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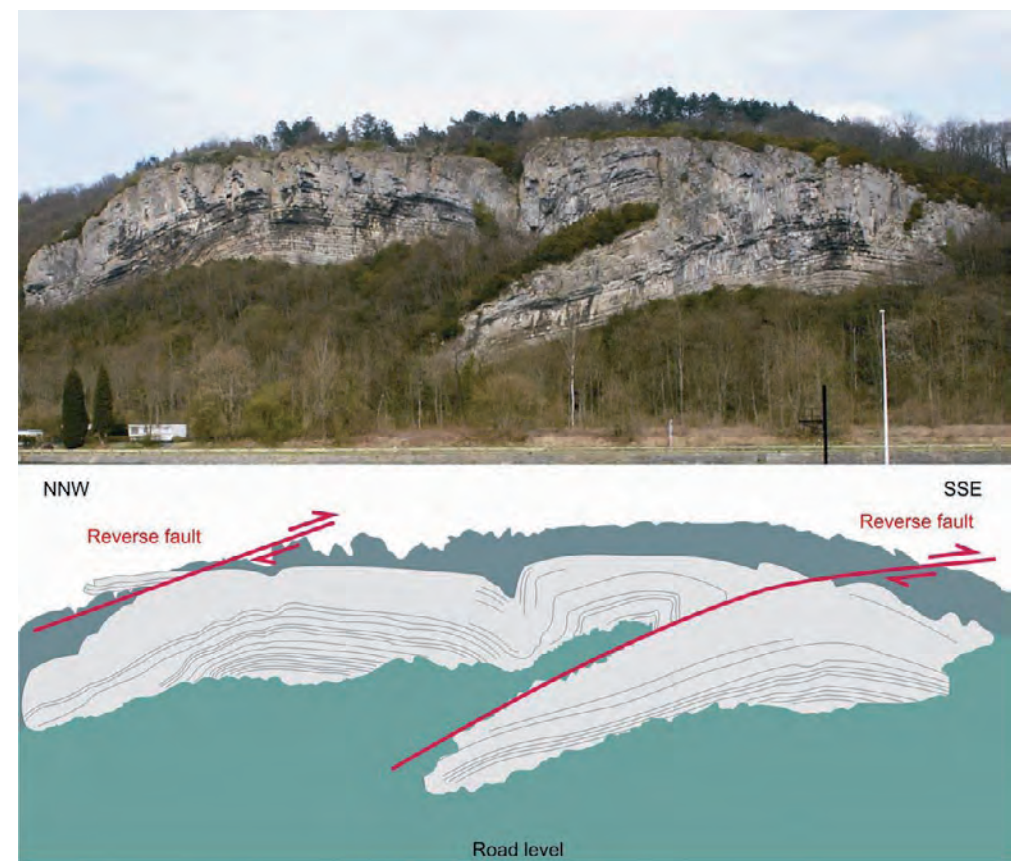
Geoffrey CAMBIER & Léon DEJONGHE



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(95 pages, 119 figures, 1 table)

Cover illustration: the Chamia Rocks on the western bank of the Meuse river near Waulsort (Dinant Synclinorium). Tournaisian crinoidal limestones (Landelies Formation) have been affected by Variscan shortening and diastrophism: two gently north-dipping reverse (thrust-type) faults bounding three tectonic stacks. Photo: L. Dejonghe.

Content

SYSTEMATIC INVENTORY AND ORDERING OF FAULTS IN BELGIUM – PART 1

Geoffrey CAMBIER & Léon DEJONGHE

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ABSTRACT. The cataloguing of the major Belgian faults started up through the so-called "Faults project", which aims at to prepare an inventory compiling the structural information and the tectonic interpretations of each fault concerned. The evolution of the ideas observed in the literature over the years and the divergent points of view are taken into account without taking position for one of them if a major consensus is not emerging. Bibliographic research constitutes the basis of the work of which completion will enable to clarify the large and scattered literature. The results will be brought out as Professional Paper(s) of the Geological Survey of Belgium and as a national-scale structural map of the Belgian fault network. An electronic open access database will be considered.

Keywords: inventory, faults, Belgium.

1. Introduction

For many years in Belgium, numerous faults have been described in the literature or drawn on geological maps. These fractures are rarely obvious and their justification comes generally from abnormal lithostratigraphic contacts. The structural complexity of the folded and faulted Belgian terrains, coupled with the difficulty in observing physical traces of the faults, has contributed to the development of a large and scattered literature. Indeed, some authors have advanced strongly divergent points of view about a single fault with regards to its location, geometric features and tectonic interpretations. A cataloguing of the faults therefore appears essential to clarify the literature.

The aim of this work is to prepare an inventory compiling the main structural (geometrical and interpretative) information and describing the evolution of ideas observed in the Belgian literature over the years. It is not intended to come out for or against one or other divergent opinion but to provide a practical tool of consultation. The approach is essentially based on bibliographic research; no fieldwork has been performed to verify the data in the literature.

A first chapter summarises the theoretical structural basis of fault studies according to international terminology. The systematic approach that is used to make this inventory as clear and simple as possible is then developed and, as a reminder, a brief description of the Belgian geological setting is presented. Next, a history is given of deliberations on faults in the Belgian literature. The subsequent and major part of this document is devoted to descriptive data sheets of the faults in alphabetic order.

2. Descriptive terminology and classification of faults

This chapter is a reminder of the common geological terminology applied to brittle structures based on the work of Ramsay & Huber (1987) and Twiss & Moores (1992).

Faults are breaks, brittle features or fracture discontinuities in rocks along which a significant displacement has occurred. The displacement, also known as offset, slip, or even throw, takes place along the **fault plane**, which, if intersected with the ground surface, defines the mappable **fault trace** (or **fault line**).

A fault separates the rock masses into two **fault blocks**. If the fault plane is inclined, geologists assign the **hanging wall** to the block overlying the fault and the **footwall** to the rocks located below the plane (Fig. 1).

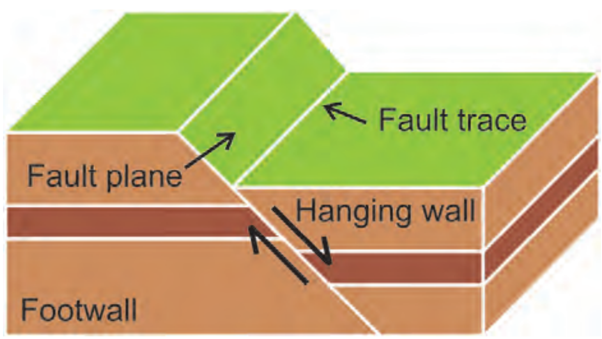

Fig. 1. Schematic block-diagram of a normal fault.

A fault can be differently described and classified according to (1) the strike of the fault trace, (2) the degree of inclination, (3) the direction of the movement, and (4) the nature of the relative offset between blocks (Fig. 2).

(1) A fault is said to be **longitudinal** when the orientation of its trace strikes parallel to the strata direction and **transverse** when oblique to the strata direction.

(2) Considering the dip of the fault plane, geologists refer to a gently dipping fault (dip less than 45°) as a **low-angle fault** and a steeply dipping fault (dip more than 45°) as a **high-angle fault**.

(3) The direction of movement defines three major kinds of faults:

- a **dip-slip fault** (Fig. 2a & 2b), where the offset is parallel to the dip. The vertical component of the dip-slip is called the throw and the horizontal component, the heave;
- a **strike-slip fault**, or **wrench fault**, (Fig. 2c) is used where the offset is parallel to the strike of the fault trace, or in other words where the main component of the displacement is horizontal;
- an **oblique-slip fault** (Fig. 2d), where both vertical and horizontal components exist.

(4) The relative movement between fault blocks defines other types of fault:

- The vertical offset of a dip-slip fault can be further described as normal (Fig. 2a) if the hanging wall block has moved downward relative to the footwall block (extension), or reverse (Fig. 2b) for the inverse case (shortening). In the case of a gently dipping reverse fault, the term thrust fault is preferred.
- The horizontal offset of a strike-slip fault is said to be sinistral or left-lateral (Fig. 2c) when the block on the other side of the fault (located in front of the "observer") has moved to the left, and dextral or right-lateral when the block has moved to the right.
- A last type of fracture, the rotational fault, has a changing slip along the trace.

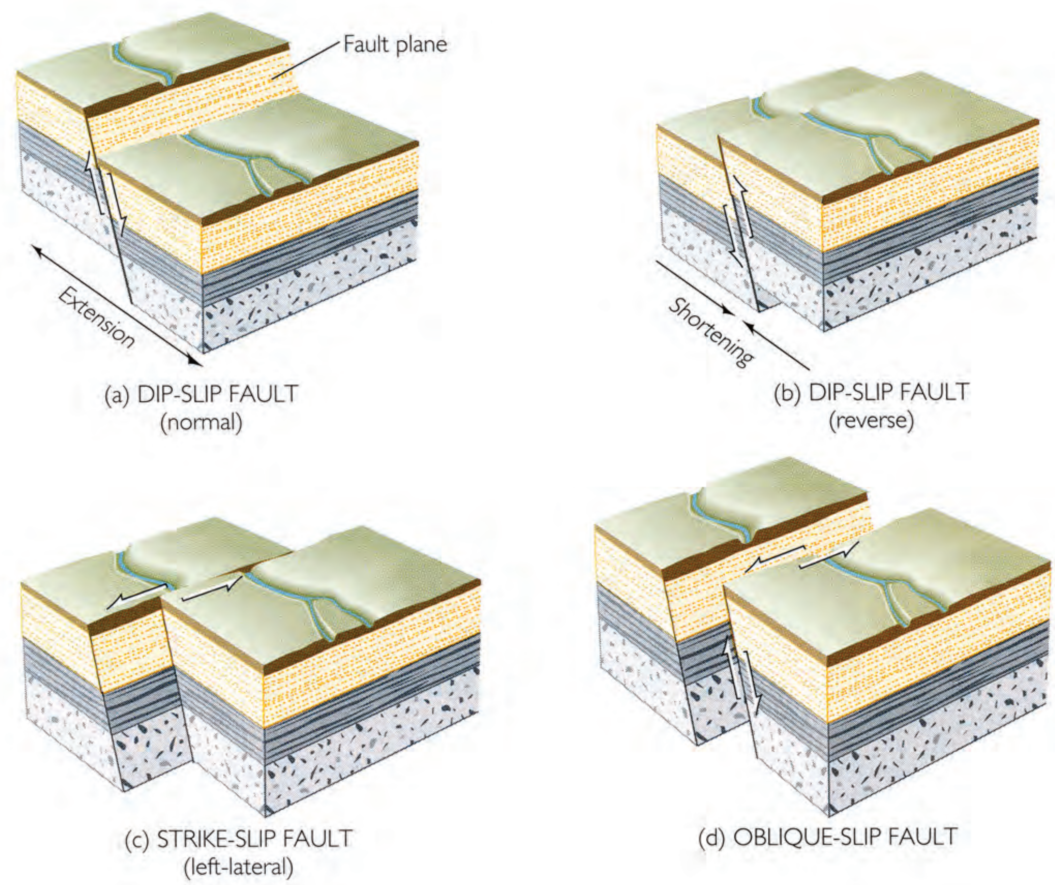

Fig. 2. Schematic representations of the different kinds of faults (Press & Siever, 2000). Explanations are in the text and the figure.

3. Method

Each fault is described using a systematic framework. Depending on data availability, information will be given on:

Name(s) of the fault

Location (i.e. general introductive note giving the first author(s) to describe the fault, the localities concerned and the regional geological setting)

Lithology and **stratigraphy** (i.e. the names of formations and/or groups and their constitution)

Amerois Fault

Location

Dewalque (1897)[1] drawn a 3.4 km long and SE-striking fault in the north-eastern vicinity of Muno. That fracture, which was not yet named, corresponds precisely to the location of the Amerois Fault drawn by Beugnies in 1960[2]. The fault is located south of the Eifel Synclinorium, running from the north of Bouillon to approximately 1 km east of Muno[2] (Fig. 1). In its southern segment, the transverse Amerois Fault crosscuts the periclinal termination of the E-plunging and N-verging overturned Givonne Anticline[3], which is made up of a Cambrian core. In its northern segment, the fault cuts the southern border of the Lower Devonian Eifel Synclinorium. This one constitutes the Variscan unconformable cover on the Cambrian Givonne Inlier.

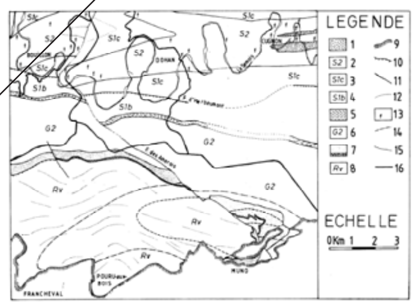

Fig. 1. Geological map of Bouillon-Muno region[4]. See Beugnies[4] for the description of the legend. Note that the Amerois Fault crosscuts and displaces the lithologic contacts, the Hercynian metamorphic isogrades and the Herbeumont Thrust.

Lithology and stratigraphy of the country rocks[2,5]

The fault thrusts the Upper Cambrian of the Givonne Inlier over the Lower Devonian cover (Fig. 2). According to Beugnies (Fig. 1, 1988)[4], the fault disrupts:

- the Revinian (Upper Cambrian). See the Aiglemont-Herbeumont Fault for a description;
- the Mondrepuits Fm (Lower Lochkovian), mainly made up of shales and micaceous silstones;
- the Oignies and the Saint-Hubert formations, respectively "G2a" and "G2b" (Upper Lochkovian), composed by shales, sandstones and quartzites;
- the Verlaine Fm ("Sg1a", Lower Praguian), made up of dark blue phyllites;
- the Mohret Fm ("Sg1b", Lower Praguian), made up of phyllites and quartzites;
- and the Alle Fm ("Sg1c", Lower Praguian), made up of phyllites.

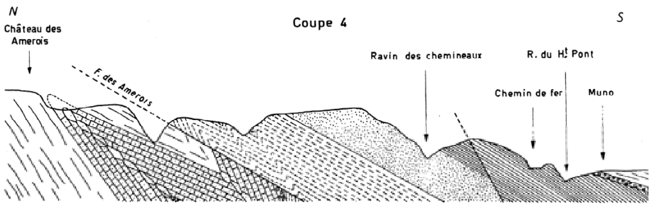

Fig. 2. Geological section through the eastern periclinal termination of the Givonne Anticline[2]. The Cambrian formations are thrusted northwards on the Lower Devonian terrains.

Geometry

The trace has a general NW strike that curves northwards in the Bouillon vicinity. It extends for at least 14 km long (Fig. 1). The transverse Amerois Fault is subdivided into two segments that display different inclinations[4]. The western segment is a low-angle (20 to 30°) fault that dips to the SW while the eastern segment dips steeply (about 45°) to the same direction. Beugnies (1988) assumed that the fracture is an oblique-slip fault:

- the SW fault block is upthrown and thrusted on the NE compartment, the reverse dip-slip component reaches 200 m;
- the western block has moved to the north, the dextral strike-slip component reaches between 1200 and 1600 m.

The Amerois Fault extends probably southwards under the Jurassic and monoclinal cover of the Paris basin (not affected by the fracture).

Interpretations

The fault disrupts many formations that are dated to the Cambrian but also to the Lower Devonian. Those terrains have undergone the Caledonian and/or the Variscan diastrophism. However, the hypothesis of the Variscan reactivation of a pre-existing Caledonian fracture is not envisaged by Beugnies[2].
Precisely, the overthrusting that displaced the Givonne Inlier over the Eifel Synclinorium is probably related to the contractional constraints acting during the Variscan Orogeny. Moreover crosscutting relations can constrained the Amerois Fault to be late-Variscan in age[4]. In that way, the fault crosscuts and displaces the Hercynian metamorphic isogrades and the Herbeumont thrust fault. Both are dated to the Asturian stage. No Mesozoic reactivation is assumed.

References

1. Dewalque, 1897.
2. Beugnies, 1960.
3. Ghysel & Belanger, 2006.
4. Beugnies, 1988.
5. Beugnies, 1985.

Interpretations (origin of the fault: geodynamic process and approximate age)

References (each refering to the detailed bibliography at the end of the manuscript)

Geometry (shape and direction of the trace, direction and value of the dip, type and value of the offset, possible relations with other faults…)

4. Geological setting

Basically, Belgian geology comprises a Caledonian Cambrian-Silurian basement that is unconformably covered with a thick Variscan Devonian-Carboniferous series. Palaeozoic rocks are intensely folded and faulted and are overlaid by flat-lying post-Variscan deposits of various Permian to Quaternary ages. Mesozoic-Cenozoic cover is discontinuous, both in space and time.

The southern part of Belgium belongs to the Rhenohercynian Zone, a geotectonic region of the Variscan area in Europe (Fig. 3). Kossmat (1927) has actually defined several tectono-metamorphic zones corresponding to the northern frontal regions of the Variscan orogen in western and central Europe. The Rhenohercynian foreland fold-and-thrust belt represents the northern extremity, or northern external parts of the European Variscides.

The northern part of Belgium belongs to the London-Brabant Massif (Pharaoh *et al.*, 1993) (also known as the Anglo-Brabant Massif or Anglo-Brabant Fold Belt). Its Belgian section, the Brabant Massif, forms the eastern termination of the British-Belgian Caledonides. Because of an extended, mainly Eocene cover, for the most part the Brabant Massif does not outcrop.

The Asturian stage of the Variscan shortening, Westphalian in age (~300 Ma), accounts for the present layout of the tectono-stratigraphic units in Belgium (Fig. 4 & 5). The compressive stresses are responsible for progressive deformation of the Rhenohercynian basin area and the northward regional thrust of a large allochthonous domain, the Ardenne Allochthon (also known as "Charriage du Condroz" or "Dinant Nappe"), over its foreland, the Brabant Parautochthon. The allochthon exposes the typical structures found in fold-and-thrust belts that are established in the peripheral foreland of an orogenic zone. Thin-skinned tectonics characterizes the Variscan deformation.

The Variscan front thrust (**1**, Fig. 4) is subdivided into several connected segments that are from west to east: the Midi Fault, the Sambre-et-Meuse (or Condroz) Inlier, the Eifelian Fault and the Aachen Fault. The frontal fault system of the Ardenne Allochthon is easily confirmed in the vicinities of Hainaut and Liège. However, the Variscan front remains problematic along the Sambre-et-Meuse Inlier where the connection between the Midi and Eifelian faults is controversial and also to the east of Liège where it splits into several thrusts. In eastern Belgium, the position of the frontal thrust depends on the way the problematic Aguesses-Asse Fault(s) is conceived (see Aguesse-Asse Fault(s) in section 6.1 for detaila). In fact, the transition between the parautochthonous and autochthonous domains is distributed between several thrusts and a sharp limit between these units cannot therefore be defined.

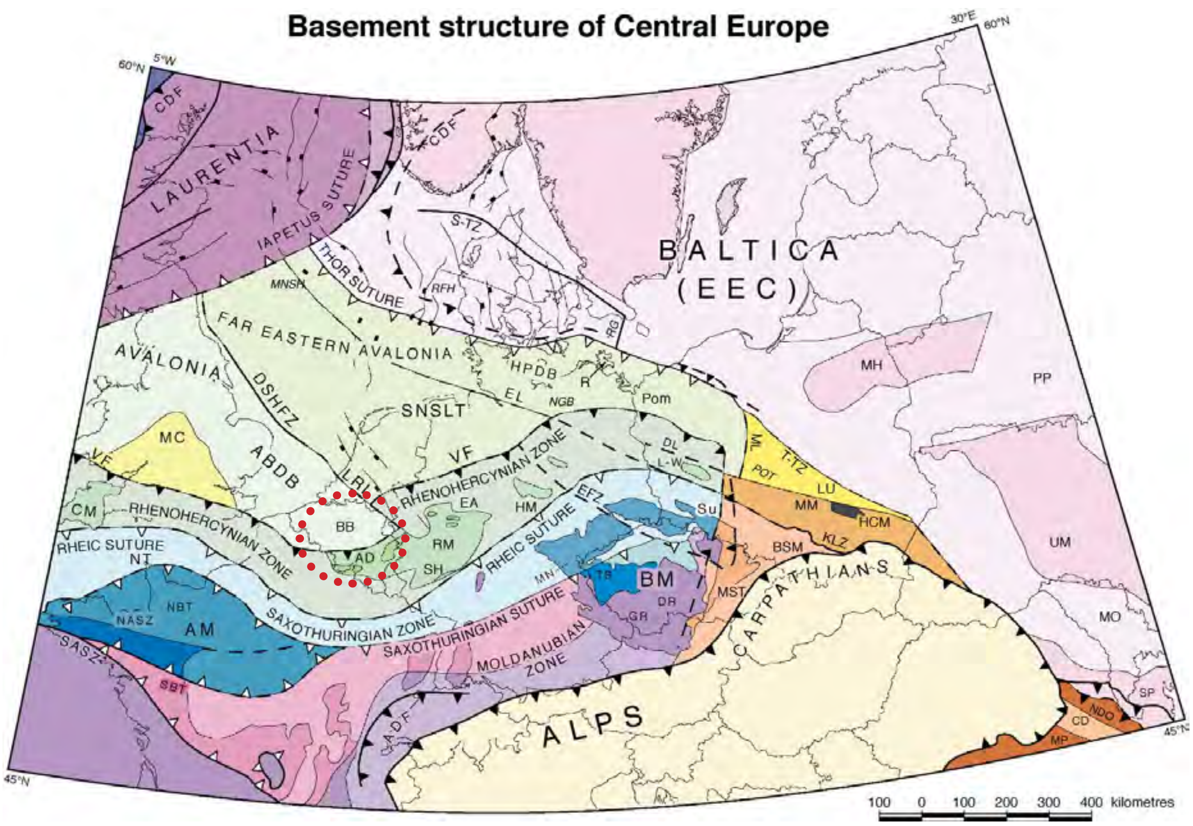

Fig. 3. Disposition of the Central European terranes and Palaeozoic deformation belts (Winchester & PACE TMR Network Team, 2002). Abbreviations of the units concerned: ABDB = Anglo-Brabant Deformation Belt; AD = Ardennes Massif; BB = Brabant Massif; VF = Variscan Front.

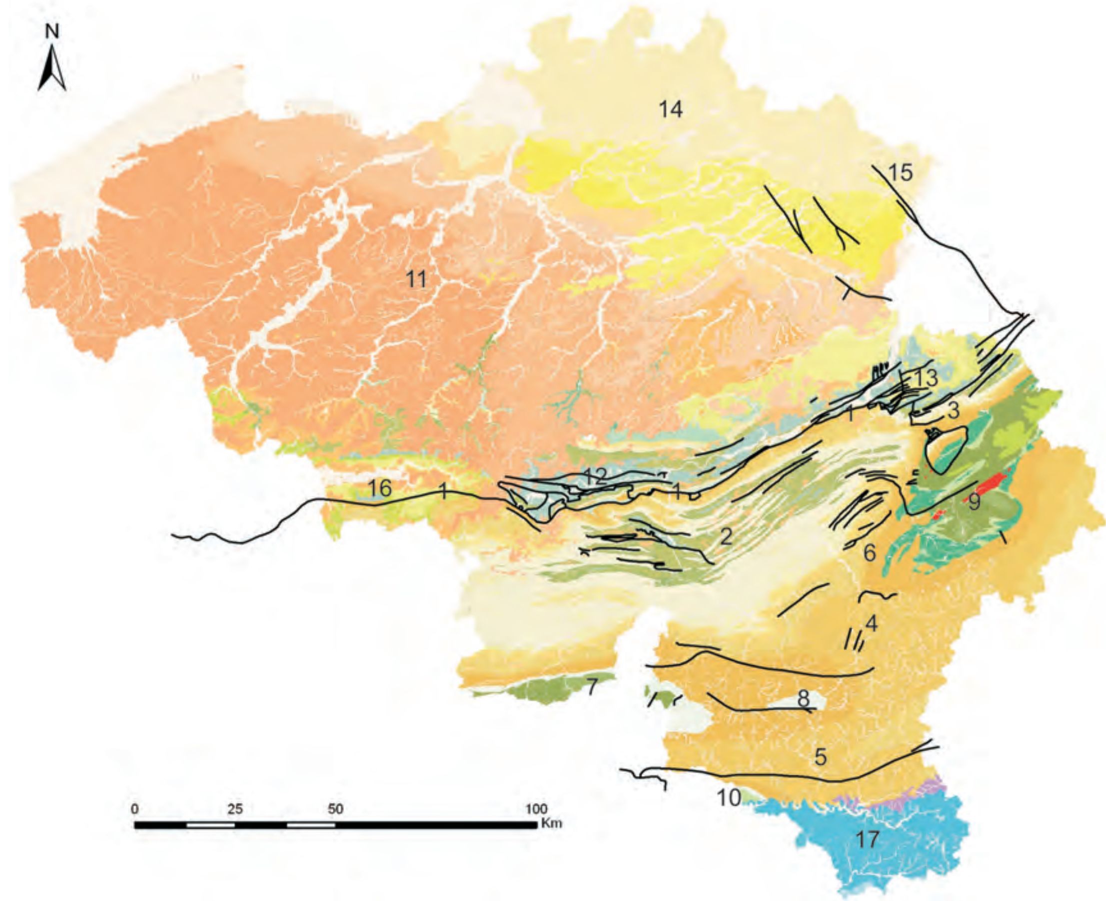

Fig. 4. Geological map of Belgium (modified from http://www.onegeology.org). See the International Stratigraphic Chart (http://www.stratigraphy.org) for the legend. Fault component is from de Béthune (1965). The numbers refer to the main lithological and structural units. See the text for their description.

The frontal area of the Ardenne Allochthon comprises the Dinant fold-and-thrust belt (**2**, Fig. 4) (or Dinant Synclinorium) and its lateral equivalent to the northeast, the Vesdre Nappe (**3**, Fig. 4). Both are made up of Devonian-Carboniferous rocks that form a sequence of interbedded competent (limestone) and incompetent (sandstone) layers. During the Variscan compression, an association between north-vergent folds and south-dipping reverse faults (fold-and-thrust belt) developed. These longitudinal faults are plentiful in the Dinant Synclinorium and are generally related to the northern limbs of the anticlines.

The inner part of the Ardenne Allochthon comprises the High-Ardenne slate belt, which can be subdivided in the Ardenne Anticlinorium (**4**, Fig. 4) to the north and the Neufchâteau-Eifel Synclinorium (**5**, Fig. 4) to the south. These units consist of a homogeneous sequence of Lower Devonian pelitic rocks of incompetent character. A dominant slaty cleavage is developed in response to the Variscan compression. Faults described in this framework may belong to various networks of different origin:

(1) a main network of longitudinal, E-W trending and gently south-dipping thrust faults, related to the main compressive Variscan (Asturian) stage;

(2) the Ourthe dextral strike-slip fault system (**6**, Fig. 4), constituting a dozen transverse, NNE-striking faults related to the stop-pin behaviour of the Caledonian Brabant Massif during the northward thrust of the Ardenne Allochthon;

(3) a network of longitudinal and normal faults that probably appeared during the post-Variscan extensional relaxation stage; and

(4) a network of transverse NNW-SSE-striking sub-vertical normal (and seismogenic) faults in eastern Belgium and related to the opening of the Rhine-Roermond Graben.

Several Lower Palaeozoic inliers crop out in the axial zone of the Ardenne Anticlinorium, from west to east, the Rocroi (**7**, Fig. 4), the Serpont (**8**, Fig. 4) and the Stavelot-Venn (**9**, Fig. 4) massifs respectively. The Givonne Massif (**10**, Fig. 4), of Cambrian age, is located to the south of the Eifel Synclinorium. As these Cambrian-Ordovician basement inliers are supposed to have been affected by both Caledonian and Variscan orogenies, the interpretations of the faults disrupting these areas remain generally problematic.

The Brabant Parautochthon comprises the Lower Palaeozoic Brabant Massif to the north (**11**, Fig. 4) and the “Namur Synclinorium” (**12**, Fig. 4) and Liège Syncline (**13**, Fig. 4) to the south. The latter constitute the unconformable Upper Palaeozoic cover of the Brabant Massif and are directly located in the footwall of the Midi-Eifelian Fault. The Namur and Liège units are therefore parts of the foreland Variscan basin over which the Ardenne Allochthon is thrust. Many longitudinal, south-dipping thrust faults linked to the Variscan front thrust disrupt the southern part of the parautochton unit. In the Hainaut area, the southern Devonian-Carboniferous extremity of the Brabant Parautochthon is subdivided into two main units. The first relatively undeformed northern unit rests unconformably over the Brabant basement and is located at the footwall of the major Masse-Barrois Fault. The second southern unit comprises numerous imbricate thrust sheets. It lies between the reverse Masse-Barrois and Midi faults and is thrust over the undeformed Devonian-Carboniferous cover of the Brabant Massif. This structural view of the Hainaut coal-basin implies the disparition of the “Namur Synclinorium” concept, as both “limbs” of the “synclinorium” do not belong to the same tectonic entity (Fig. 5).

The Campine Basin (**14**, Fig. 4) constitutes the Devonian-Carboniferous cover of the northeastern flank of the Brabant Massif. The area shows typically NW-SE striking normal faults that were mostly reactivated in a contractional way. Palaeozoic formations of the Campine Basin are overlaid by rocks of Permian to Jurassic age.

In the northeasternmost part of Belgium, the Roer (Ruhr) Valley Graben (**15**, Fig. 4) constitutes a seismically active subsiding area of the Rhine Graben rift system. The graben is bounded by two antithetic, normal and NNW-SSE striking faults of Quaternary age: the Feldbiss Fault to the west, partly in Belgium, and the Peelrand-Rurrand Fault to the east (in the Netherlands and Germany). Cenozoic deposits more than 2000 m thick have filled the basin from the Late Oligocene.

The Mons Basin (**16**, Fig. 4) constitutes a Cretaceous to Early Tertiary sedimentary filling located in the western Belgian Variscan front zone. Four main extensional (subsidence) stages and synsedimentary tectonics associated with temporary contractional events have enabled the filling and structuring of the basin. Various networks of differently striking normal faults are related to that tectonics.

The Belgian Lorraine (**17**, Fig. 4) in the southernmost area of Belgium belongs to the northeast border of the Paris basin. It displays flat-lying gently south-dipping Triassic-Jurassic rocks. The formations of various lithologies unconformably cover the southern limb of the folded Variscan Eifel Synclinorium. Many NNE-striking and subvertical faults crosscut this Mesozoic cover. Interpretations assume an origin in relation to the post-Variscan opening of the “Gulf of Luxembourg”.

For more details on Belgian tectonics, the reader may, for example, consult the papers of Meilliez & Mansy (1990), Hance *et al.* (1999) and Sintubin *et al.* (2009) and their exhaustive bibliographies.

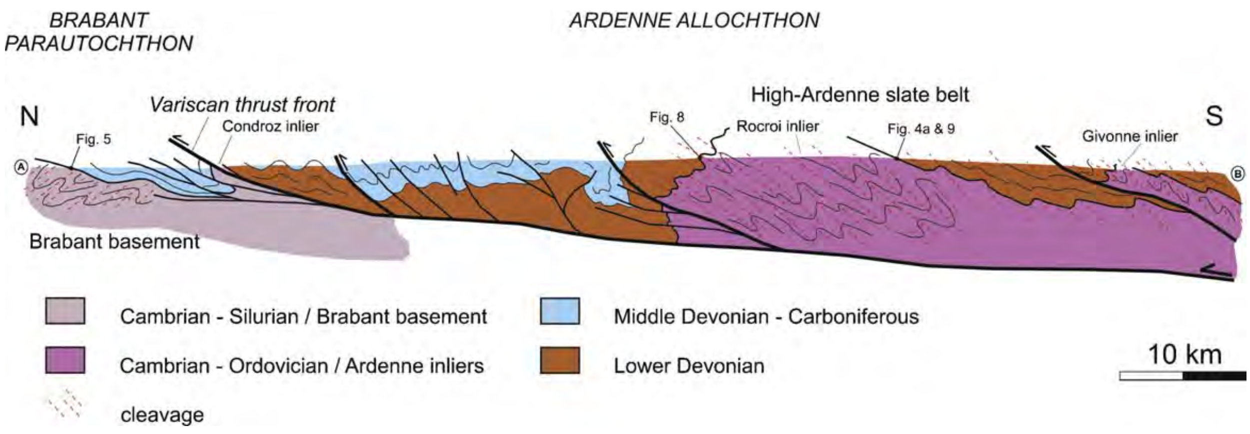

Fig. 5. Schematic cross-section of the Belgian Variscan frontal regions (Sintubin et al., 2009).

5. Evolution of some structural concepts in Belgium

Faults in Belgium have probably been known for a long time by miners. The mining industry and its related geological interests were developed early on from the end of the 12th century and especially during the 18th and 19th centuries (Dollé, 1985). When exploiting vein-type ore deposits, miners worked at rock discontinuities where ore was abundant. When exploiting stratiform deposits, miners had to search for the continuity of a seam disrupted by a fault. They used to refer to the "hanging wall" and the "footwall" blocks, the hanging wall block being the rock mass above the fault where the miner hangs his lantern and the footwall block, under the fault, being the place where he stands. Nowadays, these old mining terms still apply to fault studies.

Considering the abundance of outcrops both in the collieries of the "Sillon Houiller" and in the numerous valleys of the Ardenne Massif, most of the history of the study of faults in Belgium concerns compressive faults of the Variscan Rhenohercynian Zone. Moreover, as discussed above, the most outstanding structural feature of Belgian geology is undoubtedly the Variscan front thrust. Attempts at the interpretation of faults have therefore always paid special attention to the compressive tectonic regime and in general to "thrust tectonics".

The appearance of fault concepts in the Belgian earth science literature occurs properly during the 19th century. The structural model of rock deformation is related to the discovery of an important discontinuity, the Eifelian Fault, by André Hubert Dumont in 1832, to the south of the Upper Carboniferous Liège basin. The fracture, which was at that time considered to be of local significance, is therefore the first fault to be the focus of detailed studies and numerous publications. Dumont is also well-known for his detailed geological and structural map of the Liège basin (Fig. 6). Indeed, his map constitutes one of the first structural works of fault cartography in Belgium.

Jean-Baptiste Julien d'Omalius d'Halloy, Belgian geologist of the 19th century, is known as the "father of Belgian geology". He provides for the first time ever, in 1832 (in Cauchy *et al.*, 1832), a description of thrust phenomena in Belgium (Province of Liège). Without speaking explicitly of "thrusts", Omalius d'Halloy properly alludes to their existence. Indeed, the geologist talks about "dislocations of the earth's crust" and "movements of separated blocks" in which the origin is the same as that of earthquakes. He also indicates that strata, after their formation, have undergone violent movements and consequently acquired a specific structure that results from a "glide" on an inclined plane. Omalius d'Halloy was the first Belgian geologist to publish the existence of "horizontal overlap" as a particular kind of tectonic movement in the Ardenne.

Alphonse Briart and François-Léopold Cornet, two other Belgian geologists, suggest in 1863 that a major northward "horizontal translation" of the Ardenne occurs in the region between the French-Belgian boundary in the west and Germany in the east in which extended Devonian cover overlies Upper Carboniferous rocks. Cornet & Briart therefore developed in 1863 the structural concept of the "thrust nappe", which is generally attributed to Marcel Alexandre Bertrand who published in 1884 a comparison of tectonic structures between the "Glaris Alps" and the "Northern Houiller basin" (Trümpy & Lemoine, 1998). However, the structural concepts of the work of Bertrand (the "nappe de recouvrement") were inspired from the work of Gosselet (1880), who himself took inspiration from the work of Cornet & Briart (1863).

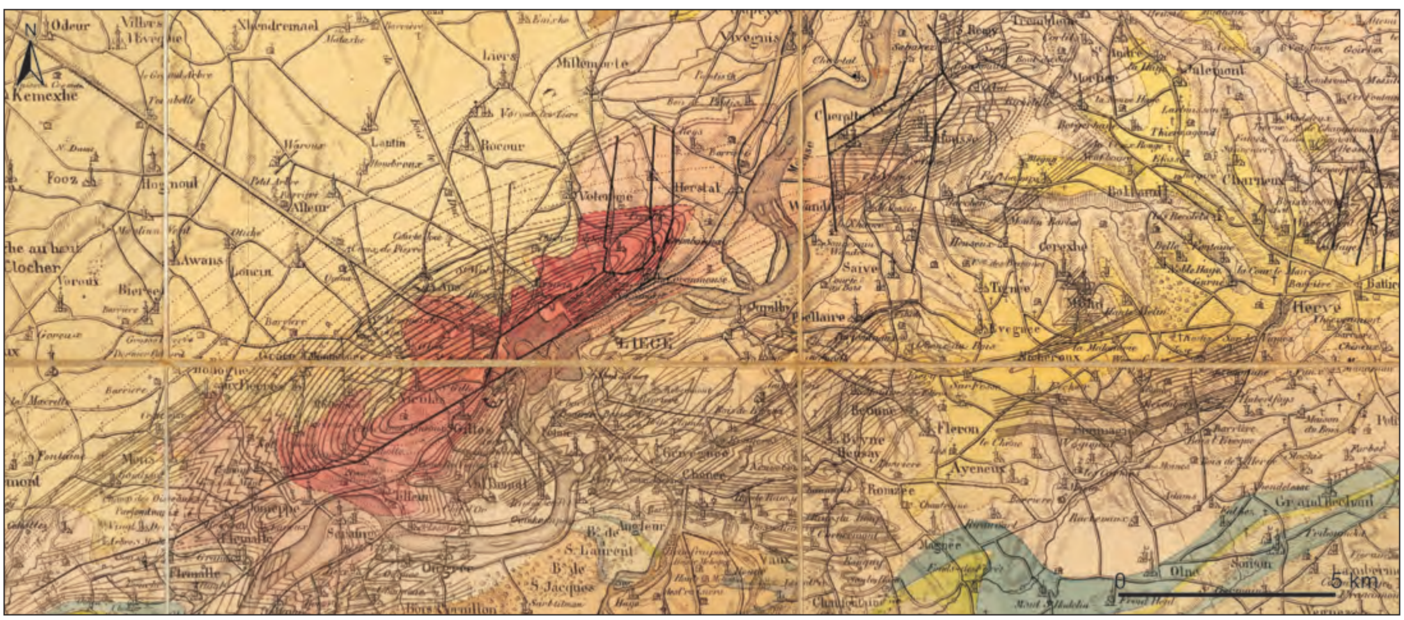

Fig. 6. Extract of the geological map of the Liège basin (Dumont, 1832).

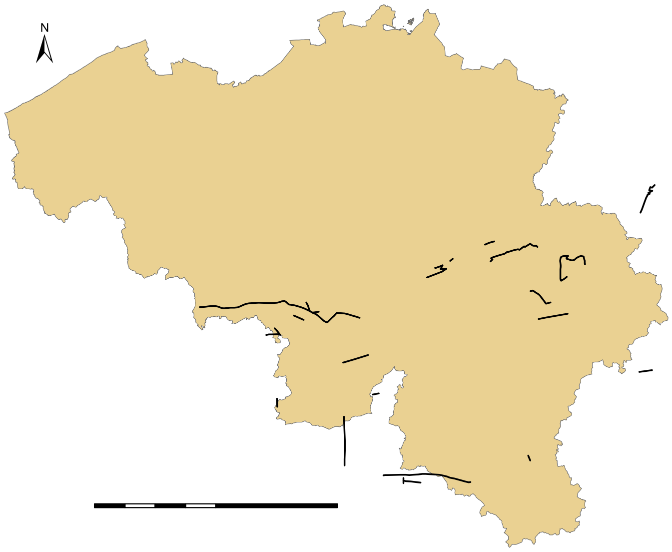

Fig. 7. Fault mapping in 1888, by Gosselet.

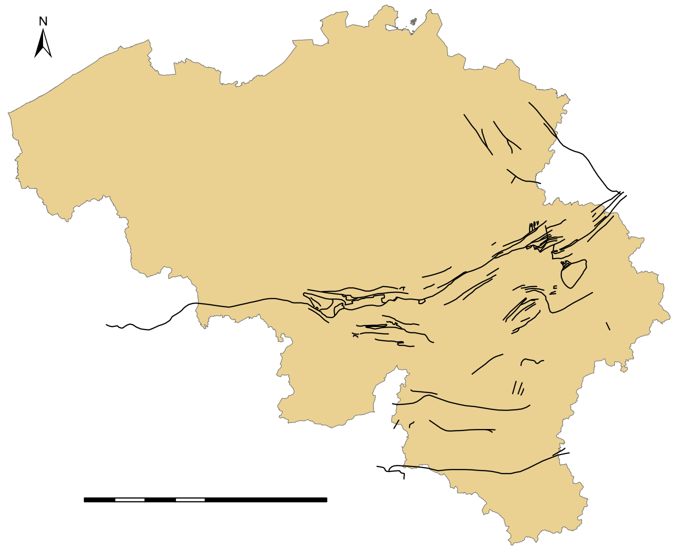

Fig. 8. State of the fault knowledge and cartography in 1965 (de Béthune, 1965).

Cornet is also directly implicated in the discovery of another major structural concept, that of the "thrust sheet". Indeed, he indicates in 1873 that the Midi Thrust fault plane is punctuated by rock masses that moved from depth and then pushed up along the thrust plane. This former concept is consistent with the current notion of thrust sheets.

The French geologist Jules Gosselet also made a major contribution to Belgian geology by studying some of the most significant rock discontinuities. His map (Fig. 7), dated to 1888, presents the state of knowledge about faults at the end of the 19th century. A twenty of fractures are traced; some of them correspond to the recognised Herbeumont, Vireux, Theux, Eifelian, Midi and Xhoris faults.

The study of a particular Belgian fault, the Theux Fault, has enabled the development of an important tectonic concept in the Rhenohercynian fold-and-thrust belt that is nappe transport and thin-skinned tectonics. The Belgian geologist de Dorlodot envisages in 1901 an interpretation of the Theux Unit (see the Theux Fault in section 6.27) as an "eyelet" of a large autochthonous zone probably resulting from the erosion of the overlying thrust nappe. This description accurately matches the notion of "tectonic window" developed at the same time in the Alps (Bertrand, 1899).

During the 20th century, many Belgian and French geologists have studied the numerous Belgium faults. In addition to the geologists cited above, Forir, Fourmarier, Macar, Kaisin, Ancion, Lohest, Stainier, Asselberghs, Renier, Geukens, Graulich, etc., have contributed to the discovery of new fractures and proposed tectonic interpretations. Fig. 8 presents the structural component of the well-known geological map of de Béthune (1965). The map is a compilation of geological data acquired by many geologists before 1965. In addition to the major discontinuities drawn by Gosselet in 1888, the cartography of the fault network is particularly improved in the Charleroi and Liège Houiller basins. About 60 "significant" faults are traced on the de Béthune's map.

The principle and major faults in Belgium are located along the Variscan front thrust and to the south of it (i.e. within the Ardenne Allochthon). As noted previously, the latter belong to the Rhenohercynian fold-and-thrust belt, the former foreland area to the Variscan orogenic belt. This region is characterized by a recurrent association between folds and reverse (thrust) faults. Boyer & Elliot (1982) and Butler (1982) first developed this structural concept of the fold-and-thrust belt. Its recent application to the Ardenne domain is by Meilliez (1988) and Meilliez & Mansy (1990). As a consequence, most Belgian faults, mainly of Variscan origin, are integrated in one regional tectonic unit that has undergone thin-skinned tectonics. This model constitutes the latest structural concept of the regional geology of southern Belgium.

6. Descriptive data sheets of the faults

6.1. Aguesses-Asse Fault(s)

Location

In 1899, Forir defines the Aguesses Fault in the "puits des Aguesses" of the Angleur colliery (south of Liège) but the fault was actually already known as Malherbe had drawn it on his geological map in 1873. Later, in 1942, Raucq identifies the Asse Fault in the northern limb of the Cointe Anticline, to the NE of Julémont. Graulich, who proposes the name of Aguesses-Asse Fault in 1955, envisages a connection between the fractures although this junction had already been indicated by Fourmarier at least as early as 1951. The link between the Aguesses and the Asse faults is still a subject of debate and the latest considerations by Hance *et al.* (1999) and Barchy & Marion (2000) indicate two different fractures (Fig. 9).

The Aguesses-Asse Fault(s) bounds the Herve Unit (i.e. the former "Herve Massif") to the south and the Liège Unit (i.e. the former "Liège Massif") to the north. The fault has received particular attention for more than a century and remains a subject of controversy today. The problem is related to how important the fault is considered: a minor, second-order, reverse thrust-type fault or a major, regional, Eifelian Thrust-related fault. The position of the Variscan front thrust in eastern Belgium depends, therefore, on the way the Aguesses-Asse Fault(s) is conceived unless the Variscan front most likely splits and distributes along several thrusts (forming a frontal fault system) as noted previously in chapter 4.

Stratigraphy and lithology of the country rocks

The 1:40 000 scale geological maps of Forir (1896a, 1897, 1902) indicate terrains of Upper Carboniferous age ("Houiller", mainly "H2", Namurian) on either side of the fault. Rocks are (micaceous) sandstones, shales and various types of coal. The southern block at the western termination displays more variable lithologies with ages ranging from the Emsian to the Namurian. The map of 1897, displaying the western termination of the fault, is shown on Fig. 10.

The geological map of Dalhem – Herve (2000) shows that the Asse Fault disrupts the Hodimont Formation (shales and micaceous siltstones, Famennian in age), the Montfort and Evieux Formation (mainly various sandstones, Famennian in age) and the Houiller Group. The latter, dating from the Namurian to the Westphalian A, is made up of interlayered shales, black siltstones, clayey sandstones, sandstones and quartzites. Coal seams and fossiliferous plant horizons are characteristic. The same map, where it covers the eastern segment of the Aguesses Fault, indicates that the latter disrupts the Houiller Group.

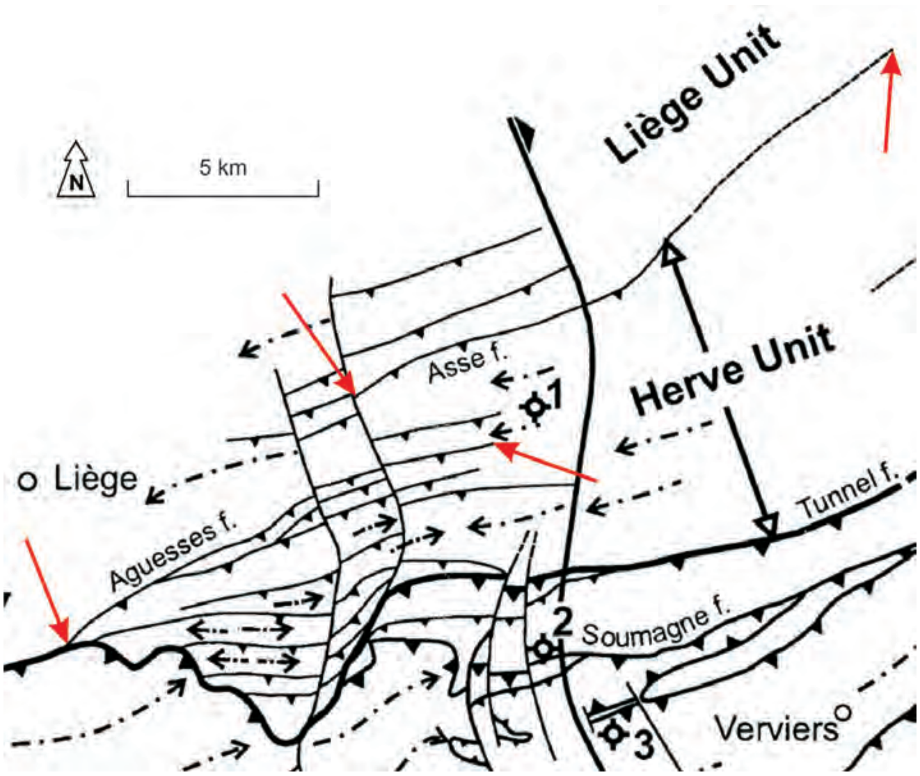

Fig. 9. Extract of the map of Hance et al. (1999). Main fold axis, plunge directions and main deep boreholes are also given. 1-2. Pépinster. 3. Soiron. Arrows show the positions of the Aguesses and the Asse faults.

Fig. 10. Extract of the geological map of Seraing – Chênée (n°134; Forir, 1897). Arrows indicate the western segment of the Aguesses-Asse Fault traced over 8.4 km.

Geometry

In 1873, Malherbe considers that beyond Kinkempois, the Eifelian Fault would continue in a northeast direction in a region between the Liège and the Herve "basins". This extension is currently recognised as a segment of the Aguesses Fault (Hance *et al.*, 1999). However, Gosselet demonstrates in 1878 that the continuation of the Eifelian Fault would be in a southeast direction.

In 1899, in the northeastern vicinity of Kinkempois, in the colliery of Angleur, Forir observes and identifies a fracture that, according to Gosselet (1878), is not the eastern continuation of the Eifelian Fault. Forir calls it the Aguesses Fault. The author measured a direction of N77°E and a plunge of 50° to the south. These data are very different to that of the Eifelian Fault and, consequently, Forir suggests that the Eifelian and the Aguesses faults constitute distinct, non-related fractures. He considers the Aguesses Fault to be a minor fault.

Already before the 20th century, the case of the Aguesses Fault constituted a sensitive and debatable topic. Malherbe (1873) and Dewalque (in Forir, 1899) envisage the Aguesses Fault as the true continuation of the Eifelian Fault, while Gosselet (1878) and Forir (1899) oppose this idea.

The Aguesses Fault can be traced on the geological maps of Forir (1896a, 1897, 1902) despite no name being attributed to the fracture. The western segment appears on the maps of Seraing – Chênée (n°134, 1897) and Alleur – Liège (n°121, 1902). The NE-striking trace is recognised over 8.4 km and constitutes a good apparent eastward extension of the Eifelian Fault (Fig. 10). Both fractures join to the west of Angleur. The Aguesses Fault probably continues to the east but no lineament appears on the neighbouring geological map of Dalhem – Herve (n°122, 1896a). However, the latter map shows in the area directly south of Saive, a small fracture of 700 m in length, located on the extension of the Aguesses Fault and currently recognised as a segment of it (Barchy & Marion, 2000). Extensions at either end of this small segment were not mapped because of the Cretaceous cover, which is not disrupted by the Aguesses Fault.

Fourmarier (1905, 1906) suggests a subdivision of the Eifelian Fault to the east of Kinkempois in which the thrust would split into two branches, the first striking to the NE and the second to the SE. The first, the Aguesses Fault, also known as the "lower branch of the Eifelian Fault" or the Moresnet Fault (Fig. 11), has a gentle dip of about 25° to 30° to the south. The fracture strikes in the same direction as the Eifelian Fault and represents a thrust surface that enabled the overthrusting of the Herve basin over the Liège basin. The total length of the fault, from Angleur in the vicinity of Liège to a point NW of Eschweiler in Germany, reaches 52 km.

In 1906, Forir indicates that the Palaeozoic substratum of the Herve Unit is intensely folded and faulted. The ENE-striking Aguesses Fault is restricted to Primary rocks; the Cretaceous terrains being unaffected by the fault.

In 1912, Dessard indicates stratigraphic (facies) similarities in both fault blocks and suggests therefore that the fracture that separates the Herve from the Liège basins cannot be a "significant" thrust.

