<u>Version 7 Revision Lithostratigraphy Ieper Group NCS website 11/2015</u>

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The working group was installed by the Paleogene-Neogene subcommission meeting in 2014 (S.Louwye chair, K.De Nil ,secretar) . Working Group Members are Marleen De Ceukelaire, Tim Lanckacker , Johan Matthijs , Peter Stassen, Etienne Steurbaut, Hervé Van Baelen , Noël Vandenberghe (coordination by N.Vandenberghe and M. De Ceukelaire). A first meeting was held 20 th December 2014 and a discussion text was drafted 20 th February 2015. Comments received were discussed by the Paleogene-Neogene subcommission on 13 th July 2014. A revised draft was discussed by a working group meeting on 14 th August 2015. This new version 7 is based on these discussions and has been complemented by a series of geophysical well logs interpreted in terms of the lithostratigraphic subdivisions proposed and discussed in the text. The document is forwarded to the Working Group in October 2015 for approval to submit it to the Subcommission for posting as discussion text on the NCS website . This version also includes some remarks deliverd by Johan Matthijs and Michiel Dusar October 2015.

An update of the lithostratigraphy of the Ieper Group.

To be submitted to the Paleogene-Neogene subcommission as a discussion text.

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Introduction

Briefly discussed are the context of the review , the reason for the emphasis on geophysical wells, and the role of biostratrigraphic data in the lithostratigraphic interpretation.

Context of the review.

The objective of the present revision is to complement the lithostratigraphy of the Ieper Group published in 2001 (Laga et al.,2001). This last publication reflected the activities in the Tertiary Subcommission at that time. The review published in 2001 framed in an initiative of the National Stratigraphic Commission and was limited to the lithostratigraphy at formation level. The Laga et al (2001) reference document has been the basis for the NCS website until now.

The Ieper Group is characterised by clay-dominated sediments overlying, in most situations, the Landen Group strata and, if not outcropping, underlying the sand-dominated Zenne Group sediments. According to Laga et al. (2001) in their reference document for Paleogene and Neogene lithostratigraphy, the Ieper Group consists of the Kortrijk, Tielt and Gentbrugge Formations and members in these Formations are only listed. These subdivisions are also used on the 1:50 000 geological maps of Flanders, edited in the last decades of the 20th century.

Especially the additional description of the members, and eventually horizons, identified in the Formations made the present review necessary and

also modifications at the formation level itself arisen since 2001 needed to be integrated in a new synthesis.

The present update is based on the earlier description of members in Maréchal & Laga (1988), Geets et al. (2000) and Steurbaut (1998) as far as appropriate. All modifications, discussions and additions are supported by literature references.

The use of geophysical well logs and a compendium of reference logs.

In the present update the use of geophysical borehole logs in the characterisation and definition of lithostratigraphical units is formally introduced. This is a logical evolution as substantial amounts of data on the Ieper Group are derived from subsurface reconnaissance studies.

In comparison to common field observations, geophysical logs in boreholes offer the advantage of characterising the vertical succession of several stratigraphic units and commonly offer a continuous characterisation of the transition and boundaries between lithostratigraphic units.

Natural gamma ray (GR) logs and resistivity (RES) logs are the commonly available geophysical data, but also other logs can serve as proxies for lithology .

Continuously recorded data in geophysical borehole logs offer a consistent way to subdivide the stratigraphic column in ' lithological intervals' with similar properties. Such intervals can be based upon upward coarsening or fining up trends, levels of changing trends, or any particular log signature. Trends and levels can be correlated between boreholes. Although a purely geophysical stratigraphic subdivision can be made irrespective of known lithostratigraphic units, in this review it is chosen for the logical approach to accommodate the traditional field and core borehole-based lithostratigraphy into the newly discussed geophysical log subdivisions. It is also realised that at this stage a one to one relationship between a geophysical log-defined limit and a field defined boundary between units ~~is~~ will not always be possible.

The lithostratigraphic subdivision and interpretation of the Ieper group geophysical well log interval has benefited from several previous attempts.

An early attempt correlated logs irrespective of existing lithostratigraphic nomenclature: based on trends and events 9 correlation levels were identified in 8 large plates (Vandenberghe et al. ,1991). Subdivisions and correlations have been published by Steurbaut (1998) and Vandenberghe et al. (1998). A subdivision of the Kortrijk Formation using resistivity logs was proposed by De Ceukelaire & Jacobs (1998). Welkenhuysen & De Ceukelaire (2009) and Walstra et al. (2014) applied pattern recognition and correlation in numerous examples across North Belgium.

To illustrate the subdivisions discussed in the text a set of 19 well log interpretations is added as a reference compendium. The borehole localities are chosen to cover the whole area of occurrence of the Ieper Group.

Brugge 023W0454, Gent 055W1020, Kallo 014E0355, Kester 101W0079, Kerksken 086E0340, Knokke 011E138 , Kruishoutem 084E1412, Merchtem 072E0229, Merksplas 017W0280, Mol 031W0237, Oosterzele 070E0237, Pittem 053W0073, Rijkevorsel 007E0200 , Tielt 053E0061, Torhout 052E0195, Wieze 072W0159 , Wortegem 084W1475, Zemst-Hofstade 073E0397, Zemst-Weerde 073E0359.

On these logs, most but not all the units are always identified in an exemplary way, depending on the quality of the logs.

Subdividing logs requires particular attention to boundary levels between units, straightforward in case marked jumps in properties are observed. In the Ieper Group, lithological properties such as grain size are often evolving within units and not constant as the definition of a lithostratigraphic unit intuitively might suggest. In such cases the precise definition of the upper and lower limiting surfaces can be more subject to debate. The guideline in the choice should be the picking of those boundary surfaces that have the best chance of being recognised in the field and in borehole descriptions.

Relationship between lithostratigraphy and bio-chronostratigraphy.

The subdivisions aimed at in this review are exclusively lithostratigraphic. For many current purposes a coherent and consistent lithostratigraphic nomenclature in a region, such as proposed in this review, is a prerequisite. Obviously a deeper stratigraphic understanding of strata needs lithostratigraphic data to be complemented by biostratigraphic data. This is not the aim of this review.

On the other hand, in the case of lithologically similar packages, as is the case in the Ieper Group, biostratigraphy can be required to differentiate such packages and eventually confirm suspected hiati or lateral lithofacies changes. Geophysical well log correlation is helped by paleontological support.

Biostratigraphy is also the key methodology to correlate between regions and basins and to situate the deposits in the international chronostratigraphic chart. The Ieper Group strata are all Ypresian or Lower Eocene. Details of the bio- and chronostratigraphy are to be discussed separately on the website. Basic biostratigraphic data are given in Steurbaut (1987, 1998, 2006, 2011) for calcareous nannoplankton zonations, in De Coninck (1976, 1991, 1996) for dinoflagellate data and in Kaaschieter (1961) and Willems (1982) for foraminifera data. Summary descriptions are available in Steurbaut et al. (2003). Magnetostratigraphy is another means for interregional and inter-basin correlations. In the Ieper Group, clay-pit sections have been investigated for magnetostratigraphy by Ali et al. (1993). A methodology for integrating all stratigraphic data, and including in particular the obvious cyclicity in the Ieper Group strata, is the sequence stratigraphy approach, also relying heavily on geophysical well logs. Such an approach however is already interpretative and strongly depends on biostratigraphic calibration; therefore it will be dealt with in the chronostratigraphy section of the website.

IEPER GROUP

Authors:

The term Ieper Group was introduced by Maréchal (1993, p 224), and described by Steurbaut (1998, p 109) and in Geets et al. (2000). The Ieper Group includes all strata previously grouped in the Ieper and Vlierzele formations by Steurbaut & Nolf (1986). The present revision of the stratigraphic hierarchy between the different formations and members within the newly defined group is based on their suitability for mapping and their lithological and faunal distinctive properties.

The Ieper Group is named after the town of Ieper (Ypres in French) in West Flanders , which also serves as reference for the Ypresian global stage .

Description:

The Ieper Group contains marine sediments which consist dominantly of clay in the lower part of the Group and become silty towards the top of the middle part and evolve to fine sandy sediments in the upper part of the Group.

Age:

The Ieper Group almost coincides with the Ypresian or early Eocene age. Only the Tienen Formation of the Landen Group, below the Ieper Group, represents the very earliest Ypresian and the basal part of the Zenne Group above represents the very late Ypresian. Therefore the age of the Ieper Group can be estimated between about 55 and 49 Ma (see Vandenberghe et al. in GTS 2012).

Regional distribution:

The Ieper Group occurs in the western, central and northern part of Belgium. The Group outcrops are located especially in northern Hainaut, south and central West and East Flanders, west and southwest of Brabant ; the Group occurs in the subsurface of the Antwerp and Limburg Campine. Outliers occur in the Mons basin south of the Sambre river. Towards the east in the Brabant, Limburg and Antwerp provinces, the Ieper Group thins and disappears. Maps of the different Formations in the Ieper Group, recognised at different moments in the development of the Ieper Group stratigraphic research and practice, can be found in Maréchal (1993), (Walstra et al. , 2014) and can be

consulted at the D.O.V. website: https://dov.vlaanderen.be/dovweb/html/3isohypsen.html#waar. https://dov.vlaanderen.be/dovweb/html/services.html#NPisohypsen or https://dov.vlaanderen.be/dovweb/html/3G3Ddata.html .

The Ieper Group overlies the Landen Group or locally Paleozoic rocks. In the Gent area and in the northwest the Ieper group is covered by the Aalter Formation of the Zenne Group. To the north and the east the Group is overlain by the Brussels or Lede Formations of the Zenne Group. In the exceptional case of the absence of these formations the Ieper group can be covered by the Maldegem Formation or the Sint-Huibrechts-Hern Formation in the southeast. In the coastal plain, the alluvial plains of the Leie and the Upper-Scheldt, the Ieper Group is overlain by thick late Quaternary sediments.

The maximal thickness is about 200m and thinning occurs towards the south and the east.

Stratotype:

The lower boundary stratotype is defined in Steurbaut (1998) at 288m depth in the Knokke borehole (011E0138) at the contact between the Tienen Formation (Oosthoek Member) and the Kortrijk Formation (Zoute Member) , topographic map sheet 5/6 Westkapelle with coordinates X = 78.776, Y = 226.370, Z = +4,91 m.

The upper boundary stratotype is defined in Steurbaut (1998) in the profile of the Mont-des-Récollets (Cassel, France) at the contact of the Vlierzele Member and the Aalter Formation of the Zenne Group described in Nolf & Steurbaut, 1990, mapsheet XXIII-3 ,Cassel , France with coordinates X = 62.000, Y = 344.500, Z = +143 m.

Subdivisions:

The subdivisions recognised and ranked by the working group in the present synthesis are represented in the table below and will be discussed in their stratigraphic order, from older to younger.

LITHOSTRATIGRAPHIC TABLE IEPER GROUP version 13/09/2015

Zenne Group	**Aalter Formation**	
Ieper Group	**Gentbrugge Formation**	
		Aalterbrugge Bed
		Vlierzele Member
		Pittem Member
		Hooglede Bed
		Merelbeke Member
		Kwatrecht Member
	Hyon formation	**Mont-Panisel Member**
		Bois-la-Haut Bed
		Egem Member
	Tielt Formation	**Egemkapel Member**
		Kortemark Member
	Mons-en-Pévèle Formation	
	Kortrijk Formation	**Aalbeke Member**
		Roubaix Member
		Orchies Member
		lower Orchies member
		upper Orchies member
		Mont-Héribu Member
		Het Zoute Member
Landen Group	**Tienen Formation**	
	....	

Kortrijk Formation.

Authors: **Geets (1988), Steurbaut (1998).**

Description: **the formation is an essentially marine deposit, consisting mainly of clayey sediments.**

A standard sequence contains from bottom to top:

- an alternation of horizontally laminated, glauconiferous clayey sands or sandy clay, and compact, silty clay or clayey silt, locally bioturbated. The base consists of oxidized and indurated clayey sand, with lenses of pure sand;

- a homogeneous deposit of very fine silty clay, with some thin intercalations of coarse silty clay or clayey, very fine silt;

- a less homogeneous deposit of clayey, coarse or medium silt, with some sand containing layers; fossil rich layers occur; the whole deposit becomes more sandy to the east and the south;

- a very fine silty clay.

To the east, in the Brabant and the Campine, and towards the Mons basin, the deposits become more sandy.

Stratotype: **the formation is defined by boundary stratotypes (Steurbaut, 1998). The lower boundary stratotype is placed at 288 m depth in the Knokke borehole (011E0138) at the base of the Het Zoute Mbr. Sheet 5/6 (Westkapelle). Co-ordinates: x = 78.776, y = 226.370, z = +4.91 m. The upper boundary has been placed in the Tielt bore-hole (068E0169) at the top of the Aalbeke Mbr. This upper boundary is located at 48.5 m in the compendium (Tielt 053E0061); in earlier versions (Geets, 2000), the Aalbeke top was mislocated at 71 m. Steurbaut (1998) correlated the in-the-present-text top of Aalbeke member (see also further details under Aalbeke Mbr) with the top of his unit D in the Tielt borehole located at 46.7 m. Sheet 21/6 (Wakken). Co-ordinates: x =76439, y = 187576, z = +48 m.**

Area**: the formation is found in the western and central part of Belgium. It outcrops in the north of Hainaut, the southern and central part of West-Flanders, the south of East-Flanders Flanders and the southwest of Brabant. Outliers occur in the Mons Basin and south of the river Sambre.**

The regional distribution map of the occurrence of the Kortrijk Formation in Belgium is figured in Maréchal (1993, p 221) (Walstra et al., 2014) and can be consulted at the D.O.V. website (dov.vlaanderen.be).

Thickness**: 125 m in the northern part of West-Flanders, but the thickness decreases in eastern and southern direction.**

Members**: the formation is subdivided into the Het Zoute Mbr, Mont Héribu Mbr, Orchies Mbr, Roubaix Mbr and the Aalbeke Mbr.**

Age**: early and middle Ypresian.**

Remarks**: the formation is also discussed by Cornet (1874), De Ceukelaire & Jacobs (1998), De Coninck (1975), De Coninck et al. (1983), de Heinzelin & Glibert (1957), De Moor & Geets (1975), Geets (1990), Gosselet (1874), Gulinck (1965, 1967), Gulinck & Hacquaert (1954), King (1990), Laga & Vandenberghe (1980), Maréchal (1993), Ortlieb & Chelloneix (1870), Steurbaut (1988), Steurbaut & Nolf (1986), Vandenberghe et al. (1990) and Wouters & Vandenberghe (1994).**

Het Zoute Member

Authors **: based on King (1990), Steurbaut (1998) ,Geets et al. (2000)**

Description **:**

Silty to sandy clay, bioturbated and with irregular pockets and lenses of very fine silty sand. Fine grained mica, woody debris and glauconite are present in sieve residues throughout the unit (King, 1990). Coarse grained angular to subangular grains are identified as degraded volcanic ash. Pebbles occur in the base of the overlying clay.

Regional occurrence and previous name:

The Zoute Member is a thin unit of almost 5 m thickness found at the base of the Ieper Group section in the Knokke borehole (011E0138) at the Zoute hamlet and first described in detail by King (1990,p70) and named Member X by this author. The name Het Zoute Member was proposed by Steurbaut (1998, p110). It was erroneously interpreted as Mont- Héribu Member by Geets & De Geyter (1990, p25).

This unit has no equivalent in other sections of the Ieper Group in Belgium where it corresponds to a hiatus between the Landen and Ieper Groups; this is confirmed in Steurbaut (2006, p77).

The volcanic ash:

The indication of volcanic activity is a particular property of this unit. The other indication of volcanic grains in the basal sediments of the Ieper Group clays are the heavy mineral types in the basal clays, identified as Mont-Héribu, reported by Geets (1993).

This volcanic activity is related to the ash series at base of the Eocene in the North Sea Basin and correlates to the A1 Division of the London Clay Formation (King, 1990, p 80).

Stratotype

Knokke borehole 011E0138 , interval 288 to 284,1 m depth. Geological Map 5/6 (Westkapelle)

Coordinates: X = 78.776 , Y = 226.370, Z = + 4,91 m.

Mont-Héribu Member

Authors **: De Coninck et al. (1983, p 98), Steurbaut and Nolf (1986,p 123), Steurbaut (1998), Geets et al. (2000) ,**

Description **:**

Alternating horizontal laminae of glauconite bearing clayey sand or sandy clays with compact silty clays or clayey silts. Locally burrows are present. The base of the unit consists of cemented clayey sand and lenses of just sand. The unit occurs at the very base of the Ieper Group.

The definition of the Mont-Héribu is limited to the sandy base of the Ieper Group. This sandy base is 6 m in the Mons Basin, maximal 10 m southwest of Brussels but in most boreholes it is limited to 1 to 2m and rarely noticed in most boreholes (see for example sections in Gulinck, 1967). Therefore the interpretation of the extension of the Mont-Héribu Member in the 1:50 000 mapping of Flanders is exaggerated and comprises for a large part the overlying Orchies Member. The definition refers to a grain-size distribution with only a limited clay fraction and a coarser fraction that gradually evolves upward over a short distance to the larger clay content of the Orchies Member. This short pattern of rapidly fining upwards is the typical signature on GR and RES logs (see borehole logs ON-Kallo-1 014E0355, Rijkevorsel 007E0200).

Regional occurrence and previous names:

The unit was first reported as 'Argile de l' Eribus' (Cornet , 1874, p 567) at the locality Eribus ('Mont de l'Heribu', south of Mons) which geology was studied by Ortlieb & Chelloneix (1870, p 168). In the Mons Basin the unit can reach up to 6m and; its maximum thickness is reported from Bierghes (southwest of Brussels) where it reaches 10m (Geets, 1991 , including grain-size data). In many borehole descriptions this unit is not formally recognised as an individual unit, or supposed to be reduced to just a few cm thickness; King (1991) interprets the occurrence of the Mont-Héribu Member in central West Flanders and not in the Knokke well 011E0138.

What is mapped as Yb on the Geological maps 1:40 000 logically corresponds to the Mont-Héribu Member. In the Stratigraphic Register (1929, 1932) it is included in the Lower Ypresian Y1a.

Stratotype **:**

Sand pit at the Mont de l'Héribu south of Mons between +57.5 en +51.4 m topographic height on the geological map 151 Mons-Givry (topographic map 45/7).

Coordinates: X = 119.750, Y = 124.510, Z = + 57,5 m.

Orchies Member

Authors **: Gosselet (1874, p 611), Steurbaut (1998), Geets et al. (2000)**

Description:

Compact and heavy stiff bluish-grey clay occurring at the base of the Ieper Group only separated from the base itself by the underlying sandy Mont-Héribu Member where this latter is present. The Orchies Member is overlain by more sandy or silty clay deposits of the Roubaix Member or Mons-en-Pévèle Formation. The thickness can be up to 25 m. A pebble layer has been reported occasionally at its base (Ya on the 1:40 000 geological maps).

Whereas in the visual description of macroscopic samples, even from cores, it is very hard to see any further lithological subdivision of the Orchies Member, the geophysical log signatures do show a systematic variability interpreted as grain size variations . The top of the very high gamma-ray section at the base of the Orchies Member, about 10 to 15 m thick, is a correlatable surface. It corresponds to the top of the mistakenly named Mont-Héribu Member (KoMh) unit in the correlation figures in Welkenhuysen and De Ceukelaire (2009 figs 12,14,16,18, 20, 22,24) and approximately to the level 1 in the plates in Vandenberghe et al. 1991). Therefore the Orchies Member can be subdivided in a lower (lower Orchies) and an upper part (upper Orchies) of the Orchies Member.

Regional occurrence and previous names:

The Orchies Member consistently occurs where the Ieper Group occurs in Belgium. In the Hainaut area thickness is between 10 - 16 m whilst in central Flanders and north Belgium thickness can be over 40 m. However it needs to be kept in mind that at present two definitions for the top level have been proposed in the literature, with a difference of 10m (see further Stratotype), marking the boundary with the overlying Roubaix Member. Towards the east in Brabant its thickness is reduced to a few meter.

Originally the name was introduced by Gosselet (1874, p 611) to indicate the compact and stiff clays at the base of what is now known as the Ieper Group sediments; later, as a refinement of the lithostratigraphy, the sandy and silty Mont-Héribu Member at its base was individualised as a separate unit and the name Orchies Member was reserved for the compact heavy clays above

the Mont-Héribu Member (Steurbaut, 1998). The later introduced name Saint-Maur Member (Belgian stratotype area , Geets, 1988 ; Maréchal, 1993), used in the legend of the 1:50 000 mapping in Flanders is a synonym of the Orchies Member although it was generally used in a more restructive way, the lower part of the Orchies Member being erroneously assigned to the Mont Héribu Member; it is preferred to maintain the original name Orchies, a small locality to the southeast of Roubaix in Northern France.

On maps 1:25 000 of the Brabant Wallon (Nivelles-Genappe , Braine-le-Comte -Féluy) the 'Formation de Carnières' is used for a unit 'close to Orchies'.

On the legend of the geological maps 1:40 000 the Orchies Member was included in the Yc clayey deposits and in the stratigraphic register (1929,1932) in the Y1a.

The 'argilite de Morlanweltz' is a lateral equivalent of the Orchies Member (Steurbaut, 1991).

The Wardrecques and Bailleul members are reported in King (1991). The lower part of the Wardrecques member belongs to the Orchies Member whilst the upper part and the Bailleul member correspond to the Roubaix Member (King, 1991). This subdivision is not commonly used in the literature but the position of Wardrecques and Bailleul members is well documented in boreholes of the Moeskroen-Kortrijk-Marke-Ooigem area by King (1991, fig. 11). In this area at least 5 glauconiferous beds occur, each less than 15 cm thick (King, 1991).

