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QUANTITATIVE APPROACH OF THE CLEAVAGE EVOLUTION IN THE DINANT ALLOCHTHON (ARDENNES, FRANCE - BELGIUM)

Manuel SINTUBIN[1]

(11 figures & 1 table)

1. Laboratorium voor Algemene Geologie, Katholieke Universiteit Leuven, Redingenstraat 16, B-3000 Leuven

ABSTRACT. A qualitative description of the cleavage evolution in the Dinant Allochthon indicates a gradual decrease in intensity of the cleavage development from the Ardennes Anticline towards the North. In this paper the cleavage evolution in the Dinant Allochthon is approached more quantitatively by means of an X-ray texture analysis, in which the phyllosilicate preferred orientation, causing cleavage development, is determined. This quantitative approach shows that the Dinant Allochthon can definitively not be considered as a domain with a uniform cleavage development. Only the Ardennes Anticline is characterised by the development of a pervasive slaty cleavage, which can be associated with the Variscan metamorphism. Towards the North the cleavage development rapidly decreases in intensity. Lithological composition and local strain conditions become the controlling parameters. Only in the direct proximity of faults or in localised shear zones does the phyllosilicate preferred orientation indicate a tectonic origin of the cleavage fabric.

KEYWORDS: Dinant Allochthon, cleavage, phyllosilicate, orientation, X-ray, texture.

RESUME. Approche quantitative de l'évolution du clivage dans l'Allochtone de Dinant (Ardennes, France-Belgique). Une description qualitative de l'évolution du clivage dans l'Allochtone de Dinant indique qu'il y a une décroissance graduelle de l'intensité de développement du clivage de l'Anticlinal des Ardennes vers le Nord. Dans cet article, l'évolution du clivage dans l'Allochtone de Dinant est approchée plus quantitativement en appliquant l'analyse de texture par rayons X. Par cette méthode, l'orientation préférentielle des phyllosilicates, qui détermine le clivage, est mesurée. Cette approche quantitative montre que l'Allochtone de Dinant ne peut certainement pas être considéré comme un domaine avec un développement de clivage uniforme. Seul l'Anticlinal des Ardennes est caractérisé par le développement d'un clivage pénétrant, qui peut être associé au métamorphisme varisque. Vers le Nord l'intensité de ce développement du clivage décroît rapidement. La composition lithologique et les conditions locales de déformation deviennent les paramètres contrôlants. Seulement dans la proximité immédiate des failles où dans des zones localisées de cisaillement, l'orientation préférentielle des phyllosilicates indique une origine tectonique du clivage.

MOTS-CLES: Allochtone de Dinant, clivage, phyllosilicates, texture, rayons X.

1. INTRODUCTION

Even in recent works (Raoult, 1986; Raoult & Meilliez, 1986; Raoult & Meilliez, 1987) the presence or absence of a cleavage is still used as a criterion to distinguish structural domains in the Variscan fold-and-thrust belt in the Ardennes (Fig. 1). Homogeneous 'schistose' domains, such as the Dinant Allochthon or the Brabant Basement, are considered separated from 'aschistose' domains, such as the Namur Parautochthon or the Campine Basin, by major tectonic or sedimentary discontinuities. Also the determination of structural affinities, such as illustrated in the models for the Sambre-et-Meuse Massif (Fourmarier, 1939; Graulich, 1961; Michot, 1978), are based on the recognition of schistose and aschistose units.

