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FRASNIAN

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(3 figures)

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ABSTRACT. The name Frasnian, which comes from the locality of Frasnes near Couvin in Belgium, was introduced by Gosselet in 1879 and was formally retained for the lower stage of the Upper Devonian by the Subcommission on Devonian Stratigraphy in 1981. The modern definition of the Frasnian is based on conodonts and the historical background of the stage is developed in detail herein. Data about the lithostratigraphy, sedimentology, biostratigraphy, chronostratigraphy and absolute age of the Frasnian can also been found in this contribution.

KEYWORDS: Frasnian, Belgium, Historical background, Lithostratigraphy, Reference sections, Conodonts.

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1. Name

Frasnian (English), Frasniaan (Dutch), Frasnium (German), Frasnien (French).

2. Age

385.3 to 374.5 Ma according to Gradstein *et al.* (2004).

3. Author

The term «Frasnien» was formally introduced by Gosselet (1879a, p. 396) in a footnote where he wrote: «Je divise le Dévonien supérieur en deux assises: le Frasnien comprenant la zone à Rh. cuboides et la zone à Cardium palmatum; le Famennien où je réunis les schistes de Famenne, les Psammites du Condros, les calcaires d'Etroeungt.» However, the term «Frasnien» is already present in another paper concerning the area of Maubeuge in the Avesnois, France and published by Gosselet (1879b, pp. 130 and 133) a few months before, in the same volume as Gosselet (1879a); in this work, the Frasnian from the area of Maubeuge is subdivided into two parts: «Calcaire de Ferrière" at the base and "Schistes à Acervularia" at the top. One year later, Gosselet (1880, pp. 95-107) described in detail the Frasnian from the different areas of outcrop known in Belgium. Moreover, he mentioned that the Frasnian from the south side of the Dinant Synclinorium consists of two units: "Schistes et calcaires de Frasne" at the base and "Schistes de Matagne à Cardium palmatum" at the top.

4. Historical type area

The term Frasnian introduced by Gosselet in 1879 is clearly related to the "Système du calcaire de Frasne" mentioned for the first time by d'Omalius d'Halloy (1862, p. 514) and described among others by Gosselet (1874, p. 100) under the heading "schistes et calcaire de Frasne à *Rhynchonella cuboides*". So the area for the naming of the stage is the locality of Frasnes near Couvin (Fig. 1), on the geological map Chimay-Couvin 57/7-8 revised by Marion & Barchy (1999).

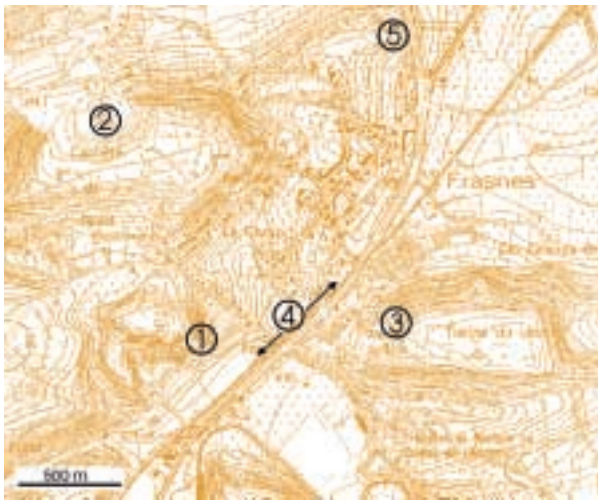

Figure 1. Topographic map showing the locality of Frasnes near Couvin and the reference sections of the Frasnian: 1= Arche quarry; 2= North quarry; 3= Lion quarry; 4= railway section to the south of Frasnes; 5= roadcut along the Couvin-Philippeville highway to the north of Frasnes.

