GEOLOGICA BELGICA (2001) 4/1-2: 69-94

Dinantian lithostratigraphic units (Belgium)

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(6 figures)

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ABSTRACT. Six paleogeographic sedimentation areas (s. a.) are recognized in the Namur-Dinant Basin: (1) the Hainaut s. a., (2) the Namur s. a., (3) the Condroz s. a., (4) the Dinant s. a., (5) the Visé-Maastricht s. a., and (6) the southern Avesnois s. a. (only in northern France). Together with the sea-level variations (third-order sequences), local controls influenced the nature of the sedimentary deposits, so the lithostratigraphic successions in each sedimentation area are distinctive. The depositional setting was that of a carbonate platform which evolved from a ramp in the early Tournaisian to a rimmed shelf during the early Viséan and then to a regionally extensive shelf during the middle and late Viséan. Before the Livian, open marine facies were developed to the south, but from the Livian onwards open marine facies were restricted to the north while evaporites developed in the south. This inversion of the normal pattern was probably related to an early phase of Variscan shortening. Dinantian biostratigraphy is mainly based upon foraminifera, rugose corals and conodonts. Fifty formations (including members), 3 groups and 2 informal lithostratigraphic units are briefly described.

KEYWORDS: Dinantian, Belgium, Lithostratigraphy.

REFERENCE TO THIS VOLUME. Poty, E., Hance, L., Lees, A. & Hennebert, M., 2001. Dinantian lithostratigraphic units (Belgium). In Bultynck & Dejonghe, eds., Guide to a revised lithostratigraphic scale of Belgium, *Geologica Belgica*, 4/1-2: 69-94.

1. Introduction

The synthesis of the bio- and lithostratigraphy of the Dinantian of Belgium published by Paproth *et al.* in 1983, followed an earlier one by Mortelmans & Bourguignon (1954) which was based on more than a century of investigations. The 1983 synthesis included the numerous advances in sedimentology and biostratigraphy which had occurred during this period and proposed a stratigraphic chart of the Dinantian which until now served as a reference for the Tournaisian and Viséan series.

The resumption of the geological mapping in 1990, after a pause of almost a century, has provided many new observations, but has also raised new questions stimulating a revision of the existing lithostratigraphic scheme.

Re-evaluation, by Hance *et al.* (2001), of the Dinantian biostratigraphic pattern and the application of the concept of sequence stratigraphy to the whole Dinantian succession of southern Belgium, northern France (Avesnois, Boulonnais) and south-west England (Bristol area), has improved the understanding of the sedimentary history and clarified the stratigraphic succession of the sedimentary units in many places. In particular, the recognition of a third-order sequence (sequence 5 of Hance *et al.*, 2001, corresponding to most of the Sovet Fm), developed only in the deeper part of the outer shelf and missing on the shallow shelf, has led to a better understanding of the Tournaisian-Visean boundary and more accurate lithostratigraphic correlations. In addition, the identification of paleogeographic sedimentary areas distinct from the structural units inherited from the Variscan orogeny and

having their own tectono-sedimentary history, has shed some light on several lithostratigraphic features. These include, for example, the lithostratigraphic changes recorded in the Visé area, and the absence of Ivorian deposits in the Huy – Engis area.

These developments justify the updating of the synthesis of Paproth *et al.* (1983).

2. Geological and paleogeographical setting
(figs 1,2)

The Dinantian Subsystem of southern Belgium and south-western England lies in the northwestern part of the Rheno-Hercynian Fold Belt. In southern Belgium, outcrops are distributed on both sides of the Midi-Eifel fault zone and occur in two main structural units (Fig. 2A). From north to south these are: (1) the Brabant Parautochthon of Hance *et al.* (1999) and Mansy, *et al.* (1999), also formerly known as the Namur Synclinorium, (2) the Ardenne Allochthon of the same authors. These structural units were part of the Namur-Dinant Basin during the time of deposition. The following sedimentation areas (Fig. 2B) can be recognized (Poty, 1997; Hance *et al.*, 2001):

– The **Hainaut sedimentation area (HSA)** ("Auge Hennuyère" of Paproth *et al.*, 1983) was an area in which subsidence allowed accumulation of about 2500 m of Dinantian rocks, including several thick evaporitic intercalations (Groessens *et al.*, 1982, Rouchy *et al.*, 1993).

– The **Namur sedimentation area (NSA)** displays an incomplete stratigraphic succession characterized by proximal facies. The total thickness increases locally from south to north due to tectonic tilting in the eastern part of the area (Poty, 1997). The Dinantian succession of the Boulogne area (northern France) is similar (Hoyez, 1971; Poty, 1994).

– The **Condroz sedimentation area (CSA)** also exposes proximal facies with stratigraphic gaps in the east and a more complete succession to the west.

– The **Dinant sedimentation area (DSA)** ("Auge dinantaise" of Paproth *et al.*, 1983) was strongly influenced by the development of thick Waulsortian buildups which formed a discontinuous barrier, during the Late Tournaisian. Relatively deep water sedimentation occurred in the depression lying between the transition to the inner shelf to the north and the Waulsortian buildups to the south.

– **The Visé-Maastricht sedimentation area (VSA)** was of local extent and suffered block faulting during Devono-Carboniferous. It was connected with the NSA during the Upper Devonian and Tournaisian and evolved to a graben which was open to the Campine Basin during the Viséan but separated from the NSA by the Booze –

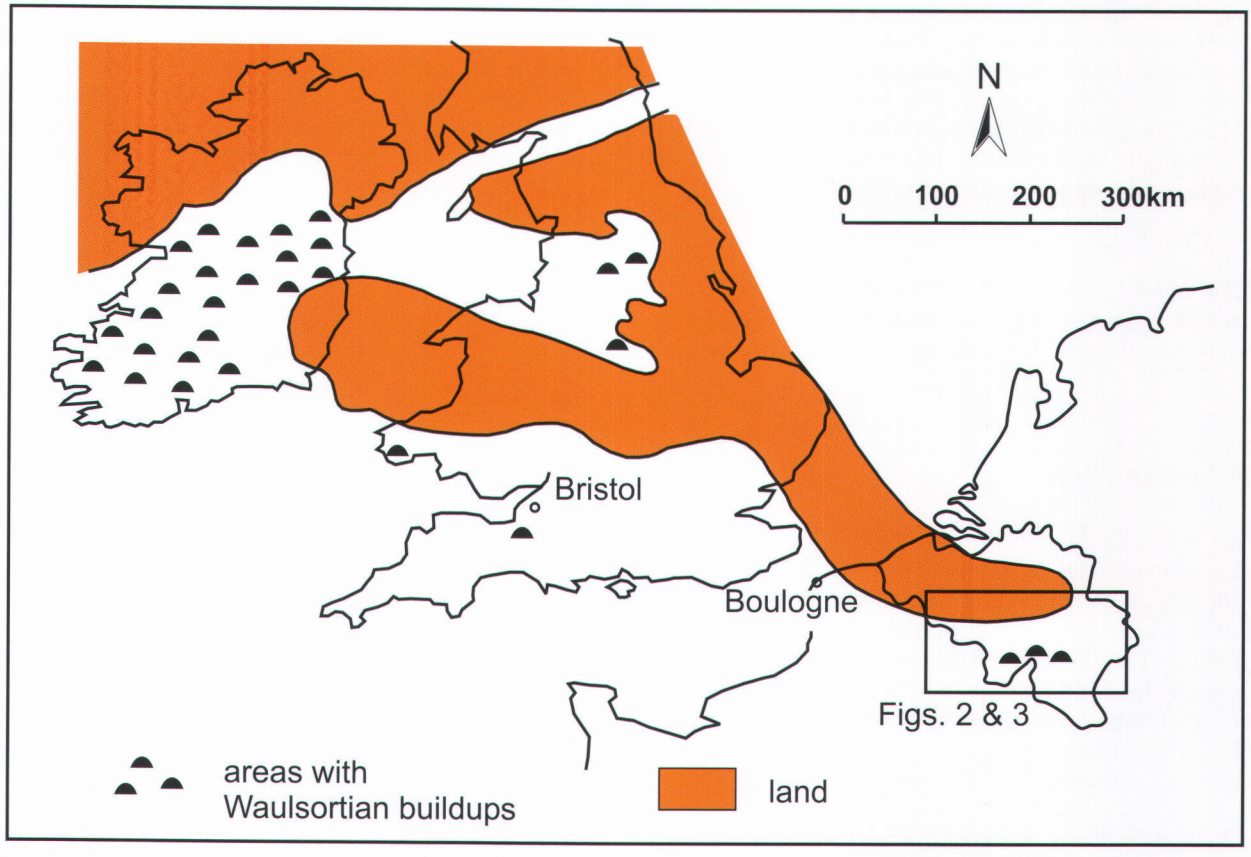

Figure 1. General context of Dinantian sedimentation in north-western Europe. Distribution of emergent areas and Waulsortian buildups at the end of the Tournaisian.

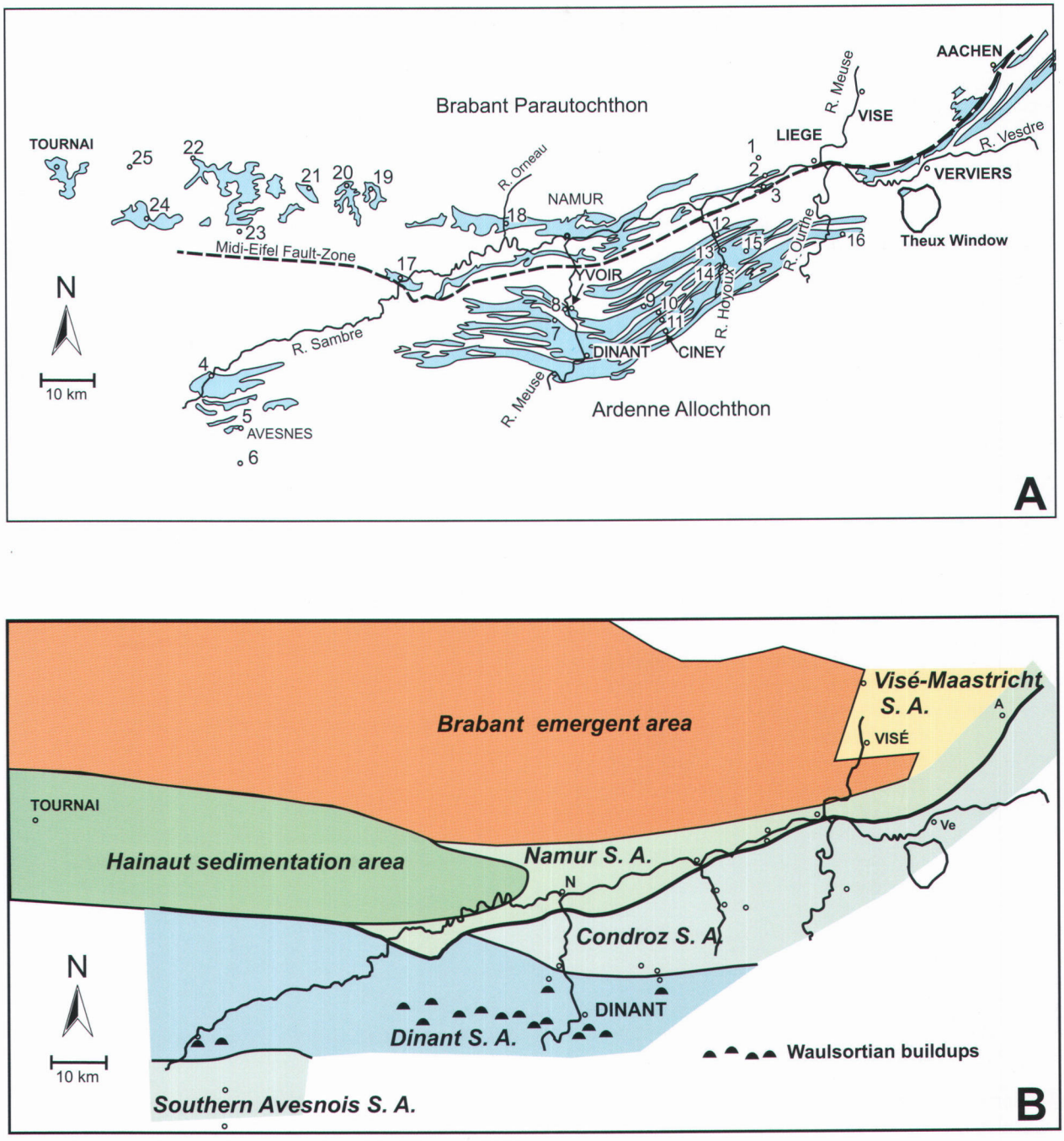

Figure 2. A. Distribution of Dinantian rocks in southern Belgium and northern France (Avesnois).1, Horion-Hozémont; 2, Chokier-Flémalle; 3, Engihoul; 4, Bachant; 5, Avesnes; 6, Etroeungt; 7, Salet; 8, Yvoir; 9, Sovet; 10, Halloy; 11, Ciney; 12, Royseux; 13, Modave; 14, Les Avins; 15, Terwagne; 16, Comblain; 17, Landelies; 18, Onoz; 19, Feluy; 20, Ecaussines; 21, Soignies; 22, Ath; 23, Saint-Ghislain; 24, Basècles; 25, Leuze. B. Dinantian sedimentation areas in the Namur-Dinant Basin (not palinspastic).

Val-Dieu ridge (Poty, 1997). The Dinantian of this area outcrops only in the vicinity of Visé where the succession includes numerous stratigraphic gaps.

– The **southern Avesnois sedimentation area (ASA)**, northern France, of which the eastern extent is unknown, displays facies similar to those in the CSA. The northern Avesnois, where Dinant-type facies occur, belongs to the Dinant sedimentation area.

After the late Devonian regression, the depositional setting was that of a carbonate platform which evolved from a ramp in the early Tournaisian to a rimmed shelf during the early Viséan and then to a regionally extensive shelf during the middle and late Viséan (Hance *et al.*, 2001). The shoreline was situated along the southern border of the Brabant emergent area.

