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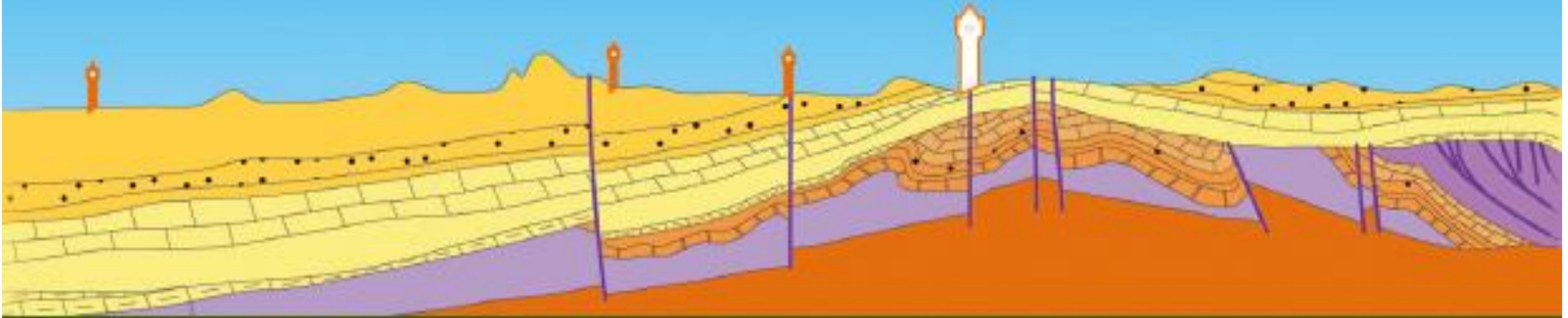

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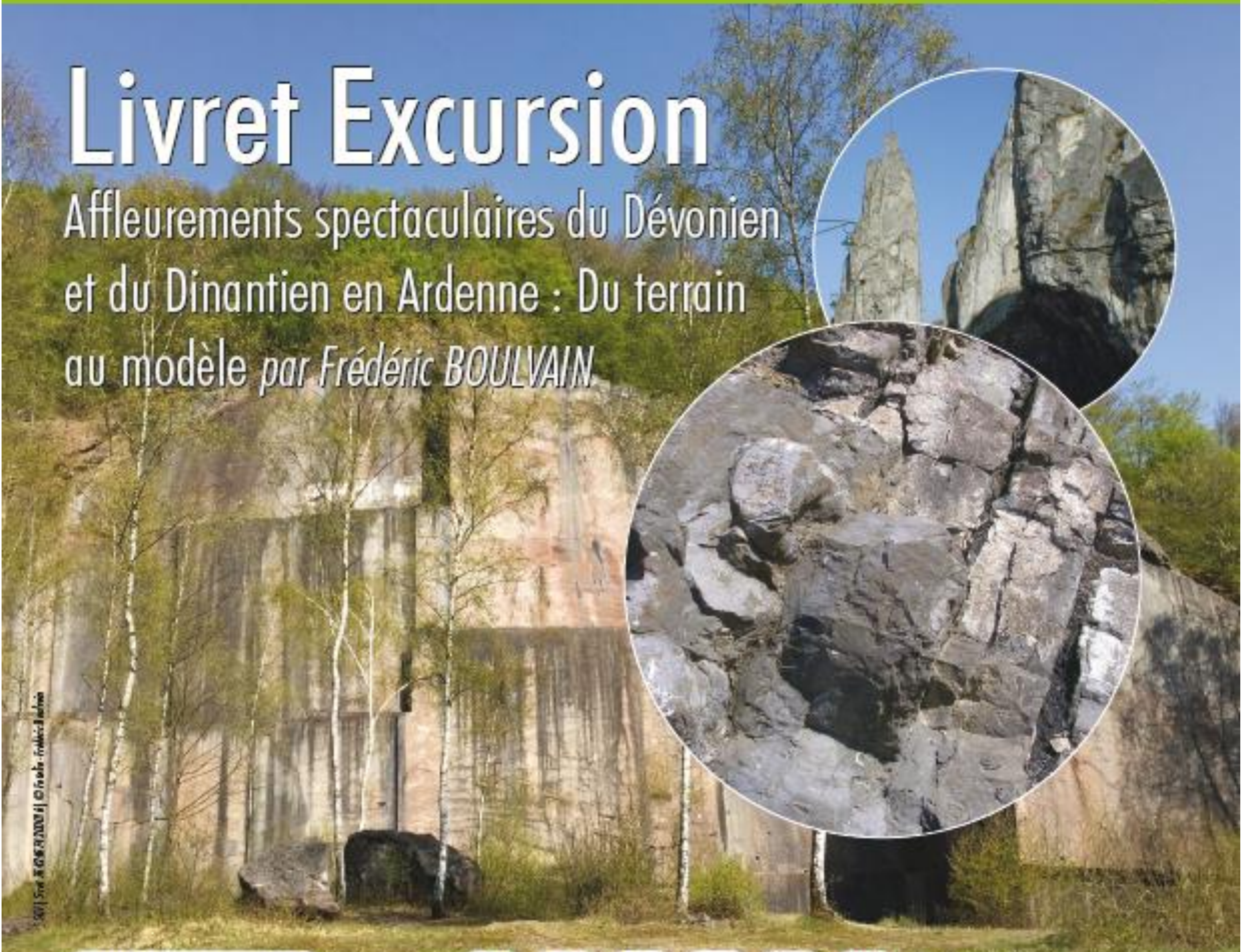

Livret Excursion

Affleurements spectaculaires du Dévonien et du Dinantien en Ardenne : Du terrain au modèle *par Frédéric BOULVAIN*

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Carbonate facies from Middle Devonian and Dinantian of Belgium

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1. Introduction

Despite the relative geological shortness of Belgian territory, the cumulative thickness of formations is thought to reach 18 km. Stratigraphically, these formations range from the Lower Cambrian to the Quaternary, with only minor hiatuses. More than a half billion years of Earth history is thus exposed (Boulvain & Pingot, 2015).

The Belgian subsurface is mostly characterized with sedimentary rocks. Magmatic rocks are subordinate and metamorphism has never reached more than the epizone (green slate facies). The sedimentation periods and subsequent deformation events shaped the Belgian substrate in four major sedimentary-structural units, which are: (1) the Lower Paleozoic inliers, (2) the Devonian-Carboniferous faulted and folded belt including the formers, (3) the monoclinal Triassic-Jurassic series and (4) the subhorizontal Cretaceous (4a)-Cenozoic (4b) cover (Figs 1 & 2). The faulted and folded belt includes three tectonic units which are: the Brabant parauthochton (BP), the Haine-Sambre-Meuse thrust sheets (HSM) and the Ardenne allochthon (AA), separated by the Midi-Eifel thrust fault (F) and finally, the Ardenne allochthon is itself structured in major anticlines and synclines which are, from north to south, the Dinant Syncline and its eastern equivalent, the Ardenne Anticline, the Neufchâteau-Wiltz-Eifel Syncline and the Givonne Anticline.

The following provides a description of the different sedimentary units, starting from the oldest and ending with Upper Carboniferous. The two orogenic phases that shaped the Lower Paleozoic inliers and the Devonian-Carboniferous faulted and folded belt will also be shortly addressed.