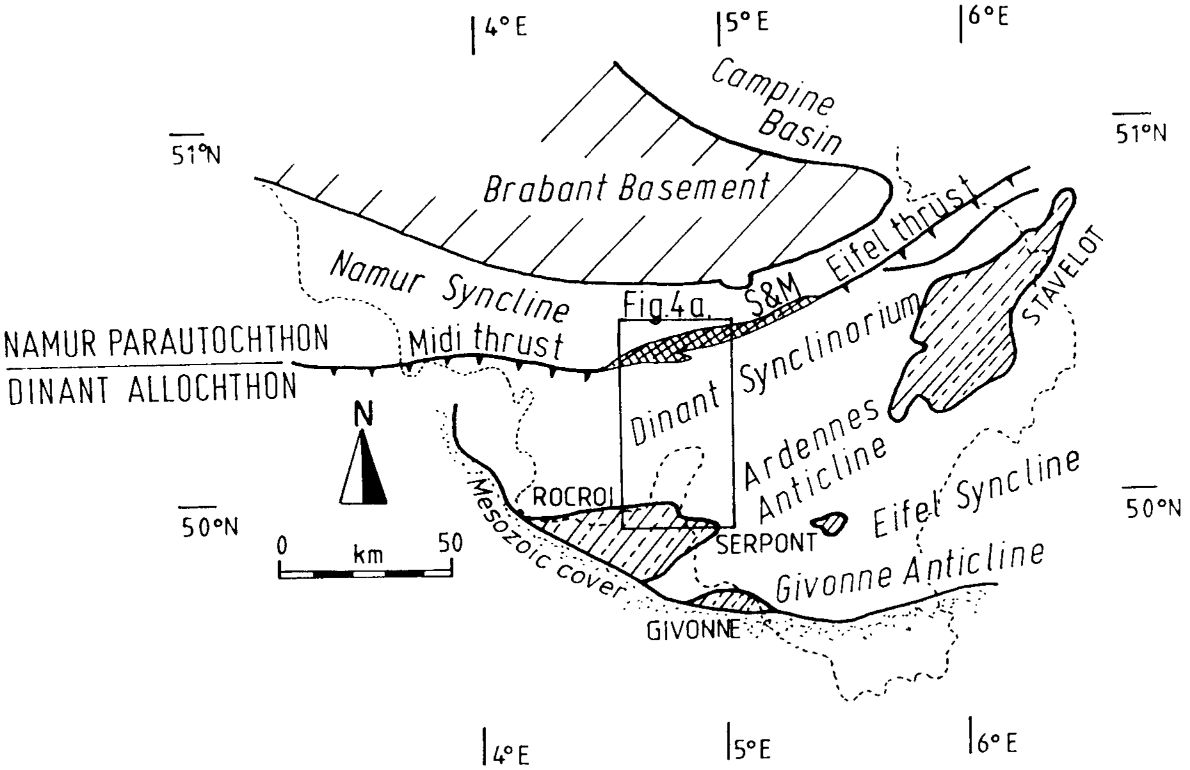

Figure 1. Schematic map of the major structural domains of the Variscan fold-and-thrust belt in Belgium. The Midi thrust, Sambre-et-Meuse Massif (S&M) and the Eifel thrust are the composing elements of the «Midi-Condroz-Eifel Thrust Complex» or Variscan Front Complex, separating the Dinant Allochthon and the Namur Parautochthon.

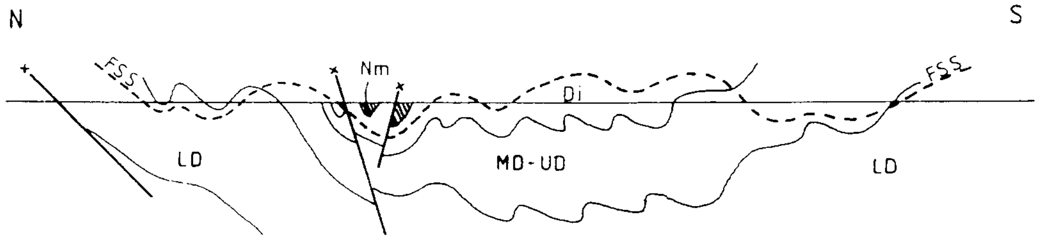

Figure 2. The cleavage front ('FSS' = 'Front Supérieur de Schistosité) in the Dinant Synclinorium, according to Fourmarier (1965) (LD = Lower Devonian; MD = Middle Devonian; UD = Upper Devonian; Di = Dinantian; Nm = Namurian).

But already in the classic works of Fourmarier (e.g. Fourmarier *et al.*, *1954*; Fourmarier, 1965) this generalisation is considered not to be an accurate reflection of reality. Fourmarier described a cleavage front ('Front Supérieur de Schistosité') within the Dinant Allochthon (Fig. 2). In the central part of the Dinant Synclinorium the cleavage front is recognised in Tournaisian pelites. Towards the North and South this front cuts down the sedimentary sequence. Taken into account Fourmarier's model considering a cleavage as a burial phenomenon which needs at least an overburden of 5 to 6 km, the course of the cleavage front implies that the sedimentary Dinant Basin is the deepest in its central part. To the North the basin becomes shallower, while to the South the dipping cleavage front is explained by the incipient Variscan orogenetic pulse, responsible for a tectonic uplift of the southern part of the basin.