3. Stratigraphic setting (figs 3,4)

Dinantian biostratigraphy is mainly based upon foraminifera, rugose corals (Poty, 1985) and conodonts. The biozonation synthesis published by Conil *et al.* (1991) is followed here except for minor corrections and refinements (Hance *et al.*, 2001).

The Devonian/Carboniferous (D/C) boundary is defined by the entry of the conodont *Siphonodella sulcata* within an evolutionary lineage *S. praesulcata – S. sulcata*. This entry follows the Hangenberg event, responsible for the demise of Devonian fauna and reflecting a drastic sea-level drop (Paproth, 1986; Dreesen *et al.*, 1988). In southern Belgium, this event is recorded by a metre-thick bed of rudstones and grainstones with lithoclasts, ooids, crinoids and a reworked Devonian fauna. The D/C boundary has classically been placed at its top, but the diagnostic conodont is lacking at this level (Paproth *et al.*, 1983; Conil *et al.*, 1986).

The boundary between the Dinantian and Silesian subsystems corresponds to Viséan/Namurian (Serpukhovian) boundary, whereas the Mississippian/Pennsylvanian boundary corresponds to the Serpukhovian/Bashkirian boundary.

The Dinantian is divided into two series, Tournaisian and Viséan. Five stages were distinguished by Conil *et al.* (1977) and Paproth *et al.* (1983), from base to top: Hastarian (Lower Tournaisian), Ivorian (Upper Tournaisian), Moliniacian (Lower Visean), Livian (Middle Viséan) and Warnantian (Upper Visean). However, subsequent work (Conil *et al.*, 1989) has shown that the Ivorian/Moliniacian boundary (base of Cf4α1 foraminifera Subzone) does not correspond to, and is lower than the Tournaisian/Viséan boundary (which lies at the base of Cf4α2).

Nine third-order sequences have been recognized by Hance *et al.* (2001) in the Dinantian of Belgium and northern France. The earliest of these starts in the latest Famennian and extends across the D/C boundary.

4. General evolution of the Namur-Dinant basin during the Dinantian

The Hastarian succession displays rather similar facies throughout the Namur-Dinant Basin, reflecting a homoclinal ramp setting. Lithostratigraphic correlations are well documented. Towards the north, formations thin and stratigraphic gaps increase.

During the Ivorian, the facies pattern was more varied. Inner ramp facies cover the Namur-Condroz and southern Avesnois areas, whereas outer ramp facies are restricted to the Dinant area where a discontinuous barrier of Waulsortian buildups developed. During the upper Ivorian, the ramp evolved to a shelf and a break of slope separating the inner and outer shelf facies prograded southward and reached the Ciney-Yvoir line during the earliest Viséan. A deep-water basin with culm facies may have existed to the south, as in southwest England and southwest Ireland, but this is not exposed.

Submarine topographic irregularities produced during the Tournaisian by varying sedimentation rates including, notably, growth of Waulsortian buildups, were smoothed out by late Moliniacian times. After that time, middle and late Viséan sedimentation across the area from western Germany to southern Ireland was governed by an aggrading shelf with parasequences of wide extent.

During the Livian, open marine facies were restricted to the north, while evaporites developed in the south. This inversion of the normal pattern was probably related to an early phase of Variscan shortening.

Warnantian deposits are locally missing. In the DSA this gap only includes the uppermost Warnantian and basal Namurian (E1 goniatite Zone), whereas in the northern part of the NSA it extends stratigraphically downwards to the uppermost Livian. Silesian siliciclastic deposits overlie the Visean limestones.

5. Formal lithostratigraphic units (figs 5, 6)

In this section, the lithostratigraphic units are briefly described. Bibliographic references are usually limited to the first nominative citation of the unit and those containing significant information. Further references concerning their sedimentology or their stratigraphy can be found in Paproth et al., 1983 and Hance et al., 2001. Synonyms are given in Paproth et al.

Fifty-three units are presented here, arranged in order of their age, from the oldest to the youngest.

5.1. Hastière Formation – HAS

Authors: de Dorlodot, 1895; Van Steenwinkel, 1980; Paproth *et al.*, 1983.

Description: The formation can be divided into 3 members. The lower member ("Tn1bα") starts in the DSA with a metre-thick grainstone to rudstone overlain by thin-bedded crinoidal packstones interbedded with shales. The middle member ("Tn1bβ") consists of thick-bedded crinoidal packstones. The upper member ("Tn1bγ") is similar to the lower member, but it is usually more shaly.

Stratotype: Abandoned and partly filled quarry (the Demanet quarry in de Dorlodot, 1895) along the road from Hastière-Lavaux to the hamlet of Insemont, in front of the Pont d'Arcole cave (DSA). The section by the railway bridge at Anseremme, south of Dinant, is a parastratotype.

Area: This unit can be recognized almost everywhere in the Namur-Dinant Basin.

Thickness: In the DSA, the formation has a thickness of about 20 to 35 m, whereas it is only 7.25 m thick in the eastern NSA (Vesdre area).

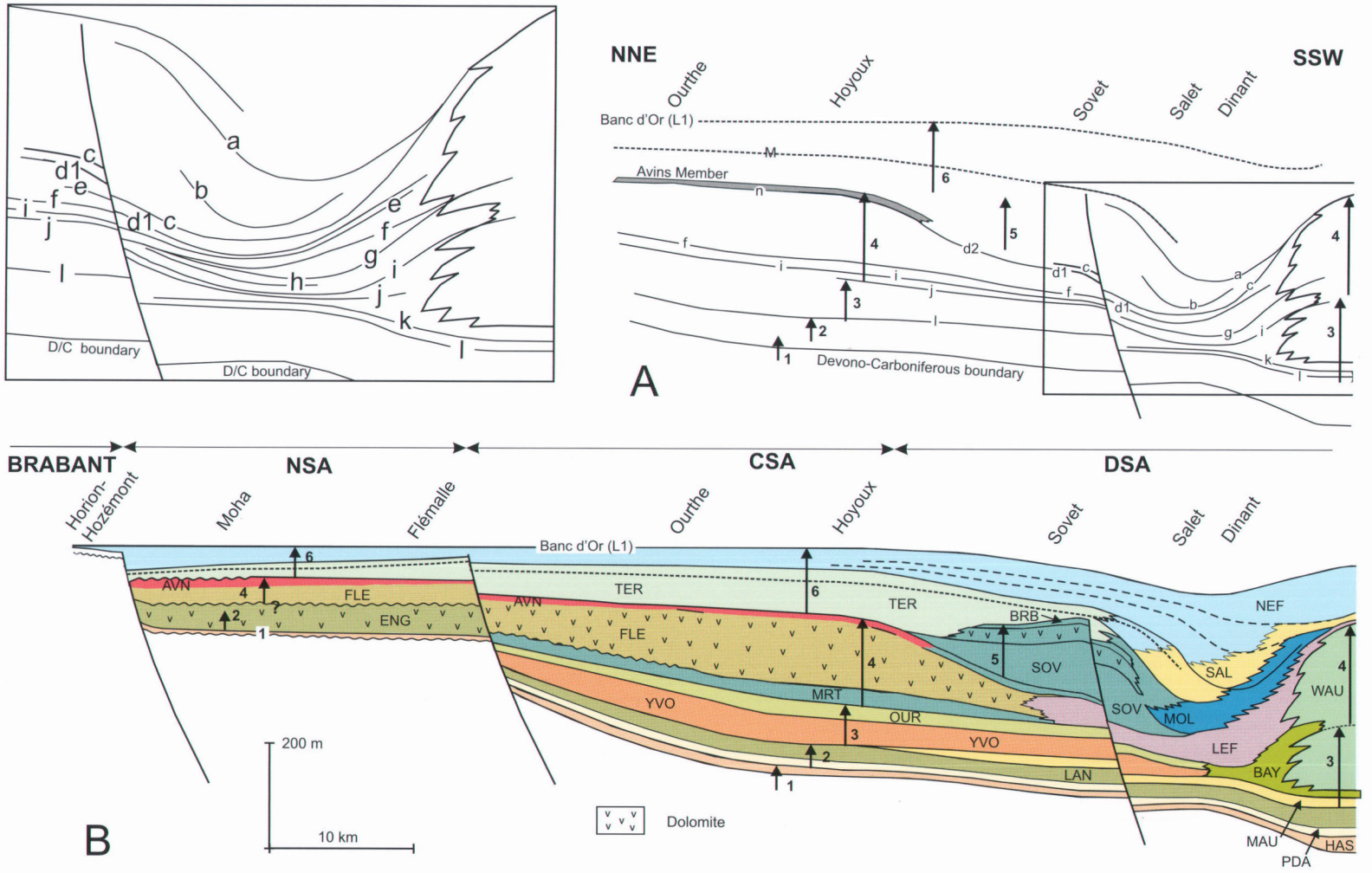

Figure 3. A. Main criteria used for correlation across the Namur-Dinant Basin during the Tournaisian and Lower Viséan. The third-order sequences are indicated with numbered black arrows. The boxed area is enlarged on the left of the figure. The correlation criteria are first appearances unless otherwise stated. a, *Paraarchaediscus* sp.; b, primitive Archaediscidae; c, *Eoparastaffella* morphotype 2; d1, *Mestognathus praebeckmanni*; d2, *Biseriella bristolensis*; e, *Polygnathus bischoffi*; f, last occurrence of *Polygnathus communis communis*; g, *Doliognathus latus*; h, *Scaliognathus anchoralis europensis*; i, *Dollymae bouckaerti*; j, *Eotaphrus bultyncki*; k, *Polygnathus communis carina*; l, last occurrence of *Siphonodella*; n, *Levitusia humerosa* and *Amygdalophyllum* sp.; L1, M, bentonites. B. Organization of Tournaisian and Lower Visean third-order sequences (numbered black arrows) across the Namur-Dinant Basin. The clinoform profile of sequences 4 to 6 indicates the importance of progradation. NSA: Namur sedimentation area; CSA: Condroz sedimentation area; DSA: Dinant sedimentation area. Formations: BAY: Bayard; ENG: Engihoul; HAS: Hastière; LAN: Landelies; LEF: Leffe; MRT: Martinrive; MAU: Maurenne; MOL: Molignée; NEF: Neffe; OUR: Ourthe; PDA: Pont d'Arcole; SAL: Salet; SOV: Sovet; TER: Terwagne; WAU: Waulsort; YVO: Yvoir. Members: AVN: Avins; BRB: Braibant; FLE: Flémalle.

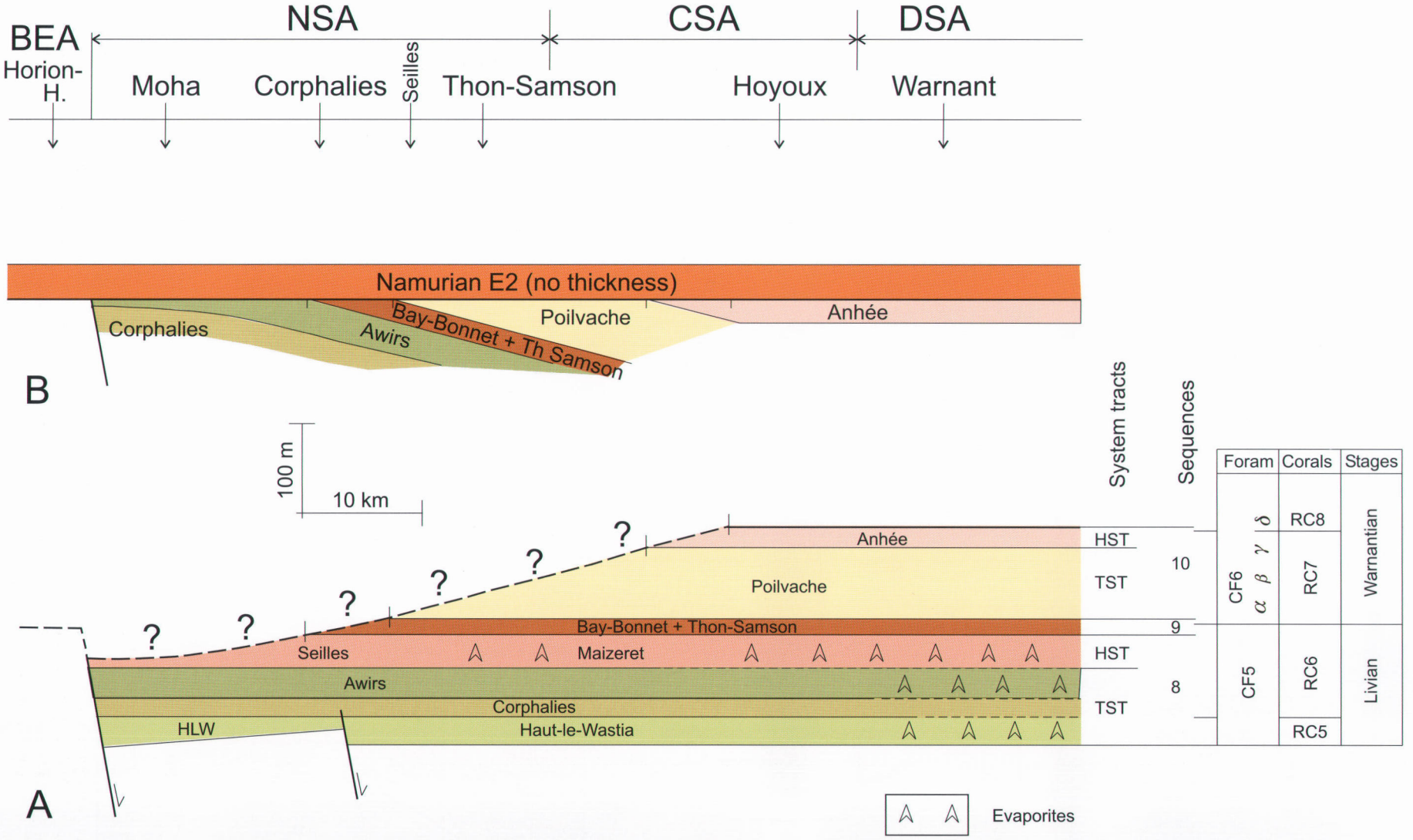

Figure 4. A: evolution of the Namur-Dinant basin architecture from the base of the Middle Viséan (Livian) to the Namurian E2. N-S palinspastic section. The lateral regularity of the deposits suggests an aggradation system.

