Lithostratigraphic Information Sheets

Proposal for discussion

(this version is replacing Vandenberghe & Wouters, 2011 presently at the NCS website)

RUPEL GROUP

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Content

Rupel Group

Hierarchical unit name : not existing

Type: Group

Authors of the LIS: Noël Vandenberghe & Laurent Wouters

Alternative names: The present LIS is a further elaboration of the previous NCS website version of the Rupel Group by the same authors. Note however that in contrast to earlier versions of the stratigraphic inventory, the Voort Sand is no longer included in the present definition of the Rupel Group. This follows from the integration of the mainly Chattian sand and clay units, such as the Voort Sand, into the Veldhoven Formation of Chattian to Aquitanian age (De Nil & Verhaegen, 2022) occurring dominantly in the RVG; hence further including these units in the Rupel Group would expand this group too far outside its core area of occurrence.

Origin of the name: Following the tradition of the Subcommission Paleogene-Neogene Stratigraphy formations have been grouped under the name of rivers or of a geographic area in the region of the main occurrence of the formations (Maréchal, 1993).

The Rupel river area is the iconic outcrop area of the Boom Clay which is at the same time the main lithostratigraphic unit of the Group and the unit stratotype of the 'Rupélien' introduced by Dumont (1849) for the middle part of a threefold subdivision of the Oligocene time. Therefore, although the term Rupelian is the international chronostratigraphic stage name for the lower part of a twofold Oligocene subdivision (ICS International Chronostratigraphic time scale and discussed in Van Simaeys & Vandenberghe (2006)), the name of the river Rupel is also given to the lithostratigraphic group in which the Boom Clay occurs.

Formal

Date LIS: edited May 2023

How to refer: …………….

1. Characterizing Description (Figs. 4 & 5)

The term Rupel group is referring to the **Boom Clay Formation**, the main clay unit in the group, and to the other fine-grained sandy or clayey deposits which are sedimentologically, paleogeographically and geometrically related to the Boom Clay. These comprise on the one hand the superjacent much sandier **Eigenbilzen** Sand Formation displaying in some outcrops the typical rhythmicity of the Boom Clay and considered as a geometrical and mainly lateral equivalent of part of the Boom Clay. On the other hand in East-Limburg a sandy unit, the Kerniel Sand, splits up the main clay unit in two parts: the overlying clay designated as Boom Clay and the thinner underlying clay unit as the Kleine-Spouwen Clay (Van den Broeck, 1883a,b). Also included in the Rupel Group is the coastal Berg Sand, underlying the Kleine-Spouwen Clay; in some areas the Berg Sand also occurs below the Boom Clay where it is a paleogeographical lateral evolution of the lower part of the Boom Clay. The Kerniel Sand, Kleine-Spouwen Clay and Berg Sand are grouped as members into the **Bilzen Formation**.

Lithologically and from a sedimentary sequence genetic perspective the lagoonal to shallow marine Ruisbroek Sand unit underlying the Boom Clay in the northwestern part of the occurrence area of the Rupel Group could be included into the Rupel Group (Vandenberghe et al., 2002), but as it occurs in the top of an alternation of lithostratigraphic clay and sand units, originally abbreviated a (argile) and s (sable) and grouped as the 'Complexe argilo-sableux de Kallo' by Gulinck (1969), it has been grouped as a member in the Zelzate Formation of the Tongeren Group (see NCS website). An analogous remark could be made about the Borgloon Formation of the Tongeren Group underlying the Rupel Group in its southern and eastern occurrence area as these deposits make up the initial sediments of the important transgression that will later deposit the Rupel Group sediments (Vandenberghe et al., 2003).

2. Type section, type locality, type borehole, type geophysical borehole.

The Rupel Group is slightly dipping to the north-northeast (Figure 1b). It reaches the surface at the south-southwestern rim of its occurrence area, except in the northern Hageland, where channel erosion and channel infill has removed the Rupel Group sediments and replaced it by the Neogene Diest Formation. As a consequence, two main outcrop areas can be considered: a western area comprising the Land van Waas, the Rupel area and the Nete-Dijle interfluvium, and an eastern area comprising the southern Hageland and the Demer area in Limburg (Figure 1a).

As reference sections for the Rupel Group in the Antwerp Campine, the cored and geophysically logged boreholes at Weelde (SCK 98) and Mol (SCK-15), together with ON-Mol-1 and ON-Dessel-1, are chosen as representative for the Eigenbilzen and Boom Formations (Figure 2). In the Limburg area the geophysically logged Koewijde-KS2 borehole and the temporary outcrop along the Albert Canal near Eigenbilzen are chosen showing the Bilzen, Boom and Eigenbilzen Formations (Figure 3) (Vandenberghe et al., 2001).

3. Description of upper boundary

Generally in the Antwerp province the Rupel Group has been eroded and its top is now situated in the Boom Clay Formation, or in the north of the province the Eigenbilzen Formation (Figure 1b). The upper boundary is easily recognized as this clay is overlain by glauconitic sands of commonly Neogene age or locally of Chattian age. However towards the east and in the Limburg province the Chattian Voort Sand overlies the Eigenbilzen Sand of the Rupel Group, making the recognition of the Rupel Group top in some cases more tedious, in particular in non-cored rotary drilled boreholes. Indeed the Voort Member covers the Eigenbilzen Formation without noticeable gravels or reworked deposits at its base. The boundary however can be recognised by a colour transition from grey Eigenbilzen Sand to green glauconite-enriched Voort Sand, by a slightly lower clay content and coarser grain-size in the Voort Sand, and especially by the common occurrence of shell fragments in the Voort Sand.

Geophysical well log characteristics are not very helpful to locate the boundary between the Eigenbilzen Fm and the Voort Sand. On regional reflection seismic profiles a slight unconformity is observed between the Eigenbilzen Formation and the Voort Member, the logical extension of the observed important erosional top of the Rupel Group in the west (Dusar & Vandenberghe, 2020).

4. Description of the lower boundary

In the area where the Boom Clay Formation of the Rupel Group directly overlies the Ruisbroek Sand of the Zelzate Formation (Tongeren Group), the base of the Rupel Group is relatively easily picked where the fine sand of the Ruisbroek Sand is relayed by the silt dominated lower part of the Boom Clay Formation. This change is also particularly well expressed on the Res geophysical log (Figure 2). In the Waasland outcrop zone (SVK pit) a phosphatic bed occurs at the boundary (Vandenberghe et al., 2002).

In the area where the base of the Rupel Group consists of the Bilzen Formation (Figure 3) the basal member systematically consists of the coastal marine Berg Sand. In outcrop sections the sand is easily distinguished from a variety of underlying coastal plain deposits belonging to the Borgloon Formation of the Tongeren Group (NCS website). A typical gravel of black flat cm-size flint generally occurs at the base of the Berg Sand.

5. Thickness

The maximal thickness in North Belgium is about 140 m (Weelde SCK 98 borehole) and about 120 m in the Mol-Dessel area (Figure 2). Compared to the North Belgium area the Rupel Group was eroded by about 80 m towards the Antwerp area (De Man et al., 2010). In the outcrop zone along the Rupel river the thickness is even further reduced to about 40 m (Reet borehole). In the Land van Waas area only the lower part of the Rupel Group is preserved, about 12 m clay is exposed in the former clay pit at Sint-Niklaas (SVK pit). Along the Albert Canal in Southeast Limburg the Rupel Group thickness is about 45 m (Figure 3).

6. Occurrence

The deposits of the Rupel Group occur north of the rivers Durme, Rupel, Dijle, and of the line Leuven-Tongeren. Along the southern rim of this area, the Rupel Group crops out. The deposits dip to the north and are therefore present in the subsurface of the Antwerp Campine and Limburg Campine areas (Figure 1b).

7. Regional correlations

Vandenberghe et al. (2001) have presented a correlation scheme, based mainly on geophysical well signatures and cored boreholes, between the clay-enriched, sand-enriched and silty to sandy clay units across North-Belgium, the Lower-Rhine area in Germany and South Limburg and the Achterhoek in the Netherlands. An actualized version for Belgium is presented in Figure 4.

8. Age

The chronostratigraphic scheme presented in Figure 5 is based on the Geological Times Scale 2020 (Speijer et al., 2020). Note that the age for the GSSP Chattian is slightly different (27,82 Ma) in the ICS chart (2023/4). Chronostratigraphic anchoring is based on magnetostratigraphy (Lagrou et al., 2004) and on nannoplankton and dinoflagellate biostratigraphy. The identification of *D. biffi* in Van Simaeys et al. (2005) has not been withheld (for arguments see 5.1 in Munsterman and Deckers, 2020). The hiatus between Rupelian and Chattian is mainly situated in Rupelian time (see also Coccioni et al., 2018). In addition age intervals within the Rupel Group are based on the obliquity cycles in the ON-Mol-2D borehole (Vandenberghe et al., 2022) starting with the base of Rupel Group at 32 Ma (NP22/NP23 boundary). A silicified foraminifera event is considered the start of the tectonic tilting with uplift and erosion in the west (De Man et al., 2010). The boundary between the Rupel Group and the overlying

Veldhoven Formation (line 4) is a low angle unconformity (Dusar and Vandenberghe, 2020 3.2) and in northeast Belgium at this level the RVG graben fault activity resumes depositing much thicker Chattian deposits in the graben. The hiatus between the top of the Rupel Group and the base of the Chattian Voort Sand is dated following De Man et al. (2010) and Coccioni et al. (2018). The age of the basal Voort Sand is put at the start of the *Svalbardella* interval including the *Asterigerina* horizon almost at the NP24/NP25 boundary (Coccioni et al., 2018 table 1; Speijer et al., 2020 fig.28.11). Assuming the latter boundary only slightly deviates from the North Sea NP24*/NP25* proxy (De Man et al., 2010), the Voort Sand outlier in the Antwerp area is correlated to this nannoplankton boundary (Vandenberghe et al., 2004).

Bilzen Formation

Unit Name: Bilzen Formation

Hierarchical unit: Rupel Group

Type: Formation

Authors of the LIS: Vandenberghe Noël & Wouters Laurent

Alternative names: The formation has been coded as Bi on the 1:50 000 geological maps. Its components are coded with R (from Rupelian) on the former 1:40 000 map and in the Stratigraphic register (Anonymous, 1929 & 1932).

Origin of the name: The name Bilzen for the formation was first introduced by Marechal (1993) based on the Nationale Commissie voor Stratigrafie: Tertiair (1988). Bilzen is a village in South East Limburg. The village lends its name to the first detailed geological map sheet in the area (1:20 000) on which the different components of what is today known as the Bilzen Formation are mapped (Van den Broeck, 1883a; Van den Broeck & Rutot, 1883).

Formal

Date: May 2023

How to refer ……..

1. Characterizing description

The formation consists essentially of fine-sized and quartz-dominated sandy sediments (the **Kerniel Member** and the **Berg Member**) and a mollusc-rich (*Nucula compta* Goldfuss, 1837) calcareous clayey intercalation (the **Kleine-Spouwen Member**) between both. The formation rests on the Tongeren Group below and underlies the Boom Formation.

2. Type section, type locality, type borehole, type CPT and/or geophysical borehole.

A complete succession of the formation is seldom accessible in outcrop. In a detailed description of a profile between Tongeren and Waltwilder, Cadee et al. (1976) represent only the Berg Sand and the

Kleine-Spouwen or Nucula Clay. Halet (1932) presents a complete profile along the Albert Canal west of Maastricht close to the profile in Vandenberghe et al. (2001, fig.10) drafted during the enlargement of the Canal section in the area of Gellik-Eigenbilzen (Steurbaut et al., 1999; Baut & Génault, 1999). Therefore the area bordering the Albert Canal northeast of the village of Bilzen is indicated as type area for the Bilzen Formation (Figure 3). A characteristic geophysical log signature of the Bilzen Formation is recorded in the borehole Koewijde-KS2 (Figures 3,9) located north of the reference Canal area (Figure 1a).

3. Description upper boundary

The Bilzen Formation is always capped by the Boom Clay Formation. The contact is a clear lithological contrast if the top of the Bilzen Formation consists of the Kerniel Sand or the Berg Sand. However towards the west and northwest the Kerniel Sand disappears and the Kleine-Spouwen Clay is in direct contact with the Boom Clay. Although in the subsurface Gulinck (1975) still could follow the Kleine Spouwen Clay Member as an individual layer in the base of the massive Boom Clay as far westwards as the Winterslag colliery shaft, such distinction is tedious and therefore the entire clay section is considered as the Boom Clay Formation. This means that the upper boundary of the Bilzen Formation in this situation equals the upper boundary of its Berg Sand Member. In such situation, geophysical logs in the overlying Boom Clay show a marked change in signature from sand to clay, marked by a black arrow 1, correlating laterally with the base of the Kleine Spouwen Clay (examples in Figures 6, 8a,b,c,d and Vandenberghe et al. (2001 figs. 5 to 9)); this correlation is confirmed by paleontology as far as in the Waasland and Brabant areas (Steurbaut et al., 1999; Vandenberghe et al., 2001 p 71).

4. Description lower boundary

The transgressive Berg Sand is always present at the base of the Bilzen Formation and in the western part of the formation's occurrence area it is even the sole unit of the formation (see in 3.). Its base overlies a variety of coastal plain deposits of the Formation of Borgloon (Tongeren Group) displaying a very different sediment type from the Berg Sand and hence the base of the Bilzen Formation is generally easily recognised. If geophysical logs show the presence of a similar sand type below the Berg Sand, the boundary is tentatively put at the base of the upper broad gamma ray or resistivity lobe and thereby respecting the general thickness of the Berg Sand (e.g. Donderslagse Heide KS29 (Figure 6), Opglabbeek Industrie KS19 (Figure 8a)).

5. Thickness

Depending on the presence of all 3 composing members of the Bilzen Formation its thickness varies between 5 and 25 m.

6. Occurrence

The formation crops out in the south of the Hageland and in Limburg (Figure 1a). Further north, the formation occurs in the deeper parts of the subsurface of the eastern Campine while in the western part it is laterally relayed by the lower part of the Boom Clay Formation (Figures 8a,8b,8c,8d). Three areas can be distinguished (Figure 7): a zone southeast of the line Maaseik, Genk, Hasselt where the three members of the Formation occur, a central zone around Aarschot-Leopoldsburg with only the Berg

Member present and the northwest zone including Mol-Dessel, the Antwerp Campine and the Boom Formation type area, where the Bilzen Formation is laterally entirely replaced by the Belsele-Waas and Terhagen Members of the Boom Clay Formation. Note that the quality of presently available data in the boundary areas between the 3 zones makes the exact interpretation of the stratigraphic unit present remaining debatable (for example compare the Kerkhoven borehole in Figure 8a and in Vandenberghe et al. 2001 fig. 5).

7. Regional correlations

Geophysical borehole logs allow to correlate the different members of the Bilzen Formation in Belgium and also into the neighboring areas in the Netherlands and Germany (Vandenberghe et al., 2001). In Germany, the Berg Sand is known as the Walsumer Sand and the Kleine-Spouwen Clay as the Ratinger Ton. In Belgium to the west, as discussed above (3. & 6. and Figures 8a,b,c,d), the Kleine-Spouwen Member is relayed by the lower part of the Terhagen Member of the Boom Clay Formation, the Kerniel Sand by the main part of the Terhagen Member and the Berg Sand Member is relayed by the Belsele-Waas Member of the Boom Clay Formation (Steurbaut et al., 1999; Vandenberghe et al., 2001). Note that Figures 8c & 8d suggest that it is possible that the upper finest grained part of the Berg Sand already correlates to the lowermost part of the Terhagen Member.

8. Age

The base of the Berg Sand, the lower member of the Bilzen Formation, occurs at the start of the nannoplankton biozone NP23 (Steurbaut et al., 1999) estimated at 32 Ma. Therefore the Bilzen Formation can be situated in the lower part of this biozone as figured in Vandenberghe (2017, fig.4) (Figure 5).

Berg Sand Member

Unit : Berg Sand Member

Hierarchical unit name: Bilzen Formation, Rupel Group

Type: Member

Authors of the LIS: Vandenberghe Noël and Wouters Laurent

Alternative names: No other names have been used. However it should be noted that the Ruisbroek Sand unit occurring below the Belsele-Waas Member of the Boom Clay Formation has sometimes been mistaken for the Berg Sand, simply because geometrically both sand units occur under the clay.

On the geological maps 1:40 000, the Berg Sand Member has been labelled R1b and its basal gravel has been separately labelled R1a (Anonymous 1892, 1896, 1900, 1909) while in the Stratigraphic register (Anonymous 1929,1932) the Berg Sand was labelled R1. On the recent 1: 50 000 map, the Berg Sand Member is coded as BiBe.

Origin of the name: The name was introduced by Van den Broeck (1883b) in an explanatory note of the 1/20.000 geological map Bilzen. Berg is a hamlet northeast of Tongeren, and is a dependent municipality of the city of Tongeren (Limburg province).

Formal

Date: May 2023

How to refer …..

1. Characterizing description

The base of the Berg Sand Member is a regionally occurring transgressive surface characterized by black and flat flint pebbles generally about 2 to 3 cm in diameter. In the exposure area Leuven-Tienen-Tongeren, the Berg Member consists of yellowish to pale grey, slightly glauconitic, medium-grained quartz sand. It is expected that under the water table the sand may turn more greyish. In the about 6 m thick outcrop section the lower part is clearly horizontally bedded with a 150-175 µm grain-size modal value but the upper part is more homogeneous and cohesive with a modal size of 100-125 µm and clay fraction approaching 10% at the top (Gullentops, 1988 p. 242-243). Probably the twofold nature of the geophysical signal of the Berg Sand Member in some borehole logs reflects the same lithological subdivision as observed in outcrops (Figures 8c,8d,10). At particular levels (Figure 10) occur sparse molluscs, a.o. *Astarte trigonella* (Nyst, 1845), *Glycymeris obovata* (Lamarck,1819) and *Arctica islandica rotundata* (Agassiz, 1845) (Glibert & de Heinzelin, 1954; Glibert, 1955 & 1957 and for nomenclature see also Marquet et al., 2012).

2. Type section, type area, type borehole, type geophysical borehole

Van den Broeck (1883b) refers to the "gîte classique de Berg", an outcrop along a road on the southern slope of the small hill on which the hamlet Berg (north of Kleine Spouwen, southeast of Bilzen) is located. For the ancient references to this historical stratotype see Glibert & de Heinzelin (1954 p. 301, point 200 and map fig.4) (Coordinates: X = 233.040; Y = 171.340; Z = + 105 m). In the archives of the Geological Survey of Belgium more recent information on investigations at this site can be found (Archives Geological Survey 93W0243).

A long standing outcrop of the Berg Sand Member is the Roelants extraction pit at Lubbeek near Leuven (Figure 10). In the subsurface, the geophysical signature of the Berg Sand Member is well expressed on resistivity and gamma-ray logs (Figures 8a, 8b, 9 and figs. 8, 9 in Vandenberghe et al., 2001).

3. Upper boundary description

The Berg Sand Member is overlain by a grey clay deposit, either the Kleine Spouwen Member or the Boom Clay Formation and therefore the upper boundary contact is always sharp (Figure 10).

4. Lower boundary description

The Berg Sand Member is overlying a variety of coastal plain facies of the Borgloon Formation of the Tongeren Group. The contact is always fairly easily recognizable as an extensive subhorizontal transgressive surface with characteristic small flattened black pebbles occurring at its base; even if the underlying Borgloon Formation facies also consists of sand, differences in colour and in sedimentary structures allow an easy recognition of the base of the Berg Member. However if in the subsurface geophysical logs show the presence of a similar sand type below the Berg Sand unit itself, the boundary is tentatively put at the base of the upper broad gamma ray or resistivity lobe respecting the general thickness of the Berg Sand as is shown in the Donderslagse Heide KS29 log (Figure 6) and the Opglabbeek Industrie KS19 log (Figure 8a).

5. Thickness

The thickness of the Berg Sand Member is between about 5 and 10 m.

6. Occurrence

The Berg Member occurs in outcrops and in the shallow subsurface in the Leuven-Tienen-Tongeren area, and slightly north of this area. Towards the northwest the Berg Sand Member continues in the subsurface but will be relayed by the Belsele-Waas Member of the Boom Clay Formation northwest from the area Mechelen Geel Mol onwards (Vandenberghe et al., 2002; Vandenberghe et al., 2001 figs. 4,5) (Figure 7).

7. Regional correlations

For paleogeographical reasons the Berg Sand Member transits to the northwest into the Belsele-Waas Member of the Boom Clay Formation. The Berg Sand corresponds to the Walsumer Sand in Germany.

8. Age

The Berg Sand Member contains nannoplankton biozone NP23. The transition from the NP22 to NP23 biozone occurs precisely at the base of the member which is exactly the same biostratigraphic position of the base of the Belsele-Waas Member of the Boom Clay Formation overlying the Ruisbroek Member of the Zelzate Formatie. The age estimate for this biostratigraphic boundary is 32 Ma (Speijer et al., 2020).

Kleine Spouwen Clay Member

Unit: Kleine Spouwen Member

Hierarchical unit name: Bilzen Formation, Rupel Group

Type: Member

Authors LIS: Vandenberghe Noël and Wouters Laurent

Alternative names: A short historical review of the stratigraphic classification of the clay unit called nowadays the Kleine Spouwen Member is given in Glibert & de Heinzelin (1954 p 283-284 and Tableau I). Based on his mapping of the Bilzen 1:20 000 sheet, Van den Broeck (1883a,b) individualized the now-named Kleine Spouwen clay unit and separated it from underlying units. This clay unit was labelled as R1c on the geological maps 1:40 000 (Anonymous, 1892,1896, 1900, 1909). However the name used to refer to the clay unit, already as long ago as Bosquet (1851), was 'the clay with *Nucula comta* (or *compta*)' as this shell is commonly present in the clay. In the Legend of the geological map 1:40 000 the clay is described as 'argile en masse lenticulaire à *Nucula compta'* (Anonymous 1909), as 'clays with Nucules' in the Stratigraphic register (Anonymous, 1929,1932) where it is labeled R2a and as 'Argile sableuse à nucules' in Glibert & de Heinzelin (1954). Gulinck (1954) reports on 'l'argile à Nucula comta, dite aussi argile de Klein-Spauwen'. 'Argile sableuse à Nucula comta' is also reported by de Heinzelin & Glibert in the Lexique Stratigraphique International (Denizot, 1957 p 142). At the occasion of their study in the Sint-Truiden area Bor et al. (1980) have also presented a detailed historical nomenclature review used for the clay unit and concluded with the proposition to use the name Nucula Clay Lyell,1852, emend. However in the logic of naming lithostratigraphic units with reference to a locus typicus, the Nationale Stratigrafische Commissie (1988) decided to further use the term Kleine Spouwen Member. On the recent 1:50 000 geological maps the Kleine Spouwen Clay Member is coded BiKs. Note that several spelling variants have been used in literature used (Kleine-Spauwen, Klein-Spauwen, Kleyn-Spauwen,...).

Origin of the name: The clay unit was individualized as a separate stratigraphic unit by Van den Broeck (1883b) in an explanatory note of the geological map Bilzen (scale 1/20.000). However it was originally named the 'argiles à Nucules' (see Alternative names) and the term 'Klein-Spauwen Clay' was only introduced later (Gulinck, 1954). Kleine Spouwen is a village in South East Limburg, today a dependent municipality of Bilzen.

Formal

Date: May 2023

How to refer …..

1. **Characterizing description**

The member consists of greenish to yellowish grey clay, turning brownish when oxidized. The member is frequently calcareous, rich in foraminifera and with numerous *Nucula comta* accompanied by some more rare shells. Calcareous concretions have been described by Gulinck (1954). The fossils indicate a fully marine depositional environment (see also Janssen, 1979). The presence of sand has been described by several authors and Gulinck (1954) even reports that it may grade into the underlying sand of the Berg Member accompanied with a thickness reduction.

2. **Type section, type area, type borehole, type geophysical log**

The type area undoubtedly is the Kleine and Grote Spouwen area between Bilzen and Tongeren. Glibert & de Heinzelin (1954) refer to the 'gisement classique de l'argile à nucules' in the outcrop points 205-206 in Kleine Spouwen (op.cit. p 301 and map fig.4) and present a section through the Kleine Spouwen hill (op.cit. p 306 fig. 12) that was also referred to by Van den Broeck (1883b). This section through the hill has coordinates between X = 233.180, Y = 170.420, Z = + 117 m and X = 232.860, Y = 170.250, Z = + 122 m. This is also the type locality reported in the Lexique Stratigraphique International (Denizot, 1957). In the subsurface, the geophysical signature of the Kleine Spouwen Clay Member is well expressed on resistivity and gamma-ray logs (Figure 9; Vandenberghe et al., 2001 figs. 8 ,9).

3. **Upper boundary description**

When the Kleine Spouwen Clay Member is overlain by the Kerniel Sand Member, generally the lithological contrast is easily picked, although Matthijs (1999 p. 41) also reports that the transition can be gradual. Westwards from its type area (map Figure 7) the Kerniel Sand wedges out and the geophysical logs loose the individual signatures of the Kerniel and Kleine Spouwen Members (Figure 8a and Vandenberghe et al., 2001 fig. 9). There the Kleine Spouwen Clay becomes overlain directly by the Boom Clay and the entire clay unit is described as part of the Terhagen Member of the Boom Clay and it directly overlies the Berg Sand Member of the Bilzen Formation. Gulinck (1975) could still identify the Kleine Spouwen Clay Member as an individual layer directly under the Boom Clay, till the Winterslag colliery shaft, slightly more westwards than where the geophysical borehole logs loose the individual Kleine-Spouwen and Kerniel Member signals (Figure 8a). On geophysical logs, where the Berg Sand is directly overlain by the Boom Clay, a characteristic sharp increase in clay content is observed just above the Berg Sand Member and labelled with a black arrow 1 (Figures 6, 8a). This arrow 1 signal can be observed westwards above the Berg Sand and even further westwards above the Belsele-Waas Member in the Rupel area (Figures 8d, 11). Remarkably the clay section between this arrow 1 above the Belsele-Waas Member in the Waasland area and the base of the Boom Clay Formation above the Berg Sand in Brabant has the same biostratigraphic content as the Kleine Spouwen Clay Member in its type area in the east (Vandenberghe et al., 2001 p 71). Steurbaut et al. (1999) have correlated the biostratigraphic content of the type Kleine Spouwen Clay with the interval between the top of the Belsele-Waas Member (from bed IV/5 in Figure 12) and the septaria level S 10 in the Boom Clay Formation area (see Figures 8d, 12).

