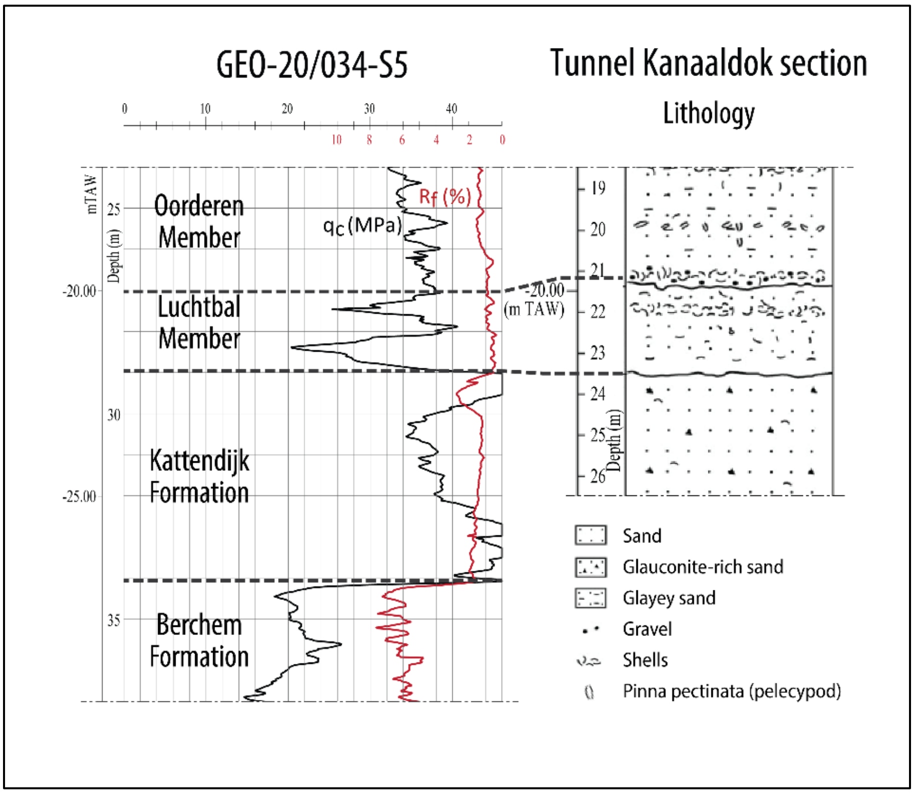


Figure 54-1 The Kattendijk Formation at the Tunnel Kanaaldok section as described and interpreted by Laga (1972) and its expression on a nearby CPT by this study.

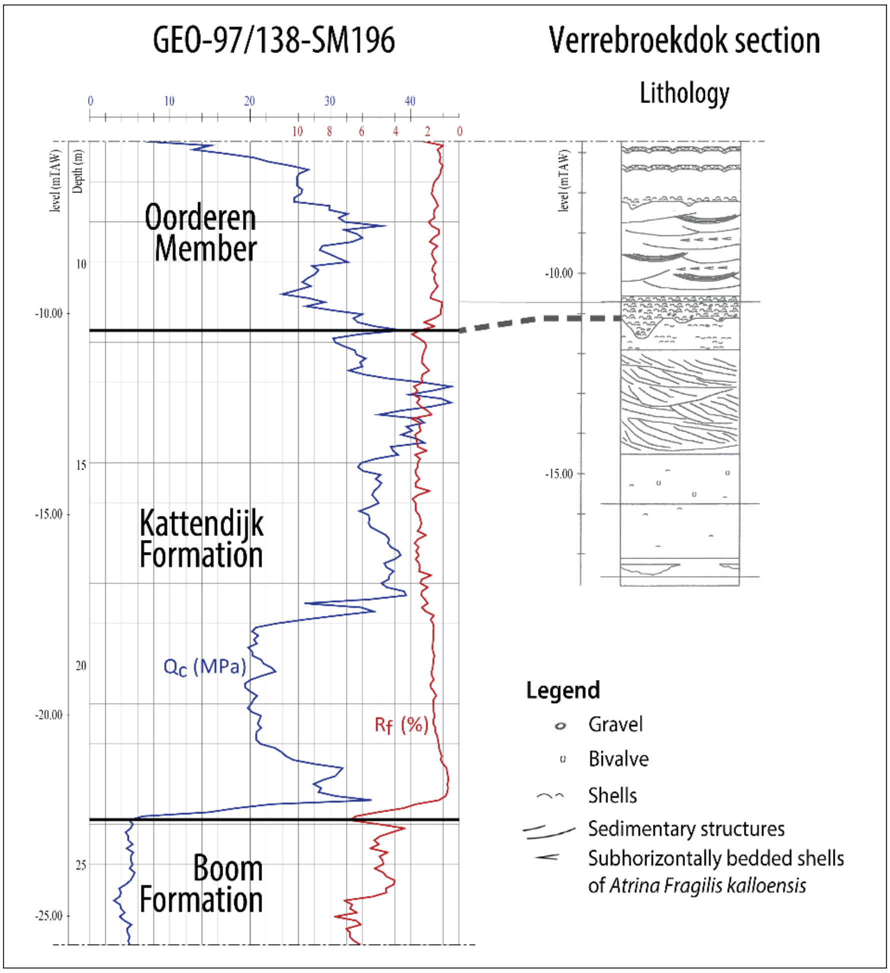


Figure 54-2: The Kattendijk Formation at the Verrebroekdok section as described and interpreted by Goolaerts (2000) and its expression on a nearby CPT, modified after Deckers et al. (2020)..

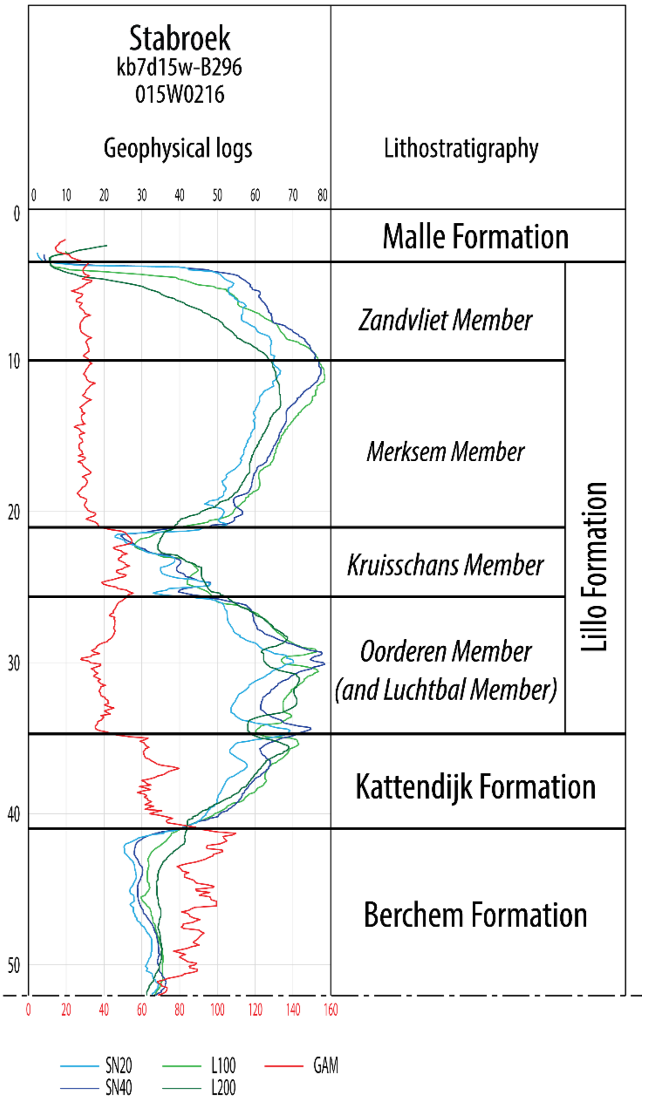


Figure 54-3: Log-expression of the Kattendijk Formation in borehole Stabroek (modified after Laga (1979).

55 Lillo Formation

Unit name: Lillo Formation

Hierarchical unit name: /

Type: Formation

Code: Li

Author(s):

- Compiled by: Deckers Jef, Louwye Stephen & Goolaerts Stijn
- Modification of: De Meuter & Laga (1976)

Alternative names: /

Origin of the name: former village, north of Antwerpen, disappeared with the digging of the Kanaaldok between the Churchilldok and the Zandvlietsluis.

Status: Formal

Date: 01/05/2022

How to refer: Deckers, J., Louwye, S. & Goolaerts, S., 2023. The Lillo Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Lillo-Formation

55.1 Characterizing description

Shelly sand with a clayey admixture in the central part and with several distinct shell layers. The colour is grey, grey-brown to light grey-brown. A gradual decrease of the clay and shells occurs in the upper part of the formation. Locally, the uppermost part can be decalcified. Glauconite content is fairly constant and varies between 6 and 12% with locally some higher content up to 20% in the basal part (Luchtbal Member; Laga, 1972).

The formation was subdivided by De Meuter & Laga (1976), from base to top, into the Luchtbal Member, the Oorderen Member, the Kruisschans Member, the Merksem Member and the Zandvliet Member. Now, the Poederlee Member (former formation) and the Broechem Bed (new) are also included in the Lillo Formation.

De Meuter & Laga (1976) stressed the fact that whereas only the lower Luchtbal Member has distinct boundaries, a gradual change is observed between all other members.

55.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The type locality is to the north of the city of Antwerp in the Lillo district, where the former eponymous village disappeared during the construction works of two docks.

The type section was visible in a temporary outcrop during the digging of the Tunnel Kanaaldok, later called the Tijsmanstunnel (GSB 015W0304; DOV BGD015W0304), at between 3 m and 23.5 m depth (Fig. 1). This section can be correlated to the nearby type CPT (DOV GEO-20/034-S5) which shows high cone resistance (20-40 MPa) and low friction ratio (1%) at the sandy units and low cone resistance (10 MPa) and higher friction ratio (> 2%) at the clayey central unit of the Lillo Formation.

Type geophysical borehole is borehole Stabroek (GSB: 015W0216; DOV kb7d15w-B296) with the Lillo Formation between 4 to 36 m depth (modified after Laga, 1979; Fig. 2).

55.3 Description upper boundary

In its southernmost area, it is overlain by Quaternary strata, while further north, it is overlain by the Malle or Merksplas Formation. The contact with the Malle and Merksplas formations is characterized by the upwards decrease in glauconite, coarsening of the grain-size and discoloration (grey-green to grey). On gamma-ray logs, this boundary coincides with an upwards decrease in gamma-ray values and increase in resistivity values (Fig. 2). On Cone Penetration Tests, this boundary generally (excluding when the Zandvliet Member forms the top of the Lillo Formation) coincides with a sharp decrease in cone resistance values (Fig. 1).

55.4 Description lower boundary

It generally overlies either the Kattendijk Formation, and in the southeast also the Kasterlee Formation. The contact with the Kattendijk and Kasterlee formations coincides with a gravel layer. The transition from the Kattendijk Formation towards the Lillo Formation also coincides with a strong increase in shell content, decrease in glauconite content and related change in colour from dark green or grey green towards green grey. This contact is not obvious on Cone Penetration Tests, and coincides with an upwards decrease in gamma-ray values and increase in resistivity values on geophysical borehole logs (Fig. 2).

The transition from the Kasterlee Formation towards the Lillo Formation coincides with an increase in shells or shell-imprints and a decrease in glauconite content.

55.5 Thickness

Maximum around 30 m (Deckers et al., 2019).

55.6 Occurrence

From the Waasland area in the west, across the City of Antwerp and Port of Antwerp areas into the western Campine area. East of the city of Turnhout, it transitions into the time equivalent white sands of the Mol Formation.

55.7 Regional correlations

It largely correlates with the Oosterhout Formation in the Netherlands.

55.8 Age

Early to Late Pliocene. See Louwye et al. (2020) and references therein.

55.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Outcrop Tunnel Kanaaldok	015W0304	BGD015W0304	http://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0304.txt	https://www.dov.vlaanderen.be/data/boring/1999-161693

Extra data:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
CPT Tunnel Kanaaldok		GEO-20/034-S5		https://www.dov.vlaanderen.be/data/sondering/2020-079300
Borehole Stabroek	015W0216	kb7d15w-B296	http://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0216.txt	https://www.dov.vlaanderen.be/data/boring/2016-147541

55.10 References

Deckers, J., De Koninck, R., Bos, S., Broothaers, M., Dirix, K., Hambsch, L., Lagrou, D., Lanckacker, T., Matthijs, J., Rombaut, B., Van Baelen, K. &Van Haren, T., 2019. Geologisch (G3Dv3) en hydrogeologisch (H3D) 3D-lagenmodel van Vlaanderen. Studie uitgevoerd in opdracht van het Vlaams Planbureau voor Omgeving, departement Omgeving en de Vlaamse Milieumaatschappij. VITO, Mol, VITO-rapport 2018/RMA/R/1569. https://archief-algemeen.omgeving.vlaanderen.be/xmlui/handle/acd/251494

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/3-4, 133–152.

Laga, P., 1972. Stratigrafie van de mariene Plio-Pleistocene afzettingen uit de omgeving van Antwerpen met een bijzondere studie van de foraminiferen. Unpublished Ph.D. Thesis. Katholieke Universiteit Leuven - Faculteit Wetenschappen, Leuven. 3 vol., 252 p.

Laga, P., 1979. Borehole description Stabroek GSB 015W0216. http://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0216.txt, accessed 01/12/2021.

Louwye, S., Deckers, J. & Vandenberghe, N., 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica, 23/3-4, 297-313. https://doi.org/10.20341/gb.2020.016

55.11 Annexes

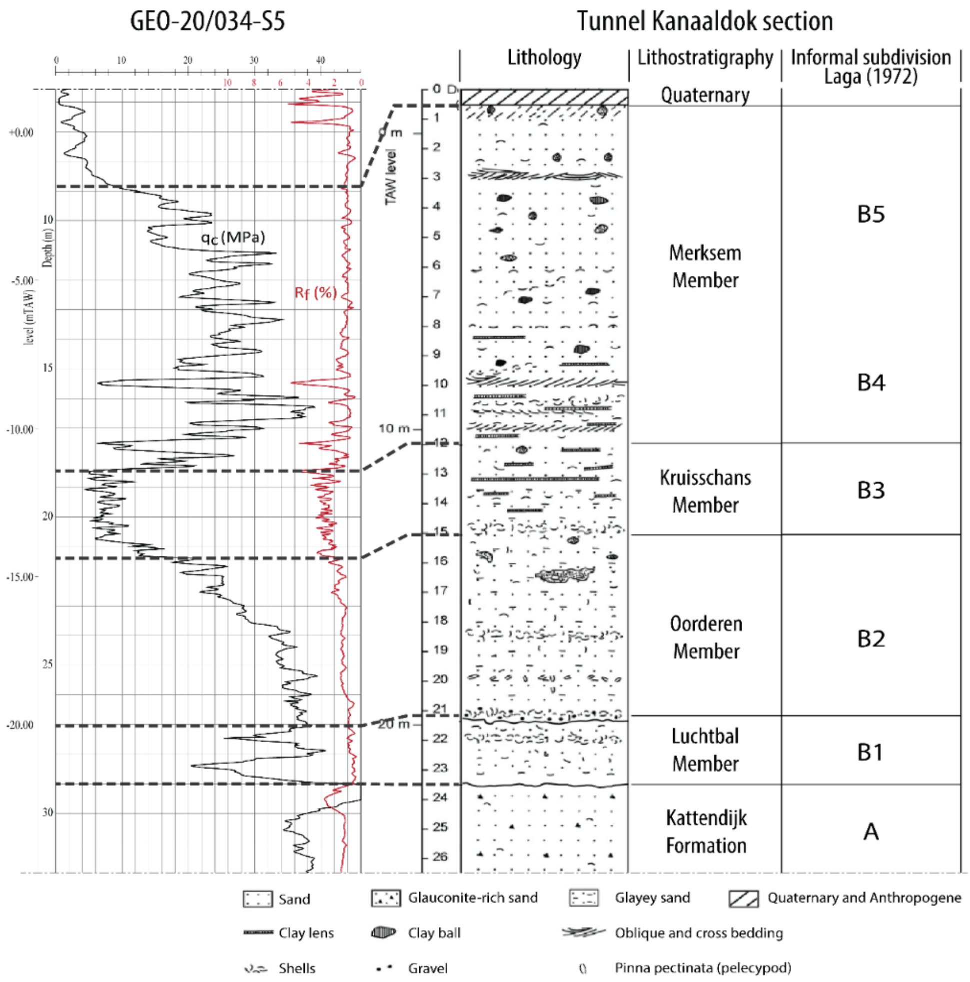


Figure 55-1: The Lillo Formation at the Tunnel Kanaaldok section as described and interpreted by Laga (1972) and correlation with a nearby CPT by this study.