B: relations between the earliest Namurian deposits (E2) and the Viséan formations, showing the increase of the stratigraphical gap to the north. On the field, there is a disconformity and not an unconformity between the Namurian and the Visean deposits as suggested by the figure. NSA: Namur sedimentation area; CSA: Condroz sedimentation area; DSA: Dinant sedimentation area.

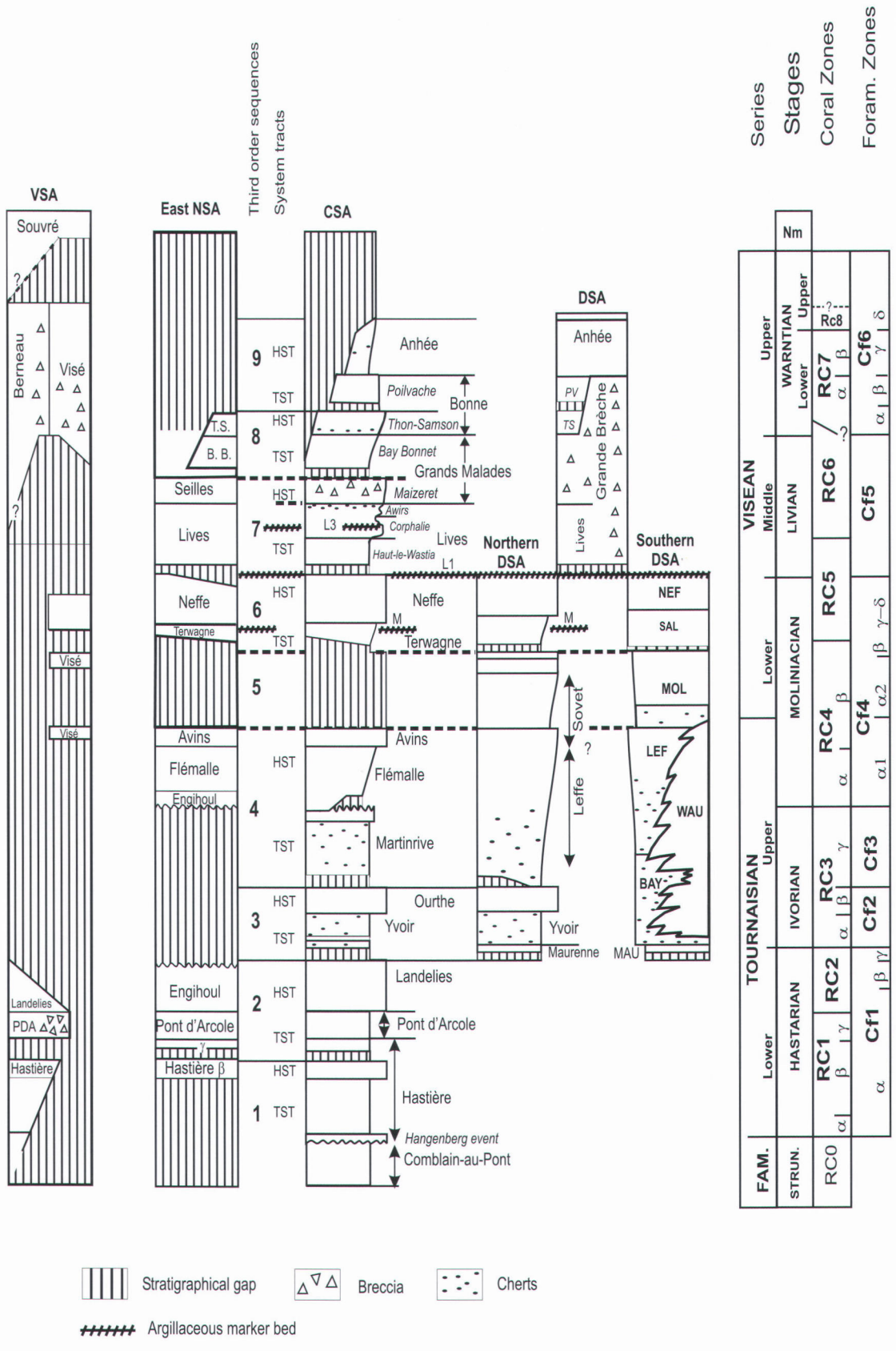

Figure 5. Stratigraphical pattern of the Dinantian in southern Belgium with indication of the third-order sequences. CSA: Condroz sedimentation area; DSA: Dinant sedimentation area; NSA: Namur sedimentation area; VSA: Visé-Maastricht sedimentation area. BAY: Bayard Fm; LEF: Leffe Fm; MAU: Maurenne Fm; MOL: Molignée FM; NEF: Neffe Fm; PDA: Pont d'Arcole Fm; SAL: Salet Fm; TER: Terwagne Fm; WAU: Waulsort Fm. FAM: Famennian; Nm: Namurian; STRUN: Strunian

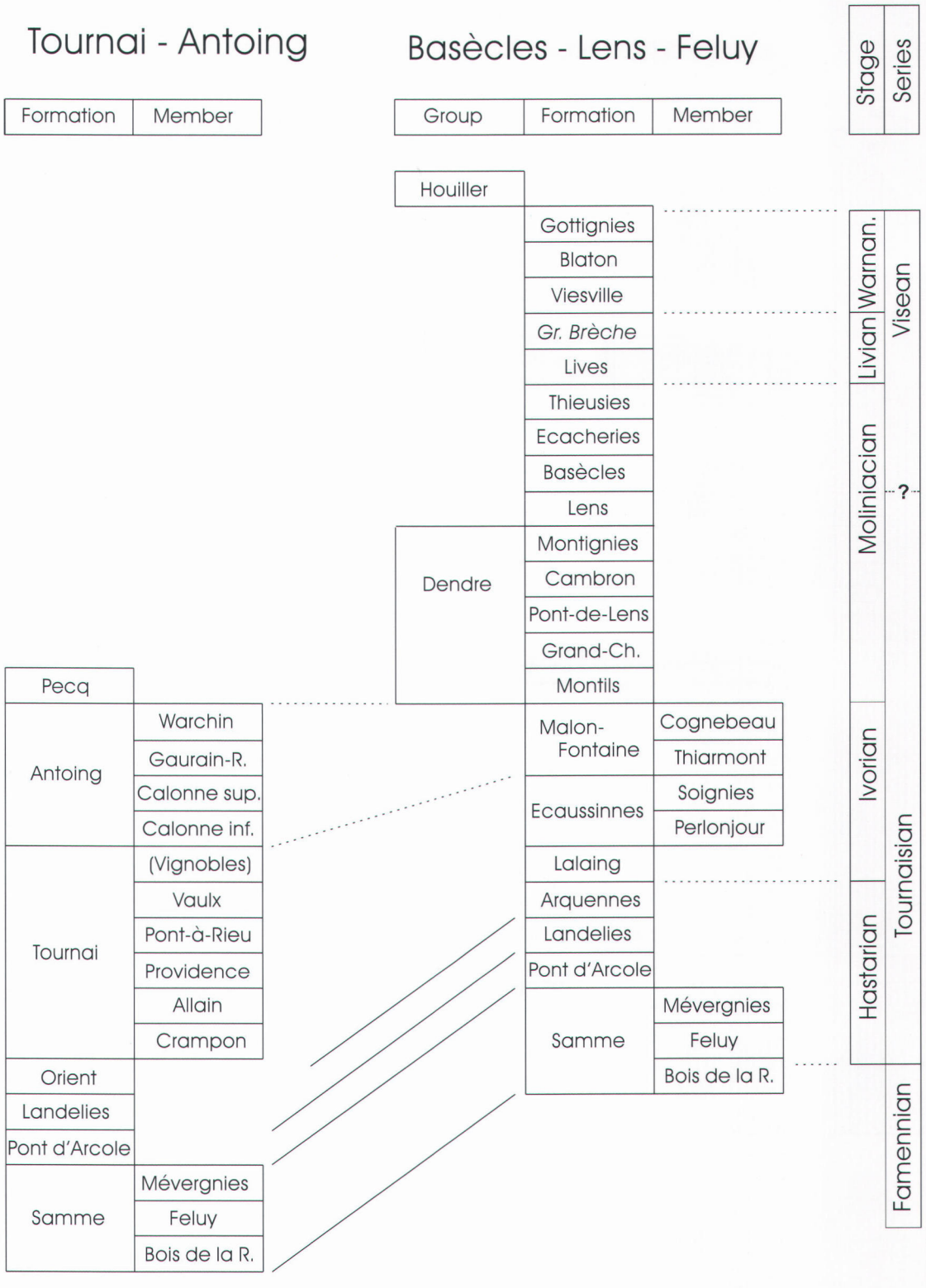

Figure 6. Lithostratigraphy of the Hainaut sedimentation area.

Age: Early Tournaisian (Hastarian). *Siphonodella* Conodont Zone; Cf1 Foraminifer Zone; RC1α, β Rugose Coral Subzones). The thick basal bed of the formation has yielded typical elements of a Devonian fauna, for the most part reworked. *Siphonodella duplicata* enters 8.5 m above the base of the formation (Van Steenwinkel, 1980). There are rare occurrences of *Tournayellina beata* and *Chernyshinella* sp. in the lower and middle members. *Septabrunsiina minuta* and *S. rudis* enter in the upper member (Tohogne borehole; Bouckaert *et al.*, 1978). Corals of the RC1 Zone (*Conilophyllum priscum*, *Melanophyllum kremersi*) appear at the base of the formation or just above the basal thick bed when it is present. The basal bed itself yields reworked corals from the RC0 Zone. The lower and middle members correspond respectively to the end of the TST and to the HST of the third-order sequence 1 of Hance *et al.* (2001). The upper member forms the lower part of the TST of sequence 2.

5.2. Samme Formation – SAM

Authors: Doremus & Hennebert, 1995a, 1995b.

Description: The formation includes 3 members: the Bois de la Rocq Mbr, the Feluy Mbr and the Mévergnies Mbr, reading from base to top.

– ***Bois de la Rocq Mbr – BDR*** (Doremus & Hennebert, 1995a, 1995b). Sandy and dolomitic micaceous rocks, with some calcareous or dolomitic levels. The member overlies the Famennian shales of the Franc-Warêt Fm. In the stratotype area, it consists of dolomitic sandstones, including calcareous or dolomitic layers and thin shaly interbeds. In the Tournai borehole, conglomerates, red and green sandstones and shales form the lower part, and dolomitic sandstones the upper part.

– ***Feluy Mbr – FEL*** (Paproth *et al.*, 1983; Doremus & Hennebert, 1995a, 1995b). This member is dominantly calcareous, but it includes various lithologies, such as sandy, argillaceous or dolomitic limestones, and breccia.

– ***Mévergnies Mbr – MEV*** (Paproth *et al.*, 1983; Doremus & Hennebert, 1995a, 1995b). The member, which lies between the Feluy Mbr and the Pont d'Arcole Fm, displays various lithologies, mainly siliciclastic. In the stratotype, it consists of thick-bedded and lenticular, light-coloured, dolomitic sandstones, sometimes micaceous, with thin blue shale intercalations in the lower part. Macrofossils are rare.

Stratotype: The Samme Fm was defined in the Samme Valley, between Feluy and La Rocq castle. The members are located as follows. Bois de la Rocq Mbr: old quarry "du Bois de la Rocq" at Feluy, on the right bank of the River Samme, in the southern part of the Bois de la Rocq. Feluy Mbr: old quarry "Exploitation des Prés" at Feluy, on the right bank of the R. Samme. Mévergnies Mbr: old quarry "Duchâteau" at Mévergnies.

Area: Western HSA. Bois de la Rocq and Feluy Mbrs: at least from Tournai to Seneffe. Mévergnies Mbr: at least from Tournai to Soignies; it does not exist in the Samme Valley but is known further westward.

Thickness: Bois de la Rocq Mbr: about 44 m in the type area; about 29 m in the Tournai borehole. Feluy Mbr: about 22 m in the type area, but it is thicker in the Leuze and Tournai boreholes, with 43 and 52 m respectively. Mévergnies Mbr: about 8 m in the type area, but thicker in the Leuze and Tournai boreholes, with 18 and 22 m repectively.

Age: Bois de la Rocq Mbr: late Famennian (Strunian) to early Hastarian (Groessens *et al.*, 1982; Streel, 1969). Feluy Mbr: earliest Hastarian (Cf1? Foraminifer Zone; Cc1? Conodont Zone; Palynological Zone VI = zone TE in Streel, 1977). Mévergnies Mbr: early Hastarian.

5.3. Pont d'Arcole Formation - PDA

Authors: Dupont, 1863 (Schistes vert sombre à *Spirifer octoplicatus*); Groessens, 1975 (Schistes du Pont d'Arcole); Paproth *et al.*, 1983.

Description: The formation is dominantly greenish to black shales. The carbonate content increases in the upper part with a few beds of crinoidal limestone. Bryozoans, crinoids, brachiopods including the guide *Spiriferina peracuta*, and some corals are usually common. In the VSA, the shales of the Pont d'Arcole Fm include numerous boulders reworked from the Hastière Fm (debris flow, ***La Folie Facies - LAF***).

Stratotype: Outcrops along the road from Hastière-Lavaux to the Insemont hamlet, in front of the Pont d'Arcole cave (DSA) (Groessens, 1975). La Folie Facies, La Folie quarry, 2 km SE of Visé in the Berwine valley (Pirlet, 1967a; Poty, 1982).

Area: This unit can be recognized almost everywhere in the Namur-Dinant Basin.

Thickness: The thickness does not exceed 20 m in the DSA and can be as little as 3 m in the NSA.

