Proposal to NCS – Middle Devonian lithostratigraphy

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- Newly defined units are indicated in green.
- Units defined in recent literature (mostly Carte géologique de Wallonie), formally introduced here are in blue.
- Units changing of statute (formation > members, members > facies) are indicated in yellow.
- Significative changes to existing units are indicated in red.

Alvaux Formation – ALV

Origin of name. From the Alvaux village in the Orneau River valley, *Calcaire d'Alvaux* D^{8} in Gosselet (1860, p. 90) or *Calcaires d'Humerée* in Stainier (1887, p. 75).

Description. The Alvaux Formation consists in dark grey or bluish well-bedded limestone, crinoidal and bioclastic at the base, then finer-grained, with an increasing proportion of calcshale and nodular argillaceous limestone upwards. The base is still locally sandy. Some beds are relatively rich in fossils (brachiopods, rugose and tabulate corals, stromatoporoids, trilobites); a metre-thick stromatoporoid biostrome is recognised near the top (Lacroix, 1974b). This last limestone bed is overlain by a few metres of nodular calcshale rich in brachiopods. In subsurface, the unit is known to include anhydrite horizons (Coen-Aubert et al., 1980).

Stratotype and sections. The Alvaux Formation is partly exposed in the disused quarries on both sides of the river in Alvaux (also spelled Al vau). (Delcambre & Pingot, 2008).

Area and lateral variation. The Alvaux Formation is present all along the margin of the Brabant Inlier from the Mehaigne River valley to the Dyle River valley near Nivelles. The transition between the Alvaux Formation and the Bois du Planti Formation, described by Lacroix (1991a), occurs between the Dyle River and Thisnes River valleys, (Delcambre & Pingot, 2008; Hennebert & Eggermont, 2002). The Alvaux Formation is also known in subsurface from the Hermalle-sous-Argenteau, Tournai and Leuze boreholes and from boreholes in the Lille area (Graulich et al., 1975; Coen-Aubert et al., 1980, Lagrou & Coen-Aubert, 2017).

Thickness. In the type section, the formation is 67 m thick (Delcambre & Pingot, 2008) but decreases rapidly westwards and eastwards (Hennebert & Eggermont, 2002; Delcambre, 2023) and thins out in the Mehaigne River valley (Delcambre & Pingot, 2013).

Age. Lacroix (1974b) reported the conodont *Icriodus eslaensis* in the upper part of the Alvaux Formation indicating the *timorensis* to *rhenanus–varcus* zones. *Polygnathus denisbriceae*, reported from the upper part of the formation, suggests the *ansatus* Zone (Gouwy & Bultynck, 2003a). The coral assemblage allows the correlation of the Alvaux Formation with the Névremont and Mont d'Haurs formations (Lacroix, 1991a). Both emblematic fossils of the Alvaux Member (*Calcaire d'Humerée à Dechenella striata* et *Spirifer pentameroïdes* [sic] (= *Kelusia pentameroides*) in Malaise & Stainier, 1892) were recently discussed in Mottequin (2019, 2021).

Bois de Bordeaux Group – BOR

Origin of name. From the Bois de Bordeaux, between Les Mautiennes and Mazy in the Orneau River valley, *Formation du Bois de Bordeaux* in Lacroix (1991a, p. 81).

Remarks. The group is a three-fold assemblage consisting of a carbonate unit intercalated between two siliciclastic and usually reddish units. In the type area, the three units were described as three members corresponding, in the classical literature to three units (*Poudingue d'Alvaux, Calcaire d'Alvaux* and *Roches rouges de Mazy* in Stainier, 1894) or two

assises (*Assise d'Alvaux* and *Assise de Mazy* in Asselberghs, 1936). However, the lithological contrasts and sufficient thickness allow considering the three units as formations gathered in a group. Lacroix (1974a, 1974b, 1991a) summarized the equivalence between the published names.

Content. From the base to the top, the formation is composed of the Mautiennes, Alvaux and Mazy Formations. In the western part of the Brabant Parauthochton, the middle formation is replaced by the Bois du Planti Member. In the eastern part of the Parautochton, the distinction is not obvious as the carbonate middle part is reduced (Delcambre & Pingot, 2013).

Bois de Boussu Formation – BBO

Origin of name. From the village of Bois de Boussu (now Boussu-Bois), west of Mons, where the conglomerate was recognised in several coal mine shafts and boreholes, *poudingue de Boussu* (Cornet & Briart, 1877, p. 86), *Poudingue du Bois de Boussu* (Rutot & Cornet, 1902).

Description. This unit is a conglomerate with few matrix and centimetre- to decimetre-sized pebbles of dark green sandstone and white quartz, often angular in shape. It includes some coarse-grained brownish sandstone beds. It rests unconformably on the Lower Paleozoic shale.

Stratotype and sections. Boussu borehole (Dejonghe et al., 1973) between 172.26 and 175.55 m. A discontinuous outcrop is visible along the disused railway between Warquignies and Boussu-Bois.

Area and lateral variation. Only known in the Boussu Massif, west of Mons (Delmer, 2004).

Thickness. Highly variable, from 3 m in the Boussu borehole to 35 m in the Saint-Homme shaft at Boussu (Asselberghs, 1949).

Age. A Middle Devonian age is supposed based on the overlying Névremont Formation but no fossil has been found so far in this unit. This conglomerate is probably a lateral equivalent of the Naninne Conglomeratic Beds of the Rivière Formation.

Bois du Planti Formation – BDP

Origin of name. From the Bois du Planti in the Thisnes River valley near Monstreux (Nivelles), *Membre du Bois du Planti* in Hennbert & Eggermont (2002, p. 19).

Description. It displays a succession of greyish sandstone with oblique stratifications, greyish to reddish shale with thin sandy intercalations and an upper unit of greyish, brownish or black sandstone, siltstone and shale extremely rich in coalified plant remains. This unit yielded the renowned Ronquières fossil flora (Stockmans, 1968; Gerrienne et al., 2004; de Ville de Goyet et al., 2007; Cornet et al., 2012 and references therein). Dolomitic horizons occur near the top.

Stratotype and sections. The Bois du Planti Formation is discontinuously exposed in the banks of the Thisnes and Pont-à-Mousson rivers west of Monstreux (Nivelles). This member is also particularly well exposed along the *Plan incliné de Ronquières* (Hennebert & Eggermont, 2002).

Area and lateral variation. The Bois du Planti Formation is present along the margin of the Brabant Inlier west of the Dyle River valley. Eastwards, it passes to the Alvaux Formation west of Sombreffe (Lacroix, 1991a; Delcambre & Pingot, 2008)

Thickness. In the type section, the formation is 15-17 m thick (Hennebert & Eggermont, 2002).

Age. Based on the palynological content of the fossiliferous horizons within the Bois du Planti Formation, Gerrienne et al. (2004) and de Ville de Goyet et al. (2007) indicate a middle to late Givetian age (uppermost part of the Lem Interval Zone to the lowermost part of the TCo Oppel Zone). The supposed Couvinian age for this lithological unit indicated by Legrand (1967) is therefore ruled out.

Couvin Formation – CVN

Origin of name. From the town of Couvin, *Calcaire de Couvin* in Gosselet (1860, p. 46–50).