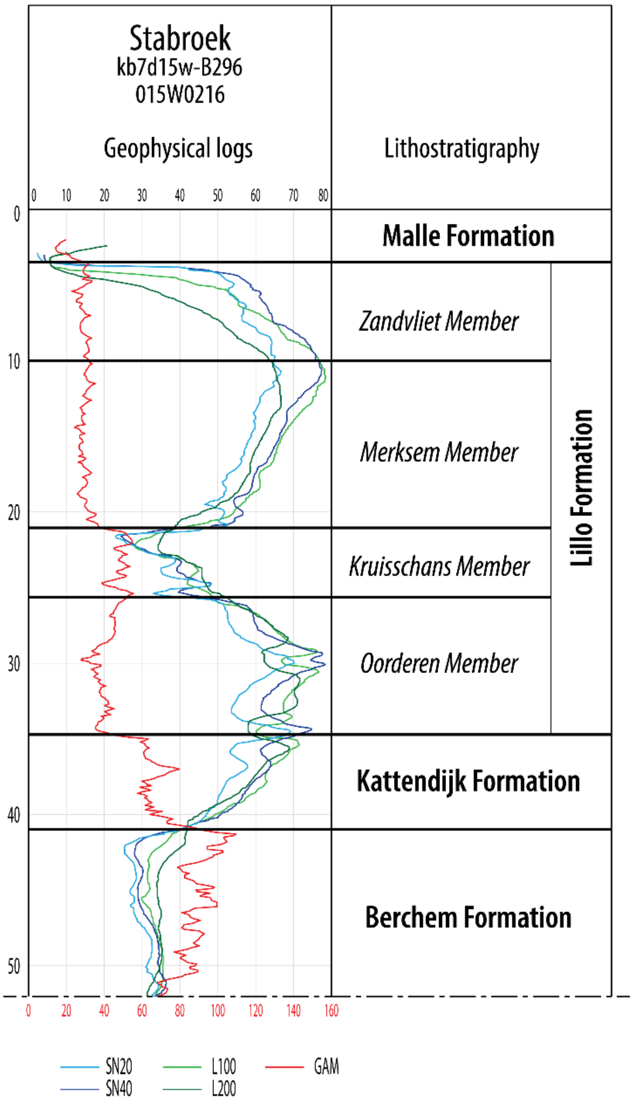


Figure 55-2: Log-expression of the Lillo Formation in borehole Stabroek. Modified after Laga (1979).

56 Broechem Bed (Lillo Formation)

Unit name: Broechem Bed

Hierarchical unit name: Lillo Formation

Type: Bed

For the time being, given its limited thickness and the limited understanding on its occurrence, a bed status is preferred. Possibly, in the future, an upgrade of its rank to member status may be necessary.

Code: LiBr

Author(s):

- Compiled by: Vandenberghe Noël, Goolaerts Stijn & Wesselingh Frank

Alternative names: Broechem Unit or Unit 3 (Wesselingh et al. (2020)

Status: Formal

Date: 01/05/2022

How to refer: Vandenberghe, N., Goolaerts, S. & Wesselingh, F., 2023. The Broechem Bed, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Broechem-Bed

56.1 Characterizing description

The sediment composition is a fine quartz sand unlike the other glauconite rich Neogene units in the area. Due to the near absence of observed glauconite, the bed is attributed to the Lillo Formation, for which it now forms the oldest known deposit. Lag characteristics are present such as some coarse-grained quartz admixture, worn glauconite pellets, fish teeth and shell fragments, and some flint and phosphoritic sandstone pebbles. In addition, individual sandstone nodules themselves eroded from the Broechem Bed were observed as basal load of overlying stratigraphic units, such as the Luchtbal Member (Wesselingh et al., 2020).

56.2 Type section, type locality, type borehole, or type geophysical borehole

At present the observations of the Broechem Bed are still very limited. In the present LIS, the type Broechem Bed refers to the Broechem Unit or Unit 3 as described by Wesselingh et al. (2020). The etymology refers to temporary outcrops related to the construction of a water basin between Broechem and Oelegem, from which a lot of 'Broechem nodules' were collected, and of which accounts on the fauna found within and its age were published by Marquet (1980) and van Baekel et al. (2003). At Antwerp International Airport (AIA), this fauna is found in brown-reddish spherical sandstone nodules of up to circa 15 cm long, partially as moulds and include often paired large bivalves including Cyrtodaria angusta, Arctica islandica, Acanthocardia aff. aculeata, Cardiidae indet., Callista chione and Pygocardia rustica forma tumida.

56.3 Description upper boundary

The upper boundary is truncated, and an unknown amount of sediment was eroded, evidenced by observations of reworked nodules at the base of overlying Pliocene beds. However, limited observations, and post-depositional deformation by cryoturbation of the entire Pliocene sequence at the reference section (AIA), the fine details of the contact remain difficult to interpret.

56.4 Description lower boundary

The lower boundary is interpreted to be erosive and incisive, although that post-depositional deformation related to cryoturbation post-dating the entire Pliocene sequence at the reference section made it difficult to interpret the lower boundary in all of its details.

56.5 Thickness

A few dm only.

56.6 Occurrence

The Broechem Bed has been observed in the southeast of the Antwerp area.

56.7 Regional correlations

The Broechem Bed is characterised by faunal assemblages that are very similar as those occurring at the base of the Oosterhout Formation at Langenboom (The Netherlands) that have a Zanclean age. Comparisons have been made with the Coralline Crag (England). The Broechem Bed must postdate the first arrival of Pacific fauna immigrants at circa 4.7–4.8 Ma (Wesselingh et al., 2020).

56.8 Age

Zanclean, early Pliocene.

56.9 Dataset

Data in the LIS are part of the 'NCS_Neogene 2020_Wesselingh et al., 2020' dataset, a subset of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

56.10 References

Marquet, R., 1980. De stratigrafie van Neogene afzettingen in een bouwput voor een water-reservoir te Broechem (prov. Antwerpen, Belgie). Mededelingen Werkgroep voor Tertiaire en Kwartaire Geologie 17, 57–64.

van Bakel, B.W.M., Jagt, J.W.M. & Fraaije, R.H.B., 2003. A new Pliocene cancrid crab from Oelegem, province of Antwerpen (NW Belgium). Cainozoic Research, 2, 79–85.

Wesselingh, F. P., Busschers, F. S. & Goolaerts, S., 2020. Observations on the Pliocene sediments exposed at Antwerp International Airport (northern Belgium) constrain the stratigraphic position of the Broechem fauna. Geologica Belgica 23 (3-4), 315-321. https://doi.org/10.20341/gb.2020.026

56.11 Annexes

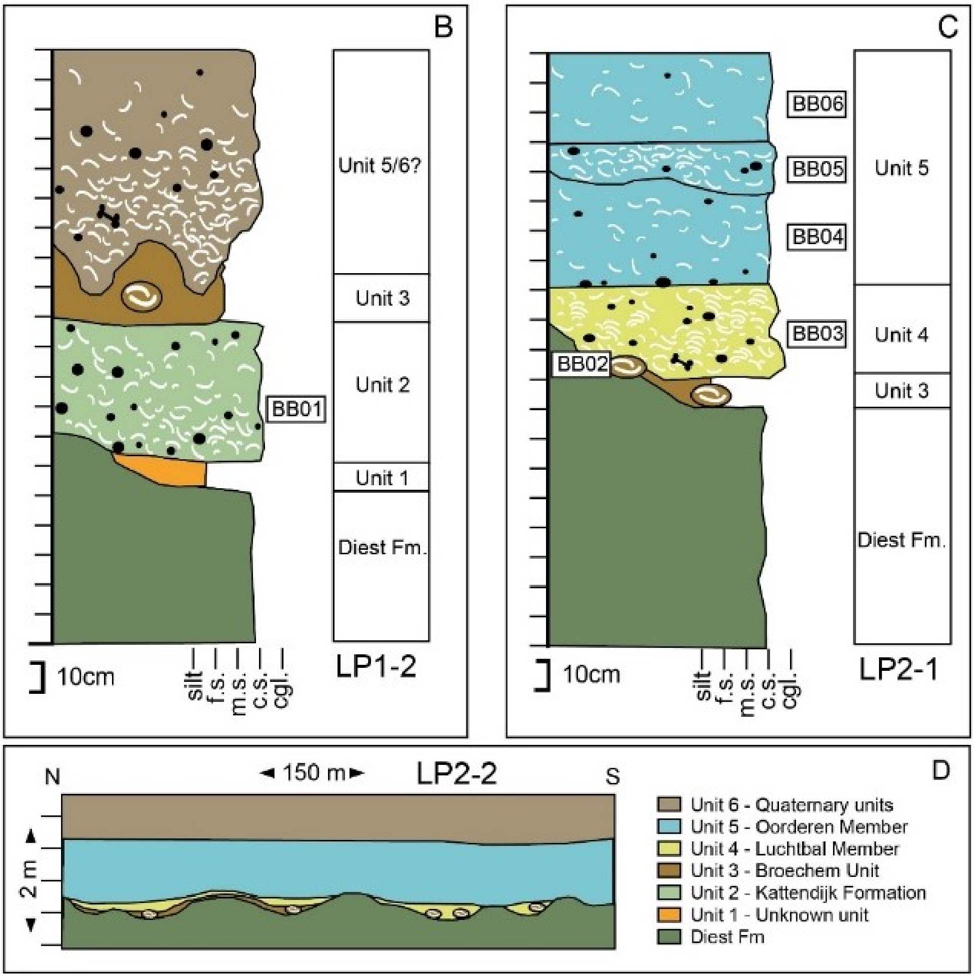


Figure 56-1: Observations at the Antwerp International Airport outcrop. (a) General view on observation point LP1-1. Pliocene fossiliferous sediments (PSU) being strongly deformed by cryoturbation occur on top of upper Miocene Diest Formation (DFm) and below Quaternary deposits (LQF). (b) Schematized succession at observation point LP1-2. (c) Schematized succession at observation point LP2-1. (d) Schematized layer structure at observation point LP2-2. F.s. – fine sand, m.s – medium sand, c.s. – coarse sand, cgl. – gravel (Figure 2 from Wesselingh et al., 2020)

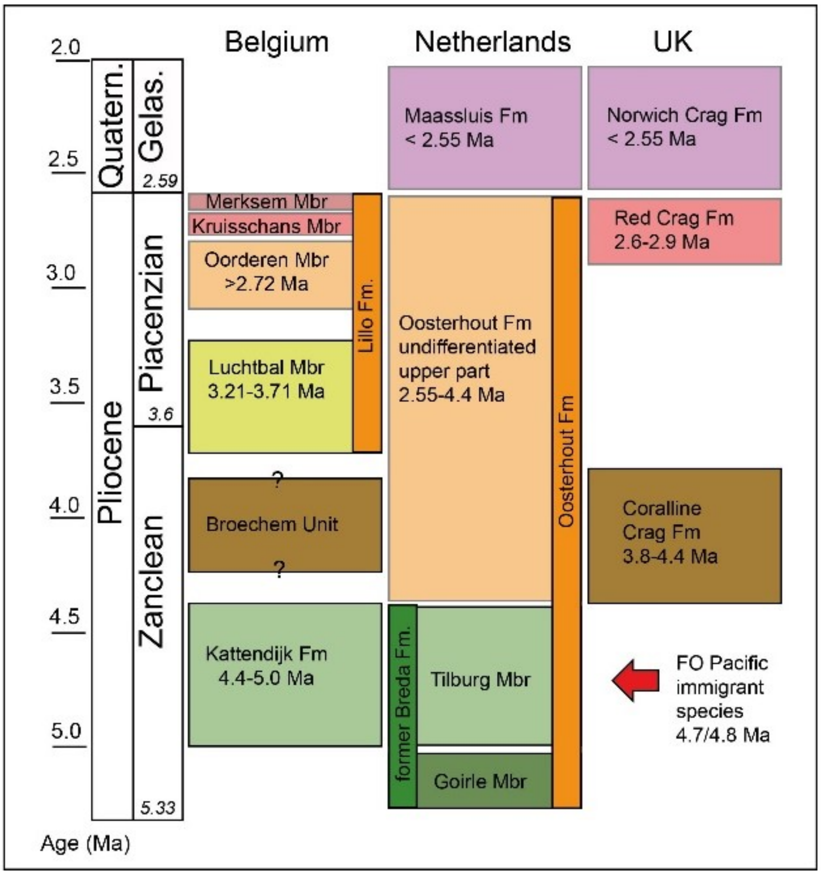


Figure 56-2: Stratigraphic framework of Pliocene units in the southern North Sea Basin and the position of the Broechem unit (adapted from Vervoenen et al., 2014 and Munsterman et al., 2020). Abbreviations: FO: first occurrence; Quartern.: Quaternary; Gelas.: Gelasian; Fm: Formation, Mbr: Member. (Figure 4 from Wesselingh et al., 2020)

57 Luchtbal Member (Lillo Formation)

Unit name: Luchtbal Member

Hierarchical unit name: Lillo Formation

Type: Member

Code: LiLu

Author(s):

- Compiled by: Deckers Jef, Louwye Stephen & Goolaerts Stijn
- Modification of: De Meuter & Laga (1976)

Alternative names: "Sables gris blanchâtres à la base du Scaldisien"; "Faluns blanchâtres"; "Zone à Pecten gerardi"; "Zone à Modiolus", ''Horizon du Luchtbal"; "Sables et Faluns du Luchtbal" (see De Meuter & Laga (1976) and Louwye et al. (2020) for references and more historical details)

Origin of the name: Named after neighborhood Luchtbal

Status: Formal

Date: 01/05/2022

How to refer: Deckers, J., Louwye, S. & Goolaerts, S., 2023. The Luchtbal Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Luchtbal-Member

57.1 Characterizing description

The Luchtbal Member as formally defined by De Meuter & Laga (1976) is a light brown-grey to whitish, glauconiferous quartz sand with abundant well-preserved shells and large amounts of shell grit. The bivalve Palliolum gerardi is conspicuously present, sometimes in dense accumulations forming beds, together with the calcareous tubes of polychaete Ditrupa, bryozoans and echinoderm spines. In the Port of Antwerp area, there is a lower part with dispersed shells, and an upper part with shells beds (Marquet & Herman, 2009).

57.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The type locality is the neighborhood Luchtbal north of Antwerp and east of the harbor.

The type section of the member lies in the Tweede and Derde Havendok (Second and Third Harbour Docks), situated west of the Luchtbal district, between 10 m and 8 m below the natural land surface.

In the Tunnel Kanaaldok section of Laga (1972) (now named Tijsmanstunnel) (GSB 015W0304; DOV BGD015W0304), which is the stratotype-section of the Lillo Formation, the member outcropped from 21.20 m to 23.50 m depth (Figure 57-1). On the nearby CPT (DOV GEO-20/034-S5), the Luchtbal Member is characterised by relatively low friction ratios (< 1%).

57.3 Description upper boundary

The upper boundary is truncated, and in many localities, in particular on the left bank of the Scheldt in the Port of Antwerp area, the member is fully eroded with only some reworked pieces of yellowish grey sandstone and shells in the basal bed of the overlying Oorderen Member (Lillo Formation) as a trace of its previous presence. On CPTs, the upper boundary is expressed by a subtle increase in friction ratios from < 1% in the Luchtbal Member towards > 1% in the Oorderen Member.

In its southernmost occurrence, the Luchtbal Member is covered by Quaternary strata.

