

LITHOSTRATIGRAPHY OF THE VLIERZELE FORMATION (YPRESIAN, NW BELGIUM).

Bart FOBE¹

SUMMARY. A complete section of the redefined Vlierzele Formation in northern Belgium consists of 5 units : the Hijfte Member (coarse sand), the Lochristi Member (clayey sand), the Oosterzele Member (sand), the Beernem Member (sandy clay, sand with clay layers, sandstone beds, shellbeds) and on top the Drongengoed Member (sand). The Formation is only complete in boreholes in the north of the country. The Drongengoed Member is missing in the outcrop area.

The original type section of the «Vlierzele sands» (Kaasschieter, 1961) and many other sandpits (including the Aalterbrugge lignitic Bed) in the outcrop area southeast of Gent only expose the Oosterzele Member. The underlying Lochristi Member corresponds to the clayey sediments under the extracted sands and often described as the transition zone between the Vlierzele sand Member and the Pittem sandy clay Member.

The limit between the «Vlierzele sands» and the Pittem clay is not a gradual transition but a sharp contact at the base of the Hijfte Member.

The Beernem member of the Knesselare Formation (*sensu* Jacobs & Geets, 1977) is actually part of the Vlierzele Formation. In complete sections in northern Belgium, it occurs in the middle of the formation. In or close to the outcrop area near Brugge and southeast of Gent, where the Drongengoed member is missing, it is encountered as the youngest part of the Vlierzele Formation.

KEYWORDS: Ypresian, Vlierzele Formation, lithostratigraphy, correlations.

SAMENVATTING. De volledige sequentie van de Formatie van Vlierzele in het noorden van België bestaat uit 5 leden : het Lid van Hijfte (grof zand), het Lid van Lochristi (kleiig zand), het Lid van Oosterzele (zand), het Lid van Beernem (zandige klei, zand met kleilagen, zandsteenbanken, schelplagen) en bovenaan het Lid van Drongengoed (zand). De complete sequentie van de Formatie is enkel aangetroffen in boringen in het noorden van het land. Het Lid van Drongengoed ontbreekt in het ontsluitingsgebied.

De oorspronkelijke typesectie van de «zanden van Vlierzele» (Kaasschieter, 1961) en de ontsloten sectie in vele andere zandgroeven in het ontsluitingsgebied ten zuidoosten van Gent tonen enkel het Lid van Oosterzele. Het onderliggende Lid van Lochristi vormt een laag kleiig zand onder de ontgonnen zone en stemt overeen met wat gewoonlijk beschreven wordt als de graduele overgang tussen het «zand van Vlierzele» en de «zandige klei van Pittem». Tussen het Lid van Lochristi en het Lid van Pittem bevindt zich echter nog een laag middelmatig fijn zand met een grove basis, het Lid van Hijfte, dat onderaan scherp begrensd wordt.

Het Lid van Beernem van de Formatie van Knesselare (Jacobs & Geets, 1977) maakt in feite deel uit van de Formatie van Vlierzele. In complete secties in noord België, wordt het midden in de Formatie van Vlierzele aangetroffen, onder het Lid van Drongengoed. Het plaatselijk lignietrijke Lid van Oosterzele (het zgn Aalterbrugge facies) werd er ten onrechte als het einde van de Ieperiaanse cyclus beschouwd. Het Lid van Beernem wordt ook aangetroffen in het ontsluitingsgebied ten zuidoosten van Gent.

SLEUTELWOORDEN: Ieperiaan, Formatie van Vlierzele, lithostratigrafie, correlaties.

¹ Laboratory Mineralogie, Petrografie and Micropedologie, State University of Gent, Krijgslaan 281/S8 - B-9000 Belgium.

RESUME. La séquence complète de la Formation de Vlierzele dans le Nord de la Belgique se divise en 5 unités : le Membre de Hijfte (sable grossier), le Membre de Lochristi (sable argileux), le Membre d'Oosterzele (sable, parfois à lignite), le Membre de Beernem (argile sableuse, alternances de sable et d'argile, bancs de grès, bancs coquillers) et au sommet le Membre de Drongengoed (sable).

Une telle séquence complète de la Formation de Vlierzele ne se rencontre que dans le nord du pays. Le Membre de Drongengoed fait défaut dans la zone étudiée. La section type originale des «Sables de Vlierzele» (Kaasschieter, 1961), exposée dans de nombreuses sablières dans l'aire d'affleurement au sud-est de Gent, ne montre que le Membre d'Oosterzele. Le Membre de Lochristi sous-jacent est un niveau de sable argileux, décrit traditionnellement comme le «passage graduel entre le Sable de Vlierzele et l'Argile de Pittem». En effet, entre les Membres de Lochristi et de Pittem se rencontre le Membre de Hijfte, composé de sable devenant grossier vers le bas et limité par une base nette.

Le Membre de Beernem de la Formation de Knesselare (Jacobs & Geets, 1977) est inclus dans la Formation de Vlierzele. Dans des sections complètes du Nord du pays, le Membre de Beernem se rencontre dans la partie médiane de la Formation de Vlierzele. Le faciès localement ligniteux du Membre d'Oosterzele (le faciès dit d'Aalterbrugge) a été considéré à tort comme indiquant la fin du cycle sédimentaire yprésien. Le Membre de Beernem se rencontre aussi dans l'aire d'affleurement au sud de Gent.

MOTS-CLÉS: Yprésien, Formation de Vlierzele, lithostratigraphie, corrélations.

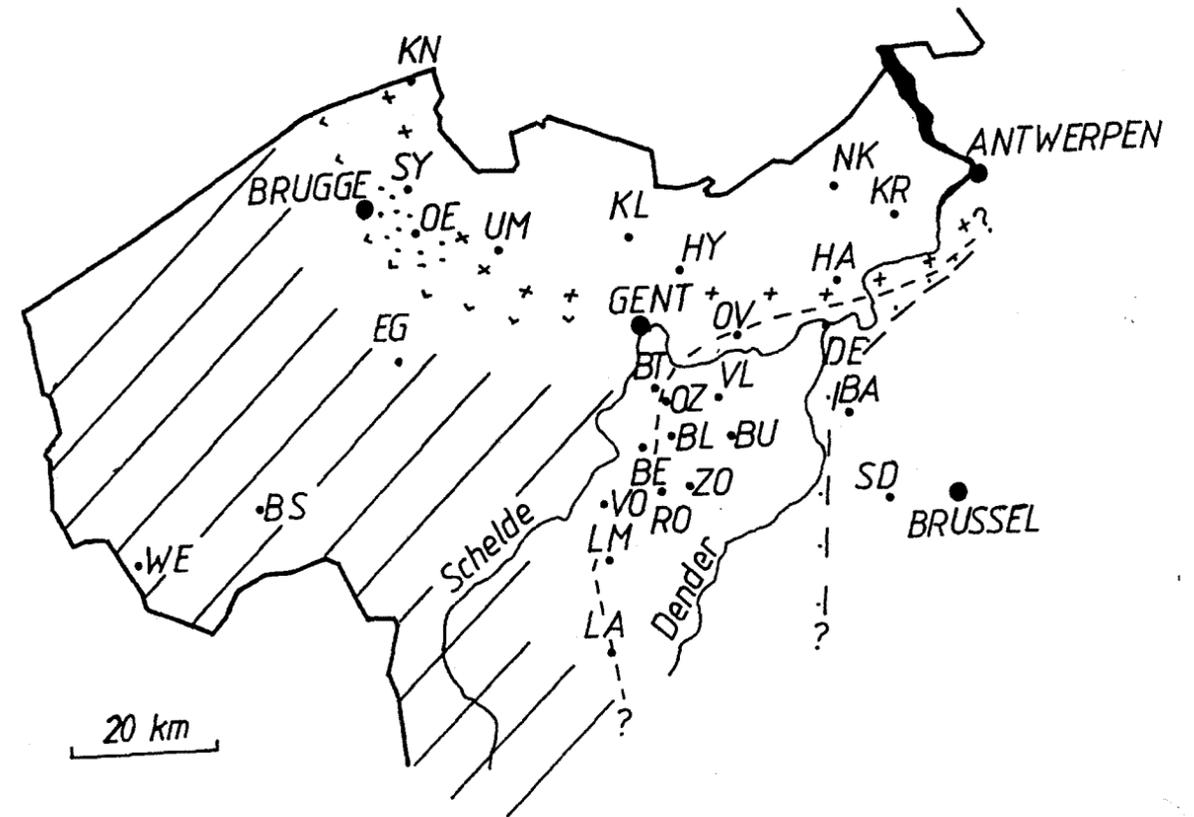
1. INTRODUCTION

The concepts of the lithostratigraphy in the Belgian Cenozoic were founded by Gulinck & Hacquaert (1954) and Kaasschieter (1961). In the deposits formerly known as Lower Paniselian (then Upper Ypresian), Gulinck & Hacquaert (1954) distinguished, in upward direction, the P1m clay, the P1c sandy clay and the P1d sand. Kaasschieter (1961) introduced the name Mont Panisel Formation, including the Roncq clay (P1m), the Anderlecht sandy clay (P1c) and the Vlierzele sand (P1d). According to Gulinck &

Hacquaert (1954) and Kaasschieter (1961), the Vlierzele sand grades downward into the Anderlecht clay, without a sharp limit (Gulinck & Hacquaert, 1954, p. 474 : «Les sables P1d» passent graduellement vers le bas à des sables argileux et des argiles sableuses... (P1c de la carte). «Kaasschieter, 1961, p. 24 : «.. the Upper part of the Anderlecht Member becomes more sandy, and there is a gradual transition into the Vlierzele sands. The limit between these two becomes artificial.» The lithostratigraphic context of the Vlierzele sands is shown in Table 1.