Stratotype:

The Wahagnies clay pit ("Briquetterie de Libercourt") in northern France, map sheet XXV-5 (Carvin). Ortlieb & Chelloneix (1870, p25) had already used the name 'Argile de Wahagnies' to indicate the Orchies Member compact clays (Steurbaut, 1998). In the clay pit, the base is defined by the basal pebble bed below about 8 m of stiff clays. Coordinates: X = 649.250, Y = 310.600, Z = +50 m.

The upper boundary , marking the limit with the overlying Roubaix Member , is proposed in the Kallo well – 027E0148 (Gulinck, 1969) at 341m depth (Steurbaut, 1998, p 112) (see also below).

Geophysical borehole references

On geophysical well logs the boundary between lower and upper Orchies is picked at the top of the high GR (and high RES !) interval where the first marked shift towards a lower GR is observed; as it is a general feature it is illustrated on most logs in the compendium.

The top of the Orchies Mbr has been defined in the literature in 2 different ways by Steurbaut (1988 , 1998). In the Kallo log 014E0355 (Steurbaut,1988) the boundary between the Orchies and Roubaix Members is put at the top of heavy clay at 331,5m whilst in the 1998 definition the boundary is put 10m lower at 341m. The correlation between the Kallo well 027E0148 (without geophysical logs) and the ON-Kallo-1 014E0355 with geophysical logs (courtesy Peter Stassen) allows to identify the log signatures associated with the two definitions. The 1998 definition is also plotted on a series of logs by Steurbaut (1998, Fig.10) located in West-Flanders but also on the Rijkevorsel well 007E0200. Therefore the two boundaries are systematically indicated as OR ES 88 and OR ES 98 on ON-Kallo-1 and Rijkevorsel and on many other borehole logs in the compendium (see also Mons-en-Pévèle Fm).

The description of a series of boreholes (AROL) by G.De Geyter (1990, Archives Belgian Geological Survey) systematically describes a transition from silty clay above to heavy clay below at the OR ES 88 level (courtesy Marleen De Ceukelaire) .

Roubaix Member

Authors: **Gosselet (1874), Steurbaut & Nolf (1986,p 123), Steurbaut (1998), Geets et al. (2000).**

Description:

In contrast with the underlying (Orchies Member) and overlying (Aalbeke Member) compact heavy clays, the Roubaix Member consists of more silty to fine sandy calcareous clays. The thickness varies from about 40m in south

Belgium to 60m in North Belgium. Calcareous fossils like nummulites and molluscs are present. Glauconite rich horizons occur. The more heterogeneous composition of the sediment is shown by layering (see e.g. Marke quarry in Steurbaut, 2006 fig. 7), also well visible in the geophysical well logs.

Several of these specific layers, numbered 1 to 6 in the attached log examples (see compendium) , can be recognised and correlated between well logs with a reasonable degree of confidence.

Based on the correlation of these levels, Welkenhuysen and De Ceukelaire (2009) have selected a specific level as the boundary level between the Orchies and the Roubaix Member which corresponds to the position of the Steurbaut (1988) definition (OR ES 88 on the geophysical reference wells).

Regional occurrence and previous names:

The Roubaix Member occurs over northwest France, north Hainaut , east and west Flanders. Towards the south the occurrence of sandy layers becomes more pronounced whilst to the northwest the Member becomes more clayey and hardly distinguishable from the underlying Orchies Member (Geets et al., 2000). Towards the southeast and the east the Roubaix Member evolves into a fine sandy unit, the Formation of Mons-en-Pévèle (see further).

The later introduced Moen Member (Belgian stratotype area, Geets, 1988; Maréchal , 1993) used in the legend of the 1:50 000 mapping of Flanders, is synonymous with the Roubaix Member. Roubaix is a town in North France and was the original reference for this clay type as described by Gosselet (1874) and therefore the name Roubaix Member is retained.

In the 1:40 000 mapping the Roubaix Member was mapped in the Yc unit, however in the Kortrijk area it was erroneously mapped as Yd (Steurbaut & Nolf, 1986; Geets et al., 2000). In the stratigraphic register (1929,1932) the Roubaix Member is included in the Y1a unit.

Stratotype:

The Roubaix Member was previously exposed along the Bossuit Canal at Moen (near Kortrijk) (Steurbaut & Nolf, 1986) and in the Marke and Heestert clay pits near Kortrijk. As these outcrops are no longer accessible a reference

section for the lower boundary is choosen in the Kallo well (Gulinck , 1969) at 341m depth (see further) whilst an upper boundary with the overlying stiff clays has been visible in the Kobbe clay pit (DOV kb29d97e-B989) at Aalbeke (x= 68.450, y= 164.300, z= 49 m) Steurbaut (1998).

Geophysical borehole references

The base of the Roubaix Mbr has been defined in the literature in 2 different ways by Steurbaut (1988 , 1998). In the Kallo log (014E0355) (Steurbaut,1988) the boundary between the Orchies and Roubaix Members is put at the top of heavy clay at 331,5m whilst in the 1998 definition the boundary is put 10m lower at 341m. The correlation between the Kallo well 027E0148 (without geophysical logs) and the ON-Kallo-1 014E0355 with geophysical logs (courtesy Peter Stassen) allows to identify the log signatures associated with the two definitions. The 1998 definition is also plotted on a series of logs by Steurbaut (1998, Fig.10) located in West-Flanders but also on the Rijkevorsel well – 007E0200. Therefore the two boundaries can systematically be indicated as OR ES 88 and OR ES 98 on ON-Kallo-1 – 014E0355 and Rijkevorsel – 007E0200 and on many other borehole logs in the compendium (see also Mons-en-Pévèle Fm).

The boundary level selected by Welkenhuysen and De Ceukelaire (2009, e.g. in the Merchtem and the Gent boreholes) corresponds to the position of the Steurbaut (1988) definition (OR ES 88). In fact , the description of a series of boreholes (AROL) by G.De Geyter (1990, Archives Belgian Geological Survey) systematically describes a transition from silty above to heavy clay below at the OR ES 88 level (courtesy Marleen De Ceukelaire), favouring the selection of this level as the boundary between the Orchies and Roubaix members .

Aalbeke Member

Authors: **De Moor & Geets (1975) ,Steurbaut & Nolf (1986), King (1991) , Steurbaut (1998)**

Description:

A very compact heavy clay without sand fraction of some 10 m thickness sharply contrasting with more silty to fine sandy overlying (Tielt or Hyon

Formations) and underlying units (Roubaix Member or Mons-en-Pévèle Formation). The Aalbeke Member is often non calcareous. Small pale brown to yellow phosphate nodules are common in the Aalbeke Member.

It can be pointed out that this pure clay unit is relatively thin and therefore can be mistaken for other even thinner clay units above, namely the Egemkapel and the Merelbeke units. To unequivocally identify these layers a complete vertical succession is often required or support by micropaleontological characterisation.

In most geophysical log responses the lower boundary of the Aalbeke Member is sharply marked; at present there is no field outcrop of the contact between the Roubaix and Aalbeke Members.

It is suspected that the top of the Aalbeke Member is an erosive contact: in clay pits in Aalbeke, the Member is overlain by the Mont-Panisel Member, member of the Hyon Formation, in central Flanders by the Kortemark Member, and in SE Flanders and Brabant by the Hyon Formation. The upper boundary can be sharp (e.g. Kerksen borehole 086E0340 in compendium, data Geological Service Company ; Brugge - 023W0454) or more generally the upper part of the clay unit shows a gradual coarsening upward. In the latter case, the upper boundary of the Aalbeke Member in contact with the Kortemark Member is put at the top of this coarsening upwards section.

Regional occurrence and previous names:

The Aalbeke Member is exposed in the hills around Kortrijk, where also the type locality Aalbeke is located, and in the adjacent border area of north France where it corresponds to the 'argile de Roncq' (see De Coninck, 1991 fig.9). It occurs in the subsurface of the whole Flanders and has an average thickness of about 10 m varying between 5 and 15 m.

On the geological maps 1:40 000 the Aalbeke Member was part of the Yc unit and in the stratigraphic register (1929,1932) it is part of Y1a. In the Kortrijk area, on the 1:40000 sheets it was mapped erroneously as the P1m unit (Merelbeke Member of the Gentbrugge Formation).

Stratotype:

Several clay pits exist in Aalbeke and the De Witte clay pit , the extension of the now filled-up Kobbe clay pit – DOV kb29d97e-B989 (X = 68.450, Y = 164.300, Z = + 49 m), designated as stratotype by Steurbaut (1998) (map sheet 29/5-6 (Mouscron - Zwevegem), is the logical new unit stratotype locality.

Geophysical borehole references

Exemplary log signatures with the identification of a base and a top of the Aalbeke Member are the boreholes logs of Gent 055W1020, Kallo 014E0355, Merchtem 072E0229, Pittem 053W0073, Rijkevorsel 007E0200 , Torhout 052E0195, Wieze 072W0159 .

‘pink silt’ bed

Within the Aalbeke Member outcrops in the Kortrijk area a pronounced pinkish silty layer of some dm thickness occurs. It might serve as a stratigraphic marker bed. However the bed is not given an official bed status as it is not yet established that only one such layer occurs in a complete Aalbeke Member section.

Mons-en-Pévèle Formation

Authors :

King (1991), Steurbaut & Nolf (1986), Steurbaut & King (1994, p180), Steurbaut (1998)

On the Formation status:

Although in this discussion text the Formation status is proposed, the Mons-en-Pévèle sand unit could as well be considered as a Member of the Kortrijk Formation. A member status could logically reflect the lateral transition zone with vertically alternating sandy layers and clay layers (such as e.g. in the

Mouscron borehole in fig.10 of King (1991)) as an undifferentiated Kortrijk Formation). However the Mons-en Pévèle sand unit can be properly mapped with considerable thickness in Hainaut where it links up with the Cuise Sand of the Paris Basin; such a map unit usually gets the formation status. Also , the 1:25 000 mapping in Wallonia uses the status 'Formation de Mons-en-Pévèle'. Therefore in the present review it has been chosen to rank the Mons-en-Pévèle sandy unit as a Formation.

Description :

Dominantly very fine grained silty micaceous bioturbated sands, at some levels laminated or ripple-cross-stratified, with common very fine glauconite; interbedded with sandy silts and sandy clays and thin beds of silty clay. Several coarser beds packed with Nummulites are present.

The Mons-en-Pévèle unit is not included in the Kortrijk Formation because of the sandy nature of the former in contrast with the clay nature of the latter.

Regional occurrence and previous names :

The Mons-en Pévèle Formation is occurring southeast of a line through Lille (North France) (see map in King, 1991), from Mons-en- Pévèle (North France) to Tournai and Ronse and further eastwards. Mons-en-Pévèle is a locality south of Lille in North France and the name 'Sables de Mons-en-Pévèle' was introduced by Ortlieb & Chellonneix (1870, p 27).

Towards the east in Brabant, the Ieper Group thins and a typical clayey basal part is distinguished from an upper fine sandy unit. The basal clay corresponds to the Orchies Member of the Kortrijk Formation whilst the sand has been given a lithostratigraphic name, the Vorst/Forest sand. It was shown by King (1991) that these fine sands are equivalent to the Mons-en-Pévèle Member. Logically therefore the Bierbeek sand above the Orchies Member in the Leuven area (geological map 1:50 000 sheet 32 Leuven , Vandenberghe & Gullentops, 2001) can be considered as a decalcified sand of the Mons-en-Pévèle Member, in a similar way as the sands above a thin clay unit in north Brabant (Rillaar) and Limburg (e.g. Veldhoven, Beringen) as figured by Gulinck (1967) and discussed by Fobe (1989a).

From a nomenclature point of view, in the transition zone of laterally interfingering units such as the Roubaix and Mons-en Pévèle units, the ICS Stratigraphic Guide recommends that a somewhat arbitrary boundary should be chosen in mapping and borehole description, obviously accompanied by an appropriate explanation in the legend or description. In the case of the Roubaix/Mons-en-Pévèle limit the present review suggest that if the unit consists of over 50 to 60% sand layers, the unit should be named Mons-en-Pévèle Fm and otherwise the unit should be classified as Roubaix Member of the Kortrijk Formation. For example the 368-407 m section in the Mol SCK borehole 031W0237 is mainly described as fine sand with minor clay layers (Gulinck & Laga , 1976) and is therefore to be named Mons-en-Pévèle Fm. Localities with Mons-en-Pévèle sand are listed in Steurbaut & Nolf (1991, Fig.3) and appear systematically between Ronse and Brussels. According to the lithological description (sand/clay proportion) the log signature in the borehole Merchtem 072E0229 should be classified as the Roubaix Mbr and in the Kester borehole 101W0079 as Mons-en-Pévèle Fm; grain-size data in the borehole Kattem (087W0479) south of Aalst allow to apply the criterion in the present review and describe the unit below the Aalbeke Member as the Mons-en-Pévèle Member (Geological Service Company , 2003).

Lithological trends and paleogeography:

Paleogeographically, from central Flanders towards the east and the south, several clay enriched facies of the Kortrijk Formation are replaced by more sandy deposits (maps in Steurbaut, 2006). The lateral transitions are well documented and figured in King (1991). As can be expected from the lithology of the Roubaix Member, the sands are best expressed when laterally interfingered with the Mons-en-Pévèle Fm. However the more southwards to the Paris basin the closer to the base of the Ieper Group starts the occurrence of the sand unit (profiles in King, 1991). The sands are known as the Mons-en- Pévèle Member and grade into the 'Cuisian ' sands in the Paris Basin. The Aalbeke Clay extends over the Mons-en-Pévèle Sand into the Paris basin where it corresponds to the Laon clay (King, 1991). Where the 'argilite de Morlanweltz' is a lateral equivalent of the Orchies Member (Steurbaut, 1991) more sandy facies in southern direction in the Hainaut province with specific

names such as the Godarville sand and the Peissant sand (Steurbaut & Nolf, 1986) are included, without a specific stratigraphic status in the Mons-en-Pévèle Member. The Morlanweltz Sand, with a Formation status, is figured in Steurbaut (1998 p 145; Steurbaut et al. , 2003 p 11) as a lateral equivalent of the Roubaix Member but as a separate unit underlying the Mons-en-Pévèle Sand Formation (see also Steurbaut, 1998 p 110). This subdivision is not retained formally in the present review due to a lack of precise data.

It should be noticed that the reverse lithological trend logically is also present in the north direction leading King (1991, p 361, 370) to introduce the name Flanders member for the homogeneous Ieper Group clays beneath the Egem Member in the Knokke well. In this review this suggestion is not followed as these very clay rich sections can still be subdivided using existing nomenclature such as 'the Tielt and Kortrijk Formations ' (see Welkenhuysen and De Ceukelaire, 2009 fig. 16) (see also Knokke well in the compendium) and as the geophysical well log divisions of these clay-rich sections can even be recognised further north in the Netherlands (de Lugt, 2007).

Stratotype:

No formal stratotype has been designated. Logically the Mons-en-Pévèle hill south of Lille and north of Douai in North France is the preferred reference area (see Steurbaut, 1998 p 116); also the Waaienberge (Wayenberghe) railway section near Ronse (King ,1991 ; described in King 1988(1990) p 359 and figured in Steurbaut & Nolf 1988 (1990) p 328) is a potential stratotype section..

Geophysical borehole references

The following borehole logs in the reference compendium have a Mons-en-Pévèle signature Zemst-Hofstade – 073E0397, and are confirmed by analysis in the Mol – 031W0237, Kester- 101W0079 wells.

Typical Roubaix Mbr log response confirmed by clay dominated lithology can be observed in Kallo - 014E0355, Knokke - 011E0138.

The signature in the Merchtem – 072E0229 borehole is somewhat intermediate but according to the borehole description the sand intervals represent only 24 % and therefore the interval is classified as Roubaix Mbr (criterium put at 50-60% sand , see above).

The analysis of the Mol borehole log (031W0237) shows an interesting relation between the OR ES 88 and the base of the Mons-en-Pévèle sand Fm (core description, M.Gulinck): both coincide ! If the OR ES 98 is chosen as the Orchies-Roubaix Mbrs boundary , it would mean that a short interval of about 10m has to be classified as Roubaix Mbr , above the Orchies Mbr and below the Mons-en-Pévèle Fm.

As reported already in discussing the OR ES 88,98 in the Orchies and Roubaix Mbrs section , the description of a series of boreholes (AROL) by G.De Geyter (1990, Archives Belgian Geological Survey) systematically describes a transition from silty above to heavy clay below at the OR ES 88 level .

Tielt Formation

On the position of the Egem Member

The Egem Member, traditionally ranked into the Tielt Formation (see a.o. also 1:50 000 map legend), has in this review been ranked in the Hyon Formation . The Hyon Formation has been introduced in the literature by Steurbaut (1998, p 115) and described in the review by Geets et al. (2000) but was not retained in the official NCS stratigraphy by Laga et al., (2001). The grouping of the Egem Member in the Hyon Formation has been suggested by Steurbaut (2011); the logic is to group the sandy deposits , like the Egem Member, in the Hyon Formation and the clayey deposits like the Kortemark and Egemkapel Members in the Tielt Formation. This definition is also practical when no distinction can be made between the sand members (Egem and Mont-Panisel) of the Hyon Fm, as is the case in the subsurface occurrence in northeast Belgium

Tielt Formation

Author**: Geets (1988b), Steurbaut (1998).**

Description: **this marine unit consists in general of a very fine sandy, coarse silt and clay.**

Stratotype: **the formation is defined by boundary stratotypes (Steurbaut, 1998). The lower boundary stratotype has been placed in the Tielt bore-hole (068E0169) at the top of the Aalbeke Mbr. This upper boundary is located at 48.5 m in the compendium (Tielt 053E0061); in earlier versions (Geets, 2000), the Aalbeke top was mislocated at 71 m. Steurbaut (1998) correlated the in-the-present-text top of Aalbeke member (see also further details under Aalbeke Mbr) with the top of his unit D in the Tielt borehole located at 46.7 m. Sheet 21/6 (Wakken). Co-ordinates: x =76439, y = 187576, z = +48 m.**

The upper boundary is placed at the base of the Egem Mbr in the "Ampe" quarry - 053W0060. Sheet 21/1 (Wingene). Co-ordinates: x = 70.150, y = 190.150, z = +44 m.

Area: **the western and northern part of Belgium. The formation outcrops in the north of Hainaut, the south and the centre of East- and West-Flanders and the western and southwestern part of Brabant. Outliers occur in the Mons Basin and south of the river Sambre. The regional distribution map of the Tielt Formation is figured in Maréchal, R. (1993, p 222), Walstra et al. (2014) and in https://dov.vlaanderen.be**

Thickness: **maximum 25 m in the centre of the outcrop area. It decreases to the south and the east, and probably to the north.**

Members: **the formation is subdivided into the Kortemark Mbr, the Egemkapel Mbr.**

Age: **Middle to Late Ypresian.**

Remarks: **the formation is also discussed by De Coninck (1973), De Moor & Geets (1973), Geets (1979), Laga et al. (1980), Maréchal (1993), Steurbaut (1988), Steurbaut & Nolf (1986).**

Kortemark Member

Authors**:** **Steurbaut & Nolf (1986), Steurbaut (1998), Geets (1988), Geets et al. (2000).**

Description**:**

A grey silty clay unit with sandy layers of several dm thickness have been observed near the base. The presence of silt and sand is distributed in layers of cm to dm. Several subunits can be distinguished as proposed by Jacobs et al. (1996a,b) and Steurbaut (1998). The Kortemark Member occurs between heavy clay units : the Aalbeke Member below and the Egemkapel Member above. The maximal thickness is about 25 m (Geets et al. ,2000).

In the top of the underlying Aalbeke Member ~~is~~ a gradual coarsening upwards occurs , ended by a sharp coarsening that marks the start of coarser sediments in the Kortemark Member (see analyses from Geets (1991) and interpreted in Steurbaut (1998)). In geophysical log patterns the start of the coarsening upwards interval in the Aalbeke Mbr above its very clay-rich main part , as well as the sharp coarse shift at the top of the coarsening upwards part of the Aalbeke Mbr which marks the position of a fine sand layer, can be observed fairly consistently (e.g. Torhout 052E0195 , Tielt 053E0061, Gent 55W1020, On-Kallo 1 014E0355) . The formal boundary between the Aalbeke and Kortemark Members is drawn at the position of the major grain-size shift and the income of the first fine-sand layer (correlation profiles in Welkenhuysen and De Ceukelaire, 2009). This boundary definition at the base of the lowest fine-sand layer has the advantage to correspond to an observable horizon with water outflow in the upper part of the Desimpel clay pit in Kortemark.

Detailed lithological analyses of the Kortemark Member sections in the Tielt borehole 068E0169and the Kortemark and Egem extraction pits, are figured in Geets (1991) and Steurbaut (1998, p 117). Details in the geophysical well

log signature in the Kortemark Member can be correlated between wells, especially the significant higher values of the resistivity, standing for more sandy layers, can be correlated between the different logs.

Regional occurrence and previous names:

The Kortemark Member occurs north of Kortrijk and in particular in the west of Flanders where it can reach 25 m thickness. It is also known towards the east and northeast of Flanders (Antwerp Province) where it becomes thinner.

In the southeast of East Flanders and the neighbouring eastern Brabant provinces, the Mont-Panisel Member overlies the Aalbeke clay Member in Kerksken (086E0340) and Kattem (087W0479) (Geological Service Company, 2003), implying the disappearance towards the east of the Kortemark Member and the Egemkapel Member (see also Mont-Panisel Member). Also on the map sheet 23 Mechelen , Buffel et al. (2009) note that the Kortemark Member disappears to the east and is only present in the western part of the map.

In the 1:40 000 geological map legend the Kortemark Member is included in the Yc unit and in the stratigraphic register (1929,1932) in the Y1a division.

