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AN HISTORICAL EVALUATION OF THE GEOSTRUCTURAL RESEARCH ON THE VARISCAN FRONT ZONE IN BELGIUM (WEST OF NAMUR)

by

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ABSTRACT

The Variscan Front Zone, west of Namur, consists of different structural domains : the Brabant Basement, the Devono-Dinantian Cover, the Central Basin, and the Southern Massifs. The Variscan Front itself varies along strike : the Midi Overthrust towards the west, and the Sambre-et-Meuse Massif towards the east.
In this paper a historical review is given of the current geostructural models, developed for these domains. Recent contributions of seismic surveys and deep drillings are evaluated in this respect.
The three-dimensional image of the northern Variscan Externides, as well as the presence of thick evaporitic intercalations within the front zone, can be considered as two major contributions of recent research. Both observations support the concept of a thin-skinned fold-and-thrust belt.
On the other hand, when applying the present-day structural terminology, it becomes clear that the general kinematic image of the Variscan Front Zone, as generally accepted nowadays, has already been put forward early in history. For the structuration of the southern part of the Variscan Front Zone Cornet and Briart (1863) introduced the concept of, what is now called, a fault propagation fold, while Kaisin (1936) introduced the ramp-flat concept for the structuration of the northern part of the Variscan Front Zone.

KEY WORDS

Historical review, structural geology, variscan front zone (Belgium).

1. INTRODUCTION

The northern Variscan Front marks the outer limit of the external part of the Variscan fold-and-thrust belt. This structural complex separates an allochthonous from an autochthonous domain. In Belgium the allochthonous domain, the Midi Massif or Dinant Allochthon, is structurally considered as a dominant thrust sheet. This domain contains the Dinant Synclinorium, the Neufchâteau Syncline, as well as the Lower Paleozoic Stavelot-Venn -, Serpont -, Rocroi -, and Givonne Massifs (fig. 1). Characteristic for the Devono-Carboniferous sequence within the Dinant Allochthon is its schistose nature and the presence of important Lower Devonian deposits. Both characteristics are absent in the autochthonous foreland, which consists of the Lower Paleozoic Brabant Basement and its Devono-Carboniferous cover, the Namur Synclinorium or Namur Parautochthon. The latter domain, structurally characterized by a trailing imbricate thrust system, actually forms the Variscan Front Zone.
The nature of the Variscan Front itself varies along strike. The western and eastern segment of the front is materialised by major overthrusts : the 'Faille du Midi' (Cornet and Briart, 1877), or Midi Overthrust in the west, and the 'Faille Eifélienne', or 'Aachener Uberschiebung' in the east. The central segment consists of the Lower Paleozoic Sambre-et-Meuse Massif.

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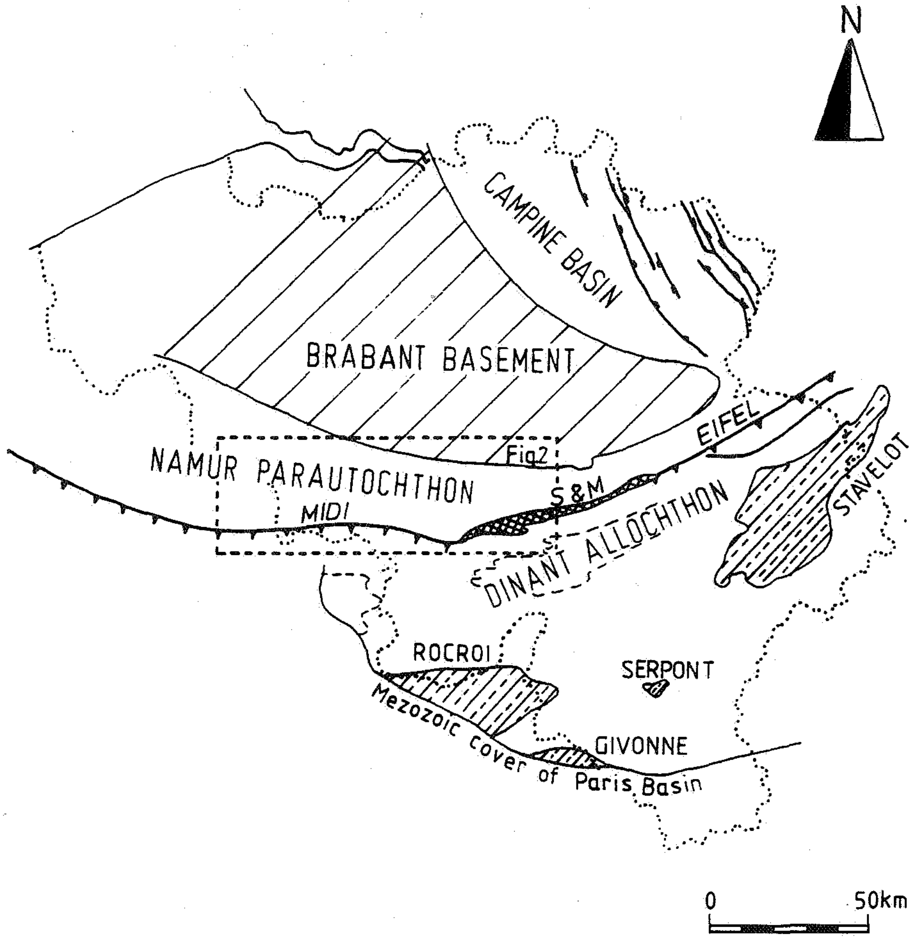

Figure 1. Simplified geostructural map of the Variscan fold-and-thrust belt in Belgium. The Variscan Front, separating the Dinant Allochthon from the Namur Parautochthon, consists of the Midi and Eifel Overthrusts and the Sambre-et-Meuse Massif (M & S).

The main question, dealt with in this paper, is to what extent recent geostructural data, obtained in seismic surveys and deep drillings, contribute to the general understanding of the structuration of the Variscan Front Zone. The significance of earlier observations and interpretations, mainly based on outcrop and mining data, is furthermore evaluated in a historical review, which forms the synthesis of a selection from a very extensive literature. Although the emphasis in this paper lies on a historical inventory of the existing structural models, the author's ideas on the structuration of the Variscan Front Zone are reflected in the applied present-day structural terminology, as well as in personal comments. Further research is however needed to evaluate these ideas and comments.
The presented study is limited to the western segment of the front zone (west of Namur) because of its homogeneous structuration. This homogeneity doesn't apply to the structuration of the eastern segment, which is complicated by the eastwards plunge of the Brabant Basement, as well as by the direct proximity of the Lower Paleozoic Stavelot-Venn Massif within the allochthon.

As a starting point for the discussion the different structural and/or lithostratigraphic domains within the western segment of the front zone are identified. For each of the defined domains the current structural models, as found in literature, are evaluated. Finally, the recent contributions of seismic surveys and deep drillings are placed within this historical context.

2. STRUCTURATION OF THE WESTERN FRONT ZONE

The presented structural map of the western segment of the Variscan Front Zone (fig. 2a) is a compilation of the work of several authors (Renier, 1919 ; Michot, 1927 ; Michot, 1944a ; Bouckaert, 1967 ; Legrand, 1968 ; Beugnies, 1976). The individual maps are mainly based on outcrop and mining data.

The main characteristics of the geometry of the front zone is the general EW-trend of all major fold and fault structures. A general broadening and deepening of the front zone towards the west is

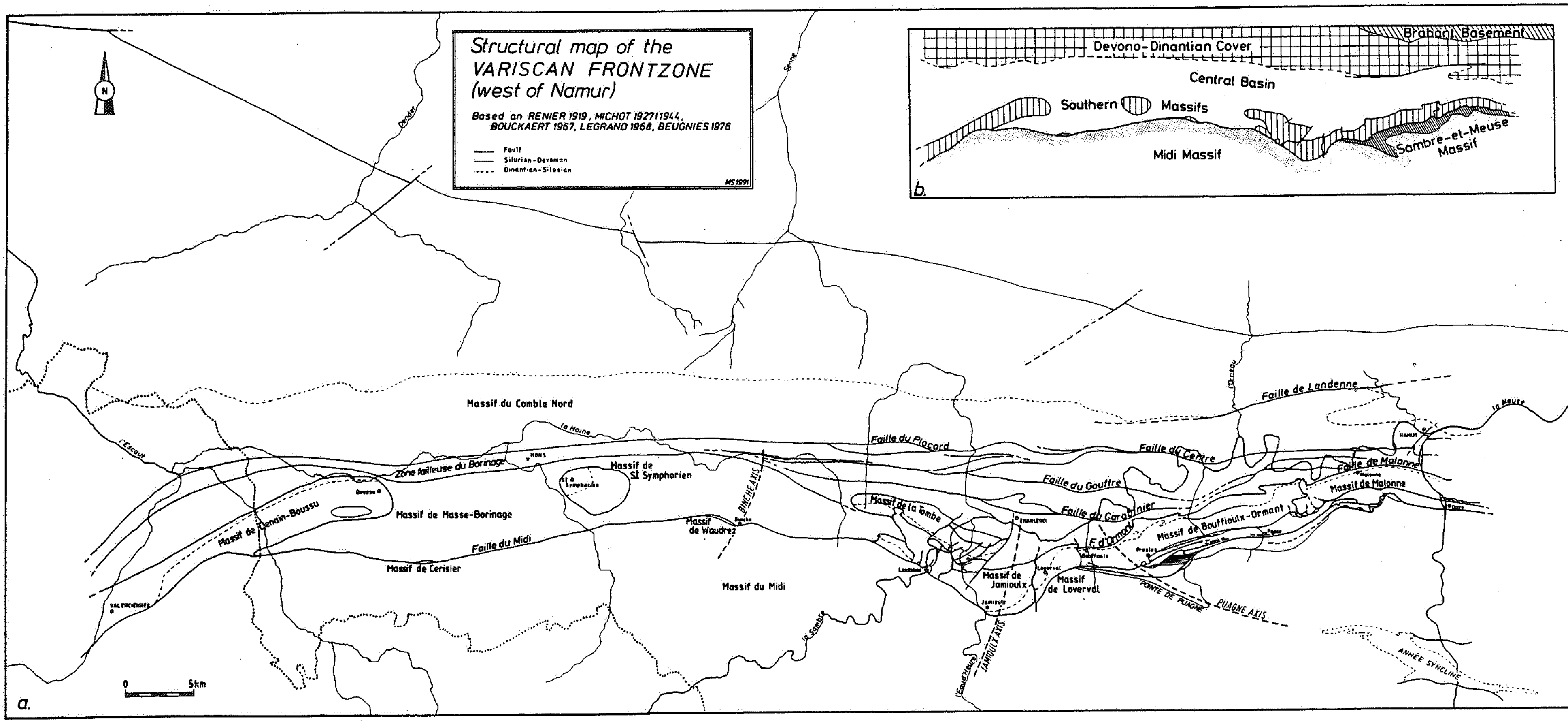

Figure 2. a. Structural map of the Variscan Front Zone, west of Namur (based on Renier, 1919, Michot, 1927/1944 ; Bouckaert, 1967 ; Legrand, 1968 ; Beugnies, 1976). b. Different structural domains in the western Variscan Front Zone.

furthermore observed. The front zone has always been considered as an overturned synclinal structure, mainly because of the occurrence of equivalent Devono-Carboniferous formations in a geometric different disposition on both sides of the central coal basin.
On the basis of lithostratigraphic and geometric criteria, different domains are identified within the front zone (fig. 2b). The autochthonous Brabant Basement, underlies the outermost domain of the front zone, the Devono-Dinantian Cover. This domain consists of gently south dipping, competent, formations of Givetian to Visean age. Geometrically it is considered as the northern limb of the Namur Syncline. The Central Basin, on the other hand, consists of incompetent formations of Silesian age. An imbricate structure is observed. To the west this domain is situated in the direct footwall of the Midi Overthrust. It forms the French-Belgian coal basin. The Southern Massifs, situated just north of the Variscan Front, are structurally considered as the thrusted remnants of the overturned southern limb of the Namur Syncline. The overturned, to totally inverted, internal geometry is typical for this domain. These different massifs are made up of mainly competent formations of Couvinian to Namurian age. To the south the front zone is bounded by the Midi Overthrust. Eastwards, however, this major thrust fault apparently disappears in the Sambre-et-Meuse Massif, which consists of incompetent, schistose, formations of Ordovician to Silurian age. Because this massif forms on the one hand part of the Variscan Front itself, and, on the other hand, is considered closely related to the Southern Massifs, a key role is reserved for this massif in the understanding of the structuration of the front zone.