57.4 Description lower boundary

The lower boundary is erosive. It cuts into the underlying Kattendijk Formation and in the eastern outskirts of Antwerp also into the Broechem Bed (Lillo Formation), and marked by a thick shell bed containing gravel. The Luchtbal/Kattendijk boundary is sharp and expressed by strong differences in shell-content (from shell-rich to shell-bearing), a transition in colour from grey-yellowish to dark green related to an increase in glauconite content. Load casting from shell accumulations into the top of the Kattendijk Formation frequently occurs. On CPTs, the lower boundary is expressed by a subtle increase in friction ratios from < 1% in the Luchtbal Member towards > 1% in the Kattendijk Formation (Figure 57-1).

57.5 Thickness

De Meuter and Laga (1976) stressed the irregular thickness of the unit, maximum 2 m to absent, due to local erosion. However, thicknesses of up to 10 m are documented in the Campine area north of Antwerp (see profiles http://collections.naturalsciences.be/ssh-geology/geology/profiles-neogeen2020).

57.6 Occurrence

Described in outcrops to the north of the City of Antwerp and in the Port of Antwerp area. Also interpreted in boreholes in the western Campine area, to the west of Turnhout.

57.7 Regional correlations

Lateral equivalent to part of the Oosterhout Formation in the Netherlands.

57.8 Age

Early Pliocene, see Louwye et al. (2020).

57.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Outcrop Tunnel Kanaaldok	015W0304	BGD015W0304		https://www.dov.vlaanderen.be/data/boring/1999-161693

Extra data:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
CPT Tunnel Kanaaldok		GEO-20/034-S5		https://www.dov.vlaanderen.be/data/sondering/2020-079300

57.10 References

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/3-4, 133–152.

Laga, P., 1972. Stratigrafie van de mariene Plio-Pleistocene afzettingen uit de omgeving van Antwerpen met een bijzondere studie van de foraminiferen. Unpublished Ph.D. Thesis. Katholieke Universiteit Leuven - Faculteit Wetenschappen, Leuven. 3 vol., 252 p.

Louwye, S., Deckers, J. & Vandenberghe, N., 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica, 23(3-4), 297-313.

Marquet, R. & Herman, J., 2009. The stratigraphy of the Pliocene in Belgium. Palaeofocus 2, 1-39.

57.11 Annexes

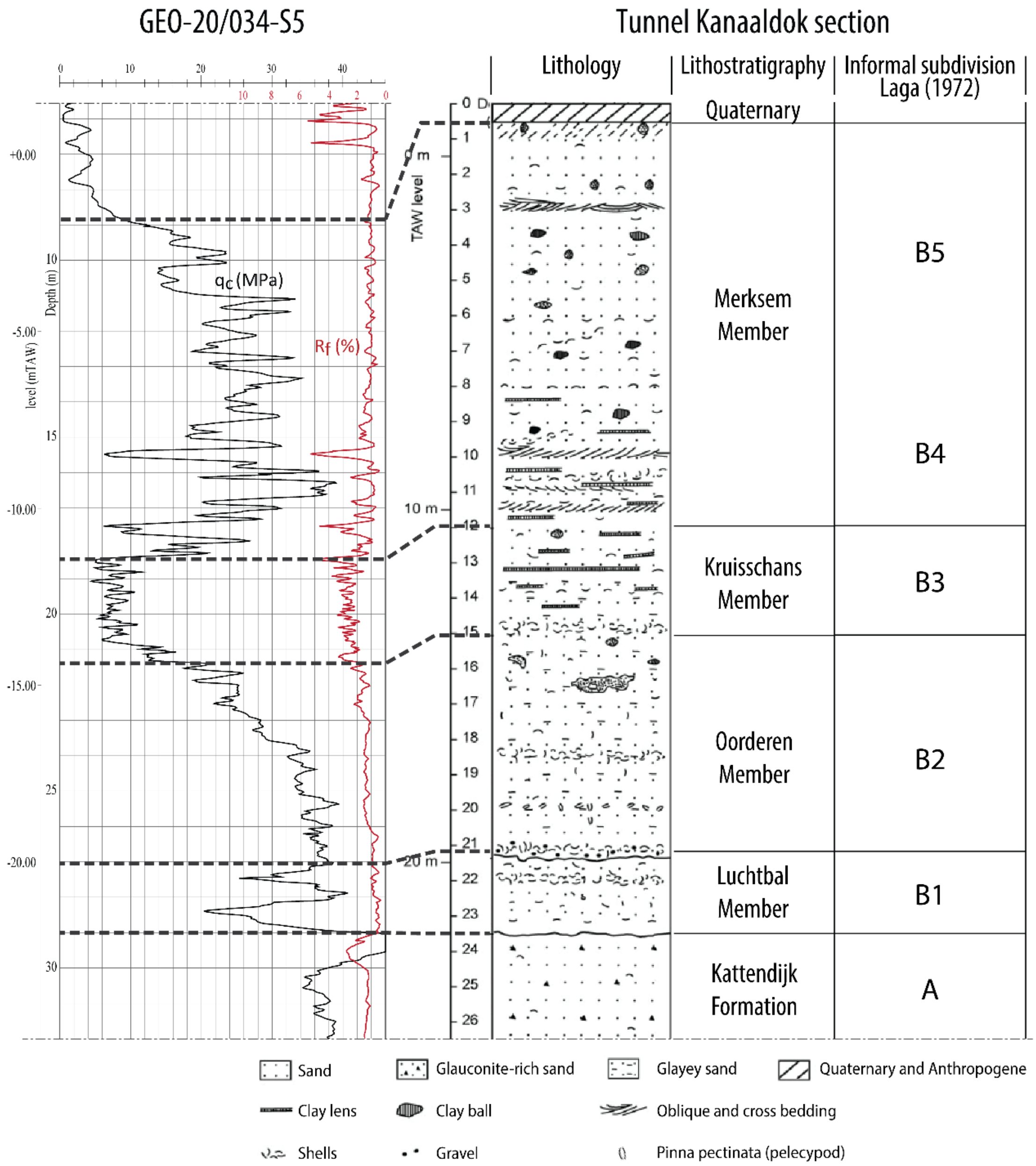


Figure 57-1: The Luchtbal Member at the Tunnel Kanaaldok section as described and interpreted by Laga (1972) and correlation with a nearby CPT by this study.

58 Oorderen Member (Lillo Formation)

Unit name: Oorderen Member

Hierarchical unit name: Lillo Formation

Type: Member

Code: LiOo

Author(s):

- Compiled by: Deckers Jef, Louwye Stephen & Goolaerts Stijn
- Modification from: De Meuter & Laga (1976)

Alternative names: "Sables à Trophon antiquum"; "Sables à Fusus contrarius"; "Sables à Neptunea contraria"; "Sables de Kallo » (see De Meuter & Laga (1976) and Louwye et al. (2020) for references and more historical details)

Origin of the name: former village of Oorderen in the Harbour of Antwerp region, situated north of the Churchilldok.

Status: Formal

Date: 01/05/2022

How to refer: Deckers, J., Louwye, S. & Goolaerts, S., 2023. The Oorderen Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Oorderen-Member

58.1 Characterizing description

The Oorderen Member as introduced by De Meuter & Laga (1976) is a greyish fine-grained, shelly unit containing numerous shells and shell grit, both dispersed in a glauconiferous quartz sand matrix as well as arranged into a number of cm to dm thick shell beds. The basal shell layer is generally several dm thick, contains also gravel with large pebbles, reworked shells and cetacean bones. Major shell beds show load casting, and generally, three of these can be followed over adjacent outcrops several kilometres apart. Three intervals characterized by different sedimentary structures (respectively: throughs and storm beds, predominantly homogenized sand, predominantly bioturbated clayey sand) and mollusc fauna composition (respectively frequent occurrence of: Atrina fragilis kalloensis (previously Pinna pectinata), Cultellus cultellatus, Angulus (or Tellina) benedeni benedeni), and separated by shell beds that experienced load coasting, can be recognized all over the Port of Antwerp area, namely the Atrina (previously Pinna) level, the Cultellus level and the benedeni level (previously Angulus or Tellina benedeni level, or clayey Oorderen) (see Vervoenen, 1995; Marquet, 1998; Marquet & Herman, 2009 and others).

58.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

De Meuter & Laga (1976) named Oorderen, a former village to the north of the city of Antwerp as type locality. These authors also selected the temporary outcrop of the Boudewijnsluis (DOV kb7d15w-B282) described by De Heinzelin de Braucourt (1955) and where the member occurs between -10.5 and -13.5 m TAW as type section.

In the Tunnel Kanaaldok section of Laga (1972) (now named Tijsmanstunnel) (GSB 015W0304; DOV BGD015W0304), the stratotype-section of the Lillo Formation, the member corresponds to the interval between 15 and 21 m depth, translating to -13.5 m TAW to -19.5 m TAW (Figure 58-1). On the nearby CPT

(DOV GEO-20/034-S5), the Oorderen Member is characterised by relatively uniform friction ratios (between 1 and 2%) and cone resistance values of on average around 30 MPa.

In the Verrebroekdok section of Goolaerts (2000) (DOV TO-19990901), the member outcropped between -5.8 and -11.2 m TAW (fide Deckers et al., 2020; Figure 58-2).

Type geophysical borehole is borehole Stabroek (GSB: 015W0216; DOV kb7d15w-B296) with the Oorderen Member from 26 m to 36 m depth (Laga, 1979; Figure 58-3).

58.3 Description upper boundary

In its southernmost area, it is overlain by Quaternary strata, while further north, it is consistently overlain by the Kruisschans Member of the Lillo Formation. The Oorderen/Kruisschans boundary is not always easy to pinpoint, the main criterion as defined by De Meuter & Laga (1976) is the change from the sand and clay being mixed by burrowing (Oorderen Member), to being separated in cm-thick layers or lenses (Kruisschans Member). On Cone Penetration Tests, the boundary correlates to an upwards decrease in cone resistance combined with an increase in friction ratio (Deckers et al., 2020; Figure 58-1 and Figure 58-2)). On geophysical borehole logs, this boundary coincides with an upwards increase in gamma-ray values and decrease in resistivity values (Figure 58-3).

58.4 Description lower boundary

The lower boundary overlies erosively the Luchtbal Member, or where it has removed the latter it overlies the Kattendijk Formation. In outcrops, the boundary with the Luchtbal Member or Kattendijk Formation is rather easy to pinpoint. In boreholes however, this can be more difficult. The main differences with the underlying Kattendijk Formation are different contents of glauconite (10% versus 20%), much higher amounts of shells & shell grit and, as a result of the two former, a difference in color (brown-grey versus more green-grey). On Cone Penetration Tests, the boundary with the Kattendijk Formation and Luchtbal Member can be difficult to identify, although the latter generally shows lower friction ratios than the Oorderen Member (Figure 58-1). On geophysical borehole logs, the boundary with the Kattendijk Formation coincides with an upwards decrease in gamma-ray values and increase in resistivity values (Figure 58-3).

58.5 Thickness

In the Port of Antwerp area, the member has a maximum thickness of up to 7 m (Van Haren et al., 2021). It is truncated in southern direction by the Kruisschans Member, so that it becomes absent in the City of Antwerp area. Further east, in the Grobbendonk outcrop (DOV TO-19970101), the member is thought to be lacking in between the Luchtbal and Kruisschans members (Vandenberghe et al., 2000). Further north in the Campine area, the member seems to have a rather uniform thickness (between 5 to 10 m; Deckers et al., 2019).

58.6 Occurrence

From the Waasland area in the west (Laga, 1971), across the City of Antwerp and Port of Antwerp areas into the western Campine area. It presumably covers the western Campine area up to roughly the SW-NE line between Beerse and Weelde in the east. Here, the transition towards the time-equivalent Poederlee Member is proposed (Louwye et al., 2020).

58.7 Regional correlations

It correlates with part of the Oosterhout Formation in the Netherlands.

58.8 Age

Early late Pliocene. See Louwye et al. (2020) and references therein.

58.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Outcrop Boudewijnsluis		kb7d15w-B282		https://www.dov.vlaanderen.be/data/boring/1952-080889
Outcrop Tunnel Kanaaldok	015W0304	BGD015W0304	https://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0304.txt	https://www.dov.vlaanderen.be/data/boring/1999-161693
Outcrop Verrebroekdok		TO-19990901		https://www.dov.vlaanderen.be/data/boring/1999-161693
CPT Verrebroekdok		GEO-97/138-SM196		https://www.dov.vlaanderen.be/data/sondering/1998-005094
Grobbendonk outcrop		TO-19970101		https://www.dov.vlaanderen.be/data/boring/2020-175886

Extra data:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
CPT Tunnel Kanaaldok		GEO-20/034-S5		https://www.dov.vlaanderen.be/data/sondering/2020-079300
Borehole Stabroek	015W0216	kb7d15w-B296	https://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0216.txt	https://www.dov.vlaanderen.be/data/boring/2016-147541

58.10 References

Deckers, J., De Koninck, R., Bos, S., Broothaers, M., Dirix, K., Hambsch, L., Lagrou, D., Lanckacker, T., Matthijs, J., Rombaut, B., Van Baelen, K. &Van Haren, T., 2019. Geologisch (G3Dv3) en hydrogeologisch (H3D) 3D-lagenmodel van Vlaanderen. Studie uitgevoerd in opdracht van het Vlaams Planbureau voor Omgeving, departement Omgeving en de Vlaamse Milieumaatschappij. VITO, Mol, VITO-rapport 2018/RMA/R/1569. https://archief-algemeen.omgeving.vlaanderen.be/xmlui/handle/acd/251494

Deckers, J., Louwye, S. & Goolaerts, S., 2020. The internal division of the Pliocene Lillo Formation: correlation between Cone Penetration Tests and lithostratigraphic type sections. Geologica Belgica, 23/3-4, 333-343. https://doi.org/10.20341/gb.2020.027

de Heinzelin de Braucourt, J., 1955. Deuxième série d'observations stratigraphiques au Kruisschans. Coupes de l'écluse Baudouin : I. Analyse stratigraphique. Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre, 31/66, 1–29.

De Meuter, F. & Laga, P. 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/3-4, 133–152.

Goolaerts, S., 2000. Sedimentologische, stratigrafische en paleoecologische studie van de Pliocene en Quartaire afzettingen aangetroffen in fase 2 van het Verrebroekdok, provincie Oost-Vlaanderen. Proefschrift Licentiaat Geologie (unpublished Master Thesis), KULeuven, Leuven, 133 p.

Laga, P., 1971. De Neogene afzettingen van het Waasland (kb Beveren-Waas). Belgische Geologische Dienst, Professional Paper, 1971/7, 11 p.

Laga, P., 1972. Stratigrafie van de mariene Plio-Pleistocene afzettingen uit de omgeving van Antwerpen met een bijzondere studie van de foraminiferen. Unpublished Ph.D. Thesis. Katholieke Universiteit Leuven - Faculteit Wetenschappen, Leuven. 3 vol., 252 p.

Louwye, S., Deckers, J. & Vandenberghe, N., 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica, 23/3-4, 297-313. https://doi.org/10.20341/gb.2020.016

Marquet, R., 1998. De Pliocene gastropodenfauna van Kallo (Oost-Vlaanderen, België). Belgische Vereniging voor Paleontologie, 17, 246 p.

Marquet, R., Herman, J., 2009. The stratigraphy of the Pliocene in Belgium. Palaeofocus 2, 1-39.

Vandenberghe, N., Herman, J., Laga, P., Louwye, S., De Schepper, S., Vandenberghe, J., Bohncke, S.J.P. & Konert, M., 2000. The stratigraphic position of a Pliocene tidal clay deposit at Grobbendonk (Antwerp Province, Belgium). Geologica Belgica, 3/3-4, 405–417. https://doi.org/10.20341/gb.2014.040

Van Haren T., Deckers J., De Koninck R., Dirix K., Maes R., Hambsch L. en Van Baelen K., 2021. Ondiep geologisch 3D lagen- en voxelmodel van regio Antwerpen. Studie uitgevoerd in opdracht van de Vlaamse overheid, departement Omgeving, Vlaams Planbureau voor Omgeving, https://archief-algemeen.omgeving.vlaanderen.be/xmlui/external-handle/Onderzoek-2639700

Vervoenen, M., 1995. Taphonomy of some Cenozoic seabeds from the Flemish Region, Belgium. Professional Paper 272, 1-115.