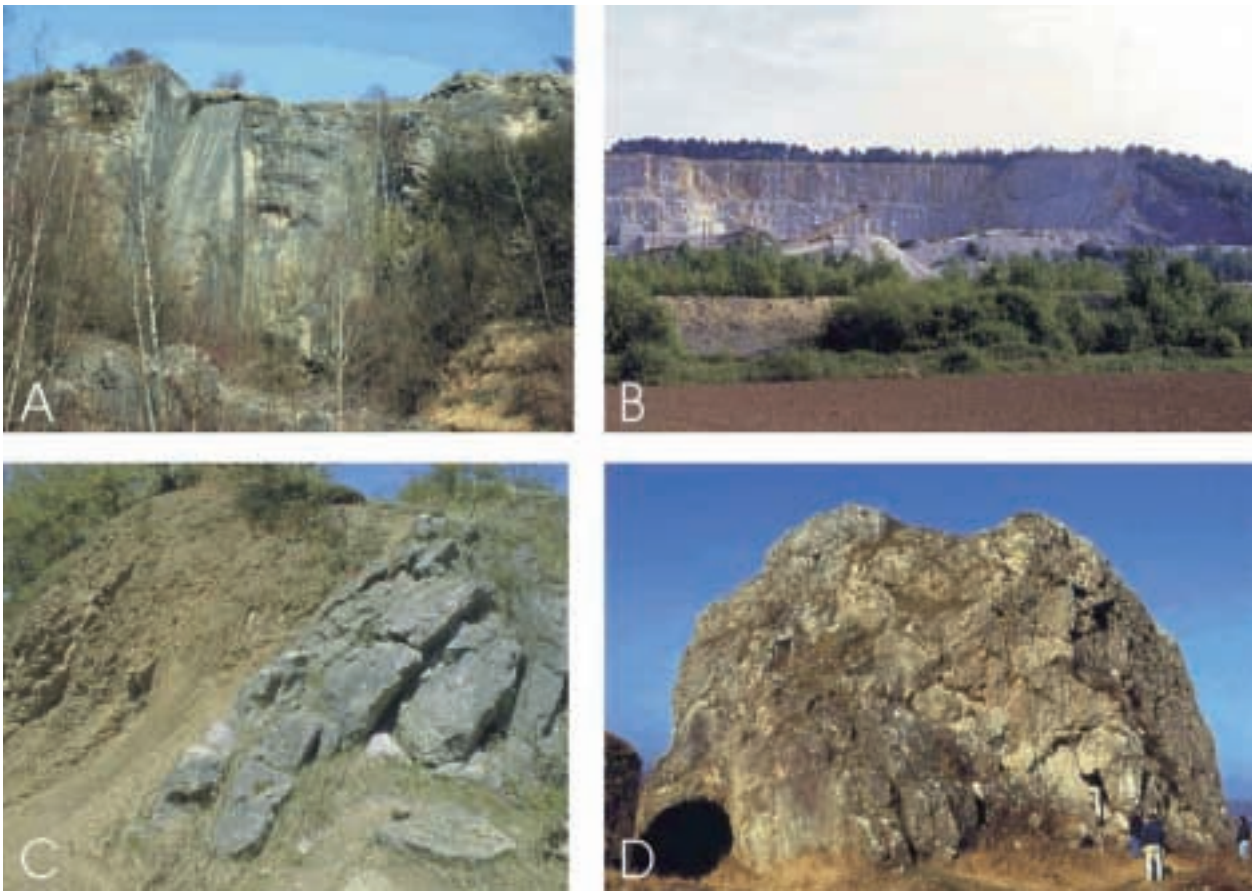

Figure 2. Pictures of the Frasnian from the south side of the Dinant Synclinorium. A. General view of the disused Arche quarry at Frasnes, Arche Member of the Moulin Liénaux Formation. B. General view of the active North quarry at Frasnes, Lion Member of the Grands Breux Formation. C. In the Lion quarry at Frasnes, transition between the Lion Member (to the right) and the overlying and shaly Boussu-en-Fagne Member (to the left) belonging to the Grands Breux Formation. D. The Fort Condé mud mound near Givet, Petit-Mont Member of the Neuville Formation.

In different papers, Gosselet (1860, 1874, 1880 and 1888) described the following outcrops in the area of Frasnes, Nismes and Boussu-en-Fagne:

- the big hill to the west of Frasnes with the Cross of Frasnes (today excavated by the North quarry, Fig.2B);
- the big hill to the southeast of Frasnes (today excavated by the Lion quarry, Fig. 2C);
- the railway sections located to the south and the north of Frasnes;
- the three "Terniats" surrounded by the Matagne shales, along the road to Nismes;
- the section of Boussu-en-Fagne with the Cimetière quarry.

The Matagne shales were also observed by this author near Matagne-la-Grande and Matagne-la-Petite.

5. Description

The Frasnian of Frasnes consists of shales with beds of dark limestone and lenses of reefal limestone that are grey or in some cases red (Fig. 2).

