Geologie en Mijnbouw **72**: 305–310, 1994.

Structural and paleogeographic inferences from a texture analysis of Ordovician and Silurian pelites of the Wépion borehole (Ardennes, Belgium)

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Received 8 July 1992; accepted in revised form 29 October 1993

Key words: Brabant basement, Caledonian massifs, phyllosilicate textures, Sambre-et-Meuse massif, Variscan front

Abstract

A preliminary microfabric and texture analysis of shales, siltstones and a slate, collected in the Ordovician and Silurian of the Wépion borehole (Ardennes, Belgium), enables us to comment on the structural and paleogeographic significance of the Caledonian Sambre-et-Meuse massif as part of the Variscan front. The texture image in the massif only reflects a compaction strain, which is in accordance with the poorly evolved character of the fabric, in which no clear signs of a secondary cleavage can be distinguished. The shales and siltstones seem to have evolved within a shallow structural level under diagenetic circumstances. In this respect the Sambre-et-Meuse massif forms an exception with regard to the other Caledonian basement massifs in the Variscan fold-and-thrust belt in Belgium, which are all characterised by the development of a slaty cleavage in low-grade metamorphic circumstances. Such a secondary cleavage also occurs at the bottom of the Wépion borehole in the Brabant basement.

Introduction

The Sambre-et-Meuse massif forms the central segment of the Variscan front in Belgium, where this front separates the Dinant allochthonous from the Namur parautochthonous. Towards the west and east the structural role of the massif is taken over by two major overthrusts, the Midi overthrust and the Eifel-Aachen overthrust respectively (Fig. 1). The elongated (70 km long, up to 1500 m wide) massif is mainly composed of incompetent pelitic formations of Ordovician and Silurian age.

The exact structural relationship between the massif and both overthrusts, as well as the massif's structural and paleogeographic significance with respect to the geodynamic evolution of the whole Variscan front zone is still a matter of debate (Kaisin 1936; Beugnies 1964; Klein 1977; Raoult 1986; Raoult & Meilliez 1987; Bless et al. 1989; Hance et al. 1991). Most of the current models are mainly based on the macroscopic structural geometry observed in the field. To date, a quantitative study of the deformation, which can eventually lead to a kinematically-sound model for the massif, has to our knowledge never been performed. With the application of phyllosilicate textures as strain markers such a quantitative approach comes within reach. Phyllosilicate textures are very suitable for this purpose due to their exceptional omnipresence in pelitic sequences.

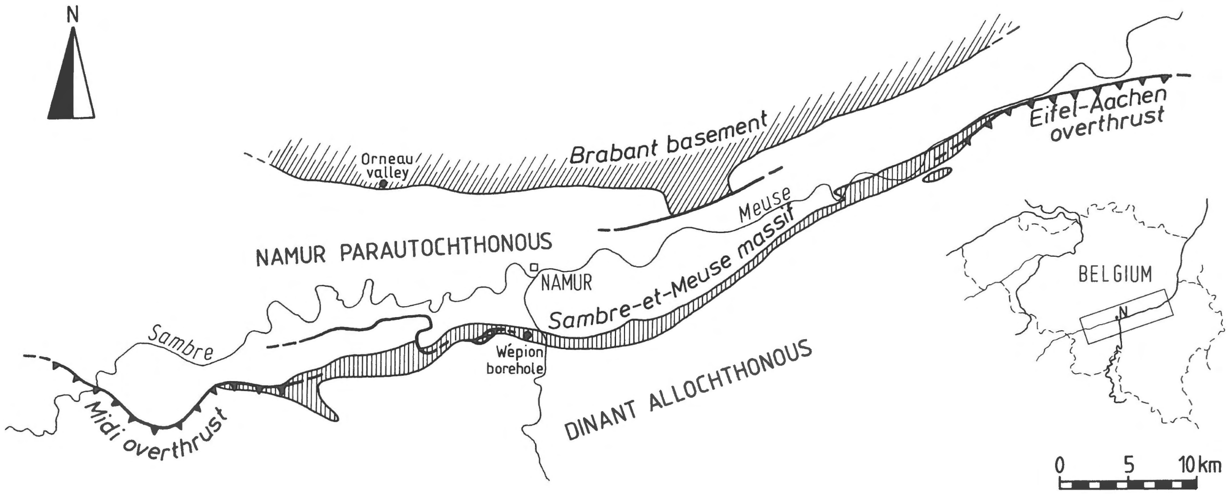

Fig. 1. Simplified geostructural map of the Variscan front zone in Belgium, showing the locations of the Wépion borehole and the 'Orneau valley' outcrops. Vertical hatching indicates the Sambre-et-Meuse massif . Oblique hatching indicates the Brabant basement.

