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Paleogene and Neogene lithostratigraphic units (Belgium)

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(3 figures)

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ABSTRACT. The presented lithostratigraphy of the Paleogene and Neogene deals only with the formal lithostratigraphic units of formation rank or higher (groups). The names of the lower rank units (members and beds) are just mentioned without description or other information. This lithostratigraphy corresponds largely with the legend of the new series of geological maps of Belgium – Flanders Region on scale 1:50.000, edited since 1993.

KEYWORDS: Belgium, lithostratigraphy, Paleogene, Neogene

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1. Paleogene lithostratigraphic units

1.1. Introduction

The Paleogene of Belgium is divided into 23 formations. Eighteen formations are placed into 7 groups: the Haine Group (Ciply Fm, Mons Fm and Hainin Fm), the Haspengouw Group (Houthem Fm, Opglabbeek Fm), the Landen Group (Hannut Fm, Tienen Fm), the Ieper Group (Kortrijk Fm, Tielt Fm and Gentbrugge Fm), the Zenne Group (Aalter Fm, Brussel Fm and Lede Fm), the Tongeren Group (Zelzate Fm, Sint-Huibrechts-Hern Fm and Borgloon Fm) and the Rupel Group (Bilzen Fm, Boom Fm and Eigenbilzen Fm). The Bertaimont, Heers, Maldegem and Voort Formations are not placed into a group. The occurrences of the paleogene formations are illustrated in Figs. 1, 2 and 3. A subdivsion of the formations into members or layers is given. However, this subdivision must not be considered formal since some of the members are still under debate. Stratigraphic units with a rather local significance such as the Hyon Fm and the Onhaye Fm are not yet incorporated in this overview. The latter formation is considered a Tertiary relic found in sinkholes of the Sambre and Meuse region.

1.2. Lithostratigraphic descriptions

1.2.1. Haine Group

1.2.1.1. Ciply Formation - Ci

Authors: Le Hardy de Beaulieu (1861), Robaszynski (1988a).

Description: The Ciply Formation consists of a white-yellowish, marine calcarenite, with locally different silicification levels. The lime content is very high, attaining sometimes more than 99%. In outcrops the formation starts with a conglomerate, composed of fragments from the underlying Upper Cretaceous sediments: brown pebbles of phosphatic hardgrounds, more or less rounded, and phosphatised fossil fragments: the "Malogne Conglomerate".

Stratotype: Not formally designated. The formation was most completely exposed in the now abandoned and infilled quarry "André" along the road from Mons to Bavay (Ciply). The most closely located outcrop is in the quarry "Vandamme", where at the base of the quarry the "Tuffeau de Ciply" and the "Poudingue de Malogne" outcrop in an approximately 10 m thick section (sheet

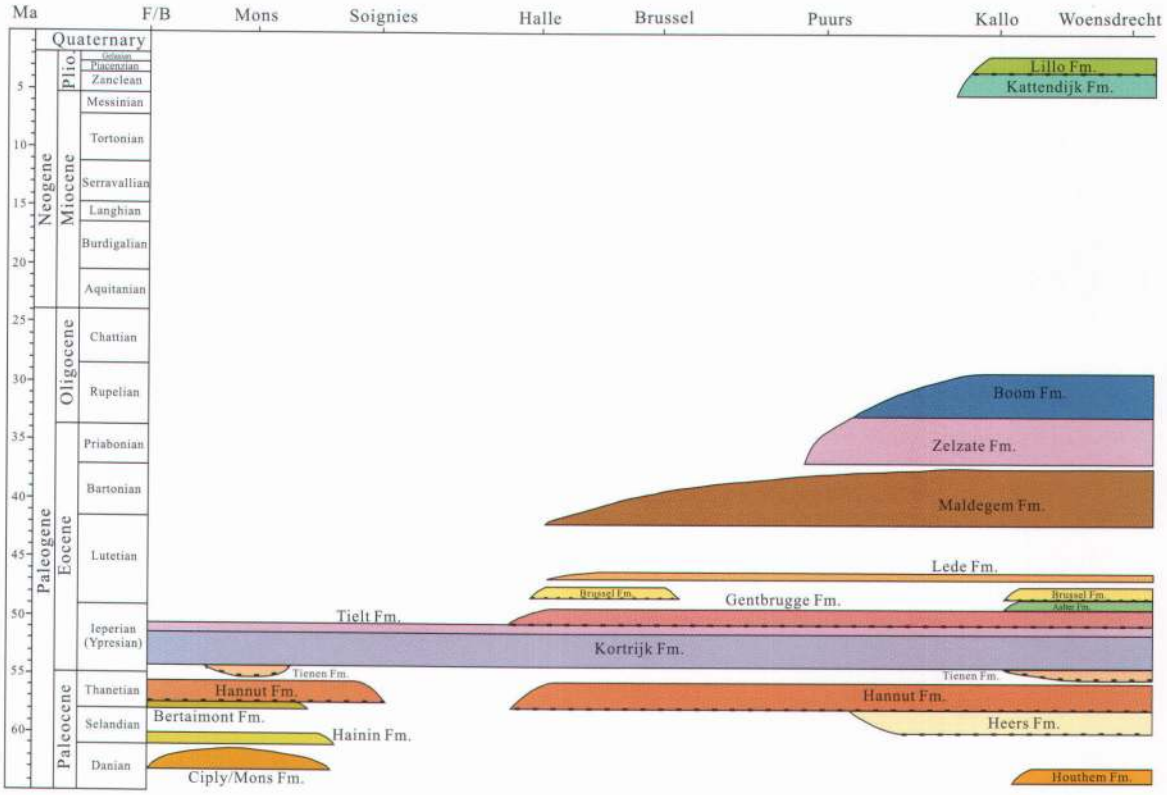

Figure 1. Occurrence of the Paleogene and Neogene formations along a transection from the French – Belgian border to Woensdrecht.