Age: Hastarian. *Siphonodella* Conodont Zone; Cf1α" Foraminifer Zone, RC1γ Rugose Coral Zone, Palynological Zone VI (Conil *et al.*, 1991). The formation corresponds to the upper part of the TST of the third-order sequence 2 of Hance *et al.* (2001).

5.4. Landelies Formation – LAN

Authors: de Dorlodot, 1895 (Calcaire de Landelies); Mamet et al., 1970; Paproth et al., 1983.

Description: The dominant facies comprises crinoidal packstones to rudstones with numerous rugose corals and brachiopods. A subdivision into three units can be recognized in many places: (1) a basal, metre-thick bed of crinoidal limestone, which abruptly overlies the argillaceous limestones and shales of the Pont d'Arcole Formation; (2) a succession of calcareous shale-limestone parasequences; and (3) thick-bedded crinoidal limestones.

The contact with the overlying Maurenne Formation is sharp.

Stratotype: Abandoned quarry on the western bank of the River Sambre, 1.5 km north of the church at Landelies (DSA).

Area: The formation outcrops widely in the CSA, DSA and ASA. The lower member of the Engihoul Dolomite Fm is its lateral equivalent in the NSA.

Thickness: 23 m in the stratotype, up to 85 m in the western part of the NSA, 10 m or less in the eastern part of the CSA (Vesdre area).

Age: Hastarian. Cf1α and β Foraminifer Subzones; *Siphonodella* Conodont Zone; RC2 Rugose Coral Zone (Conil *et al.*, 1991). The Landelies Fm corresponds to the HST of the third-order sequence 2 of Hance et al. (2001).

5.5. Engihoul Formation – ENG

Author: Poty, this paper.

Description: The formation includes a lower member of thick-bedded to massive, brown to dark, dolomite, with some calcite nodules, and an upper member of crinoidal dolomite with layers of dolo-mudstone and prismatic calcite, very rich in pluricentimetric to pluridecimetric nodules of coarse calcite, pluricentimetric prismatic calcite and sometimes quartz. The top of the formation is locally karstified and its upper member missing. It is overlain by the Flémalle Mbr (Longpré Fm).

Stratotype: Engihoul quarry, on the southern side of the Meuse valley (Conil *et al.*, 1988), near the Engis bridge (NSA).

Area: The formation is known only in the eastern part of the NSA.

Thickness: About 75 m in the stratotype where the upper member is 15 m thick.

Age: Late Hastarian to early Moliniacian. The basal beds overlie the Pont d'Arcole Shales and yield rugose corals of the base of the RC2 Zone, suggesting that the lower member of the formation could correspond to a dolomitized equivalent of the Landelies Fm. The crinoidal layers of the upper member yield *Sychnoelasma hawbankense*, a guide of the RC4α Coral Subzone. There is probably a stratigraphic gap between the lower and upper members, corresponding to the Ivorian. The lower member probably corresponds to the HST of the third-order sequence 2 of Hance *et al.* (2001), and the upper member corresponds to the lower part of the HST of the third-order sequence 4.

5.6. Vesdre Formation – VES

Authors: Boonen, 1979; Swennen *et al.*, 1982; Paproth *et al.*, 1983; Laloux *et al.*, 1996a, 1996b.

Description: The lower part comprises brown to grey-brown, thick-bedded, coarse-grained dolomite, whereas the upper part has pale, thick-bedded, coarse-grained dolomite alternating with dark, thin-bedded, fine-grained dolomites. Chert and calcite, quartz or dolomite nodules are abundant locally. The calcite, quartz and dolomite nodules are interpreted as pseudomorphs after anhydrite. In the uppermost part of the formation, the ***Walhorn Mbr (WAL)*** (Paproth *et al.*, 1983) is distinguished as a dolomitic breccia composed of dark, coarse-grained elements in a grey-brown dolomitic matrix.

Stratotype: The base of the formation is exposed in the section situated 500 m north of Dolhain station (R. Vesdre area) and the boundary with the overlying Belle-Roche Breccia can be observed in the Walhorn quarry.

Area: Eastern NSA – eastern CSA.

Thickness: About 150 m deduced from geological mapping.

Age: Late Hastarian (early Tournaisian) to Moliniacian (early Visean, Cf4α2 Foraminifer Subzone), based on foraminifera preserved in chert nodules (Laloux *et al.*, 1996a, 1996b).

5.7. Namur Group - NAM

Authors: Dupont, 1863; Paproth *et al.*, 1983.

Description: The Engihoul Dolostone and the Longpré, Terwagne and Neffe formations, when dolomitized, compose the Namur Group. It comprises dark to brown, usually thick-bedded, coarse-grained dolomites. Calcite and dolomite nodules are abundant locally. Dolomitized macrofossils (brachiopods, corals) are more or less common.

Stratotype: Rochers de Marche-les-Dames on the north side of the Meuse valley, downstream of Beez.

Area: NSA. To the east, the group extends up to Solière, from where the Longpré, Terwagne and Neffe formations are not dolomitized.

Thickness: About 200 m in the stratotype. The thickness varies from 100 to 200 m, depending of the extension of the dolomitization upwards.

Age: Late Hastarian and Moliniacian (based on the age of the corresponding non dolomitized formations).

5.8. Maurenne Formation – MAU

Authors: Bouckaert *et al.*, 1974; Paproth *et al.*, 1983. The formation was previously known as the Calcschistes de Maredsous (de Dorlodot, 1895).

Description: The formation rests abruptly on the thick-bedded crinoidal limestones of the Landelies Formation. It consists of calcareous shales and argillaceous limestones. Shelly layers are numerous in the lower part (tempestite). The fauna is more diversified in the upper part with numerous small rugose corals. The formation ends with a few beds of argillaceous cherty limestones.

Stratotype: Maurenne village; abandoned quarry situated 1900 m NW of the bridge at Hastière (DSA).

Area: The formation is restricted to the DSA.

Thickness: The thickness in the stratotype is about 13 m. It never exceeds 20 m.

Age: Latest Hastarian based on the last occurrence of the conodont *Siphonodella* (Conil *et al.*, 1991). Corals are poorly known. The Maurenne Fm marks the base of the TST of the third-order sequence 3 (Hance *et al.*, 2001).

5.9. Arquennes Formation - ARQ

Authors: Groessens, 1978; Paproth *et al.*, 1983; Doremus & Hennebert, 1995a, 1995b.

Description: The lower part comprises irregularly stratified, sandy limestones and calcareous sandstones with micaceous, shaly intercalations. Cherts and pyrite occur locally. The upper part consists of alternating marlstones and limestones. The formation overlies the Landelies Fm.

Stratotype: Old quarry "Rousseau", 1300 m NE of the church at Feluy.

Area: Western HSA, at least from Ath to Seneffe.

Thickness: 28-29 m in the type area.

Age: Late Hastarian (Cc1 Conodont Zone, Groessens, 1978)

5.10. Orient Formation – ORI

Authors: de Dorlodot, 1909; Camerman, 1944; Mortelmans, 1969; Hennebert & Doremus, 1997a, 1997b.

Description: Dark grey calcareous shales, with crinoidal and fossiliferous limestone beds, sometimes sandy. The formation overlies the Landelies Fm.

Stratotype: Not exposed at present.

Area: Western HSA (Tournai area).

Thickness: 60 m in the Tournai borehole and 58 m in the Leuze borehole.

Age: Latest Hastarian (based on the macrofauna, Paproth *et al.*, 1983).

5.11. Tournai Formation - TOU

Authors: De Koninck, 1842-1844; Camerman, 1944; Mortelmans, 1969; Paproth *et al.*, 1983; Hennebert & Doremus, 1997a, 1997b. The Tournai Fm corresponds here to the lower part of the Tournai Limestone (sensu Camerman, 1944), below the Gras Délit (marker bed).

Description: Dark, thin-bedded (25 to 45 cm-thick), argillaceous and siliceous limestones with shaly intercalations. Chert nodules are concentrated at some levels ("carbonniaux"). The Gras Délit is an argillaceous layer that caps the formation. Macrofossils are locally abundant and diversified: crinoids, bryozoans, brachiopods, rugose and tabulate corals, gastropods, bivalves, nautiloids, trilobites and blastoids. Goniatites are scarce.

The Tournai Fm includes 6 members, from the base to top: Crampon, Allain, Providence, Pont-à-Rieu, Vaulx and Vignobles Mbrs.

– ***Crampon Mbr – CRA*** (Mortelmans, 1963) Dark grey to black, argillo-siliceous, crinoidal limestones, rich in macrofossils, alternating with dark marlstone levels.
– ***Allain Mbr – ALL*** (de Dorlodot, 1910): Dark grey to black, argillo-siliceous, crinoidal limestones, with calcareous shale layers, fairly rich in macrofossils. Cherty level at the top ("Carbonniaux d'Allain").
– ***Providence Mbr – PRO*** (Camerman, 1919): Dark grey to black, argillo-siliceous, crinoidal limestones, fairly rich in macrofossils. Chert occurs in the upper third. A very fossiliferous level occurs at the top of the member ("Banc à Moules").
– ***Pont-à-Rieu Mbr – PAR*** (de Dorlodot, 1909): Dark grey, argillo-siliceous, crinoidal limestones, fairly rich in fossils. Some chert occurs in the middle and upper parts.
– ***Vaulx Mbr – VAU*** (de Dorlodot, 1910): Dark grey, argillo-siliceous, crinoidal limestones, rich in macrofossils. Abundant chert. Where the Vignobles Mbr is absent, the Vaulx Mbr extends up to the "Gras Délit".
– ***Vignobles Mbr – VIG*** (Camerman, 1944): A lenticular unit of dark grey, argillo-siliceous, crinoidal limestones, fairly rich in fossils.

Stratotype: The Tournai Fm is well exposed in the quarries east of Tournai. As these quarries are actively worked, no permanent section can be chosen as stratotype. The stratotypes for the members are as follows: Crampon, Allain and Providence Mbrs – "Milieu" quarry situated between Antoing, Vaulx and Gaurain-Ramecroix; Pont-à-Rieu and Vaulx Mbrs – "Antoing", "Milieu" and "Lemay" quarries, all situated between Antoing, Vaulx and Gaurain-Ramecroix; Vignobles Mbr – "Lemay" and "Prince" quarries, at Vaulx.

Area: Western HSA (Tournai area).

Thickness: 134 to 145 m in the type area. Crampon Mbr, 11 – 12 m; Allain Mbr, 28 to 31 m in the Tournai area, 32 m in the Leuze borehole; Providence Mbr, 40 to 45 m in the Tournai area, 30 m in the Leuze borehole; Pont-à-Rieu Mbr, 21-22 m in the Tournai area, 23 m in the Leuze borehole; Vaulx Mbr, 32 to 35 m in the Tournai area, 32 m in the Leuze borehole; Vignobles Mbr, 0 to 20 m.

Age: Crampon Mbr: Hastarian or Ivorian; overlying members: Ivorian. Microfossils are scarce and do not allow correlation with well-dated sections in the Namur – Dinant Basin.

5.12. Yvoir Formation – YVO

Authors: Conil, 1960; Groessens, 1975; Paproth *et al.*, 1983.

Description: The formation is characterized by dark limestones (mainly packstones) with crinoidal and shelly layers. Chert nodules are abundant throughout. The lower and the upper parts of the formation are partially dolomitized in places. Sandy limestones with thin shaly intercalations and thin layers of brachiopods form a distinct lower member in the Yvoir section, the Hun Member (HUN) which is 13.5 metres-thick (Paproth *et al.* 1983). In the CSA, the Yvoir Fm is mainly composed

of cherty, crinoidal limestones (packstones to grainstones) with numerous corals and brachiopods.

Stratotype: Abandoned quarry behind the station at Yvoir (DSA).

Area: DSA and CSA. The formation is absent elsewhere. In areas close to Waulsortian buildups, the bulk of the Yvoir Formation passes laterally into the Bayard Formation and is thus contemporaneous with the lower part of the buildup succession.

Thickness: The formation is 64 m thick in the stratotype section.

Age: Mainly early Ivorian. The conodont *Siphonodella* is present in the lowermost part of the formation (Cc1 Conodont Zone, Hastarian). *P. c. carina* enters a few metres above the base of the formation, indicating an Ivorian age. The first tuberculate endothyrid foraminifera (*Spinoendothyra*, *Tuberendothyra*) were recorded from the first few metres of the formation (Cf1γ Foraminifer Subzone) whereas the *Paraendothyra-Granuliferella* foraminiferal association (Cf2 Foraminifer Zone) enters in the upper part. The formation lies in the RC3α Coral Subzone, corals being particularly abundant and diversified in the Condroz area. Most of them belong to species or genera that are widespread in Eurasia. The Yvoir Fm corresponds to the main part of the TST of the third-order sequence 3 (Hance *et al.*, 2001).

5.13. Pont-à-Nôle Formation – PNL

Authors: Delcambre & Pingot, 2000.

Description: Well-bedded, dark grey dolomitic limestones, with calcite nodules. The formation comprises three units:

– A lower unit composed of some beds of crinoidal limestone.

– A middle unit of crinoidal limestone with dark chert.

– An upper unit of limestone including beds of decayed, brown dolomite, rich in corals and brachiopods.

The formation overlies the Maurenne Fm and is overlain by the Mont-sur-Marchienne Fm.

Stratotype: Gralex quarry at Mont-sur-Marchienne, in the Eau d'Heure valley.

Area: Mont-sur-Marchienne area (NSA). The formation, when dolomitized, passes laterally to the lower part of the Namur Group.

Thickness: About 100 m.

Age: Ivorian and Early Moliniacian (Late Tournaisian). Cf3 and Cf4α1 Foraminifer Zones.

5.14. Bayard Formation – BAY

Authors: Conil, 1968; Groessens & Noël, 1975; Paproth *et al.*, 1983; Delcambre & Pingot, 1993.

Description: Well-bedded (although some is solution-seam pseudo-bedding), dark grey or brownish-grey, crinoidal limestones, locally cherty. The formation forms the proximal lateral equivalent of the lower part of the Waulsortian buildups, and locally occurs immediately below and as intercalations in the buildups. It overlies the Maurenne Fm and grades up into the Leffe Fm.