Remark. The Couvin Formation was almost entirely based on the stratotype section along the Eau Noire River and in the Abîme cliff in Couvin (Lecompte, 1960; Tsien, 1969; Bultynck, 1970,

1991a). In these type sections, Bultynck (1970) described four lithological units: the 'first biostrome' (unit 1, sub-units I–k in Bultynck, 1970); the 'first subsidence period' (unit 2, sub-unit l); the 'second biostrome' (unit 3, sub-units m-q); and then the 'third biostrome' (unit 4, sub-units r-z). Bultynck (1991a, p. 21) introduced two members: the la Foulerie Member including the units 1–3 and the Abîme Member for the last unit (except sub-unit r still in the Foulerie Member). However, the Foulerie Member groups three lithological units that were described as distinct members by Denayer (2019). The Abîme Member is preserved without change even if lithological variations are detected, notably based on sections in Villers-la-Tour (Bertrand et al., 1993) and Nismes (Denayer, 2019).

Description. The base of the Couvin Formation is defined above the last thick shaly bed of the Moulin de la Foulerie Formation (Denayer & Mottequin, this volume). The lower member of the formation is the Villers-la-Tour Member – VLL (Denayer, 2019, p. 151 = unit 1: *premier biostrome* in Bultynck, 1970; member I in Bultynck & Godefroid, 1974), a unit dominated by bluish finely bioclastic argillaceous packstone with shaly interbeds. Above a basal c. 10 m thick unit, there is a first roughly stratified biostromal unit (c. 22–25 m thick) that is made of large lamellar stromatoporoids and corals encrusting a coarse-grained crinoidal rudstone. The biostrome is an autobiostrome with in situ elements in the lower part and a parabiostrome with reworked and broken stromatoporoids randomly accumulated in the upper part. The biostromes display a cyclic pattern with large stromatoporoids and corals at the base and fining-upwards with crinoidal and bioclastic limestone.

The Petigny Member – PET (Denayer, 2019, p. 152 = unit 2: *première période de subsidence* in Bultynck, 1970; member II in Bultynck & Godefroid, 1974) is a c. 40 m thick unit of dark grey or bluish-grey, argillaceous and fine-grained limestone alternating with some shaly beds. The bioclasts (crinoids, bryozoans and brachiopods) are scarce in a matrix containing up to 25% of clay and silt in the lower part (Bultynck, 1970). Large bivalves are the most notable faunal component of the Petigny Member (Denayer, 2019).

The Cul d'Èfer Member – CUE (Denayer, 2019, p. 152 = unit 3: *second biostrome* in Bultynck, 1970; member III in Bultynck & Godefroid, 1974) contains two phases. The first is a c. 25 m thick unit of autobiostromes composed of globular stromatoporoids and tabulate corals that alternate with and cover crinoidal rudstone. The second part essentially comprises cyclic deposits. Each cycle starts with coarse bioclastic rudstone passing to large bulbous

stromatoporoids, *Heliolites* colonies and large solitary rugose corals forming parabiostromes. They pass upwards to finer-grained bioclastic grainstone-packstone, then to darker wackestone with abundant amphiporids, small coral branches (mostly *Dendrostella* and *Fasciphyllum*) and common cystimorph rugose corals. The cycles vary in thickness from 2 m up to 9 m and some of them show a clear shallowing-upwards trend. The reworked aspect of the fauna also suggests a deposition under high hydrodynamic settings. The upper part of the member is thickly bedded and often dolomitised.

The Abîme Member – ABI (*Membre de l'Abîme* in Bultynck, 1991a, p. 21 = unit 4: *troisième biostrome* in Bultynck, 1970; members IV-V in Bultynck & Godefroid, 1974) starts with bedded stromatoporoids and tabulate corals parabiostromes with an abundant packstone matrix. An interval c. 4–6 m thick of dark argillaceous limestone can be recognised in the Eau Noire section and in the Villers-la-Tour, Saint-Remy (Chimay) and Saint-Joseph quarries (Nismes). The facies is darker but the fauna is abundant and includes thin laminar stromatoporoids and tabulate corals, solitary rugose corals, brachiopods, ostracods and trilobites. This dark argillaceous limestone constitutes the Saint-Remy Facies (Denayer, 2019, p. 154). Above, the development of cyclic biostrome starts again in the Couvin area. One to 5 m thick stromatoporoid biostromes alternate with accumulations of broken branches of corals (ramose tabulate and branched rugose corals) and amphiporid stromatoporoids. These facies seem to disappear westwards where they are replaced by massive accumulations of coarse bioclastic grainstone–rudstone with stromatoporoids and corals (e.g. in the Villers-la-Tour quarry, Denayer, 2019). East of Nismes the 'third biostrome' and associated facies are the only remnants of the Abîme Member and the lower members of the Couvin Formation are replaced by siliciclastics of the Jemelle Formation (see this name more details). At the Roche Trouée (Nismes), a similar succession is exposed: a 15 m thick unit of thinly-bedded bioclastic packstone–grainstone with rare tabulate corals is overlain by a c. 5 m thick stromatoporoid and tabulate coral biostrome that serves as a basis for a small bioherm c. 50 m in diameter and 20 m in height (Roche Trouée Facies, new term). This peculiar facies is very rich in bulbous stromatoporoids, large colonies of dendroid rugose corals and ramose tabulate corals. The bioclastic matrix is abundant. The bioherm passes laterally to bioclastic rudstone beds still rich in corals and stromatoporoids. Upwards, the bioherm is capped by a poorly

stratified bioclastic limestone (wackestone-packstone) unit containing layered accumulations of small branches of tabulate corals and amphiporids.

At the Roche Trouée, only the upper 100 metres of the l'Abîme Member are still present, but the thickness of the limestone decreases drastically eastwards, reaching less than 10 m in Olloy-sur-Viroin, then increases again to 50 m in Vierves-sur-Viroin before decreasing again as far as Givet. In parallel, the facies changes, becoming more argillaceous where the thickness is minimum. This limestone unit, well individualised between two shaly members of the Jemelle Formation, is defined as the Vierves Member – VRV (Denayer, 2019, p. 155). In the Vierves-sur-Viroin road section, the base of the Vierves Member is defined by the first laterally-continuous bed of bioclastic limestone (mudstone to wackestone) overlying the calcareous siltstone and shale of the Vieux Moulin Member (see Jemelle Formation). Shaly and silty interbeds are 1 to 10 cm thick and often contain calcareous nodules and abundant bryozoans, brachiopods, trilobites, ostracods, solitary rugose and lamellar tabulate corals. Upsection the argillaceous content of the limestone decreases and the shaly interbeds disappear. Solitary rugose corals (including cystimorphs and *Calceola sandalina*), *Heliolites* and alveolitids forming large colonies are also present, whereas stromatoporoids are uncommon. The upper part of the member is thickly bedded, less argillaceous, and even dolomitic at the top. The boundary with the overlying les Chavées Member of the Jemelle Formation is not clear-cut but the latter sees the reappearance of shaly interbeds. The argillaceous character is less marked east of the Meuse valley. Conversely, east of Pondrôme, the dolomitization increases progressively and affects the entire member in Wellin (Reumont Dolomitic Facies, new term).