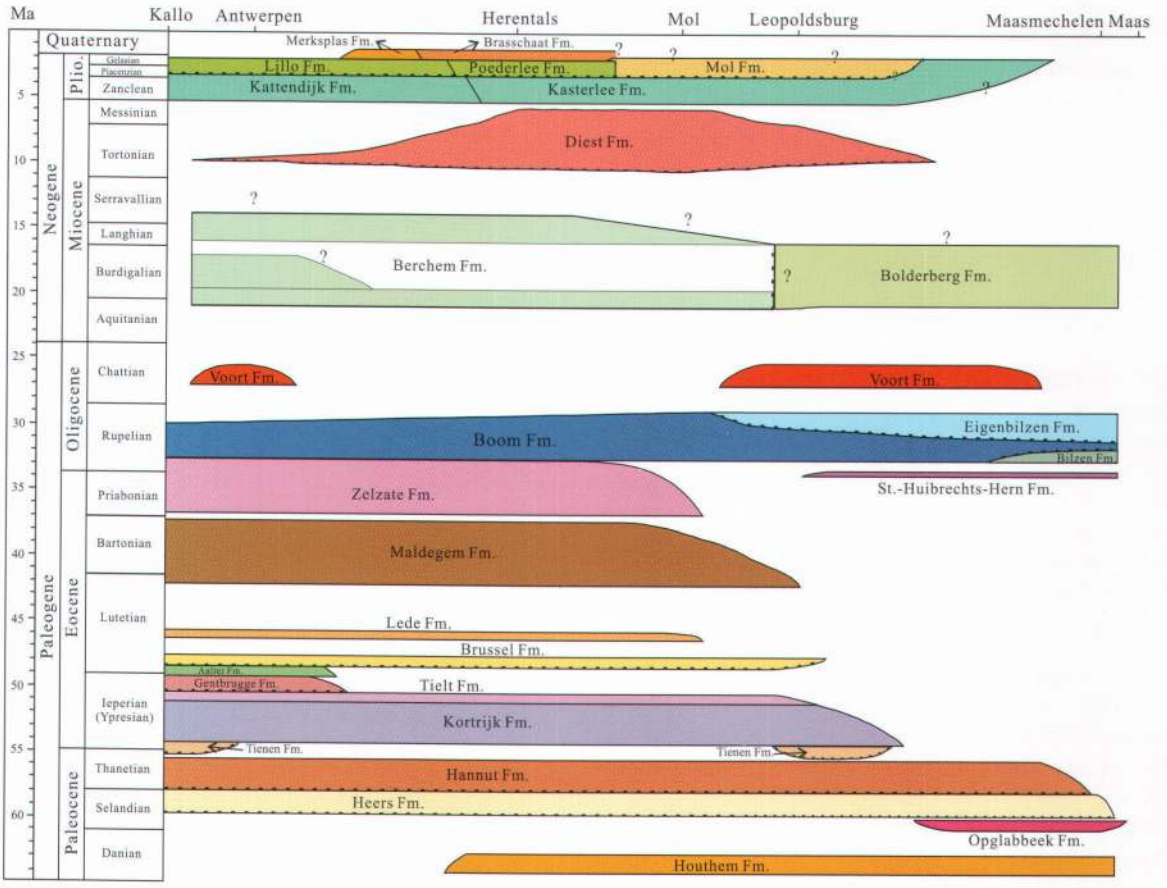

Figure 2. Occurrence of the Paleogene and Neogene formations along a transection from Kallo to the Maas river.

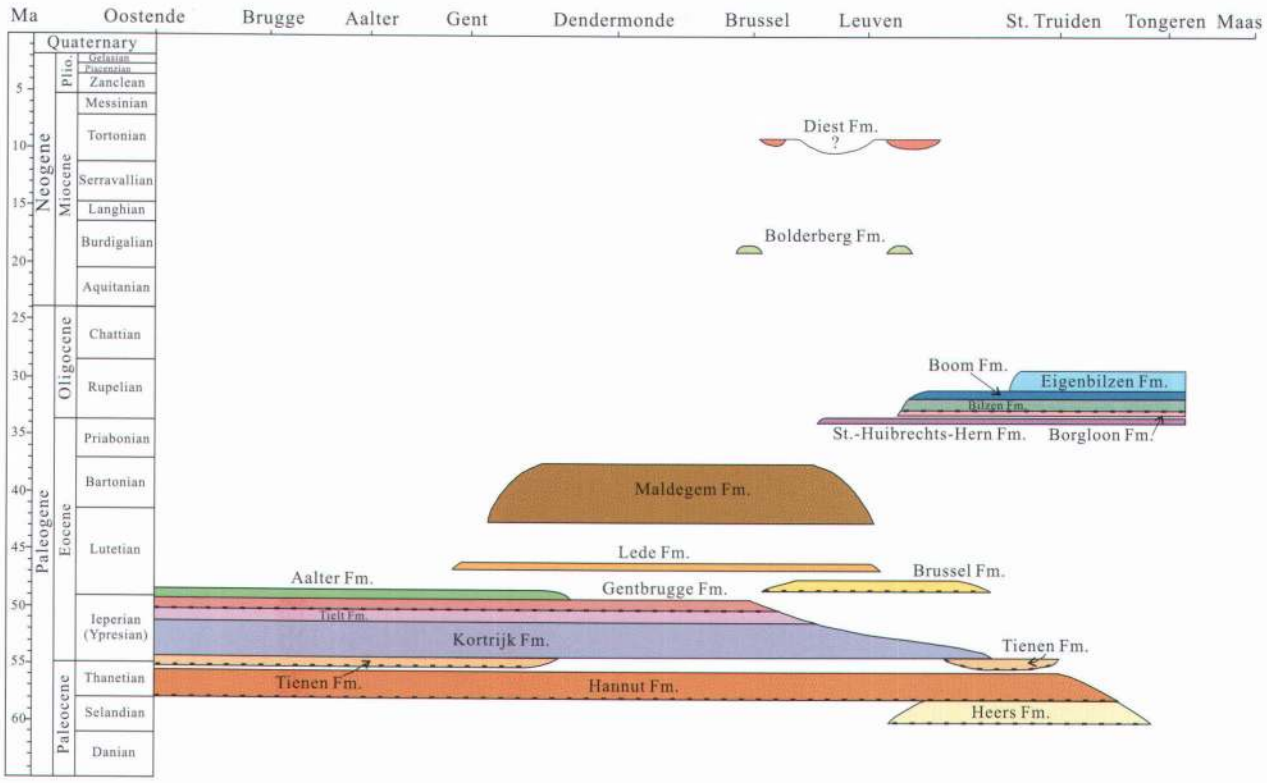

Figure 3. Occurrence of the Paleogene and Neogene formations along a transection from Oostende to the Maas river.

45/7-8, Mons - Givry). Co-ordinates: x = 119.39, y = 122.84, z = +60 m.

Area: The Mons Basin, in outcrops and in boreholes.

Members: The formation is not subdivided into members.

Thickness: Some 20 m in the quarries of Ciply and more than 30 m in boreholes.

Age: Middle and Late Danian, based on planctonic Foraminifera.

Remarks: The formation is also discussed by Cornet & Briart (1866), Maréchal (1993), Meijer (1969), Rutot & Van den Broeck (1886a, 1886b).

1.2.1.2. Mons Formation - Mo

Authors: Dewalque (1868), Robaszynski (1988b).

