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Upper Devonian lithostratigraphy of Belgium

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ABSTRACT

The lithostratigraphic scale of Belgium, which is the cradle of several global Devonian stages, has been revised after completion of the update of the Geological Map of Wallonia (*Carte géologique de Wallonie*) at a scale of 1/25,000 and recent stratigraphic and sedimentological research. As a result, 100 lithostratigraphic units (groups, formations, members, facies, horizons) for the Upper Devonian Series have been re-defined. Whereas most of the units discussed in this overview are traditional divisions of the Belgian lithostratigraphic scale, this update includes revisions to their definitions, boundaries, and ages. New terms have been introduced essentially for notable horizons and facies. Additionally, some previously described formations have been reclassified as members as they are difficult to distinguish and separate on geological maps. The Frasnian lithostratigraphic units reflect the development of mixed argillaceous-carbonate deposits during the major transgressions that culminated at the end of the stage. This was followed by the gradual emergence of littoral siliciclastic facies that took place during the Famennian regression. Re-installation of carbonate deposits was recorded during the latest Famennian (Strunian transgression), heralding the lower Carboniferous carbonate succession to come. Reefs occur in the Frasnian (buildups, mud mounds, biostromes) and their presence in the middle Famennian is remarkable.

KEYWORDS

Frasnian,
Famennian,
Strunian,
Namur–Dinant Basin,
Campine Basin,
Vesdre area

Article history

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1. Introduction

Establishing the lithostratigraphic scale of Belgium is a lengthy process dating back to the first half of the 19th century, when Dumont (1832) and Davreux (1833) published fundamental memoirs on the geology of the province of Liège. They were followed by several generations of geologists and palaeontologists, including Gosselet (1860, 1880a, 1888), Dewalque (1868), Mourlon (1875a, 1880) and Dupont (1881, 1882), to name but a few pioneers, who set out to name, date and correlate sedimentary successions. The first geological maps of the Belgian territory were published by d'Omalius d'Halloy (1822) and, above all, Dumont (1856). The almost complete geological mapping of the country was conducted in 1878–1885 and 1890–1919 (e.g. Renier, 1930; Boulvain, 1993a), and resulted in a detailed stratigraphic framework (Conseil de Direction de la Carte, 1892, 1896, 1900, 1909; Conseil géologique, 1929).

Very early on, geologists have paid considerable attention to the Upper Devonian of southern Belgium because of its wide variety of building, industrial and ornamental stones, in particular the worldwide famous black and red limestones (referred to as 'marbles' in Belgian literature, i.e. compact limestones capable of being polished) (e.g. Groessens, 1981; Tourneur, 2020). Southern Belgium played a significant role in the development of Upper Devonian stratigraphy in the late 19th century. This is due to the high quality and abundance of outcrops, as well as the rich fossil content found particularly around the village of Frasnes-lez-Couvin and in the Famenne area. This contributed to the introduction of the Frasnian and Famennian stages by Gosselet (1879a) and Dumont (1857), respectively (see Coen-Aubert & Boulvain, 2006; Thorez et al., 2006). It is not possible to cite here all the papers that contributed to the knowledge of both stages from the lithostratigraphical viewpoint but, besides the few aforementioned pioneering works, major contributions of the 20th century are those of Maillieux (1914a, 1926, 1940a), Dumon (1929), Asselberghs (1936), Dumon et al. (1954), Lecompte (1960), Coen (1973, 1974), Coen-Aubert (1974a), and Boulvain et al. (1993a, 1999a) for the Frasnian, and Beugnies (1965), Bouckaert et al. (1968), Thorez et al. (1977), Dreesen et al. (1985), Conil et al. (1986), and Thorez & Dreesen (1986) for the Famennian.

A lithostratigraphic scheme aiming at defining Frasnian mappable units was published by Boulvain et al. (1993a) for the western part of the Durbuy–Philippeville Anticlinorium and enlarged some years later to the other tectonic units of southern Belgium (Boulvain et al., 1999a), and biostratigraphically calibrated by Bultynck et al. (2000) and Weddige (2000). In the meantime, several new units were introduced on the revised sheets of the Geological Map of Wallonia (*Carte géologique de Wallonie*) at a scale of 1/25,000 and detailed in the explanatory booklets, whereas the lithostratigraphy of the Famennian was left aside, with the exception of the overviews by Bultynck & Dejonghe (2002), Thorez et al. (2006) and Denayer et al. (2016). In Flanders, Laenen (2003) and Lagrou & Coen-Aubert (2017) proposed a stratigraphic framework for the Upper Devonian of the Campine Basin that is only known from borehole observations.

The objectives of this paper are to update and supplement these previous works through the compilation of those produced by the mapping geologists and stratigraphers, who have dealt with the Upper Devonian over the last two decades.

2. Geological setting

The Upper Devonian covers large areas in the central part of southern Belgium, in contrast with rocks of Middle Devonian age that are restricted to narrow bands of outcrops (Fig. 1). The lower resistance of some upper Frasnian–lower Famennian predominantly argillaceous units to erosional processes have given rise to specific geomorphological landforms such as the Fagne–Famenne depression (e.g. Demoulin, 2018). This phenomenon is particularly evident in the Frasnes-lez-Couvin region, where the Frasnian limestone and nodular shale create pronounced topographic features in contrast to the shaly units that constitute the core of the Fagne depression or separate the more resistant units from one another (Fig. 2). Conversely, the core of the Dinant Synclinorium (Fig. 1), known as the Condroz, is characterised by a structurally controlled topography in which thick series of Famennian siliciclastics occupy the anticline axes contrary to the Carboniferous carbonates that crop out in the syncline axes (e.g. Poty, 1976). In the Ardenne Allochthon, Upper Devonian deposits are extensively encountered in the Dinant Synclinorium and in the Durbuy–Philippeville Anticlinorium (de Magnée, 1930, 1932; Barchy & Marion, 2008, see also Mottequin & Denayer, 2024). The Upper Devonian is also known, thanks to numerous outcrops and boreholes, from the Brabant Parautochthon and the Haine–Sambre–Meuse Overturned Thrust sheets (Belanger et al., 2012). Contemporaneous rocks crop out in the Theux Window (and Bolland borehole) and the Vesdre area (Fig. 1). North of the Brabant Inlier (Fig. 1), the Upper Devonian is only accessed by boreholes in the Campine Basin, whereas it sporadically crops out in the tectonic blocks of the Visé–Maastricht area, near the eastern end of the Brabant Inlier (Poty, 1991).

The Frasnian succession displays strong lithological variations between the southern and south-eastern limbs (presence of carbonate buildups and mud mounds) of the Dinant Synclinorium and its northern limb, the Haine–Sambre–Meuse Overturned Thrust sheets, and the Vesdre area (e.g. Dumon et al., 1954; Boulvain et al., 1993a, 1999a). The Brabant Parautochthon is characterised by its distinct succession (e.g. Asselberghs, 1936; Boulvain et al., 1999a), which shares similarities with that of the Heibaart and Booischot boreholes in the Campine Basin (Lagrou & Coen-Aubert, 2017). The Frasnian recognised in the deep Tournai and Leuze boreholes (Coen-Aubert et al., 1981) is characterised by the great thickness of the encountered units of which the assignment to units known to the east of the Brabant Parautochthon is problematic. The sedimentological differences observed in the Frasnian succession of the Namur–Dinant Basin (see Mottequin & Denayer, 2024 for more information about this basin) are the result of its development in a ramp–platform context, with the shallower facies occurring in the northern part of the basin. This was influenced by multiple breaks of slope during time of deposition and was also controlled by a complex eustatic history with significant transgression pulses (Johnson et al., 1985; Da Silva & Boulvain, 2012).

The Famennian of southern Belgium witnesses a large-scale regression (Thorez & Dreesen, 1986). Argillaceous sediments deposited during the early Famennian, with their maximal development recorded in the southern part of the Namur–Dinant Basin. During the middle–late Famennian, alluvial to offshore siliciclastic deposits were predominant in the basin, with subordinate carbonates developed essentially in the middle and latest Famennian (Thorez et al., 2006). The overall distribution of facies was controlled by synsedimentary block faulting (Thorez & Dreesen, 1986) starting in the Lower Devonian and culminating in the Carboniferous (Hance et al., 2001). The Famennian of the Campine Basin, which contains numerous stratigraphic gaps and lacks biostratigraphic data, was controlled by block faulting and regional irregularities of the basin palaeotopography (Laenen, 2003; Thorez et al., 2006).

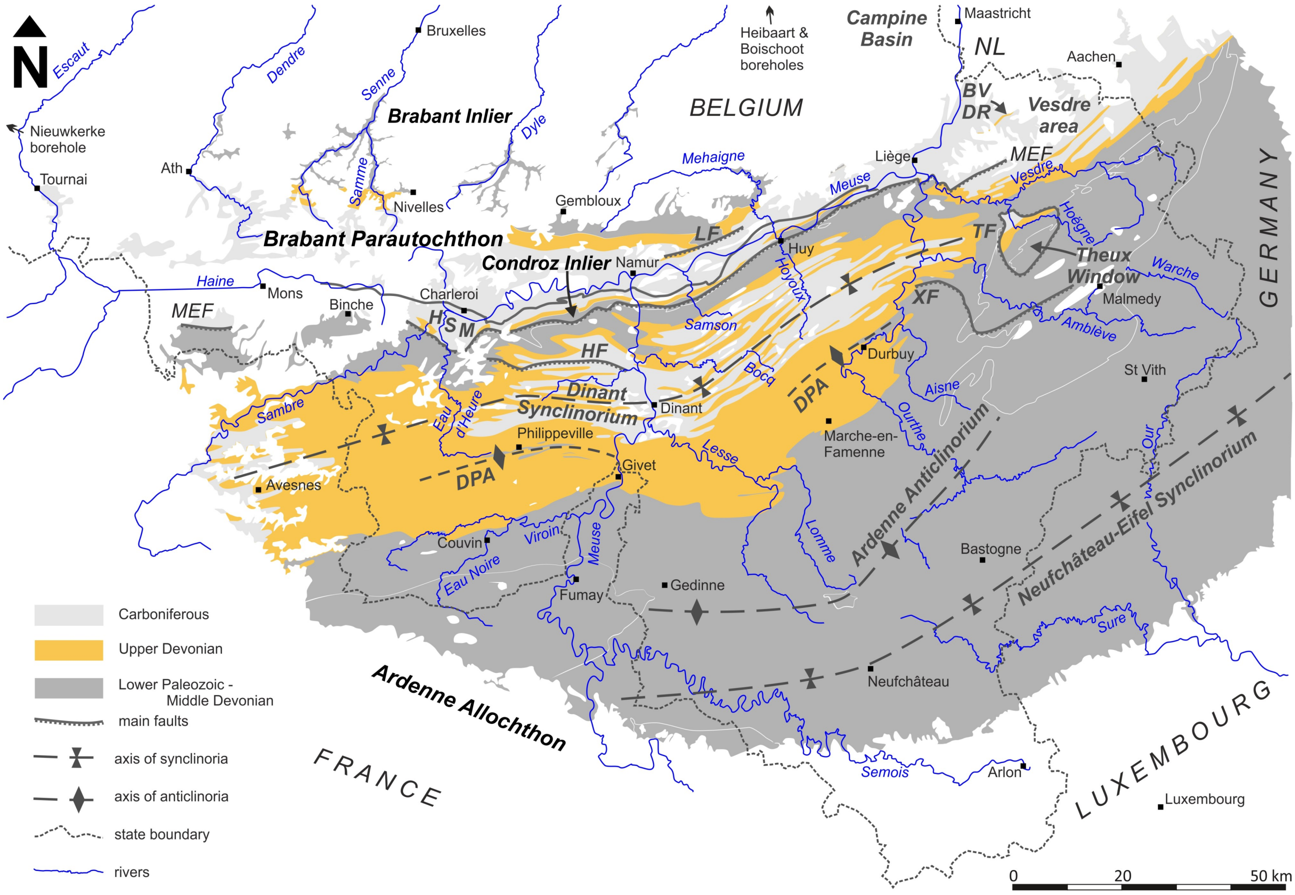

Figure 1. Simplified geological map of the Upper Devonian of central and southern Belgium and neighbouring countries (adapted from de Béthune, 1954), with indication of the main structural units, including the Caledonian inliers. Abbreviations: BVDR, Booze–Le Val-Dieu Ridge; DPA, Durbuy–Philippeville Anticlinorium; HSM, Haine–Sambre–Meuse Overturned Thrust sheets; NL, the Netherlands. Major faults: HF, Hanzinne Fault; LF, Landenne Fault; MEF, Midi–Eifel Thrust Fault; TF, Theux Fault; XF, Xhoris Fault.

3. Chronostratigraphy of the Upper Devonian

The Upper Devonian consists of the Frasnian and Famennian stages, as confirmed at the 1981 meeting in Binghampton (USA) by the Subcommission on Devonian Stratigraphy (SDS) of the International Commission on Stratigraphy (ICS) (Ziegler & Klapper, 1982); the latter officially approved the SDS proposal in 1985 (Bassett, 1985). The term *Frasnien* (Frasnian), clearly related to the *système du calcaire de Frasne* introduced by d'Omalius d'Halloy (1862, p. 514), was first used by Gosselet (1879a, p. 130, 133) in his description of the Maubeuge canton in northern France (see also Coen-Aubert & Boulvain, 2006). The term *Famennien* (Famennian) was introduced by Dumont (1857, legend of the *Carte géologique de l'Europe*) as the *Faménien* [sic] and corresponded to the lower part of the *système condrusien* that was proposed anteriorly (Dumont, 1848, p. 210) (see Thorez et al. (2006) for further information).

In a footnote, Gosselet (1879b, p. 396) subdivided the Upper Devonian into two parts, in ascending order: the Frasnian including the *zone à Rhynchonella cuboides* and the *zone à Cardium palmatum*, and the Famennian in which he put together the *schistes de Famenne*, *Psammites du Condros*, and *calcaires d'Etrœungt*. On the southern limb of the Dinant Synclinorium, the *zone à Rhynchonella cuboides* sensu Gosselet (1879b) corresponds, in terms of current lithostratigraphic units (see section 7), to the Nismes, Moulin Liénaux, Grands Breux and Marche-en-Famenne (Neuville Member) formations whereas his *zone à Cardium palmatum* corresponds to the Matagne Facies of the latter lithostratigraphic unit. It is worthwhile to remind here that the position of the Givetian–Frasnian Boundary in Belgium was placed by Maillieux & Demanet (1929) at the base of the Fromelennes Formation, thus well below the current boundary (see Denayer et al., 2024 for further information). Gosselet (1880a, p. 108) restricted the Famennian to the *faciès schisteux ou schistes de Famenne* and to the *faciès arénacé ou Psammites du Condros*. Gosselet (1880a, p. 108–111) subdivided the *Schistes de Famenne* into four zones, which are in ascending order: the *Schistes de Senzeilles à Rhynchonella Omaliusi*, *Schistes de Marienbourg à Rhynchonella Dumonti*, *Schistes de Sains à Rhynchonella letiensis*, and *Calcaire d'Etrœungt à Spirifer distans*. Nowadays, the *Schistes de Famenne* would include only the two first 'zones' (Bultynck & Dejonghe, 2002; see section 7 for more details). Originally, the Frasnian–Famennian Boundary sensu Gosselet (1877a, 1880a) was placed at the contact between the *schistes de Matagne à Cardium palmatum* and the *schistes de Famenne à Cyrthia Murchisoniana* in the Charleroi–Vireux railway trench, south of the village of Senzeille. A sketch of this outcrop was published by Gosselet (1888) and complemented by Sartenaer (1960). Unfortunately, this famous section partially disappeared in 1976 when the N978 road was built. The preservation of the southern face of the trench was organised by the Belgian Geological Survey, but the Frasnian–Famennian Boundary was no longer visible in the preserved part (Casier & Bultynck, 2000). The Royal Belgian Institute of Natural Sciences therefore undertook to dig two additional trenches exposing the missing part of the original succession in the late 1980s. Unfortunately, the three sections were illegally backfilled in 1993 (Bultynck & Martin, 1995; Casier & Bultynck, 2000). In 1995, a new trench was dug

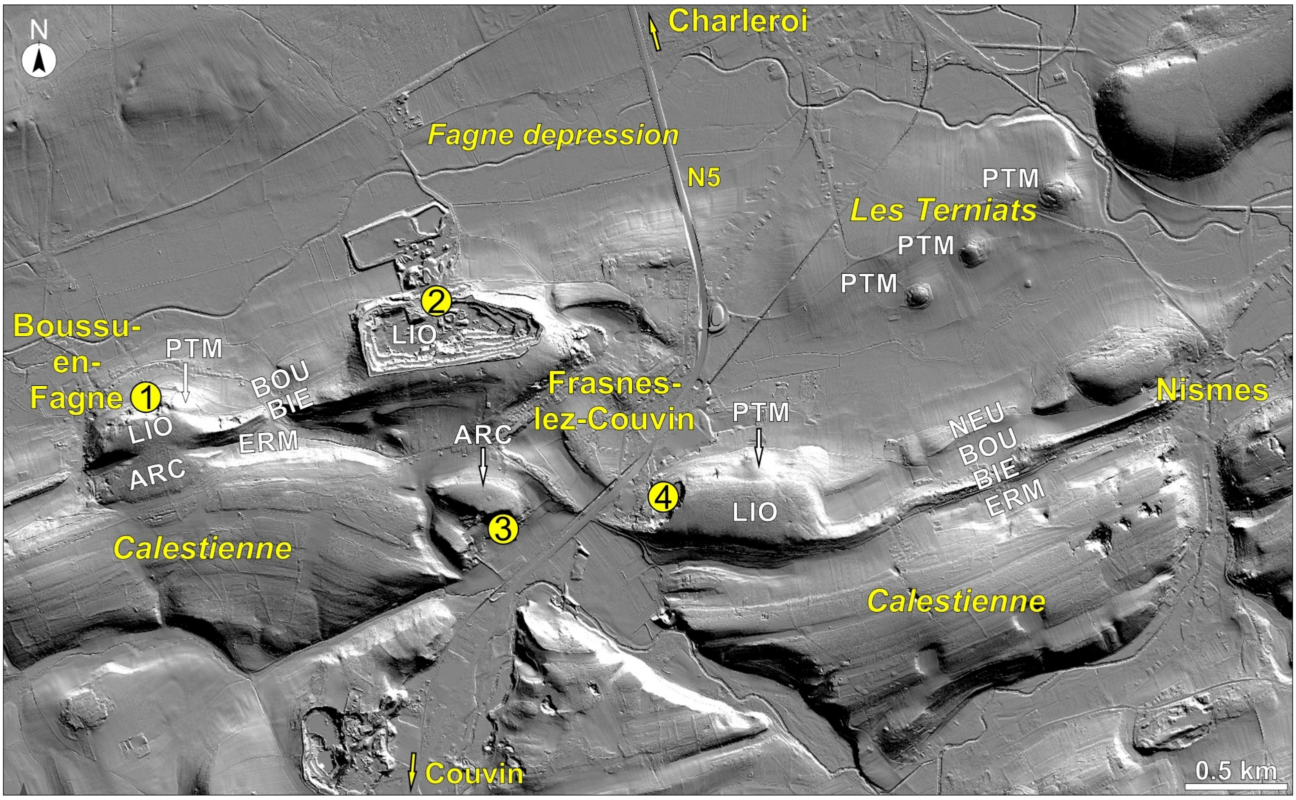

Figure 2. LIDAR-derived image of the historical type area of the Frasnian Stage in southern Belgium (Namur province) with indication of the main sedimentary bodies and their influence on topography (from Service Public de Wallonie) (to be compared with the geological map of Marion & Barchy, 1999). Quarries are numbered: 1, disused Cimetière quarry; 2, active Nord quarry; 3, disused Arche quarry (stratotype of the Arche Member); 4, disused Lion quarry (stratotype of the Lion Member). Abbreviations: ARC, Arche Member; BIE, Bieumont Member; BOU, Boussu-en-Fagne Member; ERM, Ermitage Member; LIO, Lion member; NEU, Neuville Member; PTM, Petit-Mont Member.

to restore the Senzeille section and the site was fenced off for protection (Casier & Bultynck, 2000). However, the Frasnian–Famennian Boundary is no longer exposed at the site of the original type locality and only the Lower Famennian succession outlined by Martin (1984) was still visible in 2003 (Mottequin, 2005a).

In 1986, the ICS ratified the proposal of the SDS aiming to place the base of the Frasnian at the first occurrence of the conodont *Ancyrodella rotundiloba* (Klapper et al., 1987), that is at the base of the lower *asymmetricus* conodont Zone of Ziegler (1971) or within the lower *falsiovalis* conodont Zone of Ziegler & Sandberg (1990). The Global Stratotype Section and Point (GSSP) is located at the Puech de la Suque pass near Saint-Nazaire-de-Ladarez, south-west of the Montagne Noire (France, Hérault) (Klapper et al., 1987).

The base of the Famennian coincides with that of the lower *triangularis* conodont Zone; the GSSP is located at Coumiac, near Cessenon in Montagne Noire (Klapper et al., 1993; House et al., 2000). Nevertheless, the GSSP does not correspond to the entry (first appearance datum (FAD)) of the conodont *Palmatolepis triangularis*; that is why Spalletta et al. (2017) renamed the basalmost Famennian conodont zone as the *subperlobata* Zone. Mouravieff (1974) and Streel et al. (1975) reported *P. subperlobata* in the former Senzeille railway section, but above the lowest occurrence of *P. triangularis*. Bultynck & Martin (1995) did not mention *P. subperlobata* in the lowermost Famennian exposed in the Senzeille sections dug by the Royal Belgian Institute of Natural Sciences, but they reported the species *P. delicatula delicatula* and *P. protorhomboidea* that are considered as characteristic of the *subperlobata* conodont Zone by Spalletta et al. (2017). Note that *P. subperlobata* was also cited in the Belgian Famennian notably by Bouckaert et al. (1965, 1974a), Streel et al. (1975), and Dusar & Dreesen (1984). In the absence of recent conodont investigation on the Belgian lowermost Famennian, it is currently more reasonable to use the biozonation of Ziegler & Sandberg (1990). The top of the Famennian is placed at the base of the overlying Tournaisian Stage (Carboniferous) whose GSSP is defined on the slope of La Serre Hill, near Cabrières in Montagne Noire, with the FAD of the conodont *Siphonodella sulcata* (Paproth et al., 1991). Although this limit has long been criticised, it remains valid pending further decisions by the Subcommission on Carboniferous Stratigraphy and the ICS (Aretz et al., 2020).

The Strunian regional substage was first introduced by de Lapparent (1900, p. 860) to encompass the *calcaire d'Œtrœungt* of Gosselet (1857, p. 364, p. 367, footnote) in the Avesnois area (northern France) and in western Belgium, which is replaced further to the east by the Comblain-au-Pont Formation. Barrois (1913, p. 16) considered it as a distinct stage between the Famennian and the Tournaisian. However, in the classical Belgian literature, the Strunian has often been regarded as the lower part of the Tournaisian (e.g. *sous-assise d'Étrœungt et de Comblain-au-Pont, Tn1a* in Demanet, 1958).

In the modern sense, the Strunian corresponds to the uppermost Famennian according to proposals by Streel et al. (1998) and Streel (2005) to subdivide the Famennian into four substages. As reminded by Denayer et al. (2021), the base of the Strunian is not yet formally defined but is generally correlated with that of the *Bispathodus ultimus* conodont Zone sensu Hartenfels & Becker (2018) (former upper *expansa* conodont zone). From the foraminifer viewpoint, its lower boundary corresponds to the first occurrence (FO) of *Quasiendothyra kobeitusana* (Conil & Lys, 1970). Conil et al. (1977) proposed to use the FO of the miospore *Retispora lepidophyta* as the base of the Strunian. Though its FO is well below that of the Etrœungt Formation—therefore in the upper Famennian (Streel et al., 2006; Marynowski et al., 2012)—its occurrence is very diagnostic for the Strunian substage.

The substage definitions proposed by the SDS have not yet been ratified by the ICS (Becker et al., 2020), that is why we do not use a capital for indicating the geochronologic (e.g. late Frasnian) and chronostratigraphic (e.g. upper Frasnian) units (Owen, 2009).

4. Geochronology of the Late Devonian

The Late Devonian extends from c. 378.9 Ma to c. 359.3 Ma and is subdivided into two ages: Frasnian (c. 378.9 Ma to c. 371.1 Ma) and Famennian (c. 371.1 Ma to c. 359.3 Ma) (Becker et al., 2020).

5. Biostratigraphy of the Upper Devonian

The Upper Devonian strata of Belgium (Figs 3, 4), which include a large variety of carbonate and siliciclastic lithologies, yielded a large amount of stratigraphically useful macro- (brachiopods, corals) and microfossils (e.g. conodonts, foraminifers, palynomorphs).

5.1. Conodonts

Research on conodonts of the Upper Devonian of Belgium started in the 1960s. Frasnian conodonts were notably studied by Mouravieff (1970, 1974, 1982), Coen (1973, 1974), Coen & Coen-Aubert (1974), Bultynck & Jacobs (1982), Vandelaer et al. (1989), Helsen & Bultynck (1992), Sandberg et al. (1992), and Bultynck et al. (1998). It appears that the standard conodont zonation of Ziegler & Sandberg (1990), mainly based on the key palmatolepid species, is difficult to recognise in the Namur–Dinant Basin due to the rarity of the 'pelagic' *Palmatolepis* representatives (Vandelaer et al., 1989, Dreesen & Thorez, 1994). Therefore, Coen (1999) continues to use Ziegler's (1971) zonation cautiously. Gouwy & Bultynck (2000) revised the range of 85 conodont taxa in the Frasnian of southern Belgium.

The Famennian conodont stratigraphy was explored in the pioneering works of Bouckaert et al. (1965, 1968) that were notably complemented by those of Thorez et al. (1977) and Dreesen & Houlleberghs (1980). Because of unsuitable facies, most of the pelagic markers are missing in the Belgian Famennian and the standard conodont zones are not recognised. Sandberg & Dreesen (1984) developed a parallel zonation, based on icriodontid genera widely distributed in neritic facies. The latter zonation, emended by Dreesen & Thorez (1980, 1994), Van Steenwinkel (1980, 1988), Dreesen et al. (1985, 1993), and Bultynck & Martin (1995), proves to be useful for regional and inter-regional correlations.

5.2. Brachiopods

Brachiopods from the Upper Devonian of Belgium attracted very early the attention of the geologists due to their great abundance and diversity (e.g. Murchison, 1840), although many of them are still only known by faunal lists without illustrations dating back to the first half of the 20th century (Maillieux, 1941a, 1941b). They were largely used in the past for characterising several former subdivisions of the Frasnian–middle Famennian succession (e.g. Gosselet, 1874, 1877a, 1888; Maillieux, 1914a, 1914b, 1934; Maillieux & Demanet, 1929), essentially the rhynchonellides and spiriferides: e.g. *F2a, Schistes et calcaire argileux à Cyrtospirifer Orbelianus*; *F2i, Schistes gris à Reticularia pachyrhyncha* (Maillieux, 1934, p. 414–415). Moreover, Maillieux (1914a, p. M71) qualified the Frasnian as the *étage du Spirifer Verneuili*, i.e. the *Cyrtospirifer verneuili* stage They are particularly useful for regional correlations and in the field as key fossils, especially in the monotonous shaly series such as those of the lower Famennian (Figs 5, 6).

Frasnian brachiopod faunas from the Dinant Synclinorium were largely studied in the last decades, especially the rhynchonellides and spire-bearers (athyridides, atrypides, spiriferides), and several brachiopod zones were proposed (e.g. Godefroid, 1974, 1998; Sartenaer, 1968a, 1974a, 1979, 1999a; Godefroid & Jacobs, 1986; Mottequin, 2005a, 2008a, 2008b, 2008c). However, Upper Devonian brachiopod faunas from the rest of the Namur–Dinant Basin remain largely unstudied compared with those of the Dinant Synclinorium (Asselberghs, 1912; Vandercammen, 1963; Sartenaer, 1982). On a worldwide scale, the end of the Frasnian is marked by a severe, multifaceted biotic crisis (McGhee et al., 2013; Racki, 2020; Smart et al., 2023) that considerably affected brachiopods. The extinction of the atrypides and pentamerides in the Namur–Dinant Basin is clearly linked with the demise of the reefal environments and the progressive development of anoxia (Godefroid & Helsen, 1998; Mottequin, 2008a; Mottequin & Poty, 2016). Consequently, early and middle Famennian brachiopod faunas are impoverished in comparison with their Frasnian counterparts; they are dominated by rhynchonellides, athyridides, spiriferides and productidines (e.g. Gosselet, 1877a, 1887; Sartenaer, 1956a, 1956b, 1957a, 1957b, 1958, 1968b, 1972; Mottequin, 2005a, 2008a, 2008c). Those of the upper Famennian have never been systematically investigated in the past and are only known by unillustrated faunal lists (Maillieux, 1941a, 1941b; Lecompte & Waterlot, 1957). The Strunian brachiopod fauna, mostly including rhynchonellides, spiriferides and productidines heralds the Carboniferous ones to come (Gosselet, 1857; Sartenaer & Plodowski, 1975; Conil et al., 1986; Legrand-Blain, 1991, 1995; Mottequin & Brice, 2016).

The range of selected stratigraphically important Frasnian and lower Famennian species of athyridides, pentamerides, rhynchonellides and spiriferides is indicated in Figure 5 and the latter are illustrated in Plates 1–5. Moreover, the distribution of the rhynchonellides established by Sartenaer (e.g. 1968b, 1972, 1983) in the uppermost Frasnian and lower Famennian of the southern limb of the Dinant Synclinorium is illustrated in Figure 6.

5.3. Rugose corals

In the Frasnian, rugose corals are abundant, though less diverse than in the Middle Devonian and are useful stratigraphic markers for regional correlations (Coen-Aubert, 1977; Tsien, 1977a, 1977b) (Fig. 7). Although no formal biozonation has been established, several fossil coral assemblages are recognised in the lower–middle Frasnian formations, characterised by the abundance of *Disphyllum* in the lower part, then *Peneckiella*, *Wapitiphyllum* and *Hexagonaria* (Tsien, 1977a, 1977b, Coen-Aubert, 1994, 1995, 2000, 2009; Boulvain et al., 2011) (Figs 8–9). A major faunal turnover is marked at the middle–upper Frasnian boundary, the *Hexagonaria* fauna being replaced by phillipsastreids (Tsien, 1984; Coen-Aubert, 2012). Three successive associations were described by Coen et al. (1977) in the upper Frasnian, namely *faune 1*, *faune 2* and *faune 3*, mostly characterised by species of *Frechastraea* and *Potyphyllum* (*Phillipsastrea* in the Belgian literature) (Fig. 10). Anoxic facies on top of the Frasnian caused the demise of the corals (Paquay, 2002; Mottequin & Poty, 2016).

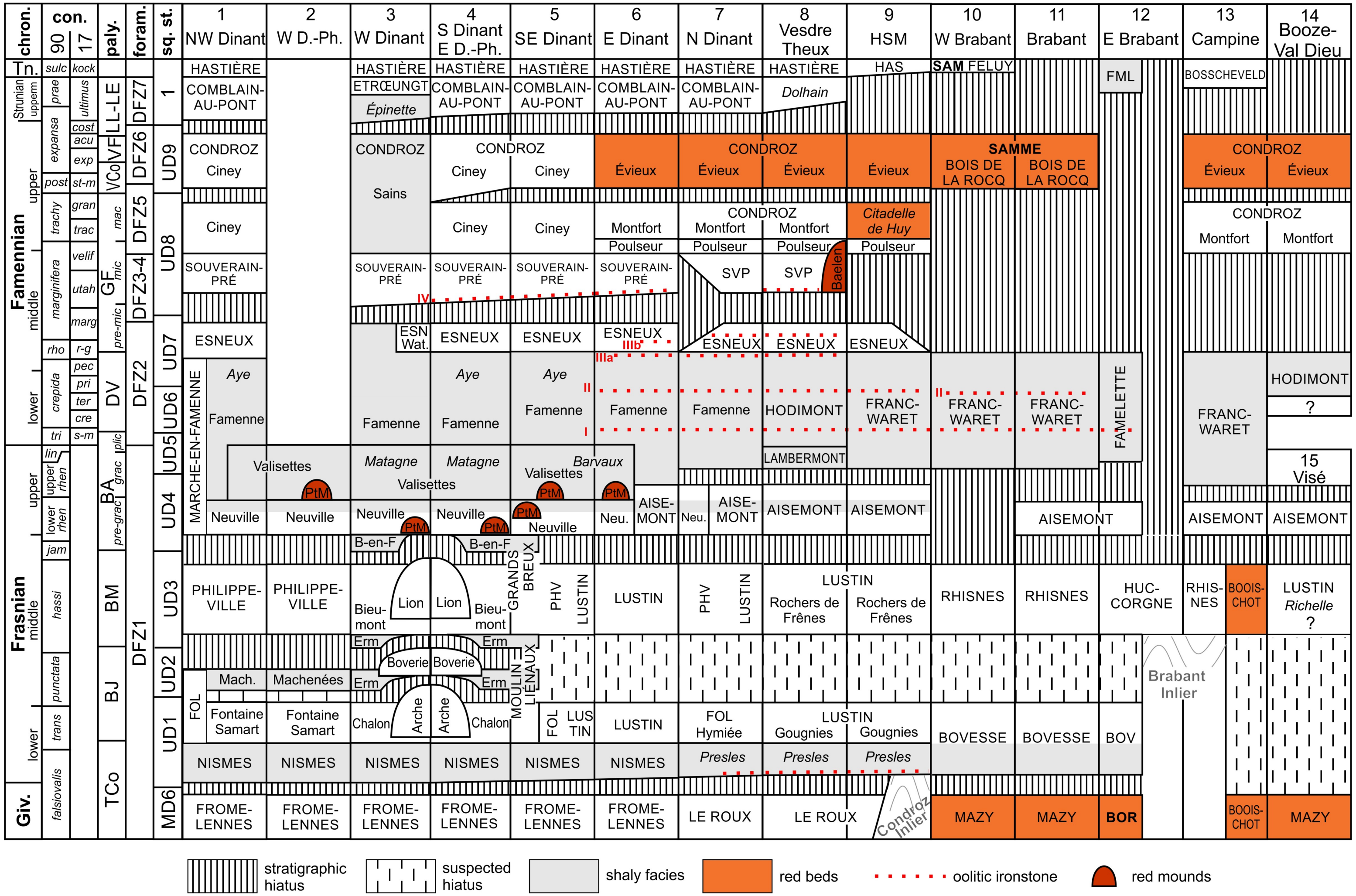

Figure 3. Chronostratigraphic chart of the Upper Devonian strata of Belgium (origin of data: see main text); numbers 1–15 refer to geographical zones. Groups are in capital and bold letters, formations in capital letters, members in regular letters, remarkable horizons and facies in italics. Abbreviations (except conodonts): B.-en-F., Boussu-en-Fagne Member; BOR: Bois de Bordeaux Group; BOV, Bovesse Formation; chron., chronostratigraphy; con., conodont zones (90, see Ziegler & Sandberg, 1990; 17, see Spalletta et al., 2017); D.-Ph., Durbuy–Philippeville Anticlinorium; Erm., Ermitage Member; ESN, Esneux Formation; FML, Famelette Formation; FOL, Pont de la Folle Formation; foram., foraminifer zones; Giv., Givetian; HAS, Hastière Formation; HSM, Haine–Sambre–Meuse Overturned Thrust sheets; Mach., Machenées; Neu., Neuville Member; paly., palynozones (e.g. Streel, 2009; Streel et al., 2021); PHV, Philippeville Formation; PtM, Petit-Mont Member; sq. st., sequence stratigraphy; SAM, Samme Group; SVP, Souverain-Pré Formation; Tn., Tournaisian; upperm, uppermost; Wat.: Watissart Member. I–IV, oolitic ironstone horizons. Conodont abbreviations: *acu*, *aculeatus*; *cost*, *costatus*; *cre*, *crepida*; *exp*, *gracilis expansa*; *gran*, *granulosus*; *kock*, *kockeli*; *jam*, *jamieae*; *lin*, *linguiformis*; *marg*, *marginifera marginifera*; *pec*, *glabra pectinata*; *post*, *postera*; *prae*, *praesulcata*; *pri*, *glabra prima*; *r–g*, *rhomboidea–gracilis gracilis*; *rhen*, *rhenana*; *rho*, *rhomboidea*; *s–m*, *subperlobata–minuta minuta*; *st–m*, *styriacus–gracilis manca*; *sulc*, *sulcata*; *ter*, *termini*; *trac* and *trachy*, *trachytera*; *trans*, *transitans*; *tri*, *triangularis*; *utah*, *marginifera utahensis*; *vel*, *velifer*.

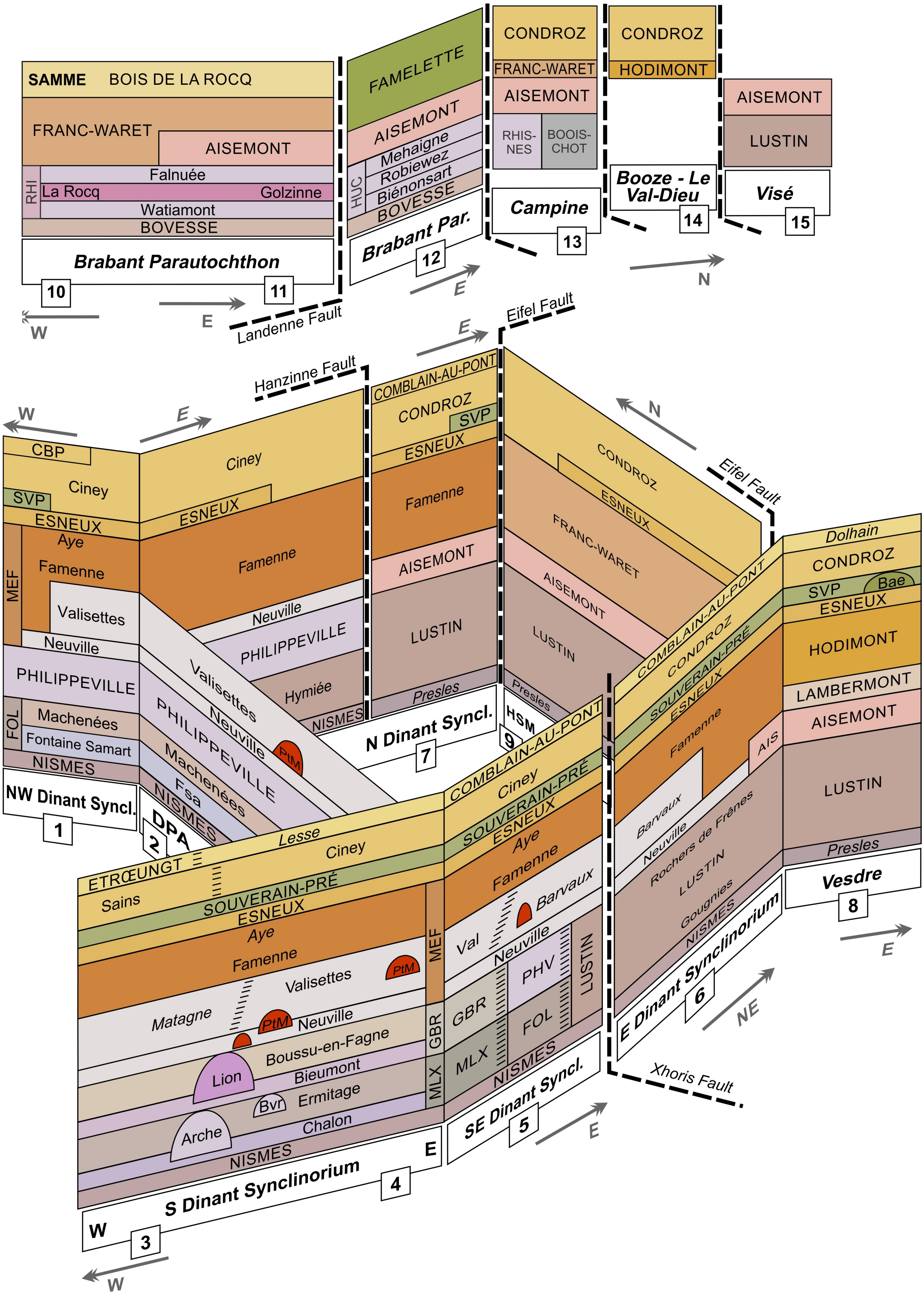

Figure 4. Schematic vertical and relationships of the Upper Devonian of Belgium. Formations are in capital letters, members are in regular letters, names in italics are remarkable horizons and facies. The stratigraphic hiatuses shown in Figure 3 are not represented here. Abbreviations: AIS, Aisemont Formation; Bae, Baelen; Bvr, Boverie Member; CBP, Comblain-au-Pont Formation; DPA, Durbuy–Philippeville Anticlinorium; FOL, Pont de la Folle Formation; Fsa; Fontaine Samart Member; GBR, Grands Breux Formation; HSM, Haine–Sambre–Meuse Overturned Thrust sheets; HUC, Huccorgne Formation; MEF, Marche-en-Famenne Formation; MLX, Moulin Liénaux Formation; Par., Parautochthon; PHV, Philippeville Formation; PtM, Petit-Mont Member; RHI, Rhisnes Formation; SVP, Souverain Pré Formation; Syncl., Synclinorium; Val, Valisettes Member.

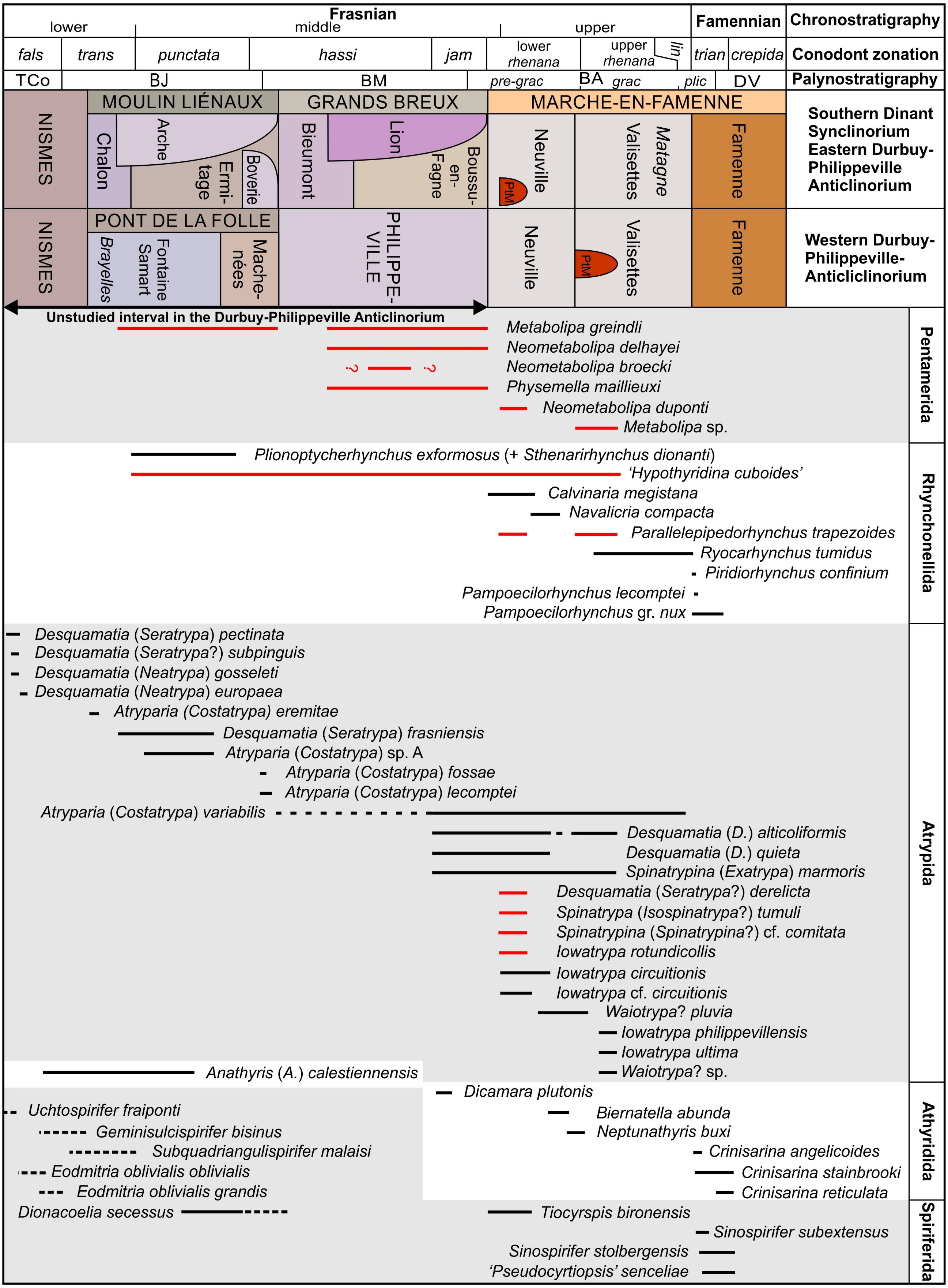

Figure 5. Distribution of selected species of rhynchonellide, atrypide, athyridide and spiriferide brachiopods in the Frasnian and lower Famennian succession of the southern limb of the Dinant Synclinorium and the Durbuy–Philippeville Anticlinorium (Godefroid, 1999; Sartenaer, 1999a; Mottequin, 2005a, 2008a, 2008b, 2008c). Red lines indicate occurrences in mounds. Formations are in capital letters, members in regular letters. Abbreviations: *fals*, *falsiovalis*; *jam*, *jamieae*; *lin*, *linguiformis*; PtM, Petit-Mont; *trans*, *transitans*; *trian*, *triangularis*.