GULINCK & HACQUAERT (1954) Kaasschieter (1961)	Staubaut & Nolf (1986) (southern facies)	(northern facies)	GEOLOGICAL MAP (Jacobs <i>al.</i> , 1993b)	THIS STUDY
MONT PANISEL FORMATION	(missing)	VLIERZELE FORMATION	GENT FORMATION	VLIERZELE FORMATION
Vlierzele Member (P1d)		(unnamed sand)	Vlierzele Member	Drongengoed Member Beernem Member Oosterzele Member Lochristi Member Hijfte Member
Anderlecht Member (P1c)		Pittem Member	Pittem Member	GENT FORMATION Pittem Member
Roncq Member (P1m)	IEPER FORMATION (Merelbeke Mbr. missing)	IEPER FORMATION Merelbeke Member	Merelbeke Member	Merelbeke Member
Mons-en-Pévèle Member (Yd) Flanders Member (Yc)	Mont Panisel Mbr (ex-P1c) Aalbeke Member (ex-P1m) Mons-en-Pévèle Mbr (ex Yd) Orchies Mbr (ex-Yc)	Egem Member (ex-Yd) Kortemark Member (ex Yc p.p.) Unnamed and undifferentiated clay (ex Yc p.p.)	TIELT FORMATION	IEPER FORMATION
			Egem Member Kortemark Member Aalbeke Member Moen Member St. Maur Member Mt Héribu Member	Egem/Mont Panisel Mbrs Kortemark Member Aalbeke Member Mons-en-Pévèle Mbr Orchies Member Mt. Héribu Mbr.

Table 1. Historic overview of the lithostratigraphic context of the Vlierzele Formation.



BA	Baardegem	KL	Kluizen	RO	Roborst
BA	Balegem	KN	Knokke	SD	Schepdaal
BE	Bearlegem	KR	Kruibeke	SY	Sijsele
BS	Beselare	LA	Lahamaide	UM	Ursel-Maldegem
BT	Betsberg	LM	Louise-Marie	VL	Vlierzele
BU	Burst	NK	Nieuwkerke-Waas	VO	Volkegem
DE	Dendermonde	OE	Oedelem	WE	Westouter
EG	Egem	OV	Overmere	ZO	Zottegem
HA	Hamme	OZ	Oosterzele		
HI	Hijfte				

LEGEND

Southern limit of the Drongengoed Member	+++
Southern limit of the Beernem Member (by post-Eocene erosion)	vvv
Eastern limit of the Beernem Member (thinning out under the Lede Formation)	---
Eastern limit of the Vlierzele Formation (thinning out under the Lede Formation)	-.-
Area where the Vlierzele Formation is only preserved in small outciers	///
Type area of the Beernem Member	•••••

Figure 1. Location of the studied outcrops and boreholes. Limits of the Vlierzele Formation and the Beernem and Drongengoed Members.

In the most recent legend of the geological map (Maréchal & Laga, 1988, Jacobs *et al.*, 1993a and 1993b, Maréchal, 1993), the principles of the lithostratigraphic subdivision introduced by Gulinck & Hacquaert (1954) and Kaasschieter (1961) are still followed, although some names have changed. The Mont Panisel Formation is now named Gent Formation and includes the Merelbeke Member (former P1m), the Pittem Member (former P1c) and the Vlierzele Member (former P1d). The concept of a gradual transition between the Pittem and Vlierzele Members is also maintained. In the legend, the Vlierzele and Pittem Members are described as a complex of about 20 m thick, grading into each other without a distinct boundary. The thickness of each of them varies between 5 and 15 m, usually at the expense of the thickness of the other one. Between Gent and Brugge, the top of the Vlierzele Member is often rich in wood fragments. The occurrence of lignite in the Vlierzele sands was discovered by Hacquaert (1939) during the construction of a new canal between Brugge and Gent. This so-called Aalterbrugge Bed is explained as a result of an increasing continental influence at the end of the Ypresian cycle.

An alternative interpretation of the Ypresian lithostratigraphy in Belgium was published by Steurbaut & Nolf (1986), who defined the following formations :

- Ieper Formation (Orchies Clay Member, Mons-en-Pévèle Sand and Roubaix Clay Members, Aalbeke Clay Member, Kortemark Sand Member, Egem Sand Member and Merelbeke Clay Member). In southern direction, the Kortemark and Egem Members pass laterally into the Mont Panisel Sand Member.
- Vlierzele Formation (including the Vlierzele sand s.s., the former P1d, and the Pittem Clay Member as a basal sandy clay deposit).

The Vlierzele Formation as defined by Steurbaut & Nolf (1986), corresponds to the Pittem and Vlierzele

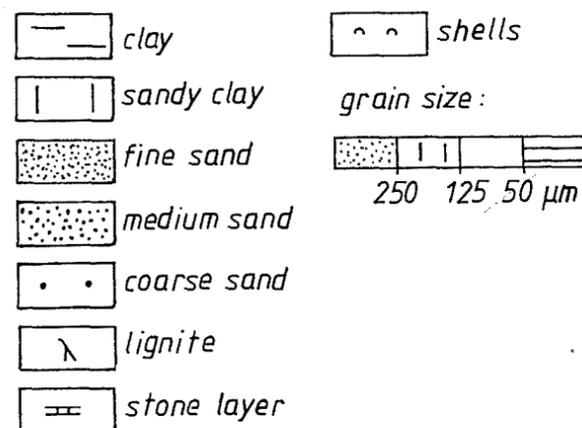


Figure 2. Lithology and grain size distribution legend of the Figures 3-10.

Members of the Gent Formation. The limit between the underlying Ieper Formation and the Vlierzele Formation was described as a major hiatus, encountered as a sharp limit at the base of the Pittem Member. This was shown by Steurbaut & Nolf (1986) in the Egem sandpit, where the Pittem Member directly covers the Egem Member by a sharp boundary, overlain by a basal shell bed (Steurbaut, 1993, has revised the importance of the boundary layer in the Egem sandpit).

Steurbaut & Nolf (1986) further emphasized that the sandy clays named Anderlecht clay (P1c) in their type locality, actually correspond to a lateral facies of the Egem Member of the Ieper Formation and not to the Pittem Member. Also the former Roncq Member in the south (now Aalbeke Member) and the Merelbeke Member in the north, which have been correlated, appear to be two different levels with similar lithology. The Mons-en-Pévèle Member, formerly thought to be the lateral facies of the Egem Member, was found to be a sandy intercalation appearing in the Flanders Member in the southern part of the basin (Figure 3 and Table 1).

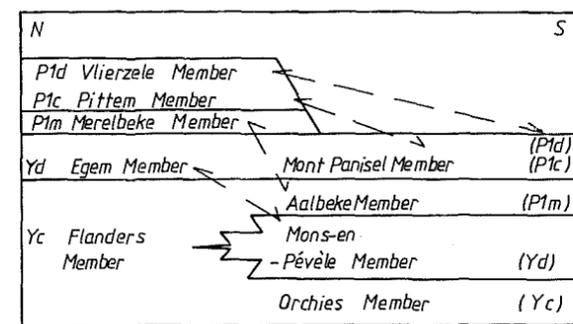


Figure 3. former correlations in the Belgian Ypresian (modified after Steurbaut & Nolf 1986). Arrows and quotes between brackets (right hand side) indicate former correlations.

Steurbaut & Nolf (1986) defined the Vlierzele Formation in the boreholes of Ursel-Maldegem in Northern Belgium. A remarkable feature in this borehole was the thickness of the Vlierzele sands : 24 m, compared to the average of 7 m in the outcrop area (De Breuck *et al.*, 1989).

The correlation between the sequences of the Vlierzele sands in subcrops and deeper borehole sections in northern Belgium and in the area between Gent and the North sea coast, and those in the outcropping (and type) area southeast of Gent has been a matter of discussion. Attempts were made to apply the stratigraphy from the outcrop area on borehole sections (e.g. De Breuck *et al.*, 1989), but sometimes it was concluded that the borehole profiles were more complicated than those in the outcrops (Vandenberghe

et al., 1990). As it was mentioned already, excessive thickness values (> 20 m) of the Vlierzele sands were reported (Mostaert, 1985, De Breuck *et al.*, 1989). After the discovery of deeply incised gullies, probably at the base of the Vlierzele sands, some 20 km off the Belgian coast by De Batist *et al.* (1989), some investigations were directed towards the recognition of similar onland features (Fobe, 1989 ; Houthuys, 1990). Houthuys (1990) mentioned that the Vlierzele sands in its type area seem to be enclosed by 2 clayey sand deposits, put forward the hypothesis that the Vlierzele sands in the outcrop area southeast of Gent, which contain wood fragments in the cross-sets, could be derived from erosion of the lignitic Aalterbrugge bed, occurring between Gent and Brugge. In this hypothesis, the Aalterbrugge facies belonged to the infilling of the gully system, while the Vlierzele sands s.s. were reworked from these gully infillings, while the gullies themselves were probably filled up with the Beernem Member.

Additional observations from new boreholes in northern Belgium (Fobe, 1993) indicated that the subcropping Vlierzele sands, are between 25 and 35 m thick

and consist of 3 main units : sand (with basal coarse sand) below, sandy clay in the middle and sand on top. Each of these units, which are further named Lower Sand Unit, Middle Sandy Clay Unit and Upper Sand Unit is about 10-12 m thick.

The base of the Vlierzele sands appears in the borehole sections as a sharp, coarse grained boundary, overlying the Pittem Member. The underlying Pittem Member in Northern Belgium is characterised by a lignitic top layer, marked by its brown or brown-gray colour. The borehole descriptions were correlated with the cored Ursel-Maldegem boreholes, from which detailed information on lithology, grain size and geophysical logs have been published (De Breuck *et al.*, 1989).

The present study attempts to detail the lithostratigraphy of the Vlierzele sands in Northern Belgium and to establish a correlation with the outcrop area. The sections in Northern Belgium are reviewed and compared to the outcrop areas near Brugge, southeast of Gent and east of the river Dender (see Figure 1 for location of the studied sites).