Stratotypes and sections. The stratotype of the Couvin Formation is situated along the Eau Noire River, completed by the Abîme cliff in Couvin. The Villers-la-Tour Member is defined along the disused railway SE of Villers-la-Tour, 3 km southwest of Chimay. The stratotype of the Petigny Member is situated in small disused quarries along the Augile street, south of Petigny, 1.5 km E of Couvin. The le Cul d'Èfer section is an open-sky cryptokarst in the woody hill west of Petigny. The Abîme section in Couvin exposes the upper member but the latter can also be observed in the Villers-la-Tour and Saint-Remy (Chimay) quarries. The Roche Trouée Facies is defined in the Roche Trouée cliff in Nismes. The Vierves Member is defined along the Vierves-sur-Viroin road. East of the Meuse valley, there are good exposures of this

member in Eclaye and in Tienne de Reumont in Wellin where the member is dolomitic (Reumont Dolomitic Facies).

Area and lateral variations. The Couvin Formation can be traced along the southern margin of the Dinant Synclinorium from Nismes to Glageon (France) where it disappears below the post-Palaeozoic cover. This area constitutes the Eau Blanche Block sensu Denayer (2019). Eastwards, the Couvin Formation is replaced by the siliciclastics of the Jemelle Formation, apart from the Vierves Member that is recognised between Nismes and Wellin on the Viroin and Lesse blocks (Denayer, 2019).

Thickness. In Couvin, the entire formation is 380 m thick. The thickness of the Villers-la-Tour member reaches 40 m, while the Petigny and Cul d'Èfer members are 45–50 m and 130–135 m thick, respectively. The l'Abîme Member is 160 m thick in Couvin but decreases to c. 100 m in Nismes. The Vierves Member is 50 m thick in Vierves-sur-Viroin, <10 m in Olloy-sur-Viroin and c. 50 m thick in Wellin.

Age. Bultynck (1970, 1991a) reported the occurrence of conodonts indicative of the lower part of the *partitus* Zone within the basal beds of the Couvin Formation, including *Icriodus retrodepressus*. The lower three members of the formation are included in the *partitus* Zone whereas the Abîme Member yields conodonts indicating the *costatus* Zone. Dumoulin & Blockmans (2008) only reported *Bipennatus montensis* from the Vierves Member, a species characteristic of the *costatus* Zone. Therefore, the Vierves Member is correlated with the top of the l'Abîme Member and the hypothesis of a diachronism of the limestone unit, proposed by Dumoulin et al. (2006) and Dumoulin & Blockmans (2008), can be rejected (see also discussion on the age of the Jemelle Formation). The Couvin Formation recorded the third-order sequences MD1 and MD2 (Denayer, 2019).

Forrières Group – FOR

Origin of name. From the village of Forrières, south of Jemelle (new term).

Content. This group gather the poorly differentiated Moulin de la Foulerie (Saint-Joseph and l'Eau Noire members) and Jemelle formations along the southeastern limb of the Dinant Synclinorium between Grupont and Izier.

Remouchamps Facies (Fromelennes Formation)

Description. In the eastern areas, sandy siltstone and sandstone progressively replace the shale of the Flohimont Member (Waleffe, 1962; Coen & Coen-Aubert, 1971), here designated as the Remouchamps Facies. Thin beds, lenses and nodules of fine-grained limestone, often dolomitic, are intercalated in the sandstone beds. T

Jemelle Formation – JEM

Origin of name. From outcrops along the road near the Jemelle station, Jemelle Formation in Bultynck & Godefroid (1974, p. 11).

Description. In the Jemelle stratotype section, the formation was divided into three members, which are in ascending order: the Station, Cimetière and Chavées members (Godefroid, 1991a). The Station Member is replaced westwards by the Vieux Moulin Member (Dumoulin & Blockmans, 2008).

The **Station Member – STA** (*Membre de la Station* in Godefroid, 1991a, p. 31) is distinctly composed of shale to silty shale with thin beds of sandstone, often micaceous (Godefroid, 1968). The fossils are rare and usually decalcified. At the base of the Jemelle Formation, in the Aisne River valley, Lessuise et al. (1979), Dusar (1989) and Marion & Barchy (in press, a) indicated the occurrence of a sandstone unit consisting of bedded arkosic sandstone alternating with bioturbated shaly carbonate interbeds and containing some dissolved brachiopod shells. Denayer (2019, p. 156) proposed to designate these siliciclastic deposits as the **Aisne Sandstone Facies**. This facies increases in thickness north-eastwards and then replaces the shaly Jemelle Formation between the Xhoris and Rouge-Minière faults (Asselberghs & Yans, 1952) where it acquires a reddish colour announcing the Pepinster Formation. Nevertheless, the red colour invades the entire succession just south of the Xhoris Fault (Asselberghs, 1952).

The Station Member passes westwards to the **Vieux Moulin Member – VXM** (*Membre du Vieux Moulin* in Dumoulin & Blockmans, 2008, p. 26, 29), a thick and homogeneous succession of dark shale and siltstone where the cleavage is usually well developed. It is mostly shaly in the lower half and often dark in colour. Carbonate intercalations and fossils

are uncommon. The famous 'Mur des Douaniers' trilobite locality in Vireux (France) exposes these facies (Dumoulin & Blockmans, 2008). The upper half of the member is dominantly silty with some carbonate coquina beds that yields a more diverse fauna. The upper silty part is lighter in colour than the lower shaly part and reminds the facies of the Cimetière Member. Slightly carbonate sandstone known as the *Grès de Najauge* (Dumoulin & Coen, 2008, p. 38) (Najauge Sandstone Facies) occurs locally at the top of the member in the Viroin and Meuse River valleys and sandy shale in similar stratigraphic position are known in the Wellin area (Godefroid, 1968). This sandstone might be the local expression of the Aisne Facies that is well developed eastwards. The Vieux Moulin Member is overlain by the Vierves Member of the Couvin Formation which is marked by an increase of carbonate content in the siltstone and the reduction of the shaly interbeds separating the limestone beds.

The Cimetière Member – CIM (*Membre du Cimetière* in Godefroid, 1991a, p. 31) is dominantly shaly and dark in colour, with some intercalated argillaceous limestone beds and nodules relatively fossiliferous in the upper part. Eastwards, the Cimetière Member is not distinguishable from the underlying Station Member. It passes upwards to the lighter-coloured and more fossiliferous Chavées Member that has a higher carbonate content.

In the type area, the Chavées Member – CVE (*Membre des Chavées* in Godefroid, 1991a, p. 31) starts with a first 40 m thick unit ('Co2c I' in Bultynck, 1970) where numerous thin beds and nodules of limestone are intercalated within shale (Godefroid, 1968, 1991a). The fauna is abundant and diverse (solitary rugose corals, brachiopods, bivalves and trilobites, particularly in the lower part). A second 60 m thick unit ('Co2c II') is characterised by the abundance of limestone nodules. Thin biostromes composed of lamellar and massive alveolitids, stromatoporoids and occasional *Heliolites* with associated solitary rugose corals and brachiopods are developed in these beds. The next unit ('Co2c III') is c. 100 m thick and composed of carbonate shale with intercalated beds of argillaceous limestone rich in brachiopods and rugose corals. The overlying 40 m thick unit ('Co2c IV' is richer in limestone beds and nodules and includes a diverse fauna. Laterally to this shale are developed the limestone bioherms of the Tienne Sainte-Anne Member. The last 10 m thick unit ('Co2c V') is composed of sandy shale alternating with sandy limestone and calcareous, commonly micaceous sandstone with decalcified brachiopods and bryozoans. These sandy lenticular bodies of several hundred metres in length are sandwiched between the underlying shale and

overlying limestone of the Hanonet Formation. This horizon corresponds probably to the westwards expression of the Fond des Valennes Member of the Lomme Formation (Denayer, 2019).