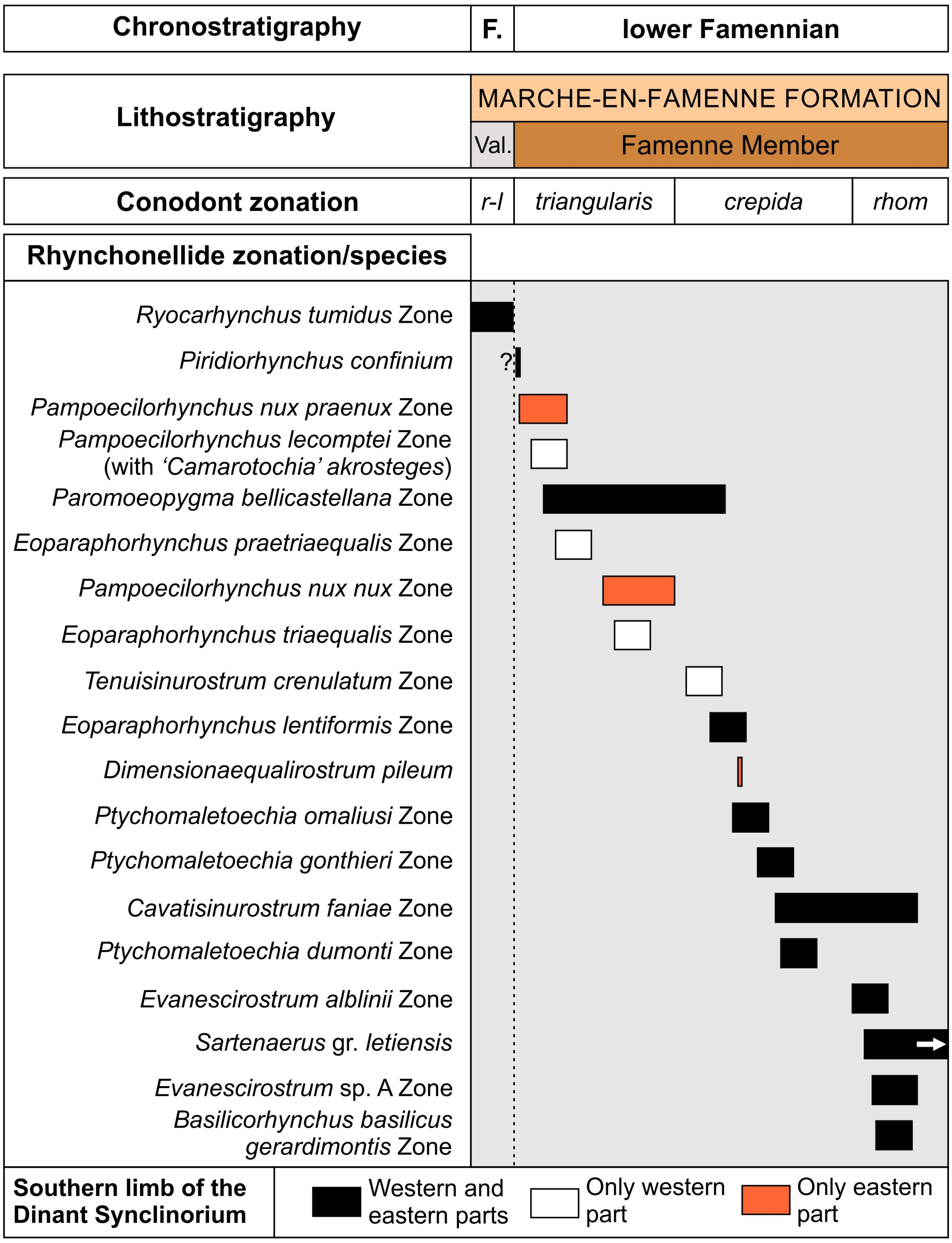

Figure 6. Rhynchonellide brachiopod zonation and species in the upper Frasnian and lower Famennian strata of the Marche-en-Famenne Formation, i.e. the Matagne Facies of the Valisettes Member and the Famenne Member, on the southern limb of the Dinant Synclinorium (modified from Sartenaer (1968b, 1972, 1983) and complemented with Sartenaer's (1980, 2001) data); conodont zonation from Dreesen (1978). No scale. Abbreviations: F., Frasnian; *rhom*, *rhomboidea*; *r–l*, upper *rhenana–linguiformis* conodont zones; Val., Valisettes Member.

Rugose corals are rare in the Famennian strata and only small undissepimented forms are described in the lower Famennian (Denayer et al., 2012). Scarce solitary corals have been described from the middle Famennian Souverain-Pré Formation (Denayer et al., 2012; Vachard et al., 2017) and its lateral equivalent in the Avesnois area (Sains Member), but most of the rugose corals are known from the upper and uppermost Famennian where Poty (in Poty et al., 2006) recognised the subzones RC0α and RC0β, respectively. The upper one includes the Strunian coral fauna dominated by *Campophyllum*, '*Palaeosmilia*', *Clisiophyllum* and *Bounophyllum*, together with rarer genera (Poty, 1999; Denayer et al., 2011a) (Fig. 11).

5.4. Foraminifers

Foraminifers (*Nanicella*, *Frondilina*) were reported in the Frasnian, but are poorly diverse (e.g. Mouravieff & Bultynck, 1967; Coen-Aubert, 1970; Mamet et al., 1985; Schmidt, 1994; Denayer & Poty, 2010). *Nanicella* has not been observed above the Frasnian–Famennian Boundary (Conil et al., 1986) and it is not before the middle Famennian that foraminifers occurred again in the Namur–Dinant Basin, i.e. within the calcareous Souverain-Pré Formation and the Baelen Member (Bouckaert et al., 1967; Conil & Lys, 1970; Dreesen, 1978; Dreesen et al., 1985; Conil et al., 1986; Vachard et al., 2017). Conil et al. (1977) introduced the Df3 Zone for the Famennian, to the exception of the strata preceding the Souverain-Pré Formation, that was based on the evolution of the plurilocular genus *Quasiendothyra* and subdivided it into several subzones (Df3α–ε). The latter were renamed DFZ3–7 by Devuyst & Hance (in Poty et al., 2006) for more coherence with the Mississippian foraminifer zonation (prefixed MFZ) (Fig. 3). Furthermore, several species formerly ascribed to *Quasiendothyra* were later assigned to *Endothyra* (see references in Devuyst & Hance in Poty et al., 2006). Although the base of the uppermost Famennian (Strunian) is not yet formally defined (see above), calcareous foraminifers became valuable for biostratigraphy from the base of the succession traditionally ascribed to this regional substage in Belgium and northern France (Bouckaert et al., 1968; Conil & Lys, 1968; Conil, 1980; Conil et al., 1986). The Strunian DFZ7 is characterised by a rich association

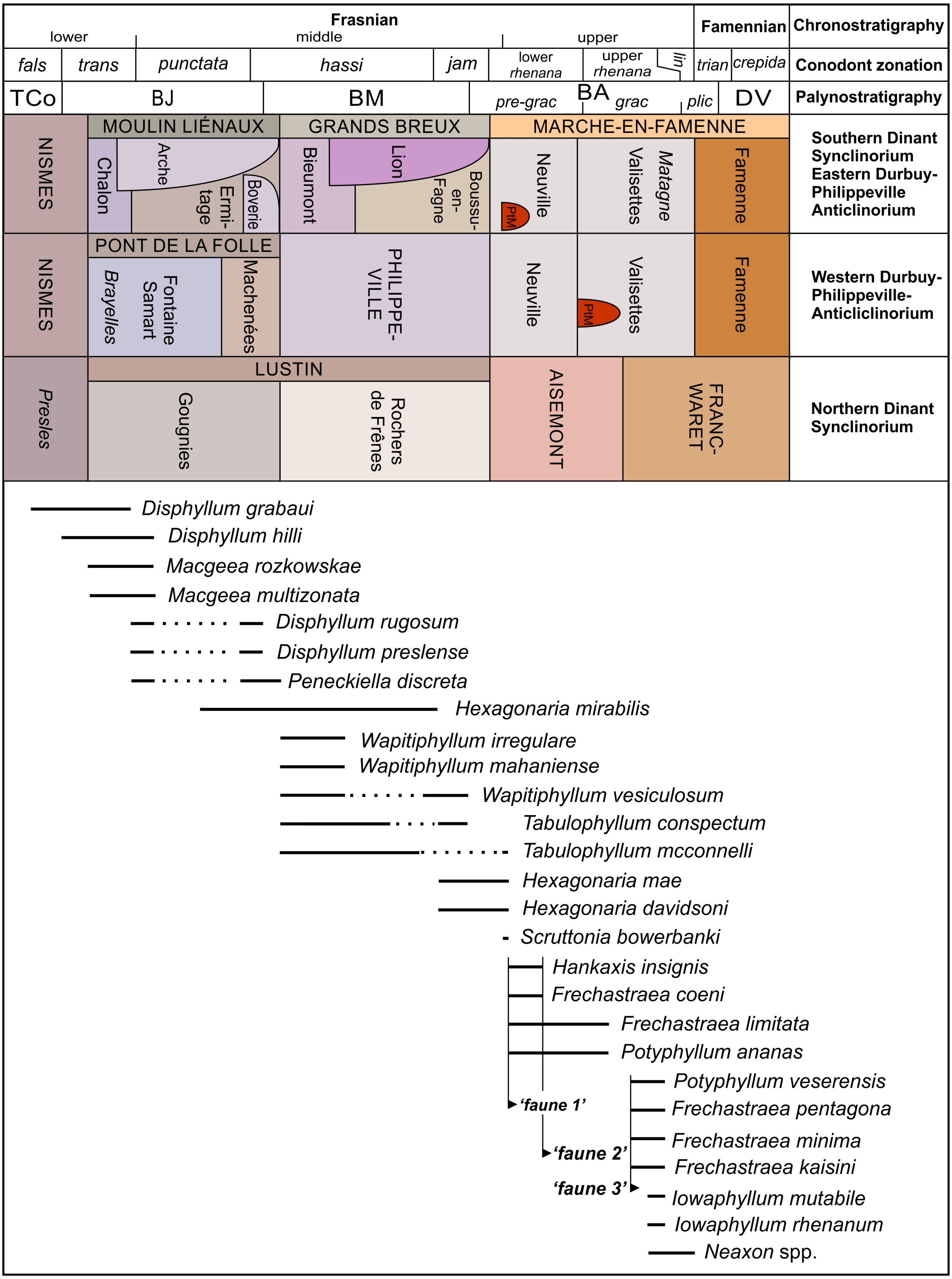

Figure 7. Biostratigraphic zonations (conodonts and spores) of the Belgian Frasnian and range of selected corals (see section 5.3 for references). Formations are in capital letters, members in regular letters Abbreviations: *fals*, *falsiovalis*; *jam*, *jamieae*; *lin*, *linguiformis* conodont zones; PtM, Petit-Mont; *trans*, *transitans*; *trian*, *triangularis*.

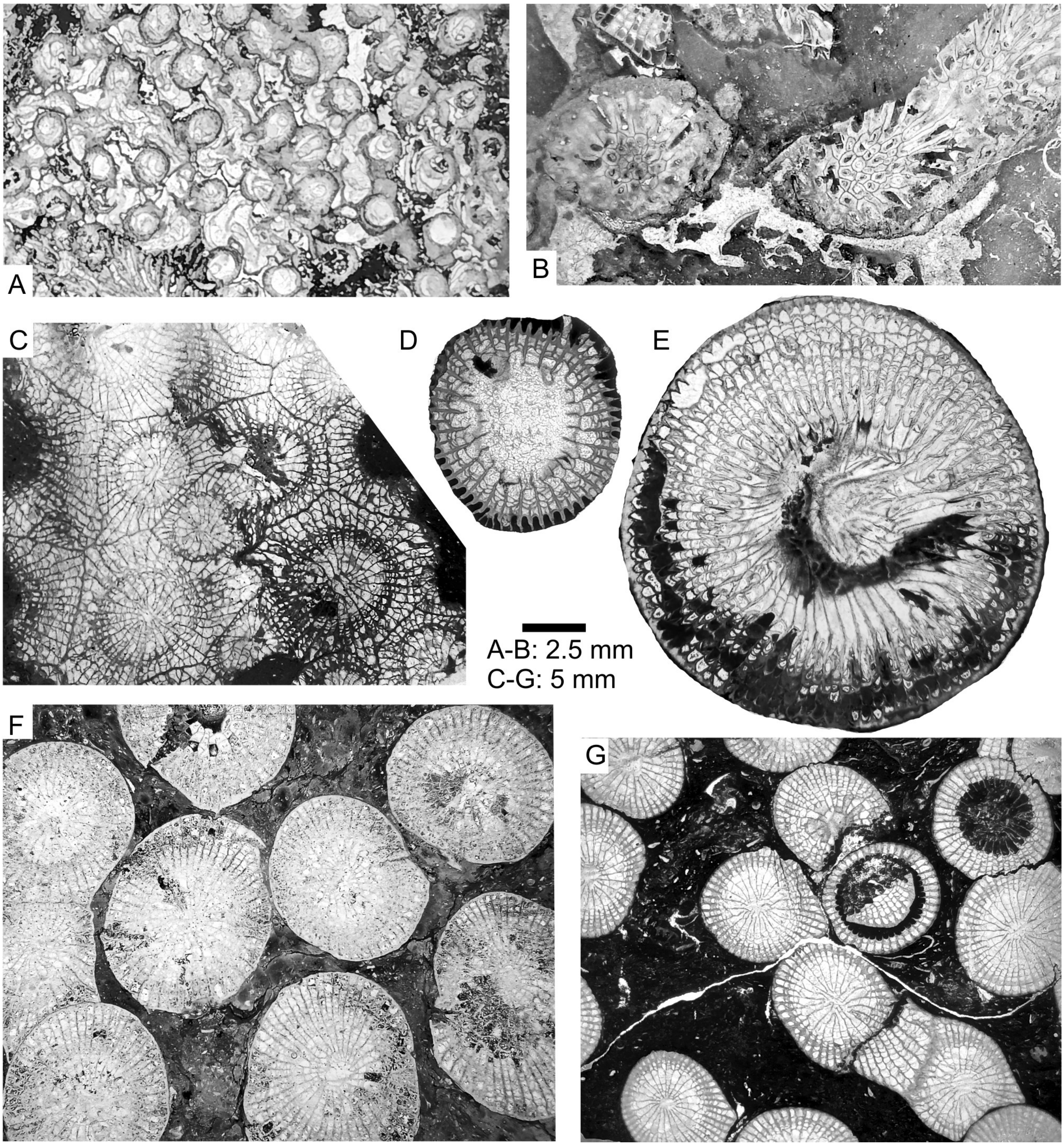

Figure 8. Lower–middle Frasnian rugose and tabulate corals. Abbreviation: TS, transverse section. **A.** *Thecostegites bouchardi* in TS (BCH/1-1); Saint-Laurent quarry, Bauche, Rochers de Frênes Member. **B.** *Thamnopora boloniensis* (PAULg.20240916.1); Lion quarry, Frasnes-lez-Couvin, Lion Member. **C.** *Hexagonaria mirabilis* in TS (PAULg.20240916.2); Lion quarry, Frasnes-lez-Couvin, Lion Member. **D.** *Macgeea rozkowskae* in TS (HUC/2-5); Huccorgne, Bovesse Formation. **E.** *Tabulophyllum conspectum* in TS (NEU.742B); Neuville section, upper part of Philippeville Formation. **F.** *Disphyllum hilli* in TS (PRA.2005.19/1); Prayon, lower part of Lustin Formation. **G.** *Disphyllum preslense* in TS (PAULg.20240916.3); Huccorgne, Bovesse Formation.

including notably *Quasiendothyra kobeitusana* and *Q. konensis* (see Denayer et al., 2021 and references therein). The former DFZ8, with *Tournayellina pseudobeata* as the guide for its base (Devuyst & Hance in Poty et al., 2006), is considered now to be coeval with the depleted MZF1, thus of basal Tournaisian age (Hastarian) (see discussion in Denayer et al., 2021).

5.5. Ostracods

Ostracods were used to establish a biostratigraphic zonation of the Upper Devonian succession of Belgium. The first was proposed by Magne (1964) for the Frasnian of the 'Namur Synclinorium' and a second was proposed by Lethiers (1974a) for the Frasnian and Famennian of the Dinant Synclinorium, based on the research of Becker (1971) and Lethiers (1973). Casier (1975, 1977, 1979, 1982) introduced another zonation (see also Casier & Coen, 1999) whereas Lethiers (1984) refined his previous one. Besides these papers, the reader will also consult Lethiers (1974b) and Casier (2018) for the ostracods at the Frasnian–Famennian boundary, and Becker & Bless (1974), Becker et al. (1974), and Casier et al. (2004) for those of the Strunian of Belgium. Note that the ostracod biozonations of the

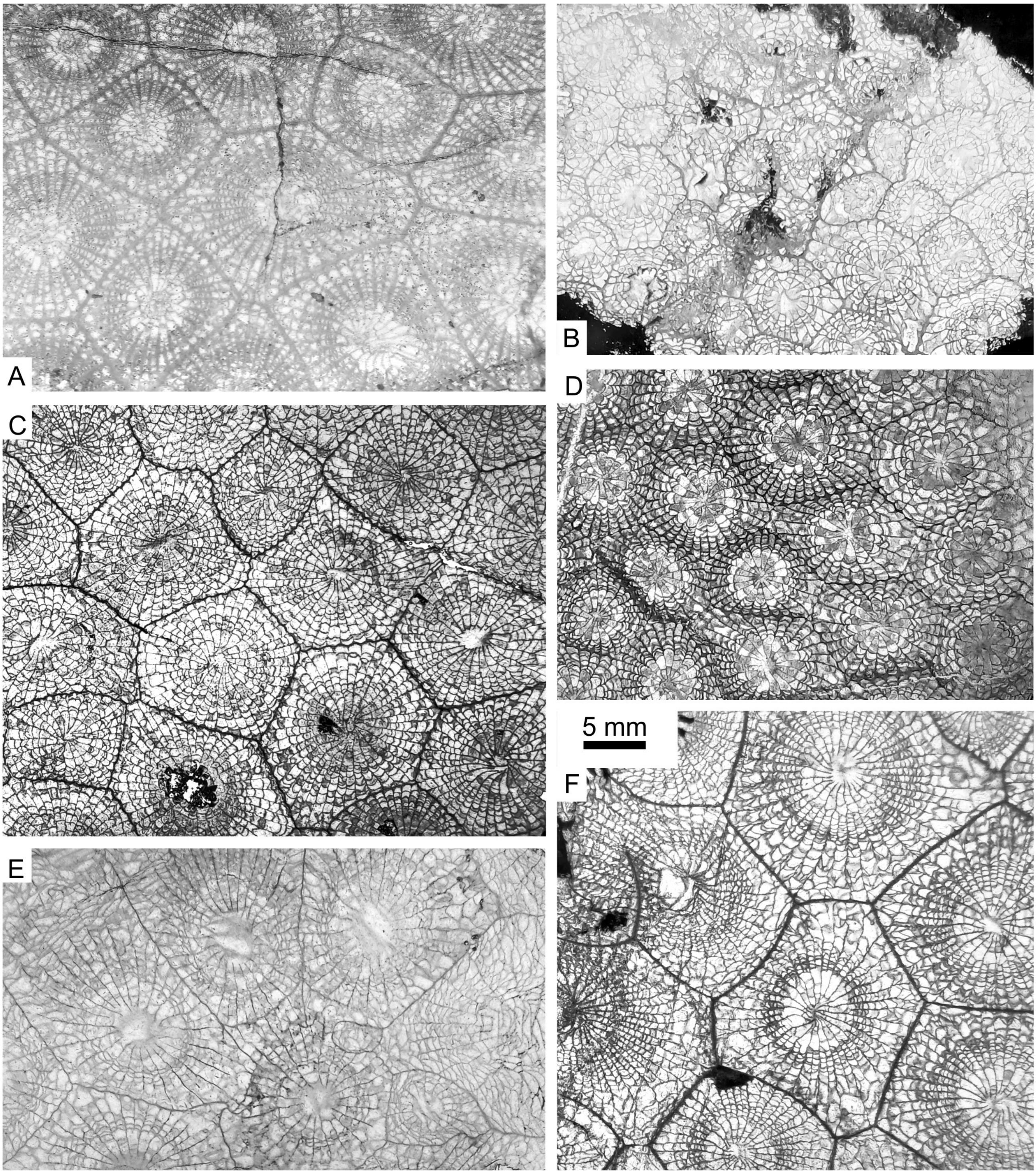

Figure 9. Middle Frasnian rugose corals. Abbreviation: TS, transverse section. **A.** *Hexagonaria mae* in TS (PAULg.20240916.4); Nord quarry, Frasnes-lez-Couvin, base of Neuville Member. **B.** *Wapitiphyllum vesiculosum* in TS (PAULg.20240916-5); Huccorgne, Mehaigne Member. **C.** *Argutastrea konincki* in TS (HUC II/2a); Huccorgne, Biénonsart Member. **D.** *Argutastrea lecomptei* in TS (HUC/2-2); Huccorgne, Biénonsart Member. **E.** *Wapitiphyllum irregulare* in TS (PAULg.20240916-7); Huccorgne, Biénonsart Member. **F.** *Wapitiphyllum mahaniense* in TS (HUC/1); Huccorgne, Biénonsart Member.

Belgian Upper Devonian are not used here.

5.6. Palynomorphs

The Frasnian formations of the proximal depositional areas yield some palynomorph assemblages, among which several biozones are recognised, mostly from subsurface (Loboziak & Streel, 1980, 1981, 1988; Loboziak et al., 1983, 1991; Streel & Loboziak, 1987). The palynological succession is better known in the French (Boulonnais) and German (Eifel) neighbouring areas due to more suitable facies (Streel et al., 1987, 2021). In the more distal zone, the palynological assemblages are largely dominated by acritarchs which were mostly studied in the middle–upper Frasnian (e.g. Dricot, 1965, 1967; Vanguestaine et al., 1999) and across the Frasnian–Famennian boundary (e.g. Vanguestaine et al., 1983; Martin, 1981, 1982, 1984; Streel & Vanguestaine, 1989; Vanguestaine, 1999).

The lower–middle Famennian interval is particularly poor in

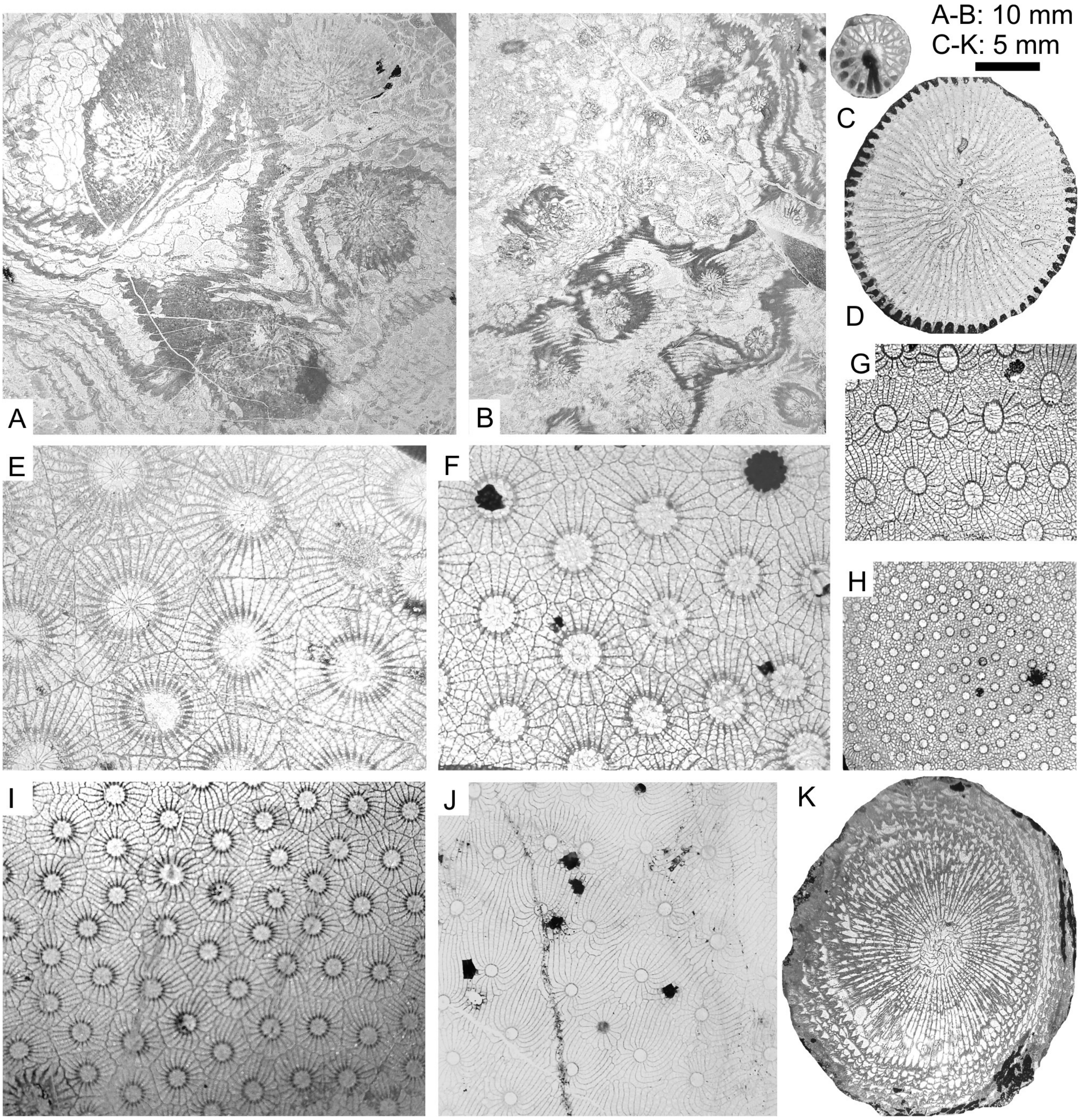

Figure 10. Upper Frasnian rugose corals. Abbreviation: TS, transverse section. **A.** *Iowaphyllum mutabile* in TS (NEU 2009/21d); Neuville railway section, Valisettes Member. **B.** *Iowaphyllum rhenanum* in TS (NEU 2009/24); Neuville railway section, Valisettes Member. **C.** *Neaxon* sp. in TS (AYE/1-I); Aye section, Barvaux Facies of Marche-en-Famenne Formation. **D.** *Macgeea gallica* in TS (HON 2001/6A-15-Ib); Hony section, lower part of Lambermont Formation. **E.** *Potyphyllum ananas* in TS (FDC 2007/14-5b); Fond des Cris disused quarry, Fond des Cris Member. **F.** *Frechastraea limitata* in TS (NEU 2009/27a); Neuville railway section, Valisettes Member. **G.** *Frechastraea pentagona* in TS (AYE/1a); Aye section, Barvaux Facies. **H.** *Frechastraea minima* in TS (NEU 2010/2); Neuville railway section, Valisettes Member. **I.** *Frechastraea coeni* in TS (ENG 1993/56-54); Tchafornis quarry, Engis, Tchafornis Member. **J.** *Frechastraea kaisini* in TS (NEU 2009/26); Neuville railway section, upper part of Valisettes Member. **K.** *Hankaxis insignis* in TS (ENG 1993/56); La Mallieue section, Tchafornis Member.

palynomorphs ('lower–middle Famennian vegetation crisis' in Streel et al., 2001), with a single zone encompassing all the Famennian strata below the Souverain-Pré Formation (Streel, 2009). The palynological zonation is much better developed and used in the upper and uppermost Famennian that displays more suitable facies and three to six zones are identified (depending on the zone concept of the authors). Streel (1966) and Bouckaert et al. (1968) introduced the first palynostratigraphic zones that were subsequently emended by Bouckaert et al. (1969, 1970), Paproth & Streel (1970), Becker et al. (1974), Streel et al. (1987), Higgs et al. (1988, 2000, 2013), and Loboziak et al. (1994) (Fig. 3). Recent palynological research particularly focused on the uppermost Famennian and the Devonian–Carboniferous Boundary (Higgs et al., 1992; Maziane & Vanguestaine, 1997; Maziane et al., 1999, 2002, 2007; Streel, 2005; Prestianni et al., 2016, Denayer et al., 2021).

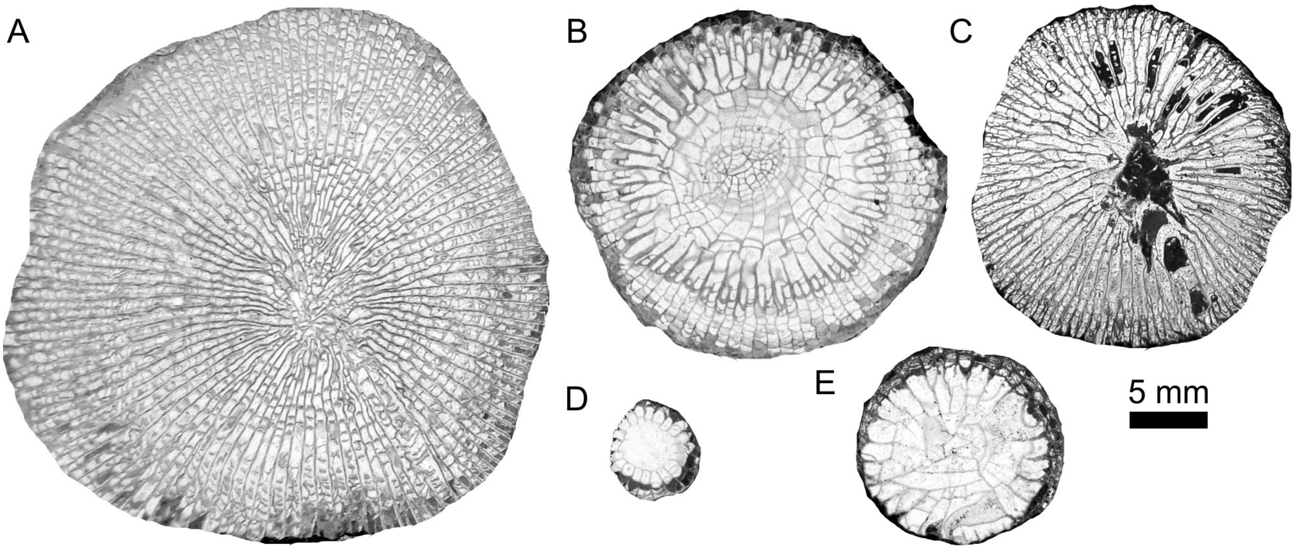

Figure 11. Famennian rugose corals in transverse section. **A.** '*Palaeosmilia*' *aquisgranensis* (DOL/74); Dolhain section, Comblain-au-Pont Formation. **B.** *Clisiophyllum omaliusi* (KLE 9/27-21c); Kleinsteinkoten quarry, Comblain-au-Pont Formation. **C.** *Campophyllum gosseleti* (ANS 145/41); Anseremme section, Comblain-au-Pont Formation. **D.** *Catactotoechus* sp. (CHE 1993/I-1); Chevetogne, Souverain-Pré Formation. **E.** *Bounophyllum praecursor* (STO 1986/189-2); Stolberg section, Comblain-au-Pont Formation.

6. Evolution of the Namur–Dinant Basin in the Late Devonian

The Frasnian starts with a shaly unit following an important gap on the carbonate platform that was initiated at the end of the Givetian (Frasnes Event sensu Becker, 1993). In some parts of the basin, it is marked by an oolitic ironstone horizon which consists of ferruginised allochems (ooids, pisoids, coated bioclasts, intraclasts). In the Presles Facies of the Nismes Formation, these grains are typically haematitised (oxidised facies) whereas in the rest of this formation, the iron is at the reduced state in complex silicates such as berthierine, chamosite and chlorite (de Magnée, 1933).

Above the shaly Nismes Formation, the carbonate factory restarts, with the development of platform carbonates throughout the basin, with the exception of its southern margin, where the carbonate production is limited to isolated buildups. A first third-order sequence (UD1 on Fig. 3) is recorded in the Moulin Liénaux Formation, with the initiation of a carbonate sole (Chalon Member) (Figs 3, 4). During the transgressive system tract, the latter allows the local development of bioherms that evolve into isolated platforms (Arche Member) in the course of the highstand system tract and are capped by an emersion surface. The lowstand system tract is recorded by argillaceous deposits (Ermitage Member) around the aforementioned limestone bodies. A second, very short third-order sequence (UD2) is recorded in the Boverie Member of the Moulin Liénaux Formation but apparently not on the shelf. The third sequence, which was designated 'Lion sequence' (UD3) in Mottequin & Poty (2016), is similarly organised, with a sole (Bieumont Member) and bioherms evolving into isolated platforms (Lion Member) surrounded by shale (Boussu-en-Fagne Member) that deposited after the development of the Lion Member bioherms. In the northern area, these three sequences are recorded in the development of the Pont-de-la-Folle (sequence UD1-2?) and Philippeville formations (UD3) and in the Lustin Formation (UD1-(2?-)3), capped by an emersion surface. The fourth sequence (UD4, named 'Aisemont sequence' in Poty & Chevalier, 2007) starts with the transgressive Neuville Member and its highstand is recorded in the Valisettes and Petit-Mont members in the southern depositional areas; it corresponds to the tripartite Aisemont Formation in the northern areas. The lower Kellwasser Event corresponds to the maximum flooding interval of this sequence and to the development of dysoxic-anoxic shale in the distal part of the Namur–Dinant Basin. The fifth sequence (UD5, named 'Lambermont sequence' in Mottequin & Poty, 2016) almost entirely records shaly argillaceous deposits (Matagne and Barvaux facies, and Lambermont Formation), with few limestone at the base (Petit-Mont and Verviers members), and is marked by the global development of oceanic anoxia triggered by the upper Kellwasser Event at the end of the Frasnian.

The argillaceous depositional context that characterises the upper Frasnian continued through a large part of the lower Famennian with no major changes of facies across the Frasnian–Famennian Boundary. In proximal areas, the basal Famennian is characterised by the oolitic ironstone beds developed in the Franc-Waret and Hodimont formations. They correspond to the horizon I of Dreesen (1981) (Fig. 3). Lithologically, they consist of lenticular limestones (packstones/grainstones) enriched with different types of ferruginised allochems (ooids, pisoids, oncoids, intraclasts of algal mat origin, rolled bioclasts) (Dreesen, 1981), whereas the source of the iron seems to be related to volcanic activity on the basis on rare earth element evidence (Laenen et al., 2002). Dreesen et al. (1986a) and Dreesen (1989a) demonstrated that they are synchronous with volcano-sedimentary events recognised in the nearby Rhenish Basin; therefore, these oolitic ironstone horizons are key stratigraphic markers that are well dated by conodonts (e.g. Dreesen, 1984). They are interpreted as lowstand deposits reworked during early stages of transgressions, probably by storm events (Dreesen, 1981, 1982a, 1982b, 1989a, 1989b), marking the base of the third-order sequences UD6-7 (Fig. 3).

Another oolitic ironstone horizon (horizon II of Dreesen, 1981) occurs within the lower Famennian shaly formations and two others (horizons IIIa and IIIb in Dreesen, 1982a) are situated at their top. The latter correlates eastwards with the *Cheiloceras* limestone of western Germany (Dreesen, 1982a). The Esneux Formation is the prelude to the sandy depositional environments that will characterise the upper Famennian succession of Belgium. The Souverain-Pré Formation is a transgressive carbonate unit locally underlined by the ironstone horizon IV of Dreesen (1982a) (third-order sequence UD8, Figs 3, 4, 12). It consists of nodular, stylo-brecciated, silty limestone, commonly sandy in proximal areas and argillaceous in distal parts, with a strongly diachronic base (upper *marginifera* conodont Zone in the south of the basin, lower *trachytera* conodont Zone in the northern parts) (Dreesen, 1978). In the Vesdre area, the Formation includes the Baelen Member that constitutes one of the rare examples of Famennian stromatactis–crinoid–calcimicrobe bioconstruction known worldwide (Dreesen et al., 1985, 2013).

After this carbonate episode, the siliciclastic sedimentation resumes with the Condroz Formation (Fig. 12). This thick formation contains a variety of coastal environments, ranging from predominantly 'fully' marine in the lower part (Poulseur and Montfort members) to non-marine environments towards the top, eventually transitioning to sabkha and fluvial channel environments in the Évieux Member. This member yielded vertebrates (including tetrapods), arthropods and a diverse flora (see Prestianni & Gerrienne, 2015; Olive et al., 2015; Denayer et al., 2016). Distally, the Montfort and Évieux members pass to a thick sequence of siliciclastic and carbonate alternations (Ciney Member), which grades to the purely marine shaly unit of the Sains Member in the south-western part of the basin (Avesnois area) (Thorez et al., 1988).

The lateral correlations of facies within the Condroz Formation were made possible by the recognition of twelve remarkable synchronous horizons of ball-and-pillow structures (*pseudonodules* in the literature; Ancion & Macar, 1947; Macar, 1948), supposedly triggered by seismic shocks related to synsedimentary tectonics (Thorez et al., 2006).

The Évieux Member and its lateral equivalents witness the maximum of regression of the Famennian age (recorded as a third-order sequence UD9, Fig. 3). It is followed by the major Strunian transgression that is marked by the return of marine conditions and the recolonisation by marine fauna (e.g. brachiopods, corals, trilobites) in the Comblain-au-Pont and Etrœungt formations. It corresponds to the lower part of sequence 1 of Hance et al. (2001). The Hangenberg Crisis is recorded at the top of this unit, where dysoxic shale locally developed (Hangenberg Black Shale Event), whereas the out-of-sequence Hangenberg Sandstone Event and the Devonian–Carboniferous Boundary is recorded within the basal bed of the overlying Hastière Formation (see Denayer et al., 2021 for a recent synopsis).

7. Description of the lithostratigraphic units

7.1. Preliminary remarks

All the lithostratigraphic units are listed alphabetically as a lexicon, notwithstanding their age and geographic distribution. The reader is referred to the Figures 3 and 4 for further information concerning the latter data, that are complemented by Figures 12, 23 and 25, and to Figures 5–7 for the distribution of selected brachiopod and rugose coral species. Macrofossils are illustrated in Plates 1–5 (e.g. brachiopods, bivalves, cephalopods, trilobites, plants) and Figures 8–11 (mostly rugose corals).

We have indicated the oldest references (e.g. including the original spelling), which may explain some discrepancies between the present work and previous ones (Boulvain et al., 1993a, 1999a; Bultynck & Dejonghe, 2002), as is notably the case for the Esneux and Comblain-au-Pont formations. A history of the subdivisions of the Frasnian of the Dinant Synclinorium, Brabant Parautochthon and Vesdre area was provided by Boulvain et al. (1999a) and complements those published by Dumon et al. (1954), Coen (1974), Tsien (1974), and Boulvain et al. (1993a), which also dealt with the units present outside these areas. Bellière (1954), Dreesen (1978) and Thorez et al. (2006) published a history of the Famennian subdivisions of the abovementioned areas. Most of the descriptions provided in this chapter are synthetised from previous publications such as the abovementioned lithostratigraphic charts, complemented by more recently published data, including those from the revised Geological Map of Wallonia. To be consistent with the latter, new names are proposed for units that were previously grouped together for mapping purposes, such as the Montfort and Évieux formations, which are here transformed into members of the newly introduced Condroz Formation, whereas units previously described as Famennian members are here considered to be facies (e.g. Beverire and Spontin facies). Moreover, informal members (e.g. *membre biostromal de Lustin*), remarkable horizons (e.g. Hony Horizon) and facies (e.g. Merlemont Dolomitic Facies) are also introduced with formal definitions. As far as possible, existing names have been retained, unless

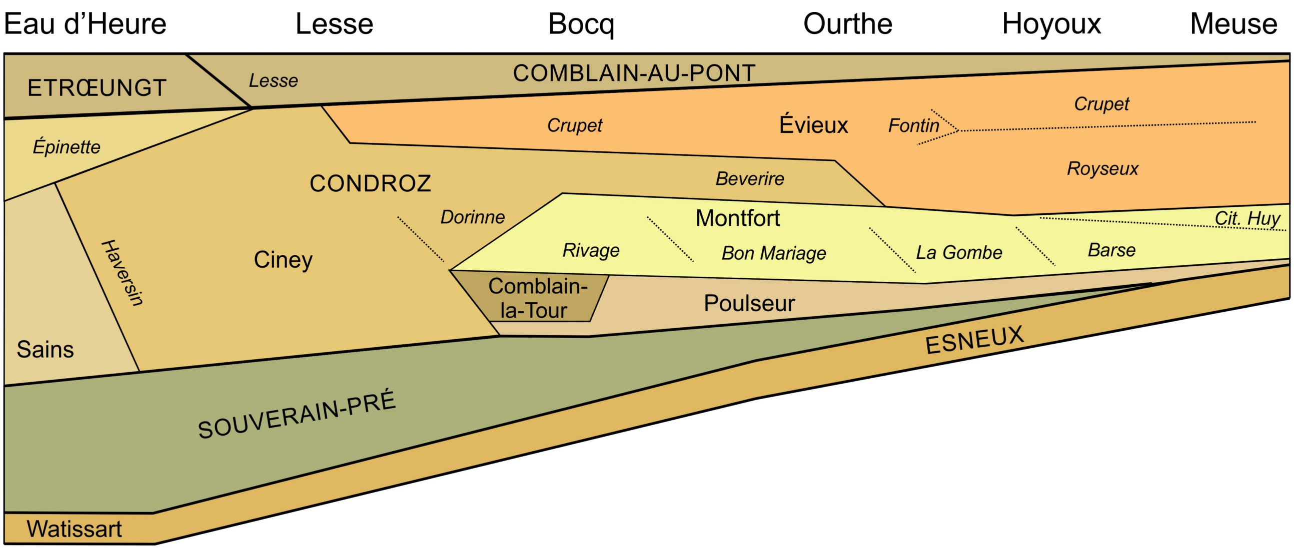

Figure 12. Middle–uppermost Famennian formations within the Dinant Synclinorium and the Haine–Sambre–Meuse Overturned Thrust sheets (origin of data: see main text). Formations are in capital letters, members in regular letters, and facies in italics. Abbreviation: Cit. Huy, Citadelle de Huy.

they are confusing or already used for distinct units. Additionally, the definition of the boundaries of some units (e.g. Lambermont and Esneux formations) has been modified to facilitate the geological mapping process.

7.2. Descriptions

Aisemont Formation – AIS

Origin of name. After the village of Aisemont, *Assise d'Aisemont* in Graulich (1961, p. 39, 68). This term does not have to be confused with the *Grès et psammites d'Aisémont* of Cornet (1923, p. 181) and the *Psammites d'Aisémont* of Cornet (1927, p. 496), which have fallen into disuse; they would correspond to the Rouillon Member of the Eifelian Rivière Formation (see Denayer et al., 2024).

Description. In its type area, the Aisemont Formation (Fig. 13) rests abruptly on the limestone of the Lustin Formation and is covered by the shale of the Franc-Waret Formation (Delcambre & Pingot, 2014b). It is characterised by two carbonate members (*premier* and *second biostrome à Phillipsastrea* sensu Coen, 1974; Coen-Aubert, 1974a, 1974b; Coen et al., 1977; Coen-Aubert & Lacroix, 1979) that are separated by a shaly interval. These lower, middle and upper terms or members of the literature (e.g. Lacroix, 1999a; Poty & Chevalier, 2007; Denayer & Poty, 2010) are formally named herein and are the following, in ascending order: the Tchafornis, Mallieue and Fond des Cris members.

In its stratotype at Engis, the c. 6 m thick **Tchafornis Member – TCH** (from the disused Tchafornis quarry at Engis) begins with c. 0.5 m thick bioturbated limestone rich in siliceous sponge spicules, crinoid ossicles and colonial corals (*Frechastraea*, *Alveolites*) (Poty & Chevalier, 2007). This is followed by an almost 4 m thick biostromal episode formed by the accumulation of discoid colonies of rugose corals (mainly *Frechastraea*) (Fig. 13A, B), which can represent up to 90% of the volume of the rock (Poty & Chevalier, 2007). The biostromal level passes vertically to argillaceous limestone, more or less dolomitized, with numerous rugose (*Frechastraea*, *Hankaxis* and *Phillipsastrea*) and tabulate (*Alveolites*, auloporides) corals, then to argillaceous dolostone. In more distal areas, tabulate corals and scarce stromatoporoids are also present in various proportions (Poty & Chevalier, 2007).

The **Mallieue Member – MLL** (from the La Mallieue section along the road N617 at Engis) is essentially composed of green to brown and black shales (Fig. 13C). In its type section, where it reaches 13 m in thickness, it starts with a 0.7 m thick bed of calcareous shale, more or less dolomitized, followed by 4 m of shale almost devoid of fossils, then 7.3 m of shale, sometimes calcareous and ends with 1 m of calcareous shale passing to argillaceous limestone. Brachiopods (e.g. lingulides, productidines, spiriferides) can be abundant, but numerous molluscs (bivalves, orthoconic cephalopods, gastropods) are also present, essentially in the third part of the Member (Mottequin et al., 2015; Goolaerts et al., 2017). The Mallieue Member may incorporate very locally (Chaudfontaine boreholes) grey and red, or even pink limestone that was interpreted as forming a bioherm similar to those of the Petit-Mont Member (Graulich, 1967; Coen-Aubert, 1974a; Graulich & Vandenven, 1978; Dejonghe, 1987a; Boulvain, 1993b), but this limestone most probably corresponds to biostrome such as those of the Tchafornis Member that are reddish in the area and thickened by local tectonics. The Mallieue Member corresponds to the lower Kellwasser Event (Poty & Chevalier, 2007; Denayer & Poty, 2010; Mottequin & Poty, 2016).

The **Fond des Cris Member – FDC** (from the disused Fond des Cris quarry at Ninane (Chaudfontaine)) consists of grey to black stylonodular bioclastic limestone (Fig. 13D), often dolomitized, with numerous oncoids and rugose (*Potyphyllum*, *Frechastraea*) and tabulate (*Alveolites*) corals (Denayer & Poty, 2010) (Fig. 10E). This Member does not have to be confused with the Famennian *psammites du Fond des Crys* introduced by Mourlon (1875b, p. 772), a local name that is no longer in use.