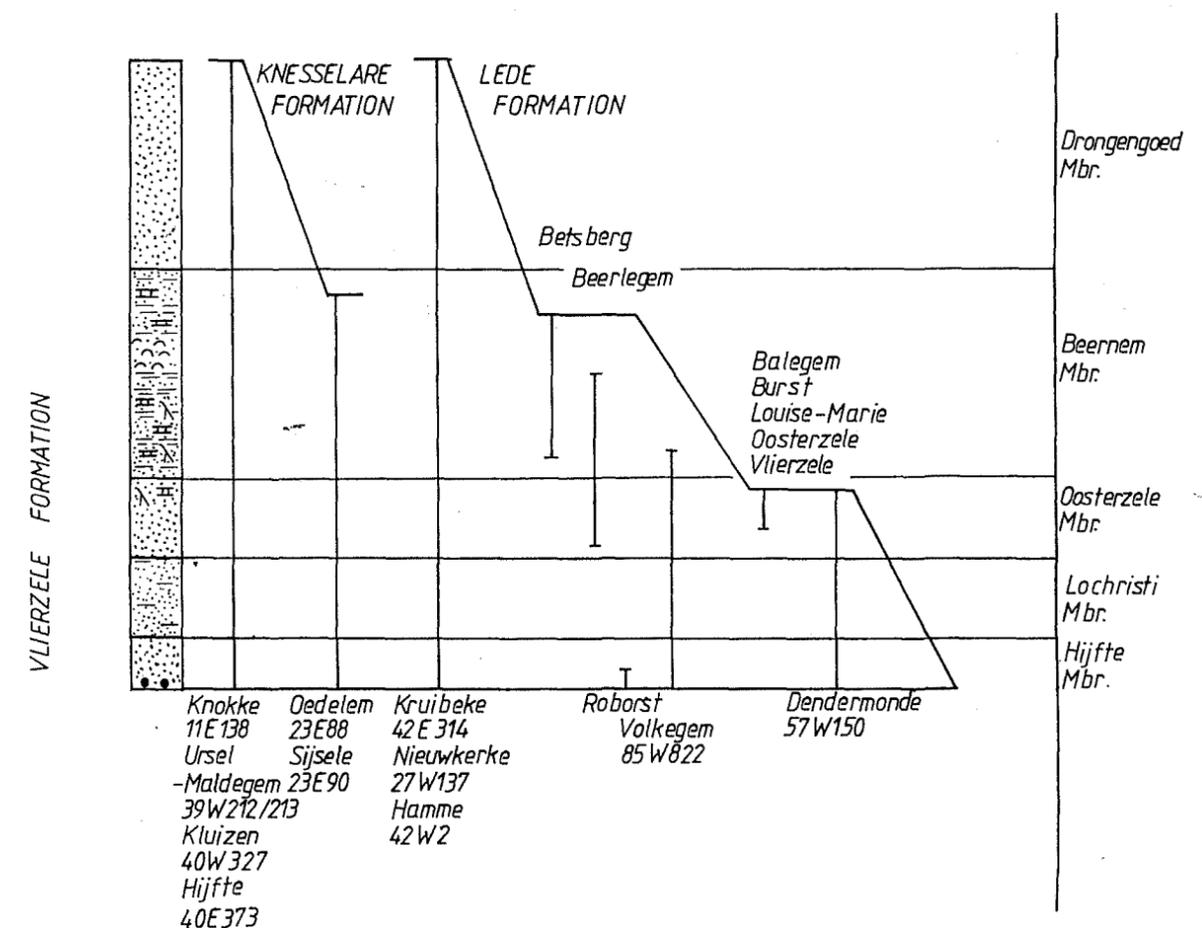


Figure 4. Stratigraphic position of the studied outcrop and borehole sections, correlated with a reference section (Ursel-Maldegem boreholes).

Annex 1 lists the studied outcrops and boreholes. A correlation table of the different observation points with the standard section of the Vlierzele Formation is shown in Figure 4.

2. STRATIGRAPHY OF THE VLIERZELE FORMATION IN DIFFERENT AREAS

2.1. THE VLIERZELE FORMATION IN NORTHERN BELGIUM

Review of the data published by De Breuck *et al.* (1989) showed that the tripartite composition of the Vlierzele sands, encountered in the Kluizen, Kruike and Nieuwkerke-Waas boreholes was clearly discernable in geophysical logs and in grain size distribution profiles of the Ursel-Maldegem boreholes : Lower Sand Unit (58 - 69.3 m), Middle Sandy Clay Unit (52 - 58 m) and Upper Sand Unit (43.7 - 52 m).

Within the Lower Sand Unit, a finer grained intercalation is encountered (63 - 66 m). A similar fine grained level was also observed in the Lower Sand Unit in the Knokke, Kluizen and Kruike boreholes (Figure 5). It was well developed in the Hijfte borehole (Figure 6), where it consists of sandy clay with thin clay seams.

Further apparent in the sections of the Vlierzele sands in northern Belgium are : the occurrence of several sandstone beds in the Middle Sandy Clay Unit (Knokke, Kluizen and Nieuwkerke-Waas boreholes), the occurrence of abundant shells in the same unit (Kluizen and Nieuwkerke-Waas boreholes) and the occurrence of lignite in the lower sand and the middle sandy clay (Ursel-Maldegem, Knokke, Kluizen).

It may be concluded that the Vlierzele Formation in northern Belgium contains five lithological units : sand with basal gravel, sandy clay, cross-stratified medium sand (all correlated with the Lower Sand Unit), sandy clay or clayey sand with sandstone beds (Middle Sandy Clay Unit), and on top again medium sand (Upper Sand Unit).

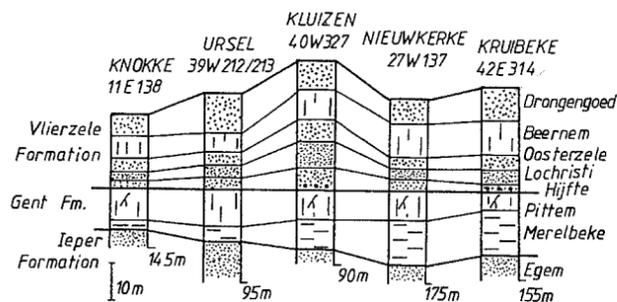


Figure 5. Lithostratigraphic correlation between boreholes in northern Belgium.

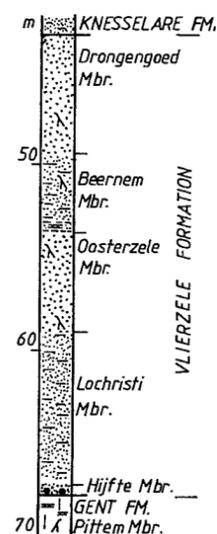


Figure 6. Section of the Hijfte 40E 373 borehole.

2.2. THE REGION SOUTH OF BRUGGE

In the neighbourhood of Brugge, the Vlierzele sands are encountered in outcrops and shallow boreholes. They are overlain by the Beernem Member, the oldest Member of the Kneselare Formation (Jacobs & Geets, 1977), consisting of sandy clay, often rich in sandstone beds. According to Jacobs & Geets (1977) and to Jacobs *al.*, (1993b), the Beernem Member is only found in the area south and southeast of Brugge (Figure 1, Table 2). The Beernem Member is ranked into the «Lutetian» Kneselare Formation, mainly because the underlying («Ypresian») Vlierzele sands are characterised by their lignitic Aalterbrugge facies, (interpreted as the result of an increased continental influence at the end of the Ypresian cycle). Compared to the nearby Ursel-Maldegem sections, the thickness of the Vlierzele sands is reduced from 27 to some 10-12 m where the Beernem Member is encountered (Fobe, 1989, Jacobs *al.*, 1993a).

During the present study, the Beernem Member facies was encountered in the Oedelem and Sijsele boreholes (Figure 10). The underlying, 10 m thick Vlierzele sands consist of a basal sand bed with gravel, a middle fine grained sand bed and an upper sand bed, often rich in lignite. The characteristics of the Vlierzele sands under the Beernem Member are comparable to the composition of the Lower Sand Unit from the Ursel-Maldegem section : (coarse) sand, clayey sand and sand with lignite). The lithology of the Beernem Member resembles the Middle Sandy Clay Unit of the Vlierzele Formation. The Upper Sand Unit is missing in this area. Thus the Beernem Member belongs to the Vlierzele Formation. The Upper Sand Unit is missing in this area. Thus the Beernem Member belongs to the Vlierzele Formation.

PROVENANCE AREA OF THE BEERNEM MEMBER	OUTSIDE PROVENANCE AREA OF BEERNEM MBR.	THIS STUDY (BOTH AREAS)	THIS STUDY AREA SE OF GENT	
KNESSELARE FORMATION Oedelem Member	KNESSELARE FORMATION Oedelem Member	KNESSELARE FORMATION Oedelem Member	LEDE FORMATION	LEDE FORMATION
Beernem Member	GENT FORMATION : Vlierzele Member	VLIERZELE FORMATION: Drongengoed Member	GENT FORMATION	VLIERZELE FM. (Drongengoed Member missing) WEST EAST
GENT FORMATION : Vlierzele Member (Aalterbrugge sands)	(undifferentiated)	Beernem Member	Vlierzele Member	Beernem Mbr.
Pittem Member Merelbeke Member	Pittem Member Merelbeke Member	Oosterzele Member		Oosterzele Mbr
		Lochristi Member		Volkegem Mbr
		Hijfte Member		Roborst Mbr
		GENT FORMATION : Pittem Member Merelbeke Member	Pittem Member Merelbeke Mbr.	Pittem Member Merelbeke Mbr

Table 2. Overview of the lithostratigraphic position of the Beernem Member.

Nieuwkerke-Waas and Kruike boreholes), it corresponds to the Middle Sandy Clay Unit and is overlain by the Upper Sand Unit which separates it from the Oedelem Member of the Kneselare Formation.

2.3. THE OUTCROP AREA SOUTHEAST OF GENT

The classic outcrops of the Vlierzele sands, where Kaasschieter (1961) defined the Vlierzele Member, are located in the area southeast of Gent, where they have been exposed in many sandpits and temporary outcrops. The exposed sands are mostly cross-stratified with thin clay laminae or show parallel laminations. Lignite lenses are often encountered in cross-sets.

