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MAASTRICHTIAN

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(2 figures)

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ABSTRACT. The stratotype of the Maastrichtian Stage named by the Belgian geologist André Dumont in 1849 is situated in the Netherlands at the St Pietersberg.
The original description of the "Maastricht Limestone" is quoted and the successive historical interpretations of the Maastrichtian Stage are outlined. The Maastrichtian Stage in Belgium is then presented in three areas: the Liège-Limburg region, the Mons Basin, and outliers at Orp-Jauche, Orp-le-Petit, as well as Hockai and some other Hautes Fagnes outcrops.

KEYWORDS: Maastrichtian, Maastricht type area, Belgium.

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1. Name

Maastrichtian (English), Maastrichtien (Dutch), Maastrichtiaan (Flemish), Maastricht (ium) (German), Maestrichtien or Maëstrichtien (French : before 1980), Maastrichtien (French after 1980).

2. Age

From 70.6 +/- 0.6 Ma to 65.5 +/- 0.3 Ma (following International Commission on Stratigraphy, ICS 2004)

3. Author

André DUMONT (1849). – Rapport sur la carte géologique du Royaume. *Bulletin de l'Académie royale des Sciences, Lettres et Beaux-Arts de Belgique*, 16, 351-373.
p. 361 : « Le dernier système [maestrichtien, p. 360], dont le nom rappelle celui de la ville de Maestricht, où il est depuis longtemps connu par les fossiles qu'il contient, commence, dans quelques localités de la province de Limbourg, par de la glauconie sableuse ou du calcaire glauconifère ; il comprend le calcaire grossier exploité aux carrières de Maestricht, celui de Folx-les-Caves et de Ciply ; et correspond au calcaire pisolithique du bassin de Paris. »
As far as the three last-named localities are concerned: Folx-les-Caves, Ciply and bassin de Paris (calcaire pisolithique), the chalk of the first is now considered early Campanian in age (Bless *et al.*, 1991c), at Ciply only the phosphatic chalk is early Maastrichtian (not basal : Robaszynski & Christensen, 1989), and the third is of Danian date.

4. Historical type area

Maastricht quarries. Although the underground galleries were worked for building stones and were well known in Dumont's time (and visited by many people, geologists and otherwise), it must have been a natural exposure along the road Lanaye-Maastricht (steep rock face close to the Lichtenberg farm, where now the main office building of ENCI is situated) where Dumont noted his famous sequence, since in the galleries only the Nekum Member of current terminology of the Maastricht Formation is exposed.
Today, the underground quarries form part of a thick lithological succession which is worked for cement in the large ENCI quarry situated in the Netherlands between Maastricht (ND) and Lanaye (B) at the St Pietersberg.

5. Description

In 1849, Dumont named the "système maestrichtien", but he did not describe it in detail. However, previously he gave data on the constitution of what was to become the "étage maestrichtien" in his 1832 Mémoire from where is drawn out what follows.
pp. 294-297 : "Calcaire de Maestricht – Il peut […] être divisé en deux étages".
« Le calcaire […] de l'étage inférieur passe vers le bas à la craie [=Gulpen Formation with Lanaye, Lixhe, Vijlen and Zeven Wegen Members] par nuances insensibles ; mais vers le haut, en prenant une texture plus grenue et une couleur jaunâtre, il acquiert les caractères qui lui sont propres [= Maastricht Formation].