Stratotype and sections. The stratotype of the Aisemont Formation is located in the northern part of the former Moreau quarry at Aisemont (e.g. Lecompte, 1960; Lacroix, 1974a; Delcambre & Pingot, 2014b), which was transformed into a controlled landfill (Lacroix, 1999a); therefore, the section is now almost lost. The Tchafornis and Mallieue sections (e.g. Poty & Chevalier, 2007; Denayer & Poty, 2010; Mottequin et al., 2012), both situated on the left bank of the Meuse River valley at Engis, are easily accessible and selected herein as the respective stratotypes of the eponymous members. Moreover, the Mallieue section (road and disused quarry) exposes the entire formation. In the latter section, the proximal facies of the Fond des Cris Member are dolomitized as is the case at Aisemont. The Fond des Cris section, located in the disused quarry close to the Ninane cemetery in the Fond des Cris Creek valley near Chaudfontaine, was described by Da Silva (2004) and Denayer & Poty (2010) and is selected here as the stratotype of the eponymous member.

Area and lateral variations. The Aisemont Formation is recognised in the Brabant Parautochthon, from the meridian of Marchovelette (Asselberghs, 1936; Delcambre & Pingot, 2015), east of the Orneau River valley, where it lies on the Rhisnes Formation, to the east of the Mehaigne River valley (Delcambre & Pingot, 2015), where it rests on the Huccorgne Formation. In the Campine Basin, the Aisemont Formation lies directly on top of the siliciclastic Booischot Formation (Booischot borehole) and probably on the Rhisnes Formation (rather than the Huccorgne Formation) in the Heibaart borehole (Lagrou & Coen-Aubert, 2017). The Formation is also recognised in the Visé area, in the eastern extension of the Brabant Inlier (e.g. Poty, 1982, 1991; Poty & Delculée, 2011) and in the Bolland borehole (Graulich, 1975a, 1984). Outside the Brabant Parautochthon and the Campine Basin, this lithostratigraphic unit invariably overlies the Lustin Formation. In the Haine–Sambre–Meuse Overturned Thrust sheets, the Aisemont Formation is known from Landelies (Delcambre & Pingot, 2000a) to Engis (Delcambre, in press, a). On the northern flank of the Dinant Synclinorium, it crops out between Lesves (Delcambre & Pingot, 2017) to the west and Remouchamps (Coen, 1974; Marion et al., in press) to the east, and from both localities, it progressively passes laterally to the Neuville Member of the Marche-en-Famenne Formation (Delcambre & Pingot, 2004; Bellière, 2015; Marion & Barchy, in press, a).

The Aisemont Formation is known from the Vesdre area, up to Raeren and the German border (Coen-Aubert, 1974a). In this area, the limestones of the Tchafornis Member are sometimes red-coloured (see below) (Delcambre et al., in press) and the Fond des Cris Member can form a thick carbonate mass separated by some shaly horizons (Coen-Aubert, 1974a; Laloux et al., 1996a). Eastwards, in Germany, the Aisemont Formation passes laterally to the *Schmidthof-Formation* (Deutsche Stratigraphische Kommission, 2016; ex *Frasnium-Knollenkalke* of Holzapfel, 1910).

According to Lacroix (1999a) and Poty & Chevalier (2007), lateral variations are observed in the thickness and the abundance of the rugose corals and brachiopods in the Tchafornis Member, and in the dolomitization and dedolomitization of the Fond des Cris Member (for more details, see, e.g., Coen-Aubert, 1974a; Dejonghe, 1987b; Denayer & Poty, 2010).

Thickness. Significant thickness changes occur laterally. In

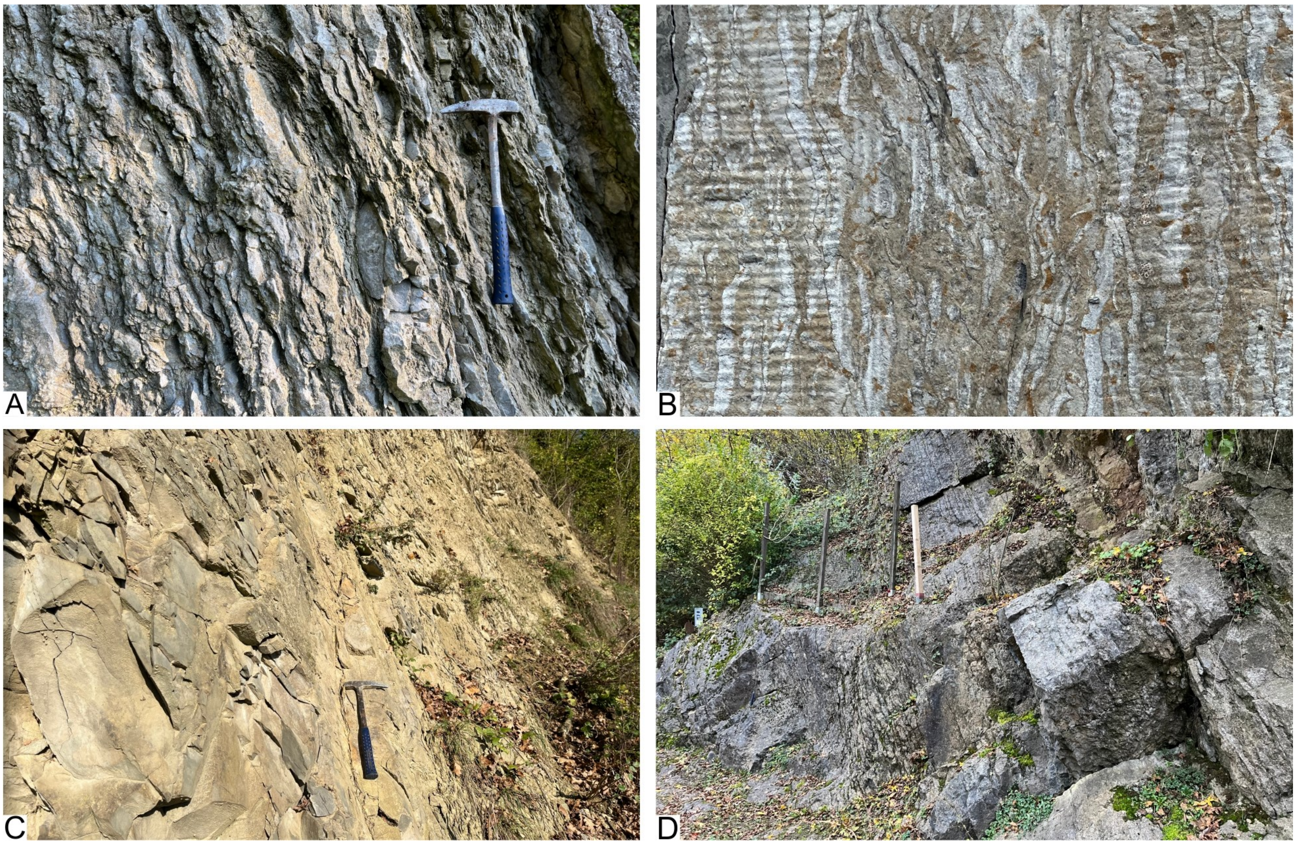

Figure 13. Illustration of the Aisemont Formation; the layers are overturned in each photograph, except D. **A.** Biostromal bed made of flat colonies of the rugose coral *Frechastraea* spp. at the base of the Tchafornis Member. Engis, Tchafornis quarry. **B.** Biostromal bed of discoid phillipsastreid rugose corals (Tchafornis Member) used as a door frame. Ninane, *rue du Centre* (width of the picture c. 17 cm). **C.** Green, fossiliferous shale of the upper part of the Mallieue Member. Engis, La Mallieue section. **D.** Lower part of the limestone of the Fond des Cris Member. Ninane, *rue Fond des Cris*.

the Brabant Parautochthon, it varies a lot: 0 m near the Orneau River valley, 10–15 m in the Gelbressée Creek valley (Delcambre & Pingot, 2015), 25 m in the Mehaigne River valley (Delcambre & Pingot, 2014b), and 33 m in the Wépion borehole (Coen-Aubert, 1988). It is 25–30 m thick in the Campine Basin (Lagrou & Coen-Aubert, 2017). In the Haine–Sambre–Meuse Overturned Thrust sheets, the following thicknesses are reported: 10 m at Landelies in the Sambre River valley (Delcambre & Pingot, 2000a), 15 m at Dave in the Meuse River valley (Delcambre & Pingot, 2017), 27 m at Huy-Statte (Coen-Aubert & Lacroix, 1979), and 29 m at Engis (Poty & Chevalier, 2007). On the northern limb of the Dinant Synclinorium, it thickness is less than 30 m at Lustin in the Meuse River valley (Delcambre & Pingot, 2017), 35 m at Vierset-Barse in the Hoyoux River valley (Coen-Aubert, 1973; Coen-Aubert & Lacroix, 1979), 46 m at Baugnée (Poty & Chevalier, 2007), and up to 60 m at Remouchamps in the Amblève River valley (Marion et al., in press). In the Vesdre area, its thickness should be quite variable (25 to 100 m), notably due to the great development of the Mallieue Member (c. 65 m) in the Les Surdents area and that of the Fond des Cris Member (c. 25 m) between Pepinster and Ensival–Lambermont (Coen-Aubert, 1974a; Laloux et al., 1996a); nevertheless, these thicknesses seem to be overestimated, probably as a result of local tectonics.

Age. Late Frasnian; lower *rhenana* and lowest part of the upper *rhenana* conodont zones (Coen-Aubert & Lacroix, 1979, 1985; Gouwy & Bultynck, 2000; Bultynck & Dejonghe, 2002). Coen et al. (1977) reported two rugose coral associations, namely *faune 1* and *faune 2* in the Tchafornis and Fond des Cris members, respectively. Both associations are dominated by *Frechastraea limitata*, *F. coeni* and *Potyphyllum ananas* (Fig. 10E, F, I). The first contains additionally *Hankaxis insignis* (Fig. 10K), whereas the second is characterised by the occurrence of *Macgeea gallica* and *Frechastraea pentagona* (Fig. 10D, G) Coen-Aubert, 1974a, 1974b, 2012, 2015, 2016). The smooth rhynchonellides *Calvinaria megistana* (probably misidentified with the spiriferide *'Minatothyris maureri'* in the Belgian literature) (Pl. 2.A) and *Navalicria compacta* (Pl. 2.B) are known from the base of the Formation as is the case of the spiriferide *Tiocyrspis bironensis* (Pl. 2.K) (Mottequin, 2005a; Poty & Chevalier, 2007; Mottequin & Poty, 2022; see Marche-en-Famenne Formation).

Use. Locally, the limestone was used for lime production and, accessorily, as building stone, notably the reddish (in fact pinkish orange) limestone of the Fond des Cris quarry that was used as an ornamental stone (e.g. Perron of Liège and Fourmarier Spring in Chaudfontaine) and known as the *Marbre rouge (et blanc) de Chaudfontaine* (Groessens, 1981).

Main contributions. Lacroix (1974a, 1999a), Coen-Aubert (1974a, 2012, 2015, 2016), Coen-Aubert & Coen (1975), Coen et al. (1977), Coen-Aubert & Lacroix (1979), Schmidt (1994), Vanbrabant et al. (2003), Da Silva (2004), Poty & Chevalier (2007), Denayer & Poty (2010).

Arche Member – ARC

See Moulin Liénaux Formation.

Aye Facies

See Marche-en-Famenne Formation (Famenne Member).

Baelen Member – BAE

See Souverain-Pré Formation.

Barse Facies

See Condroz Formation (Montfort Member).

Barvaux Facies

See Marche-en-Famenne Formation (Valisettes Member).

Beverire Facies

See Condroz Formation (Ciney Member).

Biénonsart Member – BIN

See Huccorgne Formation.

Bieumont Member – BMT

See Grands Breux Formation.

Bois de la Rocq Formation – BDR

Origin of name. After the Bois de la Rocq quarry in the Samme River valley near Feluy, *Membre du Bois de la Rocq* in Doremus & Hennebert (1995a, p. 11). Note that Mourlon (1875b, p. 789) introduced the *psammite de la Roq* that clearly refers to this formation.

Description. The Bois de la Rocq Formation (Fig. 14A) corresponds to the *complexe arénacé basal* or *séquence de base arénacée* of the literature (e.g. Coen-Aubert et al., 1981) and rests on the top of the upper Frasnian–lower Famennian shale of the Franc-Waret Formation. It contains reddish and greenish coarse-grained sandstone with some red shale intercalations near its lower boundary. Locally (e.g. Tournai borehole), conglomerate occurs at the base. The sandstone is micaceous and usually displays a dolomitic cement or, occasionally, a calcareous cement. In the lower part of the Formation, the sandstone beds are usually thin, and their thickness increases upsection. The dominant colour passes from red to yellowish grey. Locally (Orneau River valley), dark fine-grained limestone beds with ostracods occur near the base. In the upper part, calcareous sandstone, commonly fossiliferous (e.g. bivalves, Pl. 5.A), occurs. The upper boundary is defined by the first thick bed of calcareous or dolomitic sandstone of the overlying Feluy Formation.

Stratotype and sections. The stratotype corresponds to the disused Bois de la Rocq quarry along the Samme River north of Feluy. The Falnuée railway section (Conil, 1964; Delcambre & Pingot, 2008) in the Orneau valley offers a good parastratotype.

Area and lateral variations. The Formation is known from the Brabant Parautochthon from Western Flanders (Higgs et al., 1992) and Tournai and Leuze boreholes (Coen-Aubert et al., 1981) to the Ligne River valley; it then reappears eastwards in the Orneau River valley and up to the Somme Creek valley (Vezin) where it disappears along the Landenne Fault (Delcambre & Pingot, 2014b; Delcambre, 2023).

Thickness. In its type locality, the Formation is c. 50 m thick (Doremus & Hennebert, 1995a). A similar thickness is known in the Tournai borehole (Coen-Aubert et al., 1981). In the Orneau River valley, the top is probably missing and the Formation is 45 m thick and directly overlain by the Tournaisian Pont d'Arcole Formation (Delcambre & Pingot, 2014b). At Marche-les-Dames it reaches 60 m (Delcambre & Pingot, 2015).

Age. Late Famennian to Tournaisian (Hastarian). Leriche (1922) indicated the occurrence of *Holoptychius* and *Archaeopteris* in the Mévergnies quarries. Coen-Aubert et al. (1981) reported *Quasiendothyra communis* in the carbonate unit at the top of this formation, suggesting a latest Famennian (Strunian) age. In the Bossuit borehole, north of Tournai, Higgs et al. (1992) mentioned the lower Tournaisian VI to HD palynozones for the upper part of the *complexe arénacé basal*, i.e. the top of the Bois de la Rocq Formation and the base of the overlying Feluy Formation.

Use. Locally used as building stone.

Main contributions. Mourlon (1875b), Asselberghs (1936), Conil (1959), Bouckaert & Conil (1970), Coen-Aubert et al. (1981), Higgs et al. (1992), Doremus & Hennebert (1995a), Hennebert & Eggermont (2002).

Bois des Mouches formation

Remark. The Bois des Mouches formation is a disused unit introduced by Delcambre & Pingot (2000a, p. 25) corresponding to the Condroz Formation. It encompasses the entire Famennian succession between the basal Famennian shale (Franc-Waret Formation) and the Tournaisian carbonates (Anseremme Group) in the Landelies area (Haine–Sambre–Meuse Overturned Thrust sheets). In this area, a basal unit of massive sandstone, interpreted as the *Grès de Watissart* (Beugnies, 1973), corresponds to a local facies of the Esneux Formation (see this unit). Eastwards, the Esneux Formation is individualised (map Malonne–Naninne, Delcambre & Pingot, 2017) below the Bois des Mouches formation. The upper part of the formation corresponds to the Comblain-au-Pont Formation whereas the intermediate unit displays the typical facies of the Montfort and Évieux members of the Condroz Formation. In consequence, this name is abandoned in favour of the Condroz Formation.

Booischot Formation – PBI

See Denayer et al. (2024).

Bon-Mariage Facies

See Condroz Formation (Montfort Member).

Bosscheveld Formation – PBO

Origin of name. After the Bosscheveld quarry, north of Maastricht (the Netherlands), where the drilling Kastanjelaan-2 was carried out, Bosscheveld formation (informal unit) in Van Adrichem Boogaert & Kouwe (1994, p. 12).

Description. The Bosscheveld Formation is typically made of alternations of dark grey to green, argillaceous, often nodular shale, limestone, and grey, sometimes micaceous siltstone and sandstone with fossil plant debris. In the upper part the limestone and shale are dominant and get richer in crinoids, brachiopods and corals.

Stratotype and sections. Borehole Kastanjelaan-2 (between 400 m and 483.5 m) (Van Adrichem Boogaert & Kouwe, 1994) where the Bosscheveld Formation rests upon the Condroz Formation and is overlain by the Tournaisian Pont d'Arcole Formation.

Area and lateral variations. Only known from the Campine Basin where the Formation is not laterally continuous, and its occurrence is probably controlled by block tectonics (Laenen, 2003); see Van Adrichem Boogaert & Kouwe (1994) for its distribution in the Netherlands. It lacks in the Booischot borehole. The Bosscheveld Formation is a lateral equivalent of the basal clastic complex known in the Brabant Parautochthon

Figure 14. Illustration of some Upper Devonian units. **A.** Thickly bedded sandstone of the Bois de la Rocq Formation. Marche-les-Dames quarry. **B.** Lower part of the Bovesse Formation. Huccorgne road section. **C.** Robiewez (lower part) and Mehaigne (upper part) members of the Huccorgne Formation. Huccorgne quarry.

(Higgs et al., 1992); therefore, it is regarded as an equivalent of the Samme Group (at least the Feluy Formation). In the Meuse River valley, north-east of Liège, the Chertal borehole (Graulich, 1975b; Delcambre, in press, b), displays, below 494 m, an alternation of sandstone, limestone and crinoidal limestone at the top, then black-coloured finer material. According to Delcambre (in press, b), these sandstone-carbonate beds may be attributed to the Bosscheveld Formation.

Thickness. Variable, between 0 and c. 80 m.

Age. Latest Famennian (Strunian) to Tournaisian (Hastarian). In the Kastanjelaan borehole, Poty (1982) described *Conilophyllum priscum* (*Caninia tregaensis* auct.) at 446 m indicating the basal Tournaisian RC1α Subzone, just above the last specimen of *Palaeosmilia aquisgranensis* (Strunian RC0 Zone). The palynomorphs assemblages indicate the upper Famennian LE Zone to the basal Tournaisian VI Zone (Bless et al., 1981). The Devonian–Carboniferous Boundary is well documented in the Kastanjelaan borehole (Kimpe et al., 1978; Poty, 1986). The layers encountered at the base of the Chertal borehole have been dated to the latest Famennian (Strunian) based on their spore assemblage (Kimpe et al., 1978; Paproth et al., 1983). Conil (1964) assigned these beds to the Famennian and to the extreme base of the Tournaisian, characterised by the presence of ostracods (*Cryptophyllus*), calcareous algae and foraminifers. The poorly discriminating conodont faunas indicate a pre-Ivorian age (Groessens, 1975).

Use. Nil.

Main contributions. Bless et al. (1981), Muchez & Langenaeker (1993), Van Adrichem Boogaert & Kouwe (1994), Langenaeker (2000), Laenen (2003).

Bossière Member – BOS

See Bovesse Formation.

Boussu-en-Fagne Member – BOU

See Grands Breux Formation.

Boverie Member – BVR

See Moulin Liénaux Formation.

Bovesse Formation – BOV

Origin of name. After the village of Bovesse, *Calcaire de Bovesse (...)* D^8 in Gosselet (1860, p. 93).

Description. The Bovesse Formation (Fig. 14B) includes shale, limestone and dolostone. It is subdivided into three members.

The lower **Bossière Member – BOS** (*Assise de Bossières* in Conseil de Direction de la Carte, 1896, p. 54) comprises greyish to grey shale that includes siliceous to sandy dolomitic beds varying between few centimetres and one decimetre in thickness. This shale locally incorporates some haematitic oolites. A thin conglomeratic horizon is locally present at the base (Delcambre & Pingot, 2008).

The middle **Combreuil Member – CBR** (*Membre de Combreuil* in Hennebert & Eggermont, 2002, p. 21) is made of massive, coarse-grained blond-grey to pinkish dolostone, usually cavernous, that alternates with shale, dolomitic shale and argillaceous dolostone. Where the dolomitization is moderate, the rock is rich in rugose and tabulate corals and sometimes brachiopods, but where it is more pronounced, only the ghosts of fossils are visible. This member is discontinuous laterally and forms several hundred metres long and up to 20 m thick lenses embedded into the overlying Champ du Fau Member. Delcambre & Pingot (2008) suggested that these lenses may correspond to dolomitized bioherms.

The upper **Champ du Fau Member – CHF** (*Membre du Champ du Fau* in Hennebert & Eggermont, 2002, p. 21) includes grey shale with few beds containing brachiopods (atrypides, spiriferides, etc.). The shale tends to get richer in limestone (nodules, or even thin beds) in the vicinity of the dolostone lenses of the Combreuil Member (Delcambre & Pingot, 2008).

Stratotype and sections. Three sections, investigated by Coen-Aubert & Lacroix (1985, fig. 2: outcrops nos. 1–3) and located east of Huccorgne in the Mehaigne River valley, were selected by Lacroix (1999b) as the composite parastratotype of the Formation. Indeed, there is no reference section anymore in the Bovesse area, situated 8 km to the northwest of Namur; only a few scattered small outcrops remain around this village according to Delcambre & Pingot (2015). However, Delcambre & Pingot (2014a) pointed out that the Bovesse Formation as exposed in the Mehaigne River valley differs from the historical type area and the Orneau River valley because, in both latter areas, shale predominates on carbonate facies; moreover, oolitic ironstone horizons of the Bossière Member are absent at Huccorgne (Delcambre & Pingot, 2014a).

Area and lateral variations. The Bovesse Formation is recognised in the Brabant Parautochthon, from the Dendre River to the Mehaigne River valleys, around Huccorgne (Delcambre & Pingot, 2014a). It was also reported from the western part of the Brabant Parautochthon, in the Tournai and Leuze boreholes, where thicknesses of 396 m (Tournai) and 318 m (Leuze) were mentioned by Coen-Aubert et al. (1981), as well as in the Nieuwkerke-De Seule borehole (Tourneur et al., 1989; Streel et al., 2021), but the absence of dolostone means that the rocks encountered there cannot be attributed definitely to the Bovesse Formation. These deposits are also similar to those included in the Frasnian Beaulieu Formation from the nearby Boulonnais area in France (Tourneur et al., 1989).

In the Mehaigne River valley, the Caledonian rocks of the Brabant Inlier are overlain by a few metres of terrigenous and continental deposits that were ascribed to the Bovesse Formation by Asselberghs (1936) and Lacroix (1999b). Coen-Aubert & Lacroix (1985) and Delcambre & Pingot (2014a) logically assigned these siliciclastic rocks to the Givetian Bois de Bordeaux Group (see Denayer et al., 2024). However, the typical shale of the Bossière Member is lacking at Huccorgne, and the Formation starts directly with the Combreuil Member consisting of two dolomitic units separated by shale and bedded limestone with some horizons rich in fasciculate rugose corals (*Disphyllum preslense*, Fig. 8G).

Thickness. From west to east: 80–90 m at Ronquières (i.e. 15–25 m for the Bovesse, 35–45 m for the Combreuil, and 10–45 m for the Champ du Fau members, respectively, after Legrand, 1967; Hennebert & Eggermont, 2002), c. 85 m in the Orneau River valley (Delcambre & Pingot, 2008), c. 80 m north of Namur and at Huccorgne (Delcambre & Pingot, 2014a, 2015).

Age. Early Frasnian. There is no conodont data from surface outcrops. *Ancyrodella binodosa* is known from the so-called Bossière Member in the Leuze borehole (Coen-Aubert et al., 1981) whereas *A. rotundiloba*, which is the index conodont for the base of the Frasnian (see section 3), is reported from the unit in the Tournai borehole by Magne (1964) (see remarks above concerning Coen-Aubert et al.'s (1981) doubtful attribution of the rocks yielding the conodonts to the Bovesse Formation). The solitary rugose coral *Macgeea rozkowskae* is reported from beds above the first dolostone horizon at Huccorgne (Coen-Aubert & Lacroix, 1985). The spiriferide brachiopod succession was presented by Sartenaer (1982, 1999a), including notably *Eodmitria oblivialis oblivialis* (Pl. 1.J) and *E. oblivialis grandis* (Pl. 1.K) that are also known from the Nismes Formation.

Use. Locally used as building stone.

Main contributions. Stainier (1892), Malaise (1903), Asselberghs (1912, 1936), Vandamme (1981), Coen-Aubert & Lacroix (1985), Lacroix (1999b).

Brayelles Dolomitic Facies

See Pont de la Folle Formation (Fontaine Samart Member).

Chalon Member – CHA

See Moulin Liénaux Formation.

Champ Broquet formation

Disused informal unit; replaced by the Marche-en-Famenne Formation.

Champ du Fau Member – CHF

See Bovesse Formation.

Ciney Member – CIN

See Condroz Formation.

Citadelle de Huy Facies

See Condroz Formation (Montfort Member).

Comblain-au-Pont Formation – CBP

Origin of name. After the village of Comblain-au-Pont in the Ourthe River valley (*Fa3f Calcaire de Comblain-au-Pont à grandes tiges d'encrines, à Phacops granulosus* in Mourlon, 1882, p. 520).

Description. The Comblain-au-Pont Formation (Fig. 15) is typically composed of an alternation of siliciclastic and limestone arranged in couplets that correspond to climatic cycles (Poty, 2016). The base is defined by the first bed of crinoidal limestone overlying the siltstone and sandstone of the Condroz Formation. In some sections (Chanxhe (Fig. 15A), Hastière), a thin horizon with limestone clasts occurs, highlighting the base of this transgressive unit. The lower part of the Formation is still dominated by sandstone and siltstone, but the latter are not arkosic and micaceous anymore contrary to the underlying Ciney and Évieux members of the Condroz Formation. Limestone beds increase in frequency and thickness upwards whereas the sandstone facies disappear progressively. The upper part is dominated by the coarse-grained crinoidal and bioclastic limestone usually rich in macrofossils (solitary rugose corals, stromatoporoids, brachiopods, trilobites). Several fossil-rich horizons were named *premier biostrome*, *second biostrome*, and *biostrome principal* by Conil (1964) but genuine biostromes

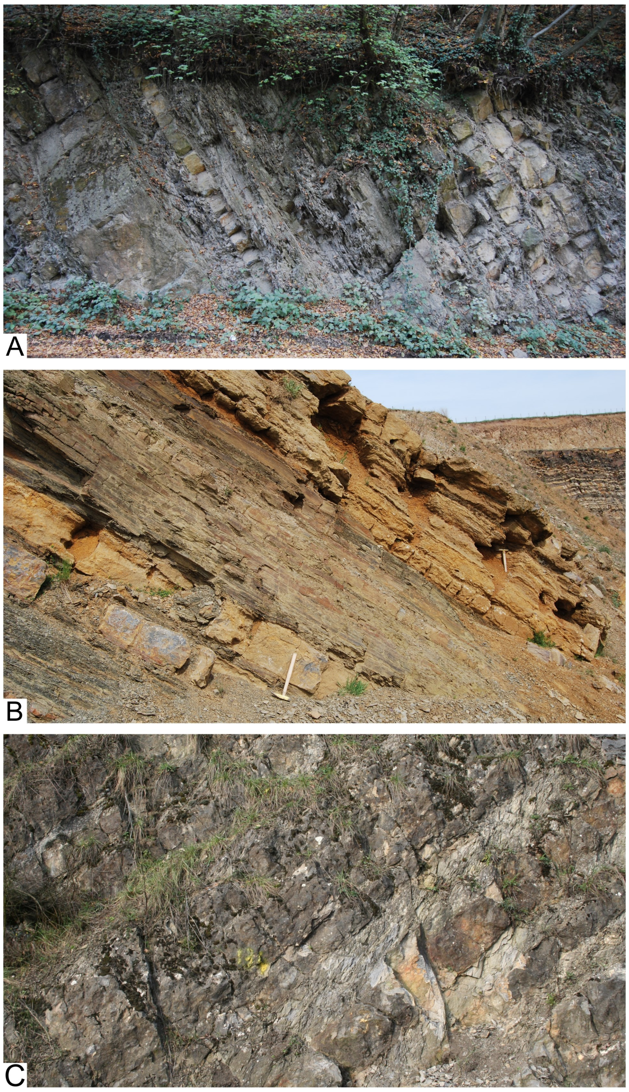

Figure 15. Illustration of the Comblain-au-Pont Formation. **A.** Typical alternation of siliciclastic and limestone beds. Chanxhe I section. **B.** First and second stromatoporoid biostromes of the Dolhain Facies. Trooz quarry (from Poty et al., 2011). **C.** Alternations of the thick beds of limestone and shale of the Lesse Facies. Anseremme railway section.

(Fig. 15B) are only known from the Vesdre area (**Dolhain Facies**, *Formation de Dolhain* in Laloux et al., 1996b, p. 36) where the upper part of the Formation is massive and locally dolomitized.

The Comblain-au-Pont Formation shows an increase in offshore features towards the south and west and passes to the Etrœungt Formation in the western part of the Dinant Synclinorium. Therefore, the successions exposed notably in Anseremme and Gendron-Celles sections are rather different from that exposed in the type locality, notably through an increase of the limestone proportion. In this area, these rocks were often designated under the name *Calcaire d'Etrœungt* (e.g. Conil, 1964; Bouckaert et al., 1974b), but their facies are not those typical of that formation either. They are thus distinct from the usual facies of the Comblain-au-Pont and are designated here as the **Lesse Facies** (Fig. 15C).

The Comblain-au-Pont Formation witnessed the re-installation of open-marine conditions at the end of the Famennian. Its upper boundary corresponds to the last bed of shale below the massive limestone basal bed of the overlying Hastière Formation.

Stratotype and sections. The historical type section situated along the road between Esneux and Comblain-au-Pont, along the Ourthe River, is partly overgrown and tectonically perturbed (Bellière, 2015). The renowned Chanxhe I section exposes particularly well the Formation, except its top, also removed by a fault. In the southern part of the Dinant Synclinorium, the Anseremme railway section exposes the entire formation, but with the typical Lesse Facies made of shale–limestone cycles. The Dolhain Facies is exposed in the eponymous locality, along the Vesdre River north of the Dolhain–Limbourg station.

Area and lateral variations. The Formation is developed in the Dinant Synclinorium between the Ourthe River and the Eau d'Heure River valleys where it becomes progressively poorer in sandstone and richer in shale. It passes gradually to the Etrœungt Formation in the south-western part of the Dinant Synclinorium, west of Walcourt. The Dolhain Facies is known in the Vesdre River valley. Eastwards, in Germany, the Comblain-au-Pont Formation is named *Etrœungt-Formation* (ex *Über Kohlenkalk*) (Deutsche Stratigraphische Kommission, 2016).

Thickness. c. 100 m in the Meuse River valley, 70 m in the Ourthe River valley (Conil, 1968).

Age. Latest Famennian (Strunian). The Comblain-au-Pont Formation almost coincides with the Strunian substage as defined by Streel et al. (2006). In the type area, the first marine limestone marking its lower boundary yielded the first *Bispathodus ultimus* indicating the base of the former upper *expansa* conodont zone and the first *Quasiendothyra kobeitusana* indicating the DFZ7 foraminifer Zone, along with the first rugose corals indicating the RC0β Subzone (bed 111 of the Chanxhe section; Denayer et al., 2021). The spore *Retispora lepidophyta*, marker of the LL Palynozone, occurs in bed 92, i.e. 8 m below the first limestone with *B. ultimus* (Maziane et al., 1999). In more distal settings (Anseremme section), the appearances of the markers are more spread out, with the first *B. ultimus* occurring c. 8 m below the first *Q. kobeitusana*, in the *Strunien gréseux* sensu Conil (1964), i.e. below the base of the Comblain-au-Pont Formation. The typical assemblage with *Campophyllum* sp., *Bounophyllum praecursor* and *Palaeosmilia aquisgranensis* (Fig. 11A, C, E) characterises the RC0 Zone that starts near the base of the Formation. Although largely unrevised, the brachiopod fauna of the Comblain-au-Pont Formation includes some productidines such as *Mesoplica nigeraeformis* (Pl. 4.Z) and *Spinocarinifera* aff. *lotzi* (Pl. 4.AA), but also three typical Strunian species, namely the rhynchonellide *Araratella moresnetensis* (Pl. 4.BB) and the spiriferides *Prospira struniana* (Pl. 4.CC) and *Sphenospira julii* (Pl. 4.DD) (Sartenaer & Plodowski, 1975; Legrand-Blain, 1991; Mottequin & Brice, 2016; Denayer et al., 2021); both latter species are also known from the Etrœungt Formation. Mourlon (1882) used the last phacopid trilobites to characterise this unit, i.e. *Omegops accipitrinus* and *O. maretiolensis* (Pl. 4.EE) (Richter & Richter, 1933; Crônier et al., 2025). The top of the Formation is still Devonian-aged (DFZ7 and LL zones, and RC0β Subzone) as the Devonian–Carboniferous boundary is situated within the first bed of the overlying Hastière Formation.

Use. The limestone was locally exploited in small quarries as building stone, notably in the Vesdre area (Laloux et al., 1996a, 1996b).

Main contributions. Streel (1966), Conil (1968), Bouckaert et al. (1970), Paproth & Streel (1970), Becker et al. (1974), Bouckaert et al. (1978), Van Steenwinkel (1984, 1990), Conil et al. (1986), Dreesen et al. (1986b), Poty (1999, 2016), Maziane et al. (2002), Poty et al. (2011), Prestianni et al. (2016), Denayer et al. (2016, 2021).

Comblain-la-Tour Member – CLT

See Condroz Formation.

Combreuil Member – CBR

See Bovesse Formation.

Condroz Formation – CDZ

Origin of name. *Psammites jaunâtres qui recouvrent, entre autres, les plateaux de la contrée nommée Condros*, the typical Famennian sandstone in the Condroz area, introduced by d'Omalius d'Halloy (1839, p. 448), and *psammites du Condros* in d'Omalius d'Halloy (1853, p. 555, footnote).

Remark. The modern lithostratigraphic scale of the Famennian of southern Belgium is based on the tremendously detailed works of J. Thorez, R. Dreesen, M. Streel and their colleagues, who developed a sedimentary and palaeogeographic depositional model for the *Psammites du Condroz*. However, most of the units they defined are based on the analysis of palaeoenvironments and have proven to be hardly distinguishable in the field. The revision of the Geological Map of Wallonia pointed towards a systematic grouping of all the lithostratigraphic units developed between the Souverain-Pré and the Comblain-au-Pont formations. Hence, it is proposed to preserve the original subdivisions of J. Thorez and his colleagues at the level of facies rather than members, and therefore to downgrade the formations into members. The lithostratigraphic mappable unit embracing the upper Famennian *Psammites du Condroz*, whatever the depositional settings recorded, is consequently designated as the Condroz Formation (Fig. 12). Attention should be drawn on the definition as it does not correspond to the *Psammites du Condroz* group introduced by Thorez & Dreesen (1986, p. 287) since the latter includes all the strata between the lower Famennian disused Famenne group (see Marche-en-Famenne Formation) and the Dinantian carbonates.

Thorez (1973) and Thorez et al. (1977) introduced the Ciney Formation for the sandy limestone-rich succession observed in the Bocq River valley. Later, Bultynck & Dejonghe (2002) considered the Ciney Formation sensu Thorez et al. (1977) to be an inshore equivalent of the Souverain-Pré Formation. However, the definition of the Ciney Formation was extended by Delcambre & Pingot (1993) to the entire mixed siliciclastic sequence overlying the Souverain-Pré Formation. This definition was subsequently used to designate the mapped units in the south-western part of the Condroz and Entre-Sambre-et-Meuse area (roughly south of the Bocq River valley and west of the Meuse River valley). Thorez et al. (2006) came to a stratigraphic concept close to that proposed by Delcambre & Pingot (1993), but they considered the well identified marine carbonate at the top as corresponding to the Comblain-au-Pont Formation. This last definition is retained here. The Ciney Member includes the Dorinne Facies at its base and the Haversin Facies. The latter was previously considered as a member of the Souverain-Pré Formation by Thorez et al. (1988) and as a separate formation by Thorez et al. (2006).

Description. The Condroz Formation (Figs 12, 16–17, 18A–B) is made up of interfingering siliciclastic and subordinate carbonate units. The facies is heterolithic: sandstone, arkose, siltstone, shale, often micaceous and dolomitic, marked by various types of sedimentary figures and commonly arranged in sequences, cycles or sets. The reddish and variegated colours, together with the development of primary dolostone, occur in the more proximal areas and locally invade the entire upper part of the Formation. The numerous units composing the Condroz Formation (previously described as formations and members) are presented here in a stratigraphical order but not all members and facies are stratigraphically superimposed as they are mostly laterally stacked and pass to each other.

The **Poulseur Member – POU** (*Membre de Poulseur* in Bouckaert et al., 1970, p. 28) is dominated by brownish to greyish sandstone and micaceous arkosic sandstone in thin beds either with planar or wavy bedding and alternating with bioturbated greyish to greenish shale and siltstone. Ball-and-pillow structures are frequent, particularly at the base. Thorez et al. (1977) referred these facies to an open marine-proximal subtidal depositional environment.

The **Montfort Member – MTF** (*psammite grisâtre, micacé et schistoïde de Montfort* in Davreux, 1833, p. 208; *assise des psammites de Montfort à Cucullaea Hardingii* in Mourlon, 1875a, p. 648) includes the strata traditionally designated as *Assise de Montfort* (Conseil de Direction de la Carte, 1892, p. 226; 1896, p. 53; Conseil géologique, 1929, p. 65) or *Monfort* (Conseil de Direction de la Carte, 1900, p. 37; 1909, p. 1652) (Figs 16, 17A). In the Ourthe and Amblève River valleys, the Member begins with sandstone beds with ball-and-pillow structures (*calamanes* of the quarrymen; Ancion & Macar, 1947; Macar, 1948) (Fig. 16A). Thorez et al. (1977) divided this unit into three members that are here interpreted as facies, from the base to the top: (1) a package of rhythmic shallowing-upwards deposits of arkosic sandstone, bioturbated or with planar laminations, siltstone (dominant) and shale with occasional crinoidal limestone at the base and micritic limestone with ostracods at the top of some rhythms (**Bon-Mariage Facies**; *Membre de Bon-Mariage* in Thorez, 1973, p. 34, table 5; *Membre de Bon Mariage* in Thorez et al., 1977, p. 26 and inset fig. 1d–e) (Fig. 16B); (2) quartzitic and arkosic sandstone arranged in metre-thick beds displaying a systematic coarsening upward grading either massive or with planar and oblique laminations and mega-ripples (**Gombe Facies**; *Membre de La Gombe* in Thorez, 1973, p. 34, table 5; Thorez et al., 1977, inset fig. 1d–e) (Fig. 16C); (3) greyish to blueish quartzitic and arkosic sandstone with massive texture or marked by (mega-) ripples intercalated with sandy and micaceous primary dolomite beds with abundant sedimentary structures such as channels, ripples, mud-cracks, flat pebbles and pseudomorphs of anhydrite clasts (**Barse Facies**; *Membre de Barse* in Thorez, 1973, p. 34, table 5; Thorez et al., 1977, inset fig. 1d–e; to not be confused with disused Gosselet's (1888, p. 598) *Schistes de Barse* [recte Les Basses, an hamlet near Haversin, and not Barse in the Hoyoux River valley]). Locally in the Ourthe River area, rhythmically-arranged arkosic siltstone and sandstone with abundant load casts, channels and oblique laminations are developed (**Rivage Facies**; *Membre de Rivage* in Thorez, 1973, p. 32, table 5; Thorez et al., 1977, inset fig. 1 d–e). North of the Condroz Inlier occurs a massive package of reddish sandstone and arkosic sandstone in usually metre-thick beds (**Citadelle de Huy Facies**; Huy Citadel Member/Formation in Thorez et al., 2006, p. 31 (fig. 4) and p. 32) (Fig. 17A), which encloses some rare reddish siltstone and shale. It is known in the old literature as the *psammites rouges de Huy* (Mourlon, 1876, p. 855; see also Mourlon, 1875b, p. 774) and the *psammite rouge amarante de Huy* (Mourlon, 1886, legend of figs 1–3). Note that the *Schistes noirs de Huy* (Malaise, 1900, p. 211) and the *calcaire de Huy* (Dumont, 1832, p. 73) correspond nowadays to the Ordovician Huy Formation and to the Frasnian Lustin Formation, respectively. The Montfort Member recorded several sand barriers and associated depositional environments as well as tidal-influenced shore environments with back-barrier evaporitic lagoon (sabkha).

The **Ciney Member – CIN** (*Formation de Ciney* in Thorez, 1973, p. 36, table 5; *Formation des Grès de Ciney* in Thorez et

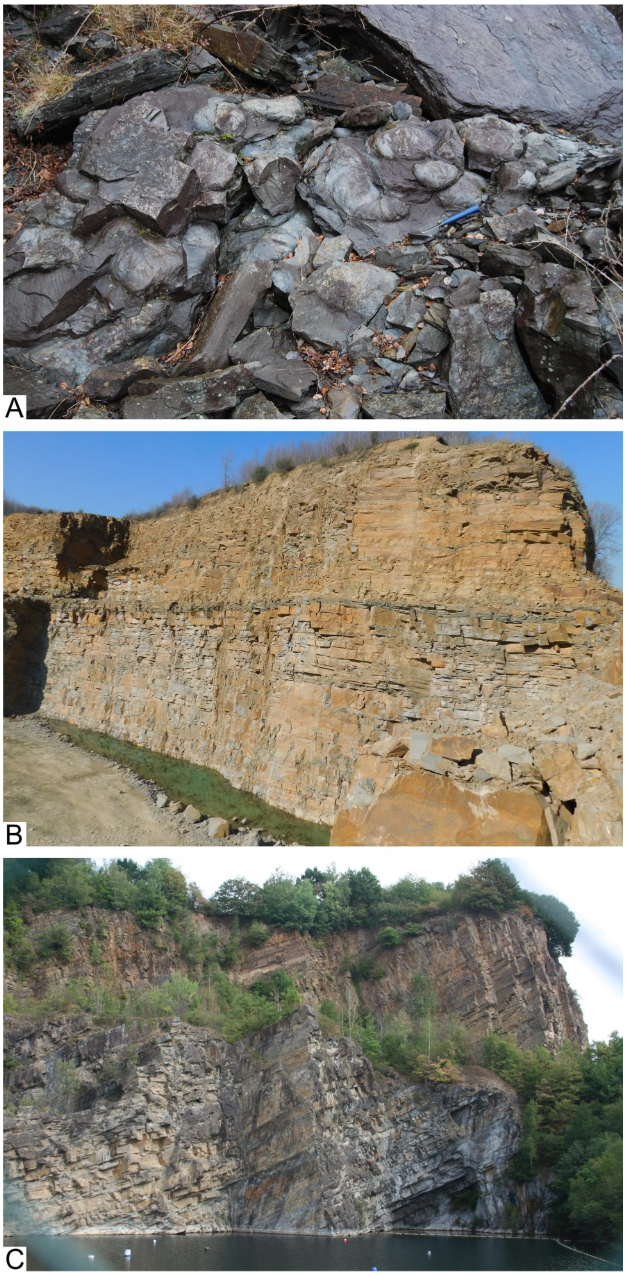

Figure 16. Illustration of the Condroz Formation. **A.** Large ball-and-pillow structures (*calamanes* of the quarrymen) at the base of the Montfort Member. Remouchamps, Heid des Gattes quarry. **B.** Homogeneous quartzitic arkosic sandstone of the Montfort Member (Bon-Mariage Facies). Anthisnes–Poulseur, Bois d'Anthisnes quarry. **C.** Thickly bedded arkosic sandstone and siltstone of the Gombe Facies of the Montfort Member. Esneux, La Gombe quarry.

al., 1977, p. 26 and inset fig. 1d–e) (Fig. 17B–C) is here re-defined as a unit of mixed siliciclastic and calcareous deposits corresponding to a distal equivalent of the Montfort and Évieux members. It does not include the sandstone–shale–limestone alternations attributed to the younger Comblain-au-Pont Formation, unlike Delcambre & Pingot (1993). This member begins with thick beds of sandstone overlying the nodular argillaceous limestone beds of the Souverain-Pré Formation. It passes to bioturbated sandy calcareous siltstone rich in brachiopod coquina beds (e.g. spiriferides) deposited as stacked 20–100 cm thick tempestites, with planar horizontal and hummocky cross-stratifications (**Dorinne Facies**; *Membre de Dorinne* in Thorez, 1973, p. 36, table 5; Thorez et al., 1977, inset fig. 1d–e). Thickly bedded and often lenticular sandstone beds alternating with siltstone and shale develop. The siltstone and shale become dominant in the upper part of the Member (**Haversin Facies**; *Schistes à nodules calcaires d'Haversin* in Mourlon, 1882, p. 519) but sandstone beds with oblique bedding and a calcareous cement still occur; some ball-and-pillow structures are present locally. Recurrent limestone (or dolostone) nodules and clasts embedded in sandstone are not rare in the lower part of the Member but tend to decrease in thickness and frequency up-section (fluxoturbidites after Thorez & Dreesen, 1986). Some sandy limestone beds, mostly brachiopod coquinas, appear near the top of the Member. Metre-thick beds of greyish to blueish micaceous and arkosic sandstone and siltstone with rare intercalations of micritic limestone (**Beverire Facies**; *Membre de Beverire* in Thorez, 1973, p. 34, table 5; *Formation des Grès, Schistes et Calcaires de Beverire* in Thorez et al., 1977, p. 26, inset fig. 1d–e) are interfingered into the Évieux Member. They were initially restricted to the southern part of the Ourthe River valley, but Dreesen & Thorez (1994) reported them in the Dinant area as well. The Ciney Member reflected an open marine subtidal depositional environment with tempestites and turbidites.

The **Comblain-la-Tour Member – CBT** (*Formation de Comblain-la-Tour* in Thorez, 1973, p. 32, table 5; Thorez et al., 1977, inset fig. 1d–e; equivalent to the *Comblain Member* in Bouckaert et al., 1970, p. 28) (Fig. 17D) is developed in the north-east of the Dinant Synclinorium. It is composed of thinly bedded crinoidal and bioclastic limestone with hummocky cross-stratifications alternating with shale, siltstone and quartzitic sandstone, deposited as tempestites. It passes vertically and laterally to the Montfort Member.