3. HISTORICAL REVIEW

3.1. The Sambre-et-Meuse Massif

The Sambre-et-Meuse Massif forms a narrow band - between 100 and 1500 meter in width - which can be traced over a distance of 70 km, between Châtelet (near Charleroi) and Engis (near Liège) (fig. 1). The massif consists of mainly incompetent pelitic formations of Ordovician to Silurian age. To the north as well to the south the massif is bounded by a Caledonian unconformity, overlain by Middle, respectively Lower Devonian conglomerates. Structurally it separates the Namur Synclinorium from the Dinant Synclinorium. To the east and the west major overthrusts take over its structural role, composing the Variscan Front. This structural line, separating the two synclinoria, also has a paleogeographical significance, forming the northern limit of the Lower Devonian deposits. In the latter case it is defined as the Condroz Axis.

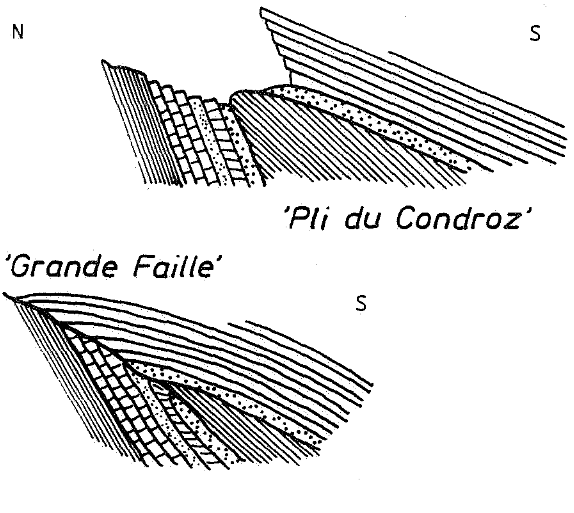

Figure 3. The "Pli du Condroz" and the development of the "Grande Faille" (Gosselet, 1888).

3.1.1. Structural Significance

The structural position of the Sambre-et-Meuse Massif inbetween two synclinoria leads most authors to the assumption that it forms the core of an anticlinal structure. The possible genetic relationship with the structural equivalent Midi Overthrust, west of the massif, gives furthermore rise to various genetic models. All these models are mainly based on direct observations in the field.

Gosselet (1888) defines the 'Pli du Condroz' (fig. 3) as an overturned anticline, which breaks through towards the west, generating the 'Grande Faille'.
A first significant genetic model is elaborated by de Dorlodot (1893/1898). The Condroz Anticline forms the core of a huge recumbent fold, overriding the coal basin (fig. 4). An important frontal extension is needed to make a normal transgressional wedge-out of the Lower Devonian deposits possible. To the west different thrust faults, like the 'Faille d'Ormont' and the 'Faille du Midi', originating in secondary fold structures, truncate the whole anticlinal structure at its base. These different faults form the frontal splay of a major overthrust, which develops westwards because of a basinwards gravitational gliding.
More recently the thesis of a simple anticlinal structure is supported by Klein (1977b). A block folding phase, reactivating the basement along the Condroz Axis, results in the formation of the Condroz Anticline (fig. 5). No important frontal extension is needed however, because of a pre-existing erosional wedge-out of the Lower Devonian deposits along the Condroz Axis.
The model of a simple anticlinal structure implies a discontinuous nature of the Variscan Front. Only

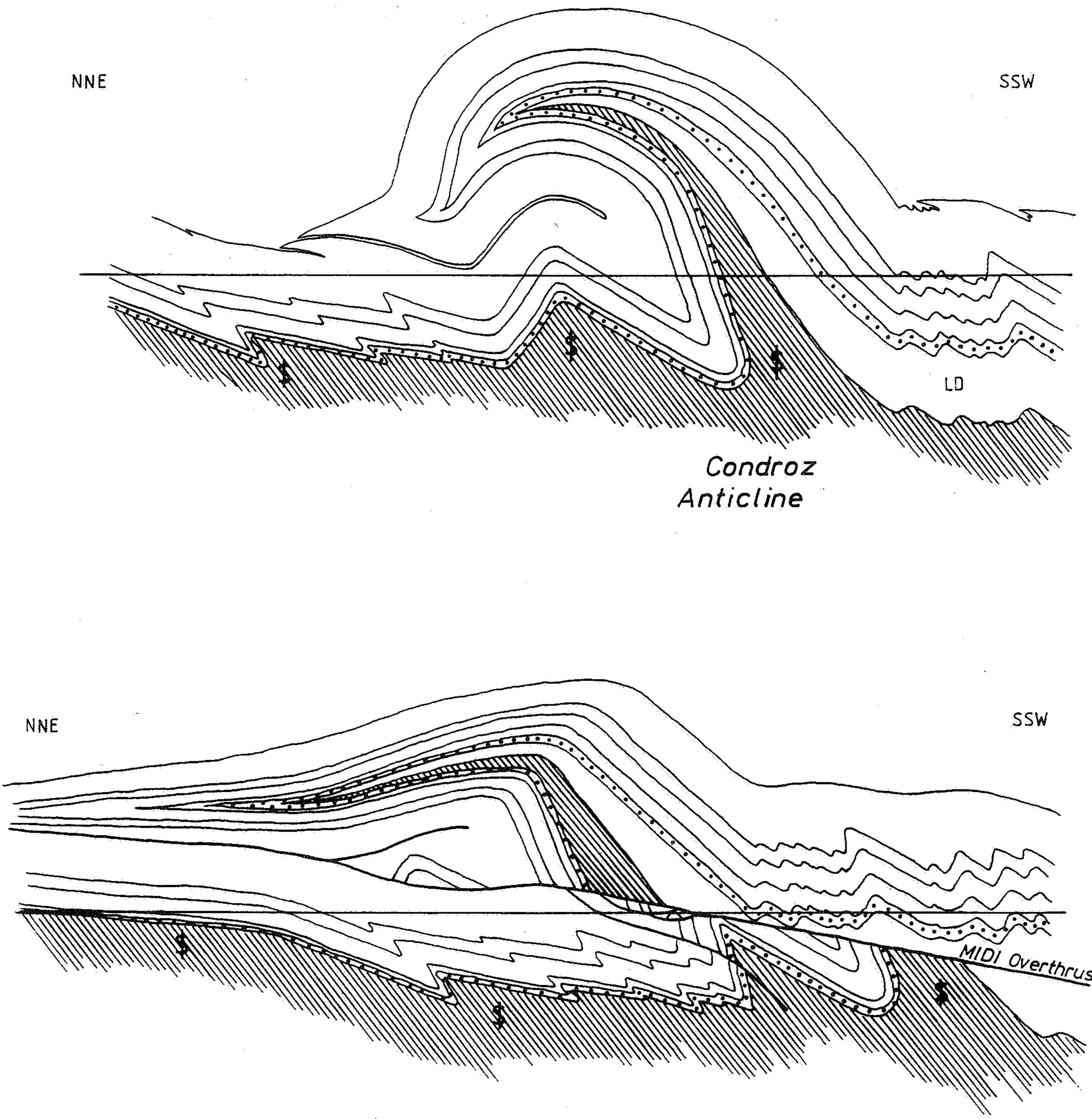

Figure 4. The recumbent fold model of de Dorlodot (1898) : the formation of the Condroz Anticline and its basal truncation by the Midi and Ormont Overthrusts ($ = Lower Paleozoic basement ; LD = Lower Devonian).

towards the west a more advanced shortening causes the development of a thrust system. The overall shortening over the Condroz Axis, as well as the net translation of the Midi Overthrust has therefore to be minimal. The latter is estimated at 13 km by de Dorlodot (1898).

In the more current models a continuous overthrusting does occur along the Variscan Front. This overthrusting is preceeded by the formation, and is the ultimate exaggeration, of a recumbent anticlinal structure. This concept of the 'pli-faille' is first introduced by Cornet and Briart (1863). Cornet (1873) extends the model with the concept of the

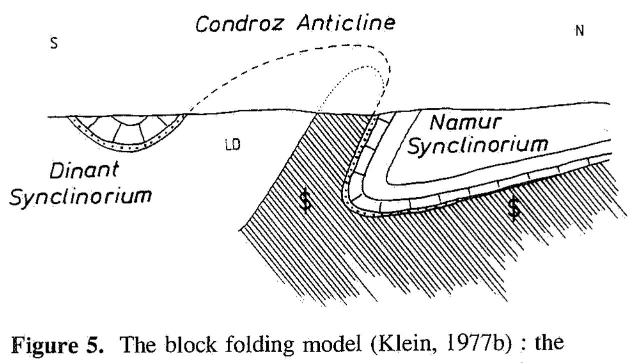

Figure 5. The block folding model (Klein, 1977b) : the Condroz Anticline with an erosional wedge-out of the Lower Devonian deposits ($ = Lower Paleozoic basement ; LD = Lower Devonian).

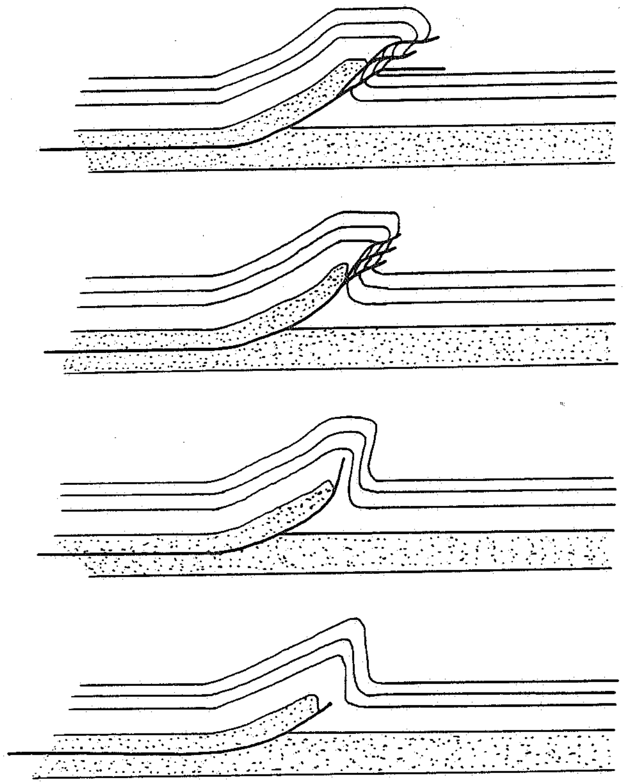

Figure 6. The development of a fault propagation fold with a forward-breaking thrust imbrication. This model is similar to the "pli-faille" model (Cornet & Briart, 1863), combined with the "lambeau de pousée" concept (Cornet, 1873).

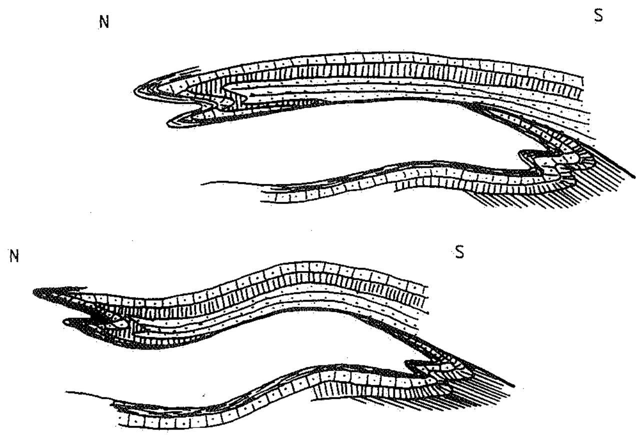

Figure 7. The stretch thrust model (Lohest, 1913).