In this communication we present the results of a preliminary microfabric and texture analysis on shales, siltstones and a slate, collected in the Wépion borehole. This borehole is situated in the central part of the Sambre-et-Meuse massif (Fig. 1). On both sides of the synclinally folded Devono-Carboniferous of the Namur parautochthonous, the borehole traverses a 'Caledonian' series (Fig. 2): the Sambre-et-Meuse massif between 6 and 515 m, and the Brabant basement between 2304 and 2310 m (= T.D.). The former massif can be divided in four distinct structural units. A detailed description and discussion are given by Graulich (1961).

Microfabric analysis

Seven samples from the different structural units of the Sambre-et-Meuse massif, and one from the Brabant basement, were analysed (Fig. 2).

The first three samples, taken from the Llanvirnian in the two upper structural units, are black, homogeneous, finely grained (μm-scale) shales, which exhibit a strongly aligned phyllosilicate fabric, parallel to the bedding. This fabric can be described as a 'continuous cleavage' (Powell 1979).

The Tremadocian sample (sample 4, unit II) is a finely laminated, black shale, in which quartz-rich laminae regularly alternate with phyllosilicate-rich laminae (mm-scale). In the latter the preferred alignment of the phyllosilicate grains is responsible for a clear mesoscopic cleavage.

The black shale of sample 5 was taken from the Llanvirnian in unit III, which is, contrary to the other units, considered to be schistose (Graulich 1961; Michot 1979). The shale is very similar to the Llanvirnian shales in the upper two units. The continuous phyllosilicate fabric is, however, slightly disturbed. At 75° to the bedding plane, the first signs of a secondary fabric can be distinguished (Fig. 4). The generated kink bands are responsible for a weak δ-lineation on the bedding-parallel cleavage planes.

The two Silurian samples (samples 6 and 7), taken from the overturned substratum of the Namur parautochthonous (unit IV), are grey siltstones. In the finely grained quartz matrix, isolated, millimetre-thick, phyllosilicate-rich laminae can be distinguished. A strong preferred alignment of the phyllosilicate grains in these laminae is responsible for an irregular mesoscopic cleavage. Sedimentary structures also contribute to this heterogeneous fabric.

Finally, a grey Silurian slate (sample 8) was collected at the bottom of the borehole from the Brabant basement. In the finely grained, homogeneous phyllosilicate matrix a pronounced secondary fabric has developed at 30° to the bedding pole (Fig. 4). This slaty cleavage can be described as a very dense 'spaced cleavage' (Powell 1979).

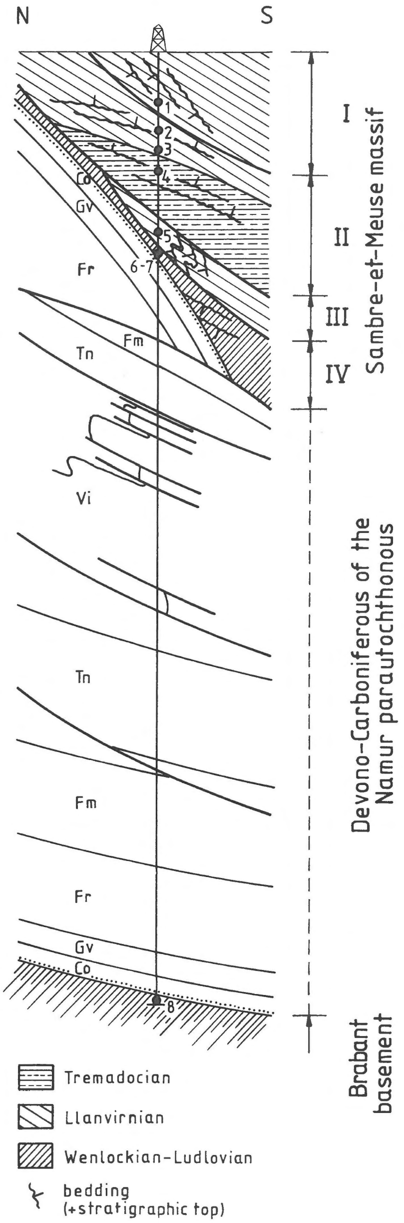

Fig. 2. Geological profile trough the Wépion borehole, according to Graulich (1961), showing the locations of the samples and the structural units I to IV of the Sambre-et-Meuse massif (Co = Couvinian; Gv = Givetian; Fr = Frasnian; Fm = Famennian; Tn = Tournesian , Vi = Visean).