The **Évieux Member – EVX** (*assise des psammites d'Évieux à végétaux* in Mourlon, 1875a, p. 649) (Fig. 18A–B) corresponds to the traditional *Assise d'Évieux* and consists of a heterolithic complex of shale, siltstone, arkosic sandstone and (very) micaceous sandstone, with subordinate calcareous sandstone and dolostone. The red colour varies from pinkish or dark red (*amarante, lie-de-vin*) to purple and is due to an iron hydroxide coating of the quartz grains (Thorez et al., 1988). The lower boundary traditionally used for this unit is the occurrence of the first red bed. However, this criterion is hardly applicable in the field as red-coloured beds are also known from older strata. We here propose to define the base of the Évieux Member by the change from the dominantly sandy to more silty-shaly lithologies. Thorez (1973) and Thorez et al. (1977) recognised three members based on the dominant colour and the dolomitic content: (1) at the base, a heterolithic package of red-coloured sandstone and siltstone beds, and greyish to greenish shale and siltstone, alternating with abundant primary dolostone and palaeosols (aridisols and dolcretes with rhizocretions, pedoturbations and desiccation cracks) (**Royseux Facies** (Fig. 18A); *Membre de Royseux* in Thorez et al., 1977, inset fig. 1d–e; to not be confused with the *Dolomie de Royseux* in Groessens (1975, p. 79), a disused local dolomitized limestone member in the uppermost part of the Tournaisian Landelies Formation (see also Conil et al., 1967; Paproth et al., 1983)); (2) a remarkable intercalation of sandy micritic limestone with ostracods and oncolites suggesting a lagoonal environment (**Fontin Facies**; *Membre de Fontin* in Thorez, 1973, p. 35, table 5; Thorez et al., 1977, inset fig. 1d–e); and (3) a package of red-coloured beds with interstratified primary dolomite and palaeosols passing to greenish shale with fluvial channels (**Crupet Facies** (Fig. 18B); *Membre de Crupet* in Thorez, 1973, p. 35, table 5; Thorez et al., 1977, inset fig. 1d–e). The diverse continental macrofauna (e.g. arthropods, vertebrates) (Pl. 5.B) and macroflora (Pl. 5.C–D) (*Flore d'Évieux* in the Belgian literature, e.g. Crépin, 1874; Stockmans, 1948; Kenrick & Fairon-Demaret, 1991; Fairon-

Figure 17. Illustration of some members of the Condroz Formation. **A.** Amaranth sandstone of the Citadelle de Huy Facies (Montfort Member) used as building stone. Strud, *rue de Strud*. **B.** Carbonate sandstone and siltstone of the Ciney Member. Leignon, section along the road N949. **C.** Yellowish weathered dolomitic sandstone of the Ciney Member, known as *pierre d'avoine* in the Condroz, used as building stone. Sorée, Saint-Martin church. **D.** Thinly bedded micaceous sandstone typical of the Comblain-la-Tour Member, Comblain-la-Tour quarry.

Demaret, 1996) of the Belgian upper Famennian are from this unit. The Évieux Member recorded a continental flood plain environment with fluvial channels, supratidal sabkha and lagoon environments.

In the western Entre-Sambre-et-Meuse area, the typical sandy facies of the *Psammites du Condroz* becomes progressively more argillaceous and passes to the **Sains Member – SNS** (*schistes calcarifères de Sains, schistes de Sains* in Gosselet, 1879b, p. 389, 395, 397) which is composed of greyish, greenish or purple micaceous shale alternating with calcareous shale, often nodular, and rare thin sandstone beds. The sandstone is micaceous and argillaceous, rarely calcareous and displays oblique laminations. The limestone nodules are usually centimetric to decimetric in size and passes to continuous beds that look like those of the Souverain-Pré Formation. Brachiopods form frequent coquina beds in the shale and nodular shale. Up-section, the facies is more coarse-grained (**Épinette Facies**, former *Strunien gréseux* or *Schistes de l'Epinette* in Conil (in Subcommission on Carboniferous Stratigraphy, 1969, p. 187)). The latter starts with siltstone with millimetre-thick sandstone laminae and interstratified decimetre-thick beds of quartzitic micaceous sandstone. The sandstone becomes dominant in the middle third of the Member and displays commonly large ball-and-pillow structures. The upper third is again dominated by siltstone and subordinated sandstone beds.

Stratotype and sections. No continuous section exposes the whole Condroz Formation, but numerous outcrops and quarries offer good exposures of the various members and facies.

The Poulseur and Comblain-la-Tour members are defined in the disused Comblain-la-Tour quarry and along the N654 road in the Ourthe River valley, between Comblain-la-Tour and Comblain-au-Pont.

The Montfort Member is exposed along a railway section, 1700 m south of the Esneux railway station in the Ourthe valley; the Bon-Mariage and Gombe facies can be observed in the Esneux ('Belle Pierre') quarry; the Rivage Facies is exposed in the eponymous quarry and along the railway at the Rivage station; the Barse Facies is visible in the Ereffe quarry at Marchin; the Citadelle de Huy Facies crops out along the section and cliffs along the Namur–Huy road (N90), just north of the Huy Citadel in the Meuse River valley.

The Évieux Member is well developed in the eponymous quarry and railway south of the Esneux station; the Royseux Facies is visible in the Chabôfosse quarry in the Hoyoux River valley at Marchin; the Fontin Facies is exposed along the railway south of the Esneux station; the Crupet Facies can be observed in the Tienne des Marteaux quarry and along the railway in Spontin.

The Ciney Member is well exposed along the railway north-west of Leignon. The Dorinne Facies can be observed in the Rochette quarry in Spontin. The Haversin Facies can be seen along the railway south of Haversin; the Beverire Facies is exposed in disused quarries at Comblain-au-Pont, on the left bank of the Ourthe River. The railway section between Sains-du-Nord and Féron in the Avesnois (France) shows the Sains Member and Épinette Facies.

Area and lateral variations. The Condroz Formation is present in the Dinant Synclinorium, Haine–Sambre–Meuse Overturned Thrust sheets, Vesdre area, Booze–Le Val-Dieu Ridge and Campine Basin, but the various members are confined to more restricted areas (see Figs 3, 4, 12). The

Figure 18. Illustration of some Famennian units. **A.** Alternation of red sandstone and yellowish paedogenetised dolomitic beds forming a palaeosol complex characteristic of the Royseux Facies of the Évieux Formation. Wierde section. **B.** Typical heterolithic alternation of sandstone, siltstone and shale forming the channel complex of the Crupet Facies of the Évieux Member. Spontin, Tienne des Marteaux quarry. **C.** Detail of the contact between the siliciclastic Esneux Formation and the calcareous Souverain-Pré Formation. Pont-de-Bonne, Limonaderie section.

Poulseur Member occurs in the Haine–Sambre–Meuse Overturned Thrust sheets and along the northern limb of the Dinant Synclinorium between the Amblève River and the Samson River valleys; the Montfort Member is only represented by the Citadelle de Huy Facies in the Haine–Sambre–Meuse Overturned Thrust sheets; the Ciney Member is mainly present in the southern part of the Dinant Synclinorium, but its Beverire Facies is developed locally in the northern part as is the case of the Comblain-la-Tour Member; the Évieux Member is recognised throughout the basin. Eastwards, in Germany, the Condroz Formation is known up to Aachen (Kasig et al., 1979) where the Montfort and Évieux members are known as the *Montfort-Formation* and *Évieux-Formation*, respectively (Deutsche Stratigraphische Kommission, 2016).

Thickness. In the central and northern parts of the Dinant Synclinorium, the Condroz Formation is 290 m thick in the Hoyoux River and Bocq River valleys (Delcambre & Pingot, 2018a; Barchy & Marion, 2021; Mottequin et al., 2021) and up to 350 m thick in the Lesse River valley (Delcambre & Pingot, 1993). In the eastern part of this tectonic unit, it is about 400 m thick in the Ourthe River valley. In the more northern tectonic units (Haine–Sambre–Meuse Overturned Thrust sheets and Vesdre area), its thickness does not reach 200 m (Delcambre & Pingot, 2014b, Laloux et al., 1996a, 1996b).

Age. Middle to latest Famennian. The Condroz Formation extends from the upper part of the middle Famennian (former 'Fa2b', see Thorez et al., 2006) to the latest Famennian ('Fa2d'), former *expansa* conodont zone (*marginifera* to *ultimus* conodont zones; Dreesen & Thorez, 1994), DFZ4 to DFZ7 foraminifer zones (Devuyst & Hance in Poty et al., 2006) and GF to LL–LE palynozones (Higgs et al., 2013). The diachronism of some members and facies has been pointed out by several authors (e.g. Thorez et al., 1977, 2006; Thorez & Dreesen, 1986).

The Poulseur Member extends from the uppermost *marginifera* to lower *postera* conodont zones (Dreesen & Thorez, 1994) and is included in the GF Palynozone. The Montfort Member extends from the uppermost *marginifera* to upper *trachytera* conodont zones and GF Palynozone. The Évieux Member spans the interval of the lower *postera* to the former upper *expansa* conodont zones and that of the VCo to LL palynozones. The Ciney Member extends from the former upper *expansa* to *praesulcata* conodont zones (Dreesen & Thorez, 1994; equivalent to the *ultimus* conodont Zone in modern terminology). In the Anseremme railway section, *Quasiendothyra kobeitusana*, i.e. the marker of the uppermost Famennian (Strunian) substage, first occurs in the *Strunien gréseux* sensu Conil (1964), thus at the top of the Ciney Member. Brachiopods of the Condroz Formation remain poorly known (Maillieux 1941a, 1941b; Lecompte & Waterlot, 1957), but the rhynchonellide *Sartenaerus letiensis* (Pl. 5.E) is traditionally considered as the characteristic taxon of the Sains Member (Gosselet, 1887; Mottequin & Brice, 2016), although representatives of the *S. letiensis* group are already present at the top of the Famenne Member (Sartenaer, 1970a; Fig. 6).

Use. The 'sandstone' of the Montfort and Évieux members and the Ciney Member were and are still exploited to produce cobblestones, rubble stone, building stone and aggregates (Ancion & Macar, 1947; Poty & Chevalier, 2004). The yellowish weathered dolomitic sandstone is used as building stone named *pierre d'avoine* in the Condroz (Fig. 17C). Some particular beds of the Évieux Member, known from the Vierset–Villers-le-Temple area (Condroz), were used in the past as acid-resistant materials, notably for textile and steel industries (Ancion & Macar, 1947).

Main contributions. Mourlon (e.g. 1875a, 1875b, 1876), Conil (1964), Thorez (1964a, 1964b), Bouckaert & Thorez (1966), Thorez et al. (1977, 1988, 2006), Beugnies (1965, 1973), Thorez (1973), Becker et al. (1974), Bless et al (1974), Goemaere (1984), Thorez & Dreesen (1986, 2002), Dreesen & Thorez (1994), Maziane et al. (1999), Higgs et al. (2013), Denayer et al. (2016), Morelle & Denayer (2020).

Cousolre Member – COU

See Philippeville Formation.

Crupet Facies

See Condroz Formation (Évieux Member).

Dolhain Facies

See Comblain-au-Pont Formation.

Dorinne Facies

See Condroz Formation (Ciney Member).

Épinette Facies

See Condroz Formation (Sains Member).

Ermitage Member – ERM

See Moulin Liénaux Formation.

Esneux Formation – ESN

Origin of name. After the village of Esneux, *assise des psammites d'Esneux à crinoïdes* in Mourlon (1875a, p. 647), which is better known in the Belgian literature as the *Psammites stratoïdes d'Esneux* (Mourlon, 1880, p. 91, 305).

Description. The Esneux Formation (Fig. 18C) is characterised by rhythmic alternations of pluricentimetric to decimetric, locally pluridecimetric, beds of greenish argillaceous siltstone (more rarely shale) and fine, micaceous, greenish grey sandstone with generally plane parallel laminations. Sedimentary structures (e.g. hummocky cross-stratifications, ripple marks) and bioturbations are common (see Thorez et al., 2006). Fossils (e.g. brachiopods, crinoids) are locally abundant but usually decalcified (internal moulds). The transition to the overlying Souverain-Pré Formation (Fig. 18C) is marked by the occurrence of light grey crinoidal limestone beds in the shale and its top is placed at the base of the first nodular limestone characteristic of the former unit. In the absence of the Souverain-Pré Formation, the top of the Esneux Formation is placed at the first occurrence of masses of quartzitic sandstone and limestone of the base of the Ciney Member (Condroz Formation). Laterally, to the south, the sandstone beds alternate with lenticular layers of siltstone and shale announcing the Aye Facies (Marche-en-Famenne Formation) that is considered as the distal equivalent of the Esneux Formation (Thorez & Dreesen, 1986). The oolitic ironstone horizon IV (Dreesen, 1981, 1982a, 1982b, 1989a) is generally developed near the top of this unit.

The **Watissart Member – WTS** ('*d6a2G'. Faciès gréseux* or *Grès de Watissart* in Waterlot et al., 1967, p. 8), introduced as the *Membre de Watissart* within the Esneux Formation by Dumoulin (2001, p. 31), is a marker level in the western part of the Dinant Synclinorium that consists essentially of pluricentimetric to plurimetric, lenticular beds of massive, grey to bluish grey quartzitic sandstone; these beds enclose rare large-sized sponges (Pl. 5.F–G) (e.g. Waterlot, 1947). The Watissart Member corresponds to the Grès de Cerfontaine, a term introduced by Gosselet (1880a, p. 112; 1880c, p. 208). To avoid confusion, note that Cerfontaine designates here a village situated in the Hauts-de-France and not the homonymous locality situated in the Belgian Namur province.

Stratotype and sections. The stratotype of the Esneux Formation corresponds to the railway trench immediately located to the south of the Esneux station (Mourlon, 1875a; Bellière, 2015). That of the Watissart Member is the disused Watissart quarry at Jeumont (France), south-west of Merbes-le-Château (Mourlon, 1885; Gosselet, 1888; Beugnies, 1965; Waterlot et al., 1967; Dumoulin, 2001).

Area and lateral variations. The Esneux Formation is recognised in the Haine–Sambre–Meuse Overturned Thrust sheets, the Dinant Synclinorium, the Vesdre area, and the Theux Window. In the Haine–Sambre–Meuse Overturned Thrust sheets, it was sometimes not distinguished from the overlying strata due to poor exposure (Delcambre & Pingot, 2014b), but it can be well recognised from Wépion and to the east of the Meuse River valley (Delcambre & Pingot, 2017). The Watissart Member is only developed in the north-western part of the Dinant Synclinorium (Dumoulin, 2001; Hennebert, 2008).

Thickness. The Esneux Formation is about 40–50 m thick in the Haine–Sambre–Meuse Overturned Thrust sheets (e.g. Delcambre & Pingot, 2017; Mottequin et al., 2021). Maximum thicknesses are reached in the central part of the Dinant Synclinorium: 250 m in the Silenrieux–Walcourt area (Dumoulin & Marion, 1997a), 250 m in the Hermeton and Lesse River valleys (Delcambre & Pingot, 1993), and 200 m in the Achêne–Leignon area (Boulvain et al., 1995). In the eastern part of this structural unit, its thickness is about 125 m in the Esneux area (Bellière, 2015) as is roughly speaking the case on the northern limb of the Dinant Synclinorium: e.g., c. 100 m in the Meuse River valley and Gesves area (Delcambre & Pingot, 2017, 2018b), 100 m near the French border (Hennebert, 2008). It is highly variable in the Vesdre area, from 25 m to the west up to 170 m in the east (Laloux et al., 1996a, 1996b). In the Theux Window, its thickness does not exceed 80 m (Marion et al., in press). The Watissart Member is 50 m thick in its type area (Dumoulin, 2001), although Beugnies (1965) indicated 80 m in the Watissart quarries at Jeumont (France).

Age. Base of the middle Famennian; *rhomboidea* and lower *marginifera* conodont zones (Dreesen, 1978; Dusar & Dreesen, 1984).

Use. The sandstone was locally used, notably for the production of aggregates (Yvoir area; Delcambre & Pingot, 2018a), whereas the sandstone of the Watissart Member was exploited as cobblestones on the French territory (Dumoulin, 2001).

Main contributions. Mourlon (1875a, 1875b, 1880), Beugnies (1965), Thorez & Dreesen (1986), Thorez et al. (2006).

Etrœungt Formation – ETR

Origin of name. After the village of Etrœungt near Avesnes-sur-Helpe in northern France, *calcaire d'Œtrœungt* in Gosselet (1857, p. 364, p. 367, footnote).

Description. The Etrœungt Formation is the southwardly lateral equivalent of the Comblain-au-Pont Formation and differs from the latter by the predominance of argillaceous facies. It contains micaceous and argillaceous sandstone at the base, rapidly replaced by blueish calcareous siltstone and shale alternating with blueish (yellowish by alteration) argillaceous limestone, either bedded or nodular. The limestone beds are commonly coarse-grained and rich in fossils (corals, stromatoporoids, brachiopods, gastropods) and some metre-thick beds are genuine biostromes built by stromatoporoids. Note that the *Calcaire d'Etrœungt* in the literature (see review in Mistiaen et al., 2013) corresponds to the top of the eponymous formation.

Stratotype and sections. The stratotype of the Etrœungt Formation is situated in the disused Parcq quarry at Etrœungt

(Gosselet, 1857; Mamet et al., 1965; Mistiaen et al., 2013), but the exposure is now very poor and both its base and top are not exposed; alternative sections are situated along the railway at Avesnelles (Conil, 1964) and along the industrial road joining the two pits of the Godin quarry in Avesnes-sur-Helpe (Denayer et al., 2021). There are few good exposures of this unit in Belgium, but some discontinuous sections situated in the Walcourt area (Dumoulin & Marion, 1997a) show the fossiliferous limestone and shale, notably the Yves-Gomezée section located along the Charleroi–Couvin motorway (N5–E420) (Dreesen et al., 1976).

Area and lateral variations. It is recognised in the south-western part of the Dinant Synclinorium, including the Avesnois area, passing north-eastwards to the Comblain-au-Pont Formation between Walcourt and Saint-Aubin (Conil & Vandenven, 1972).

Thickness. The Etrœungt Formation reaches 40 m in thickness in the Avesnelles section (Conil, 1964), whereas that of the *Calcaire d'Etrœungt* exceeds 25 m in the incomplete stratotype section (Conil, 1964; Mistiaen et al., 2013). In Belgium, the Formation is about 30 m thick in the Walcourt area (Dumoulin & Marion, 1997a).

Age. Latest Famennian (Strunian). The base of the Etrœungt Formation is situated above that of the Strunian as the underlying units yield the key foraminifer *Quasiendothyra kobeitusana* (see Condroz Formation). At Avesnelles and Etrœungt, the Formation contains the classical Strunian macrofauna including brachiopods, rugose corals and trilobites (Dehée, 1929). The Formation yielded a diverse coral fauna dominated by *Campophyllum* spp. and *Clisiophyllum* spp. (Fig. 11B, C) as well as stromatoporoids. Among the partly revised brachiopod fauna (Brice et al., 2013; Mottequin & Brice, 2016), the most characteristic Strunian species are the spiriferides *Prospira struniana* (Pl. 4.CC) and *Sphenospira julii* (Pl. 4.DD), which are also reported from the Comblain-au-Pont Formation.

Use. The limestone was exploited to produce cobblestones, building and paving stone (Dumoulin, 2001) and, very locally, lime.

Main contributions. Gosselet (1857, 1880c, 1888), Dehée (1929), Conil (1964), Sartenaer & Mamet (1964), Mamet et al. (1965), Waterlot et al. (1967), Conil & Lys (1970), Delattre et al. (1970), Mistiaen et al. (2013).

Évieux Member – EVX

See Condroz Formation.

Falisolle formation

Disused unit, replaced by the Franc-Waret Formation.

Falnuée Member – FLN

See Rhisnes Formation.

Famelette Formation – FML

Origin of name. After the Famelette road in the Mehaigne River valley, *Schistes de la Famelette* in Paproth et al. (1983, p. 213).

Description. The Famelette Formation encompasses the shaly units comprised between the top of the Frasnian Aisemont Formation and the dolostone of the Tournaisian Engihoul Formation. It begins with greenish-greyish shale that is occasionally fossiliferous and contains rare micaceous sandstone beds with calcareous cement, often decalcified at the surface. Ferruginous sandstone beds with horizontal planar laminations occur in the middle part of the Formation. About 2 m above the base, a discontinuous horizon of haematitic or chamositic oolites occurs in a sandy or calcareous matrix (Fig. 19A). In the Mehaigne River valley, the ore is divided into several centimetre-thick lenses separated by shale and siltstone beds. In the disused Couthuin mine, the ore consists of a lower horizon 1.1–1.2 m thick of haematitic oolites and an upper 0.1–0.3 m thick horizon of chamositic oolites enclosed in a pyritic matrix (Delmer, 1913). It thins out in the Famelette road section (Delcambre & Pingot, 2014a).

Stratotype and sections. Section along the road connecting the Mehaigne valley to the E42 motorway south-east of Huccorgne.

Area and lateral variations. The Formation is only recognised in the Brabant Parautochthon, between Couthuin and the Mehaigne River valley, north of the Landenne Fault. It passes laterally to the Franc-Waret Formation.

Thickness. From 12 m in the Mehaigne River valley up to 21 m in the Moha–Fosseroule borehole (Van Leckwijck & Ancion, 1956).

Age. Late Frasnian (?)–Tournaisian (Hastarian) (?). The base of the Famelette Formation might still be late Frasnian in age, but guide taxa are lacking. The age of the oolitic ironstone may be early Famennian (Dreesen, 1982b). In the Java gallery of the Couthuin mine, the shale directly resting on top of the oolitic ironstone horizon yielded a diverse Strunian fauna, including trilobites and *Prospira struniana* (Ancion et al., 1956; Vandercammen, 1956). Nevertheless, the material has not been traced in the RBINS and ULiège collections; therefore, the material remains unrevised pending further research. The top of the Formation would be Hastarian in age based on the spores according to Streel (1977), so that the Famelette Formation extends upwards to the Hastarian shaly Pont d'Arcole Formation. Therefore, according to the literature data, it seems that only the basal and topmost Famennian are recorded with a relative certainty, the rest of the stage being in hiatus.

Use. The oolitic ironstone was intensively mined as iron ore in the Couthuin mine between 1810 and 1946 (Denayer et al., 2011b).

Main contributions. Delmer (1913), Ancion et al. (1956), Damiean (1956), Van Leckwijck & Ancion (1956), Mortelmans (1959), Groessens (1975), Streel (1977), Delcambre & Pingot (2014a), Delcambre (2023).

Famenne group or formation

Disused unit, here integrated into the Marche-en-Famenne Formation.

Famenne Member – FAM

See Marche-en-Famenne Formation.

Fond des Cris Member – FDC

See Aisemont Formation.

Fontaine Samart Member – FSA

See Pont de la Folle Formation.

Fontin Facies

See Condroz Formation (Évieux Member).

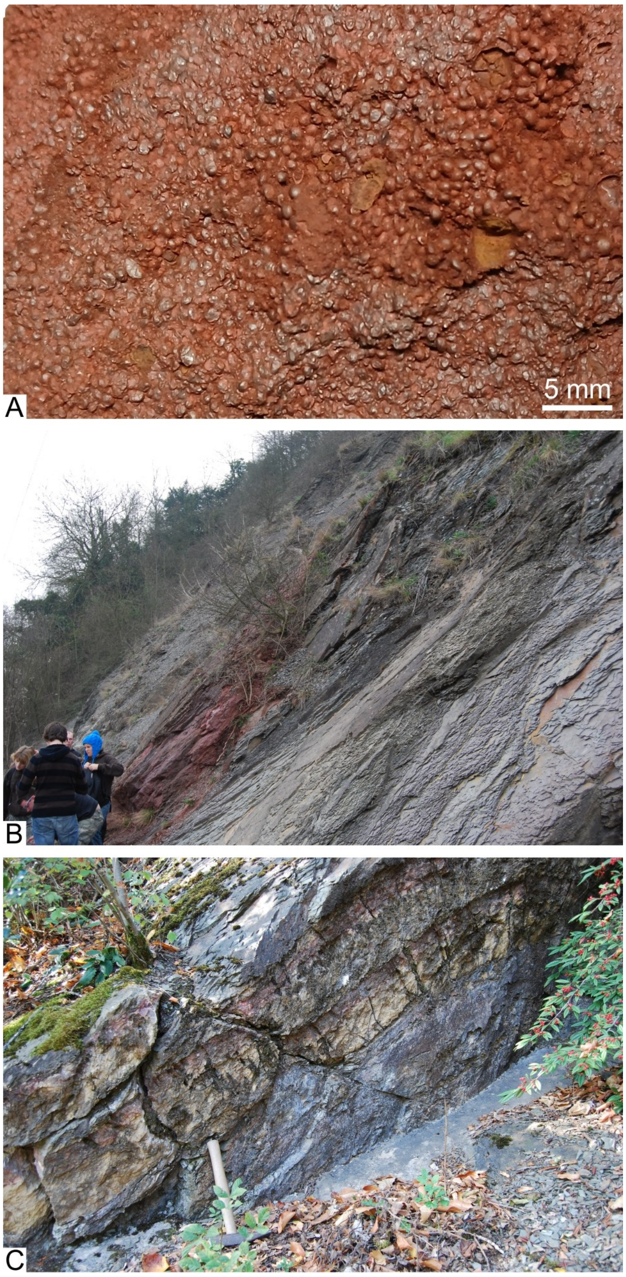

Figure 19. Illustration of some Upper Devonian units. **A.** Oolitic ironstone from the lower part of the Famelette Formation. Disused Couthuin iron mine. **B.** Seventy cm-thick oolitic ironstone horizon developed in mostly shaly Franc-Waret Formation (overturned beds). Huy, Thier Haquin section. **C.** Oolitic ironstone bed within the lower part of the Hodimont Formation (overturned layers). Lambermont section.

Franc-Waret Formation – FRW

Origin of name. After the village of Franc-Waret, *Schistes de Franc-Waret* in Stainier (1892, p. 99).

Remark. In the Brabant Parautochthon and in the Haine–Sambre–Meuse Overturned Thrust sheets, the argillaceous deposits, comprised between the last Frasnian carbonate (Aisemont and Rhisnes formations) and the Famennian sandstone, have been placed into the Franc-Waret or Falisolle (*Formation de Falisolle* in Delcambre & Pingot, 2000a, p. 23) formations (see references below). After completion of the geological mapping of these tectonic units, it now appears that the almost identical lithologies encountered do not justify the coexistence of two distinct lithostratigraphic units. Priority has been given to the Franc-Waret Formation in order to preserve the continuity with the former lithostratigraphic framework.

Description. The Franc-Waret Formation (Fig. 19B) essentially consists of greenish or purple shale frequently finely micaceous and sometimes becoming yellowish where weathered; calcareous brachiopods coquina beds, locally partly decalcified, occur sporadically. Fossils are relatively scarce and are represented essentially by bivalves and brachiopods. Sandstone and siltstone intercalations become more abundant and thicker within the upper part of the Formation. In the Brabant Parautochthon, an oolitic ironstone horizon (horizon I of Dreesen, 1982a, 1982b), up to 1.5 m thick is developed 8 to 20 m above the base of the Formation and is subdivided into two or three layers of sandy shale or even brownish red sandstone rich in haematitic oolites (Delmer, 1912; Denayer et al., 2011b; Delcambre & Pingot, 2015). In more eastern localities of the Haine–Sambre–Meuse Overturned Thrust sheets, its upper part may contain a few beds of oolitic ironstone (horizon II of Dreesen, 1982a, 1982b) Delcambre & Pingot, 2017, 2018b).

The Franc-Waret Formation overlies the limestone of the top of the Rhisnes Formation or those of the Aisemont Formation where the latter is developed (Lacroix, 1999c). However, Delcambre & Pingot (2015) noted that it is possible that the base of the shale included in the Franc-Waret Formation passes laterally to the Aisemont Formation between Marchovelette and the Orneau River valley where the latter lithostratigraphic unit is not developed.

Stratotype and sections. The historical type section of the Franc-Waret Formation was a small excavation located in the park of the eponymous castle, but it does not exist anymore. No stratotype has been selected so far due to the paucity of outcrops around Franc-Waret. Delcambre & Pingot (2015) have observed the Franc-Waret Formation in the bed of the eponymous creek, close to the castle of Franc-Waret, and in another nearby section north of Marche-les-Dames, along the N992 road, in front of the Notre-Dame du Vivier abbey. However, the quality of these outcrops is very poor. Other exposures are also reported in the railway trench in front of the Falnuée castle, between Mazy and Onoz (Delcambre & Pingot, 2008). The original section of the Falisolle formation at the entry of the former Moreau quarry at Aisemont, to the south of Falisolle (Delcambre & Pingot, 2014b, fig. 11I), has almost disappeared. Although tectonically disturbed but easily accessible, the section of Huy-Nord (e.g. Coen-Aubert & Lacroix, 1979; Vanguestaine et al., 1983) is selected as the parastratotype of the Franc-Waret Formation.

Area and lateral variations. The Franc-Waret Formation is recognised in the central part of the Brabant Parautochthon, from the Orneau River valley to Vezin (Delcambre & Pingot, 2008). Westwards it fades away and re-appears in the Ligne River valley. In the Dendre River valley, it is only known from boreholes: Mévergnies (Chabot & Laurent, 1973; Doremus & Hennebert, 1995b), former *Tannerie Gérard* at Soignies (Hennebert & Eggermont, 2002), and Feluy (Lacroix, 1999c). It was also reported in the Leuze borehole by Coen-Aubert et al. (1981) between the Rhisnes and Bois de la Rocq formations, but the encountered lithologies (dolostone, limestone; 14 m thick) are markedly different from those known to the east (Hennebert & Doremus, 1997; Lacroix, 1999c). North of the Landenne Fault and up to the Mehaigne River valley, the remains of the Franc-Waret Formation are included in the Famelette Formation (Delcambre, 2023). In the Haine–Sambre–Meuse Overturned Thrust sheets (see references below) and in the Campine Basin (Lagrou & Coen-Aubert, 2017), it was recognised as the Falisolle formation. The development of the Franc-Waret Formation upon wide areas suggests that it was deposited during a period of high sea level.

Thickness. Quite variable, from 20 m to 40 m in the type area (Delcambre & Pingot, 2015), decreasing westwards where its thickness is estimated at 15–25 m in the Soignies area (Hennebert & Eggermont, 2002), c. 10 m in two boreholes at Feluy (Lacroix, 1999c), and c. 4 m in the Mévergnies borehole (Chabot & Laurent, 1973), and reaches c. 50 m to the east of the type area (Mourlon, 1875b; Delcambre, 2023), before disappearing north-east of Vezin.

In the Haine–Sambre–Meuse Overturned Thrust sheets, its thickness is highly variable (c. 30 m up to 90 m). Delcambre & Pingot (2000b) suggested a thickness of 80–90 m in the la Tombe Massif. Eastwards, its thickness also varies: 50 m at Aisemont (Delcambre & Pingot, 2014b), 45 m in the Wépion borehole (Delcambre & Pingot, 2017), c. 30–65 m south of the Meuse River valley (Delcambre & Pingot, 2018b; Delcambre, 2023), c. 30 m at Huy (Mottequin et al., 2021), and less than 50 m at Streupas (Angleur) and Vaulx-sous-Chèvremont (Delcambre et al., in press, b). In the Booischot and Heibaart boreholes, the thickness of the Franc-Waret Formation varies between 61 m and 65 m (Lagrou & Coen-Aubert, 2017).

Age. Late Frasnian–early Famennian based on rhynchonellide brachiopods reported notably by Beugnies (1973) (‘*Porthmorhynchus ferquensis*’; Frasnian) and Sartenaer (in Coen-Aubert & Lacroix, 1979) (*Ptychomaletoechia omaliusi* (Pl. 4.L), *Pt. gonthieri* (Pl. 4.M), and *Pt. dumonti* (Pl. 4.N); early Famennian) at Huy-Nord, below and above the first occurrence of oolitic ironstone (horizon I of Dreesen 1982a, 1982b; see also Vanguestaine et al., 1983). The presence of *Basilicorhynchus basilicus gerardimontis* (Pl. 4.Q) was documented at Ben-Ahin and Vezin by Sartenaer (1986) within the oolitic ironstone.

Use. The oolitic ironstone horizon was intensively exploited in mines during the 19th century and the first half of the 20th century, mostly between Les Isnes and Vezin (e.g. Delmer, 1912; Denayer et al., 2011b).

Main contributions. Gonthier (1867), Stainier (1892), Delmer (1912), Asselberghs (1936), Van Leckwijck & Ancion (1956), Beugnies (1973), Coen-Aubert & Lacroix (1979), Vanguestaine et al. (1983), Lacroix (1999c), Delcambre & Pingot (2000a, 2000b, 2008, 2015), Delcambre (2023).

Frasnes group or formation

Disused and artificial grouping (*calcaire et schistes de Frasne* in Gosselet, 1871, p. 296; *assise de Frasnes* in Maillieux, 1922a, p. 16–18; 1922b, p. 19, pl. 1; Frasnes Formation in Tsien, 1972, p. 15; 1974, p. 4; *Groupe de Frasnes* in Sartenaer, 1974b, p. 7) that included the Nismes, Moulin Liénaux, Grands Breux, Neuville and Matagne formations (see these names).

Golzinne Member – GOL

See Rhisnes Formation.

Gombe Facies

See Condroz Formation (Montfort Member).

Gougnies Member – GOU

See Lustin Formation.

Grands Breux Formation – GBR

Origin of name. After the locality Les Grands Breux at Frasnes-lez-Couvin (*Formation des Grands Breux* in Coen-Aubert, 1994, p. 21, citing the National Commission for Stratigraphy; Coen-Aubert & Boulvain, 1999, p. 50).

Description. The Grands Breux Formation (Figs 20–21), described in detail by Coen-Aubert & Boulvain (1999), corresponds to the upper half of the disused Frasnes formation (Tsien, 1972, 1974) and includes, from base to top: the Bieumont, Lion, and Boussu-en-Fagne members. Its lower boundary is placed at the base of the first argillaceous limestone bed that overlies the shale of the top of the Ermitage Member or the summit of the massive limestone of the Arche and Boverie members, both belonging to the Moulin Liénaux Formation. The upper boundary is placed at the top of the nodular shale overlain by the first bed of nodular, argillaceous limestone of the Neuville Member of the Marche-en-Famenne Formation. The description thereafter concerns the succession observed in the type section (Coen-Aubert & Boulvain, 1999).

The **Bieumont Member – BMT** (*Membre de Bieumont* in Tsien, 1974, p. 4) rests on the shale of the top of the Ermitage Member (Fig. 30D) and starts with micritic or bioclastic argillaceous limestone, locally nodular, with crinoids and brachiopods (16 m thick). Its upper part corresponds to well-bedded, fine, argillaceous limestone with numerous shaly beds (21 m thick). It constitutes a key feature in the landscape as it is sandwiched by two thick shaly units, namely the Ermitage and Boussu-en-Fagne members. The Bieumont Member is a lateral equivalent of the Lion Member.

The **Lion Member – LIO** (*Membre du Lion* in Tsien, 1974, p. 4) consists mainly of white to greyish massive limestone forming very large masses (Figs 20A–B, 21A, C). The core part displays numerous building organisms (stromatoporoids, corals) and stromatactoid cavities and locally presents a pinkish colour. This short initial reefal phase passes upwards and laterally to fine-grained bioclastic limestone that tends to be bedded and displays talus-like structures and distributing channels. The upper third of the Member comprises thickly bedded fine-grained (mudstone–wackestone) limestone with abundant bird-eye and key vug structures (loferites, Boulvain & Coen-Aubert, 1997) and accumulation of amphiporid stromatoporoids. Fossils (e.g. brachiopods, corals) are distributed irregularly throughout the Member and rather rare outside the base. Ammonoid and orthoconic cephalopods occur commonly within neptunian dykes (Fig. 20B–C). Fossil-rich pockets occur sporadically (Maillieux, 1940a; see also Van Winkel in Lecompte, 1960). The top of the Member corresponds to an erosive emersion surface that is clear-cut (Mottequin & Poty, 2016) (Fig. 21A, C).

The **Boussu-en-Fagne Member – BOU** (*Membre de Boussu-en-Fagne* in Tsien, 1974, p. 4) (81 m thick) is essentially composed of greenish or brownish shale that includes calcareous nodules and nodular, bedded limestone, locally argillaceous or bioclastic (e.g. crinoids (Maillieux, 1940b; Pl. 3.J), gastropods, rare rugose corals) (Fig. 21B–C). The contact with the Lion Member is not interfering as usually claimed in the Belgian literature, but sharp as this shaly member deposited after the development of the limestone of the Lion Member (Fig. 21C).

Stratotype and sections. A composite stratotype was proposed by Coen-Aubert & Boulvain (1999, fig. GBR1) in the Frasnes-lez-Couvin area: the Couvin–Charleroi railway trench for the Bieumont and Boussu-en-Fagne members, and the disused Lion quarry for the eponymous member. The Nord quarry in Frasnes-lez-Couvin exposes particularly well all the carbonate facies of the Lion Member (Mottequin et al., 2015).

Area and lateral variations. The Grands Breux Formation is recognised on the southern and south-eastern limbs of the Dinant Synclinorium, from the French border to the west (Marion & Barchy, 2001) up to the Bomal-sur-Ourthe area to the east, where it progressively passes to the Philippeville

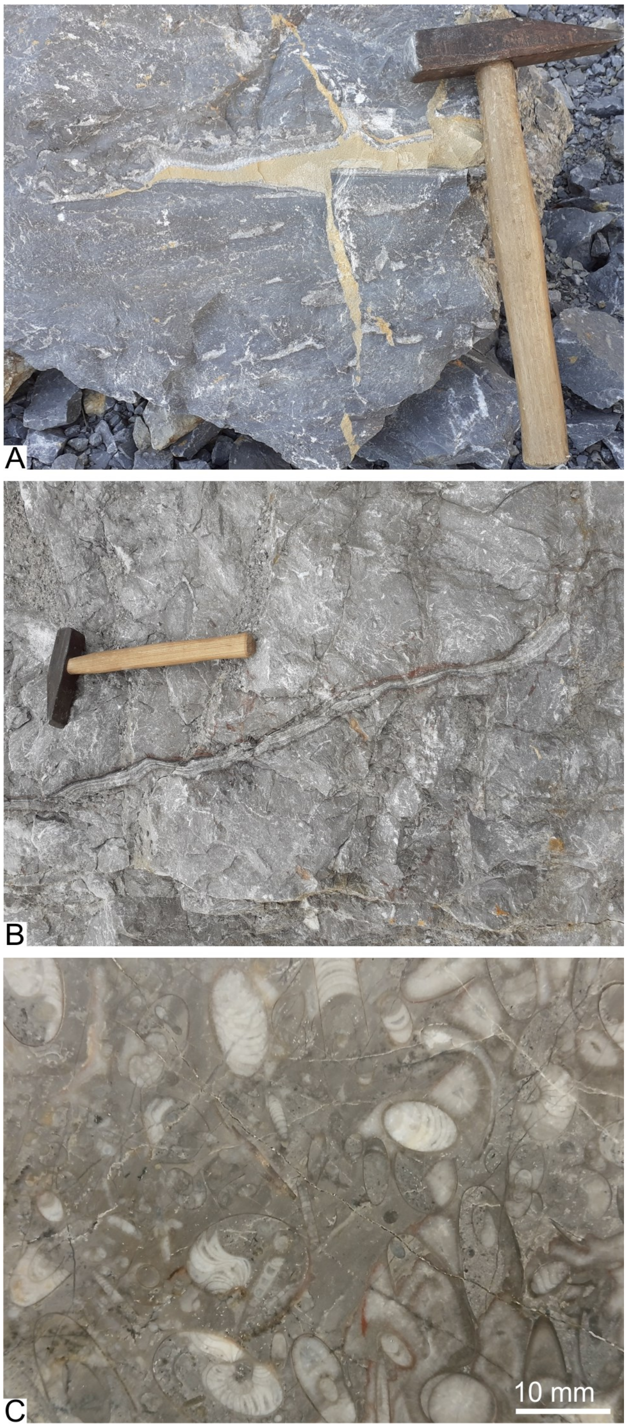

Figure 20. Illustration of the Grands-Breux Formation (Lion Member) at the Nord quarry in Frasnes-lez-Couvin. **A.** Light grey limestone with cavities infilled with yellow ferruginous dolomitic cement, lower part of the Member. **B.** Thin neptunian dyke filled with several generation of sparitic cement, crossing the massive light grey limestone. **C.** Infilling of a large neptunian dyke, crowded with cephalopod shells (goniatites and orthoconic nautiloids).

Formation (Fourmarier, 1900; de Magnée, 1930, 1932; Coen, 1974; Marion & Barchy, in press, a). Similar changes are also known from the south-western part of the Durbuy–Philippeville Anticlinorium (Maillieux, 1913, 1914a; Dumoulin & Marion, 1997b; Lemonne & Dumoulin, 1998). In this area, Dumoulin & Marion (1997b) reported many lenses of the Lion Member around Surice, Soulme, Gochenée and Romedenne. These authors have also demonstrated that the core of the Roly Massif, developed in the Fagne depression, is constituted by such large-sized limestone bodies.

Thickness. In the railway trench at Frasnes-lez-Couvin, the 118 m thick Grands Breux Formation only includes the Bieumont (37 m) and Boussu-en-Fagne (81 m) members (Coen-Aubert & Boulvain, 1999). In the Dinant Synclinorium, the respective thickness of the Bieumont and Boussu-en-Fagne members are: c. 40 m and 80 m in the Nismes area (Dumoulin & Coen, 2008), 40 m and 80 m in the Focant borehole (Boulvain & Coen-Aubert, 1997), c. 18–20 m and 80 m in the Han-sur-Lesse area where the Lion Member is not developed (Coen, 1977a), 20 m and 90 m at Biron and Hottemme (Coen, 1974), and c. 60 m at Barvaux-sur-Ourthe (Coen, 1974). The thickness of the Lion Member at the Lion quarry was estimated between 120–300 m according to the authors (Lecompte, 1960, 1963; Monty et al., 1988), but this member is 140 m thick in the Nord quarry. The overestimation of that thickness could be due to the progradation of the limestone beds and the original slope of the flanks. Considerably smaller buildups are recognised on the south-eastern limb of the Dinant Synclinorium (Coen, 1974) up to Bomal-sur-Ourthe.

Age. Middle Frasnian. The Bieumont Member and most of the Boussu-en-Fagne Member are included in the *hassi* s.l. conodont Zone, whereas the rest of the latter member successively belongs to the *jamieae* conodont Zone and to the lower part of the lower *rhenana* conodont Zone (Mouravieff, 1982; Bultynck et al., 1999; Coen-Aubert & Boulvain, 1999). The Lion Member spans the interval of the *hassi* s.l. to *jamieae* zones (Bultynck et al., 1999, fig. BIO10) but is not contemporaneous with the Boussu-en-Fagne Member. The Bieumont Member and basal part of the Lion Member yield abundant *Hexagonaria* spp. (Fig. 8C) and *Peneckiella* spp., with some species of the genera *Macgeea*, *Scruttonia*, *Mansuyphyllum* and *Tabulophyllum* (Coen-Aubert, 1996; Boulvain & Coen-Aubert, 1997), together with the tabulate coral *Thecostegites dumonti* (Coen-Aubert, 1980) and abundant *Thamnopora boloniensis* (Fig. 8B). This association is typical for the middle part of the Frasnian. The pentameride brachiopods *Metabolipa greindli* (Pl. 1.M), *Neometabolipa broecki* (Pl. 3.C), *N. delhayei* (Pl. 3.A) and *Physemella maillieuxi* (Pl. 3.B) are reported from the Lion Member (Godefroid, 1974, 1999) whereas the Boussu-en-Fagne Member yields numerous *Atryparia* (*Costatrypa*) *variabilis* (Pl. 3.D–E), some *Spinatrypina* (*Exatrypa*?) sp. (Pl. 3.H), the first *Desquamatia* (*D.*) *quieta* (Pl. 3.F) and *D.* (*D.*) *alticoliformis* (Pl. 3.G) and *Dicamara plutonis* (Pl. 3.I) (Godefroid, 1970, 1999; Godefroid & Helsen, 1998; Mottequin, 2005a, 2008a, 2008b, 2008c). Most of them are restricted to the middle Frasnian (Fig. 5).

Use. The limestone of the Bieumont Member was locally exploited for the production of aggregates (e.g. Lompret) but also as an ornamental stone (so-called *Marbre bleu belge*, e.g. in Barvaux, de Magnée, 1930; Maillieux, 1940a; note that the true *Bleu belge* is late Visean in age). The pure limestone ($CaCO_3$ > 98%) of the Lion Member is used for the production of lime and industrial carbonate (e.g. Nord, Lompret and La Boverie quarries) (Poty & Chevalier, 2004).

Main contributions. Coen (1974), Sandberg et al. (1992), Coen-Aubert (1994, 1996), Boulvain & Coen-Aubert (1997), Coen-Aubert & Boulvain (1999), Humblet & Boulvain (2000), Boulvain et al. (2011), Mottequin et al. (2015).

Haversin Facies

See Condroz Formation (Ciney Member).