In the Bolle & Jacobs (1993) nomenclature the unit Yd1c unit is tentatively correlated to the Kortemark Member. In the present review the Yd2 unit of these authors, a 5 m densily packed fine glauconitic sand underlying the Egemkapel clay Member, is also included in the Kortemark Member, notwithstanding its resemblance to the Egem Sand above. (see also Egemkapel Member)

Stratotype:

Steurbaut (1998) has proposed the level of about 71m below surface in the Tielt borehole (068E0169); map sheet 21/6 x=76.439; y=187.576; z=48) for the lower boundary with the underlying Aalbeke Member. However, in-the-

present-text the base of Kortemark has been replaced at a level in the Kortemark Desimpel quarry corresponding to the level at 48 m depth in the Tielt borehole according to the log interpretation Tielt 053E0061 in the compendium. Indeed because the top of the Aalbeke Member gradually becomes siltier upwards (see analyses in Steurbaut, 1998 fig. 5) it has been argued in-the-present-synthesis that the first marked sandy layer in the Desimpel clay pit in Kortemark (marked as ' sharp junction waterflow' at the base of subunit C in Steurbaut 1998 p 117) (map sheet 20/3-4 Kortemark-Torhout, x= 57.050,y= 190.400, z= +16m) is a more easily recognisable lithostratigraphical horizon to mark the base of the clay. In the present review this level is chosen as the formal boundary between the Aalbeke and Kortemark Members (see discussion in Description above).

The top of the Kortemark Member has during many years (80's and 90's) been exposed in the classical Egem extraction pit – 053W0060 (map sheet 21/1, x= 70.150, y= 190.150) as a an erosive contact with the overlying Egemkapel (see Steurbaut, 1998, p 117).

Geophysical borehole references

Reference boreholes with geophysical log pattern of the Kortemark Mbr between the Aalbeke and Egemkapel clay Mbrs are in the outcrop area of the unit : Tielt 053E0061, Kruishoutem – 084E1412, Gent – 055W1020, Torhout 052E0195 , Pittem -053W0073 and also Knokke – 011E0138, Rijkevorsel – 007E0200, Kallo – 014E0355.

Egemkapel Member

Authors: **Steurbaut (1998) , Geets et al. (2000).**

Description:

A thin heavy clay unit of about 6 m thick, contrasting with underlying silty to sandy clays of the Kortemark Member and the sandy overlying deposits of

the Egem Member. The unit is thinner than the Aalbeke Member. The unit has a slightly erosive basis with a characteristic lag deposit of fossils, mainly fish remains but also snake vertebrae and bird bones and even a rare mammal tooth (Steurbaut, 1998); also, a thin transgressive sandy layer, less than 1m thick, occurs just overlying the erosive basis and well expressed on some borehole logs. This thin basal lag sand is different from and should not be confused with the underlying sandy top of the Kortemark Member (the Yd2 unit ,Jacobs et al. 1996a,b). The Egemkapel Member is a clay-rich unit, contrasting sharply with the more silty and sandy unit below (Kortemark Member) and above (Egem Member) as shown in core descriptions (see e.g. unit Yd3 in Jacobs et al. ,1996a fig. 9), grain-size analysis (see Steurbaut, 1998 fig. 5;) and in the geophysical well pattern (see compendium).

Regional occurrence and previous names:

In the legend of the 1:40 000 maps it was included in the top of the Yc unit.

Steurbaut & Nolf (1986) included the Egemkapel clay in the top of the Kortemark silt unit and Jacobs et al. (1996 a,b) in the Egem Member.

As a thin unit, the Egemkapel was only individualised as a separate Member when its consistent occurrence over the whole central Flanders north of the Mons area became obvious (Walstra et al., 2014). The unit disappears towards the east of the East Flanders and Brabant but is still recognised in the Kallo wells 027E0148 & 014E0355 north of Antwerp and in the Rijkevorsel well – 007E0200.

Stratotype:

The name Egemkapel refers to the hamlet where the Ampe – 053W0060 or Egem extraction pit is located (map sheet 21/1, x= 70.150, y= 190.150). The clay unit has been exposed in this pit during a long period of time, occurring between two erosive horizons: at its base with the underlying Kortemark Member and at its top with the strongly erosive base of the Egem Member of the Hyon Formation.

A detailed description of the Ampe extraction pit anno 1994-1995 , comprising the Egemkapel, Egem and Pittem Members can be found in Willems (1995).

Geophysical borehole references

The pattern in the reference boreholes is a thin marked GR and RES excursion , exemplary expressed in boreholes : Tielt - 053E0061, Kruishoutem – 084E1412, Gent – 055W1020, Rijkevorsel – 007E0200, Brugge – 023W0454, Torhout 052E0195, Pittem- 053W0073.

Hyon Formation

Authors: **Steurbaut and King (1994), Steurbaut (1998, p 115), Geets et al. (2000)**

The Hyon Formation has been introduced in the literature by Steurbaut and King (1994) at the occasion of the study of the Mont-Panisel research borehole and formalised by Steurbaut (1998, p 115). The Hyon Formation was reported in the review by Geets et al. (2000) but not retained in the official NCS stratigraphy by Laga et al., (2001). It is officialised in this review. In addition to the original descriptions in the literature, also the Egem sand unit has been included as a Member in the Hyon Formation to make a lithological distinction more practical between a sandy Hyon Formation and a clayey Tielt Formation in which the Egem Member was traditionally included.

Description and differentiation between the Mont-Panisel and the Egem Members:

Poorly sorted, highly glauconitic sands. The glauconite can make up to 15% of the sand fraction . The maximum thickness is about 25 m.

The Mont-Panisel Member, in contrast to the Egem Member, contains numerous irregularly shaped siliceous sandstone concretions whilst sandstones in Egem are rare. Also, lithologies of different nature are observed in the Egem Member unlike the more homogeneously and more

clayey glauconitic sands of the Mont-Panisel Formation. In the practice of the 1:50 000 mapping, the Egem Member was identified whenever it could be subdivided in the subunits Yd4,5,6 introduced by Jacobs & Bolle (1993) (Jacobs et al.,1996 a,b); towards the east , in the neighbourhood of Aalst , the sediment became more clay enriched and the traditional Egem sand subdivisions could no longer be followed in the mapping and this more clayey unit, which also contained sandstones, was mapped as the Mont-Panisel Member (see Jacobs et al., 1996, a Fig.15 showing this transition).

Regional occurrence and previous names:

The Egem Member of the Hyon Formation occurs over most of the provinces West and East Flanders and part of the Antwerp Campine whilst the Mont-Panisel Member of the Hyon Formation occurs in the Brabant and Hainaut area where its thickness reaches maximum 25m (Steurbaut, 2006); further northwards the Mont-Panisel Member is only locally preserved from erosion (Steurbaut, 2006). The lateral geometrical relationship between the two sandy Members had already been noticed in the classical lithostratigraphic paper by Steurbaut & Nolf (1986), in which the Mont-Panisel Member was indicated as 'Panisel Sand'. The relationship between the sand members has been interpreted in sequence stratigraphic reconstructions (Vandenberghe et al., 1998, 2004 ; Steurbaut, 2011).

The introduction of the Hyon Formation arranges the position of the strata in the hills of Bois-la-Haut and Mont-Panisel, located in the village of Hyon southeast of Mons (map figure 1 in Steurbaut & King, 1994), and which are at the origin of the former classic but now obsolete 'Paniselian' stage (Steurbaut, 2006). The problematic geometric position of the 'Panisel sand' in Brabant and in outliers in the Hainaut area, as it was demonstrated in Steurbaut& Nolf (1986), has been solved by the introduction of the Hyon Formation.

Stratotype:

The section between 0 and 21,85m depth in the Mont-Panisel borehole (151E0340) on the topographic sheet 45/7-8 (Mons-Givry) (x=122.300 , y= 125.375, z= +102m). This location is an outlier and at this location the Egem Member does not occur.

Members : **Egem Member and Mont-Panisel Member.**

Biostratigraphy : **upper part of nannoplankton NP12 (Steurbaut,2006).**

Egem Member

Authors: **Laga et al. (1980); Steurbaut & Nolf (1986); Steurbaut (1988,1998) ; Geets (1979).**

Description:

The sediment is a finely laminated mica and glauconite containing and generally fossiliferous fine sand. Lamination is mainly horizontal and also occur cross lamination, hummocky stratification and infilling of broad shallow gullies. Heavy clay layers occur of cm and dm scale often cut by erosive sand-filled channels. The base of the Egem Member is a strongly erosive level with active channelling above the Egemkapel Member. A marked paleoseismite horizon occurs in the middle of the Egem Member exposed in the Ampe pit. Towards the top, the sediment becomes coarser and more homogeneous with numerous nummulites. A detailed section of the Egem Member in the Ampe quarry and corresponding grain-size data (Geets, 1991) in the Tielt borehole 068E0169, are shown in Steurbaut (1998, p 117). Subdivisions of the Egem Member can be regionally followed in CPT logs and borehole descriptions (Jacobs et al. ,1996a,b). On geophysical logs the base of the Egem Member can generally be recognised by a sharp increase in resistivity as it generally overlies the clay-rich Egemkapel Member (Figs.1,2,3).

Regional occurrence and previous names:

The Egem Member occurs over most of the provinces of West and East Flanders (Steurbaut & Nolf, 1986; King, 1991 p370) and extends

northeastwards into the Antwerp province. On regional profiles the base of the Egem Member is clearly erosive into underlying units (Vandenberghe et al.,1998; King ,1991).

The Ledeberg sand and Evergem sand are synonymous for the Egem Member (Geets et al. , 2000).

In the legend of the 1:40 000 maps the Egem Member is representing the Yd and the P1b units and in the stratigraphic register (1929,1932) the Y1b division (Geets et al., 2000).

Stratotype:

The Ampe extraction pit - 053W0060 in Egem (Pittem) (mapsheet 21/1 Wingene x= 70.150, y= 190.150, z= +44m) between +39.5 m tot +19 m T.A.W , between the Egemkapel Member below and the X-sandstone (in this review named the Hooglede Bed) bed underlying the Pittem Member above (Geets et al., 2000).

A detailed description of the Ampe extraction pit anno 1994-1995 , comprising the Egemkapel,Egem and Pittem Members can be found in Willems (1995).

Geophysical borehole references

In the central West Flanders type area of the Egem Mbr several boreholes can be used as reference for the Egem Mbr and its Yd4,5,6 subdivisions: Tielt 053E0061, Gent – 055W1020, Brugge – 023W0454, Torhout – 052E0195, Oosterzele – 070E0237, Kruishoutem – 084E1412.

Mont-Panisel Member and the Bois-là-Haut Bed.

Authors: **d’Omalius d’Halloy (1862, p 536 & 625), Steurbaut & Nolf (1986), Steurbaut & King (1994) , Steurbaut (1998), Geets et al. (2000).**

Name **: The Mont-Panisel hill is the twin hill of Bois-la-Haut in the village of Hyon, near Mons (map figure 1 Steurbaut & King, 1994).**

Description**:**

Poorly sorted, faintly laminated, prominently glauconitic and highly bioturbated clayey fine sand, contrasting with the coarser and well sorted at the base sands of the Bois-là-Haut Bed occurring in the lower part of this member in the reference well of the Mont-Panisel (151E0340). The Mont-Panisel Member contains also numerous irregularly shaped siliceous sandstone concretions. Locally poorly cemented nummulite-bearing sandstones occur (Steurbaut, 2006). Maximal thickness is 20 m.

At the base in the Mont Panisel borehole (151E0340, between 18 and 21,58m), a separate 3,6 m thick layer is observed, and described as the Bois-la-Haut layer, (Steurbaut & King, 1994); it is highly glauconitic, highly bioturbated, rather well-sorted fine to medium sand with clayey patches in contrast to the finer and less-sorted sand above (see section in Steurbaut and King, 1994 fig.3). Geets et al. (2000) report that somewhat coarser glauconite-rich sand in boreholes between Aalst and Brussels could correspond to the Bois-la-Haut layer. The X-stone bed (named Hooglede Bed in this review) underlying the Pittem Member in the Ampe quarry has also been tentatively suggested to be a lateral equivalent of the Bois-la-Haut layer by Steurbaut (1998) although in Steurbaut (2011, fig.8 p 255) the X-stone bed is again included in the base of the Pittem Member. As the Bois-la-Haut layer is only clearly identified in the Mont Panisel borehole, it is not ranked as a member status and given a layer or bed status.

Regional occurrence and previous names**:**

These deposits were originally described by d'Omalius d'Halloy (1862) as 'psammites, sables et argiles du Mont-Panisel' at the Mont-Panisel near Mons. The Mont-Panisel Member occurs in the area Gent-Brussel-Mons-Kortrijk. The Mont-Panisel Member overlies the Aalbeke Clay in clay pits around Kortrijk (e.g. Mulier clay pit) (Steurbaut 2006).

The sands correspond to the previously used unit 'Panisel sand' in Steurbaut & Nolf (1986) and this Member corresponds to the 'Unnamed Sand member' in the top of the Mouscron borehole and the Kortrijk outcrops of King (1991 p 365). It also occurs in the hills of North France. It corresponds to the term 'Paniselien' used by Gulinck in his profiles around Brussels (MG/00/250-329-547; MG/53/327; MG/55/335; MG/56/176-177-313-316;.MG/58/249).

Whereas in the Gent (055W1020) area the Egem Member subdivisions Yd4, Yd5, Yd6 (sensu Bolle & Jacobs, 1993) can be recognised between the Egemkapel (Yd3 unit sensu Bolle & Jacobs,1993) and the Merelbeke Clay, such identification becomes difficult to the east near the boundary with the Brabant province. It seems that in this latter area and more to the east, the Mont-Panisel Member replaces the Egem Member. Jacobs et al. (1996a p 28) have reported that the Egem Member becomes more clayey to the south.

In the southeast of East Flanders and the neighbouring eastern Brabant province, about 6 to 11 m of glauconitic sand occurs containing sandstone layers overlies the Aalbeke clay Member in Kerksken (086E0340) and Kattem (087W0479) boreholes; its description corresponds to the Mont-Panisel Member (Geological Service Company, 2003). The typical Mont-Panisel sand is overlain by a clayey sand of about 11 m which in its turn is capped by the Merelbeke clay Member. The lithostratigraphic position of this clayey sand unit overlying the Mont-Panisel sand is further discussed under the Kwatrecht Member.

The implication of this succession is also that towards the east, the Kortemark Member and the Egemkapel Member have disappeared. Also on the map sheet 23 Mechelen, Buffel et al. (2009) note that the Kortemark Member disappears to the east and is only present in the western part of the map.

More northwards in the Brabant province (east of Aalst), the Merchtem borehole (072E0229) (Buffel et al. , 2009) shows above the Aalbeke Member and below the Merelbeke Member, the same twofold borehole geophysical log signature and thickness as the Kerksken – 086E0340 and Kattem – 087W0479 boreholes, with the lower part being the typical Mont-Panisel Member below a more clayey glauconitic sand without sandstones (see Kwatrecht Member). This pattern can also be observed further west and

north-westwards in geophysical logs (Meise borehole 073W0394 in Welkenhuysen & De Ceukelaire, 2009) and in grain-size analysis of the Zemst-Weerde borehole (073E0359) (Buffel et al. 2009). The presence of Merelbeke clay in the Zemst-Weerde - 073E0359 borehole was confirmed by micropaleontological data (Buffel et al. ,2009). Note that in the Zemst-Weerde- 073E0359 interpretation by Buffel et al. (2009) these two units together were named Egem Member, an interpretation not followed in the present review. Also, just north of Brussels in Vilvoorde , Gulinck described in his profile MG 00/504 'Paniselien' above a clay rich top of the 'Ypresian' and below the Brussel and Lede Formations; this 'Paniselien' is characterised by stone layers in its lower part.

Over a short distance to the east, between Zemst-Weerde (073E0359) and Zemst-Hofstade (073E0397) the Mont-Panisel sand and the overlying clayey sand have disappeared and it appears that the Aalbeke and the Merelbeke clay Members are superposed (interpretation Johan Matthijs), although this needs micropaleontological confirmation. The latter case implies the wedging out of the Mont-Panisel and Kwatrecht units between the two clay units (Aalbeke and Merelbeke Mbrs) rather than their erosion before deposition of the overlying Zenne Group as would be the case if only Aalbeke clay is present (see also Merelbeke Member) .

On the other hand in the Kallo wells (027E0148/014E0355), more north-westwards, the Kortemark and Egemkapel Members can be recognised and between the Egemkapel and the Merelbeke clay Members the sandy unit is interpreted as Egem Member (no stone layers). Note that the sediment in this Egem Member in the Kallo borehole coarsens upwards as it does in the type area (Tielt 053E0061, Torhout 052E0195 boreholes) and that the log signature of the Egem Member in the Kallo well 014E0355 is also recognised in the Rijkevorsel 007E0200 borehole.

Stratotype:

The section between 0 and about 21.58m depth in the borehole of the Mont-Panisel (151E0340) (topographic map sheet 45/7-8 Mons-Givry , (x=122.300 , y= 125.375, z= +102m).

As the Mont-Panisel borehole is located in an outlier area of the Mont-Panisel Member, the interval 46-54 m in the borehole Zemst-Weerde (073E0359) can be considered a parastratotype of the Mont-Panisel Member (verslag Zemst, FV Matthijs-Buffel, 2000).

Geophysical borehole references

Typical log signature of the Mont-Panisel Mbr can be observed in the reference borehole logs: Merchtem - 072E0229, Zemst-Weerde - 073E0359, Wieze - 072W0159, Wortegem – 084W1475, Kerksken – 086E0340, Kester – 101W0079.

Often it is not possible to distinguish Egem and Mont-Panisel Mbrs. In that case the signatures are best described as Hyon Fm such as a prudent interpreter could do in the case in the reference logs Rijkevorsel – 007E0200, Mol – 031W0237, Kallo – 014E0355,...

In the Kallo well – 014E0355, and eventually the Rijkevorsel borehole – 007E0200, the subdivisions Yd4,5,6 are still recognisable and could be assigned to the Egem Mbr as has commonly be done in the Mol well – 031W0237 (M. Gulinck) although in this Mol well , Steurbaut (1988) has differentiated Kortemark and Egem above the Aalbeke Mbr.

The Knokke well – 011E0138 is also intriguing as the Yd4,5,6 subdivisions are apparently identifiable although only Yd6 is a sandy deposit and Yd4,5 are described as clay deposits; only the Yd6 interval is therefore considered as the Egem Mbr in the Knokke Memoir (Laga & Vandenberghe, 1990) (see also discussion in the compendium Knokke borehole).

Gentbrugge Formation

Author: **see also Geets (1988) and Steurbaut (1998).**

The formation is also discussed by de Heinzelin & Glibert (1957), De Moor & Geets (1973), De Moor & Germis (1971), Fobe (1986), Geets (1979), Gulinck (1967), Gulinck & Hacquaert (1954), Kaasschieter (1961), Maréchal (1993), Steurbaut & Nolf (1986) and Wouters & Vandenberghe (1994).

Description: **this formation of marine origin consists at the base of a very fine silty clay or clayey, very fine silt. To the south and upwards, it is followed by an alternation of layers glauconiferous, clayey silty, very fine sand and clayey sandy, coarse silt, disturbed by bioturbation. The clayey members are covered by fine sand, clearly horizontally bedded or cross bedded. The sediments contain different layers of sandstones.**

Stratotype: **stratotypes have only been designated for the members.**

Area: **the formation mainly outcrops in the centre of East- and West-Flanders and on the hills in the southern part of East- and West-Flanders. It occurs also in the subsoil of the province of Antwerp and northwest Belgium. Some outliers can be observed to the south till northern Hainaut and eastwards from the Senne River.**
The regional distribution map of the Gentbrugge Formation is figured in Maréchal (1993, p 222) as understood at that time; the extension mapped on the 1:50 000 geological maps can be consulted on https://dov.vlaanderen.be/dovweb/html/geologie.html .

Thickness: **maximum 50 m in the north and decreasing to the south and the east.**

Members: **the formation is subdivided into the Kwatrecht, Merelbeke, Pittem and Vlierzele Members. Note that in the present review the now more generally recognised , Kwatrecht Member is ranked in the Gentbrugge Formation because of its more clayey nature compared to the sediments in the Hyon Formation.**

The Vlierzele Member has been traditionally included in the Gentbrugge Formatie of the Ieper Group. It could be argued that the Vlierzele unit as a sand unit would be better ranged in the sandy Zenne Group. However it is also argued that the Vlierzele unit also contains clayey parts and therefore should remain in the Ieper Group. However, taking into account the full significance of the clayey parts of the Vlierzele unit led Fobe (1995, 1997) to differentiate different members in the Vlierzele unit and to rank the Vlierzele

unit as a Formation (see further/ to be discussed). In the present review the Vlierzele is kept as a Member and ranked in the Gentbrugge Formation (see below).

Age**: late Ypresian.**

Remark: the Gentbrugge Fm is called Gent Fm on the 1:50 000 geological maps. The name Gent Fm was changed since it was already in use for Quaternary eolian cover-sand deposits in Flanders (Paepe & Vanhoorne 1976, see website NCS Quaternary subcommission).

Kwatrecht Member

Authors**: De Moor & Geets (1973)**

Description**:**

A layered complex of greenish glauconitic and micaceous bioturbated sand and sandy clays, without stone beds, originally indicated as the Kwatrecht Complex, has been described underlying the Merelbeke Member and overlying the Egem Member in the Gent area near Merelbeke by De Moor and Geets (1973, see 2.2.3.3).