The Tienne Sainte-Anne Member – TSA (Denayer, 2019, p. 159 = 'Co2c R' in Bultynck (1970), 'BI' on the geological maps of Wallonia) corresponds to bioherms developed in the upper part of the Jemelle Formation. It starts with yellowish, thick roughly-bedded crinoidal, rudstone covered by massive and lamellar stromatoporoids and tabulate corals and large massive colonies of the rugose coral *Cyathophyllum*. Upwards finer-grained facies developed, with reddish bioclastic wackestone with stromatactoid cavities and abundant chaetetid sponge layers. This core facies was observed only in larger bioherms. The uppermost facies is an often whitish bioclastic wackestone–packstone with stromatoporoids and massive tabulate corals. The Tienne Sainte-Anne Member is entirely embedded in the shale and siltstone of the Jemelle Formation.

Stratotype and sections. The stratotype of the Jemelle Formation is a composite section including the Jemelle–Forrières road section near the Jemelle train station (Station and Cimetière members) and the trench of the disused railroad Jemelle–Rochefort (Cimetière and Chavées members) at Jemelle. The sandy facies of the base are visible in the Aisne creek between Aisne and the Roche-à-Frêne. The Vieux Moulin Member is exposed along the Treignes–Vireux road. The Tienne Sainte-Anne Member is exposed at the base of the Sainte-Anne hill southeast of Nismes.

Area and lateral variations. The Jemelle Formation crops out along the southern and southeastern limbs of the Dinant Synclinorium between Trélon (France) and Ferrières where it passes to the Pepinster Formation. The Station Member is not recognised west of the Jemelle area and is hardly distinguishable from the overlying Cimetière Member east of the type locality. The Vieux-Moulin Member is known from the Viroin and Lesse blocks but the transition to the Station and Cimetière members is not well understood. The Chavées Member extends on the Eau Blanche, Viroin, Lesse and Ourthe blocks. The bioherms of the Tienne Sainte-Anne Member occur mainly in two zones: between Macon and Nismes, including the type section in Tienne Sainte-Anne, and in Wellin. In this latter locality, the bioherm is particularly big and rests directly on the Vierves Member of the Couvin Formation, hence the lower part of the Chavées Member is absent.

Thickness. In the type section, the Jemelle Formation is c. 350 m thick (40 m for the Station Member, 110–115 m for the Cimetière Member and 190–195 m for the Chavées Member; Godefroid, 1991a). The Vieux Moulin Member varies in thickness from c. 170 m in Grupont to 250 m in Wellin (Godefroid, 1968) and attains 260 m in thickness in the stratotype in Treignes (Dumoulin & Coen, 2008). The largest bioherm of the Tienne Sainte-Anne Member, exposed in Les Marlières (Wellin), reaches 200 m in thickness and c. 1000 m in width, but most of the others are c. 100 m thick and a few hundred of metres in diameter. In the type section of the Tienne Sainte-Anne in Nismes, the eponymous member is c. 50 m thick (Bultynck, 1970).

Age. The siliciclastic sediments of the Station Member produced no diagnostic conodont fauna. From the Cimetière Member, Godefroid (1968) reported the spiriferide brachiopods *Intermedites intermedius, I. supraspeciosus* and *Spinocyrtia ostiolata*, suggesting the *costatus* Zone. In Villers-Sainte-Gertrude, the Aisne Facies yielded the brachiopod *I. intermedius* and the spore *Grandispora velata* (Lessuise et al., 1979). The joined occurrences indicate the upper *partitus* Zone. The age of the Vieux Moulin Member is not constrained biostratigraphically because facies suitable for conodonts are uncommon. However, it seems logical that it could be the lateral time-equivalent of the Station and Cimetière members known eastwards. In the Grupont area, Godefroid (1968) reported the conodonts *Polygnathus partitus and Icriodus retrodepressus* indicative of the *costatus* Zone c. 15 m above the base of the formation. In the Couvin area, the base of the Chavées Member yielded *Polygnathus costatus costatus* and *P. linguiformis* forma γ (Bultynck & Godefroid, 1974) indicating the *costatus* to *australis* zones for the oldest part (Godefroid, 1991a) and a rich brachiopod fauna (e.g. *S. ostiolata*) (Bultynck, 1970).

The middle part of the Chavées Member yielded *P. pseudofoliatus* (Bultynck & Godefroid, 1974). In the same area, the bioherms of the Tienne Sainte-Anne Member and the beds immediately below yielded conodonts indicative of the *kockelianus* Zone (Bultynck, 1966; Bultynck & Godefroid, 1974). In the Wellin area, the argillaceous limestone overlying the the Vierves Member yielded *Icriodus costatus/pseudofoliatus* transitional forms (Dumoulin & Blockmans, 2008) that clearly indicate the middle part of the Chavées Member. Therefore, a depositional hiatus covers the lower part of the Chavées Member, and the first deposit on top of the Vierves Member is equivalent to the upper part of the Chavées and Tienne Sainte-Anne Members. In the Jemelle type section, the lower part of the Chavées

Member yielded *S. ostiolata* and *Cyrtinopsis* representatives (Godefroid, 1968; see also Mottequin, 2019 for discussion) that are typical of the *kockelianus* Zone interval in the Couvin area. Again, it points to a hiatus at the base of the Chavées Member in the Jemelle area.

In Couvin *P. ensensis* has been observed by at the top of the Jemelle Formation from Couvin, in a sandy facies which recalls the Lomme Formation Bultynck & Hollevoet (1999). This suggests that the growth of the Tienne Sainte-Anne bioherm (i.e. *eiflius* or uppermost *kockelianus* Zone) was terminated before the deposition of the sandy deposits of the Lomme Formation and its equivalents.

The Station and Vieux Moulin members are interpreted as the transgressive system tract of the third-order sequence MD2 whereas the Cimetière Member is tentatively interpreted as the highstand system tract of this sequence. The Chavées and Tienne Sainte-Anne members belong to the sequence MD3 but the uppermost sandy units of the Chavées Member probably represent the lowstand system tract of the sequence MD4 (Denayer, 2019).

Mautiennes Formation – MAU

Origin of name. From the Mautiennes locality in the Orneau River valley, *Membre des Mautiennes* in Lacroix (1991a, p. 81) starting on the Silurian basement by a conglomerate (*poudingue d'Alvaux* in Gosselet, 1863, p. 773, renamed *Poudingue des Mautiennes* by Lacroix, 1991a, corresponding to the *formation détritique de base* of Coen-Aubert et al., 1980).

Description. It consists of small quartz and quartzite pebbles, centimetric in size, and occasional small, flattened pebbles of weathered slate in a reddish sandstone matrix. The conglomerate is usually matrix-supported or passes to gravelly sandstone with small plant debris. The matrix is slightly carbonated and includes bioclasts (Lacroix, 1972). Strong variations in composition and thickness advocate for the lenticular development of the conglomerate and it is absent locally (e.g. Hingeon, Asselberghs, 1936). In the Samme River valley, the matrix of the conglomerate is a loose and poorly stratified sandy siltstone, reddish or mottled (Legrand, 1967). Above these beds occur sandstone and siltstone with shaly interbeds, greenish, reddish or variegated, with frequent plant debris.