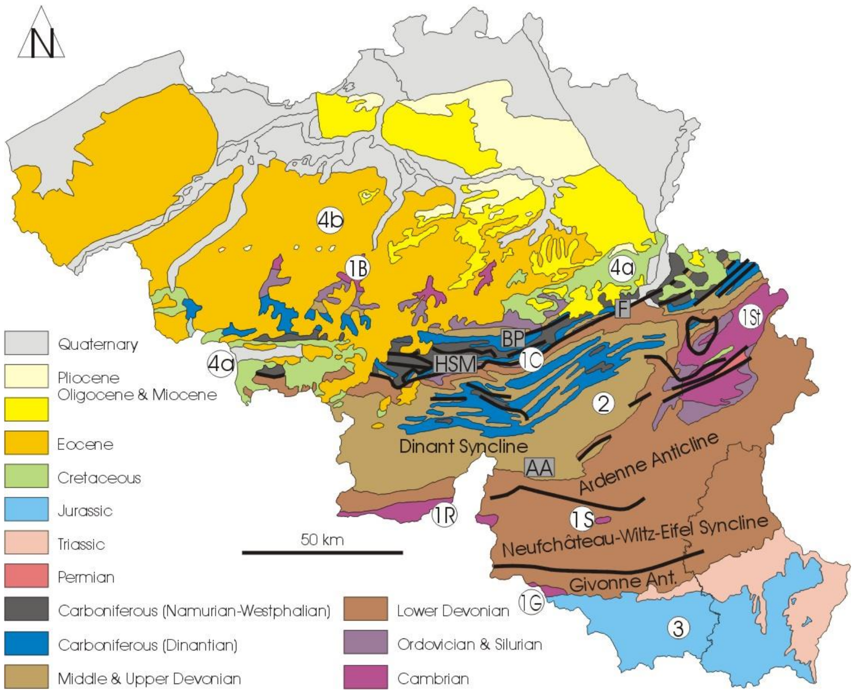

Fig. 1. Schematic geological map of Belgium and Luxemburg. (BP): Brabant parautochthon, (AA): Ardenne allochthon, (F): Midi-Eifel Fault, (HSM): Haine-Sambre-Meuse thrust sheets, (1B): Brabant Lower Paleozoic massif, (1C): Condroz LP inlier, (1St): Stavelot LP massif, (1R): Rocroi LP massif, (1S): Serpont LP massif, (1G): Givonne LP massif, (2): Devonian-Carboniferous faulted and folded belt, (3): monoclinal Triassic-Jurassic series, (4a): Cretaceous subhorizontal cover, (4b): Cenozoic subhorizontal cover.

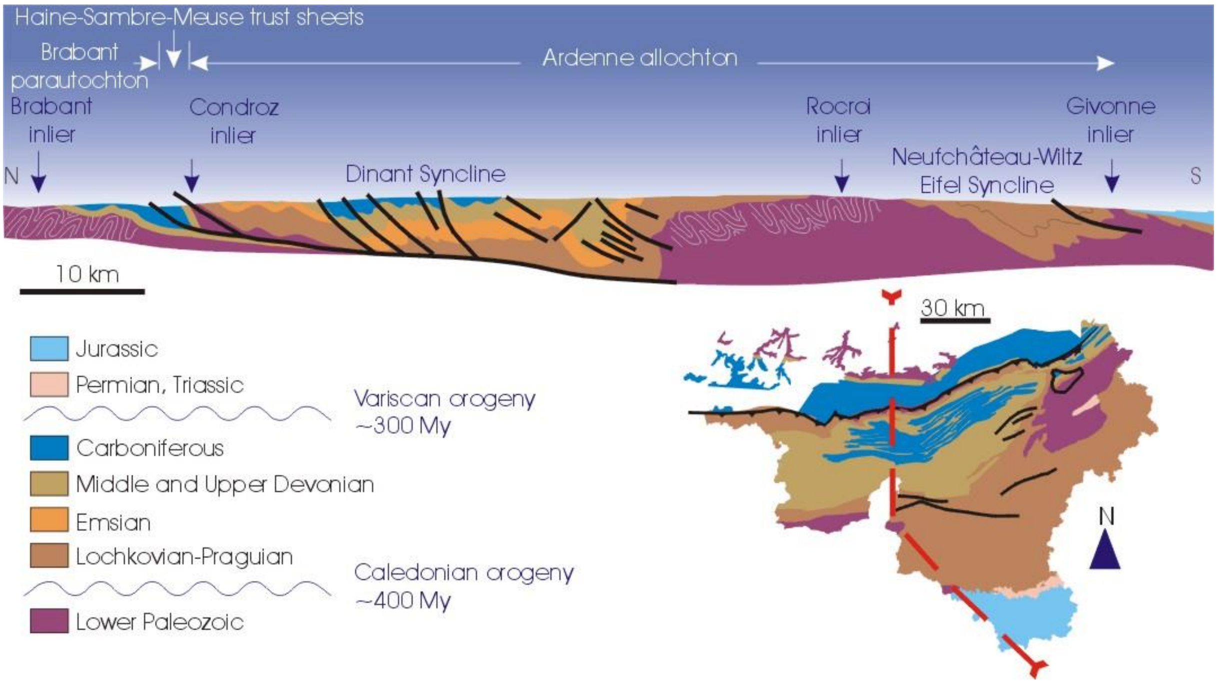

Fig. 2. Cross-section of South Belgium (Wallonia).

2. The Caledonian Cycle: the Lower Paleozoic Inliers

The sediments that constitute the Lower Paleozoic inliers were deposited during the Caledonian sedimentary-tectonic cycle. In the beginning, Belgium (microplate Avalonia) was part of the supercontinent Gondwana, situated around the South Pole (Fig. 3). At the end of the Cambrian/beginning of the Ordovician, Avalonia separated from Gondwana and started to drift away. During the end of the Ordovician, a first continental collision between Avalonia and the microplate Baltica was responsible for the Ardenne phase of the Caledonian orogeny and throughout the end of Silurian, the Avalonia-Baltica merged microplates collided with Laurentia (another supercontinent, located further north) giving rise to the Brabant phase of the Caledonian orogeny.

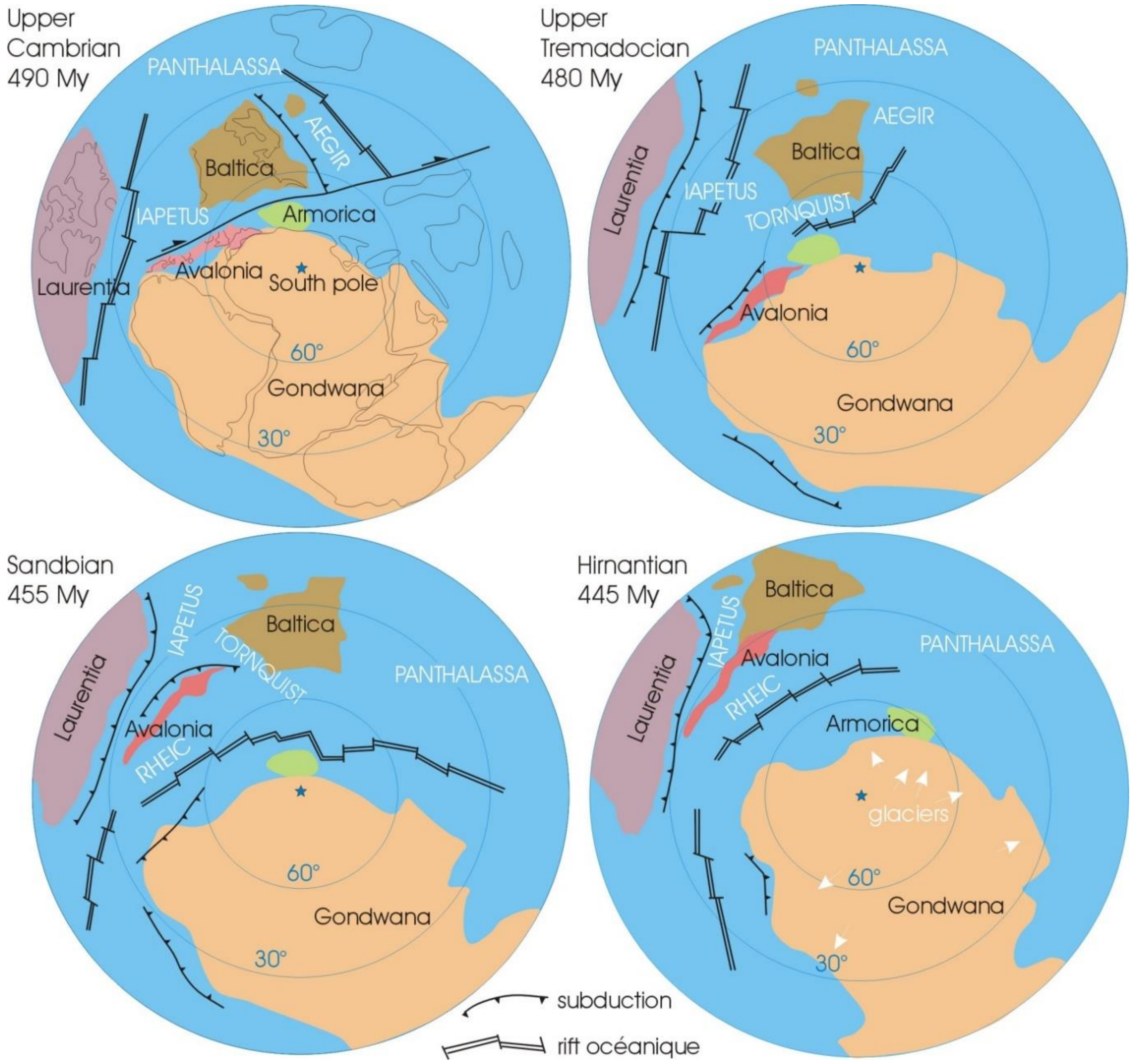

Fig. 3. Paleogeography during the Lower Paleozoic. Arrows indicate ice movements. Simplified after Cocks & Torsvik, 2002.