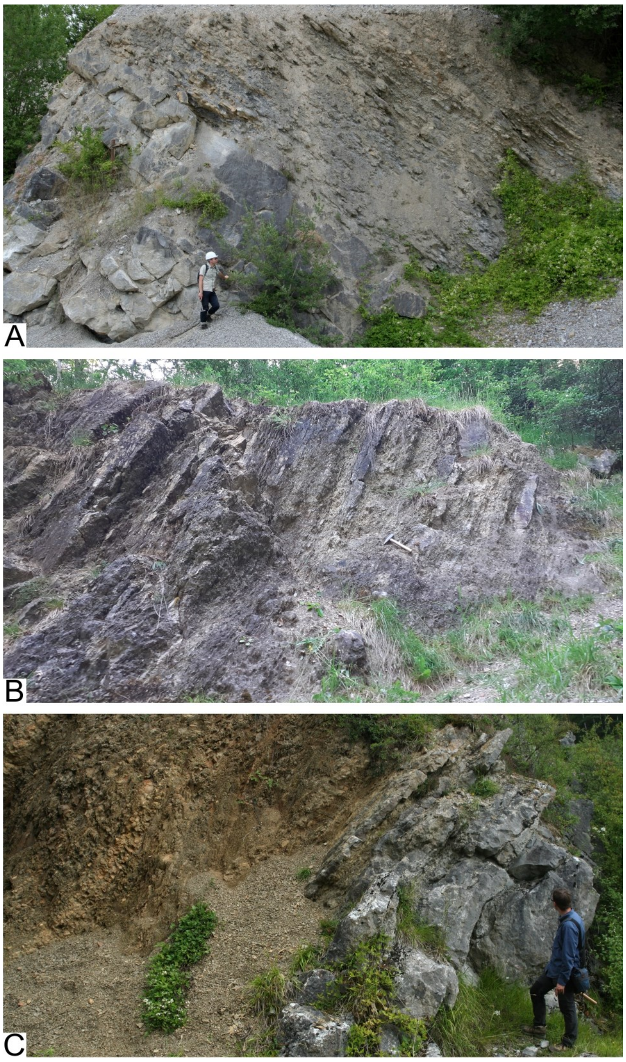

Figure 21. Illustration of the different members recognised within the Grands-Breux Formation. **A.** Sharp contact between the massive limestone of the Lion Member and the shale of the Neuville Member (Marche-en-Famenne Formation). Frasnes-lez-Couvin, Nord quarry (from Mottequin & Poty, 2016). **B.** Shale with thin beds of limestone and some large colonies of rugose corals, Boussu-en-Fagne Member. Boussu-en-Fagne, cimetière quarry. **C.** Clear-cut lateral contact between the limestone of the Lion Member and shale Boussu-en-Fagne Member. Frasnes-lez-Couvin, access trench of the Lion quarry.

Hodimont Formation – HOD

Origin of name. After the village of Hodimont, *Formation de Hodimont* in Laloux et al. (1996a, p. 28).

Remark. Contrary to Laloux et al. (1996a, 1996b) and Laloux & Ghysel (1999), who placed the lower boundary of the Hodimont Formation at the base of Dreesen's (1982a, 1982b) oolitic ironstone horizon I, its base corresponds herein to the purplish or green shale that overlies the black shale capping the Hony Horizon. The top of black shale marks the upper limit of the Lambermont Formation. Hence the boundary between the Lambermont and Hodimont formations is herein placed slightly lower than in the works of the abovementioned authors.

Description. The Hodimont Formation (Fig. 19C) is essentially made of shales and siltstones; the lithological succession is as described by Laloux et al. (1996a, 1996b), with the exception of the preliminary remark above. It starts with green, grey, and purplish shale (c. 9 m thick in the Lambermont section) containing some thin beds of grey limestone rich in brachiopods at their base and numerous calcareous nodules and brachiopod coquinas at their top (Laloux & Ghysel, 1999); these shale is capped by a first oolitic ironstone horizon (horizon I in Dreesen, 1982a, 1982b). The latter is followed by greenish grey, micaceous siltstone and shale in decimetric to pluridecimetric beds that are locally rich in decimetric calcareous nodules yielding ammonoid cephalopods and brachiopods.

The presence of several laterally discontinuous horizons of oolitic ironstone (I, II, IIIa of Dreesen, 1982a, 1982b, Fig. 3), varying in thickness from a few centimetres up to one metre, is one of the most distinctive features of the Hodimont Formation (Fig. 19C). Lithologically, these ironstone horizons correspond to mottled sandy limestone rich in brachiopods, cephalopods, crinoids and millimetric haematite oolites and haematitic coated grains. The topmost part of the Hodimont Formation comprises a package of thickly bedded, micaceous siltstone with limestone nodules or coquina beds capping the oolitic ironstone level IIIa. Upwards, the progressive increase in frequency and thickness of the sandy laminae marks the passage to the overlying Esneux Formation, the base of which is defined here in accordance with that adopted by Laloux et al. (1996a, 1996b), and thus not based on the occurrence of the oolitic ironstone horizon IIIa proposed notably by Dreesen (1982a, 1982b) and Thorez et al. (2006) (see Esneux Formation for more information).

Stratotype and sections. Embankment of the *rue de la Grappe* in Dison (Laloux et al., 1996a). Another important but hardly accessible section is visible at Limbourg, on the western slope and bank of the Vesdre River (Laloux et al., 1996b).

Area and lateral variations. The Hodimont Formation is known in the Booze–Le Val-Dieu Ridge, in the Theux Window (Laloux et al., 1996a, 1996b, 2000; Marion et al., in press) and in the Vesdre area up to the German border, where it laterally passes to the *Famenne-Schiefer* (Deutsche Stratigraphische Kommission, 2016). In Germany, Holzapfel (1910) recognised several red-coloured calcareous levels that are each topped with a horizon rich in ammonoid cephalopods (*Cheiloceras Kalk*). According to Dreesen (1982a), these red-coloured horizons correspond to the lateral equivalents of the oolitic ironstone levels reported in Belgium.

Thickness. In the eastern and central Vesdre area, it varies between 60 and 130 m (Laloux et al., 1996a, 1996b); towards the German border, due to poor exposure, the Hodimont Formation was grouped with the Lambermont Formation by Laloux et al. (2000), who estimated the thickness of the whole to be comprised between 160 and 170 m. In the Theux Window, the Hodimont Formation does not exceed 80 m in thickness (Marion et al., in press).

Age. Earliest to middle Famennian. Conodonts of the basal part of the Formation belong the *triangularis* Zone (Mouravieff, 1970), whereas those recovered from the oolitic ironstone horizons clearly indicate that the latter correspond to condensation horizons (Dreesen, 1984, 1989a): I (*triangularis–crepida* conodont zones), IIIa (*crepida* conodont Zone). The ammonoid *Cheiloceras* is known from the horizon IIIa (Sartenaer, 1957c; Dreesen, 1989b). The first post-Kellwasser rugose corals in Belgium are known from the layers directly overlying the ironstone horizon I (Denayer et al., 2012).

Use. The oolitic ironstone levels were exploited in the past at a very limited extent (Denayer et al., 2011b).

Main contributions. Macar & Calembert (1938), Dusar & Dreesen (1977), Dreesen (1982a, 1982b, 1984, 1989a, 1989b), Vanguestaine et al. (1983), Laloux et al. (1996a, 1996b, 2000).

Hony Horizon

See Lambermont and Marche-en-Famenne formations.

Huccorgne Formation – HUC

Origin of name. After the village of Huccorgne in the Mehaigne River valley, *Formation de Huccorgne* in Coen-Aubert & Lacroix (1985, p. 119).

Description. The Huccorgne Formation (Fig. 14C), which starts with coral-rich limestone, overlies the shale and argillaceous limestone of the Bovesse Formation. It was subdivided into three informal members (*inférieur*, *moyen*, and *supérieur*) by Coen-Aubert & Lacroix (1985), then formally named by Coen-Aubert & Lacroix (1999, p. 110), from base to top: the Biénonsart, Robiewez and Mehaigne members.

The c. 38 m thick **Biénonsart Member – BIN** (*Membre de Biénonsart*) consists of stratified, dark, more or less bioclastic limestone with abundant massive and solitary rugose and tabulate corals, and several brachiopod-rich levels.

The c. 16 m thick **Robiewez Member – RWB** (*Membre de Robiewez*) is characterised by thinly bedded, fine and light-coloured limestone that is often laminar or affected by dolomitization. Colonial rugose and tabulate corals and small stromatoporoids occur in its median part.

The **Mehaigne Member – MEH** (*Membre de la Mehaigne*), reaching more than 20 m in thickness, comprises dark limestone with sparse colonial rugose corals and ramose and massive stromatoporoids. It includes fine-grained limestone in its lower part and some horizons rich in brachiopods in its upper part. The upper boundary of the Huccorgne Formation corresponds to the last limestone bed overlain by the coral-rich limestone of the Aisemont Formation (Tchafornis Member).

Stratotype and sections. Several sections situated to the east of Huccorgne allow to observe the three members of the eponymous formation, mostly on the left bank of the Mehaigne River valley (Coen-Aubert & Lacroix, 1985, fig. 2).

Area and lateral variations. The Huccorgne Formation is known from the eastern border of the Brabant Parautochthon, north of the Landenne Fault, between Héron to the west and Hozémont to the east (Coen-Aubert & Lacroix, 1985; Delcambre, 2023, in press a). Westwards, the argillaceous character is more important, and the three members passes to the Rhisnes Formation. In the Heibaart borehole, 3.2 m of shale and nodular limestone, yielding stromatoporoids (*Amphipora*, *Stachyodes*), tabulate (*Scoliopora*, *Thecostegites*) and fragments of colonial rugose corals, are comprised between the Caledonian basement and the Aisemont Formation; they were assigned to the Huccorgne Formation rather than to the Rhisnes Formation by Coen-Aubert (2014) and Lagrou & Coen-Aubert (2017) on the basis of the aforementioned organisms. However, these lithologies are more characteristic of the Rhisnes Formation, but Lagrou & Coen-Aubert (2017) have highlighted the difficulties in attributing these rocks to a particular formation.

Thickness. Around 75 m in the eponymous locality (Coen-Aubert & Lacroix, 1985, 1999), the thickness of the members in the type area are indicated above.

Age. Middle Frasnian, according to the rugose coral faunas (Coen-Aubert & Lacroix, 1985, 1999). The abundance of the colonial rugose corals *Argutastrea konincki*, *A. lecomptei*, (Fig. 9C, D), *Wapitiphyllum vesiculosum*, *W. irregulare*, *W. mahaniense* (Fig. 9E, F) and *Hexagonaria mirabilis* (Fig. 8C) in the Biénonsart Member allows the correlation with the Watiamont Member of the Rhisnes Formation. *Wapitiphyllum vesiculosum* (Fig. 9B) and the tabulate coral *Thecostegites bouchardi* (Fig. 8A) are both present in the Mehaigne Member of the Huccorgne Formation and in the Rocq Member of the Rhisnes Formation (Lacroix, 1999d). All these corals allow to correlate the Huccorgne and Rhisnes formations with the Lustin Formation (Coen-Aubert & Lacroix, 1985, 1999).

Use. The limestone was used as building stone in the Mehaigne River valley (Delcambre & Pingot, 2014a).

Main contributions. Asselberghs (1936), Coen-Aubert & Lacroix (1985, 1999), Delcambre & Pingot (2014a), Delcambre (2023).

Hymiée Member – HYM

See Pont de la Folle Formation.

Lambermont Formation – LAM

Origin of name. After the village of Lambermont, *Formation de Lambermont* in Laloux et al. (1996a, p. 25).

Remark. Contrary to Laloux et al. (1996a, 1996b) and Laloux & Ghysel (1999), the boundary between the Lambermont and Hodimont formations is herein placed at the top of the black shale (upper Kellwasser Event) overlying the Hony Horizon rather than at the base of the first oolitic ironstone horizon (horizon I of Dreesen, 1982a, 1982b), because the shaly successions observed on both sides of the latter are very similar and hence indistinguishable if this ironstone horizon is not exposed.

Description. The mostly shaly Lambermont Formation (Fig. 22A–B) abruptly overlies the limestone of the top of the Aisemont Formation. The description of its lithological succession is that observed in the stratotype (Lambermont, see below) by Laloux et al. (1996a) and Paquay (2002). It is complemented by a series of unpublished data of J.-M. Graulich from numerous boreholes drilled in the vicinity of Verviers and mentioned by Laloux et al. (1996a); these data are reported below between brackets. It should be noted that numerous faults affect the succession observed in the Lambermont section and tend to lead to an overestimation of the thicknesses.

The Lambermont Formation starts with 6 m of green and grey shale with scarce calcareous nodules; they are rich in atrypide and spiriferide brachiopods and fenestellid bryozoans. Then follows a mixed argillaceous-calcareous, red to green unit, known as the *facies de Verviers* (Dubrul in Dumon et al., 1954, p. 174), referred to herein as the **Verviers Member – VER**. This c. 12 m thick unit starts with a biostromal limestone bed rich in colonial rugose corals (*Frechastraea*, *Potyphyllum* and *Iowaphyllum*) known as the *troisième biostrome à Phillipsastrea* of Coen et al. (1977) and overlain by reddish to greenish argillaceous, nodular limestone and nodular shale with colonial rugose corals (Fig. 22B). The Verviers Member is overlain by 24 m of essentially shaly deposits that were subdivided into two parts by Laloux et al. (1996a): (1) 10 m thick package of green shale and nodular limestone alternations, with very rare micaceous sandstone beds then (2) 10 m of dark grey shale (Matagne Facies; see Marche-en-Famenne Formation) with dissociated valves of lingulide brachiopods and rare calcareous nodules in the upper part, a 1 m thick set of c. 10 thin layers of limestone alternating with shale at 10 m above the base that corresponds to the **Hony Horizon** (new term; see also Marche-en-Famenne Formation) (Fig. 22C), and c. 3 m of black shale corresponding to the upper Kellwasser Event (Matagne Facies). In the eponymous locality, the Hony Horizon (bed 48t in Streel et al., 1975 (pl. 3) and Sandberg et al., 1988) is 0.5 m thick and includes thin beds of bioclastic limestone alternating with shale containing mainly bivalves and brachiopods. The Hony Horizon was interpreted by Sandberg et al. (1988) as being related to a eustatic fall, but it reflects a series of at least seven tsunamites after Poty et al. (2014) and Mottequin & Poty (2016).

Stratotype and sections. Western access road to the motorway Verviers–Prüm (A27, exit no. 4) at Lambermont (Laloux et al., 1996a; Vanbrabant et al., 2003). This is also the

Figure 22. Illustration of some Upper Devonian units. **A.** Parasequences in the basal part of the Lambermont Formation. Hony railway section. **B.** Variegated nodular calcshale of the Verviers Member. Lambermont section. **C.** Polished section of the argillaceous limestone of the Hony Horizon. Neuville railway section.

type section selected here for the Verviers Member. It can be complemented by a series of sections listed by Laloux et al. (1996a, 1996b) and Delcambre et al. (in press) in the Vesdre area, notably that located along the right bank of the Vesdre River, below the *rue des Récollets* at Renoupré and that situated immediately to the northwest of the confluence between the Vesdre River and the Fond des Cris Creek, east of Chaudfontaine.

Area and lateral variations. The Lambermont Formation is known from the Vesdre area (Laloux et al., 1996a, 1996b), but towards the German border, it crops out only sporadically (Laloux et al., 2000) and passes laterally to the *Matagne-Schichten* (Deutsche Stratigraphische Kommission, 2016; ex *Frasnium-Schiefer* of Holzapfel, 1910). The Verviers Member is particularly well developed between Pepinster and Les Surdents (Dubrul in Dumon et al., 1954); it can be traced from Chaudfontaine to the west up to Membach to the east, where it passes laterally to nodular shale with corals (*facies d'Eupen ou oriental* of Dubrul in Dumon et al., 1954, p. 175). In the Fond des Cris quarries at Chaudfontaine, the 5 m thick Verviers Member lies directly on top of the limestone of the Aisemont Formation (Dubrul, 1931; Coen-Aubert, 1974a). Nevertheless, it displays strong and fast lateral variations, notably in the Fond des Cris quarries and the Chaudfontaine school borehole (Graulich & Vandenven, 1978; Dejonghe, 1987a). At Hony, the Verviers Member is lacking. The Lambermont Formation and the Verviers Member are also known in the Theux Window (Coen-Aubert, 1974a; Graulich, 1979) and the Bolland and Soumagne boreholes (Coen-Aubert, 1974a; Dejonghe, 1987a).

Thickness. Quite variable in the Vesdre area but it could be overestimated by tectonics: from 42 m to more than 100 m (Laloux et al., 1996a, 1996b); c. 71 m at Hony (including at its top the 0.3–0.4 m thick Hony Horizon overlain by c. 1.2 m of black shale); 30 m within the Polleur viaduct boreholes in the Theux Window (Graulich, 1979).

Age. Late Frasnian–earliest Famennian. The base of the Lambermont Formation is dated from the top of the lower *rhenana* conodont Zone whereas its top is earliest latest Frasnian–earliest Famennian in age (Mouravieff, 1970; Coen-Aubert, 1974a; Dreesen, 1982a; Sandberg et al. in Bultynck et al., 1988b). The coral beds above the Verviers Member (*troisième biostrome à Phillipsastrea* of Coen et al., 1977) yield *Frechastraea pentagona*, *F. limitata* (Fig. 10G, F), *Potyphyllum veserense* and *Iowaphyllum rhenanum* (Fig. 10B) that typify the *faune 3* of Coen et al. (1977). This association is typical of the upper Frasnian and allows the correlation of the Lambermont Formation with the Barvaux Facies (Marche-en-Famenne Formation) on the south-eastern limb of the Dinant

Synclinorium and the Valisettes Member of the Marche-en-Famenne Formation in the Durbuy–Philippeville Anticlinorium (Coen-Aubert, 2016). The late Frasnian atrypides *Spinatrypa* (*S.*) *lambermontensis* (Pl. 3.T) and *S.* (*S.*) sp. (Pl. 3.U) are present in the basal shaly part of the Formation whereas *Iowatrypa ultima* (Pl. 2.X) occurs in the Verviers Member. This *Iowatrypa* species and *Radiatrypa* sp. (Pl. 3.V) are known from the shale that overlies the Verviers Member, whereas *Spinatrypa* (*S.*) sp. and *I. ultima* are also known from the Barvaux Facies of the Marche-en-Famenne Formation (Mottequin, 2003).

Use. According to Graulich (in Laloux et al., 1996a), the basal limestone bed rich in corals of the Verviers Member was extracted in the eponymous area for the production of variegated coloured ornamental stone (e.g. Groessens, 1981). Very locally, the hardest lithologies encountered in the Lambermont Formation were used as building and paving stones.

Main contributions. Coen-Aubert (1974a, 2012, 2016), Vanguestaine et al. (1983), Sandberg et al. (in Bultynck et al., 1988b), Laloux et al. (1996a, 1996b), Schmidt (1994), Laloux & Ghysel (1999), Paquay (2002), Vanbrabant et al. (2003), Mottequin (2005a), Denayer & Poty (2010).

Lesse Facies

See Comblain-au-Pont Formation.

Lion Member – LIO

See Grands Breux Formation.

Lustin Formation – LUS

Origin of name. After the village of Lustin, *Formation de Lustin* in Coen-Aubert & Coen (1975, p. 512).

Remark. Although Lacroix (1974a), Coen-Aubert & Lacroix (1979) and Coen-Aubert (1982) recognised a lower coralliferous member (*calcaire récifal*) and an upper lagoonal member (*calcaire à faciès lagunaire*) within the Lustin Formation (Marlagne Formation in Lacroix, 1974a, see this term), these members have never been formally named as reminded by Bellière (2015), although several names were proposed in the literature. For Coen-Aubert (1999a), this is because the distinction cannot be applied everywhere, especially in eastern Belgium, where Coen-Aubert & Coen's (1975) unit e, which corresponds to the boundary between both informal members, is generally poorly individualised. However, this is not a valid argument for maintaining the status quo, which is why these distinct members are formally referred to herein (see below) (Fig. 23). In fact, they should have called the lower member the 'member rich in corals and stromatoporoids' because, strictly speaking, there is no 'reefal member'. Moreover, the distinction between the 'reefal member' and the 'lagoonal member' is based primarily on colour: very dark for the former and light for the latter. Note that there are also corals and stromatoporoids in the upper member, but to a much lesser extent.

Description. Coen-Aubert & Coen (1975) and Coen-Aubert (1999a) described in detail the content of the Lustin Formation (Figs 23–24) in the Meuse River valley (see also Coen-Aubert & Lacroix, 1979).

The **Gougnies Member – GOU** (*Assise de Bovesse et de Gougnies* in Conseil de Direction de la Carte, 1896, p. 54) (Fig. 24A–D) begins with a first unit (a in Coen-Aubert & Coen, 1975) enclosing few beds of crinoidal limestone preceding a first massive 9 m thick package of beds rich in stromatoporoids and corals—i.e. the 'biostromes' of the literature. This limestone is often dark in colour and contains lots of lamellar and ramose stromatoporoids (e.g. *Stachyodes*), solitary and fasciculate (*Disphyllum*) rugose corals and ramose and lamellar (*Alveolites*) tabulate corals. This unit rich in ramose corals and stromatoporoids with sparitic cement forms the **Sainte-Anne Facies** (*marbres de Sainte-Anne* in Denys de Montfort, 1801–1802, p. 216) (Fig. 23). This thick unit is locally partly or entirely dolomitized and is capped by several usually light-coloured limestone beds rich in massive stromatoporoids. The 7 m thick unit b of Coen-Aubert & Coen (1975) corresponds to light-coloured limestone with a thin shaly horizon, overlain by argillaceous limestone with brachiopods (e.g. orthides, atrypides and spiriferides) and a level rich in very large colonies of *Disphyllum*. The unit c of Coen-Aubert & Coen (1975) (c. 10 m thick) comprises dark, stratified limestone (locally laminar in the basalmost part) with occurrence of levels with massive stromatoporoids, *Alveolites*, ramose tabulate corals, and colonial and solitary rugose corals. It is followed by light-coloured, massive limestone (c. 17 m thick) that is variably rich in stromatoporoids and corals (unit d of Coen-Aubert & Coen, 1975). The Gougnies Member ends with a remarkable stratified unit (c. 4.5 m thick; unit e of Coen-Aubert & Coen, 1975) in which lamellar stromatoporoids are predominant over *Alveolites*, branched tabulate corals, solitary rugose corals and fragments of *Hexagonaria*.

The **Rochers de Frênes Member – RFR** (after the eponymous rocks overlooking the Meuse River at Lustin; unit f of Coen-Aubert & Coen, 1975) includes c. 48 m of thinly and well-bedded limestone with, near the top of the succession, some beds rich in massive stromatoporoids and rugose corals (Fig. 24C). Three thick argillaceous horizons interpreted as paedogenetised cinerites are developed in this member and display thin brecciated level at their base (Da Silva, 2004; Rensonnet, 2005). In the bottom of the Wépion borehole (between 2019 m and 2069.2 m), Graulich (1961, p. 39) introduced the *Assise de La Marlagne* to designate the c. 50 m thick package of grey to black dolostone situated below the Aisemont Formation. This dolostone includes locally intraclasts and ghosts of dendroid stromatoporoids associated at the base with ramose tabulate corals and some fragments of colonial and solitary rugose corals (Coen-Aubert, 1988). The Marlagne formation was used by Tsien et al. (1973) and Lacroix (1974a, 1974b) for designating the Rocher de Frênes Member, whereas Delcambre & Pingot (2017) considered the Marlagne formation (sensu Coen-Aubert, 1988) as part of the Lustin Formation. Although only known from the Wépion borehole, it could be regarded as a local dolomitic facies of the Lustin Formation (**Marlagne Dolomitic Facies**). In the Visé area, the Rocher de Frênes Member is probably represented by a local facies designed herein as the **Richelle Facies** (after the village of Richelle in the Meuse River valley, south of Visé) that consists of massive, light grey, fine-grained limestone (mudstone to wackestone), sometimes slightly dolomitic, with fossils restricted to some beds (Gumusboga, 1989). These are notably tubular (amphiporids), massive and lamellar stromatoporoids, colonial (*Hexagonaria*) and solitary rugose corals, massive (*Alveolites*) and ramose (*Thamnopora*) tabulate corals, and brachiopods (Coen-Aubert in Graulich, 1975b; Lorenzi, 1981). The massive limestone of the Richelle Facies is generally brecciated (collapse breccia to megabreccia) as observed in boreholes in the disused La Folie quarry at the locality Brichtembeau (Dalhem) (Lorenzi, 1981; Poty, 1982), at Hermalle-sous-Argenteau (Graulich, 1975b) and Visé (Goemaere & Vandenven, 1989), as resulting of a solution collapse process (Poty, 1981, 1982; Poty & Delculée, 2011). In the Hermalle-sous-Argenteau borehole, the Richelle Facies overlies coarse-grained sandstone and black dolomitic shale

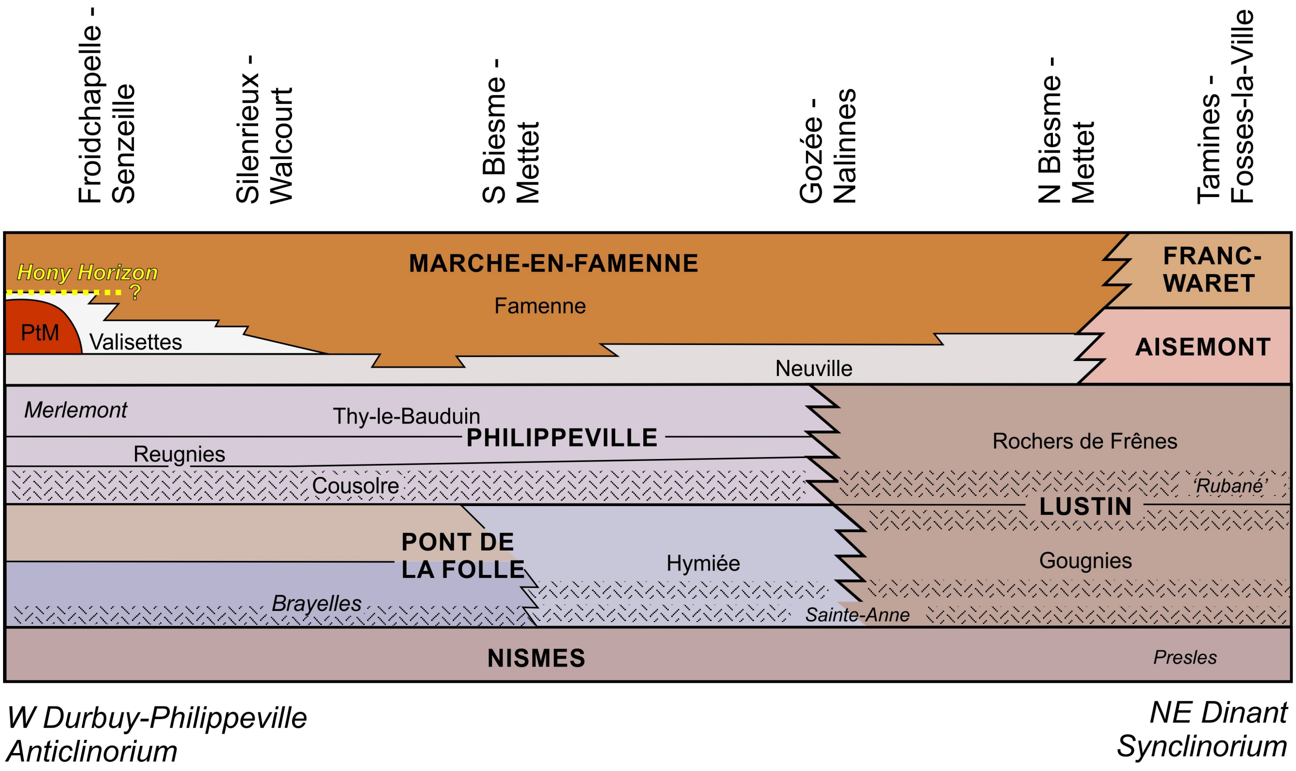

Figure 23. Lateral variations observed in the Frasnian and Lower Famennian formations within the Dinant Synclinorium and the western part of the Durbuy–Philippeville Anticlinorium (modified from Delcambre & Pingot, 2004). Formations are in capital letters, members in regular letters, and facies in italics. Shaded areas are biostromal or coralliferous beds. Abbreviation: PtM, Petit-Mont Member.

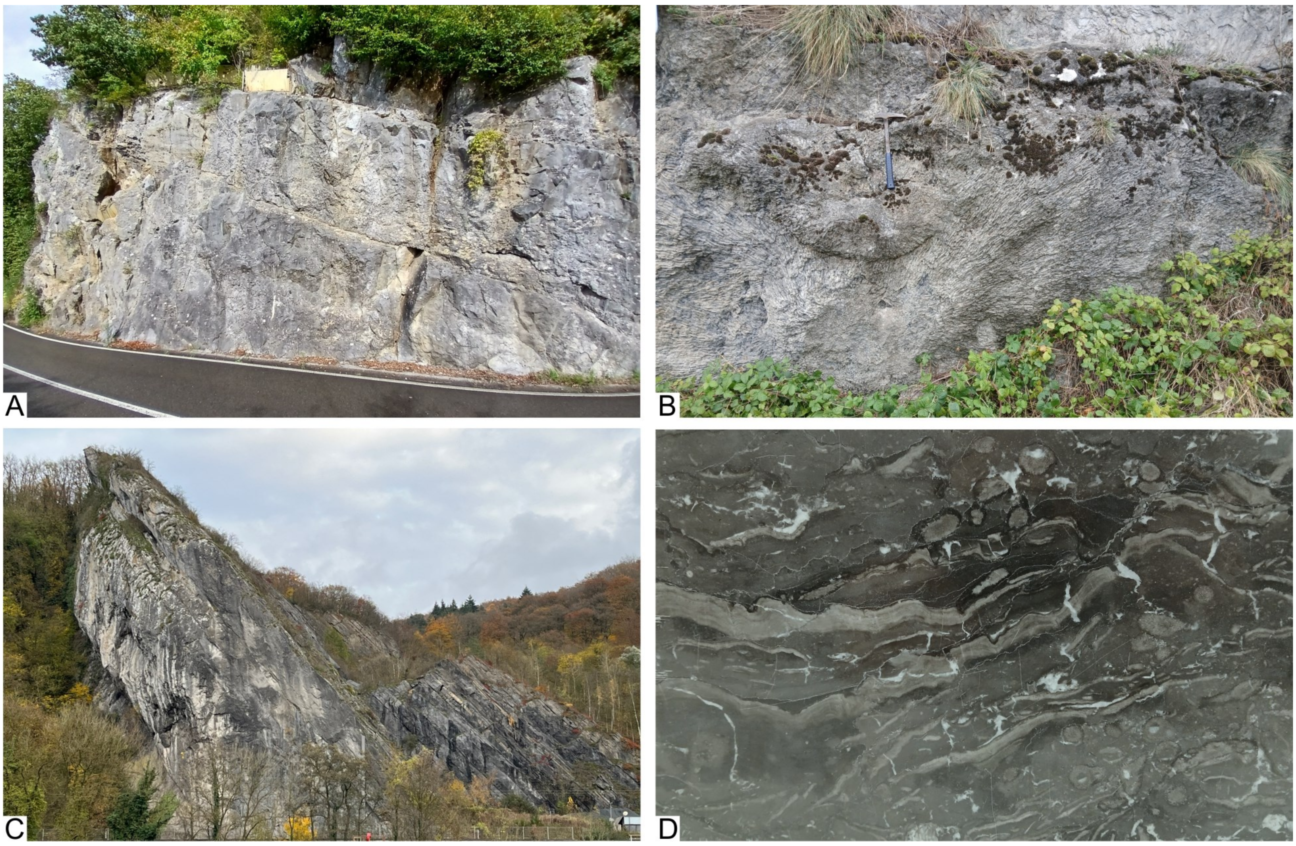

Figure 24. Illustration of the Lustin Formation. **A.** Massive limestone beds of the Gougnies Member. Godinne, *route de la Corniche*. **B.** Biostromal bed made of *Disphyllum preslense* in an argillaceous matrix, Gougnies Member. Lustin, Rochers de Frênes section. **C.** Top of the massive limestone beds of the Gougnies Member overlain by the thinly bedded limestone of the Rochers de Frênes Member. Tailfer. **D.** *Rubané de Tailfer* 'marble', upper part of the Gougnies Member, polished slab. Tailfer (width of the picture c. 35 cm).

(Graulich, 1975b) that are assigned here to the Alvaux Formation (see Denayer et al., 2024). It is overlain by the Frasnian Aisemont Formation or by Carboniferous deposits, depending on different tectonic blocks of the Visé area (Poty & Delculée, 2011).

Stratotype and sections. The section of the Rochers de Frênes at Lustin, both along the railway cut and the road from Dinant to Namur (N947), corresponds to the stratotype of the Lustin Formation. However, it is incomplete, but the contacts with the underlying and overlying formations are exposed in the woody hillside that dominates the section (Coen-Aubert & Coen, 1975; Coen-Aubert, 1999a). This is also the stratotype of the Rochers de Frênes Member. The historical type section of the Gougnies Member corresponds to the disused quarries located south of the eponymous village; nevertheless, they are partly flooded and therefore difficult to access (Delcambre & Pingot, 2004). It is complemented by the disused railway section between Biesme and Gougnies. The Richelle Facies is well exposed in the M quarry (following Horion & Gosselet's (1892) lettering) at Richelle (e.g. Pirlet, 1967; Poty, 1982), although it has been transformed into a landfill with rather difficult access (Poty, 1982).

Area and lateral variations. The Lustin Formation is known from the Haine–Sambre–Meuse Overturned Thrust sheets, from Landelies to the west (Delcambre & Pingot, 2000a) up to Engis to the east (Delcambre, in press, a). In the bottom of the Wépion borehole (between 2069.2 m and 2139.1 m; Brabant Parautochthon), above the Nismes Formation (Presles Facies), Coen-Aubert (1988) introduced the Su Wary formation to designate alternations of shale and limestone, often argillaceous, that contain occasionally stromatoporoids. This informal unit was implicitly placed in the Lustin Formation by Delcambre & Pingot (2017). These rocks are only known from the Wépion borehole and may represent a local mixed argillaceous-calcareous facies of the Lustin Formation, reminiscent of the Machenées Member of the Pont de la Folle Formation. The Lustin Formation is largely developed on the northern limb of the Dinant Synclinorium, from Gerpinnes (Delcambre & Pingot, 2000b) up to Louveigné (Marion et al., in press). South of Gerpinnes, it laterally passes to the Pont de la Folle and Philippeville formations. On the south-eastern limb of the Dinant Synclinorium, it passes, near My, to the Moulin Liénaux and Grands Breux formations, which are characteristic for the southern limb of the Dinant Synclinorium, and to the Pont de la Folle and Philippeville formations near Tohogne and Sy (Marion & Barchy, in press, a). The latter lithostratigraphic units represents the typical succession of the Durbuy–Philippeville Anticlinorium. The Lustin Formation is well developed in the Vesdre area, up to the German border (e.g. Coen-Aubert, 1974a; Laloux et al., 1996a, 1996b, 2000), as well as in the Theux Window (Coen-Aubert, 1974a), but the distinction of the two members is less obvious. In these areas, the shaly Nismes Formation, hardly reaching 2 m in thickness, was mapped together with the Lustin Formation. Eastwards, in Germany, the Formation passes laterally to the *Walheim-Formation* (Deutsche Stratigraphische Kommission, 2016; Schindler et al., 2018) (ex *Frasnium-Riffkalksteine* or *Obere Massenkalk* sensu Kasig, 1967 and Kasig & Reissner, 2008). The Richelle Facies is only known from the Visé area and is brecciated everywhere, except on the Souvré block (e.g. Hermalle-sous-Argenteau and Visé boreholes, Graulich, 1975b; Lorenzi, 1981; Poty, 1982).

Coen-Aubert (1999a) provided a thorough survey of the lateral variations observed within the Lustin Formation with the exception of the Visé area.

Thickness. The Lustin Formation is generally thick on the northern limb of the Dinant Synclinorium, but thins out from west to east: c. 160 m at Gerpinnes (Lecompte, 1960, 1963; Coen-Aubert, 1982), 104 m in the stratotype at Lustin (Coen-Aubert & Coen, 1975), 125 m at Hun, c. 80 m at Vierset-Barse (Coen-Aubert, 1974a), 62 m at Hony (Coen-Aubert, 1974a), and c. 45 m in Tilff (Delcambre et al., in press). In the Haine–Sambre–Meuse Overturned Thrust sheets, its thickness does not exceed 80 m: 78 m at Presles, 75 m at Aisemont (Lacroix, 1974a, 1974b; Coen, 1976; Coen-Aubert, 1977), 56 m at Dave (Lacroix, 1974b), and c. 50 m at Huy (Coen-Aubert & Lacroix, 1979). In the Vesdre area, the Lustin Formation becomes thicker eastwards: c. 35–40 m at Chaudfontaine, c. 45–50 m at Prayon (Trooz), 80 m at Les Surdents (Verviers), and up to 150 m (including some metres of the Nismes Formation) towards the German border (Coen-Aubert, 1974a; Laloux et al., 1996a, 1996b, 2000). In the Theux Window, it does not exceed 60 m in thickness (Coen-Aubert, 1974a). The Richelle Facies is 80 m thick in the Hermalle-sous-Argenteau borehole, south of Visé (Graulich, 1975b; Poty, 1982; Barchy & Marion, 2000, 2017). It is also brecciated and about 100 m thick in the boreholes of the 'K' quarry south of Visé (Goemaere & Vandenven, 1989; Poty & Delculée, 2011).

Age. Middle Frasnian. Although poor in conodonts (Groessens, 1971; Coen-Aubert & Coen, 1975), the range of the Lustin Formation most probably spans the interval of the *punctata* to the lower *rhenana* conodont zones according to Gouwy & Bultynck (2000). The rugose corals *Macgeea rozkowskae*, *Disphyllum hilli* and *Hexagonaria mirabilis* (Fig. 8D, F, C) are abundant respectively in the lower and upper parts of the Gougnies Member whereas *Argutastrea konincki* and *A. lecomptei* (Fig. 9C, D) are typically found in the Rochers de Frênes Member, with *Wapitiphyllum vesiculosum* (Fig. 9B). The Richelle Facies yielded *Hexagonaria mirabilis* (Fig. 8C).

Use. Besides the production of aggregate and blocks, and mainly building lime, the limestone, rich in various organisms, was used for the production of ornamental stone: *Rubané de Tailfer* (Figs 23, 24D), *Vert de Tailfer* and *Grand Antique de Meuse* (Tailfer), *Notre Dame de Dieupart* (Aywaille), *Marbre Florence* (Entre-Sambre-et-Meuse), *Marbre Saint-Laurent* (Bauche) (Dumon & Camerman, 1947; Groessens, 1981; Coen-Aubert, 1999a; De Ceukelaire et al., 2014).

Main contributions. Van Winkel (1964), Groessens (1970, 1971), Tsien et al. (1973), Tsien (1974, 1975), Coen-Aubert & Coen (1975), Graulich (1975b), Coen-Aubert & Lacroix (1979), Lorenzi (1981), Poty (1982), Gumusboga (1989), Villance (1991), Schmidt (1994), Coen-Aubert (1999a), Barchy & Marion (2000, 2017), Da Silva (2004), Da Silva & Boulvain (2004), Rensonnet (2005), Poty & Delculée (2011).

Machenées Member – MAC

See Pont de la Folle Formation.

Mallieue Member – MLL

See Aisemont Formation.

Marche-en-Famenne Formation – MEF

Origin of the name. After the town of Marche-en-Famenne (term introduced herein).

Remark. In the Dinant Synclinorium, the most appropriate subdivision of the mostly shaly succession comprised between the upper Frasnian carbonate units (Aisemont Formation and Neuville Member) and the middle Famennian Esneux Formation has been the matter of debate due to the complex intertwining of facies and usually poor outcrops (Fig. 25). In the last comprehensive lithostratigraphic overviews (Boulvain et al.,

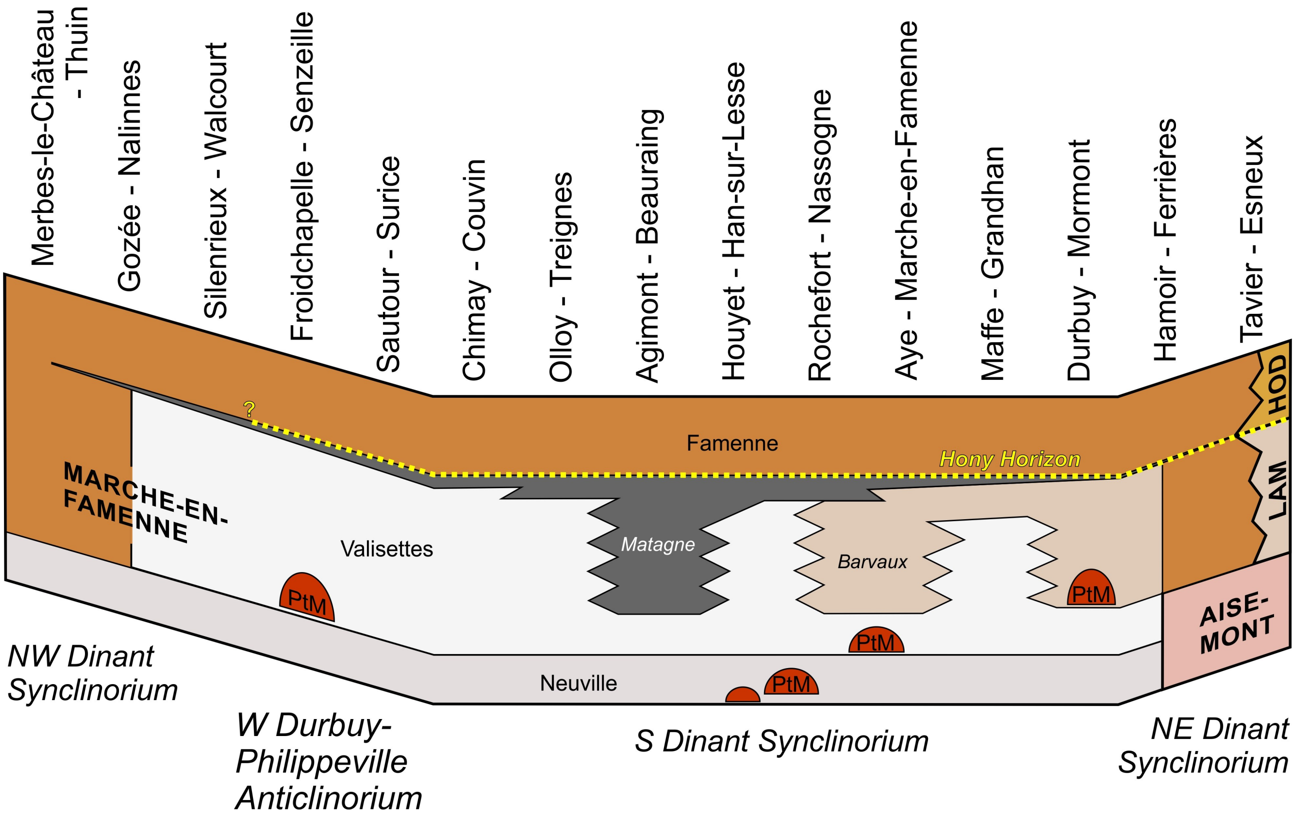

Figure 25. Lateral variations of the members and facies recognised within the Marche-en-Famenne Formation (late Frasnian–early Famennian) in the Dinant Synclinorium. The mounds of the Petit-Mont Member are represented by the red bodies. Formations are in capital letters, members in regular letters, facies in italics. Abbreviations: HOD, Hodimont Formation; LAM, Lambermont Formation; PtM, Petit-Mont Member.

1999a; Bultynck & Dejonghe, 2002; Thorez et al., 2006), several formations were proposed to subdivide the set: the Barvaux, Matagne, Valisettes, Senzeille, Mariembourg and Aye formations, with the Famenne group including the Senzeille and Mariembourg formations (see below). In order to align with the lithostratigraphic division of the Frasnian on the southern limb of the Dinant Synclinorium, which is characterised by a lower carbonate sole, a middle 'reefal' and an upper shaly units (see Moulin Liénaux and Grands Breux formations), Coen-Aubert (2015) introduced the Champ Broquet formation by retrograding to the member status the Neuville and Valisettes formations, complemented with the mud mounds ascribed to the Petit-Mont Member, notwithstanding the age of the latter. However, the revision of the Geological Map of Wallonia demonstrated the difficulties to find clear boundaries in the field between most of the previously introduced units and many of them were mapped together. Moreover, the Senzeille and Mariembourg formations (*schistes de Senzeilles à Rh. Omaliusi* and *schistes de Marienbourg à Rh. Dumonti* in Gosselet, 1879b, p. 389) were abandoned, and replaced by the imprecisely delineated Famenne formation, because the distinction between the two former units were based on rhynchonellide brachiopods and on an elusive oolitic ironstone marker (horizon I of Dreesen, 1982a, 1982b). Consequently, in order to solve the lithostratigraphic issues that arose during the geological mapping of the Dinant Synclinorium, the Marche-en-Famenne Formation is introduced herein.

Description. The Marche-en-Famenne Formation (Figs 25–29) is predominantly shaly, but it also incorporates carbonate bodies. It is characterised at its base by the Neuville Member, which is overlain by the Valisettes Member (enclosing the Barvaux and Matagne facies), and its top corresponds to the Famenne Member (with the Aye Facies at its top); the mud mounds are included in a distinct member (Petit-Mont Member). As Figure 25 shows, the relationships between all these units are complex.

The lower **Neuville Member – NEU** (Neuville Formation (pars) in Tsien, 1974, p. 4, p. 6, p. 31) consists of nodular limestone with intercalations of nodular shale (Figs 21A, 26A–C) in its type locality (western part of the Durbuy–Philippeville Anticlinorium) (Boulvain et al., 1993b, 1999b), but the latter lithology is dominant on the southern and south-eastern limbs of the Dinant Synclinorium. Brachiopods and corals can be abundant, particularly at its base.