4. Lower boundary description

The Kleine Spouwen Clay Member always overlies the Berg Sand Member and therefore the lithology contrast gives a clear lower boundary of the Kleine Spouwen Member. Gulinck (1954) reports that in some places the clay unit seems to be replaced at its base by the underlying sand (see 1.).

5. Thickness

The member has a reported maximum thickness of 10 m (Claes et al. , 2001). Gulinck (1954) notes that the development of the clay unit is very irregular.

6. Occurrence

The Kleine Spouwen Clay Member occurs in the shallow subsurface of the Sint-Truiden–Tongeren area in South Limburg (Claes et al., 2001; Claes & Gullentops, 2001), and is known northwards as far as Genk, Waterschei, Winterslag, Maasmechelen–Eisden (map Figure 7) (see also 3.). On the Hasselt geological map sheet, Matthijs (1999) reports thickness between 6 and 9 m and notes that variations in thickness suggest tectonic activity in the area.

7. Regional correlation

As discussed in section 3, a carbonate rich signature of the Kleine Spouwen Member can be traced far to the west where it is no longer recognized as the individual Kleine Spouwen Member but forms the lower part of the Terhagen Clay Member of the Boom Clay Formation, up to and including the septaria S10 level. The Kleine Spouwen Member can be traced into the Netherlands and also in the Lower Rhine area where it is named Ratingen Ton or Tonmergel and contains a septaria horizon correlated with septaria horizon S10 (Vandenberghe et al., 2001 fig. 15).

8. Age

Paleontological data show that the Kleine Spouwen Clay Member falls within the same biozonation as the interval between the top of the Belsele-Waas Member and the Terhagen Member clay around septaria level S10 (Steurbaut et al., 1999; Vandenberghe et al., 2001 p71).

Kerniel Sand Member

Unit: Kerniel Member

Hierarchical unit: Bilzen Formation, Rupel Group

Type: Member

Authors LIS: Vandenberghe Noël and Wouters Laurent

Alternative name: The labelling of the Kerniel Sand on the 1:40 000 geological map (Anonymous 1909) consists of 3 codes: R1d, R2a and R2b. The reason is that within the Rupelian stage (R), two 'assises' were distinguished (R1 & R2); within each of these marine cycles or 'assises' a theoretical sedimentary cycle was assumed with successive facies 'a' (gravel), 'b' (transgressive sand), 'c' (deeper marine clay) and 'd' (regressive sand) (Rutot, 1883). As the Kerniel Sand at Kerniel near Borgloon (Looz) interpreted by Van den Broeck (1893 p. 270) as a stratigraphically independent sand unit between two deeper marine clay units, the argile à Nucula comta (Kleine Spouwen Member) and the argile à Leda Deshayesiana (Boom Formation), this intermediate Kerniel Sand unit needs to be composed of a succession of regressive sand, a base gravel and an overlying transgressive sand, labelled respectively as R1d, R2a and R2b.

In the Stratigraphic Register (Anonymous, 1929,1932) the sand unit corresponding to the Kerniel Sand is not listed. On the recent 1: 50 000 geological maps the coding for the Kerniel Sand is BiKe.

Origin of the name: The sand unit has been recognized as an individual stratigraphic subdivision in an explanatory note of the geological map Bilzen 1/20.000 by Van den Broeck (1883a, 1883b). Van den Broeck (1893 p 270) refers to the Kerniel section near Looz (Borgloon) as an example of the sand unit between the Kleine Spouwen Clay Member and the Boom Clay Formation. The village of Kerniel lies north of Borgloon and is now a dependent municipality of Borgloon (Limburg province). The term Sand of Kerniel has been used by Glibert and de Heinzelin (1954) and Gulinck (1954).

Formal

Date: May 2023

How to refer …..

1. Characterizing description

The Kerniel Sand Member consists of medium-grained, white to yellowish quartz sand with only rare mica and glauconite grains. The sand has been described as clayey at the base and fining towards the top. Occasional layers of *Glycymeris obovata* (Lamarck, 1819) shells and marine shell imprints have been described in the upper part. Other characteristic species are *Arctica islandica rotundata* (Agassiz, 1845), *Pycnodonte queteleti* (Nyst,1853), *Hilberia hoeninghausi* (Defrance, 1825) (Vervoenen, 1995; Baut &

Génault, 1999). Except for some reworked foraminifera, no microfauna has been observed. Small lignite fragments are occasionally present. In Limburg the gravel in the middle of the sand unit is reported to be well developed and consists of rounded quartz and flint pebbles (from Van den Broeck 1893 p 285, 280; Gulinck, 1954; Batjes, 1958; Kruissink et al., 1978; Claes et al., 2001; Claes & Gullentops, 2001).

As the Kerniel Sand Member is seldom exposed, the Gellik-Eigenbilzen Albert Canal section in the early 90's of the previous century is an exceptional outcrop worth mentioning. The section was studied for fossils by Vervoenen (1995) and Baut & Génault (1999). Remarkably in the middle of the 9-10 m thick sand section the last authors describe a dm thick shell grit layer (op.cit. fig.4) with a wavy eroding base (op.cit. fig.3) containing fish and other vertebrate remains and also small white quartz pebbles, undoubtedly the same level described by Steurbaut et al. (1999) with channels, gravel and oblique lamination. This observation seems to fit the subdivision in three units labelled R1d, R2a, R2b by Van den Broeck (1893) as discussed above.

2. Type section, type area, type borehole, type CPT and/or geophysical log

Van den Broeck (1883) refers to the railroad Looz (Borgloon)-Kerniel, at Kerniel, a section in which he originally had erroneously taken the Kerniel Sand for 'boldérien sableux' (Van den Broeck, 1893 p 270) (an interpretation still held for possible by Gullentops, oral com.). This railroad section is point 163 in Glibert & de Heinzelin (1954, p 299 and map fig.4). In the close vicinity Glibert & de Heinzelin (op. cit.) report an open sand pit in the Kerniel Sand at their point 164 and a few other outcrops.

In the subsurface the sand lithology of the Kerniel Member between the clays of the Kleine Spouwen Member and the Boom Formation is easily recognized on geophysical logs (examples Figures 3, 8b, 9 and Vandenberghe et al., 2001 fig. 9).

3. Upper boundary description

Unless erosion has left Quaternary deposits directly above the Kerniel Sand, the member is overlain by the Boom Clay Formation, and therefore the top of the Kerniel Member is a clear lithological boundary.

4. Lower boundary description

Although the base of the Kerniel Sand Member is reported to contain some clay (Kruissink et al., 1978 fig.2 ; Claes et al., 2001; Claes & Gullentops, 2001) the contact with the underlying Kleine-Spouwen Clay Member is generally beyond difficulty. This is in line with the clear distinction observed on resistivity and gamma-ray logs (examples Figures 3, 8b, 9 and Vandenberghe et al., 2001 fig. 9).

5. Thickness

Thickness of the Kerniel Sand Member varies from 5-7 m on average to maximal 10 m (Claes et al., 2001; Claes & Gullentops, 2001).

6. Occurrence

The Kerniel Member occurs in South Limburg: northeast and east on the geological map sheet Sint-Truiden and north on the map sheet Tongeren (Claes et al., 2001; Claes & Gullentops, 2001) (Figure 7). Further northwards in the subsurface, the member can be identified on geophysical logs as far north as the boreholes Koewijde-KS2 (Figure 3, 9), Dornerheide-KS6 (Figure 8a), and Ruwmortelsheide-KS22

(063E0222 and Vandenberghe et al. 2001 fig. 9), whilst west of these boreholes the Kerniel Member, as well as the Kleine-Spouwen Member are absent in the Opglabbeek-KS19 borehole (Figure 8a and Vandenberghe et al. 2001 fig. 9).

7. Regional Correlations

The Kerniel Sand Member is relayed westwards by the Terhagen Clay Member of the Boom Clay Formation (Figures 4, 8a, 8b). Steurbaut et al. (1999) demonstrated that the paleontological content of the basal part of the Kerniel Sand section along the Albert Canal correlates with the clay layer above septaria S10 in the Boom Clay type area and its middle part with the layers 12-18 (Figure 12 numbering III). It is possible that the higher sandy or silty intervals in the Terhagen Clay Member above the interpreted Kerniel Sand Member interval in the boreholes Koewijde KS2 (numbers 1-5 in the Terhagen Member in Figure 9) and Driepaalhoeve KS3 (Vandenberghe et al., 2001 fig.9) are indicative of the lateral transition between Terhagen Clay and the thickening Kerniel Sand towards the east; in the Lower Rhine area the thicker Kerniel Sand replaces a large part of the Terhagen Member below the level with septaria S40 (Vandenberghe et al. 2001 fig. 15).

8. Age

The chronostratigraphic position of the Kerniel Sand Member is in the lower part of nannoplankton zone NP23 and is geometrically equivalent to part of the Terhagen Member of the Boom Clay Formation (Figure 4).

Boom Clay Formation

Unit name: Boom Clay Formation

Hierarchical unit name: Rupel Group

Type: Formation

Authors LIS: Noël Vandenberghe & Laurent Wouters

Alternative names: informally this unit has also been referred to as Rupelian clay or Rupel clay. In the description of the area around Bilzen, Van den Broeck (1883b) used the term “glaise schistoïde du Limbourg”. Coding on the geological maps and the stratigraphic legends has differed through time: R2c on the 1:40 000 map (Anonymous 1892,1896,1900,1909), R2b in the stratigraphic registers (Anonymous 1929,1932) and Bm on the most recent 1:50 000 geological maps in use today (https://www.vlaanderen.be/publicaties/lithostratigrafische-tabel-van-het-neogeen-en-paleogeen-tertiair-lithostratigrafic-of-the-paleogene-and-the-neogene-in-flanders).

Origin of the name: The reference to Boom has been made for the first time in literature by De Koninck (1837) describing ‘l’argile de Basele, Boom , Schelle etc.’. Boom is the main town along the Rupel river where the clays have been extensively exploited for structural clay products like bricks, floor and roof tiles.

Formal

Date: May 2023

How to refer : ……….

1. **Characterizing description**

1.a. General lithological properties of the Boom Clay Formation

An extensive synthesis on the Boom Clay geology is given in Vandenberghe et al. (2014). The Boom Clay is a grey silty clay or clayey silt with fairly constant chemical and mineralogical properties. Macroscopic fossil content is limited and mostly single shells of the mollusc *Portlandia deshayesiana* (in the literature also reported as *Nuculana* and *Leda*) are observed.. The ecological analysis of all observed fauna and flora in the clay proves the marine character of the clay deposit. The Boom Clay has been deposited in an open shelf sea under warm climatic conditions as a life-supporting mud at an approximate depth of about 100 m for the most clay-enriched parts, although the water depth fluctuated with several tens of meters due to eustatic variations during the full history of the clay sedimentation. The most silty horizons contain glauconite pellets. The clay contains a few percent of very early diagenetic, mm to cm and even dm scale concretionary pyrite that formed clearly associated with the presence of organic matter in the clay. Black staining of the clay is due to the presence of an increased amount of fine particles of land-derived plant remains. Small quantities of marine organic matter adsorbed on the clay minerals are always present. Marl horizons occur and typically large septaria concretions have developed in the most calcareous horizons. The septaria are an iconic property of the Boom Clay Formation (Septarienton in Germany). Detailed clay mineralogy of the Boom Clay can be found in Zeelmaekers et al. (2015).

1.b. The micro-lithostratigraphy of the Boom Clay

The clay is typically banded with layers of about 20 to 50 cm thickness, expressed by rhythmic variations in silt content producing shades of grey, black layers with increased amounts of land-derived plant remains and paler clay enriched in carbonates. Some originally marl horizons are now almost completely converted into septaria horizons.

Importantly, all these thin layers can be correlated in outcrops or by geophysical log signatures in the subsurface and hence they define a constant vertical succession for the entire Boom Clay (Vandenberghe, 1978; Vandenberghe et al., 2001). Therefore the layers can be used as a microstratigraphic instrument. Eastwards in the Limburg Campine area however the upper part of the clay becomes more sandy and grades into the Eigenbilzen Formation (Figure 4).

The succession of the layers in the outcrop area have been established and numbered by Vandenberghe (1978, p.39) and a more complete numbering scheme has been further developed by Mertens & Wouters (2003) based on the detailed analysis of cores and geophysical borehole logs in several boreholes related to the NIRAS/ONDRAF SCK/CEN research project for the deep storage of nuclear waste in the Mol-Dessel area (Figure 12).

As numbering has been developed over the years some authors have used numbering systems slightly deviating from the original and all explained in Figure 12 under the roman-figure headings (I,II,III, IV, V). Especially in the lower thick silt layers of the Boom Clay a consistent numbering between areas remains difficult as the thickness of this basal part of the clay increases to the northeast as illustrated with the boreholes Reet (Rupel cuesta) and ON-Dessel-1 (Campine) correlated in Vandenberghe et al. (2001, fig.7) (Figure 11).

It is not excluded that the number of microstratigraphic layers detected will still increase if in the future more of the detailed signals on the geophysical logs could become consistently identified between boreholes. An example is the layer 39 sensu Abels et al. (2007) (heading II in Figure 12). This layer is recognisable on resistivity logs but not individually numbered as it is less well outspoken in field logging (see Vandenberghe, 1980 fig. 139) although the original grain-size data (Vandenberghe 1978) already suggested the presence of an additional silt horizon, later confirmed by detailed analyses by Van Boven (1998). Another example of an additional silt horizon identified on geophysical logs compared to the field log is marked 68? on the Mol-Dessel reference section between septaria levels S70 and S80 (Figure 12), or septaria level S75 in De Craen (1998 fig.V-4).

1.c. Bed status for key layers.

In the microstratigraphic succession, not all individual layers have prominent properties that allow their easy identification in a section. However in the outcrop area some layers do and have been the key for correlating between clay pits. Therefore such layers can be considered as key-horizons and could eventually be given an official 'bed 'status. At present they are considered as informal beds. These key layers in the Boom Clay Formation outcrop area are (indicated by the number under heading III on Figure 12):

- the slightly pink to brownish horizon R (nr 21) with a thin white horizon at its base (Figure 14);
- the boundary surface between grey and black clay (between layers nr 31 and 32) , also very well expressed in the natural gamma ray logs (Figures 13,18);
- the very silty to fine sandy double layer labelled db or DB (nr 39-41) (Figures 14,17,18);
- septaria layer S20 characterised by large and numerous septaria (in layer nr 14);
- septaria layer S50 characterized by large platy septaria containing multicoloured pyrite crystals precipitated in the septae (nr 49);
- septaria layer S60 , containing siderite, rusty coloured, with visible bioturbation tracks (nr 56).

These layers are figured in Vandenberghe (1978, photographs 3, 4, 5 and 6) and in Vandenberghe et al. (2014 figs 10, 36 and 42). Other layers in the subsurface could also be singled out for their particular correlation potential such as the numbered high-resistivity signals in the Boeretang Member (heading I in Figure 12, see LIS Boeretang Member). Another particular horizon proposed for a 'bed' status is the phosporitic fragment bed at the base of the Belsele-Waas Member in the Waasland area (see LIS Belsele-Waas Member 4.).

1.d. Subdivision of the Formation into Members.

The boundaries of the 4 members in the Boom Clay Formation are indicated in Figure 12. At the base occurs the **Belsele-Waas Member** with characteristically thick silty clay layers, thereby limiting the Belsele-Waas Member to the truly silty base of the Boom Formation as shown in Figure 12; in previous studies the top of the Belsele-Waas Member was put just below the clay bed containing S10 and labelled 'original boundary' in Vandenberghe et al. (2014 fig. 12) in which study the present top was labelled as 'proposed boundary'. The **Terhagen Member** above the silty clay is a grey coloured and typically banded clay containing the S20 septaria horizon and the pinkish-brownish R bed (key layers). The overlying **Putte Member** is a black stained typically banded clay containing the silty DB bed and the characteristic S50 and S60 septaria beds. The black staining of the clay is caused by the systematic occurrence of black layers, of comparable thickness as the silty-clayey layers, characterized by increased amounts of land-derived plants. The **Boeretang Member** at the top is characterised by a coarsening upwards trend with relatively thick very silty layers alternating with clayey layers; this member is typically well expressed on geophysical well logs (Figure 2). From geometric and lithological considerations, the distinction in Limburg by Halet (1936) between light grey clays labelled R2c below sandy clay with 'schistoid' (s) black or brown plastic clay horizons labelled R2cs, could well fit the distinction Putte Member and Terhagen Member as defined in the present LIS (see Vandenberghe 1978 fig. 1.3).

2. Type section, type area , type borehole, type CPT and/or geophysical log

The area in which the Boom Clay Formation traditionally has been and still is exploited for brick making or other structural clay products, along the Rupel river between Rumst and Boom (Rupel Cuesta) and along the Scheldt between Temse and Antwerpen, is designated as the type area of the Boom Clay (Figure 1a). Instead of the former numerous brick yards with their own clay extraction pits, nowadays only two actively exploited large pits are active: the Wienerberger clay pit at Rumst and the Argex clay pit at Kruibeke-Burcht. Both clay pits are therefore the practical type sections at present. Many sections of former clay pits in the type area are documented in Vandenberghe (1978) and the cored and geophysical borehole at Reet (water tower) documents the Rupel cuesta section (Van Echelpoel, 1991 fig. 4.5; Vandenberghe et al., 2001 fig. 3).

As the upper part of the Boom Clay Formation is considerably eroded in the designated type area (Figures 4 and 5), a group of additional boreholes around Mol-Dessel in the Antwerp Campine (Mol SCK 15, ON-Mol-1 and ON-Dessel-1), is selected as reference boreholes to demonstrate the complete Boom Clay Formation section (Figures 2 and 12). The geophysical well logs of the three boreholes presented in Figure 2 are interpreted in terms of the 4 members of the Boom Clay Formation and a few key horizons. The link of the geophysical logs to the lithology section of the boreholes is easy as the same interpretation terms are figured on the lithology section of the same Mol-Dessel area in Figure 12 which is representing the most complete information extracted from cores and geophysical logging including core imaging. A correlation between the Reet borehole section in the outcrop area and the equivalent part in the Mol-Dessel area is shown in Figure 11.

3. Description upper boundary.

Where eroded, the Boom Clay section is overlain by late Oligocene or Neogene glauconitic sands. This lithological contrast is easy to pick in outcrop and on geophysical logs. If overlain by the Eigenbilzen Formation, the distinction is where the silt-and-clay-fraction- dominated Boom Clay Formation is replaced by the very-fine-sand dominated Eigenbilzen Formation. In geophysical well logging the transition is marked by a sudden change in the resistivity and gamma ray signal (Matthijs, 1999, figs. 10 & 11). In the geophysical well log collection of Vandenberghe et al. (2001), the lower part of the Eigenbilzen Fm is coded A (see Figures 3,4,6,9). Also on geophysical well logs the banded signal so typical for the Boom Clay Formation is replaced by broader lobes in the Eigenbilzen Formation (see Figure 2). In the legend accompanying the 1:50 000 map sheet 25 Hasselt, Matthijs (1999) could show that there is a gradual transition of the Eigenbilzen Formation west and northwards to the clay-enriched Boom Clay Formation (see e.g. Matthijs, 1999, fig. 12 and Figures 4 and 5).

4. Description lower boundary

The lower boundary of the Boom Clay Formation overlying the Ruisbroek Sand of the Zelzate Formation (Tongeren group), the Berg Sand or the Kerniel Sand of the Bilzen Formation (Rupel Group) is easily picked by the sharp lithological contrast between clay and sand.

5. Thickness

In the Campine subsurface, the maximal thickness of the Boom Clay Formation is about 100 to 120 m, but the formation thickness is reduced where its top is either eroded or where it is replaced by the Eigenbilzen Formation and/or the Bilzen Formation pro parte (Figure 5): e.g. a few meter thickness in the southern part of the Waasland area, 40 m in Rupel area, 40 m in the Hasselt area, 80 m in the Antwerp area and about 10 m in the Albert-Canal section near Eigenbilzen.

6. Occurrence

The Boom Clay Formation outcrops in the Waasland area, north of the Rupel river, between the Grote Nete and the Dijle-Demer rivers, and in southern Limburg (Figure 1a). North of this outcrop area the clay occurs in the subsurface, except for some locations in the Hageland where the erosion surface underlying the late Miocene Diest Formation has locally completely removed the Boom Clay Formation.

7. Regional correlations

Using geophysical logs and cored boreholes, the internal subdivisions in the Boom Clay Formation at layer scale and at member level can be straightforwardly correlated within Belgium and into the neighboring countries the Netherlands and Germany (Vandenberghe et al., 2001; Vandenberghe et al., 2014, fig. 14).

8. Age

Based on available chronostratigraphic data (Figure 5) the Boom Clay Formation is older than about 29.3 Ma and younger than 32 Ma.

Belsele-Waas Silt Member

Unit: Belsele-Waas Member

Hierarchical unit: Boom Clay Formation of the Rupel Group

Type: Member

Authors of LIS: Noël Vandenberghe and Laurent Wouters

Alternative names: In a now obsolete two-fold subdivision of the Boom Clay, Vandenberghe (1974, fig. 8.1. and p. 186; Vandenberghe, 1978) distinguished a lower grey clay and an upper black clay, respectively named Waasland clay and Putte clay. The Waasland clay included the present Belsele-Waas and Terhagen Members. The silty base of the Boom Clay Formation to which the Belsele-Waas Member refers has been long recognized and although no formal name was given to this silty base in the type area of the Boom Clay Formation it has been indicated by the special symbol 'R2b' by Halet (1936) and Gulinck (1965) (discussion in Vandenberghe, 1974, p. 186). The silty base of the Boom Clay Formation is included pro parte in the unit labelled R2c on the geological map 1:40 000 (Anonymous, 1892,1896,1900,1909) and pro parte in the unit labelled R2b in the Stratigraphic Register (Anonymous, 1929, 1932). On the recent 1: 50 000 geological maps, the Belsele-Waas Member is coded BmBw.

Origin of the name: The name Belsele-Waas Member refers to the several clay pits close to each other exploited by Scheerders-Van Kerchove, SVK nv in the second half of the 20th and first decade of the 21st century in the locality Belsele-Waas, part of the town of Sint-Niklaas (East- Flanders province).

Formal

Date: May 2023

How to refer : ……

1. Characterizing description

The Belsele-Waas Member consists of very silty grey clay, very low in carbonate and in organic matter and forms the base of the Boom Clay Formation. In the Waasland area (Figure 1a) the silt-enriched clay is divided in two parts by a thinner 50-60 cm clay horizon (bed 3 heading IV in Figure 12) (Vandenberghe, 1978 photo 9; Vandenberghe, 1980 p 162;Vandenberghe 2017 fig. 8). In the top of the lower thick silt layer occasionally small and poorly consolidated septaria-like carbonate nodules have been observed (labelled S05 in Figure 12). Compared to the Waasland area, in the subsurface of the Campine area an additional thick silty layer overlain by another thinner clay bed occurs at the base of the geophysically interpreted Belsele-Waas Member (labelled 0 in Figure 11).

Grain-size analyses of the member in the Waas area in Vandenberghe and Van Echelpoel (1987, fig. 12) show the sand fraction to be limited to 20-30% except for the very basal part. Analyses in the On-Mol-1 borehole show an upward decreasing sand content, from about 70% at the very base to about 5% in the top (Frederickx,2019 fig.35); the coarsest samples occur in the level 0 at the base of the Belsele-Waas Member in the Mol-Dessel area (Figure 11).

Compared to the overlying part of the Boom Clay, the alternation of clay and silty beds is missing in the Belsele-Waas Member. Still banding as stacked silt layers is present (Vandenberghe 1978; Vandenberghe, 2017 fig. 8) and its origin is explained in Vandenberghe et al. (2014 §4.2.1.). Characteristic regionally-consistent flat gully levels indicating wave erosion at the sea bottom are present in the silty clay (Vandenberghe, 1978 photo 8 p 37; Vandenberghe , 2017 fig. 10) and occasionally even a gutter fill was observed (Vandenberghe et al., 2002 fig. 3). Beds of *Pycnodonta callifera* (Lamarck, 1810) have been reported although these oysters were also found in the Ruisbroek

Sand (Vandenberghe and Van Echelpoel, 1987). According to Marquet & Herman (2012) *Arctica islandica rotundata* (Agassiz, 1845) is characteristic for the lowermost part of the Belsele-Waas Member.

2. **Type section, type locality, type borehole, type CPT and/or geophysical borehole**

In the past several decades, the now abandoned clay exploitation pits of the company Scheerders-Van Kerkhove (S.V.K.) at Sint-Niklaas, Belsele-Waas, have been the reference for studies of the Belsele-Waas Member (topographic map sheet 15/5-6 Sint-Niklaas-Temse, last open pit located at X = 132.500 , Y = 205.000, Z = + 17 m). Sections, analyses and photographs can be found in Vandenberghe (1978; 2017) and Vandenberghe & Van Echelpoel (1987).