The six Paleozoic inliers in Belgium are as follows, from North to South: Brabant, Condroz, Rocroi, Serpont, Stavelot and Givonne massifs (Fig. 1). Sedimentation is dominated by gravity flows (turbidites, grain flows, debris flows) giving rise to alternating sandstones and slates.

The Caledonian orogeny is characterized by a marked diachronism between the southern Ardenne inliers and the northern Condroz and Brabant inliers due to different continental plate dockings. The Ardenne orogenic phase started during the Middle Ordovician and is related to the Avalonia-Baltica docking while the Brabant phase started at the end of Silurian and is a consequence of the final Avalonia-Baltica-Laurentia collision. It is important to note that the first post-Caledonian sediments are also diachronic since they are attributed to the Lowermost Lochkovian in the Ardenne and to the Givetian around the Brabant massif. Finally, another major fact to take into account when interpreting the Caledonian orogeny in Belgium is that the Variscan orogeny affected the Ardenne and Condroz inliers but not the Brabant massif, which is located North of the Variscan deformation front. As a result, the Ardenne and Condroz inliers are affected by two orogenic phases while the Brabant massif is only affected by the Caledonian orogeny.

3. The Variscan Cycle

The Variscan sedimentary-tectonic cycle took place in Belgium and Luxemburg during the Upper Paleozoic. It begins with renewed detrital sedimentation on the shores of the Old Red Sandstone Continent (Lower Devonian) and ends with the Variscan orogeny (Upper Carboniferous). This cycle is responsible for the formation of the supercontinent Pangea.

The Lower Devonian detrital sediments, the Middle and Upper Devonian mixed carbonate-detrital formations, the Dinantian carbonates, the Namurian detrital sediments and finally, the Westphalian coal measures constitute the sedimentary pile which will be deformed by the Variscan orogeny.

4. The Lower Devonian Detrital Formations

The Lower Devonian is widespread, covering large areas in the Ardenne Anticline, and in the Neufchâteau-Wiltz-Eifel Syncline. Sediments largely consist of sandstones, siltstones, slates and shales. The regional seascape follows the east-west trending southern coast of the Old Red Continent, which has been bathed by the northern Rheic Ocean (Fig. 4a).

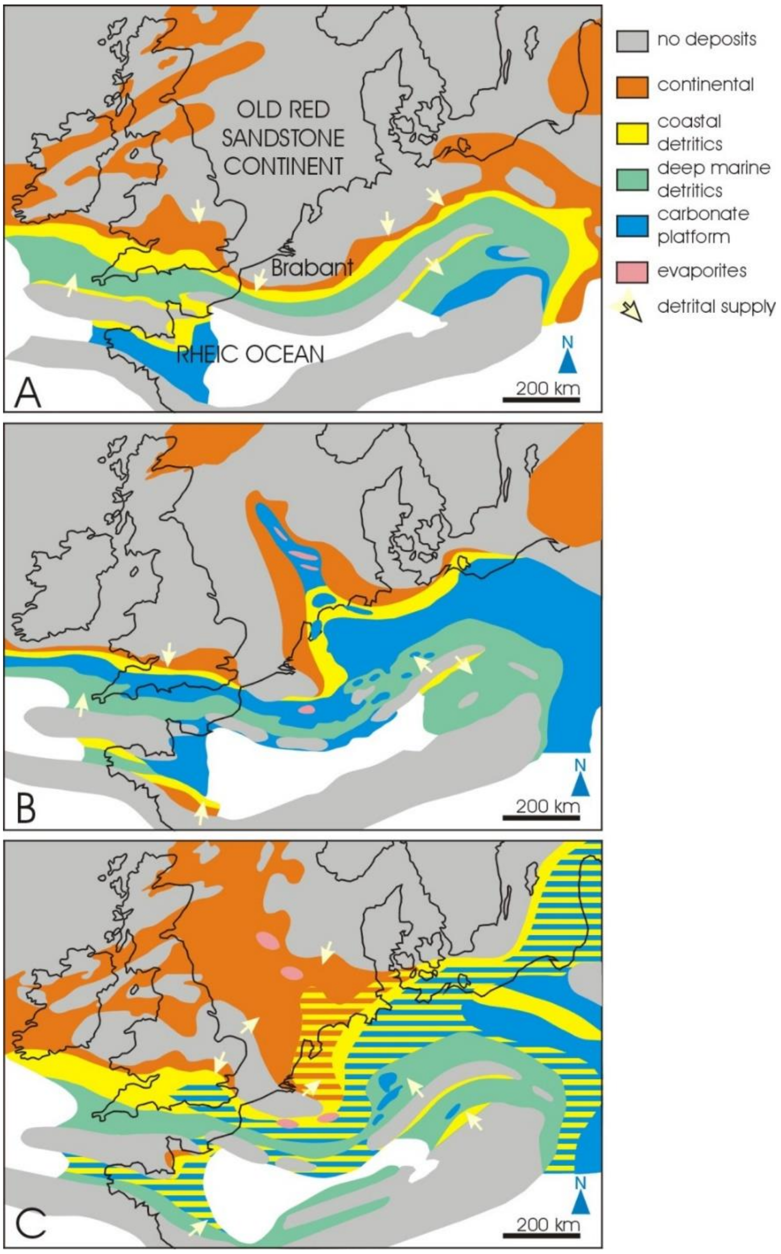

Fig. 4. Schematic paleogeographical map of northwestern Europe during the Devonian, **a** Lower Devonian, **b** Middle Devonian, **c** Upper Devonian. Simplified after Ziegler (1982).

The tectonic context is one of a passive margin, with a rapid increase of sediment thickness from north to south: the Lower Devonian totals 1.3 km along the northern border of the Dinant Syncline, 3.1 km along its southern border and 4.5 km in the Neufchâteau-Wiltz-Eifel Syncline. There is no Lower Devonian sedimentation north of the Midi-Eifel Fault. The sediment supply originated from the Old Red Sandstone Continent.

The first Lower Devonian sediments deposited on the Caledonian substrate are conglomerates. They are interpreted as continental alluvial fans (Meilliez, 2006). They rapidly pass upwards to versicolored shale and siltstones, including sandstone lenses. These patterns correspond to alluvial plain and channel systems. The first marine sediments are littoral and platform sandstones/quartzites or shales/slates (Goemaere & Dejonghe, 2005). They are younger along the northern border of the Dinant Syncline (Pragian) than along its southern border, reflecting the progression of the Lower Devonian marine transgression. The transgression peak is reached during the Pragian, with external platform shales and slates in the south and alluvio-littoral sandstones found again in the north. The Emsian shows a marked regressive trend: alluvio-littoral environments prograded southward at the expense of marine facies.

5. The Middle Devonian Mixed Carbonate-Detrital Formations

The Middle Devonian formations crop out along the borders of the Dinant Syncline and eastern equivalents. Formations from this time also appear in the Haine-Sambre-Meuse thrust sheets and the Brabant parautochthon.

During the Middle Devonian, a more drastic transgressive regime was aroused. The rising sea level is responsible for an extension of the ocean north of the future Midi-Eifel fault, up to the Brabant parautochthon and simultaneously, the Lower Devonian detrital facies gave way to argillaceous limestone and to the first carbonated platforms (Fig. 4b).

The Eifelian marks the transition between the old detrital and the new carbonate world. Facies are still mixed and carbonate platforms, laterally restricted, and still surrounded by shale. At the onset of the Givetian however, a huge carbonate platform is established over southern Belgium. The coast at this time was located near the Brabant massif. The spectacular development of carbonates was probably related to a warmer climate (Belgium was situated between the Equator and the Capricorn tropic) and to a dramatic decrease in detrital supply coming from the Old Red Sandstone Continent.