The **Petit-Mont Member – PTM** (*Membre du Petit-Mont* in Boulvain et al., 1999b, p. 74; MM for *monticule micritique* on the Geological Map of Wallonia) corresponds to the reddish to grey carbonate mounds (Figs 27A–B, 28) that develop at different stratigraphic horizons laterally to the Neuville Member (Les Bulants type of mounds in Boulvain, 1993b) and the Valisettes Member (Les Wayons–Hautmont type of mounds in Boulvain, 1993b). In the type section (Petit-Mont quarry at Vodelée), the mound is 60 m thick in its central part and composed of massive limestone in which three successive lithofacies are recognised (Boulvain, 1993b), from base to top: (1) red limestone with stromatactis, (2) pink limestone with rugose and tabulate corals, incertae sedis (*Receptaculites*, Pl. 3.M), crinoids, brachiopods and bryozoans, and (3) grey limestone with diverse rugose and tabulate corals, brachiopods, and a lot of calcimicrobial structures. Some mounds display in their upper parts a fourth unit of recurrent red mudstone with stromatactoid cavities; they display a sharp surface on their top that is interpreted as an emersion surface by Sandberg et al. (1992) and Muchez et al. (1996) and correlated with the top of the Fond des Cris Member of the Aisemont Formation by Denayer & Poty (2010) and Mottequin & Poty (2016). It should also be noted that the geometrical relationships between the carbonate mounds and the surrounding shale are variable. In the

Figure 26. Illustration of the Marche-en-Famenne Formation. **A.** Base of the nodular limestone of the Neuville Member. Frasnes-lez-Couvin, access trench of the Lion quarry. **B.** Contact between the limestone of the Neuville Member and the dark to black shale of the Matagne Facies of the Valisettes Member. Lompret quarry. **C.** Contact between the nodular shale of the Neuville Member and the purplish shale of the Barvaux Facies of the Valisettes Member. Marche-en-Famenne, WEX road section.

Les Bulants type of mounds, the red limestone forms a low tabular lens with its margins interdigitated within the lateral nodular limestone and displays only a vertical variation of facies. In the Les Wayons–Hautmont type of mounds, the red limestone forms an elevated lens with margins inclined at c. 30 degrees, with few interdigitations into the lateral shale and displays both vertical and lateral facies differentiation (Boulvain, 1993b).

The **Valisettes Member – VAL** (*Formation des Valisettes* (pars) in Boulvain et al., 1993c, p. 27) is essentially shaly but, in the vicinity of the mud mounds of the Petit-Mont Member, as is the case in its stratotype (Neuville railway section), nodular limestone can be abundant. There, contrasting with the more calcareous Neuville Member, it starts with about 50 m of dark grey to green shale with four thin beds of limestone at its base and a scarce fauna, followed by 34 m of red or green nodular limestone and shale with calcareous nodules (Boulvain et al., 1993c, 1999c). The macrofauna is abundant and include brachiopods (e.g. athyridides, atrypides, spiriferides), colonial rugose corals (*Frechastraea*, *Iowaphyllum*, *Tabulophyllum*; *faune 3* of Coen et al., 1977), lamellar (*Alveolites*) and ramose (*Senceliaepora*) tabulate corals, crinoids (Maillieux, 1940b; Pl. 3.K–L) and locally abundant sponges (Termier et al., 1981). This thick carbonate interval is overlain by c. 13 m thick purplish shale containing few nodular levels that include very small reddish mud mounds, reaching 1–2 m in width and 0.2–0.4 m in thickness (Mottequin et al., 2015; Mottequin & Poty, 2016). The usual shaly facies of the Valisettes Member passes laterally to the singular Matagne and Barvaux facies or is overlain by them (see below). On the southern and south-eastern limbs of the Dinant Synclinorium, the dark grey to green shale of the base of the Valisettes Member yield abundant brachiopods (e.g. athyridides, spiriferides) (Mottequin, 2004a, 2005a) and is less thick than in the western part of the Durbuy–Philippeville Anticlinorium (Bultynck et al., 1998; Coen, 1999). They generally pass to the Matagne or Barvaux facies. The **Matagne Facies** (*Schistes de Matagne* and *Schistes de Matagne à Cardium palmatum* in Gosselet, 1871, p. 296, p. 298) consists of a monotonous series of fine dark greenish-brown to black shale (Fig. 26B) that include few flattened calcareous nodules and rare thin sandstone lenses. One or several beds of limestone with ammonoid cephalopods and bivalves is/are encountered at the base of this facies. Although poorly diverse, the fauna is very distinctive and includes buchiolid bivalves (e.g. *Buchiola*, *Glyptohallicardia*) (e.g. Maillieux, 1936; Grimm, 1998) (Pl. 3.P–Q), smooth thin-shelled rhynchonellide brachiopods (Sartenaer, 1974a) (Pl. 3.S), ammonoids, including large gephuroceratids (Pl. 3.N–O) (e.g. Matern, 1931; House & Kirchgasser, 1993; Goolaerts et al., 2018), and even dendroid graptolites (Pl. 3.R) (e.g. Maletz et al., 2020; Mottequin et al., 2023). The particular lithology and faunal assemblages reflect a dysoxic environment (Mottequin & Poty, 2016). Similar facies is also known from the Lambermont Formation. The **Barvaux Facies** (*schistes de Barvaux* in Gosselet, 1880b, p. 199) is predominantly composed of purplish shale, but also greenish locally (Coen, 1999) (Fig. 26C). The lower and upper parts of the Barvaux Facies include some calcareous nodules whereas the middle part contains many coquina beds, which are composed essentially of large, transverse cyrtospiriferid brachiopods (e.g. Gosselet, 1894; Vandercammen, 1959; Mottequin, 2019) (Pl. 2.Z) and/or smaller strophomenides (Fig. 27C, Pl. 2.V–W), and thin sandstone lenses. The residual macrofauna includes notably scarce bivalves, and few solitary (*Macgeea*) and colonial (*Frechastraea*) rugose corals (e.g. Maillieux, 1939; Coen, 1999). The uppermost part of the Valisettes Member is marked by the **Hony Horizon** (Figs 22C, 23, 25; see Lambermont Formation) reaching a thickness of 0.2 m at Neuville and 0.3 m at Deulin, respectively. This singular horizon is overlain by the ultimate occurrence of dark shale corresponding to the Matagne Facies (upper Kelwasser Event) and also to the top of the Valisettes Member.

The **Famenne Member – FAM** (s*chistes, qui se développent principalement dans les deux petites contrées nommées Famenne et Fagne* in d'Omalius d'Halloy, 1839, p. 448; *schiste de Famenne* in d'Omalius d'Halloy, 1853, p. 553, p. 555, both in footnotes) consists of shale primarily olive green to greyish green in its lower part and grey to purplish in its upper part (Fig. 29A). Thin beds of siltstone and sandstone increase in abundance towards the top of the unit; calcareous nodules can be locally abundant as is the case of coquina beds (Fig. 29B), largely dominated by rhynchonellide, athyridide and

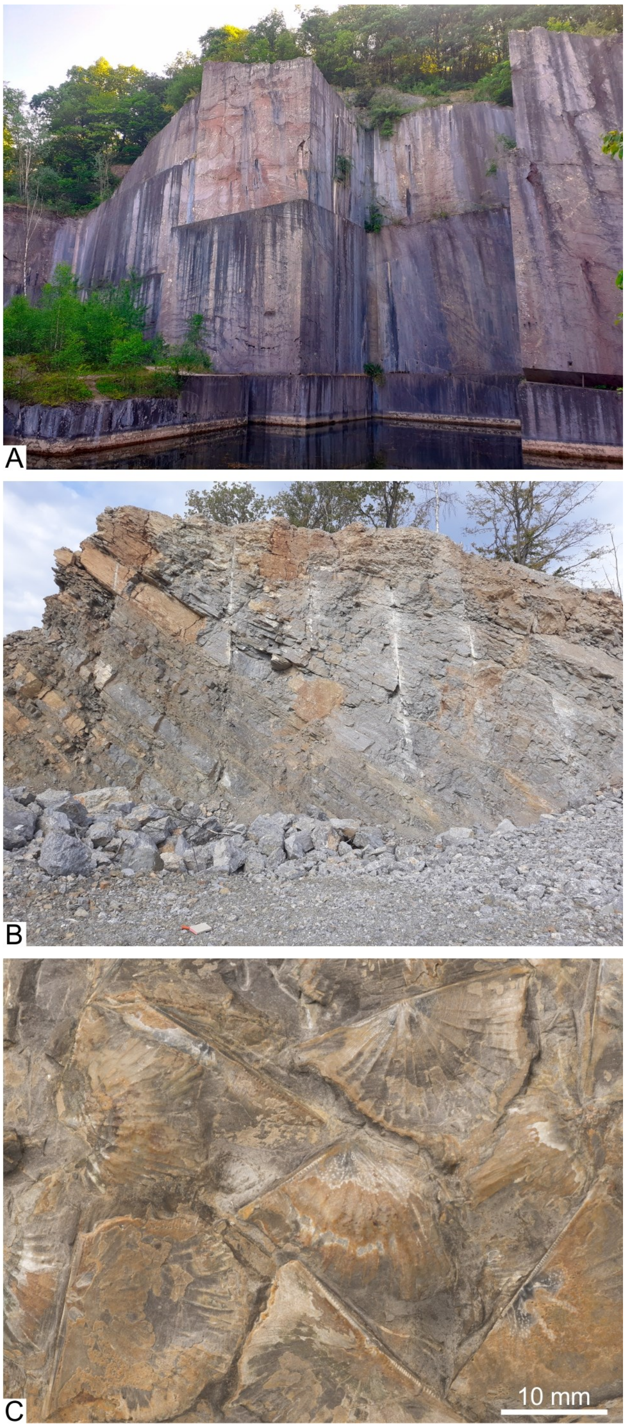

Figure 27. Illustration of the Marche-en-Famenne Formation. **A.** Reddish massive limestone of the Petit-Mont Member (from Denayer & Mottequin, 2023). Senzeille, Beauchâteau quarry. **B.** Small pinkish-grey limestone lens of the Petit-Mont Member at the base of the Marche-en-Famenne Formation. Frasnes-lez-Couvin, Nord quarry. **C.** Coquina including only strophomenide brachiopods (*Retrostrophia retrorsa*) (RBINS a14086), Barvaux Facies of the Valisettes Formation. Durbuy 5337.

spiriferide brachiopods (Pl. 4.A–W, Y). Outside the coquina beds, brachiopods, which never reach the size of the large ones encountered in the Barvaux Facies even if they become larger in the upper part of the Famenne Member, are associated with bivalves and orthoconic cephalopods (Pl. 4.X). One or two oolitic ironstone horizons are developed in the middle of the Member (Dreesen, 1982a, 1982b). The **Aye Facies** (*Formation des Schistes d'Aye* in Thorez et al., 1977, p. 26) is locally developed and characterised by the alternation of greenish shale and shaly siltstone beds and lenticular, usually centimetric to pluricentimetric (more rarely thicker) beds of fine-grained siltstone and sandstone (Fig. 29C). However, the transition between both lithotypes is generally gradual. The sandstone can display cross laminations. According to Boulvain et al. (1995), bioturbation can be so important that it gives rise to quite poorly sorted 'mixed' sediments. Carbonate nodules and pluricentimetric lenses of limestone with brachiopods and crinoids are also present (Dreesen, 1978). Note that Dusar & Dreesen (1984) reported up to 3 m thick domal shaped accumulations of large crinoidal debris in shales, just above Dreesen's (1982a) oolitic ironstone horizon IIIb in the Ourthe River valley (Hamoir area; Marion & Barchy, in press, a); they could correspond to aborted Baelen-type mounds (Dreesen et al., 2013).

Stratotype and sections. Characterisation of the Marche-en-Famenne Formation is based on type sections of the former units that make it up. However, the area around the town of Marche-en-Famenne offers good outcrops exposing the main facies (Barchy & Marion, 2014; Denayer & Mottequin, 2023).

The stratotype of the Neuville Member is composed of the northern and southern railway trench sections of the Couvin–Charleroi railway line west-south-west of Neuville, also known as the old and new Neuville trenches in the literature, whereas that of the Valisettes Member corresponds to the southern section, and the disused Petit-Mont quarry at Vodelée is the type section of the eponymous member (Boulvain et al., 1993b, 1993c, 1999b, 1999c). The latter is no longer accessible, but the neighbouring Hautmont quarry (Vodelée) and the Beauchâteau quarry (protected site) in Senzeille are good parastratotypes (e.g. Boulvain, 1993b; Boulvain & Coen-Aubert, 1991, 1992).

As reminded by Sartenaer (1974c), Gosselet (1871) did not mention a particular section in the vicinity of the villages of Gimnée, Matagne-la-Grande and Matagne-la-Petite for the Matagne Facies, which could be considered as the historical type section. Coen et al. (1999) selected the Nismes railway section, on the left bank of the Eau Blanche River valley south-west of the Tienne aux Pauquis, as the stratotype of the Matagne formation due to its historical value because it was firstly sketched by Gosselet (1888), although they considered other outcrops as more characteristic of this lithostratigraphic unit: Charleroi–Couvin (N5–E420) road section at Frasnes-lez-Couvin (Sartenaer, 1974a; Bultynck et al., 1998), protected outcrop behind the Saint-Sulpice church of Boussu-en-Fagne (Casier, 1975), and Lessive section (Coen, 1977a; Bultynck et al., 1998).

Although Coen (1974, 1999) referred to the Liège–Marloie railway section located in the trench on both sides of the disused railway station of Biron as the type section of the Barvaux Facies, it appears that Gosselet (1880b) has never cited this outcrop, but he mentioned the section located to the south-west of the Barvaux station, as noted by Sartenaer (1974d). Moreover, this author clearly demonstrated that Gosselet (1880b, p. 195–198) designated the Bruxelles–Luxembourg railway trench to the north of the Aye station as the type section of the *Schistes brunâtres et violacés (...) de Barvaux* (see also Gosselet, 1882, 1888).

The Famenne Member is well exposed in the Bruxelles–Luxembourg railway trench at Hogne (Gosselet, 1888; Mottequin, 2005a), north of the railway station of Aye, at least its contact with the Valisettes Member (Barvaux Facies). In the same area, the Aye Facies is visible in the section located in the railway trench located south-east of the hamlet of Les Basses, near Haversin, and described by Dreesen & Dusar (1975).

Area and lateral variations. The Marche-en-Famenne Formation is recognised throughout the Dinant Synclinorium. The Neuville Member is well developed on the southern and

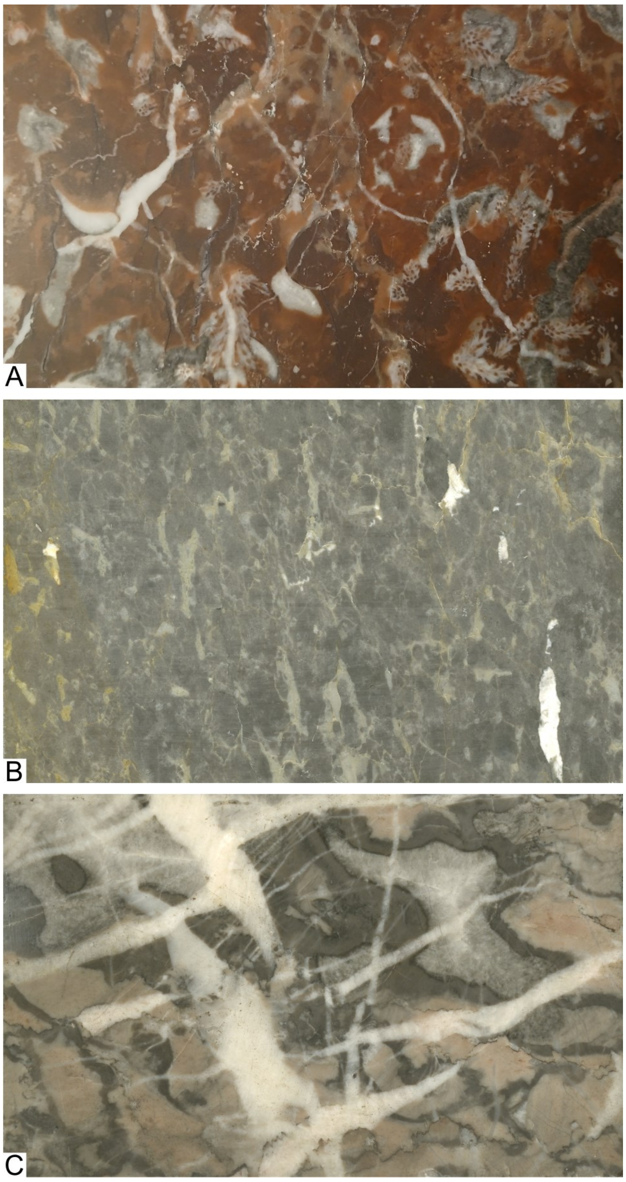

Figure 28. Illustration of upper Frasnian 'marble' varieties from the Petit-Mont Member of the Marche-en-Famenne Formation. The width of each picture is 10 cm. **A.** *Griotte* with numerous ramose tabulate corals (*Thamnopora* sp.). Rance. **B.** *Gris cendre nuance*. Vodelée, Hautmont quarry. **C**. *Malplaquet* (or *Malplaqué*, even *Malplaquais*) consisting in a finely veined and contrasted 'marble' variety. Humain quarry.

south-eastern limbs of the Dinant Synclinorium, from the French border (Marion & Barchy, 2001) up to the lower Ourthe River valley, where it passes laterally to the Aisemont Formation between Xhignesse and Awan (Bellière, 2015; Marion & Barchy, in press, a). In the north-western part of the Dinant Synclinorium, the transition with the Aisemont Formation is unclear due to the absence of outcrops and the thinning out of the Neuville Member, notably between Thuillies and Villers-Poterie, and up to Maison (Saint-Gérard) (Delcambre & Pingot, 2000b, 2004; Hennebert, 2008).

In the Durbuy–Philippeville Anticlinorium, the Valisettes Member was invariably grouped with the former Neuville formation (= Neuville Member) (e.g. Dumoulin & Marion, 1997b) and also with the former Matagne formation (= Matagne Facies) (Lemonne & Dumoulin, 1998). In the Famenne depression, it was grouped with the former Barvaux formation (= Barvaux Facies) as the facies are intricately intertwined (e.g. Barchy & Marion, 2014). The Matagne Facies occurs on the southern limb of the Dinant Synclinorium and in the western part of the Durbuy–Philippeville Anticlinorium. A study of the distribution of brachiopods within the Valisettes Member in the Neuville railway section (Mottequin, 2005a) did not confirm the existence of two successive occurrences of the Matagne Facies as hypothesised by Bultynck et al. (1998, fig. 11). Coen & Coen-Aubert (1974) and Godefroid & Helsen (1998) had already indicated a repetition by fault of the Valisettes Member in this section. The Barvaux Facies is known from the south-eastern limb of the Dinant Synclinorium; the lateral transition with the Matagne Facies and the Valisettes Member occurs in the Ciergnon–Lessive area (Sartenaer, 1970b; Coen, 1999; Blockmans & Dumoulin, in press). It was recognised up to the Ourthe River valley where it disappears east of Comblain-la-Tour (Marion & Barchy, in press, a).

Along the northern limb of the Dinant Synclinorium, the distinction between the Valisettes and Famenne members is elusive, albeit reddish facies are occasionally developed (e.g. Hoyoux River valley, Mottequin et al., 2021), and the former Neuville and Famenne formations were grouped for mapping purposes (Hennebert, 2008). Eastwards, the Valisettes Member passes in the Vesdre area to the Lambermont Formation whereas the Famenne Member passes to the Hodimont Formation (Laloux et al., 1996a). The Aye Facies is recognised in the central and southern parts of the Dinant Synclinorium, from the French border (Dumoulin, 2001; Marion & Barchy, 2004; Hennebert, 2008) to the west, up to Borlon (Durbuy) Barchy & Marion, 2018) and Comblain-Fairon (Marion & Barchy, in press, a) to the east. As pointed out by Donnay & Ramelot (1948) and Bouckaert et al. (1968), the Esneux Formation passes to the more argillaceous Aye Facies in the central part of the Dinant Synclinorium (i.e. in a more offshore position).

Thickness. On the south-eastern limb of the Dinant Synclinorium, the estimated thickness of the Marche-en-Famenne Formation is c. 450 m in the eponymous area (Barchy & Marion, 2014), but the thicknesses of the individual members show great variations. The Neuville Member is rather thin in the western part of the Durbuy–Philippeville Anticlinorium with a relatively constant thickness: 16–24 m in the stratotype sections (e.g. Boulvain et al., 1993b, 1999b). On the southern limb of the Dinant Synclinorium, its thickness increases up to c. 40 m in the Frasnes-lez-Couvin and Matagne-la-Grande areas (e.g. Marion & Barchy, 1999; Dumoulin & Marion, 1997b); elsewhere, it reaches c. 25 m at Olloy-sur-Viroin (Dumoulin & Coen, 2008), 40 m at Givet (Lemonne & Dumoulin, 1998), 110 m at Han-sur-Lesse (Coen, 1977a; Boulvain et al., 1999b), and 35–100 m in the Marche-en-Famenne area (Barchy & Marion, 2014). On the south-eastern limb of the Dinant Synclinorium, the Neuville Member is 50 m thick at Sy (Boulvain et al., 1999b; Marion & Barchy, in press, a). Along the northern limb of the Dinant Synclinorium, the Neuville Member reaches 20 m at Merbes-le-Château (Hennebert, 2008) and a tens of metres to the west of Hymiée (Delcambre & Pingot, 2000b). In their type section, the Valisettes and Petit-Mont members are about 90 m and 60 m thick, respectively (Boulvain et al., 1993b, 1993c, 1999b, 1999c). The maximum thickness (c. 50 m) of the Matagne Facies is recorded on the southern limb of the Dinant Synclinorium. In the western part of the Durbuy–Philippeville Anticlinorium, it decreases to c. 10 m. That of the Barvaux Facies varies from a few dozen metres to over 90 m (Coen, 1999; Barchy & Marion, 2014).

The Famenne Member varies in thickness from 70–90 m in the Meuse River valley (Delcambre & Pingot, 2017) along the northern limb of the Dinant Synclinorium, to 260 m in the Silenrieux–Walcourt area (Dumoulin & Marion, 1997a) and 400

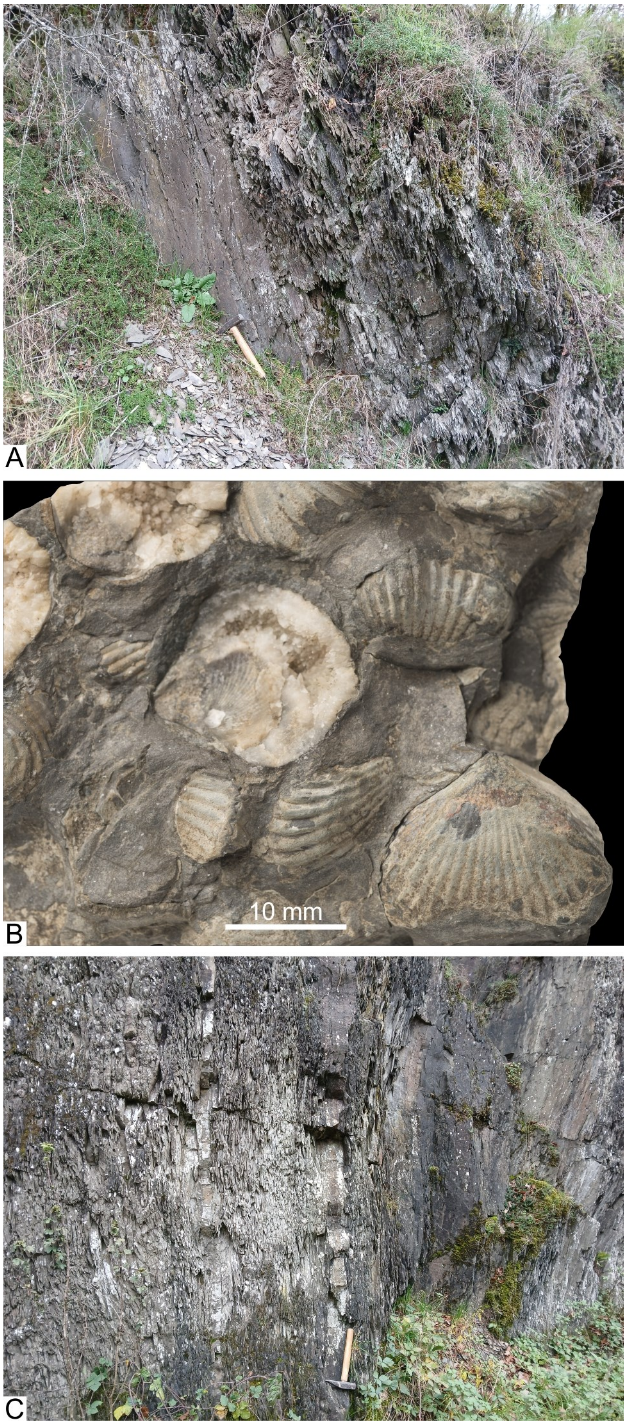

Figure 29. Illustration of the Marche-en-Famenne Formation. **A.** Green shale of the Famenne Member. Hérock, section along the road N94. **B.** Coquina including exclusively rhynchonellide brachiopods (*Ptychomaletoechia gonthieri*) (RBINS a14087), Famenne Member. Han-sur-Lesse 59/2 3a. **C.** Shale and thin beds of sandstone, Aye Facies of the Famenne Member. Vignée, section along the road N94.

m in the Achêne–Leignon area (Boulvain et al., 1995) in the central part of the Dinant Synclinorium, and it reaches its maximum thickness along the southern limb of the Dinant Synclinorium between the Meuse River and the Lesse River valleys (>400 m in the Han-sur-Lesse area, Blockmans & Dumoulin, in press). Nevertheless, such thicknesses are probably overestimated due to the presence of numerous faults. The thickness of the Aye Facies is quite variable locally; the maximal thickness (c. 220 m) is encountered in the Hermeton River valley (Boulvain & Marion, 1994), but it tends to decrease progressively westwards (e.g. 100–150 m in the Grandrieu–Beaumont area, Dumoulin, 2001) and eastwards (e.g. 50–100 m in the Natoye–Ciney area, Barchy & Marion, 2018; 0–100 m in the Hamoir–Ferrières area, Marion & Barchy, in press, a).

Age. Late Frasnian to early middle Famennian. The Neuville Member is assigned to the lower *rhenana* conodont Zone (Bultynck et al., 1998; Boulvain et al., 1999b), but its base is diachronous and becomes younger northwards (Poty & Chevalier, 2007). Characteristic brachiopods of the Neuville Member (Fig. 5, Pl. 2.A–K) are notably *Navalicria compacta* (Pl. 2.A), *Calvinaria megistana* (Pl. 2.B), *Pseudoatrypa godefroidi* (Pl. 2.C), *Warrenella* (*W.*) *aquaealbae* (Pl. 2.J) and *Tiocyrspis bironensis* (Pl. 2.K) (e.g. Sartenaer, 1988, 1989; Mottequin, 2005a, 2008b, 2008c). Several of these species are also known from the Aisemont Formation (Tchafornis Member).

The conodonts from the carbonate mounds of the Petit-Mont Member developed in the western part of the Durbuy–Philippeville Anticlinorium were discussed by Coen et al. (1977), Tourneur (1982), Bultynck et al. (1988b), Boulvain et al. (1988), and Boulvain & Coen-Aubert (1992). Along the southern limb of the Dinant Synclinorium, the carbonate mounds are restricted to the lower *rhenana* conodont Zone and yield the rugose corals typical of the *faune 1* of Coen et al. (1977). Some small mounds developed precociously, i.e. almost at the base of the Neuville Member, notably in Frasnes-lez-Couvin, north of Nismes (the Ternias), Givet (Fort Condé), and Rochefort (Saint-Rémy mounds). In the Durbuy–Philippeville Anticlinorium, the carbonate mounds extend from the lower to upper *rhenana* conodont zones and yield rugose corals typical of both the *faune 1* (*Frechastraea coeni* and *Hankaxis insignis* in red limestone, Fig. 10I, K) and *faune 2* (*Frechastraea limitata* and *Potyphyllum ananas* in pink and grey limestone, Fig. 10F, E). Within the brachiopod fauna (Fig. 5, Pl. 2.L–R), *Neometabolipa duponti* (Pl. 2.L), *Parallelepipedorhynchus trapezoides* (Pl. 2.M) and *Iowatrypa rotundicollis* (Pl. 2.R) rank among the most characteristic taxa of the Petit-Mont Member (Godefroid, 1970, 1974, 1994; Sartenaer, 2006). Outside the mud mounds, the rugose corals typical of *faune 3* (*Iowaphyllum rhenanum*, *I. mutabile*, *Frechastraea minima*, *F. kaisini*, Figs 10A, B, H, J) occur sporadically.

In matter of conodont zonation, the base of the Valisettes Member is almost coincident with the boundary between the lower and upper *rhenana* conodont zones whereas its top is placed at the transition between the *linguiformis* and *triangularis* conodont zones (Bultynck et al., 1998; see remarks concerning the lower Famennian conodont zonation in section 3). The Valisettes Member yields characteristic late Frasnian atrypides including *Spinatrypina* (*Exatrypa*) *marmoris* (Pl. 2.S), *Iowatrypa philippevillensis* (Pl. 2.T), *I. ultima* (Pl. 2.X) and *Waiotrypa*? sp. (Pl. 2.U) (Mottequin, 2003, 2004b, 2008b). The early development of the Matagne Facies is recorded at the base of the upper *rhenana* conodont Zone (Frasnes, Nismes) or is just below (top of the lower *rhenana* conodont Zone, Lessive) on the southern limb of the Dinant Synclinorium (Bultynck et al., 1998); in the Philippeville Anticlinorium, this facies is included in the *linguiformis* conodont Zone (Bultynck et al., 1998). The argillaceous limestone of the Hony Horizon is in fact the only carbonate unit that yields conodonts from the *linguiformis* conodont Zone (Gouwy & Bultynck, 2000). The leiorhynchid brachiopod *Ryocarhynchus tumidus* (Pl. 3.S) is present throughout the Matagne Facies (Sartenaer, 1968a, 1974a). The Barvaux Facies belongs to the upper *rhenana* Zone (Coen, 1999; Gouwy & Bultynck, 2000; Bultynck & Dejonghe, 2002). *Douvillina area* (Pl. 2.V), *Retrorstrophia retrorsa* (Fig. 27C, Pl. 2.W), *Iowatrypa ultima* (Pl. 2.X), *Cleiothyridina* sp. A sensu Mottequin (2008c) (Pl. 2.Y), and *Cyrtospirifer ambosulcatus*

(Pl. 2.Z) are key brachiopod species of this shaly facies (Mottequin, 2003, 2008a, 2008b, 2008c, 2019). It also yields rare colonial (*Frechastraea pentagona*, Fig. 10G) and undissepimented rugose corals (e.g. *Neaxon* spp., Fig. 10C).

The Famenne Member is usually early Famennian to early middle Famennian in age (*triangularis–marginifera* conodont zones) and is marked by a renewal of the brachiopod fauna following the late Frasnian Crisis. Nonetheless, its base could be also late Frasnian in age where the Valisettes Member is not developed (Fig. 25). Sartenaer (e.g. 1968b, 1972, 1983, 2001) established a detailed rhynchonellide zonation for this member (Fig. 6, Pl. 4.A–Q), confirming the biostratigraphic value of these brachiopods already pointed out by Gosselet (1877a, 1879b, 1887). Furthermore, orthotetides (*Floweria pseudoelegans* (Pl. 2.AA)), athyridides (*Crinisarina angelicoides* (Pl. 4.R), *C. stainbrooki* (Pl. 4.S), *C. reticulata* (Pl. 4.T)), and spiriferides (e.g. *Sinospirifer stolbergensis* (Pl. 4.U), *S. subextensus* (Pl. 4.V), '*Pseudocyrtiopsis' senceliae* (Pl. 4.W), *Dmitria* cf. *angustirostris* (Pl. 4.Y) are also particularly helpful in the field to recognise the lower Famennian (Fig. 5). The Aye Facies yields conodont from the *rhomboidea* conodont Zone up to the transition between the lower and upper *marginifera* conodont zones (Dreesen, 1982a; Thorez et al., 2006).

Use. The red, pink and grey massive limestone of the Petit-Mont Member (Fig. 27A–B) were intensively quarried as ornamental stone, known in Belgium as 'marbles' (see section 1). It was largely appreciated as decorative stone in the past, and this, since the Roman period. It was notably used by the architects of Louis XIV for the decoration of the Versailles Castle in the second half of 17th century (Biron et al., 1983). Many varieties were quarried, such as the *Marbre griotte* (dark red) (Fig. 28A), *Marbre rouge royal* (red with grey fossils and stromatactis), *Marbre rouge Impérial* (dark red with white stromatactis), *Marbre doré* (with yellowish matrix), *Marbre Byzantin* (pinkish with grey cavity fillings and veins), *Marbre Saint-Édouard* (pinkish-grey), and *Gris des Ardennes* (grey facies with many white calcite veins) (Fig. 28B). Some varieties are named after a locality, such as *Malplaquet* (brownish, coming originally from the Malplaquet quarry south of Philippeville) (Fig. 28C), *marbre jaspé de Saint-Remy* (Fig. 33C), red with bluish-grey stromatactis, coming from the Saint-Remy quarry near Rochefort), and *Rance* (dark red with many ramose tabulate corals) (e.g. Groessens, 1981; Cnudde et al., 1990; De Ceukelaire et al., 2014; Boulvain, 2014). Nowadays, only the Hautmont quarry of Vodelée still produces remarkable red 'marbles' (see section 1).

The weathered shale of the Marche-en-Famenne Formation was abundantly quarried in the Lesse, Hermeton and Ourthe River valleys as raw material for the clay brick industry up to the early 20th century (Camerman, 1940; Paepe, 1969).

Main contributions. Gosselet (1877a, 1879b, 1880a, 1880b, 1882, 1888), Dupont (1881, 1882, 1892), Delhaye (1908, 1913), Maillieux (1913, 1914a, 1914b), Dumon (1932, 1964, 1982), Lecompte (1937, 1954, 1959), Donnay & Ramelot (1948), Dumon et al. (1954), Thonnard (1964), Tsien (1971, 1975, 1977a, 1977b, 1980), Bouckaert & Thoreau (1972), Bouckaert et al. (1972), Coen (1974, 1999), Coen-Aubert (1974b, 1980, 2012, 2015, 2016), Sartenaer (1957d, 1960, 1970b, 1974a, 1974c, 1974d), Dreesen & Dusar (1974, 1975), Dusar (1976, 1989), Coen et al. (1977), Bouckaert & Dreesen (1977), Tsien et al. (1980), Dreesen (1982a, 1982b), Monty et al. (1982), Tourneur (1982), Biron et al. (1983), Dusar & Dreesen (1984), Casier (1987a, 1988), Mamet & Boulvain (1988, 1992), Boulvain (1989, 1993b, 2001), Boulvain & Coen-Aubert (1991, 1992), Boulvain et al. (1988, 1993a, 1993b, 1993c, 1995, 1999a, 1999b, 1999c), Helsen & Bultynck (1992), Bultynck & Martin (1995), Muchez et al. (1996), Bultynck et al. (1998), Coen et al. (1999), Poty & Chevalier (2007), Boulvain (2014), Mottequin & Poty (2016).

Mariembourg formation or member

Disused unit, integrated into the Marche-en-Famenne Formation.

Marlagne Dolomitic Facies

See Lustin Formation.

Matagne Facies

See Marche-en-Famenne Formation (Valisettes Member).

Mehaigne Member – MEH

See Huccorgne Formation.

Merlemont Dolomitic Facies

See Philippeville Formation.

Montfort Member – MFT

See Condroz Formation.

Moulin Liénaux Formation – MLX

Origin of name. After the locality Moulin Liénaux, corresponding to the point where the Aine Creek passes below the Charleroi–Couvin road (N5–E420), south of Frasnes-lez-Couvin (*Formation du Moulin Lienaux* in Coen-Aubert, 1994, p. 21, citing the National Commission for Stratigraphy; *Formation du Moulin Liénaux* in Bultynck & Mouravieff, 1999, p. 38).

Description. In the Frasnes-lez-Couvin area, the Moulin Liénaux Formation (Figs 30, 31A), thoroughly described by Bultynck & Mouravieff (1999), was divided into three members originally defined by Tsien (1974, p. 4) within the lower half of his disused Frasnes formation, from base to top: the Chalon, Arche and Ermitage members. A fourth member (Boverie Member) was recognised posteriorly by Boulvain & Coen-Aubert (2006). The base of the Formation corresponds to the first shale–limestone alternations that markedly contrast with the shale of the top of the underlying Nismes Formation.

The **Chalon Member – CHA** (Fig. 31A) begins with brownish-grey shale alternating with pluricentimetric beds of blackish-grey argillaceous limestone, sometimes finely bioclastic (brachiopods, solitary rugose corals). Its upper part includes calcareous shale rich in lamellar tabulate corals and fasciculate rugose coral (*Disphyllum hilli*), in which limestone beds are more frequent and thicker. Where carbonate buildups are developed (see below), the Chalon Member becomes clearly calcareous and well stratified, and its thickness can increase considerably (Marion & Barchy, 1999).

The **Arche Member – ARC** (Fig. 30A–B) consists of large carbonate buildups, reaching up to 120 m in thickness. The massive limestone varies in colour from reddish pink in the lower part (with the exception of the lowest part where the limestone is greyish) to light grey in the upper part. Stromatoporoids, rugose and tabulate corals are abundant in the lower part, together with brachiopods (e.g. pentamerides, atrypides, spiriferides), bivalves, cephalopods and gastropods (Maillieux, 1940a). *Receptaculites neptuni* forms local accumulations (Tsien, 1980). The reddish (or pinkish to orange)

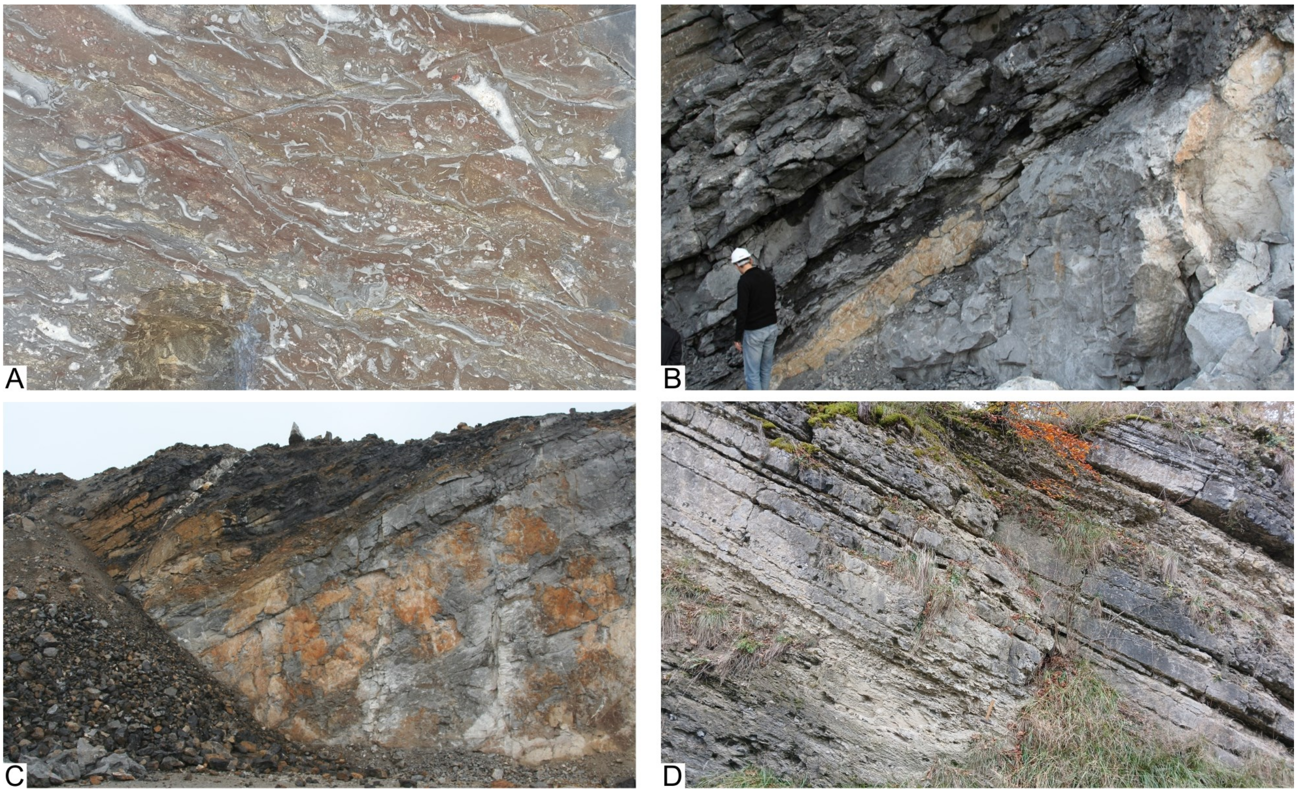

Figure 30. Illustration of the Moulin Liénaux Formation. **A.** Sawn face in pink marble facies of the Arche Member. Frasnes-lez-Couvin, Arche quarry. **B.** Contact between the top of the Arche Member and the Boverie Member. Rochefort, La Boverie quarry. **C.** Top of the Boverie Member. Rochefort, La Boverie quarry. **D.** Contact between the top of the Ermitage Member and the Grands Breux Formation (Bieumont Member). Road section along the RN94 between Ave and Génimont.

core is rich in small stromatactis and lamellar tabulate corals. Their development is initiated in the upper part of the Chalon Member, which acts as sole for the buildups. The contact with the overlying shaly Ermitage Member is clearcut.

The **Ermitage Member – ERM** (Fig. 30D) is mostly composed of greenish-grey shale that includes some levels of calcareous nodules and thin beds of argillaceous nodular limestone usually poor in fauna, but with local accumulations of *Receptaculites*. Trilobites (e.g. Richter & Richter, 1926; Maillieux, 1927; Van Viersen & Vanherle, 2018) are locally abundant in the shale (Pl. 1.U–X).

The **Boverie Member – BVR** (La Boverie Member in Boulvain & Coen-Aubert, 2006, p. 32) includes the limestone developed above the Arche Member and below the Grands Breux Formation (Fig. 30B–C). Its lower part corresponds to bedded, often argillaceous or bioclastic limestone with locally fasciculate colonies of rugose corals, whereas its upper part consists of light grey massive bioclastic limestone rich in fragmented corals and stromatoporoids. Contrary to the Arche Member, the Boverie Member does not expose build-up facies. The contact with the overlying Grands Breux Formation is irregular.

Stratotype and sections. A composite stratotype was proposed by Bultynck & Mouravieff (1999, fig. MLX1) with several sections located south and south-south-west of the village of Frasnes-lez-Couvin. The lower limit of the Moulin Liénaux Formation was formerly observed in the disused Arche quarry, whereas its upper limit is recognised in the trench of the Couvin–Charleroi railway, south of the bridge of the *rue des longues haies* at Frasnes-lez-Couvin. Additional outcrops were mentioned by these authors in the Nismes and Boussu-en-Fagne areas. The Boverie Member is defined in the active eponymous quarry at Rochefort (Boulvain & Coen-Aubert, 2006), which also well exposes the upper part of the Arche Member and the Lion Member.

Area and lateral variations. The Moulin Liénaux Formation and its three classic members are recognised on the southern and south-eastern limbs of the Dinant Synclinorium, from the French border (Marion & Barchy, 2001) to the Bomal-sur-Ourthe area in the Ourthe River valley, where it passes laterally to the Pont de La Folle Formation in the Durbuy–Philippeville Anticlinorium (Marion & Barchy, in press, b). It is also known from the south-eastern portion of the western part of the Durbuy–Philippeville Anticlinorium (Dumoulin & Marion, 1997b; Lemonne & Dumoulin, 1998). The buildups of the Arche Member are not numerous and the largest are located around Frasnes-lez-Couvin and Nismes (Marion & Barchy, 1999; Dumoulin & Coen, 2008), and in the vicinity of Rochefort (Barchy et al., 2024). According to Boulvain & Coen-Aubert (2006), the Boverie Member is known from the southern limb of the Dinant Synclinorium (Frasnes-lez-Couvin, Nord quarry; Rochefort, La Boverie quarry) and in the southern portion of the western part of the Durbuy–Philippeville Anticlinorium (Moulin Bayot sections at Vodelée, Boulvain et al., 2005).

Thickness. The Chalon Member is c. 10–30 m thick (see remarks above), whereas the buildups of the Arche Member can reach 100–120 m in thickness (Bultynck & Mouravieff, 1999) and a hecto- to kilometric lateral extension (Dumoulin & Coen, 2008). The Boverie Member is less thick: 31–34 m at Rochefort, 28–45 m at Frasnes-lez-Couvin (Boulvain & Coen-Aubert, 2006). Lecompte (1963) and Bultynck & Mouravieff (1999) estimated the thickness of the Ermitage Member at 100–115 m in the Frasnes-lez-Couvin area.

Age. Early and middle Frasnian (Bultynck & Dejonghe, 2002). The Moulin Liénaux Formation spans the interval of the upper part of the *transitans* conodont Zone up to the lower part of *hassi* s.l. conodont Zone (Vandelaer et al., 1989), but it mostly represents the *punctata* conodont Zone (see Bultynck et al., 1999). The Chalon Member and the basal part of the Arche Member yield *Disphyllum hilli*, *D. grabaui* and *Macgeea rozkowskae* (Fig. 8 D, F), three species also recognised at the base of the Lustin Formation (Coen-Aubert, 2009). The Boverie Member yields species of *Sinodisphyllum* and *Macgeea* that are mostly unknown outside this member. The Chalon and Ermitage members are characterised by a succession of atrypide brachiopods (Godefroid, 1998, 1999), of which the presence within the Pont de la Folle Formation has not yet been reported, pending further investigation as is the case for most of the brachiopod species recognised on the southern and south-eastern limbs of the Dinant Synclinorium: *Atryparia* (*Costatrypa*) *eremitae* (Pl. 1.L), *A.* (*C.*) sp. A sensu Godefroid (1998) (Pl. 1.O), *A.* (*C.*) *fossae* (Pl. 1.P), *A.* (*C.*) *lecomptei* (Pl. 1.Q), and *A.* (*C.*) *variabilis* (Pl. 3.D–E). Furthermore, the Ermitage Member also yields the spiriferide *Dionacoelia secessus* (Mottequin, 2005b, 2019) (Pl. 1.R) and the rhynchonellides *Plionoptycherhynchus exformosus* (Pl. 1.S) and *Sthenarirhynchus dionanti* (Pl. 1.T) (Sartenaer, 1979, 1999a, 1999b). The Arche Member yields *Metabolipa greindli* (Pl. 1.M), also known from the Pont de la Folle Formation (Godefroid in Dumoulin, 2001) and the Lion Member, and *Desquamatia* (*Seratrypa*) *frasniensis* (Pl. 1.N) (Godefroid, 1970, 1974, 1999).