Stratotype: Dinant, immediately south of the Roche à Bayard (DSA).

Area: The formation is restricted to the peri-Waulsortian areas of the DSA and passes laterally into the lower part of the Yvoir Fm when traced away from the buildups.

Thickness: 5 to 30 m. 11.6 m in the stratotype.

Age: Early Ivorian based on the entry of the conodont *Polygnathus communis carina* near the base of the formation. *Spatognathodus bultyncki* enters near the top of the formation in the type section. Corals are uncommon and poorly known. Plurilocular foraminifera are absent. The Bayard Fm corresponds to the third-order sequence 3 and to the TST of the sequence 4 of Hance *et al.* (2001).

5.15. Waulsort Formation – WAU

Authors: Dupont, 1883; Lees *et al.*, 1977, 1985; Paproth *et al.*, 1983; Lees, 1997.

Description: The formation comprises buildups formed from individual carbonate mudmounds or, more commonly, from mudmound aggregates which developed on the distal part of the ramp during the late Tournaisian (Lees 1982).

Waulsortian rocks are usually massive, pale grey to beige limestones and diagenetic dolomites, devoid of chert. The main lithofacies are:

– A spar-rich facies (including the "veines bleues" of early authors) which is typical of the lower and middle part of the buildups. Some sparry masses represent cavity fillings, including voids formed after decay of soft-bodied organisms (and sometimes modified subsequently by local collapse and dissolution) as well as fracture fillings. Other sparry fabrics were formed by neomorphism. The matrix material surrounding the sparry masses is predominantly wackestone.

– Bedded to massive, crinoidal packstones to rudstones, which occur mainly in the lower part (some are related to intercalations of Bayard facies);

– Massive or poorly stratified, bioclastic wackestones, which tend to dominate in the upper part of the buildups.

Fenestrate bryozoans are abundant, particularly in the lower parts of the buildups, where fronds are common. A rich macrofauna of brachiopods and molluscs is common in the spar-rich facies (Demanet, 1958). Microbial processes probably played an important role in producing and fixing the carbonate muds.

The Bayard and Leffe Formations form the proximal lateral equivalents of the lower and upper parts of the buildup sequence, respectively.

Stratotype: Road and rail sections at Gendron-Celles for the base of the formation (Groessens, 1975); Moniat

ravine section, between Dinant and Anseremme on the left bank of the River Meuse for the top of the formation (Lees *et al.* 1977; Conil *et al.*, 1988; Lees, 1997). The Pauquys crags, N of Waulsort, on the left bank of the R. Meuse were previously designated as the stratotype (Paproth *et al.*, 1983), but it proved to be a poor one as it exposes neither the base nor the top of the formation, it does not show the whole range of lithotypes; and the rocks are extensively dolomitized (Dehantschutter & Lees, 1996).

Area: Restricted to the DSA. Most of the Waulsortian rocks are concentrated in a more-or-less continuous buildup complex along the southwestern border of the DSA. Towards the north and east, the buildups become increasingly scattered, finally disappearing in the area beyond Ciney and Sosoye.

Thickness: From zero to more than 300 m.

Age: Early Ivorian to early Moliniacian (latest Tournaisian). The Waulsortian facies started to develop early in the Ivorian, close to the level of appearance of the conodont *Polygnathus communis carina*, and declined during the late Tournaisian. The upper parts of the youngest buildups have early Moliniacian foraminifera (e.g. Lees, 1997) but no Viséan Waulsortian has yet been demonstrated in Belgium. Not all buildups extend through the whole stratigraphic range (e.g. those in the Pauquys area described by Dehantschutter and Lees, 1996). Corals are mainly represented by *Amplexus coralloides* and do not allow to establish biozonation. Development of the Waulsortian facies occurred through third-order sequences 3 and 4 (Hance *et al*, 2001).

5.16. Lalaing Formation - LAL

Authors: Conil & Delcourt, 1989; Doremus & Hennebert, 1995a, 1995b.

Description: In the west (Mévergnies), the formation comprises grey to brown, crinoidal dolomite, locally calcareous, with silicified fossils. Black and grey chert occurs in the lower part. In the east, the formation becomes mainly limestone with dolomitic and cherty levels ("Cliquantes" partim). In the stratotype, grey to blue-grey argillaceous limestones form the dominant lithology. Crinoidal and shelly layers are interbedded with thin marlstone layers. Chert nodules occur locally.

Stratotype: Section at Lalaing castle, at Ecaussinnes-Lalaing.

Area: Western HSA, at least from Ath to Seneffe.

Thickness: 19 to 21 m.

Age: Early Ivorian (*Polygnathus communis carina* Conodont Zone, Conil *et al.*, 1991).

5.17. Ecaussine Formation - ECA

Authors: Bouckaert *et al.*, 1971; Paproth *et al.*, 1983; Hibo, 1994; Doremus & Hennebert, 1995a, 1995b.

Description: The formation includes 2 members: the Perlonjour Mbr overlain by the Soignies Mbr.

– ***Perlonjour Member – PLJ*** (Hibo, 1994): Argillaceous and siliceous, cherty limestones, in metre-thick beds with some thin shaly intercalations.

– ***Soignies Member – SOI*** (Groessens, 1978): This member corresponds to the well-known "Petit Granit". It comprises thick-bedded to massive, dark blue-grey limestones which are very crinoidal (encrinite). The rich and varied fauna is mainly of brachiopods and corals. An argillaceous marker bed, the "Délit à la terre bleue", occurs 3 to 5 metres below the top of the member.

Stratotype: Perlonjour Mbr: Perlonjour quarry, east of Soignies. Soignies Mbr: Hainaut quarry at Soignies.

Area: Western HSA, at least from Ath to Seneffe.

Thickness: 52 – 54 m. Perlonjour Mbr, 22 m in the type area; Soignies Mbr, 30-32 m in the type area.

Age: Ivorian (Cc2α Conodont Zone, Conil *et al.*, 1991).

5.18. Leffe Formation – LEF

Authors: de Dorlodot, 1895; Groessens, 1973; Paproth *et al.*, 1983.

Description: Dominantly well-bedded, violet-grey to purplish blue limestones (wackestones to packstones), tending to become darker in the passage to the overlying Molignée Fm. Commonly cherty. Locally contains slumps and breccia layers. In the neighbourhood of some Waulsortian buildups (to the upper parts of which it forms the lateral equivalent), a "rhythmic Leffe" facies occurs in which (storm-related?) coarse-grained limestone beds, often graded (with packstone-grainstone bases) are intercalated in the normal fine-grained facies. The macrofauna is extremely poor. The contact with the overlying Molignée Formation is progressive.

Stratotype: The exposures in the park of Leffe Abbey and along the adjacent road to Spontin (DSA) were designated as the stratotype of the Leffe Facies by Paproth *et al.* (1983). This is not a good formal stratotype as the position and age of the base of the formation are not clear and the top of the formation is missing due to faulting. The Rocher du Bastion, at Dinant, displays a complete section of the formation (Conil *et al.*, 1988; Conil *et al.*, 1989), but parts of it are difficult of access. Two other sections are therefore designated as stratotype: (1) the Roche à Bayard, just south of Dinant, where the lower part of the formation and the contact with the underlying Bayard Fm are well-exposed (Groessens & Noël, 1975); and (2) the section in the side road leading to the village of Salet, in the Molignée valley about 4 km WSW of Yvoir, where the upper part of the formation and the contact with the overlying Molignée Fm (see description of that formation for definition of limit) are completely exposed (Hance *et al.*, 1994).

Area: This formation is a proximal lateral equivalent of the upper part of the Waulsortian buildups and hence has the same distribution area (DSA).

Thickness: From a few metres to several tens of metres, with a tendency to increasing thickness with increasing proximity to Waulsortian buildups. In the Bastion section the thickness is about 55 m. In the Freyr syncline, the formation attains a thickness of nearly 70 m (Lees, 1997).

Age: Late Ivorian (*Scaliognathus anchoralis europensis* Conodont Zone) to early Moliniacian. Both base and top are diachronous. The lower and middle parts of the formation have yielded a poor (ecological) foraminiferal association with *Tetrataxis* and *Eotextularia diversa*, assigned to the Cf3 Zone by Conil *et al.* (1977, 1991). The upper part contains grainstone layers with a more diversified association derived from shallower areas (Lees, 1997). This association is latest Ivorian and early Moliniacian, and predates the entry of *Eoparastaffella*. Corals are uncommon and do not allow biozonation. The Leffe Fm corresponds to the third-order sequence 4 of Hance *et al.* (2001).

5.19. Ourthe Formation – OUR

Authors: Fourmarier, 1922; Groessens, 1975; Paproth *et al.*, 1983.

Description: Grey-blue, thick-bedded to massive, crinoidal limestones (packstones to rudstones). Macrofossils (rugose and tabulate corals, brachiopods) are common but are not diversified. The limestones produce a fetid smell when freshly broken.

Stratotype: Bunker section, 450 m north of the Scay bridge, on the left bank of the R. Ourthe, at Comblain-au-Pont (CSA).

Area: CSA and DSA. The formation is well developed in the CSA where it is extracted as an ornamental stone ("Petit Granit"). It passes laterally into the Bayard Fm in the DSA.

Thickness: About 25 m.

Age: Ivorian (*Polygnathus communis carina* Conodont Zone, RC3β Coral Subzone, Conil *et al.*, 1991). Foraminifera of the Cf2 Zone die out within the formation. The Ourthe Fm corresponds to the main part of the HST of the third-order sequence 3 (Hance *et al.*, 2001).

5.20. Malon-Fontaine Formation - MAF

Authors: Cornet, 1927; Groessens, 1978; Paproth *et al.*, 1983; Doremus & Hennebert, 1995a, 1995b.

Description: Thin-bedded, fine-grained, argillaceous limestones with thin marlstone intercalations. Fossils are rare. The distinction between the ***Thiarmont Mbr - THI*** (Doremus & Hennebert, 1995a, 1995b) and the overlying ***Cognebeau Mbr – COG*** (Doremus & Hennebert, 1995a, 1995b) is based on the abundance of chert nodules and bands in the latter whereas they are absent in the former.

Stratotype: Thiarmont Mbr: old quarry "Goffart" at Thiarmont, two km SW from Lalaing castle. Cognebeau Mbr: Hainaut quarry, at Soignies, situated NW of the Cognebeau stream.

Area: Western HSA, at least from Ath to Seneffe.

Thickness: The formation is 65 m thick in the type area (Thiarmont Mbr: 33 m; Cognebeau Mbr: 32 m).

Age: Ivorian (Cc2β-δ Conodont Zones, Cf2 Foraminifer Zone, Conil *et al.*, 1991).

5.21. Antoing Formation – ANT

Authors: Camerman, 1944; Hennebert et Doremus, 1997a, 1997b.

Description: The formation is lithologically similar to the underlying Tournai Formation, except that beds are slightly thicker and macrofossils become rare upwards. The trace fossil *Zoophycos* is common. Chert nodules are concentrated at some levels ("carbonniaux"). The Antoing Fm includes 4 members, from base to top: Lower and Upper Calonne, Gaurain-Ramecroix and Warchin Mbrs.

– ***Lower and Upper Calonne Mbrs – CAI and CAS*** (de Dorlodot, 1895; Paproth *et al.*, 1983): Two units of dark grey, argillo-siliceous limestone, containing some chert, separated by a thick argillaceous layer. Poorly fossiliferous ("Banc à *Chonetes*" at the base), but *Zoophycos* is abundant at some levels.

– ***Gaurain-Ramecroix Mbr – GAU*** (Camerman, 1944; Paproth *et al.*, 1983): Dark grey argillo-siliceous limestone, with chert at the base. Poorly fossiliferous but with numerous *Zoophycos* at some levels.

– ***Warchin Mbr – WAR*** (Camerman, 1944; Paproth *et al.*, 1983): Dark grey to black, argillo-siliceous limestones with some very cherty levels. Poorly fossiliferous.

Stratotype: Four actively worked quarries expose the formation: the Antoing, Milieu and Lemay quarries, all situated between Antoing, Vaulx and Gaurain-Ramecroix, and the C.C.B. quarry at Gaurain-Ramecroix, which is the most complete in the upper part of the formation (as it exposes the CAS, GAU and WAR members).

Area: Western HSA, Tournai area.

Thickness: About 170 m. Lower Calonne Mbr, 22 m; Upper Calonne Mbr, 28-29 m; Gaurain-Ramecroix Mbr, 17 m; Warchin Mbr, at least 105 m in the Tournai area and about 157 m in the Leuze borehole.

Age: Ivorian, although the Warchin Mbr could be partly Moliniacian in age (Zones 10 of Mamet, *in* Legrand *et al.*, 1966). The Antoing Fm is separated from the Tournai Fm by an argillaceous layer (Gras Délit) resting on a hard ground. This surface could be correlated with the surface separating the third-order sequences 3 and 4 of Hance *et al.* (2001) in the CSA.

5.22. Martinrive Formation – MRT

Authors: Groessens, 1975; Paproth *et al.*, 1983.

Description: Most of the formation consists of dark limestones (packstones to wackestones) with crinoidal concentrations and numerous chert nodules. The lowermost part contains abundant calcite nodules with chicken-wire structure (pseudomorphs after anhydrite). The uppermost part of the formation is thick-bedded, with fine-grained, peloidal grainstones and lime mudstones, locally dolomitized and devoid of chert. In the Ourthe valley, chicken-wire nodules are also present at this level.

Stratotype: Left bank of the River Amblève, along the Aywaille road immediately downstream from the Martinrive bridge.

Area: The formation is restricted to the western part of the CSA. It passes laterally into the Leffe Formation.