Description: The Mons limestone is a pale, marine limestone, friable or sometimes very coherent; it contains a very abundant neritic macrofauna. An erosional surface separates the Mons Fm from the Spiennes Chalk in the borehole of the stratotype. A clear superposition of the Mons limestone on the sediments of the Ciply Fm has never been demonstrated.

Stratotype: "Goffint" pit at Mons (*cf.* Cornet & Briart, 1865), "Coppée" pit at Mons (*cf.* Cornet & Briart, 1865; Robaszynski, 1981). Mons borehole (*cf.* Marlière, 1977). Sheet 45/7-8 (Mons - Givry). Co-ordinates: x = 123.10, y = 128.14, z = +56.8 m.

Area: The central part of the Mons Basin, only in boreholes.

Members: The formation is not subdivided into members.

Thickness: Strongly fluctuating, from 15 to nearly 70 m.

Age: Middle and Late Danian.

Remarks: The formation is also discussed by Briart & Cornet (1870-1889), Cornet & Briart (1865), Maréchal (1993), Marlière (1977) and Robaszynski (1979, 1981).

1.2.1.3. Hainin Formation - Ha

Authors: Le Hardy de Beaulieu (1861), Robaszynski (1988c).

Description: The sediments are of lacustrine - continental origin and consist of limestones, grey and white marls, black clays and lignites, and some sands. They rest in the Mons region on the limestones of the Mons Fm.

Stratotype: Outcrop along the railroad from Mons to Quiévrain, between Boussu and Thulin. Sheet 45/5-6 (Quiévrain - Saint-Ghislain). The borehole HA1 (1970) near the outcrop penetrated about 30 m of the Hainin Fm. Co-ordinates: x = 107.25, y = 124.89, z = +26 m.

Area: The formation is known in outcrops and boreholes in the region of Hainin and St.-Ghislain (western part of the Mons Basin), and only in boreholes in the region of Mons and Ghlin.

Members: The formation is not subdivided into members.

Thickness: Approximately 30 m.

Age: Early Selandian.

Remarks: The formation is also discussed by Godfriaux & Thaler (1972), Godfriaux & Robaszynski (1974), Maréchal (1993), Robaszynski (1978), Rutot (1886) and Steurbaut (1998).

1.2.2. Haspengouw Group

1.2.2.1. Houthem Formation - Ho

Authors: Romein (1962), Felder (1975), De Geyter & Laga (1988a).

Description: This marine entity consists of soft, pale grey to pale yellow, mostly coarse and porous limestone with firm shell layers and limestone knolls. The basal part looks more greenish and contains glauconite grains. At the contact with the underlying Maastricht Fm, a hard layer with bioturbations ("hardground") is found.

Stratotype: The section between – 240 m and – 274 m in the borehole Opoeteren (KS 22 or 63E222) can be considered as a hypostratotype. Sheet 26/2 (Opoeteren). Co-ordinates: x = 238.831, y = 191.238, z = +88 m.

Area: The formation is found in the subsoil of Central and North Limburg and in the northern part of the province of Antwerp. It is locally found in outcrops southwest of Maastricht (Vroenhoven).

Members: The formation is subdivided into the following members in The Netherlands (Felder, 1975): Geleen Chalk, Bunde Chalk and Geulhem Chalk.

Thickness: Probably maximum 63 m (Turnhout).

Age: Early and Middle Danian.

Remarks: The formation is also discussed by Cogels & Van Ertborn (1886), Felder *et al.* (1985), Gulinck (1961), Hofker (1957), Legrand R. (1968), Marlière (1968), Meijer (1965), Moorkens (1972a, 1982), Slimani (1994), Streel *et al.* (1977) and Vincent (1928).

1.2.2.2. Opglabbeek Formation - Op

Authors: De Geyter & Laga (1988b).

Description: A heterogeneous deposit, consisting of dark and reddish clay, small lignitic layers, plant remnants, shell-layers and fine sands, locally calcareous. In northeast Limburg a homogeneous sand complex (37 m thick) covers a more clayey entity, whereas in many boreholes only the clayey facies is found.

Stratotype: Stratotypes have only been designated for the members.

Area: The northeastern part of Limburg, only in boreholes.

Members: The formation is subdivided into the Opoeteren Mbr and the Eisden Mbr.

Thickness: 25 m in the type area, 60 m in the Molenbeersel well.

Age: Early Selandian.

Remarks: The formation is named after the village of Opglabbeek where the Opoeteren and Eisden members are well represented in borehole 63W215 (KS19). The Maasmechelen beds are considered a calcareous zone with the sandy Eisden Mbr. The formation is also discussed by Felder (1975), Felder *et al.* (1985), Halet (1932a), Maréchal (1993), Marlière (1968), Moorkens (1972a, 1972b, 1982), Schmitz & Stainier (1909), Stainier (1931), Steurbaut (1998) and Vincent (1930).

1.2.3. Bertaimont Formation - Be

Author: Dupuis (1988).

Description: This marine unit contains, from base to top, three units:

– a grey, sandy, smectite clay, poorly calcareous and glauconiferous, with some pebbles;

– green, very glauconitic, clayey sands, with some marl layers; disseminated pebbles are present. Polymorphina are frequent, few lamellibranchs and gasteropods occur;

– marls, lithified calcareous marls, grey or yellowish, glauconiferous limestone, with detritic quartz grains and pebbles. Foraminifera, gasteropods and lamellibranchs occur frequently, sometimes abundantly.

Stratotype: For the first time described as the "Heersien" in the "Brasserie Paternostre" borehole at Mons (Delvaux, 1877). Sheet 45/7-8 (Mons - Givry). Co-ordinates: x = 120.32, y = 126.44, z = +31 m. The formation is most complete in borehole no. 7 of the "Charbonnage du Hainaut" (1918) between 65.5 m and 97 m depth (incomplete core recovery) (Saint-Ghislain 138, *in* Marlière, 1969). Sheet 45/5-6 (Quiévrain - Saint-Ghislain). Co-ordinates: x = 108.90, y = 128.15, z = +24 m.

Area: Deepest parts of the Mons Basin, only known from boreholes.

Members: The formation is not subdivided into members.

Thickness: Probably not more than 40 m.

Age: Thanetian.

Remarks: The formation is also discussed by De Geyter (1981), Delvaux (1877), Dupuis & Robaszynski (1986), Cornet (1927), Maréchal (1993), Marlière (1969), Moorkens (1982) and Robaszynski (1978).

1.2.4. Heers Formation - Hs

Authors: Dumont (1849a), Laga & De Geyter (1988).

Description: This marine unit consists mainly of whitish grey, calcareous marl with imprints of leaves, covering green, glauconitic sand.