58.11 Annexes

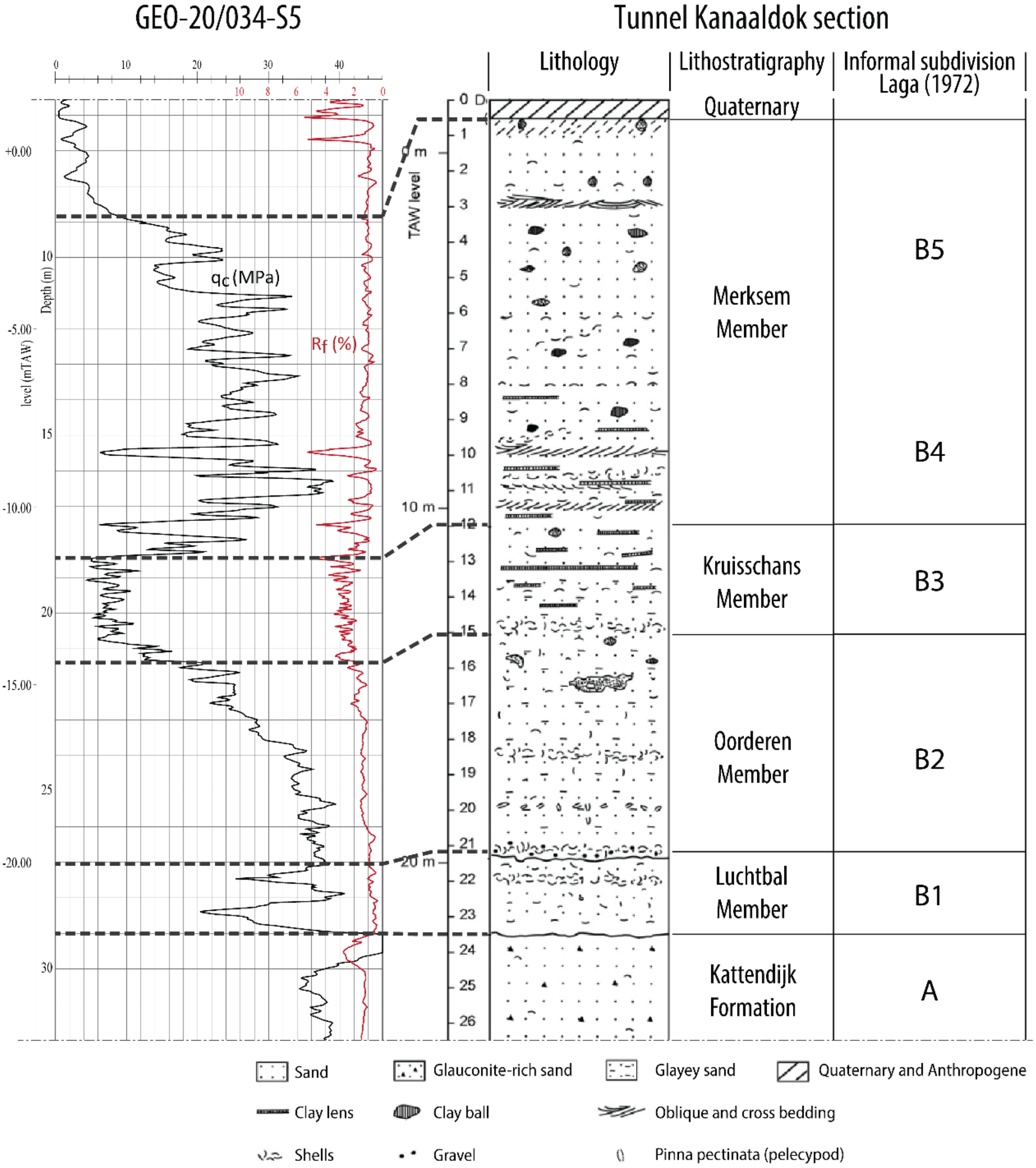


Figure 58-1: The Oorderen Member at the Tunnel Kanaaldok section as described and interpreted by Laga (1972) and correlation with a nearby CPT by this study.

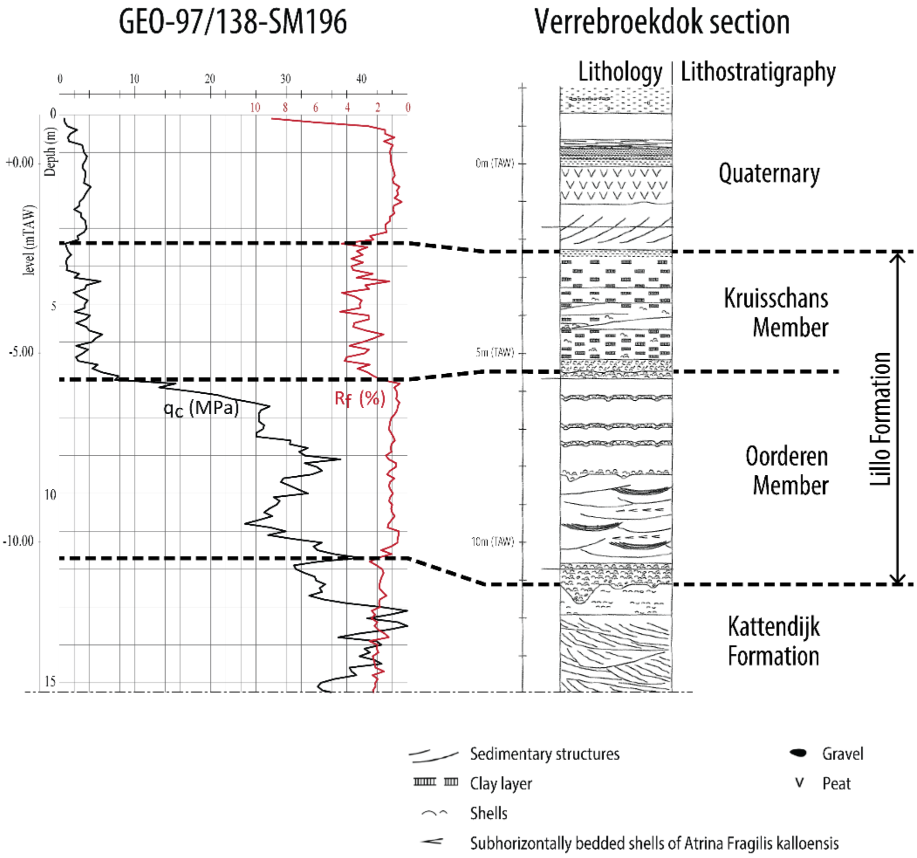


Figure 58-2: The Oorderen Member at the Verrebroekdok section of Goolaerts (2000), with formal lithostratigraphic interpretation and expression on a nearby CPT by Deckers et al. (2020).

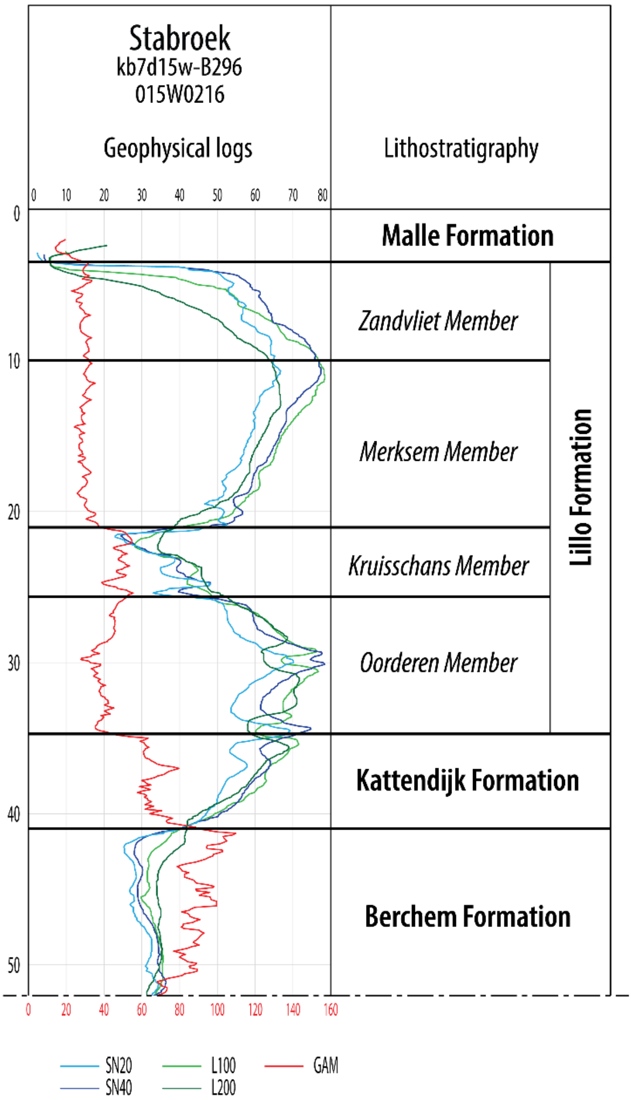


Figure 58-3: Log-expression of the Oorderen Member in borehole Stabroek after Laga (1979).

59 Kruisschans Member (Lillo Formation)

Unit name: Kruisschans Member

Hierarchical unit name: Lillo Formation

Type: Member

Code: LiKr

Author(s):

- Compiled by: Deckers Jef, Louwye Stephen & Goolaerts Stijn
- Modification of: De Meuter & Laga (1976)

Alternative names: The Kruisschans Member as defined here includes the America Dock gravel (de Heinzelin, 1955 after Vincent, 1889 and Delheid, 1895) and the Grobbendonk clay (Vandenberghe et al., 2000). Former names: "Sables à Laevicardium parkinsoni" (see De Meuter & Laga (1976) and Louwye et al. (2020) for overview and references)

Origin of the name: after the former 'fortress of Kruisschans', situated on the right bank of the river

Scheldt, in the former municipality of Oorderen

Status: Formal

Date: 01/05/2022

How to refer: Deckers, J., Louwye, S. & Goolaerts, S., 2023. The Kruisschans Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Kruisschans-Member

59.1 Characterizing description

The Kruisschans Member was formally redefined by De Meuter and Laga (1976) as a grey-green, fine-grained to medium fine-grained, locally coarse-grained, glauconiferous quartz sand with shell debris and abundant small shells. Many clay lenses and clay layers occur. The thickness of the clay layers varies between 1 to 1.5 cm but can sometimes reach 10 cm to 20 cm. The sediment can be strongly bioturbated.

A gravel layer was described at the base of the Kruisschans Member in the America Dock (de Heinzelin, 1955 after Vincent, 1889 and Delheid, 1895) and the Boudewijn Sluice (de Heinzelin, 1952) temporary outcrops in the Port of Antwerp.

59.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

De Meuter & Laga (1976) named Kruisschans, a former village to the north of the city of Antwerp as type locality. These authors also selected the temporary outcrop of the Boudewijnsluis (DOV kb7d15w-B282) described by de Heinzelin de Braucourt (1955) and where the member occurs between -5.5 and -7.5 m depth TAW.

In the Tunnel Kanaaldok section of Laga (1972) (now named Tijsmanstunnel) (GSB 015W0304; DOV BGD015W0304), which is the stratotype-section of the Lillo Formation, the member outcropped between 15 and 21 m depth, translating to -10.5 and -13.5 m TAW (Figure 59-1). On the nearby CPT (DOV GEO-20/034-S5), the Kruisschans Member is characterised by relatively high friction ratios (between 2 and 3%) and low cone resistance values of around 10 MPa.

In the Verrebroekdok section of Goolaerts (2000) (DOV TO-19990901), the member outcropped between and -2.2 and -5.8 m TAW (fide Deckers et al., 2020; Figure 59-2).

Type geophysical borehole log is borehole Stabroek (GSB: 015W0216; DOV kb7d15w-B296) with the Merksem Member from 21 to 26 m depth (modified after Laga, 1979; Figure 59-3).

59.3 Description upper boundary

In its southernmost areal, it is overlain by Quaternary strata, while further north, it is consistently overlain by the Merksem Member, which is also part of the Lillo Formation. This contact is gradual, and characterized by a decrease in the number of clay layers. On Cone Penetration Tests, the boundary is, however, sometimes obvious by an upwards increase in cone resistance and decrease in friction ratio (Deckers et al., 2020; Figure 59-1). On geophysical borehole logs, this boundary coincides with an upwards decrease in gamma-ray values and increase in resistivity values (Figure 59-3).

59.4 Description lower boundary

It predominately overlies the Oorderen Member of the same formation. This contact is erosional and overlain by a shell bed. The boundary is not distinct, and the main criteria as defined by De Meuter & Laga (1976) is that the sand and clay is mixed by burrowing within the Oorderen Member, and separated in cm-thick layers or lenses in the Kruisschans Member. On Cone Penetration Tests, the boundary is more obvious by an upwards decrease in cone resistance and increase in friction ratio (Deckers et al., 2020; Figure 59-1 and Figure 59-2). On geophysical borehole logs, this boundary marks an upwards increase in gamma-ray values and decrease in resistivity values (Figure 59-3).

Only in the southernmost areas of its geographic extend, such as the northern City of Antwerp area or Grobbendonk outcrop (DOV TO-19970101), the Oorderen Member is removed by erosion and the Kruisschans Member directly overlies the Luchtbal Member or even locally even the Kattendijk Formation.

Gravel may occur at the base of the Kruisschans Member (Amerikadok or America Dock gravel of Vincent (1889), see 'Characterising description' (this LIS) and discussion in Louwye et al. (2020)).

59.5 Thickness

The thickness of this member seems rather uniform around 3 m (Deckers et al., 2019).

59.6 Occurrence

From the Port of Antwerp area in het west up to the western Campine area in the east. It presumably covers the western Campine area up to roughly the SW-NE line between Beerse and Weelde in the east. Here, the transition towards the time-equivalent Poederlee Member can be assumed (Louwye et al., 2020).

59.7 Regional correlations

It correlates with the Wouw Member of the Oosterhout Formation in the Netherlands (Vernes et al., in prep.).

59.8 Age

Early late Pliocene. See Louwye et al. (2020) and references therein.

59.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Outcrop Boudewijnsluis	015w0131	kb7d15w-B282	https://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0131.txt	https://www.dov.vlaanderen.be/data/boring/1952-080889

Outcrop Tunnel Kanaaldok	015W0304	BGD015W0304	http://collections.naturalsciences.be/ssh-geology-archives/arch/015w/304.txt	https://www.dov.vlaanderen.be/data/boring/1999-161693
Outcrop Verrebroekdok		TO-19990901		https://www.dov.vlaanderen.be/data/boring/1999-161693
CPT Verrebroekdok		GEO-97/138-SM196		https://www.dov.vlaanderen.be/data/sondering/1998-005094
Grobbendonk outcrop		TO-19970101		https://www.dov.vlaanderen.be/data/boring/2020-175886

Extra data:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
CPT Tunnel Kanaaldok		GEO-20/034-S5		https://www.dov.vlaanderen.be/data/sondering/2020-079300
Borehole Stabroek	015W0216	kb7d15w-B296	http://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0216.txt	https://www.dov.vlaanderen.be/data/boring/2016-147541

59.10 References

Deckers, J., De Koninck, R., Bos, S., Broothaers, M., Dirix, K., Hambsch, L., Lagrou, D., Lanckacker, T., Matthijs, J., Rombaut, B., Van Baelen, K. &Van Haren, T., 2019. Geologisch (G3Dv3) en hydrogeologisch (H3D) 3D-lagenmodel van Vlaanderen. Studie uitgevoerd in opdracht van het Vlaams Planbureau voor Omgeving, departement Omgeving en de Vlaamse Milieumaatschappij. VITO, Mol, VITO-rapport 2018/RMA/R/1569. https://archief-algemeen.omgeving.vlaanderen.be/xmlui/handle/acd/251494

Deckers, J., Louwye, S. & Goolaerts, S., 2020. The internal division of the Pliocene Lillo Formation: correlation between Cone Penetration Tests and lithostratigraphic type sections. Geologica Belgica, 23/3-4, 333-343. https://doi.org/10.20341/gb.2020.027

de Heinzelin de Braucourt, J., 1952. Note sur les coupes de l’écluse Baudouin à Anvers. Bulletin de la Société belge de Géologie, de Paléontologie et d’Hydrologie, 61, 106–108.

de Heinzelin, J., 1955. Considérations nouvelles sur le Néogène de l’Ouest de l’Europe. Bulletin de la Société belge de Géologie, de Paléontologie et d’Hydrologie, 64/3, 463–476.