Cet étage [inférieur = Gulpen Fm] se distingue du supérieur [= Maastricht Fm] par des bancs continus de silex [Lanaye Mbr = upper part of the Gulpen Fm] qui d'abord sont puissants, nombreux, de couleur grisâtre, ensuite noirs ; et qui plus haut deviennent moins épais, plus distincts et passent du noir au gris [= Valkenburg, Gronsveld, Schiepersberg, Emael Mbrs of the Maastricht Fm]. » […]
« C'est au point où les couches de silex disparaissent que finit l'étage inférieur [= Gulpen Fm] et que commence le supérieur [= Maastricht Fm].
Le calcaire qui constitue la partie inférieure de ce dernier est plus grenu et généralement plus jaunâtre que celui de l'étage inférieur. Certains bancs sont remplis de fragments de coquilles, de polypiers ou d'échinides […], les silex y sont assez rares et ne sont jamais en couches […].
C'est dans cette partie de l'étage supérieur que sont situées les carrières souterraines de Maestricht [= Nekum Mbr of the Maastricht Fm], […].
La partie supérieure [Meerssen Mbr = upper part of the Maastricht Fm] est peu distincte de la partie inférieure, quoiqu'elle ait généralement une couleur plus foncée et un grain plus gros ; mais elle est caractérisée par du grès blanc, et par la présence dans certains bancs de petits cailloux de quartz noir et de quartz blanc […] ».
Later on, in 1878, Mourlon gathered Dumont's notes and observations on the Cretaceous, and presented more details on the lithology of the "craie" and the "calcaire de Maestricht". It is of note that in this paper the "système maestrichtien" is restricted to the "étage supérieur", which matches the currently employed Maastricht Formation.

6. Historical background

The status of the Maastrichtian Stage has been reconsidered several times following its introduction by Dumont (1849) both in the Boreal and Tethyan realms. The historical evolution of the concept of Maastrichtian Stage in the Maastricht area is presented in Figure 1 (following Robaszynski, 1985b). A detailed review of the historical stratotype of the Maastrichtian has recently been presented by Jagt (2001). In what follows, only several steps in the evolution of use of the stage name will be outlined.
The "type Maastrichtian" of Dumont was defined only on a lithological basis as this author was not really convinced of the usefulness of fossil markers for correlation of distant sections showing diverse lithologies (Dumont, 1847).
In 1912, the "calcaire de Maestricht" which referred to the entire Maastrichtian at that time (as in the interpretation given by Mourlon, 1878), was subdivided into the lithological units Ma, Mb, Mc and Md by Uhlenbroek. However, at the start of the 19th century, there was a tendency to identify stages and stage boundaries by using fossil markers especially cephalopods such as ammonites and belemnites, complemented later on by inoceramids, echinoids and microfossils such as foraminifera, dinoflagellates, calcareous nannofossils, etc.
In the same year, the *"Lanceolata* Beds" (*Belemnitella lanceolata* Zone) were first identified by Arkhangelsky, who assigned them to the Lower Maastrichtian (*fide* Naidin, 1983, 1995, 1998). This lowered the base of the Maastrichtian, also recommended subsequently by Leriche (1929), who characterised the base of the stage by the first appearance datum (FAD) of several fossil species such as *Scaphites constrictus*.
But it is only after Jeletzky's publication on belemnites (1951) that most of the biostratigraphers in the Boreal realm accepted the concept of an extended Maastrichtian Stage equating with the first appearance of *Belemnella lanceolata*. This is the opinion supported, for example, by Van der Heide (1954), Romein (1962), Schmid (1967), W.M. Felder (1975), Christensen (1975), Schulz (1979), Błaszkiewicz (1980) and Schulz & Schmid (1983). The proposals made during the Cretaceous Stage Boundaries Symposium at Copenhagen in 1983 (Birkelund *et al.*, 1984) mark an agreement of a very large majority of earth scientists to place the base of the Maastrichtian in the Boreal realm at the first appearance of *Belemnella (Belemnella) lanceolata*. This matches results obtained by Błaszkiewicz (1980) for the Upper Cretaceous of Poland, who used a zonation based mainly on ammonites and who demonstrated the existence of two additional uppermost Campanian zones (*Didymoceras donezianum* and *Nostoceras pozaryskii* = *N. hyatti*) above the *Bostrychoceras polyplocum* Zone (which was considered by a number of authors to be the last zone of the Campanian), the lower Maastrichtian being characterised by the first occurrence of *B.(B.) lanceolata* and a subspecies of *Pachydiscus neubergicus*.
In Belgium, this zonal scheme was the guide for the study of the Campanian-Maastrichtian boundary in the chalk of the Belgian Limburg and Liège provinces, and of the Mons Basin (Robaszynski *et al.*, 1985 a,b and Robaszynski & Christensen, 1989, respectively).
Since 1990 this scheme has also been the basis for correlation of the Campanian-Maastrichtian boundary in the Tethyan realm. The successive works of Schönfeld & Burnett (1991), Burnett *et al.* (1992), Hancock *et al.* (1992), Kennedy *et al.* (1992), Kennedy & Cobban (1993) and Robaszynski *et al.* (2000), have demonstrated that the extinction of the Tethyan key species planktonic foraminifera *Radotruncana calcarata* (corresponding approximately to the end of the *Bostrychoceras polyplocum* Zone), is well below the Campanian-Maastrichtian boundary.
Nowadays, the base of the Maastrichtian Stage is defined as a GSSP (Global Stratotype Section and Point) in the Tercis section near Dax, SW France (cf. Odin, 2001), and its top equate with the K/T boundary defined at El Kef, Tunisia. It should be noted that the GSSP for the base of the stage uses a combination of a dozen of criteria depending on several bio-marker horizons around the