The cored and geophysically logged Reet borehole is the type section of the Belsele-Waas Member in the Boom Clay Formation reference area (Figure 11).The geophysical silt and clay intervals labelled 1, 2, 3 and 4 in Figure 11 can be well traced to the actual grain-size analysis of the member in Vandenberghe & Van Echelpoel (1987 fig. 12); note that the labelling of the layers in Figure 11 is not related to the labelling systems in reference Figure 12 and only serves the purpose of comparing the Reet and ON-Dessel-1 boreholes in this particular Figure 11. The reference section of the member in the Campine subsurface is based on the ON-Mol-1 and ON-Dessel-1 boreholes presented in Figure 12. The relationship between the Rupel area and the Mol-Dessel area is illustrated in Figure 11 displaying the thickening of the Belsele-Waas Member towards the northeast as discussed in 1. (from Vandenberghe et al., 2001, fig.7).

3. **Description upper boundary**

Based on the grain-size evolution, the Belsele-Waas Member originally was defined as the unit between the base of the Boom Clay and the base of septaria or calcareous bed S10 (see Vandenberghe et al., 2001, fig. 2; Vandenberghe et al., 2014 fig. 12). However on geophysical resistivity logs, the thick silt layers at the base delineate an easily recognizable unit that is much more practical for subsurface correlation purposes. As geophysical borehole logging has become a common practice, the top of the thick silty layers is now chosen as the top of the Belsele-Waas Member (many examples can be found in the figures in Vandenberghe et al. (2001) with the present top indicated as 'top silt B-W'). The original definition, below S10, is often labelled as 'original boundary' on past stratigraphic schemes.

4. **Description lower boundary**

The silt-enriched Belsele-Waas Member overlies the sand-enriched Ruisbroek Member of the Zelzate Formation (Tongeren Group). This lithology change can be easily observed in occasional excavations as figured in the SVK exploitation pit at Belsele-Waas itself (Vandenberghe, 2017 fig. 8). Also on resistivity logs the boundary can fairly accurately be picked where the signal markedly changes as shown on the Reet and ON-Dessel-1 borehole logs in Figure 11.

At the basis of the Belsele-Waas Member in its type area, a gravelly layer of cms to dm scale fragments of mainly phosphatised internal shell molds and worm tracks has been observed. The phosphate impregnated sediment is the fine glauconite bearing sand of the underlying Ruisbroek Sand (Vandenberghe, 1978; Janssen, 1981) and also bivalves typical for the Ruisbroek Sand occur in the phosphate bed (Marquet & Herman, 2012). These last authors have given a detailed description of the bed composition and proposed a formal bed status to this phosphorite horizon as part of the Ruisbroek Sand. However Vandenberghe and Van Echelpoel (1987) and Vandenberghe et al. (2002) argued the horizon was broken up at the base of the transgressive Belsele-Waas Member meaning that the fragmented phosphorite horizon could be considered part of the latter member. Also, as no indications of this bed have been observed in the subsurface outside the type area, a formal bed status remains debatable.

5. Thickness

The thickness of the Belsele-Waas Member is usually slightly less than 10 m.

6. Occurrence

The Belsele-Waas Member is accessible in the shallow subsurface of the Waasland and Rupel area and it can be systematically mapped on the Mechelen and Aarschot map sheets 1:50 000 (Buffel et al., 2009; Schiltz et al., 1993). To the north, in the deeper subsurface, the Belsele-Waas Member overlying Ruisbroek Sand has been observed in the Herentals and the Geel-Mol-Dessel-Balen area (Figures 7,8).

7. Regional correlations

The Belsele-Waas Member is the silt-enriched base of the Boom Clay Formation and laterally to the east and to the south in the direction of the Oligocene coast, the silt is replaced by sand, the Berg Sand of the Bilzen Formation. The transition occurs in the subsurface and probably is gradual (Figures 7, 8a, 8b, 8c, 8d). This lateral correlation is supported by the lowest part of the NP23 nannoplankton biozone present in the Belsele-Waas Member and the Berg Sand. In southern direction, Berg Sand is unmistakably present in the Leuven area (Vandenberghe et al., 2001, fig.4) and in the eastern direction the transition occurs around the border of the provinces Antwerpen and Limburg (Balen and Kerkhoven boreholes in Vandenberghe et al., 2001 fig. 5) (Figures 7, 8a).

Age

The transition between the underlying Ruisbroek Sand and the Belsele-Waas Member coincides with the transition of the NP 22 to NP23 nannoplankton biozones dated at 32 Ma (Figure 5).

Terhagen Clay Member

Unit: Terhagen Clay Member

Hierarchical unit: Boom Clay Formation of the Rupel Group

Type: Member

Authors LIS: Vandenberghe Noël and Wouters Laurent

Alternative names: In a now obsolete twofold subdivision of the Boom Clay, Vandenberghe (1974, fig. 8.1. and p. 186; 1978) distinguished a lower grey clay and an upper black clay, respectively named Waasland clay and Putte clay. The Waasland clay included the present Belsele-Waas and Terhagen Members. In the section by Vandenberghe (1980) it was indicated as part of the ‘Argile grise’.

The Terhagen Member of the Boom Clay Formation is included pro parte in the unit labelled R2c on the geological map 1:40 000 (Anonymous, 1892,1896,1900,1909) and pro parte in the unit labelled R2b in the Stratigraphic Register (Anonymous, 1929, 1932). On the recent 1: 50 000 geological maps the Terhagen Member is coded BmTe.

Origin of the name: The name Terhagen Member refers to the locality Terhagen along the Rupel cuesta, presently part of the municipality of Rumst in the Antwerpen province. The name was first introduced by the Nationale Commissie Stratigrafie (1988) (see also Marechal, 1993) as the middle member of a threefold subdivision of the Boom Clay Formation.

Formal

Date: May 2023

How to refer ….

1. **Characterizing description**

The Terhagen Member is the part of the Boom Clay in between the Belsele-Waas Member and the Putte Member. If the former member is not present, the Terhagen Member occurs at the base of the Boom Clay Formation above the Bilzen Formation. The Terhagen Member is a banded pale grey clay consisting of a several-dm-scale alternation of silt-enriched and clay-enriched layers (Figure 12). This banded nature is in contrast with the thick silt layers of the underlying Belsele-Waas Member. The pale grey colour is in contrast with the overlying Putte Member which is darker grey to even black stained. The black staining is due to layers with a few percent silt-sized detrital plant particles and such layers in the Terhagen Member are well expressed only at two levels, although under particular conditions a few more very subtle ones can be observed (Figures 13, 14, 15, 16). In the middle of the Terhagen Member occurs a characteristic pinkish to brownish stained silty layer labelled R-horizon (Figures 12, 14, 15, 16). In its part below the R-horizon the clay is calcareous (Figure 15), above the R-horizon carbonate is only occasionally present (Vandenberghe et al., 2014 fig. 11). Septaria horizons S10, S20 (key layer for correlation), S30 and S40 (Figures 12, 13, 14 and photographs 2 & 7 in Vandenberghe (1978)) occur in the Terhagen Member. In the subsurface of the Mol-Dessel area a geophysical continuous carbonate content log has shown a periodicity in the carbonate content all along the complete Boom Clay section, also in the Terhagen Member (Vandenberghe et al., 2022).

2. **Type section, type area, type borehole, type CPT and/or geophysical log**

The Terhagen Member type area is the Rupel-cuesta exploitation area where it general forms the lower part of the extracted clay. The active clay extraction pits have shifted in the past but are located around x= 154 000 , y= 197 500 and Z =+30. An almost complete section of the Terhagen Member is given by Vandenberghe (1978, photo 2 p. 25). In the field and on geophysical well logs, the Terhagen Member is fairly easily picked between the top of the silty Belsele-Waas Member (Figures 2 and 15) and the overlying Putte Member (Figures 13, 16). The boundary with the Belsele-Waas Member is identified by the sudden incursion of clay expressed by a low resistivity signal (lowest oblique black arrow 1 on logs in Vandenberghe et al., 2001 figs. 3, 5-7 /Figures 8a, 8b, 8c, 8d, 11). On geophysical GR logs the boundary with the overlying Putte Member is identified by a sudden increase in GR announcing the organic richer Putte Member (Figure 2).

3. Description upper boundary

The limit of the Terhagen Members occurs at the first black organic rich horizon marking the start of the overlying Putte Member (bed 32 of Vandenberghe 1978) (Figures 13, 16, 17). On geophysical logs the sudden increase of the gamma ray signal can be used to delineate the top of the Terhagen Member (see 2).

4. Description lower boundary

The lower boundary is marked by the thick silty beds of the Belsele-Waas Member: two in the type area, or three in the Campine subsurface (see LIS Belsele-Waas Member). Therefore the lower boundary of the Terhagen Member coincides with the start of the regular alternation of a few dm-thick silt-enriched and clay-enriched beds (Vandenberghe, 1978 in the middle of photo 8; Vandenberghe, 2017, fig. 8 at top of black vertical arrow) (Figures 12 and 15). On geophysical logs the base of the Terhagen Member occurs at the first sudden low resistivity signal indicating clay incursion above the Belsele-Waas Member silty clay (Figure 2) and labelled by oblique black arrow 1 on logs in Vandenberghe et al. (2001 figs. 3, 5-7) (Figures 8a, 8b, 8c, 8d).

5. Thickness

The thickness varies between 20 and 25 m.

6. Occurrence

The Terhagen Member occurs in the same area as the Boom Clay Formation. The Boom Clay Formation outcrops in the Waasland area, north of the Rupel river, between the Grote Nete and the Dijle-Demer rivers, and in southern Limburg (Figure 1a). North of this outcrop area, the clay occurs in the subsurface except for some locations in the Hageland where the erosion surface underlying the late Miocene Diest Formation has locally removed the Boom Clay Formation.

7. Regional Correlations

Towards the east, the lower part of the Terhagen Member with the oblique black arrows and in between the septaria level S10 (Figure 2) and the main part of the Terhagen Member grade into respectively the Kleine-Spouwen Member and the overlying Kerniel Sand, both of the Bilzen Formation (Figures 4 and 5). Therefore the Boom Clay Formation that occurs above the Bilzen Formation in Limburg starts at a level within the upper part of the Terhagen Member as it is known in the type area and in the Mol-Dessel area (Figures 4 and 5).

8. Age

The Terhagen Member contains the lowest part of nannoplankton biozone NP23 (Figure 5).

Putte Clay Member

Unit: Putte Member

Hierarchical unit: Boom Clay Formation of the Rupel Group

Type: Member

Authors LIS: Vandenberghe Noël and Wouters Laurent

Alternative names: The Putte Member was included pro parte in the unit labelled R2c on the Geological maps 1: 40 0000 (Anonymous 1892,1896, 1900, 1909) and pro parte in the unit labelled R2b in the Stratigraphical register (anonymous 1929,1932). The coding on the recent 1: 50 000 geological maps is BmPu. On the section in Vandenberghe (1980) it was named 'Argile noire'.

Origin of the name: The name Putte Clay has been introduced by Vandenberghe (1974, fig. 8.1., p. 16) and accepted by the National Stratigraphic Commission (Nationale Commissies Stratigrafie Commissie Tertiair, 1988) (see also Marechal, 1993). Putte is a municipality in the south of the Antwerp province (photograph of the abandoned clay pit at Putte in Vandenberghe et al., 2014, fig. 36).

Formal

Date: May 2023

How to refer …..

1. Characterizing description

The Putte Member overlies the Terhagen Member and underlies the Boeretang Member. The Putte Member consists of an alternation of silt-enriched and clay-enriched layers, several dm thick up to over a meter near its top (Vandenberghe & Mertens, 2013). Also the Terhagen Member is layered but in contrast to it, the Putte Member additionally has black stained layers of a few dm at the basis of the clay-enriched layers (Figures 13 and 16). Therefore the Putte Member can be described as a dark grey clay in contrast to the paler grey Terhagen Member (Vandenberghe et al. 2014 fig.10; Vandenberghe, 1978, photo 6, p. 33). Characteristic beds in the Putte Clay are the 2 DB silty beds (Figures 17, 18), the platy septaria bed S50 and the sideritic septaria horizon S60 (Figure 12). From its base to about level S50, the Putte Clay has the thinnest layers of the Boom Clay Formation (Vandenberghe & Mertens, 2013). These features can be particularly well observed in the outcrop area (Figures 13, 16, 17, 18). However in the outcrop area the upper part of the Putte Member is significantly eroded compared to its more complete development in the subsurface. The Putte Clay Member in the subsurface keeps a fairly constant average gamma-ray and resistivity signal across the small wiggles which reflect the alternating silt-enriched and clay-enriched layers. This constant geophysical signal is in contrast with the overlying Boeretang Member of which the resistivity starts to markedly increase upwards, across the wiggles pointing to a much larger silt content than the underlying Putte Member (Figure 2).

2. Type section, type area, type borehole, type CPT and/or geophysical log

The type section of the Putte Member is exposed in the upper part of the active clay exploitation front along the cuesta between Rumst and Boom (topographic map sheet 23/3-4 Boom-Mechelen) around the coordinates x =154 000, y = 197 500, z = + 30 m. As along the cuesta since some time the exploitation is limited to the Wienerberger clay pit at Rumst and the exploitation has changed from bucket bagger extraction to dragline excavating, also the Argex clay extraction pit at Kruibeke-Burcht can serve as reference section. Remark that the Putte Clay Member in the outcrop area is always eroded and incomplete. Therefore boreholes with cores and geophysical logs have also to be considered for reference to the complete Putte Member such as the Mol-Dessel area borehole sections and geophysical logs (Figure 2).

3. Description upper boundary

The top of the complete Putte Member can only be observed in the subsurface. It occurs where the resistivity log changes from a fairly constant average value in the Putte Member to marked increasing values (Figure 2). This change occurs at the base of silty bed 99 (under III in Figure 12), the first marked resistivity wiggle and labelled wiggle 0 (under I in Figure 12) in the numbering system of the outspoken silty layers in the overlying Boeretang Member. Silty bed 99 is topped by the clay layer containing the septaria couple S180 & S185 (Figure 12).

4. Description of the lower boundary

The base of the Putte Member corresponds to the base of the lowest of a series of black organic rich layers in the dark or black clay of the Putte Clay Member: this base is always a well observable contrast with the underlying grey Terhagen Member in the outcrop area (Figures 13,16,18). It occurs at the base of clay bed 32 (under III in Figure 12) and septaria level S40 is situated almost one meter below the Terhagen/Putte boundary (Figures 12, 13, 18; Vandenberghe et al., 2014 fig. 10). In subsurface conditions the base of the Putte Member is picked at the start of the marked gamma-ray signal increase caused by the uranium content of the organic matter in the black clay (Figure 2).

5. Occurrence

The Putte Member occurs in the same area as the Boom Clay Formation; it outcrops in the northeast of the Waasland area as in the clay pits Steendorp-Kruibeke, north of the Rupel river, between the Grote Nete and the Dijle-Demer rivers, and in southern Limburg (Figure 1a). North of this outcrop area, the Putte Member occurs in the subsurface except for some locations in the Hageland where the erosion surface underlying the late Miocene Diest Formation has locally removed parts and even locally the total Boom Clay Formation.

6. Thickness

The maximal thickness is slightly over 50 m in the northern Campine (Weelde SCK 98 borehole) but in the reference outcrop area it is reduced by erosion (15 m in Kruibeke-Burcht clay section and 8 m along the Rupel cuesta).

7. Regional correlations

The lower part of the Putte Member has a widespread consistent occurrence as shown by geophysical log correlations (Vandenberghe et al., 2001). East of the Mol-Dessel area the Eigenbilzen Formation of the Rupel Group is well developed and replaces the upper part of the Putte Member (Figures 3, 4, 5).

8. Age

According to the review in (Figure 5) the nannoplankton biozones NP23 is present in the Putte Member. The presence of the NP24 biozone as reported in literature (see Vandenberghe et al., 2014; Vandenberghe, 2017) is uncertain as the NP24 range figured in De Man et al. (2010), Vandenberghe et al. (2012) and Coccioni et al. (2018) is different from the range in the review in Speijer et al. (2020) and used in the biostratigraphy zonation in Figure 5. The discrepancy is probably linked to the absence in the North Sea Basin of the typical NP24 markers (see discussion in De Man et al. (2010).

Boeretang Member

Unit: Boeretang Member

Hierarchical unit: Boom Clay Formation of the Rupel Group

Type: Member

Authors of the LIS: Vandenberghe Noël and Wouters Laurent

Alternative names: Since the particular silty top of the Boom Clay Formation was recognised as an individual component in the wells at Mol, Dessel, Balen and Retie (018E0132), this silty top was designated as 'transition layers' (Neerdael et al.,1981). Because the layers within this silty top component can be well correlated on the basis of characteristic resistivity wiggles on logs, the interval has also been designated as '10-Wig package'. Based on further subdivisions of the geophysical well log signals in the top of this silty Boom Clay, an informal system W0, W1, W2, W3 was applied in Vandenberghe et al. (2001).

Origin of the name: Boeretang is small locality in the municipality of Mol. The introduction of the term Boeretang Member for the upper interval in the Boom Clay with outspoken silt layering and particularly well expressed in geophysical resistivity logs, is the outcome of extensive borehole investigations related to the NIRAS-ONDRAF nuclear waste disposal research in the Campine area and in particular at the Mol-Dessel research site (Mertens & Wouters, 2003). The term has been approved by the National Stratigraphic Commission (Vandenberghe & Wouters, 2011).

Formal

Date: May 2023

How to refer …..

1. **Characterizing description**

The Boeretang Member occurs in the top of the Boom Clay Formation and exclusively in the subsurface where it is well characterised by geophysical borehole logs. It differs from the underlying Putte Member by its steadily increasing resistivity values on the geophysical log and by the prominent high resistivity values of the silt-enriched layers leading to marked wiggles on the curve. However the grain size of the Boeretang Member, expressed on a silt-sand-clay triangular diagram, is similar to the grain size of the

Putte and Terhagen Members (see Vandenberghe et al., 2014 fig. 27 and Frederickx, 2019 fig. 35). The Boeretang Member silt layers that alternate with the clay layers can be well identified in cores. The pronounced expression on the geophysical logs of the silt and clay layers makes it possible to apply a coherent numbering of the silt beds and to correlate boreholes (Figure 2 and 12). The full Boeretang Member detailed lithological layering, including septaria horizons S180, S185, S190 and S200, was established by Mertens and Wouters (2003) (Figure 12 with codes under heading I).

2. Type section, type area, type borehole, type CPT and/or geophysical log

The reference boreholes are located in the Mol-Dessel area and in Weelde (SCK-NIRAS 98). The geophysical borehole measurements are presented in Vandenberghe et al. (2001 figs. 5 & 6; 2014 fig. 13) (Figure 2). Foraminifera and dinoflagellate cyst data in the Weelde SCK 98 borehole are described respectively in De Man (2006) and Van Simaeys (2004), and Sr-isotope dating is reported in De Man et al. (2010).

3. Description upper boundary

The upper boundary corresponds to the upper boundary of the Boom Clay Formation. The top of the Boeretang Member is characterized by the change in lithology from its silt and clay dominated lithology to the sandy lithology of the overlying units, either Neogene or Chattian glauconite sand units or even the very-fine-sand dominated Eigenbilzen Formation of the Rupel Group. In geophysical borehole logs of the overlying Eigenbilzen Formation, the signals of cyclic clayey and silty layers are organized in broader lobes instead of in a coarsening upward trend like in the Boeretang Member. Conform the NIRAS-ONDRAF practice in the Mol-Dessel area, the top of the Boeretang Member is put at the top of resistivity wiggle 9 (Figure 2), or wiggle 9b in the reference section of the area by Mertens and Wouters (2003) (Figure 12 under heading I).

4. Description lower boundary

As the Boeretang Member only occurs in the subsurface, geophysical borehole logs are required to designate a proper lower boundary. The base of the upward increasing resistivity log is the level with the best correlation potential and therefore used as the base of the Boeretang Member. This level corresponds to the base of the resistivity wiggle 0 (Figures 2, 12 under heading I) and corresponds to the base of silt bed 99 in Figure 12 (under heading III).

5. Thickness

When completely developed with the wiggles 0 to 9 present, the thickness of the Boeretang Member varies between 23 and 29 m.

6. Occurrence

The Boeretang Member is typically present in the northern Antwerp Campine subsurface. It is absent in borehole ON-Doel-2b in the west, but eastwards part of the member is already identified in the boreholes Zoersel and Herentals (see Vandenberghe et al., 2001 figs. 5, 6). East of the Mol-Dessel area, the Boeretang Member evolves into part C of the Eigenbilzen Formation (see 7. and Figure 4).

7. Regional Correlations

East of the Mol-Dessel zone geometrical considerations supported by similar resistivity patterns, indicate that the Boeretang Member of the Antwerp Campine is relayed by part C of the sandy Eigenbilzen Formation (Figure 4). The geophysical similarity consists of the upward coarsening trend superimposed on well-expressed cyclic high resistivity signals that even allows a numbering of the wiggles as demonstrated for example in the Koewijde borehole (Figure 9).

8. Age

The lower part of the Boeretang Member, up to almost S190 level, has nannoplankton biozone NP23. Possibly also biozone NP24 occurs above (De Man et al., 2010). However the presence of the NP24 biozone as reported in literature (see Vandenberghe et al., 2014; Vandenberghe, 2017) is uncertain as the NP24 range figured in De Man et al. (2010), Vandenberghe et al. (2012) and Coccioni et al. (2018) is different from the range in the review in Speijer et al. (2020) and used in the biostratigraphy zonation in Figure 5. The discrepancy is probably linked to the absence in the North Sea Basin of the typical NP24 markers (see discussion in De Man et al. (2010).

Eigenbilzen Formation

Unit: Eigenbilzen Formation

Hierarchical name unit: Rupel Group

Type: Formation

Authors LIS: Noël Vandenberghe and Laurent Wouters

Alternative names: The Eigenbilzen Formation is a sandy unit lying above the Boom Clay that was already recognized in Limburg by Van den Broeck (1884, 1893) and coded by the symbol R2d in his stratigraphic system as well as in the legends of the 1:40 000 geological maps (Anonymous 1892, 1896, 1900, 1909). On the recent 1:50 000 geological map the Eigenbilzen Formation is coded Eg.

Origin of the name: Gulinck (Archives Geological Survey of Belgium-document MG/75/338) introduced the term Eigenbilzen Sand in his borehole descriptions for the sand meant by Van den Broeck (1884, 1893). Eigenbilzen is a village belonging to the municipality of Bilzen in the Limburg province (Figure 1a).

Formal

Date: May 2023

How to refer: ….

1. Characterizing description

The Eigenbilzen Formation consists of grey to grey-green clayey fine sand and silt containing some glauconite pellets especially towards the top. It contains bioturbations but no macroscopic fossils. The Eigenbilzen Formation is well studied in the subsurface of the map sheet 25 Hasselt (Matthijs, 1999) where a consistent threefold subdivision could be demonstrated and characterized by typical resistivity and gamma-ray signatures, labeled A,B,C on Figures 19 and 20. These subdivisions A,B,C have also been identified in geophysical borehole logs outside the Hasselt map sheet and it was demonstrated that the sandy units A and B laterally grade into clay to the west (Vandenberghe et al., 2001) (Figure 4). The unit C is characterized by a coarsening upward trend with higher frequency cycles superposed very similar to the signal of the Boeretang Member of the Boom Clay Formation. Above this part C with high frequency cycles, a sandier top called unit D in Figure 4 is recognized; it was already reported by Matthijs (1999, p. 37) east of the map sheet Hasselt. Matthijs (1999) in his study on the map sheet 25 Hasselt confirmed the lateral transition of the Eigenbilzen Formation into the Boom Clay Formation also to the north (Matthijs, 1999 fig.11) (Figure 19). These units A,B,C,D in the Eigenbilzen Formation have not been ranked as official subdivisions of the formation. Geophysical logs (Figures 2, 6, 9) and the few outcrops (Vandenberghe, 1978 fig 1.1e) show the presence of more clayey and more sandy layers in the formation.

In the Mol area the Eigenbilzen Formation always contains a few percent >125 µm size grains and about 20 to 75 % >62 µm grains, in contrast to the underlying Boeretang Member of the Boom Clay Formation with <1% >125 µm grains and <10% >62 µm grains (a.o. Frederickx, 2019). In the Hasselt-Diepenbeek area (Vandenberghe, 1978 fig. 1.1e) the >32 µm content is about 60% in the more clayey layers and about 80% in the sandy layers, similarly to the about 50 to 70% reported in the Mol area. In the Antwerp Campine subsurface, the Eigenbilzen Formation consists of almost-10 m-sized resistivity lobes or intervals superposed on shorter alternating several-dm-sized clay and silt layers (Figure 2); the latter is confirmed by core inspection (see Weelde borehole in Figure 2) and by the geophysical pattern of the formation in the Weelde and Meer borehole (Vandenberghe et al., 2001 fig. 6).

2. Type section, type locality, type borehole, type CPT and/or geophysical borehole logs

No permanent outcrop of the Eigenbilzen Formation exists and the formation is seldom exposed. The sand has been studied in temporary outcrops during the works for the extension of the locks on the Albert Canal near Diepenbeek and Hasselt (Vandenberghe, 1978 fig. 1.1e), and during the enlargement of the same canal near Gellik (Steurbaut et al., 1999) (Figure 3). The latter outcrop allowed a calibration of the boundary between the Boom Clay and the Eigenbilzen Sand near the place of its original definition by Halet (1932), the village of Eigenbilzen (Vandenberghe et al., 2001).