Use. The massive limestone of the Arche Member was quarried as ornamental stone in the Arche quarry in Frasnes-lez-Couvin, notably a *Marbre royal* (Fig. 30A) coming from the base of the Member and a grey marble called *Gris léopard*, coming from its upper part (Groessens, 1981). Nowadays, the pure limestone of the Arche and Boverie members are exploited at the La Boverie quarry (Fig. 30B–C) in Rochefort to produce lime and industrial carbonate (Poty & Chevalier, 2004).

Main contributions. Dupont (1881, 1882), Lecompte (1937, 1963), Tsien (1974, 1975, 1980), Tsien et al. (1980), Monty et al. (1982), Coen-Aubert (1994, 1995, 1996, 2009), Bultynck & Mouravieff (1999), Boulvain et al. (2005), Boulvain & Coen-Aubert (2006), Casier & Olempska (2008).

Neuville Member – NEU

See Marche-en-Famenne Formation.

Nismes Formation – NIS

Origin of name. After the village of Nismes in the Eau Noire River valley, *Formation de Nismes* in Coen-Aubert et al. (1985, p. 7), who cited an unpublished document by Bultynck et al. (1983), and Nismes Formation in Sartenaer (in Bultynck et al., 1988a, p. 253).

Remark. On the Geological Map of Wallonia, two different names were applied to the mixed argillaceous-carbonate deposits that overly the Givetian carbonate, namely the Nismes and Presles formations (e.g. Bultynck & Coen, 1999; Coen-Aubert, 1999b). According to Coen-Aubert (1999b), the Presles Formation would be distinguished from the Nismes Formation by the development of argillaceous limestone and dolostone frequently enclosing haematitic oolites whereas the latter unit is essentially shaly. However, the criteria used to distinguish both former units are quite tenuous as ferruginous oolites are also present locally within the Nismes Formation (e.g. Marche-en-Famenne, Ny), and it is more logical to consider herein the Presles formation as a facies of the Nismes Formation.

Description. The Nismes Formation (Fig. 31) is essentially shaly and the contact to the underlying Givetian Fromelennes Formation is progressive (e.g. Nismes) or abrupt (e.g. Sourd d'Ave, Fig. 31B). This formation was subdivided into three members by Godefroid & Jacobs (1986, p. 69), who referred to an unpublished document (Bultynck et al., 1983), as the *Membre du Pont d'Avignon*, *Membre du Sourd d'Ave* and *Membre de La Prée* that are developed on the southern and south-eastern limbs of the Dinant Synclinorium. Herein the Presles Facies is added; it is known from the northern and eastern depositional areas (see below).

The former basal member is regarded herein as a horizon (**Pont d'Avignon Horizon**) due to its insignificant thickness (1.15 m thick). It includes pluridecimetric beds of argillaceous, bioclastic and greyish limestone with somewhat nodular to sub-nodular aspect. It is rich in large-sized atrypide and spiriferide brachiopods (*niveau des monstres* (pars) in Gosselet, 1871, p. 296; see also Sartenaer, 1974e, 1982; Sartenaer in Bultynck et al., 1983, 1988a; Godefroid & Jacobs, 1986). The basal bed of the Pont d'Avignon Horizon is marked by a reddish-brown alteration colour due to a relatively high content in limonite (Bultynck & Jacobs, 1982; Godefroid & Jacobs, 1986).

The **Sourd d'Ave Member – SAV** (16.3 m thick) can be subdivided into a lower part consisting of greenish, very nodular shale with some thin sub-nodular limestone lenses and an upper part composed of shale with less calcareous nodules, but with thicker sub-nodular limestone beds. Brachiopods are less abundant than in the Pont d'Avignon Horizon, but the lower half of this member was also included in the *niveau des monstres*. Between Ny and Humain, a decimetre-thick limestone bed full of chamositic oolites occurs near the base of the Member (de Magnée, 1933; Coen, 1973, 1974) (Fig. 31C).

The **Prée Member – PEE** (c. 20–22 m thick) starts above the last conspicuous limestone bed of the Sourd d'Ave Member and is essentially shaly. The greenish to brownish shale includes few nodules of greyish, very argillaceous limestone and, very rarely, thin limestone lenses. Brachiopods are generally less abundant than in the Pont d'Avignon Horizon and Sourd d'Ave Member (Sartenaer, 1982; Bultynck & Jacobs, 1982; Mottequin et al., 2016).

The **Presles Facies** (*Formation de Presles* in Coen-Aubert et al., 1985, p. 8, 25) is predominantly argillaceous and sandwiched between two carbonate lithostratigraphic units, i.e. the Le Roux and Lustin formations (Coen-Aubert, 1999b). It often incorporates thin dolostone beds at its base as well as several horizons of haematitic or chamositic oolites. Thanks to these characteristics, it is a good marker in the field to recognise the basal Frasnian. According to Coen-Aubert (1988, 1999b), the Presles Facies, in its type section, starts with argillaceous, bioclastic, dark limestone (3.4 m thick) with crinoids and brachiopods that overlies the fine-grained limestone, locally rich in rugose and tabulate corals, of the Givetian Le Roux Formation (see Denayer et al., 2024). One or several beds of argillaceous limestone with haematitic oolites are present in the middle part. The argillaceous limestone is overlain by green to brownish shale (6.3 m thick) that comprises some beds of argillaceous limestone and some haematitic oolite horizons near the top of this facies. Locally (Ourthe River valley), a level rich in *Disphyllum* is developed below the contact with the overlying Lustin Formation.

The boundary with the overlying Moulin Liénaux (Chalon Member), Pont de la Folle (Fontaine Samart Member) and Lustin (Gougnies Member) formations is placed at the top of the last shale bed situated below the first limestone bed.

Stratotype and sections. A composite stratotype, including four sections located on the northern margin of the Bois de Mousti at Nismes, was proposed by Bultynck et al. (1988a) (see Bultynck & Coen, 1999) for the Nismes Formation and the Sourd d'Ave and Prée members. The stratotype is complemented, among the outcrops described by Bultynck &

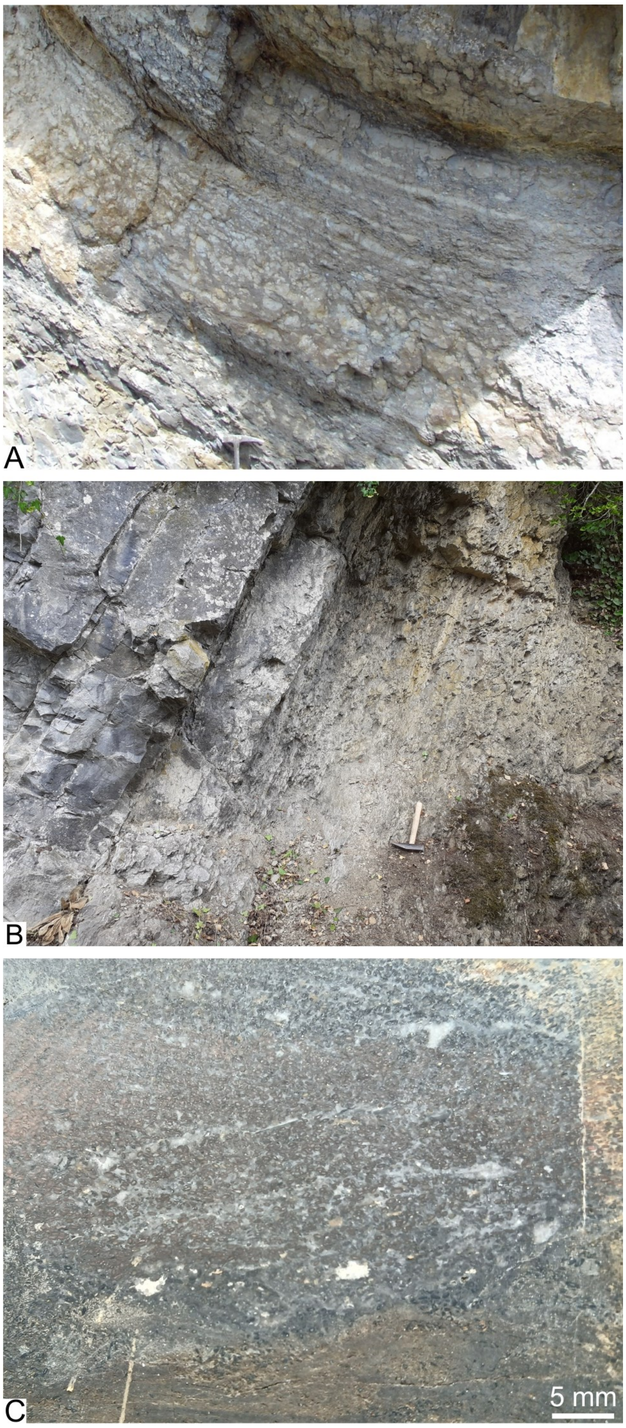

Figure 31. Illustration of the Nismes Formation. **A.** Contact between the Nismes Formation (Prée Member) and the Chalon Member of the Moulin-Liénaux Formation. Barvaux-sur-Ourthe, Glawan rocks. **B.** Contact between the Fromelennes (late Givetian) and Nismes formations (Pont d'Avigon Horizon and Sourd d'Ave Member) (overturned layers). Wellin, Sourd d'Ave section. **C.** Chamositic oolites from the lower part of the Nismes Formation. Marche-en-Famenne, Fond-des-Vaux railway section (width of the picture c. 5 cm).

Jacobs (1982) and Godefroid & Jacobs (1986), by the easily accessible Sourd d'Ave section at Wellin (Bultynck & Jacobs, 1982) and the railway trench at the Fond des Vaulx at Marche-en-Famenne (Barchy & Marion, 2014). However, in both latter sections, the contact with the overlying Moulin Liénaux Formation is not exposed. Coen-Aubert et al. (1985) and Coen-Aubert (1999b) proposed the section mentioned by Lacroix (1974a, 'Presles' without any information) and Coen (1976), along the Namur–Charleroi road (N922) in the by-pass of Presles, as the stratotype of the Presles Facies. This outcrop is very overgrown nowadays.

The Nismes composite section was selected by the Subcommission on Devonian Stratigraphy of the IUGS (Prague, August 1986) as an auxiliary stratotype (parastratotype) for the Givetian–Frasnian boundary in neritic facies (Bultynck et al., 1988a, 1988b).

Area and lateral variations. The Nismes Formation has a widespread distribution in southern Belgium. It is observed along the southern and eastern limbs of the Dinant Synclinorium, from the French border to the west (Marion & Barchy, 2001) up to Deigné (Louveigné) (Coen, 1974; Marion et al., in press) to the east. Though discontinuous laterally, the chamositic horizon is developed between the Wamme River (Lomme River affluent) and Ourthe River valleys.

The Nismes Formation is recognised in the Durbuy–Philippeville Anticlinorium (e.g. Coen, 1977b; Boulvain & Marion, 1994; Dumoulin & Marion, 1997b), but is essentially shaly with no clear distinction into members (Bultynck & Coen, 1999) as is the case on the northern limb of the Dinant Synclinorium. The Nismes Formation is recognised in northern France, south of Honnelles (Hennebert & Delaby, in press), and south of Solre-sur-Sambre (Hennebert, 2008; Pas et al., 2015), Gerpinnes (Delcambre & Pingot, 2000b), between Biesme and Gougnies (Delcambre & Pingot, 2004) up to the Meuse River valley where the Presles Facies begins to develop north of the Rivière Syncline (Coen-Aubert & Coen, 1975; Delcambre & Pingot, 2018a).

In the Vesdre area, the Nismes Formation was recognised within the Membach boreholes (Coen-Aubert et al., 1985) where it consists of shale with thin calcareous beds at its base and top. To the west, the Presles Facies stands out from the rest of the Formation. To the east, in Germany, the Nismes Formation corresponds to the *Grenzeschiefer-Formation* (Holzapfel, 1910; Deutsche Stratigraphische Kommission, 2016).

The Presles Facies is recognised in the Haine–Sambre–Meuse Overturned Thrust sheets (e.g. Lacroix, 1974a, 1974b; Coen-Aubert, 1988), in the Brabant Parautochthon (Wépion borehole; see Coen-Aubert, 1988; Delcambre & Pingot, 2017), in the northern and eastern parts of the Dinant Synclinorium (e.g. Coen-Aubert, 1973; Marion et al., in press), the western part of the Vesdre area (e.g. Coen-Aubert, 1974a; Laloux et al., 1996a) and in the Theux Window (Graulich, 1979).

Thickness. The Nismes Formation is c. 39 m thick in its stratotype (Bultynck & Coen, 1999). Eastwards, its thickness varies between 20 and 35 m on the southern and south-eastern limbs of the Dinant Synclinorium (e.g. Dumoulin & Blockmans, 2013; Barchy & Marion, 2014; Barchy et al., 2024; Marion & Barchy, in press, b). On the eastern limb of the Synclinorium, the Nismes Formation is 13 m thick at Aywaille (Fourmarier, 1900; Coen, 1974) and drastically thins northwards. Comparable thicknesses are observed in the western part of the Durbuy–Philippeville Anticlinorium (e.g. Boulvain & Marion, 1994; Dumoulin & Marion, 1997b). In the northern part of the Dinant Synclinorium, an average thickness of 35 m (20–50 m thick) in the Sambre River valley is mentioned by Hennebert (2008); elsewhere, the following thicknesses are indicated: c. 20 m at Hymiée (Delcambre & Pingot, 2000b), 15–20 m between Biesme and Gougnies (Delcambre & Pingot, 2004), c. 10 m at the maximum in the Rivière Syncline (Coen-Aubert & Coen, 1975; Delcambre & Pingot, 2018a). In the Membach boreholes, its thickness does not exceed 7 m (Coen-Aubert et al., 1985).

The Presles Facies is c. 10 m thick in its type section and 16.6 m thick in the bottom of the Wépion borehole (Coen-Aubert, 1988), which corresponds to its maximum thickness.

Usually, it is around 5 m thick in the Dinant Synclinorium and in the Haine–Sambre–Meuse Overturned Thrust sheets (Lacroix, 1974b; Coen-Aubert & Lacroix, 1979). In the eastern extremity of the Dinant Synclinorium, at Colonster (Ourthe River valley), the Presles Facies consists of few metres of argillaceous limestone rich in spiriferide brachiopods. Due to its thinness in the Vesdre area (only 2 m thick at the maximum; Coen-Aubert, 1974a), it was mapped together with the overlying Lustin Formation (Laloux et al., 1996a; Delcambre et al., in press). In the Theux Window (Polleur viaduct boreholes), it reaches 6 m in thickness (Graulich, 1979).

Age. Latest Givetian–early Frasnian (lower *falsiovalis*–*transitans* conodont zones) (Bultynck & Coen, 1999; Bultynck et al., 1999). The Pont d'Avignon Horizon is of latest Givetian age at Nismes and Wellin. The first occurrence of the conodont *Ancyrodella rotundiloba*, which is the index fossil for the base of the Frasnian (see section 3), is recorded in the basalmost part of the Sourd d'Ave Member in both sections (Bultynck & Jacobs, 1982). The top of the Prée Member yielded a few specimens of *Palmatolepis transitans* (Vandelaer et al., 1989). *Ancyrodella rotundiloba* occurs at the base of the Presles Facies in several sections located on the northern limb of the Dinant Synclinorium and in the Haine–Sambre–Meuse Overturned Thrust sheets, between Aisemont and Vierset-Barse (Coen-Aubert, 1973; Mouravieff in Lacroix, 1974a; Coen-Aubert & Coen, 1975). The atrypide brachiopod succession (Fig. 5), includes, in ascending order, the *Desquamatia* (*Seratrypa*?) *suppinguis* (Pl. 1.B), *D.* (*Neatrypa*) *gosseleti* (Pl. 1.C) and *D.* (*N.*) *europaea* (Pl. 1.D) zones (Godefroid & Jacobs, 1986). These zones are observed within the Pont d'Avignon Horizon and the Sourd d'Ave Member on the southern and south-eastern limbs of the Dinant Synclinorium and allow to confirm the diachronism documented by the conodonts in these areas (Godefroid & Jacobs, 1986, fig. 25); indeed, the base of the Nismes Formation becomes younger from the south (Nismes, Martouzin) to the north-east (Sy). Besides *D.* (*S.*) *pectinata* (Pl. 1.A) and *Anathyris* (*A.*) *calestiennensis* (Pl. 1.E) (Godefroid & Jacobs, 1986; Mottequin et al., 2016), on the southern (S) and south-eastern (SE) limbs of the Dinant Synclinorium, the Nismes Formation yields a succession of spiriferide species that has yet to be further documented (Fig. 5): *Uchtospirifer*? *fraiponti* (the so-called *Spirifer orbelianus* in the Franco-Belgian literature; see Mottequin, 2019 and Serobyan et al., 2022) (S, SE; Pl. 1.F), *Eodmitria oblivialis oblivialis* (SE; Pl. 1.J), *E. oblivialis grandis* (SE; Pl. 1.K), *Geminisulcispirifer bisinus* (S, SE; Pl. 1.G) and *Subquadriangulispirifer malaisi* (S, SE; Pl. 1.I). In the Presles Facies, only the presence of *E. oblivialis oblivialis* and *E. oblivialis grandis* is well documented (Sartenaer, 1982; Delcambre et al., in press). Both *E. oblivialis* subspecies are also known from the Bovesse Formation (Sartenaer, 1982). Although they need to be revised, representatives of the distinctive genus *Apousiella* (Pl. 1.H) can be frequent in the Presles Facies.

Use. The oolitic ironstone layer of the Presles Facies was exploited as iron ore in underground mines at Tailfer and Profondeville in the Meuse River valley, essentially during the 19th century (e.g. Delmer, 1913; Denayer et al., 2011b), but also well before the Roman colonisation, notably to produce red pigment (Bosquet et al., 2016).

Main contributions. Delmer (1913), de Magnée (1933), Coen-Aubert (1973, 1974a, 1988, 1999b), Lacroix (1974a, 1974b), Coen-Aubert & Lacroix (1979), Bultynck & Jacobs (1982), Godefroid & Jacobs (1986), Casier (1987b), Bultynck et al. (1988a, 1988b), Bultynck & Coen (1999), Devleeschouwer et al. (2010), Mottequin et al. (2015).

Petit-Mont Member – PTM

See Marche-en-Famenne Formation.

Philippeville Formation – PHV

Origin of name. After the town of Philippeville, *Formation de Philippeville* in Boulvain et al. (1993d, p. 14).

Description. The carbonate Philippeville Formation (Fig. 32A–B) abruptly overlies the shaly upper part of the Pont de la Folle Formation (Machenées Member). It is frequently, but irregularly affected by dolomitization (Coen & Coen-Aubert, 1976; Boulvain et al., 1993d, 1999d). This thick unit is herein subdivided into three members based on distinct lithologies firstly recognised in the Entre-Sambre-et-Meuse area (e.g. Beugnies et al., 1963) (Fig. 23). The description hereafter is based on the succession observed in its type section at Philippeville (Coen, 1977b; Boulvain et al., 1993d, 1999d).

The **Cousolre Member – COU** (*marbre de Cousolre* in Gosselet, 1877b, p. 253–254; *Assise F5 (marbre de Cousolre ou dolomie de Renlies)* in Beugnies et al., 1963, p. 220) is essentially composed of light-coloured limestone. It starts with limestone yielding lamellar tabulate corals and pentameride brachiopods (3–4 m), followed by 7 m of argillaceous limestone with brachiopods, and ends with 5 m of fairly massive, light-coloured limestone with lamellar tabulate corals (*Alveolites*), fenestellid bryozoans and fenestrae. The argillaceous limestone is sometimes absent (Neuville railway section). This member should not be confused with the *schistes de Cousolre*, a disused Famennian unit proposed by Gosselet (1880a, p. 112; 1880c, p.206; 1888, p. 562).

The **Reugnies Member – REU** (*Assise F6 (Calcaire noir lité de Reugnies)* in Beugnies et al., 1963, p. 223; *Membre de Reugnies* in Delcambre & Pingot, 2000b, p. 39) starts with 16 m of decimetre-thick beds of black limestone with small bioclasts (brachiopods, solitary rugose and ramose tabulate corals are abundant locally) corresponding to the *marbre noir de Reugnies* (Beugnies et al., 1963, p. 223), then followed by 3 m of black shale and argillaceous dolomitic limestone, and ends with 7–8 m of black limestone with ramose tabulate corals, occasional solitary rugose corals and rare lamellar stromatoporoids.

The **Thy-le-Bauduin Member – THY** (*Assise de Rhisnes et de Thy-le-Baudouin* in Conseil de Direction de la Carte, 1896, p. 54) (Fig. 32A) consists of alternations of decimetre-thick beds of frequently laminar limestone and of metric-bedded limestone rich in massive and ramose stromatoporoids (60 m thick); colonial rugose corals become frequent at the top of this second unit, which is also known as the *complexe biostromal* (Cornet, 1978). Its top is placed just below the first bed of nodular limestone characteristic of the Marche-en-Famenne Formation (Neuville Member).

Locally, the dolomitization affects large parts of the Philippeville Formation and forms dolomitic masses reaching 70 m in thickness and several kilometres in lateral extension (Dejonghe et al., 1989), notably in the western part of the Durbuy–Philippeville Anticlinorium, around the villages of Merlemont and Sautour. These masses are here named the **Merlemont Dolomitic Facies** (Fig. 32B). Four types of dolostone were distinguished by Dejonghe et al. (1989): (1) greyish, fine- to medium-grained dolostone (with fossil ghosts), (2) whitish to yellowish dolostone (no fossils, and frequently with numerous vacuoles), (3) banded (or zebra) with rhythmic, plurimillimetric to pluricentimetric alternations of greyish to whitish dolostone, and (4) greyish, coarse-grained dolostone with no fossils. Cherts and diffused silicifications occur in the dolostone.

Stratotype and sections. Trench of the Charleroi–Couvin

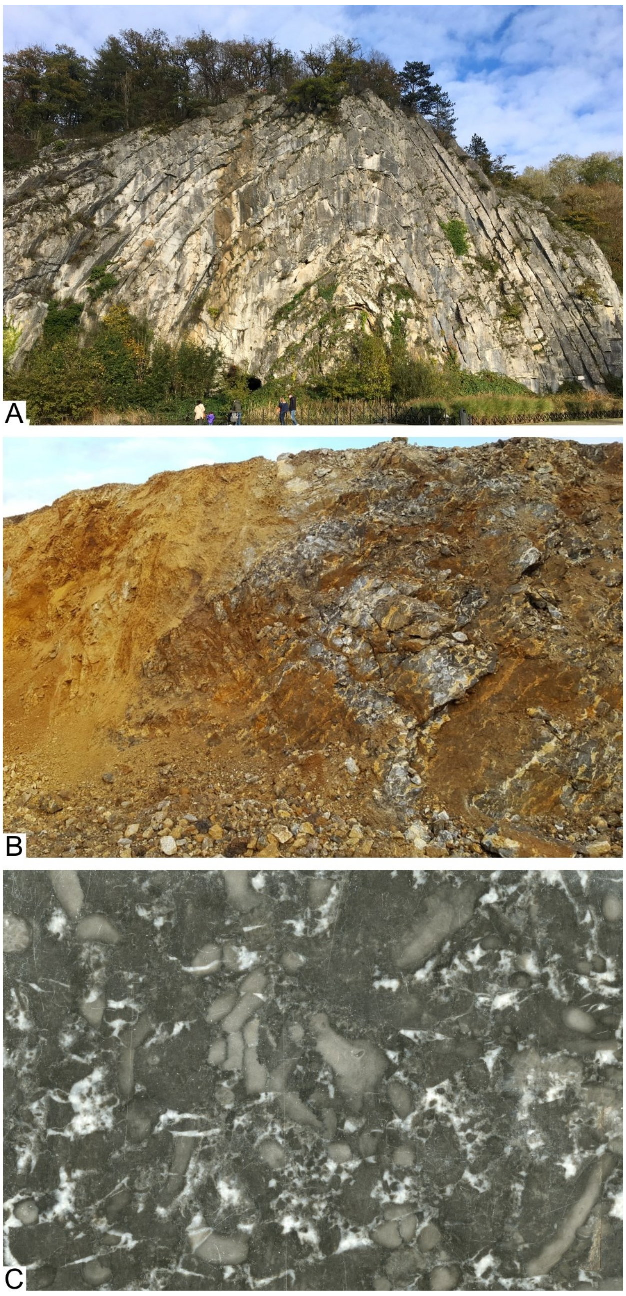

Figure 32. Illustration of the Philippeville and Pont-de-la Folle formations. **A.** Anticline in the Philippeville Formation (Thy-le-Bauduin Member) at Durbuy-sur-Ourthe. This famous outcrop is also known as the Omalius Rock (or the Falize Rock), as d'Omalius d'Halloy was the first to describe this Variscan tectonic structure in the early 1800s. **B.** Yellow and grey dolostone of the Merlemont Dolomitic Facies (Philippeville Formation) (courtesy of Valentin Jamart). Merlemont quarry. **C.** *Marbre Sainte-Anne*, *Petit Mélange* variety, coarse-grained bioclastic limestone quarried as an ornamental stone, lower part of the Fontaine Samart Member (Pont de la Folle Formation) (width of the picture c. 10 cm).

road (N5–E420) south of Philippeville, north of km 79 (Boulvain et al., 1993e, fig. 2). The stratotype is complemented by the Neuville railway section where the upper part of the Philippeville Formation is better exposed (Boulvain et al., 1993d, fig. 4, section 2). The historical type section of the Cousolre Member corresponds to the quarries mostly located on the right bank of the La Thure River at Cousolre in Avesnois (France) (Gosselet, 1877b), whereas that of the Reugnies Member comprises the quarries situated on the hillside of the French eponymous village (e.g. Gosselet, 1888). The Thy-le-Bauduin Member was originally based on the sections located around this village (Delcambre & Pingot, 2000b).

Area and lateral variations. On the northern limb of the Dinant Synclinorium, the Philippeville Formation is known from the Avesnois and the French border (Beugnies et al., 1963; Hennebert, 2008) up to Hymiée (Delcambre & Pingot, 2000b, 2004) where it laterally passes to the Lustin Formation. It is known from the anticlines in the central western part of the Dinant Synclinorium (Entre-Sambre-et-Meuse area) up to Rance (Marion & Barchy, 2004) and in the western part of the Durbuy–Philippeville Anticlinorium. There, the Philippeville Formation laterally and progressively passes to the Grands Breux Formation south-east of a virtual line linking Sautour and Omezée (Dumoulin & Marion, 1997b). East of the Meuse River valley, this lithostratigraphic unit is recognised in the Durbuy–Philippeville Anticlinorium, from Sinsin to Nettine (Coen, 1974; Barchy & Marion, 2008, 2014) and from Petite-Somme to Tohogne where it passes laterally, north-eastwards, to the Lustin Formation (Marion & Barchy, in press, a). The south-eastern lateral passage to the Grands Breux Formation takes place between Bohon and Barvaux-sur-Ourthe (Marion & Barchy, in press, b). The Reugnies Member is only recognised in the Entre-Sambre-et-Meuse area and tends to disappear northwards (Delcambre & Pingot, 2004).

Thickness. The Philippeville Formation is c. 100–110 m thick in the western part of the Durbuy–Philippeville Anticlinorium, i.e. 103 m in the stratotype and 113 m in the Neuville railway section according to Coen (1977b) and Boulvain et al. (1993d, 1999d), as is the case in its eastern part where similar thicknesses were reported (Barchy & Marion, 2008; Marion & Barchy, in press, a, b). In the anticlines of the western central part of the Dinant Synclinorium (e.g. Beaumont, Renlies), the thicknesses vary between 70–100 m (Préat & Lapierre, 1986; Dumoulin & Marion, 1997a; Dumoulin, 2001; Marion & Barchy, 2004). On the north-western limb of the Dinant Synclinorium, its thickness reaches c. 85 m in the Labuissière area (Hennebert, 2008) and 100 m south of Gerpinnes and in the Hanzinne area (Delcambre & Pingot, 2000b, 2004).

Age. Middle Frasnian. Although poorly constrained due to the rarity of conodonts (Coen, 1977b), Gouwy & Bultynck (2000) and Bultynck & Dejonghe (2002) suggested an interval comprised between the lower part of the *hassi* s.l. conodont Zone and the lower part of the lower *rhenana* conodont Zone. The rugose corals *Hexagonaria mirabilis* (Fig. 8C) and *Peneckiella fascicularis* are typically found in the Cousolre Member whereas *Argutastrea konincki*, *A. lecomptei* and *Tabulophyllum conspectum* (Figs 8E, 9C, D) are abundant in the Thy-le-Bauduin Member (Coen-Aubert, 2009), allowing the correlation of these units with the Rochers de Frênes Member of the Lustin Formation and with the Grands Breux Formation.

Use. The upper part of the Formation (*complexe biostromal*) is still exploited at Merlemont and Franchimont where grey and zebra dolostone is used to produce fertilisers, whereas the yellow dolostone is valorised as paving gravel (Boulvain & Marion, 1994). The light-coloured limestone was largely exploited in the past to produce the *Marbre de Cousolre* in the Entre-Sambre-et-Meuse area (e.g. Groessens, 1981). Locally, the limestone of the Philippeville Formation was used as building stone or to produce aggregates (Boulvain & Marion, 1994; Delcambre & Pingot, 2000b). Near Tohogne, where the Formation is strongly dolomitized, it was quarried as dolomitic sand (Marion & Barchy, in press, a).

Main contributions. Beugnies et al. (1963), Thonnard (1964), Coen (1974, 1977b), Coen & Coen-Aubert (1976), Dejonghe & Mardaga (1989), Dejonghe et al. (1989), Boulvain et al. (1993d, 1994, 1999d), Coen-Aubert (2009).

Pont d'Avignon Horizon

See Nismes Formation.

Pont de la Folle Formation – PFL

Origin of name. After the Pont de la Folle locality, between Philippeville and Samart, *Formation du Pont de la Folle* in Boulvain et al. (1993e, p. 9).

Description. The Pont de la Folle Formation (Fig. 32C) rests on the shaly Nismes Formation. In the western part of the Durbuy–Philippeville Anticlinorium, where it was originally defined, it was subdivided, in ascending order, into the Fontaine Samart and Machenées members (Boulvain et al., 1993e). Later, the Brayelles member was proposed by Dumoulin & Marion (1997a), but overlooked by Boulvain et al. (1999e). The Hymiée Member, originally presented as a local member of the Lustin Formation (Delcambre & Pingot, 2000b), has all the characteristics of the Pont de la Folle Formation with a few peculiarities due to its northern position in the Dinant Synclinorium, close to the transition with the Lustin Formation.

In its type section, the **Fontaine Samart Member – FSA** (*Membre de la Fontaine Samart* in Boulvain et al., 1993e, p. 9; units b–b' in Coen, 1977b, p. 26) is c. 35 m thick (including an 8 m exposure gap) and starts with about ten of metres of light grey limestone with small stromatactis, brachiopods and crinoids of which the upper 5 m are massive and rich in stromatactis, lamellar and bulbous stromatoporoids, crinoids, lamellar tabulate corals (*Alveolites*) and pentameride brachiopods, with an abundant sparitic cement. This massive black-and-white-coloured limestone corresponds to the **Sainte-Anne Facies** or *Marbre Sainte-Anne* (Figs 23, 32C) of the authors (Groessens, 1981), or *niveau R1* in Delcambre & Pingot (2000b). The top of the Member corresponds to 14 m of well-bedded, black and bioclastic limestone becoming gradually more argillaceous upwards (calcshale according to Coen, 1977b) and yielding some solitary rugose corals, brachiopods and crinoids. In the western central part of the Dinant Synclinorium (Barbençon–Boussu-lez-Walcourt, Solre-Saint-Géry and Grandrieu anticlines), the lower part of the Fontaine Samart Member, which includes light-coloured and massive limestone corresponding to the *Marbre Sainte-Anne* of the authors, is dolomitized. This dolostone is named **Brayelles Dolomitic Facies** (*Membre de Brayelles* in Dumoulin & Marion, 1997a, p. 17). It corresponds to a thick package of black, beige or grey-beige saccharoidal and/or pulverulent dolostone with a few ghosts of reef-building organisms which have escaped the dolomitization process (Dumoulin, 2001). This unit, overlying the Nismes Formation, is developed laterally to the *Marbre Sainte-Anne* (see above). It is capped by stromatoporoid-rich bedded limestone belonging to the top of the Fontaine Samart Member.

The **Machenées Member – MAC** (Membre des Machenées in Boulvain et al., 1993e, p. 9; unit c in Coen, 1977b, p. 26) is composed of shale more or less nodular that incorporates some beds of nodular limestone with crinoids and, sometimes, stromatoporoids and lamellar tabulate corals.

On the north-western limb of the Dinant Synclinorium, between Hymiée and Gerpinnes, the Pont de la Folle Formation is represented by the **Hymiée Member – HYM** (*Membre d'Hymiée* in Delcambre & Pingot, 2000b, p. 40) that essentially consists of a succession of two or three reefal carbonate units with metre-thick beds rich in fasciculate rugose corals (*Disphyllum*) at their base; bedded limestone is also present. At Hymiée, the first reefal unit is dolomitized and the top of the Member corresponds to several metre-thick shale beds (<10 m), whereas the latter progressively thins to attain only 1 m north of the Gerpinnes Anticline, before disappearing northwards.

Stratotype and sections. The stratotype of both the Pont de la Folle Formation and the Fontaine Samart and Machenées members is located south-west of Philippeville and corresponds to the eastern trench of the Charleroi–Couvin road (N5–E420), on both sides of the railway bridge, but is largely overgrown nowadays. Other sections have been proposed in the western part of the Durbuy–Philippeville Anticlinorium notably by Dumoulin & Marion (1997b). In the western central part of the Dinant Synclinorium (Barbençon–Boussu-lez-Walcourt and Solre-Saint-Géry anticlines), Dumoulin & Marion (1997a) and Dumoulin (2001) listed a series of important outcrops. The Brayelles Facies has been intersected in two boreholes in Brayelles, 3.5 km north-east of Barbençon (Dumoulin, 2001). The stratotype of the Hymiée Member corresponds to the section along the road from Gerpinnes to Hanzinne (N975), 400 m to the north of the bifurcation leading to the village of Hymiée (Delcambre & Pingot, 2000b); it is complemented by the Evrard quarry (also known as the Société wallonne des eaux quarry) to the south of Gerpinnes (Coen-Aubert, 2009).

Area and lateral variations. The Pont de la Folle Formation is recognised in the north-western part of the Durbuy–Philippeville Anticlinorium (e.g. Boulvain et al., 1993e, 1999e) and, to the south-east of this tectonic structure, it passes laterally to the Moulin Liénaux Formation (Dumoulin & Marion, 1997b). In the eastern part of the Durbuy–Philippeville Anticlinorium, the Pont de la Folle Formation (and its classic members) crops out from the Heure Creek valley, south of Nettine (Barchy & Marion, 2008), up to Tohogne (Coen, 1974; Marion & Barchy, in press, a) where it passes laterally to the base of the Lustin Formation. In the transitional zone between the Durbuy–Philippeville Anticlinorium and the south-eastern limb of the Dinant Synclinorium, the Pont de la Folle Formation passes laterally to the Moulin Liénaux Formation in the Bomal-sur-Ourthe area (Marion & Barchy, in press, a). In this region, the Brayelles Facies is recognised within the Herbet Creek valley (Marion & Barchy, in press, a; Boulvain et al., 2022). It is also reported in different anticlines from the western central part of the Dinant Synclinorium (see above). The Hymiée Member is only known around Gerpinnes; it marks the transition between both usual members of the Pont de la Folle Formation to the south and the basal part of the Lustin Formation to the north.

Thickness. In the type section (Philippeville), the whole formation is c. 90 m thick, with 35 m and 55 m for the Fontaine Samart and Machenées members, respectively (Boulvain et al., 1993e, 1999e); eastwards, it is c. 70 m thick in the Durbuy area with about 20 m for the Machenées Member (Coen, 1974; Marion & Barchy, in press, b). The thickness of the Brayelles Facies varies from 55 m to 75 m between Barbençon and Boussu-lez-Walcourt (Dumoulin, 2001; Dumoulin & Marion, 1997a) and reaches 48 m at Bomal-sur-Ourthe (Boulvain et al., 2022). Delcambre & Pingot (2000b, 2004) estimated the thickness of the Hymiée Member at around one hundred metres.

Age. Early to middle Frasnian. The Pont de la Folle Formation spans the interval of the upper part of the *transitans* up to the lower part of the *hassi* s.l. conodont zones (Coen, 1977b; Bultynck & Dejonghe, 2002). The Machenées Member yielded a characteristic association of rugose corals, namely *Hexagonaria mirabilis* (Fig. 8C), *Scruttonia focantensis*, *S. balconi*, *Mansuyphyllum elongatum*, and *Tabulophyllum mcconelli* (Boulvain et al., 1999e). At Gerpinnes, the rugose coral fauna recognised within the shaly upper part of the Hymiée Member includes *Sinodisphyllum kielcense*, *T. mcconnelli* and *H. mirabilis* (Coen-Aubert, 2009). The presence of *Metabolipa greindli* (Pl. 1.M) in the Fontaine Samart Member (Godefroid in Dumoulin, 2001) has to be noted as this pentameride also occurs in the Moulin Liénaux Formation

(Arche Member).

Use. The massive limestone of the Fontaine Samart Member was used as ornamental stone (*Marbre Sainte-Anne*) in the Entre-Sambre-et-Meuse area (e.g. Groessens, 1981). Several varieties, defined by the size of the fossil fragments and proportions of cement, exist: *Grand Mélange, Petit Mélange* (Fig. 32C). The Hymiée Member was also quarried to produce aggregates (Delcambre & Pingot, 2004).

Main contributions. Maillieux (1926), Beugnies et al. (1963), Thonnard (1964), Delattre et al. (1970), Coen (1974, 1977b), Boulvain et al. (1993e, 1999e, 2022), Dumoulin & Marion (1997a, 1997b), Dumoulin (2001), Delcambre & Pingot (2000b, 2004), Barchy & Marion (2008), Coen-Aubert (2009), Marion & Barchy (in press, a).

Poulseur Member – POU

See Condroz Formation

Prée Member – PEE

See Nismes Formation.

Presles Facies

See Nismes Formation.

Reugnies Member – REU

See Philippeville Formation.

Rhisnes Formation – RHI

Origin of name. After the village of Rhisnes, *Calcaire noduleux de Rhisnes D⁴* (Gosselet, 1860, p. 93).

Description. The dominantly calcareous Rhisnes Formation (Fig. 33) is subdivided into four members of similar thickness, from base to top: the Watiamont, Rocq, Golzinne, and Falnuée members (see below). The base of the Formation corresponds to the first bed of nodular limestone overlying the shale and argillaceous limestone of the Bovesse Formation whereas its top is placed at the last limestone bed underlying the shale of the Franc-Waret Formation.

The **Watiamont Member – WAT** (*Membre de Watiamont* in Hennebert & Eggermont, 2002, p. 22, from unpublished Lacroix's (1972) data) is composed of nodular, blue-grey, bioclastic limestone becoming yellowish grey where weathered (Fig. 33A). It is generally fossiliferous and includes brachiopods and corals. The nodular aspect is particularly well developed where the limestone is weathered and is due to the presence of thin, irregular argillaceous beds. Some beds are partially dolomitized and brownish.

The **Rocq Member – RCQ** (*Membre de la Rocq* in Doremus & Hennebert, 1995a, p. 9) consists of well-bedded, grey to dark grey, fine-grained limestone, of which the bed thickness varies between 20 and 30 cm, separated by 10–20 cm thick beds of marlstone and grey to greenish-grey calcareous shale. This member is relatively fossiliferous and yields locally numerous colonial rugose corals. This name should not be confused with the *psammite de la Roq* introduced by Mourlon (1875b, p. 789), which corresponds to the Famennian Bois de la Rocq Formation (see this name).

The **Golzinne Member – GOL** (*marbre noir de Golzinne* in d'Omalius d'Halloy, 1839, p. 448) consists of very fine-grained black limestone (mostly mudstone and wackestone) (Fig. 33B–C) that is well stratified into sub-metric beds separated by thick intercalations of dolomitic limestone with a brecciated appearance, shale and marlstone. Besides gastropods, fossils are scarce; some vertical burrows occur. In the type area, the 'marble' beds are grouped into two 'veins' of unequal plurimetric thickness separated by an intercalation of argillaceous limestone (Dumon, 1933).

The **Falnuée Member – FLN** (*Calcaire de la ferme Fanué, D²* in Gosselet, 1860, p. 93) is similar to the Watiamont Member and includes nodular shale and nodular limestone, locally very rich in cyrtospiriferid brachiopods forming coquina beds as is also the case of large gastropods. The limestone is greyish to brownish where weathered.

Stratotype and sections. As emphasised by Lacroix (1999d), there is no stratotype for the whole Rhisnes Formation due to the lack of good outcrops in the type area. Nevertheless, type sections and parastratotypes were proposed for each member. The Watiamont Member is well exposed on the right bank of the Sennette River valley, just to the north of Watiamont (Lacroix, 1999d; Hennebert & Eggermont, 2002, p. 22). The type section of the Rocq Member corresponds to the disused quarry on the western bank of the Samme River valley situated in front of the La Roque castle and the outcrops located just east of this building, north of Feluy (Lacroix, 1999d, Hennebert & Eggermont, 2002). The underground quarries situated to the south-west of Golzinne and to the east of Mazy (Dumon, 1933; Delcambre & Pingot, 2008) expose the Golzinne Member. Outcrops exhibiting the upper part of the Falnuée Member, close to the old eponymous farm, are situated in the Orneau River valley, south of Mazy (Delcambre & Pingot, 2008), whereas the disused La Rocq quarry (see above) also exposes this member (Hennebert & Eggermont, 2002).

Area and lateral variations. The Rhisnes Formation occurs in a large part of the Brabant Parautochthon and comes up against the Landenne Fault, east of Houssoy (Vezin Syncline) (Delcambre, 2023). East of this hamlet, it disappears and is replaced by the Huccorgne Formation in the Lavoir–Huccorgne Syncline (Delcambre, 2023). From the Orneau River valley and eastwards, the Golzinne Member replaces the Rocq Member, but thins considerably eastwards as reflected by the few black, thinly bedded limestone reported by Delcambre (2023) in one of the disused quarries situated north-east of Ville-en-Waret. Besides the Tournai and Leuze boreholes that fully drilled the Rhisnes Formation (Coen-Aubert et al., 1981), the latter was not totally penetrated in several boreholes located in the western part of the Brabant Parautochthon, where the limestone is generally dolomitized (e.g. Chabot & Laurent, 1973; Dusar & Loy, 1986; Doremus & Hennebert, 1995b; Laenen, 2003).

Thickness. In the Orneau River valley, the Rhisnes Formation is c. 110–135 m thick, with c. 30–45 m for the Watiamont Member, c. 20 m for the Golzinne Member, and 60–70 m for the Falnuée Member (Delcambre & Pingot, 2008). In its easternmost extension, its tripartite subdivision is unclear due the lack of outcrops and its thickness is estimated at 100 m (Delcambre, 2023). Westwards, in the Samme River and Sennette River valleys, Hennebert & Eggermont (2002) suggested 80–85 m for the thickness of the whole formation, with c. 20–35 m for the Watiamont Member, c. 15–25 m for the Rocq Member, and c. 15–20 m for the Falnuée Member. In the Senne River valley, Doremus & Hennebert (1995a) proposed a thickness of c. 120 m for the entire Rhisnes Formation with a subequal thickness for the three aforementioned members. It is just 13 m thick in the Tournai borehole where it is only represented by its base, but much thicker (83 m) in the nearby Leuze borehole (Coen-Aubert et al., 1981; Coen-Aubert & Lacroix, 1985).

Age. Middle Frasnian. Lacroix (1999d) reported the presence of the rugose corals *Hexagonaria mirabilis* and *Wapitiphyllum mahaniense* (Figs 8C, 9F) in the Watiamont and

Figure 33. Illustration of the Rhisnes Formation. **A.** Argillaceous limestone with brachiopods, Rhisnes Formation (Watiamont Member). Mazy, section along the road N93. **B.** Blocks of deeply black limestone (*Marbre noir de Golzinne*), characteristic of the Golzinne Member (Rhisnes Formation), that has been freshly mined from the last working underground quarry in Mazy. **C.** Jube of the Saint-Aubain cathedral (19th century) at Namur, consisting of *Marbre noir de Golzinne* (Golzinne Member, Golzinne), *Marbre jaspé de Saint-Remy* (Petit-Mont Member of the Marche-en-Famenne Formation, Rochefort), and Carrara marble (Italy, Tuscany).

Rocq members that allow correlating the Rhisnes Formation with the Huccorgne Formation and indicates a middle Frasnian age.

Use. The limestone of the Rocq Member was intensively exploited in the Samme River valley for the production of building and ornamental stone (*Marbre Sainte-Anne* and *Marbre Saint-Jean*, Groessens, 1981; Hennebert & Eggermont, 2002), whereas in the Namur area, that of the Watiamont Member was used to produce lime as was the case of the limestone of the Falnuée Member (Malaise, 1875). The latter also served for cement and building stone rock production (Delcambre & Pingot, 2015). In Dutch it is popularly known as leopard stone (*luipaardsteen*) because of the patchy distribution of light-coloured calcareous nodules surrounded by more argillaceous limestone (De Ceukelaire et al., 2014). Five beds of black limestone of the Golzinne Member, forming a 3.5 m thick set, are exploited under the names *noir de Golzinne*, *noir de Mazy* or *noir belge* in the Mazy underground quarry (Fig. 33B) (Dumon, 1933; Tourneur, 2020), plus a sixth which was used as a floor for the mine galleries.

Main contributions. Kaisin (1912, 1935), Dumon (1933), Asselberghs (1936), Mamet (1964a, 1964b), Vandamme (1981), Netels (1989), Doremus & Hennebert (1995a), Lacroix (1999d), Delcambre & Pingot (2008, 2015), Boulvain et al. (2020), Tourneur (2020), Delcambre (2023).