Figure 1. Historical evolution of the concept of Maastrichtian Stage in the Maastricht area (after Robaszynski *in* Robaszynski *et al.*, 1985b; for literature see this reference).

guide event represented by the first presence of *Pachydiscus neubergicus*. The main "proxies" correspond to appearances or extinctions of ammonites, inoceramids, dinoflagellates, calcareous nannofossils, and planktonic and benthic foraminifera (Odin, 2002).

7. Lithology, sedimentology, palaeogeography, palaeontology, chronostratigraphy, geochronology and structural setting of the Maastrichtian Stage in Belgium

The presentation of the main characteristics of the Maastrichtian Stage in Belgian sections will be arranged according to the geographical position of the outcrops presently available, successively in the Liège-Limburg region (closest to the stratotype area), the Mons Basin and in some outliers in Haute-Ardenne (Hockai) and in the Méhaigne valley (Orp-Jauche). This is justified by the simple reason that the Maastrichtian is quite different in these regions.

7.1. The Liège-Limburg region

7.1.1. Lithology

a. General description. The lower part of the stage consists of a fine-grained white chalk which passes progressively in the upper part (in the extended sense, following Jeletzky, 1951) to a fine to coarse and then very coarse-grained calcarenite ("calcaire grossier" or "tuffeau"). Flint nodules are distributed all along the succession : some black flints are present in the basal fine white chalk and become more abundant up to the upper white chalk where nodules are blue-grey and form beds. Above, in the coarse-grained calcarenites, flint nodules are light grey to grey and randomly distributed, and they become very rare in the upper part. *In situ* flints are absent in the Meerssen Member which is the uppermost part of the Maastricht Formation
Total thickness : 120 to 170 m and more.

b. Formations and Members (following the description of Robaszynski *et al.*, 2002).
From the base to the top:

GULPEN FORMATION (upper part of this unit)

Vijlen Member (15-25 m, locally about 100 m): yellowish grey, glauconitic fine-grained chalks, with basal glauconite-rich portion. On mesofossil evidence, the Member was subdivided into 7 intervals (0-6) in the type area (P.J. Felder & Bless, 1994).

Lixhe Member (up to 25 m): white, fine-grained chalks with irregular dark blue-grey to black flint nodules. West of the River Meuse a three-fold subdivision is possible on flint type and abundance.

Lanaye Member (about 20 m): white, fine-grained chalks with a maximum of 23 light to dark blue-grey flint bands.

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Valkenburg Member (2.5 to 45 m): poorly indurated, white to yellowish grey, fine to coarse-grained calcarenites with greyish brown flint nodules of varying size. Base with coarse-grained, phosphatic/glauconitic and pyritic bioclastic sand.