In regional sections, the Kwatrecht Member is geometrically positioned between the Egem and Merelbeke Members by Steurbaut & Nolf (1986), Steurbaut (1991) and Willems & Moorkens (1991). Based on geometry and biostratigraphy the Kwatrecht Member has been related to the Hyon Formation by Vandenberghe et al. (2004). However more recently the Kwatrecht Complex is ranged in the Gentbrugge Formation by Steurbaut (2006, 2011).

Regional occurrence and stratigraphic position:

The occurrence described in the Gent area (Merelbeke) as reported by De Moor & Geets (1973) is not well documented and an analogue profile around Gent (Jacobs et al. 1996a fig. 9) even omitted the Kwatrecht unit below the Merelbeke Member. Vandenberghe et al.(1998 & 2004) have suggested it

could be an erosion remnant as a consequence of intense erosion phases in the late Ypresian and early Lutetian.

Steurbaut (2006, p 79) has reported the presence of the Kwatrecht Member in the Zemst-Weerde borehole (073E0359 , Buffel at al. , 2009); according to the description of this borehole in the present review (see Mont-Panisel Member) , the about 5 m clayey sand between the Mont-Panisel Member and the Merelbeke Member, are meant as Kwatrecht Member by Steurbaut (2006). Consequently this Kwatrecht Member is now also recognised in the east of the Brabant province (boreholes Kerksken – 086E0340, Kattem – 087W0479, Meise – 073W0394, Merchtem .- 072E0229.see Mont-Panisel Member).

Stratotype:

The Gent area (Merelbeke) section as described by De Moor & Geets (1973). As data from this stratotype are not easily accessible , the 41-46 m interval in the Zemst-Weerde (073E0359) borehole could be considered as the parastratotype.

Geophysical borehole references

A twofold subdivision of a sand layer between the Aalbeke and Merelbeke Mbrs allows to distinguish an upper Kwatrecht Mbr signature above a Mont-Panisel Mbr signature in the reference boreholes Merchtem – 072E0229 , Zemst-Weerde – 073E0359, Kerksken – 086E0340, Wortegem – 084W1475, (Wieze – 072W0159?) and in the analysis of the Kattem borehole – 087W0479 (Geological Service Company, 2003) and the published Meise borehole (073W0394)(Welkenhuysen & De Ceukelaire, 2009   Fig. 32).

Merelbeke Member

Authors: **De Moor & Germis (1971,p 57), Steurbaut & Nolf (1986, p 128), Geets et al. (2000).**

Description:

The Merelbeke Member is a compact heavy to silty clay. Thin sand laminae with organic matter and small pyritic concretions have been described by De Moor & Geets (1974). The Merelbeke Member thickness is generally limited to about 6 to 7 m but execptionally up to 14 m near Melle in the profile 3 by De Moor & Geets (1973).

Regional occurrence and previous names:

The Merelbeke Member occurs in the western part of the Brabant provinces and in the north of the provinces of East and West Flanders. Its distribution is irregular because of erosion by later Eocene deposits (Vandenberghe et al., 1998, 2004).

Where the Merelbeke Member occurs, it overlies either the Egem Member or the Mont-Panisel Member as in the Ronse-Aalst-Brussel area or the Kwatrecht Member in the east. The Member is overlain by the Pittem Member.

On the 1:40 000 maps the Merelbeke Member is mapped as P1m, a code also often used in borehole descriptions. In the stratigraphic register (1929,1932) it is part of the Y2 division. In the 1:40 000 mapping, Merelbeke and Aalbeke Members have been confused in the southwest of Flanders.

In the area west of Mechelen (Hombeek, Zemst ...), the Merelbeke Member has been confused in some borehole descriptions with the P1n clay (1:40.000 map legend), which is a unit occurring above or in the top of the Vlierzele Member (Buffel et al., 2009). This confusion in North Belgium was already pointed out by Fobe (1995).

Stratotype:

The section described between +5,6 and -4,9 m T.A.W. in the borehole Melle (055E0783) (222/E3/SWK/F/DB11), topographic map sheet 22/1-2 ,Gent-Melle (X= 109.125, Y = 188.775, Z = + 12.6 m) (Geets et al. , 2000).

Geophysical borehole references

The Merelbeke Member signature in the reference borehole logs can be observed in many boreholes: Merchtem – 072E0229, Zemst-Weerde –

073E0359(confirmation by biostratigraphy in Buffel et al., 2009), Kerksken – 086E0340, Brugge – 023W0454, Knokke – 011E0138, Kallo – 014E0355, Rijkevorsel – 007E0200, Oosterzele – 070E0237, Kruishoutem – 084E1412, Merksplas – 017W0280.

The Zemst-Hofstade – 073E0397 borehole presents an interesting case. The top clay unit, consisting of two parts on the log , is either entirely the Aalbeke Clay or it might be composed of the Aalbeke clay overlain directly by the Merelbeke clay (interpretation Johan Matthijs); the latter case implies the wedging out of the Mont-Panisel and Kwatrecht units between the two clay units (Aalbeke and Merelbeke Mbrs) rather than their erosion before deposition of the overlying Zenne Group as would be the case if only Aalbeke clay is present.

It should be noted that in the reference borehole Knokke – 011E0138, and also Mol-SCK15 – 031W0237, also a similar two fold Aalbeke Mbr signature is observed.

Pittem Member

Authors: **Geets (1979) , Geets et al. (2000) , Steurbaut et al. (2003)**

Description:

The Pittem Member consists of a bedded alternation of thin, dm scale, layers of silty clay and clayey fine glauconitic sand, locally cemented into thin sandstone and siltstone beds which can be microporous after dissolution of sponge spiculae and fossils. Bioturbation is common. Tidal gullies have been reported by Geets et al. (2000). The thickness of the Pittem Member is about 15 to 20 m. Traces of lignite have been reported in the Pittem Member occurring between Knokke and Kruibeke in the north of West and East Flanders by Fobe (1993).

The lower boundary is easily distinguished from either the underlying Merelbeke Member, the Egem Sandstone Bed or the Egem Member. The often reported gradual transition between Pittem Member and the overlying Vlierzele unit in boreholes, is erroneous and due to a confusion between the

Pittem Member and clayey parts of the Vlierzele unit sensu Fobe (1995) (Fobe , 1995 p 143).

Also, in typical cases, the limit between the clayey sediment of the Pittem Member and the overlying Vlierzele Sand can be traced with reasonable confidence in the geophysical log correlation profiles by Welkenhuysen and De Ceukelaire (2009).

Fobe (1997) reports that in the subsurface of northwest Belgium the upper part of the Pittem Member is a conspicuous horizon, brown coloured by lignitic material.

Regional occurrence and previous names:

The Pittem Member occurs almost continuously in a small zone north of a line Torhout-Tielt-Oudenaarde-Ninove and in West Brabant but subcrops over a larger area north of this line. South of this line it occurs only in the South Flemish hills. Towards the south the Pittem Member becomes more sandy.

On the geological maps 1:40 000 the Pittem Member is represented by the P1c unit and in the stratigraphic register (1929,1932) as part of the Y2 division. On the 1: 40 000 maps of the Kortrijk area, clayey deposits of the Tielt Formation have been incorrectly interpreted as P1c. The name 'sandy clay of Anderlecht' is a synonym.

Stratotype :

Geets (1979) considered the now abandoned Claerhout extraction pit in Pittem (topographic map 21/5-6 , Izegem-Wakken , X = 74.250, Y = 187.540, Z = + 46 m) as the reference section for the Pittem Member. An identical section is exposed in the Ampe pit – 053W0060 between +43.5 and +40 m T.A.W (topographic mapsheet 21/1 Wingene x= 70.150, y= 190.150, z= +44m) above the X-stone Bed.

Geophysical borehole references

The Pittem log signature can be observed in the reference boreholes of the type area of central Flanders such as Tielt 053E0061, Brugge – 023W0454,

Knokke – 011E0138, Oosterzele – 070E0237, Kruishoutem – 084E1412 but also in the borehole logs of Merchtem – 072E0229, ON-Kallo-1 – 014E0355, Rijkevorsel – 007E0200 and Merksplas – 017W0280.

Hooglede Sandstone Bed

Authors: **Bolle & Jacobs (1993) , Fobe (1997b), Steurbaut et al. (2003, p 33,34)**

Description:

A pale yellowish brown, with limonite stains, about 40 cm thick cemented and originally shelly coarse-grained sandstone layer; most shells have been dissolved and left large voids. Typically, numerous very coarse glauconite grains are dispersed across the sandstone and sometimes glauconite staining occurs in the dissolved shell voids. The fossils in the layer are bivalves, oysters, nautiloids and shark teeth; also phosphatic nodules are reported (Steurbaut, 2006). The sandstone bed overlies the Egem Member and underlies the Pittem Member.

Because of its characteristic aspect, it is preferred to attribute a bed status to the stone bed. It has been named bed X in Steurbaut (1998, fig. 5), bed 22 in Steurbaut (1998) and Steurbaut et al. (2003, p34). It is proposed in this review to name the bed the Hooglede Sandstone Bed of the Pittem Member after Fobe (1997b).

Regional occurrence and previous names:

The bed occurs in the classical Ampe extraction pit – 053W0060 at Egem and is named bed 22 in the classical section of the pit published by Steurbaut (1998). Lithotratigraphically, the Egem Sandstone Bed has generally been considered as the base of the Pittem Member (a.o. Steurbaut, 2003) as several thin and fine-grained sandstone beds also occur in the Pittem Member ; it was tentatively suggested to be a lateral equivalent of the Bois-la-Haut Member by Steurbaut (1998) (reported also in Geets et al. , 2000), although in Steurbaut (2011, fig.8 p 255) the Egem Sandstone Bed (X-stone bed) is again included in the base of the Pittem Member.

Stratotype :

The Ampe extraction pit – 053W0060 in Egem (Pittem) (mapsheet 21/1 Wingene x= 70.150, y= 190.150, z= +44m) between the Egem Member and the Pittem Member.

Vlierzele Member

Comment on the stratigraphic ranking:

Traditionally the Vlierzele Member has been included in the Gentbrugge Formation of the Ieper Group. However it could be argued that the Vlierzele Member as a sand unit better fits in the Zenne Group overlying the clay dominated Ieper Group. This would be partly in line with Fobe (1995) who argues that the Merelbeke and Pittem Members as clayey units should be united in the Gentbrugge Formations and distinguished from the sandy Egem and Vlierzele units , respectively below and above.
As the lower part of the Vlierzele unit can also be clayey (see Jacobs et al. , 1996a Fig. 13; Lochristi unit sensu Fobe ,1995 p 142) , and also for historical reasons, the present review keeps the Vlierzele unit in the Gentbrugge Formation as a Member.

Authors: **Kaasschieter (1961), Geets et al. (2000) , (Fobe 1995,1997)**

Description:

Traditionally, based on outcrops, the Vlierzele Member is described as consisting of fine glauconitic green-grey mostly bioturbated sand, finely laminated horizontally and in cross stratification. Towards the base the sands becomes clayey and more homogeneous. Towards the top individualised clay layers occur together with humic intercalations. Macrofossils are very rare. Thin cemented siliceous sandstone beds commonly occur (Geets et al., 2000); irregularly shaped siliceous sandstone concretions are also common. The maximal thickness is about 20 m ; in the type locality the cross bedded sand above is 7m thick and the lower homogeneous sand 5 m (see sections in Houthuys & Gullentops, 1988 p 142).

Fobe (1995), after reviewing information available from more than 25 localities, considers the 'traditional Vlierzele sand sensu stricto' as only one of 5 members in a formation between the Pittem Member and the Aalter Sand in the Zenne Group. Steurbaut (2006) reports erroneous correlations in Fobe's (op.cit.) subdivisions ; the Beernem sand , traditionally a member of the Aalter Formation of the Zenne Group (Maréchal & Laga,1988 p 120-121; Geets et al., 2000), is included in the Vlierzele unit by Fobe and the existence of a distinct Aalterbrugge unit is refuted by this author. Therefore the present review is not following the interpretations by Fobe (1995,1997) but recognizes that the clayey basis , a 3-10m very fine clayey sand with mm-thick clay layers, (Lochristi layer sensu Fobe) and eventually a thin coarser basal layer (Hijfte layer sensu Fobe) merit a separate mention aside the traditional Vlierzele sand sensu stricto (which according to Fobe 1995,1997 could be named Oosterzele unit).

Regional occurrence and previous names**:**

The Vlierzele Member outcrops in the northern and central parts of the provinces East and West Flanders and in the western part of the Flemish Brabant province. It also occurs as outliers in the top zones of the South-Flemish hills. On a regional scale the base of the Vlierzele is erosive into underlying strata (see also Fobe, 1989b, 1995). In northern Flanders the grain-size properties of the Vlierzele Member seem to be more variable (Laga & Vandenberghe, 1990 p 1 ; Fobe, 1993, 1995). The boundary between the clayey sediment of the Pittem Member and the overlying Vlierzele Sand can mostly be traced with reasonable confidence in the geophysical log correlation profiles by Welkenhuysen and De Ceukelaire (2009).

On the legend of the 1:40 000 maps the Vlierzele Member is coded P1d and P1n for the upper clayey facies. In the stratigraphic register (1929,1932) the Vlierzele Member is included in the Y2 division.

The P1n-clay, defined by Rutot (1890) and described as a local top clay in the Vlierzele Sand (Gulinck & Hacqaert, 1954) is believed to correspond in fact to the Merelbeke Clay (Fobe, 1995; Buffel et al. ,2009).

Stratotype : **The Vlierzele locality is part of the Sint-Lievens-Houtem municipality in the East Flanders province where several extractions have been active in the past. The sand pit, formerly known as the Verlee or Balegem sand pit (at present Balegro sand pit)– 070E0050, is the stratotype; it is located on topographic map sheet 22/7-8 , Oordegem-Aalst (X = 116.650, Y = 181.725, Z = + 45 m) (Geets et al. , 2000).**

However this stratotype is limited to the Vlierzele sand sensu stricto. Following Fobe (1995), as far as the Vlierzele sensu stricto, the Lochristi and Hijfte layers are concerned, the Ursel borehole (039W0212 x= 87.910 , y= 204.260 , z= + 29 m TAW) shows the Vlierzele Member between 58 and 69,3 m with the Vlierzele sand sensu strict between 58-63 m , Lochristi layer between 63-66 m and the Hijfte layer between 66-69,3 m .

Geophysical borehole references

The Vlierzele Mbr has been identified on top of the Pittem clay Mbr in the following reference borehole logs : Brugge, Merchtem, Knokke (comprising the Hyfte,Lochristi and Oosterzele units sensu Fobe 1995,1997), ON-Kallo-1, Rijkevorsel.

Aalterbrugge Bed

Authors: **Hacquaert (1939); Gulinck & Hacquaert (1954); De Moor & Geets (1973); Fobe (1995).**

Description:

The Bed consists of clays and sand occurring in a complex geometrical relationship as usually encountered in continental deposits; also lignite beds and drift wood , sometimes silicified , occur. It occurs between the Vlierzele Member and the Aalter Formation (Zenne Formation) (Maréchal & Laga, 1988; Steurbaut, 2006, both more homogeneous, glauconitic, marine sediments.

In the synthesis on Belgian geology (P.Fourmarier, 1954, Prodrome d'une description géologique de la Belgique , Soc. Géol. Belg.) Gulinck & Hacquaert (1954) describe in the chapter XIV the Complexe d'Aalterbrugge occurring in the top of the Vlierzele sand unit as follows : " Ces sables prennent souvent dans les zones supérieures, quelquefois aussi dans les parties moyennes, un facies plus grossier, pauvre en galuconie, parfois ligniteux, avec bois flottés percés de tarets et souvent silicifiés. On y rencontre également des niveaux de galets de glaise, spécialement dans la région de Torhout (Rutot [explic.carte géologique 1:40 000])et d'Aalter (Hacquaert, [1939]).

Les bois flottés sont parfois très volumineux. Leur nature fragmentaire permet rarement une détermination précise , mais on a pu y distinguer une dizaine d'espèces (F. Stockmans [région de Bruxelles])".

The Aalterbrugge unit as represented on the section in De Moor & Geets (1973, fig.4) attains 10m thickness. The temporary exposure described by Jacobs (2015 p 137) was at maximum 3m thick (Steurbaut or. com.). Van Simaeys (1999) shows the presence of the Aalterbrugge Complex in the Hyfte borehole section between 46,1 and 53,1 m depth.

No Aalterbrugge unit is reported in Geets et al. (2000) and also in the explanatory notes of the 1:50 000 map sheet 22 Gent , the Aalterbrugge unit is not reported (Jacobs et al. , 1996).

From his extensive data review, Fobe (1995) even concludes that the Aalterbrugge layer does not exist as a separate facies and has been confused with lignitic rich zones occurring at different levels in the Vlierzele unit.

Boundaries:

The section in De Moor & Geets (1973, fig.4) suggest an erosive base into the underlying Vlierzele Sand. Also Hacquaert (1939) reports intraformational clasts at the lignite level, suggesting erosion during the complex formation. Also Steurbaut (2015 p132) suggests that with the regression after the Vlierzele Sand deposition gullies were formed in the area of Aalterbrugge . Maréchal & Laga (1988, p 119) attribute a bed status to the Aalterbrugge layer between the Gent Fm and the Aalter (at that time named Knesselare) Formation and note that the transition between the Aalterbrugge bed and

the overlying marine Aalter Sand is continuous. Jacobs (2015 , fig.3.21 p 137) shows the Aalterbrugge unit in Wetteren as a continuous transition between the Vlierzele and Aalterbrugge unit, but reports that the top of the Aalterbrugge unit is eroded.

Regional Occurrence**:**

The Aalterbrugge Bed is most often reported between Aalterbrugge and Beernem (Jacobs, 2015). It was also described in the Hijfte borehole - 040E0373 northeast of Gent. A recent outcrop along the E40 in Wetteren also showed the presence of the Aalterbrugge Bed.

Roche (1988-1991, p 375) and DeConinck (1988-1991, fig. 9 p 304) report the presence of the Aalterbrugge Complex in the boreholes Kallo - 027E0148 (level 203 m) and Woensdrecht (NL) (level 385 m).

Stratotype**:**

sections along the Gent-Brugge canal (Hacquaert 1939 section).

Parastratotype in the Hijfte borehole (040E0373) section between 46,1 and 53,1 m depth (Van Simaeys, 1999).

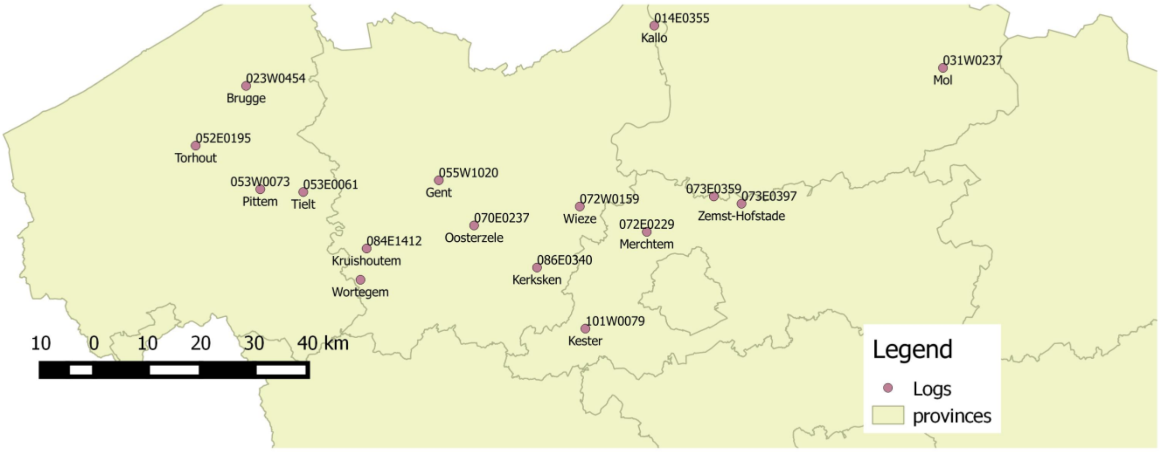
Remark **: The 'Aalterbrugge Member' of the Hijfte borehole (Van Simaeys, 1999) contains isolated records of the freshwater fern Azolla sp. which occurs massively in the North Sea and even the Atlantic Ocean at the base of chron C21r (Vandenberghe et al., 2004).**

COMPENDIUM OF REFERENCE LOGS WITH COMMENTS

Attention ! Some logs in this compendium still need rescaling ! Work in progress !

The location of the reference boreholes in this compendium is shown in the map below.

In the comment section of each borehole only those issues are addressed that make the proposed interpretation debatable. If the given interpretation follows from the definitions explained in the text no further comments are given. In the comments also reference is made to specific intervals in other boreholes for comparison.