Stratotype: Stratotypes have only been designated for the members.

Area: The eastern part of northern Belgium. Outcrops are locally found in the Hesbaye area, a.o., at Heers and Orp-Jauche.

Thickness: Maximum about 60 m in the east. It decreases to the west and to the north.

Members: The formation is subdivided into the Orp Mbr and the Gelinden Mbr.

Age: Middle and Late Selandian.

Remarks: The formation is also discussed by De Geyter (1981), De Saporta & Marion (1873, 1877), Dumont (1851), Gosselet (1874), Gulinck (1965a), Herman (1972), Leriche (1903), Moorkens (1972b, 1982), Schumacker-Lambry (1978), Steurbaut (1998), Thielens (1871) and Vincent (1873).

1.2.5. Landen Group

1.2.5.1. Hannut Formation - Hn

Author: De Geyter (1988a).

Description: This marine unit consists of clay, sandy clay and silt, siliceous limestone, siltstone and sandstone, mostly covered by glauconitic, fine sand.

Stratotype: Stratotypes have only been designated for the members.

Area: The formation extends almost over the whole northern part of Belgium. The outcrops are mainly situated in the Hesbaye area and in Hainaut.

Thickness: The formation thickens to the northeast and reaches more than 100 m in the Campine (Mol borehole). In the Mons Basin the maximum thickness is about 55 m. In East- and West-Flanders the thickness mostly varies between 20 and 40 m, but markedly decreases in the north of West-Flanders (Knokke borehole).

Members: The formation is subdivided into the Chercq Mbr (Hainaut), the Lincent Mbr (Hesbaye area), the Halen Mbr and the Waterschei Mbr (northeast Belgium), and the Grandglise Mbr (almost the whole northern part of Belgium).

Age: Early and Middle Thanetian.

Remarks: The formation is also discussed by Baudet (1939), Cornet (1899), De Geyter (1980, 1981), D'Omalius d'Halloy (1939, 1842), Gullentops *et al.* (1995), Gulinck (1948), Gulinck & Hacquart (1954), Kaaschieter (1961), Lyell (1852a), Macar *et al.* (1947), Maréchal (1993), Moorkens (1972b, 1982), Nijs & De Geyter (1985), Steurbaut (1998) and Vincent & Rutot (1879).

1.2.5.2. Tienen Formation - Ti

Author: De Geyter (1988b).

Description: The continental-lagoonal unit mainly consists of lignitic clay and lignite, white sand, pale marl and shell beds. Locally silicified wood fragments, traces of roots and quartzites occur. Important fossil vertebrates have been found at Dormaal and Erquelinnes.

Stratotype: Stratotypes have only been designated for the members.

Area: Outcrops are known in the Hesbaye area and in Hainaut. The formation occurs in the subsurface in the northern part of West- and East-Flanders and in a part of northeastern Belgium with an extension to the Tienen-Landen area.

Thickness: The maximum thickness is about 35 m.

Members: The formation is subdivided into the Erquelines Mbr (Hainaut area), the Knokke Mbr (northwest Belgium), the Loksbergen Mbr (northeast Belgium) and the Dormaal Mbr (Hesbaye area).

Age: Late Thanetian (- Early Ypresian).

Remarks: The formation is also discussed by Casier (1967), De Coninck *et al.* (1981), De Geyter (1980, 1981), D'Omalius d'Halloy (1862), Feugueur (1955), Gulinck (1973, 1967), Kaasschieter (1961), Laga & Vandenberghe (1990), Leriche (1899, 1902), Maréchal (1993), Moorkens (1972b), Nijs & De Geyter (1984), Quinet (1966, 1969), Rutot (1881, 1884, 1903), Smith & Smith (1995), Stevens (1913), Steurbaut (1998) and Teilhard de Chardin (1927).

1.2.6. Ieper Group

1.2.6.1. Kortrijk Formation - Ko

Authors: Geets (1988a), 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 at the base of the Het Zoute Mbr. Sheet 5/6 (Westkapelle). Co-ordinates: x = 78.776, y = 226.37, z = +4.91 m. The upper boundary is placed at 71 m depth in the Tielt boreholes at the top of the Aalbeke Mbr. Sheet 21/6 (Wakken). Co-ordinates: x = 67.425, y = 187.55, 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 and the southwest of Brabant. Outliers occur in the Mons Basin and south of the river Sambre.

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 (1973), De Coninck *et al.* (1983), De Heinzelin & Glibert (1964), De Moor & Geets (1975), Geets (1990), Gosselet (1874), Gulinck (1965a, 1967), Gulinck & Hacquaert (1954), King (1990), Laga *et al.* (1980), Lyell (1852b), Maréchal (1993), Ortlieb & Chelloneix (1870), Steurbaut (1988), Steurbaut & Nolf (1986), Vandenberghe *et al.* (1990) and Wouters & Vandenberghe (1994).

1.2.6.2. Tielt Formation - Tt

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

Description: This marine unit consists in general of a very fine sandy, coarse silt, upwards there is a transition into very fine sand.

Stratotype: The formation is defined by boundary stratotypes (Steurbaut, 1998). The lower boundary stratotype is placed at 71 m depth in the Tielt borehole at the base of the Kortemark Mbr. Sheet 21/6 (Wakken). Co-ordinates: x = 76.425, y = 187.55, z = +48 m. The upper boundary is placed at the top of the Egem Mbr in the "Ampe" quarry. Sheet 21/1 (Wingene). Co-ordinates: x = 70.15, y = 190.15, 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.

Thickness: More than 50 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 and the Egem 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) and Subgroup Lithostratigraphy and Maps (1980).

1.2.6.3. Gentbrugge Formation - Ge

Author: New name; see also Geets (1988c) and Steurbaut (1998).

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 of 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 as far as northern Hainaut and eastwards from the Senne River.

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

Members: The formation is subdivided into the Merelbeke Mbr, the Pittem Mbr and the Vlierzele Mbr.

Age: Late Ypresian.

Remarks: The Gentbrugge Fm is still called Gent Fm on the geological maps. The name Gent Fm was changed since it was already in use for Quaternary eolian coversand deposits in Flanders (Paepe & Vanhoorne 1976). The formation is also discussed by De Heinzelin & Glibert (1957), De Moor & Geets (1973), De Moor & Germis (1971), Dumont (1851), Fobe (1996), Geets (1979), Gulinck (1967), Gulinck & Hacquaert (1954), Kaasschieter (1961), Maréchal (1993), Steurbaut & Nolf (1986) and Wouters & Vandenberghe (1994).