'Lambeau de poussée', which he defines as a thrust slice, formed in the overturned limb within the direct footwall of the major overthrust. Such a structural disposition can, in the author's opinion, best be described as a fault propagation fold with a forward-breaking thrust imbrication (fig. 6).
Contrary to this model, in which the thrusting occurs along the axial plane of the recumbent Condroz Anticline, Lohest (1913) suggests a stretch thrust model (fig. 7), in which the thrust plane is the result of an extensive stretching of the inverted limb. To date no major stretching has however been observed in the Variscan Front Zone.
Fourmarier (1913), on the other hand, defines the 'Charriage du Condroz' as a series of thrust complexes, like e.g. the 'Maulenne Complex' (de Dorlodot 1907 ; Fourmarier 1908 ; Michot 1944b). These thrust complexes assure the continuity of the Variscan front thrust across the Sambre-et-Meuse Massif. Also Michot (1927/1944a) recognises a series of longitudinal thrust faults of Hercynian age within the massif. Both authors suggest that the Midi-Condroz Overthrust truncates the, originally broader, Condroz Anticlinorium (fig. 8), which is essentially very similar to the model of de Dorlodot (1893/1898). According to Geukens (1964), however, these thrusts, although the result of an Hercynian shortening active since Devonian time, have no genetic relationship with the Midi Overthrust, which itself can not be identified within the massif.
Based on recent contributions from deep drillings and seismic surveys, Raoult and Meilliez (1987) propose a model, which partly falls back on the fault propagation fold model of Cornet and Briart (1863). The geometry of the direct footwall of the Midi-Condroz Overthrust, as observed in the Wépion borehole (Graulich 1961), is considered as the result of a summital truncation of a secondary detachement fold, which developed in front of the dominant thrust sheet (fig. 9). Therefore, the Sambre-et-Meuse Massif is the sliced remnant of the secondary Condroz Anticline, which developed on a basal decollement surface in front of the prograding Dinant Allochthon. The final overthrusting of the latter results in the summital truncation of the whole secondary fold structure.
Le Gall (1992), on the other hand, considers the Sambre-et-Meuse Massif as a remnant of a basement slice, forming part of a ramp anticline, which developed on a blind decollement thrust. He furthermore applies this ramp-flat type of deformation to explain the structuration of the whole front zone (fig. 10).

Finally, some authors (Stainier 1920 ; Renier 1931 ; Raoult 1986) do not call upon the primary formation of the Condroz Anticline. They consider the Sambre-et-Meuse Massif as a thrust sheet within the footwall of the Midi-Condroz Overthrust. Because of its characteristic lithological incompetence, Kaisin (1936) even considers the massif as a broad fault zone, the 'Zone failleuse du Charriage du Condroz' (fig. 11).

The existence of a continuous Midi-Condroz Overthrust, which can be followed over a distance of more than 200 km, implies a major tectonic event within the northern Variscan Externides. Seismic surveys show a hindwards extension of 125 km (Cazes *et al.*,1985) (fig. 19). The maximum thickness of this dominant thrust sheet is estimated at 10 to 15 km. The emplacement of such a major tectonic unit is often related with important net translations. Fourmarier (1913/1933) suggests a net translation of 25 to 40 km, an estimation also

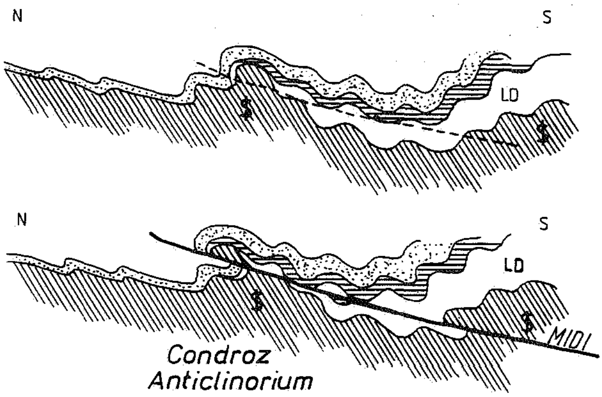

Figure 8. The basal truncation of the Condroz anticlinorium by the Midi-Condroz Overthrust (Fourmarier *et al.*, 1954) ($ = Lower Paleozoic basement ; LD = Lower Devonian).

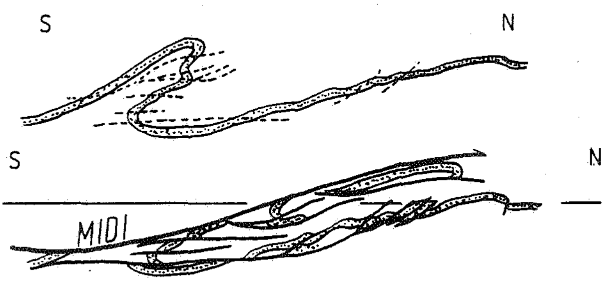

Figure 9. The Condroz Anticline as a thrusted secondary detachement fold in the footwall of the dominant thrust sheet (Raoult and Meilliez, 1987).

supported by Bless *et al.* (1977). Even values of 100 to 120 km has been put forward (Raoult and Meilliez 1987).

Some authors, on the other hand, minimise the importance of the overthrusting within the front zone, based on the lithostratigraphic concordance on both sides of the longitudinal thrust faults within the Sambre-et-Meuse Massif (Bertiaux 1913), or based on the facial resemblance of the Middle Devonian formations on both sides of the Condroz Axis (Coen-Aubert 1988). Even a fixistic model has been proposed (Paproth 1987).

These two viewpoints are however not incompatible when considering the model of a thin-skinned fold-and-thrust belt (Chapple 1978), in which the net translation, although considerable hindwards, can be minimal in the front zone, due to a tectonic thickening within the thrust sheet. This thin-skinned nature of the Variscan Externides is first suggested by Bless *et al.* (1977). Also Meissner *et al.* (1981) support this concept.

Eversince Cauchy *et al.* (1832) suggested a northwards movement of the Dinant Allochthon, the absolute sense of the translation has rarely been questioned. Some authors suggest however an inverse sense. Gosselet (1888) doesn't exclude the possibility of a southwards movement of the Namur Syncline under the Dinant Synclinorium, resulting in scraping tectonics. Paproth (1987) defines a southwards subfluence as the motor of the Variscan Orogeny. Also Matte and Xu Zhi (1988) call upon a southwards, intracontinental, subduction. Finally, because of a contrast in degree of deformation, Bouroz (1989) suggests a southwards subsidence of an actively deformed Namur Basin under a passive Dinant Allochthon.

The presence or absence of a schistosity within the pelitic formations has served for many authors as the main parameter for the determination of the structural dependence of the Sambre-et-Meuse Massif.

Both Michot (1927) and Fourmarier (1939) conclude from the observed absence of a schistosity that the massif is structurally independent of the Dinant Allochthon, which itself is characterised by the overall presence of a schistosity. The massif therefore forms the direct substratum of the Namur Basin. An exception, however, forms the 'Pointe de Puagne' (fig. 2a), an isoclinal Variscan anticline, exhibiting an Hercynian schistosity. This structure belongs therefore to the Dinant Allochthon (Michot 1927). A possible tectonic relationship with structures in the Yvoir area (Anhée Syncline - fig. 2a) is furthermore suggested by Raoult and Meilliez (1987) and Khatir (1990).

After the description of a schistose unit within the Wépion borehole, Graulich (1961) proposes a

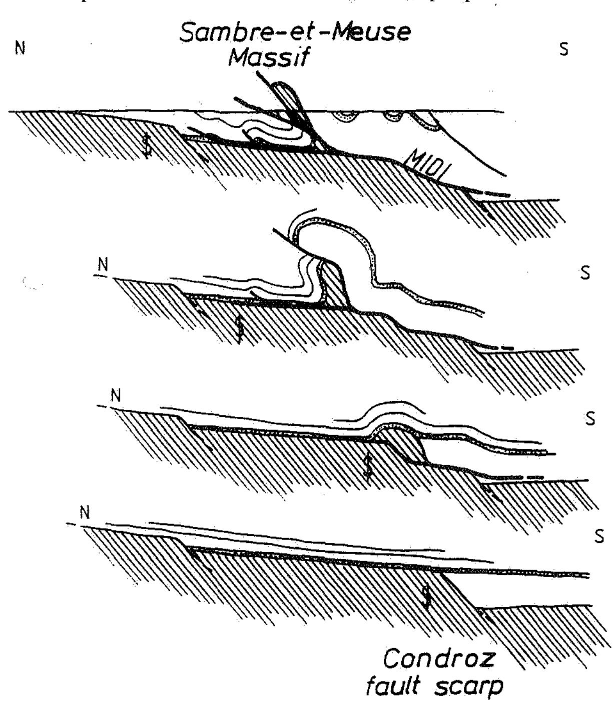

Figure 10. The ramp-flat model with basement involvement (Le Gall, 1992) ($ = Lower Paleozoic basement).

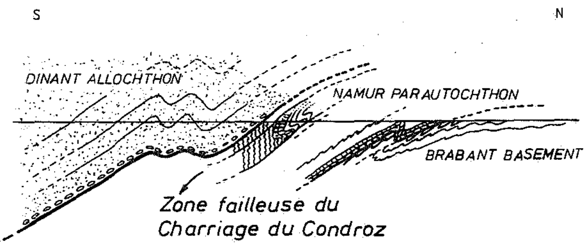

Figure 11. The "Zone failleuse du Charriage du Condroz" and the Variscan front Zone (Namur Parautochthon and Brabant Basement), dominated by ramp-flat type of deformation (Kaisin, 1936).

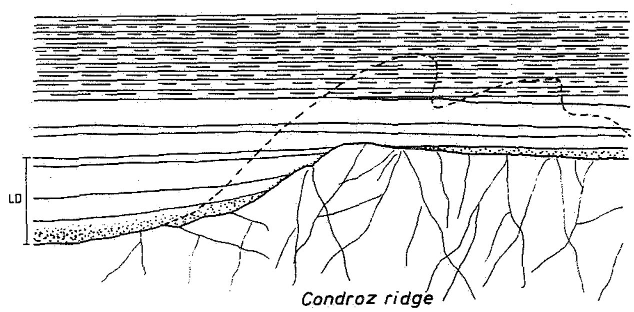

Figure 12. The "Crête du Condroz" (Cornet and Briart, 1877) (LD = Lower Devonian).

threefold subdivision of the massif. An aschistose Sambre-et-Meuse Massif is considered completely independent of both the Namur Syncline and the Dinant Synclinorium, of which the substratum is characterised by a Caledonian, respectively Hercynian schistosity. Based on the same observations, Michot (1978) considers a Neocaledonian overthrusting event, generating the 'Faille mosane', responsible for the superposition of an aschistose Condroz tectofacies on a schistose Brabant tectofacies.

This whole subdivision is however invalidated by Geukens (1964), who recognises a schistosity in the whole massif.

In the author's opinion, the main problem, concerning this discussion on the schistosity, is the lack of a proper definition of the observed schistosity in question. Sintubin (1992) deals with this problem more extensively.

3.1.2. Paleogeographic Significance

In most models the Condroz Axis is considered as a primary structure. Only in the structural model of Raoult and Meilliez (1986) the Condroz Anticline forms a secondary structure within the folded foreland of the Dinant Allochthon (fig. 9).

As a primary structure the Condroz Axis plays a key role in the disappearance of the Lower Devonian deposits as well as in the emplacement of the Midi-Condroz Overthrust system. To explain the sudden disappearance of the Lower Devonian deposits north of the Condroz Axis sedimentary as well as tectonic causes are adopted.