Thickness: About 50 m

Age: Upper Ivorian. The formation straddles the *Polygnathus communis carina* (*Dollymae bouckaerti* Subzone) and *Scaliognathus anchoralis europensis* Conodont Zones; *Protognathodus cordiformis* is present in its uppermost part in the Ourthe valley. The upper part of the formation has yielded *E. michoti*, *C. modavensis*, *Eoforschia* sp., and *Tournayella* sp., an association which is assigned to the Cf3α Foraminifer Subzone. The formation lies in the RC3γ Rugose Coral Zone. The formation corresponds to the TST of the third-order sequence 4 of Hance *et al.* (2001).

5.23. Longpré Formation – LPR

Authors: Hance & Poty, this paper.

Description: The Longpré Fm includes two members, from base to top, the Flémalle and the Avins Mbrs, which were formerly described as formations. The formation overlies the Martinrive Formation (CSA) or the top, sometimes karstified, of the Engihoul Formation (NSA), and is abruptly overlain by the Terwagne Formation. The Longpré Fm can be more or less dolomitized (the Modave Fm of Hance, 1988, is now part of the Longpré Fm).

– ***Flémalle Member – FLM*** (Malpica, 1973; Paproth *et al.*, 1983; Hance *et al.*, 1994)

Thick-bedded to massive, pale grey, crinoidal limestones (packstones and grainstones), with numerous megachonetids, large gastropods and solitary rugose corals.

– ***Avins Mbr – AVN*** (Bless *et al.*, 1976; Groessens *et al.*, 1982; Paproth *et al.*, 1983; Hance *et al.*, 1994)

Thick-bedded to massive, pale coloured, oolitic limestones (grainstones). The macrofauna is poorly diversified and is usually restricted to numerous productid brachiopods (*Levitusia humerosa*) and rare rugose corals. The contact with the underlying Flémalle Mbr is progressive in the NSA. In contrast, in the CSA it is sharp and irregular and was identified as a paleokarstic surface by Conil (1967) and Hance (1988). However, a dolomitization front could also produce such a contact.

Stratotype: Longpré quarry in Longpré village, 7 km west of Huy (NSA). The stratotypes of the members are as follows. Flémalle Mbr: railway cutting below Chokier castle, Chokier (Flémalle-Haute, NSA). Avins Mbr: road section on the right bank of the R. Hoyoux, below the church at Les Avins-en-Condroz (CSA).

Area: Eastern part of the NSA and CSA. The Flémalle Mbr, dolomitized, is present in the upper part of the Huré Dolomite in the Boulonnais (Poty, 1994). The Avins Mbr can be correlated with the main part of the Godin Fm in the ASA, the few meters of crinoidal limestone at the base being the equivalent of the Flémalle Mbr (Mansy *et al.*, 1989).

Thickness: The thickness is unknown in the stratotype where the base of the formation is not exposed. At Chokier (NSA) it is 30 m thick (Flémalle Mbr, 26 m; Avins Mbr, 4 m), and it reaches about 78 m in the Ourthe valley (CSA; Flémalle Mbr, 70 m; Avins Mbr, 8 m). In its stratotype the Avins Mbr is 15 m thick, but it is thicker in the western part of the CSA (up to 40 m) and thinner in the eastern part of the CSA and in the NSA (4-8 m). In the ASA it reaches 68 m (Godin Fm).

Age: Early Moliniacian (latest Tournaisian). RC4α Coral Subzone (*Sychnoelasma hawbankense* and *Cyathoclisia modavensis*as main taxa) for the Flémalle Mbr; RC4β Coral Subzone for the Avins Mbr. Cf4α1 Foraminifer Subzone, mainly characterized by the occurrence of *Brunsia, Bessiella, Florennella* and *Latiendothyranopsis*, in Flémalle Mbr, and of *Biseriella bristolensis* and *Loeblichia fragilis* in Avins Mbr. The presence of *Protognathodus cordiformis* in the lower part of the formation in the Ourthe valley is indicative of the *Scaliognathus anchoralis* Conodont Zone. The Longpré Fm corresponds to the HST of the third-order sequence 4 of Hance *et al.* (2001).

5.24. Mont-sur-Marchienne Formation – MSM

Authors: Delcambre & Pingot, 2000.

Description: Thick-bedded, pale limestone with calcite nodules, rich in corals and brachiopods (*Levitusia humerosa*). The limestone comprises layers rich in oncoliths and algal ribbons. The boundary with the underlying Pont-à-Nôle Fm is marked by the change of colour and the occurrence of algal limestones. The formation is overlain by the Terwagne Fm.

Stratotype: North part of the Gralex quarry at Mont-sur-Marchienne, in the Eau d'Heure valley.

Area: Mont-sur-Marchienne area (NSA). The formation, when dolomitized, passes laterally to the upper part of the Namur Group.

Thickness: At least 40 m.

Age: Moliniacian (Cf4α1/Cf4α2 Foraminifer Subzones).

5.25. Visé Formation - VIS

Authors: d'Omalius d'Halloy, 1828; Pirlet, 1967b; Poty, 1982, 1991; Barchy & Marion, 2000.

Description: Pale to grey limestones including 4 main facies:

– sedimentary limestone breccias with centimetric to pluridecametric boulders of Frasnian age ("cyclopean breccia");
– thick-bedded packstones to rudstones, with sedimentary breccias, forming fining-upwards pluridecimetric to metric sequences often laminated in their upper part;
– thick-bedded to massive packstones to rudstones;
– massive algal and bioclastic boundstones forming buildups, rich in fossils (mainly brachiopods).
During the 19th century, the Visé Fm yielded an abundant and diversified macrofauna which was of fundamental importance for the understanding of the palaeontology of the Lower Carboniferous.

Stratotype: "F" to "L" abandoned quarries south of Visé (see Pirlet, 1967b, for their location), east side of the Meuse valley.

Area: VSA. The formation outcrops only in the Visé area.

Thickness: More than 100 m in the Visé quarries. Because of the strong synsedimentary tectonics of the area (Poty, 1991), the thickness of the formation varies from zero to some hundreds of metres.

Age: Early Moliniacian (late Tournaisian), mid and late Moliniacian (early Viséan) and Warnantian (late Viséan). Cf4α1 to Cf6δ Foraminifer Subzones (Kimpe *et al.*, 1978; Paproth *et al.*, 1983), RC4α to RC7β-RC8? Coral Subzones. There are numerous stratigraphic gaps, varying in duration from place to place (Poty, 1991), but the Livian is always absent. The HST of the third-order sequences 4, 5 and 6 have been recognized (Hance *et al.*, 2001).

5.26. Pecq Formation – PEC

Authors: Legrand *et al.*, 1966; Groessens *in* Coen-Aubert *et al.*, 1981; Paproth *et al.*, 1983.

Description: Generally massive, coarse grained, crinoidal limestones and dolomites, with some silicification. Shell beds with *Chonetes papilionacea*.

Stratotype: The formation is not exposed in surface sections but is known from boreholes situated north of the Tournai area.

Area: Western HSA.

Thickness: About 70 m in the northern part of Tournai area and at least 81 m in the Leuze borehole.

Age: Moliniacian (Foraminifer Zones 10 and 11 of Mamet, *in* Legrand *et al.*, 1966).

5.27. Molignée Formation – MOL

Authors: Groessens, 1975; Mamet, 1964; Conil & Groessens, in Groessens *et al.*, 1976; Paproth *et al.*, 1983; Hance, 1988; Hance et *al.*, 1994).

Description: The formation is characterized by alternations of thin-bedded (centimetric to decimetric), often laminated, black limestones ("black marble" composed of lime mudstones with radiolarians, and packstones) and thick-bedded, dark-grey limestones (lime mudstones to wackestones). These alternations are the poly- and monosequences of Mamet (1964). The ratio black/dark-grey limestones increases upwards. Slumping is common. Nodular chert occurs locally. The formation is famous for the exceptional preservation of the (rare) macrofossils including echinoids, molluscs, graptolites, brachiopods, medusae and fish.

The basal contact with the underlying Leffe Fm can be progressive. The Molignée Fm is overlain by the Salet Fm and does not extend up to the Neffe Fm as described by Delcambre and Pingot (1993).

Stratotype: Road section along the side road leading to the village of Salet from the main road along the Molignée valley, about 4 km WSW of Yvoir. The base of the formation is considered here as corresponding to bed 169 (as suggested by Hance *et al.*, 1994), the level at which the "black marble" facies becomes a significant component, and not to bed 52 as previously stated (Conil *et al.*, 1977; Paproth *et al.*, 1983).

Area: DSA. The Molignée Fm extends in a narrow band, oriented WNW-ESE, bordered by the Waulsortian discontinuous barrier to the south and the flank of the shelf to the north. It can locally overlie the Waulsortian buildups.

Thickness: The thickness varies from a few metres to more than 100 m. It is 57.6 m thick in the stratotype.

Age: Moliniacian (early Viséan). In the stratotype, the base of the formation postdates the entry of the foraminifer *Eoparastaffella* (bed 162) and that of the conodont *Gnathodus homopunctatus*. It ends at the top of the Cf4β Subzone at Salet, but can extend into the Cf4γ Subzone near Dinant. At Salet, the Molignée Fm includes the TST and HST of the third-order sequence 5 of Hance *et al.* (2001).

5.28. Sovet Formation – SOV

Authors: de Dorlodot, 1910; Conil, 1967; Segura, 1973; Hance, 1988.

Description: The Sovet Fm overlies the purplish-blue limestones of the Leffe Fm. The lower two-thirds of the unit consists of thin- to medium-bedded, dark-coloured, fine to medium grained, bioclastic limestones (packstones). Ooids and clasts are locally abundant in the lower part. Secondary dolomitization can be important, hampering detailed observation. The upper third of the formation, which corresponds to the ***Braibant Mbr – BRB*** (Hance *et al.* 2001) comprises thick-bedded, crinoidal dolomites with brachiopods and rugose corals capped by a few metres of thick-bedded, light-coloured limestones (packstones to grainstones (with ooids, intraclasts and lithoclasts).

Stratotype: Railway section at Sovet, 5.5 km NW of Ciney.

Area: DSA. The formation characterizes a narrow band, oriented WNW-ESE, forming the transition between inner shelf and outer shelf facies. Towards the border with the inner shelf it is overlain by the Terwagne Fm, whereas towards the outer shelf it is overlain by the Salet

Fm. To the south, the Sovet Fm passes laterally into the upper part of the Leffe Fm and into the Molignée Fm.

Thickness: In the type section, the formation is 126 m thick.

Age: Moliniacian (latest Tournaisian – early Viséan). The Viséan guide, the foraminifer *Eoparastaffella* enters in the lower part of the formation. Archaediscids are absent. The corals belong to the lower and upper parts of the RC4β Subzone. The base of the formation corresponds to the HST of the third-order sequence 4 of Hance *et al.* (2001) and the rest to the sequence 5.

5.29. Salet Formation – SAL

Authors: Conil & Lys, 1964; Paproth *et al.*, 1983; Hance, 1988; Hance *et al.*, 1994.

Description: The Salet Formation overlies the Molignée Formation and is succeeded by the thick-bedded limestones of the Neffe Formation. After a basal, dolomitized breccia bed, the lower part of the formation consists of medium-bedded, light-grey to grey, bioclastic limestones (packstones and grainstones). The upper part is thicker-bedded and contains cherty limestones. Dolomitization can affect the base and the upper part of the formation. The macrofauna is poor. The formation as described here includes the first sequence of the Neffe Limestone *sensu* Conil & Naum (1977). Delcambre & Pingot (1993) do not recognize the Salet Fm and they include the rocks of the formation into the Molignée Fm.

Stratotype: Road section along the side road leading to the village of Salet from the main road along the Molignée valley, about 4 km WSW of Yvoir. From bed 295 to top of bed 480.

Area: DSA. To the south, the lower part of the Salet Fm passes laterally into the Molignée Fm. The Terwagne Fm is its lateral equivalent on the inner shelf.

Thickness: 100 m in the stratotype.

Age: Moliniacian (early Visean). In the stratotype, a rich archaediscid association allows recognition of the boundary between the Cf4β and γ Foraminifer Subzones within the formation. The rugose coral *Dorlodotia briarti densa* has been found in the base, indicating the RC5 Zone. The Salet Fm corresponds to the TST of the third-order sequence 6 of Hance *et al.* (2001).

5.30. Terwagne Formation – TER

Authors: Conil, 1967; Paproth *et al.*, 1983; Hance, 1988.

Description: The formation rests abruptly on the pale, thick-bedded limestones (grainstones) of the Avins Mbr of the Longpré Fm. In the type section, the lower part of the formation comprises brecciated dolostones and thin-bedded limestones (lime mudstones and peloidal grainstones). The middle and upper parts are characterized by limestones of peritidal facies (oolitic and peloidal grainstones, fenestral lime mudstones to packstones). Thin beds of crinoidal limestone (packstones to grainstones) occur in the upper part. The formation is dolomitized and brecciated (Belle Roche Breccia) in places. Fossils are uncommon.

Stratotype: Discontinuous road section, 500 m ENE of Terwagne church (CSA).

Area: NSA, CSA, ASA. The formation is typical of the inner shelf areas. It is present in the Boulonnais (lower member of the Haut-Banc Limestone; Poty, 1994).

Thickness: The thickness is at its maximum of 100-110 m in the type section. It is only of 20 to 35 m in the NSA.

Age: Moliniacian (early Visean). The foraminiferal association is ecological but is probably younger than Cf4α. Rugose corals found in the upper part are indicative of the RC5 Zone (*Dorlodotia briarti densa*). The Terwagne Fm corresponds to the TST of the third-order sequence 6 of Hance *et al.* (2001), in the inner shelf.

5.31. Basècle Formation - BAS

Authors: Dupont, in De Koninck, 1878; Bouckaert *et al.*, 1961; Groessens *et al.*, 1982; Paproth *et al.*, 1983; Doremus & Hennebert, 1995a; Hennebert, 1999.

Description: Dark grey to black, fine-grained, sometimes argillaceous, limestones with argillaceous layers. Cherty at the base. The macrofauna is poor. Several lithostratigraphic units can be recognized within the formation. One of them, the ***Basècle Breccia Mbr – BBA*** (Groessens *et al.*, 1982; Paproth *et al.*, 1983), is composed of limestone breccia. In the middle part of the formation, two levels of black, very regular bedded, homogeneous micritic limestone occur ("marbre noir de Basècles").