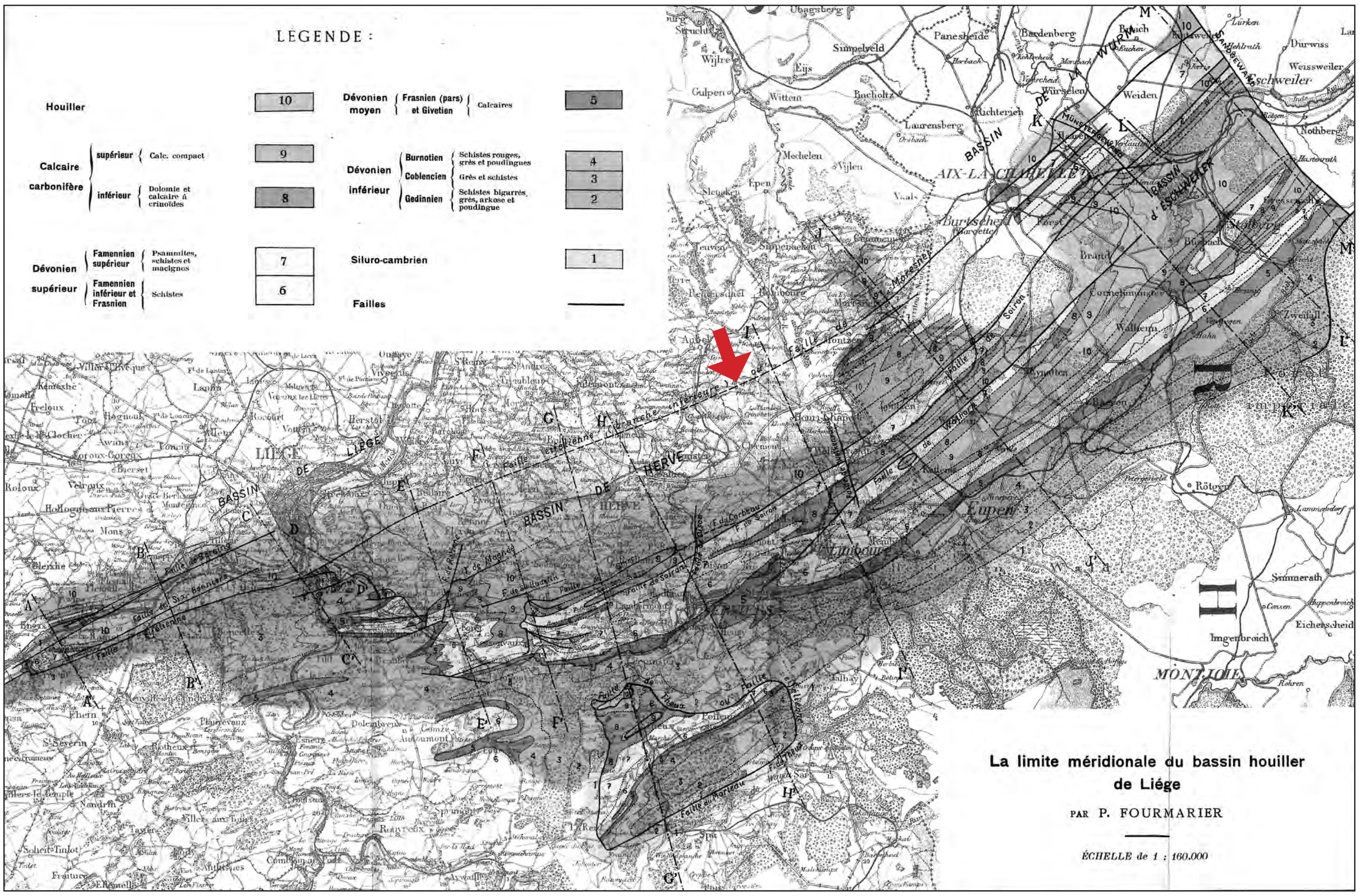

Fig. 11. Geological map of the southern area of the Houiller Liège basin (Fourmarier, 1905).

In 1912, Fourmarier proposes a map with an unchanged trace compared with previous publications. The Aguesses Fault connects eastwards with the Aachen Fault, forming the Aguesses-Aachen Fault. Fourmarier does not consider the Aguesses Fault as the lower branch of the regional Eifelian thrust anymore but as a complex fracture of unknown relationship to the Eifelian Fault. The author demonstrates that the Ourthe Fault constitutes the true east extension of the Eifelian Fault (Fourmarier, 1908). Fourmarier (1912) raises doubts, therefore, about the significance of the Aguesses Fault and its offset of the thrust between the Herve and Liège basins.

Renier (1919) proposes the same hypothesis as Dessard (1912). Because of the absence of sufficient facies variation between the blocks, the Aguesses Fault would not be a branch of the Eifelian Thrust but a "second-order" fracture with a "non-significant" displacement.

In 1920, in the Angleur colliery, Fourmarier makes the following observations: the Aguesses Fault strikes to the NE (N70°E) and dips gently (~30°) to the south. The author proposes a revised trace of the fault, which is henceforth positioned farther to the north but which again strikes towards Aachen in Germany (Fig. 12). Consequently, the fracture no longer connects with the Moresnet Fault. Fourmarier estimates that the Aguesses Fault is not a minor fracture because of (1) the highly variable offset from place to place (in the vicinity of Aachen, Famennian rocks are thrust over Upper Carboniferous rocks) and (2) the shape of the trace of the western termination (the flat fault plane at depth indicates that the Herve basin represents a tectonic wedge thrust over the Liège basin). Fourmarier summarizes in 1920 that current knowledge did not allow a decision in favour of the major or minor character of the fault, though he believes that the fault is not a secondary thrust.

Fourmarier (1920) also publishes a schematic cross-section (Fig. 13), which presents two hypotheses. The first ((1) on Fig. 13) considers the Aguesses Fault as the "lower branch of the Eifelian Fault", or in other words, the northern re-appearance of the Theux Fault; and the second ((2) on Fig. 13) as another but deeper major thrust. Three years later, in 1923, Fourmarier proposes another cross-section that envisages the Aguesses Fault being located even farther to the north. The fracture would therefore not be directly linked to the Condroz Nappe but would be cogenetic with the front thrust. The displacement is probably minor.

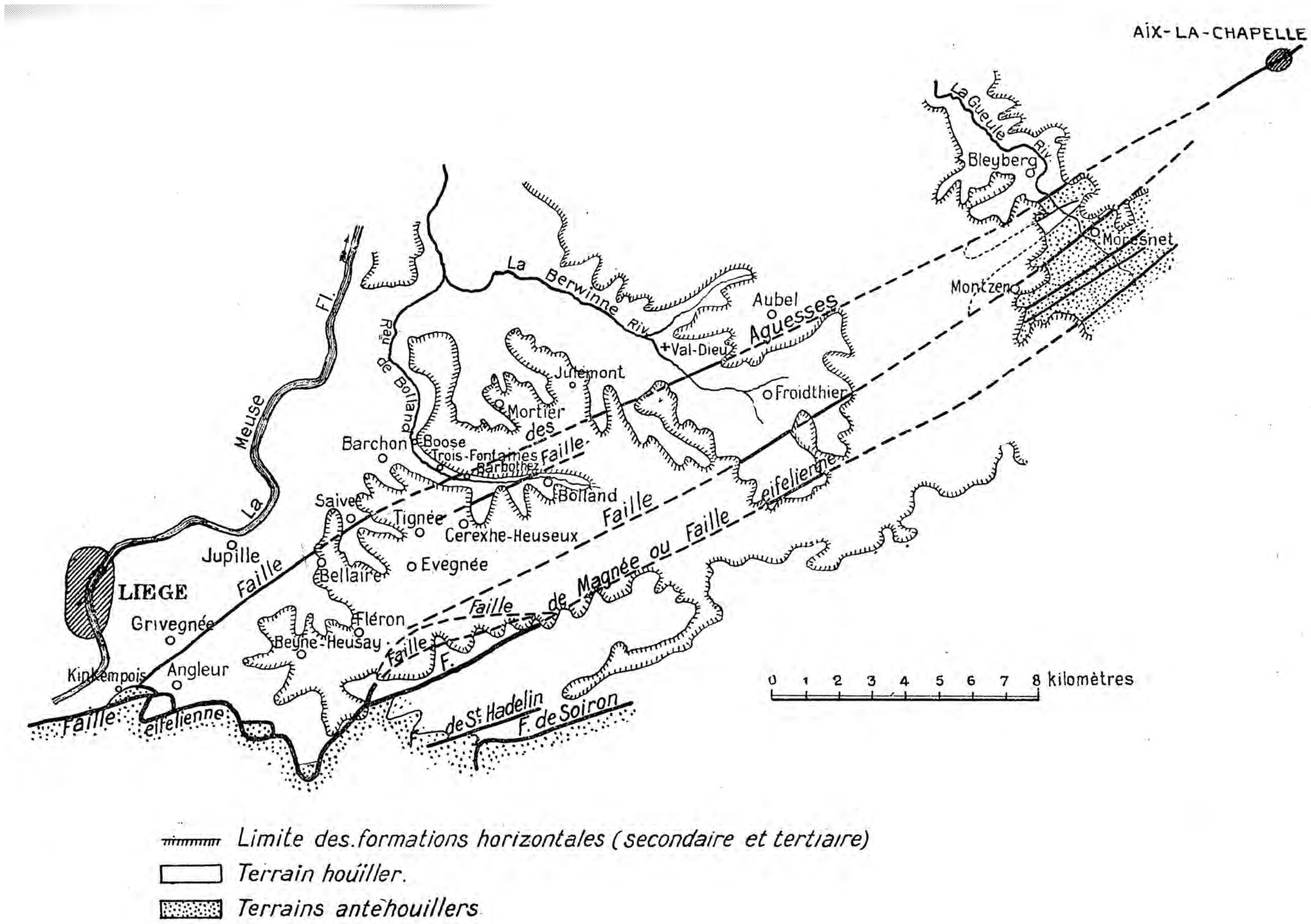

Fig. 12. Trace of the Aguesses Fault (Fourmarier, 1920).

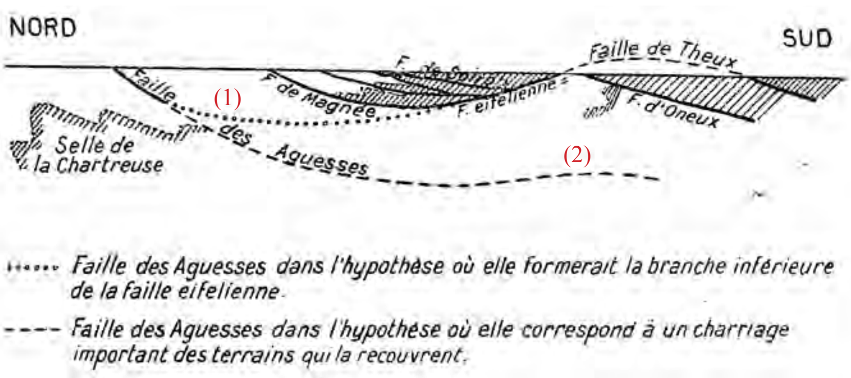

Fig. 13. Cross-section through the Aguesses Fault (Fourmarier, 1920). See the text for explanations.

As strong facies similarities are found between the Liège and the Herve basins, Humblet (1920), just like Forir (1899), Dessard (1912) and Renier (1919), indicates the minor and secondary characters of the Aguesses Fault. In 1921, Humblet measures a displacement of 200 m in the "puits de Homvent" and justifies the minor character of the fault. However, later in 1941, the same author observes a significant offset of about 1200 m and suggests the idea of a major thrust-type fracture. He recognises the Aguesses Fault over a distance of 7 km along the southern limb of the Chartreuse Anticline (Fig. 14).

Legraye (1941) reports volatile matter variations in coals within the Liège basin and notably on either side of the Aguesses Fault (variation up to 4%), evidence that these coals would have formed in different sedimentary environments initially far from each other. Consequently, the Aguesses Fault is interpreted as a major thrust with a significant offset that brought together those initially separated rocks.

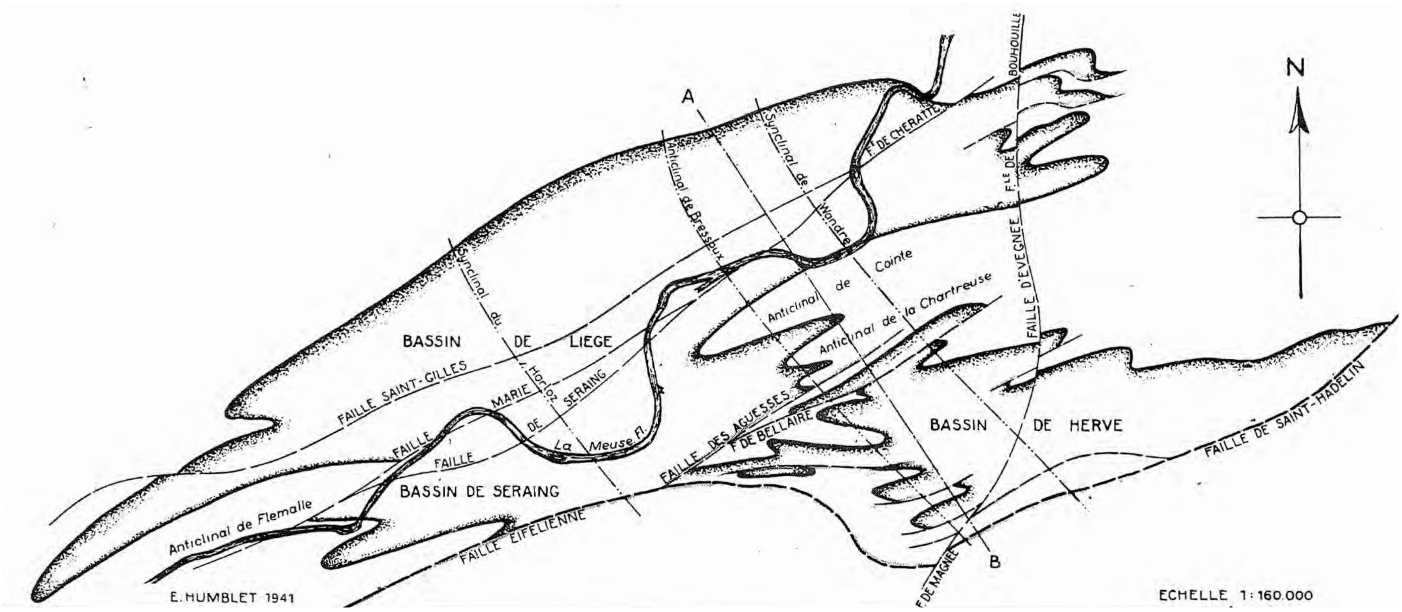

Fig. 14. Locations of the main faults of the Houiller Liège basin (Humblet, 1941).

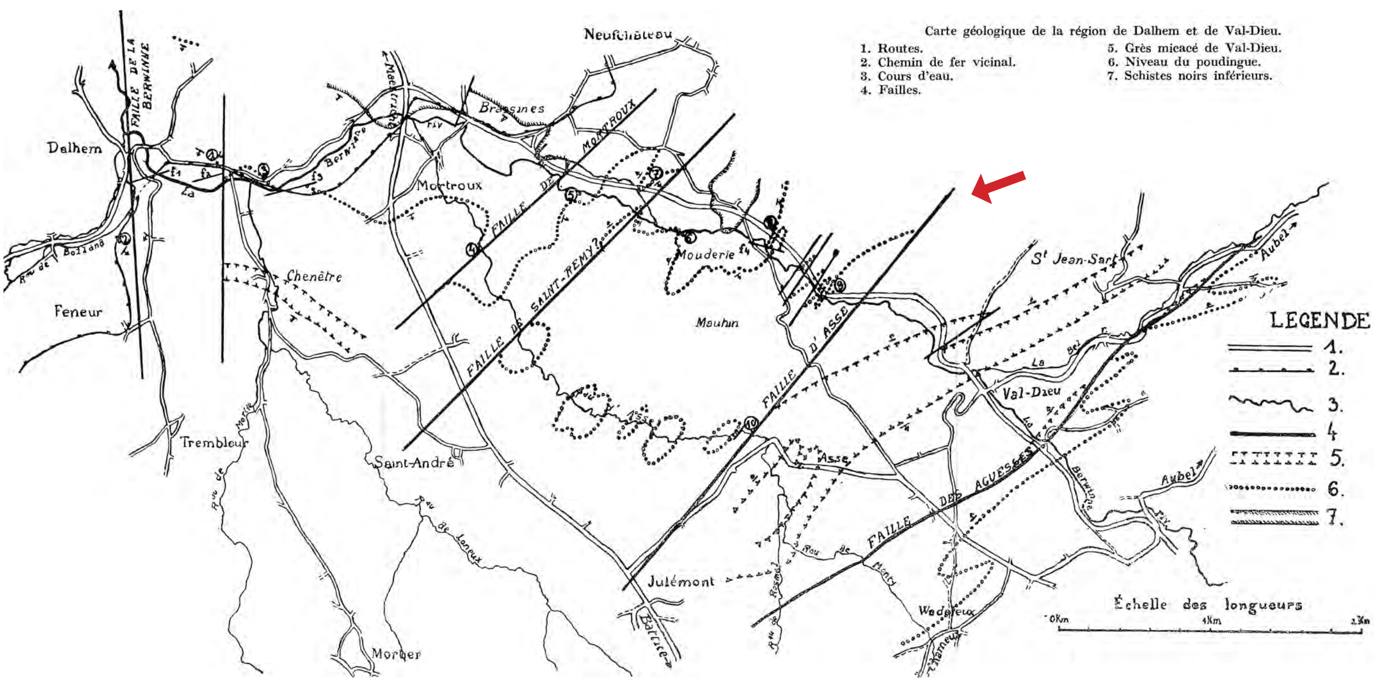

Fig. 15. Geological map of the Dalhem and Val-Dieu vicinities (Raucq, 1942).

In 1942, Raucq discovers the Asse Fault (Fig. 15) in the vicinity of Julémont. The fault strikes to the NE and can be traced for 3.5 km. The Aguesses Fault also appears on the map to the south of the Asse Fault. The Aguesses and the Asse faults therefore constitute two distinct fractures. The apparent displacement of the Asse Fault is estimated to be at least 300 m but the true offset may be more significant. In the "Bois de Mortroux", the fault dips gently (~30°) to the SE and strikes in a N45°E direction. A thrust-type fault ("charriage cisaillant") is envisaged. Raucq also suggests that the Aguesses and the Asse faults join at depth to form the Eifelian Thrust where it splits into two branches to create a tectonic wedge. Both the Aguesses and Asse faults are related to the Condroz Thrust. Their displacements are probably "significant".

In 1943, Ancion *et al.* draw the Asse Fault from Barchon to the Val Dieu abbey, i.e. over a strike length of 8.5 km (Fig. 16). The fault strikes ENE and dips to the south (20-30°). The western termination abuts the N-S-striking, transverse Bouhouille Fault and the eastern termination, not covered by the map, is not known. The fault probably continues farther eastwards. On the basis of stratigraphic similarities between the Booze

– le Val-Dieu region to the south of the fault and the eastern Hesbaye located to the north, the authors believe that the displacement is probably small. Like other minor fractures located in the Upper Carboniferous (Houiller) Herve basin, the Asse Fault contributes to the disruption and shortening of the basin. The Herve basin shows imbricated tectonic wedges. After Ancion *et al.* (1943), this structure can be considered characteristic of the "Namur Synclinorium".

After considering the Aguesses Fault as a major regional thrust (1905), and then later as a complex fracture with unknown relationships to the Eifelian Fault (1912, 1920), Fourmarier indicates in 1951 the minor character of the Aguesses Fault. He says "the Herve Massif is confined between two faults, the Saint-Hadelin Fault in the south and the Aguesses (or Asse) Fault in the north". The author specifies that the Saint-Hadelin Fault, located to the south of the Aguesses Fault, constitutes the true re-appearance of the Theux Fault. Consequently, the longitudinal faults of the Herve "Massif", north of the Variscan Thrust, such as the Aguesses Fault, belong to the "Namur Synclinorium" and are not related to the thrust domain. Following this hypothesis, the Upper Carboniferous rocks of the Theux Window and the Herve "Massif" would belong to the same entity. Moreover, Fourmarier indicates that stratigraphic and paleontological similarities are found within the Herve and the Liège units and therefore they cannot be separated by a major regional thrust.

However, for some geologists (e.g. Chaudoir, 1951), the facies variations that appear on either on side of the Aguesses Fault are considered sufficient to justify its regional character.

Graulich proposes in 1955 that the Asse Fault constitutes the eastward continuation of the Aguesses Fault, therefore forming the Aguesses-Asse Fault (Fig. 17), which itself is one of the continuations of the Eifelian Fault. However, the connection between the Aguesses and the Asse faults was already envisaged in 1951 and again in 1954 as Fourmarier combined the two fractures into a single one. The Aguesses-Asse Fault is disrupted by a nearly N-S-striking transverse fault, which has an apparent (cartographic) sinistral offset of about 340 m.

The cross-section proposed by Graulich (1955) considers the Aguesses-Asse Fault as a major thrust surface connected at depth with the Eifelian-Theux Fault (Fig. 18). Many other reverse faults within the Herve Massif join the Aguesses-Asse Fault that thrusts the "Herve Massif" over the "Liège Syncline".

However, the various authors do not agree on what is the correct mutual continuity between the Aguesses and Asse faults. For example, in 1958, Lohest represents the Aguesses Fault to the south of the Asse Fault.

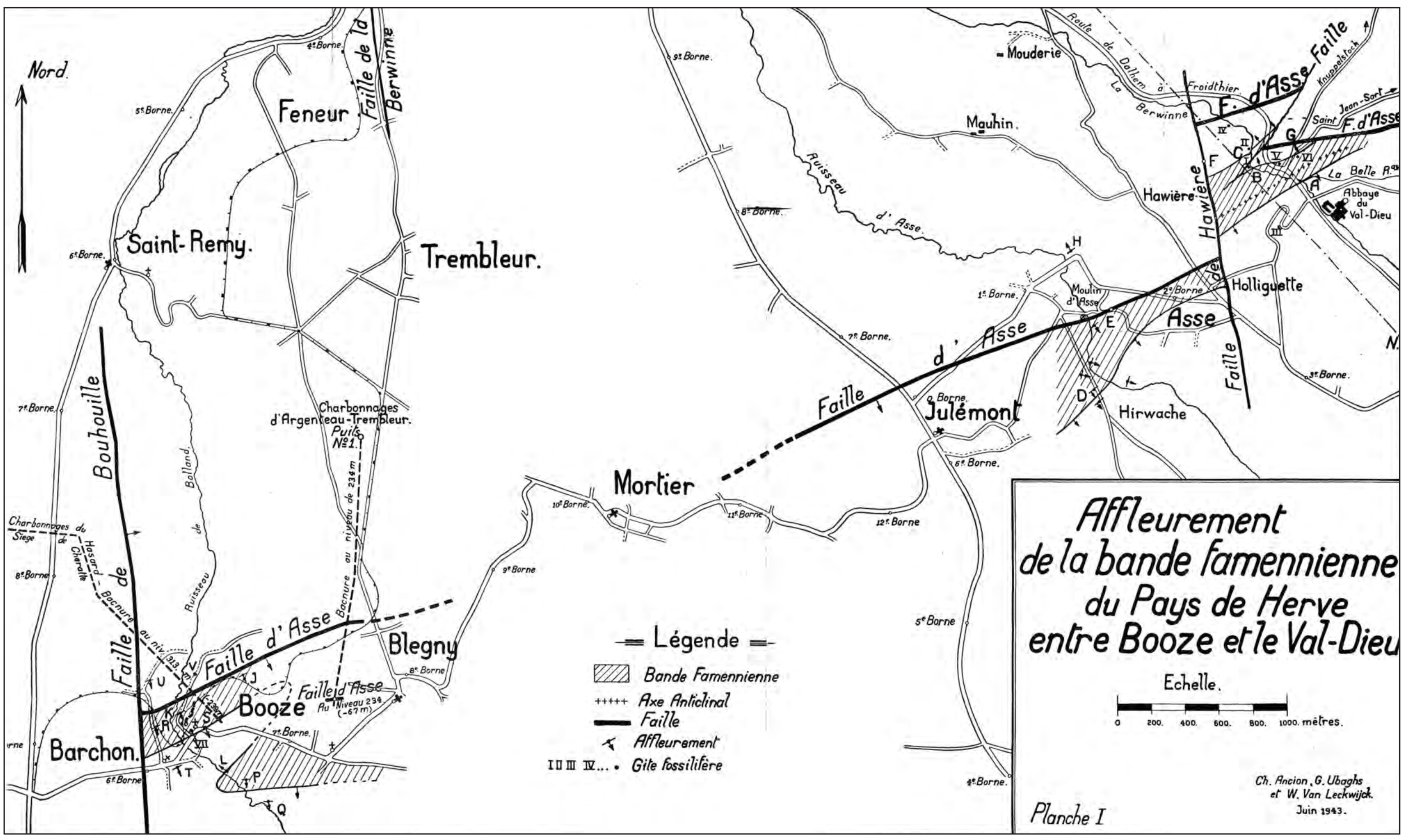

Fig. 16. Location of the Asse Fault (Ancion et al., 1943).

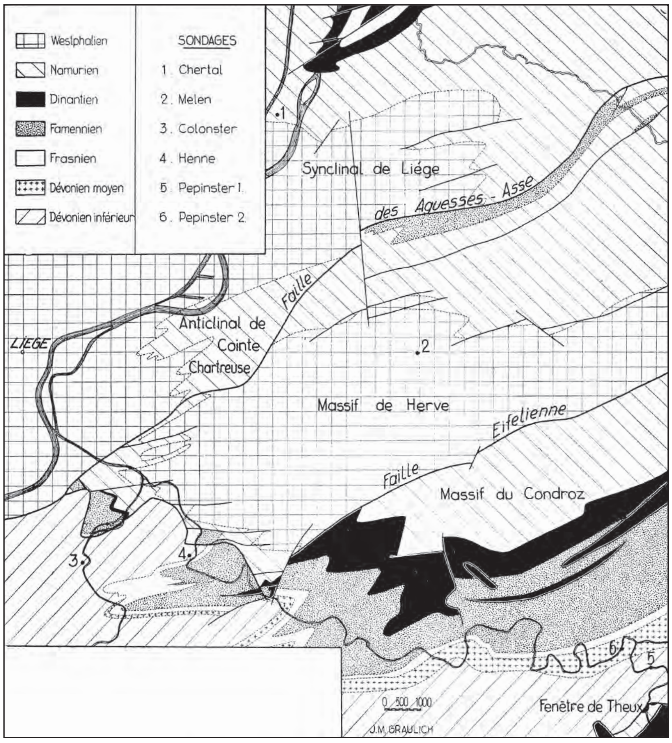

Fig. 17. Trace of the Aguesses-Asse Fault (Graulich, 1955).

During the eighties, two authors (Michot and Graulich) published many papers with strongly divergent opinions. Briefly, Michot (1980, 1986, 1988, 1989) considers the Aguesses-Asse Fault to be a minor fracture, while Graulich (1955, 1984, 1986) and Graulich *et al.* (1984, 1986) consider it to be the eastward continuation of the regional Eifelian Thrust.

In 1980, Michot introduces the concept of the "Herve Synclinorium" (Fig. 19) that is comprised of part of the Variscan autochthonous domain (the "Liège-Herstal Syncline" and the "Herve Massif" in the north) and part of the Variscan allochthonous domain (the "Vesdre Massif" and the Theux Window in the south). The Aguesses-Asse Fault, positioned between the Liège and the Herve units, has a gentle dip to the south. The reverse offset measured on the cross-section of 1988 (Fig. 19) reaches at least 2000 metres.

Accepting the argument of Graulich (1955, 1984) that the Aguesses-Asse Fault is a major fault that thrusts the Herve basin over the Liège basin, Graulich *et al.* (1984) suggest the invalidity of the "Herve Synclinorium" concept of Michot. Indeed, the latter authors' point of view incorporates the Liège and the Herve units as the same entity (Fig. 19). Graulich *et al.* (1984) reiterates that the Liège Unit belongs to the "Namur Synclinorium" (i.e. the Variscan autochthonous domain). The authors also introduce the concept of the "Verviers Synclinorium". This large structure (Fig. 20) belongs entirely to the Variscan allochthonous domain and, from north to south (Fig. 21), comprises the Upper Carboniferous "Herve Massif", the "Vesdre Massif" and the Theux Window. In this context, the Aguesses-Asse Fault is envisaged as a continuation of the Eifelian Fault and to constitute a branch of the Variscan front thrust that separates the Verviers and the Namur synclinoria.

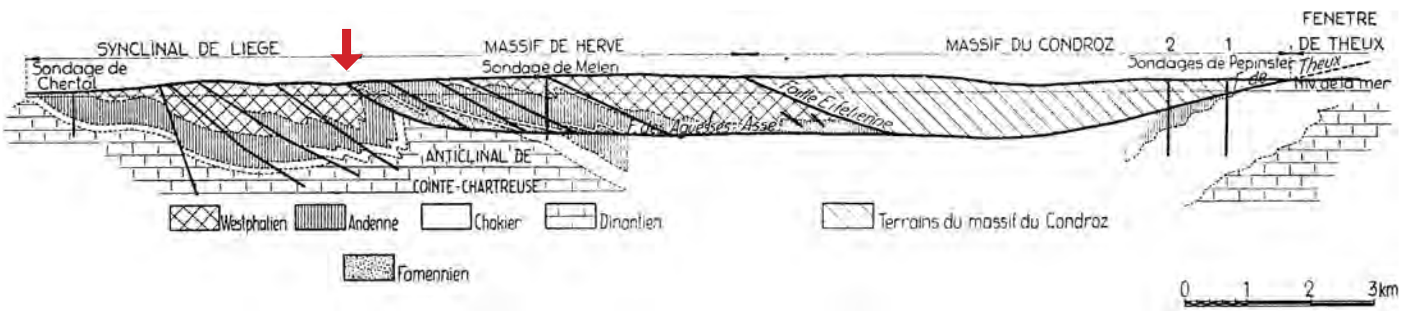

Fig. 18. Cross-section through the borings of Chertal, Melen, Pepinster 1 & 2 (Graulich, 1955).

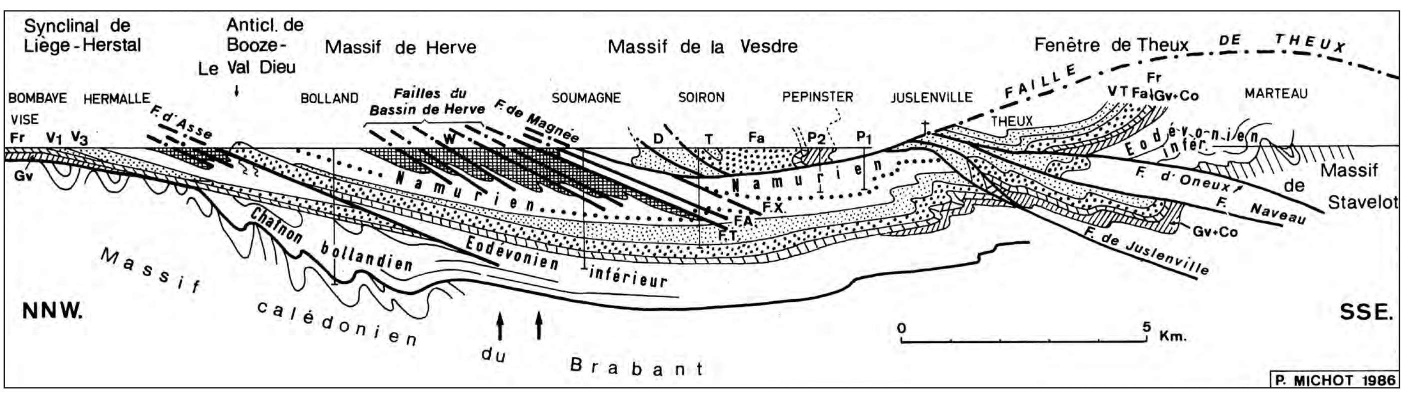

Fig. 19. Cross-section through the Herve Synclinorium (Michot, 1988).

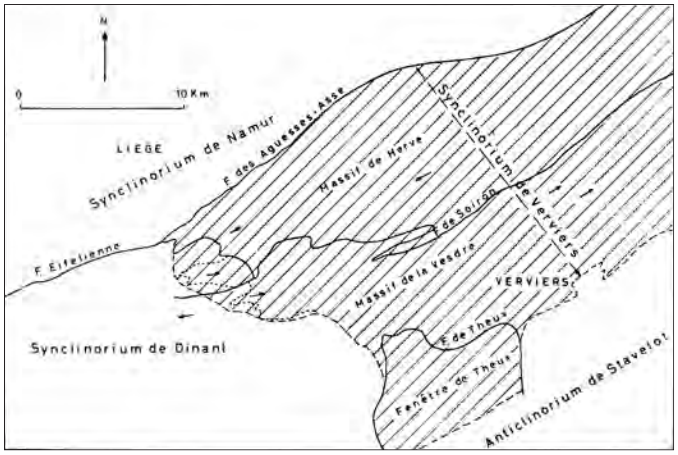

Fig. 20. Limits of the Verviers Synclinorium (Graulich et al., 1984).

In 1989, Michot indicates that the Aguesses-Asse Fault is independent from the Eifelian Thrust. Moreover, the Aachen Fault (which is currently recognised as a branch of the Variscan front thrust) may constitute the eastward extension of the Aguesses-Asse Fault. The Aachen Fault is therefore a non-significant thrust with no link with, or even any relationship to, the Eifelian Fault. Moreover, after Michot (1989), the total displacement of the Condroz Nappe, along the entire Midi-Eifelian-Theux Fault, would not exceed 15 or even 10 km.

Poty (1991) observes similarities between the stratigraphic sequences and facies on either side of the Aguesses-Asse Fault. He suggests, therefore, that the displacement along the Asse Fault cannot be significant (as Ancion *et al.* propose in 1943), even if the Asse Fault is directly linked to the Eifelian Fault or is one of its satellites.

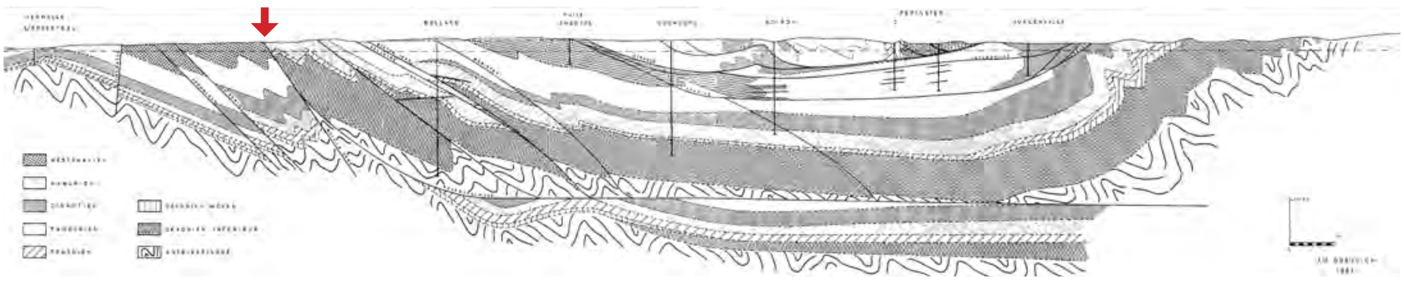

Fig. 21. Cross-section through the Aguesses-Asse Fault (Graulich, 1984).

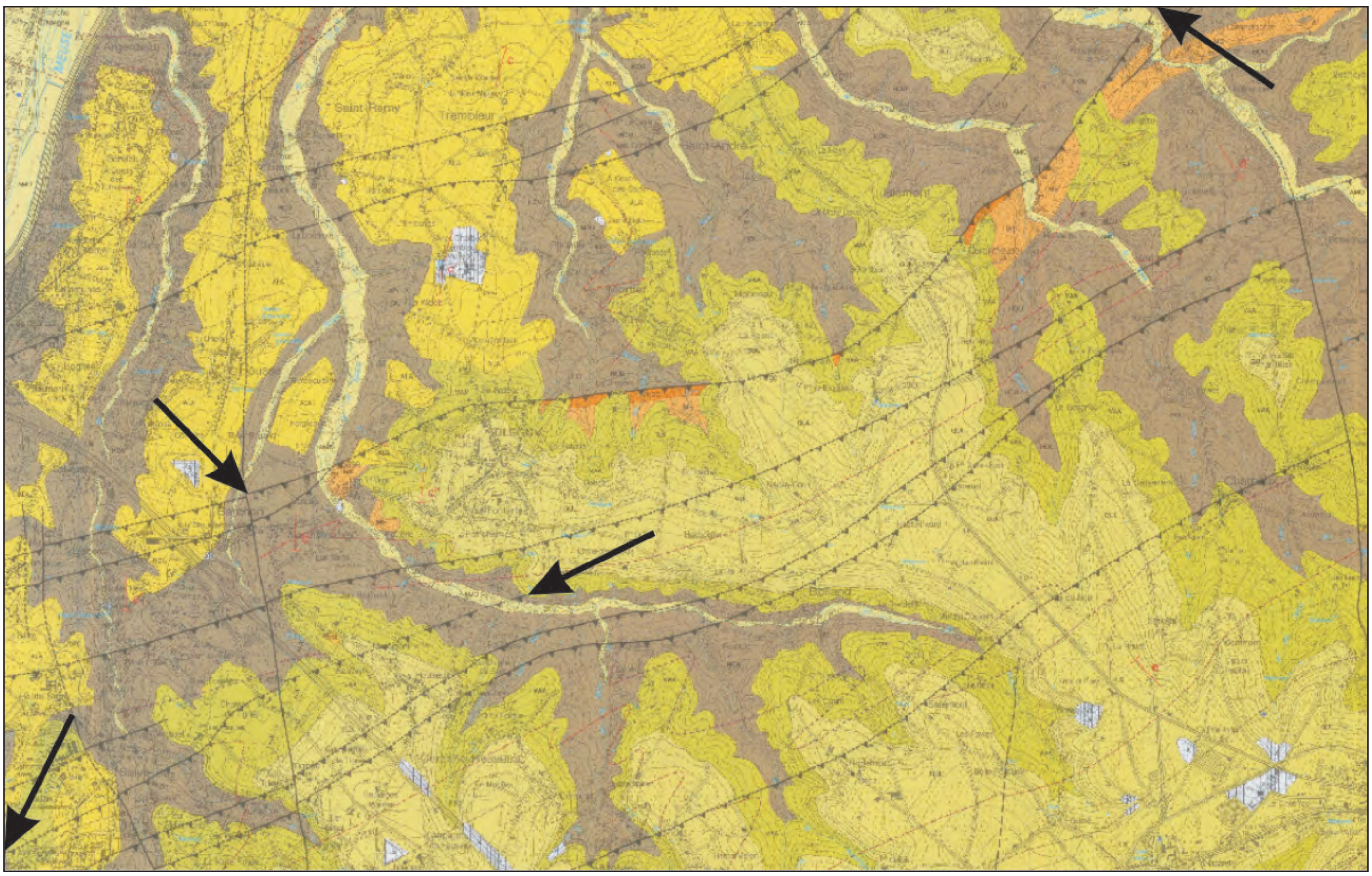

Fig. 22. Extract of the geological map of Dalhem-Herve (Barchy & Marion, 2000).

For Hollmann & Walter (1995), the Aguesses-Asse Thrust is a part of the Midi-Aachen Thrust that acted as a foreland detachment. As Fig. 84 of the Theux Fault shows, the hanging wall of the Aguesses-Asse Fault, which consists of the Theux Window, the Vesdre Nappe and the Herve Imbricate Zone, is interpreted as an allochthonous domain. The Aguesses-Asse Thrust, as it appears in their paper, limits the south of the Liège Syncline and the north of the Herve Imbricate Zone. The latter is combined with the Theux Window in a thrust complex that is bounded at its base by the Aguesse-Asse Thrust and the Midi-Aachen Thrust.

The structural map (Fig. 9) and the geological cross-section in northeastern Belgium (see Theux Fault, Fig. 86), of Hance *et al.* (1999), show respectively that the Aguesses Fault is not on the alignement with the Asse Fault and that the reverse, south-dipping Asse Fault connects at depth with a major décollement level. Southwards, many others thrust fractures, like the Theux Fault, connect at that level too. According to Hance *et al.* (1999), the Tunnel Fault limits the Vesdre Nappe to the north and is considered as the northernmost trace of the Variscan front zone that splits into several thrusts in the region. The Asse Fault that belongs to the Liège-Herve units is located in the Brabançon parautochthonous domain ("Namur Synclinorium"). The reverse offset measured on the cross-section (Theux Fault, Fig. 84) reaches 1100 metres. The fault is not considered as a major regional thrust. Hance *et al.* (1999) believe, therefore, that the main, regional thrust of the Ardenne Allochthon is located farther to the south. The Tunnel Fault would be connected to the Aachen Fault, recognised in Germany as the trace of the Variscan front thrust.

In 2000, Barchy & Marion publish the revised geological map of Dalhem – Herve (Fig. 22). The eastern termination of the Aguesses fault segment is traced over 4.5 km and is slightly displaced by apparent sinistral strike-slip faults. The Asse Fault, traced over 8.5 km, does not appear to be in direct alignment with the Aguesses Fault (1500 m being the distance that separates the two segments).

As a consequence of these new observations, Barchy & Marion (2000) propose a different geometrical point of view. Like Raucq (1942) and Lohest (1958), they differentiate between and consider independent the Aguesses and Asse faults. Indeed, they assume that the Asse Fault does not constitute the true continuation of the Aguesses Fault but of the Bois-la-Dame Fault. In this case, the eastward continuation of the Aguesses Fault is not known.

The cross-section in Fig. 23, of Barchy & Marion (2000) illustrates the gentle southern dip (~13°) of the Asse Fault segment and its disruption by a longitudinal sub-vertical fault. The Asse Fault does not affect the upper flat-lying cover of Cretaceous age.

Barchy & Marion (2000), just like Poty in 1991, notice an identical sedimentary and stratigraphic evolution on either side of the Aguesses and Asse faults. This confirms the hypothesis of Michot who states that the Herve Unit was initially proximal to the Liège Unit.

Interpretations

Already in 1905, Fourmarier indicates that all authors (i.e. Forir, Malherbe, Gosselet, Dewalque, etc.) agree with the thrust character of the south-dipping Aguesses Fault. This would enable the northward displacement of the Herve Unit over the Liège Unit. However, from the end of the 19th century to today, disagreement prevails on the significance of the Aguesses(-Asse) Thrust. It is either:

(1) a minor thrust (Forir, Gosselet, Dessard, Renier, Ancion, Fourmarier, Michot, Poty, Barchy & Marion, etc.) separating the Herve and the Liège units, both of which are located in the autochthonous domain north of the Variscan front thrust; or

(2) a major thrust (Malherbe, Dewalque, Fourmarier, Raucq, Graulich, Hollmann & Walter, etc.) constituting an eastern segment of the Variscan front thrust (the eastern continuation of the Eifelian Fault) and therefore separating the Variscan allochthonous and autochthonous areas in eastern Belgium.

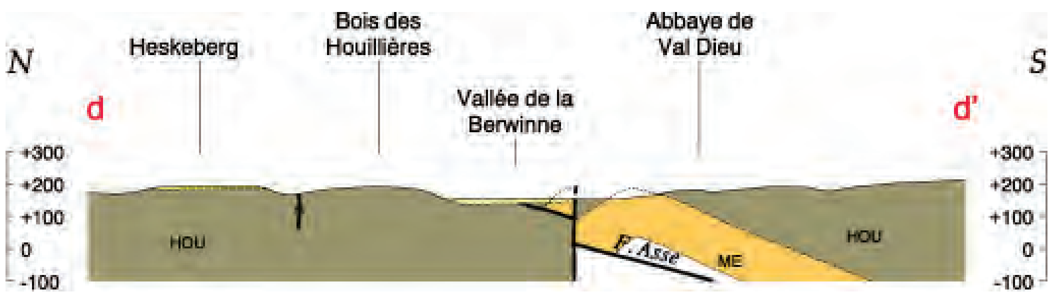

Fig. 23. NW-SE cross-section through the Val Dieu abbey (Barchy & Marion, 2000).

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Dessard, 1912.
Forir, 1896a.
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Fourmarier, 1905.
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Fourmarier, 1920.
Fourmarier, 1951.
Fourmarier, 1954.
Gosselet, 1878.
Graulich, 1955.
Graulich, 1984.
Graulich, 1986.
Graulich *et al.*, 1984.
Graulich *et al.*, 1986.
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Hollmann & Walter, 1995.
Humblet, 1920.
Humblet, 1921.
Humblet, 1941.
Legraye, 1941.
Lohest, 1958.
Malherbe, 1873.
Michot, 1980.
Michot, 1986.
Michot, 1988.
Michot, 1989.
Poty, 1991.
Raucq, 1942.
Renier, 1919.

6.2. Aiglemont Fault

Location

The Aiglemont Fault was identified in 1883 by Gosselet in the area north of St-Quentin (France). The fracture is also mentioned on the geological map of Mézières (1:80 000, 1888) (Gosselet & Nivoit, 1888). Later, in 1921, Asselberghs introduces the Herbeumont Fault. For a long time, the discussion focused on the possible connection between the Aiglemont and Herbeumont faults. However, as shown on the French geological map of Hatrival *et al.* (1973) (Fig. 24), it is currently considered that there is no continuation between the two fractures. The location of the Aiglemont Fault is therefore restricted to the southern limb of the Charleville Syncline (in the vicinity of Aiglemont) in France.

Lithology and stratigraphy of the country rocks

The stratigraphic subdivision is taken from the geological map of Asselberghs, published in 1946. The French geological map of 1973 has a different subdivision that is not considered here. The southern (thrust) fault block is made up mainly of Lower Devonian terrains:

- Lower Lochkovian rocks (the former Lower Gedinnian “G1”);
- The “G2a” and “G2b” formations (the equivalent of the Oignies and the Saint-Hubert formations respectively) of Pragian age.

The northern footwall block is made up of the same rocks present in the southern block but also of Lower and Middle Pragian rocks (the former Siegenian), the “S1” and the “S2” respectively. All of these Devonian terrains are composed essentially of slates, quartzites, silty slates, shales and (micaceous) sandstones.

Geometry

In 1921, Asselberghs defines a fault in the vicinities of Bouillon and Herbeumont. The author considered it to be the eastward continuation of the Aiglemont Fault of Gosselet. This fracture probably extends eastward, initially through a fault observed north of Mellier and in Thibésart and subsequently through a fault detected in Martelange. The fracture, recognized over a distance of about 65 km and named the Herbeumont Fault, has a reverse offset that probably decreases from west to east.

Due to the presence of extensive Mesozoic terrains, observations within the Palaeozoic are scarce. With this in mind, Asselberghs (1927) considers the Aiglemont Fault as a fracture with complex relations with the Montcy Fault (the Aiglemont Fault would be a branch of it) and with the Mazy Fault. At first sight (Fig. 25), the Mazy Fault seems to be the eastern extension of the Montcy Fault but the chosen hypothesis is that the Montcy Fault lies under the Mazy Fault.

Macar (1933) summarises that the Aiglemont Fault is a reverse fracture with a rapidly decreasing offset to the west. The fault appears 7 km to the north of Charleville and to the NE of Aiglemont. The mainly ESE-striking sinuous trace indicates a gentle south dip and a thrust-type fracture (Fig. 26). The Mesozoic rocks of the Paris basin cover its extremities. Macar also proposes a badly constrained hypothesis for continuity between the Aiglemont and Herbeumont faults.

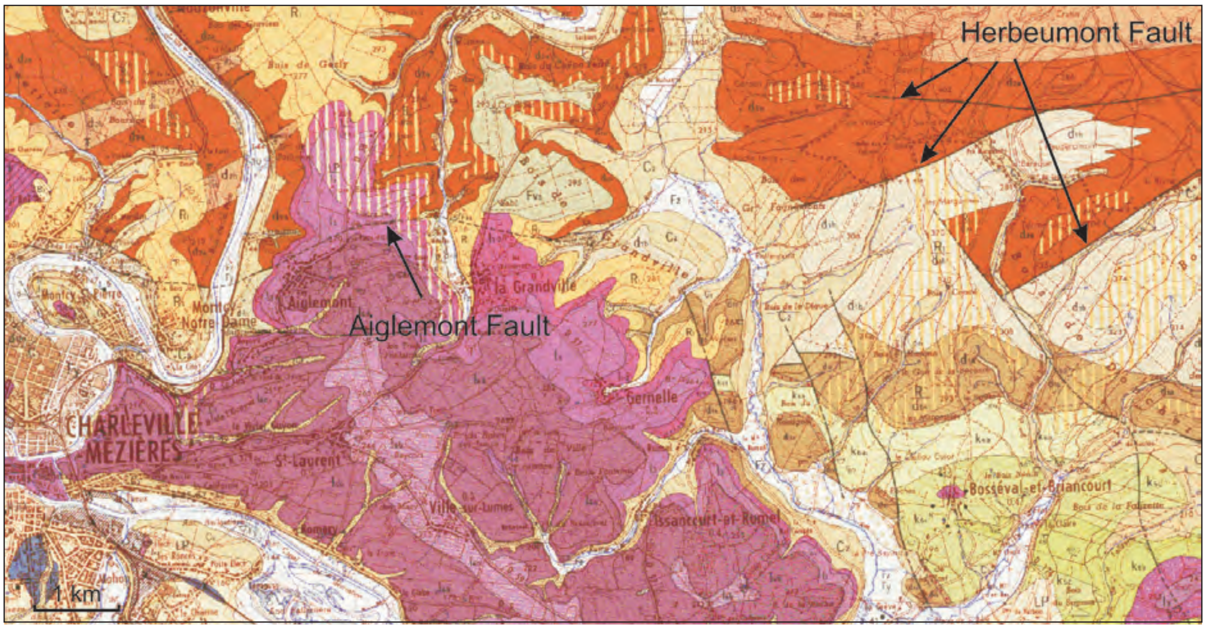

Fig. 24. Extract of the geological map of Charleville-Mézières (Hatrival *et al.*, 1973).