The interpreted geophysical logs of the boreholes Genk (KB136/ 77E0300) and Houthalen (62E0269 and 62E0266) in the map sheet 25 Hasselt and figured and interpreted by Matthijs (1999, fig. 10) can be used as reference geophysical borehole logs (Figure 20). The Eigenbilzen Sand section thickens to the north and an additional unit D can be identified as shown for the Koewijde KS2 borehole in Figures 3 and 9 ; note however that to the north the Eigenbilzen Formation becomes more clay-enriched (boreholes in Vandenberghe et al., 2001 fig. 9 and Matthijs, 1999 fig. 12). Matthijs (1999) suggests that changes in thickness and clay content can be influenced by late Oligocene differential tectonic activity in the area.

3. Description upper boundary

Where the Eigenbilzen Formation is overlain by the Chattian Voort Member of the Veldhoven Formation (Dusar & Vandenberghe, 2020) the boundary can easily be picked by lithology because in contrast to the grey to grey-greenish fine sands without macrofossils of the Eigenbilzen Formation, the Voort Sand is dark green, rich in glauconite pellets, shell bearing and coarser grained with grains >250 µm (see grain-size profiles of the boreholes 62E0223 at Houthalen-Molenberg and 62E0261 at Helchteren figured in Matthijs 1999 fig. 11). This lithology contrast is reflected in the resistivity and gamma-ray borehole logs as shown on Figures 19 and 20.

4. Description lower boundary

Generally the boundary between the underlying clay-enriched Boom Clay Formation and the sandy Eigenbilzen Formation is sharp as was observed in the outcrops along the Albert Canal (Vandenberghe, 1978, fig. 1.1e; Vandenberghe et al., 2001 fig. 10). Also on the geophysical logs a marked contact is well expressed (Figures 6, 19, 20) although in boreholes there are transitions towards the Boom Clay Formation where the boundary is harder to trace as discussed by Matthijs (1999) (see also Figure 9). Therefore the option remains to include the interval A within the Boom Formation rather than in the the Eigenbilzen Formation. East of the Mol-Dessel area the three intervals A,B,C in the Eigenbilzen Formation (see 1.) have different clay contents, most clay-rich at the base of interval A and least clay in the upper part C. Geometric considerations and correlation of key horizons in the Boom Clay Formation show that the base of the interval A, hence the base of the Eigenbilzen Formation, correlates in the west to a level some meter above the DB in the Putte Member of the Boom Clay and the boundary between A and B intervals to a level somewhere in the higher part of the Putte Member (Figure 4).

5. Occurrence

The formation crops out along the Albert Canal east of Hasselt (Figure 1a). Borehole log analysis in the Antwerp and Limburg provinces indicates the systematic presence of the Eigenbilzen Formation in the subsurface north of its outcrop zone and east of the Mol-Rauw Fault zone.

The most western occurrence of the Eigenbilzen Formation overlying the Boeretang Member of the Boom Clay Formation is situated in the Antwerp Campine (a.o. Weelde, Meer, Lichtaart, Geel boreholes) (Figures 1a & 1b). In this area it can be distinguished from the Boeretang Member by its higher sand content (see 1.) as also expressed on geophysical logs (Figure 2). For geometric reasons this most western extension of the Eigenbilzen Formation probably corresponds to the uppermost parts of the Eigenbilzen Formation east of the Mol Rauw Fault (see 7.) (Figures 4 and 5).

6. Thickness

On the Tongeren geological map the Eigenbilzen Formation is generally eroded and only 5 to 10 m thickness is left (Claes et al., 2001); this is the case in the eroded Albert Canal section near Eigenbilzen where thickness is about 10 m. Where the formation is complete under the Voort Sand as in the Hasselt geological map area, the Eigenbilzen Formation is about 50 m thick. In the most western occurrence area of the Eigenbilzen Formation thickness is reduced to 20 m or less.

7. Regional correlations

Geometrically the Eigenbilzen Formation in the Limburg Campine occurs laterally from the Boom Clay Formation in the Antwerp Campine and there are many indications that the sandy Eigenbilzen Formation is a lateral facies development of the Boom Clay Fm (Vandenberghe et al., 2001; Vandenberghe, 2017) (Figure 4). The Mol-Dessel area succession of Putte and Boeretang Members overlain by Eigenbilzen Formation can be traced on geophysical logs as far as the boreholes Balen, Kerkhoven KB 186, Hemelburg KS13. Further eastwards the A and B units of the Eigenbilzen Formation are the lateral sandy developments of the Putte Member of the Boom Fm; the base of the unit A, at the base of the Eigenbilzen Formation, correlates to a level a few meter above the DB layer in the Putte Member of the Boom Clay Formation (Figure 4). The base of the unit C in the Eigenbilzen Formation is the start of a coarsening upwards trend consisting of a succession of clay-silt alternations, possibly numbered as for example in Figure 9, and very similar to the geophysical pattern in the Boeretang Mbr of the Boom Fm (Figures 4, 6, 9). Therefore this unit C correlates with the Boeretang Member. Logically the top, about 10 m, of the Eigenbilzen Formation lacking the regular layering of silt and clay layers on the geophysical logs and indicated as unit D (Figures 4, 9), correlates with the Eigenbilzen Fm above the Boeretang Member in the Mol-Dessel area and further westwards (Figures 4 & 5). Unfortunately in the Limburg Campine subsurface neither sediment nor micropaleontological analyses are available to further characterize and calibrate the geophysical subdivisions of the Eigenbilzen Formation.

8. Age

The chronostratigraphic interpretation of the Eigenbilzen Formation is sketched in Figure 5. Based on data by Steurbaut, literature reports nannoplankton biozone NP24 in the Eigenbilzen Fm unit D (o.a. Vandenberghe et al., 2004). However the position of the NP24 range in the GTS2020 (Speijer et al. 2020 and used in Figure 5) does not fit the range usually assumed in the North Sea Basin, a discrepancy linked to the absence of the typical NP24 markers in the North Sea Basin (see discussion in De Man et al. (2010). According to Munsterman & Deckers (2020) the Eigenbilzen D Sand in the ON-Mol-1 borehole contains dinocyst zone NSO 4b-5a; these authors also invalidate the *Distatodinium biffi* identification by Van Simaeys et al. (2005).

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Legends Figures

Figure 1a. Location list and map of data points referred to in the text. The coordinates and details of the data points are given in the section Data List. The southern outcropping rim of the Rupel Group with the Boom Clay, Bilzen and Eigenbilzen Formations is mapped. The Rupel Group dips slightly northwards where it is accessible in boreholes except where it has been locally eroded under the Diest Formation in the Hageland (see Figure 1b).The faults figured are those affecting the top of the Rupel Group and the pattern is based on Deckers et al. (2019) in https://dov.vlaanderen.be/page/geologisch-3d-model-g3dv3 *(figure designed by VITO)*

Figure 1b. Isohypse map of the top of the Rupel Group (Boom Clay Formation and Eigenbilzen Formation). The overlay grid figures the 1:50 000 geological map outlines. The geographic extent is based on the G3Dv3-model (Flemish Government, DOV). In particular the western extent of the Eigenbilzen Formation is based on a thin geophysical borehole log interval above the Boom Clay Formation most probably interpreted as Eigenbilzen Sand (e.g. in boreholes Lichtaart 30E090, Geel 046W0388, Loenhout DZH21 016E0237); note that previous maps show a more restricted western occurrence (based on Welkenhuysen et al., 2011). The faults figured are those affecting the top of the Rupel Group, based on presently available seismic sections and on the 1:50 000 maps (Deckers et al., 2019); note that other fault patterns have been presented on tertiary geology maps (a.o. Vancampenhout, 2004). *(figure designed by VITO)*

Figure 2. The GR and RES geophysical logs of the Boom and Eigenbilzen Formations of the Rupel Group in the reference wells Mol SCK-15, ON-Mol-1, ON-Dessel-1 and Weelde SCK-98 in the Antwerp Campine. In the Boom Clay Formation, characteristic log signature levels define its 4 members (Belsele-Waas, Terhagen (T), Putte (P) and Boeretang); R and DB horizons are labeled as they can easily recognized in field section by respectively a slight pink to brownish colour and a very silty character of 2 closely spaced layers. The main flooding surface horizons, mfs, are sequence stratigraphic interpretations with mfs 1 = R horizon and mfs3 is the sideritic septaria layer S60. The sequence boundaries (SB) and ransgressive surface (TS) are also sequence stratigraphic interpretations. The boundaries between the formations and members and the labeled horizons allow to link these geophysical logs to the lithological reference section of the same area in Figure 12. The Chattian present in the ON-Mol-1 and ON-Dessel-1 consists of the Voort Sand Member of the Veldhoven Formation. The position of the base of the Chattian Voort Sand is based on the dinoflagellate cyst study by Van Simaeys (2004); its precise top position is slightly differently interpreted (stars) by Van Simaeys (op.cit) and by Munsterman & Deckers (2020) . *(figure modified from Vandenberghe et al., 2014 fig. 13)*

Figure 3. The Rupel Group in Limburg interpreted in terms of the Bilzen, Boom and Eigenbilzen Formations in the temporary outcrop section along the Albert Canal in northeast Limburg and in the GR and RES geophysical log signatures of the Koewijde-KS2 borehole. The Eigenbilzen Formation is subdivided in A,B,C,D units following Matthijs (1999). Meaning of the levels labelled db, R, SB, TS is as in Figure 2; codes a to d and 4 to 0 are events recognised in several borehole logs in Limburg (see Vandenberghe et al. , 2001 fig. 9). *(figure based on Vandenberghe et al., 2001 and Steurbaut et al., 1999)*

Figure 4. Regional correlation of the Rupel Group in Belgium between the type outcrop areas in the Antwerp and Brabant provinces, the Antwerp Campine and Limburg Campine using characteristic levels, such as the boundaries between formations and between members, the R and db horizons (see Figs. 2 & 3), and several septaria horizons (S) including 2 sideritic horizons (S60 and an upper one identified in Doel2b, Zoersel and Mol SCK-15 boreholes). Note the geometrical lateral correlations of the Belsele-Waas Mbr of the Boom Formation with the Berg Member of the Bilzen Formation, of the Kerniel and Kleine Spouwen Members with the lowest part of the Terhagen Member above Berg Sand or Belsele-Waas Silty Clay , of the Eigenbilzen A and B units with part of the Putte Clay Member and of the Eigenbilzen C unit with the Boeretang Member while the Eigenbilzen D unit is the Eigenbilzen Formation occurring above the Boeretang Member. The codes a to d and 4 to 0 are the events within the Terhagen Member in Limburg as in Figure 3. Note also that below the Rupel Group, the Borgloon Formation of the Tongeren Group is geometrically lateral of the Ruisbroek Member of the Zelzate Formation. (*modified from Vandenberghe et al., 2001 fig. 15 and Vandenberghe et al.,2014 fig. 14).*

Figure 5. Chronostratigraphic position of the Rupel Group. The lithostratigraphic scheme is a synthesis of Figure 4 and the thickness given is for the Mol-Dessel area. The chronostratigraphic scheme is based on the Geological Times Scale 2020 (Speijer et al., 2020). Note that the age for the GSSP Chattian is slightly different (27,82 Ma) from the ICS chart (2023/4). Chronostratigraphic anchoring is based on biostratigraphy, nannoplankton for line 1 and dinoflagellates for line 3 (note that that the identification of *D. biffi* in Van Simaeys et al. (2005) has not been withheld (see 5.1 in Munsterman and Deckers, 2020), on magnetostratigraphy for line 2 (Lagrou et al., 2004). In addition age intervals within the Rupel Group are based on the obliquity cycles in the ON-Mol-2D borehole (Vandenberghe et al., 2022) and integrated starting with the base of Rupel Group at 32 Ma (line 1); the corresponding ages obtained are the stippled lines a to line e. The silicified foram event is considered the start of the tectonic tilting with uplift and erosion in the west (De Man et al., 2010). The boundary between the Rupel Group and the overlying Veldhoven Formation (line 4) is a low angle unconformity (Dusar and Vandenberghe, 2020 3.2). In northeast Belgium at this level the RVG graben fault activity resumes depositing much thicker Chattian deposits in the graben. The hiatus between the top of the Rupel Group and the base of the Chattian Voort Sand (line 4) is dated following De Man et al. (2010) and Coccioni et al. (2018). The age of the basal Voort Sand (line 5) is put at the start of the *Svalbardella* interval including the *Asterigerina* horizon almost at the NP24/NP25 boundary (Coccioni et al., 2018 table 1; Speijer et al., 2020 fig.28.11); assuming the latter only slightly deviates from the North Sea NP24*/NP25* proxy (De Man et al., 2010) the Voort Sand outlier in the Antwerp area (line 6) is correlated to this nannoplankton boundary (Vandenberghe et al., 2004). The red dashed curve across the Boom Clay are the sedimentary sequences figured in Vandenberghe (2017, fig. 4 and Vandenberghe et al. 2014 fig. 24).

Figure 6. Donderslagse Heide, stratigraphic interpretation of the geophysical borehole logs. The Berg Sand Member is identified by the difference between the SN and LN pointing to a permeable lithology. Note above the Berg Sand a marked clay content increase (black arrow) interpreted as the geometrically lateral position of the Kleine Spouwen Clay. The R and DB levels are the positions of the classical marker layers in the Boom Clay, respectively the slightly pink to brownish key horizon in the outcrop area and two closely spaced very silty horizons identified by the sharp increase in GR signal. P/T is the boundary between the Terhagen (below) and Putte (above) Members of the Boom Clay Fm. A,B,C are the subdivisions of the Eigenbilzen Formation based on the Houthalen KS11 (062E0269) interpretation (Matthijs, 1999 fig. 10) located nearby borehole Donderslagse Heide KS9 (see correlation in Vandenberghe et al. ,2001, fig. 8).

Figure 7. Map showing: in the southeast the presence of the three members of the Bilzen Formation, in the middle part only the Berg Sand Member of the Bilzen Formation occurring below the Terhagen Member of the Boom Clay Formation, in the northwest the area with the Belsele-Waas Member at the base of the Boom Clay Formation and without the Bilzen Formation. The boundaries are mapped based on stratigraphic interpretations in DOV, in Welkenhuysen and De Ceukelaire (2009) and in particular on the borehole interpretations along section lines I (Fig. 8a), II (Gulinck,1975), III (Fig. 8b), IV (Fig.8c) and V (Fig.8d). Distinguishing between Berg Sand and Belsele-Waas Silty Clay in these sections is based on the GR and RES values including the SN-LN difference. It is admitted that interpretations based only on geophysical logs without additional data can be debatable. Modal grain size of the Berg Sand is 150-175 µm evolving to 100-125 µm near the top a few % <44 µm and almost free of clay fraction (Gullentops, 1988; Gulinck, 1966). At the very top the 175-88 µm fraction is dominant with the <44 µm fraction still well below 10 %. In contrast the Belsele-Waas Member of the Boom Clay in its type area (Vandenberghe & Van Echelpoel 1987) barely has a >88µm size fraction, except for the lowest meter with even a limited >125 µm fraction. The 88-62 µm and 62-32 µm fractions are both 30 to 40 % and the fraction <25 µm contains 30-35%. In the subsurface of the Mol area (Frederickx, 2019) the sand fraction is diminishing upwards from 60% to 20% accompanied with an increase in clay fraction from 25-50%. Not only the grain-size distribution differs between Berg Sand and Belsele-Waas Member but also the heavy mineral content (see Gullentops, 1963, fig.23; Vandenberghe, 1978, p 74,76).

illustrating the signals of the members of the Bilzen Formation and the Boom Clay Formation demonstrating the boundaries mapped on Figure 7. Log data in the boreholes Herselt, Geel, Meerhout are from

Figure 8a. Section I on Figure 7. Resistivity SN and LN (left) and GR (red,right) curves illustrating the 3 members of the of the Bilzen Formation in the Dornerheide (063E0216) borehole, the Berg Sand Member below the Terhagen Clay Member of the Boom Clay Formation in the Opglabbeek (063W0215) borehole, and the Belselse-Waas Member below the Terhagen Member in the boreholes ON-Dessel-1 (031W0300) and Balen (031E0338). In the Kerkhoven borehole (047W0264) Berg Sand is interpreted from the GR and RES signatures (Vandenberghe et al., 2001) although log quality does not allow to exclude the Belsele-Waas Member instead. The marked clay increase at black arrow 1 corresponds to the geometrically lateral position of the Kleine Spouwen Clay in the Terhagen Member. Black arrow 2 is another marked clay increase that can be correlated between boreholes ; septaria level S10 (star in ON-Dessel-1 borehole) is situated between the arrows 1 and 2 as shown by the FMI log in ON-Mol-1.

Figure 8b. Section III on Figure 7. Resistivity SN and LN (left) and GR (red,right) curves (Hasselt in Vandenberghe et al., 2001; Geel and Meerhout in Welkenhuysen and De Ceukelaire, 2009). South of Hasselt (borehole Hasselt stad, 092E0503) the 3 members of the Bilzen Formation are identified while north of Hasselt (Hasselt Concentra and Meerhout boreholes) the Berg Sand underlies the Terhagen Member of the Boom Formation (Belsele-Waas Mb is interpreted in the Meerhout borehole by Welkenhuysen and De Ceukelaire, 2009 fig.48 Profiel D). In the Geel borehole the Belsele-Waas Member signature occurs. The black arrows are as in Figure 8a.

Figure 8c. Section IV on Figure 7. The Pellenberg outcrop section shows the Terhagen Clay Member above the Berg Sand Member. Resistivity SN and LN (left) and GR (red,right) curves in the Herselt (060E0289) and Herentals (045W0337) boreholes. Berg Sand below the Terhagen Clay Member of the Boom Clay is interpreted in the borehole Herselt but note the interpretation of a transition between Berg and Belsele-Waas units in Welkenhuysen and De Ceukelaire (2009 , fig. 36). The dashed line with ? is suggesting a possible delineating of a finer upper part in the Berg Sand unit. In the Herentals borehole Belsele-Waas Member is interpreted below the Terhagen Member (Vandenberghe et al., 2001, fig.5). The black arrows 1 & 2 indicating increased clay content are the same as in Figures 8a and 8b.

Figure 8d. Section V on Figure 7. Correlation between outcrop sections in the Boom Clay Formation from Antwerp to Pellenberg-Lubbeek. The paleontological content in the basal meter of the Terhagen Clay below S20 in Pellenberg is similar to S10 in the Kleine Spouwen Clay Member of the Bilzen Formation (see LIS Kleine Spouwen Clay) and to the S10 and S20 interval in the Rupel type area (see Vandenberghe et al., 2001 p.71). Although lithologically the correlation between the top of the outspoken silty Belsele-Waas Member (below arrow 1 in the Rupel and Waasland area section) with the top of the Berg Sand would seem logical, based on the paleontological correlation of S10 with the very base of the Boom Clay in Pellenberg, it is suggested that the top of the silty Belsele-Waas Member correlates with a level near the base of the more fine grained top part of the Berg Sand at arrow 1 (n Pellenberg section); such a correlation also honours the observation of the occurrence of S10 between the 2 major clay influxes labelled by the arrows 1 and 2 (Figure 8a)(see also correlation scheme in Vandenberghe et al., 2001 fig. 4, note however in that figure the previous Belsele-Waas Member definition). *(figure based on Vandenberghe et al., 1998 fig.16; Vandenberghe et al., 2003b Stop 3 fig.4; Vandenberghe et al., 2014, fig.35)*

Figure 9. Stratigraphic interpretation of the Koewijde borehole (064W0259) geophysical logs: the Bilzen Fm with the Berg Sand Member (B), Kleine Spouwen Clay Member (N) and Kerniel Sand Member (K), the Terhagen and Putte Members of the Boom Clay Formation with the R and db (or DB) key horizons, and the overlying units A,B,C,D of the Eigenbilzen Formation. The layering 1 to 6 in a coarsening upward trend in the Eigenbilzen C unit is interpreted as the similar structuring in the Boeretang Member of the Boom Clay (Figure 4). For codes a to d and 0 to 4 in the Boom Formation, see Figures 3 and 4.

Figure 10. The classical Roelants extraction pit at Lubbeek. Left: Photograph of the subhorizontal contact of the Berg Sand Member with the underlying Heide and Kerkom sand units of the Borgloon Formation (Tongeren Group). For a discussion of the ‘chocolate coloured sand ‘ see van Riessen &

Vandenberghe (1996) and Vandenberghe (2017). Right: Profile combining different outcrop sections around the Roelants sand pit. Note the internal stratified structure of the Berg Sand and its more fine grained top (see also Figure 8). The clear transgressive nature of the Berg Sand Member regionally overlying different coastal plain facies of the Borgloon Formation is the reason for taking the base of the Berg Sand as the base of the Rupel Group although pebbles including typical base Berg Sand black flattened flint pebbles are already arriving in the area at the base of the Heide Sand.

Figure 11. The correlation between the Belsele-Waas and the Terhagen Members of the Boom Clay Formation in the Reet and ON-Dessel-1 boreholes. Note that the numbering of the layers on this figure only serves the purpose of the correlation of signals between the 2 boreholes in the figure and is not related to the reference numbering in Figure 12. The package labelled 0 is interpreted as stratigraphic thickening and contains the most sandy clay in the diagram figured in Vandenberghe et al. (2014 fig. 27). The black arrows pointing to sudden clay incursions are the same as Figures 2 & 8 bed with the lower arrow the lateral geometrical equivalent of the base of the Kleine-Spouwen Member of the Bilzen Formation (see LIS Kleine Spouwen Member). The R and db key horizons are as in Figure 4. *(figure adapted from Vandenberghe et al., 2001).*

Figure 12. Boom Clay Formation reference microstratigraphy elaborated in the Mol-Dessel area by Mertens & Wouters (2003). It is mainly based on the FMI logs of the On-Mol and ON-Dessel boreholes, complemented by observations around the URL and other reliable observations in outcrops and boreholes. Silty-clay layers are stippled yellow, clay-enriched layers are in grey and septaria horizons are shown by white ellipsoids coded S05, S10,..etc. The boundaries between the members of the Boom Clay Formation are indicated. URL is the position of the Euridice underground research laboratory. The main coding used is given under the heading III. In the Boeretang Member geophysical wiggles are easily numbered and are coded under heading I; numbering under headings IV and V (Van Simaeys, 2004, fig.C2, p 175) is related to the lowest part of the Boom Clay Formation and the system under heading II is only used in the periodicity study by Abels et al. (2007). *(figure adapted from Mertens & Wouters, 2003)*

Figure 13. Photograph of the clay pit at **Schelle** (90's 20th century). Note the change from grey coloured clay of the Terhagen Member below to dark stained clay of the Putte Member above. The dark staining is due to the systematic occurrence of organic rich layers. Note also the occurrence of a similar black stained layer in the lower Terhagen Clay (white arrow). Septaria levels S40 and S20 are visible.

Figure 14. Photograph of the Terhagen Member in the lower part of a clay extraction pit at **Terhagen-Rumst** (70's of the 20th century). Note the alternation of several-dm-scale layers of pale grey silt-enriched clay with darker grey clay-enriched clay. Black arrows at the right side point to blackish-grey organic rich horizons. Other characteristic levels observed are the pink to brown R horizon, with a typical very thin whitish staining at the base (arrow) due to the presence of a layered pyrite. At the top right a septaria of horizon S40 is visible. The levels of septaria horizons S20 and S30 are indicated but on this photograph no septaria can be observed. The altered abandoned clay face in the upper part of the photograph is the Putte Member with only the position of the DB (or db) still recognisable by its darker staining. Note that all the relative shades of grey depend on the humidity conditions of the clay face.

Figure 15. Left photograph shows a part of the Terhagen Member displaying the R horizon and the S30 and S20 septaria in the clay. Right column shows sediment analyses of the lower part of the Terhagen Member in the **Rupel cuesta** area. The >32 µm content illustrates the alternation in silt-clay enrichment

and shows the very silty nature of the Belsele-Waas Member. The low content in organic matter basically varies with the amount of clay fraction and the carbonates are only systematically present below the R horizon. The vvv symbols in the lithological column indicate the position of two black horizons in the Terhagen Member (see also Figures 13 & 14) *(figure from Vandenberghe et al., 2020).*

Figure 16. Photograph **Steendorp Bolderik** clay pit (2000's). The change from grey coloured clay of the Terhagen Member to dark stained clay of the Putte Member at the white line. Numbering of the beds as in Figure 12 under heading III. Presence of the pink R horizon is indicated. Silty beds are pale and clay rich beds darker stained.

Figure 17. The Putte Member along the Rupel cuesta (Terhagen-Rumst /1986). Alternation of pale grey silt-enriched and darker grey clay-enriched layers; the latter are friable by alteration at the exploitation face. Note the systematic blackish colour at the base of the clay-enriched layers; these black layers are the characteristic feature of the Putte Member of the Boom Clay Formation and one such black layer is particular marked at the base of the Putte Member. Note also the presence of the very silty DB double layer and the whitish hue of the septaria level S41 in its top. Also the S50 septaria level is slightly paler than the other silty layers. Shovel 40 cm for scale.