Gronsveld Member (4.5 to 10 m): poorly indurated, white to yellowish grey, fine to coarse-grained calcarenites. Dark flint nodules in the lower portion, arranged in more or less regular beds in the higher portion.

Schiepersberg Member (5 to 6 m): poorly indurated, white yellowish, fine to coarse-grained homogeneous calcarenites with numerous regular beds and randomly distributed, light-grey to bluish-grey flint nodules.

Emael Member (5 to 7.5 m): same calcarenites as below, with grey flint nodules, some of which are highly typical (large, regular flat and pipe-shaped).

Nekum Member (7 to 15 m): poorly indurated, white yellowish, coarse-grained, homogeneous calcarenites, in its lower part with few randomly distributed greyish brown flint nodules. In past centuries, the quarry galleries for building stones were excavated mostly in this Member.

Meerssen Member (7 to 15 m): same calcarenites as above, coarse to very coarse-grained, with clearly developed hardgrounds and fossils, hash layers and omission surfaces. Flints are absent.

c. Stratotypes

Vijlen Mbr: road cutting between Mamelis and Bocholtzerheide, on the Dutch-German border (coordinates: 312.330/196.450).
Lixhe Mbr: disused Dierkx quarry, Lixhe, Belgium (coord.: 308.400/174.500).
Lanaye Mbr: western portion of Albert Canal outcrop, north of bridge at Lanaye, Belgium (coord.: 311.000/176.150).
Valkenburg Mbr: disused quarry east of Valkenburg aan de Geul, The Netherlands (coord.: 318.520/186.770).
Gronsveld Mbr: quarries east of Gronsveld, The Netherlands (coord.: 314.050/180.150).
Schiepersberg Mbr: disused quarry at Cadier en Keer, The Netherlands (coord.: 315.880/182.680).
Emael Mbr : Marnebel quarry, Emael, Belgium (coord.: 310.850/175.050).
Nekum Mbr : disused de Tombe quarry, St Pietersberg, Maastricht, The Netherlands (coord.: 315.130/175.350).
Meerssen Mbr: Ankerpoort-Curfs quarry, Geulhem, The Netherlands (coord. 320.120/182.100).

7.1.2. Lateral variations

From Belgian Liège-Limburg towards the Dutch part of the Rur Valley in the NE, the fine-grained and soft chalks of the Gulpen Formation (Vijlen, Lixhe and Lanaye Members, in the CPL-Haccourt = Halembaye quarry) pass laterally to the "pre-Valkenburg strata" which consist of a silty to sandy, frequently glauconitic marl (P.J.Felder *et al.*, 1985; Bless *et al.*, 1987). In the same way, the white to yellowish coarse-grained calcarenites of the Maastricht Formation (Valkenburg to Emael Members) pass towards the NE into the "Kunrade Limestone" characterised by cyclic alternation of chalk beds of varying induration.

7.1.3. Sedimentology and palaeogeography

In the chalks and calcarenites of the Gulpen Formation and the Maastricht Formation, the study of grain size and of the distribution of macro- and microfossil bioclasts (benthic agglutinated foraminifera, echinoids, crinoids, belemnites, prismatic bivalves, bryozoans…) has led to well-defined ecozones which show a gradient from the Rur Block towards the SW (Halembaye for example), see P.J. Felder & Bless (1994).

From east to west, the Early to Late Maastrichtian Vijlen, Lixhe, Lanaye and "Kunrade" chalks or calcarenites overlap the Vaals Formation of Santonian to earliest Campanian age. These members correspond to subtidal, tidal or intertidal environments with high-energy in the eastern settings whereas in the western part calcareous nannofossil chalks formed, for example at Halembaye and Lixhe (cf. Bless & Fernandez Narvaiza, 1996, 2000).