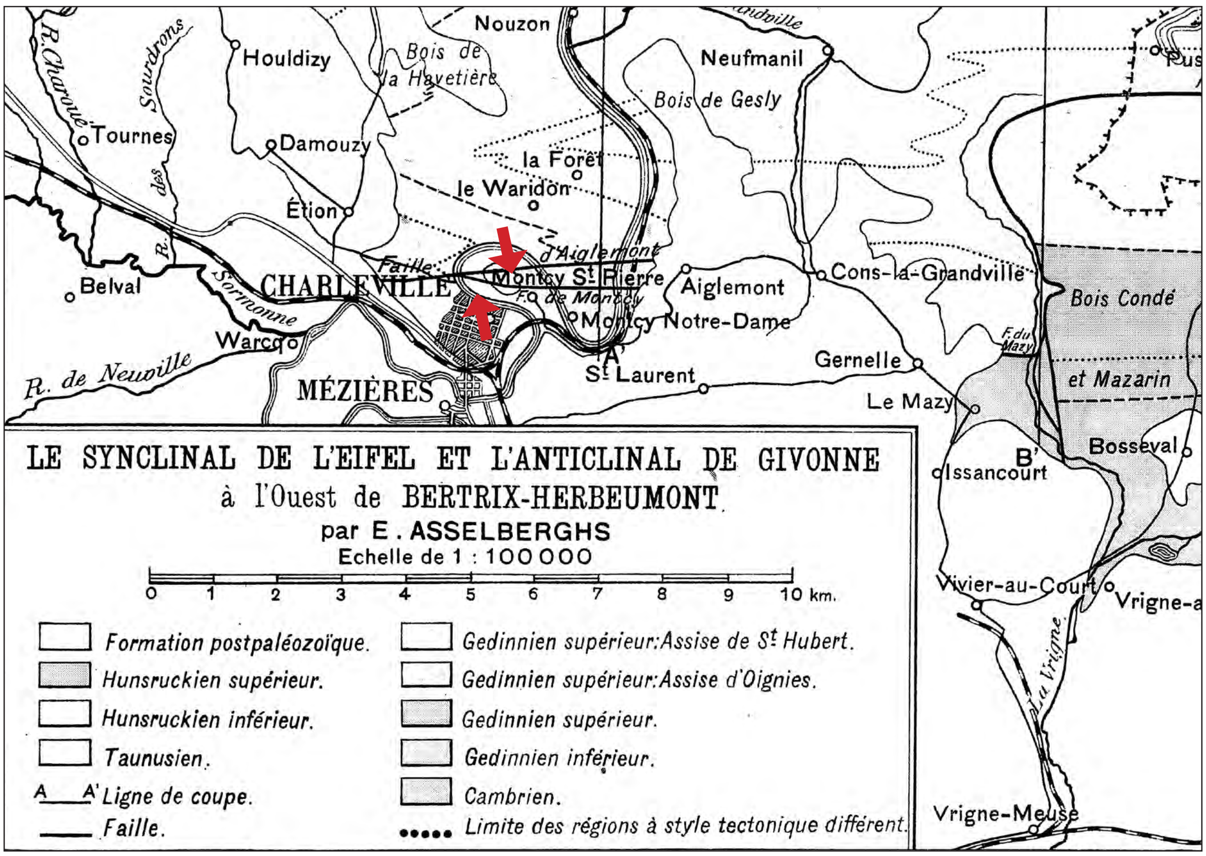

Fig. 25. Extract of the geological map of Asselberghs (1927) showing the Aiglemont, the Montcy and the Mazy faults in the Charleville vicinity.

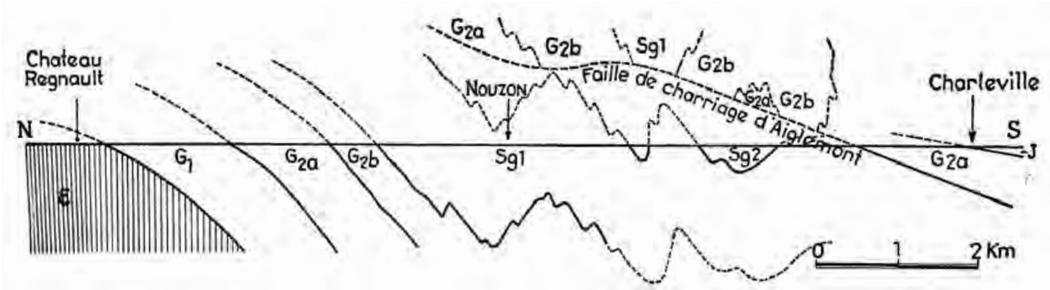

Fig. 26. Cross-section of the Eifel Synclinorium in the Meuse valley (Asselberghs, 1946).

In 1936, Macar introduces the "Ruisseau des Gravis" Fault, a probable eastward extension of the Herbeumont Fault. The "Ruisseau des Gravis" Fault shows a N-S strike in the Vrigne valley where it disappears under Mesozoic rocks and probably farther southward under the Aiglemont Fault itself. He assumes, therefore, no connection between the Aiglemont and the Herbeumont faults.

Asselberghs indicates in 1940 that the Aiglemont Fault affects the central part of the Givonne Anticline. The reverse offset in the Vrigne valley is estimated to be 2000 m. However, considering the displacement of the Herbeumont Fault, the total thrust displacement of the Aiglemont Fault probably reaches between 5 and 6 km. This point of view considers the Aiglemont Fault as an inner thrust within a unit itself displaced along the Herbeumont Fault.

The geological map released in 1946 by Asselberghs places the Aiglemont Fault from the north of Charleville to the west of Bosseval (i.e. over a distance of 10 km entirely within French territory). The fracture is covered at both extremities by Mesozoic rocks and is therefore probably longer than shown on the map. The offset is about 5-6 km to the north. No connection with the Herbeumont Fault is assumed. This later fault would extend under the Aiglemont Fault.

The French geological map of 1973 (Hatrival *et al.*) (Fig. 24) recognizes the Aiglemont Fault over 7 km from the north of Charleville to the northeast of La Grandville. The fault is generally hidden under monoclinal Mesozoic deposits and is only clearly detected in a few places in the Meuse valley. No connection with the Herbeumont Fault is envisaged.

Interpretations

As stated previously, Asselberghs proposes in 1921 an eastward continuation of the Aiglemont Fault. These new geometrical considerations allow him to propose that, from the Meuse river in France to the Grand Duchy of Luxembourg, the Eodevonian rocks of the Givonne Anticline are thrust over the Lower Devonian formations of the Eifel Syncline. In this case, the Aiglemont Fault would be a small branch and the western extremity of the major Herbeumont Thrust. However, the Aiglemont Fault can still be considered as an important thrust as the reverse offset is estimated to be 5-6 km (Asselberghs, 1940).

New considerations on the Aiglemont Fault are presented by Macar in 1933. The major thrust component, from south to north, is estimated to be at least 10 km. A strike-slip component is possible. The formation of the thrust is dated to the Lower Carboniferous (Variscan diastrophism). Macar also noticed some similarities between the Midi Thrust and the "Charleville Thrust" (i.e. the Aiglemont Fault) that thrust the Charleville Syncline over the Eifel Syncline.

As previous authors envisaged (Asselberghs, 1940; 1946; Macar, 1936), Fourmarier produces (in 1954) the main evidence for the non-continuity between the Aiglemont and Herbeumont fractures. He indicates that in the case where there is a connection between these faults, the Lower Devonian rocks located south of the single "Aiglemont-Herbeumont Thrust" would all belong to the same tectonic unit. However, the facies in the two hanging wall blocks are very different. The conclusion, therefore, is that the "thrust region", which affects the southern limb of the Eifel Synclinorium, is composed of two stacked thrust sheets separated by the Aiglemont Fault.

References

Asselberghs, 1921.

Asselberghs, 1927.

Asselberghs, 1940.

Asselberghs, 1946.

Fourmarier, 1954.

Gosselet, 1883.

Gosselet & Nivoit, 1888.

Hatrival *et al.*, 1973.

Macar, 1933.

Macar, 1936.

6.3. Amerois Fault

Location

Dewalque (1897) draws a 3.4 km long and SE-striking fault in the north-eastern vicinity of Muno. This fracture, which was not then named, corresponds precisely to the location of the Amerois Fault drawn by Beugnies in 1960.

The fault is located south of the Eifel Synclinorium, running from north of Bouillon to approximately 1 km east of Muno (Fig. 27). In its southern segment, the transverse Amerois Fault crosscuts the periclinal termination of the east-plunging and north-verging overturned Givonne Anticline, which is made up of a Cambrian core (Ghysel & Belanger, 2006). In its northern segment, the fault cuts the southern border of the Lower Devonian Eifel Synclinorium, which constitutes the Variscan unconformable cover on the Cambrian Givonne Inlier.

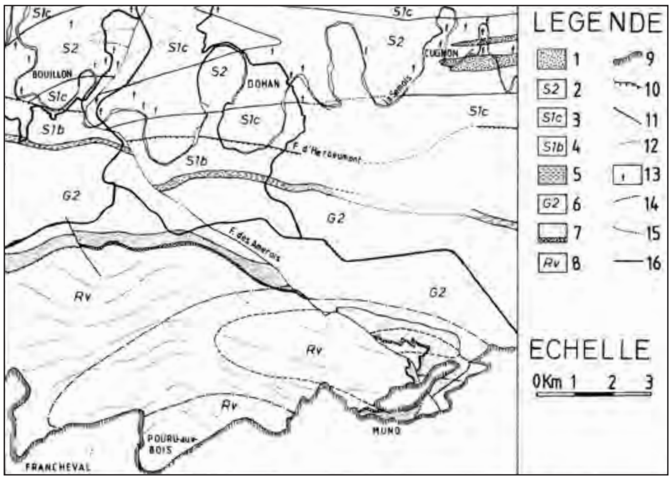

Fig. 27. Geological map of Bouillon-Muno region (Beugnies, 1988). See Beugnies (1988) for a description of the legend. Note that the Amerois Fault crosscuts and displaces lithologic contacts, Hercynian (i.e. Variscan) metamorphic isograds and the Herbeumont Thrust.

Lithology and stratigraphy of the country rocks (Beugnies, 1960; 1985)

The fault thrusts the Upper Cambrian of the Givonne Inlier over the Lower Devonian cover (Fig. 28). According to Beugnies (Fig. 27, 1988), the fault disrupts:

- the Revinian (Upper Cambrian). See the Aiglemont Fault for a description;
- the Mondrepuits Formation (Lower Lochkovian), mainly made up of shales and micaceous siltstones;
- the Oignies and the Saint-Hubert formations, the “G2a” and “G2b” respectively (Upper Lochkovian), composed by shales, sandstones and quartzites;
- the Verlaine Formation (“Sg1a”, Lower Pragian), made up of dark blue phyllites;
- the Mohret Formation (“Sg1b”, Lower Pragian), made up of phyllites and quartzites; and
- the Alle Formation (“Sg1c”, Lower Pragian), made up of phyllites.

Geometry

The trace has a general NW strike that curves northwards in the vicinity of Bouillon. It extends for at least 14 km (Fig. 27). The transverse Amerois Fault is subdivided into two segments that display different inclinations (Beugnies, 1988). The western segment is a low-angle (20 to 30°) fault that dips to the SW while the eastern segment dips steeply (about 45°) in the same direction. Beugnies (1988) assumes that the fracture is an oblique-slip fault:

- the SW fault block is upthrown and thrusted over the NE block, the reverse dip-slip component reaches 200 m;
- the western block has moved to the north, the dextral strike-slip component reaches between 1200 and 1600 m.

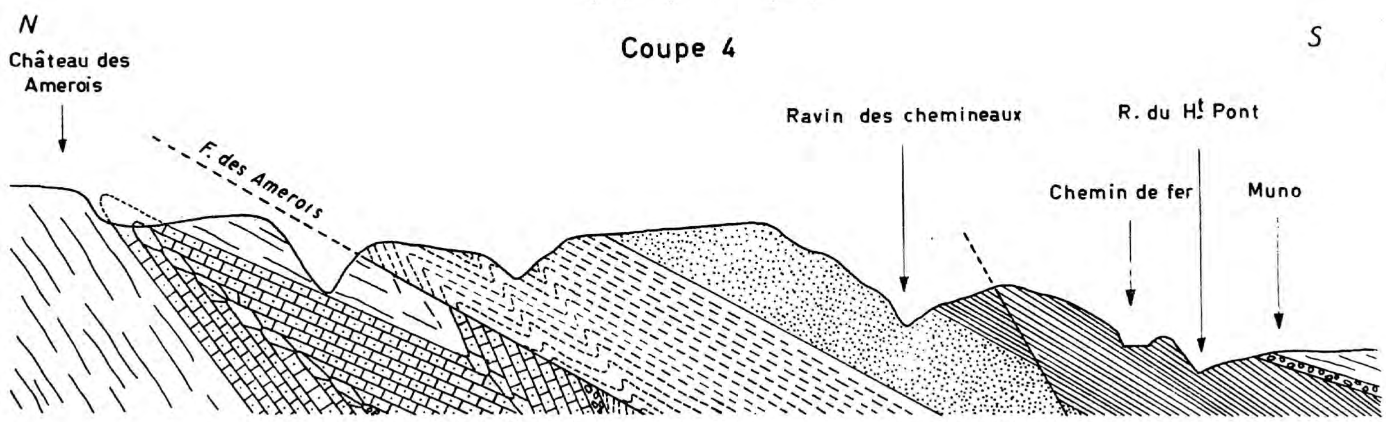

Fig. 28. Geological section through the eastern periclinal termination of the Givonne Anticline (Beugnies, 1960). The Cambrian formations are thrusted northwards on the Lower Devonian terrains.

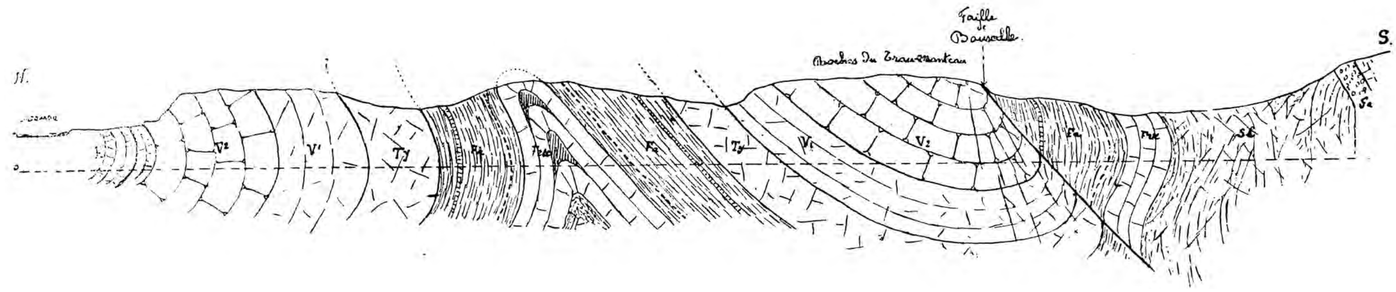

Fig. 29. Cross-section through the Solière stream valley (Fourmarier & Lespineux, 1908).

The Amerois Fault probably extends southwards under the Jurassic and monoclinal cover of the Paris basin (not affected by the fracture).

Interpretations

The fault disrupts many formations that are dated to the Cambrian as well as those of Lower Devonian age. These terrains have undergone Caledonian and/or Variscan diastrophism. However, the hypothesis of Variscan reactivation of a pre-existing Caledonian fracture is not envisaged by Beugnies (Beugnies, 1960).

The overthrusting that displaced the Givonne Inlier over the Eifel Synclinorium is probably related to the contractional stresses acting during the Variscan Orogeny. Moreover, crosscutting relationships constrain the Amerois Fault to be late-Variscan in age (Beugnies, 1988). Likewise, the fault crosscuts and displaces the Hercynian metamorphic isograds and the Herbeumont thrust fault. Both the isograds and the Herbeumont Fault are dated to the Asturian stage. No Mesozoic reactivation is assumed.

References

Beugnies, 1960.

Beugnies, 1985.

Beugnies, 1988.

Dewalque, 1897.

Ghysel & Belanger, 2006.

6.4. Boussale Fault

Location

The Boussale Fault, introduced by Stainier in 1894, also known as the Bousalle Fault on the geological map of Stainier (1901a), is located in the south of Andenne. From west to east, the fracture extends from 600 m north of Strud to the city of Huy. The fault is situated north of the "Bande de Sambre-et-Meuse" that forms an Ordovician-Silurian inlier trapped between the southern limb of the "Namur Synclinorium" and the northern limb of the Dinant Synclinorium (see the Landenne Fault in section 6.16, Fig. 49).

Stratigraphy and lithology of the country rocks

Many formations dated from the Frasnian to the Namurian are cut by the fault. The following stratigraphic subdivision is from Stainier (1901a):

- the Rhisnes & Thy-le-Baudouin Formation (Frc – Frasnian) is made up of nodular limestones;
- the Mariembourg, Monfort and Evieux formations (Fa1b, Fa2b & Fa2c respectively – Famennian) are mainly made up of micaceous sandstones, shales or even siliceous limestones in the case of the Evieux Formation;
- the Hastière and the Ecaussines & Waulsort formations (T1y & T2 – Tournaisian) both composed of crinoidal limestones and dolostones;
- the Dinant and the Visé formations (V1 & V2 – Visean) are made up of various dolostones, breccias and limestones; and
- the Lower and Middle Houiller Group (H1 & H2 – Namurian) are composed of sandstones, micaceous sandstones, shales and coal measures.

Geometry

The NE-striking Boussale Fault is mapped over a distance of nearly 15 km (Dewalque *et al.*, 1898; Stainier, 1901a; 1901c). The lineament is also parallel to the strata direction. The dip is minor towards the south

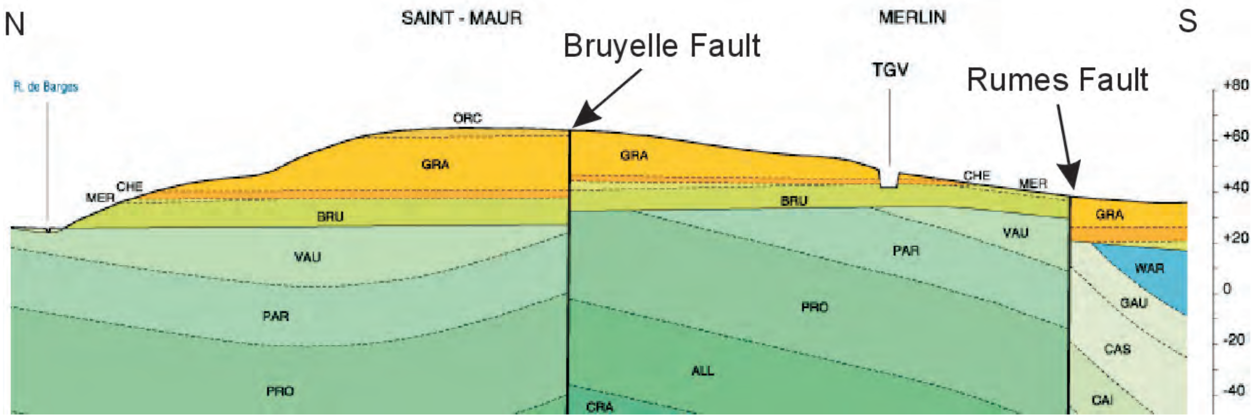

Fig. 30. N-S geological cross-section through the Mélantois-Tournaisis Anticline (from Hennebert & Doremus, 1997a).

(Fig. 29). The southern hanging wall block has moved upward and was thrust northward on the footwall block. The reverse offset is not known.

Interpretations

Fourmarier & Lespineux (1908) notice the reverse and thrust character of the Boussale Fault. Moreover, Stainier (1894) assumes that the fault shares strong similarities with significant faults like the Midi-Eifelian, Ormont and Boussu faults. The Boussale Fault is therefore a possible continuation or is intimately related to these faults. The origin of the Boussale Thrust, which defines a tectonic stack within the southern border of the "Namur Synclinorium", is likely to be the same as the Midi-Eifelian thrust front, i.e. the Asturian stage of the Variscan Orogen.

References

Dewalque *et al.*, 1898.

Fourmarier & Lespineux, 1908.

Hance *et al.*, 1991.

Stainier, 1894.

Stainier, 1901a.

Stainier, 1901c.

6.5. Bruyelle Fault

Location

The Bruyelle Fault is located to the south of Tournai. It runs from about 300 m to the north of Froidmont to 1 km to the south of Vezon. The fault cuts the southern limb of the ESE-plunging Mélantois-Tournaisis Anticline in the western part of the "Namur Synclinorium".

Lithology and stratigraphy of the country rocks

Due to Cenozoic reactivation, many formations from the Silurian to the Eocene are disrupted by the fault. The lithostratigraphy is equivalent to that of the Gaurain-Ramecroix Fault.

Geometry

The Bruyelle Fault can be traced for at least 13 km. The WNW orientation changes laterally eastwards to an E-W strike. The fracture exhibits a northward concave fault plane or, in other words, a probable centripetal slope dipping to the north (not clearly visible on the geological cross-section shown on Fig. 30). These geometrical features are characteristic of a positive flower structure (Christie-Blick & Biddle, 1985).

Within the Palaeozoic basement, the northern hanging wall block has subsided between 10 and 220 m (Fig. 30). The fault has a normal sense of throw. Within the Mesozoic-Cenozoic cover, the Bruyelle Fault presents a normal displacement of 5 m that changes towards the east where the southern fault block is downthrown by approximately 14 m (reverse displacement).

Interpretations

The Bruyelle Fault is observed within the Mélantois-Tournaisis Anticline in which longitudinal faults are characterized by dextral strike-slip and normal dip-slip combinations. Like other neighbouring lineaments, this fault is attributed to a regional transpressive tectonic setting that created the Nord-Artois shear zone. This brittle deformation stage is considered to be Stephano-Permian in age (late- or post-Variscan). Moreover, many recent reactivations have been identified that are responsible for the recent faulting of the Mesozoic-Cenozoic subhorizontal cover. Variscan fractures were reactivated as contractional faults.

Considering both the northern concavity and slope, the Bruyelle Fault is probably part of a positive flower structure. This E-W-striking fracture zone developed within the Mélantois-Tournaisis Anticline and the Marchiennes Transverse Structure. Christie-Blick & Biddle (1985) assume that those longitudinal faults join at depth to form a single deep strike-slip structure called the "principal displacement zone".

References

Christie-Blick & Biddle, 1985.

Hennebert, 1993.

Hennebert, 1998.

Hennebert & Doremus, 1997a.

Hennebert & Doremus, 1997b.

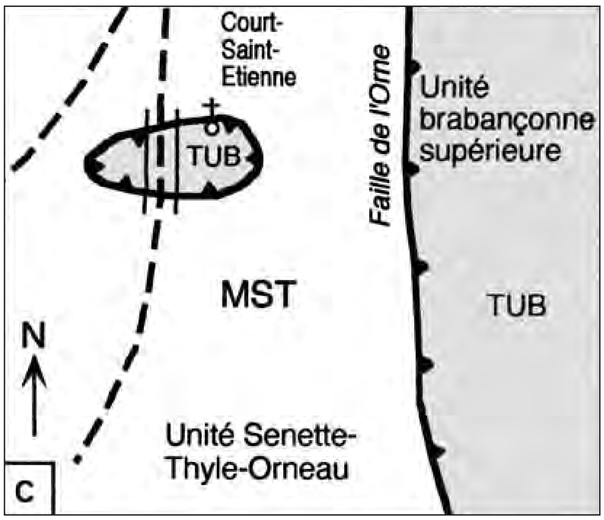

Fig. 31. Schematic geological map of the vicinity of Court-St-Etienne (Delcambre & Pingot, 2002). The circumference of the Court-St-Etienne Fault is about 1,5 km.

6.6. Court-Saint-Etienne Fault

Location

The fault of Court-Saint-Etienne (Anthoine & Anthoine, 1943) lies on the Lower Palaeozoic basement of Court-Saint-Etienne without disturbing the Mesozoic-Cenozoic cover. Indeed, this elliptic thrust fault forms the boundary between the Upper Cambrian Sennette-Thyle-Orneau Unit and the Lower Cambrian Court-Saint-Etienne Klippe (in the southern border of the regional Brabant Anticline; see the Fig. 31 below and the Orne-Noirmont-Baudecet Fault in section 6.22, Fig. 61). The Court-Saint-Etienne Fault is interpreted as being a separate segment of the Orne-Noirmont-Baudecet Fault (see below).

Lithology and stratigraphy of the country rocks

The fault thrusts the Tubize Formation over the Mousty Formation (Delcambre & Pingot, 2002). Both formations are made up of shales, siltstones and fine sandstones and are dated to the Lower and Upper Cambrian respectively.

Geometry and interpretations

Delcambre & Pingot (2002) discuss the validity of the Court-St-Etienne Klippe. According to these authors, the klippe properly belongs to the Tubize Formation and unconformably overlies the Mousty Formation. The existence of a thrust fracture is therefore essential. With this tectonic perspective, the northern vicinity of Gembloux is disrupted by a major thrust that is the Orne-Noirmont-Baudecet Fault. As mentioned previously, the reverse offset along this gently NE-dipping fracture may reach several kilometres. The low-angle dip of the Orne-Noirmont-Baudecet Fault, which is located 600 m east of the klippe, reinforces the klippe hypothesis that was proposed by Anthoine & Anthoine (1943) and by Mortelmans (1955).

However, the interpretation of the Orne-Noirmont-Baudecet Thrust as a pre-cleavage and pre-folding extensional detachment (Debacker *et al.*, 2004; see section 6.22) is associated with the re-interpretation of the supposed "klippe" of Court-Saint-Etienne. The latter is considered henceforth as an anticlinal culmination with a periclinal shape. See the Orne-Noirmont-Baudecet Fault for detaila.

References

Anthoine & Anthoine, 1943.

Debacker *et al.*, 2004.

Delcambre & Pingot, 2002.

Mortelmans, 1955.

6.7. Denée-Thynes Fault

Location

The Denée Fault, observed west of the Meuse river, was drawn on the geological maps of Bayet *et al.* (1904) and Soreil *et al.* (1908) but first named by Deslagmulder (1925). The Thynes Fault (Bourguignon, 1945?), observed east of the Meuse river, was traced on the geological maps of Lohest & Mourlon (1900) and de Dorlodot *et al.* (1919). Deslagmulder (1925) envisages their extension and connection (as the Denée-Thynes Fault) in the Meuse valley.

The Denée-Thynes Fault lies about 2.5 km southeastwards Mettet running from a point 500 m north of Biesmerée to a point 300 m south of Thynes, i.e. is about 24 km long. It cuts several E-W-trending folded structures, which are, from west to east: the Furnaux Anticline, the Denée Syncline, the Lisogne Anticline and the Thynes Anticline. These features belong to the southern border of the Namurian Anhée basin (Dinant Synclinorium).

Lithology and stratigraphy of the country rocks

The lithostratigraphic framework of the country rocks is equivalent to that of the Hanzinelle-Biesmerée Fault, which displays a contact between Lower Famennian and Visean rocks (Delcambre & Pingot, 2004). See the Hanzinne-Wagnée Fault for their description.

Geometry

The Denée-Thynes Fault is longitudinal and recognized over a distance of 24 km. The western segment strikes in an ENE direction while the central segment has an ESE strike. The eastern termination strikes E-W and is shorter on the map of Boulvain *et al.* (1995) than the original trace of Lohest & Mourlon (1900). The fracture dips southwards but the inclination is unsure being either a low-angle fault of about 30° (Deslagmulder, 1925) or a steeply-dipping fault (Bourguignon, 1945).

The southern hanging wall fault block moved upward. By investigating the displaced lithostratigraphic limits, Deslagmulder (1925) assumes a “quite significant” reverse displacement. The recent cross-sections enable a rough measurement of the stratigraphic shifts: the vertical offsets for the western (Delcambre & Pingot, 2004) and eastern (Boulvain *et al.*, 1995) segments are at least 900 metres (Famennian rocks are thrust on Molanician formations, Fig. 32) and 200 metres respectively.

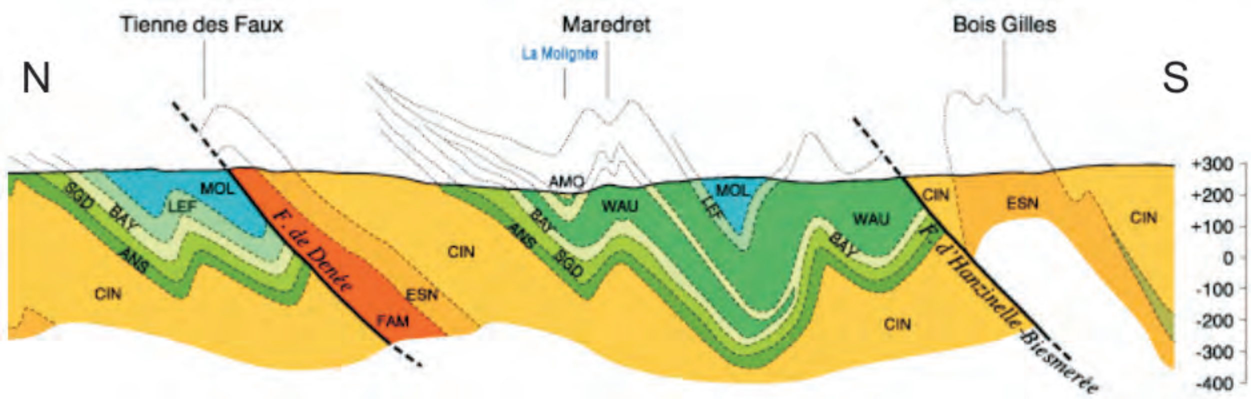

Fig. 32. N-S geological cross-section at the longitude of Saint-Gérard (Delcambre & Pingot, 2004). The Fault has a dip of 45° to the south.

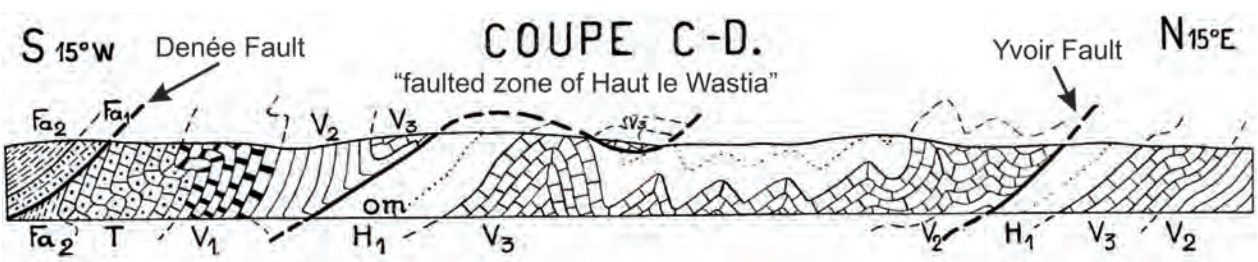

Fig. 33. SSW-NNE cross-section between the localities of Bioul and Warnant (Kaisin, 1936).

Interpretations

Deslagmulder (1925) and Kaisin (1936) consider the Denée-Thynes Fault as a low-angle thrust fault with satellites fractures that isolate a few tectonic stacks (both authors talk about three "lambeaux de poussées"). Moreover, the sinuous trace of the fault as well as the existence of a small Visean klippe overlying Namurian rocks (Fig. 33) are evidence for the northward thrust. On the basis of these arguments and in view of the proximity to the Midi Fault, Deslagmulder proposes a possible link between the two thrust fractures (i.e. the Denée and the Midi faults). Later, Bourguignon (1945) considers that the fault has a probable moderate or steep but not a gentle dip. According to his paper, no tectonic stacks accompany the fault.

From a regional aspect, the Denée-Thynes Fault is located in the Dinant fold-and-thrust belt. The numerous longitudinal faults of the shortened basin were initiated during the Variscan Orogeny of Westphalian age (Asturian stage) (Meilliez & Mansy, 1990).

References

Bayet *et al.*, 1904.

Boulvain *et al.*, 1995.

Bourguignon, 1945.

De Dorlodot *et al.*, 1919.

Delcambre & Pingot, 2004.

Deslagmulder, 1925.

Kaisin, 1936.

Lohest & Mourlon, 1900.

Meilliez & Mansy, 1990.

Soreil *et al.*, 1908.

6.8. Dondaine Fault

Location

The Dondaine Fault is situated close to Tournai (about 1.5 km south of the town). The fault runs from 500 m to the north of Camphin-en-Pevèle (France) in the west to Ramecroix (Belgium) in the east (Hennebert & Doremus, 1997a; 1997b). It disrupts the northern limb of the ESE-plunging Mélantois-Tournaisis Anticline (positive flower structure; Christie-Blick & Biddle, 1985) in the western part of the "Namur Synclinorium".

Lithology and stratigraphy of the country rocks

The lithostratigraphic setting of the fault is exactly the same as that of the Gaurain-Ramecroix Fault, i.e. the formations that are intersected are of Silurian to Eocene age. See the Gaurain-Ramecroix Fault for more explanation.

Geometry

The E-W-striking and north-dipping Dondaine Fault has a trace 16 km in length. Within the Palaeozoic basement, the fault has a concave plane that probably corresponds to a positive flower structure. A drilling campaign (Tournai drillhole, GSB reference 124E0455) showed a dip of 70° at 245 m depth as well as the downthrown movement of the southern footwall block (Fig. 34). The reverse throw there was measured at 22 m but the maximum displacement (60 m) is observed at the junction between the Dondaine and the Gaurain-Ramecroix faults.

Displacement within the superficial Mesozoic-Cenozoic cover is unknown. It is supposed that in the Tournai region, the fault has a downward movement (6 m) of the northern block (Fig. 34), while in the Ramecroix region, a downward movement (3 m) of the southern block.

Interpretations

The fault is related to a late- or post-Variscan transpressive regime. See the Bruyelle Fault (located 2 km farther south) for detailed interpretations.

References

Christie-Blick & Biddle, 1985.

Hennebert, 1993.

Hennebert & Doremus, 1997a.

Hennebert & Doremus, 1997b.

Legrand, 1981.

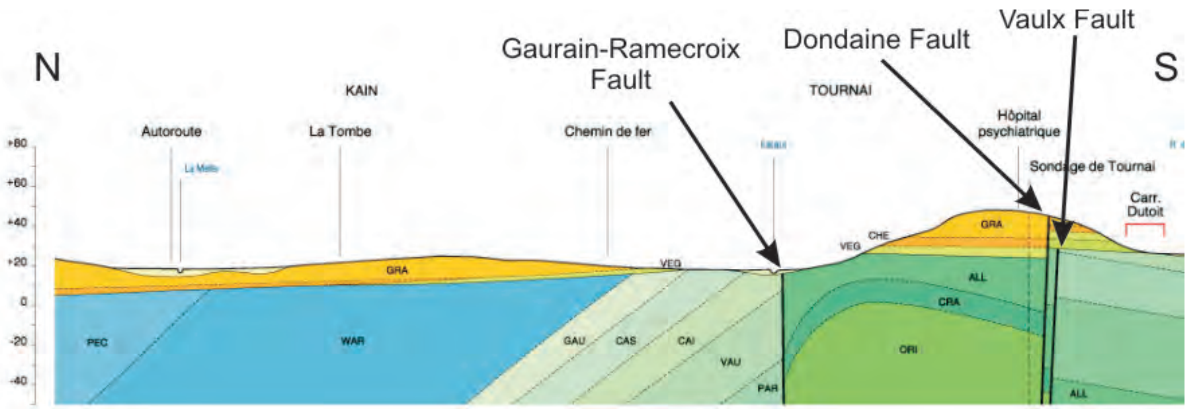

Fig. 34. N-S geological cross-section through the Mélantois-Tournaisis Anticline (from Hennebert & Doremus, 1997a).

6.9. Gaurain-Ramecroix Fault

Location

The Gaurain-Ramecroix Fault cuts the substratum of Tournai. It extends from about 1 km to the west of Willems (France) to about 2 km to the east of Vezon (Belgium) (Hennebert & Doremus, 1997a, b). The fault puts in contact the northern limb of the ESE-plunging Mélantois-Tournaisis Anticline in the south and the Roubaix Syncline in the north. Both structures are located in the western part of the "Namur Synclinorium".

Lithology and stratigraphy of the country rocks

Many formations from the Silurian to the Visean, as well as formations of Palaeocene and Eocene age, are disturbed by the fault. From the oldest to the youngest these are:

- the Silurian: mudstones;
- the Bois de Bordeaux Formation (Givetian): made up of red or green conglomerates, sandstones, shales interlayered with various limestones and anhydrite intercalations;
- the Bovesse Formation (Frasnian): composed of shales and crinoidal or nodular limestones;
- the Rhisnes Formation (Upper Frasnian): composed of nodular limestones;
- the Franc-Waret Formation (Frasnian-Famennian boundary): made up of sandy dolostones;
- the Samme Formation (Famennian-Hastarian): same lithologies as the Bois de Bordeaux Formation without anhydrite and with more dolomitised rocks;
- the Pont d'Arcole Formation (Hastarian): made up of shales;
- the Landelies and the Orient formations (Hastarian), made up of crinoidal limestones, shales and calcshales;
- the Tournai Formation (Ivorian) is subdivided into 6 members with a general carbonate lithology (clay-siliceous limestones);
- the Antoing Formation (Ivorian-Molanician), also subdivided into 4 members, is composed of clay-siliceous limestones;
- the Vert Galand (Turonian): made up of grey marl;
- the Esplechin Formation (Upper Turonian): made up of chalk;
- the Hannut Formation (Thanétian): composed of various green glauconious sands, clays, sandstones, etc.; and
- the Kortrijk Formation (Ypresian): composed of (sandy) clays.

The most abnormal chronostratigraphic contact observed along the fault trace is a Carboniferous (Ivorian, Tournai Formation) – Cenozoic (Thanetian, Hannut Formation) contact.

Geometry

In 1919, Camerman-Asou recognizes the Gaurain Fault in the eastern vicinity of Tournai. An offset of at least 75 m is envisaged. In 1927, Camerman proposes to extend the fault westerly through the city of Tournai where the displacement is now estimated to about 100 metres. Mortelmans (1948) confirms the point of view of Camerman and considers the Gaurain-Ramecroix Fault as a major structural feature of the Tournai region geology. The fault is supposed to have a constant offset along its recognized trace, which probably continues further west- and eastward.

The revised geological maps of Hennebert & Doremus (1997a, b) show the fault along 21 km. The WNW orientation in its western segment changes eastwards to a SE trend. The dip is to the south and shows a relative downward movement of the northern footwall block (Fig. 35). The maximum reverse displacement observed in Palaeozoic rocks in the middle segment of the fault

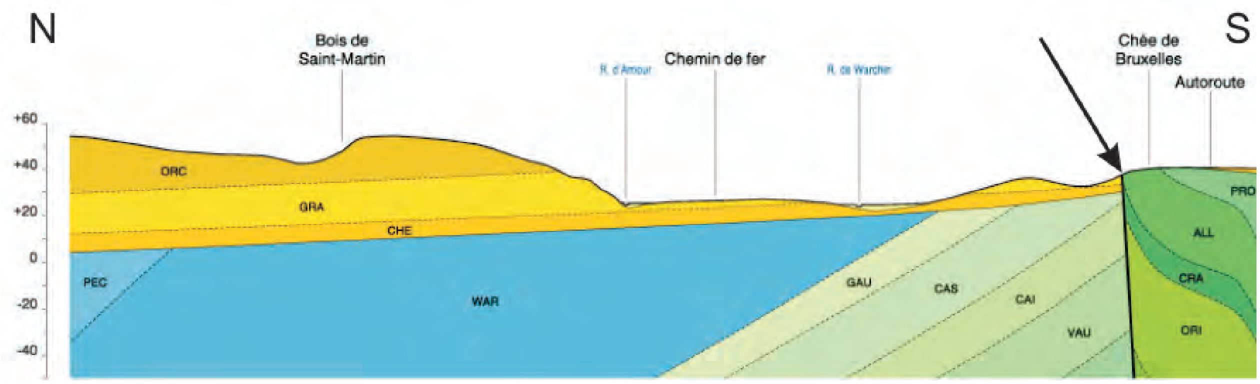

Fig. 35. N-S geological cross-section through the Mélantois-Tournaisis Anticline (from Hennebert & Doremus, 1997b).

reaches 160-170 metres (Hennebert & Doremus, 1997b). The fault extends to a depth of at least 1.4 km.

The Gaurain-Ramecroix Fault also affects Cenozoic formations (Fig. 35). The northern block is downthrown by 10 m (reverse throw), amplifying the reverse Variscan displacement within the Palaeozoic country rocks.

According to electrical tomography prospection, Geuse (2003) presents (locally) the Gaurain-Ramecroix Fault as a faulted zone of at least 40 m-thick. The zone is limited by two major fractures of which the northernmost corresponds to the mapped Gaurain-Ramecroix Fault (Hennebert & Doremus, 1997a,b). Other conclusions of the Geuse's work are the confirmation of the Tertiary reactivation and the absence of current activity along the fault as no disruption of the Quaternary loess is observed.

Interpretations

The Gaurain-Ramecroix Fault cuts the Mélantois-Tournaisis Anticline longitudinally. Fractures within the anticline present a combination of dextral strike-slip and normal dip-slip (Hennebert, 1993). The fault is probably the result of a regional transpressive tectonic setting in relation to the Nord-Artois shear zone, and is dated to the Stephano-Permian (late- or post-Variscan). Displacement within the Cenozoic cover suggests obvious post-Variscan reactivation. The Mélantois-Tournaisis Anticline is supposed to represent a positive flower structure (Christie-Blick & Biddle, 1985). See the Bruyelle Fault for an explanation.

References

Camerman-Asou, 1919.
Camerman, 1927.
Christie-Blick & Biddle, 1985.
Geuse, 2003.
Hennebert, 1993.
Hennebert & Doremus, 1997a.
Hennebert & Doremus, 1997b.
Mortelmans, 1948.

6.10. Genappe Fault

Location

The Genappe Fault is reported by Fourmarier (1921a, 1921b) in the Dyle valley. Later, Anthoine & Anthoine (1943) confirm the fault in the Dyle and the Cala valleys, exactly where it is currently traced on the latest geological map (Herbosch & Lemonne, 2000). The Genappe Fault affects the Cambrian rocks of the southern margin of the Brabant Anticline. These formations are unconformably overlain by extensive Eocene deposits that restrict the Lower Palaeozoic outcrop to only few valleys. The trace of the Genappe Fault is therefore badly constrained. However, recent aeromagnetic maps allow some interpretation (see below).

Lithology and stratigraphy of the country rocks (Herbosch & Lemonne, 2000).

The rocks north of the fault belong to the Tubize Formation ("Unité tectono-stratigraphique inférieure", Fig. 36), of Lower Cambrian age, which is made up of magnetite-rich sandstones, siltstones and shales. The formations located south of the fault ("Unité tectono-stratigraphique supérieure") are younger. They are:

- the Mousty Formation, of Upper Cambrian age, made up of shales; and
- the Chevlipont and the Abbaye de Villers formations, of Tremadoc and Arenig age respectively, made up of various siltstones.

Geometry

The Genappe Fault is seen in the Dyle and the Cala valleys (Anthoine & Anthoine, 1943; Herbosch & Lemonne, 2000). The cumulative length of the proven segments of the fault does not exceed 1700 metres (see the Thy Fault, Fig. 88) because of the Cenozoic cover that prevents the Cambrian rocks from outcropping.

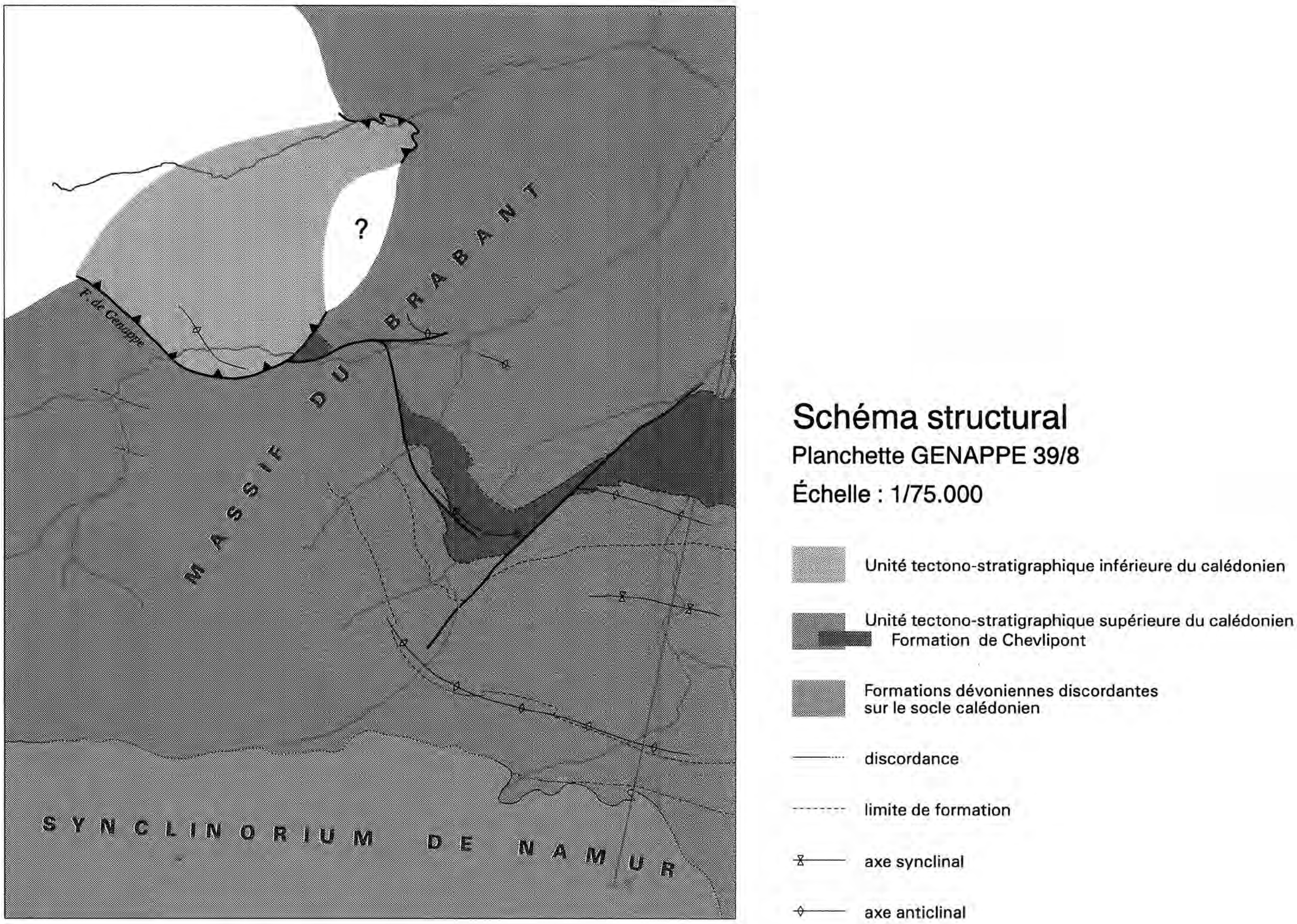

Fig. 36. Structural scheme of the Genappe map (39/8) (Herbosch & Lemonne, 2000).

Fourmarier (1921) considers the Genappe Fault as a reverse north-dipping fracture. He also proposes a connection between the Genappe Fault in the east and the Fauquez Fault in the west. However, Leriche who emphasized the long distance that separates the faults criticized this hypothesis. De la Vallée Poussin (1931) suggests a general E-W strike in the Dyle valley. With that perspective, the fault would run through Genappe, Bousval and Sart-Messire-Guillaume. Later, Anthoine & Anthoine (1943) introduce the strike-slip character of the fault. The fault has a northwestward plunge and a NNE strike near the locality of Ways (east of Genappe). The reverse offset is probably significant, in the order of several kilometres according to the stratigraphic displacement.

Interpretations

Fourmarier (1921a) was first to identify several faults in the southern margin of the Brabant Massif. Folding and faulting in this region are due to contractional stresses directed from north to south and related to the Caledonian shortening. The north-dipping fractures, which display reverse offset, are explained by the break-up of south-verging folds.

Anthoine & Anthoine (1943) draw a possible connection between the Genappe and the Orne faults (Fig. 37). The latter (see the Orne-Noirmont-Baudecet Fault in section 6.22) is interpreted as a major thrust of the Lower Cambrian core of the Brabant Massif over the Cambrian-Silurian foreland (Anthoine & Anthoine, 1943; Delcambre & Pingot, 2002).

On the basis of aeromagnetic maps, Sintubin (1997) proposes a tectonic framework for the southern margin of the Brabant Massif. He assumes a lateral escape of the Lower Cambrian core of the Brabant Massif and its thrusting over the Cambrian-Silurian foreland. This composite displacement is related to Caledonian compressive stresses acting from north to south. The presence at depth of an elongated granitic intrusion under the Brabant Massif would have a stop-pin behaviour that hindered the southward displacement of the Brabant Massif. The southward movement of the Lower Cambrian basement was blocked by the rigid granitic block and a dextral transpressive shear zone developed, allowing the lateral escape.

Herbosch & Lemonne (2000) studied in detail the aeromagnetic maps in the vicinity of Nivelles-Genappe.

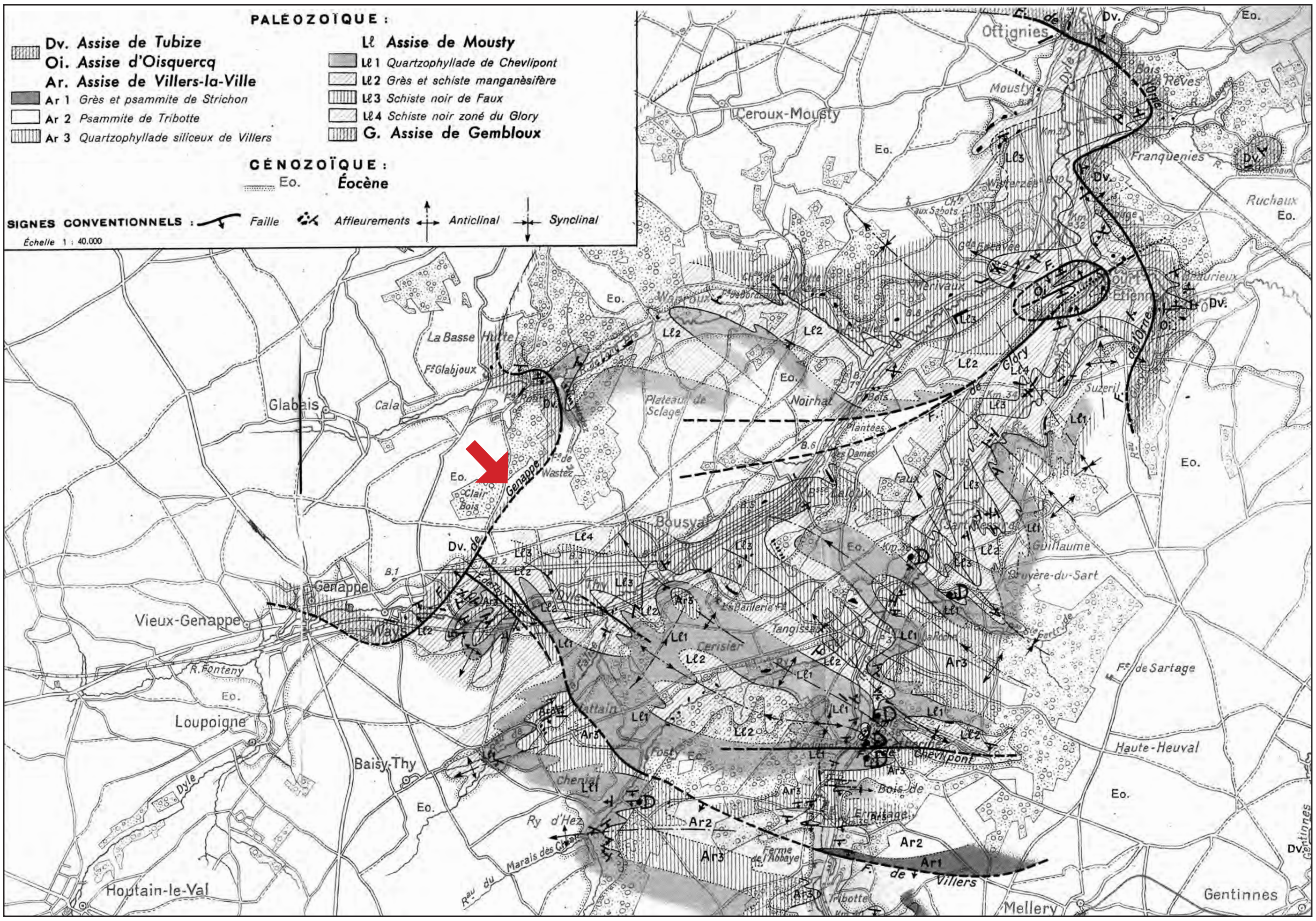

Fig. 37. Geological map of the upper basin of the Dyle river. Note the structural relation between the Genappe Fault and the Orne Fault (Anthoine & Anthoine, 1943).