Figure 18. Boom Clay outcrop in Terhagen-Rumst. The layered nature of the clay, i.e. the alternation of clay-enriched and silty clay layers, is clearly visible. The black staining is due to admixture of land-derived organic matter. Whitish-grey marly bands as one observed at the bottom of the picture at S40 level, contain septaria carbonate concretions. The pronounced two pale grey and closely spaced layers of silty clay in the middle in the middle of the picture correspond to the double band (DB). Note the sharp boundary between the Terhagen and Putte Members of the Boom Clay Formation. *(figure from Vandenberghe et al., 2014 fig.10).*

Figure 19. South-North profile across the geological map sheet 25 Hasselt between Bokrijk (77E0230) and Beringen (62W0302) showing the consistent occurrence of the threefold subdivision of the Eigenbilzen Formation, labelled units A,B,C . Note in the north of the profile the lateral transition of the A and even B units into the clay rich Boom Clay Formation *(figure from Matthijs, 1999 fig. 11).*

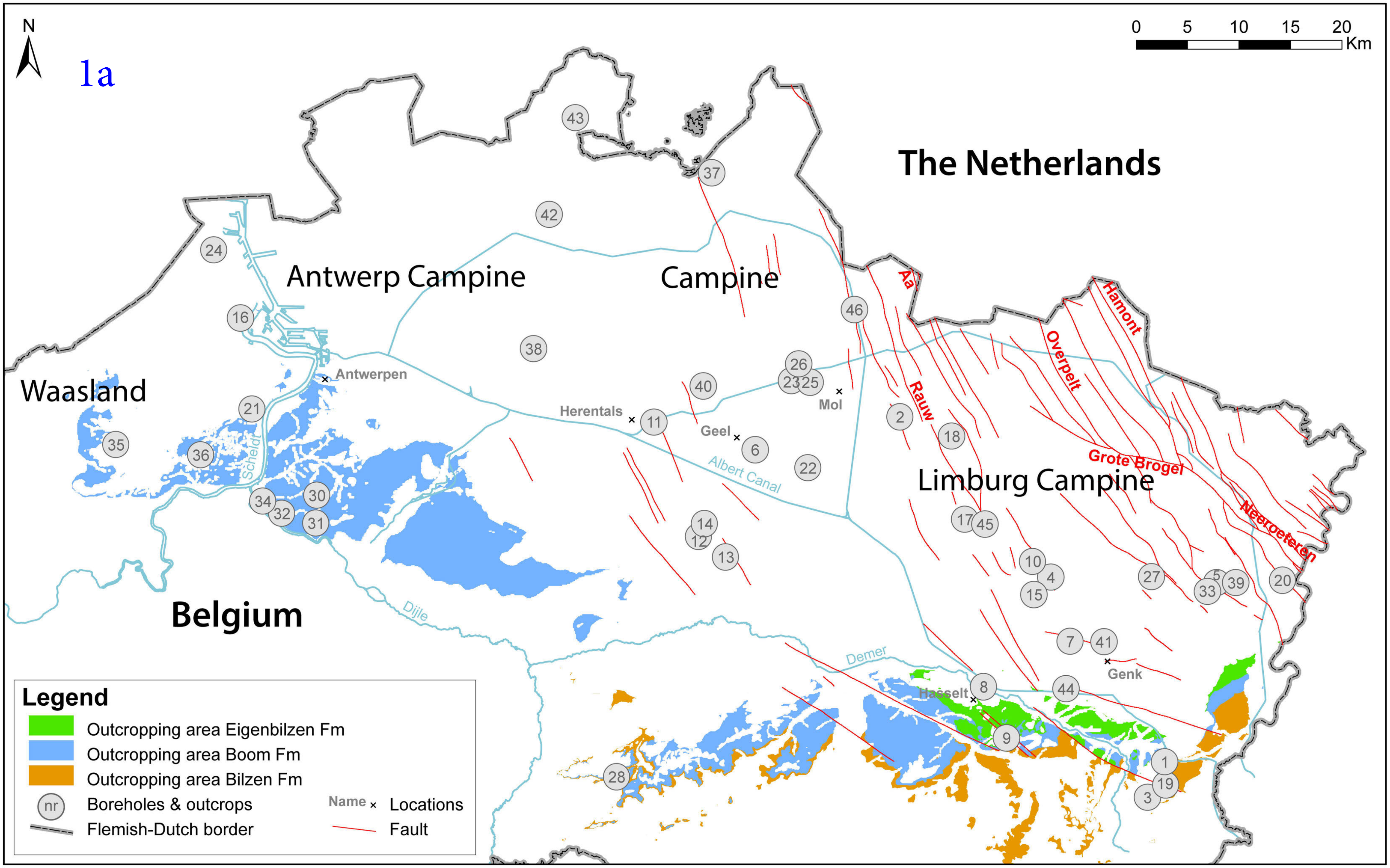
Figure 20. Reference boreholes Genk 77E300, Houthalen 62E269 and 62E266 on geological map sheet 25 Hasselt showing the the borehole resistivity and gamma-ray signatures of the threefold subdivision of the Eigenbilzen Formation *(figure from Matthijs, 1999 fig. 10)*.

Data list

locatie	alternatieve naam	info locatie	BGD-nr	DOV-proefnummer	DOV-URL
Albert-Canal section (near Eigenbilzen)		als kernzone van de coupe ongeveer 1300 m vanaf de Gellik brug naar het westen			
Balen B30			BGD031E0338	kb17d31e-B320	https://www.dov.vlaanderen.be/data/boring/1980-085151
Berg 'gîte classique de Berg	93W0243		BGD093W0243	kb34d93w-B253 t.e.m kb34d93w-B265	https://www.dov.vlaanderen.be/data/boring/1972-082725
Donderslagse Heide	KS9		BGD062E0270	kb25d62e-B274	https://www.dov.vlaanderen.be/data/boring/1981-103185
Dornerheide	KS6		BGD063E0216	kb26d63e-B223	https://www.dov.vlaanderen.be/data/boring/1980-024463
Geel	046W0388		BGD046W0388	B/1-1100	https://www.dov.vlaanderen.be/data/boring/2006-063660
Genk	KB136 077E300		BGD077E0300	kb25d77e-B305	https://www.dov.vlaanderen.be/data/boring/1979-098935
Hasselt Concentra	B129		BGD077w0379	kb25d77w-B390	https://www.dov.vlaanderen.be/data/boring/1990-072875
Hasselt south = stad	B61		BGD092e0503	kb33d92e-B508	https://www.dov.vlaanderen.be/data/boring/1990-044613
Helchteren	062e0261		BGD062e0261	kb25d62e-B265	https://www.dov.vlaanderen.be/data/boring/1964-031715
Herentals	B39		BGD045w0337	BGD045w0337	https://www.dov.vlaanderen.be/data/boring/1981-070192
Herselt	060E0289		BGD060E0289	B/1-1115a	https://www.dov.vlaanderen.be/data/boring/2005-060166
Houthalen	060E0269		BGD060E0269	kb24d60e-B330	https://www.dov.vlaanderen.be/data/boring/1992-084846
Houthalen	060E0266		BGD060E0266	kb24d60e-B274	https://www.dov.vlaanderen.be/data/boring/2016-140534
Houthalen Molenberg	062E0223		BGD062E0223	kb25d62e-B225	https://www.dov.vlaanderen.be/data/boring/1923-084300
Kallo	027E0148		BGD027E0148	kb15d27e-B149	https://www.dov.vlaanderen.be/data/boring/1965-103793
Hemelburg	KS13		BGD047w0260	kb17d47w-B258	https://www.dov.vlaanderen.be/data/boring/1982-086487
Kerkhoven	KB186		BGD047w0264	kb17d47w-B262	https://www.dov.vlaanderen.be/data/boring/1986-038291
Kleine Spouwen hill		between X = 233.18, Y = 170.42, Z = + 117 m and X = 232.860, Y = 170.250, Z = + 122 m			
Koewijde-KS 2 B73	KS2		BGD064W0260	kb26d64w-B271	https://www.dov.vlaanderen.be/data/boring/2016-123810
Kruibeke-Burcht Argex clay pit					
Meerhout	046W0389		BGD046W0389	B/1-1117a	https://www.dov.vlaanderen.be/data/boring/2006-067363
Mol SCK 15	031w237		BGD031w237	B/1-0158	https://www.dov.vlaanderen.be/data/boring/1975-117398
ON-Doel 2b			BGD014e0242	BGD014e0242	https://www.dov.vlaanderen.be/data/boring/1998-170939
ON-Mol-1	031w314		BGD031w314	ON-Mol-1	https://www.dov.vlaanderen.be/data/boring/1997-160115
ON-Dessel-1	031w0300		BGD031w0300	ON-Dessel-1	https://www.dov.vlaanderen.be/data/boring/1993-160110
Opglabbeek Industrie	KS19		BGD063W0215	kb26d63w-B218	https://www.dov.vlaanderen.be/data/boring/1983-098675
Pellenberg Lubbeek Roelants pit	TO-20171107		geen	TO-20171107	https://www.dov.vlaanderen.be/data/boring/2017-164496
Point 163 in Glibert & de Heinzelin 1954					
Reet watertoren	B37		BGD043W0301	B/1-0709	https://www.dov.vlaanderen.be/data/boring/1990-081839
Rumst Wienerberger clay pit		zone langs kleifront			
Rupel cuesta		around x =154 000, y = 197 500, z = + 30 m			
Ruwmortelsheide	KS22		BGD063E0222	kb26d63e-B229	https://www.dov.vlaanderen.be/data/boring/1984-111198
Schelle , Damman Clay pit		ongeveer x= 149 000, y= 201000 , 51°07'01.22'' N, 4°21'21.30'' E			
SVK Sint-Niklaas clay pit			042W0190	kb15d42w-B207	https://www.dov.vlaanderen.be/data/boring/1957-122096
Steendorp Bolderik clay pit		x=142100 en y=203050			
Weelde SCK 98	008E159		BGD008E159	kb8d8e-B161	https://www.dov.vlaanderen.be/data/boring/1996-098751
Zoersel			BGD029E0348	kb16d29e-B393	https://www.dov.vlaanderen.be/data/boring/1996-069600
Driepaalhoeve	KS3		BGD063E0217	kb26d63e-B224	https://www.dov.vlaanderen.be/data/boring/1980-082436
Lichtaart (parking)	030E0290		BGD030e0290	B/1-0414	https://www.dov.vlaanderen.be/data/boring/1981-001260
Winterslag (koolmijn schacht) in de figuur van Gulinck https://collections.naturalsciences.be/ssh-geology-archives/profiles-boreholes/Varia%20profiles%20boreholes/mg/mg-75-338-profielen-van-de-tertiaire-dekterreinen-in-n-o-belgie.jpg			BGD078w0206	kb26d78w-B207	https://www.dov.vlaanderen.be/data/boring/2016-124625
Loenhout	DZH21 0160237		BGD016e0237	BGD016e0237	https://www.dov.vlaanderen.be/data/boring/1995-166563
Meer-geothermie	07E0205 =KB149		BGD007e0205	kb8d7e-B224	https://www.dov.vlaanderen.be/data/boring/1981-082884
Bokrijk (vlgs profile Johan Matthijs op kaartblad Hasselt)	77E0230		BGD077e0230	kb25d77e-B232	https://www.dov.vlaanderen.be/data/boring/1928-035676
Beringen-Fonteintje	62W0302		BGD062W0302	kb25d62w-B305	https://www.dov.vlaanderen.be/data/boring/1981-084407
Retie (een SCK-NIRAS boring van begin jaren 80)			BGD018e0132	kb9d18e-B174	https://www.dov.vlaanderen.be/data/boring/1981-122355

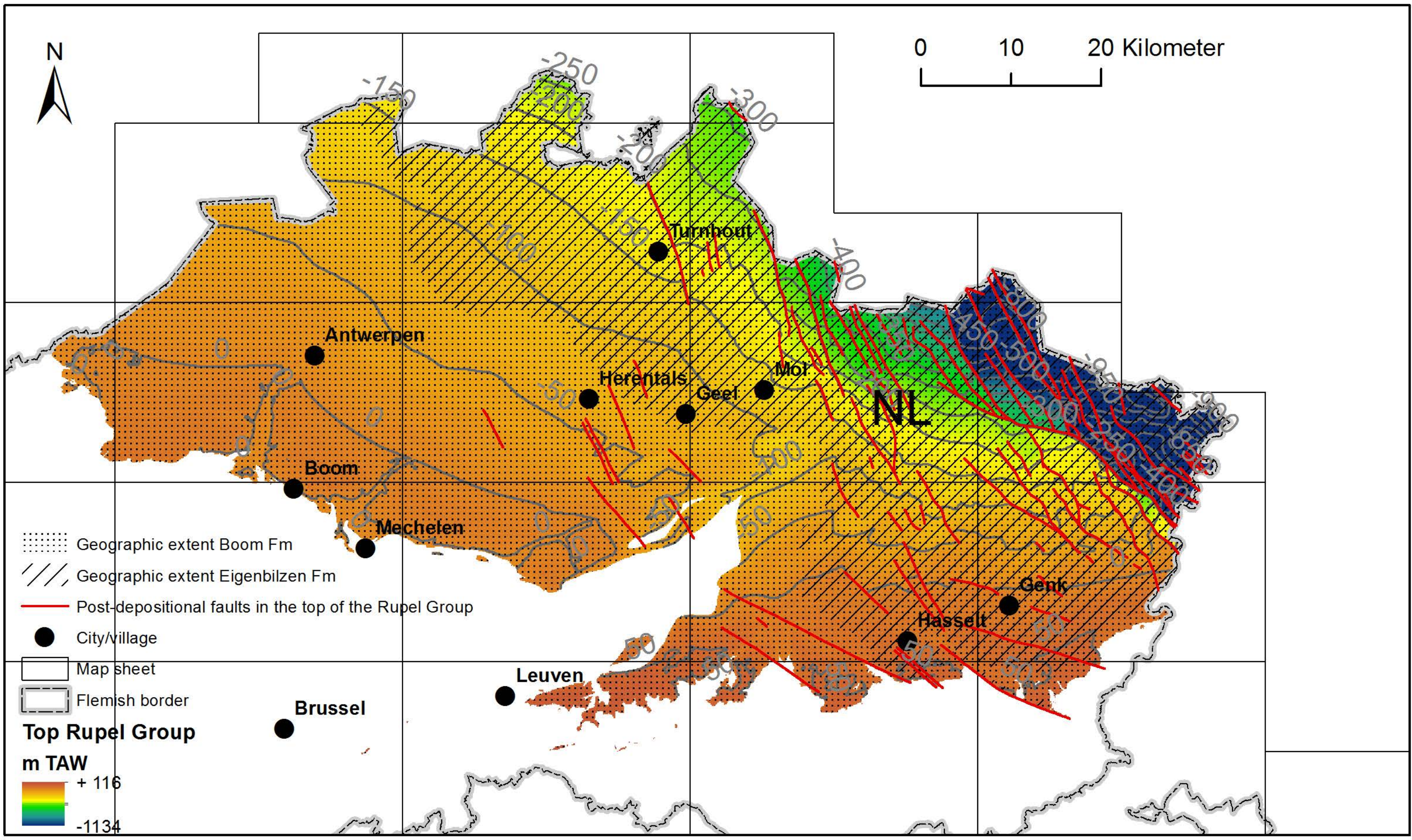
Laag: Boringen
Datum: 07/06/2023
Bron: Databank Ondergrond Vlaanderen <https://www.dov.vlaanderen.be>
Aansprakelijkheidsclausule: De gegevens worden enkel meegedeeld ter informatie. De Vlaamse overheid kan niet verantwoordelijk worden gesteld voor de gevolgen van welk gebruik dan ook.

Boornummer	DOV-URL	Diepte tot (m)	Datum aanvang	Namen	X (mL72)	Y (mL72)	Z (mTAW)
ON-Dessel-1	https://www.dov.vlaanderen.be/data/boring/1993-160110	613.49	13/10/1993	BGD031W0300, Boring ON-Dessel-1	199117.0	213382.3	24.76
B/1-1100	https://www.dov.vlaanderen.be/data/boring/2006-063660	205.0	17/05/2006	1-N01, Boring Geel, BGD046W0388	194861.0	205033.0	20.39
kb25d62e-B265	https://www.dov.vlaanderen.be/data/boring/1964-031715	180.0	01/05/1964	Boring Helchteren, BGD062e0261	221821.2	194187.6	70.5
B/1-1117a	https://www.dov.vlaanderen.be/data/boring/2006-067363	224.0	11/08/2006	1-N18, Boring Meerhout, BGD046W0389	200001.0	203296.0	24.15
kb17d31e-B320	https://www.dov.vlaanderen.be/data/boring/1980-085151	322.0	17/12/1980	Peilput 16, BGD031e0338	208953.2	208235.1	38.0
BGD045w0337	https://www.dov.vlaanderen.be/data/boring/1981-070192	200.0	24/03/1981	B/1-0411, Peilput nr.1, BGD045w0337	185006.48	207734.28	17.71
kb25d77e-B232	https://www.dov.vlaanderen.be/data/boring/1928-035676	12.92	01/01/1928	BGD77e0230	225077.3	181828.1	44.8
kb24d60e-B274	https://www.dov.vlaanderen.be/data/boring/2016-140534	20.0		BGD60e0266	189930.0	197880.0	14.0
TO-20171107	https://www.dov.vlaanderen.be/data/boring/2017-164496	2.0	07/11/2017	Ontsluiting Pellenberg	181416.0	173274.0	88.0
ON-Mol-1	https://www.dov.vlaanderen.be/data/boring/1997-160115	572.5	01/05/1997	BGD031w0314, Boring ON-Mol-1	200191.28	211621.76	24.88
kb34d93w-B253	https://www.dov.vlaanderen.be/data/boring/1972-082725	2.7	23/07/1972	BGD093w0243	233004.5	171246.0	100.0
kb24d60e-B330	https://www.dov.vlaanderen.be/data/boring/1992-084846	160.0	01/01/1992	BGD60e0269	192010.0	194620.0	17.0
kb8d8e-B161	https://www.dov.vlaanderen.be/data/boring/1996-098751	528.5	01/01/1996	Boring SCK, Vlieghaven, Weelde S46, BGD008e0159	190649.38	231963.48	30.9
kb15d42w-B207	https://www.dov.vlaanderen.be/data/boring/1957-122096	15.5	01/01/1957	BGD042w0190	132733.0	205521.0	17.0
kb34d93w-B256	https://www.dov.vlaanderen.be/data/boring/1972-082717	4.5	23/07/1972	BGD93w0243-3	233004.5	171246.0	100.0
kb34d93w-B258	https://www.dov.vlaanderen.be/data/boring/1972-082718	2.75	24/07/1972	BGD93w0243-5	233004.5	171246.0	100.0
kb34d93w-B254	https://www.dov.vlaanderen.be/data/boring/1972-082726	6.2	23/07/1972	BGD093w0243-1	233004.5	171246.0	100.0
kb34d93w-B255	https://www.dov.vlaanderen.be/data/boring/1972-082727	4.4	23/07/1972	BGD93w0243-2	233004.5	171246.0	100.0
kb34d93w-B259	https://www.dov.vlaanderen.be/data/boring/1972-082729	5.75	24/07/1972	BGD93w0243-6	233004.5	171246.0	100.0
kb34d93w-B260	https://www.dov.vlaanderen.be/data/boring/1972-082730	4.6	24/07/1972	BGD93w0243-7	233004.5	171246.0	100.0
kb34d93w-B262	https://www.dov.vlaanderen.be/data/boring/1972-082732	2.5	24/07/1972	BGD93w0243-9	233004.5	171246.0	100.0
kb34d93w-B257	https://www.dov.vlaanderen.be/data/boring/1881-082728	6.0	23/07/1972	BGD93w0243-4	233004.5	171246.0	100.0
kb25d62e-B225	https://www.dov.vlaanderen.be/data/boring/1923-084300	956.25	23/12/1923	KOEN-B91, BGD62e0223	221949.0	190950.0	73.2
kb25d77w-B390	https://www.dov.vlaanderen.be/data/boring/1990-072875	212.0	07/05/1990	BGD077w0379	217067.36	182035.46	28.93
kb25d77e-B305	https://www.dov.vlaanderen.be/data/boring/1979-098935	805.0	01/01/1979	KB136, KOEN-B136, KKS1, BGD077E0300	225504.0	186415.0	68.0
kb25d62w-B305	https://www.dov.vlaanderen.be/data/boring/1981-084407	982.4	01/01/1981	KOEN-B152, BGD062W0302, BGD62w0302, KKS10, KB152	217190.0	197810.0	66.76
BGD016e0237	https://www.dov.vlaanderen.be/data/boring/1995-166563	505.0	01/01/1995	DZH21, 016e0237	174826.0	227929.0	32.7
kb34d93w-B263	https://www.dov.vlaanderen.be/data/boring/1972-204160	2.5	24/07/1972	BGD93w0243	233004.5	171246.0	100.0
kb34d93w-B265	https://www.dov.vlaanderen.be/data/boring/1881-204162	6.6	03/06/1881	BGD093w0243, boring nr. 60	233004.5	171246.0	100.0
kb34d93w-B261	https://www.dov.vlaanderen.be/data/boring/1972-082731	2.0	24/07/1972	BGD93w0243-8	233004.5	171246.0	100.0
kb34d93w-B264	https://www.dov.vlaanderen.be/data/boring/1972-204161	3.15	24/07/1972	BGD93w0243	233004.5	171246.0	100.0
kb33d92e-B508	https://www.dov.vlaanderen.be/data/boring/1990-044613	183.0	01/11/1990	BGD092e0503	219306.9	177066.2	62.0
kb26d64w-B271	https://www.dov.vlaanderen.be/data/boring/2016-123810	1027.0	01/01/1979	BGD064W0259, KB140, KKS2, KOEN-B140	246160.0	192360.0	37.02
BGD014e0242	https://www.dov.vlaanderen.be/data/boring/1998-170939	173.49	01/04/1998	ON-DOEL-2b, 014e0242	142228.0	224453.0	8.07
B/1-0414	https://www.dov.vlaanderen.be/data/boring/1981-001260	132.0	01/03/1981	Boring Lichtaart, BGD030e0290, kb16d30e-B294	189823.04	211239.36	15.32
B/1-0709	https://www.dov.vlaanderen.be/data/boring/1990-081839	108.0	06/12/1990	kb15d43w-B368, BGD043w0301	152249.53	200606.53	25.4
kb15d27e-B149	https://www.dov.vlaanderen.be/data/boring/1965-103793	622.0	13/07/1965	BGD027e0148, UG-TGO-87/33-27E148	144820.0	217840.0	2.0
kb25d62e-B274	https://www.dov.vlaanderen.be/data/boring/1981-103185	980.96	13/10/1981	KB153, KKS9, BGD062E0270, KOEN-B153	223610.0	192660.0	79.19
kb8d7e-B224	https://www.dov.vlaanderen.be/data/boring/1981-082884	2517.0	27/07/1980	Boring Meer-Hoogstraten, KB149, BGD007e0205	177378.47	237303.54	13.22
kb26d78w-B207	https://www.dov.vlaanderen.be/data/boring/2016-124625	700.75	28/07/1914	BGD78w0206, Schacht I, Winterslag	228762.4	186354.2	76.5
B/1-0158	https://www.dov.vlaanderen.be/data/boring/1975-117398	577.0	01/08/1975	SCK15, GEO-75/441-B1, kb17d31w-B224, BGD031w0237	198406.0	211750.0	24.5
kb17d47w-B258	https://www.dov.vlaanderen.be/data/boring/1982-086487	1200.3	01/01/1982	BGD047w0260, KKS13, Boring Koersel, Hemelbrug, KOEN-B167, KB159	215220.0	198270.0	59.12
kb26d63e-B223	https://www.dov.vlaanderen.be/data/boring/1980-024463	1075.5	01/01/1980	BGD063E0216, KB147, KKS6, KOEN-B147	239730.0	192120.0	87.43
kb26d63e-B224	https://www.dov.vlaanderen.be/data/boring/1980-082436	1188.4	01/01/1980	Boring Dilsen, Driepaal, KB139, KKS3, BGD063E0217, KOEN-B139	241570.0	192130.0	90.69
kb26d63e-B229	https://www.dov.vlaanderen.be/data/boring/1984-111198	1236.0	01/01/1984	BGD063E0222, KB167, KOEN-B176, KKS22	238820.0	191250.0	90.52
kb26d63w-B218	https://www.dov.vlaanderen.be/data/boring/1983-098675	1228.0	01/01/1983	KKS19, KOEN-B172, KB164, BGD063W0215	233420.0	192710.0	86.75
B/1-1115a	https://www.dov.vlaanderen.be/data/boring/2005-060166	165.0	16/11/2005	BGD060E0289, 1-N16, Boring Herselt	189384.0	196607.0	15.04
kb16d29e-B393	https://www.dov.vlaanderen.be/data/boring/1996-069600	300.0	01/01/1996	BGD029e0348	173320.87	214840.74	13.09
kb17d47w-B262	https://www.dov.vlaanderen.be/data/boring/1986-038291	1504.0	01/06/1986	BGD047w0264, KB186	213939.9	206367.8	46.0
kb9d18e-B174	https://www.dov.vlaanderen.be/data/boring/1981-122355	344.0	01/04/1981	BGD018e0132, Peilput nr 5	204520	218665	29