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/3-4, 133–152.

Goolaerts, S., 2000. Sedimentologische, stratigrafische en paleoecologische studie van de Pliocene en Quartaire afzettingen aangetroffen in fase 2 van het Verrebroekdok, provincie Oost-Vlaanderen. Proefschrift Licentiaat Geologie (unpublished Master Thesis), KULeuven, Leuven, 133 p.

Laga, P., 1972. Stratigrafie van de mariene Plio-Pleistocene afzettingen uit de omgeving van Antwerpen met een bijzondere studie van de foraminiferen. Unpublished Ph.D. Thesis. Katholieke Universiteit Leuven - Faculteit Wetenschappen, Leuven. 3 vol., 252 p.

Laga, P., 1979. Borehole description Stabroek 015W0216. http://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0216.txt, accessed 01/12/2021.

Louwye, S., Deckers, J. & Vandenberghe, N., 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica, 23/3-4, 297-313. https://doi.org/10.20341/gb.2020.016

Vandenberghe, N., Herman, J., Laga, P., Louwye, S., De Schepper, S., Vandenberghe, J., Bohncke, S.J.P. & Konert, M., 2000. The stratigraphic position of a Pliocene tidal clay deposit at Grobbendonk (Antwerp Province, Belgium). Geologica Belgica, 3/3-4, 405–417. https://doi.org/10.20341/gb.2014.040

Vernes, R.W., et al. Geologisch en hydrogeologisch 3D model van het Cenozoïcum van de Belgisch-Nederlandse grensstreek van de Voorkempen (H3O – De Voorkempen). In prep.

Vincent, G., 1889. Documents relatifs aux sables pliocènes à Chrysodomus contraria. Annales de la Société malacologique de Belgique, Bulletins, 24, 25–31.

59.11 Annexes

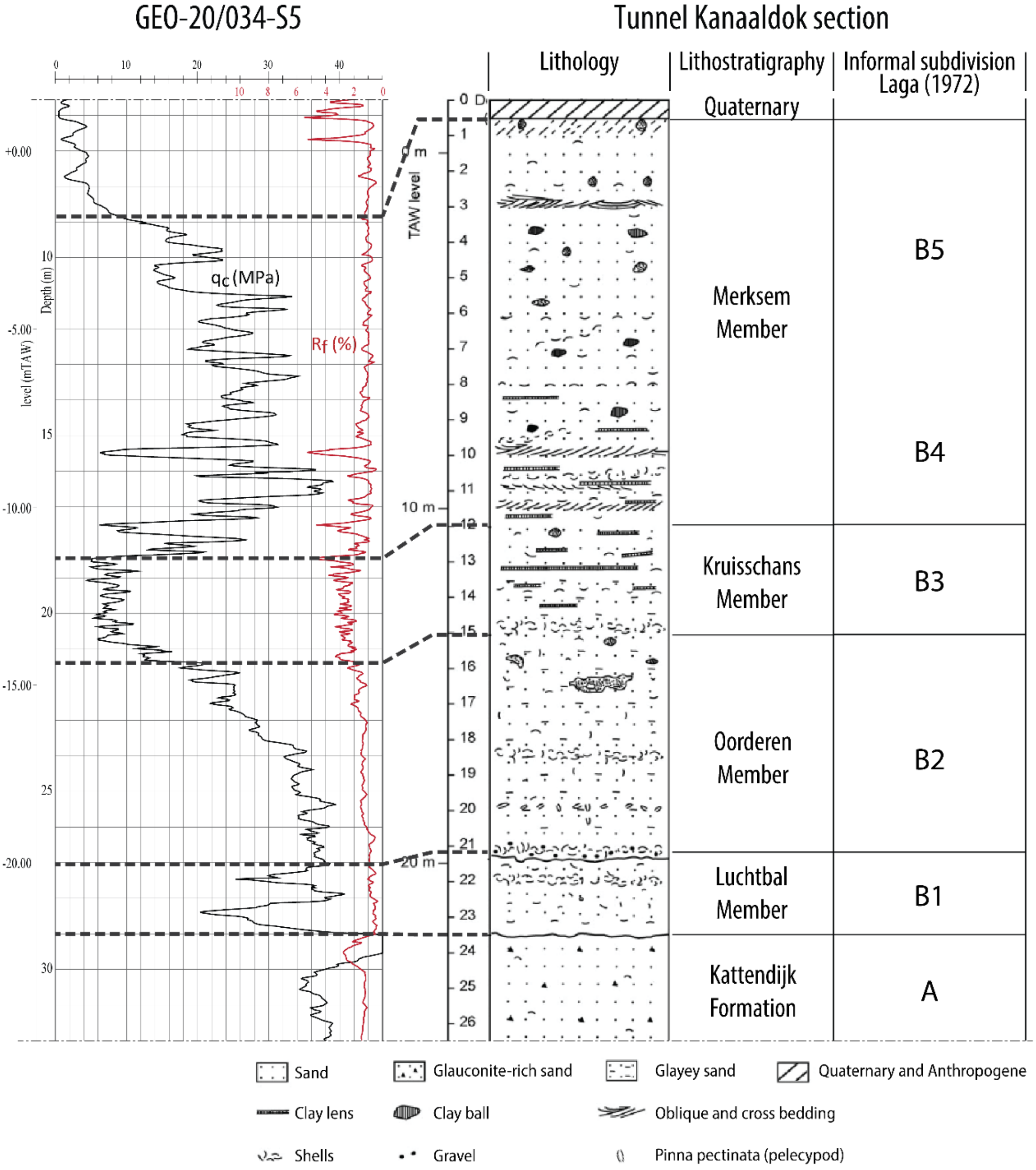


Figure 59-1: The Kruisschans Member at the Tunnel Kanaaldok section as described and interpreted by Laga (1972) and correlation with a nearby CPT by this study.

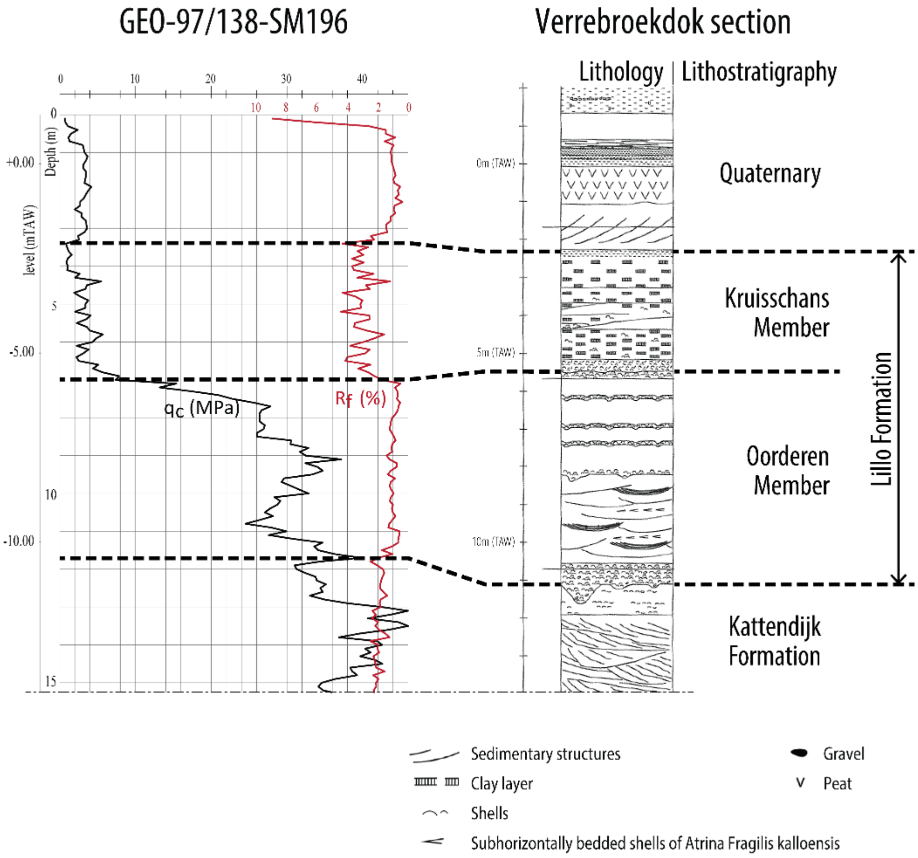


Figure 59-2: The Kruisschans Member at the Verrebroekdok section of Goolaerts (2000), with formal lithostratigraphic interpretation and expression on a nearby CPT by Deckers et al. (2020).

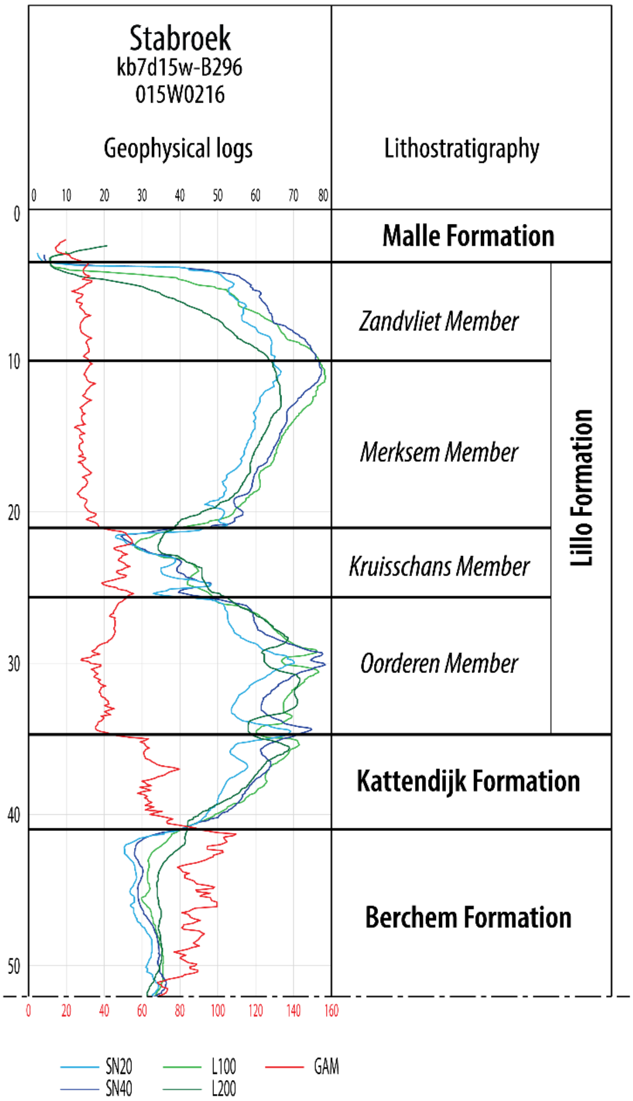


Figure 59-3: Log-expression of the Kruisschans Member in borehole Stabroek. Modified after Laga (1979).

60 Poederlee Member (Lillo Formation)

Unit name: Poederlee Member

Hierarchical unit name: Lillo Formation

Type: Member

Code: LiPd

Author(s):

- Compiled by: Louwye Stephen, Deckers Jef & Vandenberghe Noël
- Modification of: De Meuter & Laga (1976) after Vincent (1889);

Alternative names: Former Poederlee Formation, including Heiende facies, Hukkelberg gravel

Origin of the name: The origin of the unit name is discussed in De Meuter & Laga (1976) and Louwye, Deckers & Vandenberghe (2020)

Status: Formal

Date: 01/05/2022

How to refer: Louwye, S., Deckers, J., & Vandenberghe, N., 2023. The Poederlee Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Poederlee-Member

60.1 Characterizing description

The unit is defined as a fine-grained, slightly glauconitic (< 5%) unit with discrete lenses of clay in the base. The sediments are bioturbated. The upper part of the member is oxidized in the type area, and sometimes limonitic sandstone with moulds of shells occurs (Geets, 1962). The grain-size distribution of the Poederlee Member is very well sorted with a modal size between 175 and 200 µm and fines (<44 µm) content around 5 % (Gullentops, 1963; Buffel et al., 2001). The Heiende facies (c. 2 m) is a fine-grained without glauconite present in the upper part of the unit in the Antwerp Campine area (Buffel et al., 2001). A distinct basal gravel, the Hukkelberg gravel, is present at the base of the member. The discoidal pebbles show long distance transport and the rates of flattening and roundness at different localities are indicative of transport from the west. The gravel also contains silicified ooliths typical for the Kieseloolite Formation in in the east and ultimately derived from northeastern (Gulinck, 1960; Gullentops & Huyghebaert, 1999).

60.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The type area is the village Poederlee (c. 30 km east of Antwerp) and the type section is in the hills north of Poederlee.

The type borehole is the Oud-Turnhout borehole (GSB 017E 0401; DOV kb8d17e-B497) between 30.5 and 38.71 m depth (Buffel et al., 2001).

The type log is from the Turnhout borehole (GSB 017E0398; DOV kb8d17e-B494) between 31 and 38 m depth (Louwye et al., 2020).

60.3 Description upper boundary

The Poederlee Member outcrops in the type area and is to the north unconformably covered by the Merksplas Formation and the Mol Formation.

60.4 Description lower boundary

The Poederlee Member rests unconformably on the upper Miocene Kasterlee Formation.

60.5 Thickness

According to Schiltz et al. (1993) the thickness of the Poederlee Member is maximum 10 m.

60.6 Occurrence

The Poederlee Member occurs in the central part of the Antwerp Campine area in northern Belgium, roughly between the villages of Poederlee in the south and Beerse in the north.

60.7 Regional correlations

A correlation of the Poederlee Member with the Oorderen Member of the Lillo Formation of the Antwerp area is proposed (Buffel et al. 2001; Louwye & De Schepper, 2010). A large number of mollusc moulds in the limonitic sandstone were studied in great detail by Geets (1962) and indicated faunal similarities with the mollusc fauna from the Kruisschans Member.

60.8 Age

Biostratigraphical analysis with dinoflagellate cysts on samples from the Oud-Turnhout borehole (GSB 017E 0401; DOV kb8d17e-B497) indicates deposition during the late Zanclean – Piacenzian (Louwye & De Schepper, 2010).

60.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Borehole Turnhout	017E0398	kb8d17e-B494	https://collections.naturalsciences.be/ssh-geology-archives/arch/017e/017e0398.txt	https://www.dov.vlaanderen.be/data/boring/1996-083221
Borehole Oud-Turnhout	017E0401	kb8d17e-B497	https://collections.naturalsciences.be/ssh-geology-archives/arch/017e/017e0401.txt	https://www.dov.vlaanderen.be/data/boring/1998-083226

60.10 References

Buffel, P., Vandenberghe, N., Goolaerts, S. & Laga, P., 2001. The Pliocene in four boreholes in the Turnhout area (North-Belgium): the relation with the Lillo and Mol Formations. Aardkundige Mededelingen, 11, 1–9.

Geets, S., 1962. Stratigrafische positie van het Poederliaan in de Antwerpse Kempen. Natuurwetenschappelijk Tijdschrift, 44, 143–152.

Gulinck, M., 1960. Un gisement de kiezeloolithes à Lichtaart (Campine). Comparaison avec les cailloutis à kiezeloolithes des collines flamandes. Bulletin Société belge de Géologie, de Paléontologie et d’Hydrologie, 69, 191–204.

Gullentops, F., 1963. Etude de divers faciès quaternaires et tertiaires dans le Nord et l’Est de la Belgique. Excursion O-P. 6e Congrès International de Sédimentologie, Belgique et Pays-Bas, 20 p.

Gullentops, F. & Huyghebaert, L., 1999. A profile through the Pliocene of the Northern Kempen, Belgium. Aardkundige Mededelingen, 9, 191–202.

Louwye, S., Deckers, J. & Vandenberghe, N., 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica, 23/3-4, 297-313. https://doi.org/10.20341/gb.2020.016

Louwye, S. & De Schepper, S., 2010. The Miocene–Pliocene hiatus in the southern North Sea Basin (northern Belgium) revealed by dinoflagellate cysts. Geological Magazine, 147/5, 760–776. https://doi.org/10.1017/S0016756810000191

Schiltz, M., Vandenberghe, N. & Gullentops, F., 1993. Geologische kaart van België, Vlaams Gewest: Lier, kaartblad 16. 1/50 000. Belgische Geologische Dienst en Bestuur Natuurlijke Rijkdommen en Energie, Brussel.