Along the southern border of the Dinant Syncline, the Givetian platform is well developed and characterized by 450 m of limestone including fore-reef, reef and lagoon environments (Boulvain et al., 2009) (Fig. 5). This thickness decreases northerly to a hundred of meters, with typical littoral carbonates.

6 The Upper Devonian Mixed Carbonate-Detrital Formations

During the Frasnian, a transgressive phase brought the coastline farther to the north, perhaps flooding the entire Brabant massif. A shale unit, several tens of meters thick (Nismes Formation) concealed the entire drowned Givetian platform. After this episode, a carbonate platform redeveloped, shifted northward relative to the Givetian platform (Fig. 5).

The southern border of the Dinant Syncline shows three stratigraphic levels bearing Frasnian carbonate mounds (Boulvain, 2007). These are, in stratigraphic order, the Arche, the Lion and the Petit-Mont Members (Fig. 5). In the Philippeville Anticline, only the upper level contains mounds (Petit-Mont Member). The other carbonate mound levels are replaced laterally by bedded limestone, with local back-reef character. At the northern border of the Dinant Syncline and in the Brabant parautochton, the entire Frasnian consists of bedded limestone and argillaceous strata (Da Silva & Boulvain, 2004).

The Petit-Mont mounds are 30 to 80 m thick and 100 to 150 m in diameter. They are embedded in shale and nodular shale. The first carbonate mound facies consists of red limestone with sponges, and becoming progressively enriched in crinoids and corals, then in stromatopores (calcified sponges) and cyanobacteria. The red pigment is derived from microaerophilic iron bacteria.

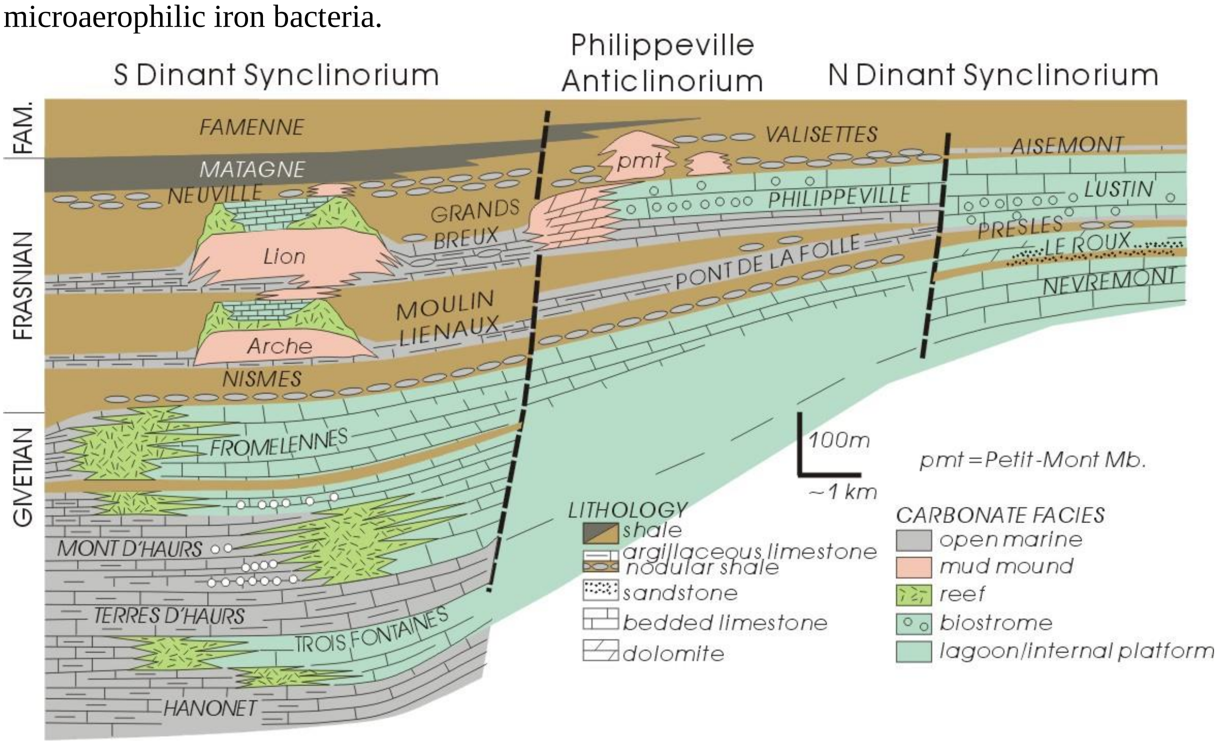

Fig. 5. North-south transect through the Dinant Syncline before Variscan tectonism showing the Givetian and Frasnian formations.

After the drowning of the Frasnian carbonate platform under transgressive shale, the Famennian Stage marked a complete renewal of seascapes (Fig. 4c). A clear regressive trend brought the coastline south of the Brabant massif and carbonates were replaced by detrital sediments (Thorez et al., 2006): first the Famenne shale (deposited below the storm wave base), then the Esneux Formation (rhythmic shale-sandstone alternation, marking the storm wave zone) and finally, after a minor carbonate episode, the Montfort and Evieux formations, consisting in littoral and alluvio-littoral sandstones. These stones (Condroz Sandstone) are still used in many public and private buildings.

7 The Dinantian Carbonates

The Carboniferous in Belgium is traditionally subdivided into three series: the Dinantian, the Namurian, and the Westphalian. Carbonates, (Fig. 6a), detrital sediments (Fig. 6b) and mixed detrital sediments and coal (Fig. 6c) dominate each respective series. During the Carboniferous, the Rheic Ocean is located near the equator and is in the process of closing, as is made evident by the forthcoming collision of Gondwana and Laurussia (the Old Red Sandstone Continent). This major tectonic event gave rise to the huge Variscan mountain belt and to the formation of the supercontinent Pangea.