7.1.4. Palaeontology

For more than two centuries in NE Belgium, large and small quarries have enabled large-scale collecting of macrofossils, especially of belemnites which constitute, with ammonites, the best correlation tools yet. In the second half of the 20th century, microfossils were also intensively used for stratigraphic correlations especially in the case of boreholes (benthic foraminifera following Hofker 1966, calcareous nannofossils, dinoflagellates…). Below are listed some macro- and microfossil markers, significant for example to distinguish the early from the late Maastrichtian.

Early Maastrichtian

Belemnites : *Belemnitella pulchra*, *Bt.* ex. gr. *junior, Belemnella (Belemnella) lanceolata*, *Bn. praearkhangelski* and *Bn. fastigata*, *Bn.*(*Pachybelemnella) inflata*, *Bn.(P.) obtusa*, *Bn.(P.) sumensis* and *Bn.(P.) cimbrica*. Ammonites : *Scaphites gibbus*, *Trachyscaphites spiniger*, *Acanthoscaphites (A.) tridens*, *A. (Euroscaphites) varians blaszkiewiczi*, *Pachydiscus neubergicus*. Foraminifera : *Bolivinoides regularis*, *B. australis* (with 6 pustules on the last chamber), *B. draco miliaris*, first *B. draco draco*, last *Eponides beisseli*. Ostracods : *Bythoceratina laevis*. Calcareous nannofossils : *Eiffelithus eximius, Broinsonia parca*, *Lithraphidites praequadratus.*

Late Maastrichtian

Belemnites : *Belemnitella junior*, *Belemnella (Neobelemnella) kazimiroviensis*. Ammonites : *Baculites vertebralis, Pachydiscus gollevillensis, P. jacquoti, Sphenodiscus binckhorsti, Menuites terminus, M. fresvillensis, Hoploscaphites constrictus, Jeletzkytes dorfi.* Brachiopods : *Thecidea papillata, Trigonosemus pectiniformis.* Serpulids : *Pyrgopolon mosae.* Inoceramids *: Tenuipteria argentea, Spyridoceramus tegulatus.* Echinoids : *Oolopygus pyriformis, Hemiaster prunella, Hemipneustes.* Vertebrates : *Mosasaurus, Alloppleuron, Plioplatecarpus.*

7.1.5. Biozonations

The two zonations generally used are based on belemnites and benthic foraminifera (Figure 2).
For belemnites, the lower Maastrichtian is subdivided into 6 interval zones defined by species of the genus *Belemnella*, from the base to the top : *lanceolata*, *pseudobtusa, obtusa,*

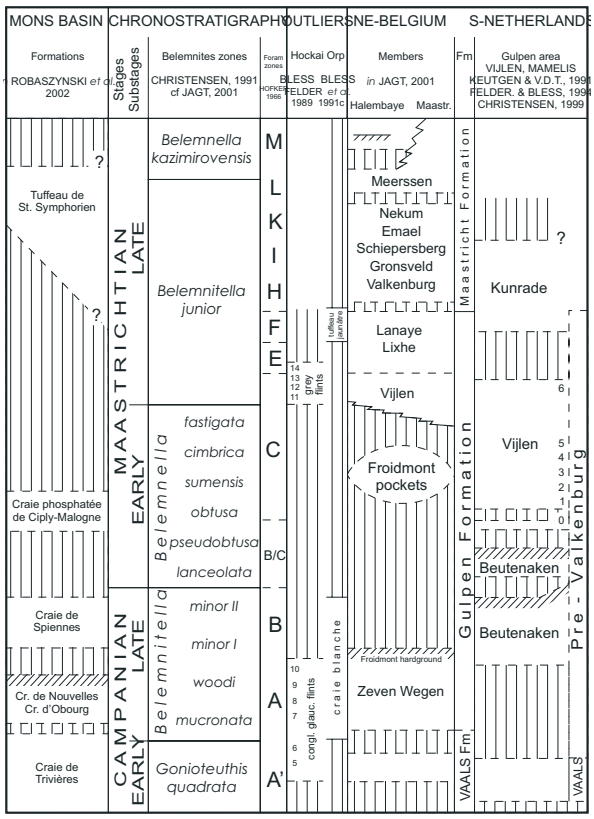

Figure 2. Stratigraphical position of main lithological units of the Maastrichtian Stage in Belgium and the southeast Netherlands.