Stratotype and sections. The type section of the formation is a composite section along the path on the eastern side of the Orneau River between the hamlet of Les Mautiennes and the village of Mazy (Delcambre & Pingot, 2008).

Area and lateral variation. The Mautiennes Formation is present all along the margin of the Brabant Inlier from the Mehaigne River valley to the Dendre River valley. It is also known in subsurface from the Hermalle-sous-Argenteau, Tournai and Leuze boreholes and from boreholes in the Lille area (Graulich et al., 1975; Coen-Aubert et al., 1980, Lagrou & Coen-Aubert, 2017). Although it varies in composition, it is recognisable in all outcropping areas.

Thickness. In the type section, the formation is 17 m thick. Eastwards, it thins to a few metres in the Mehaigne River valley (Delcambre & Pingot, 2013).

Age. The Givetian age of the basal conglomerate, established on the occurrence of *Stringocephalus burtini*, has been known for a long time (Dewalque, 1877; Stainier, 1894). Gouwy & Bultynck (2003b) reported the conodont *Polygnathus xylus* from the basal conglomerate of the Mautiennes Formation.

Mazy Formation – MAZ

Origin of name. From the Mazy village in the Orneau River valley, *Grès et poudingue de Mazy* D^5 in Gosselet (1860, p. 93) and *grès de Mazy* in Stainier (1894, p. 198).

Description. The formation is characterised by the reoccurrence of siliciclastic red beds. The composition of this member is very variable laterally, but commonly starts with red shale passing to sandstone and conglomerate of various colours. Greyish to pinkish carbonate sandstone and sandy limestone, bioclastic or dolomitic are present in the middle part and overlain by reddish clayey sandstone and siltstone. These rocks are typically poorly stratified and display no cleavage (*roches rouges* in Legrand, 1967). Palaeosols and rhizocretions are frequent in these lithologies. The base of the overlying Bovesse Formation (see Mottequin et al., this volume) is marked by a ferruginous conglomerate.

Stratotype and sections. The type section of the formation is a composite section along the path on the eastern side of the Orneau River upstream the village of Mazy (Delcambre & Pingot, 2008).

Area and lateral variations. The Mazy Formation is present all along the margin of the Brabant Inlier from the Mehaigne River valley to the Dendre River valley. It is also known in subsurface from the Tournai and Leuze boreholes and from boreholes in the Lille area (Coen-Aubert et al., 1980; Lagrou & Coen-Aubert, 2017).

Thickness. In the type section, the formation is 45 m thick (Delcambre & Pingot, 2008) but decreases rapidly eastwards (Delcambre, 2023) and thins out in the Mehaigne River valley (Delcambre & Pingot, 2013).

Age. The red beds of the Mazy Formation yielded no diagnostic element for datation but the Givetian age is inferred from the age of the underlying and overlying formations. The supposed Couvinian age for this lithological unit indicated by Legrand (1967) is therefore ruled out.

Pepinster Formation – PER

Origin of name. From the village of Pepinster (also spelled Pépinster) where the formation is well exposed, *Formation de Pépinster* in Dejonghe et al. (1991a, p. 93).

Description. In the type section and in the Vesdre River valley, the Pepinster Formation starts with a c. 12 m thick unit of dark then red and green shale and siltstone with carbonate and sulphate nodules overlying the basal conglomerate of the Vicht Conglomeratic Bed (see Denayer & Mottequin, this volume). A 24 m thick package of greenish arkosic ('kaolinic') sandstone and conglomeratic sandstone is individualised as the Heusy Member (*Membre d'Heusy*, Hance et al., 1989, p. 5). The conglomerate has a distinct pinkish colour with pink quartz pebbles. Plant macrofossils occur in the lower part whereas the upper one is calcareous and rich in marine fossils such as crinoids, brachiopods and tentaculites. The latter has the typical characters of the *Grauwacke de Rouillon*, i.e. decarbonated fossiliferous sandstone with dissolved fossils (Asselberghs, 1955). Within this member, a conglomeratic horizon with quartz and limestone is fossiliferous and yielded stringocephalid brachiopods. It is considered as marking the base of the Givetian in the Vesdre River valley (Liégeois, 1955). The rest of the formation is dominated by red shale and siltstone in which sandy limestone or dolomitic beds with stringocephalids occurs near the top, forming the transition to the overlying Névremont Formation (Liégeois, 1955, 1956; D'Heurs, 1970; Coen-Aubert, 1974).

In the Dinant Synclinorium, the Pepinster Formation is divided into three units (three *assises* in Asselberghs, 1955 or three *formations* in Liégeois, 1955). The lower one, starting on top of the last conglomeratic bed of the Burnot Formation is an alternation of reddish and greenish sandstone and siltstone with dissolved carbonate nodules. The middle one includes carbonate sandstone with dissolved fossils (crinoids, brachiopods, tentaculites) reminding the *Grauwacke de Rouillon* but interstratified with wine-red siltstone and shale. It is certainly the local expression of the Heusy Member. The upper unit is made of wine-red micaceous sandy siltstone with decalcified nodules and sandstone with dissolved crinoids and occasional haematite oolites.

Marine intercalations are more frequent in the middle unit, particularly south of Harzé. Westwards, in the Hoyoux valley, the formation starts with a first thin conglomeratic bed, probably a lateral equivalent of the Tailfer Conglomeratic Horizon of the Rivière Formation, characterised by its light grey to green colour and its content in dissolved crinoids (Thonon, 1980). Its passes upwards to variegated then red siltstone and sandstone with palaeosols and root traces (Molenaar, 1984), then a thick package of conglomerate. This unit, referred as the Marchin Member – MRC by Mottequin et al. (2021; *Poudingue de Marchin* in Forir, 1897, p. 34) is a homogenous conglomerate in metre-thick beds, with dominant white quartz pebbles in a light grey to white quartzitic matrix (Fig. 16A). The first bed of limestone marks the base of the overlying Névremont Formation.

Stratotype and sections. Section along the left bank of the Hoegne River between El Fagne and Mousset in Pepinster. Sections along the railroad towards Verviers and Spa serve as complementary stratotypes. The Heusy Member was defined in the embankment of the E42 motorway but this section is particularly overgrown nowadays. An alternative type section is situated in the quarry Brandt Nord (Goé) in the Gileppe River valley (Hance et al., 1994). The Marchin Member is exposed on both sides of the Hoyoux River at Marchin. The railway section near the Remouchamps station is also a good hypostratotype of the Pepinster Formation.

Area and lateral variation. The Pepinster Formation is known from the Vesdre area and the Theux Window as well as along the northern limb of the Dinant Synclinorium. South of the Vesdre River valley, the composition changes slightly. In Louveigné, the formation is reduced in thickness and consists of a lower unit of coarse-grained badly washed greenish sandstone

and an upper unit of reddish sandy siltstone; then the three-fold division described by Asselberghs (1955) and Liégeois (1955) develops up to Xhoris where the red colour disappears progressively from the middle part and then in the lower and upper parts. Southwards, it passes to the marine facies of the Forrières Group (Asselberghs & Jans, 1952; Marion & Barchy, in press, b). In the Ourthe River area, the Pepinster Formation exists only south of Tilff (Liégeois, 1955; Bellière & Marion, 2015). Westwards, it passes laterally to the Rivière Formation between the Hoyoux River and Samson River valleys (Delcambre, 2023). In the Vesdre area, it passes in Germany, south of Aachen, to the *Friesenrather-Schichten* (Kasig & Reissner, 2008).