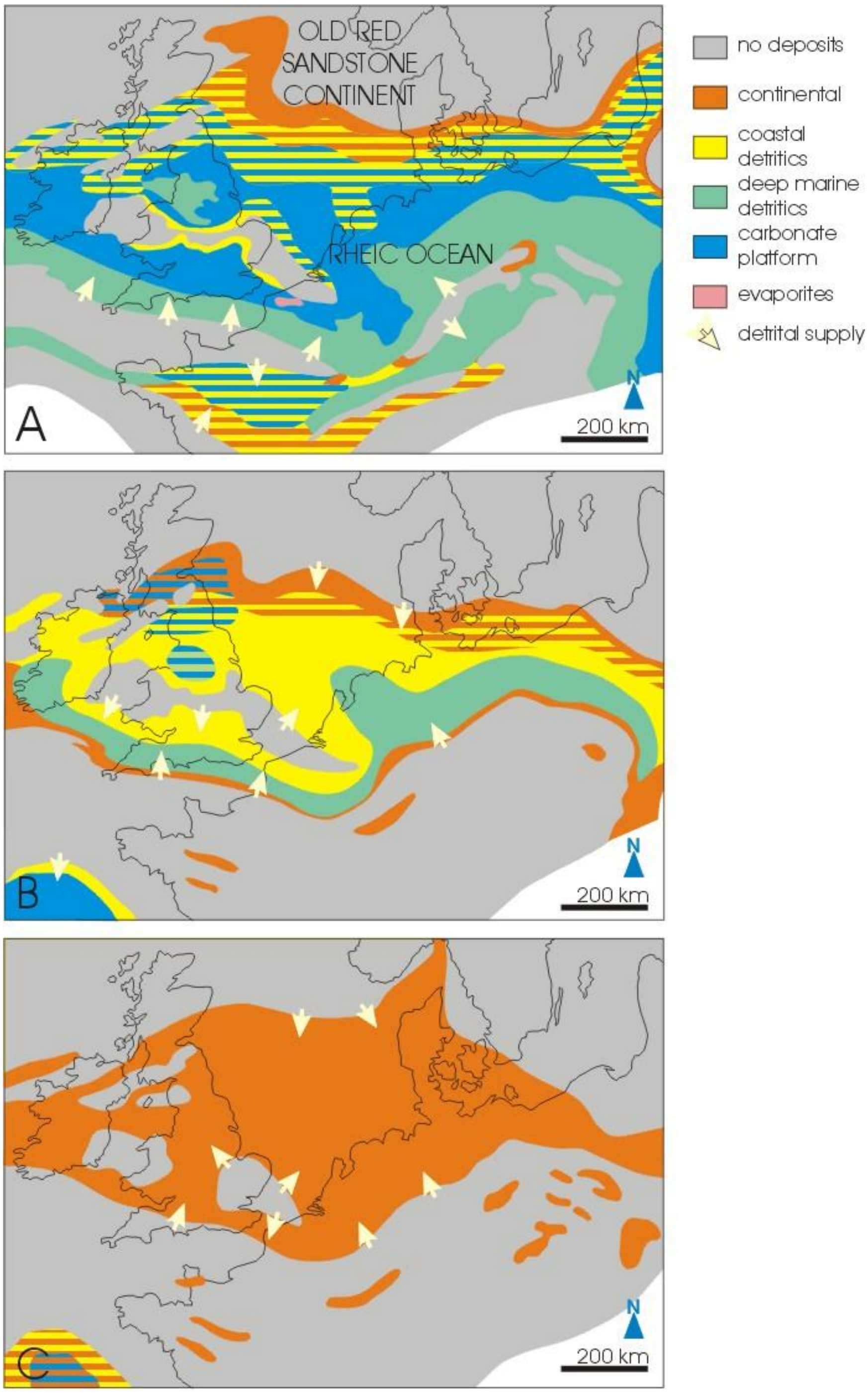

Fig. 6. Schematic paleogeographical map of northwestern Europe during the Carboniferous, **a** Dinantian, **b** Namurian, **c** Westphalian. Simplified after Ziegler (1982).

Following the alluvio-littoral environment of the Upper Famennian, the Dinantian sedimentation (Tournaisian-Visean) marks a return to pure marine conditions. A dramatic decrease of detrital supply favored the resumption of a carbonate factory, and a large carbonate platform subsequently developed south of the Brabant massif (Fig. 6a). This platform was divided into several sedimentation areas (Condroz, Dinant, Hainaut, Namur, Visé; Hance et al., 2001) with different types of limestones and variable accommodation. The maximum thickness of the Dinantian reaches 2.5 km in the Hainaut sedimentation area. Several Dinantian formations from the Dinant-Condroz areas will be further detailed (Fig. 7) because of their economic significance or international status.

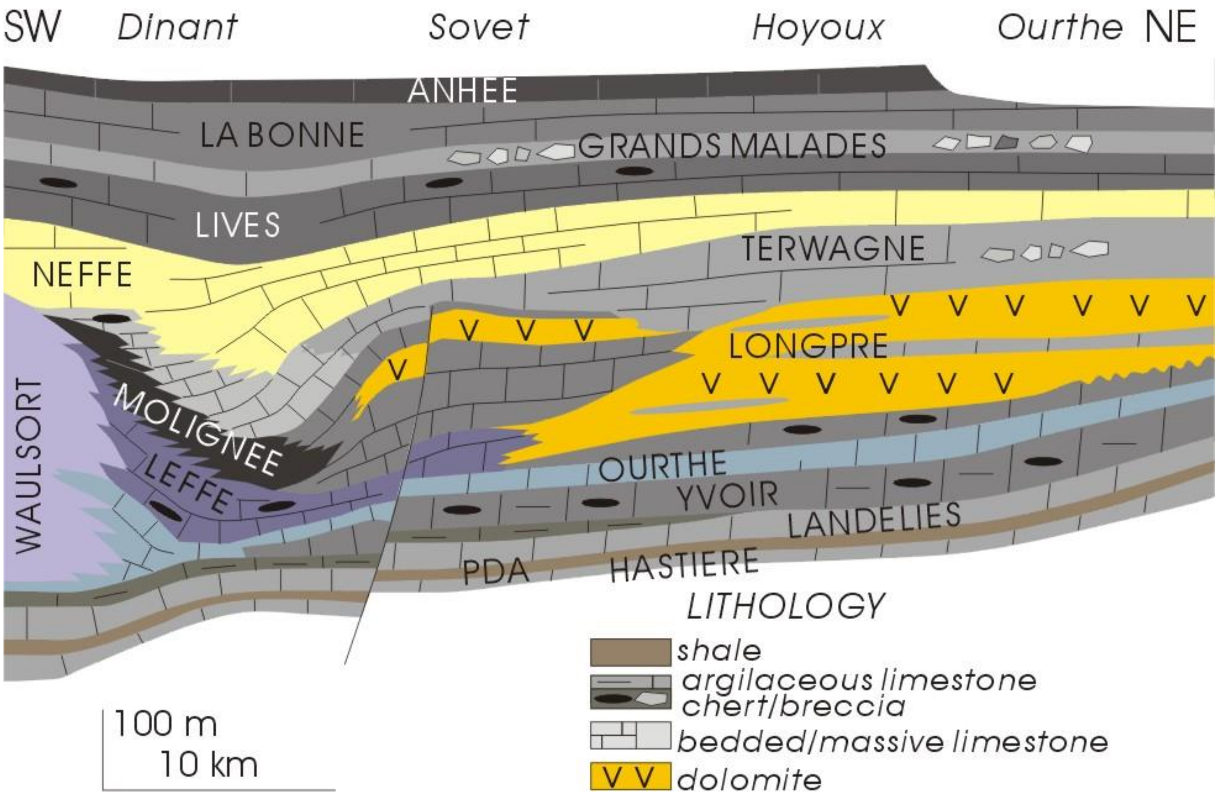

Fig. 7. North-south transect through the Dinant Syncline before Variscan tectonism showing Dinantian formations. PDA= Pont d'Arcole.

The first Dinantian formations (up to the Ourthe Formation, Fig. 7) show only moderate lateral variation. The Ourthe Formation is extensively quarried for "Petit-granit" (crinoid-rich limestone), as are several other equivalent units from the Hainaut area. Following this formation, a significant differentiation separated a shallow, locally dolomitic platform (Condroz and Namur areas) from a more subsiding area where high accommodation allowed carbonate mounds to build. These mounds are called Waulsortian reefs, are nearly 400 m high and are rich in bryozoans and sponges (Lees et al., 1985). They are surrounded by chert-rich flank sediments. The final filling of the Dinant trough includes restricted fine-grained black limestone (the world famous "black marble" of the Molignée Formation). The Neffe Formation, consisting of bioclastic shoals, is a very pure light grey limestone. Quarries are intensely worked here for chemical purposes. Following is the Grand Malade Formation, characterized by evaporite beds. The dissolution of these evaporite beds was responsible for developing the Grande Brèche, which is a collapse breccia of several decameters thickness. Finally, the Anhée Formation registered a gradual decrease in carbonate production, progressively replaced by fine-grained detrital sediments.

8 The Namurian Detrital Formations

The Namurian series (Serpukhovian-base of Bashkirian) is essentially characterized by several hundreds of meters of black shale with subordinate marine limestone (Chokier Formation) (Nyhuis et al., 2014), followed by shale and coarse-grained sandstones or conglomerates (Andenne Formation). Small beds of coal announce the future development of the great equatorial coal forest (Fig. 6b).

9 The Westphalian Coal Measures

The Westphalian (Bashkirian-Moscovian) includes the bulk of the coal measures in Belgium. The uplift of the Variscan mountain belt led to a general retreat of the seas, leaving behind lagoons and marshes (Fig. 6c). Huge amounts of detrital sediments coming from the Variscan Mountains mixed with plant remains and accumulated due to long-lasting subsidence, now locally extending in over 2 km of formations. Even the Brabant massif was covered by kilometers of sediment. The Westphalian sedimentation shows a characteristic cyclicity: each cycle starts with a sandstone bed, followed by a coal seam and topped by shale. The sandstone was a soil, topped by organic matter from plants of the equatorial forest, accumulated in a reducing environment and drowned by shale. The ocean was confined to the Netherlands and made only episodic excursions, depositing marine sediments whose fossils are now very useful for stratigraphy.

10 The Variscan Orogeny

The remains of the Variscan mountain belt crop out from Spain to Bohemia, going through the Vosges, Massif Central, Ardenne and Cornwall. Variscan tectonics are responsible for the general structure of Belgium, with a major thrust fault having been formed and separating the Brabant parautochthon from the Ardenne allochthon. The Ardenne allochthon itself is structured in large-scale anticlines and synclines (Figs 1 & 2). The current model involves the closing of the Rheic Ocean during the end of the Carboniferous through the continental collision of Laurussia and Gondwana (Matte, 1986).