Stratotype: Old quarries in the Basècles - Quevaucamps area. Basècle Mbr: Km 65.6 – 65.8 in the railway cutting between Basècle and Blaton.

Area: Western HSA, at least from Péruwelz to Fleurus.

Thickness: About 250 m in the type area.

Age: Moliniacian, Cf4α?, Cf4β, γ Foraminifer Subzones (Groessens *et al.*, 1982).

5.32. Onoz Formation – ONO

Author: Hance, this paper.

Description: The formation overlies the Namur Dolostones and includes 2 members, from base to top:

– ***Parc Member (PRC)***: Alternating dark limestones (bioclastic packstones to grainstones), dolomitic limestones and dolomites. Bed thickness varies widely. The limestones have yielded a poorly diversified fauna of rugose corals, brachiopods and vermetid gastropods. Fenestral limestones occur in the upper third of the member.

– ***Leurquin Member (LEU)***: Dark, thin- to thick-bedded limestones with a remarkable development of algal facies (*Ortonella* and *Solenopora* oncoids) including also beds of oolitic grainstones and some breccias.

Stratotype: Two abandoned quarries on the left bank of the R. Orneau at Onoz (NSA).

Area: The formation extends across the Orneau and Ligne valleys on the northern border of the NSA. Eastwards, it passes into the Terwagne Formation and into the Neffe Formation.

Thickness: Parc Member, at least 37 m; Leurquin Member, more than 45 m.

Age: Moliniacian (early Visean). *Dorlodotia briarti* occurs in the lowermost part and indicates the RC5 Zone. Cf4β (?) – δ Foraminifer Subzones.

5.33. Dendre Group – DEN

Authors: Groessens *et al.*, 1982; Paproth *et al.*, 1983; Conil & Delcourt, 1989; Hennebert, 1999.

Description: The Montils, Grand-Chemin, Pont-de-Lens, Cambron and Montignies formations are included in the Dendre Group. They comprise dark limestones and dolomites, often crinoidal, rich in brachiopods and fasciculate corals (Conil & Delcourt, 1989; Hennebert, 1999). Black chert is locally very abundant. Paproth *et al.* (1983) included the Lens Fm into the group, but this formation is usually pale and easily distinguishable from the others justifying to be not grouped with them.

Stratotype: The Dendre Valley between Lens and Ath.

Area: Western HSA, at least from Péruwelz to Seneffe.

Thickness: About 460 m in the type area (Doremus & Hennebert, 1995a); about 550 m in the Laplaigne – Péruwelz area (Hennebert, 1999).

Age: Moliniacian (Groessens *et al.*, 1982).

5.33.1. *Montils Formation* – MOT

Authors: Groessens *et al.*, 1982; Paproth *et al.*, 1983; Conil & Delcourt, 1989; Doremus & Hennebert, 1995a, 1995b.

Description: Brown, coarse-grained, oolitic dolomite with inconspicuous undulating or lenticular bedding. Black or grey chert is present. Several levels of hard grounds have been recognized. Towards the west, an oolitic limestone level occurs at the base of the formation. The formation overlies the Malon-Fontaine Fm.

Stratotype: Old quarry situated SE of the old tannery of the Montils, at Brugelette.

Area: Western HSA, at least from Péruwelz to Seneffe.

Thickness: About 80 m in the type area.

Age: Moliniacian (Groessens *et al.*, 1982).

5.33.2. *Grand-Chemin Formation* - GRC

Authors: Groessens *et al.*, 1982; Paproth *et al.*, 1983; Conil & Delcourt, 1989; Doremus & Hennebert, 1995a, 1995b.

Description: Brown, crinoidal dolomite with brachiopods and corals (mainly syringoporids), with some variations from bottom to top. The dolomites are dark and fine-grained with chert in the lower part, but become well-bedded, medium grained, and almost devoid of chert in the upper part. Concentrations of calcite geodes typically occur at some levels. The formation overlies the Montils Fm.

Stratotype: Several small exposures along the "Grand Chemin" at Brugelette.

Area: Western HSA, at least from Péruwelz to Seneffe.

Thickness: About 150 m in the type area.

Age: Moliniacian (Groessens *et al.*, 1982).

5.33.3. Pont-de-Lens Formation – PDL

Authors: Groessens *et al.*, 1982; Paproth *et al.*, 1983; Conil & Delcourt, 1989; Doremus & Hennebert, 1995a, 1995b.

Description: Dark, argillaceous limestones, with dolomitic intercalations and black chert. Very fossiliferous (brachiopods). The limestones produce a fetid smell when freshly broken. The formation overlies the Grand-Chemin Fm.

Stratotype: Old quarry on the right bank of the R. Dendre, at Pont de Lens (Brugelette).

Area: Western HSA, at least from Péruwelz to Seneffe.

Thickness: 35 m in the type area.

Age: Moliniacian (Groessens *et al.*, 1982).

5.33.4. Cambron Formation – CAB

Authors: Groessens *et al.*, 1982; Paproth *et al.*, 1983; Conil & Delcourt, 1989; Doremus & Hennebert, 1995a, 1995b.

Description: Dark, medium- to coarse-grained, crinoidal dolomite with corals and brachiopods. Chert nodules are abundant and pale silicification occurs locally, with corals and brachiopods. The formation is similar to the Grand-Chemin Fm, but is more cherty. It overlies the Pont-de-Lens Fm.

Stratotype: Old quarry at Bollignies (Cambron-Casteau).

Area: Western HSA, at least from Péruwelz to Seneffe.

Thickness: About 130 m in the type area.

Age: Moliniacian (Groessens *et al.*, 1982).

5.33.5. Montignies Formation - MOG

Authors: Groessens *et al.*, 1982; Paproth *et al.*, 1983; Conil & Delcourt, 1989; Doremus & Hennebert, 1995a, 1995b.

Description: Dark, argillaceous, cherty and very fossiliferous limestones. The limestone produces a fetid smell when freshly broken.

Stratotype: Exposures in the "Val de la Marquette" at Montignies-lez-Lens.

Area: Western HSA, at least from Péruwelz to Seneffe.

Thickness: 65 m in the type area.

Age: Moliniacian (Groessens *et al.*, 1982).

5.34. Lens Formation - LEN

Authors: Groessens *et al.*, 1982; Paproth *et al.*, 1983; Conil & Delcourt, 1989; Doremus & Hennebert, 1995a, 1995b; Hennebert, 1999.

Description: Generally pale, grey-blue to brownish grey, thick-bedded, fine- to coarse-grained, crinoidal and paleoechinoidal limestones. There is a rich macrofauna (*Megachonetes*, productids, *Syringopora*, gastropods). Dolomitic levels and chert occur at the base; oolitic levels in the upper part.

Stratotype: Old quarry and some exposures at Lens.

Area: Western HSA, at least from Péruwelz to Seneffe.

Thickness: 250 m in the type area.

Age: Moliniacian (Groessens *et al.*, 1982).

5.35. Ecacheries Formation – ECH

Authors: Bouckaert *et al.*, 1961; Groessens *et al.*, 1982; Paproth *et al.*, 1983; Hennebert, 1999.

Description: Dark, thin-bedded, coarse- to fine-grained limestones, with marly interbeds. Chert is common in the upper part. A rich macrofauna of corals and brachiopods occurs locally. The formation overlies the Basècles Fm and is overlain by the Thieusie Fm.

Stratotype: Cutting along the towpath, on the right bank of the Blaton-Ath canal, at the "Ecacheries" (Blaton).

Area: Western HSA, at least from Péruwelz to Fleurus.

Thickness: About 74 m in the type area.

Age: Moliniacian. Cf4 Foraminifer Zone; Cf4δ and RC5 Coral Zone (*Siphonodendron ondulosum*) in the upper part.

5.36. Thieusies Formation – THS

Authors: Bouckaert *et al.*, 1961; Groessens *et al.*, 1982; Paproth *et al.*, 1983; Hennebert, 1999.

Description: Pale grey, thick-bedded, rather coarse-grained, limestones containing layers of crinoid debris, megachonetids and corals, alternating with dark, cherty limestones. Breccia occurs locally. The formation overlies the Ecacheries Fm and is overlain by the Lives Fm.

Stratotype: Exposures at "La Saisinne", at Thieusies.

Area: Western HSA, at least from Péruwelz to Fleurus.

Thickness: About 118 m in the type area.

Age: Late Moliniacian, Cf4δ Foraminifer Subzone (Paproth *et al.*, 1983).

5.37. Neffe Formation – NEF

Authors: de Dorlodot, 1895; Conil & Naum, 1977; Hance, 1982; Paproth *et al.*, 1983; Delcambre & Pingot, 1993.

Description: The Neffe Fm as defined here does not include the first sequence of Conil & Naum (1977), which displays the typical characters of the underlying Salet Fm. In the stratotype area (eastern part of the DSA), the formation comprises thick-bedded, pale crinoidal limestones (bioclastic packstones to grainstones). In contrast, the uppermost part is finer-grained and locally contains oncoids and stromatolites. In the ASA, CSA, NSA and in the western part of the DSA, the dominant facies (***Moha facies - MOH***; Laloux *et al.*, 1996a, 1996b) comprises thick-bedded to massive, pale, oolitic limestones (grainstones) with abundant clasts. Locally, the uppermost part of the formation can be similar as in the eastern part of the DSA. In the Vesder area (eastern part of the CSA), the formation is locally dark-grey to black in colour (***Dison Facies - DIS***; Laloux *et al.*, 1996a, 1996b). Locally, the Neffe Fm is more or less dolomitized, mainly in the lower part. Macrofossils are abundant (brachiopods, gastropods and rugose corals).

Stratotype: The railway cutting on the left flank of the Meuse valley, 400 m south of the bridge at Dinant, was designated as the stratotype of the Neffe Fm (Paproth *et al.*, 1983). The access of this section is dangerous. Furthermore, the section is of limited interest because it is incomplete. The railway cutting in the Dinant station exposes a complete section (Conil & Naum, 1977) and is designated here as the new stratotype, as suggested by Delcambre & Pingot (1993).

Area: The Neffe Fm is widespread in the Namur – Dinant basin, extending from the Boulonnais to Aachen area, except in the HSA.

Thickness: This ranges from 20 m at the eastern extremity of the NSA up to 170 m in some part of the DSA. It is about 65 m in the stratotype.

Age: Late Moliniacian (Cf4δ Foraminifer Subzone, Conil & Naum, 1977; RC5 Coral Zone). The oldest *Siphonodendron* (*S. ondulosum*) appears at the base of the formation; *Dorlodotia briarti* is common in the Moha facies. The Neffe Fm corresponds to the HST of the third-order sequence 6 of Hance *et al.* (2001).

5.38. Berneau Formation – BEU

Author: Poty, this paper.

Description: Thin to thick-bedded, dark limestones (mainly packstones and grainstones), with cross

bedding, shaly layers and some boulders of Frasnian limestone (Pirlet, 1968b; Poty, 1982). Brachiopods and corals are common.

Stratotype: Berneau railway cutting, north of Visé (Pirlet, 1968b).

Area: VSA. The formation was deposited on the slope of the Maastricht graben.

Thickness: 90 m in the stratotype where the base and the top are not exposed

Age: Most of the formation is Warnantian (Cf6α-Cf6δ), but its base is older, yielding foraminifera from the biozones Cf4, Cf5 and Cf6 (Kimpe *et al.*, 1978). RC6 and RC7 coral Zones.

5.39. Lives Formation – LIV

Authors: Demanet, 1923; Michot *et al.*, 1963; Paproth *et al.*, 1983.

Description: Well-bedded, pale grey to dark limestones, arranged in parasequences. 3 members can be recognized.

– ***Haut-le-Wastia Member – HLW*** (Laloux *et al.*, 1996a, 1996b)

Thick-bedded, pale grey to grey limestones in parasequences in which stromatolites and lime mudstones are dominant. There are some beds of breccia and oolitic limestone but bioclastic limestone is uncommon. The member is brecciated in places due to dissolution of evaporitic layers ("Petite Brèche Viséenne"). It corresponds to "V2bα" of Conil *et al.* (1967). The Haut-le-Wastia Mbr is separated from the underlying Neffe Fm by a bentonite, locally transformed into a palaeosol ("Banc d'or de Bachant").

– ***Corphalie Member – CIE*** (Laloux *et al.*, 1996a, 1996b)

The lower part is composed of thick-bedded, dark, bioclastic limestones with brachiopods and corals (mainly *Siphonodendron*, heterocorals and *Lithostrotion araneum* at the base), whereas the upper part comprises thin-bedded, dark, lime mudstones, with an argillaceous bed (weathered ash). The member forms a single, thick parasequence (sequence 0 or "V2bβ" of Conil *et al.*, 1967).

– ***Awirs Member – AWI*** (Laloux *et al.*, 1996a, 1996b)

The member includes 3 units: 1) a lower one, composed of 6 parasequences mainly of dark grey, bioclastic limestone, sometimes cherty, rich in colonial corals (*Siphonodendron martini*), followed by a micritic or stromatolitic top (="V2bγ"); 2) a middle unit of dark, bioclastic limestone rich in chert (="V2bδ"); and 3) an upper unit composed of 4 parasequences mainly of pale to dark grey, bioclastic limestones (="V2bε").

Stratotype: Quarry and cliff situated on the south side of the Meuse valley, downstream from the Beez motorway bridge, at Lives (NSA). Haut-le-Wastia Mbr: Haut-le-Wastia quarry, on the north side of the Molignée valley (DSA). Corphalie Mbr: old quarry at the top of the north slope of the Meuse valley at Corphalie (NSA). Awirs Mbr: eastern Awirs quarry, below Aigremont castle, north of the Meuse valley between Engis and Flemalle (NSA).

Area: The Lives Fm is known everywhere in the Namur-Dinant Basin, and extends to the Boulonnais (Haut-le-Wastia Mbr = upper part of the Haut-Banc Limestone; Corphalie Mbr = top of the Haut-Banc Limestone and base of the *Siphonodendron martini* Dolomite; Awirs Mbr = *Siphonodendron martini* Dolomite). The formation corresponds to the Blaton Limestone of Dupont, 1875, in the western part of the HSA.