They confirm the presence of a thrust fault near Genappe (the Genappe Fault) and also affirm that the Lower Cambrian rocks in the Dyle and Cala valleys (already observed by Anthoine & Anthoine in 1943) belong to a same entity as the thrust core of the Brabant Massif.

To conclude, the Genappe Fault is a probable segment of a major thrust located on the southern border of the Brabant Massif, along which the Lower Cambrian (Tubize Formation) is thrust over younger Cambrian-Silurian rocks (Herbosch & Lemonne, 1997). Consequently, the Genappe Fault is probably intimately related to, or is the continuation (Anthoine & Anthoine, 1943) of, the Orne-Noirmont-Baudecet Fault and also to the Court-St-Etienne Fault located 5 km eastwards (see the data sheets for these faults). If this relationship can be justified, the cumulative length of the fractures would reach at least 50 km (without considering the western and the eastern extensions in regions where re-mapping is in progress).

However, if the 2004 structural view of Debacker *et al.* (which considered the Orne-Noirmont-Baudecet trace as a pre-cleavage and pre-folding extensional detachment, see section 6.22) were verified, the Genappe Fault might be reinterpreted differently.

References

Anthoine & Anthoine, 1943.

De la Vallée Poussin, 1931.

Debacker *et al.*, 2004.

Delcambre & Pingot, 2002.

Fourmarier, 1921a.

Fourmarier, 1921b.

Herbosch & Lemonne, 1997.

Herbosch & Lemonne, 2000.

Leriche, 1921.

Sintubin, 1997.

6.11. Hanzinelle-Biesmerée Fault

Location

As the geological map of Bayet *et al.* (1904) proves, the fault was already known at the beginning of the 20th century. Located in the area south of Mettet, the Hanzinelle-Biesmerée Fault disrupts the northern limb of the Falaën Syncline in the Dinant Synclinorium. It is 16 km long, running from about 750 m south of Hanzinelle to about 400 m SW of Sosoye.

Lithology and stratigraphy of the country rocks

The most abnormal stratigraphic contact concerns the formations of Esneux (Lower Famennian) and Molignée (Lower Visean). Twelve formations are involved here. The lithostratigraphic environment is the same as for many other faults in the Dinant Synclinorium (see for example the Hanzinne-Wagnée Fault).

Geometry

The lineament of Hanzinelle-Biesmerée has a general E-W strike recognized over a distance of 16 km. The southward plunge of the fracture (of about 50°) shows an upward movement of the southern hanging wall block (Fig. 38). The reverse offset is significant as cross-sections indicate a thrust displacement of at least 225 metres.

Interpretations

The fracture belongs to a major fault family in Belgium that disrupts longitudinally the Dinant fold-and-thrust belt. Each of these thrust faults contributes to the shortening of the Devonian-Carboniferous Dinant basin by the superposition of numerous tectonic stacks. The contractional Asturian stage of the Variscan Orogeny of Westphalian age is related to this major regional faulting.

References

Bayet *et al.*, 1904.
Delcambre & Pingot, 2004.
Meilliez & Mansy, 1990.

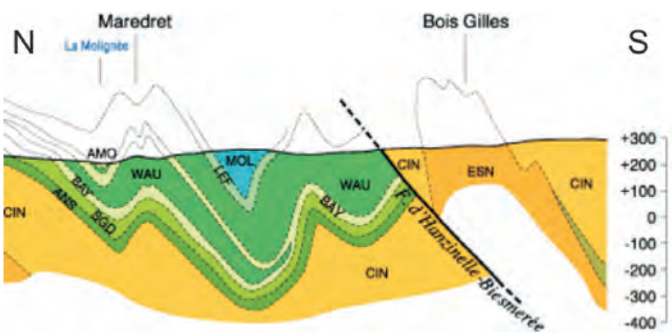

Fig. 38. N-S geological cross-section through Saint-Gérard (Delcambre & Pingot, 2004).

6.12. Hanzinne-Wagnée Fault

Location

The Hanzinne-Wagnée Fault is located on the northern border of the Dinant Synclinorium, in the vicinities of Gerpinnes and Mettet. From west to east, the fault extends from 2.5 km E of Nalinnes to 1 km NE of Denée, i.e. is around 20 km long. The western part of the lineament, which is only 3 km southeast of the regional Midi-Eifelian Thrust, crosscuts many folded structures, while the eastern segment affects essentially the E-W-trending Prée-Mettet Syncline (Delcambre & Pingot, 2000; Delcambre & Pingot, 2004). The fault was already known on the geological map of Bayet *et al.* (1904).

Lithology and stratigraphy of the country rocks

Many formations are displaced. These range from the Emsian to the Visean. The following description (Delcambre & Pingot, 2000; Delcambre & Pingot, 2004) is also appropriate for numerous other faults in the Dinant Synclinorium:

- the Burnot Formation (Upper Emsian): conglomerates, sandstones, siltstones and shales;
- the Rivière, Trois-Fontaines, Terres d'Haurs, Mont d'Haurs and Fromelennes formations (Eifelian-Givetian): various nodular and argillaceous limestones;
- the Nismes and the Pont de la Folle formations (Lower Frasnian): shales;
- the Philippeville Formation (Frasnian): bioconstructed (reef) limestones;
- the Neuville and the Famenne formations (Upper Frasnian and Lower Famennian): mainly shales;
- the Esneux and the Ciney formations (Famennian): (micaceous) sandstones and siltstones;
- the Anseremme Group (Lower Hastarian): limestones and shales;
- the Station de Gendron Group (Upper Hastarian): various limestones;
- the Bayard Formation (Lower Ivorian): crinoidal limestones;
- the Leffe, Molignée and Neffe formations (Upper Ivorian to Upper Molanician): various limestones.

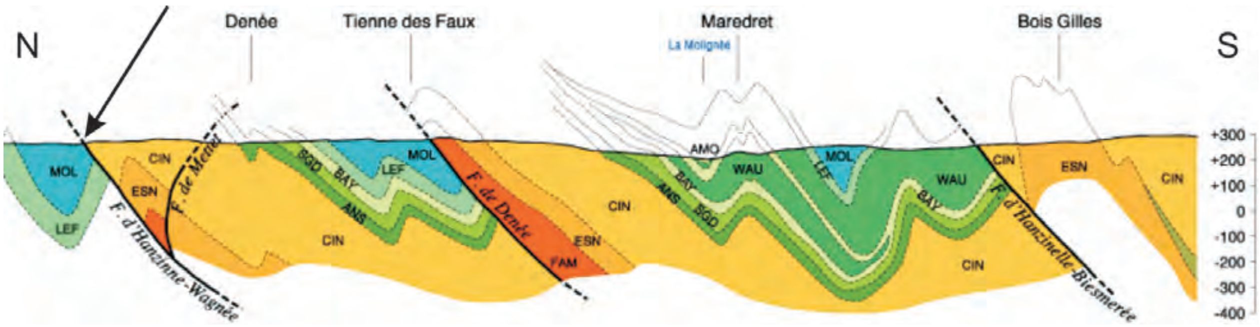

Fig. 39. N-S geological cross-section at the meridian line of Saint-Gérard (Delcambre & Pingot, 2004).

Geometry

The E-W-striking Hanzinne-Wagnée Fault is a reverse fracture that reaches 20 km in length. The trace is probably longer than this as the fault extends farther eastwards where the revision of the map of Bayet *et al.* (1904) has not been completed. The fault has a southern plunge and displays the uplift movement of the hanging wall block. Cross-sections allow an estimate of a displacement of at least 125 m for the western and 300 m for the eastern segments respectively. The dip is about 45-55° to the south, which reduces to 35° at a depth of 500 m below the surface. The southern dip of the fault in the Mettet region is coupled with a north-dipping antithetic fault. The latter, the Mettet Fault (see section 6.18), is interpreted as a backthrust allowing the extrusion of a small Famennian tectonic pop-up (Fig. 39).

Interpretations

The fracture belongs to a major fault family in Belgium that disrupts longitudinally the Dinant fold-and-thrust belt (Meilliez & Mansy, 1990). Each of these thrust faults contributes to the shortening of the Devonian-Carboniferous Dinant basin during the Asturian stage of the Variscan Orogeny of Westphalian age. As the Hanzinne-Wagnée Fault is located very close to the Midi Thrust, a hypothesis concerning a possible connection between the Hanzinne-Wagnée Fault and the North Variscan Front has been suggested (Delcambre & Pingot, 2000).

References

Bayet *et al.*, 1904.

Delcambre & Pingot, 2000.

Delcambre & Pingot, 2004.

Meilliez & Mansy, 1990.

6.13. Haversin Fault

Location

The Haversin Fault (identified by Simoens in 1900) was initially considered as quite a long fracture of 17 km (see the maps of Forir, 1900 and Lohest & Mourlon, 1900). The fracture was interpreted as a normal north-dipping fault. However, the recent mapping of Boulvain *et al.* (1995) of the region has not found a fault at the location where it was traced one century before. In 1975, Dreesen & Dusar observe a stratigraphic discontinuity near the locality of Haversin. They re-employed the term Haversin Fault for a new fracture (Fig. 40) that has absolutely nothing to do with the first Haversin Fault drawn farther south in 1900.

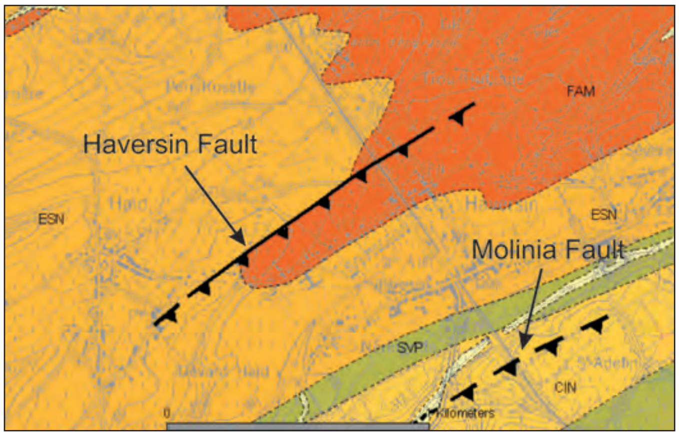

Fig. 40. Current considerations about the Haversin Fault (Boulvain *et al.*, 1995).

Current considerations of Dreesen & Dusar (1975) envisage the Haversin Fault as a small 1.5 km long lineament located about 5 km southeastwards Leignon. The fault disrupts the northern limb of the Famennian and NE-striking Chaviamont Anticline in the Dinant Synclinorium.

Lithology and stratigraphy of the country rocks

The tectonic movement along the Haversin Fault affects two Famennian formations: the Famenne and the Esneux formations. Both are mainly made up of green shales and sandstones.

Geometry

The longitudinal Haversin lineament strikes northeastwards. The geological map of Boulvain *et al.* (1995) indicates a south dip along which the upward movement of the southern hanging wall block has operated. The reverse displacement is not known.

Interpretations

The Haversin Fault belongs to a regional fault family that disrupts longitudinally the Dinant fold-and-thrust belt. The Variscan shortening (Asturian stage of Westphalian age) is probably the cause of the faulting.

References

Boulvain *et al.*, 1995.

Dreesen & Dusar, 1975.

Forir, 1900.

Lohest & Mourlon, 1900.

Simoens, 1900.

6.14. La Roche Fault

Location

Asselberghs first describes the La Roche Fault in 1931 just north of La Roche-en-Ardenne. The fracture runs from Marcouray in the west to about 1 km east of Samrée in the east. It has been mapped over a distance of at least 10 km on the Hotton-Dochamps and Champlon – La Roche-en-Ardenne geological maps (Fig. 41). An eastward continuation remains possible. The fault cuts the southern or the northern limb of the "Samrée Anticline" located in the Lower Devonian cover of the southern part of the Cambrian Stavelot-Venn Inlier.

Stratigraphy and lithology of the country rocks

The geological maps of Hotton – Dochamps and Champlon – La Roche-en-Ardenne (Fig. 41) indicate that the La Roche Fault displaces 7 Lower Devonian formations (from Lower Lochkovian to Upper Pragian in age). All formations occur on both sides of the fault. These are:

- the Oignies Formation (Mid Lochkovian), mainly made up of red shales;
- the Saint-Hubert Formation (Upper Lochkovian), made up of green shales and siltstones;
- the Mirwart Formation (Lower Pragian), made up of slates, shales and siltstones;
- the Villé Formation (Mid Pragian), made up of various sandstones, quartzites, shales and siltstones;
- the La Roche Formation (Mid Pragian), made up of blue slates;
- the Jupille and the Pèrnelle formations (Upper Pragian), made up of interlayered sandstones and slates.

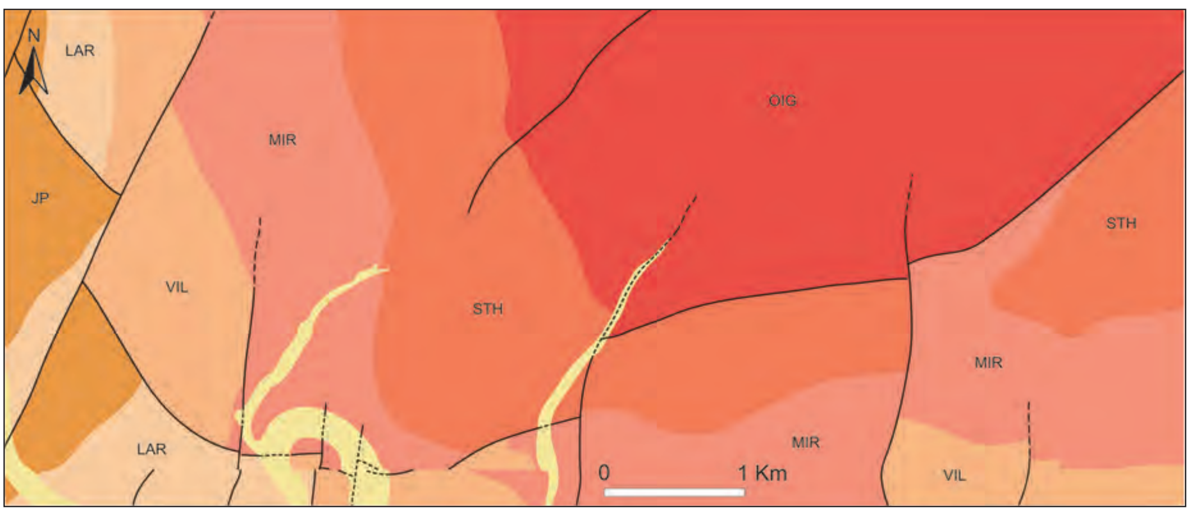

Fig. 41. Extract of the geological maps of Hotton – Dochamps (Dejonghe & Hance, 2008) and Champlon – La Roche-en-Ardenne (Dejonghe & Hance, 2001). OIG = Oignies Formation; STH = Saint-Hubert Formation; MIR = Mirwart Formation; VIL = Villé Formation; LAR = La Roche Formation; JP = Jupille and Pèrnelle formations.

Geometry

In 1931, Asselberghs makes the observation that Pragian rocks of the southern cover of the Stavelot Inlier are separated from the Pragian terrains of the western cover by a fracture. He proposes to name it the "Laroche Fault". The mainly E-W-striking and S-dipping Laroche Fault is recognized over a distance of at least 1200 m (Fig. 42). Indeed, the trace may continue westwards to Cielle and eastwards to the "Ruisseau des Pierreux", i.e. for a total length of 3.5 km.

Fig. 42. Location of the Laroche Fault. The map shows the apparent sinistral strike-slip component of the fault (Asselberghs, 1931).

The schematic map (Fig. 42) shows that the Mid Pragian, N-S striking strata of the western border of the Stavelot Inlier are in contact to the south with Upper Pragian slates of the southern border of the massif. The Laroche Fault has, therefore, an apparent sinistral offset, a strike-slip component estimated at between 1500 and 2000 m. The cross-section below in Fig. 43 illustrates the quite steep, southern plunge of the fault.

Asselberghs & Leblanc (1934) observe numerous abnormal contacts between the localities of Laroche and Bérismenil. These contacts correspond to the 11 km long, thrust-type and south-dipping Laroche Fault. The southern hanging wall block (i.e. the "Massif" de Laroche) is thrust northwards over Pragian rocks of the western and southern cover of the Cambrian Stavelot Massif (Fig. 44). The cross-section draw by the same authors (Fig. 45) allows us to measure the northward reverse offset to about 700 m.

The revised geological maps that cover the trace of the La Roche Fault were released in 2001 (Dejonghe & Hance; Champlon – La Roche-en-Ardenne) and in 2008 (Dejonghe & Hance; Hotton – Dochamps). The maps illustrate the western termination of the fault (Fig. 41), for about 10 km long. However, the fracture is probably longer as it may continue further eastwards where remapping has still to be finished.

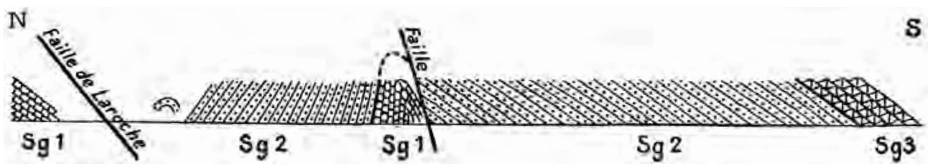

Fig. 43. N-S cross-section at the meridian line of La Roche-en-Ardenne (Asselberghs, 1931).

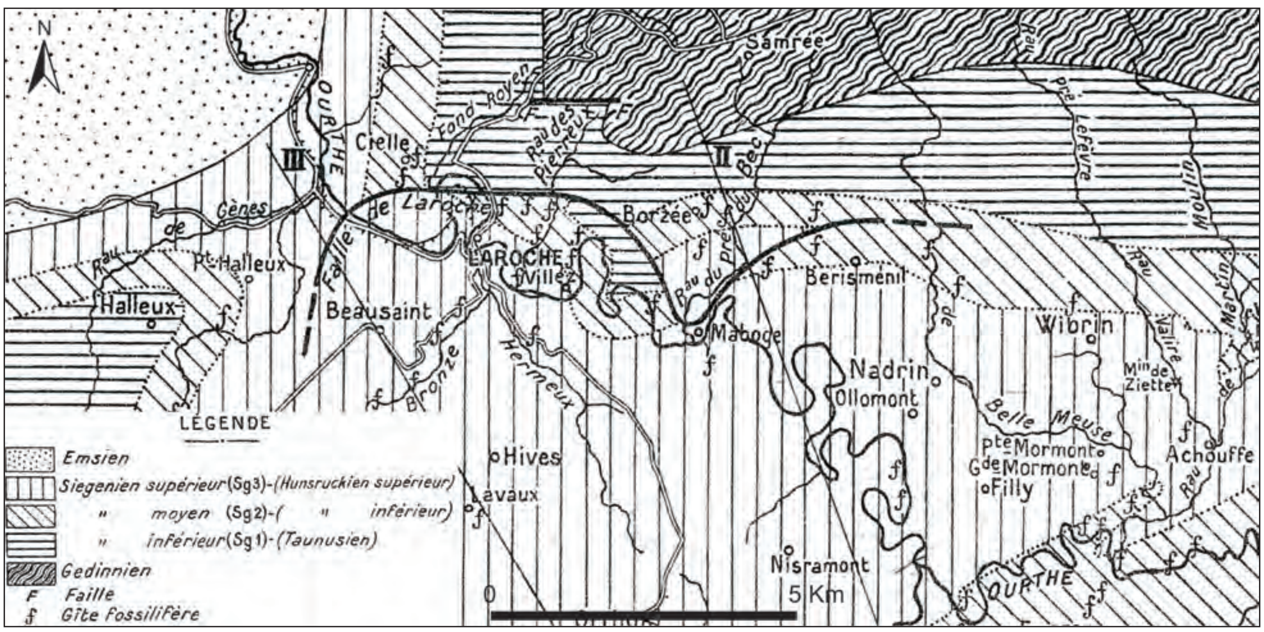

Fig. 44. Extract of the geological map of the vicinity of Laroche (Asselberghs & Leblanc, 1934). The fracture is 11 km long. The northern part of the cross-section II is given in Fig. 45.

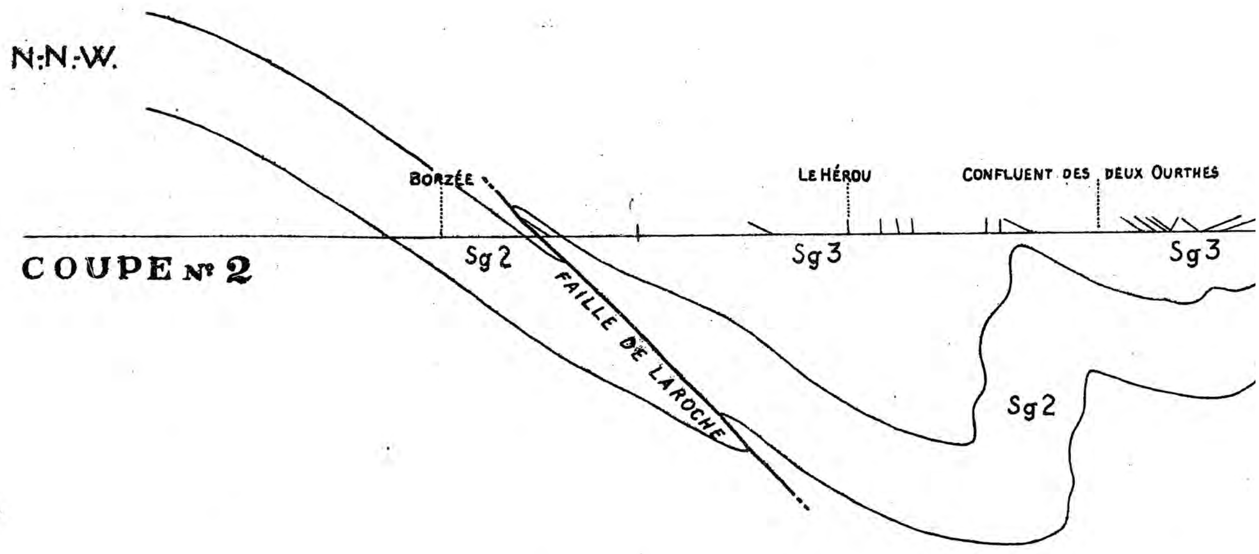

Fig. 45. Extract of the NNW-SSE cross-section (n°II) between Maboge and Bérismenil (Asselberghs & Leblanc, 1934). Location and legend are shown in Fig. 44.

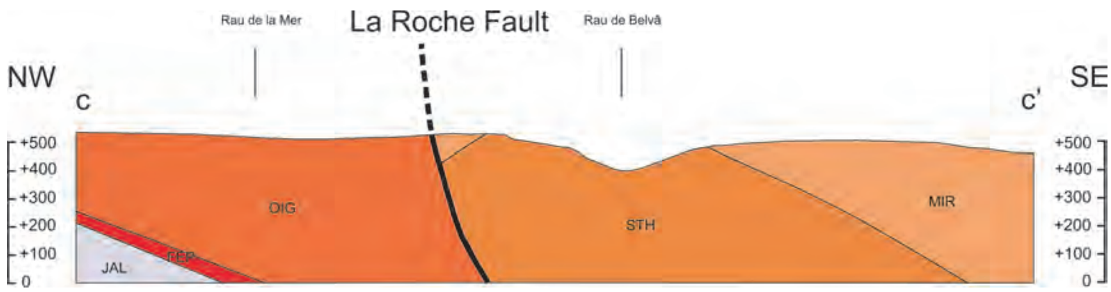

Fig. 46. NW-SE cross-section through the Lower Devonian southern cover of the Stavelot Inlier (Samrée area) (Dejonghe & Hance, 2008). JAL = Jalhay Formation; FEP = Fépin Formation; OIG = Oignies Formation; STH = Saint-Hubert Formation; MIR = Mirwart Formation.

Dejonghe & Hance (2008) assume that the western, central and eastern segments of the fault have a SE, E-W and NE strike respectively (Fig. 41). The La Roche Fault dips steeply (about 75°) to the south (Fig. 46) and enables the downthrow movement of the southern hanging wall fault block. The offset is therefore normal. Tricot (1954) already suggested a steep southern plunge and a normal displacement.

The La Roche Fault is frequently disturbed and displaced by several transverse faults that have apparent dextral or sinistral strike-slip component. As an example, the transverse Vecpré Fault crosscuts and displaces the La Roche Fault. The measured apparent cartographic right-lateral displacement is about 650 m.

Interpretations

Asselberghs & Leblanc (1934) assume the La Roche Fault to result from contractional stresses. The fracture was considered at that time to be a thrust fault that moved the northern limb of the La Roche Syncline over the southern border of the Stavelot Inlier. Asselberghs considers, in his 1946 work on the Eodevonian of the Ardenne, that the La Roche Fault is a typical example of a thrust fault.

According to their observations, Tricot (1954) and Dejonghe (2008) suggest that the fault has a normal slip. Dejonghe (2008) assumes that the La Roche and the Lamsoul faults, both longitudinal and normal fractures, have the same interpretation. The faults would either be initiated during the early phases of the Variscan Orogen, or later during the relaxation stage following the main deformation events.

References

Asselberghs, 1931.

Asselberghs, 1946.

Asselberghs & Leblanc, 1934.

Dejonghe, 2008.

Dejonghe & Hance, 2001.

Dejonghe & Hance, 2008.

Tricot, 1954.

6.15. Lamsoul Fault

Location

The Lamsoul Fault was first introduced and named by Stainier in 1900 on the geological map of Rochefort – Nassogne (n°186). The fault is drawn next on the map of Lohest & Forir in 1902 (Aye – Marche, n°177), where it is shown running over a total distance of nearly 15 km from a point 3 km SE Rochefort to 3 km south of Marenne. The first written reference is by Asselberghs (1946) and the latest complete mapping of the fault was released in 1977 by Leblanc (the trace is 21 km long, Fig. 47). The fault disrupts and places side by side the northern limb of the "Bois de On" Anticline in the north and the southern limb of the "la plaine d'Harsin" Syncline in the south. The fault is located in both the southern border of the Dinant Synclinorium (western segment) and in the Eodevonian northern border of the Ardenne Anticlinorium (eastern segment).

Stratigraphy and lithology of the country rocks

The eastern extremity of the fault has been mapped recently by Dejonghe (2008) and Dejonghe & Hance (2008) where he recognizes two displaced formations: the Chooz Formation and the Hampteau Formation. The first is dated to the Emsian, while the second is of Emsian-Eifelian age. Both formations are made up of various shales and siltstones.

The map of Leblanc (1977) uses the former lithostratigraphic division made up of "Assises", which are equivalent to the Chooz Formation, the Hampteau Formation, the Jemelle-Eau Noire-St Joseph Group, the Lomme Formation and the Hanonet Formation (see Godefroid *et al.*, 1994 for the exact equivalences).

- The Jemelle-Eau Noire-St Joseph Group, of Lower and Middle Eifelian age, is made up of various shales and siltstones;
- the Lomme Formation, Upper Eifelian in age, is made up of clayey sandstones, sandy shales and quartzites; and
- the Hanonet Formation, Upper Eifelian-Lower Givetian in age, is made up of argillaceous limestones.

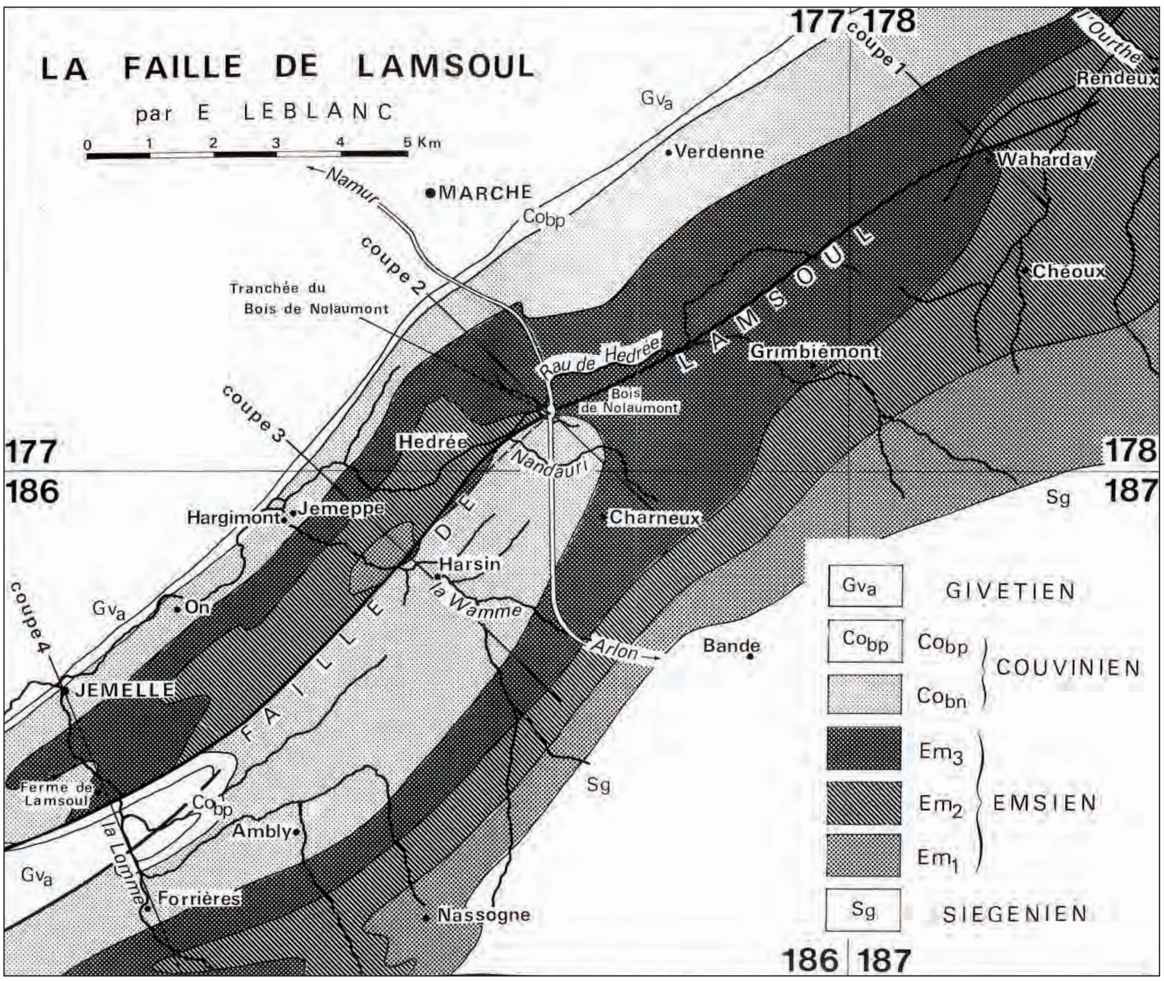

Fig. 47. Mapping around the Lamsoul Fault (Leblanc, 1977).

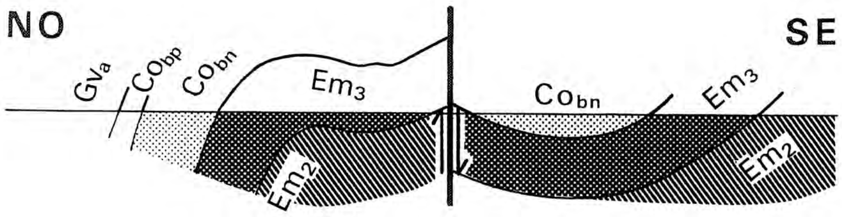

Fig. 48. Cross-section in the Wamme Valley (Leblanc, 1977). See the Fig. 47 for the legend.

Geometry

The Lamsoul Fault has a general NE strike and displays a vertical or steep dip to the south along which the southern block has moved downward (Asselberghs, 1946; Leblanc, 1956; 1977) (Fig. 48). The normal offset may reach or exceed 1000 metres, notably in the SW part of the fault (the displacement increases from the NE to the SW) and specifically in the Lomme Valley (Fig. 48).

In 1985, Delvaux de Fenffe estimates the normal offset in the Lomme valley (between Jemelle and Forrières) to a maximum of 600 m. The author also proposes to extend the Lamsoul Fault farther to the west to Eprave through the fault of Jemelle; the all fracture being therefore recognized over a distance of 29 km. The normal offset of this segment decreases from east to west (from the Lomme valley to Eprave) to a value of 100-200 m. The Jemelle Fault shows a southerly dip of 60°.

Five years later, in 1990, Delvaux de Fenffe assumes another westerly continuation of the Lamsoul Fault. In his work, Delvaux de Fenffe precises the trace of the Ave-et-Auffe Fault in the vicinity of Lavaux-Saint-Anne. This fracture is located in the continuation of the Lamsoul Fault, near Eprave, and proposes therefore to connect the two segments. Both the Ave-et-Auffe and Lamsoul faults are normal fractures that disrupt the southern border of the Dinant Synclinorium along a distance of 34 km.

The geological cross-section through the eastern termination of the Lamsoul Fault, from the cartographic work of Dejonghe & Hance (2008), indicates an dip of 70-75° to the south.

Interpretations

In 1946, Asselberghs considers four ‘significant’ steeply dipping normal faults in the Eodevonian Ardenne Anticlinorium: the Opont, the Vireux, the Lamsoul and the Oe faults. The interpretation for these faults is the probable re-equilibrium of the northern border of the Ardenne Anticlinorium following the Variscan contractional regime and thrusting movements.

Graulich (1983) considers that the Lamsoul Fault is a branch of a major landslide bulge (i.e. “loupe de glissement”), which, through its link with the Bra Fault, is connected eastwards to the Xhoris Fault (see Fig. 116 in section 6.36). The late-Variscan uplift of the Stavelot Inlier would have resulted in this major SE slide shifting. However, according to Geukens (1984), the connections between these three faults are not valid (see the Xhoris Fault for details).

Delvaux de Fenffe (1990) interprets the Lamsoul Fault as resulting from a regional tectonic explanation: the late-Variscan extension, directed N-S and marking the end of the Variscan Orogeny.

Finally, Dejonghe (2008) proposes a connection between the normal Lamsoul Fault in the west with the reverse Bardonwé Fault in the east. However, he noticed that this kind of tectonic behaviour is quite unusual in that part of the Ardenne Allochthon.

References

Asselberghs, 1946.
Dejonghe, 2008.
Dejonghe & Hance, 2008.
Delvaux de Fenffe, 1985.
Delvaux de Fenffe, 1990.
Geukens, 1984.
Godefroid *et al.*, 1994.
Graulich, 1983.
Leblanc, 1956.
Leblanc, 1977.
Lohest & Forir, 1902.
Stainier, 1900.

6.16. Landenne Fault

Location

The Landenne Fault is first drawn by Stainier in 1902, although it has been described previously as the "faille silurienne du Champ d'oiseaux" by Firket (1878). For an unknown reason, it has been renamed as the Landenne Fault by Stainier (1901a) on his geological map. The fault is located 2 km north of Andenne. It runs from Couthuin in the east to about 1600 m to the ESE of Boninne (in the area NE of Namur), i.e. for a total length of about 15 km (Stainier, 1901a; 1901b). The fault disrupts the northern limb of the "Namur Synclinorium" and shows, within its central segment, the contact between Silurian rocks in the north with Lower Carboniferous rocks in the south (Fig. 49). The Landenne Fault may therefore be interpreted as a significant discontinuity separating two main tectono-stratigraphic units of Belgian regional geology, the Caledonian Brabant Massif in the north and the Variscan "Namur Synclinorium" in the south.

Stratigraphy and lithology of the country rocks

As noted previously, the central part of the fault shows a Silurian / Visean contact. However, the segments located at the extremities of the fracture display less significant displacements. There, Middle and Upper Devonian rocks are in contact with Tournaisian and Visean rocks. In total, more than 10 formations from the stratigraphic subdivision of Stainier (1901a, 1901b) are disrupted. We refer the reader to the geological maps for a description of the lithologies.

Geometry

The longitudinal fracture is a 14.6 km long, ENE-striking and steeply dipping lineament. In detail, the western segment has a N75°E direction and an average northerly dip of 61° (Firket, 1878). The main characteristic of the fault is the northward plunge (Fig. 50), along which the northern block, made up of Silurian rocks, was uplifted. The variable reverse displacement may reach 920 metres. A minor dextral strike-slip component is possible as shown by the apparent (cartographic) offset (see Stainier, 1901a).

Interpretations

No interpretation on the origin of this fault has been found. However, contractional tectonics related to the Caledonian and/or Variscan shortenings have to be taken into account.

References

Firket, 1878.

Stainier, 1901a

Stainier, 1901b.

Stainier, 1902.

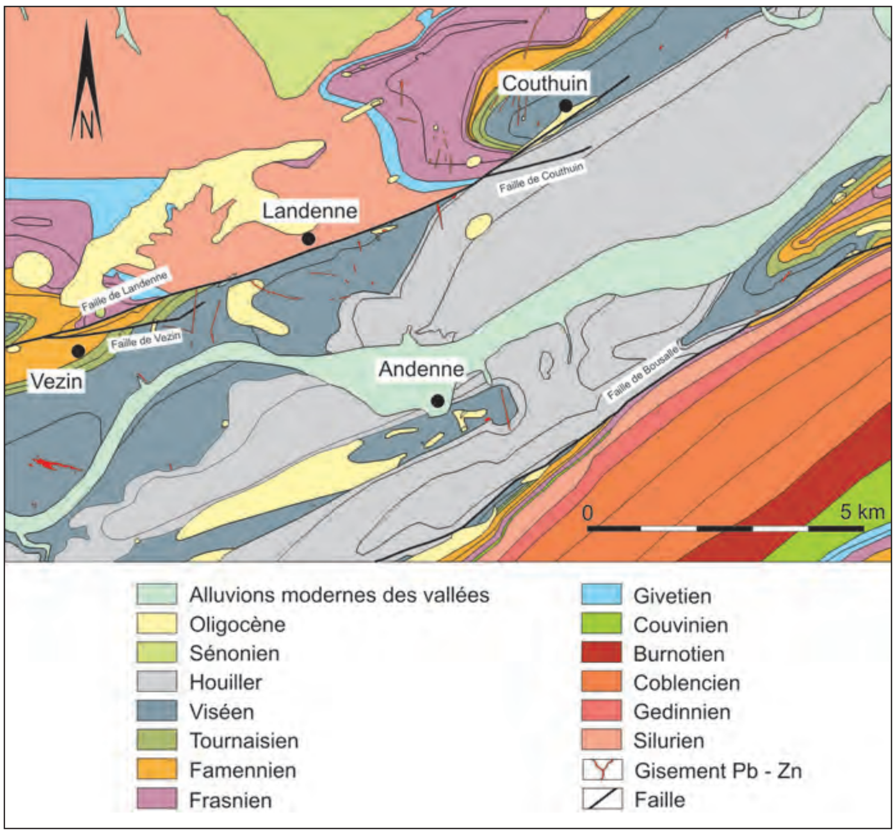

Fig. 49. Simplified and schematic geological map of the Andenne region (from Stainier, 1901a; modifed).

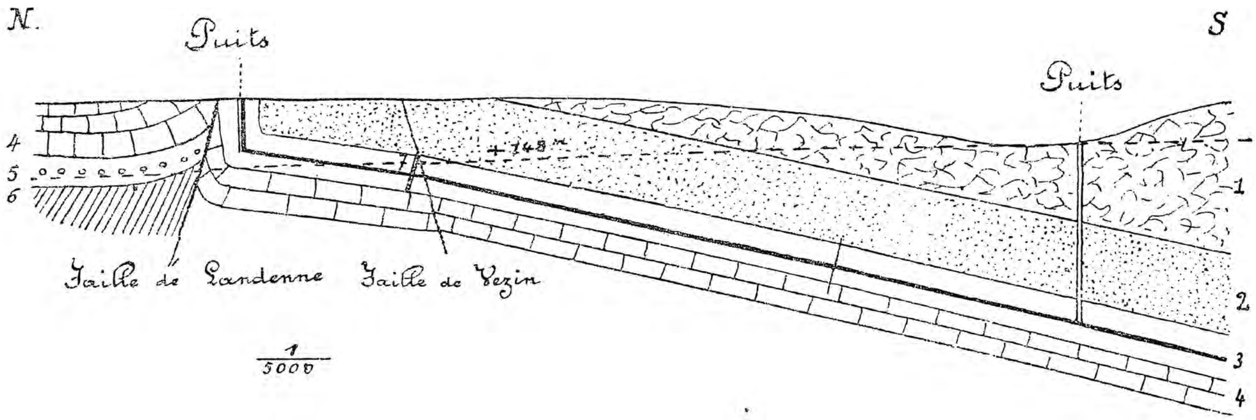

Fig. 50. Cross-section in the vicinity of Vezin (Stainier, 1902). Frasnian limestones crop out north of the fault while Famennian shales and sandstones are found to the south. 1. Carboniferous dolostones. 2. Micaceous sandstones. 3. Famennian shales. 4. Frasnian limestones. 5. Givetian “red rocks”. 6. Upper Silurian shales. 7. Pyrite veins.

6.17. Malsbenden Fault (or Troisvierges – Malsbenden Fault)

Location

Breddin introduces the Troisvierges – Malsbenden Fault in 1963 in the Urft valley in north Eifel (Germany). The fault is a major structural feature of the Ardenne geology since it is recognized over a distance of 90 km roughly from the SE of Bastogne in Belgium to the north of Schleiden in Germany (Furtak, 1965) (Fig. 51). In detail, the main localities concerned are, from SW to NE, Wincrange, Troisvierges, Sankt-Vith, Bullange and Malsbenden. The Troisvierges – Malsbenden Fault marks the boundary between the Ardenne Anticlinorium in the north and the Eifel Synclinorium in the south. The Troisvierges – Malsbenden Fault is different from most of the Variscan thrust faults due to its northward plunging and backthrusting character (Oncken *et al.*, 2009).

Lithology and stratigraphy of the country rocks

In the vicinities of Troisvierges and Sankt-Vith, Furtak (1965) indicates 2 “rock complexes” separated by the Malsbenden Fault: the “B” and “C” complexes (Fig. 52). The “B” complex, located north of the fault, is Upper Pragian in age and is made up of sandy slates, while the “C” complex, in the southern footwall block and Lower Emsian in age, is made up of sandier slates.

The revision of the (German) Aachen geological map of Ribbert *et al.* (1992) takes into consideration the eastern extremity of the Malsbenden Fault. The northern block is represented by 2 formations: the “Wüstebach-Schichten” (“semW”), made up of shales, and the “Heimbach-Schichten” (“semH”) made up of sandstones and shales. These rocks are dated to the Pragian-Emsian boundary. The southern block may be composed of these two formations but also of one other: the “Schleiden-Schichten” (“emS” and “emS1”), Lower Pragian in age and made up of sandstones and shales.

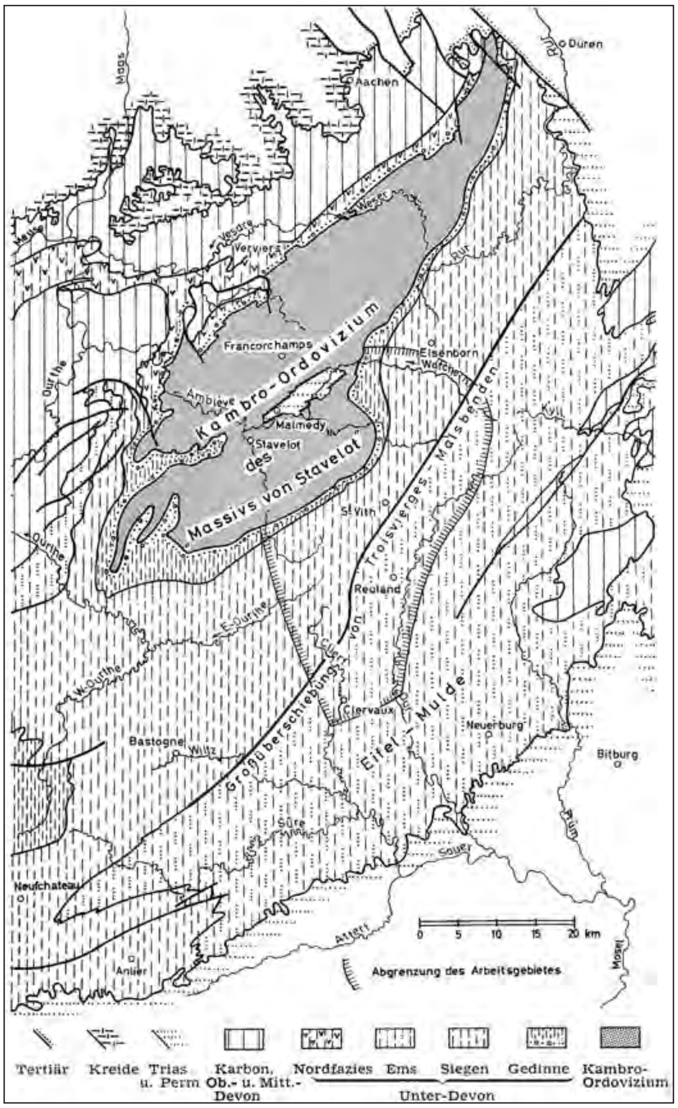

Fig. 51. Simplified geological map of the East Ardenne and West Eifel (Furtak, 1965).

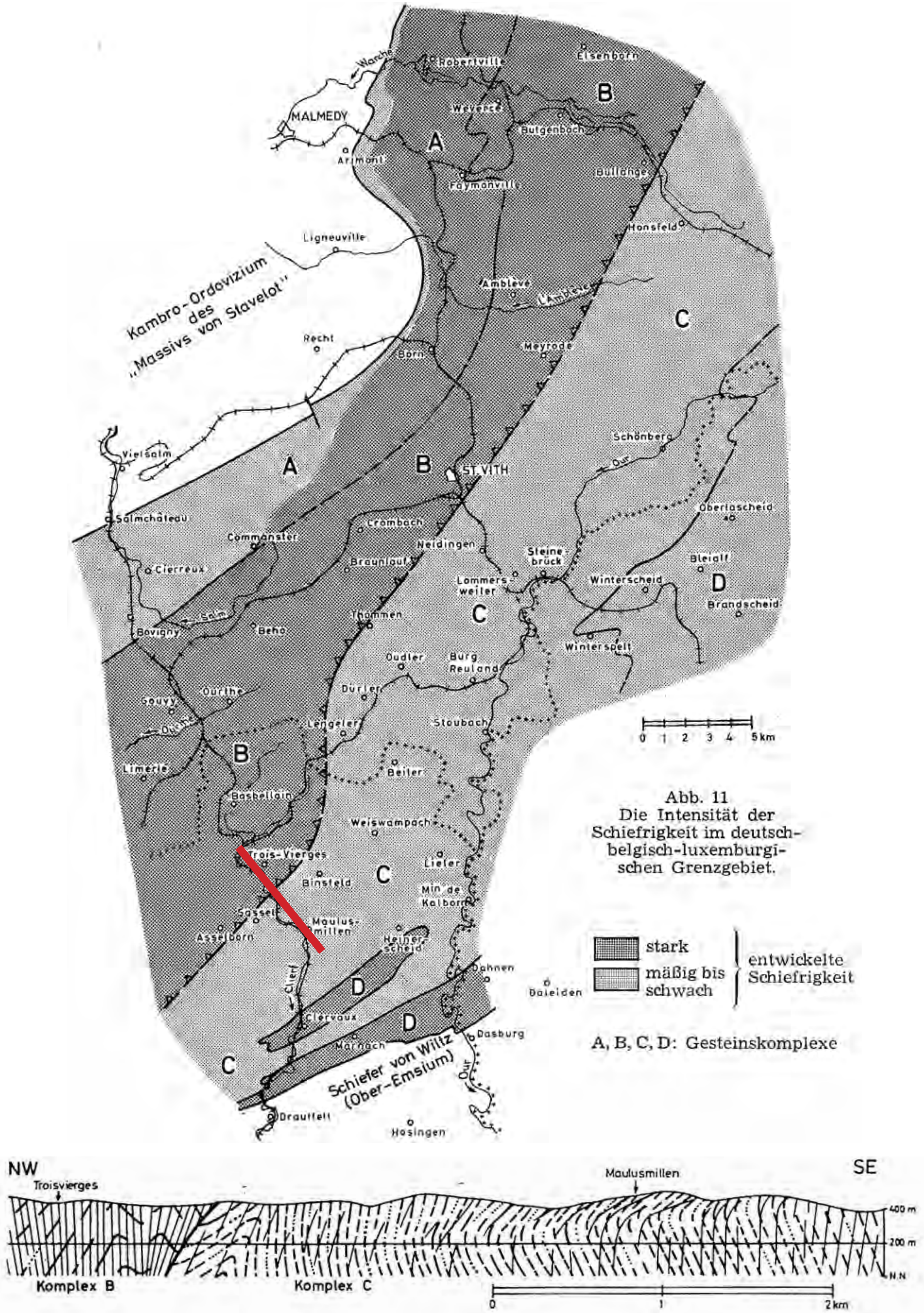

Fig. 52. Study area of Furtak's work (1965). The map shows the thrust of the high schistosity "B" complex southwards over the low schistosity "C" complex. The cross-section between Troisvierges and Maulusmillen, and its location on the map, are also given.