61 Merksem Member (Lillo Formation)

Unit name: Merksem Member

Hierarchical unit name: Lillo Formation

Type: Member

Code: LiMe

Author(s):

- Compiling authors: Deckers Jef & Louwye Stephen
- Modification of: De Meuter & Laga (1976)

Alternative names: /, including 'Sables à Corbula'

Origin of the name: Merksem suburb, situated north-east of Antwerpen

Status: Formal

Date: 01/05/2022

How to refer: Deckers, J., & Louwye, S., 2023. The Merksem Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Merksem-Member

61.1 Characterizing description

The Merksem Member, redefined by De Meuter & Laga (1976), is a grey-green fine-grained to medium fine-grained glauconiferous quartz sand. Coarse-grained sandy intercalations occur. The lower part of the unit is characterised by cross-bedded stratification and thin (1 up to 20 cm) clay layers, while the upper part is horizontally to subhorizontally stratified with rare clay lenses. Sandstone and siderite concretions have been observed. The bivalve Corbula gibba is the characteristic fossil in this member. The Merksem Member as defined here includes the Sables à Corbula described in boreholes of the Antwerp Campine in the Archives of the Geological Survey of Belgium.

61.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The type locality is the village Merksem near Antwerp, and the type section was in a temporary outcrop of a fortification at Merksem at 4.4 m depth. In the type section in the Tunnel Kanaaldok (GSB 015W0304; DOV BGD015W0304) the member lies between 12 m and 3 m depth (Laga, 1972; Figure 61-1). On the nearby CPT (DOV GEO-20/034-S5), the Merksem Member is characterised by relatively low friction ratios (generally below 2% in the basal part towards 1% in the upper part) and fluctuating cone resistance values between 15 and 40 MPa.

Type geophysical borehole is borehole Stabroek (GSB: 015W0216; DOV kb7d15w-B296) with the Merksem Member from 10 to 21 m depth (Figure 61-2).

61.3 Description upper boundary

In its southernmost areal, it is overlain by Quaternary strata. Further north, it is overlain by either the Zandvliet Member of the same formation, or by the Malle Formation. The contact with the Zandvliet Member is characterized by the upwards disappearance in carbonate and the contact with the Merksplas Formation with the upwards decrease in shell-content and glauconite, coarsening of the grain-size and discoloration (grey-green to grey). On Cone Penetration Tests, the boundary with the Zandvliet Member frequently coincides with a sharp upwards decrease in cone resistance (Deckers et al., 2021; Figure 61-3). On geophysical borehole logs, the boundary with the Zandvliet Member is not obvious (Figure 61-2). The boundary with the Malle Formation is on Cone Penetration Tests very similar to the boundary with the Zandvliet Member, and on geophysical borehole logs it is expressed by an upwards decrease in gamma-ray values and increase in resistivity values.

61.4 Description lower boundary

It overlies the Kruisschans Member of the same formation. This boundary is not distinct, and the main criteria as defined by De Meuter & Laga (1976) is the downwards increase in the number of clay layers. On Cone Penetration Tests, the boundary is more obvious by a downwards decrease in cone resistance and increase in friction ratio (Deckers et al., 2020; Figure 61-1 and Figure 61-3). On geophysical borehole logs, this boundary coincides with an upwards decrease in gamma-ray values and increase in resistivity values (Figure 61-2).

61.5 Thickness

Up to 15 m. At the Zandvlietsluis, a decrease in thickness resulted in an increased thickness of the overlying Zandvliet Member (Deckers et al., 2021).

61.6 Occurrence

From the Waasland area in the west, across the Port of Antwerp areas into the western Campine area. It presumably covers the western Campine area up to roughly the SW-NE line between Beerse and Weelde in the east. Here, the transition towards the time-equivalent Poederlee Member can be assumed (Louwye et al., 2020).

61.7 Regional correlations

It probably correlates with the lower part of the Maassluis Formation in the Netherlands.

61.8 Age

Late Pliocene. See Louwye et al. (2020) and references therein.

61.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Outcrop Tunnel Kanaaldok	015W0304	BGD015W0304	http://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0304.txt	https://www.dov.vlaanderen.be/data/boring/1999-161693

Extra data:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
CPT Tunnel Kanaaldok		GEO-20/034-S5		https://www.dov.vlaanderen.be/data/sondering/2020-079300
Borehole Stabroek	015W0216	kb7d15w-B296	http://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0216.txt	https://www.dov.vlaanderen.be/data/boring/2016-147541
Borehole Zandvlietsluis	014E0153	GEO-79/205-A	https://collections.naturalsciences.be/ssh-geology-archives/arch/014e/014e0153.txt	https://www.dov.vlaanderen.be/data/boring/1979-027043

CPT Zandvlietsluis		GEO-79/202-SIII		https://www.dov.vlaanderen.be/data/sondering/1979-007441

61.10 References

Deckers, J., Louwye, S. & Goolaerts, S., 2020. The internal division of the Pliocene Lillo Formation: correlation between Cone Penetration Tests and lithostratigraphic type sections. Geologica Belgica, 23/3-4, 333-343. https://doi.org/10.20341/gb.2020.027

Deckers, J., Verhaegen, J., Vergauwen, I., 2021. Characterization by Cone Penetration Tests of the decalcified Zandvliet Sand (Lillo Formation, North Belgium). Geologica Belgica, 24/3-4, 159-167. https://doi.org/10.20341/gb.2021.006

De Meuter, F. & Laga, P., 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/3-4, 133–152.

Laga, P., 1972. Stratigrafie van de mariene Plio-Pleistocene afzettingen uit de omgeving van Antwerpen met een bijzondere studie van de foraminiferen. Unpublished Ph.D. Thesis. Katholieke Universiteit Leuven - Faculteit Wetenschappen, Leuven. 3 vol., 252 p.

Laga, P., 1979. Borehole description Stabroek, GSB 015W0216. http://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0216.txt, accessed 01/12/2021.

Louwye, S., Deckers, J. & Vandenberghe, N., 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica, 23/3-4, 297-313. https://doi.org/10.20341/gb.2020.016

61.11 Annexes

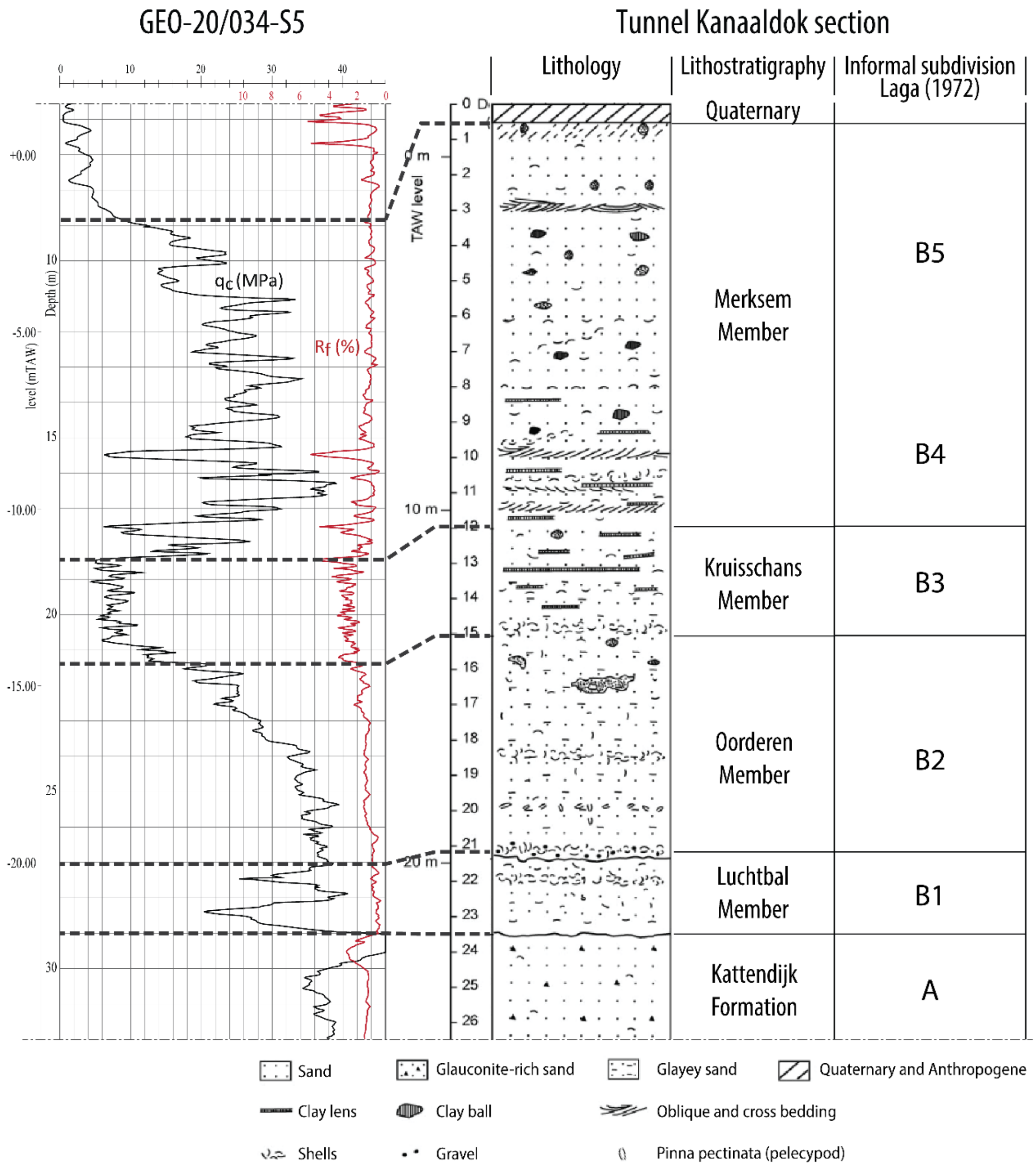


Figure 61-1: The Merksem Member at the Tunnel Kanaaldok section as described and interpreted by Laga (1972) and correlation with a nearby CPT by this study.

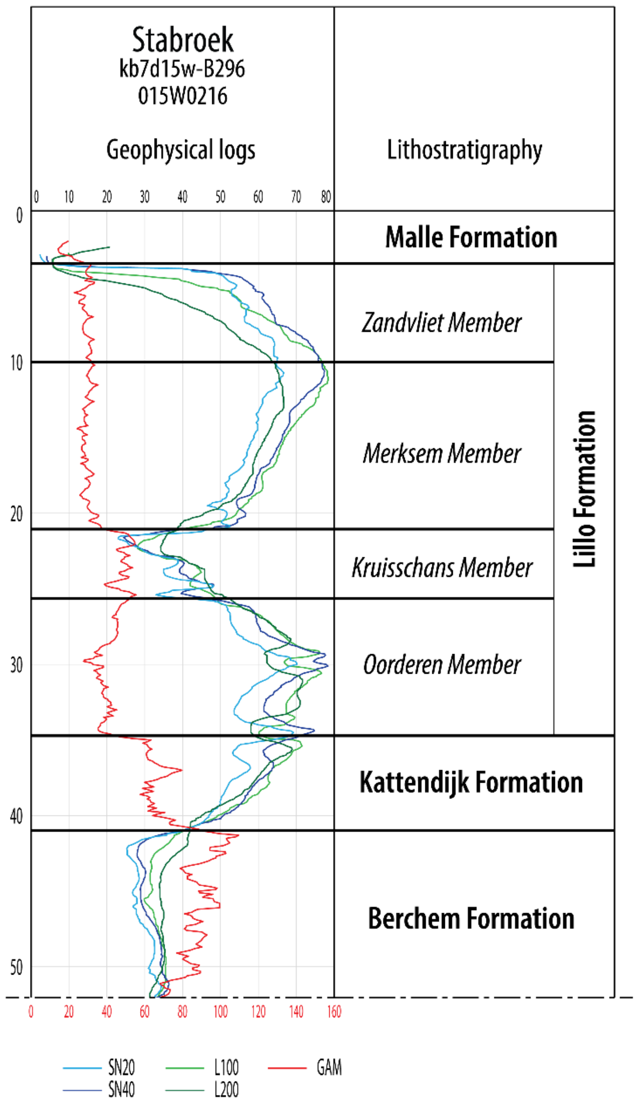


Figure 61-2: Log-expression of the Merksem Member in borehole Stabroek, modified after Laga (1979). The latter author located the upper boundary of the Merksem Member at 14 m depth. However, between 10 and 14 m, the presence of carbonate is mentioned which is why this interval is now re-interpreted as also belonging to the Merksem Member.

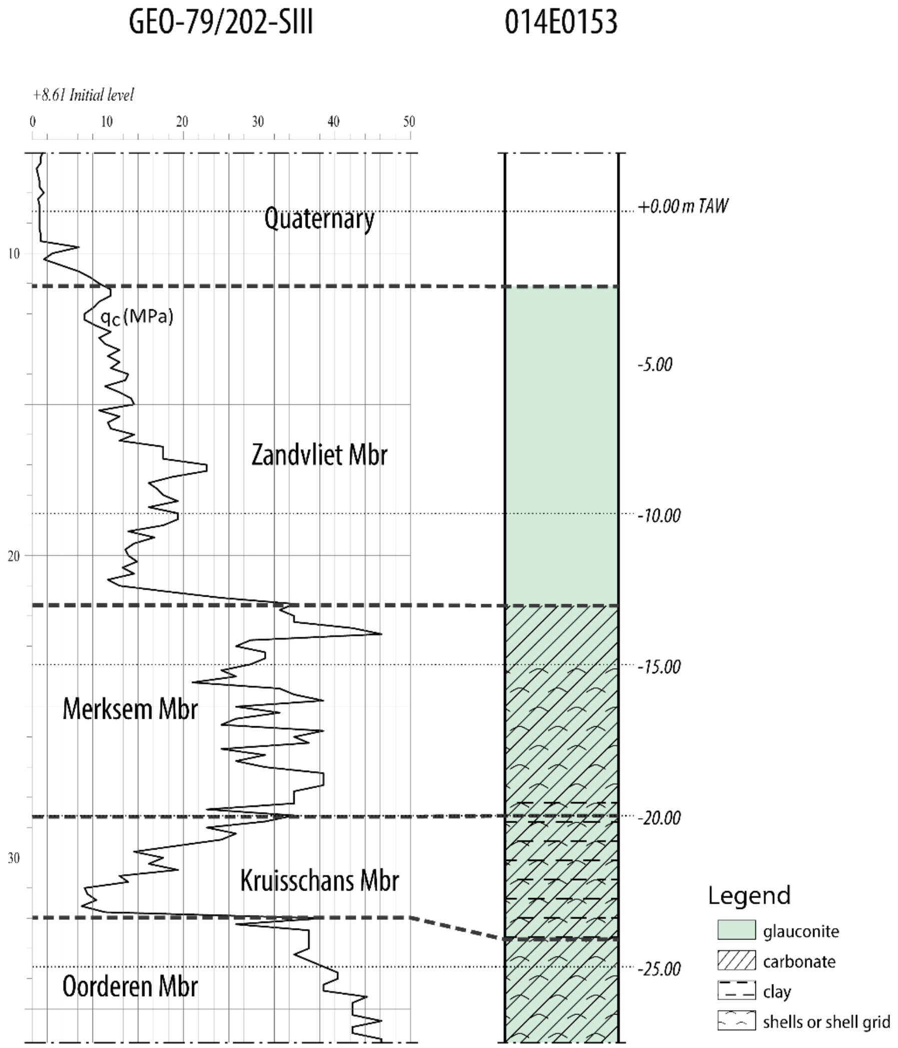


Figure 61-3: The boundary between the Merksem and Zandvliet Members as established in borehole 014E0153 (DOV GEO-79/205-A) and its correlation to a nearby CPT (Deckers et al., 2021).