11 The Variscan Metamorphism

A well-developed yet low-grade metamorphic phase (anchizone-epizone, around 400°C) is recorded in the Ardenne (Fielitz & Mansy, 1999). Geographically, this metamorphic area has an elliptic shape, whose long axis is nearly 120 km long, located between Sévigny-la-Forêt (French Ardennes) and Trois-Vierges (Luxemburg) and whose short axis never exceeds 16 km. In addition to the development of various metamorphic minerals (garnet, chloritoid, magnetite, andalousite…), Variscan metamorphism is responsible for the transformation of shale into fine slate, used locally for roof tiles (Martelange). The age of the Variscan metamorphism is pre-orogenic and probably related to burial.

12 The Post-orogenic Times

Since the Variscan orogeny, no additional tectonic phases have influenced the Belgian and Luxemburg regions other than some local brittle deformations (Vandycke, 2002). Limited subsidence, however, has made further sedimentation possible. Monoclinal or horizontal unfolded formations have been locally accumulating from the Permian to the present.

13. Fieldtrip

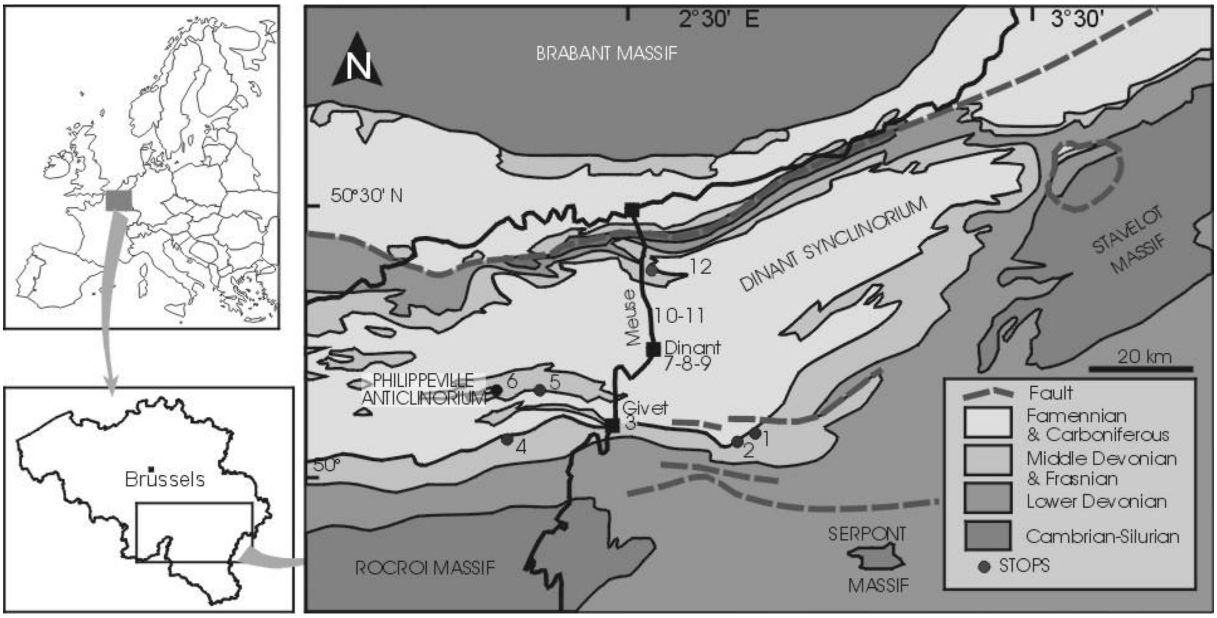

Fig. 8. Schematic geological map and general location of stops.

STOP 1 RESTEIGNE
Location: Disused quarry near the Lesse River in Resteigne. Southern border of the Dinant Synclinorium (Fig. 9).
Stratigraphy: Hanonet Fm. (Givetian), Trois-Fontaines Fm (Givetian), Terres d'Haurs Fm. (Givetian).
Observations: detailed bed-by-bed survey of Givetian facies. System tracts.

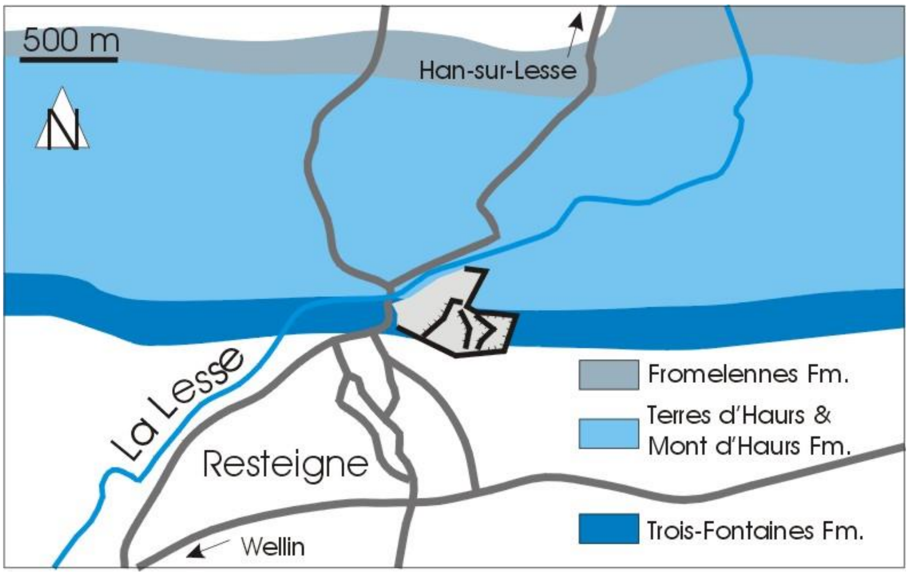

Fig. 9. Schematic geological map of the Resteigne area.

STOP 2 SOURD D'AVE
Location: Sourd d'Ave crossroad section. Southern border of the Dinant Synclinorium.
Stratigraphy: Fromelennes Fm (Givetian), Nismes Fm (Frasnian).
Observations: Givetian-Frasnian boundary.

STOP 3 FROMELENNES-FLOHIMONT

Location: Section along the road from Fromelennes to Flohimont, near Givet (Fig. 10). Southern border of the Dinant Synclinorium.
Stratigraphy : Trois-Fontaines Fm (Givetian), Terres d'Haurs Fm. (Givetian), Mont d'Haurs Fm. (Givetian), Fromelennes Fm. (Givetian), Nismes Fm. (Frasnian).
Observations: Givetian facies. Givetian-Frasnian boundary.

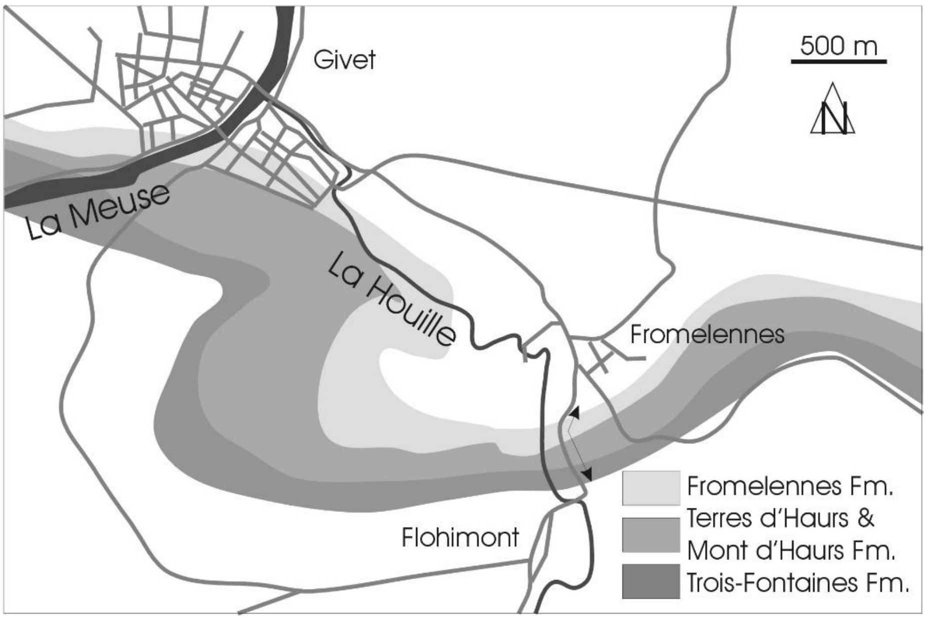

Fig. 10. Schematic geological map of the Givet area. Arrowed: the Fromelennes-Flohimont road section.