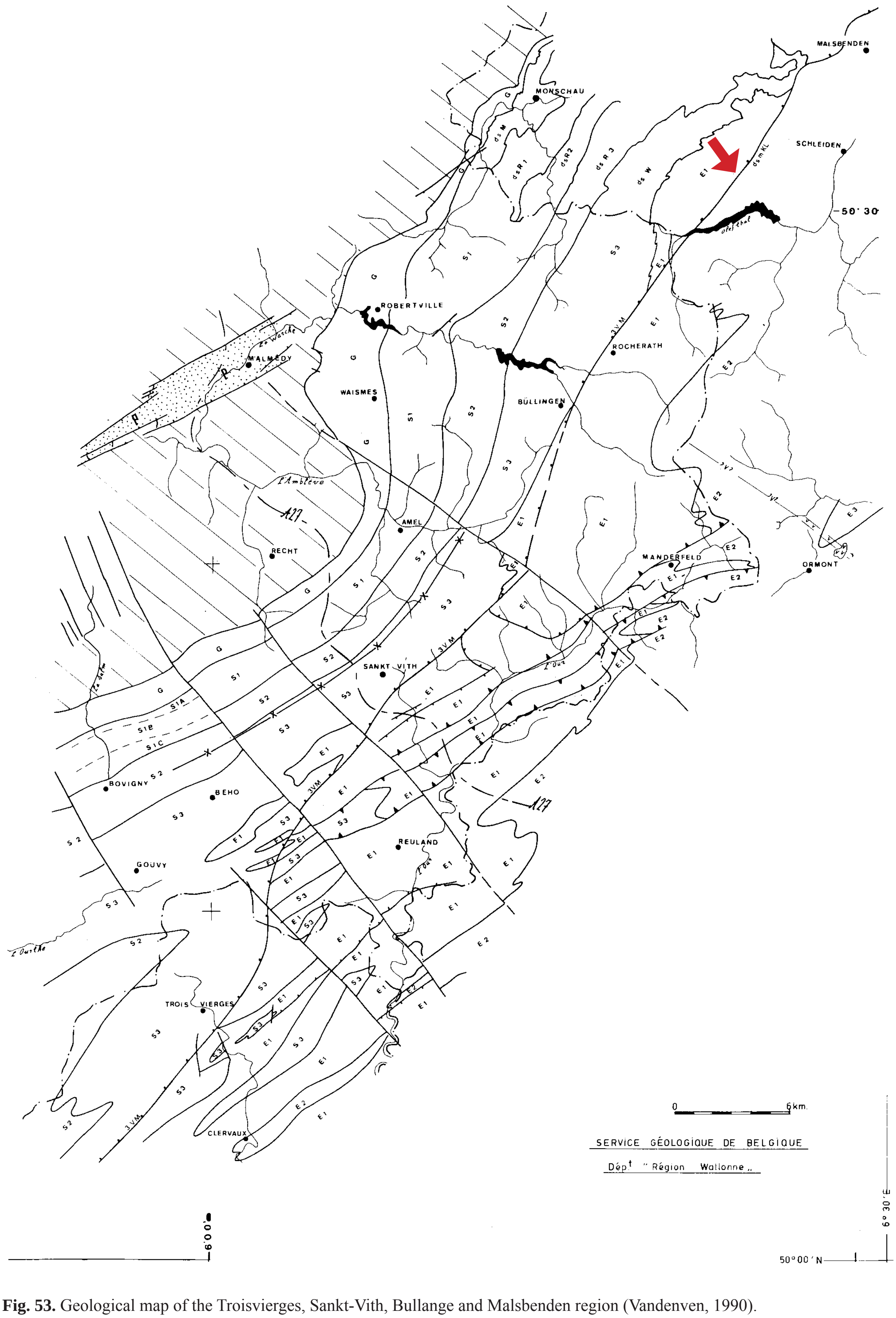

Fig. 53. Geological map of the Troisvierges, Sankt-Vith, Bullange and Malsbenden region (Vandenven, 1990).

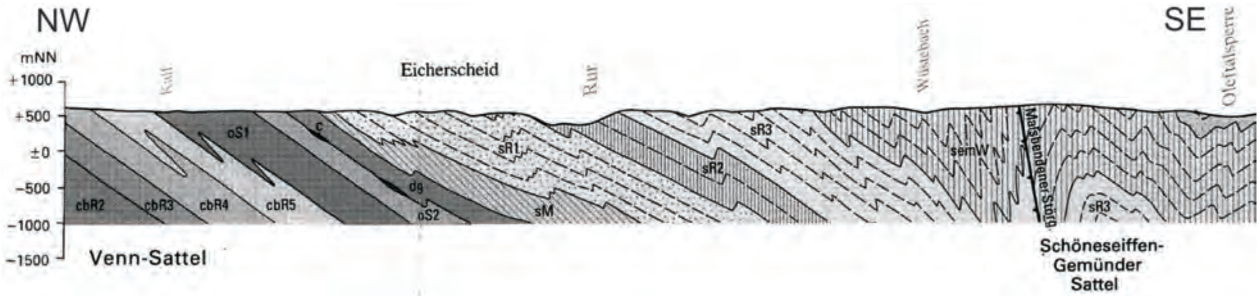

Fig. 54. NW-SE cross-section in the vicinity of Monschau (Ribbert *et al.*, 1992). The steeply south-dipping "Malsbendener Störung" has an apparent normal offset.

Geometry

In 1963, in the Urf valley, close to Malsbenden in Germany, Breddin observes an abnormal contact in Emsian formations. He proposes, therefore, the presence of a major fault: the "Malsbendener Überschiebung". Not much information is given with the exception of the northward dip and a thrust-type movement. The fault is recognized from the Warche valley (near Bullange) to the Urf valley, i.e. over a distance of 30 km at most. The eastern extremity of the fault disappears under Triassic deposits while the western continuation is not traceable because of the lack of outcrops.

In 1965, Furtak indicates a major NE-striking and north-dipping fault in the vicinities of Bullange, Sankt-Vith and Troisvierges. He detects an obvious connection between this fracture and the fault of Breddin, which now reaches a significant length of 85-90 km. Furtak proposes to name this fault the "Großüberschiebung von Troisvierges – Malsbenden" or the "Grand Charriage de Troisvierges – Malsbenden". In his study area, detection of the fault is based on an abnormal lithostratigraphic contact between two "rock complexes" displaying different degrees of schistosity (Fig. 52). The "B" complex, located north of the fault, is thrust over the older "C" complex in the southern footwall block.

In 1990, Vandenven publishes a lithostragraphic and structural map of the Gouvy-Sankt-Vith-Elsenborn region. The Malsbenden Fault appears on the map but the mapped zone is not large enough to represent the fracture entirely. The fault is traced over a distance of about 58 km from the SW of Troisvierges to its eastern extremity in Germany. Vandenven did not directly observe the Troisvierges-Malsbenden Fault in his study area but a few considerations are given, such as the cutting and displacement of the fault by several transverse, NW-striking, sinistral strike-slip fractures (Fig. 53). Vandenven suggests that the lack of outcrops in the Hautes-Fagnes area does not allow measurement of the geometrical features of the Malsbenden Fault in Belgium. He proposes, therefore, various alternative ideas (see below).

The revised German geological map of Aachen of Ribbert *et al.* was published in 1992. The most striking feature of the Malsbenden Fault on this map is probably the discontinuity of the trace. A first segment is drawn in the Bullange region and another is traced in the vicinity if Malsbenden. Moreover, the cross-section attached to the map (Fig. 54) does not refer to the "Troisvierges-Malsbenden Fault" but to the "Malsbendener Störung". Another important feature seen on the cross-section is the steep southward dip of the fault, which acquires therefore an apparent normal offset.

Interpretation

Keeping in mind that the northward dip of the Malsbenden Fault is only justified in the Urft valley and that the fault cannot be characterized in Belgian territory because of the lack of outcrops, Vandenven (1990) proposes various theories.

His first attempt was to compare the Troisvierges-Malsbenden Fault to a kind of listric overthrust as described in the Sauerland and Taunus regions (Germany) by Weber (1981). This author interprets the listric thrusts as reverse faults with decreasing upward offset that is progressively compensated for by folding and which eventually dies out at high tectonic levels. Considering these listric overthrusts, Vandenven proposes a cross-section through Sankt-Vith (Fig. 55, C). This model considers the Malsbenden Fault as a south-dipping fracture corresponding to a branch of the "Our" Thrust. The southward block is uplifted.

A second interpretation envisaged by Vandenven is the truncation of the "Our" Thrust by the reverse Troisvierges-Malsbenden Fault. This model (Fig. 55, D) indicates a subvertical dip with an upward movement of the northern block.

In 1999, Oncken *et al.* provides a map of the Ardennes and the Rhenish Massif. A cross-section related to the interpretation of DEKORP seismic profiles shows a northwestward dip and considers the Malsbenden Fault as a backthrust. Fig. 56 represents the Malsbenden Fault as it is currently understood.

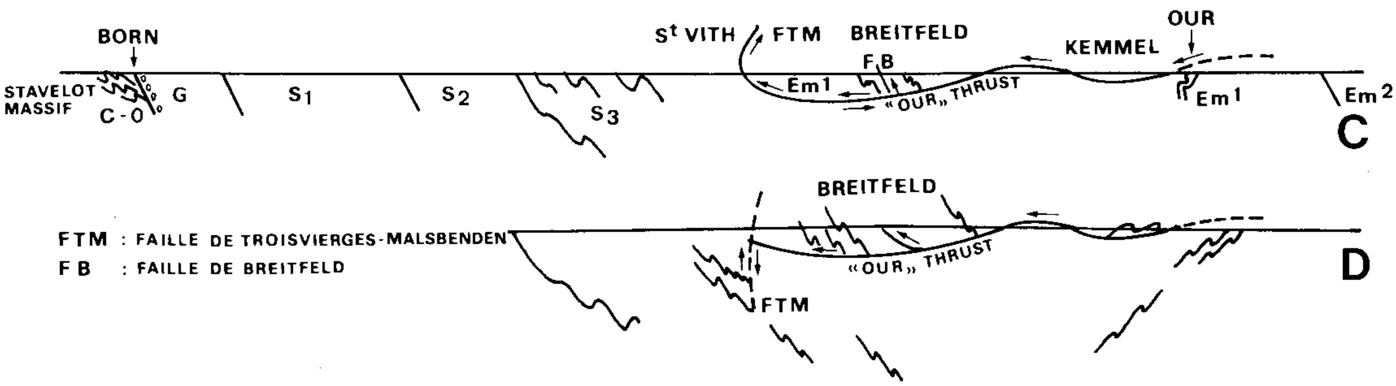

Fig. 55. NW-SE cross-sections in the vicinity of Sankt-Vith (Vandenven, 1990).

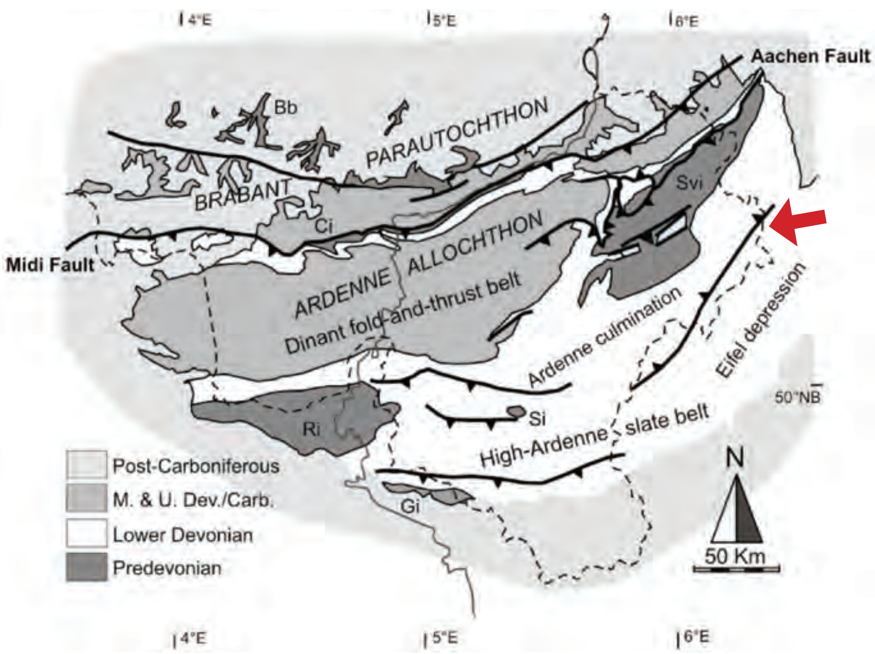

Fig. 56. Geological framework in southern Belgium. The regional Malsbenden Fault backthrust the Ardenne Anticlinorium to the south.

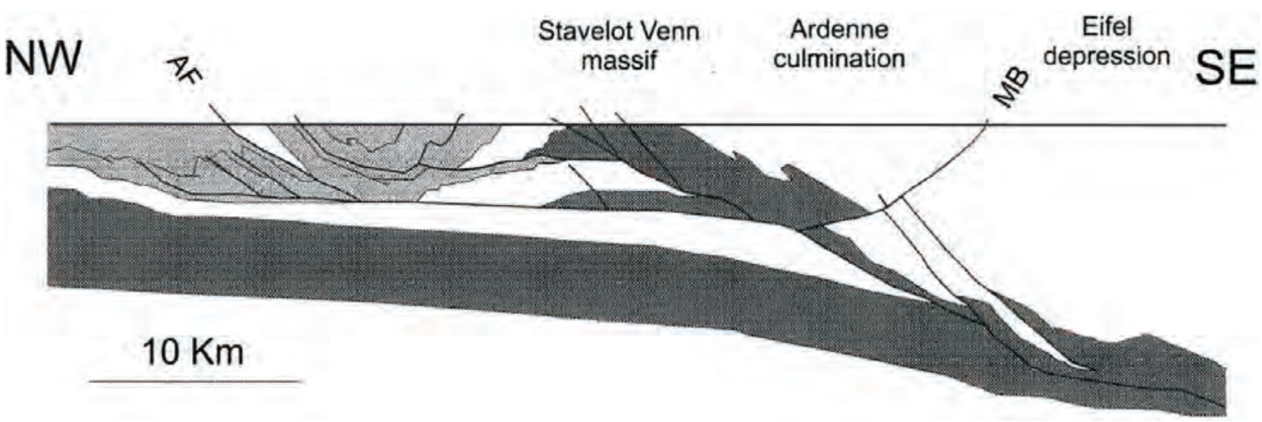

Fig. 57. NW-SE cross-section along the DEKORP seismic profile (after Oncken *et al.*, 2009; Kenis, 2004). AF = Aachen Fault; MB = Malsbenden backthrust.

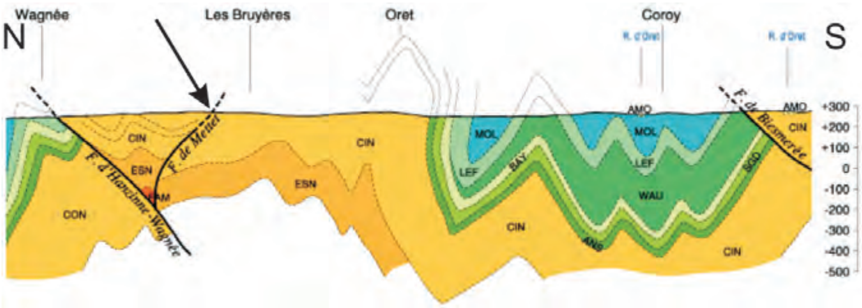

Fig. 58. N-S geological cross-section at the longitude of Biesme (Delcambre & Pingot, 2004).

In 2004, Kenis considers the Troisvierges-Malsbenden Fault as a major backthrust bounding the Ardenne Anticlinorium in the north and the Eifel Synclinorium in the south. Considering that the Ardenne Anticlinorium would have been thrust southward along this north-dipping fracture, the author proposes that the unit north of the Malsbenden backthrust is a pop-up structure (Fig. 57). Fig. 57 shows that the Troisvierges-Malsbenden Fault is connected to a deep décollement level that is considered to be the downward extension of the Midi-Aachen Thrust.

References

Breddin, 1963.

Furtak, 1965.

Kenis, 2004.

Oncken *et al.*, 2009.

Ribbert *et al.*, 1992.

Vandenven, 1990.

Weber, 1981.

6.18. Mettet Fault

Location

The Mettet Fault, named by Delcambre & Pingot in 2004, is located 500 m south of Mettet. It runs from about 1 km east of Les Bruyères to about 1 km west of Denée, i.e. over a distance of 9 km. The fault displaces the northern limb of the Denée Syncline that is located a few kilometres south of the North Variscan Front (i.e. the Midi-Eifelian Fault). Note that the fault was already known and drawn at the time of preparing the 1:40 000 scale geological map (see Bayet *et al.*, 1904).

Lithology and stratigraphy of the country rocks

The Mettet Fault affects three Famennian formations. These are the Famenne, the Esneux and the Ciney formations, mainly composed of shales, siltstones and sandstones.

Geometry

The E-W-striking Mettet Fault is mapped over a distance of 9 km. The dip has never been observed but is likely to plunge in a northerly direction. The hanging wall block has moved upward with an unknown offset. The fault is antithetic to the regional southward dip and to the Hanzinne-Wagnée Fault. A reverse displacement is also identified along that fault. Thrust movements along both faults allow the upward expulsion of a small Famennian tectonic wedge (or "pop-up", Fig. 58). The cross-section indicates a moderate dip of 45° and a displacement of about 100 m.

Interpretations

Contractional stresses were necessary to shorten and deform the Dinant basin. The numerous northward thrusts that affect the Dinant fold-and-thrust belt are related to the Variscan Orogeny of Westphalian age. The Mettet Fault may be considered as a backthrust of Variscan origin.

References

Bayet *et al.*, 1904.

Delcambre & Pingot, 2004.

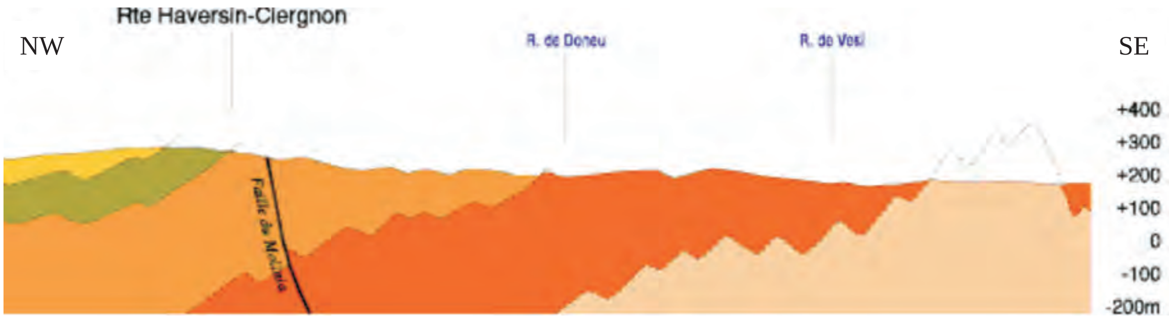

Fig. 59. NW-SE cross-section at the meridian line of Ychippe (northeastwards Chevetogne) (Boulvain *et al.*, 1995).

6.19. Molinia Fault

Location

The Molinia Fault is first mentioned by Boulvain *et al.* in 1995. The fracture is located to the east of Dinant, running from about 2 km to the NE of Mont-Gauthier to about 500 m to the SE of Haversin (i.e. over a distance of about 5.5 km). The fault cuts the NE-trending Chevetogne-Haversin Syncline in the Famenne depression (Dinant Synclinorium).

Lithology and stratigraphy of the country rocks

The Molinia Fault disturbs four Famennian formations:

- the Famenne and the Esneux/Aye formations are mainly made up of green shales and sandstones;
- the Souverain-Pré Formation is made up of bioclastic nodular limestones; and
- the Ciney Formation is composed of grey siltstones and sandstones.

Geometry

The Molinia Fault is a NE-striking, 5.5 km long lineament. The fault has a moderate to steep dip directed to the south. The footwall block moved downward along an unknown but probably small reverse offset. Indeed, the cross-section in Fig. 59 enables measurement of the dip-slip component with a probable range of between 25 and 50 m. The displaced lithostratigraphic limits display an apparent (cartographic) sinistral strike-slip of less than 125 m.

Interpretations

Variscan shortening is responsible for the brittle deformation in the Dinant basin. The Silesian Asturian orogenic stage is believed to be the origin of contractional stresses leading to the Molinia Fault

References

Boulvain *et al.*, 1995.

6.20. Monty Fault

Location

The Monty Fault, first described by Dumont in 1832, is located about 3 km to the north of Charneux and strikes southwards very close to the SW of Verviers. The trace is recognized over 13 km. The fault intersects the NE-striking Tunnel Fault that is considered to be the eastward continuation of the major overthrusting Eifelian Fault (Hance *et al.*, 1999). In other words, the northern segment of the Monty Fault belongs to the Herve Unit (Brabant foreland) while the southern segment belongs to the Vesdre Nappe (Variscan Front Zone). The lineament also bounds the western flank of the N-S-trending Minerie Graben (see the Ostende Fault, Fig. 63). See also the Mouhy Fault.

Lithology and stratigraphy of the country rocks

The fault disturbs the Namurian-Westphalian Houiller Group. This is made up, in the Verviers area, of interlayered black shales and siltstones, various sandstones and coal seams. The Monty Fault also disrupts three flat-lying Cretaceous formations: the Aachen Formation (made up of fine grained sandstones), the Vaals Formation (made up of clays and glauconiferous sandstones) and the Gulpen Formation (made up of white chalk).

Geometry

In 1906, Forir already indicates that the fault disrupts the Cretaceous formations. Ancion & Evrard (1957) recognize the N-S-striking Monty Fault over 2 km. The fracture is subvertical at surface but displays an eastward dip of about 55° at a depth of 320 m. As the fold axis are not displaced, no strike-slip component is assumed. The eastern fault block is downthrown. The normal offset is about 60 m and can be distributed between both the Monty fracture and its “Satellite Fault” (Fig. 60).

Revision of the geological map (Laloux *et al.*, 1996b; Barchy & Marion, 2000) shows that the Monty Fault has a general NNW strike and a steep dip towards the east. It has a length of at least 13 km. The eastern hanging wall block is downthrown and the normal displacement is estimated at between 30 and 90 m. The dip-slip Monty Fault does not show any left-lateral strike-slip component contrary to other normal faults within the Minerie Graben (see for example the Ostende Fault in section 6.23).

Interpretations

Ancion & Evrard (1957) suggest that the fracturing in the Minerie Graben is quite compatible with a contractional stage directed from south to north (see the major sinistral strike-slip of the Ostende Fault in Fig. 63). The hypothesis is based on a late-Variscan compressive regime (a more coherent extensional framework will be proposed later, see below). They also observed a less significant normal offset in the Cretaceous formations than in the folded Carboniferous substratum. For Ancion & Evrard (1957), the Monty Fault is probably activated during the Variscan Orogeny and then reactivated during the Cretaceous.

According to Barchy & Marion (2000), Palaeozoic structural units (the Herve Unit and the Vesdre Nappe) are disrupted by the Monty Fault. This tectonic feature therefore post-dates the Variscan formation of the E-W folded and faulted structures. Moreover, the Monty fault displaces the three Cretaceous formations and attests to a post-Variscan extensional setting.

The Minerie Graben forms part of a Permian collapse system, called the Rhine-Roermond Graben that was probably reactivated during the Mesozoic-Cenozoic. Recent seismic activity in eastern Belgium may suggest tectonic movements along faults subjected to E-W extensional stress and related to the opening of the Rhine-Roermond Graben (Camelbeek, 1990). The Monty Fault is therefore potentially active.

References

Ancion & Evrard, 1957.
Barchy & Marion, 2000.
Camelbeek, 1990.
Dumont, 1832.
Forir, 1906.
Hance *et al.*, 1999.
Laloux *et al.*, 1996b.

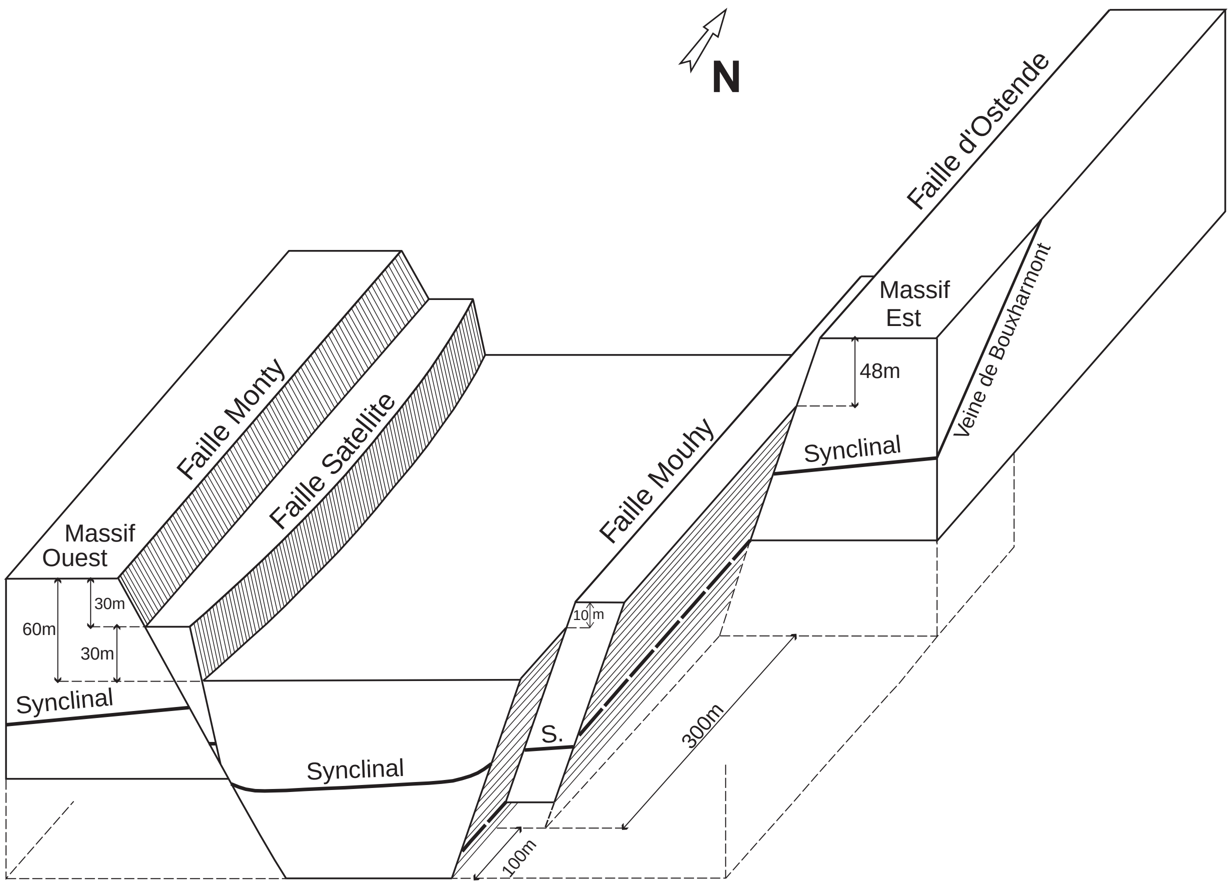

Fig. 60. Block-diagram of the Minerie Graben (from Ancion et Evrard, 1957).

6.21. Mouhy Fault

Location

Dumont discovers the fault in 1832 in the northeastern vicinity of Battice. The Mouhy Fault is currently recognized from 2 km to the ENE of Charneux to Verviers, i.e. over a distance of 10 km. The lineament cuts across the Herve Unit (Brabant foreland) in the north and the Vesdre Nappe (Variscan Front Zone) in the south (Hance *et al.*, 1999). In addition, the eastern flank of the Minerie Graben is bounded by both the Mouhy and the Ostende faults (see the Ostende Fault, Fig. 63).

Lithology and stratigraphy of the country rocks

The fault disrupts not only the Namurian-Westphalian Houiller Group but also the subhorizontal Cretaceous formations (Barchy & Marion, 2000). See the Monty Fault for their description.

Geometry

Forir (1906) already indicates the disruption of the Cretaceous formations. In 1957, Ancion & Evrard suggest an approximate 60 to 70° dip to the west for the mainly SSE-trending Mouhy Fault. The eastern block has moved to the north. The fault is an oblique-slip fracture with a principal sinistral strike-slip component (displacement of about 100 m) and a secondary normal dip-slip component (the western block subsided about 28 m). The reviewed geological maps (Laloux *et al.*, 1996b; Barchy & Marion, 2000) recognize the fault along a strike length of 10 km. The authors agree with the geometrical considerations of Ancion & Evrard.

Interpretations

Ancion & Evrard (1957) indicate that the faulting in the Minerie Graben is compatible with a contractional (late-Variscan) stage directed from south to north (a more coherent extensional framework will be proposed later, see below). They also observe a less significant normal offset in the Cretaceous formations than in the folded Carboniferous substratum. The Mouhy Fault is therefore probably activated during the Variscan Orogeny and then reactivated during the Cretaceous.

According to Barchy & Marion (2000), Palaeozoic structural units (the Herve Unit and the Vesdre Nappe) are disrupted by the Mouhy Fault. The fault therefore post-dates the Variscan formation of the E-W folded and faulted structures. Moreover, a post-Variscan extensional setting is assumed to explain the disruption of the Cretaceous rocks.

The same authors remind readers that the Minerie Graben forms part of a Permian collapse system called the Rhine-Roermond Graben that was probably reactivated during the Mesozoic-Cenozoic. Present seismic activity in eastern Belgium might suggest tectonic movements along faults subjected to E-W extensional stress related to the Rhine-Roermond Graben opening (Camelbeek, 1990). The Mouhy Fault is therefore potentially active.

References

Ancion & Evrard, 1957.

Barchy & Marion, 2000.

Camelbeek, 1990.

Dumont, 1832.

Forir, 1906.

Hance *et al.*, 1999.

Laloux *et al.*, 1996b.

6.22. Orne-Noirmont-Baudecet Fault

Location

The Orne fault segment, introduced by Anthoine & Anthoine (1943), is located in the Glory valley between Mont-Saint-Etienne and Mont-Saint-Guibert and has a general N-S strike that changes to an E-W direction near Ottignies. Data on the Noirmont-Baudecet fault segment (discovered recently, Delcambre & Pingot, 2002) are poorly constrained because of the lack of outcrops. However, this segment was detected in several places during drilling campaigns. It is believed to have a general E-W strike and is interpreted to be the eastern continuation of the Orne segment, which would therefore have a strong bend towards the east (Delcambre & Pingot, 2002) (Fig. 61). The fault disrupts the southern border of the major Brabant Anticline (i.e. the Cambrian-Silurian basement of the Brabant Massif) without disrupting the unconformable Cenozoic cover.

Lithology and stratigraphy of the country rocks

The Orne segment places the Tubize Formation (Lower Cambrian) made up of siltstones and sandstones against the Mousty Formation (Upper Cambrian) composed of black siltstones and shales. The Noirmont-Baudecet segment brings into contact the Blanmont Formation (Lower Cambrian) of quartzitic sandstones with the Mousty Formation (Delcambre & Pingot, 2002).

Geometry

The Orne-Noirmont-Baudecet Fault is recognized over a distance of at least 35 km between Court-Saint-Etienne and Branchon (Delcambre & Pingot, 2002; Pingot & Delcambre, 2006). However, the Orne segment probably extends farther northwards then westwards (running through Ottignies), while the Noirmont-Baudecet segment probably continues farther eastwards. The Orne fault segment curves strongly in the southern part where the general trend becomes E-W. The Orne and

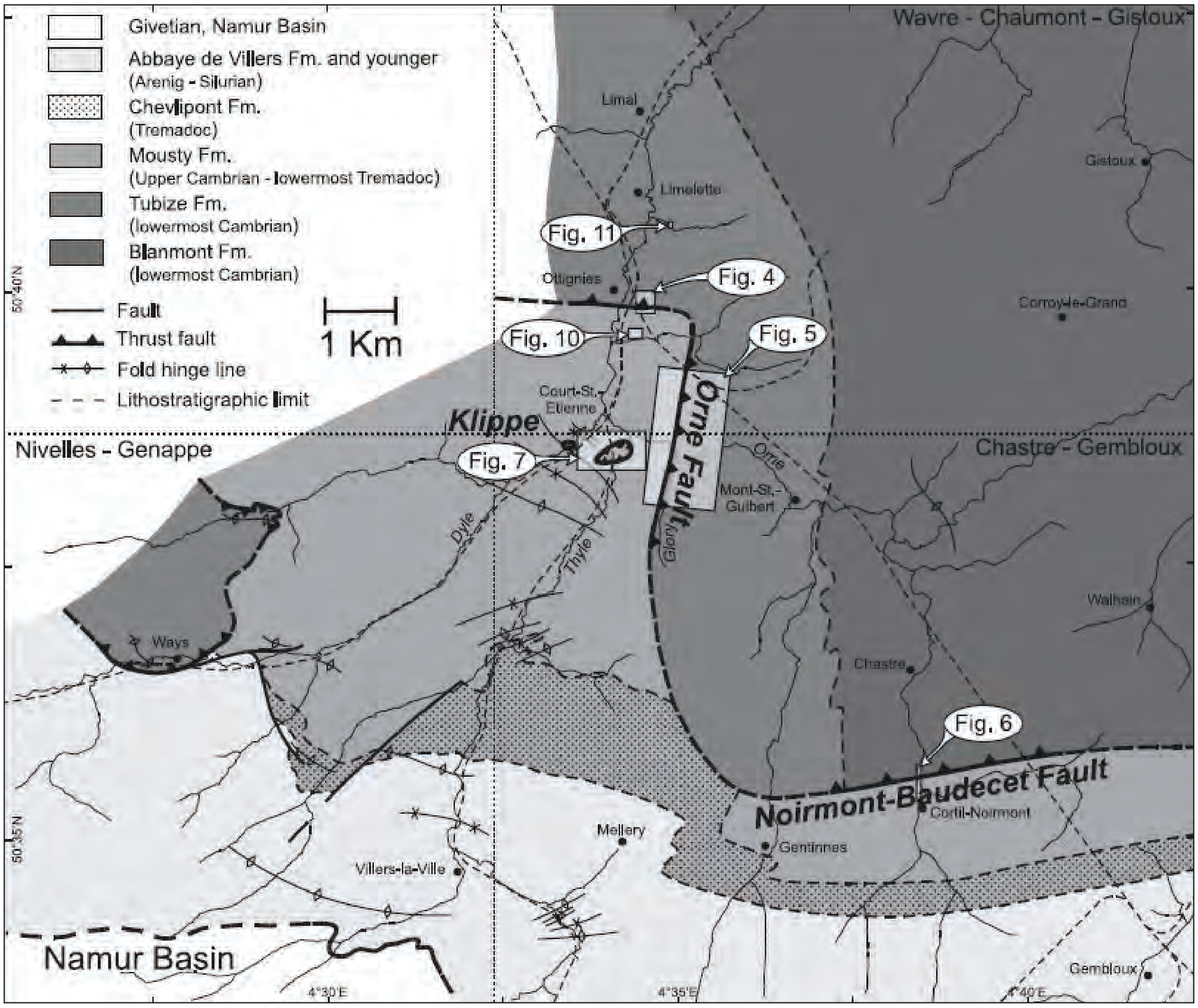

Fig. 61. Simplified geological map of the Lower Palaeozoic of the Dyle-Thyle area (from Herbosch & Lemonne (2000), Herbosch *et al.* (2000, 2001, 2002a) and Delcambre & Pingot (2002), modified (Debacker *et al.*, 2004)).

the Noirmont-Baudecet fault segments dip gently to the northeast or the east and to the north respectively. The north-eastern hanging wall block is upthrown and overthrust onto the south-western footwall block (Fig. 62).

On the basis of outcrop, borehole and geophysical data, Debacker *et al.* (2004) believe that the Orne-Noirmont-Baudecet Fault cannot be considered as a gently north-dipping, large displacement thrust. The authors propose a new model that envisages the fault as a “pre-cleavage and pre-folding low-angle extensional detachment”. The irregular fault trace and the presence of the supposed “klippe” of Court-Saint-Etienne, which were considered as evidence for a gentle dip and thrust-type fracture are therefore reinterpreted differently. Debacker *et al.* attribute the irregular character of the subcrop trace to the particular folding of the detachment: the trace is affected by both gently and steeply plunging folds that show transition zone between each other and that have moreover variable orientations. This structural view reinterprets the “klippe” of Court-Saint-Etienne as anticlinal culmination with a periclinal shape.

Interpretations

Allowing to the conception of Delcambre & Pingot (2002), the curved shape and gentle dip of the fault, as well as the presence of a Lower Cambrian klippe (see the Court-St-Etienne Fault for details), suggest a reverse fracture related to the thrusting of the Lower Cambrian core of the southern margin of the Brabant Massif over the Cambrian-Silurian foreland. The displacement, from the northeast to the southwest, is estimated to be several kilometres (Delcambre & Pingot, 2002). The fault is probably related to, or is the continuation of the Genappe Fault. We advise the reader to refer to the data sheet of the Genappe Fault for more details and interpretations.

The low-angle and reverse Orne-Noirmont-Baudecet Fault is a contractional fault formed during the Brabantian event of the Caledonian Orogeny. The fault is therefore Lower Devonian in age. No reactivations after the Caledonian shortening are suspected.

Following the conception of Debacker *et al.* (2004), the anomalous contact between Cambrian formations observed in the Dyle-Thyle area cannot be assimilated to a major thrust. The Lower Cambrian core of the Brabant Massif would be outlined by a system of pre-cleavage and pre-folding, low-angle extensional detachments (of which the Orne-Noirmont-Baudecet Fault belongs) probably formed between the Caradoc and the cleavage development.

References

Anthoine & Anthoine, 1943.
de Magnée & Raynaud, 1944.
Debacker *et al.*, 2004.
Delcambre & Pingot, 2002.
Pingot & Delcambre, 2006.

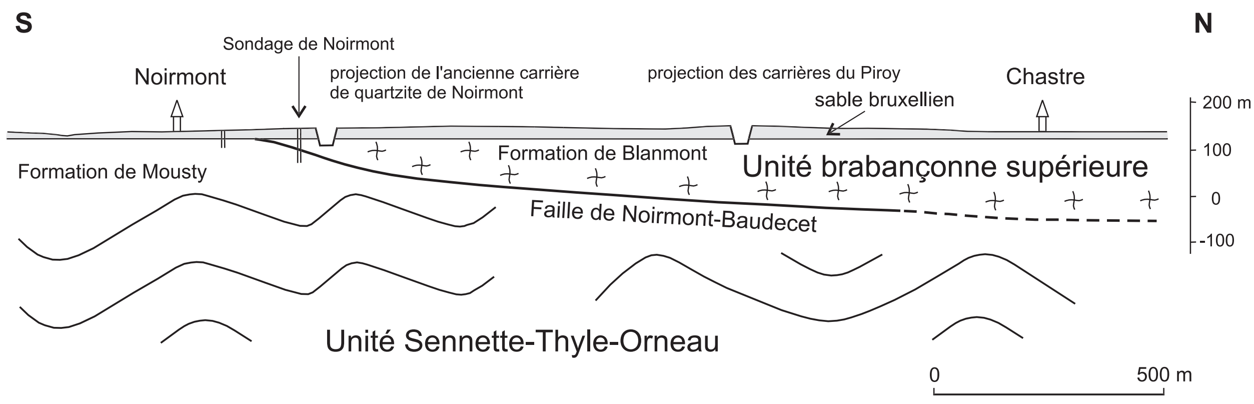

Fig. 62. North-south geological cross-section located between Chastre and Cortil-Wodon (Delcambre & Pingot, 2002).

6.23. Ostende Fault

Location

The Ostende Fault, identified in 1832 by Dumont, runs over a distance of 7.5 km from about 2 km to the east of Charneux to 750 m to the east of Dison. The fault crosscuts many major longitudinal thrusts, such as the Walhorn and the Soiron faults, and also cuts the Tunnel Fault that is considered to be the connection between the Midi and the Aachen faults (Hance *et al.*, 1999). The northern part of the Ostende Fault cuts across the Herve Unit (i.e. the eastward continuation of the "Namur Synclinorium"), while the southern part is located within the Vesdre Nappe (i.e. the front of the Ardenne Allochthon). The Ostende Fault (and the Mouhy faults, see section 6.21) bounds the eastern flank of the Minerie graben (Fig. 63).

Lithology and stratigraphy of the country rocks (Barchy & Marion, 2000)

The Mouhy Fault displaces the Houiller Group, dated to the Namurian-Westphalian. The flat-lying Cretaceous formations that overlie the folded Palaeozoic rocks are also affected by the fault. We refer the reader to the Monty Fault for the lithological description.

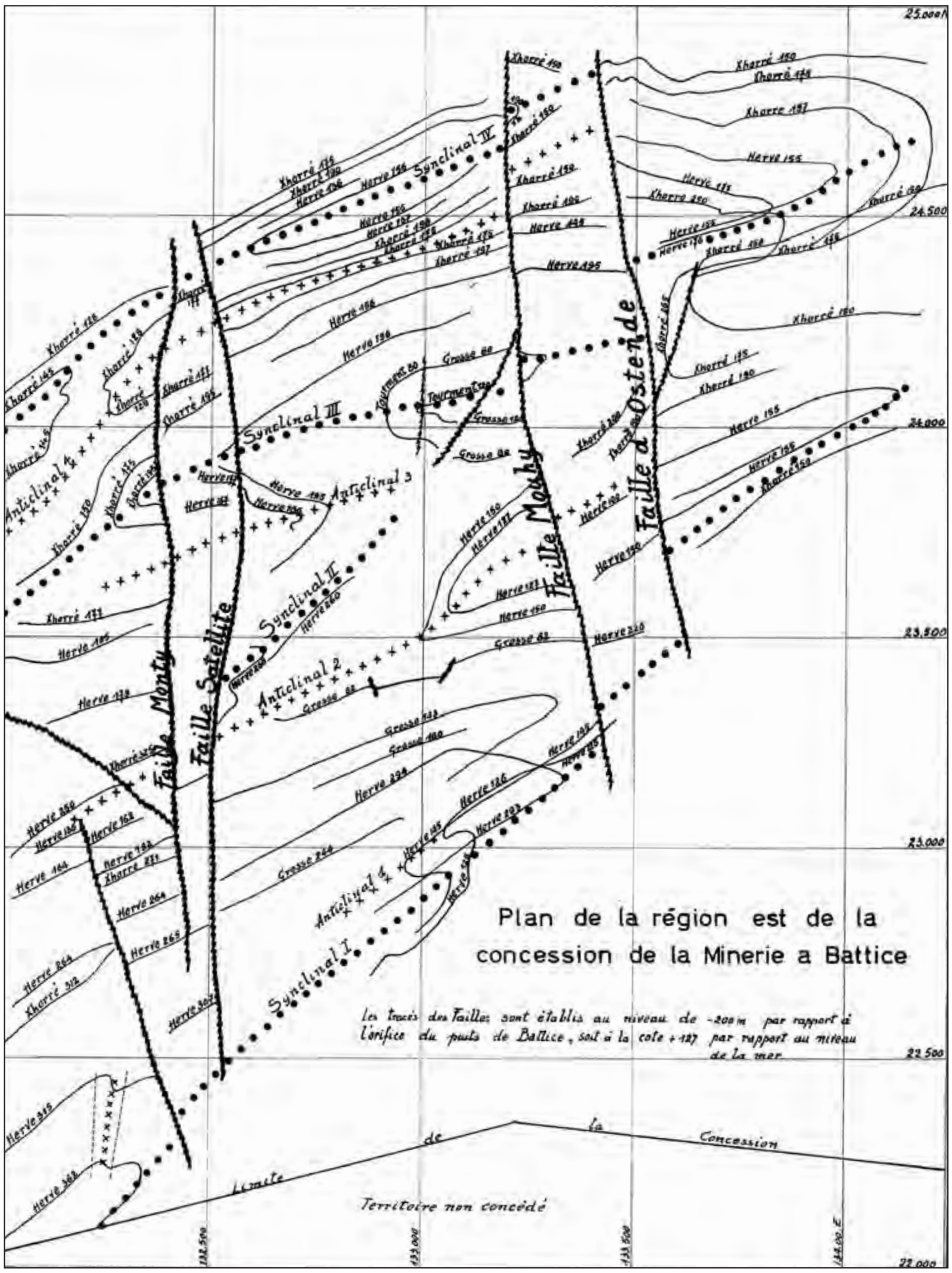

Fig. 63. Structural map of the Minerie Graben (from Ancion & Evrard, 1957). The Monty and "Satellite" faults bounds the western flank of the graben, while the Mouhy and Ostende faults bounds the eastern flank.

Geometry

Forir (1906) indicates a disruption of the Cretaceous rocks. Later, Ancion & Evrard (1957) draw the Ostende Fault as a small, 2 km long, SSE-striking fracture. The dip is to the west and is similar to that of the Mouhy Fault (i.e. about 60 to 70°). The eastern fault block has moved upward and northward relative to the western block. The sinistral strike-slip is as much as 300 m and the normal offset is about 50 m.

Map revisions (Laloux *et al.*, 1996; Barchy & Marion, 2000) show that the fault is 7.5 km long. These authors agree with the geometrical ideas of Ancion & Evrard. The southern part of the fault is connected with another mainly SSE- to SE-striking fracture. The latter seems to constitute the continuation of the Ostende Fault, running for an additional 8 km through Stembert as far as a point 2.5 km to the east of Jalhay.

Interpretations

Ancion & Evrard (1957) assume that the normal faulting in the Minerie Graben is compatible with a contractional stage directed from south to north (a more coherent extensional framework will be proposed later, see below). They also observe a less significant normal offset in the Cretaceous formations than in the folded Carboniferous substrata. Briefly, the Ostende Fault was initiated during a late-Variscan compressive setting. A Cretaceous reactivation is also then assumed.

According to Barchy & Marion, Palaeozoic structural units (the Herve Unit and the Vesdre Nappe) are disrupted by the Ostende Fault. This strike-slip fracture therefore post-dates the Variscan formation of the E-W folded and faulted structures. Moreover, a post-Variscan extensional setting is assumed to explain the disruption of the Cretaceous rocks.

The same authors indicate that the Minerie Graben forms part of a Permian collapse system, called the Rhine-Roermond Graben that was probably reactivated during the Mesozoic-Cenozoic. Present seismic activity in eastern Belgium might suggest tectonic movements along faults subjected to E-W extensional stresses and related to the Rhine-Roermond Graben opening (Camelbeek, 1990). Consequently, the Ostende Fault may be active.

References

Ancion & Evrard, 1957.

Barchy & Marion, 2000.

Camelbeek, 1990.

Dumont, 1832.

Forir, 1906.

Hance *et al.*, 1999.

Laloux *et al.*, 1996.

6.24. Oster Fault

Location

In 1926, Anten detects a fracture in the vicinity of Malempré that is introduced later (1939) in the literature by de Dycker under the name of the Oster Fault. The fault is located between points 2.5 km to the south of Amonines and about 2.6 km to the south of Bra. It crosscuts the Ordovician rocks of the SW border of the Stavelot-Venn Massif and dies out progressively westwards within the Lower Devonian of the Ardenne Anticlinorium that constitutes the peripheral cover of the inlier (Dejonghe & Hance, 2008; Geukens, 2008a).

Stratigraphy and lithology of the country rocks

Mapping of the northeastern termination of the fault was recently carried out by Geukens (1999, 2008a). The geological map of 1999 shows the Jalhay Formation (Early Ordovician) in the northern block and the Ottré Formation (Late Tremadoc to Mid Ordovician) in the southern block (see the Xhoris Fault for a description of the lithologies). The revised map of Bra-Lierneux (55/3-4) (Geukens, 2008a) shows the Jalhay Formation (Solwaster Member of Lower Tremadoc age) to the north of the fault and the Ottré Formation (Meuville Mbr of Arenig age) to the south of the fault. The rocks are mainly slates and silty slates.

The southeastern termination of the Oster Fault is mapped by Dejonghe & Hance in 2008 (Fig. 64). In addition to the Ordovician Ottré and Jalhay formations, here again affected by the fault, the Fépin, Oignies, Saint-Hubert, Mirwart, Villé and La Roche formations are also disrupted. These formations are Lochkovian and Pragian in age and generally comprise shales, siltstones and slates.

Geometry

Anten (1926) shows that “Salmian” rocks (i.e. Ordovician) are disrupted in the vicinity of Malempré and within the southern part of the Cambrian Stavelot Inlier by a major tectonic discontinuity that is attributed to a Variscan thrust.

The geological map released by de Dycker in 1939 presents the Oster Fault as a longitudinal ENE-striking fracture of at least 2200 m long. Neither western nor eastern continuations of this small segment are traceable because of the Lochkovian cover that hides the Cambrian of the Stavelot Massif. The Fault puts the base of the “Lower Salmian” (i.e. Tremadoc) in contact with the “assisse I” of the base of the “Upper Salmian” (i.e. Middle Ordovician).

In 1986, Geukens considers the faults of Oster, Vielsalm and Poteau as being the same fracture, 35 km long, that crosscuts the southern part of the Stavelot Inlier (Fig. 65). From west to east, the following localities (and their vicinities) are affected by the fault: Oster, Hoût-si-Ploût, Vielsalm and Petit-Thier.

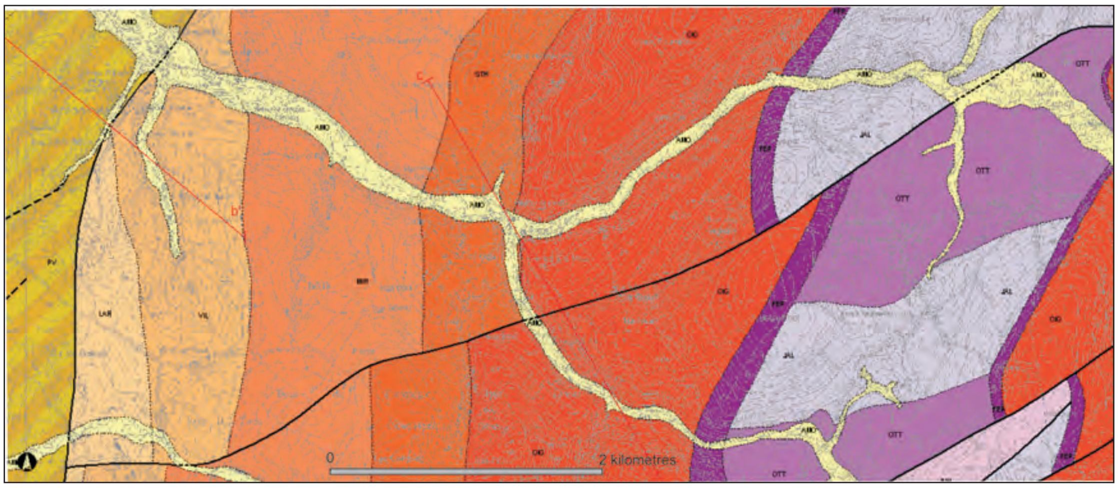

Fig. 64. Extract of the geological map of Hotton-Dochamps (55/5-6) (Dejonghe & Hance, 2008). The Oster Fault affects both the Ordovician of the Stavelot Inlier (in purple) and the Lower Devonian of the Ardenne Anticlinorium (in red).

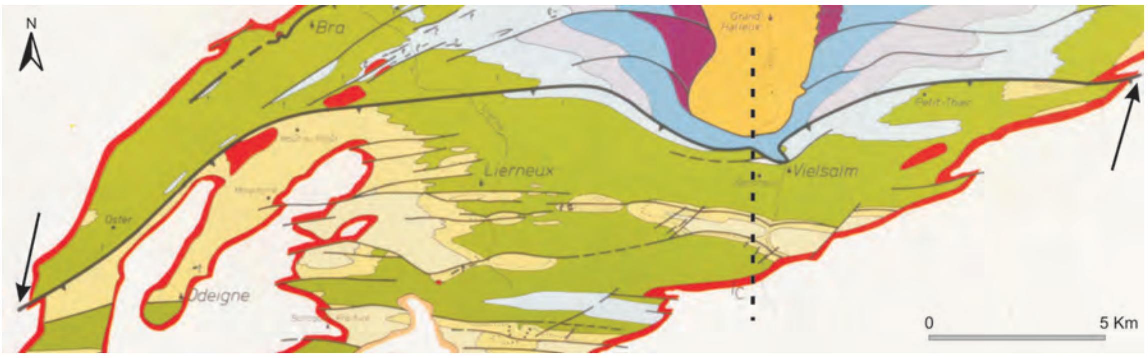

Fig. 65. Extract of the geological map of Geukens (1986) (see the Theux Fault in section 6.27, Fig. 78 for legend). The position of the cross-section (below on Fig. 66) is given (dashed line).

Geukens (1986) subdivides the Stavelot Massif into 4 major Caledonian nappes. According to this author, the thrust would have a southern dip and would demarcate a "Nappe 1" in the south from a "Nappe 2" in the north (Fig. 66), both nappes belonging to the southern part of the inlier.