Texture analysis

Methodology

The crystallographic preferred orientation, or texture, of the phyllosilicates in the samples was measured by means of an X-ray pole figure goniometer, applying CuKα-radiation. The measurements were performed in the transmission mode. The procedure followed is described by Sintubin (1992). The resulting orientation distributions, expressed in 'multiples of random distribution' (mrd), are represented on equal-area projections onto the upper hemisphere (Fig. 3). In all samples, chlorite (002) reflections, corresponding to d = 14 Å, were measured. When possible, illite (001) reflections, corresponding to d = 10 Å, were also measured.

The application of the phyllosilicate texture as a strain marker is based on the March theory (March 1932), in which a unique relationship is put forward between the orientation distribution of the platy phyllosilicate grains and the finite-strain ellipsoid. The applicability of this model to the studied pelitic material is discussed by Sintubin (1992). The qualitative interpretation of the phyllosilicate textures is based on the symmetry of the orientation distribution, as well as on the specific geometrical relationship with the different mesoscopic structural elements (bedding, cleavage, lineation, etc.). The quantitative interpretation, on the other hand, is based on the texture intensity.

Results

Both, the chlorite and the illite textures are identical with regard to their orientation and symmetry (Fig. 3). In the six samples in which they can be compared, both phyllosilicates seem to have undergone a similar finite strain. The observed intensity difference between the chlorite and illite texture (Table 1) is attributed to a difference in concentration of both minerals in the fabric (Sintubin 1992).

With the exception of sample 5, all analysed samples from the Sambre-et-Meuse massif exhibit an identical texture image (Fig. 3). The orientation distribution has an axial symmetry and is centred around the bedding pole. The texture intensity is moderate (2.3 mrd to 8.2 mrd). This texture image is interpreted as the typical result of a compaction strain (Sintubin 1992).