62 Zandvliet Member (Lillo Formation)

Unit name: Zandvliet Member

Hierarchical unit name: Lillo Formation

Type: Member

Code: LiZa

Author(s):

- Compiled by: Deckers Jef & Louwye Stephen
- Modification of: De Meuter & Laga (1976)

Alternative names: /

Origin of the name: Zandvliet, district near the border with the Netherlands, north of Antwerpen

Status: Formal

Date: 01/05/2022

How to refer: Deckers, J., & Louwye, S., 2023. The Zandvliet Member, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Zandvliet-Member

62.1 Characterizing description

The Zandvliet Member, introduced as a new member by De Meuter & Laga (1976), is as a fine-grained, glauconiferous and slightly clayey quartz sand. It is horizontally stratified and contains sandstones and siderite concretions. Characteristically and contrary to the other members of the Lillo Formation, it is decalcified and holds no shells or shell debris.

62.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The type locality is the village Zandvliet, located north of Antwerp. The type section was in a temporary outcrop for the construction of the Zandvlietsluis north of the city of Antwerp (GSB 014E0153, 014E0154, 014E0155, 014E0156; DOV GEO-79/205-A, GEO-79/205-B, GEO-79/205-C, GEO-79/205-D; Figure 62-1). These were correlated with CPTs by Deckers et al. (2021; GEO-79/202-SIII; GEO-83/033-SXXXV; GEO-79/202-SVI; GEO-79/202-SVIII; see also Figure 62-2).

Type geophysical borehole log is borehole Stabroek (GSB: 015W0216; DOV kb7d15w-B296) with the Zandvliet Member from 4 to 10 m depth (Figure 62-3).

62.3 Description upper boundary

In its western and southern areal, it is overlain by Quaternary strata. Further east and north, as it deepens, it is overlain by the Malle Formation. The contact with the Malle Formation is characterized by the upwards decrease in glauconite, coarsening of the grain-size and discoloration (grey-green to grey). On Cone Penetration Tests, the boundary with the Malle Formation is not obvious, and on geophysical borehole logs it is expressed by an upwards decrease in gamma-ray values and increase in resistivity values (Figure 62-3).

62.4 Description lower boundary

It overlies the Merksem Member of the same formation. This boundary is characterized by the upwards disappearance in carbonate. On Cone Penetration Tests, in case the Merksem Member is carbonate-rich, the boundary coincides with a sharp upwards decrease in cone resistance (Deckers et al., 2021; Figure 62-2). On geophysical borehole logs, the boundary with the Merksem Member is not obvious on the gamma-ray log (Figure 62-3).

62.5 Thickness

Up to 15 m. Near the type section, a decrease in thickness results in an increased thickness of the underlying Merksem Member (Deckers et al., 2021).

62.6 Occurrence

Probably restricted to the northern part of the Port of Antwerp and nearby the villages of Zandvliet, Berendrecht and Stabroek.

62.7 Regional correlations

It probably correlates with the lower part of the Maassluis Formation in the Netherlands.

62.8 Age

No age information is available.

62.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Outcrops Zandvliet Sluice	014E0153, 014E0154, 014E0155, 014E0156	GEO-79/205-A, GEO-79/205-B, GEO-79/205-C, GEO-79/205-D	https://collections.naturalsciences.be/ssh-geology-archives/arch/014e/014e0153.txt, …154.txt, ..155.txt and …156.txt	https://www.dov.vlaanderen.be/data/boring/1979-027043, , …044, …045, …046

Extra data, compared to the DOV-Neogene data collection, including links to the GSB-collection data sheets:

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Outcrops Zandvliet Sluice	014E0153, 014E0154, 014E0155, 014E0156	GEO-79/205-A, GEO-79/205-B, GEO-79/205-C, GEO-79/205-D	https://collections.naturalsciences.be/ssh-geology-archives/arch/014e/014e0153.txt, …154.txt, ..155.txt and …156.txt	https://www.dov.vlaanderen.be/data/boring/1979-027043, , …044, …045, …046
Cone Penetration Tests Zandvliet Sluice		GEO-79/202-SIII; GEO-83/033-SXXXV; GEO-79/202-SVI; GEO-79/202-SVIII		https://www.dov.vlaanderen.be/data/sondering/1979-007441, https://www.dov.vlaanderen.be/data/sondering/1983-062172, https://www.dov.vlaanderen.be/data/sondering/1979-007468, https://www.dov.vlaanderen.be/data/sondering/1979-007492

Borehole Stabroek	015W0216	kb7d15w-B296	https://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0216.txt	https://www.dov.vlaanderen.be/data/boring/2016-147541

62.10 References

Deckers, J., Verhaegen, J., Vergauwen, I., 2021. Characterization by Cone Penetration Tests of the decalcified Zandvliet Sand (Lillo Formation, North Belgium). Geologica Belgica, 24/3-4, 159-167. https://doi.org/10.20341/gb.2021.006

De Meuter, F. & Laga, P. 1976. Lithostratigraphy and biostratigraphy based on benthonic Foraminifera of the Neogene deposits of northern Belgium. Bulletin van de Belgische Vereniging voor Geologie, 85/3-4, 133–152.

Laga, P., 1979. Borehole description Stabroek, GSB 015W0216. http://collections.naturalsciences.be/ssh-geology-archives/arch/015w/015w0216.txt, accessed 01/12/2021.

Laga, P., 1980. Boringen Tweede Zandvlietsluis. Archives Geological Survey of Belgium. https://collections.naturalsciences.be/ssh-geology-archives/profiles-boreholes/Varia%20profiles%20boreholes/pgl/neogeen/pgl-80-217.jpg/view

Louwye, S., Deckers, J. & Vandenberghe, N., 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica, 23/3-4, 297-313. https://doi.org/10.20341/gb.2020.016

62.11 Annexes

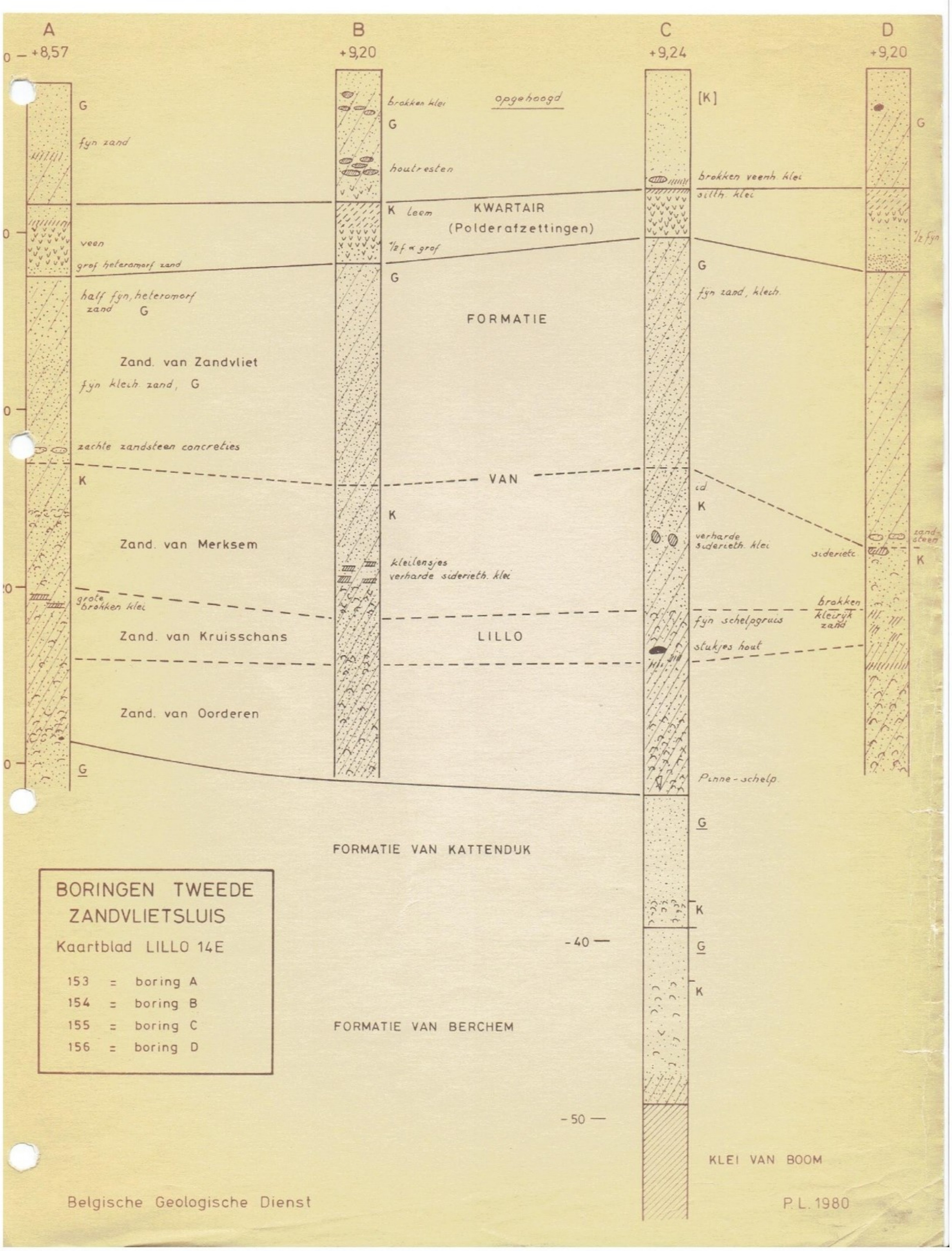


Figure 62-1: The Zandvliet Member as identified in boreholes at the Zandvlietsluis by Laga (1980).

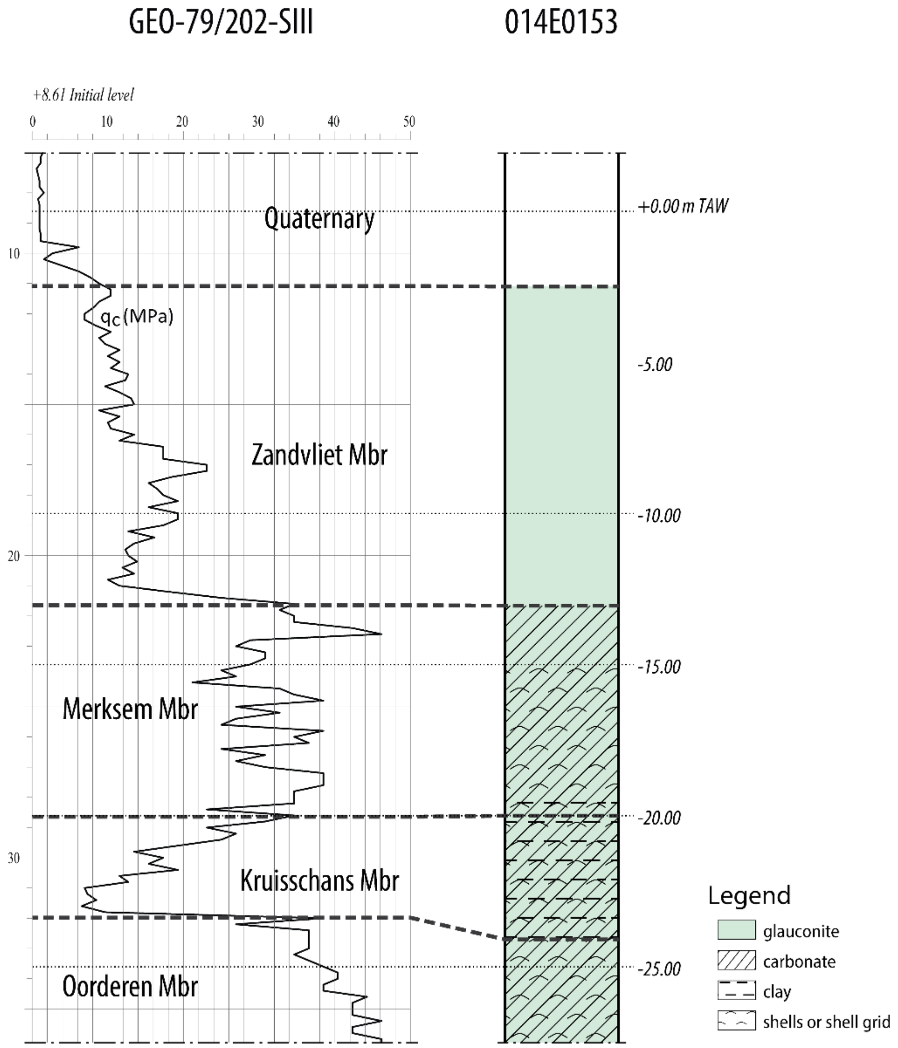


Figure 62-2: The typical CPT expression of the Zandvliet Member at the Zandvlietsluis after Deckers et al. (2021).

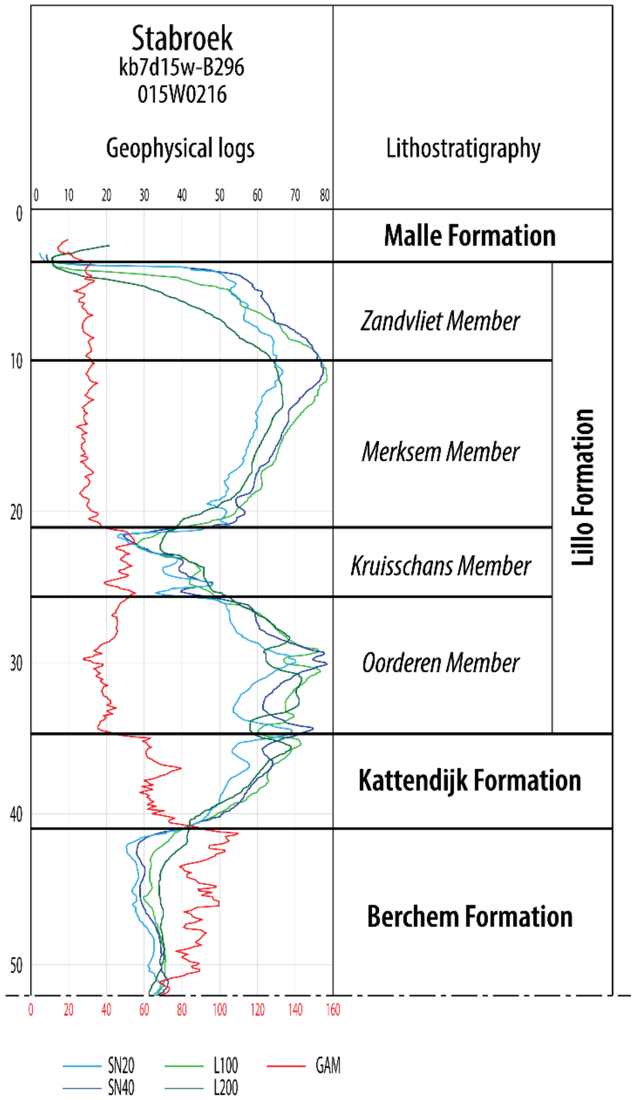


Figure 62-3: Log-expression of the Zandvliet Member in borehole Stabroek, modified after Laga (1979). The latter author located the lower boundary of the Zandvliet Member at 14 m depth. However, between 10 and 14 m, the presence of carbonate is mentioned which is why this interval is now re-interpreted as belonging to the Merksem Member.

63 Merksplas Formation

Unit name: Merksplas Formation

Hierarchical unit name: /

Type: Formation

Code: Me

Author(s):

- Compiled by: Deckers Jef, Bogemans Frieda, Lanckacker Timothy, Louwye Stephen, Vandenberghe Noël & Walstra Jan
- Modification of: Bogemans & Lanckacker (2014)

Alternative names: /

Origin of the name: The term Merksplas ('Sables grossiers de Merksplas') is used for the first time by Gulinck (1962)

Status: Formal

Date: 14/02/2023

How to refer: Deckers, J., Bogemans, F., Lanckacker, T., Louwye, S., Vandenberghe, N. & Walstra, J., 2023. The Merksplas Formation, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Merksplas-Formation

63.1 Characterizing description

Medium to very coarse sand that is grey coloured, quartz-rich. Typical is the presence of peaty material, vegetation remains and wood fragments. Can contain clay laminae or lenses and some glauconite. It can contain some gravel and in the lower part (reworked) shell fragments or grit. The dominant stratification is massive, horizontal and planar. The silt/clay lenses are often deposited as flasers.

63.2 Type section, type locality, type borehole, type CPT and/or type geophysical borehole

The type locality is the subsurface of the village of Merksplas in the Campine area in northernmost Belgium.