Cornet and Briart (1877) (fig. 12), as well as Gosselet (1888), describe the 'Crête du Condroz' as a ridge, against which the Lower Devonian deposits wedge out rapidly.

de Dorlodot (1898), on the other hand, considers an, originally broader, Condroz Ridge as the northern limit of the Lower Devonian deposits, which thin out gradually. A similar normal transgressional onlap, but more to the north onto the Brabant Basement, is put forward by Klein (1977) and Graulich (1982). A Neocaledonian uplift of the Brabant Basement, followed by erosion (Klein 1977), or by the Midi-Condroz overthrusting itself (Graulich 1982) (fig. 13), is finally considered responsible for the sudden disappearance of the Lower Devonian deposits north of the Condroz Axis.

This Neocaledonian uplift is also called upon by Fourmarier *et al.* (1954) to dismantle a northern Devonian Brabant Basin, separated from the Dinant Basin by a narrow Condroz Ridge. According to his model for the development of a slaty cleavage, Fourmarier did indeed need this Lower Devonian overburden on top of the Brabant Basement to explain the presence of a schistosity within the Cambro-Silurian formation of the basement.

For Michot (1980) this Neocaledonian phase is a major compressional event, generating the 'Ride Bollandienne', a mountain chain parallel to the Condroz Axis.

Beugnies (1964) defines the 'flexure condrusienne' as a cratonic flexure line, which influences the whole paleozoic history of the northern Variscides. Because of a pronounced subsidence during the Early Devonian south of this line, a thick pile of sediments is generated, rapidly wedging out to the north.

A similar model, making use of extensional growth faults along a Condroz Fault Scarp is suggested by Bless (1989) (fig. 14a), Meilliez and Mansy (1990) and Le Gall (1992) (fig. 14b). Both views can in fact be considered as a modern variant of the configuration, which Cornet and Briart (1863), as well as Beugnies (1964), proposed.

Recent petrographic (Hance *et al.*, 1991) and textural work (Sintubin submitted) finally shows the very low degree of evolution of the Caledonian sediments within the Sambre-et-Meuse Massif, supporting the idea of a cratonic high along the Condroz Axis.

The emplacement of the Midi-Condroz Overthrust is determined by this cratonic flexure line (Beugnies

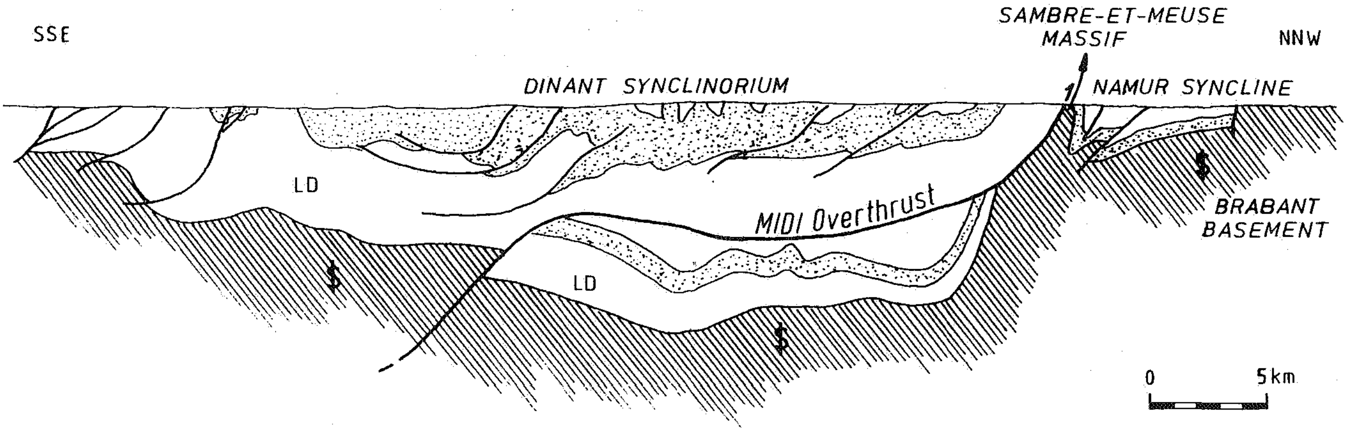

Figure 13. The sudden dissapearance of the Lower Devonian deposits in the Variscan Front Zone explained by the overthrusting (Midi Overthrust) over the "missing link (Graulich, 1982) ($ = Lower Paleozoic basement ; LD = Lower Devonian).

1964). Already Briart (1893b) considers the Condroz Axis as a weak feature within the Variscan substructure. The sudden disappearance of a 1600 m thick competent series, due to an erosional, a tectonic, or a transgressional wedge-out, creates a supplementary weakness in the whole structure. In the tension-compression model of Bless (1989) the growth faults are inverted, ultimately generating listric overthrusts.

More to the west of the Sambre-et-Meuse Massif other Lower Paleozoic massifs are observed within the front zone.
In the inverted Denain-Boussu Massif (fig. 2a) pelitic formations of Ordovician to Silurian age "underlie" Middle Devonian formations (Dejonghe 1973). This complex is the thrusted remnant of the northern overturned limb of the Boussu Anticline, which exhibits an 'en echelon' relationship with the Condroz Anticline (Michot 1980).
Also within an intensive shear zone in the evaporitic series, drilled in the Epinoy borehole, a thrust slice, consisting of Lower Paleozoic material, is described (Bouroz 1989).
Finally, near Liévin and in the Boulonnais, formations of Ordovician to Silurian age are observed conformably underlying Lower Devonian deposits within the hangingwall of the Midi Overthrust (Bouroz 1960/1989). Raoult (1986) considers these conformable massifs as thrust slices within the footwall of the major overthrust, suggesting a similar origin for all the Lower Paleozoic massifs in the Variscan Front zone.

3.2. The Southern Massifs

The Southern Massifs, situated north of the Variscan Front, are a series of structural complexes, consisting of mainly competent Devono-Carboniferous formations.
The internal structure is characterised by an overturned, or even inverted, geometry. Towards their northern front complex folding is observed systematically within the inverted series.
The presence of important overturned massifs in the direct footwall of a major overthrust can be considered as a main argument in favour of the concept of a fault propagation fold (Raoult and Meilliez 1987). Recently Meilliez and Mansy (1990) described this overturned disposition rather as the result of an 'enroulement' of pre-existing structures during the final overthrusting of the Dinant Allochthon.

Two groups of massifs are distinguished. Both are separated by the transverse Jamioulx Axis (fig. 2a). The eastern group, consisting of the Malonne -, Bouffioulx-Ormont -, Loverval -, and Jamioulx Massifs (Bouckaert 1967 ; Kaisin Jr. 1935), is considered as the thrusted remnant of the overturned southern limb of the Namur Syncline (de Dorlodot 1892). Part of the Sambre-et-Meuse Massif forms the direct substratum of the Middle Devonian formations within the Malonne - and Bouffioulx-Ormont Massifs (Michot 1944a), which implies a close genetic relationship. Therefore Michot (1980) puts forward the hypothesis that all massifs of the eastern group originate as part of a west-dipping Condroz Anticline.
The distinct massifs are closely related, which is supported by a clear similarity in both the internal geometry and the lithostratigraphic sequence. In the classical model (de Dorlodot 1892 ; Kaisin Jr. 1935 ; Michot 1944a) the mutual geometric relationship is one of an imbrication of thrust slices within the footwall of the major Midi-Condroz Overthrust. Delmer (1988), on the other hand, considers all these massifs as remnants of one unique thrust sheet, which broke up by means of transverse faulting.

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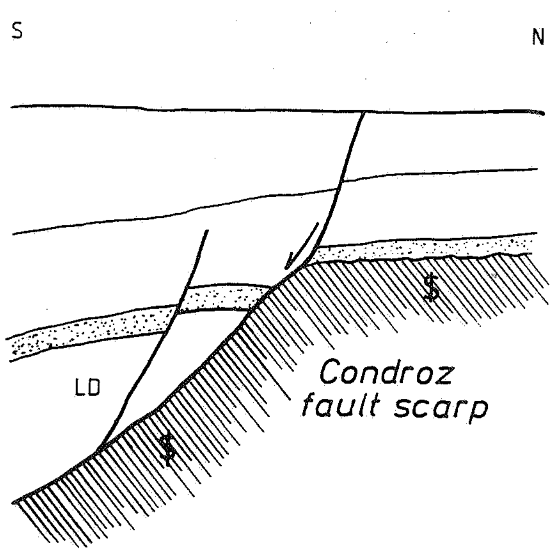


Figure 14. The Condroz Fault Scarp ($ = Lower Paleozoic basement ; LD = Lower Devonian) : a. as a growth fault (Bless *et al.*, 1989).

When considering a possible relationship with neighbouring domains, the observed facial analogy (Lacroix 1974 ; Coen-Aubert 1988) between the Middle Devonian sequence within the massifs and the equivalent sequence in the Dinant Allochthon, just south of the Condroz Axis, does imply a close genetic relationship between both domains. No such relationship can be derived for the Devonian formations on both sides of the Namur syncline.
Another question concerns the possible continuation of this series of massifs west of the Jamioulx Axis. Fourmarier (1913) first considers the Masse-Borinage Massif as the western continuation of the Bouffioulx-Ormont Massif. A similar concept is suggested by Renier (1931) and Kaisin Jr. (1947), when discussing the 'Zone failleuse d'Ormont-Chamborgneau'. Fourmarier (1920b) finally proposes the disappearance to the west of these massifs, all combined in the huge Carabinier Massif.

The western group consists of the La Tombe - (Briart 1893a ; Fourmarier 1911 ; Beugnies 1976), St. Symphorien -, and Boussu-Denain Massifs (fig. 2a), all type examples of the 'lambeau de poussé' concept of Cornet (1873). All three massifs are situated along the axis of the Flénu-Maurage Syncline within the Masse-Borinage Massif. Only the La Tombe Massif is still exposed. The St. Symphorien Massif is only known from mining activity and borehole data. This also applies to a large extend to the Boussu-Denain Massif, of which an outcrop existed near Boussu (in the valley of the Ruisseau d'Haneton). The internal geometry is characterised by a pronounced overturning, or even a total inversion, of the Devono-Carboniferous sequence.

Both the specific disposition of the massifs in the middle of the Central Basin, and the inverted internal geometry is explained by Delmer (1977a), as well as by Michot (1980), as the result of a post-Hercynian halokinesis. The basinwards gravitational gliding caused the total inversion, as well as the separation of the massifs of their rootzone. Remnants of the latter are found in the Waudrez - (Faly 1878) and Cerisier Massifs (fig. 2a). Within the direct footwall of the Midi Overthrust similar horses, consisting of Dinantian limestone, are furthermore observed (Delmer 1977b). Renier (1934), however, considers these massifs as part of the overturned limb of the Flénu-Maurage Syncline. Already Cornet (1873) and Briart (1893a) put forward a mutual genetic relationship between the three massifs. Fourmarier (1913) considers them as the erosional remnants of a unique massif. Briart (1893a) furthermore suggests a genetic relationship with the eastern massifs. Building on his hypothesis, Delmer (1988) extends his unique thrust sheet in the east towards the west, thus defining the 'Grande Massif Charrié', for which he proposes however a northern origin.

b.