Thickness. The formation is c. 100 m thick (24 m for the Heusy Member) in the type area but decreases westwards (c. 50 m in Prayon, Coen-Aubert, 1974). It increases southwards (> 200 m in Remouchamps) and eastwards (> 450 m in Vicht) (Dejonghe et al., 1991a). In the Hoyoux valley, the Pepinster Formation reaches 180 m, including c. 20 m for the conglomeratic Marchin Member (Mottequin et al., 2021).

Age. In the northern part of the Vesdre area (Goé Nappe), the basal shale beds of the Pepinster Formation are dated of the early Givetian 'Lem' subzone of the AD palynozone, encompassing the Eifelian-Givetian boundary. In Goé, however, the co-occurrence of the spores *Rhabdosporites langii* and *Grandispora protea* suggests an older age (not older than the 'Vel' subzone, equivalent to the *costatus* Zone). However, in the southern part of the Vesdre area (Gileppe Nappe), the Pepinster Formation is dated 'pre-Lem' (Hance et al., 1994). In Remouchamps, the basal part of the formation yielded *Icriodus corniger* and *I. retrodepressus* that both indicate the *partitus* Zone (de Decker, 1994), i.e. the lower part of the Eifelian. The occurrence of stringocephalid brachiopods and the rugose coral *Argutastrea tenuiseptata* c. 10 m below the top of the formation confirms that the upper part of the Pepinster Formation is Givetian in age, in the *timorensis* conondont Zone characterising the top of the lower Givetian (Gouwy & Bultynck, 2003b; Coen-Aubert, 2019). The Heusy Member yields macrofauna that were attributed to the early Eifelian (Kayser, 1895; Asselberghs, 1922). The formation is clearly diachronous and its base is older in the Dinant Synclinorium than in the Vesdre area. Thin shaly intercalations within the Marchin Member yielded palynomorphs indicative of the earliest Givetian (Mottequin et al., 2021).

Rouillon Member – RLL (Rivière Formation)

begins with a c. 15 m thick unit of shaly and sandy red and greenish beds with plant fragments. Within these sandstone and shale, a second thin (c. 1 m thick) conglomeratic horizon, known as the Tailfer Conglomeratic Bed (*poudingue de Tailfer* in Stainier, 1890, p. 26), consist of a poorly cemented conglomerate and coarse-grained sandstone with small quartz pebbles embedded in a light-coloured greenish, often ferruginous matrix with small cavities left by dissolved fossils. They are associated with micaceous corase-grained sandstone rich in plant remains (Groessens, 1970). It is overlain by a second unit of greenish to reddish shale and sandstone with scarce, often dissolved, bioclastic limestone intercalations (*Grauwacke de Rouillon* sensu Gosselet, 1873 and Asselberghs, 1955) (Fig. 17A). The abundance of fossil varies from section to section (Delcambre & Pingot, 2018b).

North of the Condroz Inlier, where these beds are the first deposit resting unconformably on the Ordovician–Silurian bedrock, the Rivière Formation starts with the Naninne Conglomeratic Bed (*Poudingue de Naninne* in Gosselet, 1888, p. 439), composed of small pebbles (quartz, sandstone and tourmalinite) embedded in a fine-grained light-coloured matrix, often ferruginous. The Naninne Conglomeratic Bed is locally double, separated by sandstone and passes locally to coarse-grained sandstone or disappears. These beds are overlain grrenish siltstone and sandy siltstone with plant remains and coarse-grained sandstone that possibly corresponds to a proximal development of the Tailfer Conglomeratic Bed, itself overlain with reddish sandstone and siltstone.

In the Honnelle River valley, the lower part of the Rivière Formation displays a facies somewhat different from those known in the type area. This facies is designated as a new unit: the Roisin Member – ROI (*grauwacke supérieure de Roisin* in Cornet, 1923, p. 186; *Macigno de Roisin* in Marlière, 1970, p. 13). This member is composed of brownish to greenish fine-grained argillaceous and micaceous sandstone alternating with micaceous shale beds with abundant internal moulds of brachiopods and crinoids. It passes upwards to poorly bedded sandstone showing numerous pseudonodules (*miches* in Marlière, 1970). The upper part of the member is made of yellowish sandstone with numerous lenticular beds of dissolved bioclasts.

Stratotype and sections. No good section exposing the entire formation is known but each member has its stratotype section. The Rouillon Member is exposed along the Namur–Dinant road at Rivière on the left bank of the Meuse River. The Naninne Conglomeratic Bed is exposed along the Bruxelles–Luxembourg railroad south of the eponymous station. The Roisin Member is exposed in the Honnelle valley, south of the place known as the Caillou-qui-Bique.

Area and lateral variations. Along the northern flank of the Dinant Synclinorium, the Rivière Formation occurs between Roisin and west of the Hoyoux River valley where it passes laterally to the Pepinster Formation (Delcambre & Pingot, 2018a; Mottequin et al., 2021) through progressive development of reddish facies. In the Haine-Sambre-Meuse Overturned Thrust Sheets, the formation is known from Presles to Ben-Ahin but the Claminforge Member is less developed or even lacking (Lacroix, 1974c). The transition between the Rouillon and Roisin members occurs in the Thuin area, whereas more carbonate facies are already developed in the Eau d'Heure River valley (Delcambre & Pingot, 2000).

Age. According to Bultynck & Boonen (1976), the basal beds of the Rouillon Member yielded the *Icriodus retrodepressus*, indicating the *partitus-costatus* Zones boundary interval (Bultynck, 1991d).

Remark. The term *Poudingue de Naninne*, introduced by de Gosselet (1860) (in replacement of the name Pairy-Bony since the later locality disappeared from the military topographic maps), predates the introduction of the term *Assise de Naninne* (a Silurian shaly unit of the Condroz Inlier) introduced by Malaise (1900). Though the latter name is commonly used, it should be abandoned.

Héblon Facies (Terres d'Haurs Formation)

Description. The upper part of the formation is made of coarser-grained bioclastic, crinoidal or oolitic, limestone with less argillaceous interbeds than below. In Hotton and Givet the argillaceous interval is situated in the upper part whereas the lower part displays more carbonate restricted facies (Coen-Aubert, 2003; Barchy et al., 2004). This unusual development is referred here as the Héblon Facies (from the Héblon castle facing the Hotton quarry, since the name Hotton was previously used to designate the Trois-Fontaines Formation).

Wancennes Formation – WAN

Origin of name. From the village of Wancennes, Wancennes Formation in Denayer (2019, p. 156).