1.2.7. Zenne Group

1.2.7.1. Aalter Formation - Aa

Authors: Dewalque (1868).

Description: Marine unit, consisting of a grey green, glauconiferous, clayey sand with fine sandy clay layers and many thin sandstone layers. It is followed upwards by grey, fine sand, very fossiliferous at the top. The whole is covered by brown green to dark green glauconiferous, very fine, locally silty sand, with many fossil fragments.

Stratotype: A composite stratotype was designated by Steurbaut & Nolf (1989) between Aalter, Molenstraat ("Oude Molen" area), sheet 21/3-4 (Aalter - Nevele), co-ordinates: x = 85.90, y = 197.82, z = +26 m, and Aalter, Weibroekdreef bridge, sheet 21/3-4, co-ordinates: x = 86.15, y = 198.20, z = +19 m. The first mentioned area is considered a lectostratotype.

Area: The formation occurs in the northeastern part of West-Flanders and the northwestern part of East-Flanders. It outcrops in the region of Aalter, at the base of the hillrow in the northern part of West- and East-Flanders and in a few outliers (Gent, the hills in the south of West-Flanders).

Thickness: 30 m, decreasing to the east.

Members: The formation is subdivided into the Beernem Mbr and the Oedelem Mbr.

Age: Late Ypresian to Early Lutetian.

Remarks: The formation is also discussed by Depret & Willems (1983), Dewalque (1868), Dumont (1839), Geets & Jacobs (1988), Gulinck (1967), Gulinck & Hacquaert (1954), Hacquaert (1939), Jacobs (1975), Jacobs & Geets (1977), Maréchal (1993), Mourlon (1873), Nolf (1970, 1972) and Steurbaut & Nolf (1989).

1.2.7.2. Brussel Formation - Br

Authors: Dumont (1839), Houthuys & Fobe (1988).

Description: This rather heterogeneous formation consists of an alternation of strongly and poorly calcareous sets. The non calcareous sands (silica facies) are homogeneous or crossbedded with thin clay layers. They show a lot of silicified borings, spherical or platy concretions. Locally silicified marl layers may occur. The calcareous facies consists of finer sands. Subhorizontal laminations are frequently disturbed by bioturbation. Limestone layers occur frequently, together with silicified concretions. The formation has been deposited in a marine environment with strong tidal currents. The calcareous sands were deposited in quiet, protected areas.

Stratotype: A lectostratotype is defined in Jodoigne (Zétrud - Lumay area). Sheet 32/7-8 (Meldert - Tienen). Co-ordinates: x = 185.375, y = 161.2, z = +90 m.

Area: Brabant and the north of Hainaut and Namur. The most important outcrops are between the Zenne and the Gete Valleys.

Thickness: 20 to 40 m, exceptionally 70 m.

Members: The formation is subdivided into the Archennes Mbr, the Bois de la Houssière Mbr, the Chaumont - Gistoux Mbr, the Diegem Mbr and the Neerijse Mbr.

Age: Early Lutetian.

Remarks: See Lede Fm.

1.2.7.3. Lede Formation - Ld

Authors: Mourlon (1873), Fobe (1988).

Description: This marine unit consists of calcareous and glauconiferous, fine sand. Some layers of sandy limestone or calcareous sandstone occur (normally three). The base is formed by a pebble layer with reworked elements (fossil fragments and rock fragments) from older deposits. The stone layers are frequently associated with coarse sediment layers (with the coarse base too). *Nummulites variolarius* is abundantly present.

Stratotype: Oosterzele - Balegem Quarry. Sheet 22/5-6, (Gavere - Oosterzele). Co-ordinates: x = 110.8, y 179.10, z = +66 m.

Area: The formation occurs in the north of East-Flanders and Brabant and in a large part of the Antwerp Province. It continually outcrops in the Dender-Zenne region and forms the subsoil of the Flemish Valley in a narrow zone between Zomergem and Dendermonde. It occurs in outliers, as the southern hills of West- and East-Flanders and adjacent areas of Hainaut and Brabant.

Members: The formation is not subdivided into members.

Thickness: 10 to 15 m.

Age: Middle Lutetian.

Remarks: The Lede and Brussel formations are also discussed by Dumont (1839, 1851), Fobe (1986, 1988), Fobe & Spiers (1992), Gulinck & Hacquaert (1954), Houthuys & Gullentops (1985, 1988), Kaasschieter (1961), Leriche (1912), Mignion (1969), Mourlon (1873, 1880, 1887), Rijksgeologische Dienst & Nederlandse Aardoliemaatschappij (1980), Rutot & Vincent (1879), Subgroup Lithostratigraphy and Maps (1980) and Vincent (1887).

1.2.8. Maldegem Formation - Ma

Author: Jacobs (1988).

Description: Marine deposit, consisting of a succession of sharp based clays, gradually coarsening upwards into sands. The formation starts with grey, glauconiferous, fine sand, growing more clayey at the top and covered by a strongly glauconiferous clay, with locally coarse glauconitic sand at the base. A homogeneous, less glauconiferous, grey blue, heavy clay is followed by a dark grey, silty fine sand, glauconiferous and micaceous. This sand is covered by a grey blue, heavy clay, which passes into a dark grey, silty fine sand. The formation ends by a grey blue, heavy clay, with perforations at the top, filled by humic, grey, fine sand and a lot of organic material, indicating a soil development or a gap in the sedimentation.

Stratotype: Stratotypes have only been designated for the members.

Area: The formation outcrops in a part of the north of West- and East-Flanders and in the region between the Dender and Zenne rivers. It occurs in the subsoil in the whole northern part of West- and East-Flanders and disappears to the east in the Antwerp Campine; it forms outliers in the Brabant and South Flanders hillrows.

Thickness: 50 m in the northeast, but only a few meters in the southern outliers.

Members: The formation is subdivided into the Wemmel Mbr, the Asse Mbr, the Ursel Mbr, the Onderdale Mbr, the Zomergem Mbr, the Buisputten Mbr and the Onderdijke Mbr.

Age: Late Lutetian and Bartonian.

Remarks: The formation is also discussed by Jacobs (1975, 1978, 1998), Gulinck (1965b, 1969), Leriche (1921), Rutot (1882), Vincent & Lefevre (1872) and Vincent & Rutot (1878).

1.2.9. Tongeren Group

1.2.9.1. Zelzate Formation - Zz

Authors: Jacobs (1975, 1978), Jacobs & Vandenberghe (1988).

Description: This marine unit starts with a dark grey, moderately fine, silty sand, glauconiferous and micaceous, with intercalations of thick lenses of grey clay; it is covered by dark green, sandy clay. The top is formed by green grey sands, rich in fossils, with large sandstone concretions.