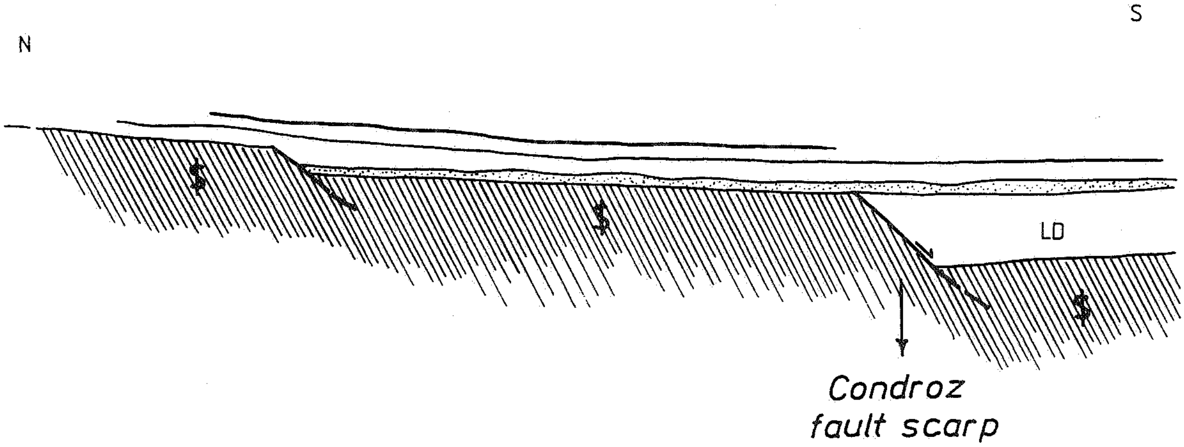


Figure 14. The Condroz Fault Scarp ($ = Lower Paleozoic basement ; LD = Lower Devonian). b. as a normal fault (Le Gall, 1992).

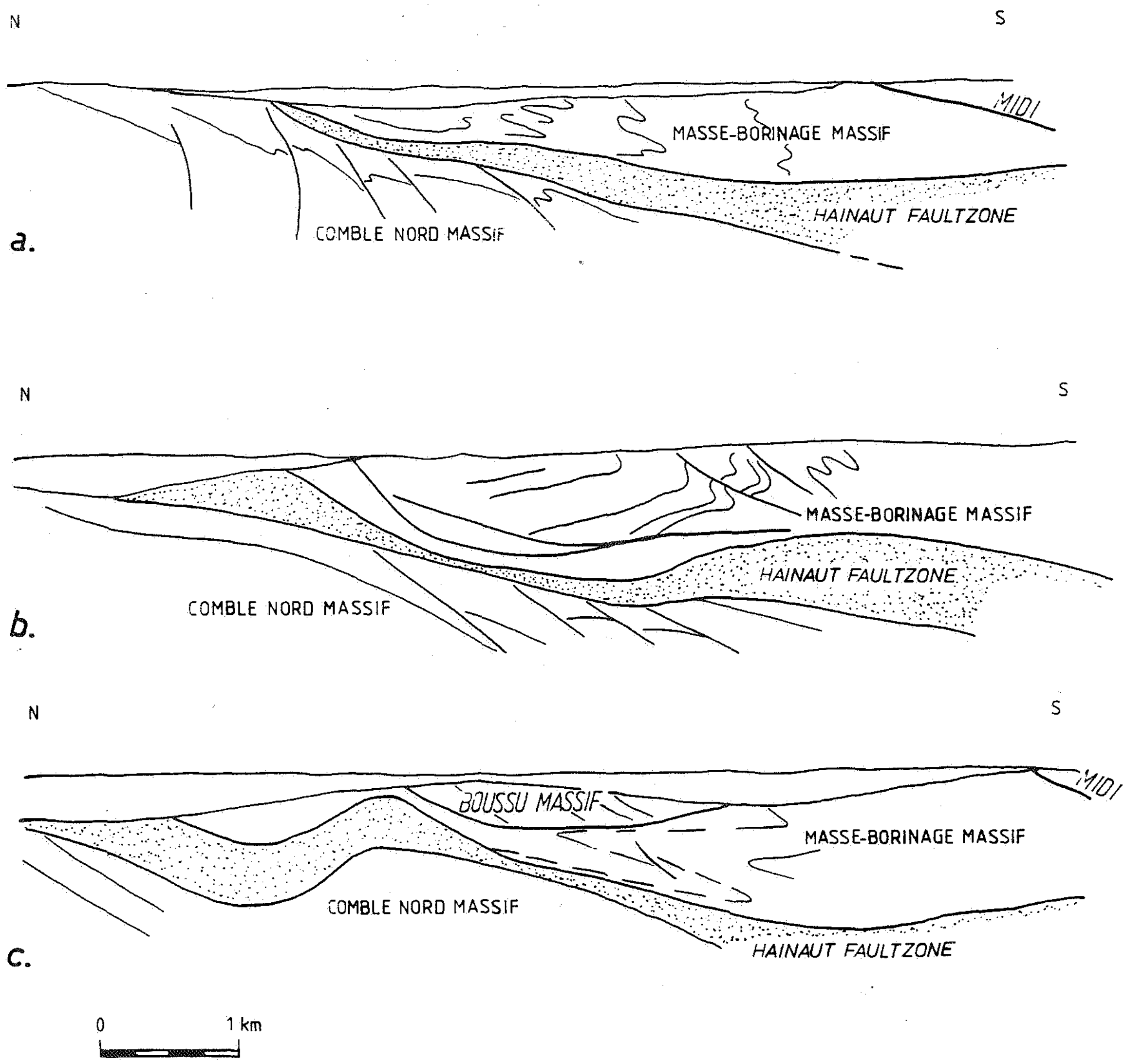


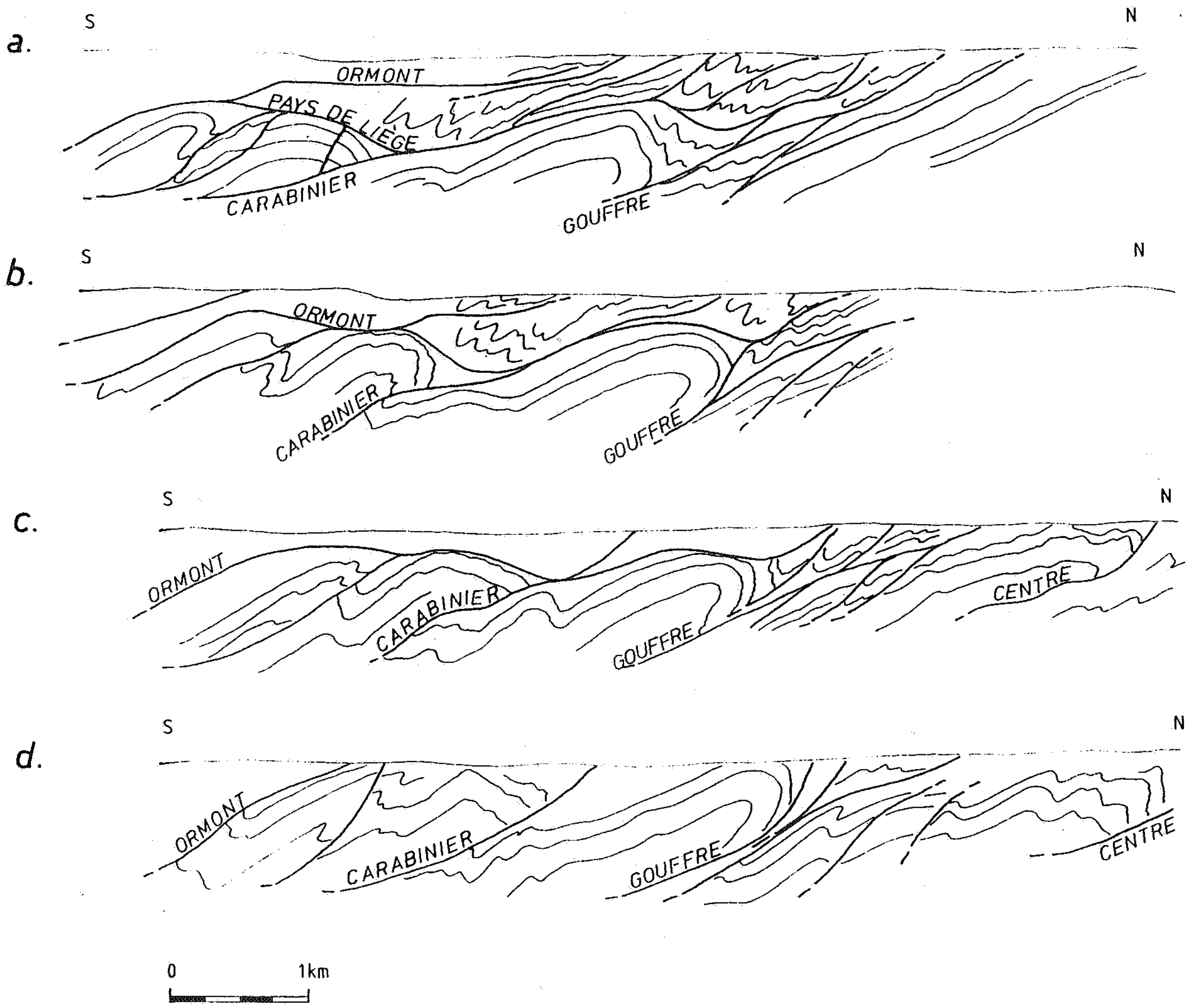
Figure 15. Typical structural profiles across the western part of the Central Basin (after Delmer, 1977b), with the dominant presence of the Hainaut Fault Zone : a. 16.8 km east of Mons ; b. 6 km west of Mons ; c. 16 km west of Mons.

According to Kaisin (1936) no direct genetic relationship exists between both groups of massifs.The Dinantian formations, observed in the western massifs, exhibit a more southern facies. This observation does support the model of Michot (1980) in which the Condroz Anticline has an 'en echelon' relationship with the more southern Boussu Anticline, from which the eastern, respectively western massifs originate. In this latter case a relationship between the eastern massifs and the Masse-Borinage Massif seems more likely.
More to the west, in the Epinoy borehole, equivalent, 1500 m to 2000 m thick, overturned massifs are observed in the footwall of the Midi Overthrust (Raoult 1986).
By placing the anticlinal structure, from which these overturned massifs originate, at least 60 km hindwards in the footwall of the Midi Overthrust, Raoult (1986) finally implies important displacements during the overthrusting of the allochthon.

3.3. The Central Basin

The central part of the Namur Syncline consists of incompetent molasse deposits of Silesian age. Both the characteristic incompetent nature of these paralic deposits, and the contrast in competence with regard to the Devono-Dinantian formations in the neighbouring domains determines the structural behaviour within the Central Basin.

The internal geometry of the Central Basin differs on both sides of the transverse Binche Axis (Marlière 1950) (fig. 2a).
The western part is characterised by a threefold structural disposition (Delmer 1949) (fig. 15). The Comble Nord Massif is commonly considered as part of the autochthonous Devono-Carboniferous Cover of the Brabant Basement (Delmer 1949). Kaisin (1936), however, suggests a structural independence with the Dinantian formations. This



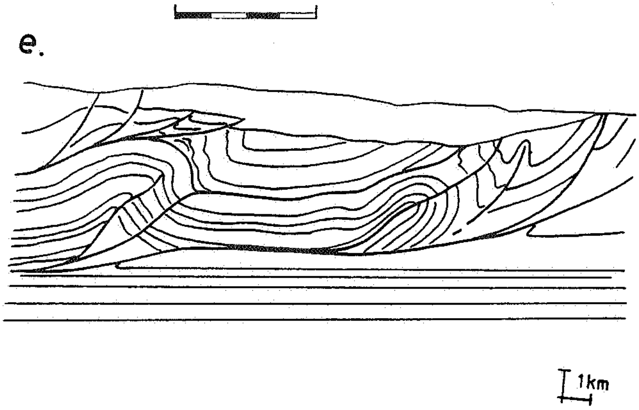


Figure 16. Typical structural profiles across the eastern part of the Central Basin (after Kaisin, 1947), with the characteristic ramp anticlines in the hangingwall of the Carabinier and Gouffre thrusts : a. 38 km east of Mons ; b. 39 km east of Mons ; c. 40 km east of Mons ; d. 41 km east of Mons ; e. type-example of a fault bend fold system : Whitney Canyon and Ryckman Creek Anticlines (Wyoming, USA) (after Lamerson, 1982).

concept of a decollement surface at the Silesian-Dinantian interface is taken over by Raoult (1986). The 'Zone failleuse du Hainaut' is the dominant feature within this part of the Central Basin (Briart 1897 ; Delmer 1949). In the classical model (Fourmarier 1913) this fault zone, which can be up to 500 m thick, is caused by the westwards convergence of the thrust faults, observed in the eastern part of the basin. Other authors (Renier 1934 ; Kaisin Jr. 1947 ; Marlière 1950) suppose that the imbricate structure, observed in the eastern part of the Central Basin, can be traced under this subhorizontal fault zone, which itself forms the base of an important thrust sheet. In the latter case the fault zone can be followed towards the east into the 'Zone failleuse d'Ormont-Chamborgneau' (Kaisin Jr. 1947), which implies the identity of the Masse-Borinage - and the Bouffioulx-Ormont Massifs. With the discovery of evaporitic levels in the underlying Devono-Dinantian formations, Delmer (1977a), as well as De Magnée *et al.* (1986), describe the Hainaut Fault Zone as the result of a halokinesis, which led to the formation of a gravitational olistostrome on a continental surface, generating the observed structural configuration.