Description. The Wancennes Formation is dominated by massive light grey limestone rich in reefal organisms. The basal 20 m of the formation consist of light grey crinoidal rudstone that include large lamellar stromatoporoids and is extremely rich in brachiopods, gastropods, trilobites and tabulate corals; upwards, the latter corals and stromatoporoids display bulbous shapes. Above, a 40 m thick massive unit is almost entirely composed of large lamellar stromatoporoids with few corals and light grey crinoidal rudstone. The middle part of the formation is composed of c. 40 m of massive light grey framestone with lamellar and bulbous stromatoporoids, ramose (pachyporids), lamellar and dome-shaped tabulate (alveolitids) and rugose corals (*Fasciphyllum, Australophyllum*, *Sociophyllum*). Locally, the crinoidal and bioclastic matrix is abundant, as are the cemented cavities. A 10–20 m thick unit of fine-grained, argillaceous wackestone, usually rich in *Fasciphyllum* and ramose tabulate corals, appears on the top of this middle part. The rest of the reef displays similar light grey framestone on a thickness of 70–80 m, with an extremely diverse coral fauna, including very large colonies. The reef-crests are dominated by large bulbous stromatoporoids and *Heliolites* colonies embedded in thick accumulations (up to 25 m) of whitish crinoidal rudstone with fragments of branched coral colonies (Denayer, 2023). The top of the reef is overlain by the shale of the Chavées Member of the Jemelle Formation.

Stratotype and sections. Section along the creek and in the crops north-east of Wancennes, 1 km south of Beauraing.

Area and lateral variations. The formation is only developed between Dion and Pondrôme, along the southern margin of the Dinant Synclinorium (Lesse Block of Denayer, 2019).

Thickness. The Wancennes bioherm is 275–300 m thick and 3000 m long, while that exposed in Dion is smaller (100 m thick and 300 m long).

Age. Eifelian. No data on conodonts is available but the reef is bracketed by the Moulin de la Foulerie Formation (*partitus* Zone) and the Chavées Member of the Jemelle Formation

(*costatus* Zone). Moreover, the top of the Wancennes Formation yields *Fasciphyllum varium* (= *Beugniesastraea varia* sensu Coen-Aubert, 1988a) that is only known from the upper part of the Abîme and Vierves Members of the Couvin Formation in the Couvin area (Coen-Aubert, 1988a; Denayer, 2019); therefore, this species provides a significant correlation.

The reef recorded two third-order sequences (MD1 and MD2), the argillaceous limestone occurring within the reef marks the first sequence boundary, whereas the sharp surface capping the reef corresponds to the sequence boundary of the sequence MD2 (Denayer, 2019).

Remark. The Wancennes Formation was not recognised on the geological map Felennes–Vencimont, where Dumoulin & Blockmans (2013b) interpreted this limestone unit as a recurrence of the Couvin Formation.

Wellin Formation – WEL

Origin of name. From the village of Wellin where the formation is exposed along the Fond des Vaux River valley, Wellin Member in Denayer (2019, p. 163).

Remarks. Locally, the typical argillaceous limestone of the Hanonet Formation is replaced by coarse-grained bioclastic and crinoidal grainstone that was described by Coen-Aubert (1990a, 1991a) and Coen-Aubert et al. (1991) under the provisional name of *Formation X*, whereas Denayer (2019) assigned them to a new member (Wellin member) of the Hanonet Formation. Astonishingly, Coen-Aubert (1991c, p. 15) proposed the acronym WEL for this *Formation X*, implicitly acknowledging the future name to come. Denayer's (2019) Wellin member is here promoted to formation status.

Description. The Wellin Formation starts with greenish-grey, well-bedded coarse-grained crinoidal grainstone and shaly interbeds with an abundant fauna of corals and stromatoporoids (Coen-Aubert et al., 1991). It passes upwards to a massive light grey limestone rich in large bulbous and domal stromatoporoids. The matrix between the stromatoporoids is often abundant and rich in tabulate and rugose corals. Coarse-grained crinoidal rudstone with abundant stromatoporoids and tabulate corals are recurrent in its upper part. Thin shaly interbeds occur throughout the unit. In the Fondry des Chiens

(Nismes), the unit is mostly dominated by bedded crinoidal rudstone below the massive stromatoporoidal framestone forming the basal biostrome of the Trois-Fontaines Formation. Laterally, the crinoidal grainstone passes progressively to the typical facies of the Hanonet Formation via an intermediate facies, notably at Baileux (Monts de Baileux quarry) and Nismes (disused Roche Nanette quarry) (Denayer, 2019).

Upwards, the crinoidal limestone of the Wellin Formation inconspicuously grade into the purer ones of the Trois-Fontaines Formation (Coen-Aubert, 1990; Coen-Aubert et al., 1991a), though the top of the Wellin Formation is irregular and intercalations of the Hanonet Formation exists as in the Fond-des-Vaux section in Wellin (Coen-Aubert et al., 1991). The boundary between both units is thus not clear-cut. Nevertheless, the massive aspect of the basal beds of the Trois-Fontaines Formation compared with the bedded limestone of the Wellin Formation and the disappearance of the shaly interbeds are the most conspicuous differences between the two formations.

Stratotype and sections. The Wellin Formation is exposed in road embankments and disused quarries along the Fond-des-Vaux creek north of Wellin.

Area and lateral variations. Besides the stratotypic area, the Wellin Formation also crops out at Nismes (Coen-Aubert, 1992) and Baileux (Jamart & Denayer, 2020); therefore, it is developed locally on the Lesse and Eau Blanche blocks (Denayer, 2019).

Thickness. The Wellin Formation is c. 100-120 m thick in Wellin in the Monts de Baileux but in the Fondry des Chiens sections, it reaches only 45 m (Préat et al., 2007; Mabille & Boulvain, 2008) with a limited development of reefal facies.

Age. The conodont *Polygnathus ensensis* indicating the eponymous zone has been reported from the middle part of the Wellin Formation (Bultynck, 1987; Coen-Aubert et al., 1991a) and its top locally enters in the *hemiansatus* Zone, notably in the Fondry des Chiens (Coen-Aubert, 1992). It recorded the transgressive system tract of the third-order sequence MD4 of Denayer (2019).