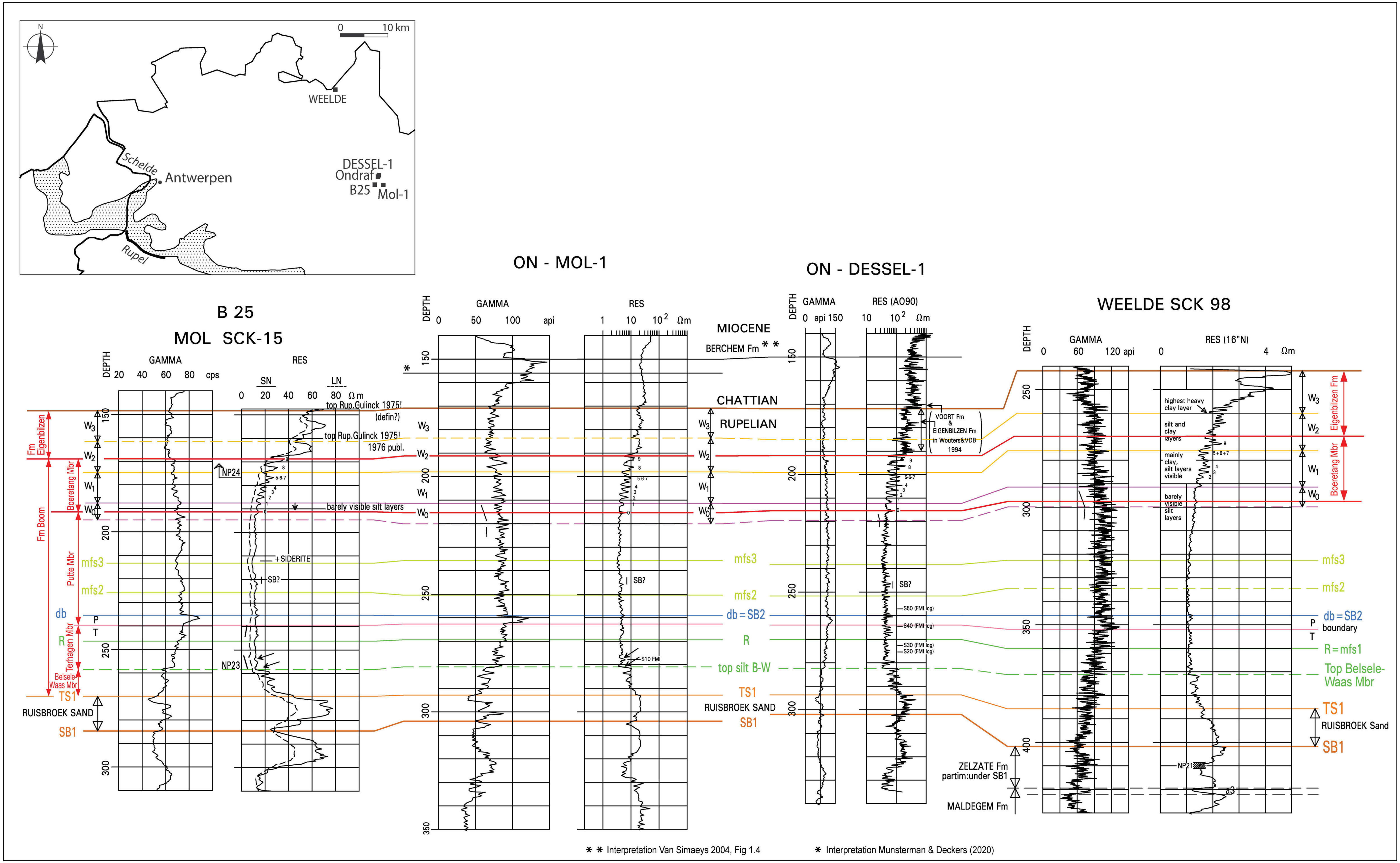


Name	Nr
Albert-Canal section (near Eigenbilzen)	1
Balen B30	2
Berg ‘gîte classique de Berg	3
Donderslagse Heide	4
Dornerheide	5
Geel	6
Genk	7
Hasselt Concentra	8
Hasselt south = stad	9
Helchteren	10
Herentals	11
Herselt	12
Houthalen	13
Houthalen	14
Houthalen Molenberg	15
Kallo	16
Hemelburg	17
Kerkhoven	18
Kleine Spouwen hill	19
Koewijde-KS 2 B73	20
Kruibeke-Burcht Argex Clay pit	21
Meerhout	22
Mol SCK 15	23
ON-Doel 2	24
ON-Mol-1	25
ON-Dessel-1	26
Opglabbeek Industrie	27
Pellenberg Lubbeek Roelants pit	28
Point 163 in Glibert & de Heinzelin 1954	29
Reet watertoren	30
Rumst Wienerberger Clay pit	31
Rupel cuesta	32
Ruwmortelsheide	33
Schelle Damman Clay pit	34
SVK Sint-Niklaas Clay pit	35
Steendorp Bolderik Clay pit	36
Weelde SCK 98	37
Zoersel	38
Driepaalhoeve	39
Lichtaart	40
Winterslag	41
Loenhout	42
Meer-geothermie	43
Bokrijk	44
Beringen-Fonteintje	45
Retie	46

1b

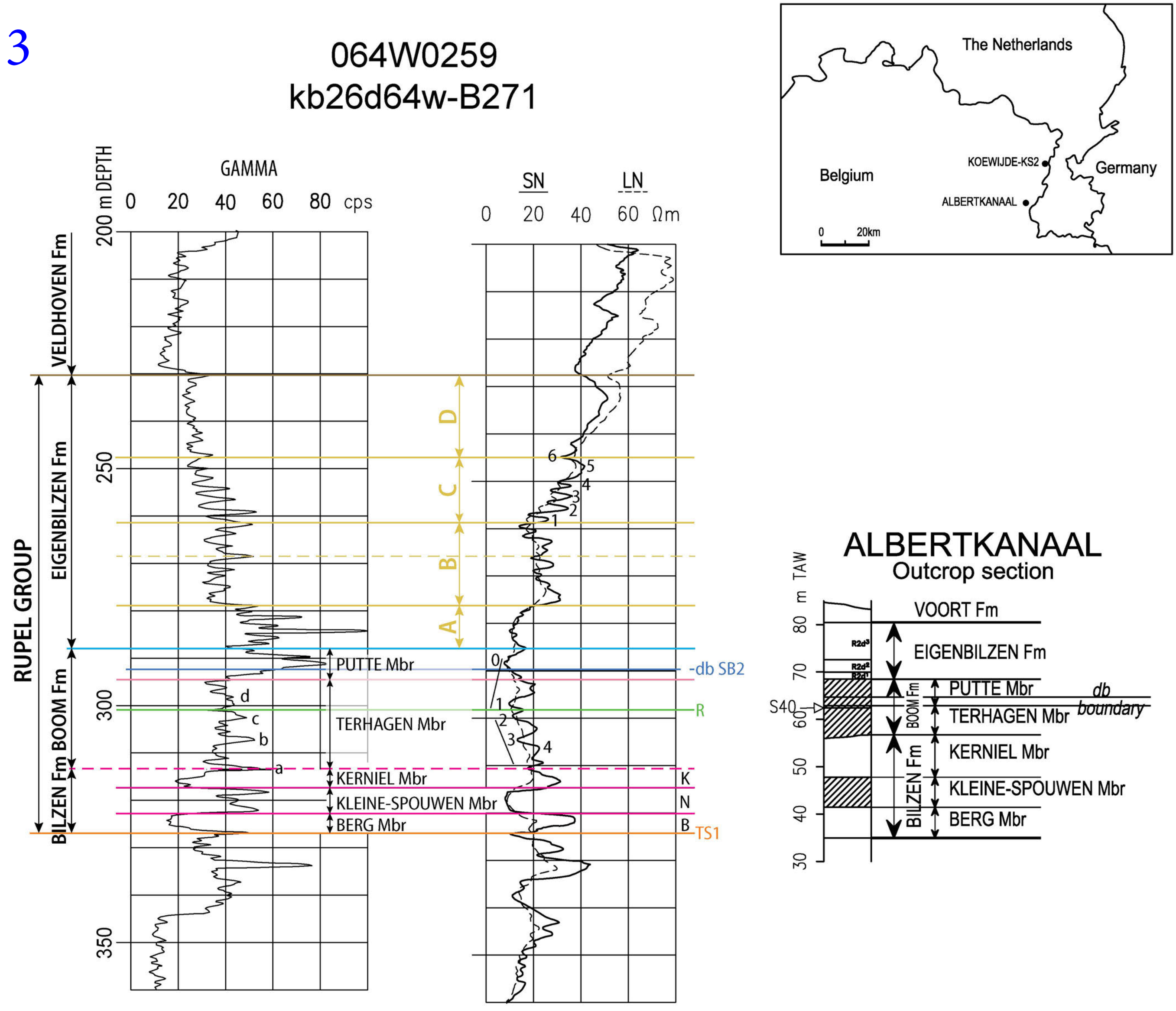

N
0 10 20 Kilometer
Turnhout
Antwerpen
Herentals
Geel
Mol
NL
Boom
Mechelen
Genk
Hasselt
Leuven
Brussel
Geographic extent Boom Fm
Geographic extent Eigenbilzen Fm
Post-depositional faults in the top of the Rupel Group
City/village
Map sheet
Flemish border
Top Rupel Group
m TAW
+ 116
-1134

2



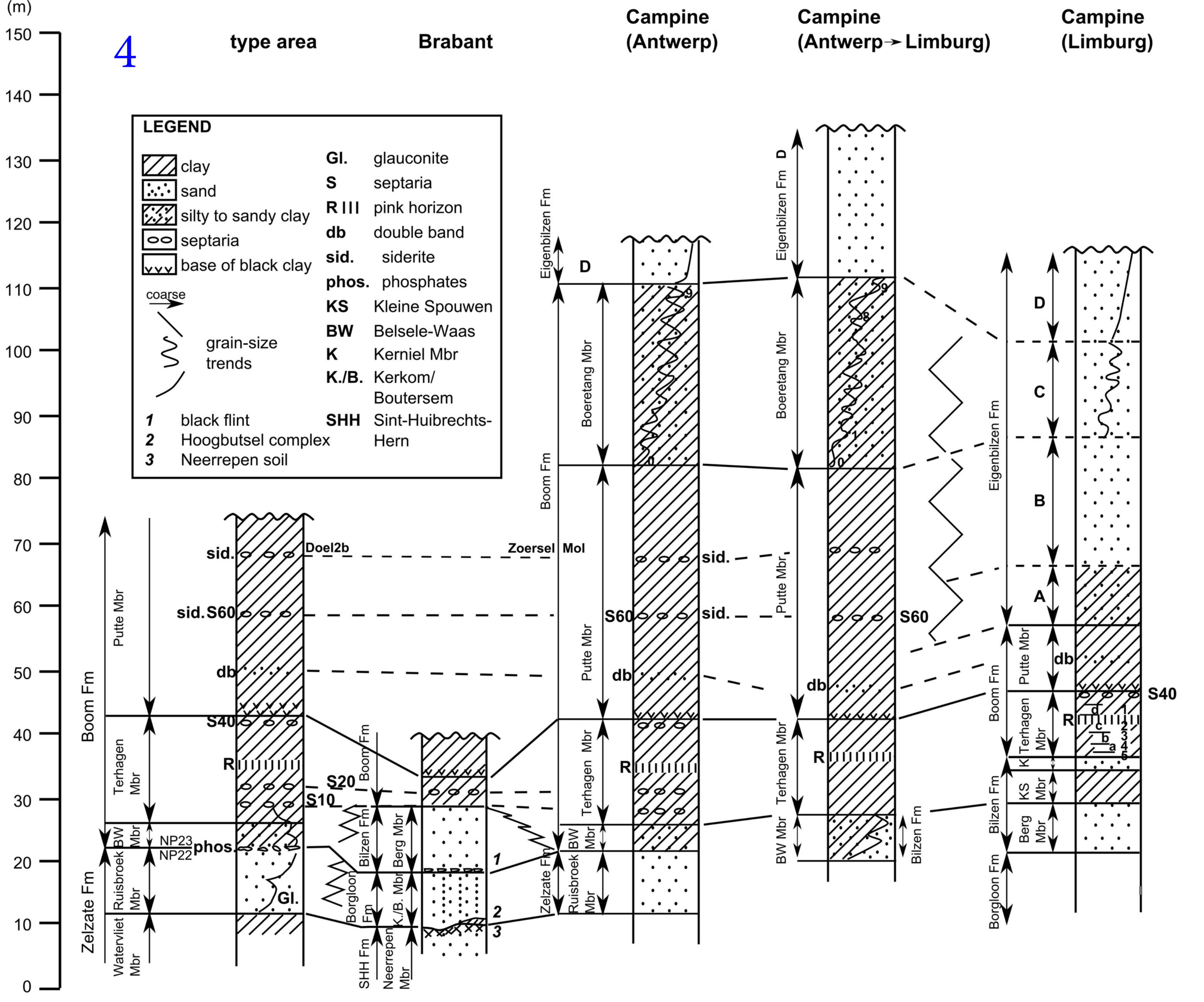
N
0
10 km
WEELDE
Schelde
Antwerpen
DESSEL-1
Ondraf
B25
Mol-1
Rupel
B 25
MOL SCK-15
ON - MOL-1
ON - DESSEL-1
WEELDE SCK 98
DEPTH
GAMMA
20 40 60 80 cps
RES
SN
LN
0 20 40 60 80 Ω m
top Rup.Gulinck 1975!
(defin?)
top Rup.Gulinck 1975!
1976 publ.
NP24
barely visible silt layers
+ SIDERITE
SB?
NP23
0 50 100 api
1 10 10^2 Ωm
MIOCENE
BERCHEM Fm * *
CHATTIAN
RUPELIAN
S10 FMI
0 api 150
RES (AO90)
10 10^2 Ωm
VOORT Fm & EIGENBILZEN Fm in Wouters&VDB 1994
S50 (FMI log)
S40 (FMI log)
S30 (FMI log)
S20 (FMI log)
0 60 120 api
RES (16"N)
0 4 Ωm
highest heavy clay layer
silt and clay layers
mainly clay, silt layers visible
barely visible silt layers
NP21
a3
Fm Eigenbilzen
Fm Boom
Boeretang Mbr
Putte Mbr
Terhagen Mbr
Belsele-Waas Mbr
Eigenbilzen Fm
W3
W2
W1
W0
mfs3
mfs2
db
db=SB2
P
T
boundary
R
R=mfs1
top silt B-W
Top Belsele-Waas Mbr
TS1
RUISBROEK SAND
RUISBROEK Sand
SB1
ZELZATE Fm partim:under SB1
MALDEGEM Fm
* * Interpretation Van Simaeys 2004, Fig 1.4
* Interpretation Munsterman & Deckers (2020)

3



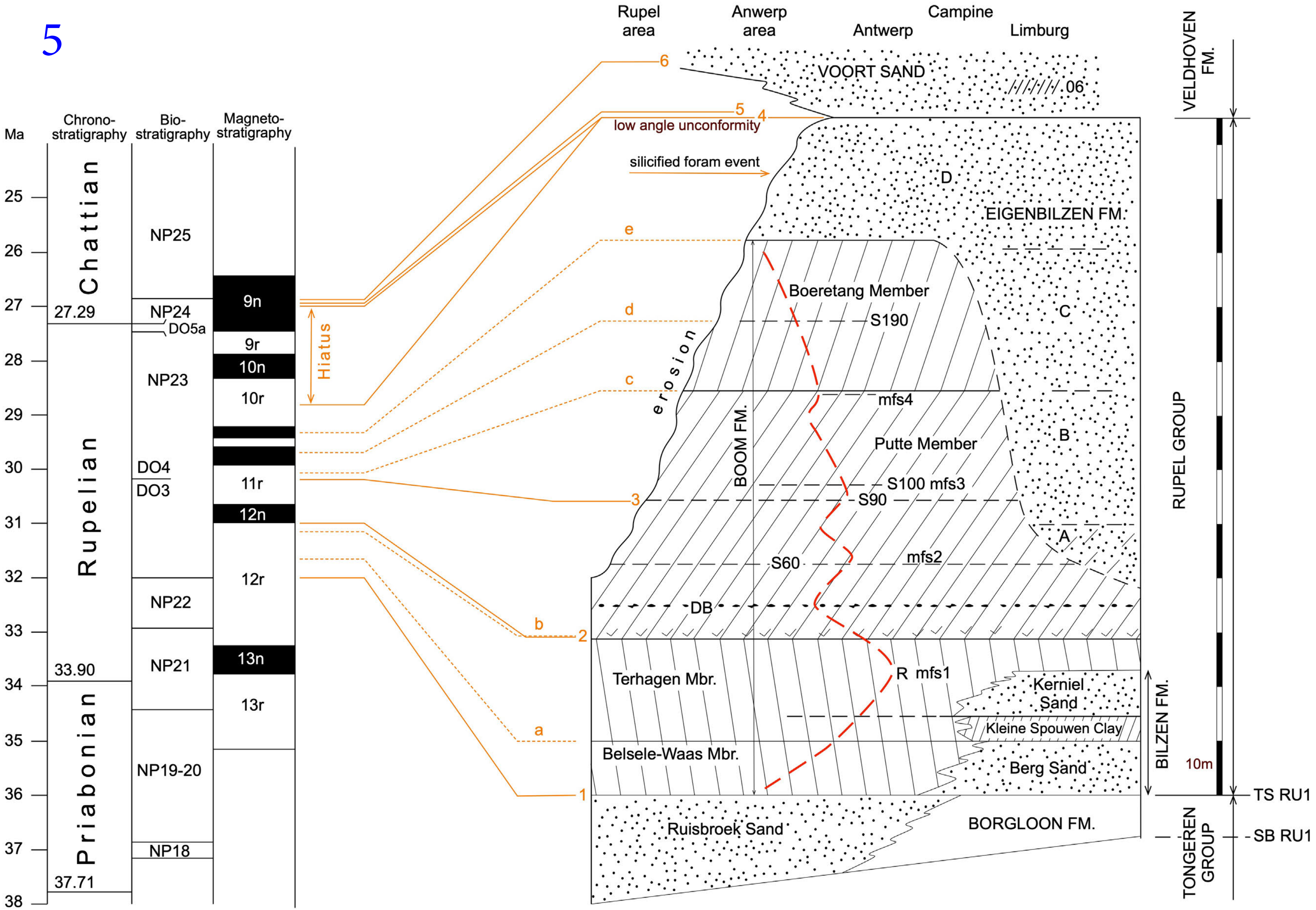
064W0259
kb26d64w-B271
DEPTH
m
GAMMA
0 20 40 60 80 cps
200
250
300
350
SN
LN
0 20 40 60 Ωm
VELDHOVEN Fm
RUPEL GROUP
EIGENBILZEN Fm
BOOM Fm
BILZEN Fm
D
C
B
A
6
5
4
3
2
1
0
PUTTE Mbr
-db SB2
d
c
b
a
TERHAGEN Mbr
R
KERNIEL Mbr
K
KLEINE-SPOUWEN Mbr
N
BERG Mbr
B
TS1
The Netherlands
Belgium
Germany
KOEWIJDE-KS2
ALBERTKANAAL
0 20km
ALBERTKANAAL
Outcrop section
m TAW
80
70
60
50
40
30
VOORT Fm
EIGENBILZEN Fm
R2d³
R2d²
R2d¹
PUTTE Mbr
TERHAGEN Mbr
KERNIEL Mbr
KLEINE-SPOUWEN Mbr
BERG Mbr
BOOM Fm
BILZEN Fm
S40
db
boundary

4



(m)
type area
Brabant
Campine (Antwerp)
Campine (Antwerp→Limburg)
Campine (Limburg)
LEGEND
clay
sand
silty to sandy clay
septaria
base of black clay
coarse
grain-size trends
1 black flint
2 Hoogbutsel complex
3 Neerrepen soil
Gl. glauconite
S septaria
R pink horizon
db double band
sid. siderite
phos. phosphates
KS Kleine Spouwen
BW Belsele-Waas
K Kerniel Mbr
K./B. Kerkom/ Boutersem
SHH Sint-Huibrechts-Hern
Boom Fm
Zelzate Fm
Putte Mbr
Terhagen Mbr
BW Mbr
Ruisbroek Mbr
Watervliet Mbr
NP23
NP22
sid.
sid. S60
db
S40
R
S20
S10
phos.
Gl.
Doel2b
Zoersel
Mol
Bilzen Fm
Berg Mbr
Borgloon Fm
K./B. Mbr
SHH Fm
Neerrepen Mbr
Eigenbilzen Fm
Boeretang Mbr
D
S60
sid.
KS Mbr
K
A
B
C

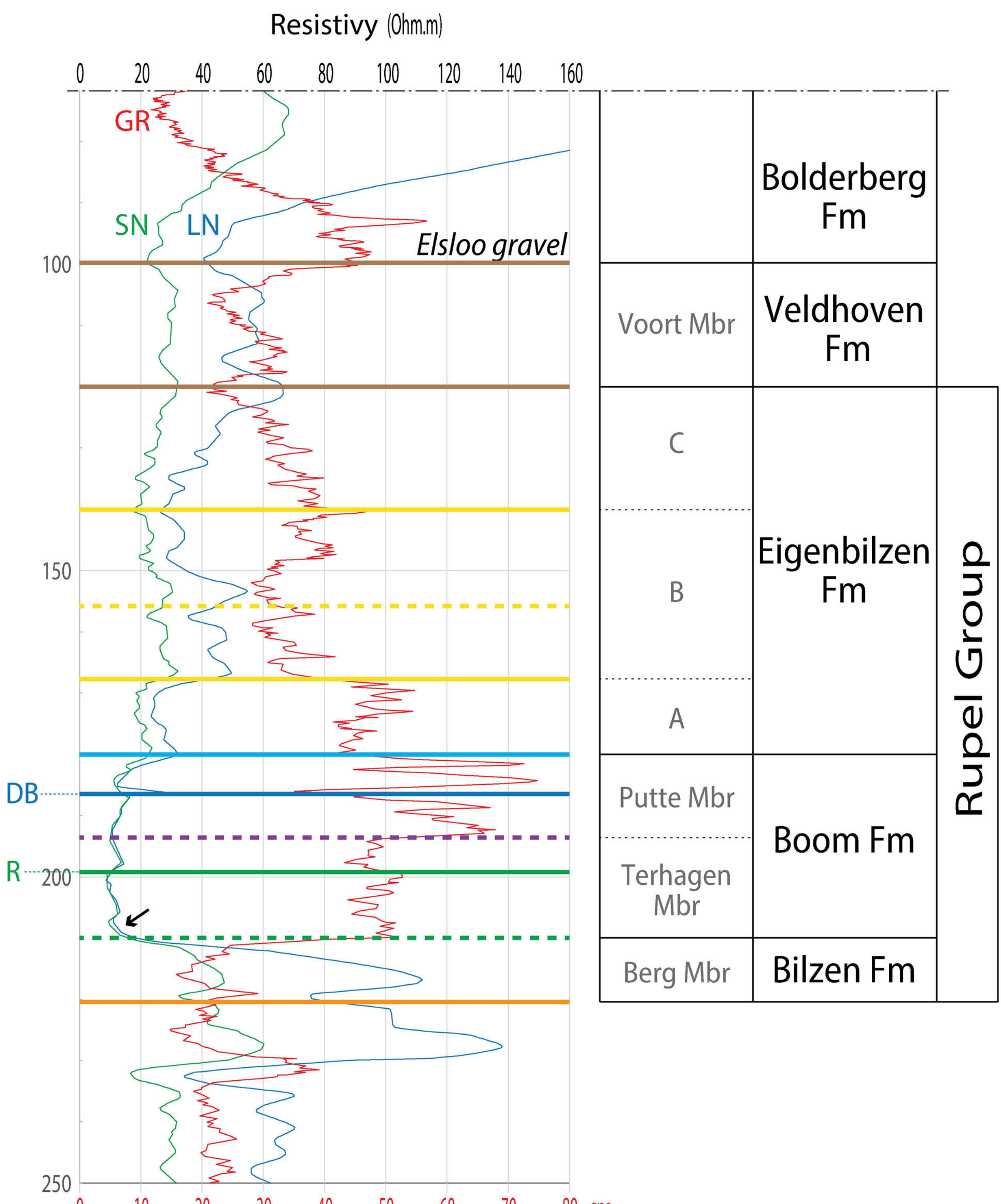
5



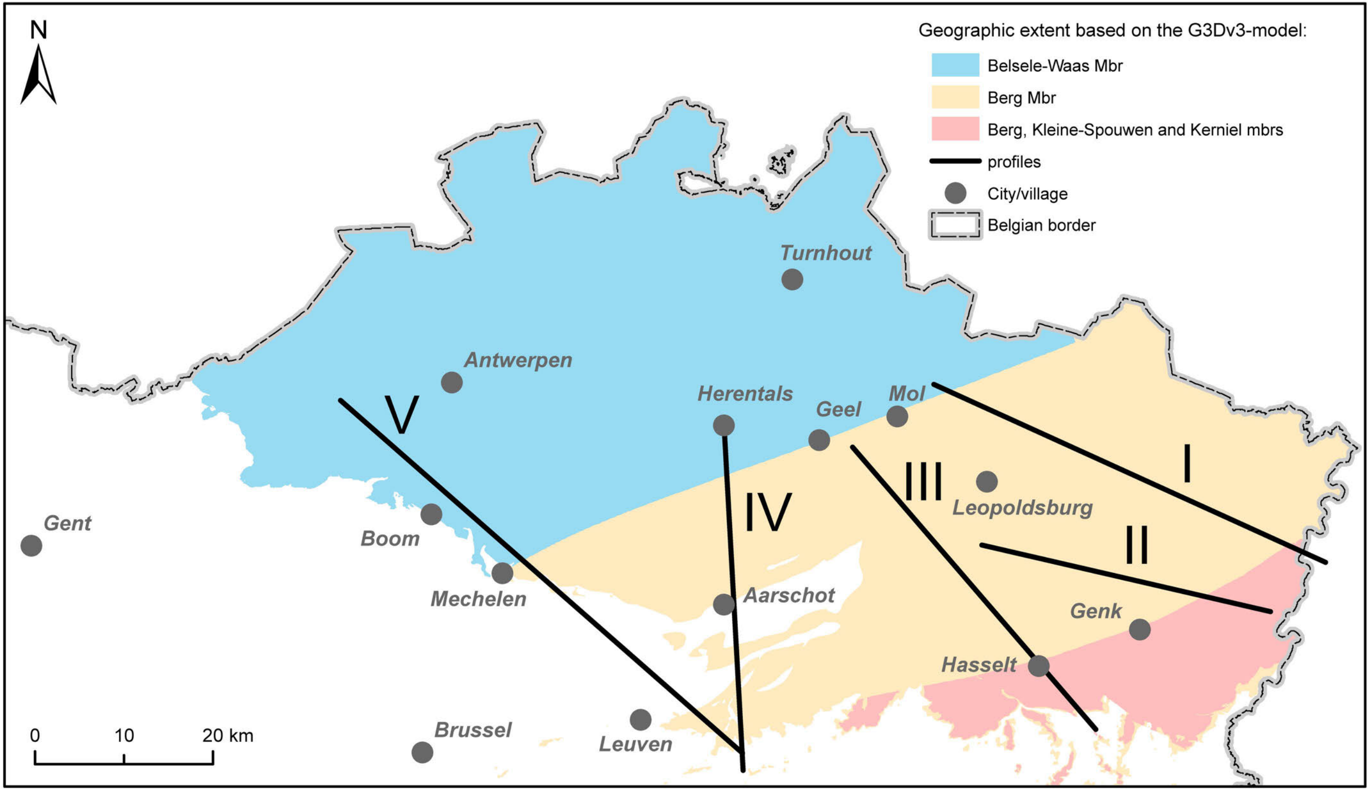
Ma
Chrono-stratigraphy
Bio-stratigraphy
Magneto-stratigraphy
25
26
27
28
29
30
31
32
33
34
35
36
37
38
Chattian
Rupelian
Priabonian
27.29
33.90
37.71
NP25
NP24
DO5a
NP23
DO4
DO3
NP22
NP21
NP19-20
NP18
9n
9r
10n
10r
11r
12n
12r
13n
13r
Hiatus
Rupel area
Anwerp area
Campine
Antwerp
Limburg
VOORT SAND
06
6
5
4
low angle unconformity
silicified foram event
D
EIGENBILZEN FM.
e
d
c
b
a
1
2
3
Boeretang Member
S190
erosion
mfs4
BOOM FM.
Putte Member
S100 mfs3
S90
C
B
A
S60
mfs2
DB
R mfs1
Terhagen Mbr.
Kerniel Sand
Kleine Spouwen Clay
Belsele-Waas Mbr.
Berg Sand
BILZEN FM.
10m
Ruisbroek Sand
BORGLOON FM.
VELDHOVEN FM.
RUPEL GROUP
TONGEREN GROUP
TS RU1
SB RU1