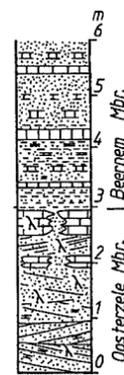


Figure 7. Section of the Beerlegem sandpit, showing the Oosterzele Member overlain by the Beernem Member.

Some outcrops in the area show a different looking facies, consisting of an alternation of sand (10 -20 cm thick) and clay beds (1-5 cm), often with sandstone beds in the sand layers. This facies may also be rich in lignite (Betsberg borehole). In the Beerlegem sandpit (Figure 7), this facies was found covering the cross-stratified facies. Both the cross-stratified (Balegem, Burst, Oosterzele, Vlierzele) and the horizontally structured facies (Betsberg) were overlain in their respective outcrops by the Lede Formation.

The base of the sandpit sections often corresponds to an increase in clay, the transition towards the Pittem Member according to the legend of the geological map. However, in the Roborst pit (Figure 8), the base of the Vlierzele sands consists of sand with a coarse grained base and with a sharp lower limit.

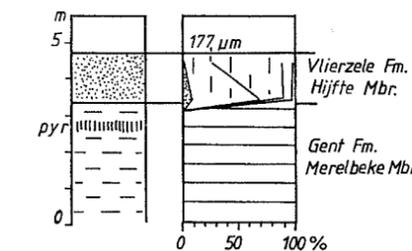


Figure 8. Section of the Roborst claypit with grain size distribution.

The Volkegem borehole (Figure 9) was drilled close to a sandpit exposing the cross-stratified facies. In the borehole, this facies was underlain by finer grained and more clayey sand. The lowermost meter of the sands consists again of coarser grained sand, covering the Mont Panisel Member of the Ieper Formation.

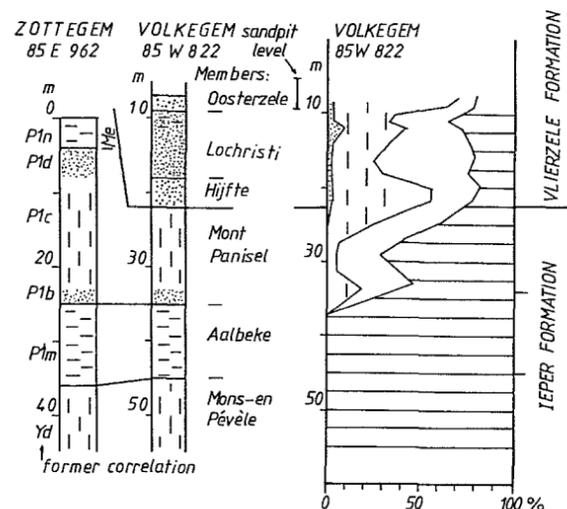


Figure 9. Compared stratigraphy of the Zottegem and Volkegem boreholes with grain size distribution of the latter.

The sequence of the Vlierzele Formation in the outcrop area consists in upward direction of: a basal sand (1-2 m), clayey sand, cross-stratified glauconitic sand (the facies exposed in many sandpits, e.g. Balegem, Vlierzele, Burst, Oosterzele, Volkegem) and the sand-sandstone-clay facies. The following correlation with the Ursel-Maldegem and Hijfte sections is proposed (Figure 11):

- the sequence between the lower limit of the formation and the top of the cross-stratified sand corresponds to the Lower Sand Unit. The fine grained intercalation in the middle of this level correlates with the clayey sand below the cross-stratified facies.

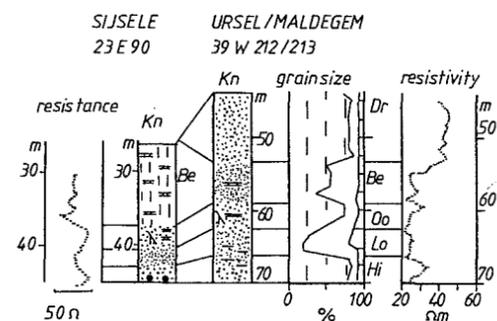


Figure 10. Correlation of the Ursel-Maldegem boreholes (complete sections of the Vlierzele Formation) with the Sijsele borehole in the area SW of Brugge (Drongengoed Member missing). The stratigraphic interpretation is supported by geophysical logs and grain size distribution.

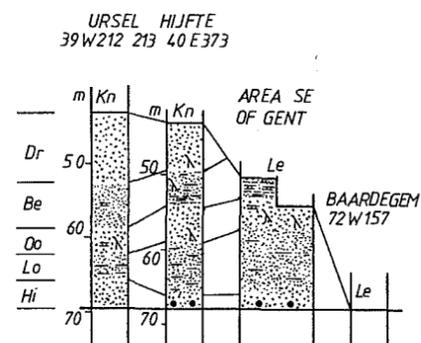


Figure 11. Characteristics of the Vlierzele Formation in the Ursel-Maldegem type section, as revealed by lithology, grain size distribution and resistivity logs (De Breuck *et al.*, 1989) correlated with the Hijfte borehole and with the outcropping area SE of Gent and with the area east of the Dender (Baardegem borehole), indicating a gradual thinning out under the Lede Formation.

- the sand-sandstone-clay facies locally covering the cross-stratified facies is correlated with the Middle Sandy Clay Unit in the Vlierzele Formation in northern Belgium and thus with the Beernem Member.

- the Upper Sand Unit from the borehole sections in Northern Belgium appears to be absent in the outcrop area.

Consequently, the «Vlierzele sands s.s.» from their classical type area only represent a part (the third lithological unit of five) of the complete Vlierzele Formation in boreholes in northern Belgium.

In the Zottegem borehole (Figure 9), a succession of the Mons-en-Pèvele Member (ex-Yd), Aalbeke Member (ex-P1m), sandy base of the Mont Panisel Member (P1b), Mont Panisel Member (ex-P1c, now Yd), sandy top of the Mont Panisel Member (considered as P1d?) and Merelbeke Member (ex-P1n, now P1m) is encountered. Indeed, as the Merelbeke Member occurs in the southern facies belt (sensu Steurbaut & Nolf 1986) (as is shown by the borehole of Zottegem and the outcrop of Roborst) where the Roubaix Member is present and where the notation P1m had been erroneously given to the Aalbeke Member, it is likely that the P1n clay defined by Rutot (1890) clay corresponds to the Merelbeke clay.

The sandy top of the Mont Panisel Member is about 4 m thick and covers some 15 m of sandy clay. Apparently, this sequence was formerly correlated with the P1c-P1d sequence. It should be noticed that the «P1c» sandy clay is much thicker (15 m) than the overlying «P1d» sand (4 m). In the northern Belgium sections, the Vlierzele sands (20 m) are thicker than the Pittem Member (7-10 m). The traditional description of the Vlierzele/Pittem boundary and the thickness variations attributed to both members may thus have been derived from erroneous correlations.

Apparently, also the joint occurrence of the Aalbeke and Merelbeke clays, together with the lithology of the Mont Panisel Member, contributed largely to the correlation problems in the former Ypresian s.s. and Lower Paniselian. The «P1n-clay», described as the «local top clay» of the Vlierzele sands (Gulinck & Hacquaert 1954) in fact corresponds to the Merelbeke Member, covering sands on top of the Mont Panisel Member sensu Steurbaut & Nolf (1986).

2.4. OUTCROP AREA EAST OF THE RIVER DENDER

The Vlierzele sands thin out in eastern direction. Steurbaut & Nolf (1986) and Houthuys (1990) already mentioned the absence of the Vlierzele Formation in the area west of Brussel. East of the river Dender, they seem to have disappeared (in the Baardegem and Schepdaal boreholes), as the Lede Formation immediately covers older Formations (Figure 11). Former observations of the P1d sands in this area were probably confused with the upper sandy part of the Mont Panisel Member (sensu Steurbaut & Nolf 1986), which was erroneously correlated with the P1c clay.

Between the Dender and Brussels, a clay bed indicated as the «P1n clay» was described as overlaying the P1d sand (Rutot, 1890). However, the Vlierzele sand appears to be missing in that area. As it was concluded above, the P1n clay corresponds with the Merelbeke Member.

3. LITHOSTRATIGRAPHY

The name «Vlierzele sands» has been applied to 3 distinct sand levels, belonging to a complex of sand, separated by sandy clay layers. This complex was found to be laterally continuous and, in contrast to the existing opinion, enclosed by sharp boundaries. It is therefore proposed to define this complex as a separate formation, the Vlierzele Formation, to be subdivided into 5 Members, from the base to the top: the Hijfte Member, the Lochristi Member, the Oosterzele Member, the Beernem Member and the Drongengoed Member. The name Vlierzele Formation was introduced by Steurbaut & Nolf (1986).

In the lithostratigraphic legend of the geological map (Maréchal & Laga 1988; Jacobs *et al.*, 1993a and 1993b; Maréchal, 1993), the Vlierzele sands are grouped into the Gent Formation, together with the Merelbeke and Pittem Members. Steurbaut & Nolf (1986) included the Pittem Member into the Vlierzele Formation and the Merelbeke Member into the Ieper Formation. It is proposed to group the Merelbeke and

Pittem Members into a new formation, (Gent Formation). Like this, the dominantly clayey Merelbeke and Pittem Members are gathered in a separate formation, different from the underlying (Egem sands) and overlying (Vlierzele Formation) sandy deposits. This solution provides an easier tool for lithostratigraphic mapping and also for hydrogeological schematisation, and matches better the philosophy of the lithostratigraphic geological map (aiming to group sets of similar lithology, rather than of similar age) (Jacobs, 1993a) than does the original composition of the Gent Formation.

3.1. GENT FORMATION

The name Gent Formation was introduced as a new name for the Mont Panisel Formation (Kaasschieter, 1961) and includes the Merelbeke, Pittem and Vlierzele Members. According to the new definition, it is restricted to the Merelbeke and Pittem Members.