The texture image of sample 5 from the Llanvir-

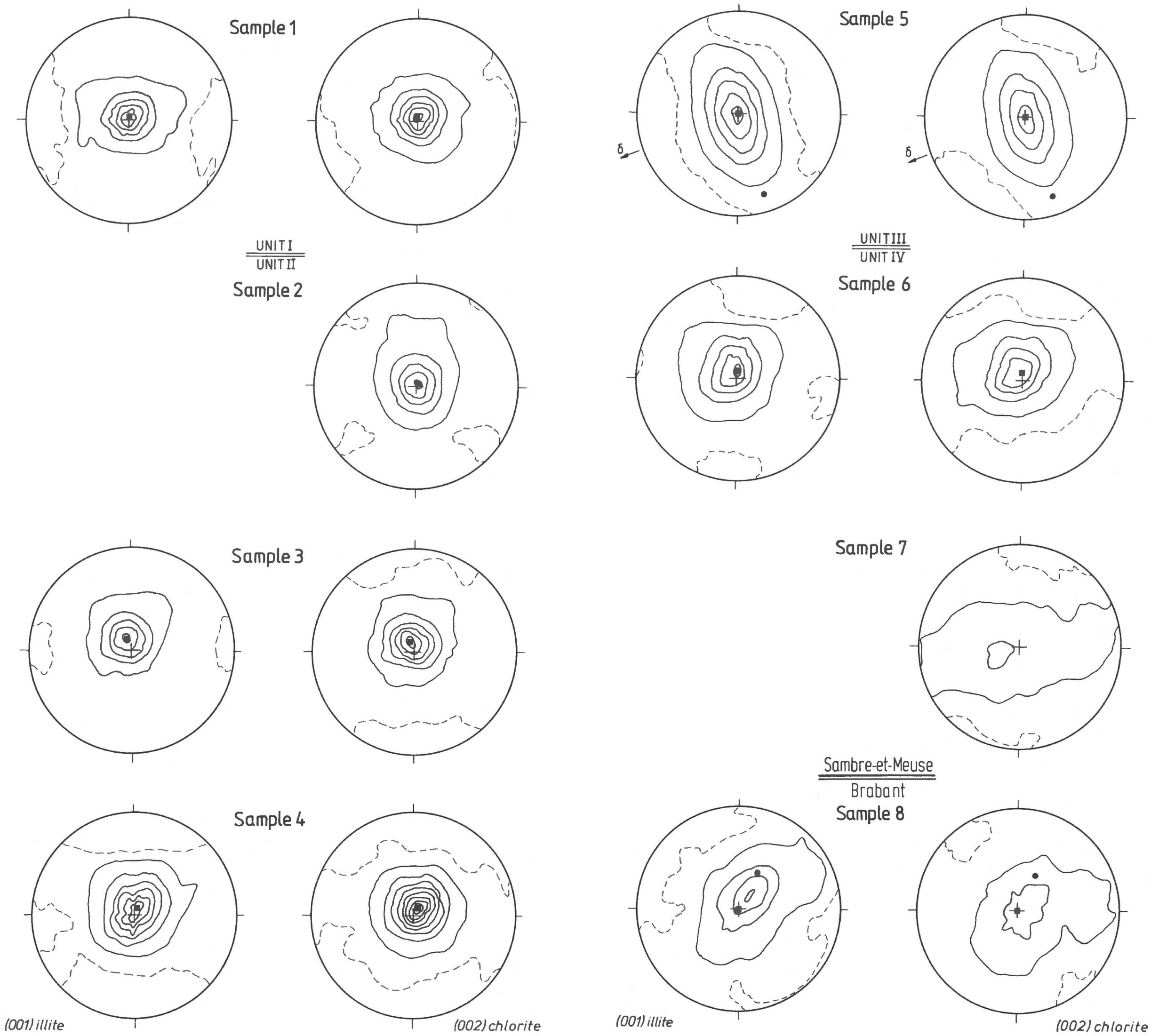

Fig. 3. Pole figures of the measured illite and chlorite textures (equal-area projections onto the upper hemisphere; contour lines = intervals of 1 mrd; dotted contour line = 0.5 mrd; ■ = bedding pole; ● = cleavage pole): sample 1, Llanvirnian shale – unit I; sample 2, Llanvirnian shale – unit II; sample 3, Llanvirnian shale – unit II; sample 4, Tremadocian shale – unit II; sample 5, Llanvirnian shale – unit III; sample 6, Silurian siltstone – unit IV; sample 7, Silurian siltstone – unit IV; sample 8, Silurian slate – Brabant basement.

nian in unit III exhibits an orthorhombic symmetry (Fig. 3). The texture peak coincides with the bedding pole. Taking into account the observations in the fabric we consider this texture image as the result of a summation of different orientation populations (Fig. 4). The central population still represents the primary compaction fabric. The observed kink bands, related to the development of a secondary fabric, on the other hand, are responsible for the symmetrical elongation of the final orientation distribution within the plane in which both foliation poles are situated (perpendicular to the δ-lineation). The result of this summation is the observed transition texture.

This transitional aspect is even more obvious in both fabric and texture of the Silurian slate, taken from the Brabant basement at the bottom of the borehole (sample 8). This texture image (Fig. 3) also exhibits an orthorhombic symmetry, but the texture peak is situated between the bedding and cleavage

Table 1. Quantitative data of the analysed samples: depth, quartz content (determined according to the method of Trostel & Wyne (1940)) and intensities of the illite and chlorite textures.

Sample	Depth (m)	Quartz%	Texture intensity (mrd) illite	chlorite
1.	143.2	25.0	6.0	6.4
2.	193.3	25.0		5.1
3.	204.5	11.0	5.3	6.6
4.	275.1	35.0	6.8	8.2
5.	469.3	11.0	5.4	4.7
6.	504.2	46.0	5.5	5.1
7.	513.6	36.0		2.3
8.	2306.0	18.0	4.1	2.7