Stratotype: Stratotypes have only been designated for the members.

Area: Northern part of East-Flanders and the Antwerp Province as far as the area between the Nete and the Demer rivers.

Members: The formation is subdivided into the Bassevelde Mbr, Watervliet Mbr and the Ruisbroek Mbr.

Thickness: Probably 25 to 30 m, decreasing to the east.

Age: Early Priabonian to Early Oligocene.

Remarks: The formation is also discussed by Dumont (1839), Gulinck (1965b, 1969), Halet (1905, 1937), Jacobs & De Coninck (1977), Janssen (1981), Matheussens (1971), Mourlon (1894-1895), Steurbaut (1986, 1992), Vandenberghe (1974) and Van Den Bosch *et al.* (1975).

1.2.9.2. Sint-Huibrechts-Hern Formation - Sh

Author: Laga (1988a).

Description: This marine (epicontinental) deposit starts with glauconiferous and micaceous, more or less clayey, fine sands, locally very fossiliferous. It is covered by finely laminated glauconiferous sand, passing into white homogeneous sand; at the base a hardened and oxidized shell layer is found.

Stratotype: Stratotypes have only been designated for the members.

Area: The formation is found in the eastern part of Belgium, east of the Dijle Valley and as far as the north of Limburg, with some outliers between the Zenne and the Dijle Valleys, especially on the hilltops, southeast and east of Brussels.

Thickness: Approximately 25-30 m.

Members: The formation is subdivided into the Grimmertingen Mbr and the Neerrepen Mbr.

Age: Early Oligocene.

Remarks: The formation is also discussed by Buurman & Langenaar (1975), Dumont (1849b), Glibert & De Heinzelin (1954a), Macar & Gulinck (1947), Maréchal (1993), Ortlieb & Dollfuss (1873) and Van den Broeck (1883a).

1.2.9.3. Borgloon Formation - Bo

Author: Laga (1988b).

Description: The continental and lagunary deposits start in Brabant with a layer of clay lenses with erosion and emersion characteristics, followed by an alternation of sand and clay layers. It is covered by grey white or brownish, cross bedded sand, locally lignitic. In Limburg the base is formed by a thick layer of grey and green clay, covered by black lignitic clay with horizontal layers of calcareous nodules and gypsum crystals, and an alternation of clayey and sandy layers. The top is formed by white yellowish, medium to coarse sand, with a lot of shells (fragments) and alternating with 2 to 3 layers of grey white, compact clay with layers of black clay.

Stratotype: Stratotypes have only been designated for the members.

Area: Southern area of Brabant and Limburg.

Thickness: 20 m in Brabant and 10 m in Limburg.

Members: The formation is subdivided in NE Belgium into the Henis Mbr and the Alden Biesen Mbr. In the Brabant area, the formation is subdivided into the Heide layer, the Kerkom Mbr, the Boutersem Mbr and the Hoogbutsel layer.

Age: Early Oligocene.

Remarks: The formation is also discussed by Dumont (1849a, 1851), Glibert & De Heinzelin (1952, 1954a, 1954b), Janssen *et al.* (1976), Macar & Gulinck (1947), Maréchal (1993), Ortlieb & Dollfus (1873), Tavernier & Gulinck (1947) and Van den Broeck (1881-1882, 1882, 1883b, 1893).

1.2.10. Rupel Group

1.2.10.1. Bilzen Formation - Bi

Author: Vandenberghe (1988a).

Description: The formation starts with white yellowish, locally glauconiferous, fine sands, homogeneous and horizontally layered, with chert pebbles at the base. They are followed by brown, green or yellow grey sandy clay, rich in fossils. The top is formed by pale, fine sand, with some clay layers.

Stratotype: Stratotypes have only been designated for the members.

Area: The formation outcrops in the south east of Brabant and Limburg and occurs in the subsoil of the Campine area.

Thickness: Approximately 15 m.

Members: The formation is subdivided into the Berg Mbr, the Kleine-Spouwen Mbr and the Kerniel Mbr.

Age: Early Rupelian.

Remarks: The formation is also discussed by Batjes (1958), De Heinzelin & Glibert (1956), Glibert (1955, 1957), Glibert & De Heinzelin (1954a), Gulinck (1975), Kruissink *et al.* (1978), Maréchal (1993), Ortlieb & Dollfus (1873), Rutot (1873), Van den Broeck (1883b) and Van den Broeck & Rutot (1883).

1.2.10.2. Boom Formation - Bm

Authors: De Koninck (1838), Vandenberghe (1988b).

Description: This marine unit, deposited in an open shelf sea, consists essentially of grey, silty clay or clayey silt, with pyrite and glauconite in the most silty horizons. The layering (20-50 cm) is typical, caused by rhythmic changes in silt content, humic material and carbonates (development of septaria); these layers occur in a well defined vertical order.

Stratotype: Stratotypes have only been designated for the members.

Area: The formation outcrops in the northeastern part of East-Flanders and north of the Rupel and Nete rivers. North of this area, the formation is covered by younger deposits.

Thickness: From a few meters in East-Flanders to 150 m in North Belgium.

Members: The formation is subdivided into the Belsele-Waas Mbr, the Terhagen Mbr and the Putte Mbr.

Age: Early to Middle Rupelian.

Remarks: The formation is also discussed by Glibert (1957), Gulinck (1965b), Halet (1936), Janssen (1981), Vandenberghe (1974, 1978), Vandenberghe *et al.* (in press), Van den Broeck (1883b) and Vincent (1889).

1.2.10.3. Eigenbilzen Formation - Eg

Authors: Gulinck (1965b), Vandenberghe (1988c).

Description: Dark green, glauconiferous, clayey fine sands, with bioturbations. A layering, caused by variations in grainsize distribution, is present.

Stratotype: No suitable permanent stratotype exists. The formation was studied in the sluice section of the Albert canal near Diepenbeek and Hasselt (Vandenberghe, 1974) and in a temporary outcrop of the enlargements works of the Albert Canal at Gellik (Steurbaut *et al.* 1999). This latter outcrop allowed a calibration of the boundary between the Boom Clay and the Eigenbilzen Sands, near the locality where they were originally defined (Eigenbilzen area), see Halet (1932b).

Area: Subsoil of Limburg and in a few outcrops along the eastern and western margin of the Campine plateau (Hasselt area and Maasmechelen area).

Members: The formation is not subdivided into members.

Thickness: 25 m.

Age: Late Rupelian.

Remarks: The formation is also discussed by Halet (1932b), Matthijs (1999), Steurbaut *et al.* (1999), Vandenberghe (1974), Vandenberghe *et al.* (2001) and Van den Broeck (1884, 1893).