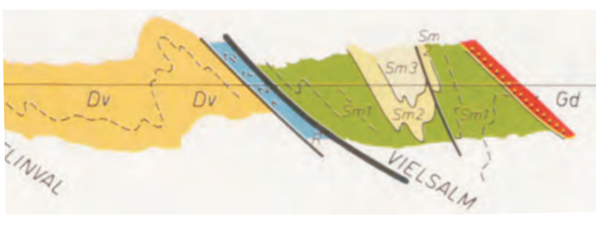

Fig. 66. N-S cross-section through Rencheux in the western vicinity of Vielsalm (see Fig. 65 for its location) (Geukens, 1986). The Oster-Vielsalm-Poteau Fault thrust a "Nappe 1" northwards over a "Nappe 2".

In 1999, Geukens proposes different ideas about the Oster Fault, which henceforth is considered to have a limited extent of 8 km (Fig. 67). The author no longer specifies the thrust character of the fault nor does he give the direction of dip. The map indicates that the southwestern extremity of the fault would be hidden by Lower Devonian cover, while the northeastern extremity would split into different branches, some of which are parallel to the Permian Malmedy Graben.

In 2008, Dejonghe & Hance and Geukens respectively publish the revised geological maps of Hotton-Dochamps (55/5-6) (Fig. 64 above) and Bra-Lierneux (55/3-4) (Fig. 69 below). Both maps illustrate the southwestern extremity of the Stavelot Inlier and its peripheral Devonian cover. The first map shows the southwestern termination of the fault, while the second map displays the northeastern termination of it.

Dejonghe (2008) summarises that the longitudinal south-dipping Oster Fault (Fig. 68) has a general ENE strike and a trace of at least 8.5 km (Fig. 64). The transverse Jupille Fault that belongs to the Ourthe dextral strike-slip fault system bounds the western extremity of the fracture. The latter shows a clear reverse offset within the western Devonian cover of the inlier. However, within the Stavelot Massif, the author specifies that the fault has a complex displacement. Indeed, keeping in mind the distinctly different dips of the rocks on either side of the fault, a normal offset remains possible.

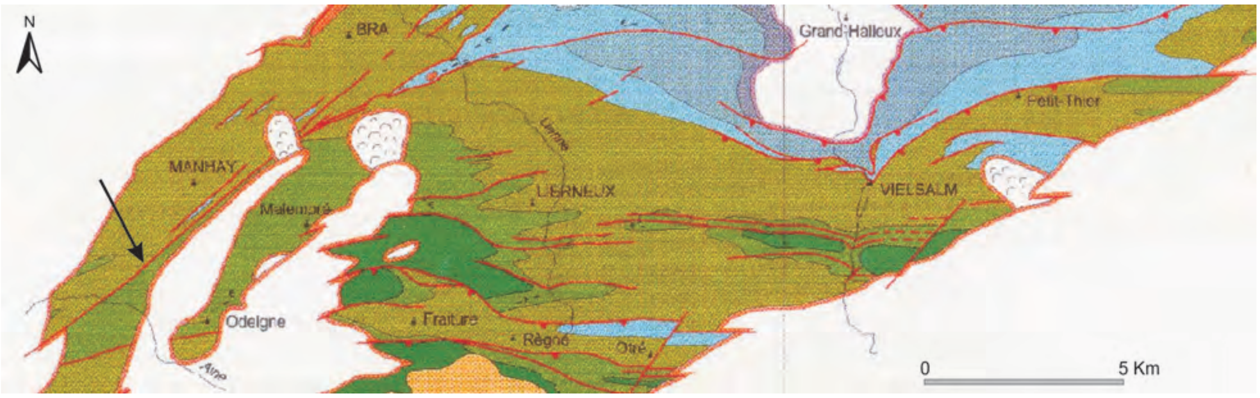

Fig. 67. Extract of the geological map of Geukens (1999) (see the Theux Fault, Fig. 79 for legend).

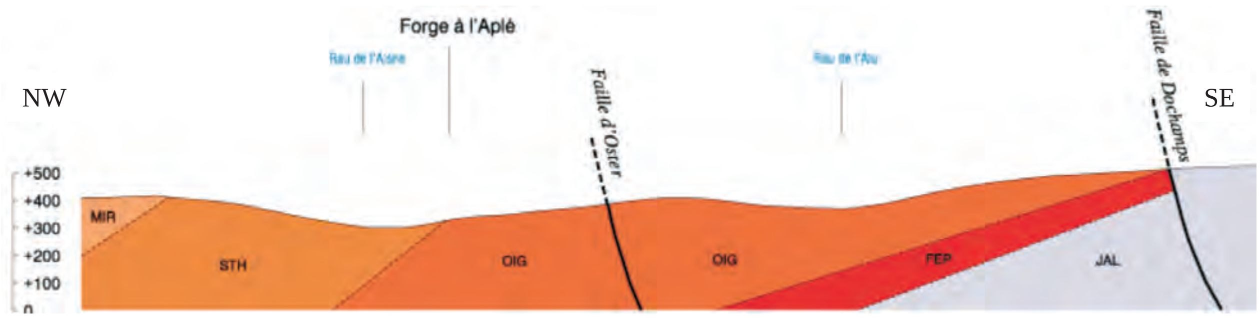

Fig. 68. NW-SE cross-section in the northwestern vicinity of Dochamps (Dejonghe & Hance, 2008).

Geukens (2008a) presents the northeastern termination of the Oster Fault (Fig. 69). However, no name appears on either the geological map or the accompanying description. Moreover, the author does not indicate the nature of the offset or even the direction of the dip. The fracture strikes northeastward for 5.5 km. Considering the maps of both Dejonghe and Geukens, the current point of view is that the Oster Fault has a strike length of 15 km at most.

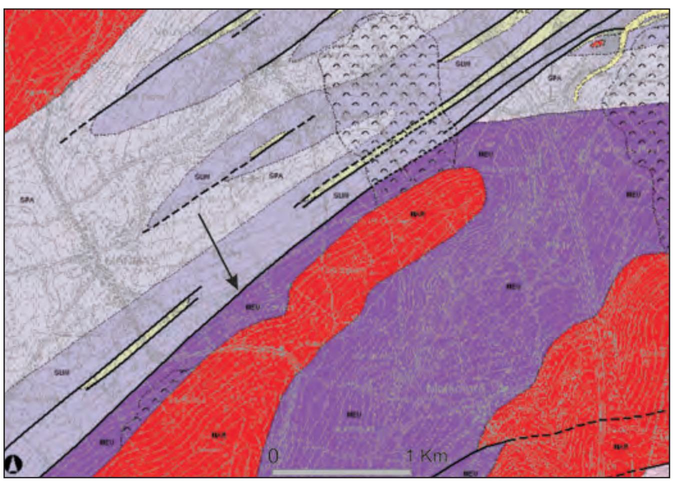

Fig. 69. Extract of the geological map of Bra-Lierneux (55/3-4) of Geukens (2008a). The arrow indicates the Oster Fault.

Interpretations

Geukens (1986) interprets the Oster-Vielsalm-Poteau Fault as a major Caledonian thrust. A Caledonian age is justified by the displacement of Cambrian-Ordovician rocks and by the non-disruption of Lochkovian formations. No assumptions about a Variscan re-activation are proposed. The second edition of Geukens's map of the Stavelot Massif, released in 1999, displays even less information. We suppose that the author still believes in a Caledonian origin.

Dejonghe (2008) considers the Oster Fault as a longitudinal thrust fracture. The fault would be coeval with the main stage of the Variscan shortening. The author summarises that during the Variscan shortening, the stop-pin behaviour of the Stavelot Inlier would hinder the northward displacement of the Ardenne Allochthon. This could probably justify the appearance of the Oster Fault.

References

Anten, 1926.
De Dycker, 1939.
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Dejonghe & Hance, 2008.
Geukens, 1986.
Geukens, 1999.
Geukens, 2008a.

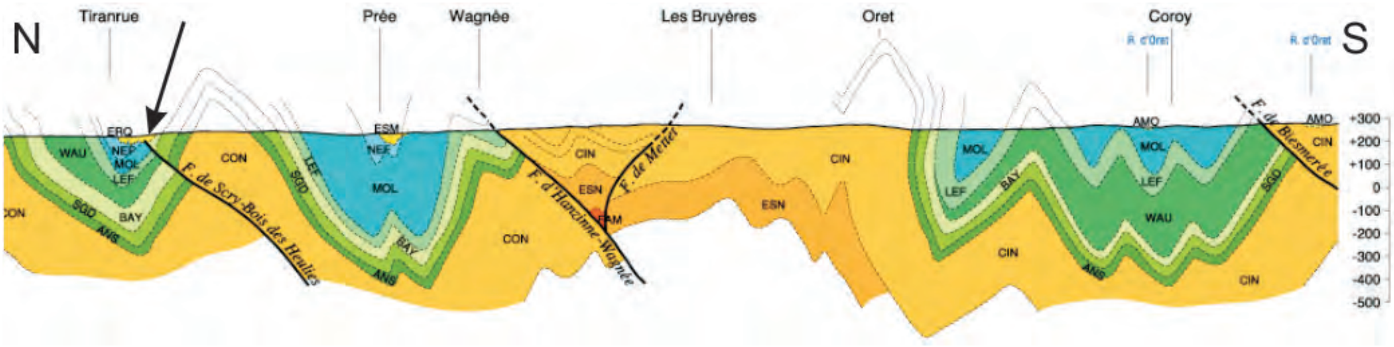

Fig. 70. N-S geological cross-section through Biesme (Delcambre & Pingot, 2004).

6.25. Scry-Bois de Neffe Fault

Location

The Scry-Bois de Neffe Fault, identified by Delcambre & Pingot (2004), is located about 1 km north of Mettet. From west to east, the fault trace runs from Fromiée to about 1500 m SE of Saint-Gérard, i.e. over a distance of 13 km. The central part of the fault is sub-parallel to a syncline structure while the western and eastern extremities are segments that cut more or less transversally across the fold axes of the Gerpinnes Anticline and the Bois de Scu Syncline in the west and the Bois de Heulies Anticline followed by the Bois de Neffe Syncline in the east.

Lithology and stratigraphy of the country rocks

In its western part, the Scry-Bois de Neffe Fault affects the northern limb of the ESE-trending Gerpinnes Anticline where it thrusts Famennian formations over Tournaisian and Visean formations. In its eastern part, the fault disrupts the southern limb of the ENE-trending Bois de Heulies Anticline, thrusting Visean rocks over Famennian formations. The thrust terrains include the Ciney Formation to the Lives Formation. See the Hanzinne-Wagnée Fault for their description.

Geometry

The length of the fault trace extends for 13 km but is probably longer as it continues further eastwards in a region where geological re-mapping is on going. The lineament has an E-W strike and a southern dip of about 45° over which the hanging wall block has moved upward (Fig. 70). The reverse displacement measured on the cross-section indicates an uplift of least 50 m.

Interpretations

The fracture belongs to a major fault family in Belgium that disrupts longitudinally the Dinant fold-and-thrust belt. Each of the thrust faults contributes to the shortening of the Devonian-Carboniferous Dinant basin by the superposition of numerous tectonic stacks. The contractional Asturian stage of the Variscan Orogeny of Westphalian age is related to this major regional faulting.

References

Delcambre & Pingot, 2004.

Meilliez & Mansy, 1990.

6.26. Soiron Fault

Location

Forir introduces the "Dison Fault" on the geological map of 1898. The fracture is later renamed the Soiron Fault by Fourmarier in 1904. The "sensu stricto Soiron Fault" (as it appears on the current geological map of Laloux *et al.* (1996b), see below) is recognized over a distance of 14 km running from west to east through or near the localities of Soiron, Dison and Welkenraedt.

According to some authors (see "Geometry" below), the fault can be extended both westwards and eastwards. The Soiron Fault is probably intimately related to the Magnée, Soumagne and Corbeau faults in the west, and to the Lontzen, Fossey and Eilendorf faults in the east. Addition of the lengths of the different segments, from Magnée in the west to a point north of Eynatten and farther eastward in Germany, gives a trace of approximately 55 km. The Soiron Fault delimits the Forêt-Andrimont Unit (Laloux *et al.*, 1996b) (see Fig. 109, Walhorn Fault) that belongs to the Vesdre Nappe (the former Vesdre Massif).

Lithology and stratigraphy of the country rocks (Laloux *et al.*, 1996b)

The block located south of the sensu stricto Soiron Fault is composed of Upper Famennian rocks (the Montfort and d'Evieux formations, mainly comprising micaceous sandstones, shales, siltstones, etc.). The northern domain is composed in the western segment, of Upper Visean rocks (Juslenville Group, various limestones) and in the eastern segment, of Namurian shales and siltstones (Houiller Group).

Geometry

Forir (1898) draws the NE- to ENE-striking « Dison Fault » with a length of 10 km. In 1904, Fourmarier renames the western segment of the Dison lineament as the "Soiron Fault". This segment bounds the Soiron window in the north and displays a probable gentle southern dip of about 35-40°. He also makes a connection between the Soiron, Henrister and Olne faults. In 1905, the same author assumes an eastward continuation beyond Aachen and a westward continuation, crossing the N-S-striking Nessonvaux Fault.

Due to the low-angle and undulating plane of the Soiron Fault, Fourmarier (1928a) infers the Soiron Nappe and the Soiron and Olne windows (Fig. 71), reinforcing the idea of continuity between the Soiron, Henrister and Olne faults. He also proposes a connection between the Soiron Fault and the Magnée Fault to the north.

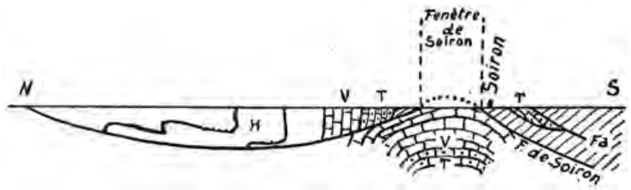

Fig. 71. Schematic cross-section at the longitude of Soiron (Fourmarier, 1928a).

Graulich (1969, 1975) suggests the discontinuity of the trace is due to several transverse fractures (some related to the Dison Fault) that crosscut the Soiron Thrust. According to Graulich, the fault would have a S to SW dip of about 25 to 45°. In 1976, the same author suggests that the Soiron, Magnée and Soumagne fault segments are all part of the same fracture. Michot (1988) does not agree with this.

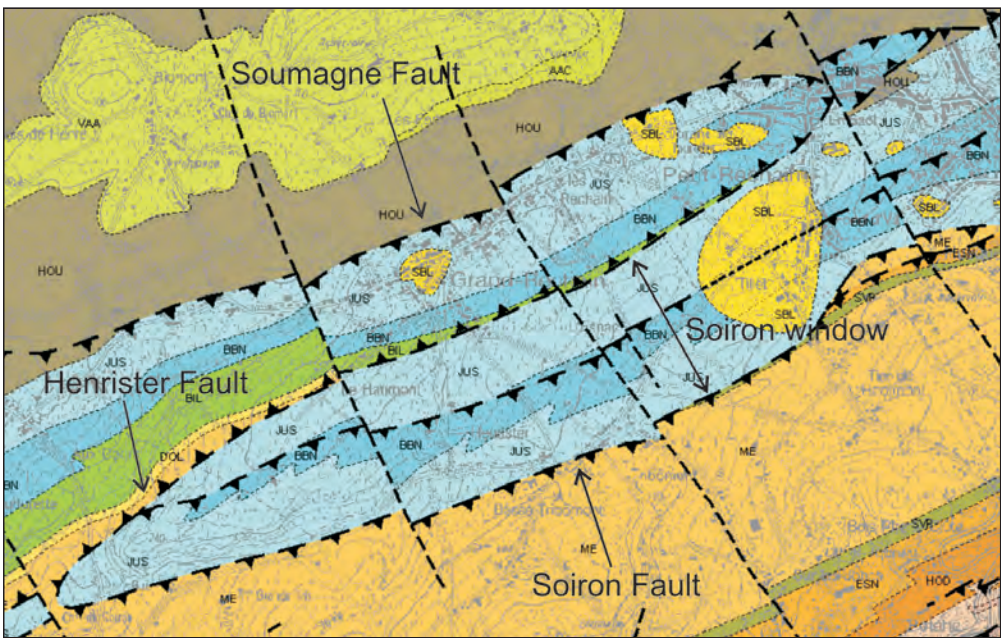

Fig. 72. Geological map of the Soiron window (Laloux *et al.*, 1996b).

The recent (1996b) geological map of Laloux *et al.* defines the sensu stricto Soiron Fault over a length of 14 km. The western segment constitutes the southern limit of the Visean Soiron window and is connected to the Henrister Fault (Fig. 72). The transverse SSE-striking Welkenraedt Fault limits the eastern segment. The northward reverse offset of the Soiron Thrust extends 800 to 1200 metres.

Interpretation

While geometrical considerations (length, connections, etc.) remain a controversial topic, tectonic interpretations have converged. Most geologists agree with the thrust character of the Soiron Fault.

In 1905, Fourmarier proposes a connection between the N-S-striking Nessonvaux Fault and the ENE-striking Soiron Fault. Fourmarier attributes the various orientation of the Soiron Fault to its thrust character directed in a westerly direction.

The revision of the geological map by Laloux *et al.* (1996b) represents the sensu stricto Soiron Fault as the boundary of the Soiron subunit. The latter, also called the Soiron "Nappe" (already introduced by Fourmarier in 1928) (Fig. 73) is an allochthonous unit that overlies the autochthonous Forêt subunit, also called the Forêt "Nappe" (also originally introduced by Fourmarier in 1904). The Soiron and the Olne windows belong therefore to the Forêt subunit.

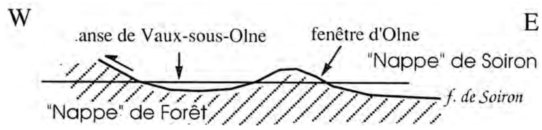

Fig. 73. Schematic W-E cross-section of the Olne Window (Laloux *et al.*, 1996b).

Laloux *et al.* (1996b) state that the sensu stricto Soiron Fault is mixed up with, or is even crosscut by, a more significant fracture that is named differently in the different segments: Magnée-Soumagne-Corbeau-Soiron. These authors also propose that the Magnée-Soumagne-Corbeau-Soiron Fault constitutes the boundary between the Herve Massif and the Vesdre Nappe. This limit is, however, currently attributed to the Tunnel Fault (see section 6.30).

References

Forir, 1898.
Fourmarier, 1904.
Fourmarier, 1905.
Fourmarier, 1928a.
Graulich, 1969.
Graulich, 1975.
Graulich, 1976.
Laloux *et al.*, 1996b.
Michot, 1988.

6.27. Theux Fault

Location

Introduced in the literature as the "grande faille courbe de Theux" in 1901 by Fourmarier, the Theux Fault had already been recognized in 1888 because Gosselet had traced it on his Palaeozoic Ardennian geological map. The fault is located in the region of Spa, Theux, La Reid and Sart.

According to current authors (Laloux *et al.*, 1997; Hance *et al.*, 1999), the Theux Fault bounds the west, north and east sides of the Theux Window in the Ardenne Anticlinorium. The Devonian-Carboniferous Theux tectonic window is surrounded by the Cambrian of the Stavelot Inlier and by the Lower Devonian of the southern limb of the Vesdre Nappe and of the eastern border of the Dinant Synclinorium (Fig. 74).

Hollmann & Walter (1995) point out the importance of the Theux Window, which is currently the only known tectonic window structure in the Ardenne Allochthon and in all of the Rhenish Massif. Indeed, the recognition of the Theux Window (and thrust) enabled the first ideas regarding nappe transport and thin-skinned tectonics in the Variscan front (de Dorlodot, 1901; Fourmarier, 1905).

Lithology and stratigraphy of the country rocks

The Theux Fault marks the boundary between the autochthonous area of the Theux Window and the surrounding allochthonous thrust nappe.

The northern part of the Theux Window is composed of Lower to Upper Devonian and Carboniferous rocks. The revision of the geological map of the northwestern part of the Theux Window (Laloux *et al.*, 1996b) shows that the rocks constitute the Bilstain, Bay-Bonnet, Juslenville and Houiller groups. The first three groups belong to the Visean and are generally made up of various limestones. The Houiller Group is here dated to the Namurian and is composed of shales and siltstones. The revised map of Laloux *et al.* (1996a) of the northeastern part of the Theux Window shows that it comprises many formations, namely the Vicht, Pépinster, Névremont, Roux, Lustin, Aisemont, Lambermont, Hodimont and Esneux formations of Eifelian to Famennian age that are made up of many different lithologies of carbonate and siliclastic facies.

The geological map of Geukens (1999) displays the southern part of the Theux Window that comprises a NE-trending Cambrian-Ordovician anticline. Two formations are distinguished:

- the La Gleize Formation (of Late Cambrian age, "Rv5"), made up of black slates and silty slates;
- the Jalhay Formation (of Tremadoc age, "Sm1"), made up of slates, sandstones and silty slates.

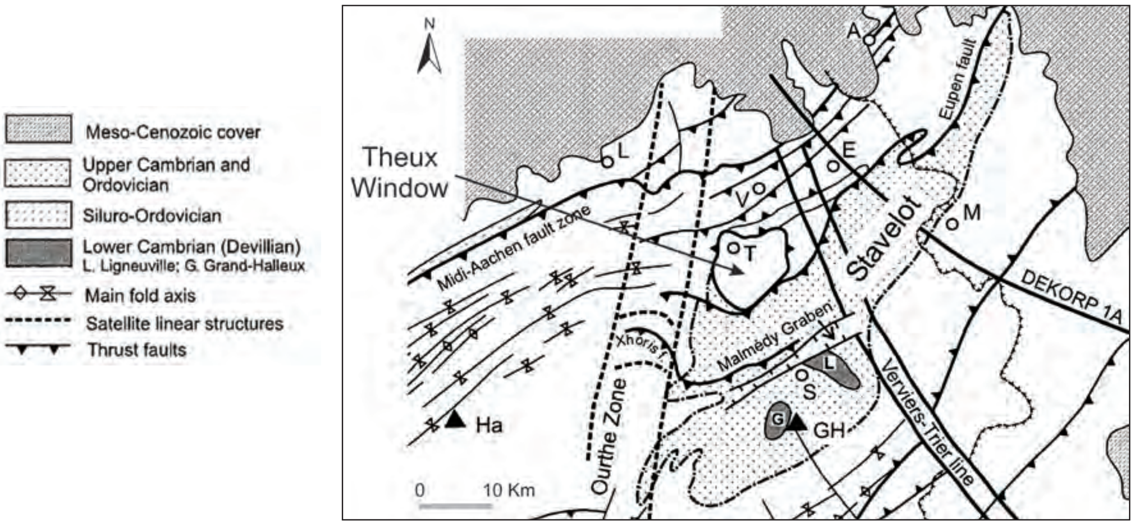

Fig. 74. Structural framework of the Theux Window (Hance *et al.*, 1999). A = Aachen, E = Eupen, GH = Grand-Halleux deep borehole, Ha = Havelange deep borehole, L = Liège, M = Monschau, S = Stavelot, T = Theux, V = Verviers.

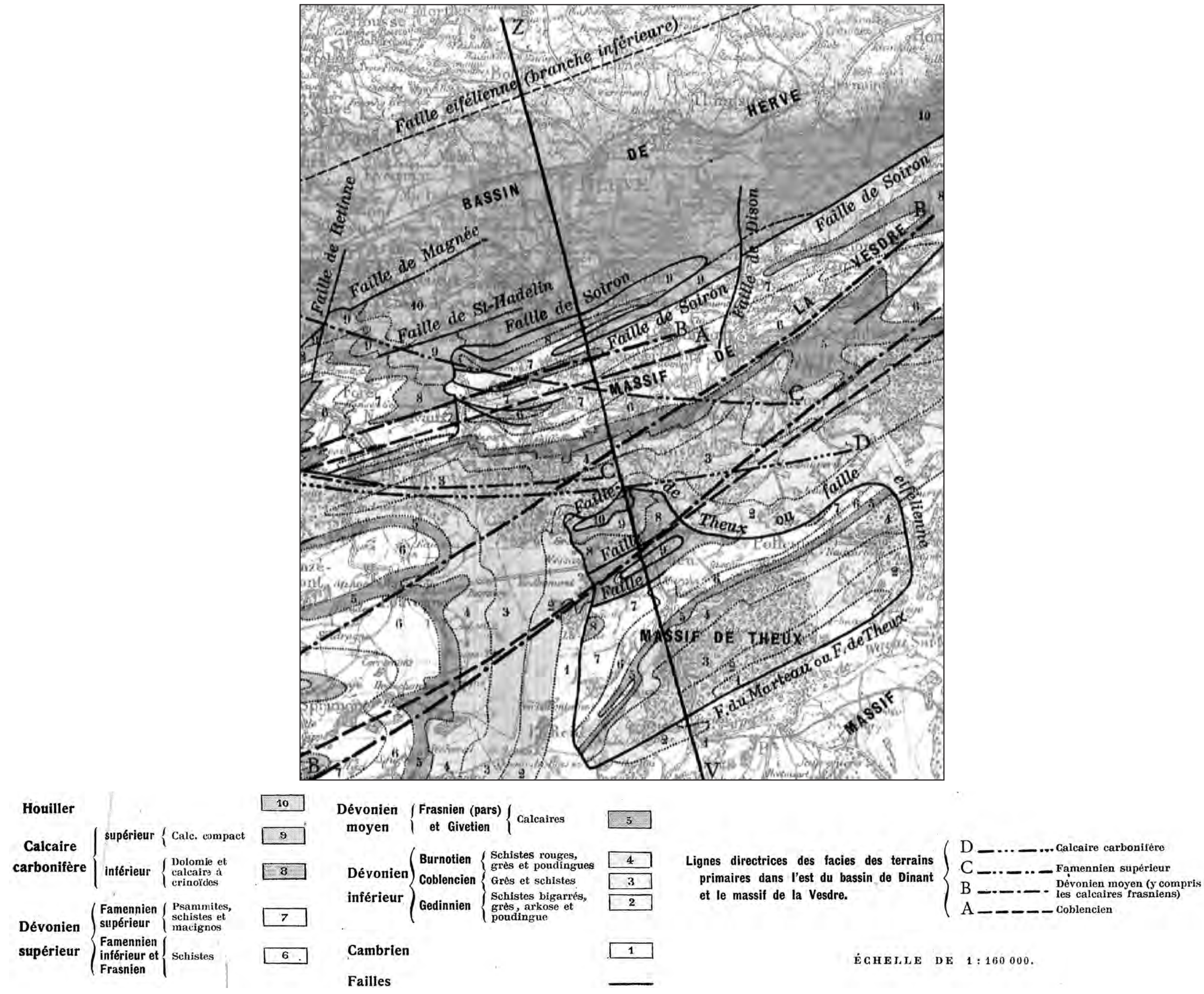

Fig. 75. Extract of the geological map of the Theux and Vesdre "massifs" and the eastern extremity of the Dinant basin (Fourmarier, 1906). The Z-V cross-section is shown below.

The same map of Geukens (1999) shows that the Stavelot Inlier, which limits the window in the south, is mainly represented by the La Venne Formation (of Mid to Late Cambrian age, "Rv3-4") that is made up of black slates and dark quartzites.

The map of Laloux *et al.* (1996b) shows that the Marteau Formation, dated to the Lower Lochkovian and made up of shales, siltstones and sandstones, constitutes the allochthonous terrain of the Vesdre Nappe just north of the window.

Geometry

Fourmarier (1901) indicates a longitudinal reverse fault bounding the north of the Devonian-Carboniferous "Theux basin". The latter shows NE-striking strata that perpendicularly or obliquely butt against Lower Devonian or Cambrian rocks surrounding the basin. The dip of the "grande faille courbe de Theux" is not easy to estimate but is probably gentle as the trace of the fault displays noticeable bends.

In 1905, Fourmarier proposes a connection between the north-dipping Theux Fault with the south-dipping Marteau Fault (discovered by Gosselet in 1888) in the southern part of the Theux Unit. From this point of view, the Theux Unit (i.e. the « Massif de Theux » in the old Belgian literature) can be considered as a Devonian-Carboniferous tectonic window surrounded by older (Cambrian and Lochkovian) rocks. In the Forges-Thiry area, the Theux Fault displays a low-angle dip of 10 to 15° to the south.

One year later, in 1906, Fourmarier provides a map and a cross-section showing the relationship between the Eifelian and Theux faults (Fig. 75 and 83). The map shows that the Theux Fault completely encircles the "Theux Massif" and the cross-section shows the contribution of the Theux fracture to the regional thrust of the Condroz Nappe.

In 1923 and 1933, Fourmarier gives an estimate of the offset of major thrusts in Belgium. An initial displacement of 10-12 km along the Theux Fault is proposed based on a comparison of facies between the Theux Window and the associated thrust nappe (i.e. the eastern border of the Dinant Synclinorium). This estimate is peculiar to the Theux Fault and has to be integrated with other branched thrusts in order to quantify the total displacement along the Variscan front thrust. Likewise, Fourmarier (1923, 1933) indicates an offset of at least 30 km along the Midi-Aachen Thrust.

Fourmarier (1928b) and Ancion (1933) envisage a probable relationship between the Theux and the Xhoris faults. As also stated in the descriptive data sheet for the Xhoris Fault (see 6.36), the two authors indicate a northeastward continuation of the south-dipping Xhoris Fault beyond Francorchamps and its connection with the south-dipping Theux Fault. The schematic cross-section of the Theux and Xhoris faults is given in Fig. 76.

From the way it is displayed on his map, Asselberghs (1946; 1954 in Fourmarier, 1954) considers the Theux Fault as a continuous, circle-shaped thrust fracture (Fig. 77). Therefore the fault is though to bound the entire window over a distance of about 35 km.

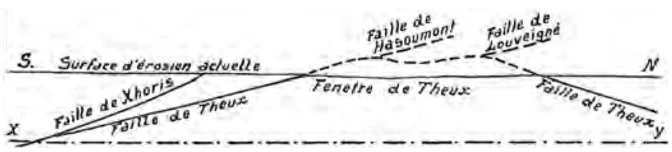

Fig. 76. S-N cross-section sketch showing the relation between the Xhoris and the Theux faults (Fourmarier, 1928b).

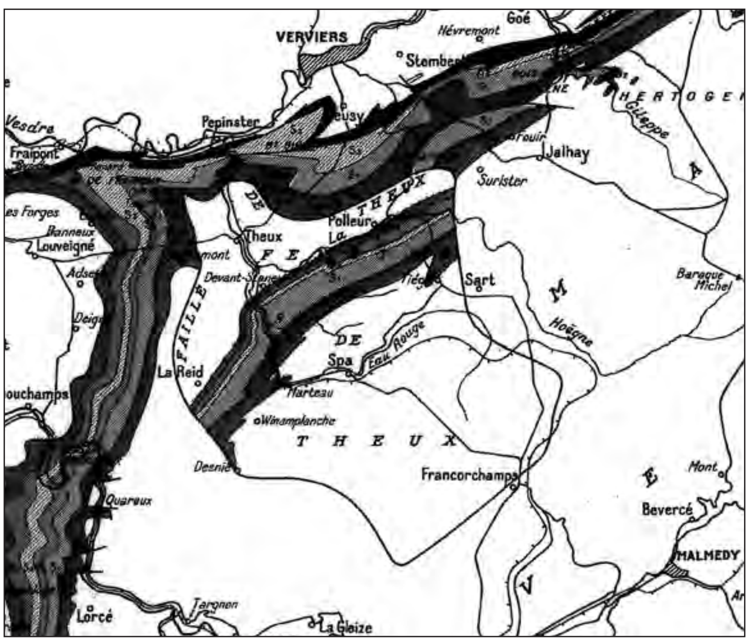

Fig. 77. Extract of the Ardenne geological map of Asselberghs (1946).

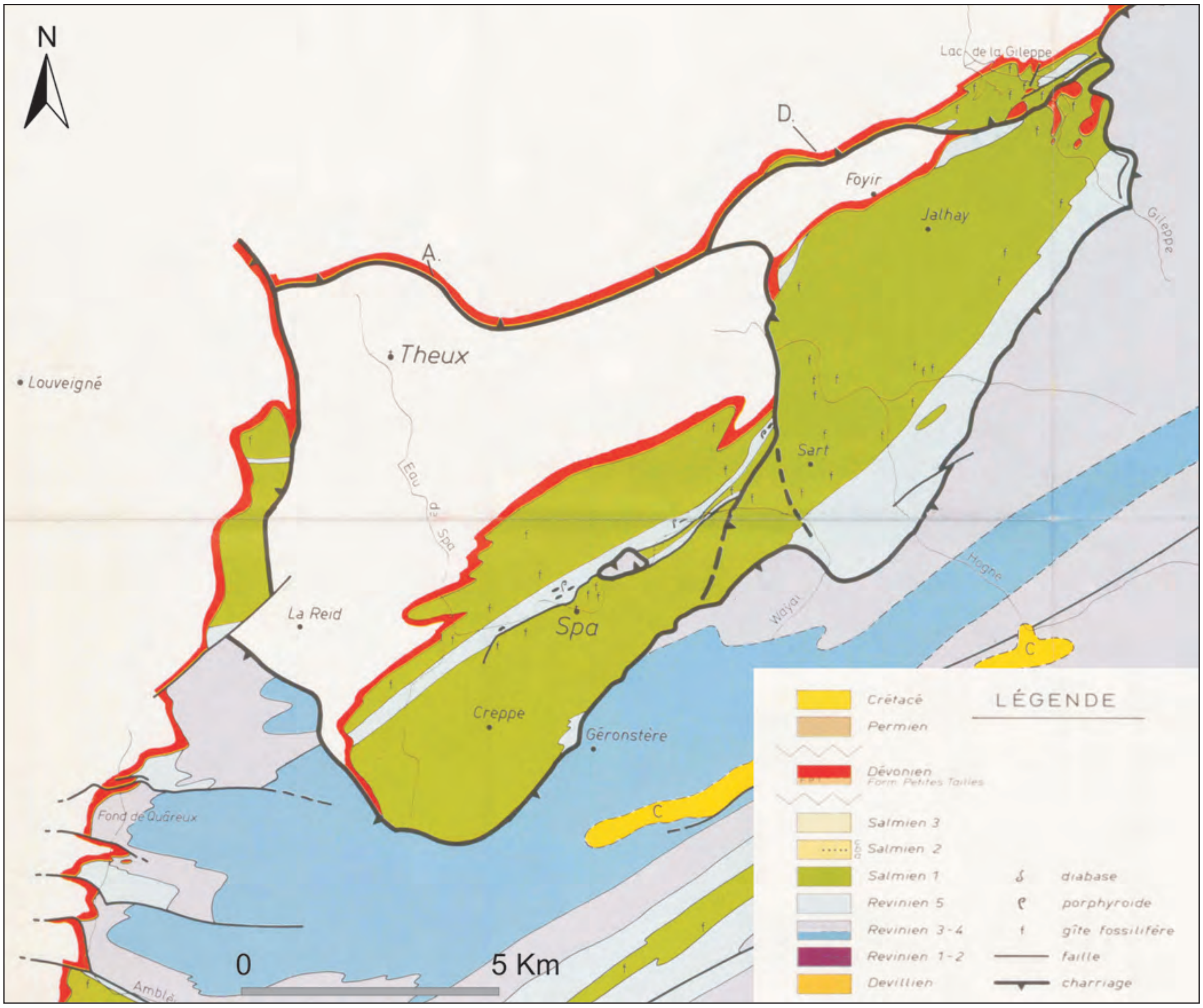

Fig. 78. Geological map of the Theux Window (Geukens, 1986).

Geukens (1959) suggests a very different point of view for the Theux Window. Individualization of the window would result from the combination of two half-circle shaped, transverse faults: the Theux Fault and the Hautes-Fagnes Fault (also know as "Venn-Ueberschiebung"). The first of these would define the northern, eastern and southern limits of the window, while the second would crosscut the Theux Fault to form the western limit of the Theux Window. Geukens points out again in 1986 that the Theux area is not a tectonic window but a "pseudo-window".

Fourmarier (1960) points out the weakness of the arguments developed by Geukens (1959) in order to discredit the validity of the concept of the Theux Window. His disagreement applies, among other things, to observational mistakes and to the significance attributed to the overturned folds of the northern limb of the Stavelot Inlier.

In 1986, Geukens publishes a first edition of the detailed geological map of the Stavelot Inlier (Fig. 78). A second edition (Fig. 79) was available in 1999.

In his work of 1986, Geukens does not talk specifically about the Theux Fault nor does he explain clearly where the fault is located. Geukens reports on a thrust fault that can be followed along the entire northern limit of the Stavelot Massif. As the cross-section attached to the map indicates, Geukens probably considers the Theux Fault as bounding the southern and western part of the Theux Window. Further east, in the vicinity of the Gileppe lakes, the Theux Fault connects with the "Eupener Uberschiebung". Moreover, the fault that bounds the northern and eastern limit of the Theux Window has no name.

Geukens's work of 1999 provides even less information about the Theux Fault. Mapping of the Stavelot Inlier allows him to propose a different structural explanation (Fig. 79). The fault that limits the southern part of the window is interpreted as the Eupen Fault but we do not know where the author places the Theux Fault with respect to the window.

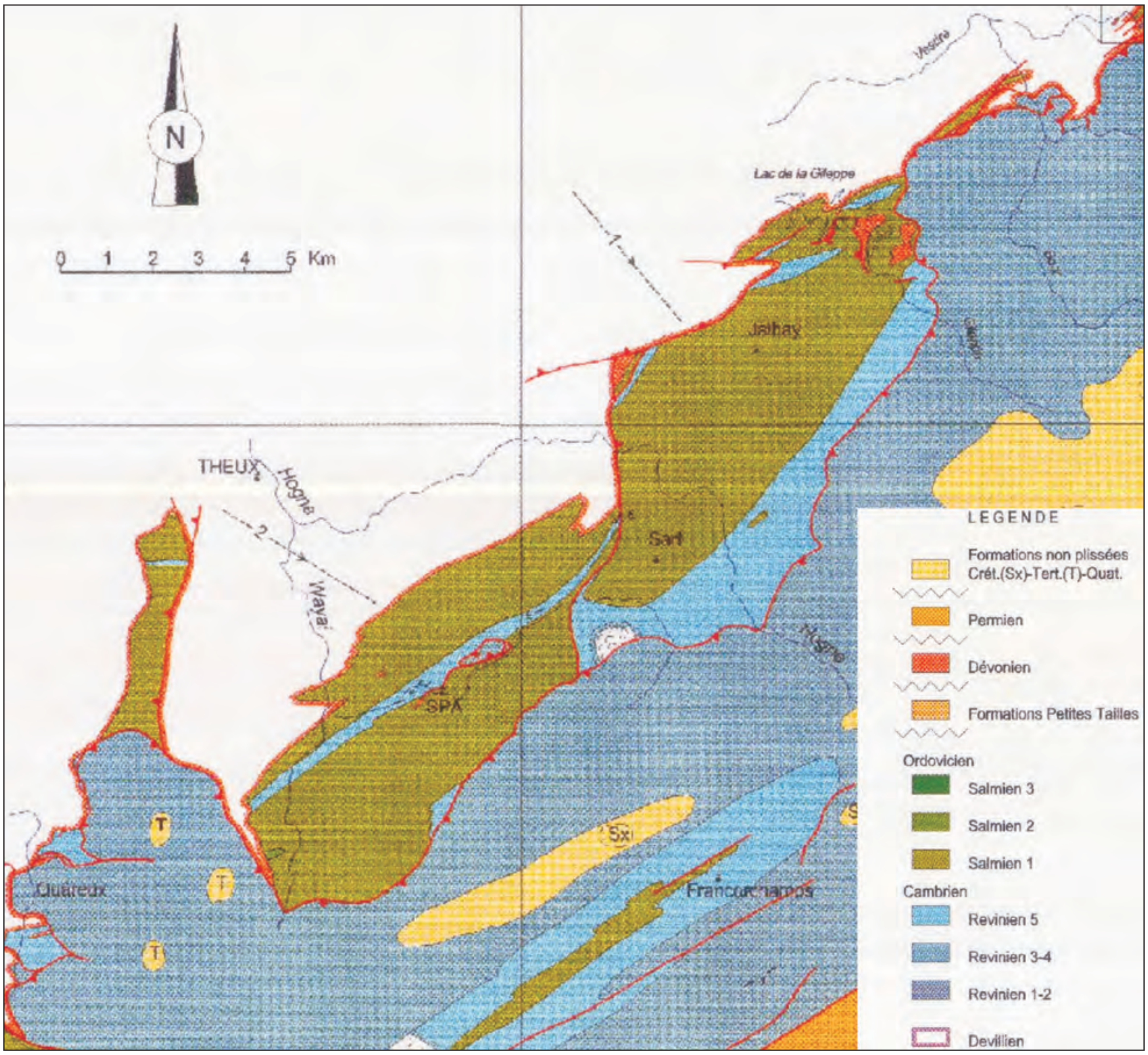

Fig. 79. Geological map of the Theux Window (Geukens, 1999).

In 1988, Michot proposes different ideas. The traces on the cross-section in Fig. 80 show that the Theux Fault would be connected at depth to the Magnée Fault. With this perspective, the Vesdre Nappe would have moved northwards above the Theux Window and along the Theux-Magnée Thrust for approximately 7 km. The Theux-Magnée Fault represents the southward continuation of the Eifelian Thrust and therefore contributes to the major thrusting of the Ardenne Allochthon in eastern Belgium. Note that the Tunnel Fault (see 6.30), which is currently understood to be the correct northward extension of the Theux Fault (instead of the Magnée Fault), is in this case located in the Herve Unit. The Tunnel Fault was interpreted then as a "simple" reverse fracture of "low significance".

Laloux *et al.* in 1997 and later Hance *et al.* in 1999 provide another point of view. The structural map of Hance *et al.* (Fig. 81) considers the Theux Fault as bounding the western, northern and eastern areas of the Theux Window (i.e. a distance of nearly 30 km). The southern part of the window would be bounded by the Eupen Fault.

As developed in the descriptive data for the Tunnel Fault (see section 6.30), Hance *et al.* (1999) indicate a connection between the north-dipping Theux Fault in the north with the south-dipping Tunnel Fault. The Theux-Tunnel Thrust is therefore considered as a junction between the Midi Fault in the west and the Aachen Fault in the east (see Fig. 91). The sections in Fig. 91 illustrate the out-of-sequence character and the eastward plunge of the fault. The authors calculate a dip of 8° to the east and suggest the fault connects to a deep flat-lying reflector that is considered to be the downward continuation of the Midi-Aachen Thrust.

In 2007, Geukens proposes a separation between the traces of the Theux and the Eupen faults in the southern part of the window. This theory considers the Theux

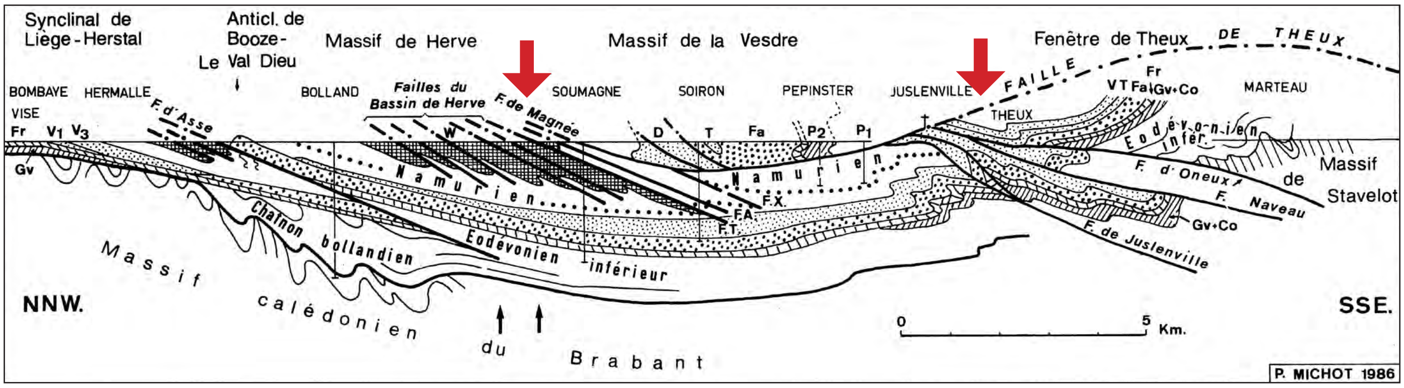

Fig. 80. Cross-section through the Herve, Vesdre and Theux units (Michot, 1988). The author believes in a connection between the Theux and Magnée faults.

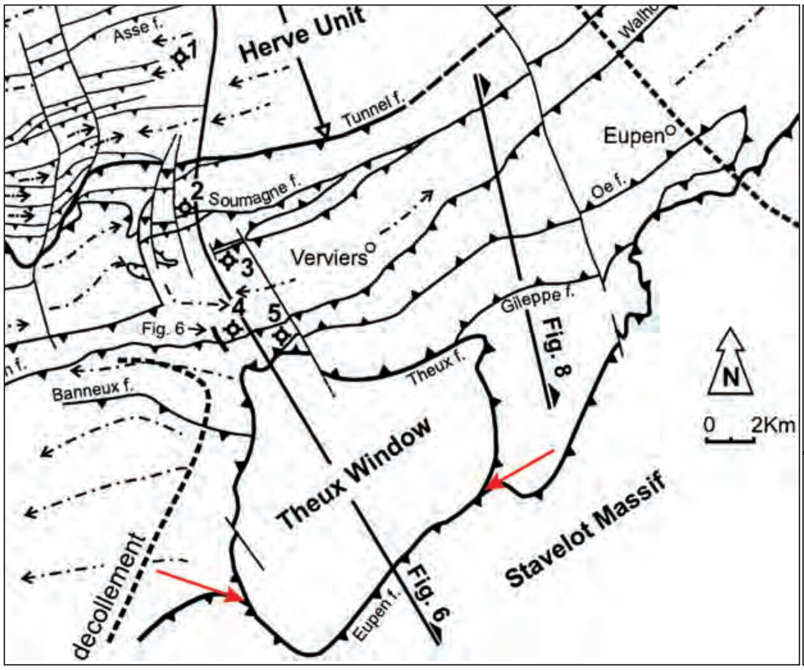

Fig. 81. Schematic structural map of the Theux Window and adjacent areas (Hance *et al.*, 1999). Main fold axis, plunge directions and main deep boreholes are also given. 1-2. Pépinster. 3. Soiron. 4. Soumagne. 5. Bolland. Red arrows show the Theux Fault segment as the authors consider it.

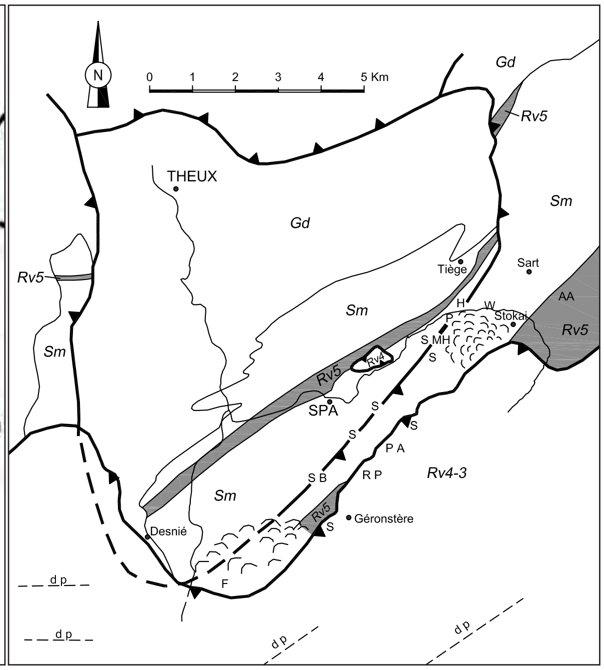

Fig. 82. Schematic structural map of the Theux Window (Geukens, 2007).

Fault as a continuous fracture that isolates the Theux Window almost entirely. The only part of the window that is not bounded by the Theux Fault but by the Eupen Fault instead is a small segment on its southwestern boundary (Fig. 82). This decoupling indicates that the Eupen Thrust postdates the Theux Fault and crosscuts it in the southwest region of the window.

In 2007 and 2008, Geukens gives an estimate of the reverse offset for the western and eastern sides of the window respectively. The western segment of the Theux Fault shows a northward displacement of about 5 km, while the eastern side presents a smaller offset of 2-3 km. The author concludes that there is decreasing thrust from west to east.

Interpretations

H. de Dorlodot already proposes a thrust hypothesis for this structure in 1901. In this case, the "Theux basin" would be a tectonic window within the main northward thrust nappe and the Theux Fault would coincide with the Eifelian Fault. The author does not talk specifically about a tectonic window and it was only in 1905 (Fourmarier) that the term "Theux Window" appears in the literature. In 1906, Fourmarier compares the significance of the Theux and Eifelian faults, dipping to the north and to the south respectively (Fig. 83). The Theux Fault is therefore implicated in the major northward thrust of the Dinant Synclinorium over the Namur basin.

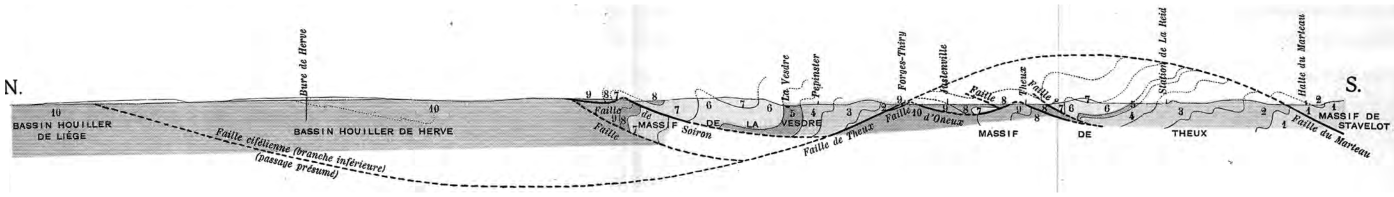

Fig. 83. Z-V cross-section (see Fig. 75 above for its location) displaying the relationship between the Theux and the Eifelian faults (Fourmarier, 1906).

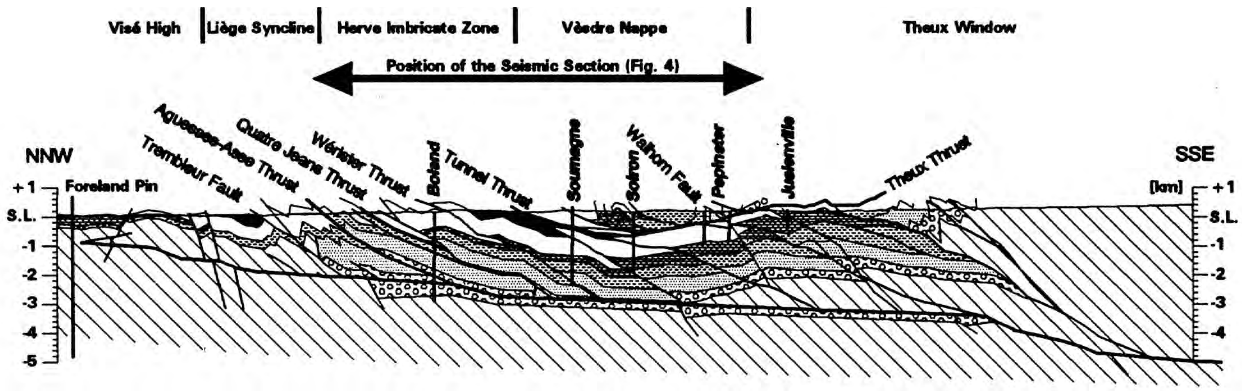

Fig. 84. Cross-section of the Liège-Theux traverse (Hollmann & Walter, 1995).