6

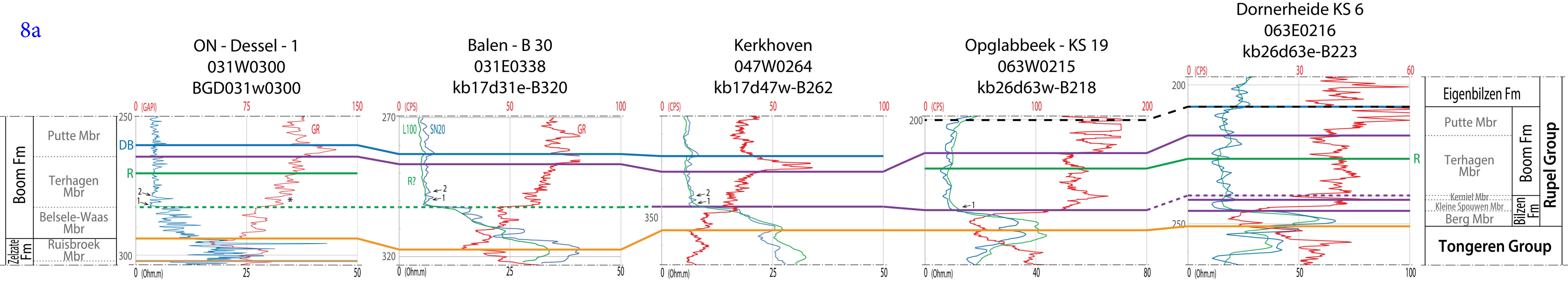
Donderslagseheide - KS 9
062E0270
kb25d62e-B274



7

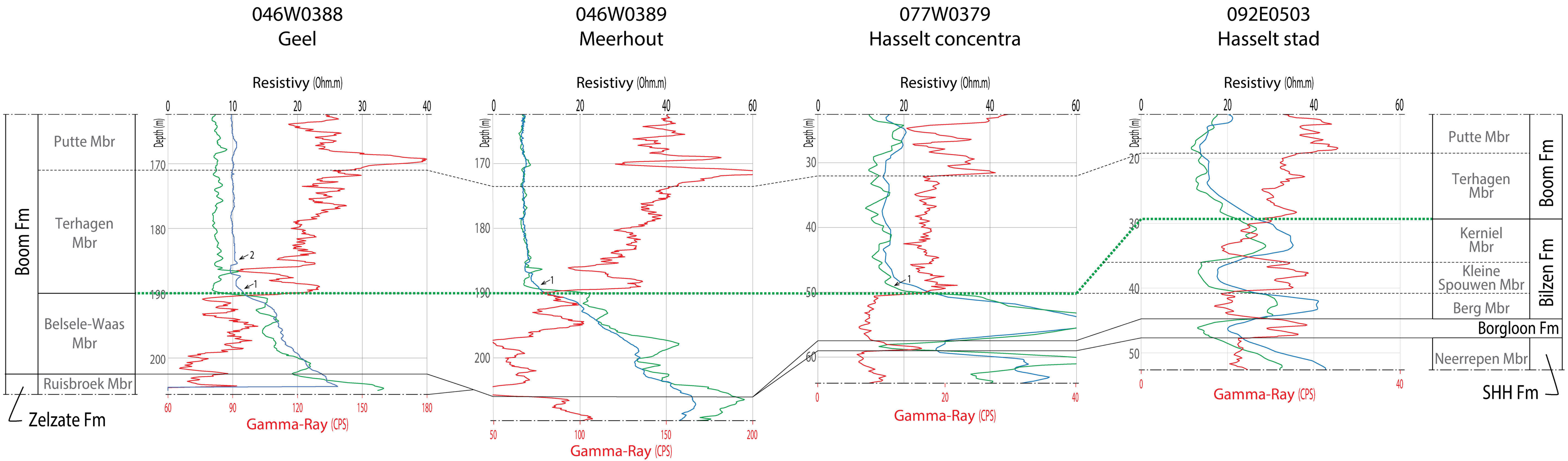

N
Geographic extent based on the G3Dv3-model:
Belsele-Waas Mbr
Berg Mbr
Berg, Kleine-Spouwen and Kerniel mbrs
profiles
City/village
Belgian border
Turnhout
Antwerpen
Herentals
Geel
Mol
Leopoldsburg
Gent
Boom
Mechelen
Aarschot
Genk
Hasselt
Brussel
Leuven
I
II
III
IV
V
0
10
20 km

8a

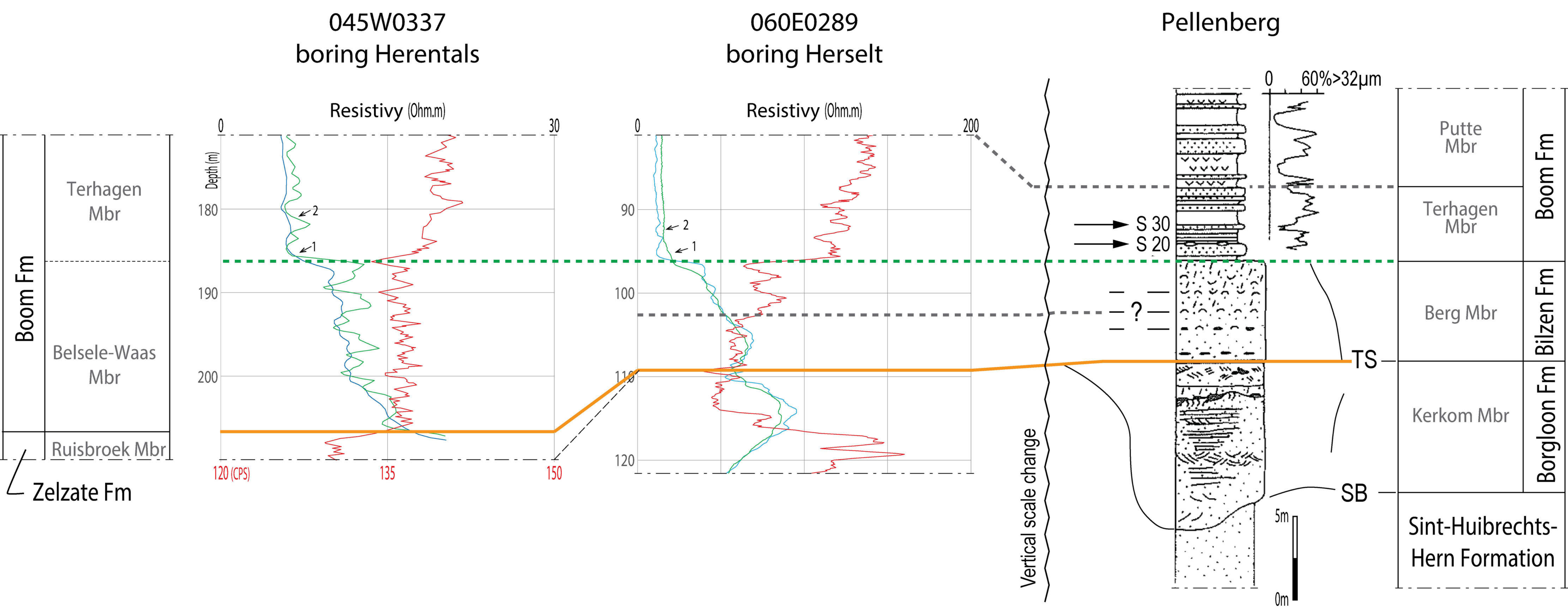


ON - Dessel - 1
031W0300
BGD031w0300
Balen - B 30
031E0338
kb17d31e-B320
Kerkhoven
047W0264
kb17d47w-B262
Opglabbeek - KS 19
063W0215
kb26d63w-B218
Dornerheide KS 6
063E0216
kb26d63e-B223
0 (GAPI) 75 150
0 (CPS) 50 100
0 (CPS) 100 200
0 (CPS) 30 60
0 (Ohm.m) 25 50
0 (Ohm.m) 40 80
0 (Ohm.m) 50 100
250
300
270
320
350
200
GR
L100
SN20
DB
R
R?
Boom Fm
Putte Mbr
Terhagen Mbr
Belsele-Waas Mbr
Zelzate Fm
Ruisbroek Mbr
Eigenbilzen Fm
Kemiel Mbr
Kleine Spouwen Mbr
Berg Mbr
Bilzen Fm
Rupel Group
Tongeren Group

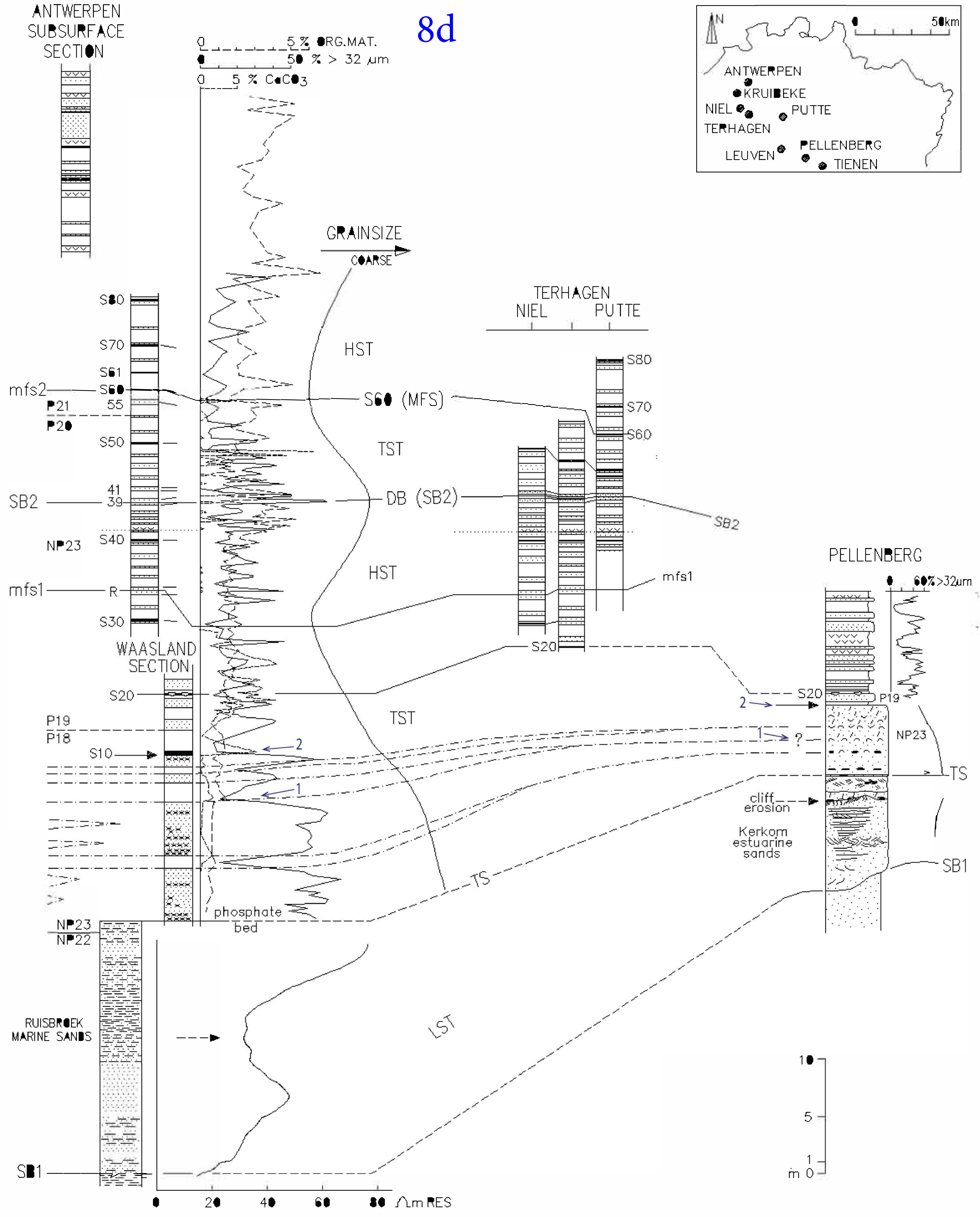
8b


046W0388
Geel
046W0389
Meerhout
077W0379
Hasselt concentra
092E0503
Hasselt stad
Resistivy (Ohm.m)
Resistivy (Ohm.m)
Resistivy (Ohm.m)
Resistivy (Ohm.m)
Depth (m)
Gamma-Ray (CPS)
Gamma-Ray (CPS)
Gamma-Ray (CPS)
Gamma-Ray (CPS)
Boom Fm
Putte Mbr
Terhagen Mbr
Belsele-Waas Mbr
Ruisbroek Mbr
Zelzate Fm
Putte Mbr
Terhagen Mbr
Kerniel Mbr
Kleine Spouwen Mbr
Berg Mbr
Bilzen Fm
Borgloon Fm
Neerrepen Mbr
SHH Fm

8c



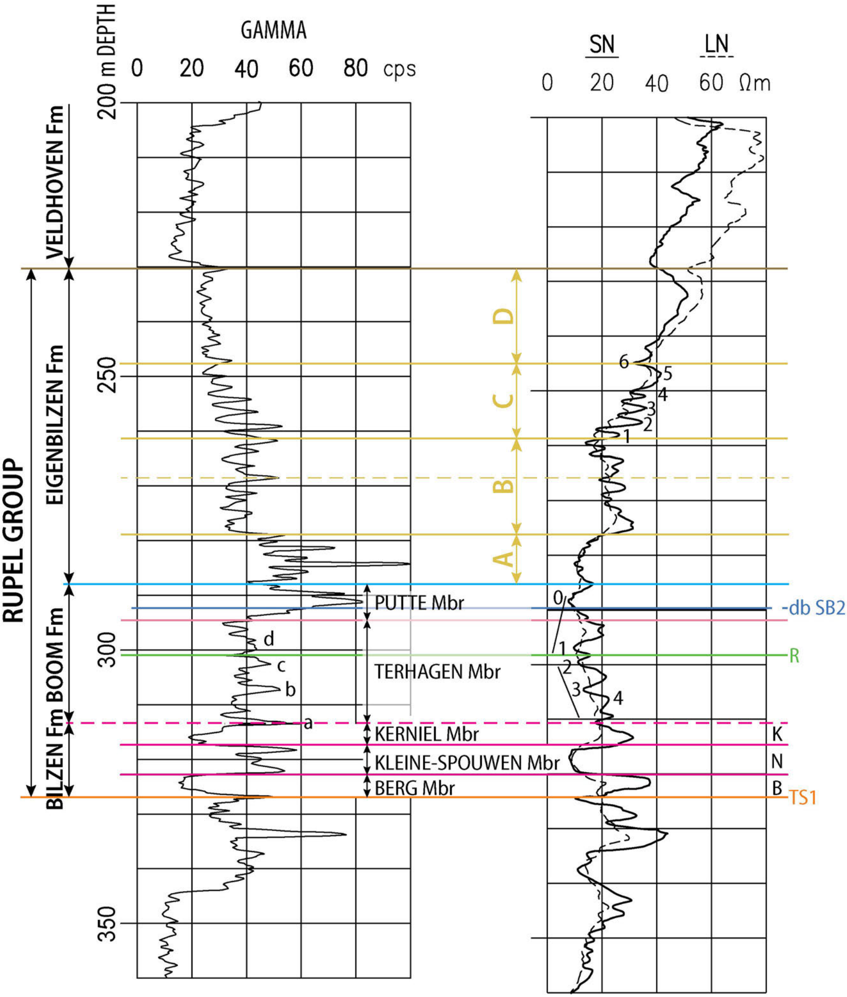
045W0337
boring Herentals
060E0289
boring Herselt
Pellenberg
Resistivy (Ohm.m)
Resistivy (Ohm.m)
Depth (m)
0
30
200
180
190
200
90
100
110
120
120 (CPS)
135
150
0
60%>32µm
Boom Fm
Terhagen Mbr
Belsele-Waas Mbr
Ruisbroek Mbr
Zelzate Fm
S 30
S 20
?
Vertical scale change
TS
SB
5m
0m
Putte Mbr
Terhagen Mbr
Berg Mbr
Kerkom Mbr
Boom Fm
Bilzen Fm
Borgloon Fm
Sint-Huibrechts-Hern Formation

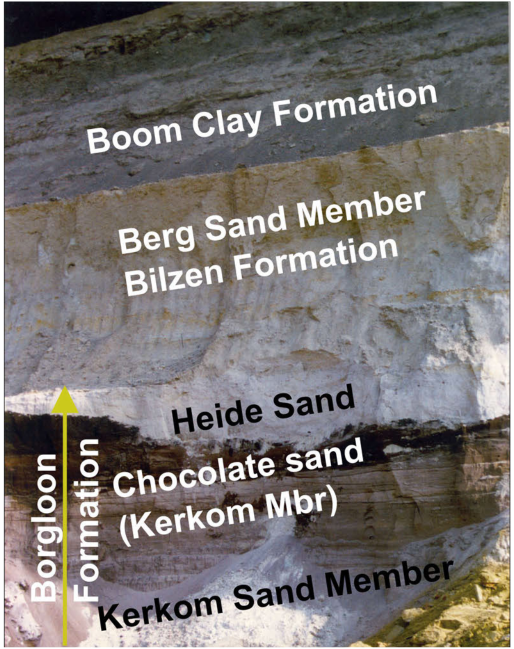


8d
ANTWERPEN SUBSURFACE SECTION
0 5 % ORG.MAT.
0 50 % > 32 µm
0 5 % CaCO3
GRAINSIZE
COARSE
HST
TST
HST
TST
LST
S80
S70
S61
mfs2
S60
P21
55
P20
S50
SB2
41
39
NP23
S40
mfs1
R
S30
WAASLAND SECTION
S20
P19
P18
S10
2
1
phosphate bed
NP23
NP22
RUISBROEK MARINE SANDS
SB1
0 20 40 60 80 Ωm RES
S60 (MFS)
DB (SB2)
TS
TERHAGEN
NIEL
PUTTE
S80
S70
S60
SB2
mfs1
S20
PELLENBERG
0 60% >32µm
S20
P19
NP23
TS
cliff erosion
Kerkom estuarine sands
SB1
?
10
5
1
m 0
N
0 50km
ANTWERPEN
KRUIBEKE
NIEL
PUTTE
TERHAGEN
LEUVEN
PELLENBERG
TIENEN