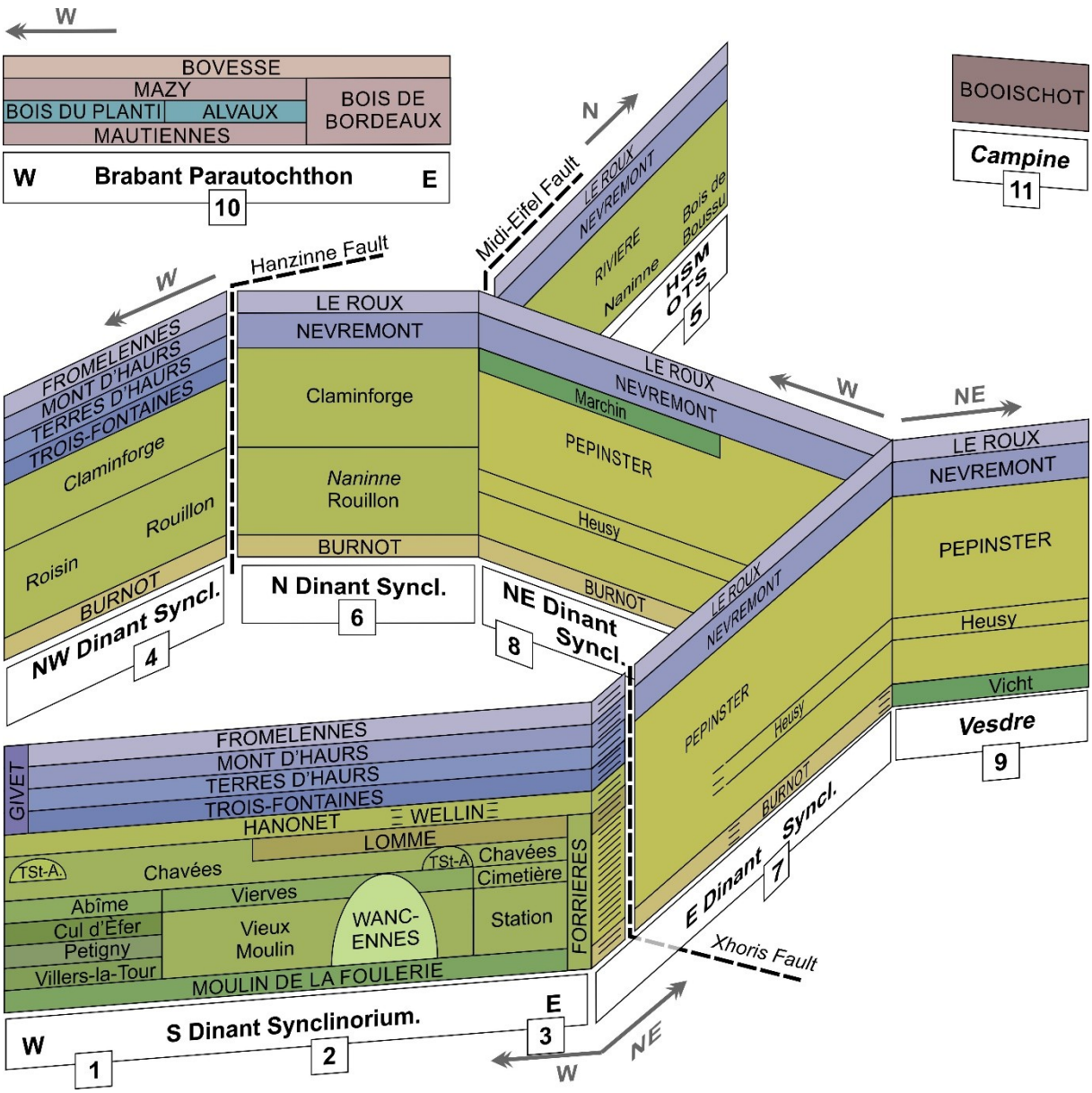

Figure 1. Schematic vertical and lateral relationships of the Middle Devonian units of Belgium. Abbreviations: Anticl., Anticlinorium; HSM OTS, Haine-Sambre-Meuse Overturned Thrust-Sheets; Syncl., Synclinorium. 1: western part of S limb of the Dinant Synclinorium, 2: central part of S limb of the Dinant Synclinorium, 3: eastern part of S limb of the Dinant Synclinorium, 4: western part of the northern limb of the Dinant Synclinorium, 5: Haine-Sambre-Meuse overturned thrust sheets, 6: central part of the northern limb of the Dinant Synclinorium, 7: SE limb of the Dinant Synclinorium, 6: eastern limb of the Dinant Synclinorium, 8: eastern part of the northern limb of the Dinant Synclinorium, 9: Vesdre area, 10: Brabant Parauthochthon, 12: Campine Basin.

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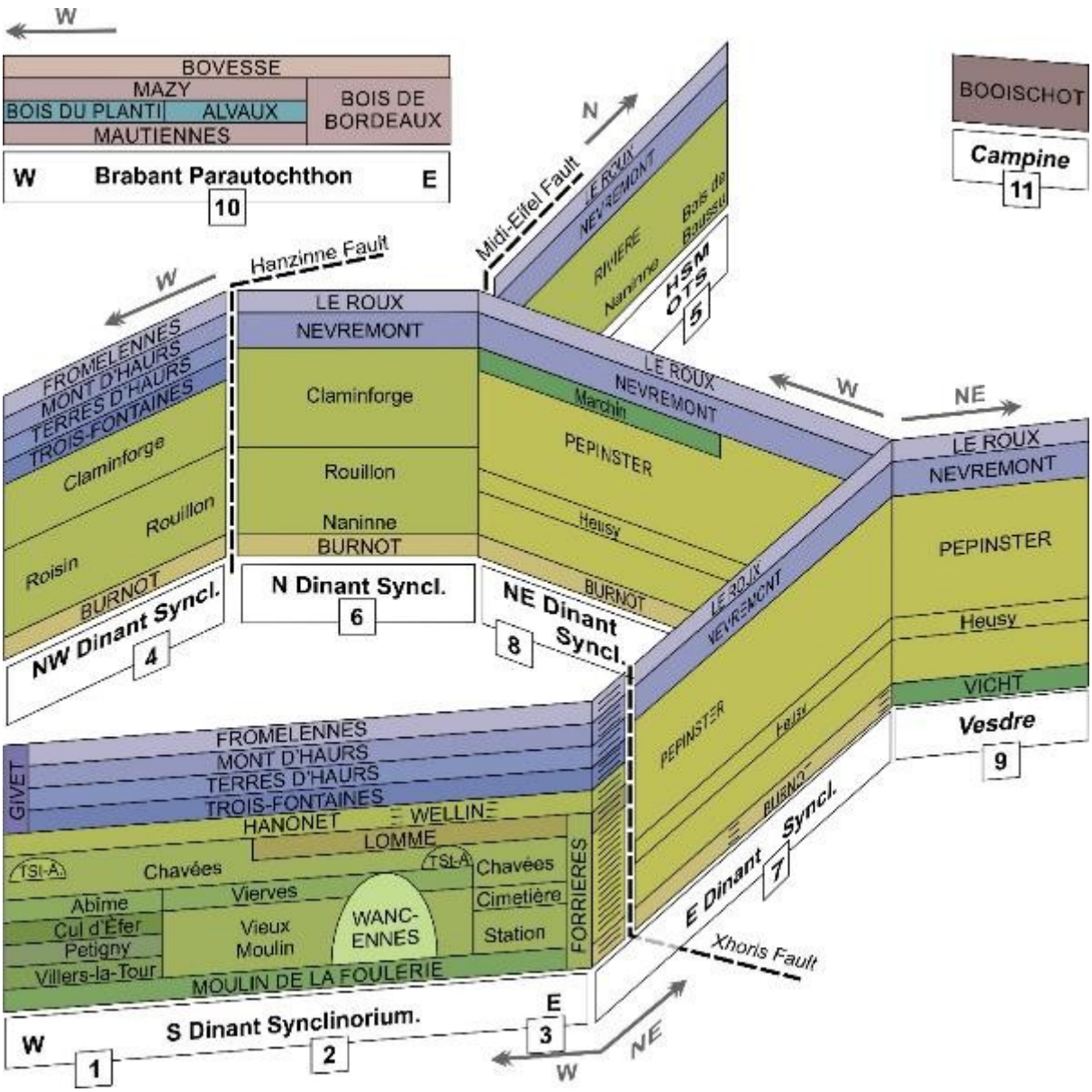

Figure 1. Schematic vertical and lateral relationships of the Middle Devonian units of Belgium. Abbreviations: Anticl., Anticlinorium; HSM OTS, Haine-Sambre-Meuse Overturned Thrust-Sheets; Syncl., Synclinorium; TSA, Tienne Sainte-Anne Member. Numbers 1-10 refers to geographical zones. Formations in capital letters, Members in regular letters.