The Hainaut Fault Zone forms the base of the Masse-Borinage Massif. Characteristic are the thick Westphalian B and C deposits (Delmer 1977a), which is caused by a pronounced subsidence in the 'Auge Hennuyère'. The internal structure is dominated by the overturned Flénu-Maurage Syncline, along which the La Tombe -, St. Symphorien -, and Boussu-Denain Massifs are situated.

The eastern part of the Central Basin is characterised by a typical imbricate thrust system, which developed in a monoclinal foreland (Briart 1893b/1897 ; Kaisin 1936 ; Fourmarier *et al.*, 1954). This trailing imbricate fan is characterised by all types of splays. The timing of the emplacement of the imbrication is suggested by Briart (1893b) as an break-back sequence. From north to south the following units are observed (fig. 2a) : Comble Nord -, Placard -, Gouffre -, Pays de Liège -, and Carabinier Massifs.
These different units, exhibiting a stratigraphic independence (Smeysters 1900), are limited by longitudinal, mutual conformable, thrust faults. Typical is the variation in net translation along strike (Smeysters 1900). The displacement is transferred from one fault to another in 'en echelon' overlap zones. Also strike-slip components are observed (Demeure 1913). Most major faults carry an anticlinal structure in their hangingwall (fig. 16). Along strike the faults disappear in these fold structures. Fourmarier (1920a) considers these structures as fault propagation folds, which goes back to the 'pli-faille' concept of Cornet and Briart (1863). Kaisin (1936), on the other hand, sees these folds rather as ramp anticlines (fig. 16e), supporting a ramp-flat model, on which he moreover calls upon to explain the structuration of the whole front zone. In this model the thrust faults do converge towards the bedding planes, along strike as well as along dip. This matches very well with the observed decrease in deformation with depth within the Silesian formations (Cornet and Briart 1863 ; Smeysters 1900 ; Fourmarier 1913). Contrary to the concept of Kaisin (1936), in which a decollement surface is considered at the Silesian-Dinantian interface, the latter authors suppose a convergence of the listric thrust faults within the Silesian formations. In the latter case, the underlying, undeformed, Comble Nord Massif occurs conformable with the Devono-Dinantian Cover.

3.4. The Devono-Dinantian Cover

The outermost domain of the Variscan Front Zone forms the direct cover of the autochthonous Brabant Basement. For most authors the Comble Nord Massif makes part of this autochthonous northern limb of the Namur Syncline. Kaisin (1936), as well as Raoult (1986), suggests however a structural independence by defining a decollement surface at the Silesian-Dinantian interface.
Structurally, this domain is characterised by a simple, south dipping, monoclinal geometry. Structures, observed in this competent sequence, show evidence for a tangential deformation (Fourmarier 1920a ; Kaisin 1936 ; Raoult and Meilliez 1987).

A dominant paleogeographic feature in the western part of this domain is the 'Auge Hennuyère' (Delmer 1977b), or 'Sillon Borain' (Michot 1980), characterised by thick Devono-Carboniferous deposits. This centre of pronounced deposition is limited to the west by the Marchiennes High (Becq-Giraudon *et al.*, 1982). The basin itself has a southeast-northwest orientation, oblique to the Variscan Front. Bouckaert (1977) even suggests that the basin can be traced under the Dinant Allochthon. The main characteristic of this basin is the presence of evaporitic intercalations within the Givetian (Coen-Aubert 1980) and Dinantian formations (Groessens *et al.*, 1979 ; Rouchy 1984). These sequences can be up to 350 m thick within the Givetian and up to 900 m thick within the Dinantian. Once these evaporitic intercalations were discovered, dissolution processes were called upon to explain different characteristic features, observed in the western front zone (Delmer 1977a) : the disposition of the La Tombe -, St. Symphorien - and Boussu-Denain Massifs (fig. 2) ; the subhorizontal geometry of the Midi Overthrust and the Hainaut Fault Zone (fig. 15) ; and the presence of the Hainaut Fault Zone itself, considered as an olistostrome by De Magnée *et al.* (1986). Bouckaert *et al.* (1977) even considers the halokinesis responsible for structures, observed in the Famenne and Theux area.
Different observations also suggest an important role for the evaporitic intercalations in the Variscan tectonisation within the front zone. In the Epinoy borehole an important shear zone, as well as a basal mylonitisation within the evaporitic series is observed (Rouchy 1986). Also in the St. Ghislain borehole an increasing tectonisation towards the base is observed (Rouchy *et al.*, 1984), resulting in a mylonitic foliation and a 'discontinuité mécanique' at the base of the evaporitic sequence. These observations fit well in a thin-skinned model, in which a weakness layer is called upon. Further hindwards these evaporitic layers can serve as decollement surfaces in the ramp-flat model, as proposed by Kaisin (1936).

The basement-cover interface is considered by Kaisin (1936) as the major decollement surface (fig. 10). Important drag deformations, which affect the southern part of the Brabant Basement, support his hypothesis. de Dorlodot (1885), on the other hand, describes a normal sedimentary unconformity, lacking any indication for any form of tectonisation. Raoult and Meilliez (1987) combine both views in their blind sole thrust concept. The interface, identified by them as the second seismic reflector, has a normal stratigraphic character in the front zone, and become a major decollement surface hindwards. In this model the whole front zone is bounded by two major structural surfaces, the Midi-Condroz Overthrust on the one hand, and the basal decollement surface on the other hand. Coen-Aubert (1988), however, suggests, based on a substantial facial difference between the Devonian formations on both sides of the Namur Syncline, that the latter major structural surface has to pass through the centre of the Namur Basin. Recently the importance of the second seismic reflector is even questioned by Mansy and Meilliez (1990). For them this reflector only represents the stratigraphic contrast between basement and cover. Dejonghe *et al.* (1992) finally show that this reflector actually represents a stratigraphic contrast within the Dinantian sequence.

4. DISCUSSION AND CONCLUSIONS

The different domains in the Variscan Front Zone all exhibit specific characteristics, determining their structural behaviour during the Variscan Orogeny. In particular, the geometric disposition and the internal competence are the main controlling factors.

On the one hand, the typical disposition of the Sambre-et-Meuse Massif, as a narrow band in the direct footwall of a major overthrust, and the characteristic incompetent composition, both fit well in the fault zone concept of Kaisin (1936) (fig. 11). In both the Epinoy and Jeumont borehole a 500 m thick hydraulically fractured zone, identified as the Midi Overthrust (Raoult 1986), can be considered as a western equivalent of the Sambre-et-Meuse Massif, but in a competent sequence. Also the Lower Paleozoic massifs near Liévin and in the Boulonnais math this concept (Raoult 1986). On the other hand, the close genetic relationship with the overturned Southern Massifs, which is apparent in the Malonne -, Bouffioulx-Ormont -, and Boussu-Denain Massifs, clearly points towards a fault propagation fold concept.

These Southern Massifs, composed of mainly competent Devono-carboniferous formations, are bounded on both sides by incompetent series, the Lower Paleozoic in the south and the Silesian in the north. Their typical overturned geometric disposition is best explained when considering a fault propagation fold model (fig. 6). If the Sambre-et-Meuse Massif is then considered as the core of this fold structure, the whole kinematic picture of the southern part of the front zone can be described as a basement involved fold-thrust uplift (fig. 17). Recently even an involvement of the whole Lower Paleozoic basement is called upon to explain the structuration of the front zone ('Socle mou' - Klein 1977a ; Meilliez and Mansy 1990 ; Le Gall 1992). The emplacement of this fold-thrust uplift is further more related to the cratonic Condroz Axis, of which the significance in the structural evolution of the front zone has been pointed out by Beugnies (1964).

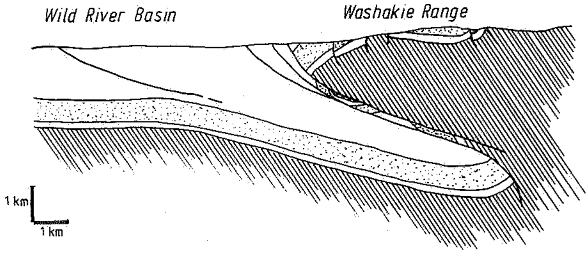


Figure 17. Type-example of a basement involved fold-thrust uplift : the Washakie Range (Wyoming, USA) (after Berg, 1962). A similar configuration can be distinguished in the southern part of the Variscan Front Zone.

a.

b.

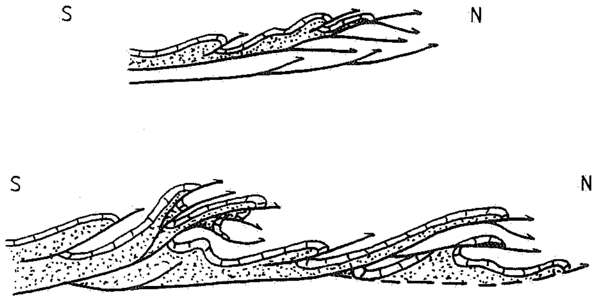


Figure 18. The Dinant Allochthon as a monolithic thrust sheet (a.), or as the compilation of thrust slices in a piggy-back sequence (b.) (Meilliez and Mansy, 1990).

The Central Basin is framed in the centre of this fold structure. This incompetent sequence has a simple monoclinal geometry, in which an imbricate thrust system developed. This disposition is favourable for a ramp-flat type of deformation (Kaisin 1936), generating typical fault bend fold structures (fig. 16).

For the same reason, this ramp-flat concept applies to the Devono-Dinantian Cover of the autochthonous Brabant Basement. With exception of the evaporitic layers, which are responsible for a substantial absorption of the tectonic energy within the front zone, the latter sequence is composed of competent formations. In this monoclinal structure different potential decollement surfaces are available : the Silesian-Dinantian interface (Kaisin 1936), the evaporitic layers, and finally the basement-cover interface (Kaisin 1936 ; Raoult and Meilliez 1987 ; Khatir 1990).