Considering the Variscan tectogenesis in the Liège region, Fourmarier (1951) proposes the following chronological succession of deformation events:

- first: a ductile deformation stage, or in other words the folding of the Devonian-Carboniferous rocks and formations of the Namur and Dinant synclinoria;
- second: a brittle deformation stage, or in other words the strain and break-up of major anticlinal areas with the formation of the first main thrust, the Rocheux Fault;
- third: a brittle deformation stage with fracturing of the induced thrust nappe, or in other words the development of another major thrust called the Eifelian Fault or Theux Fault;
- fourth: a last ductile deformation stage with folding of the thrust faults. The listric aspect of the Eifelian-Theux Thrust is created at this stage.

The Theux Window appears as a consequence of erosion of a major upward bulge in the Theux Thrust plane.

Hollmann & Walter (1995) consider the Theux-Tunnel Fault as the principal thrust of the Vesdre Nappe (Fig. 84). The offset is estimated to be 10.4 km. Many other inner faults of the Vesdre Nappe are connected to the Theux-Tunnel Thrust. The authors also indicate the broad folding of the fault due to younger deformations in the footwall of the Vesdre Nappe. As Fig. 84 shows, the Theux Window and the Herve Imbricate Zone would be combined in a thrust complex bounded at its base by the Midi-Aachen Thrust and the Aguesse-Asse Thrust respectively.

The structural map in Fig. 81 shows that the Eupen Thrust limits the southern part of the Theux tectonic window. Actually, the Eupen Fault forms the boundary between the Stavelot Massif in the south and the Vesdre Nappe in the north, but at the longitude of the Theux Window, the Eupen Thrust connects and coincides with the Theux Fault (Hance *et al.*, 1999) (see the cross-section in Fig. 85 below). In other words, as Laloux *et al.* (1996a) and Laloux *et al.* (1997) believe, the out-of-sequence Eupen Fault would crosscut, merge with, and postdate the Theux Fault in the southern part of the Theux Window.

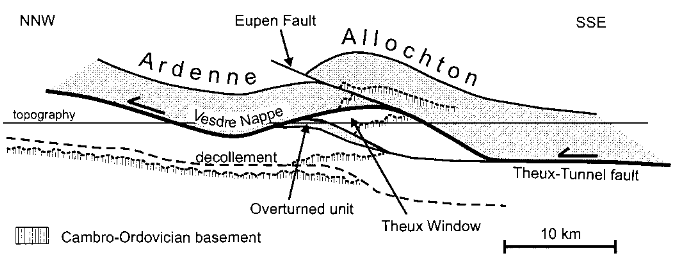

Fig. 85. Schematic cross-section through the Vesdre Nappe and the Theux Window (Hance *et al.*, 1999).

As stated in the description of the Xhoris Thrust (in section 6.36), Sintubin & Matthijs (1998) consider the four major thrusts in the northern part of the Stavelot Inlier as the equivalent of the Variscan front thrust in eastern Belgium. This means that the Theux, Eupen, Xhoris and Venn faults constitute the eastern extension of the Midi-Aachen Thrust. We refer the reader to the notes on the Xhoris Fault and to Fig. 118 for illustration.

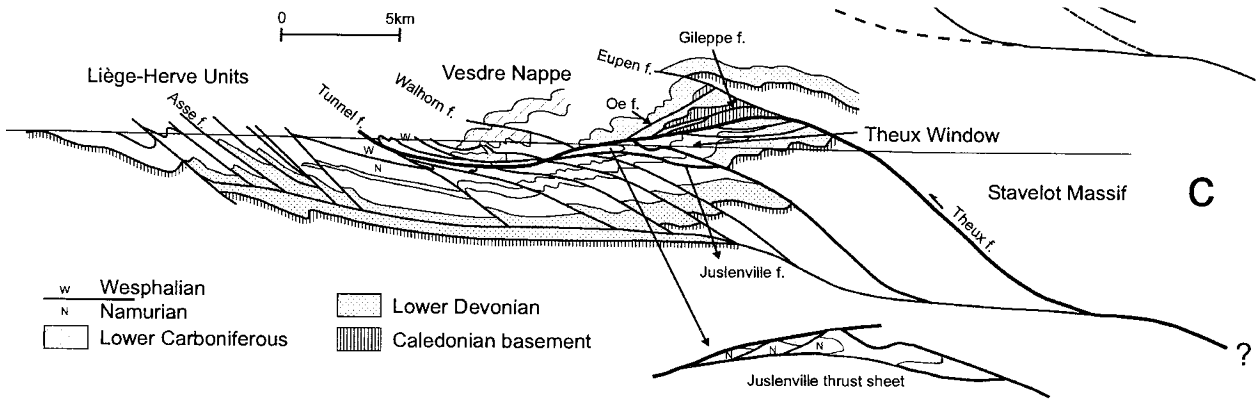

Fig. 86. Cross-section of the Theux Window (Hance *et al.*, 1999). The Variscan deformation has resulted in the out-of-sequence thrust of the Theux-Tunnel Fault and in its folding. The total shortening is about 50%.

Fig. 86 (Hance *et al.*, 1999) shows the result of the final stage of the Variscan diastrophism on a cross-section along the meridian line of the Theux Window. The Variscan deformation includes the out-of-sequence thrusting of the Theux Fault. The later development of a ramp within the footwall of the Theux-Tunnel Thrust would have induced its folding.

Hance *et al.* (1999) also propose two complementary models for the Variscan deformation history in north-eastern Belgium. Their observations highlight the importance of the overturned forelimb of a large anticline that developed at an early stage. Subsequently, this fold would probably have been truncated and transported. The out-of-sequence fault propagation model is preferentially supported than the in-sequence thrusting model.

References

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Fourmarier, 1951.
Fourmarier, 1954.
Fourmarier, 1960.
Geukens, 1959.
Geukens, 1986.
Geukens, 1999.
Geukens, 2007.
Geukens, 2008b.
Gosselet, 1888.
Hance *et al.*, 1999.
Hollmann & Walter, 1995.
Laloux *et al.*, 1996a.
Laloux *et al.*, 1996b.
Laloux *et al.*, 1997.
Michot, 1988.
Sintubin & Matthijs, 1998.

6.28. Thozée-Responette Fault

Location

The Thozée-Responette Fault (Delcambre & Pingot, 2004) is situated approximately 1.5 km north of Mettet and runs for a distance of 10 km from a point 1.2 km east of Biesme to 1.5 km NE of Saint-Gérard. The major and western part of the fault is longitudinal but it becomes more or less transverse in the eastern part where it crosscuts the southern limb of the south-verging Puagne-Saint-Gérard Anticline (Dinant Synclinorium), which is located a few kilometres south of the Midi Fault (i.e. the North Variscan Front).

Lithology and stratigraphy of the country rocks

The major part of the fault occurs along an abnormal lithostratigraphic contact between the Station de Gendron Group in the south and the Condroz Group in the north. The first of these, Lower Tournaisian in age, is made up of (argillaceous) limestones while the second, Famennian in age, is made up of sandstones and siltstones.

Geometry

The trace of the fault has an ENE direction (Delcambre & Pingot, 2004). It has been recognized over a distance of 10 km but the fracture is probably longer than this as it extends eastwards in the Neffe vicinity where the re-mapping is in progress. The 40-45° southerly dip displays uplift movement of the southern hanging wall block (Fig. 87). The cross-section allows estimation of an approximate measurement of the reverse component, which probably reaches 100 m.

Interpretations

The fracture belongs to a major fault family in Belgium that disrupts longitudinally the Dinant fold-and-thrust belt. Each of these thrust faults contributes to the shortening of the Devonian-Carboniferous Dinant basin by the superposition of numerous tectonic stacks. The contractional Asturian stage of the Variscan Orogeny of Westphalian age is related to this major regional faulting.

References

Delcambre & Pingot, 2004.

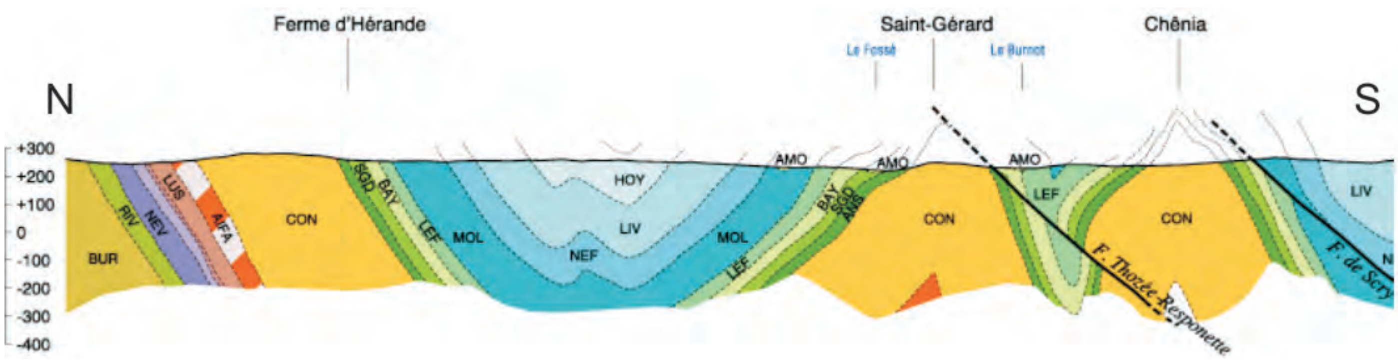

Fig. 87. N-S geological cross-section through Saint-Gérard (Delcambre & Pingot, 2004).

6.29. Thy Fault

Location

The Thy Fault is identified in 1943 by Anthoine & Anthoine in the Dyle valley. The fault disrupts Cambrian formations along the southern border of the Brabant Massif. These rocks are unconformably overlaid with extensive Eocene deposits that restrict Lower Palaeozoic outcrops to only a few valleys. Like the Genappe Fault, the trace of the Thy fracture is badly constrained but recent aeromagnetic maps allow new hypotheses.

Lithology and stratigraphy of the country rocks (Herbosch & Lemonne, 2000)

The northern block belongs to the Mousty and the Chevlipont formations, dated to the Upper Cambrian and the Tremadoc respectively. Both are composed of shales and siltstones. The southern fault block belongs to the Mousty and the Abbaye de Villers formations. The latter, of Arenig age, is made up of argillaceous siltstones. The two formations are separated by another (SSE-striking) fault.

Geometry

The western extremity of the Thy Fault is probably connected to the Genappe Thrust (Fig. 88 below, see the Genappe Fault data sheet). The fault has a general E-W strike that can be traced for 1.9 km along the Dyle valley. However, the cumulate length of the identified segments does not exceed 300 m. The dip is probably gentle and to the south (Anthoine & Anthoine, 1943). The major component of the offset is horizontal. Herbosch & Lemonne (2000) assume (in the Dyle valley, east of Ways) a sinistral strike-slip component; the offset here would be at least kilometric.

Interpretations

Anthoine & Anthoine (1943) think that the Thy Fault would display a normal offset as younger rocks constitute the hanging wall block (south of the south-dipping fault). The normal character would not be obvious because of the proximity of the Genappe thrust fault. They also emphasize the opposite structural orientation of strata on either side of the fault: the SW block shows NE-trending strata, while the NE block shows SE-trending strata. This sharp divergence in orientation justifies the position of the trace of the Thy Fault. Note that P. Fourmarier suggested in a personal communication to Anthoine & Anthoine (1943) a northerly dip with a reverse offset.

Herbosch & Lemonne (2000) do not emphasize the direction of dip or the vertical throw of the fault but highlight the left-lateral strike-slip component. They find various fold axes on the Nivelles-Genappe map with abruptly changing orientations from E-W to NW-SE. The modification of these orientations is made through "significant" faults with apparent sinistral strike-slip, such as the Thy Fault.

The strike-slip character of the fracture is probably related to the presence of an elongated granitic intrusion at depth under the Brabant Massif. The rigid granitic block would hinder the southward movement of the Cambrian core of the Brabant Massif. A transpressive shear zone would therefore develop along the margin of the intrusion. We refer the reader to Sintubin (1997) and to the Genappe Fault for explanations.

References

Anthoine & Anthoine, 1943.

Herbosch & Lemonne, 2000.

Sintubin, 1997.

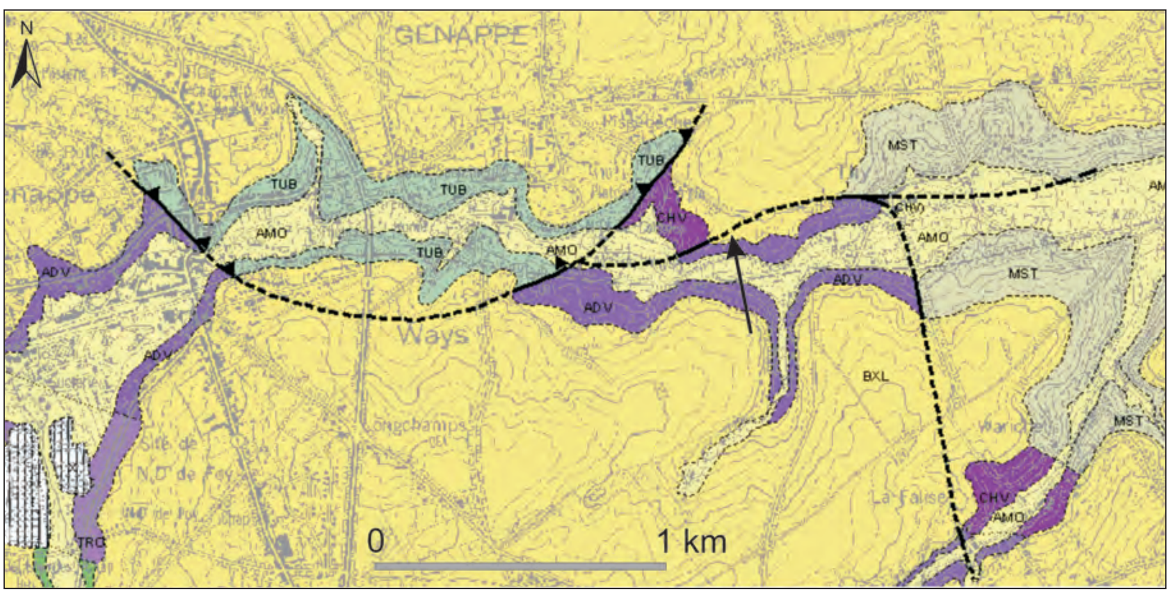

Fig. 88. Geological map of the southeastern vicinity of Genappe (Herbosch & Lemonne, 2000).

6.30. Tunnel Fault

Location

Fourmarier discovers the Tunnel Fault in 1910 in the Bay-Bonnet tunnel. The fracture is recognized for a distance of at least 16 km from about 2.5 km to the SE of Fléron to about 2 km to the S of Thimister-Clermont (Laloux *et al.*, 1996b; Barchy & Marion, 2000). The fault is of major regional significance as it separates the Herve Unit (the former Herve "Massif") to the north from the Vesdre Nappe (the former Vesdre "Massif") to the south. Hance *et al.* (1999) specify that the Herve Unit is the eastward extension of the "Namur Synclinorium" (Brabant foreland) and that the Vesdre Nappe constitutes the Variscan Front Zone (i.e. the front of the Ardenne Allochthon). The authors indicate the connective function of the Tunnel Fault between the major Midi and Aachen thrusts (Fig. 89) and the connection at depth between the Tunnel and Theux faults.

We describe the Tunnel Fault as it is considered on the reviewed geological maps of Laloux *et al.* (1996b) and Barchy & Marion (2000), i.e. with a strike length of 16 km (Fig. 89). As the fault is intimately related to the Theux Fault, we refer the reader to the extensive interpretations for this fault.

Lithology and stratigraphy of the country rocks

The fracture mainly disrupts the Houiller Group of Namurian and Lower Westphalian age. The rocks are generally siltstones and shales interlayered with coal seams.

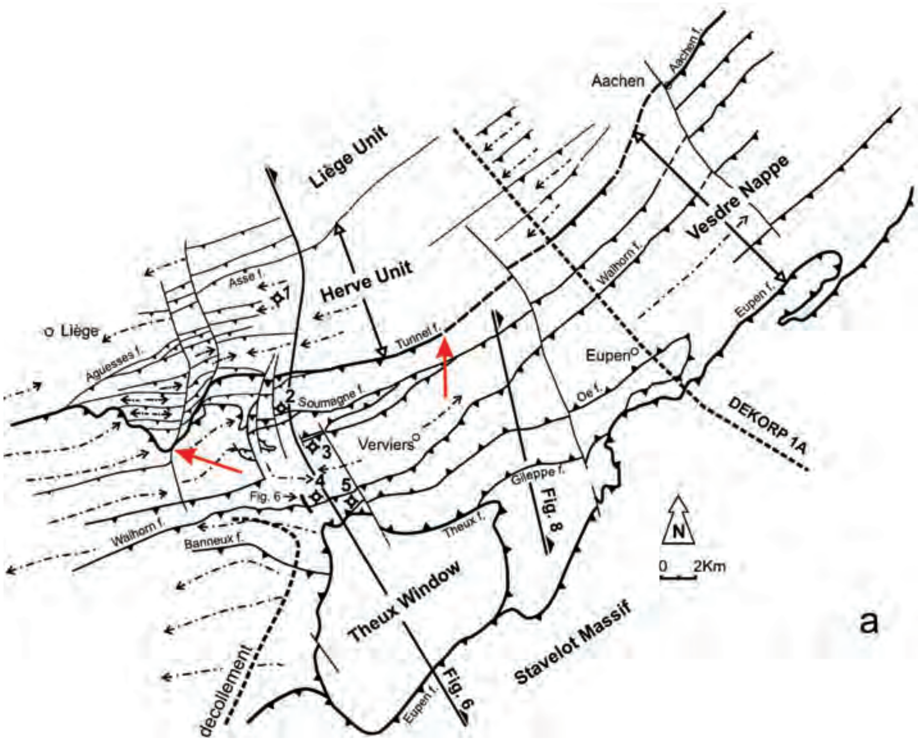

Fig. 89. Structural units and faults in northeastern Belgium and Germany (Hance *et al.*, 1999). Main fold axis, plunge directions and main deep boreholes are also given. 1-2. Pépinster. 3. Soiron. 4. Soumagne. 5. Bolland. Red arrows show the Tunnel Fault as considered in this paper.

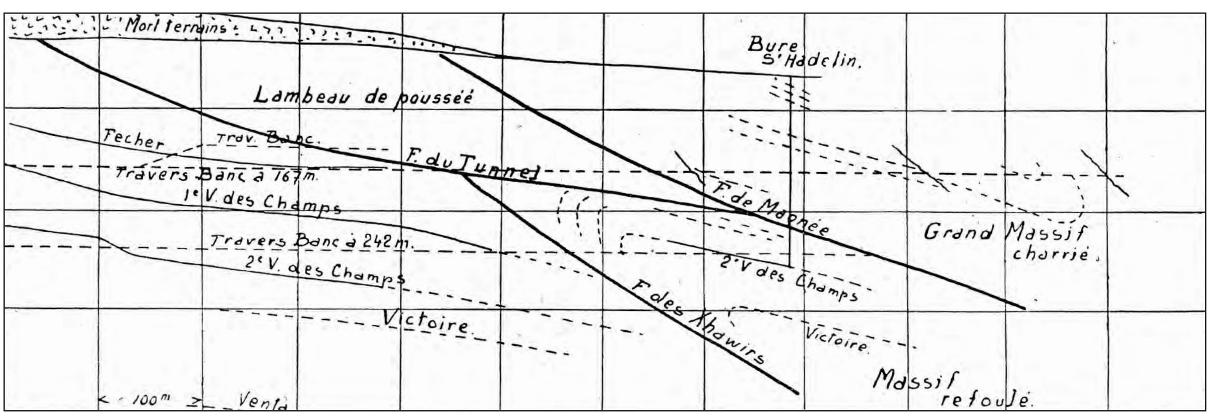

Fig. 90. Cross-section in the southwestern vicinity of Herve (Fourmarier, 1926).

Geometry

In 1910, Fourmarier indicates a gentle southward dip. The southern hanging wall block is upthrown on the northern footwall block. In this configuration, the Herve Unit is formed by the superposition of numerous tectonic slices. The same author specifies in 1926 that the very gently dipping Tunnel Fault is a secondary thrust branch of the major Magnée Fault (Fig. 90) and that the fault displaced the Xhawirs Fault as well as several folds within the substrata.

Some authors (Humblet, 1924, 1941; Chaudoir & Ancion, 1950) consider the Tunnel Fault as a similar fracture to the Micheroux or Maireux faults, or even as a continuation of one of them. These two Micheroux and Maireux faults are small thrust fractures with a reverse displacement of 140 and at least 250 metres respectively. Chaudoir & Ancion indicate the connective function of the Tunnel Fault between the Rochette Fault in the west and the Xhawirs Fault in the east. They also indicate a reverse offset of about 600 m.

In 1963(a&b) and 1976, Graulich puts forward the same observations as Fourmarier. The gently south-dipping Tunnel Fault puts the Namurian of the Saint-Hadelin “Massif” to the south in contact with the Westphalian of the Herve Unit to the north, accentuating the regional significance of the structure.

On the recent maps of Laloux *et al.* (1996b) and Barchy & Marion (2000), the Tunnel Fault is restricted to the west by the transverse Lonette Fault and disappears 16 km farther to the east under the Cretaceous flat-lying cover. The fault is a low-angle south-dipping reverse fracture that is connected at depth with the Theux Fault (see section 6.27).

Hance *et al.* (1999) propose that in eastern Belgium, the Tunnel Fault makes a connection between the Midi-Eifelian Fault to the west and the Aachen Fault to the east (Fig. 91). They also indicate that the fault is folded and connects southwards with the Theux Fault to form the Theux-Tunnel Fault. This fracture plunges to the east with a dip of about 8° and connects to a deep flat-lying reflector that is assigned to the downward extension of the Midi-Aachen Fault.

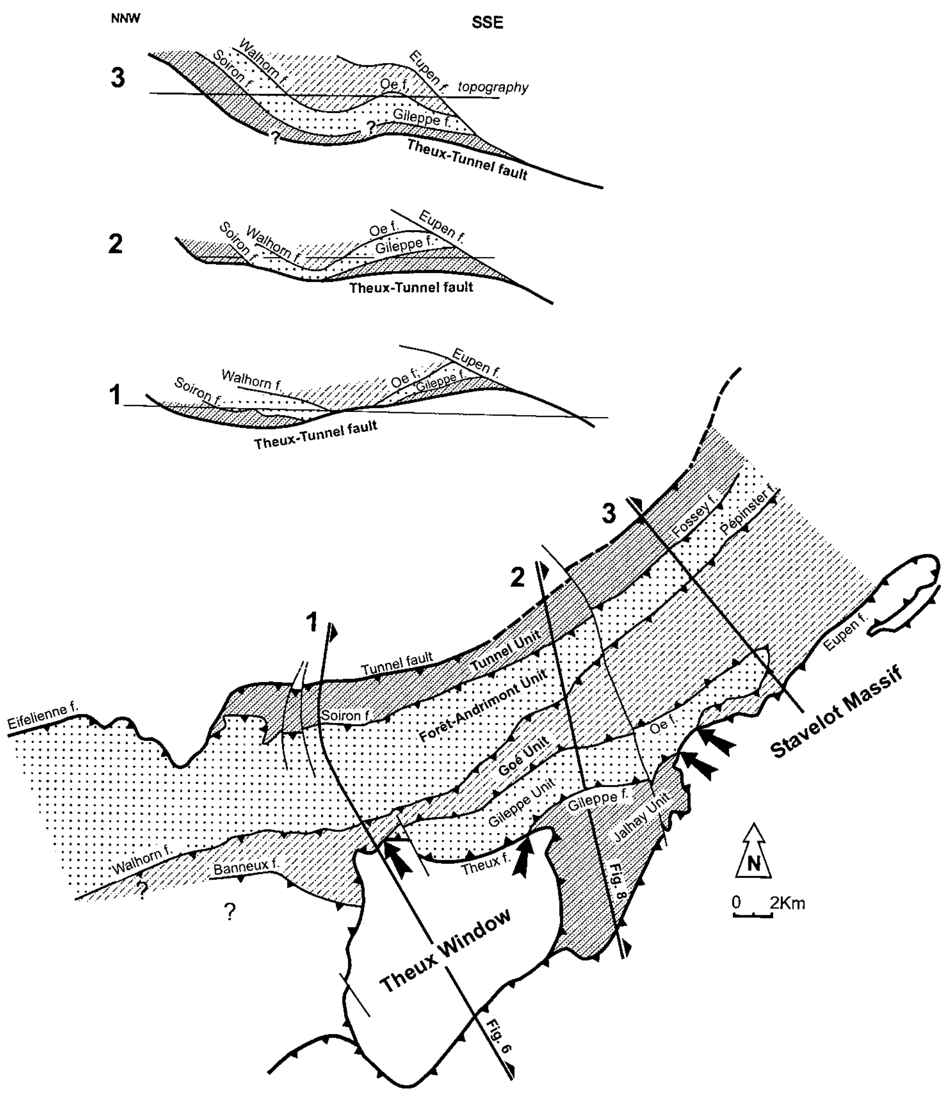

Fig. 91. Main structural units of the Vesdre Nappe (Hance *et al.*, 1999). Arrows indicate fault branching. Cross-sections indicate the eastward plunging and the out-of-sequence character of the Theux-Tunnel Fault.

Interpretation

Fourmarier (1910, 1926) recognizes the low-angle dip and the thrust character of the fault. The Tunnel Fault would be a branch of the principal thrust fracture considered to be the front of the Condroz nappe. The fault belongs, therefore, to the allochthonous Vesdre Nappe. Graulich (1963a; 1963b; 1976) believes in the same interpretation.

Humblet (1924, 1941) and Chaudoir & Ancion (1950) propose a different tectonic setting in which the Tunnel Fault would be a small thrust within the Herve Unit. These authors consider the Herve Unit to be located north of the continuation of the Midi-Eifelian Thrust. In this case, the Tunnel Fault belongs to the autochthonous "Houiller Liège basin".

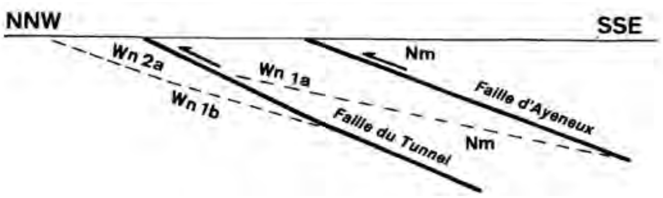

Fig. 92. Schematic cross-section of the Tunnel Unit (Michot, 1988).

Michot (1988) develops the same hypothesis as previous authors (Humblet, 1924, 1941; Chaudoir & Ancion, 1950) and supposes that the Tunnel Fault is a "simple" thrust of "low significance". Fig. 92 shows the Tunnel Unit (between the Tunnel and the Ayeneux faults) overlapped by the Ayeneux Unit. These tectonic slices are composed of "plateures" structures or gently dipping strata that belong to the central part of the Houiller Ayeneux Syncline. With this interpretation the Tunnel Fault is a "simple" reverse fracture with a non-significant displacement.

For Laloux *et al.* (1996b), the Tunnel Fault constitutes the northern boundary of the Tunnel Unit (or the Saint-Hadelin "Massif") and also the limit between the Vesdre Nappe and the Herve Unit. Fig. 93 displays the schematic cross-section of the "Verviers Synclinorium" and shows the regional tectonic significance of the Tunnel Fault. The fault is related to the Variscan Orogeny and is therefore probably dated to the Late Westphalian.

The work of Hance *et al.* (1999) exposes a Variscan deformation history in northeastern Belgium. Two complementary models are proposed. Observations indicate the importance of the overturned forelimb of a large anticline that developed at an early stage. Later the fold would probably have been truncated and transported. The out-of-sequence fault propagation model is preferentially supported than the in-sequence thrusting model.

As noted previously, these authors assume the connective function of the Tunnel Fault between the Midi and Aachen faults. The Tunnel Fault would in this case be a highly important discontinuity in the northern part of the Rhenohercynian fold-and-thrust belt. The Tunnel Fault would be directly linked with the thrust of the Ardenne Allochthon over the Brabant Para-autochthonous foreland during the Asturian stage of the Variscan Orogeny.

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Hance *et al.*, 1999.
Humblet, 1924.
Humblet, 1941.
Laloux *et al.*, 1996b.
Michot, 1988.

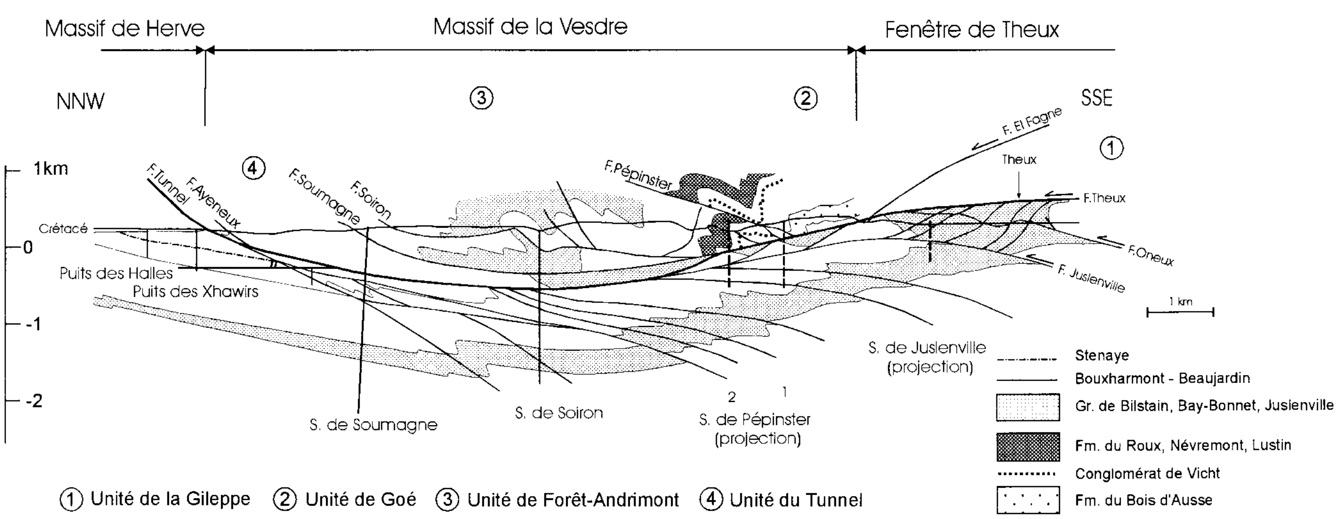

Fig. 93. Schematic cross-section through the Verviers Synclinorium (Laloux *et al.*, 1996b).

6.31. Vaulx Fault

Location

The Vaulx Fault is generally parallel to the Dondaine Fault (see section 6.8) in the area south of Tournai. It runs from Faubourg-Saint-Martin in the west to a point 200 m to the south of Gaurain-Ramecroix in the east (Hennebert & Doremus, 1997a, b). The fault affects the northern limb of the ESE-plunging Mélantois-Tournaisis Anticline in the western part of the “Namur Synclinorium”.

Lithology and stratigraphy of the country rocks

The depth of faulting reached by the fracture is less than 300 m (Fig. 94). Formations from the Ivorian (Tournaisian) to the Molanician (Visean) are disrupted by the fault. Mesozoic-Cenozoic cover is not affected. See the Gaurain-Ramecroix Fault for a description of the lithologies.

Geometry

The western extremity of the fault is connected to the Dondaine Fault, while the eastern extremity is connected to the Gaurain-Ramecroix Fault. The trace extends for 10 km at most and the E-W strike evolves eastwards to a SE direction. The dip is different at either end of the fault: it dips to the north on the western segment and to the south on the eastern segment (Hennebert & Doremus, 1997a, b). Considering the subsidence of the southern fault block, the fault is characterized by both reverse (western part) and normal (eastern part) displacements. This is compatible with a throw dominated by a (dextral) strike-slip component.

The Vaulx Fault has been detected in a drilling campaign (Tournai drillhole referenced 124E0455 at the GSB; Legrand, 1981). The fault inclination is estimated to be 60° at 270 m depth. The reverse displacement is about 12 m in the Palaeozoic country rocks.

The fault splits to form another branch just south of Faubourg de Valenciennes. This new fault (the Chercq Fault) has the same particularities as the Vaulx Fault.

Interpretations

The fault belongs to the positive flower structure of the Mélantois-Tournaisis Anticline. The tectonic setting is probably transpressive and late- or post-Variscan (Hennebert, 1993; Christie-Blick & Biddle, 1985) in age (see the Bruyelle Fault for further explanation).

To the east of the Scheldt, no field evidence was found concerning recent tectonic movement or Mesozoic-Cenozoic fault reactivation. The western part was probably reactivated in the same manner as the Dondaine Fault.

References

Christie-Blick & Biddle, 1985.

Hennebert, 1993.

Hennebert & Doremus, 1997a.

Hennebert & Doremus, 1997b.

Legrand, 1981.

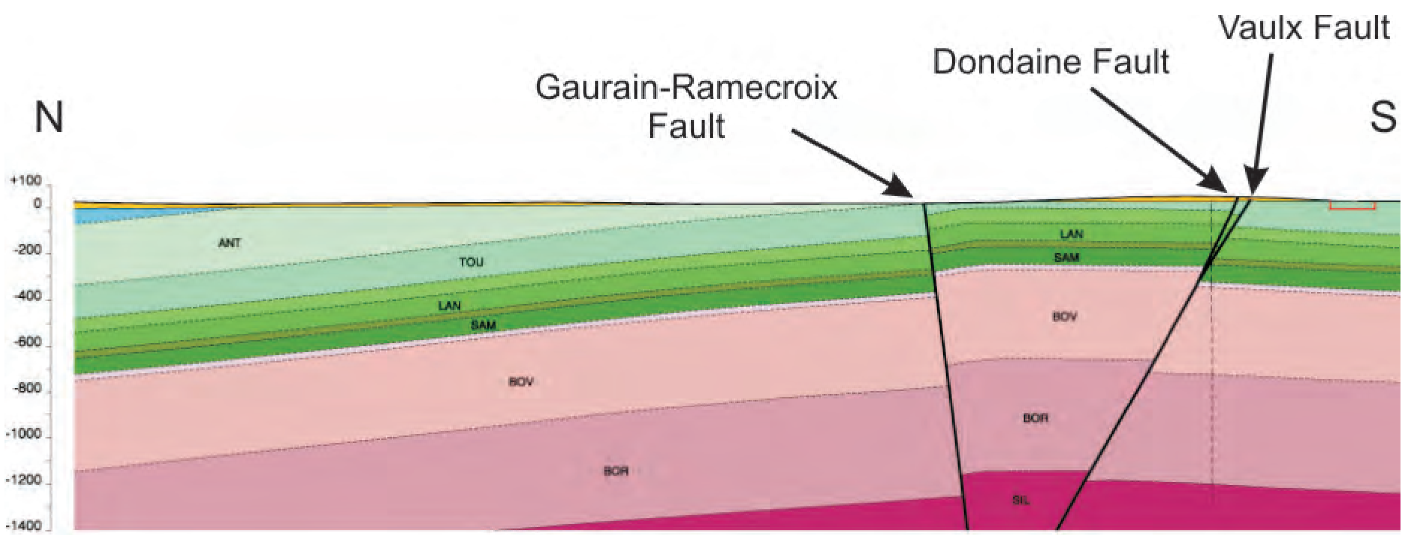

Fig. 94. N-S geological cross-section through the Mélantois-Tournaisis Anticline (from Hennebert & Doremus, 1997b).

Fig. 95. N-S cross-section in the Furfooz area (Boulvain *et al.*, 1995).

6.32. Vêves Fault

Location

The Vêves Fault is located close to Dinant, running from about 500 m southeastward of Furfooz to about 500 m southeastward of Celles (i.e. is 4 km long). The fault displaces the northern limb of the NE-trending Trussogne Anticline. A small, 600 m long segment of the fault that straddles the St-Hadelin valley was already drawn on the map of de Dorlodot *et al.* (1919).

Lithology and stratigraphy of the country rocks

The fault disrupts six Lower Carboniferous formations:

- the Marenne Formation (Tournaisian) is made up of argillaceous limestones;
- the Bayard Formation (Tournaisian) is made up of crinoidal limestones;
- the Waulsort Formation (Tournaisian and Visean) is made up of "Waulsortian" limestones; and
- the Leffe, Molignée and Neffe formations (Visean) that are made up of various limestones.

Geometry

The Vêves Fault displays a variable strike that evolves from an E-W direction in the western part to a SW-NE direction in the east. The fault trace reaches 4 km long and dips about 70-80° to the south. The southern block has moved upward and the reverse offset is unknown. However, the cross-section in Fig. 95 enables measurement of a minor dip-slip component of about 25 m.

Boulvain *et al.* (1995) observe in the park of the "château de Noisy" a breccia contact between Waulsortian and black limestones (Molignée and Waulsort formations), which correspond to contractionnal stresses that acted along the Vêves Fault.

Interpretations

The Vêves Fault belongs to a regional fault family that disrupts longitudinally the Dinant fold-and-thrust belt. The Variscan shortening (Asturian stage of Westphalian age) is probably the cause of the faulting.

References

Boulvain *et al.*, 1995.

de Dorlodot *et al.*, 1919.

Delcambre & Pingot, 1993.

6.33. Vezin Fault

Location

The Vezin Fault (Stainier, 1902) is located close to Vezin in the area northwest of Andenne. The fault is also situated south of the Landenne fracture and therefore disrupts the northern limb of the "Namur Synclinorium". The Landenne Fault is nearly 6 km long and forms the boundary between the Brabant Massif in the north and the Namur basin in the south (see Fig. 49).

Stratigraphy and lithology of the country rocks

At surface, many formations of Upper Visean to Upper Famennian age are displaced along the fracture. The following stratigraphic subdivision is from Stainier (1901a):

- the Mariembourg, Monfort & Evieux formations (Fa1b, Fa2b & Fa2c – Famennian) made up mainly of micaceous sandstones (i.e. the so-called psammites in the old Belgian literature);
- the Hastière, Waulsort & Ecaussines formations (T1y, T2y & T2 – Tournaisian) made up of crinoidal limestones and dolostones; and
- the Dinant Formation (V1by – Upper Visean) known as the "Grandes dolomies".

Geometry

The south-dipping Vezin Fault is a longitudinal, 3.2 km long and ENE-striking lineament that is connected at its western extremity to the Landenne Fault (Stainier, 1901a) (see section 6.16). The composite displacement includes the vertical downthrown movement of the southern hanging wall block and the right-lateral shifting of the northern footwall block. The normal displacement is small or absent within the central segment while it increases laterally (Stainier, 1902). The apparent (cartographic) dextral offset reaches 560 m (Stainier, 1901a).

Interpretations

No interpretations regarding tectonics were found. As the fault is connected to the Landenne fracture, we refer the reader to the data for that fault. It should be noted that the two faults have opposite dips (see Fig. 50).

References

Stainier, 1901a.

Stainier, 1902.

6.34. Vireux Fault

Location

Gosselet identifies the Vireux Fault in 1888 in French territory. The Belgian geological maps of Bayet (1899) and Forir (1896b), covering both sides of the Meuse river, do not display the Vireux Fault, for which its respective extensions will be later envisaged by various authors (see below).

From west to east, the fault runs from Olloy-sur-Viroin to a point east of Vonèche. The fault is therefore recognized for at least 28 km. Indeed, the eastern extension is not known and the fault probably continues further eastwards. West of the Meuse river, the fault splits into two branches, where it cuts the southern limb of the north-verging inclined or overturned Vireux Anticline and the northern limb of the gently-inclined Bois de Mazée Syncline (Fig. 96). The fault is located at the boundary between the southern border of the Dinant Synclinorium and the north part of the Ardenne Anticlinorium hinge line where the Rocroi Inlier outcrops.

Lithology and stratigraphy of the country rocks

To the west of the Meuse river, in both Belgian and French territory, five Lower Devonian (Emsian) formations are disrupted by the Vireux Fault (Dumoulin & Coen, 2008): the Pèrnelle, Pesche, Vireux, Chooz and Hierges formations. All of these are made up of siliciclastic rocks, mainly interlayered schists, siltstones, green and red sandstones and quartzites.

To the east of the Meuse river, also in both Belgian and French territory, the fault cuts the same formations as seen on the western bank of the Meuse, with the exception of the Saint-Hubert, Mirwart, Villé and La Roche formations that are also disrupted here. The formations range in age from the Upper Lochkovian to the Upper Pragian. See for example the Borzée Fault for a description of the lithologies.

Geometry

In 1888, Gosselet detects the disruption of the southern limb of the Vireux Anticline in the west bank of the Meuse river (Fig. 97). The Vireux Fault brings into contact the Vireux sandstones in the north with the Hierges "greywacke" (an impure decalcified limestone) in the south, and has a probable dip of 50° to the south and a normal displacement. The geological map of the Ardennian Palaeozoic terrains shows the location of the Vireux Fault only to the West of the Meuse river and for a strike length of 2.2 km.

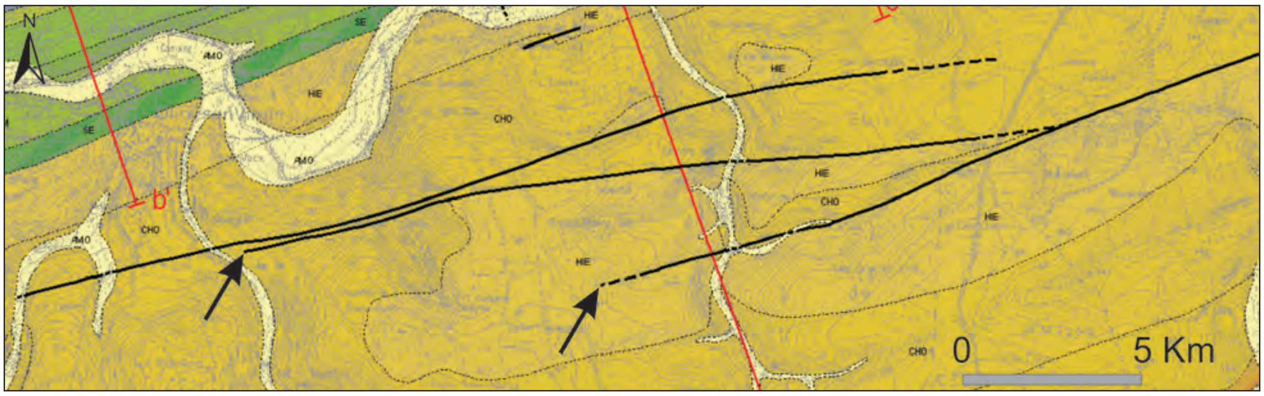

Fig. 96. Geological map of the western termination of the Vireux Fault (Dumoulin & Coen, 2008).

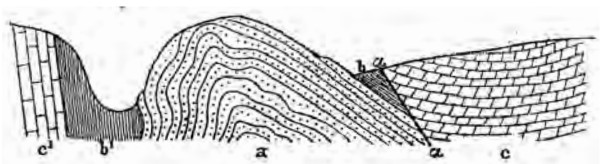

Fig. 97. N-S trending cross-section through the Vireux Fault (west bank of the Meuse river; Gosselet, 1888). a = "black sandstones of Vireux". b b' = "red schists of Burnot". c c' = "Grauwacke of Hierges". α α' = Fault.

Fig. 98. N-S cross-section through the Vireux Fault in the east bank of the Meuse river (Fourmarier, 1924).

In 1924, Fourmarier observes the Vireux Fault in the east bank of the Meuse river. He indicates a steep, nearly subvertical, northerly dip (Fig. 98). These different geometric considerations allow him to propose other interpretations (see below).

Asselberghs publishes in 1938 his mapping of the fault on both banks of the Meuse river (Fig. 99). The fault is henceforth recognized over a distance of at least 3.2 km, maybe 5.2 km. From a geometrical point of view, the mainly E-W-striking Vireux Fault has a nearly vertical, or steep northerly dip (Fig. 100), and a normal displacement. The revision of the stratigraphic chart enables dating of the rocks of the footwall block to the Middle Emsian ("E2") and the rocks of the northern hanging wall to the Lower Emsian ("E1"). The cross-section in Fig. 100 illustrates, therefore, an apparent reverse offset.

In 1946, Asselberghs reiterates that the fault has an approximate E-W direction and a probable vertical dip. The fault straddles the Meuse river and can be traced over a distance of 4.2 km (Fig. 101). The author indicates that a 5 metre-thick zone of crushed "red schists" marks the faulted contact between the Middle and the Lower Emsian.

Beugnies (1967) follows the Vireux Fault for 7 km from the Meuse river in the east to the Wet stream in the west. The direction of the trace is sinuous, being sublongitudinal in its eastern part and subtransversal in its western segment (Fig. 102). The southern block is downthrown as its constitutent rocks are younger that those located in the northern block. The fault would post-date the formation of folds. The offset is estimated to be 400 m.

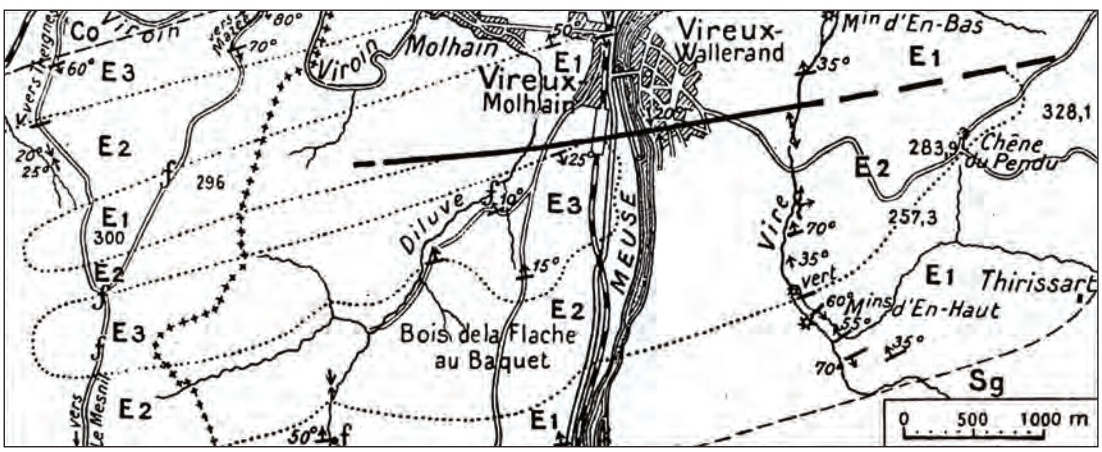

Fig. 99. Location of the Vireux Fault (Asselberghs, 1938).

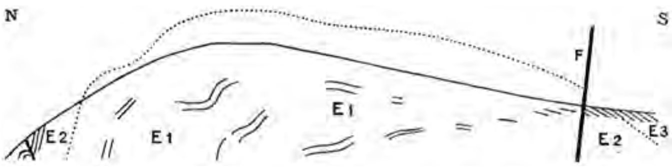

Fig. 100. N-S cross-section through the western side of the "Mont de Vireux" (Asselberghs, 1938).

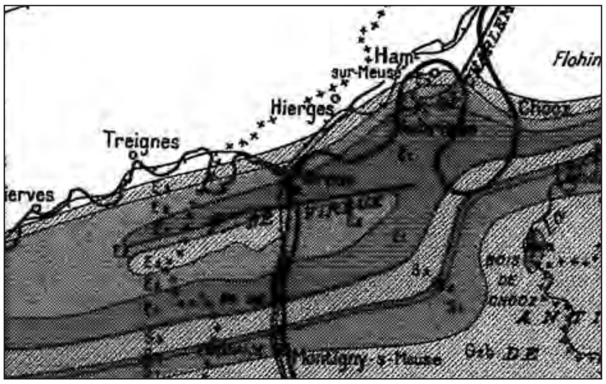

Fig. 101. Extract of the Eodevonian Ardennian geological map of Asselberghs (1946).

Later, in 1970, Beugnies proposes new ideas for the segment on the eastern side of the Meuse river (Fig. 103). He suggests a connection between the Vireux Fault in the west with the Thanville Fault in the east. The latter fault was discovered by Asselberghs in 1923 in the vicinity of Vonèche and was assumed to display a southern dip and a reverse slip. The magnitude and sense of movement of the Vireux-Thanville Fault are the same as seen on the west side of the Meuse, i.e. the southern fault block is downthrown and the offset is around 500 m. However, the eastern extremity is marked by an uplift of the southern block of approximately a few hundred metres.

According to Beugnies (1967, 1970), the cumulative total trace length of the Vireux-Thanville Fault on both sides of the Meuse river is about 26 km.

Beugnies (1967) has also discovered a new fracture, the Olloy Fault, which constitutes the apparent western continuation of the sublongitudinal segment of the Vireux Fault (Fig. 102). The scale of the offset (about few dozen metres) and the relative movement between the blocks (in which the northern one is downthrown) suggest that the Olloy Fault is not the correct continuation of the Vireux Fault but can be attributed to one of its "satellites".

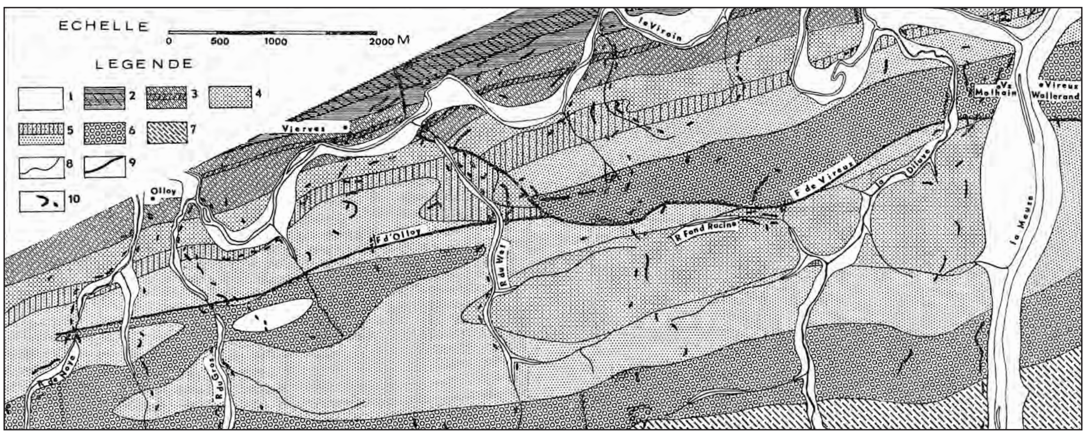

Fig. 102. Geological map of the area around Vierves and Vireux, and the location of the Vireux Fault west of the Meuse river (Beugnies, 1967).