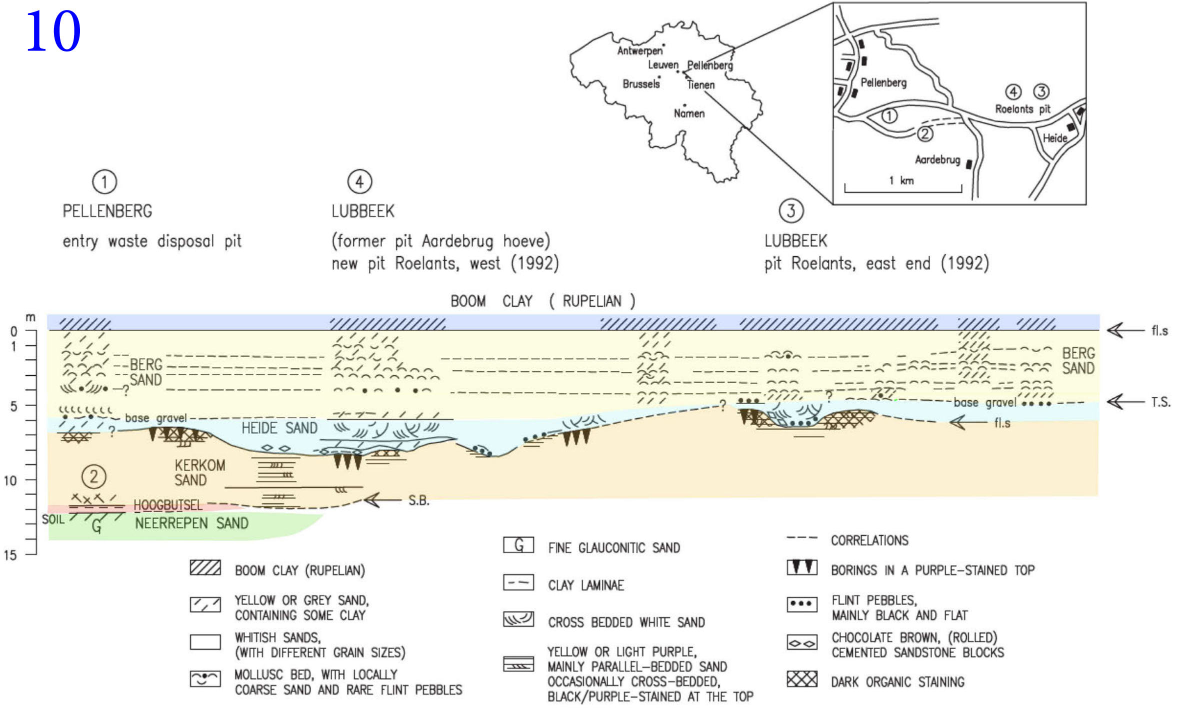
9

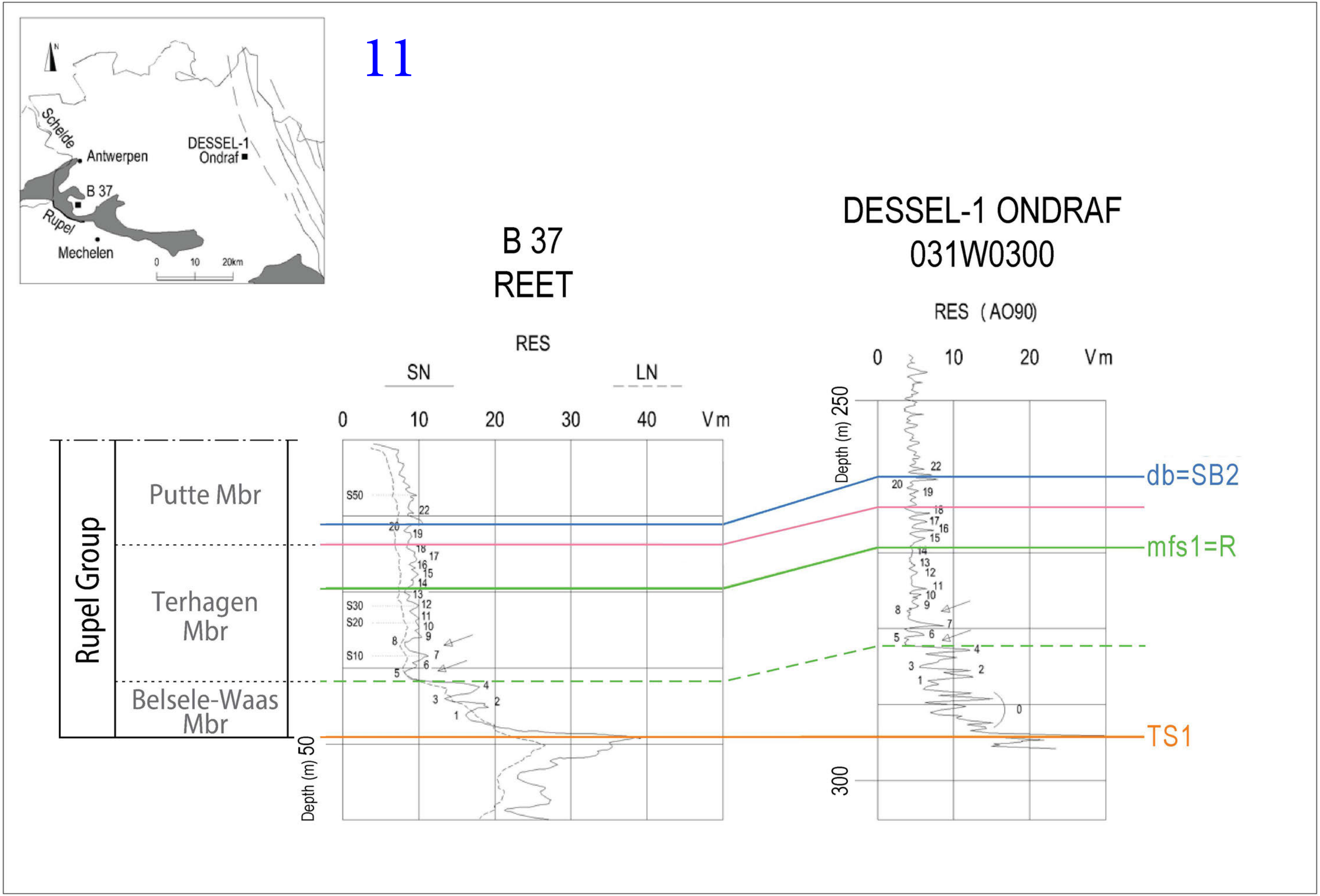
064W0259
kb26d64w-B271

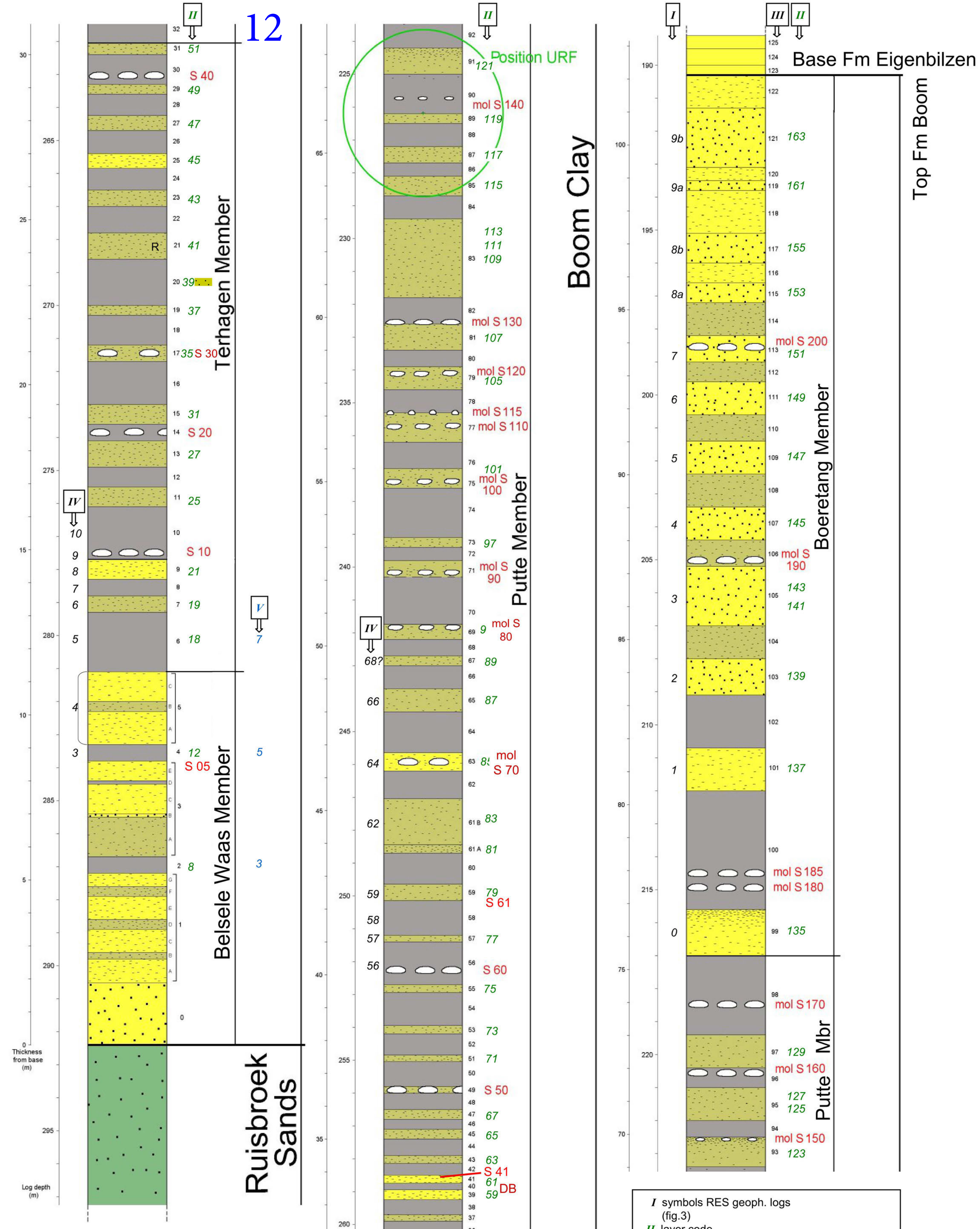



Boom Clay Formation
Berg Sand Member
Bilzen Formation
Heide Sand
Chocolate sand
(Kerkom Mbr)
Kerkom Sand Member
Borgloon
Formation

10


Antwerpen
Leuven
Pellenberg
Brussels
Tienen
Namen
Pellenberg
④ ③
Roelants pit
①
②
Heide
Aardebrug
1 km
① PELLENBERG
entry waste disposal pit
④ LUBBEEK
(former pit Aardebrug hoeve)
new pit Roelants, west (1992)
③ LUBBEEK
pit Roelants, east end (1992)
BOOM CLAY (RUPELIAN)
m
0
1
5
10
15
BERG SAND
BERG SAND
base gravel
base gravel
HEIDE SAND
KERKOM SAND
②
HOOGBUTSEL
SOIL
NEERREPEN SAND
S.B.
fl.s
T.S.
fl.s
BOOM CLAY (RUPELIAN)
YELLOW OR GREY SAND, CONTAINING SOME CLAY
WHITISH SANDS, (WITH DIFFERENT GRAIN SIZES)
MOLLUSC BED, WITH LOCALLY COARSE SAND AND RARE FLINT PEBBLES
FINE GLAUCONITIC SAND
CLAY LAMINAE
CROSS BEDDED WHITE SAND
YELLOW OR LIGHT PURPLE, MAINLY PARALLEL–BEDDED SAND OCCASIONALLY CROSS–BEDDED, BLACK/PURPLE–STAINED AT THE TOP
CORRELATIONS
BORINGS IN A PURPLE–STAINED TOP
FLINT PEBBLES, MAINLY BLACK AND FLAT
CHOCOLATE BROWN, (ROLLED) CEMENTED SANDSTONE BLOCKS
DARK ORGANIC STAINING


11
Schelde
Antwerpen
DESSEL-1
Ondraf
B 37
Rupel
Mechelen
0
10
20km
B 37
REET
RES
SN
LN
0
10
20
30
40
Vm
DESSEL-1 ONDRAF
031W0300
RES (AO90)
Rupel Group
Putte Mbr
Terhagen Mbr
Belsele-Waas Mbr
Depth (m) 50
Depth (m) 250
300
db=SB2
mfs1=R
TS1

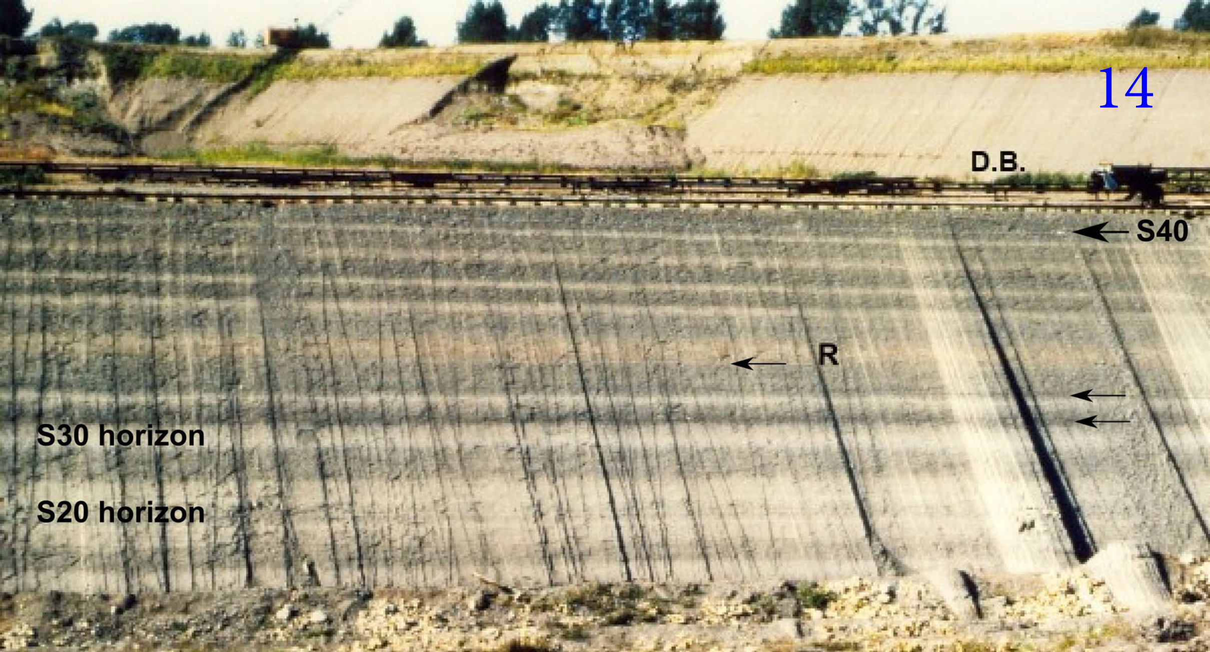


I symbols RES geoph. logs (fig.3)
II layer code Abels et al. (2007)
III layer code Mertens & Wouters (2003)
Vandenberghe (1978) between 10-59
Van Simaeys (2004) between 122-10
IV layer code Vandenberghe (1978)
V Van Simaeys (2004)

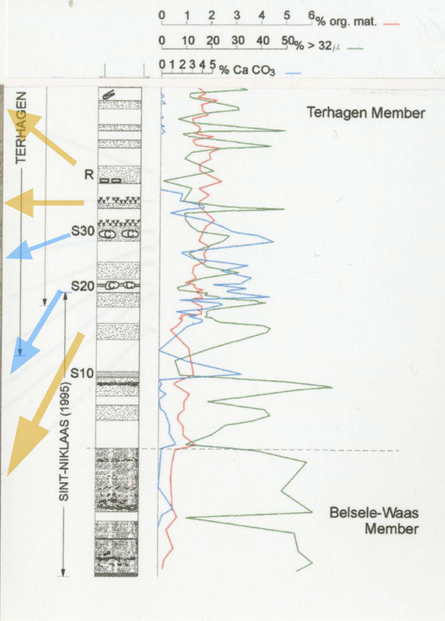
URF underground research facility at SCK-Mol

Microstratigraphic litholog of the Boom Formation based on the FMI (Full bore Formation Micro Imager) of the boreholes ON-Mol-1 en ON-Dessel-1 (Mertens & Wouters, 2003).
The existing numbering systems of the layers (Abels et al., 2007; Vandenberghe, 1978; Van Simaeys, 2004) are plotted in several columns in parallel to the layer codes introduced by Mertens & Wouters (2003) for their litholog.

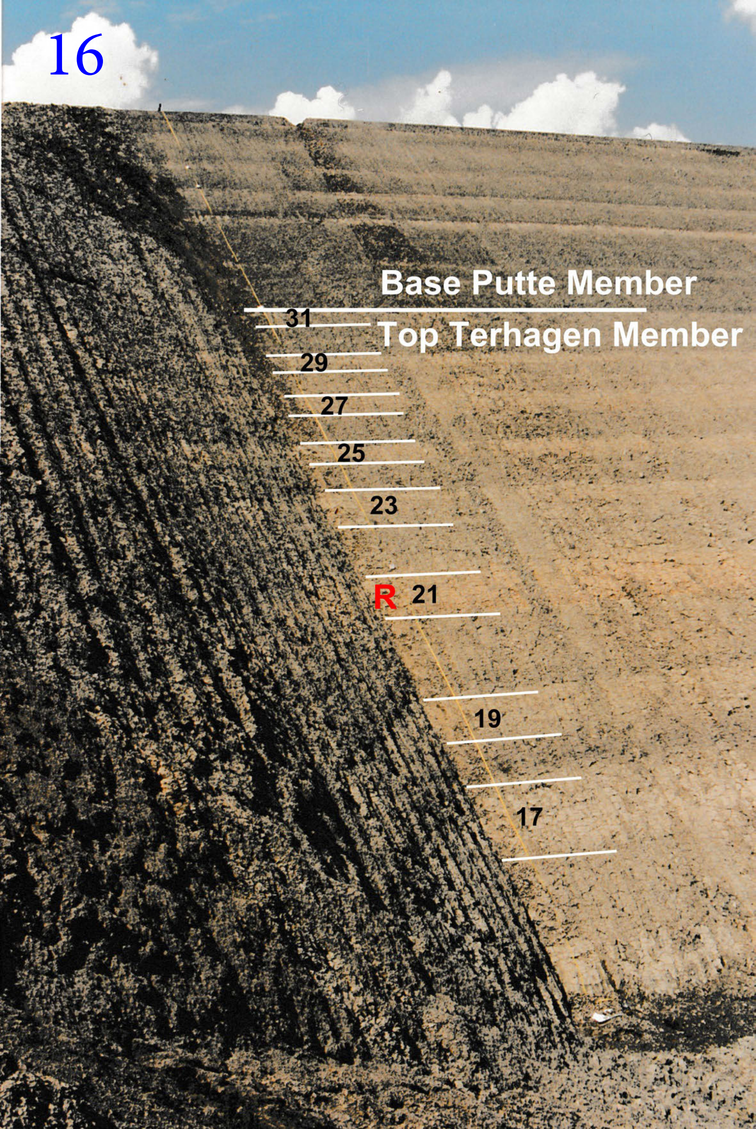

13
Putte Member
Terhagen Member
S40
S20


D.B.
S40
R
S30 horizon
S20 horizon

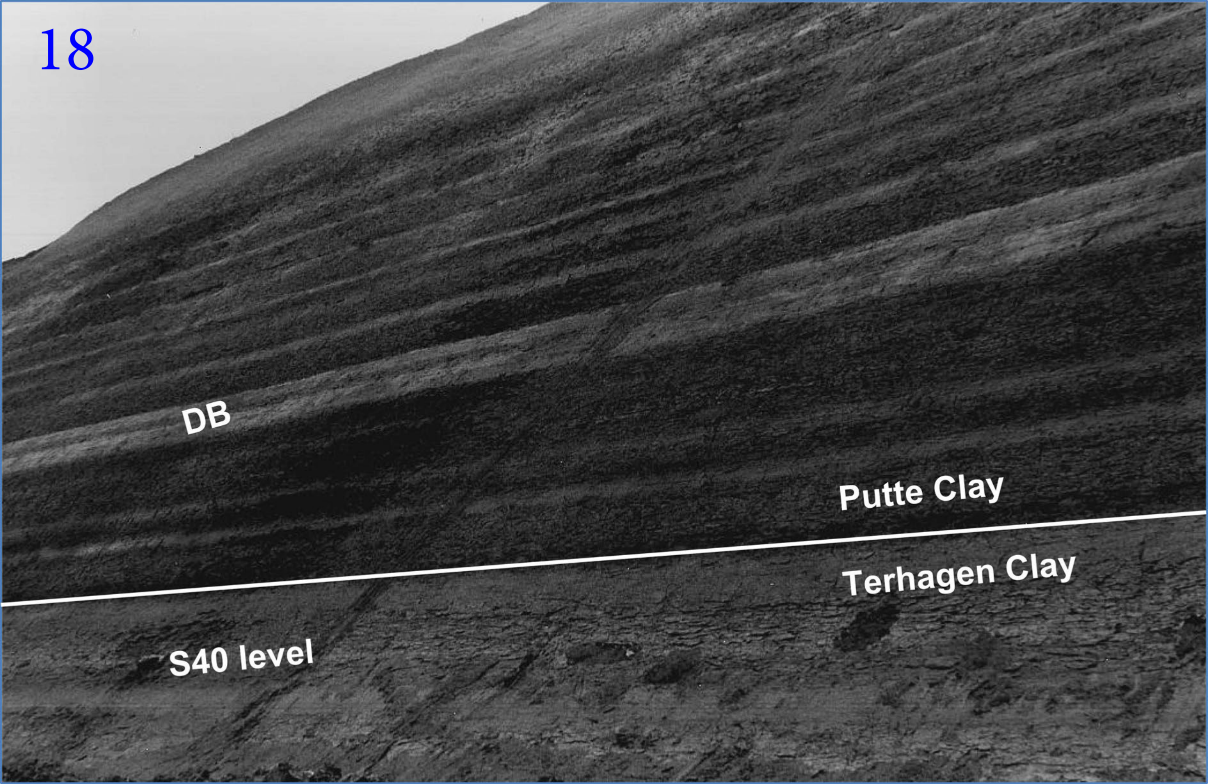
15

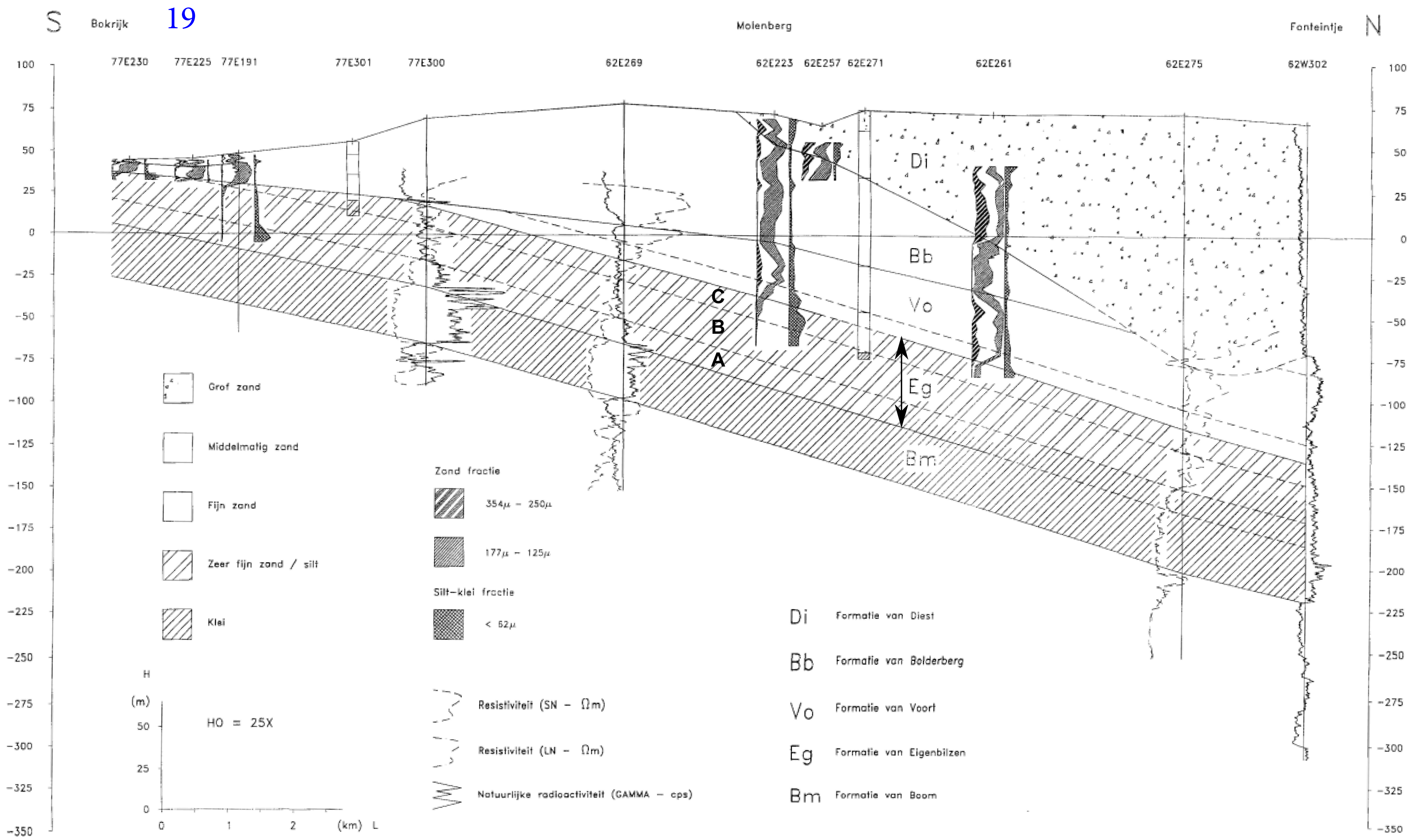


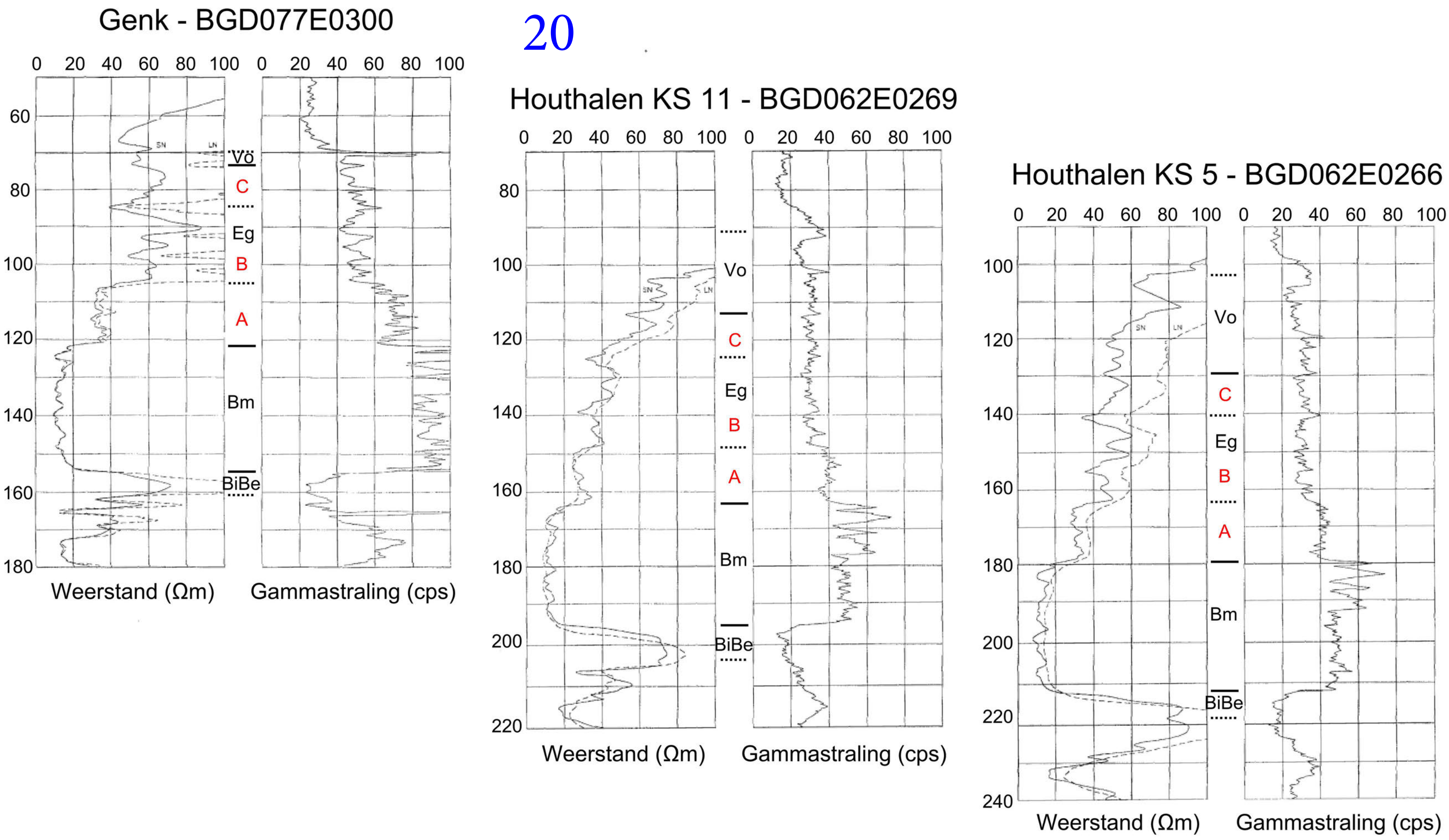
0 1 2 3 4 5 6 % org. mat.
0 10 20 30 40 50 % > 32μ
0 1 2 3 4 5 % Ca CO3
TERHAGEN
SINT-NIKLAAS (1995)
R
S30
S20
S10
Terhagen Member
Belsele-Waas Member


16
Base Putte Member
Top Terhagen Member
31
29
27
25
23
R
21
19
17

17


18
DB
Putte Clay
Terhagen Clay
S40 level


S
Bokrijk
Molenberg
Fonteintje
N
77E230
77E225
77E191
77E301
77E300
62E269
62E223
62E257
62E271
62E261
62E275
62W302
Di
Bb
Vo
Eg
Bm
C
B
A
Grof zand
Middelmatig zand
Fijn zand
Zeer fijn zand / silt
Klei
Zand fractie
354μ – 250μ
177μ – 125μ
Silt-klei fractie
< 62μ
Resistiviteit (SN – Ωm)
Resistiviteit (LN – Ωm)
Natuurlijke radioactiviteit (GAMMA – cps)
Di Formatie van Diest
Bb Formatie van Bolderberg
Vo Formatie van Voort
Eg Formatie van Eigenbilzen
Bm Formatie van Boom
H (m)
HO = 25X
(km) L



Genk - BGD077E0300
Houthalen KS 11 - BGD062E0269
Houthalen KS 5 - BGD062E0266
Vo
C
Eg
B
A
Bm
BiBe
SN
LN
Weerstand (Ωm)
Gammastraling (cps)