Lectostratotype: Ursel, borehole BGS 39 W 212 (x=87.910, y=204.260, h=+29 m): 69.3-83.7 m.

Parastratotype: Knokke, borehole BGS 11 E 138 (x=78.776, y=226.370, h=+5 m): 124-135 m.

3.2. VLIERZELE FORMATION

The Vlierzele Formation corresponds to the Vlierzele Member of the Gent Formation (in northern Belgium) and includes the Beernem Member, formerly ranked into the Knesselare Formation and to the Vlierzele Formation without the Pittem Member (Steurbaud & Nolf, 1986). The Vlierzele Member of the Gent Formation as it is exposed in the type area SE of Gent only corresponds to a part of the Vlierzele Formation. The Vlierzele Formation is subdivided into 5 Members: the Hijfte Member at the base, the Lochristi Member, the Oosterzele Member, the Beernem Member and the Drongengoed Member on top.

The Vlierzele Formation is encountered in the area of western Belgium, west of a line formed more or less by the line Antwerpen-Dendermonde and further southward following more or less the river Dender. Today's southernmost observation points are found in isolated outcrops in Lahamaide, Beselare and Westouter. The original southern limit is unknown. The extension of the Vlierzele Formation and its members is given on Figure 1.

Stratotype of the Vlierzele Formation

Holostratotype: Ursel, borehole BGS 39 W 212 (x=87.910, y=204.260, h=+29 m): 43.7-69.3 m.

Parastratotype: Hijfte borehole, BGS 40 E 373 (x=111.130, y=200.390, h=+8m); 43 - 67.8 m.

3.2.1. The Hijfte Member

Name: the hamlet of Hijfte (municipality of Lochristi).

Rank: new member

Holostratotype: Hijfte borehole, BGS 40 E 373 (x=111.130, y=200.390, h=+8m); 67.5 - 67.8 m.

Parastratotype: Ursel, borehole BGS 39 W 212 (x=87.910, y=204.260, h=+29 m): 66-69.3 m.

Lithology: The Hijfte Member consists of medium or coarse glauconitic sand, with coarse sand or fine gravel at the base. In the Hijfte borehole, a real basal gravel (clay fragments, 1-2 cm across) was encountered.

Underlying unit: The Merelbeke or Pittem Members of the Gent Formation. Where the Vlierzele Formation is ravinating, the Mont Panisel Member (sensu Steurbaut & Nolf 1986) of the Ieper Formation. Sharp lower limit.

Overlying unit: the Lochristi Member of the Vlierzele Formation.

Thickness: between 2 and 5 m.

Former correlations: part of the Vlierzele Formation sensu Steurbaut & Nolf (1986). Included into the P1d sand sensu Gulinck & Hacquaert (1954) and the Vlierzele Member sensu Kaasschieter (1961), Maréchal & Laga (1988) and Jacobs *et al.*, (1993a and 1993b), but also into the P1c sandy clay sensu Gulinck & Hacquaert (1954) or the Pittem Member sensu Jacobs *et al.*, (1993a and 1993b), together with the overlying Lochristi Member (e.g. the Hijfte borehole). Lower part of the Lower Sand Unit of the Vlierzele Formation (Fobe, 1993).

Distribution: the same as the Vlierzele Formation

3.2.2. The Lochristi Member

Name: the municipality of Lochristi.

Rank: new member.

Holostratotype: Hijfte borehole, BGS 40 E 373 (x=111.130, y=200.390, h=+8m); 59.0-67.5 m.

Parastratotype: Ursel, borehole BGS 39 W 212 (x=87.910, y=204.260, h=+29 m): 63-66 m.

Lithology: The Lochristi Member consists of very fine clayey sand with thin (several mm) clay layers, disturbed by bioturbation.

Underlying unit: Hijfte Member of the Vlierzele Formation.

Overlying unit: the Oosterzele Member of the Vlierzele Formation.

Thickness: between 3 and 10 m.

Former correlations: part of the Vlierzele Formation sensu Steurbaut & Nolf (1986). Often included in the P1d sand sensu Gulinck & Hacquaert (1954) and the Vlierzele Member sensu Kaasschieter (1961), Maréchal & Laga (1988) and Jacobs *et al.* (1993a and

1993b) but also in the P1c sandy clay sensu Gulinck & Hacquaert (1954) or into the Pittem Member sensu Jacobs *et al.* (1993a and 1993b) (e.g. the Hijfte borehole). Its existence was ignored, probably because the Lochristi Member is rarely exposed and the underlying Hijfte Member is rather thin. Middle part of the Lower Sand Unit of the Vlierzele Formation (Fobe, 1993).

Distribution: the same as the Vlierzele Formation.

3.2.3. The Oosterzele Member

Name: the municipality of Oosterzele, where the unit has been exposed in many sandpits and road cuts.

Rank: new member

Holostratotype: Balegem sandpit (x = 110.8, y = 179.1; z = +66 m).

Parastratotype 1: Hijfte borehole, BGS 40 E 373 (x=111.130, y=200.390, h=+8m); 53.4-59.0 m.

Parastratotype 2: Ursel, borehole BGS 39 W 212 (x=87.910, y=204.260, h=+29 m): 58-63 m.

Lithology: The Lochristi Member consists of fine to medium glauconitic sand, cross-stratified or laminated. Lignite, locally abundant, and small stone concretions are encountered.

Underlying unit: Lochristi Member of the Vlierzele Formation.

Overlying unit: the Beernem Member of the Vlierzele Formation in a complete sequence of the latter. Overlain by the Lede Formation in the type area and east of it.

Thickness: about 7 m.

Former correlations: the Oosterzele Member corresponds to the Vlierzele sands s.s.. The Oosterzele Member is exposed in a number of sandpits in the outcrop area southeast of Gent. The Vlierzele Member was defined in such a section by Kaasschieter (1961). Elsewhere, the Oosterzele Member is part of the Vlierzele Formation sensu Steurbaut & Nolf (1986). Implicit part of the P1d sand sensu Gulinck & Hacquaert (1954) and to the Vlierzele Member sensu Kaasschieter (1961), Maréchal & Laga (1988) and Jacobs *et al.* (1993a and 1993b). It was named Aalterbrugge facies when considerable amounts of lignite were present. Upper part of the Lower Sand Unit of the Vlierzele Formation (Fobe, 1993).

Distribution: the same as the Vlierzele Formation.

3.2.4. The Beernem Member

Name: the municipality of Beernem.

Rank: existing Member, defined by Jacobs & Geets (1977), who ranked as the lower part of the Knesselare Formation.

Lectostratotype: sandpit at Beerlegem (x=104.5, y = 178.05, alt; = +56 m).

Parastratotype 1: Hijfte borehole, BGS 40 E 373 (x=111.130, y=200.390, h=+8m); 49.8-53.4 m.

Parastratotype 2: Ursel, borehole BGS 39 W 212 (x=87.910, y=204.260, h=+29 m): 52-58 m.

Lithology: glauconitic sandy clay or clayey sand or an alternation of fine sand and clay layers. The Beernem Member contains sandstone layers (often abundant) and is locally very rich in mollusc shells. Lignite may occur.

Underlying unit: Oosterzele Member of the Vlierzele Formation.

Overlying unit: the Drongengoed Member of the Vlierzele Formation in a complete sequence of the latter. Overlain by the Lede or Knesselare Formations in the outcrop area.

Thickness: about 7 m.

Former correlations: part of the Vlierzele Formation sensu Steurbaut & Nolf (1986). Ranked in the Vlierzele Member sensu Kaasschieter (1961), Maréchal & Laga (1988) and Jacobs *et al.*, (1993a and 1993b) in the outcrop area. Corresponds to the Beernem Member of the Knesselare Formation in the region south of Brugge (Jacobs & Geets, 1977; Jacobs *et al.*, 1993b). However, the lateral distribution of this member is more widespread than originally assessed, and in a complete section of the Vlierzele Member, it is separated from the base of the Knesselare Formation by the Drongengoed Member of the Vlierzele Formation. Middle Sandy Clay Unit of the Vlierzele Formation (Fobe, 1993).

Distribution: northern Belgium, the region between Brugge and Gent and the western part of the outcrop area southeast of Gent.

3.2.5. The Drongengoed Member.

Name: the Drongengoed forest and estate (near the village of Ursel, municipality of Knesselare).

Rank: new member.

Holostratotype: Ursel, borehole BGS 39 W 212 (x=87.910, y=204.260, h=+29 m); 43.7-52 m.

Parastratotype 1: Knokke, borehole BGS 11 E 138 (x=78.776, y=226.370, h=+5 m): 104-110 m.

Parastratotype 2: Hijfte, borehole BGS 40 E 373 (x=111.130, y=200.390, h=+8m): 43 - 49.8 m.

Lithology: glauconitic medium to fine sand, locally with some sandstone beds.

Underlying unit: Beernem Member of the Vlierzele Formation.

Overlying unit: the Knesselare, Lede or Maldegem Formations.

Thickness: about 7 m.

Former correlations: part of the Vlierzele Formation sensu Steurbaut & Nolf (1986) and implicit part of the P1d sand sensu Gulinck & Hacquaert (1954) and the Vlierzele Member sensu Kaasschieter (1961), Maréchal & Laga (1988) and Jacobs *et al.*, (1993a and 1993b) in borehole descriptions in Northern Belgium. Upper Sand Unit of the Vlierzele Formation (Fobe, 1993).

Distribution: northern Belgium, its southern limit passing approximately north of Dendermonde, Gent and Brugge. Unknown in the outcrop area with exception of the Westouter area.

4. CONCLUSIONS

The redefined Vlierzele Formation consists of 5 units: the Hijfte Member (coarse sand), the Lochristi Member (clayey sand), the Oosterzele Member (sand), the Beernem Member (sandy clay, sand with clay layers, sandstone beds, shells) and on top the Drongengoed Member (sand).

The Vlierzele Formation is only complete in boreholes in northern Belgium. The Drongengoed Member is missing in the outcrop area except for the hills near Westouter (Figure 10).