sumensis, cimbrica and *fastigata*. The base of the Maastrichtian Stage is very near the first occurrence of *B. lanceolata* (Christensen *et al.*, 2000). The upper Maastrichtian is divided into two zones : *Belemnitella junior* at the base and *Belemnella kazimiroviensis* at the top.
The benthic foraminiferal zonation of the upper Campanian and Maastrichtian is based on assemblage zones defined by Hofker (1966). From the base to the top : A : with *Gavelinella clementiana* and *Bolivinoides decoratus* (3-4 pustules on the last chamber); B : *Eponides beisseli* and *Bolivinoides australis* (4-5 p.); C : *Neoflabellina praereticulata* and *B. australis* (5-6 p.); D : with *B. draco*; E : *N. reticulata* and *B. australis* (6-7 p.); F : *B. gigantea* (> 7 p.); H : *Pararotalia tuberculifera*; I : "transition zone"; K : first *Daviesina fleuriausi*; L : sudden development of Tethyan forms : *Orbitoides apiculata*, *Lepidorbitoides minor*, *Nummofallotia cretacea*…; M : added are *Siderolites laevigatus, S. calcitrapoides* and *Daviesina labanae.*
Hofker (1966) placed the Campanian-Maastrichtian boundary between zones A and B, an opinion followed by Robaszynski *et al.* (1985 a,b). However, Robaszynski & Christensen (1989), on the basis of belemnite records in the Mons Basin, assumed the base of the Maastrichtian to be between zones C and D.

7.1.6. Geochronology

In 1975, Priem *et al.* published geochronological data obtained from samples at the base of the Vijlen Member near the Campanian-Maastrichtian boundary : about 71 to 72 Ma. Odin (2001, p. 758) commented on these data and considered this age "not far from the Campanian-Maastrichtian boundary", "The mean age of 71.5 Ma can be used to characterise the age of the boundary…"

7.1.7. Structural setting

Following Bless *et al.* (1987) and Vandenberghe *et al.* (2004), during the Late Campanian to the middle Late Maastrichtian, the southern border of the Rur Valley was a shallow-marine nearshore facies (Pre-Valkenburg and Kunrade chalks) and, to the west (Limburg), the facies becomes relatively deeper, more open-marine (Gulpen white chalks and Maastricht calcarenites). The sea level rises during Santonian to Late Maastrichtian. Near the Santonian-Campanian boundary, inversion of subsidence caused uplift of the Rur Valley which became a source of clastic sediments. During the Late Campanian and early Late Maastrichtian, warping of tectonic blocks produced gaps and condensed sequences (with hardgrounds). In the Late Maastrichtian, relaxation of inversion movements coincided with a new rise of the sea level which triggered invasion of Tethyan organisms: large benthic foraminifera such as *Lepidorbitoides*, echinoids as *Hemipneustes*, corals, crabs and rudistid bivalves etc.

7.1.8. Sections

Haccourt-Halembaye : CPL quarry
Lixhe : disused North quarry

7.2. The Mons basin

7.2.1. Lithology

a. Description of formations
There are only two facies of Maastrichtian age in the Mons Basin since the underlying Craie de Spiennes Formation is considered to be Late Campanian in age on belemnite evidence (Robaszynski & Christensen, 1989; *contra* Leriche, 1929).