Thickness: About 83 m at Lives (HLW = 30 m; CIE = 18 m; AWI = 35 m). In their stratotypes, the Haut-le-Wastia Mbr is about 30 m thick, the Corphalie Mbr 16 m thick and the Awirs Mbr 35 m thick.

Age: Early Livian. Cf5 Foraminifera Zone, RC5γ Coral Subzone (Haut-le-Wastia Mbr) and RC6 Coral Zone (Corphalie and Awirs Mbrs) (Conil *et al.*, 1991). The Lives Fm corresponds to the TST of the third-order sequence 7 of Hance *et al.* (2001).

5.40. Grands Malades Formation – GMA

Authors: Conil *et al.*, 1967; Paproth *et al.*, 1983.

Description: The formation includes a lower part comprising the Seilles Mbr (formerly described as formation by Paproth *et al.*, 1983) which locally passes laterally to the Maizeret Mbr, and an upper part, the Bay-Bonnet Mbr. For Paproth *et al.* (1983), the Grands Malades Fm was restricted to limestone breccia and stromatolitic limestone and was thought to overlie the Seilles unit. As the latter is now known to be a lateral equivalent of the breccia, it is here included in the formation.

1. ***Seilles Member – SEI*** (Conil *et al.*, 1967)

Thick-bedded, pale limestones in shallowing upward parasequences dominated by bioclastic packstones and grainstones, and oolitic grainstones, and capped with algal boundstones and mudstones. Brachiopods and rugose corals are common.

2. ***Maizeret Member – MZT mbr nov.*** (Poty)

Thick-bedded, pale limestones (mainly algal boundstones and mudstones-wackestones), dolomites and breccias, with numerous thick beds of coarse or prismatic calcite (interpreted as pseudomorphs of evaporites). Breccias can dominate.

3. ***Bay-Bonnet Member – BAB mbre nov.*** (Poty)

Thick-bedded, pale, laminated stromatolitic limestones (boundstones), with numerous vermetid gastropods.

Stratotype: Old quarries and cliff on the left flank of the Meuse valley at Bouge, west of the Beez motorway bridge. Seilles Mbr: Tramaka quarry, situated along the road from Seilles to Couthuin. Maizeret Mbr: Plates-Escailles quarry at Maizeret, on the west side of the Samson valley. Bay-Bonnet Mbr: Bay-Bonnet quarry in the Magne valley, between Fléron and Trooz.

Area: The Seilles Mbr is present only in the eastern part of the NSA (including the Vesder area) and passes laterally south-westwards into the Maizeret Member (which is only known in the Samson valley). In the CSA, DSA and in the western part of the NSA, the Grands Malades Fm has been brecciated ("Grande Brèche Viséenne") by dissolution of evaporitic layers. The formation is present in the Boulonnais where the Seilles Mbr corresponds to the Lunel Limestone, and the Bay-Bonnet Mbr to the Napoléon Limestone (Poty, 1994).

Thickness: The Seilles Mbr is 35 to 40 m thick at Seilles, and reaches 55 m in the eastern part of the NSA (Engis). Maizeret Mbr: 35 m. Bay-Bonnet Mbr: 8 m.

Age: Late Livian (Cf5 Foraminifera Zone, RC6 Coral Zone). There are no foraminifera or corals for dating the Bay-Bonnet Mbr directly, but it is situated just below the base of the Warnantian stage (base of the Cf6 Foraminifera Zone). The Seilles and Maizeret Mbrs correspond to the HST of the third-order sequence 7 of Hance *et al.* (2001), while the Bay-Bonnet Mbr corresponds to the TST of the third-order sequence 8.

5.41. Hoyoux Group – HOY

Authors: Delcambre & Pingot, 2000.

Description: The Bonne River Fm and the Anhée Fm compose the Hoyoux Group (consult their descriptions).

Stratotype: Hoyoux valley between Royseux and Chabôfosse.

Thickness: About 115 m in the Hoyoux valley.

Area: DSA, CSA, western part of the NSA.

Age: Warnantian. Cf6 Foraminifer Zone, RC7 and RC8 Coral Zones.

5.41.1. Bonne River Formation – BON

Author: Poty, this paper.

Description: This formation includes the Thon-Samson Fm, the Poilvache Fm and part of the Anhée Fm of Paproth *et al.* (1983).

– ***Thon-Samson Mbr – THO*** (Conil *et al.*, 1967; Pirlet, 1968a; Paproth *et al.*, 1983)

This member includes the Thon-Samson Fm of Paproth *et al.* (1983), except for the bedded lime mudstones, stromatolitic and other limestones (packstones-grainstones) at the top of that formation which resemble those of the overlying Poilvache unit and are now included in it. The Thon-Samson Mbr is, therefore, mainly composed of massive, pale to dark limestones (grainstones-rudstones), usually crinoidal ("petit-granit" de Thon). Corals and brachiopods are locally present.

– ***Poilvache Mbr – POI*** (Conil *et al.*, 1967; Pirlet, 1968a; Paproth *et al.*, 1983; Poty *et al.*, 1988)

As defined here, the Poilvache Mbr includes (1) some limestones previously attributed to the Thon-Samson Fm by Paproth *et al.* (see above), (2) the Poilvache Fm of Paproth *et al.*, and (3) part of the overlying Anhée Formation of Paproth *et al.* It comprises bedded, pale to dark limestones, sometimes cherty, arranged in parasequences dominated by lime mudstones and stromatolitic limestones. Macrofossils (corals and brachiopods) are uncommon. The formation is locally brecciated ("Grande Brèche Viséenne").

Stratotype: The Bonne River Fm is exposed near and along the old railway in the village of Modave (Pirlet, 1968), on the east bank of the R. Bonne. Thon-Samson Mbr, Plates-Escailles quarry at Maizeret, on the west side of the Samson valley. Poilvache Mbr, north-eastern part of the Poilvache Castle Rock, on the east side of the Meuse valley, 6 km north of Dinant.

Thickness: Thon-Samson Mbr: 8 m in the stratotype. Poilvache Mbr: 80 m.

Area: NSA, CSA, DSA. The Thon-Samson and Poilvache Mbrs are known in the Boulonnais where they correspond respectively to the lower and the upper parts of the Joinville Limestone (Poty, 1994).

Age: Early Warnantian. Thon-Samson Mbr: Cf6α Foraminifer Subzone, top of the RC6 Coral Zone or base of the RC7 Coral Zone (possible appearance of *Dibunophyllum*) (Conil *et al.*, 1991). Poilvache Mbr: top of the Cf6α to lower part of the Cf6γ Foraminifer Subzones, RC7α Coral Subzone (presence of *Dibunophyllum* and *Diphyphyllum*) (Conil *et al.*, 1991). The Thon-Samson Mbr corresponds to the HST of the third-order sequence 8 of Hance *et al.* (2001), while the Poilvache Mbr corresponds to the TST of the third-order sequence 9.

5.41.2. Anhée Formation – ANH

Authors: de Dorlodot, 1909; Pirlet, 1968a; Paproth *et al.*, 1983; Poty *et al.*, 1988.

Description: The Anhée Fm, as defined here, does not correspond to the definition of Paproth *et al.* (1983) in that: (1) it excludes parasequences with dominant lime mudstones and stromatolitic boundstones which are now attributed to the underlying Poilvache Mbr of the Bonne River Fm, and (2) it includes the overlying Warnant Fm of Paproth *et al.* (1983).

The formation therefore includes two members:

– The ***Lower Member – AMI Mbr nov.*** (Poty) comprises parasequences of dark limestones dominated by wackestones and packstones, with gigantoproductids and some corals. Locally (Hoyoux valley, ***Chabôfosse Facies - CHB***, Poty), the parasequences include very fossiliferous, coarse-grained packstones and grainstones with coral biostromes (Pirlet, 1964; Poty *et al.*, 1988). This unit includes limestones previously attributed to the lower part (Lower Mbr, "lower V3c") of the Warnant Fm of Paproth *et al.* (1983).

– The ***Upper Member – AMS Mbr nov.*** (Poty) comprises argillaceous limestones, shales and siliceous shales, with phosphatic nodules, previously attributed to the upper part (Upper Mbr, "upper V3c") of the Warnant Fm of Paproth *et al.* (1983).

The formation is locally brecciated ("Grande Brèche Viséenne").

Stratotype: Old underground quarry Watrisse at Anhée, on the western bank of the Meuse valley, about 6 km north of Dinant (DSA). Chabôfosse Facies: road and hill sections at Chabôfosse (Royseux) in the Hoyoux valley, 2 km north of Pont-de-Bonne.

Thickness: Lower Mbr, 25 m; Upper Mbr, from zero to 8 m.

Area: DSA, CSA, western part of the NSA. The Upper Mbr is locally absent (i.e. Hoyoux valley).

Age: Mid and late Warnantian. Upper part of the Cf6γ and Cf6δ Foraminifer Subzones (Conil *et al.*, 1991); RC7β Coral Subzone and base of the RC8 Zone (appearance of *Lonsdaleia*) (Poty *et al.*, 1988). The Lower Mbr of the Anhée Fm corresponds to the HST of third-order sequence 9 (Hance *et al.*, 2001), whereas the Upper Mbr (previously the upper member of the Warnant Fm) possibly corresponds to the TST of a following third-order sequence.

5.42. Ronde-Haie Formation – ROH

Authors: Paproth *et al.*, 1983; Laloux *et al.*, 1996a.

Description: Black, crinoidal, ribbon, fine-grained limestones. The formation is poorly known.

Stratotype: Small exposures in the hamlet of Ronde-Haie, 1600 m NE of Theux.

Area: The formation is known only in the Theux window (eastern CSA).

Thickness: Unknown.

Age: Warnantian (Cf6γ Foraminifer Sub-Zone, Pirlet, 1976).

5.43. Viesville Formation – VIE

Authors: Briart & Bayet, 1899; Conil, 1959; Paproth *et al.*, 1983; Hennebert, 1999.

Description: The lower part of the formation comprises centimetric to decimetric beds of black, sapropelic, fine-grained limestones with shaly levels, and the upper part black siliceous shales.

Stratotype: Old quarries and outcrops at Viesville.

Area: Western HSA, at least from Péruwelz to Fleurus.

Thickness: At least 67 m according to Conil (1959).

Age: Warnantian (Paproth *et al.*, 1983).

5.44. Blaton Formation – BLA

Authors: Bouckaert *et al.*, 1961; Paproth *et al.*, 1983; Hennebert 1999.

Description: Black shales, sometimes calcareous or siliceous. Some beds of argillaceous limestone, calcareous shales and siliceous shales.

Stratotype: Canal Nimy – Péronnes, "Mont des Groseilliers" cutting, 1400 m east of Blaton.

Area: Western HSA, at least from Péruwelz to Fleurus.

Thickness: 54 m in the Blaton area.

Age: Late Warnantian (Presence of *Goniatites striatus*).

5.45. Gottignies Formation – GOT

Authors: Conil, 1959; Paproth *et al.*, 1983; Hennebert, 1999.

Description: Regular, thin-bedded, dark grey to black laminated siliceous shales, rich in radiolarian, with shaly interbeds. Thin phosphorite beds occur locally.

Stratotype: Outcrops along the Wanze valley, north-east of Gottignies.

Area: Western HSA, at least from Péruwelz to Fleurus.

Thickness: about 77 m.

Age: Latest Warnantian (Paproth *et al.*, 1983; Hennebert, 1999).

5.46. Souvré Formation – SOU

Authors: Barchy and Marion, 2000.

Description: Thin-bedded, grey to black, silicified laminar shales and limestones ("phtanites").

Stratotype: Top of the quarry "F", south of Visé, east side of the Meuse valley (see Pirlet, 1967b, for the location).

Area: VSA. The formation is present, but very poorly exposed, almost everywhere in the Visé area, overlying Frasnian as well as Dinantian formations.

Thickness: From about 10 m near Visé to more than 100 m on the southern slope of the Maastricht graben.

Age: The Souvré Fm was considered as "Upper V3c" by Pirlet (1967b), but revision of the foraminifera suggests a lower Namurian age (E2). In the north, part of the formation could be partly Warnantian.

6. Informal lithostratigraphic units

6.1. Belle Roche Breccia – BRB

Authors: Paproth *et al.*, 1983.

Description: Breccia composed of limestone or dolomite boulders, some of them reaching thousands of cubic meters ("rafts" of non-brecciated limestone). The Belle-Roche Breccia is not defined here as a formation because it originated by solution collapse of evaporitic layers in the Terwagne Fm which affected various other formations. Therefore it has no lithostratigraphical value.

Stratotype: Belle-Roche quarry, at Fraiture (Sprimont), on the north side of the Amblève valley (CSA).

Area: The breccia occurs in the eastern part of the CSA.

Thickness: About 40 m in the Belle-Roche quarry. The base of the breccia is always situated some metres above the base of the Terwagne Fm. Locally (Comblain-au-Pont), it extends up to the top of the Lives Fm, so reaching a thickness of about 200 m.

Age: At least post-Livian, possibly post-Visean.

6.2. Grande Brèche Viséenne - GDB

Authors: Pirlet, 1972.

Description: Breccia with boulders of limestone in a matrix which is often red. The "Grande-Brèche" resulted from dissolution of evaporitic levels in the Maizeret Mbr of the Grands Malades Fm (Mamet *et al.*, 1986), but was probably also related to Variscan tectonics (Pirlet, 1972). Thus, it cannot be considered here as a lithostratigraphic unit.

Area: Western NSA, CSA, DSA.

Thickness: About 40 m, but sometimes more because in places the Viséan formations overlying the Maizeret Mbr are also brecciated.

Age: Post-Livian to post-Viséan.

7. Acknowledgements

The authors thank M. Coen, B. Delcambre, F.-X. Devuyst, P. Ghysel, E. Groessens, M. Laloux and J.L. Pingot for their comments and discussions.

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