STOP 4 NISMES
Location: Paleocryptokarst in the Givetian limestone. Southern border of the Dinant Synclinorium.
Stratigraphy: Hanonet Fm, Trois-Fontaines Fm (Givetian).
Observation: karstic features, Givetian reefal facies.

STOP 5 LES WAYONS
Location: Disused quarry ("Les Wayons") near Merlemont. Philippeville Anticlinorium (Figs 11, 12).
Stratigraphy: Neuville Fm., Petit-Mont Member (Frasnian).
Observations: Frasnian mound facies, stromatactis.

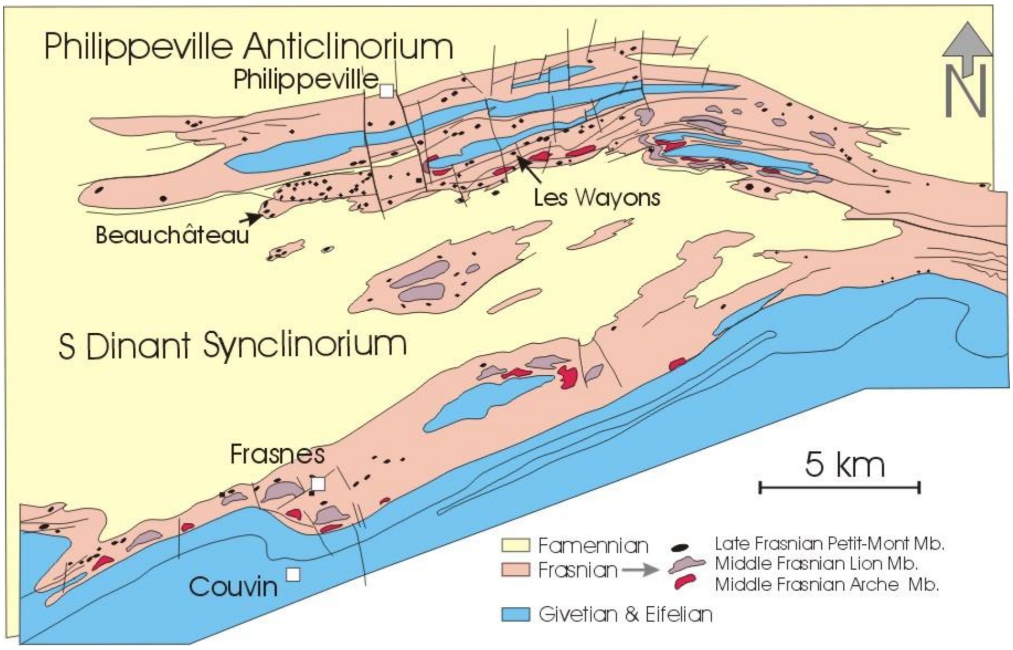

Fig. 11. Schematic geological map of the Philippeville Anticlinorium and related part of the Dinant Synclinorium.

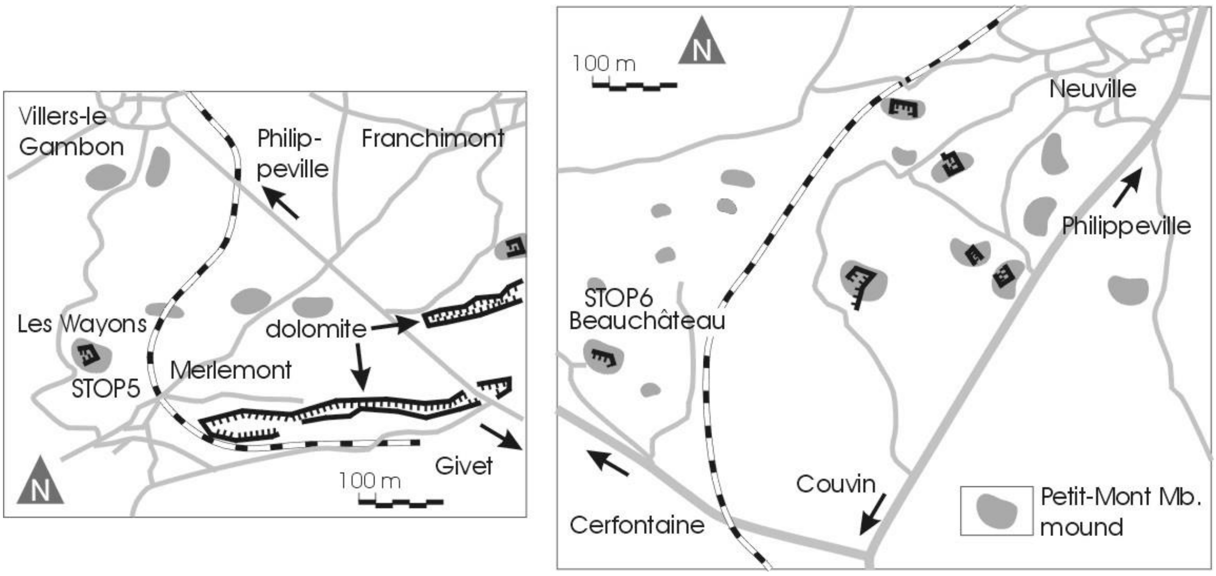

Fig. 12. Location of stops 5 and 6.

STOP 6 BEAUCHATEAU

Location: Disused quarry ("Beauchâteau") near Senzeilles. Philippeville Anticlinorium (Figs 11, 12).
Stratigraphy: Neuville Fm., Petit-Mont Member (Frasnian).
Observations: Frasnian mound facies, sedimentary geometry.

STOP 7: ANSEREMME

Location: railway section, south of Dinant. Dinant Synclinorium (Fig. 13).
Stratigraphy: Strunian, Hastarian (Hastière Fm, Pont d'Arcole Fm, Landelies Fm).
Observations: Devonian-Carboniferous boundary, sedimentological significance of system tracts.

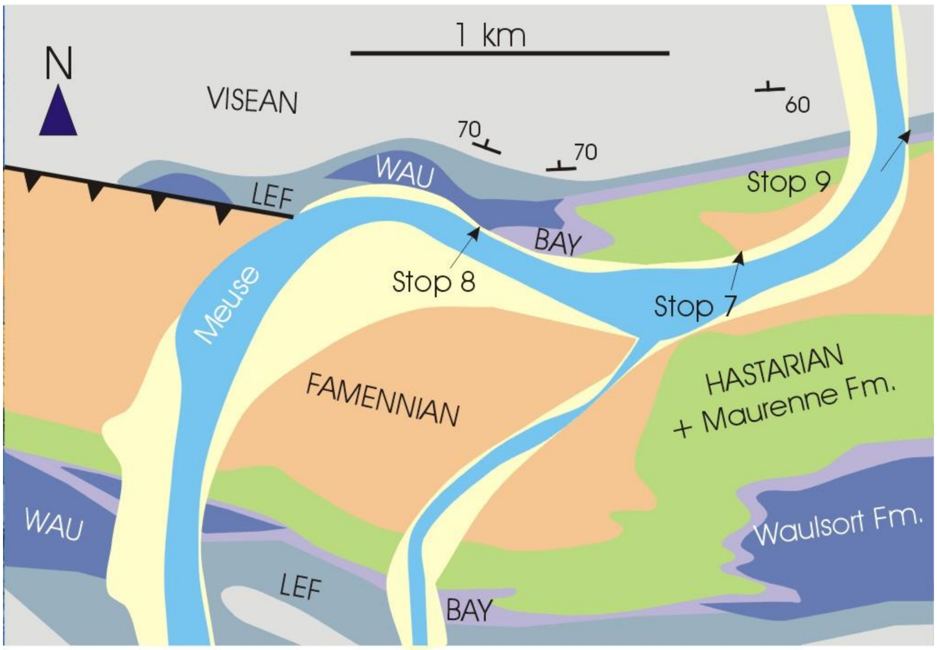

Fig. 13. Schematic geological map and location of stops 7-8-9.