CIPLY-MALOGNE PHOSPHATIC CHALK FORMATION (*in* Robaszynski *et al.*, 2002)

Cohesive or crumbly calcarenite, intensely bioturbated, consisting of phosphate granules within a chalky matrix. The granules are brown in outcrops, but grey in boreholes (no oxidation). The average P_2O_5 is around 8%. Bands with black or brown flints with phosphate grains are sometimes intercalated. Fossils are common (cf Robaszynski & Poels, 1988 and Poels & Robaszynski, 1988)
At the margins of the phosphatic basin, the base of the Formation is marked by a conglomeratic level with chalk gravel, sponges, fragments of baculitid ammonites, all of them phosphatised whereas in the central part of the basin there is a continuous transition between the underlying Spiennes Chalk Formation and this unit.
The top of the Formation is almost always marked by a conspicuous hardground, often complex in structure, 0.4 to 1.4 m thick, which was the roof of the underground quarries of the La Malogne area where the phosphatic chalk was worked at the end of the 19th century.

SAINT-SYMPHORIEN CALCARENITE FORMATION

Crumbly, porous, poorly cemented, grey when fresh, yellow to brownish at the altered surface, often bioturbated, calcarenites or calcirudites. Locally, the calcarenites may contain grey, green or brown phosphatised granules or pebbles. One or more flint bands may be intercalated within the calcarenite (or "Tuffeau" in the literature).
Numerous fossils are present: scaphopods, echinoid spines, oysters and other bivalves, belemnite guards, brachiopods… The base of the Formation is often clearly distinguished by the presence of an indurated and phosphatised chalk pebble conglomerate; the top is generally a hardground of 0.10 to 0.40 m thickness, but known in places to reach 1.40 m, burrowed, with bivalve and gastropod internal moulds and small pyrite crystals.

b. Stratotypes.

No stratotypes have been designated for these two formations. At present, for the Ciply-Malogne Formation, the only good outcrops are in the underground quarries of La Malogne below the village of Cuesmes a few km SW of Mons, and, for the St-Symphorien Formation outcrops are covered by vegetation in abandoned quarries at St-Symphorien and in parts of the Vandamme (formerly André) quarry at Ciply.

c. Thicknesses

For the Ciply-Malogne Fm: one to a few metres on the margin of the Ciply and Baudour basins, up to 76 m in the centre of the Ciply basin. In the underground quarries of La Malogne, the Formation has a thickness of 10 to 12 m.
For the St-Symphorien Fm: from one to a few metres but sometimes absent between the underlying Ciply-Malogne Fm and the overlying Ciply Calcarenite (of Paleocene age). Reaches about 10 m in boreholes near Ciply.

7.2.2. Palaeontology

The Ciply-Malogne Formation has provided cephalopods such as Belemnella obtusa, Belemnitella pulchra, Bt. minor II, Pachydiscus cf. neubergicus, Hoploscaphites constrictus, Baculites knorrianus, B. baculus. Brachiopods : Trigonosemus palissyi. Benthic foraminifera : Praebulimina laevis, Osangularia navarroana, Neoflabellina reticulata, Bolivinoides australis (5-6 pustules on the last chamber), Gavelinella bembix. Vertebrates : Hainosaurus bernardi, Mosasaurus lemonnieri, Prognathodon solvayi.
The Saint-Symphorien Formation contains numerous brachiopods such as craniids, Thecidea papillata and bivalves such as Trigonosemus pectiniformis which are good regional markers. The benthic foraminiferal content is also rich with : Mississipina binckhorsti, Bolivinoides gigantea (7-9 pustules on the last chamber), Coleites reticulosus and Tethyan forms such as Daviesina fleuriausi, Lepidorbitoides minor and Siderolites calcitrapoides (after Hofker, 1960 and Villain, 1974, 1977).

7.2.3. Biozonations

The Ciply-Malogne Phosphatic Chalk Formation represents the *Belemnella obtusa* Zone in terms of belemnite zonation (Christensen, 1999), indicating the top of the lower part of the Early Maastrichtian. Amongst benthic foraminifera, the presence of *Bolivinoides australis* (5-6 pustules on the last chamber) and the first *Neoflabellina reticulata* indicates zone C of Hofker (1966).
The Saint-Symphorien Formation does not clearly outcrop at present and its belemnite content has never been studied in detail. Benthic foraminifera were studied from a single outcrop (Hofker, 1960) and from boreholes (Villain, 1974,1977). The presence of Tethyan forms suggests the Formation belongs to the zone L or zones K-L of Hofker (1966), that is to say high in the Late Maastrichtian. Perhaps it also includes equivalents of lower portions of the Maastricht Fm if we take into account the occurrence of certain trigoniid bivalves in both facies (Jagt, *in litt*.).