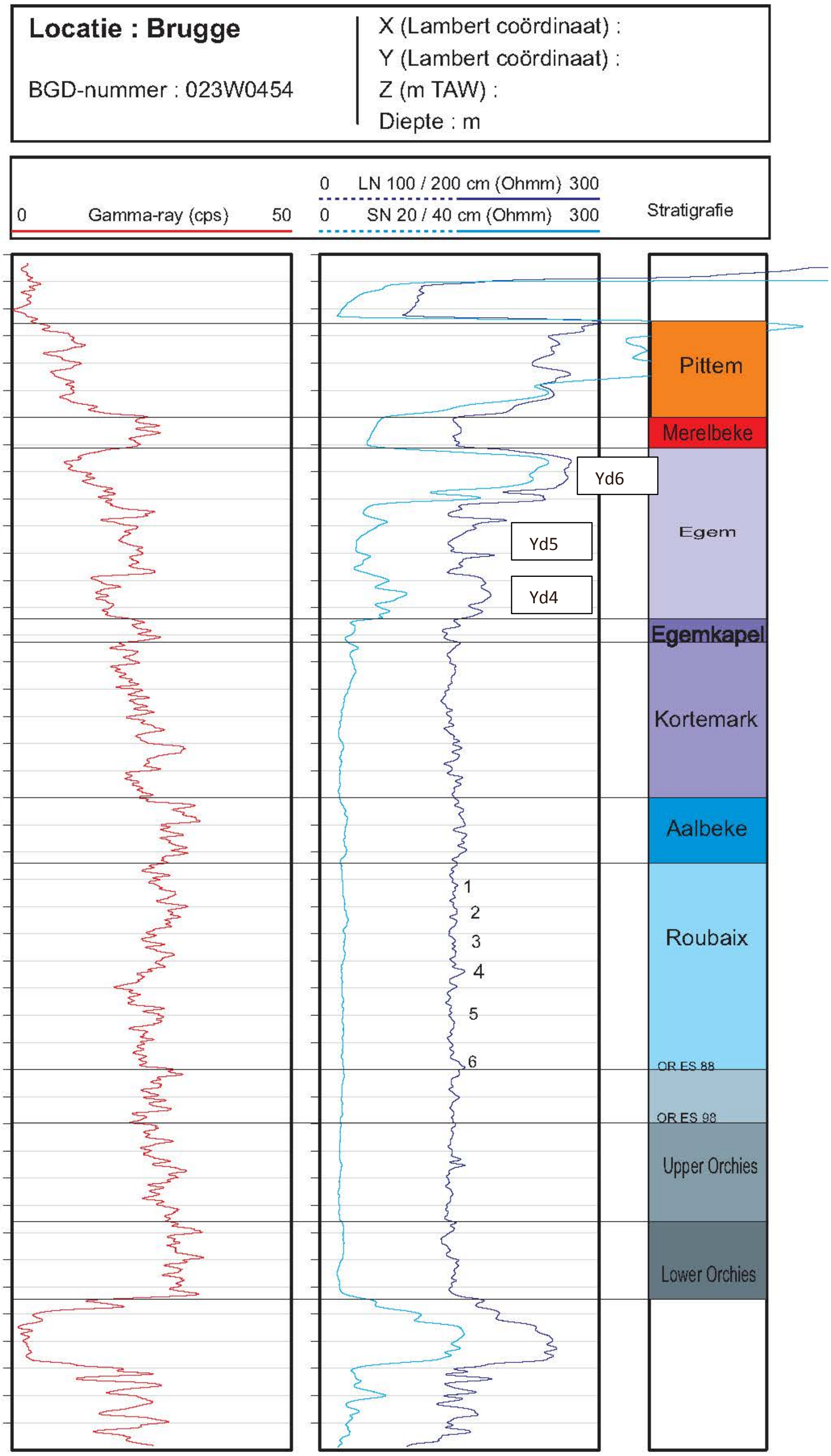


Brugge (023W0454)

The main issue in the interpretation of the Brugge log pattern is the nature and thickness of the Egem Mbr interval and linked to this issue is the exact position of the Egemkapel Mbr.

The threefold subdivision of the geophysical log pattern in the Egem Mbr interval (‘Yd4’,’Yd5’,’Yd6’ ..terminology for respectively the sandy lower part , a clayey middle part and a sandy upper part) can be recognized on the Brugge logs. However, only the upper sandy part is expressed as a manifest sand layer, the main lithology defining the Egem Mbr. This log pattern is similar to what is interpreted in the present review as the Egem Mbr interval in the Knokke borehole (011E0138) (see Knokke borehole). However in previous studies of the Knokke borehole (011E0138) and subsequent literature on the stratigraphy of this borehole, the identification of the Egem sand Mbr was limited to the upper about 10m thick sand layer (the ‘Yd6’) in the interval (see e.g. King, 1990 ; Welkenhuysen & De Ceukelaire, 2009 p. 72).

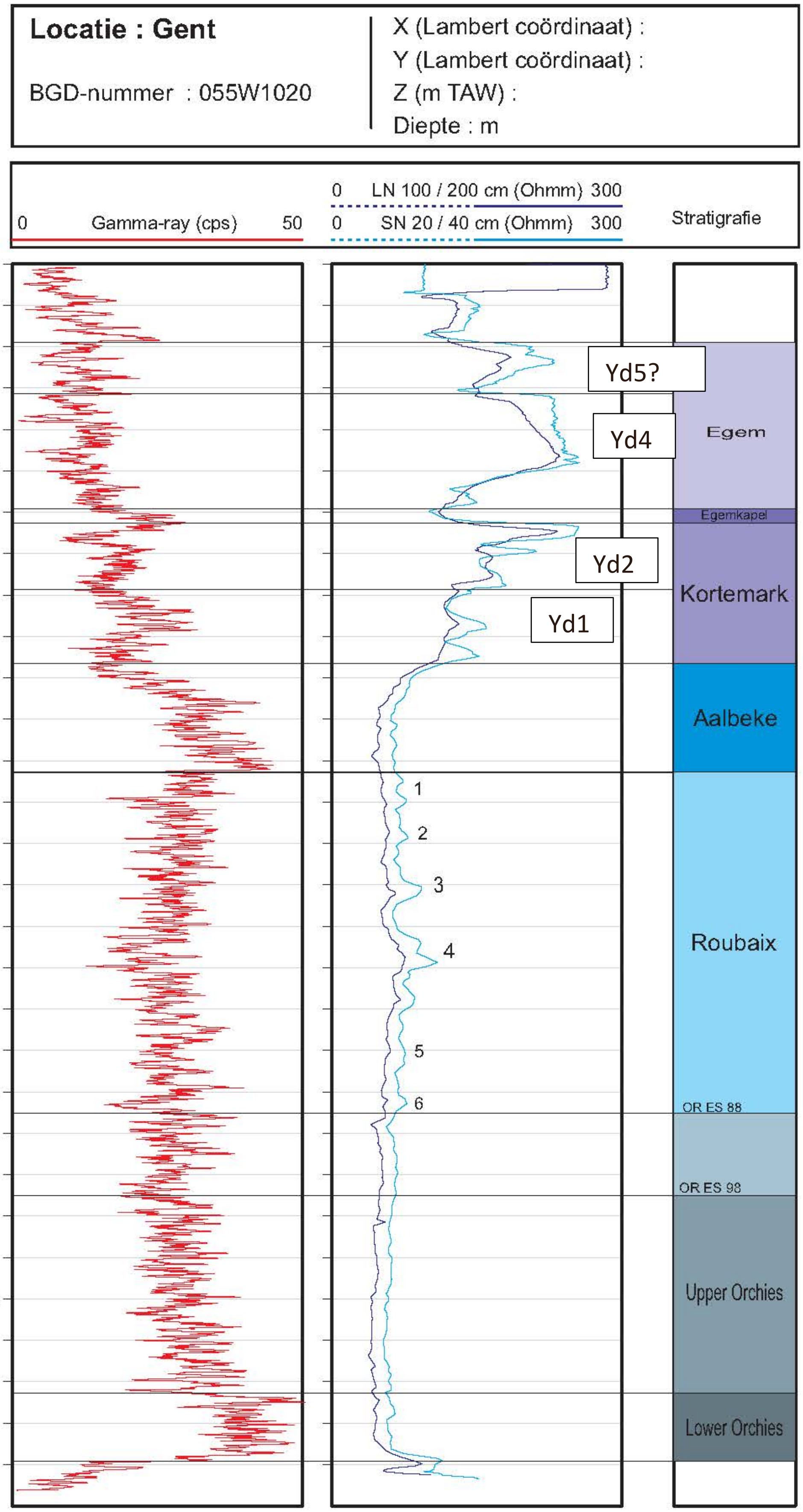
Linked to this issue is the identification of the Egemkapel Mbr. In the normal succession of lithostratigraphic units , this Member occurs below the Egem Mbr. Replacing this Member in the interpretation to the thin clay layer between about 46 and 49m depth obviously would increase the thickness of the Kortemark Mbr below it.


Locatie : Brugge
BGD-nummer : 023W0454
X (Lambert coördinaat) :
Y (Lambert coördinaat) :
Z (m TAW) :
Diepte : m
0 Gamma-ray (cps) 50
0 LN 100 / 200 cm (Ohmm) 300
0 SN 20 / 40 cm (Ohmm) 300
Stratigrafie
0
25
50
75
100
125
150
175
200
Yd6
Yd5
Yd4
1
2
3
4
5
6
Pittem
Merelbeke
Egem
Egemkapel
Kortemark
Aalbeke
Roubaix
OR ES 88
OR ES 98
Upper Orchies
Lower Orchies

1679

Gent (055W1020)

The log pattern in the Kortemark Mbr (‘Yd1’,’Yd2’) is comparable to pattern interpreted as the Kortemark Mbr in the ON-Kallo-1 (014E0355) borehole. The log pattern in the Egem Mbr section is comparable to the 2 lower subdivisions of the threefold subdivision in the Brugge **(023W0454)** borehole(‘ Yd4’,’Yd5’) pattern; the upper most sandy part , and genuine Egem sand Mbr (see comment Knokke), seems to missing under the Quaternary cover ,most logically due to erosion.



Locatie : Gent
BGD-nummer : 055W1020
X (Lambert coördinaat) :
Y (Lambert coördinaat) :
Z (m TAW) :
Diepte : m
0 Gamma-ray (cps) 50
0 LN 100 / 200 cm (Ohmm) 300
0 SN 20 / 40 cm (Ohmm) 300
Stratigrafie
0
25
50
75
100
125
Yd5?
Yd4
Yd2
Yd1
1
2
3
4
5
6
Egem
Egemkapel
Kortemark
Aalbeke
Roubaix
OR ES 88
OR ES 98
Upper Orchies
Lower Orchies

1687

ON-Kallo 1 (014E0355)

The Mont Héribu Mbr is defined by the thin silty basal sediment also containing glauconite.

The OR ES 88 , 98 boundaries as identified in the old BGD Kallo borehole , unfortunately without geophysiscal logs, are transferred to the ON-Kallo -1 borehole, with geophysical logs, using the depth conversion formula: m(ON-Kallo)=1.0016(Kallo BGD 027E0148) + 23,638 (courtesy Peter Stassen).

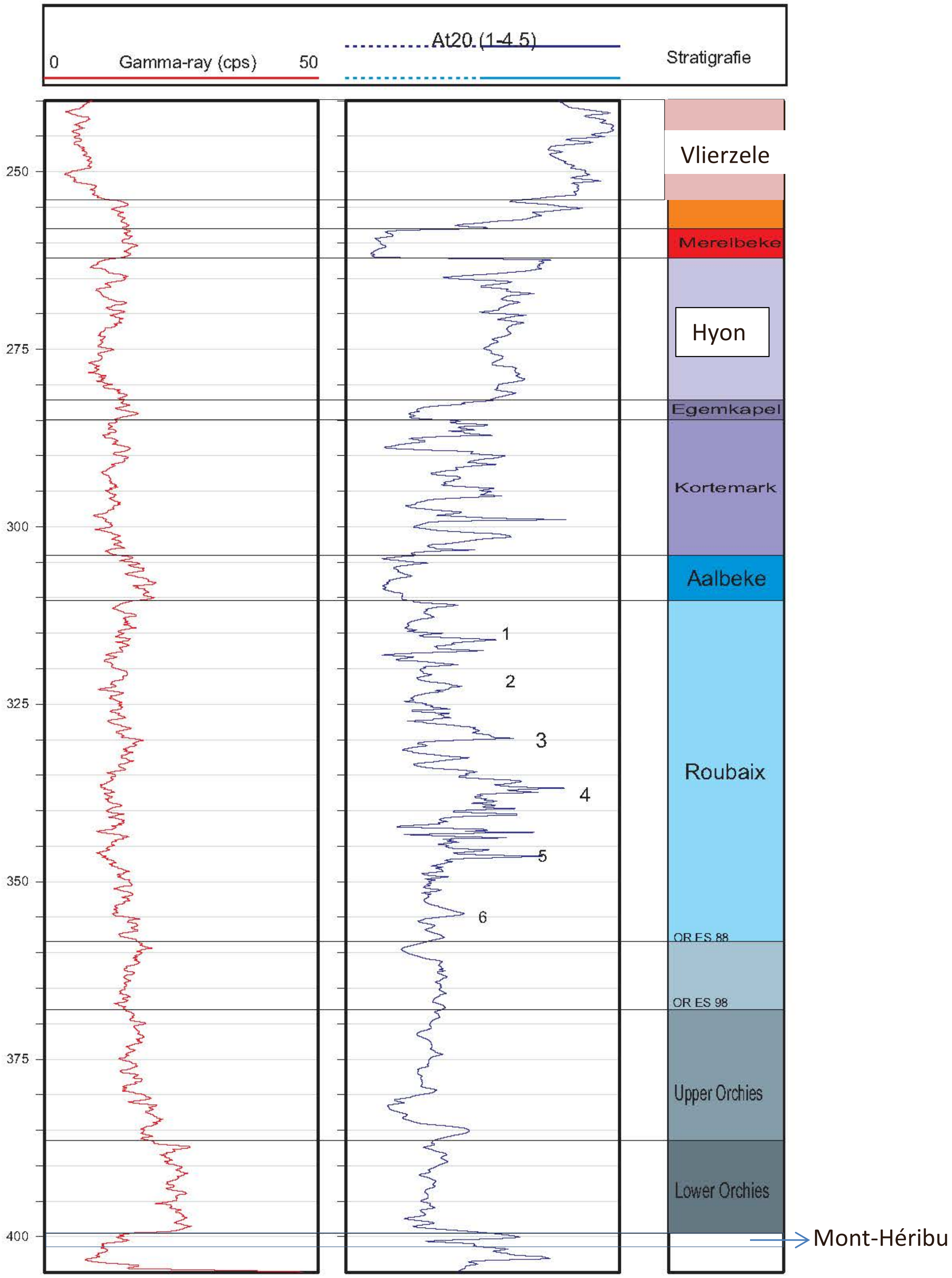
The top Aalbeke Mbr is following the silting-up trend till the first sandy interval (RES curve) marking the start of the overlying Kortemark Mbr.

The top and base of the Egemkapel Mbr, could be interpreted with some degree of freedom if solely based on GR,RES ; the boundaries are chosen based on the published grain-size data by Geets (1988).

The core description of the Hyon interval corresponds to a carbonate containing sand; stone layers are absent. A threefold subdivision can be made in the Res pattern in the Hyon Fm interval, somewhat comparable to the threefold subdivision of the Egem Mbr interval in the Knokke borehole (011E0138); however, in the Knokke well only the upper subdivision consists of fine sand and is considered Egem Sand (Laga & Vandenberghe, 1990) (see Comment Knokke). In the ON- Kallo-1, an additional subdivision could be made based on the GR curve reflecting the lithology in the cores with the lower part being a fine sand and the upper part a very fine sand and glauconitic fine sand.

Based on the log readings ,the sediments above the Merelbeke Mbr are clayey over about 5m followed by sand. Fobe (1995, Fig.5) describes in the nearby Kruibeke borehole (042E0314) 5m Pittem Mbr sediment overlying 12m Merelbeke Mbr, and overlain by at least 10m Vlierzele sand Mbr (top of the ‘sensu Fobe Oosterzele facies ‘).

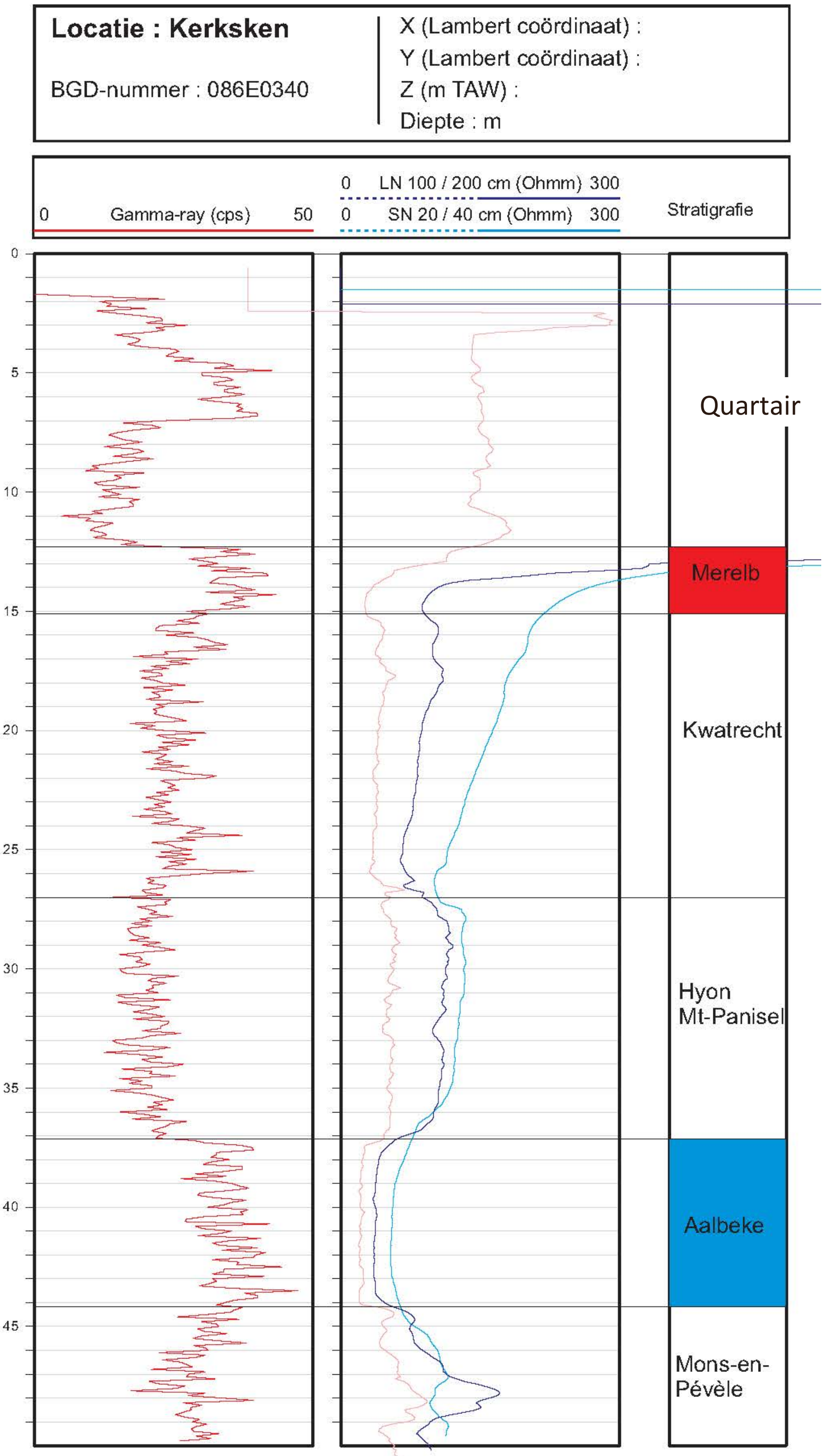
Locatie : Kallo	X (Lambert coördinaat) :
BGD-nummer : 014E0355	Y (Lambert coördinaat) :
	Z (m TAW) :
	Diepte : m



1712

Kerksken (086E0340)

The log pattern of the interpreted Mont-Panisel and Kwatrecht Mbrs Is very comparable with the interval in the Weerde-Zemst (073E0359) borehole which is also interpreted as the Mont-Panisel and Kwatrecht Mbrs.



Kester (101W0079)

Different stratigraphic interpretations exist of this borehole(see Houthuys 2014).

The sandy clay base of the Ieper Group (105-111m) is unusual. lThe low GR at the base is maybe comparable to the lower GR at the base of the Merchtem borehole (072E0229) log. The Lower Orchies unit is about 15m thick.

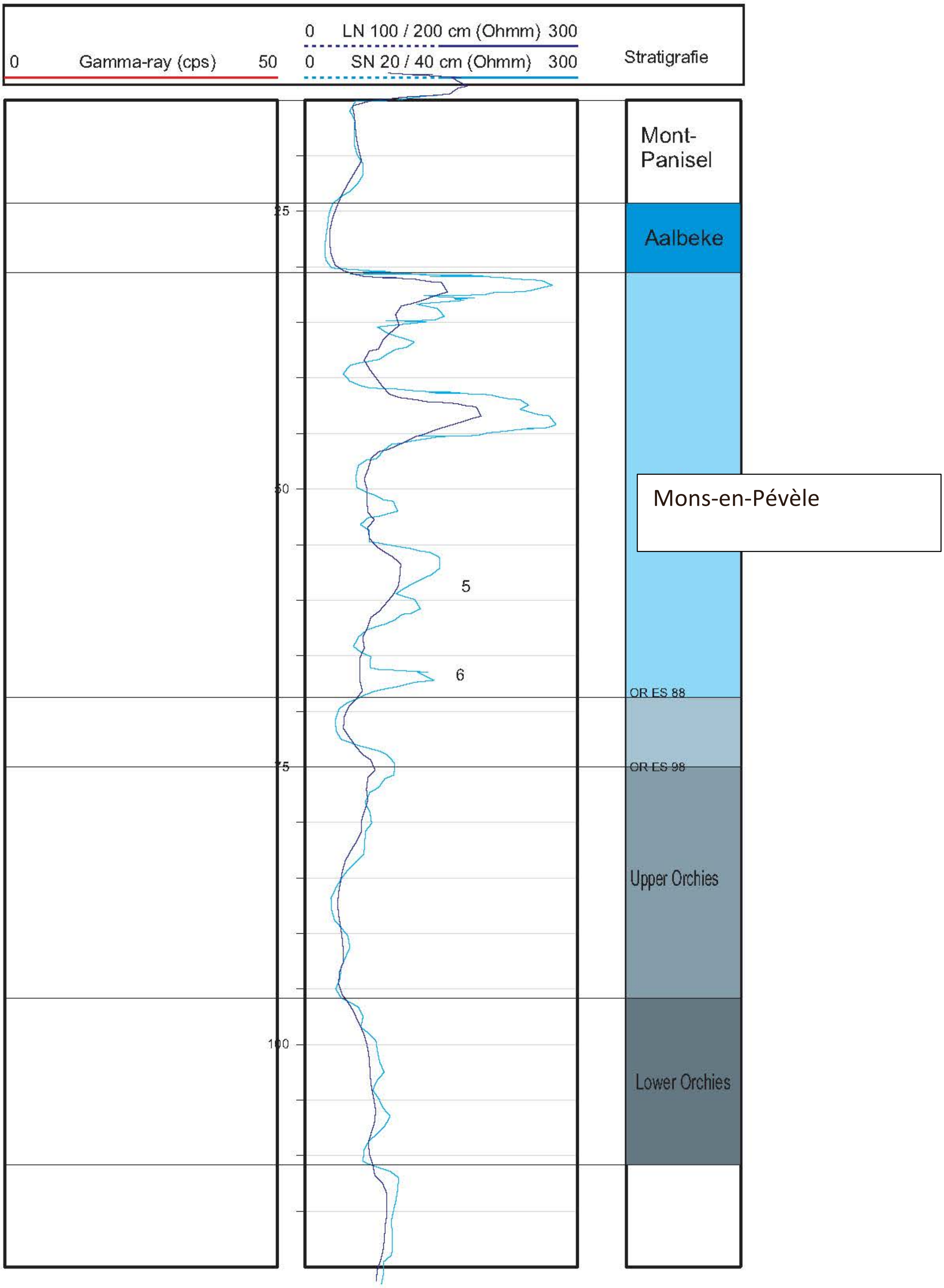
The interpretation of the Aalbeke Mbr overlain by the Mont-Panisel Mbr is based on the similar pattern observed in the Merchtem borehole (072E0229).