Richelle Facies

See Lustin Formation (Rochers de Frênes Member).

Rivage Facies

See Condroz Formation (Montfort Member).

Robiewez Member – RWB

See Huccorgne Formation.

Rochers de Frênes Member – RFR

See Lustin Formation.

Rocq Member – RCQ

See Rhisnes Formation.

Royseux Facies

See Condroz Formation (Évieux Member).

Sains Member – SNS

See Condroz Formation.

Sainte-Anne Facies

See Lustin Formation (Gougnies Member) and Pont de la Folle Formation (Fontaine Samart and Hymiée members).

Samme Group – SAM

Origin of name. After the Samme River, *Formation de la Samme* in Doremus & Hennebert (1995a, p. 11).

Content. This unit was originally introduced by Doremus & Hennebert (1995a) as a Famennian (Strunian)–Tournaisian (Hastarian) formation composed of three members, in ascending order: the Bois de la Rocq, Feluy and Mévergnies members. Delcambre & Pingot (2008) have promoted the Bois de la Rocq Member to the formation status as it can be traced all along the Brabant Parautochthon, whereas the other two are restricted to the Dendre River and Sennette River valleys. Consequently, these other two units, characterised by distinct lithologies, are also considered herein as formations within the Samme Group: the Feluy and Mévergnies formations, both of Hastarian age.

Type area. Discontinuous section in the Samme River valley between Feluy and La Rocq (or La Roque) (Doremus & Hennebert, 1995a).

Senzeille formation or member

Disused unit of the former Famenne formation; see Marche-en-Famenne Formation.

Sourd d'Ave Member – SAV

See Nismes Formation.

Souverain-Pré Formation – SVP

Origin of name. After the hamlet of Souverain-Pré, south of Esneux, *Assise du macigno noduleux de Souverain-Pré* in Mourlon (1875a, p. 648).

Description. The Souverain-Pré Formation (Fig. 34) consists of beds of limestone, fine-grained sandstone and siltstone that are all particularly rich in calcareous nodules. Micaceous siltstone beds, similar to those of the Esneux Formation, separate the nodular horizons. The nodules are frequently aligned along the stratification and deformed by the cleavage (Fig. 34A). They result of a pressure-dissolution process giving rise to a stylobreccia. The dissolution of the nodules due to weathering processes gives a characteristic cellular appearance to the different lithologies of the Souverain-Pré Formation. In the Dinant Synclinorium and the Vesdre area (western part), the base of the Formation is close to the oolitic ironstone horizon IV (Dreesen, 1982a, 1982b, 1989a) that laterally grades into a thin phosphatised black-coloured microstromatolitic hardground (Dreesen et al., 2013, fig. 3) in the eastern part of the Vesdre area. In the Dinant Synclinorium, the Souverain-Pré Formation passes gradually to the sandier and more inshore Ciney Member of the Condroz Formation.

The **Baelen Member – BAE** (*Marbre rouge, gris et blanc de Baelen ou Bailou* in Davreux, 1833, p. 154) (Fig. 34B–C) is only developed around the village of Baelen in the Vesdre area. Since Dewalque (1881) and Dewalque (in Forir & Dewalque, 1881), it has been known as the *Marbre rouge de Baelen* which corresponds to the red-coloured core of a mound complex (Dreesen & Flajs, 1984; Marion, 1984; Dreesen et al., 1985). The Baelen Member is a heterogeneous limestone complex consisting of nodular to lenticular calcimicrobial packstone and massive stromatactis-bearing microbialitic mudstone, interfingered with lenticular crinoidal grainstone or rudstone (Dreesen et al., 2013). Silty nodular bioclastic wackestones-packstone, strongly affected by pressure solution (called 'peastone' (*pierre poitée*) (Fig. 34C), due to the presence of countless white circular sections of the crinoid ossicles resembling peas), marks the transition with the laterally developed stylonodular facies characteristic of the the Souverain-Pré Formation and also occurs as interbeds within the mound core. The pink to red-coloured stromatactis-bearing massive limestone is of 'marble' quality, strongly resembling the classical Frasnian red marbles of Belgium, but are clearly distinguished by the scarcity of brachiopods, the absence of stromatoporoids and tabulate corals and the extreme scarcity of rugose corals (Dreesen et al., 2013; Vachard et al., 2017). Its base is placed at the first entry of thick, lenticular and coarse-grained crinoidal grainstone–rudstone and its top at the (re-) appearance of silty nodular limestone of the Souverain-Pré facies and/or micaceous sandstone of the Poulseur Member of the Condroz Formation, respectively (Dreesen et al., 2013).

Stratotype and sections. The locus typicus of the *Macigno noduleux de Souverain-Pré* (Mourlon, 1875a) is located along the platform of the former Souverain-Pré railway station (Bellière, 2015), between Esneux and Poulseur in the Ourthe River valley. However, the base of the Formation is not exposed there. A parastratotype, displaying the whole formation, was proposed by Dreesen (1978) and corresponds to the railway trench situated to the south of the disused Haversin station, between the km 102.6 and 101.3 (Boulvain et al., 1995). The locus typicus of the Baelen Member is at Les Forges (Laloux et al., 1996b), a hamlet of the village of Baelen.

Area and lateral variations. The Souverain-Pré is recognised in the Dinant Synclinorium, Vesdre area, and Theux Window but it lacks in proximal areas (Bocq River and Samson River valleys) as well as in the Haine–Sambre–Meuse Overturned Thrust sheets. The presence of the Baelen Member is restricted to the eponymous area (Dreesen, 1978; Dreesen et al., 1985; Laloux et al., 1996b). Stainier (1894) indicated the occurrence of red crinoidal limestone in the Famennian strata of the Lesse River valley near Gendron that might correspond to a facies similar to the Baelen Member. This outcrop is no longer visible and it is not possible to confirm this observation.

Thickness. The Souverain-Pré Formation, which is rather thin in its incomplete historical type section, varies from 10 to 30 m thick in the Ourthe River valley (Bellière, 2015), but it reaches its maximum thickness in the western part of the Dinant Synclinorium (120 to 180 m in the Silenrieux area, Bouckaert & Dreesen, 1977). It is very thin or absent on its northern limb as observed in the Hoyoux River valley: c. 10 m at Pont-de-Bonne, only 4 m at Chabôfosse (Barchy & Marion, 2018) and absent at Royseux (Mottequin et al., 2021). In the Vesdre area, Dreesen et al. (1985) and Laloux et al. (1996b) suggested 80 to 100 m and up to 150 m for the thickness of the Baelen Member, respectively, whereas that of the Souverain-Pré Formation varies between 20 and 150 m depending on the encountered facies (Laloux et al., 1996b). In the Theux Window, its thickness varies between 20 and 40 m (Dusar & Dreesen, 1977; Marion et al., in press).

Age. Middle Famennian. Its range spans the interval of the lower *marginifera* to the lower *trachytera* conodont zones, but the conodonts clearly indicate the diachronism of its base within the Dinant Synclinorium (for more details, see Dreesen, 1978). The monotonous conodont faunas of the Baelen Member suggest the (upper?) *marginifera* conodont Zone (Dreesen, 1978). Corals are very rare, dominated by simple solitary forms such as *Catachtotoechus* sp. (Fig. 11D) (Denayer et al., 2012).

Remark. Where natural outcrops of the Souverain-Pré Formation are rare, its presence can be deduced from the development of springs (Bellière, 2015); elsewhere, especially in the southern part of the Condroz, it protrudes from the underlying shale and siltstone of the neighbouring formations. Moreover, the Souverain-Pré Formation marks the re-appearance of carbonate facies after the collapse of the carbonate factory at the end of the Frasnian. According to

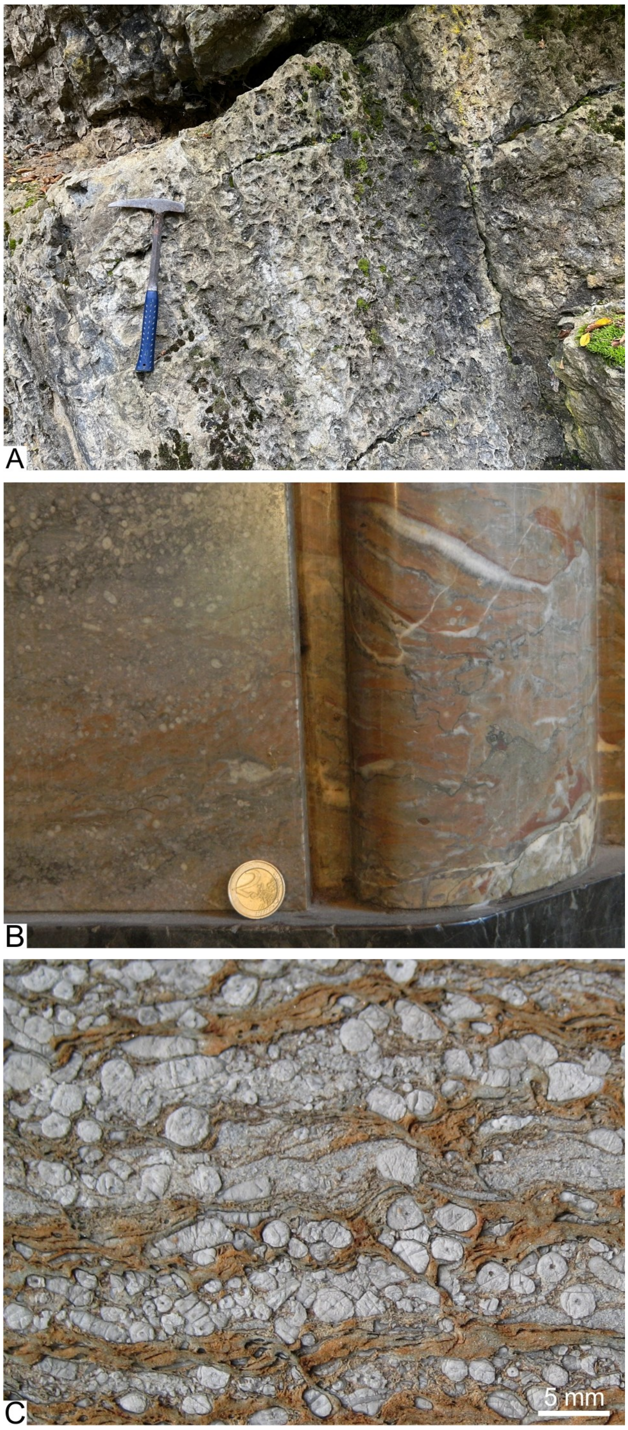

Figure 34. Illustration of the middle Famennian Souverain-Pré Formation. **A.** Stylonodular limestone. Pont-de-Bonne, Limonaderie section. **B.** Polished slab of Baelen mudmound core facies (Baelen Member) showing stromatactoid structures and crinoid ossicles. Verviers station, ticket-window ledge. **C.** Weathered surface of a building stone made of *pierre poitée*, displaying the stylocumulated fabric with many crinoid ossicles. Baelen, *Home Saint-Joseph* (from Dreesen et al., 2013).

Dreesen et al. (1985, 2013), the Baelen Member is the only Famennian mudmound complex in Belgium and probably the only well-documented, red-coloured crinoid–sponge–calcimicrobe buildup complex of middle Famennian age worldwide (Aretz & Chevalier, 2007).

Use. Most calcareous beds were exploited very locally for artisanal lime production, notably in the Sivry area and at Gomzé (Sprimont) (Marion & Barchy, 2004; Marion et al., in press). The Baelen Member (Fig. 34B–C) was quarried both in underground and in open-pit quarries as an ornamental stone since the Antiquity but was also used to produce facing stones and even cobbelstones (Dreesen et al., 2013). These rocks were known as *Marbre (rouge) de Baelen*, *Marbre de Bailou*, *Jaspe de Baelen* and, for the most crinoid-rich parts, as *Pierre poitée* (Dreesen et al., 2013, 2015; Coquelet et al., 2020).

Main contributions. Bellière (1953), Dreesen (1977, 1978, 1986), Groessens (1981), Marion (1984), Dreesen & Flajs (1984), Dreesen et al. (1985, 2013, 2015), Laloux et al. (1996b), Aretz & Chevalier (2007), Vachard et al. (2017).

Su Wary formation

Disused unit, integrated to the Lustin Formation.

Tchafornis Member – TCH

See Aisemont Formation.

Thy-le-Bauduin Member – THY

See Philippeville Formation.

Valisettes Member – VAL

See Marche-en-Famenne Formation.

Verviers Member – VER

See Lambermont Formation.

Watiamont Member – WAT

See Rhisnes Formation.

Watissart Member – WTS

See Esneux Formation.

Wérin member

Informal member of the former Valisettes formation introduced by Coen-Aubert (1994).

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Author contribution

JD and BM conceptualised the synopsis, BD, JD, JMM, BM and EP revised the field data, JD and BM contributed to the writing of the manuscript and the preparation of figures, BD, JMM and EP brought their long-standing expertise and improved the text.

Data availability

The rock and fossil samples figured here are part of the collections of the Royal Belgian Institute of Natural Sciences (prefixed RBINS, Brussels), Service géologique de Wallonie, University of Liège (prefixed PAULg, Liège), and Musée Gosselet (prefixed MGL, Lille).

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Plate 1. Lower Frasnian atrypide (A–D), athyridide (E) and spiriferide (F–K) brachiopods from the Nismes Formation (except otherwise stated). All are articulated specimens in ventral view.

A. *Desquamatia* (*Seratrypa*) *pectinata* (RBINS a2391); Sourd d'Ave, Sourd d'Ave Member. **B.** *Desquamatia* (*Seratrypa*?) *suppinguis* (RBINS a2420, holotype); Nismes, Pont d'Avignon Horizon. **C.** *Desquamatia* (*Neatrypa*) *gosseleti* (RBINS a2441, holotype); Nismes, Sourd d'Ave Member. **D.** *Desquamatia* (*Neatrypa*) *europaea*, (RBINS a2448); Wellin, Sourd d'Ave Member. **E.** *Anathyris* (*Anathyris*) *calestiennensis*, (RBINS a13023, holotype); Belvaux, Prée Member. **F.** *Uchtospirifer*? *fraiponti* (RBINS a8195); Nismes, Sourd d'Ave Member. **G.** *Geminisulcispirifer bisinus* (RBINS a2301, lectotype; from Mottequin, 2019); Givet, Prée Member. **H.** *Apousiella comprimata* (RBINS a14088); Malonne. **I.** *Subquadriangulispirifer malaisi* (RBINS a2323); Boussu-en-Fagne, Prée Member. **J.** *Eodmitria oblivialis oblivialis* (RBINS a2324, holotype); Sy, Pont d'Avignon Horizon. **K.** *Eodmitria oblivialis grandis* (RBINS a2335, holotype); Ronquières, Bovesse Formation (Bossières Member).

Middle Frasnian atrypide (L, N–Q), pentameride (M), spiriferide (R), rhynchonellide (S–T) brachiopods and trilobites (U–X) from the Moulin Liénaux Formation. All brachiopods are articulated specimens in ventral view.

L. *Atryparia* (*Costatrypa*) *eremitae* (RBINS a10669, holotype); Boussu-en-Fagne, Chalon Member. **M.** *Metabolipa greindli* (RBINS a222, lectotype; from Mottequin, 2019), Frasnes-lez-Couvin, Arche Member. **N.** *Desquamatia* (*Seratrypa*) *frasniensis* (RBINS a1905, holotype); Frasnes-lez-Couvin, Arche Member. **O.** *Atryparia* (*Costatrypa*) sp. A (RBINS a10596); Boussu-en-Fagne, Ermitage Member. **P.** *Atryparia* (*Costatrypa*) *fossae* (RBINS a10678, holotype); Boussu-en-Fagne, Ermitage Member. **Q.** *Atryparia* (*Costatrypa*) *lecomptei* (RBINS a10674, holotype); Boussu-en-Fagne, Ermitage Member. **R.** *Dionacoelia secessus* (RBINS a12111, holotype); Boussu-en-Fagne, Ermitage Member. **S.** *Plionoptycherhynchus exformosus* (RBINS a1782, holotype); Givet, Ermitage Member. **T.** *Sthenarirhynchus dionanti* (RBINS a10764, holotype); north of Marloie, Ermitage Member. **U.** *Bradocryphaeus mosanus* (RBINS a7789, holotype), pygidium in dorsal view; Givet, near the Fort Condé, Ermitage Member. **V.** *Bradocryphaeus maillieuxi*, internal mould of a cephalon in dorsal view (RBINS a7800, paratype); Nismes, Ermitage Member. **W–X.** *Heliopyge helios*; Nismes, Ermitage Member. W. internal mould of a complete specimen in dorsal view (RBINS a7807, paratype). X. external mould of a pygidium (RBINS a7808, holotype).

All specimens are whitened with ammonium chloride sublimate.

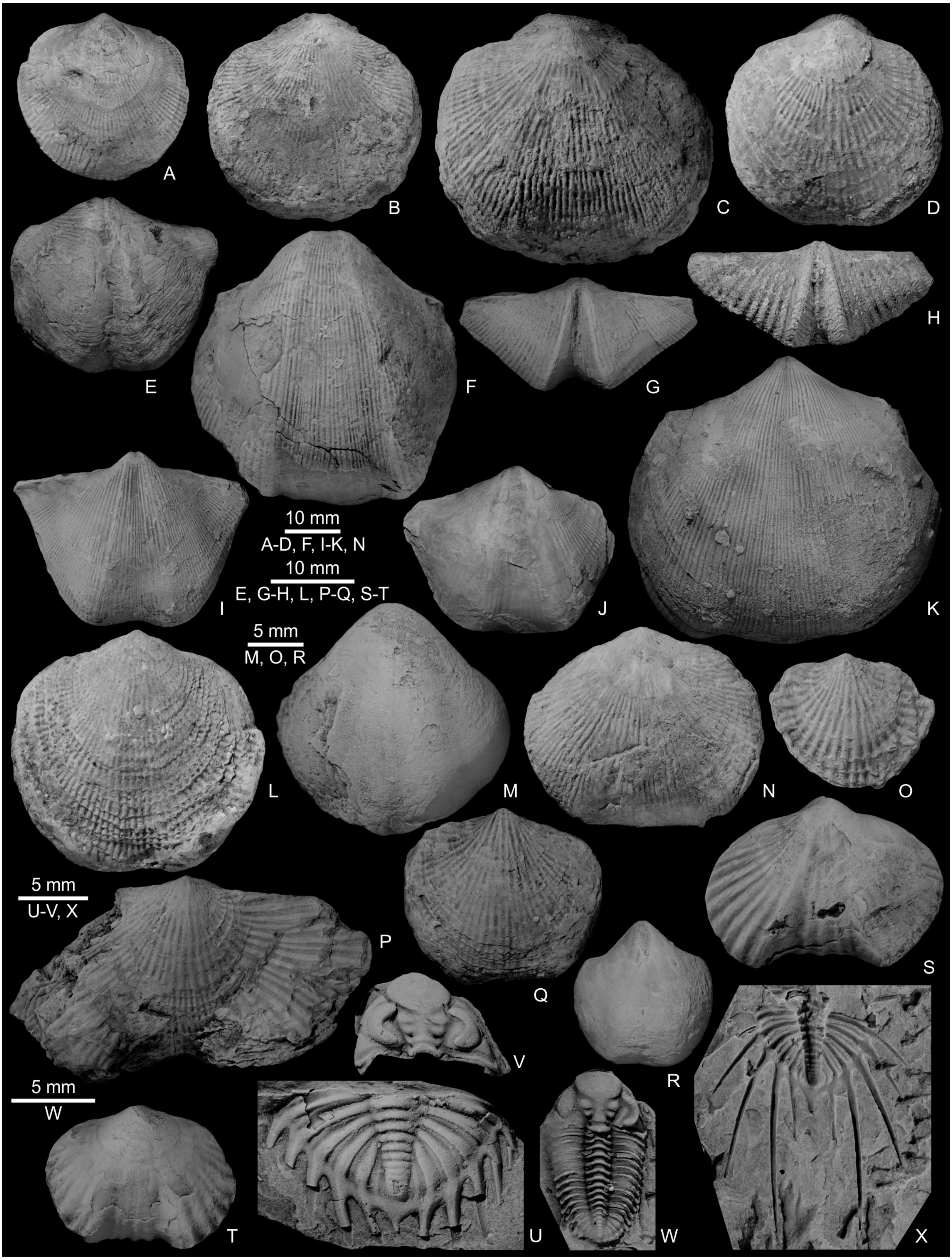
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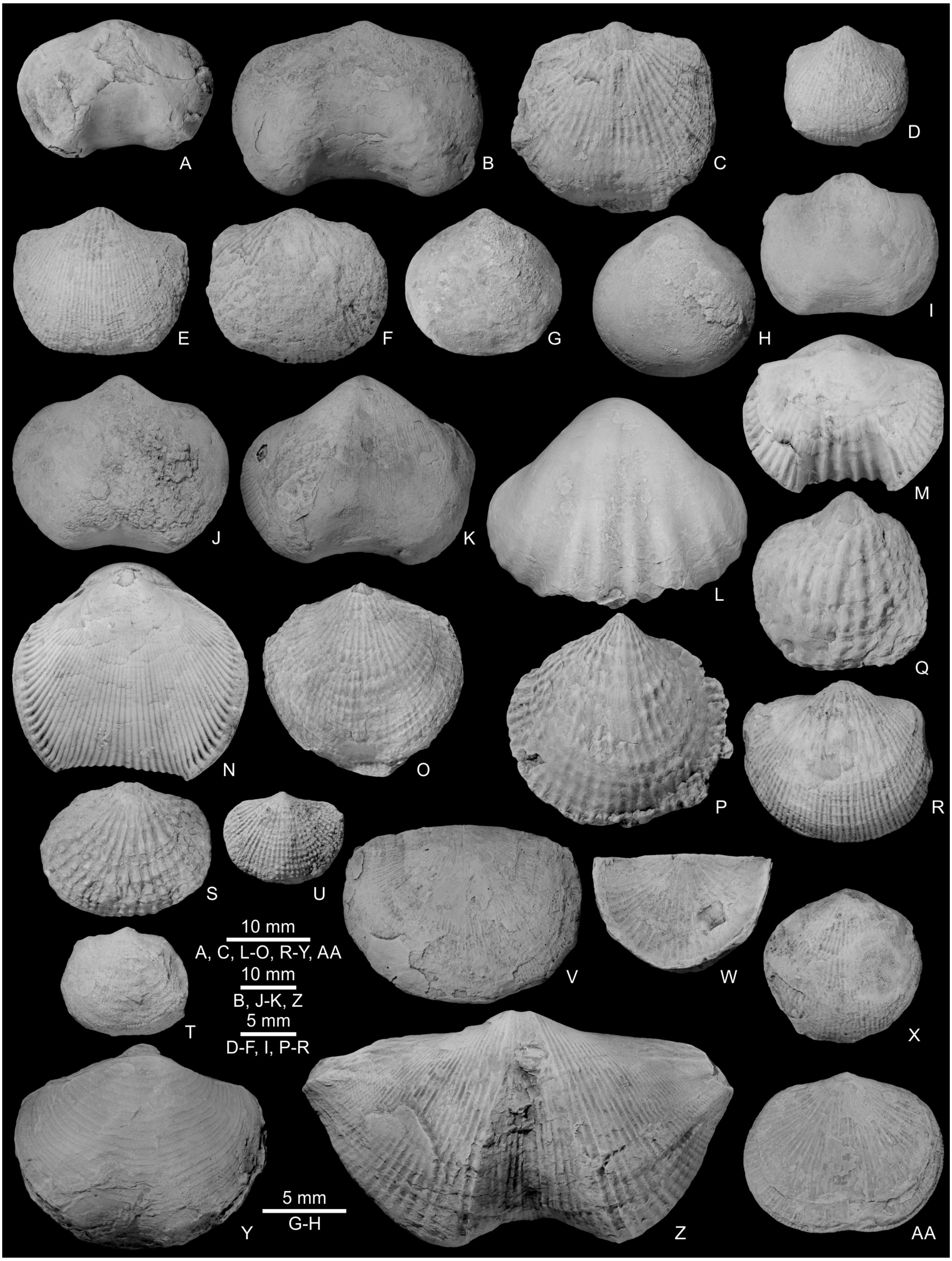
Plate 2. Upper Frasnian rhynchonellide (A–B, M–N), atrypide (C–F, O–U, X), athyridide (G–H, Y), spiriferide (I–K, Z), pentameride (L) and strophomenide (V–W) brachiopods and lower Famennian orthotetide brachiopod (AA) from the Marche-en-Famenne Formation (Neuville Member: A–K; Petit-Mont Member: L–R; Valisettes Member: S–U; Barvaux Facies: V–Z; Famenne Member: AA). All are articulated specimens in ventral view and whitened with ammonium chloride sublimate.

A. *Navalicria compacta* (RBINS a3006, holotype); Frasnes-lez-Couvin. **B.** *Calvinaria megistana* (RBINS a2760, neotype); Durbuy 8319 (from Mottequin, 2019). **C.** *Pseudoatrypa godefroidi* (RBINS a12228, holotype); Neuville. **D.** *Iowatrypa circuitionis* (RBINS a10598, holotype); Frasnes-lez-Couvin. **E.** *Iowatrypa* cf. *circuitionis* (RBINS a10605); Frasnes-lez-Couvin. **F.** *Wayotrypa*? *pluvia* (RBINS a10606, holotype); Frasnes-lez-Couvin. **G.** *Neptunathyris buxi* (RBINS a12330, holotype); Nismes. **H.** *Biernatella abunda* (RBINS a12015, holotype); Vaulx. **I.** *Thomasaria* cf. *altumbona* (RBINS a12304); Vaulx. **J.** *Warrenella* (*Warrenella*) *aquaealbae* (RBINS a12299, holotype); Nismes. **K.** *Tiocyrspis bironensis* (RBINS a8309; holotype); Durbuy 8308. **L.** *Neometabolipa duponti* (RBINS a257, holotype); Boussu-en-Fagne. **M.** *Parallelepipedorhynchus trapezoides* (RBINS a12168); Boussu-en-Fagne. **N.** *'Hypothyridina'* sp. (RBINS a14089); Boussu-en-Fagne. **O.** *Desquamatia* (*Seratrypa*?) *derelicta* (RBINS a10617, holotype); Boussu-en-Fagne. **P.** *Spinatrypina* (*Spinatrypina*?) cf. *comitata* (RBINS a10595); Boussu-en-Fagne. **Q.** *Spinatrypa* (*Isospinatrypa*?) *tumuli* (RBINS a10593, holotype); Boussu-en-Fagne. **R.** *Iowatrypa rotundicollis* (RBINS a9351, holotype); Roly. **S.** *Spinatrypina* (*Exatrypa*) *marmoris* (RBINS a12240, holotype); Soumoy. **T.** *Iowatrypa philippevillensis* (RBINS a11993, holotype); Cerfontaine. **U.** *Waiotrypa*? sp. (RBINS a12248); Neuville. **V.** *Douvillina area* (RBINS a12398, holotype); Barvaux-sur-Ourthe. **W.** *Retrorstrophia retrorsa* (RBINS a12415); Barvaux-sur-Ourthe. **X.** *Iowatrypa ultima* (RBINS a11948, holotype); Hérock. **Y.** *Cleiothyridina* sp. A (RBINS a12328); Deulin. **Z.** *Cyrtospirifer ambosulcatus* (RBINS a10299, holotype); Barvaux-sur-Ourthe (from Mottequin, 2019). **AA.** *Floweria pseudoelegans* (RBINS a12427); Senzeille.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G-H

Plate 3. Pentameride (A–C), atrypide (D–H, T–V), athyridide (I) and rhynchonellide (S) brachiopods, crinoids (K–L), incertae sedis (M), ammonoids (N–O), bivalves (P–Q) and graptolite (R) from the Frasnian of southern Belgium. All brachiopods are articulated specimens in ventral view; all specimens were whitened with ammonium chloride sublimate (except otherwise stated).

A. *Neometabolipa delhayei* (RBINS a283, holotype); Frasnes-lez-Couvin, Lion Member. **B.** *Physemella maillieuxi* (RBINS a298, holotype); Frasnes-lez-Couvin, Lion Member. **C.** *Neometabolipa broecki* (RBINS a223 lectotype; from Mottequin, 2019); Couvin 8174 (45), Lion Member. **D–E.** *Atryparia* (*Costatrypa*) *variabilis*; Boussu-en-Fagne, Boussu-en-Fagne Member. D. RBINS a14090, with long trail preserved. E. RBINS a1884 (holotype). **F.** *Desquamatia* (*Desquamatia*) *quieta* (RBINS a10614); Boussu-en-Fagne, Boussu-en-Fagne Member. **G.** *Desquamatia* (*Desquamatia*) *alticoliformis* (RBINS a10611); Boussu-en-Fagne, Boussu-en-Fagne Member. **H.** *Spinatrypina* (*Exatrypa*?) sp. (RBINS a10597); Boussu-en-Fagne, Boussu-en-Fagne Member. **I.** *Dicamara plutonis* (RBINS a11187, holotype); Boussu-en-Fagne, Boussu-en-Fagne Member. **J.** *Melocrinites dorlodoti*, calyx (RBINS a9572, holotype); Boussu-en-Fagne, Boussu-en-Fagne Member. **K.** *Hexacrinites faniensis* (RBINS a10302, holotype); Senzeille, Beauchâteau quarry. **L.** *Melocrinites dewalquei* (fide Maillieux) (RBINS 14091); Senzeille, Beauchâteau quarry. **M.** *Receptaculites* sp. (RBINS a14092); Vodecée. **N.** *Manticoceras cordatum* (fide Matern, 1931), internal mould in lateral view (RBINS a14093); Boussu-en-Fagne. **O.** *Crickites rickardi*, internal mould in lateral view (uncoated) (RBINS a1703, holotype); Surice 5461. **P.** Buchiolid bivalves (RBINS a14094); Matagne-la-Grande. **Q.** *Glyptohallicardia* sp. (RBINS a14095); Boussu-en-Fagne. **R.** *Callograptus* sp., almost complete specimen (RBINS a13822); Lompret quarry (from Mottequin et al., 2023). **S.** *Ryocarhynchus tumidus*, articulated specimen in ventral, lateral and anterior views (RBINS a10301A) (from Mottequin, 2019); Sautour 7605. **T.** *Spinatrypa* (*Spinatrypa*) *lambermontensis* (RBINS a11959, holotype); Lambermont. **U.** *Spinatrypa* (*Spinatrypa*) sp. (RBINS a11970); Hony. **V.** *Radiatrypa* sp. (RBINS a12234); Hony.

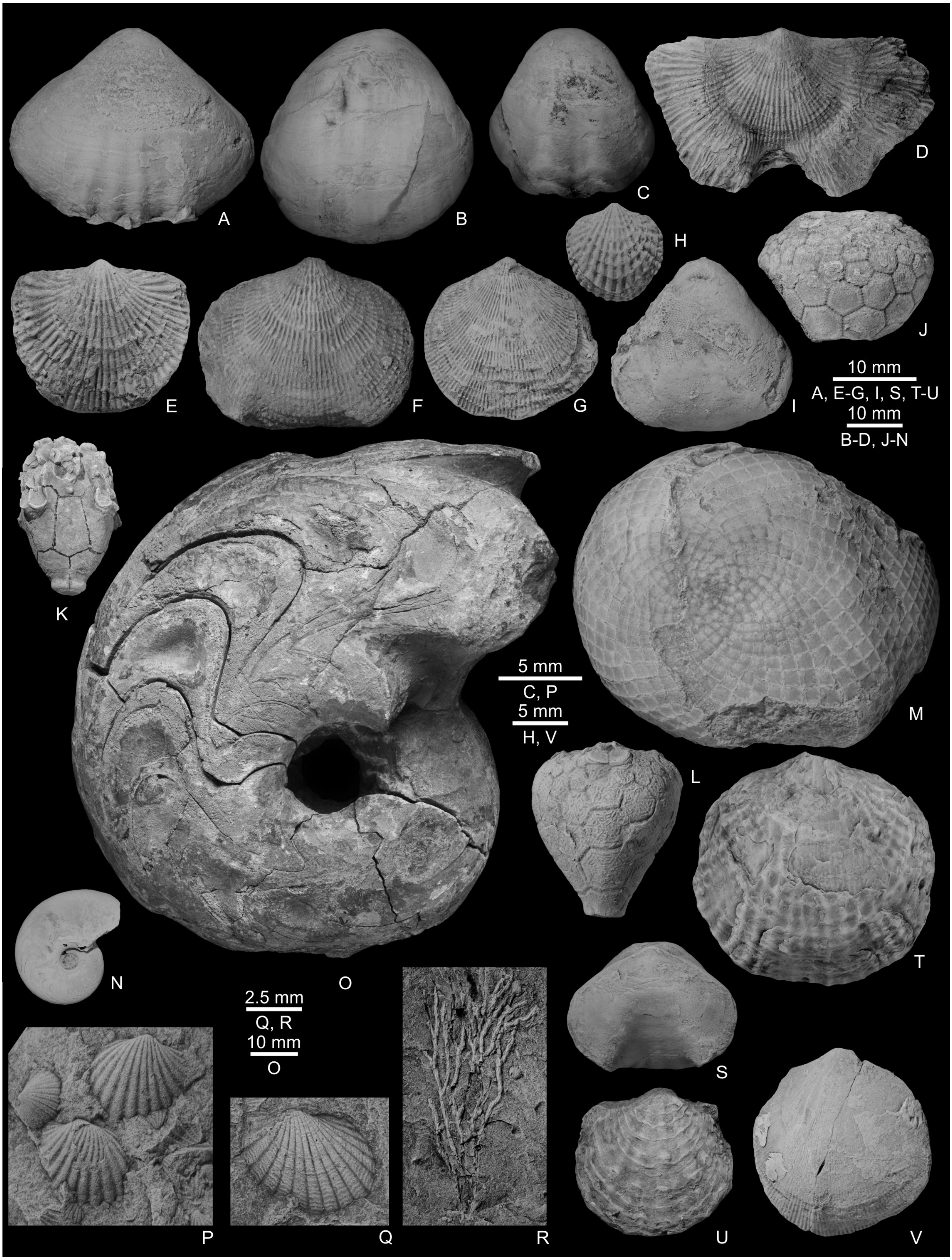
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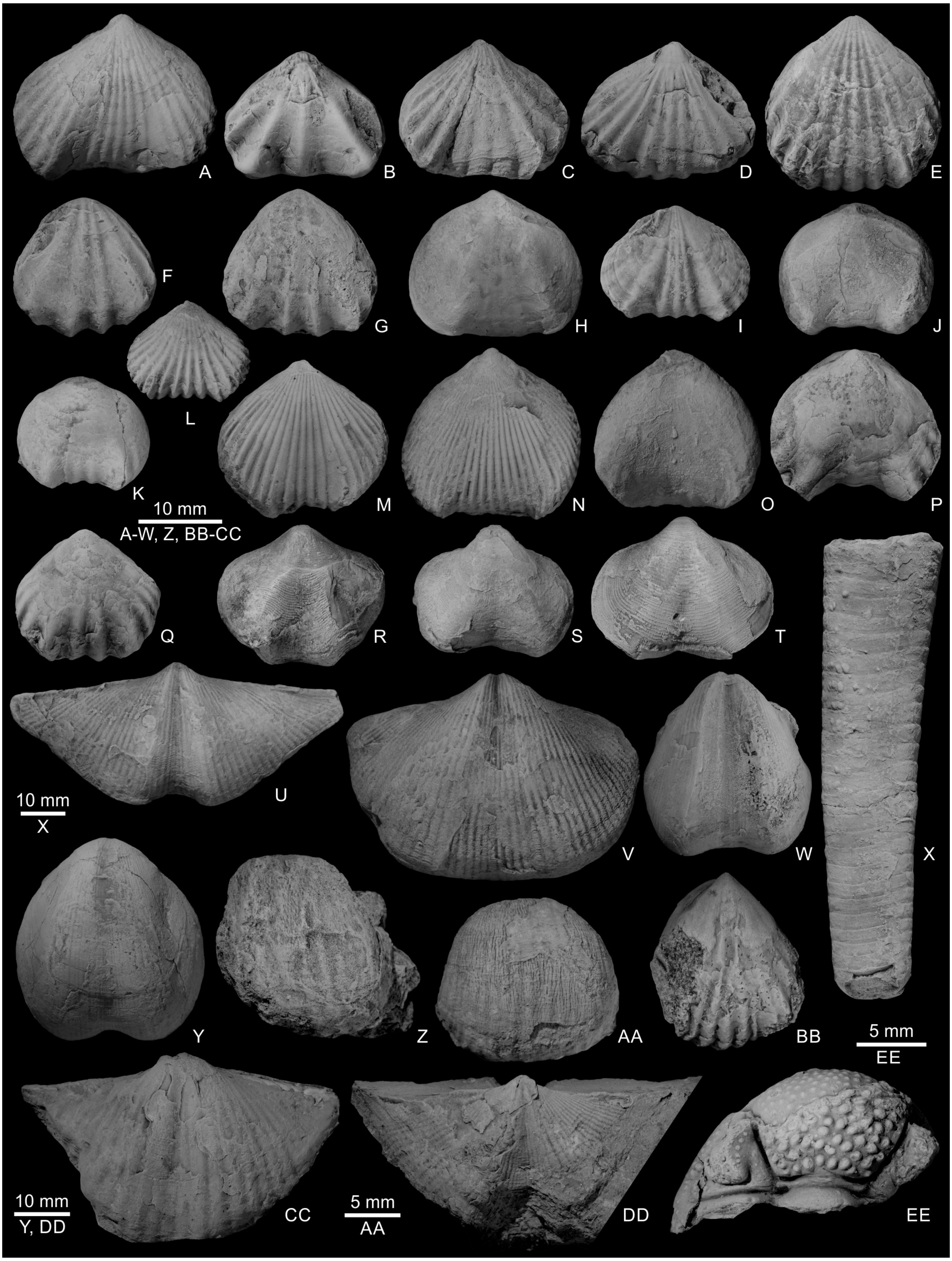
Plate 4. Lower Famennian rhynchonellide (A–Q), athyridide (R–T) and spiriferide (U–W, Y) brachiopods and orthoconic cephalopod (X) from the Famenne Member of the Marche-en-Famenne Formation. All brachiopods are articulated specimens in ventral view.

A. *Piridiorhynchus confinium* (RBINS a11447, holotype); Sinsin. **B.** *'Camarotoechia' akrosteges* (RBINS a11100); Senzeille. **C.** *Pampoecilorhynchus lecomptei* (RBINS a11096) holotype); Senzeille. **D.** *Pampoecilorhynchus praenux* (RBINS a11197, holotype); Houyet 2535. **E.** *Pampoecilorhynchus nux* (RBINS a11187); Haversin. **F.** *Eoparaphorhynchus triaequalis praetriaequalis* (RBINS a11165, holotype); Senzeille. **G.** *Eoparaphorhynchus triaequalis triaequalis* (RBINS a11156); Senzeille. **H.** *Tenuisinurostrum crenulatum* (RBINS a14096); Senzeille. **I.** *Eoparaphorhynchus lentiformis* (RBINS a11144); Senzeille. **J.** *Paromoeopygma bellicastellana* (RBINS a11436, holotype); Senzeille. **K.** *Dimensionaequalirostrum pileum*, (RBINS a2226, holotype); Senzeille. **L.** *Ptychomaletoechia omaliusi* (RBINS a11211); Senzeille. **M.** *Ptychomaletoechia gonthieri* (RBINS a14097); Han-sur-Lesse 59/2 3a. **N.** *Ptychomaletoechia dumonti* (RBINS a14098); Senzeille. **O.** *Cavatisinurostrum faniae* (RBINS a209, holotype); Senzeille. **P.** *Evanescirostrum alblinii* (RBINS a11134, holotype); Senzeille. **Q.** *Basilicorhynchus basilicus gerardimontis* (RBINS a11123, holotype); Senzeille. **R.** *Crinisarina angelicoides* (RBINS a12273); Senzeille. **S.** *Crinisarina stainbrooki* (RBINS a12279); Senzeille. **T.** *Crinisarina reticulata* (RBINS a12269); Senzeille. **U.** *Sinospirifer stolbergensis* (RBINS a14099); Senzeille. **V.** *Sinospirifer subextensus* (RBINS a14100); Deulin. **W.** *'Pseudocyrtiopsis' senceliae* (RBINS a11105, holotype); Senzeille. **X.** *'Orthoceras'* sp. (RBINS a14101); Mariembourg. **Y.** *Dmitria* cf. *angustirostris* (RBINS a11180); Villers-sur-Lesse.

Productide (Z–AA), rhynchonellide (BB) and spiriferide brachiopods (CC–DD) and trilobite (EE) from the Comblain-au-Pont Formation.

Z. *Mesoplica nigeraeformis*, internal mould (RBINS a3029); Anseremme. **AA.** *Spinocarinifera* aff. *lotzi*, internal mould with some shelly fragments (RBINS a3043); Maurenne. **BB.** *Araratella moresnetensis*, deformed articulated specimen (RBINS a1162, lectotype); Astenet. **CC.** *Prospira struniana* (RBINS a14102); Chansin. **DD.** *Sphenospira julii* (RBINS a14103); Chansin. **EE.** *Omegops maretiolensis*, incomplete cephalon in dorsal view (RBINS a7812, holotype, from Mottequin, 2021); Bioul 525.

All specimens whitened with ammonium chloride sublimate.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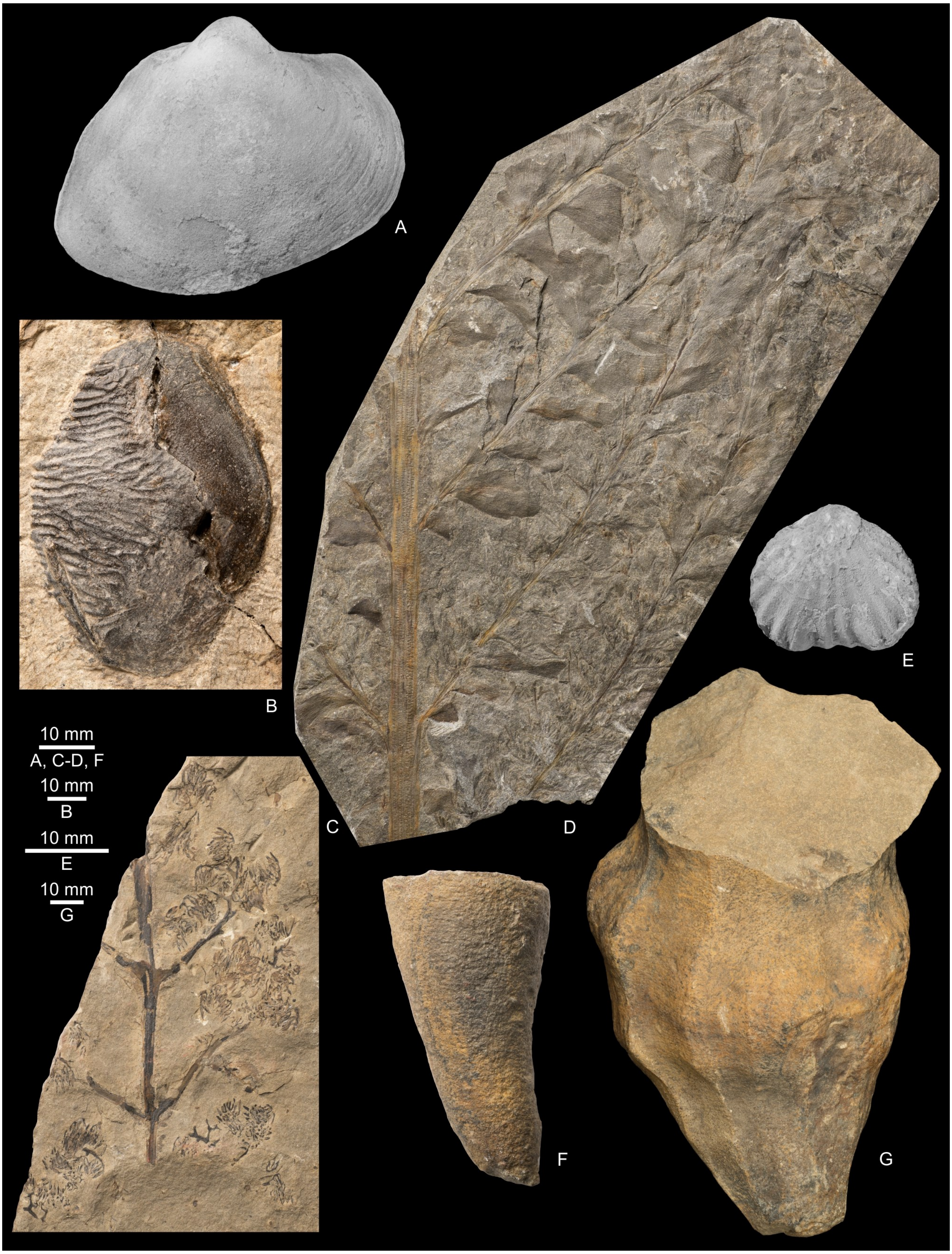

Plate 5. Bivalve (A), sarcopterigian fish (B), plants (C–D), rhynchonellide brachiopod (E) and sponges (F–G) from the middle and upper Famennian.

A. '*Dolabra'* sp. (fide Maillieux), internal mould of an articulated specimen (RBINS a14104); Les Isnes, Bois de la Rocq Formation. **B.** *Holoptychius* sp., isolated scale (RBINS P 10773); Strud, Condroz Formation (Évieux Member). **C.** *Rhacophyton condrusorum* (RBINS b7305); Esneux, Condroz Formation (Évieux Member). **D.** *Archaeopteris roemeriana* (RBINS b2424); Dorinne, Condroz Formation (Évieux Member). **E.** *Sartenaerus letiensis*, articulated specimen in ventral view (MGL 4120); Sains railway section (France), Condroz Formation (Sains Member). **F.** *Dictyospongia morini*, basal part of a skeleton (RBINS a14105); Watissart (France), Esneux Formation (Watissart Member). **G.** *Hydnoceras* sp., basal part of a skeleton (RBINS a14106); Watissart (France), Esneux Formation (Watissart Member). Specimens A and E are whitened with ammonium chloride sublimate.