7.2.4. Sections

Outcrops or old quarries cited in the literature are now filled or overgrown by vegetation, for example the disused quarries of St-Symphorien and Ciply (Vandamme quarry). Nevertheless, the Formation is known in boreholes and is always recognised by the presence of *Thecidea papillata*, generally abundant.

7.3 Outliers

7.3.1. Orp-Jauche

In the valley of Petite Gette (eastern Brabant), the underground quarry "Folx-les-Caves" shows, above the early Campanian Folx-les-Caves Chalk Member ("craie arénacée"), the Jauche Member which consists of calcarenites with *Thecidea papillata*, a brachiopod marking the upper Maastrichtian (for references on the Jauche Member, see 2.3.3. in Robaszynski *et al.*, 2002).

7.3.2. Orp-le-Petit

Two lithological units are distinguished (Bless *et al.*, 1991c), in ascending order:

"craie blanche" (4.30 m) with flints, quartz and phosphatic grains; with *Magas*, *Bolivinoides decoratus* at the base (= Late Campanian correlated with Upper Trivières and Obourg-Nouvelles Chalks Formations of the Mons basin) and, higher, partly with Beutenaken Mb, and Spiennes Chalk Formation in the Mons Basin);
"tuffeau jaunâtre" (1.10 m) : coarse-grained biocalcarenite with flints, with *Thecidea papillata*, *Belemnitella* gr. *junior, Bolivinoides* gr. *draco*, *B. giganteus*, *Siderolites* and *Daviesina* (Late Maastrichtian, correlated with the Saint-Symphorien Calcarenite Formation in the Mons Basin).

7.3.3. Hockai

In the Hautes Fagnes (NE Belgium), Cretaceous deposits have been studied in the railway cutting at Hockai (Bless & Felder, 1989). They comprise an early Campanian conglomerate, overlain by glauconitic sands with flints of late Campanian age and by a residual sandy loam of late Maastrichtian date. The residual sandy loam with grey flints (7m thick) may have been derived from a chalk similar to the top of the Vijlen and Lixhe Members as

exposed for example at the CPL Halembaye quarry. The absence of lower Maastrichtian suggests that the Hautes Fagnes were subject to the same tectonic movements as in southern Limburg.
The silicified benthic foraminiferal content of the residual sandy loam includes *Bolivinoides australis* (5-7 pustules on the last chamber.), a marker of zone C- base E of Hofker (1966), which is early to early late Maastrichtian in age.

7.3.4. Other Hautes Fagnes outliers

On the Hautes Fagnes plateau, several localities show residual Cretaceous deposits where some silicified benthic foraminifera were preserved in sandy loams with flints (Bless *et al.*, 1991a,b) as some macrofauna (Dhondt & Jagt,1997).

Trois-Hêtres: *Bolivinoides australis* (5 pustules on the last chamber) : zone C
Beleu: *B. australis* (5-6 p.) and *Neoflabellina reticulata* : zone E
Mont Rigi: *B. australis* (5-7 p.) and *N. reticulata* : zones C-E
Neu-Hattlich: *B. australis* (5-7 p.) and *N. reticulata* : zones C-E
Strata at all these localities are of early Late Maastrichtian age.

Drain Vequée: ?*Placunopsis granulosa* (bivalve of Campanian-Maastrichtian age), *Isocrania* gr. *costata* (brachiopod of Campanian-Maastrichtian age)
Croix des Fiancés: *Diplodetes* sp. (echinoid of Maastrichtian age)

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