6. Historical background

In the past, there were many discussions in Belgium about the base of the Frasnian. According to Gosselet (1874, p. 102), a French geologist in fact, there is a clear boundary between the Givet Limestone and the Frasnes Limestone which starts with the level containing *Spirifer orbelianus*; in the area of Frasnes, this boundary is figured by the author in the section of Boussu-en-Fagne. However, Gosselet (1884, p. 682) changed his mind by placing in the Frasnian the upper part of the Givet Limestone, that is to say what is now the Fromelennes Formation, after the discovery by Dupont (1882, pp. 272-273) of nodular shales at the base of this lithologic unit. The same definition of the Frasnian was used by Gosselet (1888, pp. 427 and 457) in his famous work devoted to the description of the Ardenne.

In Belgium, the opinion of Gosselet (1888) was mostly followed until 1971, for instance by Maillieux (1922, p. 18) who introduced the Fromelennes Formation, by Maillieux & Demanet (1929) with their stratigraphic scale

of the Palaeozoic of Belgium and by Lecompte (1967, p. 31) who discussed the affinities of the various faunas from the Fromelennes Formation with the Givetian and the Frasnian.
During all this time, in France, the Fromelennes Formation was maintained in the Givetian. From 1971 the situation changed quickly in Belgium. In July 1971, Coen & Coen-Aubert (1971, p. 18) suggested the return of the Fromelennes Formation to the Givetian. In October 1971, there was a meeting at Brussels, between Belgian, French and German geologists to make unanimously this decision which is mentioned by Errera *et al.* (1972, p. 34), Bultynck (1974, pp. 2-3) and Brice (1980, p. 23). Meanwhile, a National Commission on Devonian Stratigraphy was established in Belgium, in December 1971, whereas Coen (1973, p. 250) proposed to restrict the Frasnian to the *Ancyrodella*-bearing beds.
So started the modern story of the Frasnian under the auspices of the Subcommission on Devonian Stratigraphy (SDS) which depends on the International Union on Geological Sciences (IUGS) and began its work in December 1973. In its first meeting, the SDS decided to use conodonts for the definition of Devonian series and stage boundaries. In Belgium, the transition between *Ancyrodella binodosa* Uyeno, 1967 and *A. rotundiloba* (Bryant, 1921) was actively investigated at the base of the historical Frasnian by Coen (1973), Bultynck (1974) and Bultynck & Coen (1982). Between 1981 and 1986, a succession of important decisions was approved by the SDS. In 1981, the name Frasnian was formally retained for the lower stage of the Upper Devonian. In 1982, it was proposed that the Givetian-Frasnian boundary should coincide with the base of the Lower *Polygnathus asymmetricus* Zone defined by the first occurrence of *Ancyrodella rotundiloba*. In 1985, the global stratotype section and point (GSSP) for the base of the Frasnian was selected at the base of bed 42a', at the Col du Puech de la Suque in the Montagne Noire, southern France. In 1986, the section of Nismes in Belgium was adopted as an auxiliary boundary stratotype for the Givetian-Frasnian boundary, in neritic facies. In this outcrop, the entry of *A. rotundiloba* was accurately documented by Bultynck *et al.* (1988), 1.5 m above the base of the Nismes Formation and the regional historical base of the Frasnian. All these steps are mentioned in several papers and of course by Boulvain *et al.* (1999, p. 6) and Bultynck & Dejonghe (2001, p. 54).
After that, a taxonomic controversy arose with the publication of two papers by Sandberg *et al.* (1988 and 1989). According to these authors, primitive forms of *Ancyrodella* Ulrich & Bassler, 1926 have been included within the population of *A. rotundiloba* found at the GSSP of the Montagne Noire. So the Givetian-Frasnian boundary was inadvertently placed within the Lowermost *Polygnathus asymmetricus* and not at the base of the Lower *P. asymmetricus* as originally intended. Sandberg *et al.* (1989) proposed also a new standard conodont zonation across the Middle-Upper Devonian boundary and introduced the Early and Late *Mesotaxis falsiovalis* Zone to replace the former Lowermost *Polygnathus asymmetricus* Zone and the oldest part of the former Lower *P. asymmetricus* Zone. It follows that the start of the Frasnian defined by the early forms of *Ancyrodella rotundiloba* assigned to *A. pristina* Khalymbadzha & Chernysheva, 1970 and *A. soluta* Sandberg, Ziegler & Bultynck, 1989 occurs now within the Early *Mesotaxis falsiovalis* Zone. There is a good summary of these taxonomic problems in the paper of Ziegler & Sandberg (1996).
It results also that the GSSP for the Givetian-Frasnian boundary is defined by a point in the rock succession though different groups of fossils can be used to correlate it with other regions. In spite of these difficulties, the base of the Frasnian can well be recognized on a worldwide scale as it is more or less related to the first occurrence of the genus *Ancyrodella*. Moreover, it is clear that the formal definition of the Frasnian has brought more uniformity and stability in the use of this stage everywhere in the world.