The lithology between the Aalbeke and OR ES 88 level seems more clayey at the base and more sandy towards the the top. Based on the expected vertical succession of lithostratigraphic intervals , this interval could be interpreted as the Roubaix Mbr or as the Mons-en-Pévèle Fm. The Roubaix Mbr interpretation could be supported by the GR signal which is not so different from the signal in the Orchies section below. Also geophysical-log pattern events in that interval can be interpreted as similar to those observed in the boreholes Merchtem (072E0229) and Zemst-Hofstade (073E0397). However the lithological description of the section in the Kester borehole (Archives Belgian Geological Survey) reports a very dominantly sand lithology and hence the interval should be interpreted as the Mons-en-Pévèle Fm according to the criterion outline above in the text (>50-60% sand layers).

Locatie :Kester

BGD-nummer : 101W0079

X (Lambert coördinaat) :
Y (Lambert coördinaat) :
Z (m TAW) :
Diepte : m



1735

Knokke (011E0138)

The Zoute Mbr is defined (Steurbaut, 1988) between 283,4-288m.

The top of Lower Orchies seems to consist of a thin sand interval followed above by a last high GR peak; it is proposed to put the boundary at the base of the sand layer if it is well expressed on the RES log as is the case in Knokke borehole (but more difficult to do e.g. in the ON Kallo1 borehole)

The top of the Aalbeke Mbr is consistent with a clay mineralogy boundary as published by Mercier-Castiaux &Dupuis (1988).

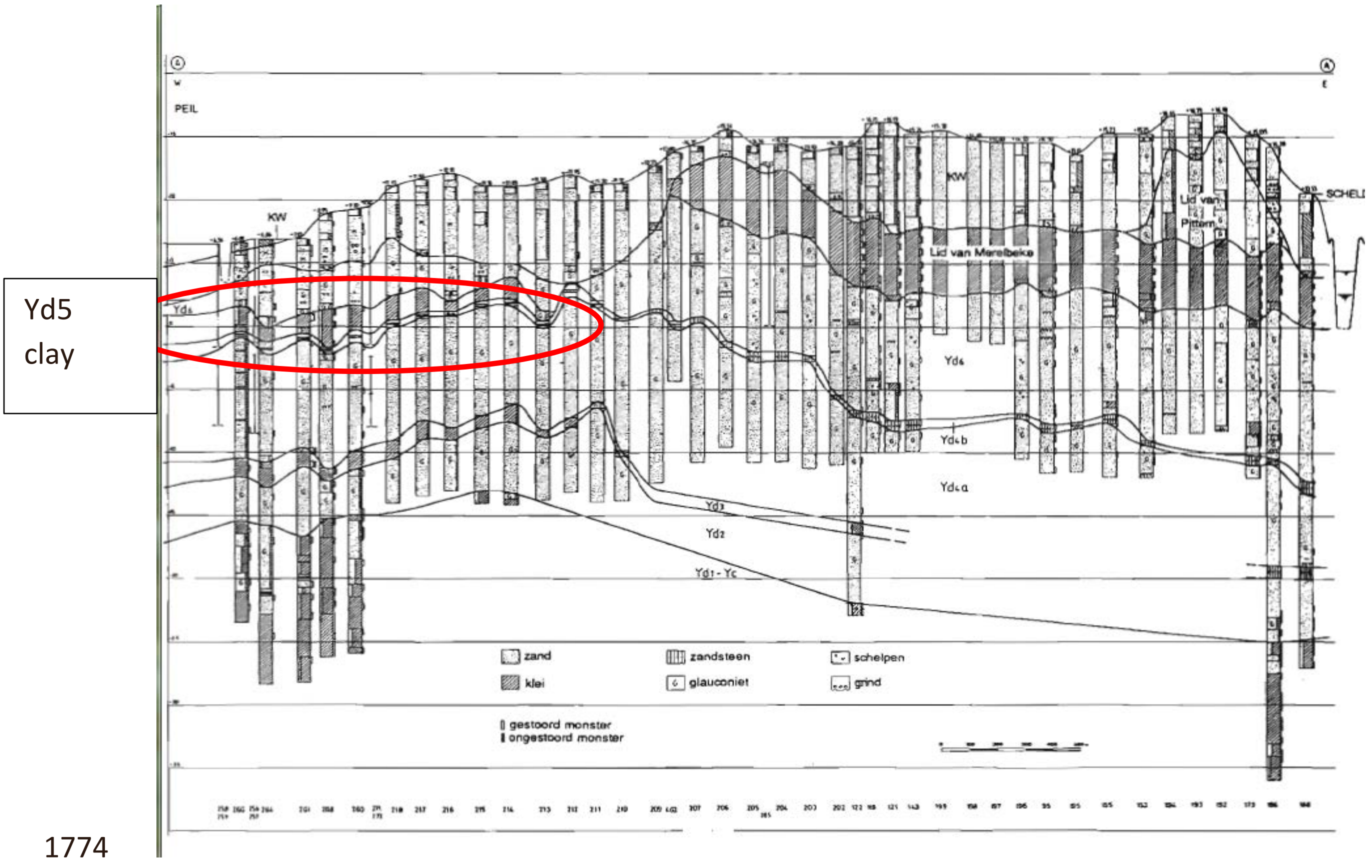
Interpreting the Egemkapel Mbr at 166-171m makes the Kortemark Mbr relatively thin. The GR and RES log signatures between 154 and 157m could also be interpreted as representing the level corresponding to the Egemkapel clay Member, reducing obviously the Egem Mbr thickness; it is in this interval that clay-breccia were reported by Laga & Vandenberghe(1990 p15), the meaning of which is not clear but they could represent submarine erosion levels.

This uncertainty of locating the Egemkapel interval also exists in the Brugge borehole (see Comment, Brugge borehole).

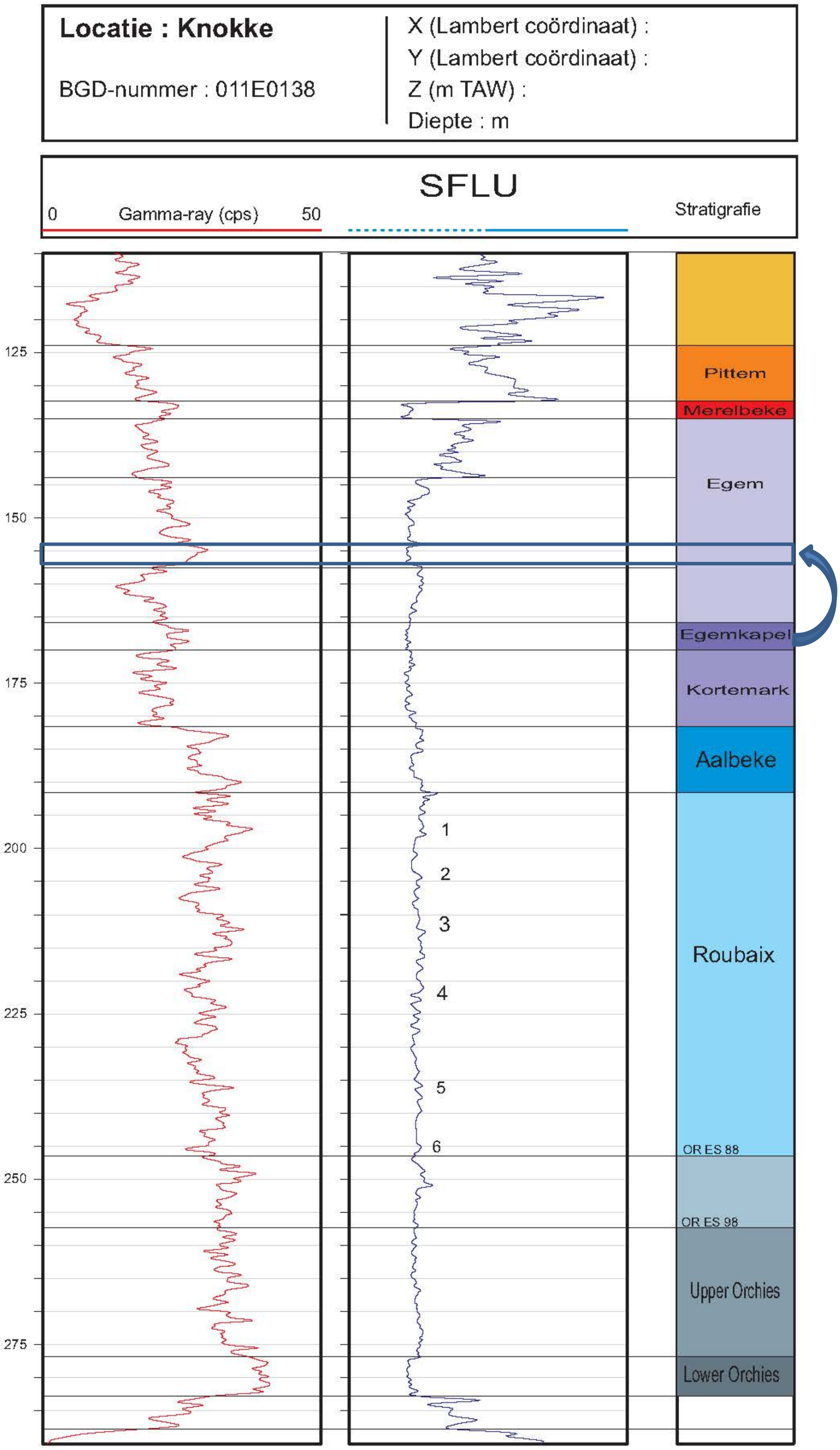
Unfortunately in a study of the nannoplankton of the Knokke borehole (Steurbaut,1990 p48) the relevant interval is barren. Dinoflagellates in the relevant interval were not studied in the Knokke borehole (see De Coninck, 1991) and the few dinoflagellate marker horizons by Hochuli in Vandenberghe et al. (1998, fig.7) are probably lacking precision. Allthough in the present interpretation Egem kapel is interpreted at 166-171 m. Its interpretation between 154 and 157 m equally be valid at present no hard data are available to support either of the two options.

In both options for the interpretation of the position of the Egemkapel Mbr however the issue remains that in previous studies of the Knokke borehole (011E0138) and subsequent literature on the stratigraphy of this borehole (see e.g. King, 1990 ; Welkenhuysen & De Ceukelaire, 2009 p. 72), the identification of the Egem sand Mbr was limited to the upper about 10m thick sand layer (‘Yd6’) in the interval identified as Egem Mbr in the present review and which is described as clay below the upper 10m of sand (see also Comment , Brugge borehole). The practice of considering the sediment interval between the Egemkapel and the Merelbeke units as the Egem member is the basis of the present interpretation which seems supported by the consistent correlation of subunits in the Egem Member Yd4-Yd5-Yd6 which is exemplary demonstrated in the Tielt-Gent area (legends geological maps Tielt and Gent, Jacobs et al, 1996a-b); however it seems that towards the north-west in the Brugge-Knokke area, the lower part of the Egem Member is developed as a clay for which however no separate name has been introduced in the present synthesis.

The profile designed by Van Burm and Bolle (Jacobs et al, 1996a) is already an indication of the appearance of a clay-layer above the Egemkapel Member. The layer called Yd5 is clearly increasing to the west.



The intervals of the Merelbeke, Pittem, and Vlierzele Mbrs are in accordance with core descriptions (see Laga & Vandenberghe, 1990) and with the Fobe (1995) interpretation, if this authors' Beernem unit ' is part of the Aalter Fm as discussed in the text (see Vlierzele Mbr).

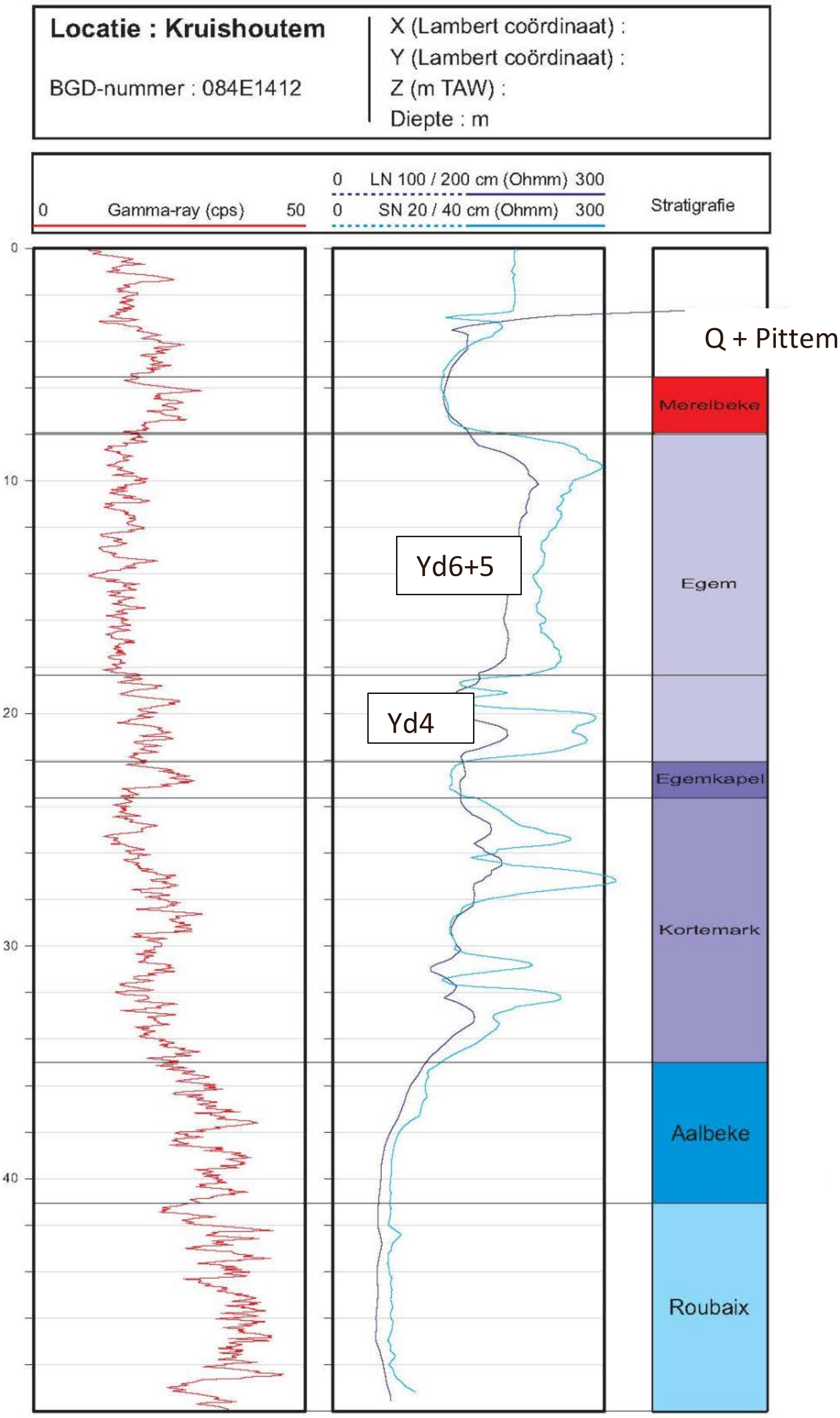

Locatie : Knokke
BGD-nummer : 011E0138
X (Lambert coördinaat) :
Y (Lambert coördinaat) :
Z (m TAW) :
Diepte : m
SFLU
0 Gamma-ray (cps) 50
Stratigrafie
125
150
175
200
225
250
275
1
2
3
4
5
6
Pittem
Merelbeke
Egem
Egemkapel
Kortemark
Aalbeke
Roubaix
OR ES 88
OR ES 98
Upper Orchies
Lower Orchies

1779

Kruishoutem (084E1412)

In the Hyon Fm interval (8-22m) , absence of stone layers and a log pattern having some resemblance to the Gent borehole Egem Mbr interval ,suggests that the Egem sand Mbr is involved.

The top of the Aalbeke Mbr is based on the GR pattern but the base of the unit is more arbitrary and could be a few m lower; both top and base of the Aalbeke Member could be placed slightly differently than in the log interpretation.

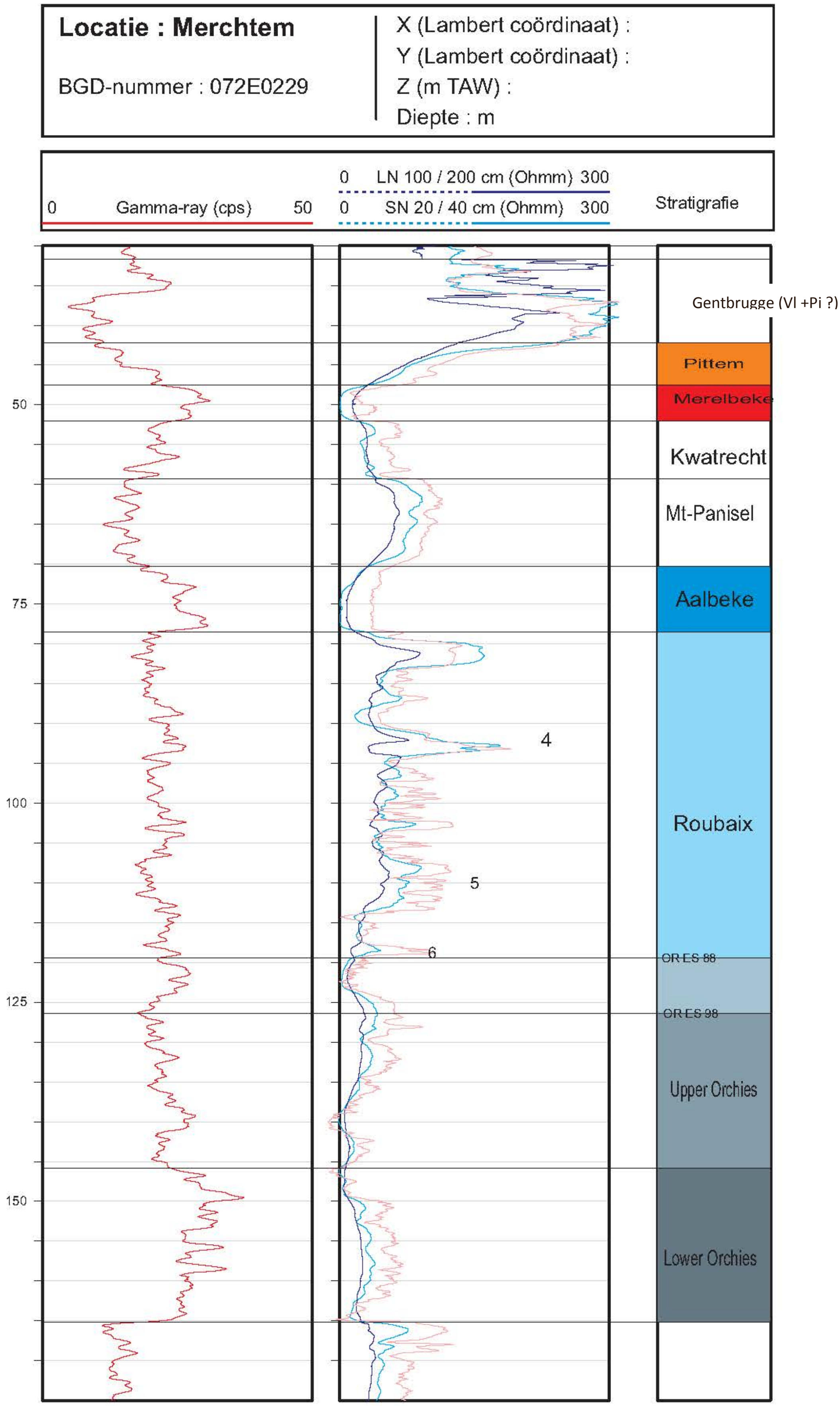


Merchtem (072E0229)

GR and RES , both showing relatively high values in the interval 76-118m, cannot decide on the distinction between RoubaixMbr and Mons-en-Pévèle Fm. From the traditional events in the Roubaix Mbr only the 4,5,6 events can be identified. An inspection of the original lithological description of the borehole (DOV) shows less than 25% sandy intervals between 76-118m is sandy and therefore the interval has to be considered the Roubaix Mbr according to the criterion discussed in the text.