A crucial question with regard to the Brabant Basement itself concerns its structural role during the Variscan Orogeny. Fourmarier (1913) suggests that the apparent rigid block situation of the massif did not exist during the orogeny. Betz *et al.* (1988), on the other hand, does consider the Brabant Base-

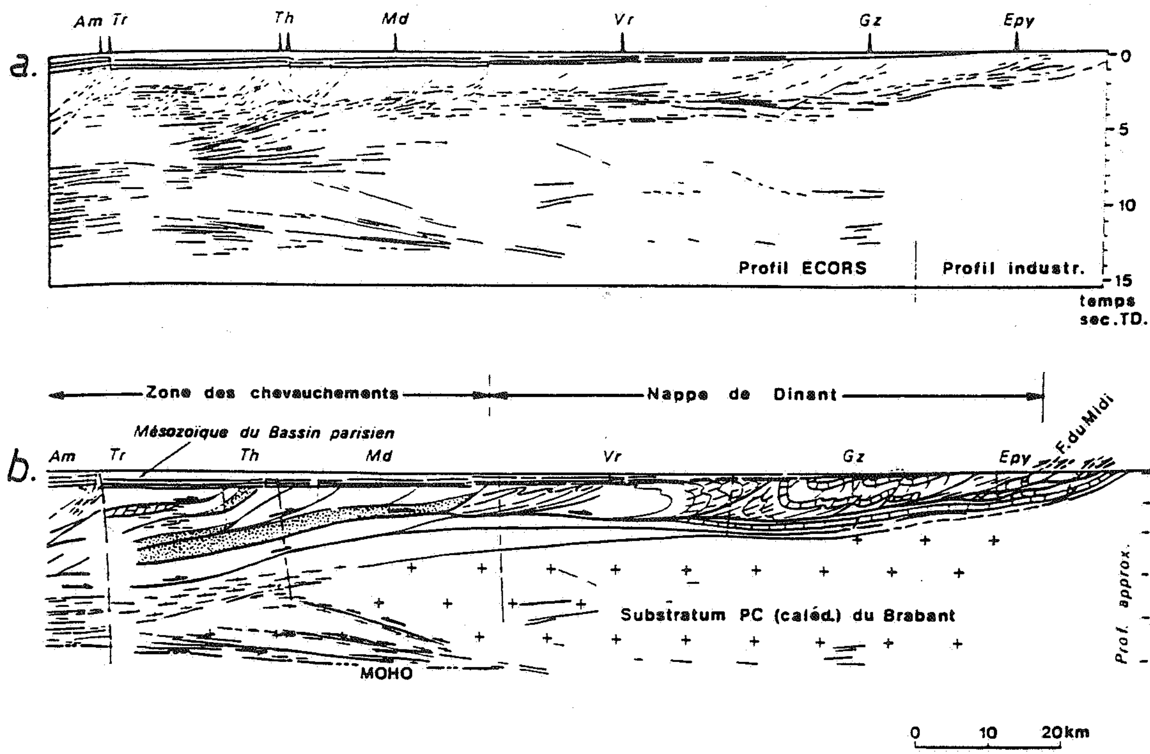


Figure 19. The 'ECORS-Nord de la France' seismic profile (Cazes *et al.*, 1985) : a. line drawing ; b. interpretation.

ment as a rigid ramp, against which the fold-and-thrust system developed.

From the recent research (deep drillings and seismic surveys) two contributions have major implications in modelling the front zone : on the one hand the three dimensional image of the fold-and-thrust belt, emphasising the extend and the continuity of the Midi Overthrust ; and, on the other hand, the presence of evaporitic series within the front zone. Both observations, the wedge form of the dominant thrust sheet and the presence of weakness layers in the front zone, fit in the model of a thin-skinned fold-and-thrust belt (Bless *et al.* 1977 ; Meissner *et al.*, 1981). An essential question with regard to this dominant thrust sheet however is if this allochthon acted as one major monolithic structure (Fourmarier 1913), or as a compilation of individual thrust slices (Kaisin 1936 ; Bless *et al.*, 1977 ; Meilliez and Mansy 1990 ; Mansy and Meilliez 1993), framed in a piggy-back sequence (Meilliez and Mansy 1990), caused by a northwards migrating orogenic pulse (fig. 18) ?
Another characteristic of a thin-skinned fold-and-thrust belt is the hindwards increase in the net translation of the overthrust, implying a possible minimal throw of the thrust fault in its front zone. This property is already suggested by Kaisin (1936) :
"Si l'on adhère à l'opinion d'une translation du Massif du Midi vers le Nord, il faut nécessairement que le rejêt aille croissant vers la profondeur et que le surface de la Grande Faille, passant sous toute la partie reconnue de l'Ardenne et de son prolongement souterrain caché par le Mésozoïque et le Cénozoïque du Bassin de Paris, aille rejoindre quelque part, très loin au Midi, la face inférieur d'une plaque rigide capable d'avoir joué le role d'arrière pays" (Kaisin 1936 - p.309). This visionary passage describes perfectly the results of the ECORS-Nord de la France survey (fig. 19).

When not taken into account some dissident models, one can conclude that a fair structural model for the Variscan Front Zone is already developed early in history. This general kinematic image did not change substantially since. The southern part of the Variscan Front Zone can be defined as a basement involved fold-thrust uplift. The applied concept of a fault propagation fold with a forward-breaking thrust imbrication agrees with the 'pli-faille' concept, extended with the 'lambeau de poussée' concept, as proposed by Cornet and Briart (1863), respectively Cornet (1873). The structural development of the northern part of the front zone, on the other hand, seems dominated by a ramp-flat type of deformation. This concept we owe to Kaisin (1936).

REFERENCES

BECQ-GIRAUDON, J.F., COLBEAUX, J.P. & LEPLAT, J., 1982 - Structures anciennes transverses dans le bassin houiller du Nord - Pas de Calais. *Ann. Soc. Géol. Nord*, **101**: 117-121.

BERG, R.R., 1962 - Mountain flank thrusting in Rocky Mountain foreland, Wyoming and Colorado. *Bull. AAPG*, **46**: 2019-2032.

BERTIAUX, A., 1913 - Contribution à l'étude de l'extension du gisement houiller du Hainaut. *Ann. Soc. Géol. Belgique*, **40**: B328-369.

BETZ, D., DURST, H. & GUNDLACH, T., 1988 - Deep crustal seismic reflection investigations across the northeastern Stavelot-Venn massif. *Ann. Soc. Géol. Belgique*, **111**: 217-228.

BEUGNIES, A., 1964 - Essai de synthèse du géodynamisme paléozoïque de l'Ardenne. *Rev. Géogr. Phys. Géol. Dyn.*, **6(4)**: 269-277.

BEUGNIES, A., 1976 - Le lambeau de poussée hercynien de La Tombe (Ardenne belge). *Ann. Soc. Géol. Nord*, **96(1)**: 27-74.

BLESS, M.J.M., BOUCKAERT, J. & PAPROTH, E., 1980 - Environmental aspects of some Pre-Permian deposits in NW Europe. *Meded. rijks Geol. Dienst*, **32(1)**: 3-13.

BLESS, M.J.M., BOUCKAERT, J. & PAPROTH, E., 1989 - The Dinant Nappes : a model of tensional listric faulting inverted into compressional folding and thrusting. *Bull. Soc. belge Géol.*, **98(2)**: 221-230.

BLESS, M.J.M., BOUCKAERT, J., CALVER, M.A., GRAULICH, J.M. & PAPROTH, E., 1977 - Paleogeography of Upper Westphalian deposits in NW Europe with reference to the Westphalian C, north of the mobile Variscan belt. *Meded. rijks Geol. Dienst*, **28(5)**: 102-127.

BOUCKAERT, J., 1967 - Carte des Mines du Bassin Houiller de la Basse-Sambre. *Mém. Expl. Cartes Géol. Min. Belgique*, **7**, 56 p.

BOUCKAERT, J., DELMER, A. & GRAULICH, J.M., 1977 - La structure varisque de l'Ardenne : Essai d'interpetation. *Meded. rijks Geol. Dienst*, **28(5)**: 133-134.

BOUROZ, A., 1960 - La structure du paléozoïque du Nord de la France au Sud de la Grande Faille du Midi. *Ann. Soc. Géol. Nord*, **80**: 101-112.

BOUROZ, A., 1989 - Réflexions sur l'orogenèse varisque dans le nord de la France. Grande Faille du Midi et tectonique globale : Essai de généralisation. *Ann. Soc. Géol. Nord*, **108**: 45-57.

BRIART, A., 1893a - Géologie de Fontaine-l'Evêque et de Landelies. *Ann. Soc. Géol. Belg.*, **21**: 35-103.

BRIART, A., 1893b - Etude sur la structure du Bassin Houiller du Hainaut, dans le district du Centre. *Ann. Soc. Géol. Belgique*, **21**: 125-149.

BRIART, A., 1897 - Les couches du Placard (Mariémont). Suite à l'étude sur la structure du Bassin Houiller du Hainaut dans le district du Centre. *Ann. Soc. Géol. Belgique*, **24**: 237-255.

CAUCHY, F.P., OMALIUS, J.B.J. d' & SAUVEUR, D., 1832 - Rapport sur les mémoires présentés en réponse à la question relative à la constitution géologique de la province de Liège. *Ann. Mines Belgique*, **8**.

CAZES, M, TOREILLES, G., BOIS, C., DAMOTTE, B., GOLDEANO, A., HIRN, A., MASCLE, A., MATTE, Ph., VAN NGOC PHAM & RAOULT, J.-F., 1985 - Structure de la croûte hercynniene du Nord de la France : premiers résultats du profil ECORS. *Bull. Soc. Géol. France*, **(8)I (nr. 6)**: 925-941.

CHAPPLE, W.M., 1978 - Mechanics of thin-skinned fold-and-thrust belts. *Bull. Geol. Soc. Am.*, **98**: 1189-1198.

COEN-AUBERT, M., 1988 - Les unités lithostratigraphiques du Dévonien Moyen et du Frasnien dans le sondage de Wépion. *Serv. Géol. Belgique, Prof. Pap.*, **1988/1 (nr. 231)**, 26 p.

COEN-AUBERT, M., GROESSENS, E. & LEGRAND, R., 1980 - Les formations paléozoïques des sondages de Tournai et Leuze. *Bull. Soc. belge Géol.*, **89(4)**: 241-275.

CORNET, F.L., 1873 - Mines et Carrières. *Patria Belgica*, **1(V)/231.**

CORNET, F.L. & BRIART, A., 1863 - Communication relative à la Grande Faille qui limite au Sud le Bassin Houiller belge. *Publ. Soc. Anc. Elèves Ecole Mines Hainaut*, **11**.

CORNET, F.L. & BRIART, A., 1877 - Sur le relief du Sol en Belgique, après les temps paléozoïques. *Ann. Soc. Géol. Belgique*, **4**: 71-115.

CORNET, J., 1898 - Notice biographique sur Alphonse Briart. *Bull. Soc. belge Géol.*, **12**: 268-299.

DEJONGHE, L., 1973 - Le sondage de Boussu. *Serv. Géol. Belgique, Prof. Pap.*, **1973/3**, 106 p.

DEJONGHE, L., DELMER, A. & HANCE, L., 1992 - Les enseignements d'une campagne sismique conduite en Belgique, dans le Hainaut, selon l'axe Erquelinnes - Saint Ghislain. *Ann. Soc. Géol. Nord*, **1(2ème sér.)**: 135-142.

DELMER, A., 1949 - Le district houiller du Couchant de Mons. Description géologique générale. *Ann. Mines Belgique*, **48**: 261-264.

DELMER, A., 1977a - Le massif de Masse, témoin d'une tectonique salifère en Hainaut. *Bull. Soc. belge Géol.*, **86(1)**: 45-49.

DELMER, A., 1977b - Le bassin du Hainaut et le sondage de Saint-Ghislain. *Serv. Géol. Belgique, Prof. Pap.*, **1977/6 (nr. 143)**, 12 p.

DELMER, A., 1988 - Le sondage de Saint-Ghislain : stratigraphie et tectonique en terrain houiller, sa liaison avec le sondage de Jeumont I. *Ann. Soc. Géol. Belgique*, **111**: 291-295.