1.2.10.4. Voort Formation - Vo

Authors: Van Straelen (1923), Vandenberghe (1988d).

Description: Dark green, glauconiferous, clayey, fine sands, laterally passing into green clay.

Stratotype: Shaft of the coal mine "Voort - Zolder" (archives Geological Survey of Belgium 62W226) between -21 m to -45 m (De Heinzelin & Glibert, 1956). Sheet 25/3-4 (Beringen - Houthalen). Co-ordinates: x = 217.33, y = 192, 725, z = +48.50 m.

Area: Only known in the subsoil of Limburg and the region of Antwerp.

Thickness: 65 m, up to 300 m in the Roer Valley Graben.

Members: Only the clayey Veldhoven Mbr is distinguished within the Voort Sands.

Age: Chattian.

Remarks: The formation is also discussed by De Heinzelin & Glibert (1956), Gulinck (1954), Hager *et al.* (1998), Van Adrichem Boogaert & Kouwe (1993), Vandenberghe & Laga (1986), Van Staalduinen *et al.* (1979) and Van Straelen (1923).

1.3. Overview and symbols of the Paleogene lithostratigraphic units

Haine Group	Ciply Formation	Ci
	Mons Formation	Mo
	Hainin Formation	Ha
Haspengouw Group	Houthem Formation	Ho
	Opglabbeek Formation	Op
Bertaimont Formation		Be
Heers Formation		Hs
Landen Group	Hannut Formation	Hn
	Tienen Formation	Ti
Ieper Group	Kortrijk Formation	Ko
	Tielt Formation	Tt
	Gentbrugge Formation	Ge
Zenne Group	Aalter Formation	Aa
	Brussel Formation	Br
Lede Formation		Ld
Maldegem Formation		Ma
Tongeren Group	Zelzate Formation	Zz
	Sint-Huibrechts-Hern Formation	Sh
	Borgloon Formation	Bo
Rupel Group	Bilzen Formation	Bi
	Boom Formation	Bm
	Eigenbilzen Formation	Eg
Voort Formation		Vo

2. Neogene lithostratigraphic units

2.1. Introduction

The occurrence of Neogene sediments is limited to northern Belgium, i.e., to the provinces of Antwerp, Limburg and the northern part of Brabant and East Flanders. They consist essentially of glauconitic sands with a varying clay admixture and are furthermore characterised by the abundant occurrence of shells, often in massive layers, and local decalcification. Basal gravels

are present between the units. Deposition took place in a shallow marine to perimarine environment at the southern margin of the North Sea Basin. An overview of the sequence stratigraphy, biostratigraphy and geometrical relationships of the Belgian Neogene units is given by Vandenberghe et al. (1998). The Neogene of Belgium is lithostratigraphically divided into 9 formations. Three formations (Berchem Fm, Diest Fm and Bolderberg Fm.) are placed in the Miocene, six in the Pliocene (Kattendijk Fm, Kasterlee Fm, Lillo Fm, Mol Fm, Poederlee Fm and Kiezeloöliet Fm). No groups are defined. A subdivision of the formations into members or layers is given. The occurrences of the neogene formations are illustrated in Figs. 1, 2 and 3.

The Brasschaat and Merksplas Formations of the Northern Campine area belong traditionally to the research domain of the Quaternary geologists, nothwithstanding the fact that the Plio-Pleistocen boundary is put on 1.75 million years (Odin, 1994). Consequently these formations are described in the contribution on the Quaternary formations (see this volume).

2.2. Lithostratigraphic descriptions

2.2.1. Berchem Formation - Bc

Authors: De Meuter & Laga (1976).

Description: Green to blackish, fine to medium fine, often slightly clayey, very glauconiferous sand; rich in shells, dispersed in the sediment or concentrated in subhorizontal, sometimes massive layers; locally decalcified; basal gravel more or less developed, consisting mainly of dark rounded flint pebbles.

Stratotype: Temporary exposures of the excavations for the "E3 - Kleine Ring" motorway around Antwerp (the present number of the motorway is E17), from Antwerp - Zuidstation to Borgerhout - Rivierenhof.

Area: Antwerp province: subsurface exposures and borings to the north and east of Antwerp.

Thickness: 100 m.

Members: The formation is subdivided in the Antwerp area into the Edegem Sands Member, the Kiel Sands Member and the Antwerpen Sands Member. In the Antwerp Campine area it is subdivided into the Antwerpen Sands Member. and the Zonderschot Sands Member.

Age: Late Aquitanian to Serravallian.

Remarks: The formation is also discussed by Cogels *in* Van Ertborn (1879), De Heinzelin (1955a), Huyghebaert & Nolf (1979), Louwye (2000), Louwye & Laga (1998), Lyell (1852), Nyst (1845, 1861a), Van den Broeck (1876).

2.2.2. Bolderberg Formation - Bb

Authors: De Meuter & Laga (1976), after Dumont (1850).

Description: Lateral succession from marine to continental sandy deposits; dark-green, medium fine, slightly clayey, often very micaceous, very slightly ligniferous, glauconiferous sand, fossiliferous in the lower part, passing into white, fairly coarse sand with lignite layers and glassy quartzite banks; basal gravel well developed with dark rounded flint pebbles and shark teeth.

Stratotype: Outcrops of the road cuttings on the Bolderberg hill.

Area: Exposures and deep borings of the western edge of the Limburg province; exposures on the hills around and to the south of Diest, Brabant province.

Thickness: 50 m, 285 m in the Roer valley Graben.

Members: The formation is subdivided into the Houthalen Sands Member and the Genk Sands Member.

Age: Late Aquitanian to Early Burdigalian.

Remarks: The formation is also discussed by de Heinzelin & Glibert (1957), Glibert (1945, 1952), Gulinck (1956, 1959, 1963), Hinsch (1952), Le Hon (1862), Leriche (1934), Mourlon (1898), Tavernier & de Heinzelin (1963), Van den Broeck (1880).

2.2.3. Diest Formation - Di

Authors: De Meuter & Laga (1976), after Dumont (1839).

Description: Grey green to brownish, mostly coarse, locally clayey, glauconiferous sand often with sandstone layers; mainly without fossils, except the very local Deurne and Dessel Sands Members; well developed basal gravel with small rounded flint pebbles and locally with bone fragments and shark teeth.

Stratotype: Exposures at the former town fortress of Diest.

Area: Exposures on the hill tops of northeastern Brabant, southwestern Antwerp and western Limburg provinces; deep borings of the more northern parts of Antwerp and Limburg provinces.

Thickness: 70 m in the type locality, and up to 185 m in the middle of the deeply eroded channels.