The 2 units between the Aalbeke and Merelbeke clay Members have an almost identical log signature to a pattern recognized in the Kerksken (086E0340), Wieze (072W0159) and Weerde-Zemst (073E0359) borehole logs and are therefore interpreted as the Mont Panisel and Kwatrecht Mbrs.

The Gentbrugge Fm above the Merelbeke unit is interpreted as the Pittem Mbr below and Vlierzele Mbr above , similar to the Rijkevorsel (007E0200) and Kallo (014E0355) borehole logs.



1803

Version october 2015

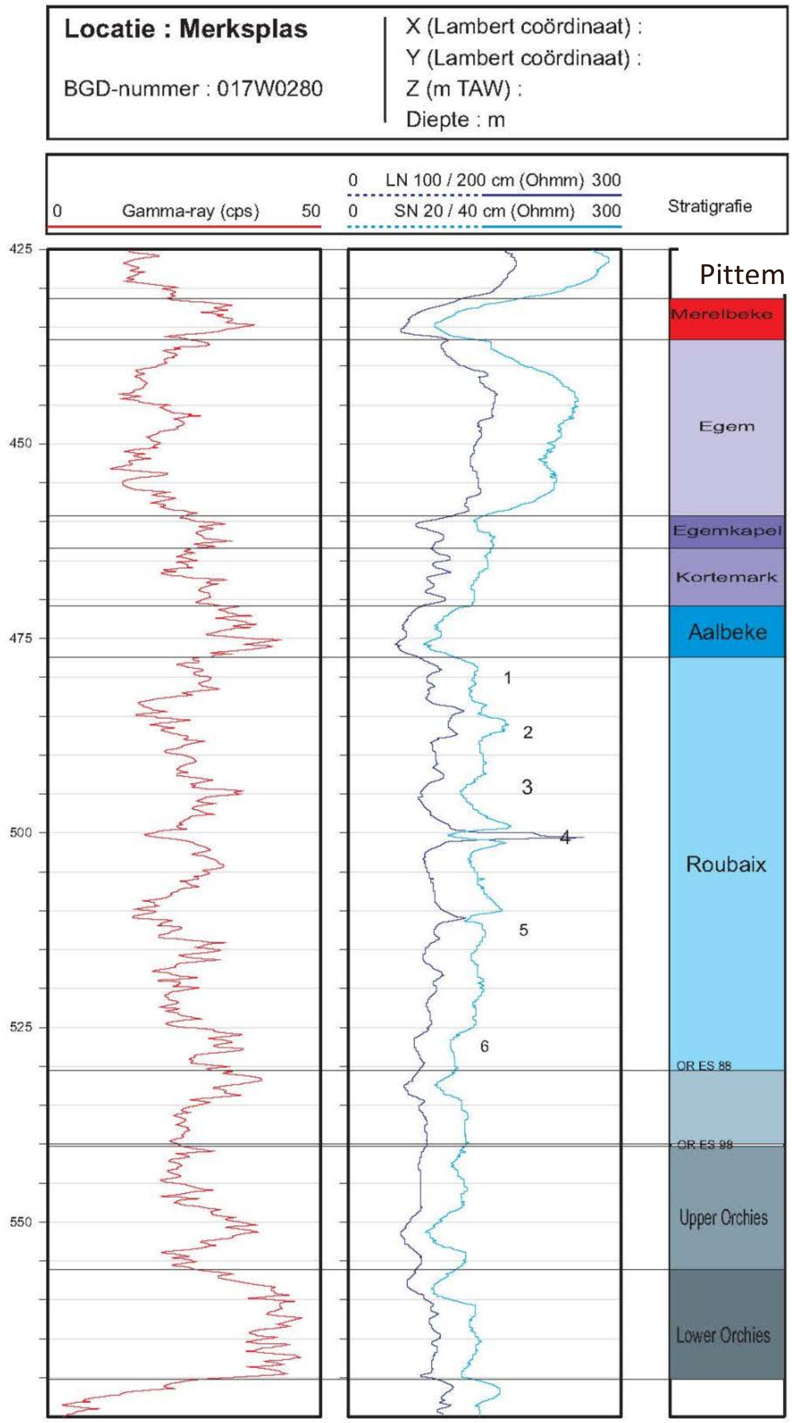
Merksplas (017W0280)

The presence of just a few meter of the Mont Héribu Mbr cannot be excluded as it is the case in e.g. the Kallo (014E0355) and Rijkevorsel (007E0200) wells .

The Kortemark Mbr has become very thin in this borehole.

No further subdivision of the Hyon Fm possible due to bad signal quality.

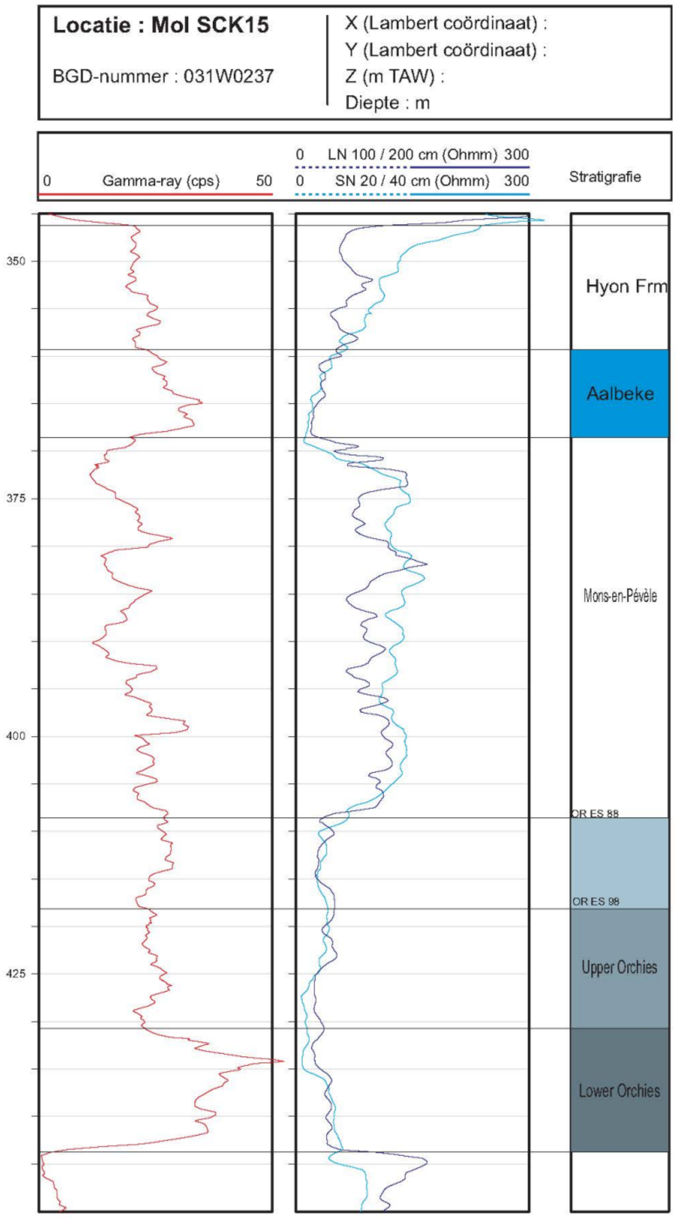
The top of the Pittem Mbr is probably not present on the log.



Mol SCK 15 (031W0237)

The top of theOrchies Mbr OR ES 88 corresponds with the base of the Mons-en-Pévèle sand Fm above according to a detailed core description by M. Gulinck(1975) showing at that level the boundary between fine sand and clay. If OR ES98 is taken as the top of the Orchies Mbr, the about 10m between this top and the base of the Mons-en-Pévèle Fm needs to be named the Roubaix Mbr.

The fine sand above the Aalbeke Mbr has clay laminations in the middle as observed in the cores . It is interpreted as the Hyon Fm because of its sandy nature while the Kortemark Mbr is more clayey. The absence of stone layers could pointing to the Egem Mbr of the Hyon Fm. Steurbaut (1988) has interpreted this interval as consisting of the Egem Mbr above 355m and the Kortemark Member below 355m.

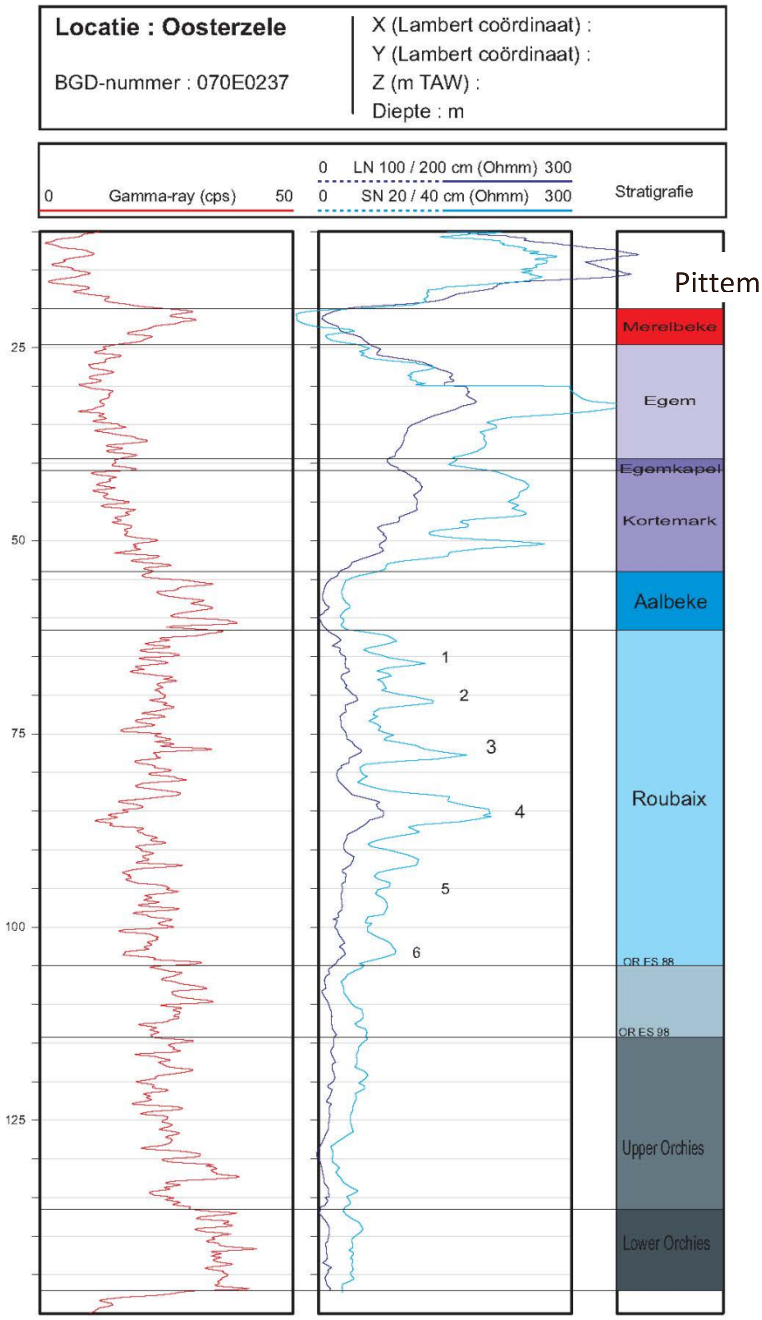


Oosterzele (070E0237)

OR ES 88 is not accurately recognizable on the GR/RES pattern itself but the position chosen is consistent with the thickness from the base of the upper Orchies Mbr as it is observed in nearby boreholes (e.g. Gent)and with the distance from R0 ES88.

In the descriptions of De Geyter (1990 , archives Belgian Geological Survey, AROL wells) , the top of OR ES 88 always systematically corresponds with the boundary between silty clay above and heavy clay below.

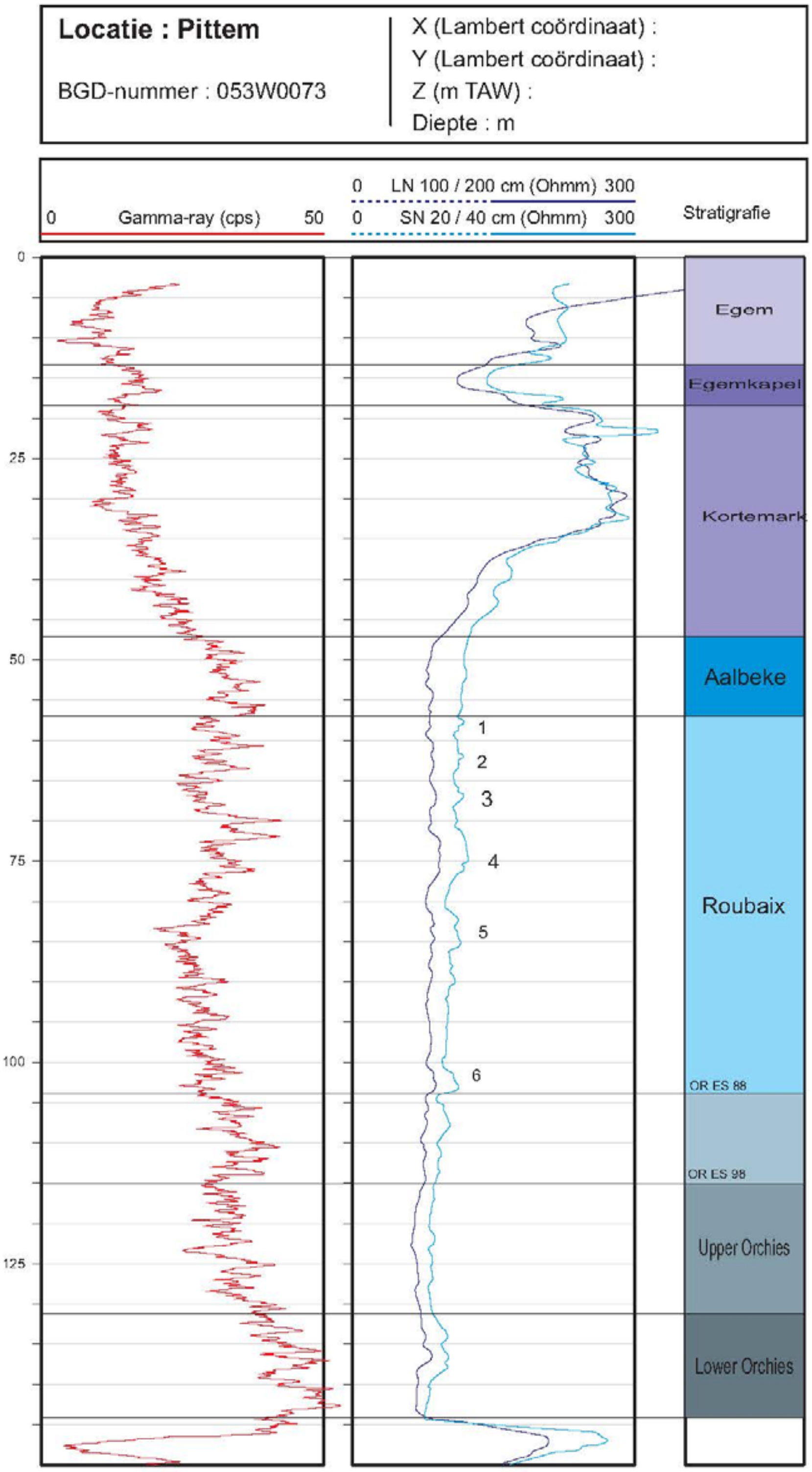
The Hyon Fm between the Egemkapel and Merelbeke Mbrs lacks stone layers and its log pattern is comparable the pattern of the Egem Mbr in the nearby Gent borehole.



Pittem (053W0073)

The expanded RES scale of the curve explains the marked Kortemark Mbr pattern.

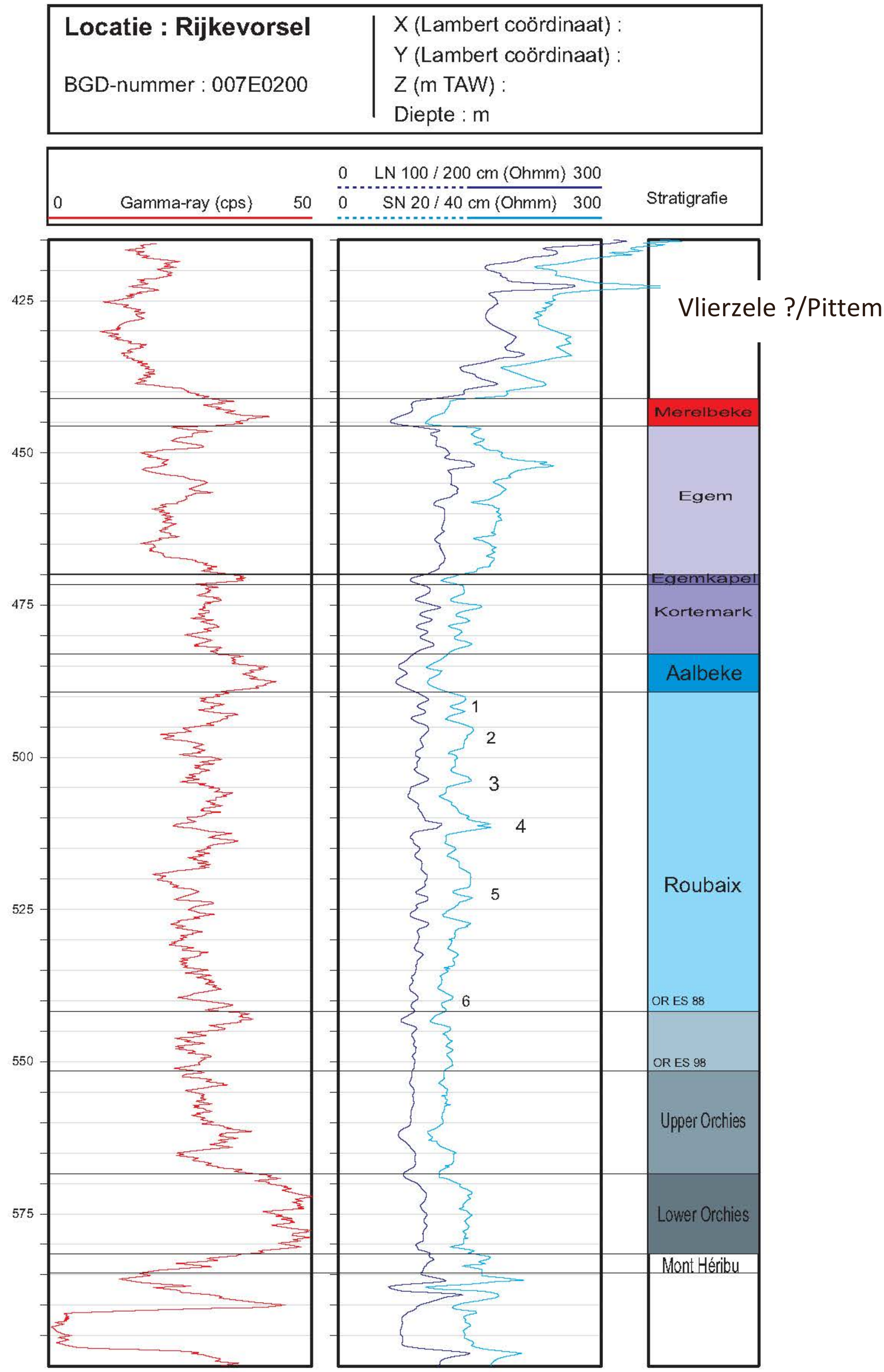
The log pattern at the base of the Egem sand Mbr ('Yd4') reflects the lithological evolution observed in the nearby Tielt borehole 053E0061 and at the base of the closeby Egem sand pit (see Steurbaut, 1988, Fig. 5).