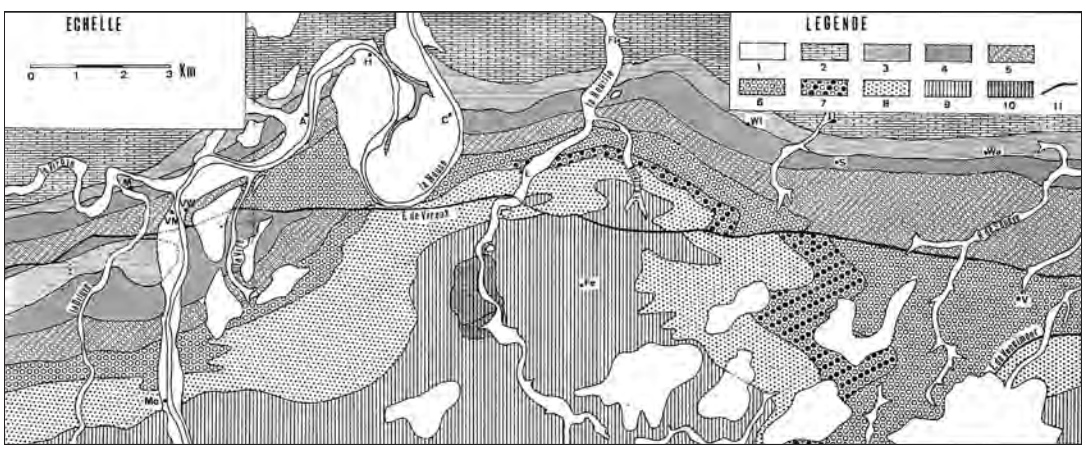

Fig. 103. Geological map of the Vireux, Felenne and Vonèche region, and location of the Vireux Fault east of the Meuse river (Beugnies, 1970).

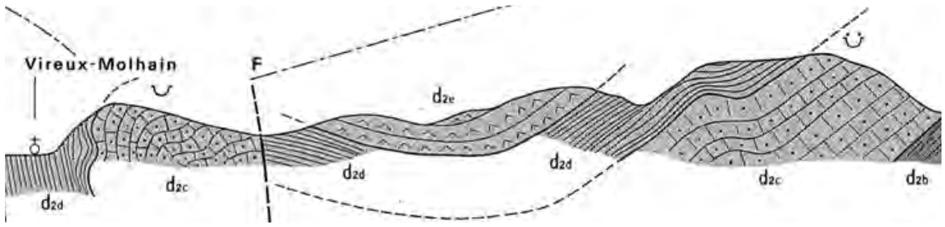

Fig. 104. Extract of the NNW-SSE cross-section through Vireux-Molhain (Delattre *et al.*, 1970). D2b = Middle and Upper Pragian. D2c = Lower Emsian. D2d = Middle Emsian. D2e = Upper Emsian.

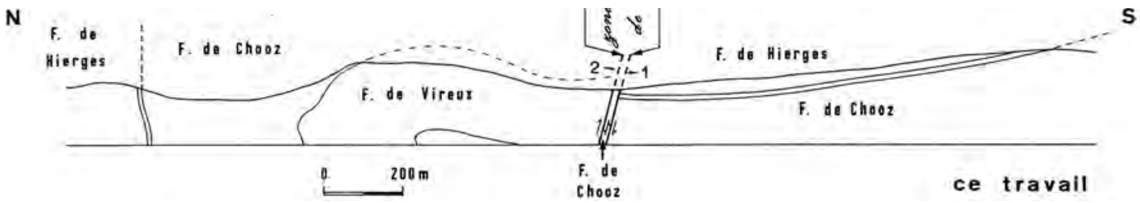

Fig. 105. N-S cross-section through the "Vireux faulted zone" on the western side of the Meuse river (Godefroid & Stainier, 1988).

The French geological map of Givet, released in 1970 by Delattre *et al.*, shows the Vireux Fault with a strike of at least 15.5 km. Both eastern and western continuations of the fault are located in Belgian territory (see below). The French geologists interpret the fault as resulting from the Variscan orogeny. No more information is given. The cross-section attached to the map (Fig. 104) displays the downthrown movement of the southern fault block along a subvertical dip.

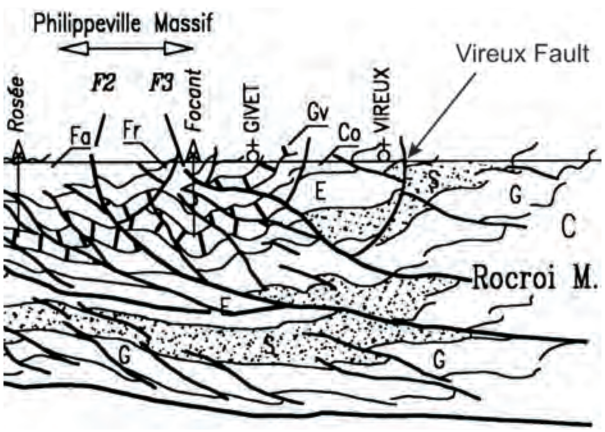

Fig. 106. Extract of the N-S, deep structural cross-section along the Meuse river (Adams & Vandenberghe, 1999).

Godefroid & Stainier (1988) observe two fractures, Fault 1 and Fault 2, between Olloy-sur-Viroin (in Belgium) and the Lire stream (on the east bank of the Meuse, in France). Both are E-W-striking faults that dip to the north and are the equivalent of the Vireux Fault (Fig. 105). They are designated as the Vireux faulted zone. In the Meuse valley, 65 m separates Fault 1 (in the south) from Fault 2 (in the north), but the distance rises to a maximum of 450 m at the longitude of Treignes. The relative movement for each fault is for a downthrow of the southern blocks with the exception of the western extremity of Fault 2, which displays an uplift of the southern fault block (such that a small and local horst is delimited here by Fault 1 and Fault 2). The offsets of each fracture cannot be separately measured, but a displacement of about 300 m is proposed for the Vireux faulted zone.

To the east of the Meuse river, Godefroid & Stainier (1988) are unable to specify if faults 1 and 2 remain distinct fractures or if they combine. The southern fault block here is again downthrown relative to the northern block.

In 1999, Adams & Vandenberghe suggest that the antithetic Vireux Fault has a northern dip. The cross-section in Fig. 106 shows that the Vireux Fault joins a quite significant S-dipping thrust fault at depth.

Recently, Lacquement & Meilliez (2006) reiterates that previous authors admit to the existence of the fault, its steep dip and late-Variscan origin but dot not agree regarding its direction of plunge. The authors make some new observations in the "Camp Romain", near Vireux-Molhain, where they report a steep dip to the south and a normal offset (Fig. 107). However, they indicate that this superficial dip may change at depth. Finally they propose innovative interpretations (see below).

The revised Belgian geological map of Olloy-sur-Viroin – Treignes, to the west of the Meuse river, was released in 2008 (Dumoulin & Coen). According to their observations, the authors propose an updated trace of the Vireux Fault (Fig. 96). The considerations of Godefroid & Stainier (1988) are taken into account. Finally, cross-sections that accompany the map show a subvertical or steep (about 70°) southward dip. In the latter case (Fig. 108), just west of the Meuse river in France, the normal slip is estimated at 375 m.

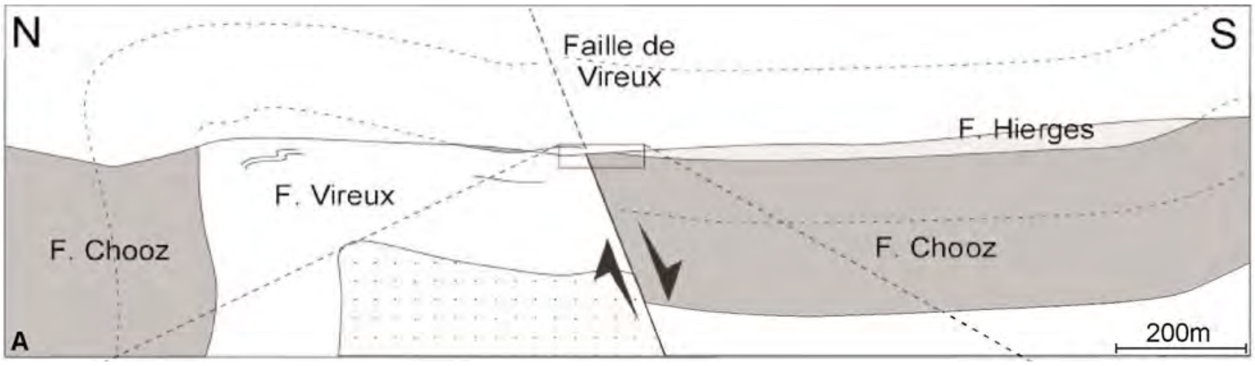

Fig. 107. N-S cross-section through the Vireux Fault on the western side of the Meuse river (Lacquement & Meilliez, 2006).

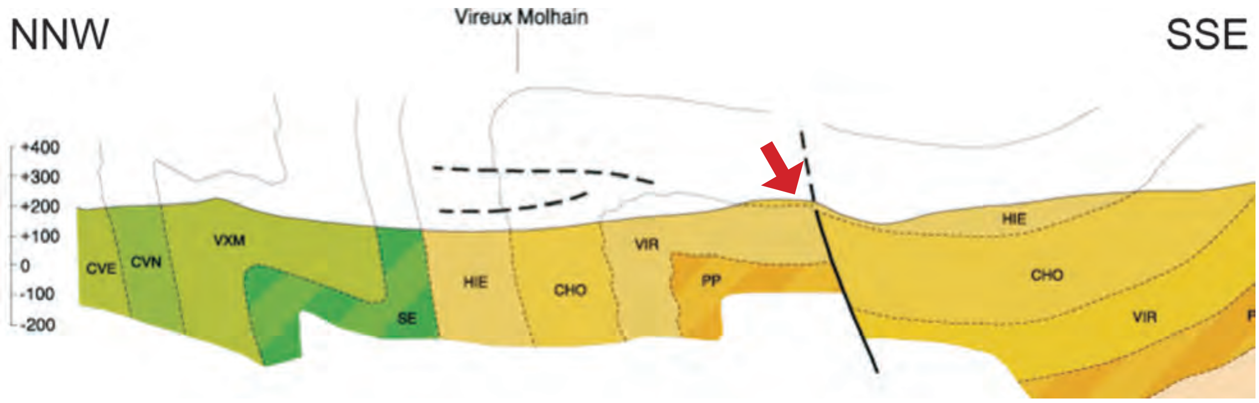

Fig. 108. NNW-SSE cross-section through Vireux-Molhain (Dumoulin & Coen, 2008).

Interpretations

Gosselet (1888) already suggests a late-Variscan origin. The displacement of the stratigraphic limits allows an estimation of the normal offset of about 350 m.

Fourmarier (1924) proposes different interpretations. He indicates that rocks located south of the north-dipping fault, within the footwall block, are younger than rocks of the hanging wall block. The author therefore proposes a reverse offset resulting from contractional stresses acting from north to south. With this interpretation the Vireux Fault constitutes an antithetic fracture to the usual south-dipping faults of the Dinant Synclinorium. Both north and south-dipping faults converge to the axial zone of the first-order (Vireux) anticline and enable the upward movement of its central part.

Asselberghs (1938) indicates that the fault results from a "readjusting" or "settling" movement that would be later than the main northward stresses responsible for the thrusts and the folds of the Ardenne.

In 1946, Asselberghs considers four « significant » steeply dipping normal faults in the Eodevonian Ardenne Anticlinorium: the Opont, Vireux, Lamsoul and Oe faults. His interpretation of their "unusual" normal slip is the probable re-equilibrium of the northern border of the Ardenne Anticlinorium after thrusting movements of the Variscan contractional regime.

Beugnies (1967) interprets the fault as resulting from a late-Variscan extensional stage. In 1970, the same author suggests that, during a late extensional stage, the Vireux Fault cuts the E-W-trending folds obliquely. The southern limbs of these folds would have simply glided along the subvertical fault plane under gravity.

Lacquement & Meilliez (2006) suggest synsedimentary movements along the Vireux Fault. Arguments for this are the substantial facies variations on either side of the fracture and synsedimentary deformation structures located near the fault and along strike for many kilometres. The synsedimentary tectonics acted in a N-S direction are dated to the Lower Devonian and would have lasted for a duration of nearly 10 Ma. The Upper Devonian is marked by contractional tectonics that impose a shortening of the layers re-using the pre-existing normal faults. The original normal displacement is not necessary fully compensated for by the reverse reactivation.

Lacquement *et al.* (2006) also propose that the normal synsedimentary Vireux Fault was folded during the contractional stage of the Variscan orogeny, and was reactivated again, but in a normal way, during an extensional stage related to the end of the Variscan orogeny ("relaxation"). The latter reactivation only involved the western, unfolded, segment of the fault.

References

Adams & Vandenberghe, 1999.
Asselberghs, 1923.
Asselberghs, 1938.
Asselberghs, 1946.
Bayet, 1899.
Beugnies, 1967.
Beugnies, 1970.
Delattre *et al.*, 1970.
Dumoulin & Coen, 2008.
Forir, 1896b.
Fourmarier, 1924.
Godefroid & Stainier, 1988.
Gosselet, 1888.
Lacquement *et al.*, 2006.
Lacquement & Meilliez, 2006.

6.35. Walhorn Fault

Location

The Walhorn Fault, named in 1905 by Fourmarier, runs from east to west from a point 4 km to the NE of Eynatten through or near the localities of Eynatten, Walhorn, Welkenraedt, Baelen, Limbourg, Stembert, Verviers, Pépinster and Fraipont to a point 2.5 km to the SW of Trooz, i.e. over a distance of 40 km. Note that a small NE-striking segment of the fault had already been detected by Dewalque and drawn on his geological map of 1901.

The fault segments are named differently depending on their geography, from east to west: the Walhorn, Renoupré, Haute-Folie and Pépinster faults. Recent mapping (Laloux *et al.*, 1996a; 1996b; 2000) has demonstrated their mutual continuations. The fault bounds the northern part of the Goé Unit (Fig. 109), a small inner thrust sheet of the Vesdre Nappe.

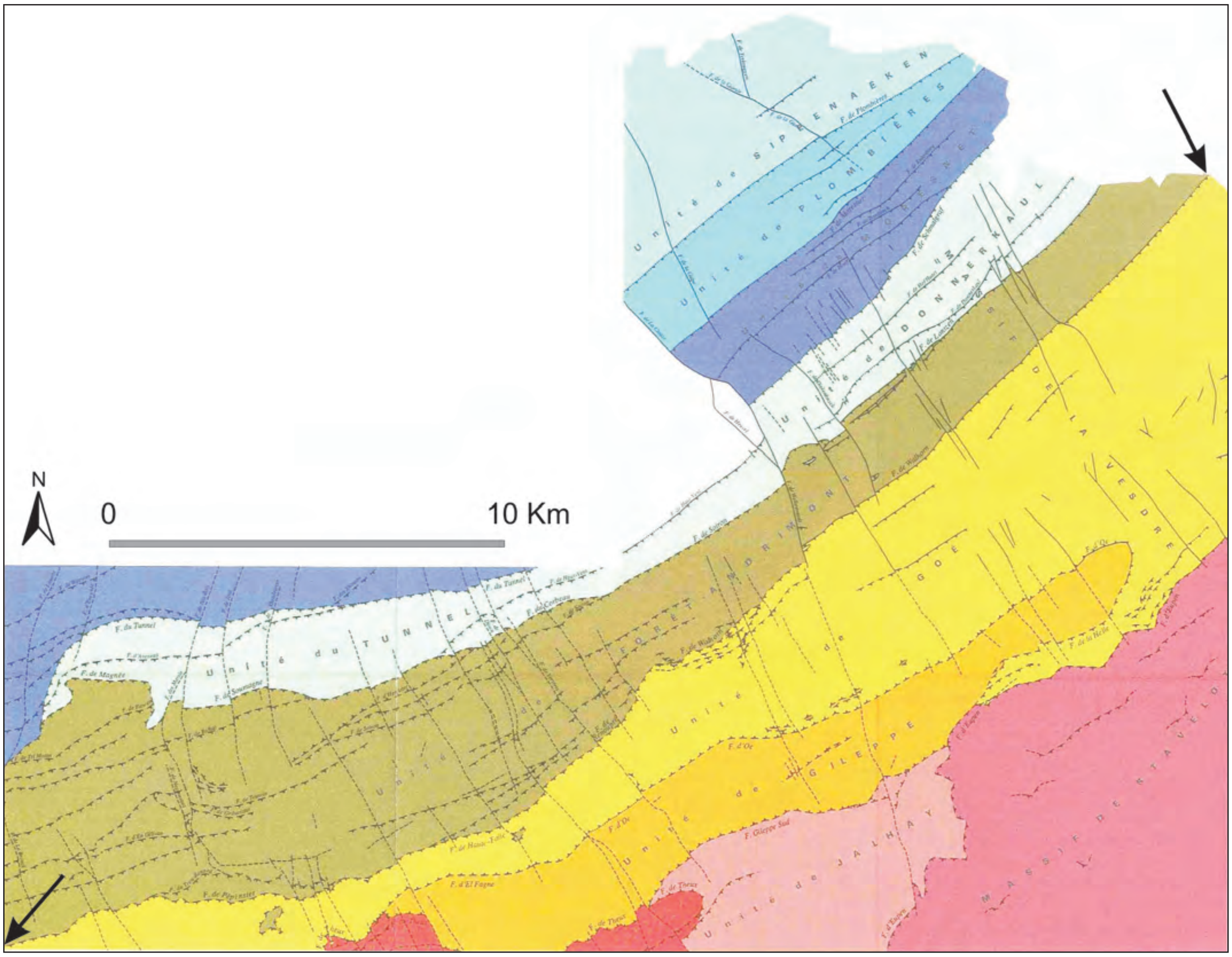

Fig. 109. Structural scheme of the northeastern vicinity of the Vesdre Nappe (Laloux *et al.*, 2000). Red arrows indicate the extremities of the Walhorn Fault. The Walhorn and Oe faults are antithetic and undulating: they form a thrust sheet (the Goé Unit) that is punctuated by small tectonic windows.

Lithology and stratigraphy of the country rocks

Many formations (13 in number) of Lower Devonian to Upper Carboniferous age are recognized. See, for example, the geological map of Laloux *et al.* (1996a) for a description of the main lithological features.

Geometry

While the fracture was only named in 1905 by Fourmarier, the geological map of Dewalque, released in 1901, displays a segment of the Walhorn Fault. The segment of Dewalque disrupts the southeastern limb of the NE-trending Calvaire Syncline and displaces Upper Famennian rocks in the south on the Visean rocks in the north. The offset increases to the northeast.

In 1905, Fourmarier emphasizes a longitudinal fracture observed in the vicinity of Walhorn that he named the Walhorn Fault along which the Upper Famennian would be upthrown northwards over the Houiller formations. Later, Aderca (1932) describes the probable very gentle dip. The fracture is then interpreted as a “true” thrust fault.

Stainier (1933) indicates a connection between the Walhorn and Verviers fractures but recent mapping has shown no continuity between these faults. Fourmarier & Dubrul (1958) propose to extend the Walhorn Fault westwards to connect it with the Pépinster Fault (defined by Fourmarier in 1927 and named by him later in 1941) and with the Theux Fault at depth (see the Theux Fault). Following this work, the fault acquired much the same geographical significance (Fig. 110) as given by current authors.

In 1970, Coen-Aubert introduces the name Renoupré Fault for a segment that previously was considered to belong to the Walhorn Fault. She justifies this modification because of the impossibility of extending the Renoupré Fault to the NE and therefore of joining it to the Walhorn Fault. Later, Hance *et al.* (1989) describe an undulating thrust fracture that they call the Haute-Folie Fault. The reverse displacement is estimated to be 800 m.

On the current maps of Laloux *et al.* (1996a, b & 2000), the Walhorn-Renoupré-Haute-Folie-Pépinster Fault has been mapped for at least 40 km. The western extremity of the Walhorn Fault joins the Trou-Renard Fault while the eastern extremity probably continues eastwards into German territory. It has a general NE strike and a gentle southern dip. The southeast side of the fault is upthrown and the reverse offset is estimated to about 900 m in the vicinity of Welkenraedt. The Walhorn Fault connects southwards with another low-angle and north-dipping fracture called the Oe Fault. These fractures constitute a thrust fault that displaced the Goé thrust sheet (Fig. 111). The Walhorn/Oe fault plane is not planar but displays several undulations that define the outcrop of a small tectonic window close to Kaulen.

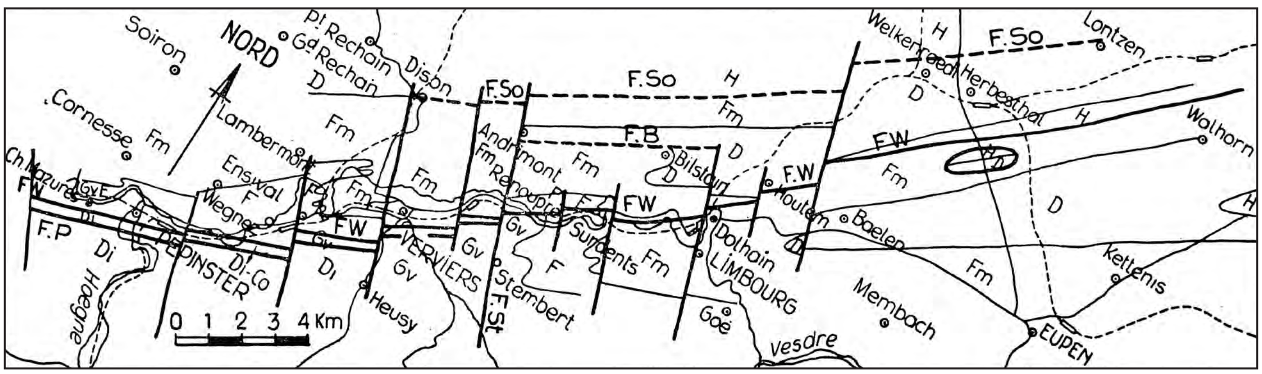

Fig. 110. Geography of the Walhorn Fault (Fourmarier & Dubrul, 1958). H = Houiller, D = Dinantian, Fm = Famennian, F = Frasnian, Gv = Givetian, Di = Couvinian and Lower Devonian, FW = Walhorn Fault, FSo = Soiron Fault, FP = Pépinster Fault, FB = Bilstain Fault, FSt = Stembert Fault.

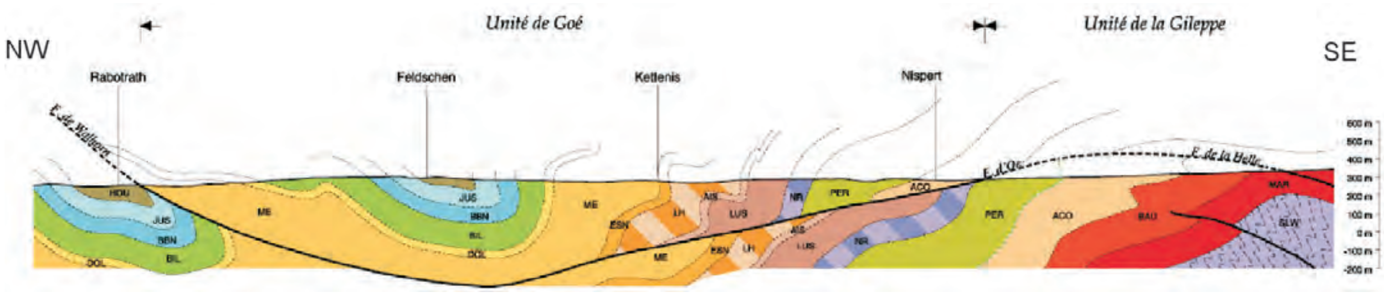

Fig. 111. NW-SE geological cross-section through the Goé Unit in the Vesdre Nappe (Laloux *et al.*, 1996a).

Interpretations

Aderca (1932) proposes a general tectonic explanation for the south-dipping fracture in the Vesdre Massif region. He identifies the Walhorn Fault with the major northward thrust of the Cambrian Stavelot Inlier.

Fourmarier & Dubrul (1958) remind readers that the Vesdre Nappe constitutes the northeastern continuation of the Dinant Synclinorium (Ardenne Allochthon), which was thrust northwards during the late-Variscan stage. The authors indicate (1) that the Walhorn Fault is connected at depth with the Theux Fault and (2) that it bounds a tectonic slice initiated during the northward progression of the Condroz Nappe.

Recent mapping shows that the Walhorn Fault connects southwards with the north-dipping Oe Fault. Together they form an inner thrust sheet (i.e. the Goé Unit) located within the greater Vesdre Nappe. The Walhorn Fault was formed during the main compressive stage (i.e. the Asturian stage) of the Variscan Orogeny. The fault is probably dated to the Late Westphalian.

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Fourmarier, 1927.
Fourmarier, 1941.
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Laloux *et al.*, 1996a.
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Laloux *et al.*, 2000.
Stainier, 1933.

6.36. Xhoris Fault

Location

The Xhoris Fault has been known since the end of the 19th century. This thrust-type fracture was already traced in 1899 on the geological map of Harzée – La Gleize (n°159, Dewalque) and later in 1902 on the geological map of Hamoir – Ferrières (n°158, Lohest & Fourmarier). The first reference to the Xhoris Fault in the written literature is by Gosselet in 1888.

The fault affects two major units of Belgian regional geology (Fielitz, 1992) (Fig. 112). The western segment disrupts the Eifelian – Frasnian formations of the eastern border of the Dinant Synclinorium, while the eastern segment displaces the Cambrian – Ordovician rocks of the Stavelot Massif in the Ardenne Anticlinorium. Over 40 km long, the fault crosses from west to east the following localities and their areas: Xhoris, Harzé, Werbomont, Chevron, Rahier, Trois-Ponts, Stavelot and Malmédy.

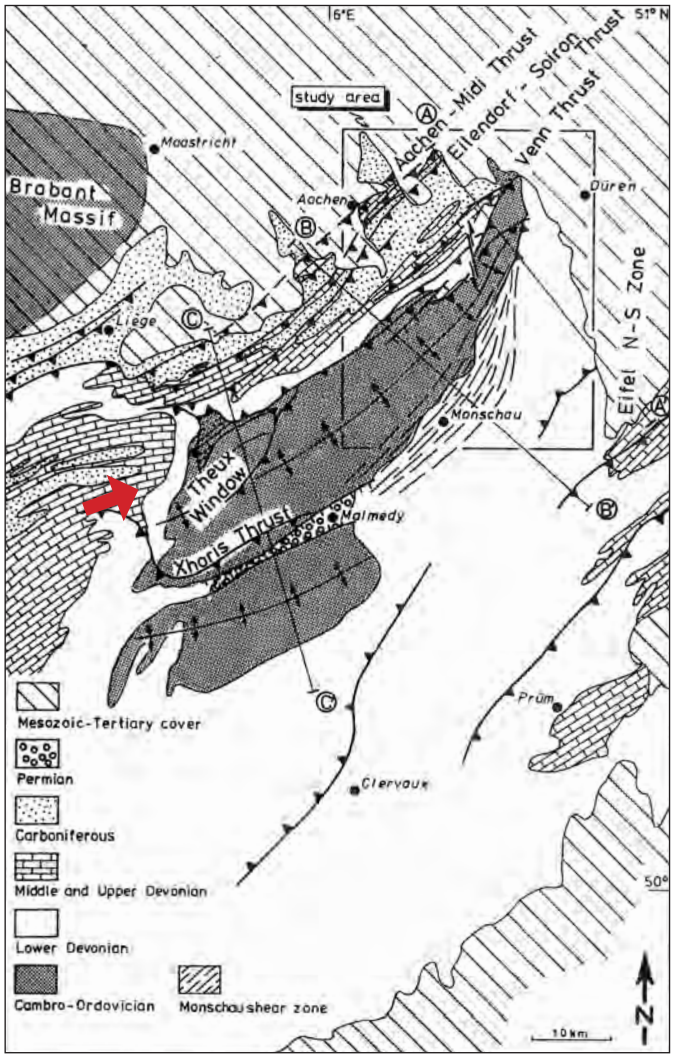

Fig. 112. Geological map of the Stavelot Massif and adjacent areas (Fielitz, 1992). The cross-section C-C' is given in Fig. 117.

Stratigraphy and lithology of the country rocks

In its western segment, the Xhoris Fault disrupts formations of the Middle and Upper Devonian eastern border of the Dinant Synclinorium and rocks that belong to the Lower Devonian cover (Ardenne Anticlinorium) of the Stavelot Inlier. The followed stratigraphic division is taken from Dewalque (1899) and Lohest & Fourmarier (1902):

- the "Gc" Formation, of Lochkovian age, is made up of shales;
- the "Cb1" Formation, Pragian in age, is made up of sandstones;
- the "Bt" Formation, of Upper Emsian age, is made up of red sandstones and shales;
- the "Cobn" and "Coa" formations, Lower Eifelian in age, are made up of shales and sandstones;
- the "Gva" and "Gvb" formations, Givetian in age, are made up of various (stromatoporoid) limestones;
- the "Fr1m" Formation, of Frasnian age, is made up of nodular shales;
- and the "Fr1o" Formation, of Frasnian age, which is made up of limestones.

In the Stavelot Inlier, the fault displaced 5 formations. The stratigraphic division is taken from Geukens (1999):

- the Wanne and the La Venne Formation (of Devillian-Revinian age, "Rv1-2" and "Rv3-4" respectively) are made up of fine grained slates and quartzites;
- the La Gleize Formation (Late Cambrian in age, "Rv5") is made up of black slates and silty slates (i.e. "quartzophyllade" in the old literature);
- the Jalhay Formation (of Tremadoc age, "Sm1") is made up of slates, sandstones and silty slates; and
- the Ottré Formation (dated between the Early and Mid Ordovician, "Sm2"), which is made up of slates and silty slates.

Geometry

The old geological maps (1899, 1902) at 1:40 000 scale (of Dewalque and Lohest & Fourmarier respectively) show a 14 km long fracture with a sigmoidal trace. The western segment displays a NE strike that becomes exactly N-S eastwards. At this time the fault was recognized between the area west of Xhoris to a point1500 m east of Werbomont. The southern dip of the fault would allow the northward uplift of the hanging wall block and the thrusting of Lochkovian rocks over the Frasnian. Another NE-striking fracture, the Herbet Fault, joins the Xhoris Fault in the area east of Xhoris.

In 1930, Blaise investigates and demonstrates the eastern continuation of the fault in the locality of La Gleize. Actually, a segment of that extension in the Cambrian formations was already known and mapped (but not named) by Dewalque in 1899. Blaise also confirms the thrust character of the fault and supposes its continuation farther eastwards.

Ancion (1933) studies the probable link between the Xhoris Thrust and the Theux Fault. He assumes a northeastward continuation of the Xhoris Fault beyond Francorchamps and a connection between the Xhoris and the Theux faults (both dipping to the south, Fig. 113). This theory had already been envisaged by Fourmarier (1928b).

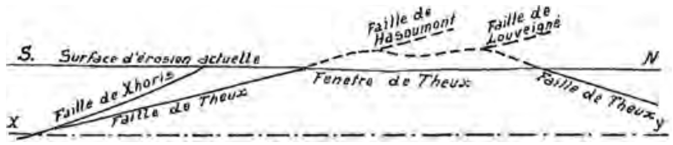

Fig. 113. S-N cross-section sketch showing the relationship between the Xhoris and the Theux faults (Fourmarier, 1928b).

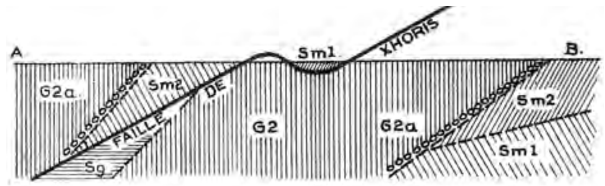

Fig. 114. WSW-ENE cross-section through Werbomont (Lhoest, 1935). Sm1 = Tremadoc. Sm2 = Early to Middle Ordovician. G2 = Lochkovian. Sg = Pragian.

Lhoest (1935) studies the eastern continuation of the fault beyond Werbomont. He considers it to be a listric fault with an undulating surface that, in the vicinity of Chevron, delimits two Upper Cambrian or Lower Ordovician klippes in the Lochkovian autochthon (Fig. 114).

A segment of the Xhoris Fault, also named the Bois de Stalon Fault, was initially a separate fracture described by Geukens in 1950. This reverse NE-striking fault was recognized over a strike length of 14 km. Studying the eastern continuation of the Xhoris Fault in 1952, Geukens himself made the connection between the Xhoris Fault in the west and the Bois de Stalon Fault in the east. The new trace of the fault extended to the NE of Stavelot.

Recent data relating to the Xhoris Fault are due to Geukens (1986, 1999) who mapped the Stavelot Massif. The map of 1986 shows the eastern extension of the Xhoris Fault under the Permian conglomerates of the Malmédy Graben, i.e. as far as Falize where it connects with the Baugnée-Thyrimont fault system. However, the revision of the map (released in 1999, Geukens, Fig. 115), which is the most recent cartographic resource, displays other interpretations. In this case, the trace of the Xhoris Fault is not continuous but is interrupted by NE-striking normal faults (see below), and moreover, the fault is thought to remain north of the Malmédy Graben.

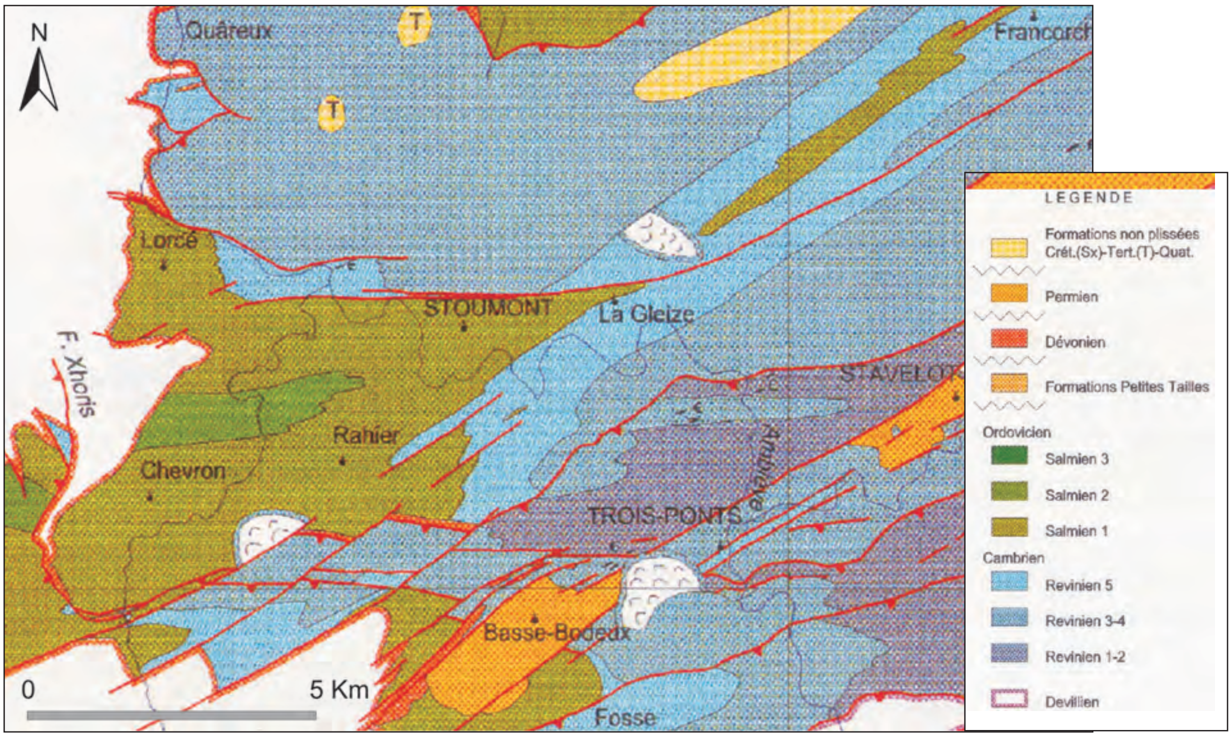

Fig. 115. Geological map and trace of the Xhoris Fault in the Stavelot Massif (Geukens, 1999).

Interpretations

In 1975, Pirlet proposes a link up between the Xhoris Fault in the west and the Jüngersdorf Fault in the east. The reverse offset may reach one or two-dozen kilometres. The major northward thrusting would be related to a late-Variscan uplift of the Stavelot Massif, dated between the "thrust production" (Asturian stage) and the post-Variscan, pre-Mesozoic peneplaination. The emplacement of a granitic intrusion under the Stavelot Inlier is considered.

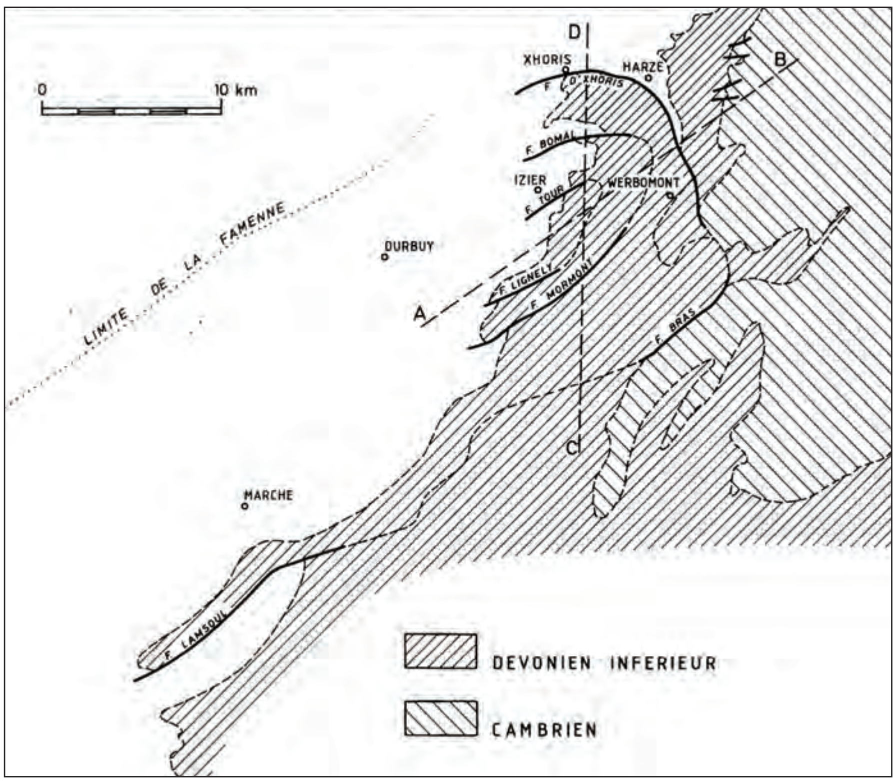

Fig. 116. Linking between the Xhoris and the Lamsoul faults (Graulich, 1983).

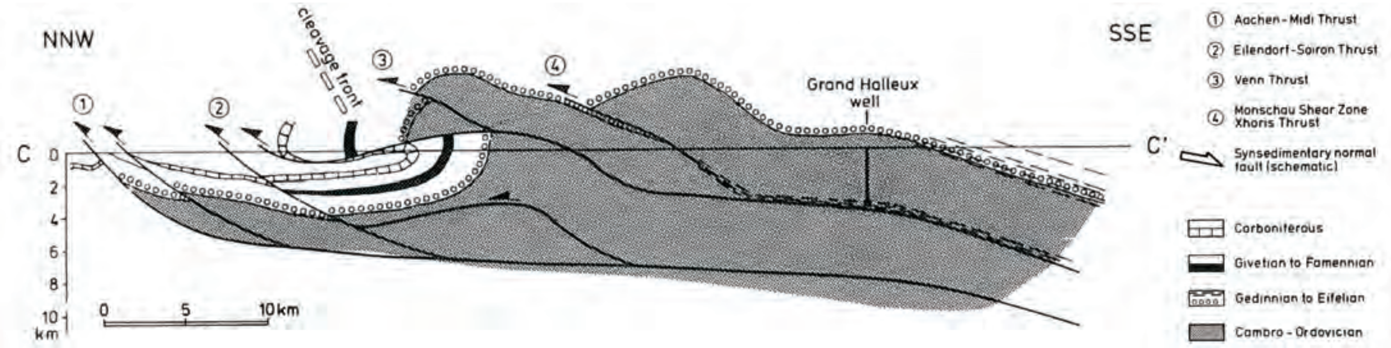

Fig. 117. NNW-SSE cross-section through the Stavelot-Venn Anticlinorium (Fielitz, 1992).

Graulich (1983) suggests that the Xhoris Fault is a branch of a major landslide bulge or "loupe de glissement". This tectonic framework involves connections between the Xhoris, Bra and Lamsoul faults (Fig. 116). The late-Variscan uplift of the Stavelot Massif would have produced this southwestward sliding movement. However, this theory is strongly criticized by Geukens (1984) who imagines that the Xhoris Fault is a major thrust that demarcates two tectonic units within the Stavelot Massif. He assumes no connection between the Xhoris and Bra faults.

In 1992, Fielitz presents new considerations of the Xhoris Fault describing it as a probable SW extension of the Monschau shear zone (Fig. 112). Interpretation of seismic profiles, (e.g. the profile C-C' in Fig. 117), suggests a connection at depth of the Xhoris Thrust-Monschau shear zone with a major subhorizontal plane. The latter is attributed to the Eilendorf-Soiron Thrust or possibly to the Midi Thrust. The Monschau shear zone is interpreted as the effect of the contractional inversion along synsedimentary normal faults that acted during the Early Devonian. The length of the apparent thrust as measured on the cross-section (Fig. 117) is 5 km.

Sintubin & Matthijs (1998) consider that the Theux, Eupen, Xhoris and Venn thrust faults (northern part of the Stavelot Inlier) form an equivalent to, or an eastern extension of, the Variscan front thrust (i.e. the Midi-Eifelian Fault). The authors suggest, "the Xhoris Thrust, and its ductile equivalent to the northeast (the Monschau Shear Zone, Fielitz, 1992), would in this case be the southernmost equivalent of the Variscan front thrust in the eastern part of the Ardenne Allochthon" (Fig. 118). Later, the post-deformational Mesozoic-Cenozoic uplift of the Hautes-Fagnes area would have resulted in the curvilinear distortion of the Xhoris Thrust.

Geukens (1999) believes that the trace of the Xhoris Fault is interrupted and displaced by normal faults that are parallel to and related to the subsiding tectonics of the Malmédy Graben. He also proposes that the northward movement of the Dinant Synclinorium is due to structures including Xhoris Thrust. The aspect of its trace is influenced by the uplift of the Stavelot inlier, which is coeval or later than the fault.

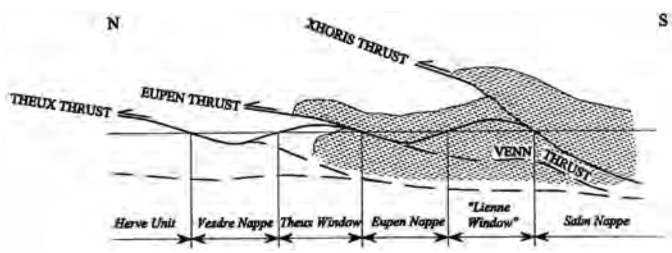

Fig. 118. The four major thrusts (Theux, Eupen, Venn and Xhoris) in an overstep sequence for the northern part of the Stavelot Inlier (not to scale) (Sintubin & Matthijs, 1998). Hatched area = Lower Palaeozoic basement.

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Gosselet, 1888.
Graulich, 1983.
Lhoest, 1935.
Lohest & Fourmarier, 1902.
Pirlet, 1975.
Sintubin & Matthijs, 1998.

7. Map ant table synthesis

As a synthesis, the cartography of the faults studied is in progress (Fig. 119). The map enables to notice the progression of the inventorying work. A table resuming the major geometric data relative to the faults is also provided (Table 1). The updatings of both the structural map and the summary table will be provided at the end of the “Faults Project”.

The inventorying of faults in Belgium will not be limited to the publication of several simple catalogues (i.e. Professional Papers of the Belgian Geological Survey). When data over multiple faults will be sufficiently available, an attempt of ordering the faults will be undertaken. This classification will enable us to establish a “hierarchy” or an “ordering” between the faults. Classification criteria are not yet well defined but the length of both the trace and the offset will most likely be taken into consideration. Finally, an electronic open access database of the descriptive data sheets of the faults will be envisaged.

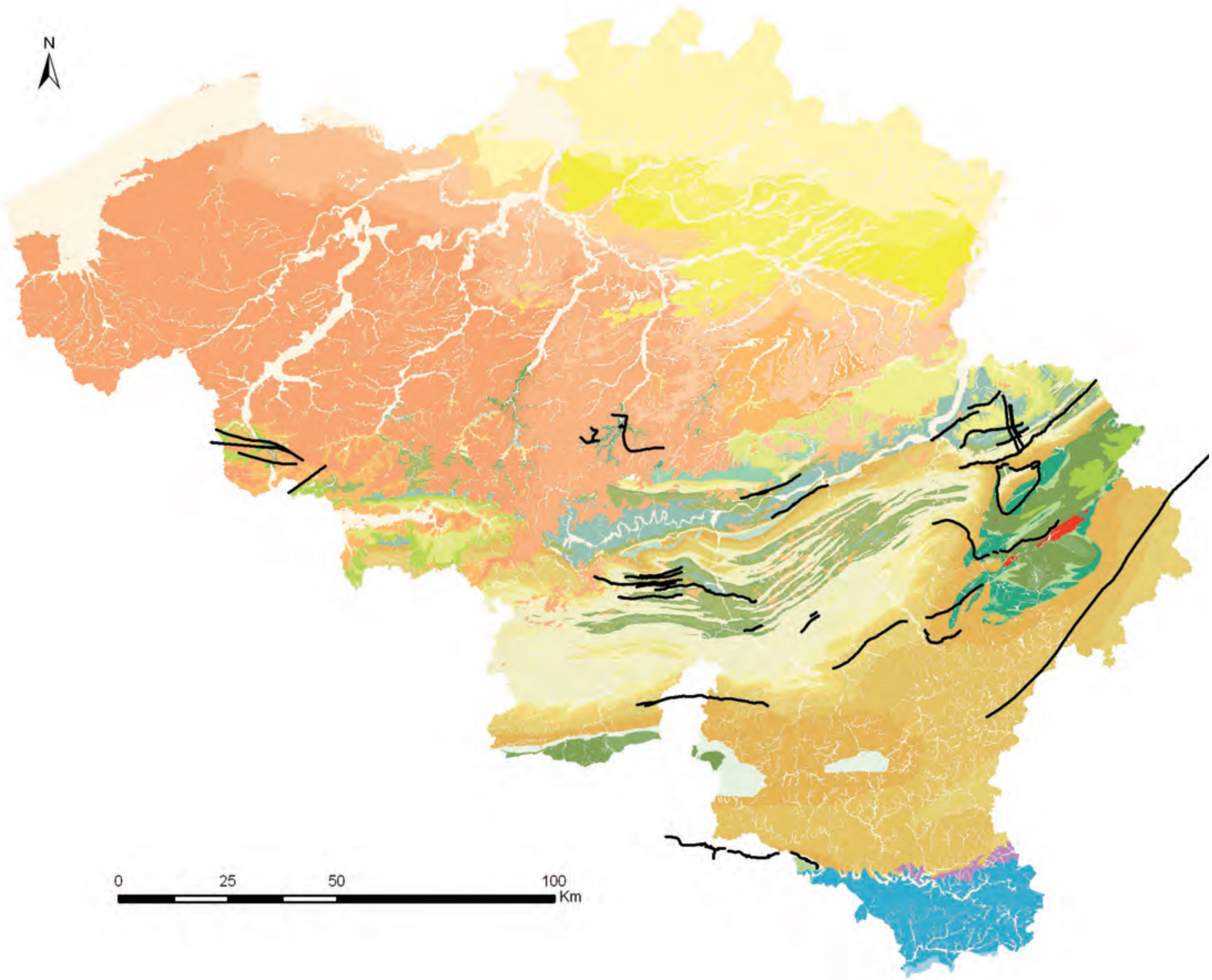

Fig. 119. Map of the faults studied. Used data are the most recent one. Lithostratigraphic background modified from http://www.onegeology.org. Legend corresponds to the International Stratigraphic Chart (http://www.stratigraphy.org).

Table 1. Summary table of the main structural features of the faults concerned. Used data are the most recent one. The direction (strike) of the fault trace is a general trend (L = longitudinal; T = transverse). The dip constitutes a local observation and corresponds generally for the thrusts and normal faults to the minimum and the maximum value observed respectively. The strike-slip is given when constituting the main component of the offset.

Name	Length (km)	Strike	Dip	Nature	Dip-slip (m)	Strike-slip (m)
Aguesses-Asse	17	L, WSW-ENE to SW-NE	Ag: 30°S; As: 13°S	reverse (thrust)	1100	
Aiglemont	7	L, E-W	gentle S	reverse (thrust)	>10,000	
Amerois	14	T, NW-SE	20-30 to 45°SW	dextral, reverse	200	1200-1600
Boussale	15	L, SW-NE	gentle S	reverse (thrust)	?	
Bruyelle	13	L, WNW-ESE to E-W	subvertical or steep N	N block downthrown	220	
Court-Saint-Etienne	1.5	circular (klippe)	subhorizontal	reverse (thrust)	see Orne Fault	
Denée-Thynes	24	L, WSW-ENE to WNW-ESE	45°S	reverse	900	
Dondaine	16	L, E-W	70°N	reverse	60	
Gaurain-Ramecroix	21	L, WNW-ESE to NW-SE	80°S	reverse	160-170	
Genappe	> 50	L, sinuous	5°N	reverse (thrust)	several km	
Hanzinelle-Biesmerée	16	L, E-W	50°S	reverse	225	
Hanzinne-Wagnée	20	L, E-W	45-55°S	reverse	300	
Haversin	1.5	L, SW-NE	?	reverse	?	
La Roche	> 10	L, NW-SE to SW-NE	75°S	reverse	700	
Lamsoul	21	L, SW-NE to WSW-ENE	70-75°S or subvertical	normal	1000	
Landenne	14.6	L, WSW-ENE	60°N	reverse	920	
Malsbenden	90	L, SSW-NNE	N	reverse	?	
Mettet	9	L, E-W	45°N	reverse	100	
Molinia	5.5	L, SW-NE	75-80°S	reverse, senestral	50	125
Monty	13	T, N-S to NNW-SSE	subvertical or steep E	normal	90	
Mouhy	10	T, N-S to NNW-SSE	60-70°W	senestral, normal	28	100
Orne-Noirmont-Baudecet	35 - 50	L, sinuous	5°N	reverse (thrust)	several km	
Ostende	7.5	T, N-S to NNW-SSE	60-70°W	senestral, normal	50	300
Oster	15	L, WSW-ENE to SW-NE	70-80°S	?	?	
Scry-Bois de Neffe	13	L, E-W	45°S	reverse	50	
Soiron	14	L, WSW-ENE	25 to 45°S	reverse (thrust)	800-1200	
Theux	30	circular (window)	10-15°various	reverse (thrust)	2000-3000 to 5000	
Thozée-Responette	10	L, E-W to WSW-ENE	40-45°S	reverse	100	
Thy	1.9	L, E-W	gentle S	senestral	?	kilometric
Tunnel	16	L, WSW-ENE	20-25°S	reverse (thrust)	see Theux Fault	
Vaulx	10	L, E-W to WNW-ESE	60°N or steep S	dextral	12	?
Vêves	4	L, SW-NE	70-80°S	reverse	25	
Vezin	3.2	L, WSW-ENE	S	dextral, normal	weak	560
Vireux	28	L, WSW-ENE to E-W	70°S to subvertical	normal	375	
Walhorn	40	L, SW-NE to E-W	10-15°S	reverse (thrust)	900	
Xhoris	40	L, sinuous	S	reverse (thrust)	5000	

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