7. Lithology

The lithostratigraphy of the Belgian Frasnian has been investigated in detail by Boulvain *et al.* (1999) and Bultynck & Dejonghe (2001). As Frasnes is located on the south side of the Dinant Synclinorium, the Frasnian of this locality is represented, in ascending order, by the Nismes, Moulin Liénaux, Grands Breux, Neuville and Matagne Formations (Fig. 3).
The stratotype for the Nismes Formation is the auxiliary stratotype for the Givetian-Frasnian boundary, lying 3 km to the east of Frasnes. In this outcrop, the Nismes Formation consists of 39 m of shales with nodular limestones rich in brachiopods at the base. The Moulin Liénaux Formation crops out to the southwest of Frasnes. It starts with the Chalon Member, which is characterized by a few metres of argillaceous limestones with shaly intercalations. The Arche Member from the Arche quarry (Fig. 2A) is a biohermal lens whose thickness reaches more than 100 m; the limestone is pinkish-reddish in the lower part and grey in the upper part. The shales of the Ermitage Member occur lateral to and above the Arche Member. The Grands Breux Formation is also exposed to the south of Frasnes, in the Lion quarry and in the nearby railway section. In this latter exposure, the Bieumont Member is represented by 37 m of argillaceous limestones that are overlain by 81 m of shales belonging to the Boussu-en-Fagne Member. Lateral to these two members, there are bioherms of grey limestone assigned to the Lion Member, which are about 150 m thick. The Lion quarry (Fig. 2C) and the North quarry (Fig. 2B) are two good examples of these lenses.
The Neuville Formation has been defined along the railway section of Neuville, in the Anticlinorium of Philippeville. In the area of Frasnes, it is represented by 35 m