Rijkevorsel (007E0200)

The log is interpreted in its ower part in Steurbaut (1998, Fig.10)

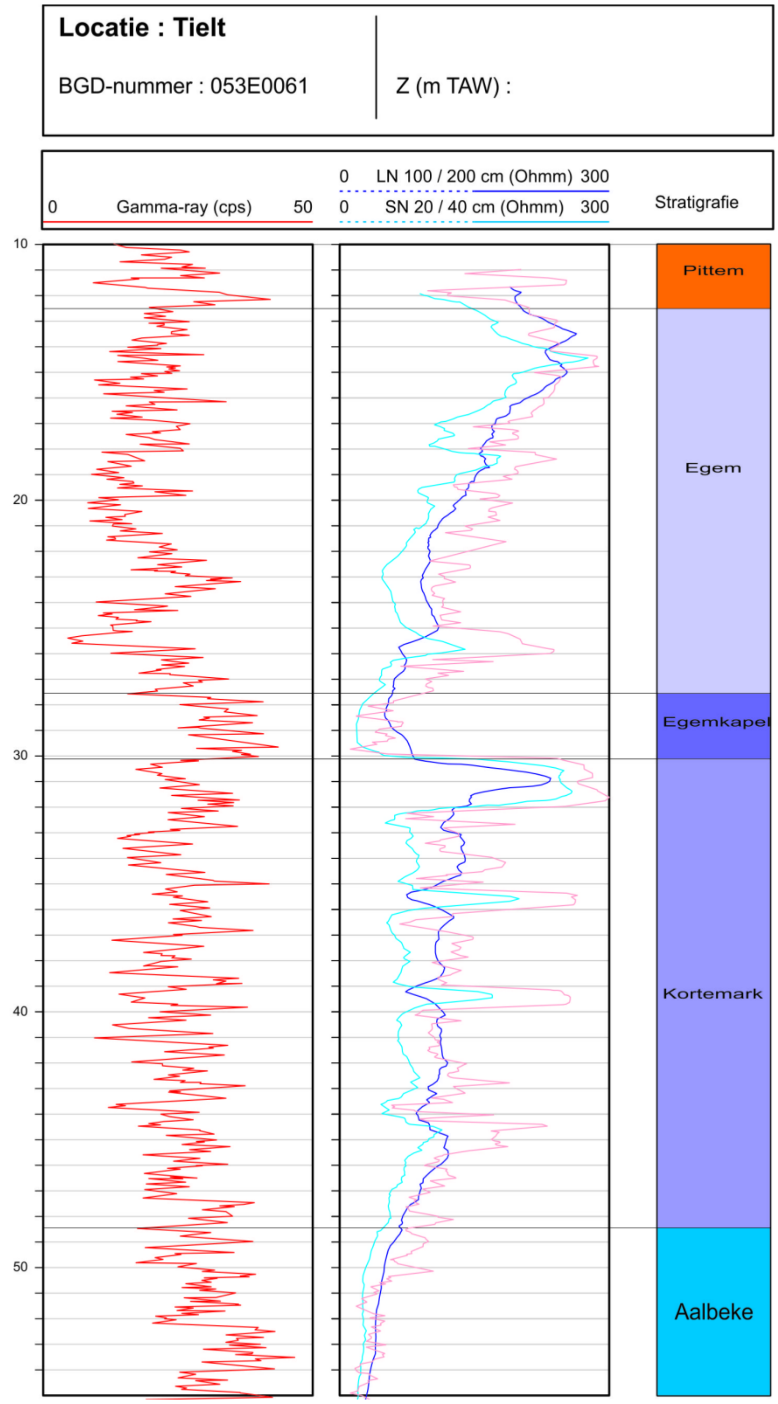
Log patterns in the Rijkevorsel and Kallo (014E0355) wells are very similar for the Kortemark Mbr (see see also Steurbaut, 1998 ,Fig.10), Hyon Fm , Pittem Mbr, Vlierzele Mbr ….



Tielt (053E0061)

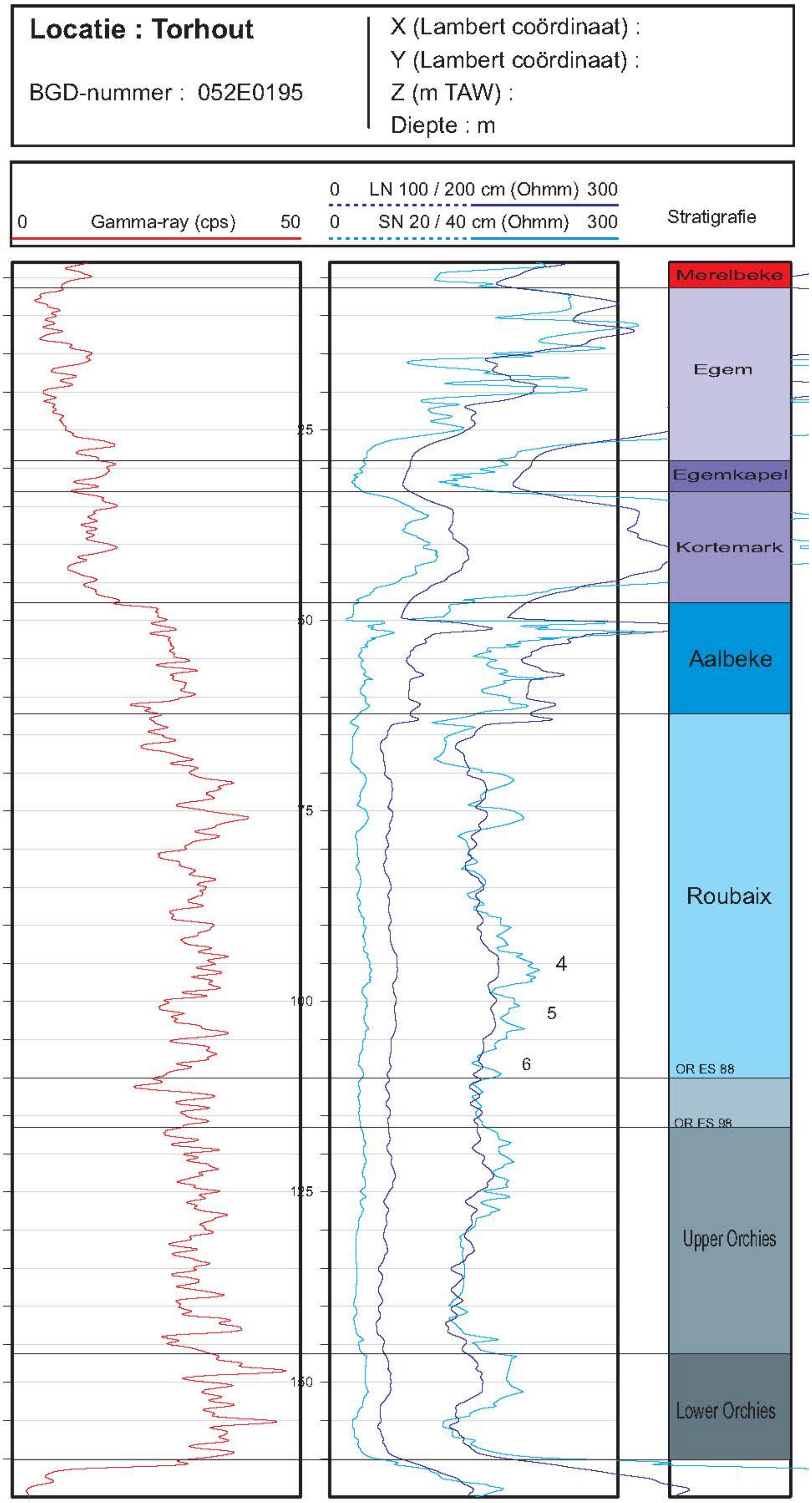
Note that the borehole represented in the Compendium is different from the classical 068E0169 borehole from which grain-size data are available (Geets 1988; and used in the interpretations by Steurbaut , 1998 , Fig16). Distance between the two boreholes is more or less 2 km.

The top of the Aalbeke Mbr is interpreted at 49,5m below which level heavy clay was described in the borehole description by GDG ; on the RES log pattern it corresponds to the coarsening upwards of the Aaalbeke Mbr (see discussion in text).



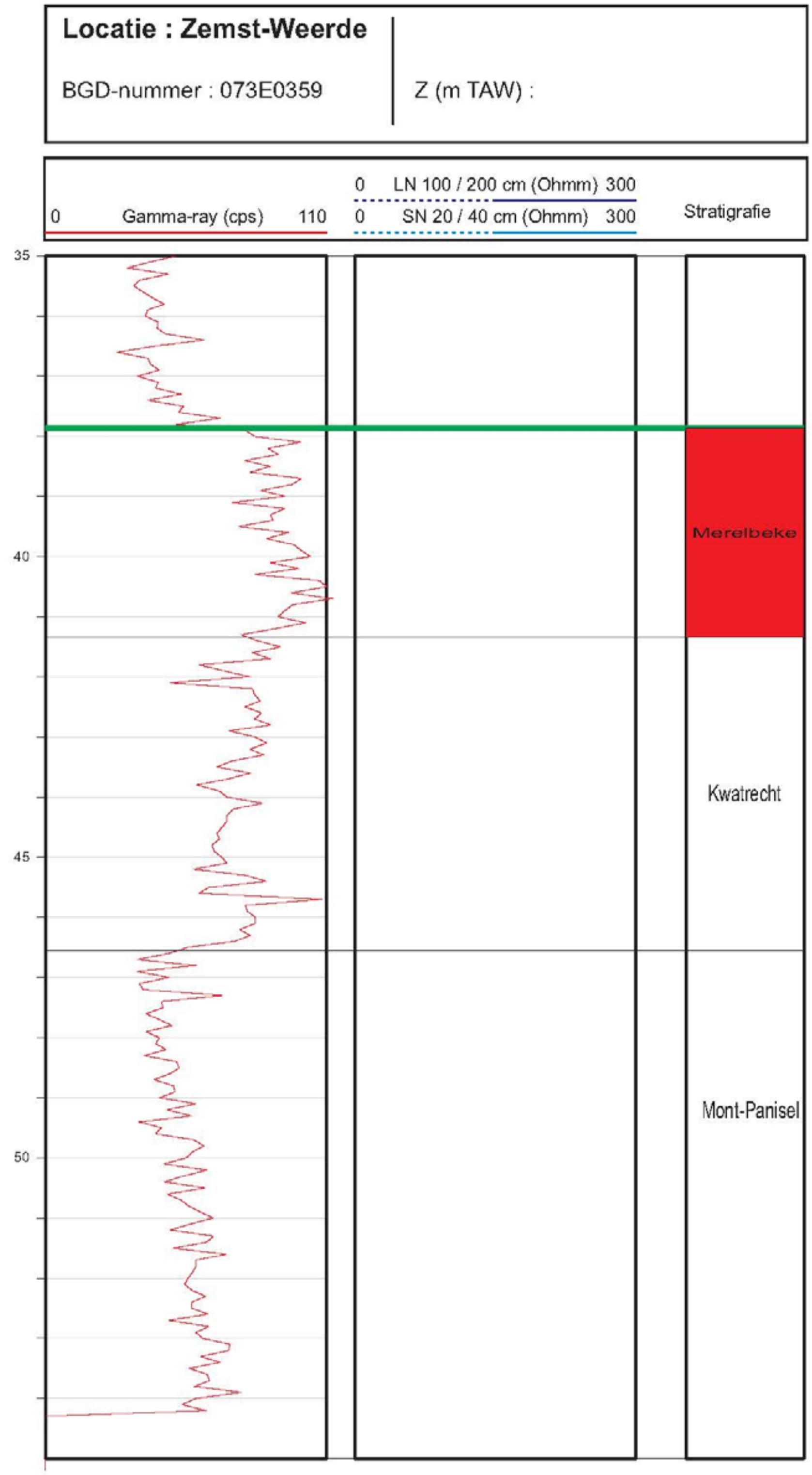
Torhout (052E0195)

Although the geophysical logs are not of very good quality, a reasonable interpretation can be made , based on a comparison with the Tielt borehole (053E0061).



Weerde-Zemst (073E0359)

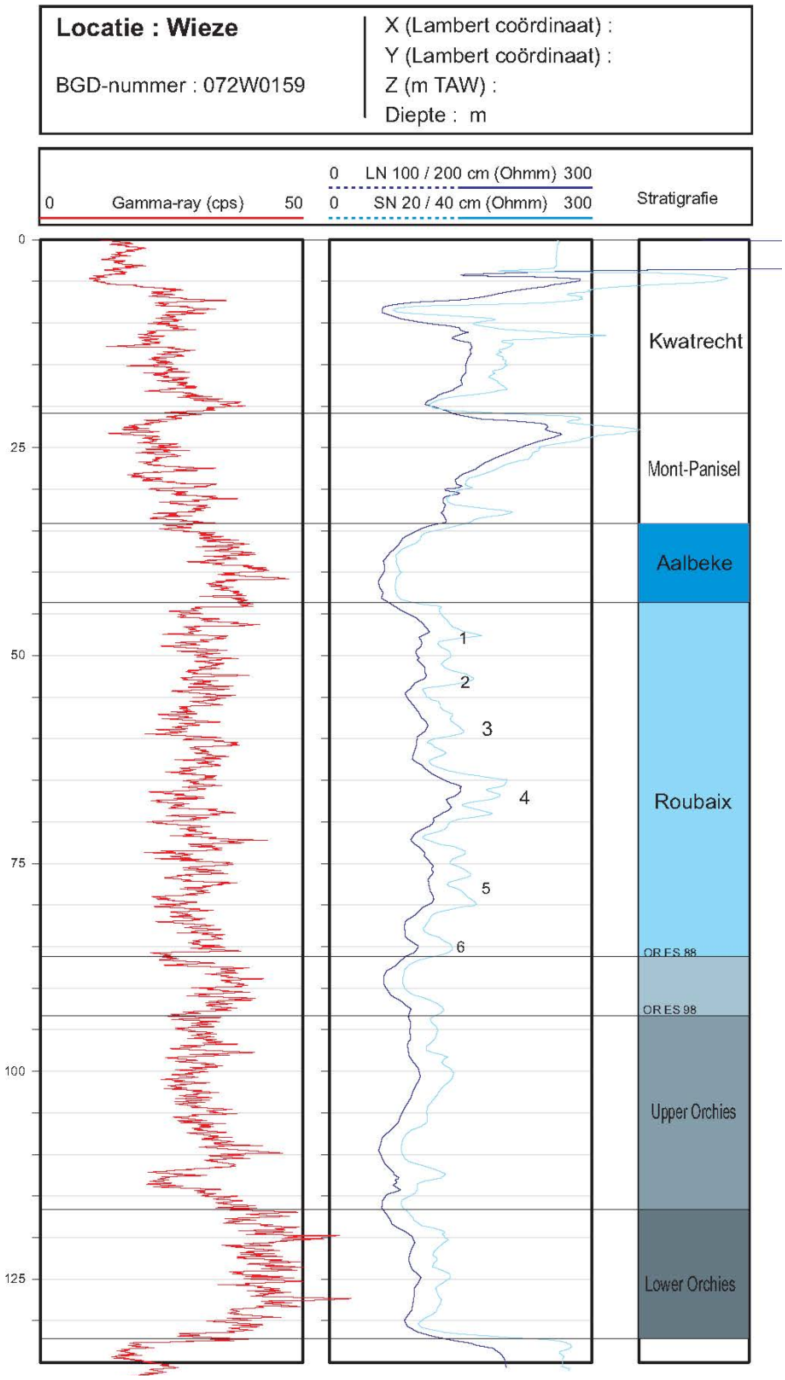
The log pattern below the Merelbeke Mbr is very comparable with the pattern of the Mont-Panisel and Kwatrecht Mbrs in the Kerksken (086E0340) borehole.



Wieze (072W0159)

The interpretation of the OR ES88 level fits the description of the top of the heavy clay by De Geyter (1990) .

Above the Aalbeke Mbr , the log pattern, in particular in the RES curve but also in the GR , resembles the pattern in the Kerksken (086E0340) borehole while there is no resemblance with the log pattern of the Kortemark Mbr. Therefore this pattern is interpreted, consistently with the Kerksken borehole , as Hyon Fm/MontPanisel Mbr overlain by the Kwatrecht Member.

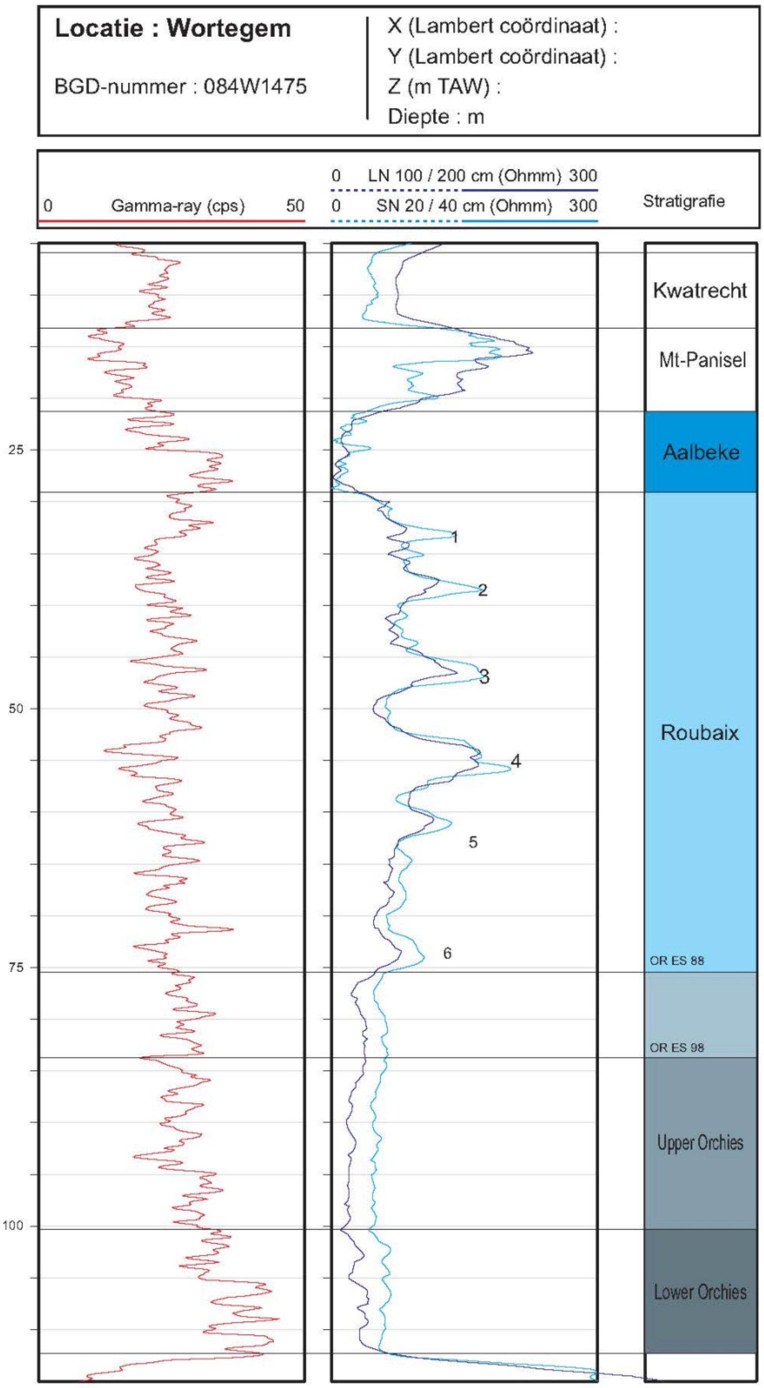


Wortegem (084W1475)

The OR ES 88 level corresponds to the systematic description by De Geyter (1990) as the limit between overlying silty clay and heavy clay below.

The Aalbeke Mbr GR , and also RES, pattern is comparable with its equivalent in the Kruishoutem borehole .

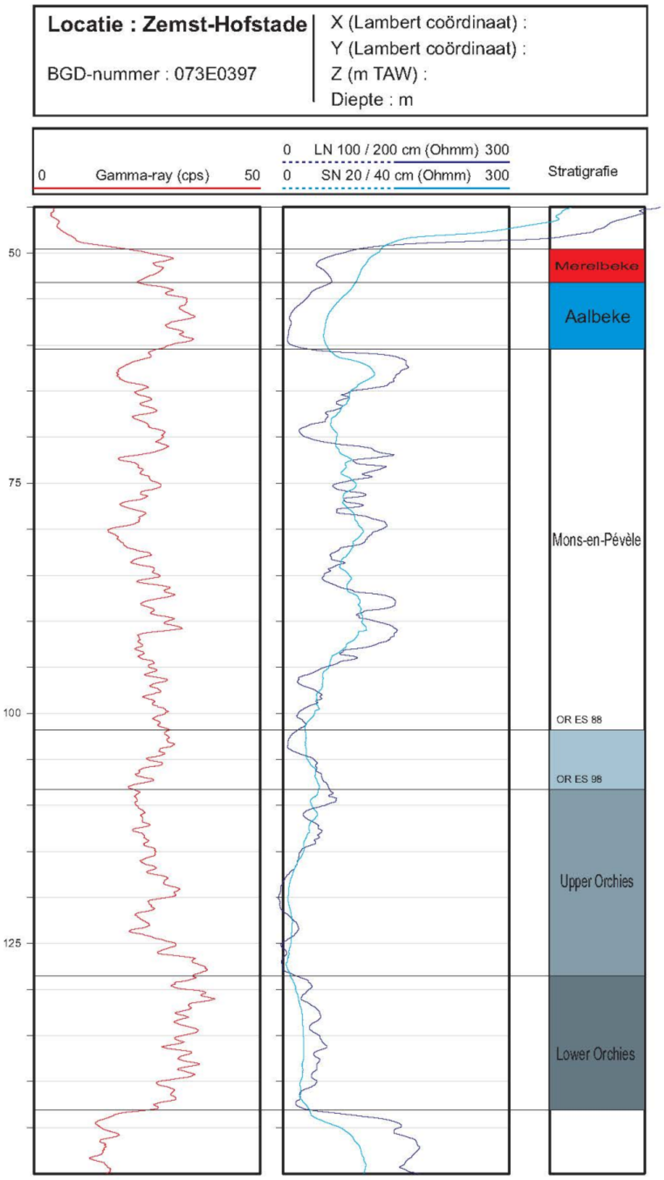
The Mont-Panisel and Kwatrecht Mbrs patterns are comparable to the patterns of these units in the Kerksken (086E0340) and Wieze boreholes



Zemst-Hofstade (073E0397)

The pattern of the Orchies- Mons-en Pévèle section is comparable to the pattern of the Orchies-Roubaix interval in the Merchtem log. However the identification as Mons-en Pévèle Fm is preferred over the Roubaix Mbr as the RES values are nearly double the ones in the Merchtem borehole and the sand layers, apparent from the RES log, are estimated to be about 50% of the total.

The top clay unit consists either entirely of the Aalbeke Clay (see comparable signal in the Knokke and Mol-SCK15 boreholes) or it might be composed of the Aalbeke clay overlain directly by the Merelbeke clay (interpretation suggested by Johan Matthijs); in the latter case the Mont-Panisel and Kwatrecht units are wedging out while in the former case, if only Aalbeke clay is present, the Mont-Panisel and Kwatrecht units were eroded before deposition of the overlying Zenne Group .



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