STOP 8: MONIAT
Location: road section, south of Dinant. Dinant Synclinorium (Fig. 13).
Stratigraphy: Ivorian (Waulsort Fm).
Observations: Waulsortian mound facies.

STOP 9: BAYARD
Location: road section, Dinant. Dinant Synclinorium (Fig. 13).
Stratigraphy: Hastarian-Ivorian (Landelies Fm, Bayard Fm and Leffe Fm).
Observations: lateral equivalents of Waulsortian mounds.

STOP 10: SALET
Location: road section, Salet. Dinant Synclinorium (Fig. 14).
Stratigraphy: Ivorian-Moliniacian (Bayard Fm, Leffe Fm, Molignée “black marble” Fm, Salet Fm, Neffe Fm).
Observations: lateral equivalents of Waulsortian mounds and post-mounds formations.

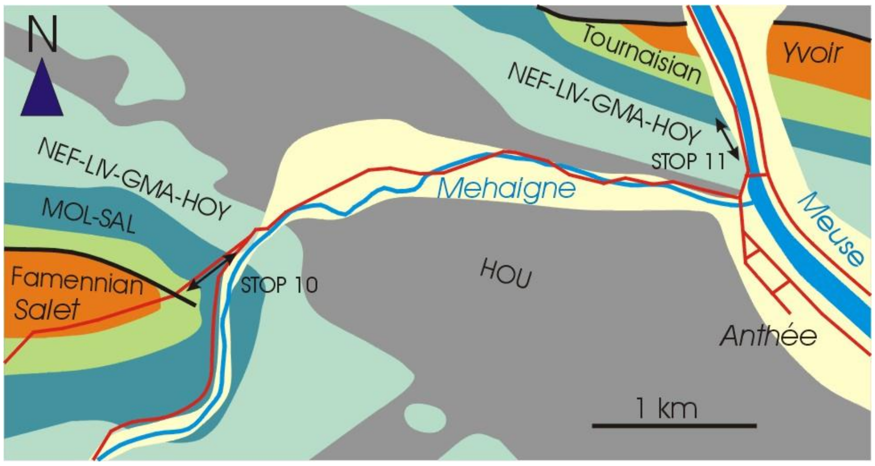

Fig. 14. Schematic geological map of the Salet-Yvoir area. MOL: Molignée Fm, SAL: Salet Fm, NEF: Neffe Fm, LIV: Lives Fm, GMA: Grands Malades Fm, HOY: Hoyoux Group.

STOP 11: YVOIR

Location: road section, Yvoir. Dinant Synclinorium (Fig. 14).
Stratigraphy: Moliniacian-Livian (Neffe Fm, Lives Fm, Grands-Malades Fm, La Bonne Fm) (Fig. 15).

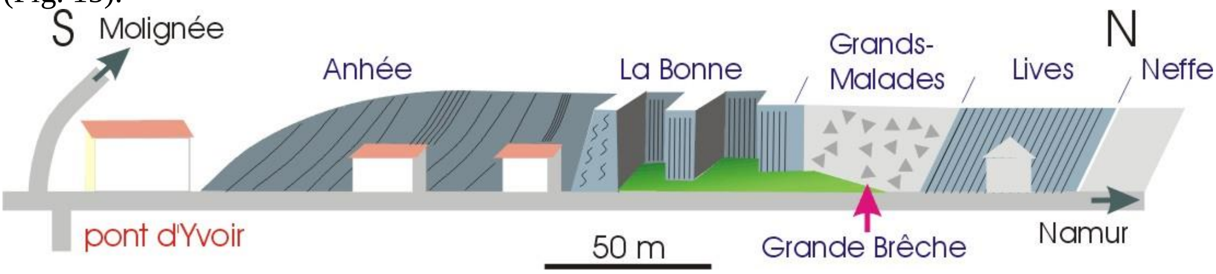

Fig. 15. The pont d'Yvoir section.

STOP 12 TAILFER

Location: Tailfer road section and Tailfer quarry. Dinant Synclinorium (Fig. 16).
Stratigraphy: Presles Fm, Lustin Fm (Frasnian).
Observations: iron oolithes, proximal Frasnian facies, different types of stromatoporoids buildups.

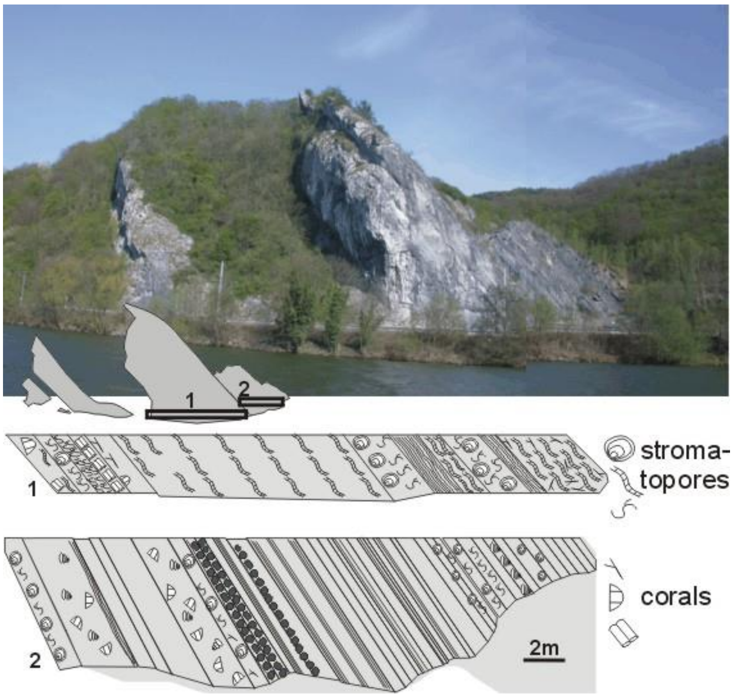

Fig. 16. The Lustin Formation in Tailfer.

14. Short reference list

Boulvain F (2007) Frasnian carbonate mounds from Belgium: sedimentology and palaeoceanography. In: Álvaro JJ, Aretz M, Boulvain F, Munnecke A, Vachard D, Vennin E (eds) Palaeozoic Reefs and Bioaccumulations: Climatic and Evolutionary Controls. Geol Soc of London, Sp Publ 275: 125-142.

Boulvain F, Mabille C, Poulain G, Da Silva AC (2009) Towards a palaeogeographical and sequential framework for the Givetian of Belgium. Geologica Belgica 12: 161-178.

Boulvain F, Pingot JL (2015) Genèse du sous-sol de la Wallonie. Acad roy Belgique, Bruxelles: 208 p.

Da Silva AC, Boulvain F (2004) From palaeosols to carbonate mounds: facies and environments of the Middle Frasnian platform in Belgium. Geological Quarterly 48: 253-266.

Goemaere E, Dejonghe L (2005) Paleoenvironmental reconstruction of the Mirwart Formation (Pragian) in the Lambert quarry (Flamierge, Ardenne, Belgium). Geologica Belgica 8: 37-52.

Hance L, Poty E, Devuyst FX (2001) Stratigraphie séquentielle du Dinantien type (Belgique) et corrélation avec le nord de la France (Boulonnais, Avesnois). Bull Soc Géol France 172: 411-426.

Lees A, Hallet V, Hibo D (1985) Facies variation in Waulsortian buildups. Part I. A model from Belgium. Geol J 20: 138-153.

Meilliez F (2006) La discordance éodévonienne de l'Ardenne: caractérisation stratigraphique et paléo-environnementale de la Formation de Fépin et ses conséquences. Géol de la France 1-2:29-33.

Nyhuis C, Rippen D, Denayer J (2014) Facies characterization of organic-rich mudstones from the Chokier Formation (lower Namurian), south Belgium. Geologica Belgica 127: 311-322.

Thorez J, Dreesen R, Streel M (2006) Famennian. In: Dejonghe L (ed) Current status of chronostratigraphic units named from Belgium and adjacent area. Geologica Belgica 9: 27-45.

Vandycke S (2002) Paleostress records in Cretaceous formations in NW Europe: extensional and strike-slip events in relationships with Cretaceous-Tertiary inversion tectonics. Tectonophysics 357: 119-136.

Ziegler PA (1982) Geological atlas of the Western and Central Europe. Shell Int Petrol Maatsch: 130 p.