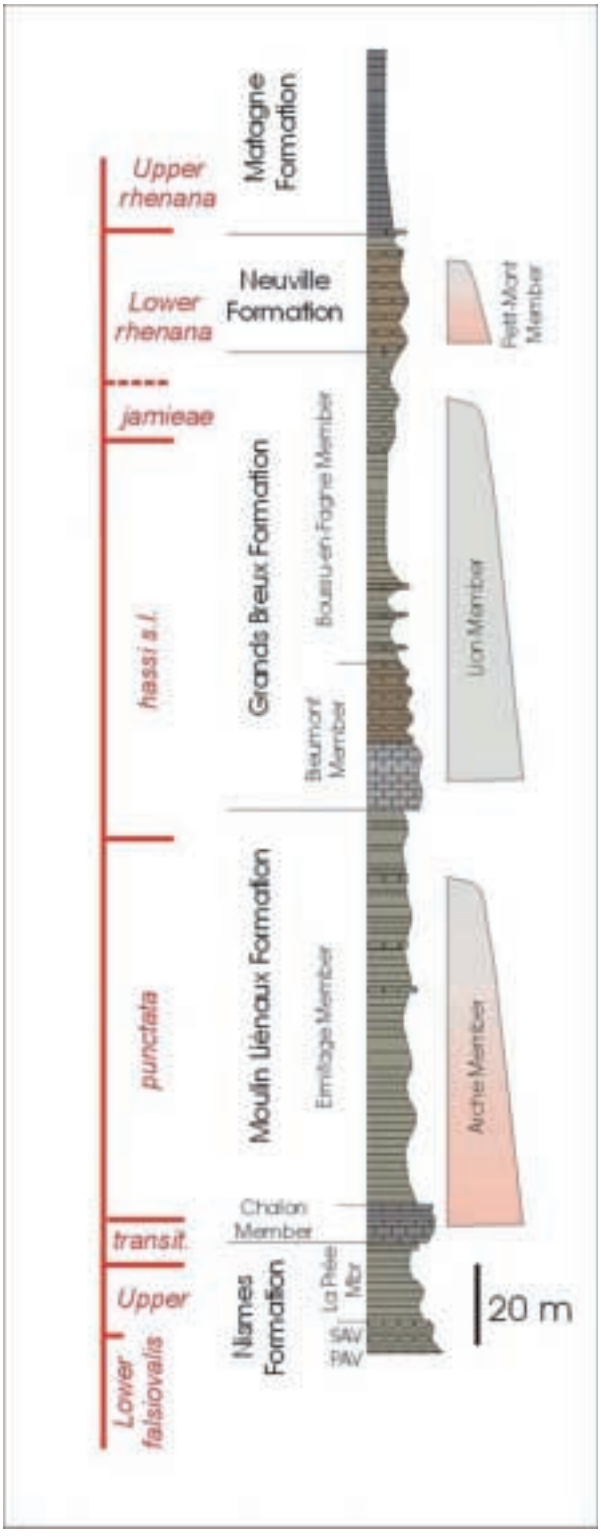

Figure 3. Schematic lithologic section of the Frasnian from the south side of the Dinant Synclinorium with the conodont zonation.

of nodular limestones and shales with some small lenses of red biohermal limestone (Petit-Mont Member). The mound in the Cimetière quarry at Boussu-en-Fagne has a thickness of 11 m. As the Matagne Formation is no longer exposed near the village of Matagne, a new stratotype has been selected by Boulvain *et al.* (1999) along the railway track between Mariembourg and Nismes. In the area of Frasnes, the lithostratigraphic unit consists of at least 50 m of black shales. In the Anticlinorium of Philippeville, the formation is diachronic and is restricted to 10 m just below the Frasnian-Famennian boundary. This transition is observed in the former railway cut of Senzeille, located 1500 m to the south of the village, where the base of the Famennian is close to the base of the Senzeille Formation and corresponds to the base of the Early *Palmatolepis triangularis* conodont Zone, according to Bultynck *et al.* (2000, p. 111).

In the Anticlinorium of Philippeville, the Moulin Liénaux and Grands Breux Formations pass laterally into the Pont de la Folle and Philippeville Formations. The Pont de la Folle Formation starts with the Fontaine Samart Member, characterized by bedded limestones with some reef building organisms at the base. The overlying Machenées Member consists of shales and nodular shales. The lower part of the Philippeville Formation is represented by thin-bedded limestones with some reefal lenses whereas its upper part is a biostromal unit with an alternation of stromatoporoid beds and lagoonal limestones. In some localities, these limestones of the Philippeville Formation can be affected by dolomitisation. Between the Neuville and Matagne Formations occurs the Les Valisettes Formation, which is 90 m thick and is composed of dark and green shales. These shales become red and nodular in the vicinity of lenses of red biohermal limestone, which can reach a thickness of 80 m. Indeed, these mounds start their development in the Neuville Formation and some of them continue to grow up in the Les Valisettes Formation.

On the north side of the Dinant Synclinorium, the south side of the Namur Synclinorium and the Vesdre Nappe, the Frasnian is much reduced and is characterized by the succession of the Presles, Lustin, Aisemont and Lambermont Formations. The Presles Formation consists of shales with a few layers of hematitic oolites at the base. The limestones of the Lustin Formation can be subdivided into a lower reefal unit and an upper lagoonal unit. The Aisemont Formation is represented by two levels of more or less argillaceous limestones separated by shales. The Lambermont Formation is mostly composed of green shales with some red nodular shales and a few corals in its middle part.

On the north side of the Namur Synclinorium, the Frasnian is thicker than in the three preceding areas. In the central and western parts of the first structural unit, it is mainly represented by the Bovesse and Rhisnes Formations. At the base of the stage, a new stratotype for the Bovesse Formation has been selected by Boulvain *et al.* (1999), at Huccorgne lying in the eastern part of the north side of the Namur Synclinorium. This lithostratigraphic unit is characterized by an alternation of shales, dolomites and limestones with some beds containing fasciculate rugose corals. It is overlain by the Rhisnes Formation,

which consists of nodular limestones rich in brachiopods; however, bedded limestones occur in its middle part with some corals and stromatoporoids, or forming the level mined as the black marble of Golzinne. At the top of the Frasnian, about 10 m of shales are poorly exposed and belong to the Franc-Waret Formation. In the area of Huccorgne, the Rhisnes Formation passes laterally into the Huccorgne Formation, which is composed of bedded limestones with several layers containing corals and stromatoporoids. Moreover, the Huccorgne Formation is capped first by the Aisemont Formation and then directly by Tournaisian deposits. Indeed, there are important sedimentary gaps within the Famennian on the north side of the Namur Synclinorium.