DEMEURE, A., 1913 - La faille du Placard seraitelle une transport important de l'est à l'ouest. *Ann. Soc. Géol. Belgique*, **40**: B310-B328.

de DORLODOT, H., 1885 - Note sur la discordance du Dévonien sur le Silurien dans le bassin

de Namur. *Ann. Soc. Géol. Belgique*, **12**: 207-241.
de DORLODOT, H., 1892 - Recherches sur le prolongement occidental du Silurien de Sambre-et-Meuse et sur la terminaison orientale de la Faille du Midi. *Ann. Soc. Géol. Belgique*, **20**: 289-426.
de DORLODOT, H., 1893 - Note sur l'origine orientale de la Faille d'Ormont. *Ann. Soc. Géol. Belgique*, **21**: 167-170.
de DORLODOT, H., 1898 - Etude de la genèse de la Crête du Condroz et de la Grande Faille. *Ann. Soc. Sc. Bruxelles*, 87 p.
de DORLODOT, H., 1907 - La faille de Maulenne. *Bull. Soc. belge Géol.*, **21**: 265-302.
DE MAGNEE, I., DELMER, A.& CORDONNIER, M., 1986 - La dissolution des Evaporites du Dinantien et ses consequences. *Bull. Soc. belge Géol.*, **95(2-3)**: 213-220.
FALY, J., 1878 - Etude sur le terrain carbonifère : la Faille du Midi. Depuis les environs de Binche jusqu'à la Sambre. *Ann. Soc. Géol. Belgique*, **5**: 23-32.
FOURMARIER, P., 1908 - La structure du bord nord du Bassin de Dinant entre Wépion sur Meuse et Fosse. *Ann. Soc. Géol. Belgique*, **35**: M47-M72.
FOURMARIER, P., 1911 - Observations sur le massif de charriage de Fontaine-l'Evêque-Landelies. *Ann. Soc. Géol. Belgique*, **39**: M2-M16.
FOURMARIER, P., 1913 - Les phénomènes de charriage dans le bassin de Sambre-Meuse et le prolongement du terrain houiller sous la Faille du Midi en Hainaut. *Ann. Soc. Géol. Belgique*, **40**: 191-234.
FOURMARIER, P., 1920a - La tectonique du Bassin Houiller du Hainaut. Les failles des districts de Charleroi et du Centre. *Ann. Soc. Géol. Belgique*, **42**: M169-M217.
FOURMARIER, P., 1920b - Observations sur le prolongement oriental du Faille du Carabinier. *Ann. Soc. Géol. Belgique*, **42**: B202-B210.
FOURMARIER, P., 1920c - Observations sur le prolongement des failles du Bassin du Hainaut sous le massif charrié du Midi. *Ann. Soc. Géol. Belgique*, **43**: B132-B142.
FOURMARIER, P., 1933 - Observations sur l'estimation de l'importance du transport suivant le "Charriage du Condroz". *Ann. Soc. Géol. Belgique*, **56**: 249-259.
FOURMARIER, P., 1939 - Quelques résultats de l'étude de la schistosité dans la bande silurienne de Sambre-Meuse. *Ann. Soc. Géol. Belgique*, **63**: B16-B24.
FOURMARIER, P., ANCION, C., ANTHUN, P., ASSELBERGHS, E., BELLIERE, J., BOURGUIGNON, P., CALEMBERT, L., DELMER, A., DENAYER, M., DUBRUL-DUMON, P., GRAULICH, J.M., GULINCK, M., HACQUART, A., LAGRAYE, M., MACAR, P., MARLIERE, R., MAUBERGE, P., MICHOT, P., MORTELMANS, G. & TAVERNIER, R., 1954 - Prodrôme d'une description géologique de la Belgique. *H. Vaillant-Carmanne S.A.*, Liège, 826 p.
GEUKENS, F., 1964 - Le prolongement oriental du Faille du Midi. *Bull. inf. A. I. Ms.*, 7-8.
GOSSELET, J., 1880 - Esquisse géologique du Nord de la France et des contrèes voisines. Imprimerie Sixhoremans, Lille, 421 p.
GOSSELET, J., 1988 - L'Ardenne. *Mém. Expl. Carte Géol. dét. France*, **4**, 849 p.
GRAULICH, J.M., 1961 - Le sondage de Wépion. *Mém. Expl. Cartes Géol. Min. Belgique*, **2**, 102 p.
GRAULICH, J.M., 1982 - Le sondage d'Havelange (Champs du Bois). *Ann. Min. Belgique*, **1982/6**: 545-561.
GROESSENS, E., CONIL, R. & HENNEBERT, M., 1979 - Le Dinantien du sondage de Saint-Ghislain. Stratigraphie et Paléontologie. *Mém. Expl. Cartes Géol. Min. Belgique*, **22**, 137 p.
HANCE, L., STEEMANS, P., GOEMAERE, E., SOMERS, Y., VANDENVEN, G., VANGUESTAINE, M. & VERNIERS, J., 1991 - Nouvelles données sur la bande de Sambre-et-Meuse à Ombret (Huy, Belgique). *Ann. Soc. Géol. Belgique*, **114**: 253-264.
KAISIN, F., 1936 - Le problème tectonique de l'Ardenne. *Mém. Inst. Géol. Louvain*, **11**, 368 p.
KAISIN, F., Jr., 1935 - Structure de la bordure sud du Bassin Houiller de la Basse-Sambre, entre Franière et le Samson. *Mém. Inst. Géol. Louvain*, **8**: 161-220.
KAISIN, F., Jr., 1947 - Le Bassin Houiller de Charleroi. *Mém. Inst. Géol. Louvain*, **15**, 119 p.
KAISIN, F., Jr. 1950 - Géologie minière des bassins houiller belges : IV. Les bassins houiller de Charleroi et de la Basse Sambre. Description géologique générale. *Ann. Mines Belgique*, **49(1)**: 6-11.
KHATIR, A., 1990 - Structuration et déformation progressive au front de l'allochtone ardennais (Nord de la France). *Publ. Soc. Géol. Nord*, **18**, 293 p.
KLEIN, C., 1977a - Ardennotype. *C.R. Acad. Sc. Paris*, **série D 284**: 1263-1266.
KLEIN, C., 1977b - Tectogenèse armoricaine et tectogenèse ardennaise. La notion de socle mou. *Bull. Soc. belge Géol.*, **86(4)**: 151-182.
KLEIN, C., 1978 - Au sujet du charriage du Condroz (Belgique). *C.R. Acad. Sc. Paris*, **série D 286**: 395-398.
LACROIX, D., 1974 - Le Mésodévonien et le Frasnien à Dave (bord sud du Synclinorium de Namur). Lithostratigraphie et comparaison avec

les coupes d'Aisémont et de Tailfer. *Serv. Géol. Belgique, Prof. Pap.*, **1974/5**, 11 pp.
LAMERSON, P.R., 1982 - The Fossil Basin area and its relationship to the Absaroka thrust fault system. *In* : POWERS, R.B. (Editor) *Geological studies of the Cordilleran thrust belt, Rocky Mountain Association Geologists*, 279-340.
LE GALL, B., 1992 - The deep structure of the Ardennes Variscan thrust belt from structural and ECORS seismic data. *J. Struct. Geol.*, **14(5)**: 531-546.
LEGRAND, R., 1968 - Le Massif du Brabant. *Mém. Expl. Cartes Géol. Min. Belgique*, **9**, 148 p.
LOHEST, M., 1913 - Les grandes lignes du problème de la présence du Houiller sous la faille eifélienne et les difficultés que présente sa solution. *Ann. Soc. Géol. Belgique*, **40**: B143-B156.
MANSY, J.-L. & MEILLIEZ, F., 1993 - Elements d'analyse structurale à partir d'exemples pris en Ardenne-Avesnois (Affleurements visités lors de l'excursion de la SGN en octobre 1991). *Ann. Soc. Géol. Nord,* **2 (2ème série)**: 45-60.
MARLIERE, R., 1950 - Géologie minière des bassins houillers belges : V. Le district houiller du Centre. Description géologique générale. *Ann. Mines Belgique*, **49(2)**: 146-153.
MATTE, Ph. & ZU XHI, Q., 1988 - Decollements in slate belts, examples from the European variscides and the Qin Ling Belt of Central China. *Geol. Rundschau*, **77(1)**: 227-238.
MEILLIEZ, F. & MANSY, J.-L., 1990 - Déformation pelliculaire différenciée dans une série lithologique hétérogène : le Dévono-carbonifère de l'Ardenne. *Bull. Soc. Géol. France*, **6(1)**: 177-188.
MEISSNER, R., BARTELSEN, H. & MURAWSKI, H., 1981 - Thin-skinned tectonics in the northern Rhenish Massif, Germany. *Nature*, **290**: 399-401.
MICHOT, P., 1927 - La bande silurienne de Sambre-et-Meuse entre Fosse et Bouffioulx. *Ann. Soc. Géol. Belgique*, **51**: M37-M105.
MICHOT, P., 1944a - La bande silurienne de Sambre-et-Meuse entre Fosse et la Meuse. *Ann. Soc. Géol. Belgique*, **68**: 75-112.
MICHOT, P., 1944b - Structure du Dévonien bordant au nord la bande silurienne de Sambre-et-Meuse entre Buzet et Sart-Saint-Laurent. *Ann. Soc. Géol. Belgique*, **68**: B67-B75.
MICHOT, P., 1978 - La faille mosane et la phase hyporogénique bollandienne, d'age emsien, dans le rameau condruso-brabançon. *Ann. Soc. Géol. Belgique*, **101**: 321-335.
MICHOT, P., 1980 - Belgique. Introduction à la Géologie générale. *Livret-guide 26ème Congrès Int. Géol. Paris*, 487-576.
PAPROTH, E., 1987 - The Variscan Front north of the Ardenne-Rhenish Massifs. *Ann. Soc. Géol. Belgique*, **110**: 279-296.
RAOULT, J.-F., 1986 - Le front varisque du Nord de la France d'après les profiles sismiques, la géologie due surface et les sondages. *Rev. Géogr. Phys. Géol. Dyn.*, **27(3-4)**: 247-268.
RAOULT, J.-F. & MEILLIEZ, F., 1986 - Commentaires sur une coupe structurale de l'Ardenne selon le méridien de Dinant. *Ann. Soc. Géol. Nord*, **105**: 97-109.
RAOULT, J.-F. & MEILLIEZ, F., 1987. The Variscan Front and the Midi Fault between the Channel and the Meuse River. *J. Struct. Geol.*, **9(4)**: 473-479.
RENIER, A., 1919 - Les relations géologiques du Bassin Houiller du Nord de la France avec les gisements belges. *Bull. Ass. Ing. sortis Ec. Liège*, **1**: 15-29.
RENIER, A., 1931 - Contribution à l'étude de la bordure méridionale du Bassin Houiller de Charleroi et de la Basse-Sambre. Description de la Coupe du Puits Nr. 3 du Charbonnage du Boubier, à Bouffioulx. *Bull. Soc. belge Géol.*, **44**: 268-338.
RENIER, A., 1934 - Recherches sur la tectonique du Massif du Borinage (Bassin Houiller du Hainaut belge). *Bull. Soc. belge Géol.*, **44**: 385-401.
ROUCHY, J.M., GROESSENS, E. & LAUMONDAIS, A., 1984 - Sédimentologie de la formation anhydritique viséenne du sondage de Saint-Ghislain (Hainaut - Belgique). Implications paléogéographiques et structurales. *Bull. Soc. belge Géol.*, **93(1-2)**: 105-145.
SINTUBIN, M., 1992 - De kristallografische voorkeursoriëntatie van phyllosilicaten als vervormingselement in de structurele geologie. Een verkennende studie naar de toepassingsmodaliteiten van de kwantitatieve textuuranalyse van phyllosilicaatmaaksels in de schieferige massieven rond het Varistisch Front in België. Unpublished Ph. D. Thesis, K.U.Leuven, 272 p.
SINTUBIN, M. - Structural and paleogeographic inferences from a texture analysis on Ordovician and Silurian pelites of the Wépion borehole (Ardennes, Belgium). *Geologie & Mijnbouw* (submitted).
SMEYSTERS, J., 1900 - Etude sur la constitution de la partie orientale du Bassin Houiller du Hainaut. *Ann. Mines Belgique*, **5**: 29-112 ; 205-245 ; 333-395.
STAINIER, X., 1920 - La bande silurienne du Condroz et la Faille du Midi. *Bull. Soc. belge Géol.*, **30**: 63-76.

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