Therefore, a type section in Northern Belgium is preferred over a section in the outcrop area. The cored Ursel-Maldegem wells are proposed as type section (Figures 3, 8 and 9).

The original type section of the «Vlierzele sands» (Kaasschieter, 1961) and many other sandpits in the outcrop area southeast of Gent only expose the Oosterzele Member.

The limit between the «Vlierzele sands» and the Pittem clay is not a gradual transition but a sharp contact at the base of the Hijfte Member. The Lochristi Member corresponds to the clayey sediments underlying the sands of the Oosterzele Member which are exposed in many sandpits, and is often confused with the Pittem Member. The concept of a gradual passage originated from a correlation error with the transition of the sandy clay of the Mont Panisel Member (formerly correlated with the Pittem Member) into glauconitic sands on top of this member. Similar correlation errors gave way to the concept of the Pittem and Vlierzele Members forming one complex with inter-nal thickness variations.

The Beernem member of the Knesselare Formation (sensu Jacobs & Geets, 1977) is actually part of the Vlierzele Formation. In or close to the outcrop area near Brugge, where the Drongengoed member is missing, the lignitic Aalterbrugge Bed (the Oosterzele Member, locally rich in wood fragments) was given the status of terminal deposit of the Ypresian. The Beernem Member is also encountered around Brugge, where it was described by Jacobs & Geets (1977) and in borehole sections in northern Belgium. Formerly unit was an (unidentified) part of the (undifferentiated) «Vlierzele Member» in these boreholes.

The Aalterbrugge Bed does not exist as a separate facies. Lignite is encountered in various amounts throughout the Vlierzele Formation, mainly in the Oosterzele, Beernem and Drongengoed Members. The name «Aalterbrugge Bed» or «Aalterbrugge Complex» was applied when one of these members locally contains higher amounts of lignite.

Together with a definition of the Vlierzele Formation, a new definition of the Gent Formation is proposed. The Gent Formation only consists of the Merelbeke and Pittem Members.

The traditional assumption, founded by Gulinck & Hacquaert (1954) and Kaasschieter (1961), that there

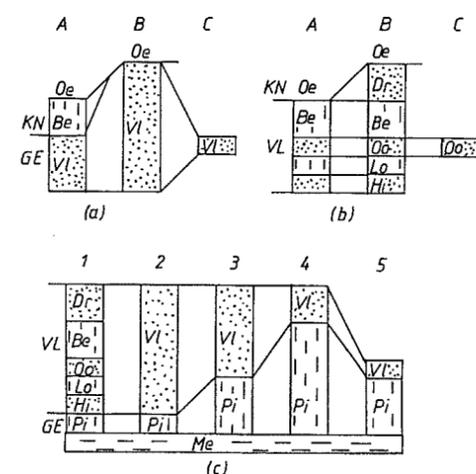


Figure 12. (a) former correlations of the undifferentiated Vlierzele Member (VI) and the Beernem Member in the area of Brugge (A), in boreholes in northern Belgium (B) and in sandpits southeast of Gent (C). The Beernem Member was ranked into the Knesselare Formation (KN), together with the Oedelem Member (Oe). These correlations yielded considerable thickness variations of the Vlierzele Member.

(b) correlation in this study: the Beernem Member (Be) in type section A and the sands (Oosterzele Member, Oo) exposed in type section C are correlated with subdivisions identified in the Vlierzele Formation (VL) in northern Belgium (section B).

(c) other correlations, entailing possible thickness variations of the Vlierzele (VI) and Pittem (Pi) Members, using the Merelbeke Member (Me) as reference horizon.

1: type section of the Vlierzele (VL) and Gent (GE) Formations as described in this study.

2: former interpretation of boreholes in Northern Belgium (e.g. Ursel-Maldegem) reaching at least the Merelbeke Member. The latter is overlain by the Pittem (Pi) and (VI) Vlierzele Members.

3: in some boreholes (e.g. Hijfte), the limit between the Vlierzele and Pittem Members was defined at the limit between the Oosterzele (Oo) and Lochristi (Lo) Members of section 1.

4: another possible limit between the Vlierzele and Pittem was between the Drongengoed (Dr) and Beernem (Be) Members of section 1.

5: outcrop sections southeast of Gent, where the upper members of the Vlierzele Formation are missing.

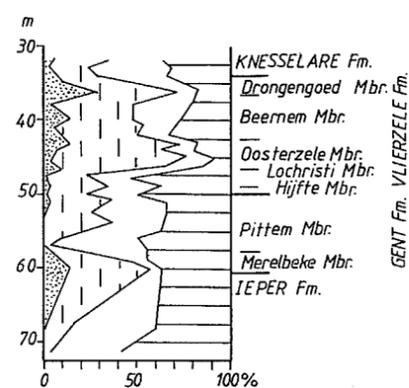


Figure 13. Grain size distribution and lithostratigraphy of the Westouter 95W 150 borehole.

is just one P1d or Vlierzele sand, overlying only one P1c or Pittem clay, leads to incorrect interpretations of borehole sections and to erroneous correlations and thickness estimations of the Pittem clay and the Vlierzele sands between boreholes and outcrops (Figure 12).

5. ACKNOWLEDGEMENT

The author wants to thank the Belgian Geological Survey and the Afdeling Natuurlijke Rijkdommen en Energie for access to borehole samples.

6. REFERENCES

DE BATIST, M., DE BRUYNE, H., HENRIET, J. & MOSTAERT F., 1989. Stratigraphic analysis of the Ypresian off the Belgian coast. In Henriet, J. & De Moor, G. (Eds), The Tertiary and Quaternary of the Southern Bight, North Sea. *Belgian Geological Survey*, 75-88.

DE BREUCK, W., FOBE, B., LEBBE, L., STEURBAUT, E., VAN DYCK, E. & WALRAEVENS, K., 1989. De boringen van Ursel en Maldegem. Bijdrage tot de kennis van het Eoceen in Noordwest-België. *Belgian Geological Survey, Professional Paper*, 236: 98 p.

FOBE, B., 1989. Some recent borings in the Ypresian and Lower Lutetian of northwestern Belgium. *Belgian Geological Survey, Professional Paper*, 240: 12 p.

FOBE, B., 1993. Ypresian lithostratigraphy in Northern Belgium. *Bulletin Belgische Vereniging voor Geologie*, 102: 254-257.

GULINCK, M. & HACQUAERT, A., 1954. L'Eocène. In *Prodrome d'une description géologique de la Belgique*. 451-493.

HACQUAERT, A., 1939. De overgang van Ieperiaan tot Lutetiaan the Aalter (Kanaal). *Natuurwetenschappelijk Tijdschrift*, 21: 323.

HALET, F., 1907. Le puits artésien de l'amidonnerie de Hamme lez Saint-Nicolas. *Bulletin Société belge de Géologie*, 21: 517-529.

HOUTHUYS, R., 1990. Vergelijkende studie van de afzettingsstructuur van getijdenezanden uit het Eoceen en van de huidige Vlaamse Banken. *Aardkundige Mededelingen*, 5: 137 p.

HOUTHUYS, R. & GULLENTOPS, F., 1988. The Vlierzele sands (Eocene, Belgium); a tidal ridge system. In De Boer, P. (Ed.): Tidal influenced sedimentary environments and facies. *Reidel Publ. Cy.*, 139-152.

JACOBS, P., DE CEUKELAIRE, M., SEVENS E. & VERSCHUREN, M., 1993a. Philosophy and methodology of the new geological map of the Tertiary formations, Northwest Flanders, Belgium. *Bulletin Belgische Vereniging voor Geologie*, 102: 231-241.

JACOBS, P., Maréchal, M., DE CEUCKELAIRE, M. & SEVENS, E., 1993b. Geologische Kaart op 1/50.000 Kaartblad 13 (Brugge). *Bestuur Natuurlijke Rijkdommen en Energie, Belgische Geologische Dienst*, 38 p.

KAASSCHIETER, J., 1961. Foraminifera of the Eocene in Belgium. *Verh. Kon. Belg. Inst. Natuurwet.*, 147: 271 p.

MARECHAL, R., 1993. A new lithostratigraphic scale for the Palaeogene of Belgium. *Bulletin Belgische Vereniging voor Geologie*, 102: 215-229.

MARECHAL, R. & LAGA, P., (Eds.), 1988. Voorstel lithostratigrafische indeling van het Paleoceen. Nationale Commissies voor Stratigrafie, Commissie: Tertiair. *Belgische Geologische Dienst*, 208 p.

MOSTAERT, F., 1985. Bijdrage tot de kennis van de Kwartairgeologie van de oostelijke kustvlakte op basis van sedimentologisch en lithostratigrafisch onderzoek. Unpubl. Ph. D. Thesis, State University of Ghent, 588 p.

RUTOT, A., 1890. Constitution géologique des collines d'Hekelgem et d'Esschene entre Assche et Alost. *Bulletin Société belge Géologie*, 4: 33-58.

STEURBAUT, E. & NOLF, D., 1986. Revision of Ypresian stratigraphy of Belgium and Northwestern France. *Med. Werkgr. Tert. Kwart. Geol.*, 23: 115-172.

STEURBAUT, E., 1988. Ypresian calcareous nannoplankton biostratigraphy and palaeogeography of the Belgian Basin. In Dupuis, C., Deconinck, J. & Steurbaut, E. (Eds): The Ypresian stratotype. *Bulletin Belgische Vereniging voor Geologie*, 97: 251-285.

STEURBAUT, E. & KING, C., 1993. Integrated stratigraphy of the Mont-Panisel borehole section (151 E 340), Ypresian (Early Eocene) of the Mons Basin, SW Belgium. *Bulletin Belgische Vereniging voor Geologie*, 102: 175-202.

VANDENBERGHE, N., LAGA, P., VANDORMAEL, C. & ELEWAUT, E., 1988. The geophysical log correlations in the Ieper clay section in Belgium. In Dupuis, C., Deconinck, J. & Steurbaut, E. (Eds): The Ypresian stratotype. *Bulletin Belgische Vereniging voor Geologie*, 97: 374-441.