Members: The formation is subdivided into the Deurne Sands Member (Antwerp area) and the Dessel Sands Member (Campine area).

Age: Tortonian - early Messinian.

Remarks: The formation is also discussed by de Heinzelin & Glibert (1957), Glibert & de Heinzelin (1955), Gulinck (1963), Laga & De Meuter (1973), Louwye & Laga (1998), Louwye et al. (1999), Nyst (1861b).

2.2.4. Kattendijk Formation - Kd

Authors: De Meuter & Laga (1976) after de Heinzelin (1955c).

Description: Dark grey to green grey, fine to medium fine, glauconitic sand, slightly clayey; sometimes mottled by tracks, locally with an important amount of Ditrupa; shells dispersed in the sand and concentrated in one or more layers; basal gravel of rounded quartz and flints, together with sharks teeth, phosphatic nodules and rounded bones.

Stratotype: The outcrop of the Verbindingsdok, described in detail by Cogels (1874), between – 4.8 m and 1.0 m.

Area: Region of Antwerp, the northern part of the Antwerp Campine and very probably the "Land van Waas".

Thickness: 7.5 m at the outcrop; 12.5 m in boreholes near the type locality. In the Campine area the thickness of this formation above the Diest Formation is very reduced (5 m, max. 10m).

Age: Early Pliocene.

Remarks: The formation is also discussed by de Cogels (1874), Halet (1931), de Heinzelin & Glibert (1957).

2.2.5. Kasterlee Formation - Kl

Authors: De Meuter & Laga (1976), after Dumont (1882).

Description: Grey fine micaceous sand, without fossils, slightly glauconiferous, with lenses of micaceous clay; at the base micaceous fine sand, often very glauconitic, burrowed and mottled; at some places, a basal gravel of flints and rare silicified fossils; often hardly distinguishable from the underlying Diest Formation; the upper limit is also hardly distinguishable from the Mol Formation.

Stratotype: Outcrops on the hills on the right bank of the Kleine Nete valley.

Area: Southern part of the Antwerp Campine and the Limburg Campine; gradual transition to the Kattendijk Formation to the north.

Thickness: Up to 15 m in the subsurface of the type locality. Possibly up to 40 m in the northeast of the Antwerp province.

Age: Zanclean to (early?) Piacenzian.

Remarks: The formation is also discussed by Halet (1935a).

2.2.6. Lillo Formation - Li

Authors: De Meuter & Laga (1976).

Description: Grey, grey brown and light grey brown shelly sand, clayey in the lower part and with several shell layers; in the upper part gradual decrease of the clay content and the thick shell layers; in the uppermost part, gradual disappearance of the shells.

Stratotype: Outcrop of the Tijsmanstunnel under the Kanaaldok between 3.00 m and 23.50 m depth.

Area: Harbour district of Antwerp and the northern part of the Antwerp Campine; to the south of the Campine gradual transition in the Poederlee Formation.

Thickness: 23 m in the type locality; 25 m in the north of the Antwerp province, but increasing considerably just north of the state border in The Netherlands.

Members: The formation is subdivided into the Luchtbal Sands Member., the Oorderen Sands Member., the Kruisschans Sands Member., the Merksem Sands Member. and the Zandvliet Sands Member.

Age: Zanclean to Piacenzian.

Remarks: The formation is also discussed by Cogels (1874), de Heinzelin (1950a, 1950b, 1952, 1955a, 1955b, 1955c, 1963), de Heinzelin & Glibert (1957), Dumont (1839, 1850), Glibert (1957), Halet (1935b), Leriche (1912, 1927), Mourlon (1880), Van den Broeck & Cogels (1877), Van Voorthuysen (1958), Vincent (1889).

2.2.7. Poederlee Formation - Pd

Authors: De Meuter & Laga (1976), after Vincent (1889).

Description: Fine slightly glauconiferous sand, with small lenses of clay in the lower part; base with gravel of rounded quartz and flint pebbles, silicified carbonates (also called the Hukkelberg Gravel); upper part largely oxidised in the type region, sometimes limonitic sandstones with shell moulds.

Stratotype: Tops of the hills north of Poederlee: iron sandstone layers.

Area: Southern part of the Antwerp Campine.

Thickness: Approximately 10 m in the type locality.

Age: Late Pliocene.

Remarks: The formation is also discussed by Cogels & Van Ertborn (1881).

2.2.8. Mol Formation - Ml

Authors: De Meuter & Laga (1976), after Mourlon (1896).

Description: White pure, coarse and medium fine sand, sometimes lignitic and with some lenses of a micaceous clay; in the type region, lower part very slightly glauconiferous.

Stratotype: Sandpits for the exploitation of glass sands.

Area: Whole northeastern part of the Campine.

Thickness: 20 m in the Mol area, but up to 70 m and more east of the faults.

Age: Late Pliocene.

2.2.9. Kiezeloöliet Formation – Kz

Authors: Doppert et al. (1975) after Fliegel and Stoller (1913).

Description: The formation consists of a wide variety of lithologies, all of fluvial and lacustrine origin. The lowest part consists of coarse grained sand, the Waubach Sand, the middle part predominantly of clay members often with lignitic horizons (the Brunssum II en Brunssum I Members) with a sand member in between (the Pey Member) and the upper part consists of fine to coarse grained sand with some clayey intercalations (the Jagersborg Member).

Stratotype: The type-section is in Germany (Fliegel & Stoller, 1913) in a former gravel pit at Duisdorf near Bonn. The type section for the Netherlands is the area of Waubach – Brunssum – Schinveld, where deposits are exposed in clay and gravel pits and have been studied in numerous wells.

Area: In Belgium, this formation name is only used for these deposits in the Roer valley graben, being the continuation of the Dutch part of the graben (Demyttenaere & Laga, 1988). The formation outcrops occur only northeast of the Feldbiss and Reppel faults (= the western limit of the Roer valley graben).

Thickness: Up to 250 m.

Members: The members are defined in the Netherlands (van Adrichem Boogaert & Kouwe, 1997) except the uppermost Jagersborg Member, approximately 45 m thick. Part of this member may be of Quaternary age (Sels, Claes & Gullentops, 2001).

Age: Tortonian, Messinian, Zanclean, Piacenzian and Gelasian.

2.3. Overview and symbols of the Neogene lithostratigraphic units

Berchem Formation	Bc
Bolderberg Formation	Bb
Diest Formation	Di
Kattendijk Formation	Kd
Kasterlee Formation	Kl
Lillo Formation	Li
Poederlee Formation	Pd
Mol Formation	Ml
Kiezeloöliet Formation	Kz
Brasschaat Formation	Bs
Merksplas Formation	Me

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