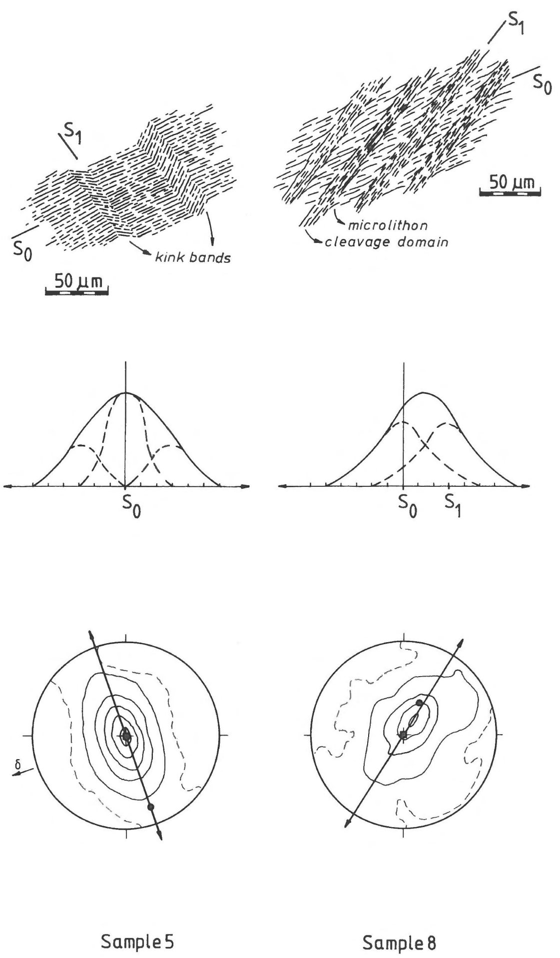

Fig. 4. The composition of the transition textures, measured in sample 5 (Llanvirnian shale, unit III, Sambre-et-Meuse massif) and sample 8 (Silurian slate, Brabant basement): idealised fabric, texture profile and pole figure of (001) illite (■ = S_0 = bedding pole; ● = S_1 = cleavage pole).

poles. This intermediate position clearly indicates that both orientation populations are equivalent in this spaced cleavage. The bedding-parallel population can be found in the microlithons, while the new cleavage-parallel population forms the cleavage domains (Fig. 4).

Discussion

The limited microfabric and texture observations described above, enable us to make some tentative comments on the structural and paleogeographic significance of the Sambre-et-Meuse massif.

Only in the Llanvirnian shale from unit III (sample 5), the development of a secondary phyllosilicate fabric is initiated, which is reflected in the transition texture. This observation seems to confirm the exceptional position of this unit with regard to the other structural units in the massif (Graulich 1961; Michot 1979).

The other investigated shales and siltstones in the massif show no signs of any development of a secondary fabric. Together with the poorly evolved fabrics, the observed compaction textures suggest that the pelitic formations in the massif have evolved under a limited lithostatic overburden in diagenetic circumstances. This view is supported by the striking similarity with the texture image observed in the Westphalian and Permian shales in the Campine basin, north of the Brabant basement, which are also exclusively characterised by a compaction history in diagenetic circumstances (Sintubin 1992). The low coalification rank of the pelitic material in the Sambre-et-Meuse massif (Steemans et al. 1990) also points in this direction.

This poor degree of evolution contrasts sharply with that of the pelitic material in the other Caledonian basement massifs in the Variscan fold-and-thrust belt in Belgium, in which a secondary slaty cleavage has developed in epizonal to mesozonal metamorphic conditions (Robaszynski & Dupuis 1983).

In our opinion these observations show that the 'Caledonian' shales and siltstones in the Sambre-et-Meuse massif have always evolved within a shallow structural level. Paleogeographically, this implies the presence of a cratonic high in the Condroz area (Hance et al. 1991). During the final Variscan overthrusting, this shallow basement block is incorporated into the Variscan front. The faulted remnant of this basement block, in which the Variscan front thrust fades out, forms the Sambre-et-Meuse massif.

Finally, the transition texture in sample 8 at the bottom of the borehole, exhibits a pronounced similarity to the textures observed in the Silurian slates in southern outcrops of the Brabant basement (Orneau valley, Fig. 1) (Sintubin 1992). A close genetic relationship between both sampling areas can be assumed. Unlike Meilliez & Mansy (1990), we therefore believe that the Brabant basement is reached at the bottom of the Wépion borehole. The contrast in fabric and texture between the slates in the Brabant basement and the shales in the Sambre-et-Meuse massif furthermore suggests the presence of a major discontinuity between the two 'Caledonian' domains (Coen-Aubert 1988).

Acknowledgements

I would like to thank L. Dejonghe (Belgian Geological Survey) for the authorisation to make use of the core material, collected in the Wépion borehole. I furthermore thank the anonymous referee for his critical review of the original manuscript, and D.A.J. Batjes for his comments on the final manuscript.

This research was made possible by the financial support of the National Fund for Scientific Research (Belgium).

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