VANDENBERGHE, N., LAGA, P., HERMAN, J. & BACCAERT, J., 1990. Lithological description of the Knokke well. *Toel. Verh. Geologische en Mijnkaarten van België, Belgian Geological Survey*, 29: 9-11.

Manuscript received on 25.01.1995 and accepted for publication on 5.09.1995.

ANNEX I. LIST OF OUTCROPS AND BORE-HOLES

2.1. *Baardegem*: borehole BGS 72 W 157 (x=134.200, y=182.820, h=+45 m) : Zelzate Formation 0-9 m ; Maldegem Formation : 9-16 m ; Lede Formation 16-23 m ; Ieper Formation : 23-49 m (glauconitic clayey sand 23-28 m, grey heavy clay 28-34 m, silty clay with glauconite 34-38 m, grey heavy clay 38-41 m (Aalbeke Member) and glauconitic very fine sand and sandy clay with stone layers 41-49 m). The Vlierzele Formation was missing in the sequence of this borehole (Figure 11).

2.2. *Balegem*: Sandpit (x = 110.8, y = 179.1; z = +66 m), exposing the top of the Vlierzele Formation (2 m), overlain by the Lede Formation (5.5 m) and the base of the Maldegem Formation (3 m). The Vlierzele Formation consists of cross-stratified sands. The cross sets often contain wood fragments.
Stratigraphy : Oosterzele Member.

2.3. *Beerlegem*: In the sandpit of Beerlegem (x=104.5, y = 178.05, alt; = +56 m) two facies were exposed (Figure 7). The lower 6 m consists of about 6 m of cross-stratified glauconitic sand with very thin clay beds. In the upper 3 m of this unit, sandstone was encountered. The lower levels were very brittle, not arranged as beds and laying parallel with the cross-beds. They contain small wood fragments. In the uppermost metre, two levels of more consistent sandstone blocks (40 cm thick), with many (often silicified) wood fragments, were exposed.

The upper unit was about 3 m thick. It showed a sub-horizontal alternation of clay and sand layers. Often, sand and clay layers were only 5 cm thick. In thicker sand intercalations (at least 10 cm), very hard and compact sandstone beds (up to 20 cm thick) often occurred. A number of 11 sandstone beds was counted, with a cumulative thickness of about 1.2 m. Sand intercalations often show subhorizontal laminations.
Stratigraphy : Oosterzele member (cross-stratified unit) overlain by the Beernem Member.

2.4. *Beselare, Nonnebossen*: (x=51.925, y=171.775, h=+60 m): temporary outcrop near the A19 motorway (september 1989). Under a cover of Pleistocene coarse sand and gravel (2-3 m), glauconitic medium sand (1 m), the Vlierzele Formation, was exposed. Probably the Oosterzele Member.

2.5. *Brugge*: In a temporary outcrop (early 1986) for the construction of a sewage collector along the Kerkebeek, south of the town of Brugge (x = 68.20, y = 207.55, h = +5 m). At the base of the excavation, 10 cm of grey glauconitic sand was encountered, overlain by 50 cm of grey clay with wood fragments. Above the clay, about 2 m of glauconitic sands with

lignite were exposed, containing small sandstone concretions. The facies resembled the Aalterbrugge sands. According to the geological map sheet Brugge (Jacobs *et al.*, 1993), this outcrop is located close to the Vlierzele-Beernem limit.

Stratigraphy : Lochristi Member (clay) overlain by the Oosterzele Member.

2.6. *Burst*: Sandpit (x = 117.55; y = 178.45; z = +61 m), exposing cross-stratified glauconitic sands (Vlierzele Formation), overlain by the Lede Formation.

Stratigraphy : Oosterzele Member

2.7. *Dendermonde*: borehole (BGS 57 W 150); x=130.860, y= 190.400, h= +5 m). This borehole started in Pleistocene sands (0-13 m), overlying the Lede Formation (13-16 m). The Vlierzele Formation occurs between 16 and 27.5 m. Sandy clay (Pittem Member) and clay (Merelbeke Member) were found between 27.5 and 33 m and very fine glauconitic sand between 33 and 47 m (Egem Member).

Stratigraphy : Oosterzele, Volkegem and Hijfte Members.

2.8. *Egem*: sand- and claypit Ampe (x=70.275, y=189.575, h=+46 m). In this outcrop, the Egem Member (20 m of sand with thin clay layers) is overlain by the Pittem Member (5 m, sandy clay with sandstone beds). The base of the latter consists of a 60-cm thick sandstone, coarse grained at its base and containing reworked macrofossils from the Egem Member (e.g. *Nummulites planulatus*).

2.9. *Hamme*: borehole (BGS 42 W 2); x= 133.250, y=198.880, h= +5 m). The borehole was drilled early this century (Halet, 1907). The base of the Lede Formation occurs at 54 m. Between 54 and 75 m, a sequence of sand (54-56 m), sandy clay with shells (56-66 m) and sand (66-75 m) was correlated with the P1d (Vlierzele sands), but the possible presence of the Knesselare Formation (the fossil containing section between 54 and 66m) was not excluded. A sandy clay (75-78 m) and a clay deposit (78-85 m) were respectively correlated with the P1c (Pittem Member) and P1m (Merelbeke Member). They covered very fine sands with nummulites (Yd), between 85 and 102 m (Egem Member).

Stratigraphy : Roborst, Volkegem and Oosterzele Members (66-75 m), Beernem Member (56-66m) and Drongengoed Member (54-56 m).

2.10. *Hijfte (municipality of Lochristi)*: cored borehole, BGS 40 E 373 (x=111.130, y=200.390, h=+8m) (Figures 7 and 11).

In the original description, the files of the BGS, the upper limit of the Pittem Member was set at 60 m. The upper portion (60-67.5 m) however, is clearly differ-

ent in colour (greenish grey) and lithology (very fine clayey sand, with thin clay laminae) than the brownish grey lower part (67.8-74 m), consisting of slightly lignitic sandy clay with stone layers and which strongly resembles the Pittem clay facies from the cored boreholes in Oedelem, Ursel-Maldegem and Knokke. Both are separated by a sandy intercalation with a marked basal gravel, 10-15 cm thick, of clay chips (67.7-67.8 m).

The Vlierzele Formation (Figure 6) further consists of two distinct levels of cross-stratified sand (43.0-49.8 m and 53.7-57.0 m). They are separated by clayey sand (49.8-53.7 m), at its base (53-53.7 m) changing into an alternation of subhorizontal medium sand (locally with sandstone) with clay layers. A similar sequence (cross-stratified sand overlain by sub-horizontal sand-clay alternations with stone beds in the sandy sets) was encountered in the Beerlegem sandpit (Figure 7). Lignite is encountered from 47 to 53.7 m.

Vlierzele Formation: 43.0-67.8 m

Drongengoed Member: 43.0-49.8 m

Beernem Member: 49.8-53.4 m

Oosterzele Member: 53.7-59.0 m

Lochristi Member: 59.0-67.5 m

Hijfte Member: 67.5-67.8 m

Gent Formation:

Pittem Member: 67.8-74 m.

2.11. *Kluizen*: borehole, BGS 40 W 327 (x=103.550, y=204.300, h=+5m). The Ypresian was overlain by the Maldegem Formation at a depth of 35 m ; 35-43 m: medium sand with sandstone (Drongengoed Member), 43-51 m: fine sand and clayey sand with sandstone, rich in shells (Beernem Member), 51-56 m: coarse sand (Oosterzele Member), 56-64 m: medium sand and 64-67 m: fine sand (Lochristi Member), 67-70 m: coarse sand (Hijfte Member) (Vlierzele Formation) ; 70-78 m silty clay, greenish grey, at the top brown (Pittem Member), 78-86 m: clay (Merelbeke Member), 86-90 m: very fine clayey sand (Egem Member) (Ieper Formation) (Figure 5).

2.12. *Knokke*: borehole 11 E 138 (x= 78.776, y=226.370, h=+5 m). The Ypresian consists of sand 104.6-110 m, clayey sand with sandstone 110-116 m, coarse sand 116-124 m (Vlierzele Formation) ; sandy clay with lignite 124-133 m (Pittem Member), heavy clay 133-135 m (Merelbeke Member) and very fine sand 135-144 m (Egem Member). The limit between the Ieper and Mont Panisel Formations was fixed on top of the Egem Member by Vandenberghe *et al.* (1990), who named the unit 110-124 m an unnamed mixed sand-clay facies because of the lack of resemblance with the outcrop area of the Vlierzele sands. Steurbaut & Nolf (1986) put the limit of the Ieper Formation and Vlierzele Formations at the top of the Merelbeke Member (Figure 5).

Stratigraphy : Hijfte Member (122-124 m), Lochristi Member (119-122 m), Oosterzele Member (116-119 m), Beernem Member (110-116 m) and Drongengoed Member (104-110 m).

2.13. *Kruibeke*: borehole BGS 42 E 314 (x=142.350, y=205.850, h=+11 m). The base of the Lede Formation was encountered at 103 m. Ypresian consists of : 103-112 m: medium sand with sandstone (Drongengoed Member), 112-122 m: sandy clay (Beernem Member), 122-125 m: medium glauconitic sand (Oosterzele Member) 125-129 m medium glauconitic sand with thin clay layers (Lochristi Member), 130-131 m: coarse sand (Hijfte Member) (Vlierzele Formation); 131-135 m: brown sandy clay (Pittem Member), 135-148 m: heavy clay (Merelbeke Member), 148-156 m: very fine sand (Egem Member) (Ieper Formation) (Figure 5).

2.14. *Lahamaide*: abandoned sandpit (x=110.025, y=154.350, h=+110 m). About 2 m of sand containing clay layers (up to 4 cm thick) and sandstone plates are exposed. At the moment, this locality is the southernmost accessible exposure of the Vlierzele Formation.
Stratigraphy : Beernem Member

2.15. *Louise-Marie*: Sandpit (x = 99.478, y = 162.388; z = +110 m), exposing cross-stratified glauconitic sands (Vlierzele Formation), overlain by the Lede Formation.