The type geophysical borehole log is borehole Essen (GSB 001e0044; DOV B/1-0358) between 46 m and 64 m depth (Figure 63-1).

Concerning the archives of the Geological Survey of Belgium: in the areas where a distinction between the Merksplas Formation and the Brasschaat Member (Malle Formation) could not be made the term Merksplas Sand is used (Louwye et al., 2020).

63.3 Description upper boundary

It is overlain by the overall finer grained Malle Formation. The boundary with the latter is, however, often difficult to depict due to lack of clearly defined distinctive criteria.

63.4 Description lower boundary

It overlies the Lillo Formation. The contact with the Lillo Formation coincides with a downwards decrease in grain size and increase in glauconite content with a related change in colour from grey to green grey. On geophysical borehole logs this boundary generally coincides with a sharp downwards increase in gamma-ray values and a strong downwards decrease in resistivity values (Figure 63-1).

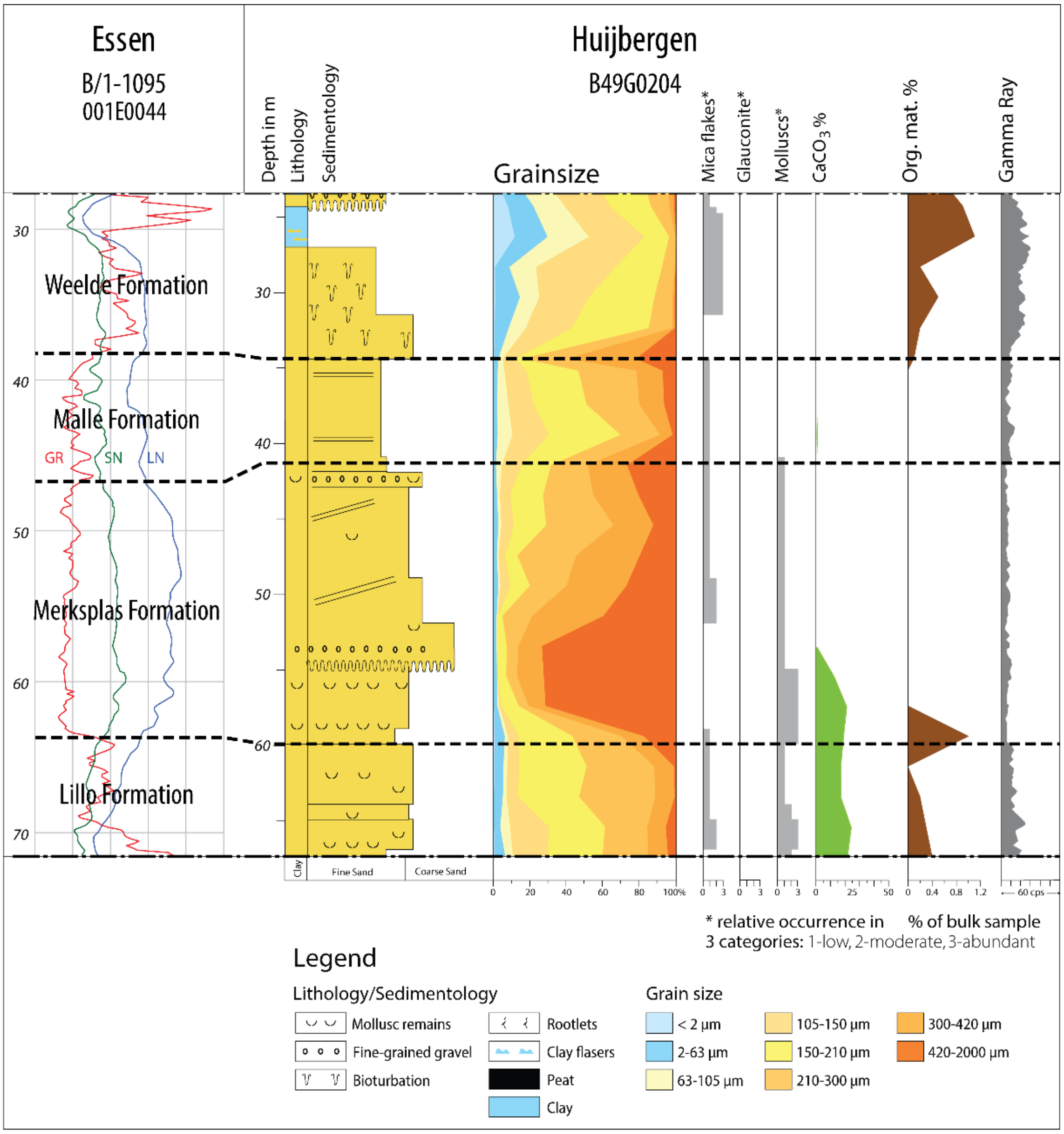


Figure 63-1: Correlation between boreholes Essen and Huijbergen to illustrate the typical geophysical log signature and grain-size of the Merksplas Formation. The figure of borehole Huijbergen was taken from Westerhoff (2009).

63.5 Thickness

On average about 15 m (Deckers et al., 2019).

63.6 Occurrence

In the subsurface of the northern Campine area. In the area around Turnhout, there is a lateral transition in eastern direction into the Mol Formation.

63.7 Regional correlations

It correlates with the Maassluis Formation and the lowermost part of the Waalre Formation in the Netherlands (Vernes et al., 2015).

63.8 Age

Probably late Pliocene and early Quaternary (Pretiglian; Bogemans (2005) and references therein).

63.9 Dataset

Extra data, compared to the DOV-Neogene data collection, including links to the GSB-collection data sheets:

Name	GSB name	DOV name	Alternative name	GSB Collections URL	DOV URL
Borehole Essen	001e0044	B/1-0358		http://collections.naturalsciences.be/ssh-geology-archives/arch/001e/001e0044.txt	https://www.dov.vlaanderen.be/data/boring/1979-001191
Borehole Huijbergen			B49G0204 (DINOloket ID)		

63.10 References

Bogemans, F., 2005. Toelichting bij de Quartairgeologische kaart [van België, Vlaams Gewest]: kaartblad 2 - 8, Meerle -Turnhout [1/50 000]. Vlaamse Overheid, Dienst Natuurlijke Rijkdommen, Brussel, 38 p.

Bogemans, F. & Lanckacker, T., 2014. Neogene – revised lithostratigraphy accepted 06/2014: 2.10. Merksplas Formation. https://ncs.naturalsciences.be/paleogene-neogene/210-merksplas-formation

Deckers, J., De Koninck, R., Bos, S., Broothaers, M., Dirix, K., Hambsch, L., Lagrou, D., Lanckacker, T., Matthijs, J., Rombaut, B., Van Baelen, K. &Van Haren, T., 2019. Geologisch (G3Dv3) en hydrogeologisch (H3D) 3D-lagenmodel van Vlaanderen. Studie uitgevoerd in opdracht van het Vlaams Planbureau voor Omgeving, departement Omgeving en de Vlaamse Milieumaatschappij. VITO, Mol, VITO-rapport 2018/RMA/R/1569. https://archief-algemeen.omgeving.vlaanderen.be/xmlui/handle/acd/251494

Gulinck, M., 1962. Essai d'une carte géologique de la Campine. Etat de nos connaissances sur la nature des terrains néogènes recoupés par sondages. Mémoires de la Société belge de Géologie, de Paléontologie et d'Hydrologie, série in-8°, 6, 30–39

Louwye, S., Deckers, J. & Vandenberghe, N., 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica, 23/3-4, 297-313. https://doi.org/10.20341/gb.2020.016

Vernes, R.W., Deckers, J., Bakker, M.A.J., Bogemans, F., De Ceukelaire, M., Doornenbal, J.C., den Dulk, M., Dusar, M., Van Haren, T.F.M., Heyvaert, V.M.A., Kiden, P., Kruisselbrink, A.F., Lanckacker, T., Menkovic, A., Meyvis, B., Munsterman, D.K., Reindersma, R., ten Veen, J.H., van de Ven, T.J.M., Walstra, J., Witmans, N., 2018. Geologisch en hydrogeologisch 3D model van het Cenozoïcum van de Belgisch-Nederlandse grensstreek van Midden-Brabant / De Kempen (H3O – De Kempen). TNO, Utrecht, TNO-rapport, TNO 2017 R11261 – VITO 2017/RMA/R/1348, 109 p.

Westerhoff, W.E., 2009. Stratigraphy and sedimentary evolution: The lower Rhine-Meuse system during the Late Pliocene and Early Pleistocene (southern North Sea Basin). Ph.D. Thesis, Vrije Universiteit Amsterdam, Amsterdam, 168 p.

64 Rees Facies

Unit name: Rees Facies

Hierarchical unit name: Although occurring geometrically between the Mol Formation and the Merkpslas Formation, its stratigraphic hierarchy with respect to both is at present uncertain and therefore the Rees Facies is not formally attributed to either of both. Note that earlier on the geological map 8/2 Turnhout-Meerle (Buffel et al., 2002) the Rees Facies was included as a member in the Formation of Mol.

Type: Facies

Code: Re

Author(s):

- Compiled by: Vandenberghe Noël and Deckers Jef

Alternative names:

Origin of the name: Buffel et al. (2001)

Status: Formal

Date: 07/03/2023

How to refer: Vandenberghe, N. & Deckers, J., 2023. The Rees Facies, 01/09/2023. National Commission for Stratigraphy Belgium. http://ncs.naturalsciences.be/lithostratigraphy/Rees-Facies

64.1 Characterizing description

The Rees Facies consists of pale grey to white structureless quartz sand. No carbonate is present. Neither macro nor micro fossils such as including dinoflagellate cysts, are present. The basal half of the Rees Facies consists almost entirely of grains 250-500 µm in size and even some gravel whilst in its upper part the sand is finer grained and well sorted and traces of bioturbation and lamination are reported in the Rees borehole (017E0399/kb8d17e-B495). The Rees Facies could be considered as a westward evolution of the Mol Formation's Donk Member to the Merksplas Formation; compared to the Donk Member the Rees Facies contains some more glauconite grains and muscovite flakes but it is less heterogeneous compared to the Merkpslas Formation (see LIS Merksplas Formation).

64.2 Type section, type locality, type borehole, or type geophysical borehole

The reference for the Rees Facies is the Rees unit in the Rees borehole (017E0399/kb8d17e-B495) between 8.6 and 17.3 m, presented in Buffel et al. (2001) with grain-size data and the stratigraphic context.

64.3 Description upper boundary

In the Rees borehole (017E0399/kb8d17e-B495) the Quaternary Vosselaar Sand Member overlies the Rees Facies. The Vosselaar Sand is finer grained than the Rees Facies and the contact between both is located at a marked increase in the 63-125 µm size fraction at the base of the Vosselaar Sand (Buffel et al. , 2001).

64.4 Description lower boundary

In the Rees borehole (017E0399/kb8d17e-B495) the Rees Facies is underlain by the glauconite bearing Poederlee Member; the contact is marked by a grain-size shift from almost entirely 125-250 µm in the Poederlee Member to an almost entirely 250-500 µm size fraction in the Rees Facies (Buffel et al., 2001; the Poederlee Formation is now ranked as Poederlee Member, see Lithostratigraphic Information Sheet Lillo Formation – Poederlee Member).

64.5 Thickness

The thickness is about 8 m.

64.6 Occurrence

The Rees Facies is occurring at the south-eastern end of the Merksplas Formation. It is bordered to the east by the finer-grained Donk Member of the Mol Formation. Geometrically the Mol Formation seems to occur laterally of the relatively coarse Merksplas Formation (Laga, 1976 – profiles 76/106/2 and 75/104/1) (see also Lithostratigraphic Identification sheet Merksplas Formation).

The Rees Facies was mapped on the 8/2 Turnhout Meerle geological map (Buffel et al., 2002) as part of the Mol Formation (see above). To the west of the Rees Facies occur the Schorvoort, Hemeldonk and Malle facies discussed in Buffel et al. (2001) and mapped as Brasschaat Formation on the 8/2 Turnhout Meerle geological map (Buffel et al., 2002). To the north in the subsurface of the Antwerp province, the identification of the Brasschaat Formation in general is not obvious (Laga, 1976 –profile PGL76/106/3) . In the Geologica Belgica Neogene Volume 2020 (Louwye et al. (2020) and Vandenberghe and Louwye (2020)), the Pliocene quartz sand in the west have been named the Merksplas Formation and not Brasschaat Member as this last name is reserved in the NCS for Pleistocene fine-sized sand.

64.7 Regional correlations

Based on geometry and on the common strongly quartz-enriched sand composition, a grouping seems obvious of the Rees Facies together with the Merksplas Formation in the west and northwest and at least part of the Mol Formation with the Kieseloolite Formation in the east.

64.8 Age

In a dinoflagellate study of the Rees borehole, Al-Silwadi (2017) found mid- to late Pliocene age dinoflagellate cysts above and below the Rees Facies but all samples in the Rees Facies itself are barren.

64.9 Dataset

Data in the LIS are part of the DOV-Neogene data collection, including links to the GSB-collection data sheets.

Name	GSB name	DOV name	GSB Collections URL	DOV URL
Borehole Rees	017E0399	kb8d17e-B495	http://collections.naturalsciences.be/ssh-geology-archives/arch/017e/017e0399.txt	https://www.dov.vlaanderen.be/data/boring/1998-083222

64.10 References

Al-Silwadi, S., 2017. Dinoflagellate cyst stratigraphy and paleoecology of the Upper Miocene and Pliocene, Rees Borehole, Northern Belgium. Unpublished MSc thesis Earth Science, Brock University, Ontario, Canada, 128 p.

Buffel, P., Vandenberghe, N., Goolaerts, S. & Laga, P., 2001. The Pliocene in four boreholes in the Turnhout area (North-Belgium): the relation with the Lillo and Mol Formations. Aardkundige Mededelingen 11, 1–9.

Buffel, Ph., Van Barel, L. & Gullentops, F., 2002. Geologische kaart van België, Vlaams Gewest: Turnhout - Meerle, kaartblad 8 - 2. 1/50 000. Belgische Geologische Dienst en Afdeling Natuurlijke Rijkdommen en Energie, Brussel.

Louwye, S., Deckers, J. & Vandenberghe N., 2020. The Pliocene Lillo, Poederlee, Merksplas, Mol and Kieseloolite Formations in northern Belgium: a synthesis. Geologica Belgica [En ligne], Volume 23 (2020), number 3-4 - The Neogene stratigraphy of northern Belgium, 297-313 URL : https://popups.uliege.be/1374-8505/index.php?id=6841.

65 Acknowledgements

All authors of the individual Lithostratigraphic Information Sheets are sincerely thanked for their expertise, discussions and collaboration amongst each other and within the Subcommission. A special thanks goes out to Noël Vandenberghe and Stephen Louwye for their persistence in compiling the Neogene stratigraphy within the Subcommission and encouraging authors to compile their insights. Marleen De Ceukelaire was a great help in searching the archives of the Belgian Geological Survey for publications, boreholes and outcrops. We are grateful that the National Commission on Stratigraphy appreciated our work on the standardization of the Lithostratigraphic Information Sheets and has accepted to discuss and to publish the renewed formal stratigraphy, based on this proposal document.

66 References

Besides these refences for the general chapters of this document, each Lithostratigraphic Information Sheet (chapters 3 to 64) has its own dedicated reference list.

Vandenberghe, N. & Louwye, S. (eds.), 2020. The Neogene stratigraphy of northern Belgium. GEOLOGICA BELGICA, vol. 23, no. 3–4, 2020, 427p. https://popups.uliege.be/1374-8505/index.php?id=6323

Vandenberghe, N. & Louwye, S., 2022. Stratigraphic chart of the Neogene of Belgium, discussion document, edition 2022. https:// ncs.naturalsciences.be/paleogene-neogene.

Verhaegen, J., Adriaens, R., Deckers, J., De Nil, K., Everaert, S., Houthuys, R. & Vandenberghe, N., 2022. Excursion through the Neogene of northern Belgium, Symposium 'Towards a revised Neogene stratigraphy of Belgium' 2022, National Commission for Stratigraphy Belgium. 38p. https://dov.vlaanderen.be/index.php/page/excursie-door-het-neogeen-van-vlaanderen