8. Sedimentology and palaeogeography

The Frasnian formations from the Frasnes area belong to an external ramp with a mixed siliciclastic-carbonate sedimentation. Accomodation is relatively high and periods of sea-level rise are characterized by large-scale argillaceous sedimentation (Da Silva & Boulvain, 2004). During periods of relative sea-level stillstand, carbonate mounds developed. The Arche and Lion Members are large atoll-like skeletal mounds capped by shallow deposits (Boulvain *et al.*, 2004) whereas the Petit-Mont Member corresponds to deeper, low-diversity sponge mounds (Boulvain, 2001). The deposit of the Matagne shales is the result of a large-scale anoxic event (Kellwasser), probably related to a stratification of the ocean water. This Late Frasnian faunal crisis is one of the five great mass extinctions known in the Phanerozoic.

9. Palaeontology

The detailed stratigraphic distribution of conodonts, rugose corals, brachiopods and ostracods throughout the Frasnian from different areas of Belgium was provided by Boulvain *et al.* (1999); some data about tabulate corals and acritarchs are also given in this paper. Further interesting information can be found in Coen-Aubert (2000) and Bultynck *et al.* (2000). As the conodonts and the rugose corals have been actively investigated for many years by P. Bultynck, M. Coen and M. Coen-Aubert, the fossils of these two groups are the most useful markers to date the various lithostratigraphic units and their precise levels.

10. Chronostratigraphy

For the Frasnian, the so-called chronostratigraphic boundaries by means of biostratigraphic data are based on conodonts. Soon after 1973, these microfossils were accepted internationally to define Devonian series and stage boundaries. They are very useful for this purpose due to their widespread distribution, rapid evolution and availability of a highly refined zonation. Index species within conodont phyletic lineages are used to define the biologic position of the different boundaries and for worldwide correlations.

11. Geochronology

The absolute ages proposed by Gradstein *et al.* (2004) for the base and the top of the Frasnian, which are much older than those used among others by Sandberg & Ziegler (1996) and Streel *et al.* (2000), were already supported by a radiometric date given by Tucker *et al.* (1998, p. 181). Indeed, these authors mentioned a U-Pb zircon age of about 381 Ma for a volcanic ash within the range of the Frasnian conodont *Palmatolepis punctata* (Hinde, 1879). This sampling comes from four K-bentonite intervals in the roadcuts exposing the Devonian part of the Chattanooga Shale at Little War Gap, eastern Tennessee (Appalachian Basin), USA. However, the biostratigraphic data concerning this isotopic dating have been severely criticized by Streel *et al.* (2000, p. 129). But now, Kaufmann *et al.* (2004) proposed a very precise U-Pb zircon age of 377.2 Ma in the famous Schmidt quarry, Kellerwald, Germany, for a thin layer of bentonite intercalated between the two Upper Frasnian Kellwasser horizons and assigned to the Upper *P. rhenana* conodont Zone, that is to say close to the Frasnian-Famennian boundary.

12. Structural setting

The Frasnes area belongs to the Ardenne Allochton and more precisely to the southern border of the Dinant Synclinorium. These structural units are parts of the Rhenohercynian fold and thrust belt. The southern border of the Dinant Synclinorium is characterized by a general WSW-ENE strike of the strata with a dip of 30°-50° N. In the Frasnes area, this relatively gentle structure is disturbed by a kilometre-scale anticline with a N60°E axis and a NE plunge. This structure is probably related to a dextral post-Variscan shearing zone.

13. Reference sections in Belgium and GSSP

GSSP: base of bed 42a', Col du Puech de la Suque section E, St. Nazaire-de-Ladarez, southeastern Montagne Noire, southern France.
Auxiliary stratotype: outcrops on the northern border of the Mousti Wood lying above the karstic spring of the Eau Noire river and 250 m to the southwest of the town centre of Nismes.
Important reference sections in Belgium: Arche quarry, Lion quarry and North quarry at Frasnes, roadcut along the Couvin-Philippeville highway to the north of Fra-

snes, Cimetière quarry at Boussu-en-Fagne, railway cut of Neuville, Beauchâteau quarry and former railway cut at Senzeille.

14. Main contributions

Boulvain *et al.*, 1999; Bultynck *et al.*, 1988; Bultynck & Dejonghe, 2002; Coen, 1973; Gosselet, 1880 and 1888; Lecompte, 1960; Maillieux, 1913.

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