Stratigraphy : Oosterzele Member

2.16. *Nieuwerkerke-Waas*: borehole BGS 27 W 137 (x=136.650, y=210.780, h=+8 m). The Ypresian is covered by the Lede Formation and consists of : 121-127 m: medium sand with sandstone (Drongengoed Member), 127-136 m: sandy clay with sandstone, fossil-rich sandy clay and sandy clay (Beernem Member), 136-139 m: medium sand (Oosterzele Member), 139-142 m: fine sand with clay (Lochristi Member) and 142-145 m: medium to coarse sand (Hijfte Member) (Vlierzele Formation) ; 145-153 m: sandy clay, usually green, but brown in the uppermost 2 m (Pittem Member) 153-170 m: clay (Merelbeke Member), 170-184 m: very fine sand with *Nummulites-planulatus* (Egem Member) (Ieper Formation) (Figure 5).

2.17. *Oedelem*: Borehole 23 E 88 x = 77.185, y = 208.902, z = +10 m.

As yet, no results have been published of this cored boring. According to the geological map sheet 13 (Brugge) (Jacobs *et al.*, 1993a), the borehole is located in the provenance area of the Beernem Member (*sensu* Jacobs & Geets, 1977). According to the map, the Vlierzele Member of the Gent Formation is only about 10-12 m thick in the area. The Vlierzele section (33-46 m) can be subdivided into 3 smaller units :

sand (33-40 m), sandy clay (40-43 m) and sand with basal gravel (43-46 m). The section of the Oedelem borehole thus strongly resembled the nearby Sijsele well.

Proposed stratigraphy of the Vlierzele Formation :

Vlierzele Formation: 23-46 m :

Beernem Member: 23-33 m

Oosterzele Member: 33-40 m

Lochristi Member: 40-43 m

Hijfte Member: 43-46 m

2.18. *Oosterzele-Betsberg*: Borehole on the Betsberg hill ($x = 109.9$; $y = 183.25$; $z = +53$ m): Quaternary (0 - 1.7 m) ; Maldegem Formation (1.7-1.9 m) ; Lede Formation (1.9-8.9 m) ; Vlierzele Formation (8.9-19 m). The Vlierzele Formation consists of an alternation of sand and clay. The sand layers contain compact sandstones. Some sand and clay levels are dark brown and rich in lignite.

Stratigraphy : Beernem Member

2.19. *Oosterzele*: Temporary outcrop for road construction ($x = 111.25$, $y = 181.60$; $z = +55$ m), exposing cross-stratified glauconitic sands (Vlierzele Formation), overlain by the Lede Formation. The same sequence was also encountered in a nearby sandpit ($x = 111.80$, $y = 181.60$; $z = +53$ m).

Stratigraphy : Oosterzele Member.

2.20. *Overmere*: borehole (BGS 56 W 149) ; $x = 120.100$, $y = 193.350$, $h = + 5$ m). Under Pleistocene sands (0-16 m), the Vlierzele Formation (16-25 m ; Oosterzele Member) was encountered, overlying the Gent Formation : sandy clay (Pittem Member) and clay (Merelbeke Member) (25-35 m) and the Ieper Formation: very fine glauconitic sands (35-43 m ; Egem Member).

Stratigraphy of the Vlierzele Formation (after geophysical logs : Hijfte Member (23-25 m), Lochristi Member (20-23 m) and Oosterzele Member (16-20 m).

2.21. *Roborst*: claypit ($x = 105.800$, $y = 172.225$, $h = +69$ m) on a smooth hill. The following profile was excavated: 3 m of heavy grey clay with 30 cm of dark, pyritic sediment 30 cm below the top (Merelbeke Member), overlain by 1.5 m of medium sand (Vlierzele Formation) and 0.6 m of loam with basal gravel (Pleistocene). The Vlierzele sand is fining upward.

Stratigraphy : Hijfte Member (Figure 8).

2.22. *Schepdaal*: boreholes BGS 87 E 2 ($x = 139.025$, $y = 169.550$, $h = +80$ m.) and 87 E 5 ($x = 139.100$, $y = 169.500$, $h = +75$ m). After Steurbaut & Nolf (1986), the Ieper Formation (Mont Panisel Member) is overlain by the Wemmel Member and the Vlierzele Formation is missing. The upper part of the Mont Panisel Member contains lignite.

2.23. *Sijsele*: Borehole BGS 23 E 90 ($x = 76.800$, $y = 210.100$, $h = +5$ m). The borehole was described by Fobe (1989), and identified the Oedelem (9-26m), Beernem (26-37 m) and Vlierzele (37-45 m) Members (Figure 10).

The Vlierzele sand section (37-45 m) was very rich in lignite and contained a few stone concretions in its upper part and coarse sand at the base. Stone layers (6 beds) were also encountered in the Beernem Member (26-37 m). The Vlierzele section (37-45 m) can be subdivided into 3 smaller units as is revealed by logs : sand (37-40 m), sandy clay (40-43 m) and sand with the basal gravel (43-45 m).

Revised stratigraphy :

Quaternary: 0-9 m

Knesselare Formation

Oedelem Member: 9-26 m

Vlierzele Formation

Beernem Member: 26-37 m

Oosterzele Member: 37-40 m

Lochristi Member: 40-43 m

Hijfte Member: 43-45 m

Gent Formation

Pittem Member: 45-53 m

Merelbeke Member: 53-57 m

Ieper Formation

Egem Member: 57-60 m (end of borehole)

2.24. *Ursel-Maldegem*: two boreholes, BGS 39 W 212 ($x = 87.910$, $y = 204.260$, $h = +29$ m) and BGS 39 W 213 ($x = 86.860$, $y = 205.900$, $h = +21$ m). Interpretation according to De Breuck *et al.* (1989): Vlierzele Member (43.7 - 69.3 m), Pittem Member (69.3-79.3 m) and Merelbeke Member (79.3-83.7 m) (Mont Panisel Formation) and Egem Member (83.7-102 m). Steurbaut & Nolf (1986) defined the Vlierzele Formation - including the Pittem Member - in this borehole (43.7-79.3 m). Present interpretation : medium sand 43.7-52 m (Drongengoed Member), clayey sand 52-58 m (Beernem Member), sand 58-63 m (Oosterzele Member), very fine sand 63-66 m (Lochristi Member) and sand 66-69.3 m (Hijfte Member) (Vlierzele Formation) ; sandy clay with lignite streaks, 69.3-79.3 m (Pittem Member), heavy clay 79.3-83.7 m (Merelbeke Member) (Gent Formation) and very fine sand 83.7-102 m (Egem Member) (Ieper Formation) (Figures 4, 5, 10 and 11).

2.25. *Vlierzele*: Sandpit ($x = 116.80$; $y = 181.50$; $z = +44$ m), described by Houthuys & Gullentops (1988). The Vlierzele Formation is some 12 m thick, overlain by the Lede Formation and covering the Merelbeke Member of the Gent Formation. The exposed part of the Vlierzele Formation shows cross-stratified and homogenous sand, deposited as a tidal ridge. The sand contains wood fragments.

Stratigraphy : Oosterzele Member.

2.26. *Volkegem*: borehole BGS 85 W 822 ($x = 98.750$, $y = 169.0$, $h = +90$ m), drilled in July 1992 : brown loam (0-7 m ; Quaternary), brown grey and green grey fine sand and very fine clayey sand (7-22 m ; Vlierzele Formation), green glauconitic sandy clay with stone layers (22-33 m) and green glauconitic very fine sand (33-35 m) (Ieper Formation, Mont Panisel Member), heavy grey clay (35-45 m ; Ieper Formation, Aalbeke Member) and brown grey silty clay with some fossils (45-58 m ; Ieper Formation; Roubaix Member).

Stratigraphy of the Vlierzele Formation : Oosterzele Member (fine sand; 7-9 m), Lochristi Member (very fine sand ; 9-18 m) and Hijfte Member (coarser sand ; 18-22 m) (Figure 9).

2.27. *Westouter*: borehole BGS 95 W 150 ($x = 36.325$, $y = 165.000$, $h = + 143$ m), described in detail by Steurbaut & Nolf (1986) : 0-10.4 m : clayey sand (Quaternary, 10.4-16 m: sand with ironstone (Diest Formation), 16-22 m : sand (Lede Formation), 22-46 m : fossiliferous clayey sand (Knesselare Formation), 46-57 m : clayey sand and 57-59.2 m: clay with shells and sandstone and 59.2-60.7 m: glauconitic sand (Vlierzele Formation), 60.7-84.5 m: clayey sand, rusty brown at the top and 84.5-90.8 m: 90.8 m: sandy clay (Mont Panisel Member), 90.8-92.5 m: clay

(Aalbeke Member). Steurbaut & Nolf (1986) interpreted the brown layer on top of the Mont Panisel Member as a possible remain of a paleosol. The interpretation of these authors differs from the original description in the files of the Belgian Geological Survey (Gulinck, 1968, unpubl.): Vlierzele sand (P1d): 34-43 m, Pittem clay (P1c) : 43-54.8 m, Merelbeke clay (P1m): 54.8-59 m, Egem sand (Yd): 59-80.2 m. Examination and grain size distribution of samples of the section between 30 and 80 m leads to the following interpretation (Figure 13):

Vlierzele Formation

Drongengoed Member: 34-37 m

Beernem Member: 37-43 m

Oosterzele Member: 43-46 m

Lochristi Member: 46-59 m

Hijfte Member: 59-61 m

2.28. *Zottegem*: borehole BGS 85 E 962 ($x = 111.90$; $y = 173.12$; $h = + 73$ m). Olive green heavy clay (0-4 m: Merelbeke Member); olive green glauconitic clayey sand (4-8 m), green sandy clay with stone layers and scarce bivalve shells (8-23 m) and very fine glauconitic sand (23-25 m) : Mont Panisel Member ; grey heavy clay (25-36 m : Aalbeke Member); sandy clay with some fossils (36-46 m : Roubaix Member) (Figure 9).