More recently, a different cleavage evolution is considered (Piqué *et al.*, *1984*; Le Gall, 1992). The cleavage development is considered directly related to the Variscan pre- to syntectonic metamorphism, which affected the Ardennes Anticline (Dandois, 1981; Huon, 1982; Piqué *et al.*, *1984*). Both metamorphism and cleavage development are said to reach their maximum along the axis of the Ardennes Anticline and show a gradual decrease in intensity towards the North. While for Piqué *et al.* (1984) this gradual decrease does not allow the determination of a cleavage front, Le Gall (1992) considers a cleavage front near Dinant.

The approach of Piqué *et al.* (1984), applying the morphological classification of cleavage fabrics, as described by Powell (1979), Borradaile *et al.* (1982) and Bons (1988), is basically qualitative. A more quantitative approach, using phyllosilicate preferred orientation, is presented in this paper. Phyllosilicate preferred orientation, measured by means of an X-ray pole figure goniometer, indeed enables a quantitative description of the cleavage fabric, which is eventually defined as a statistically preferred alignment of platy marker grains, such as phyllosilicates (Ramsay & Huber, 1983). In this paper we will demonstrate how to distinguish pole figure patterns, and to relate them to the observed cleavage fabrics. This approach allows a more quantitative appraisal of the cleavage evolution in the Dinant Allochthon.

2. GEOLOGICAL SETTING

Classically the Dinant Allochthon is considered as a monolithic thrust sheet (Fourmarier, 1913) (Fig. 3A), which consists of the Givonne Anticline, the Eifel Syncline, the Ardennes Anticline and the Dinant Synclinorium (Fig. 1). This 'Dinant Nappe' (Bless *et al., 1982*) is thrusted over the Namur Parautochthon.

Nowadays it is generally accepted that the Dinant Allochthon consists of a pile of individual thrust sheets (Kaisin, 1936; Meilliez & Mansy, 1990; Meilliez *et al.*, 1991) formed in a piggy-back overthrust sequence (Meilliez & Mansy, 1990) (Fig. 3B). The overthrusting event, which is the result of Variscan shortening, followed a pre-Variscan extension phase, in which the Devono-Carboniferous sedimentary sequence was deposited. This deposition was controlled by normal faults, along which differential subsidence occurred. These faults were reactivated during the shortening phase and acted as overthrusts (Bless *et al.*, 1989; Meilliez & Mansy, 1990; Meilliez *et al.*, 1991; Le Gall, 1992).

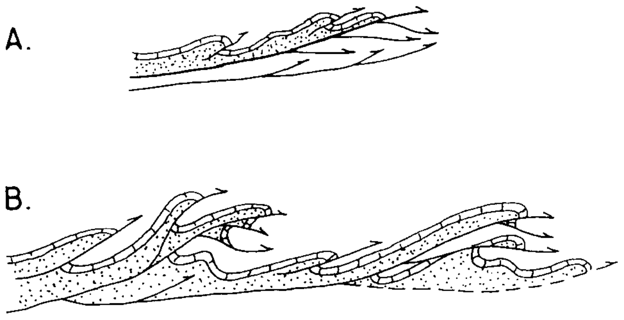

Figure 3. The Dinant Allochthon as monolithic thrust sheet (A) or as a piggy back overthrust sequence (B) (from Meilliez and Mansy, 1990).

Three such fault complexes can be distinguished North of the Rocroi Massif (Meilliez *et al.*, 1991) (Fig. 4B): the Givet-Philippeville Fault, along which a maximum differential subsidence occurred during middle Devonian time; the Yvoir-Hun Fault, active as a normal fault during mainly middle and upper Devonian time; and finally the Midi-Condroz-Eifel Overthrust Complex, which is a reactivated flexure line (Beugnies, 1964; Le Gall, 1992), that caused major differential subsidence along the Condroz Ridge during early Devonian time. These three fault complexes separate domains (Fig. 4B) with a respective characteristic structural style, determined mainly by lithological characteristics. The Aubrives Unit, in the hangingwall of the Givet-Philippeville Fault, consists of rather strongly deformed incompetent Lower to Middle Devonian series. A northward metamorphic gradient from epizonal to anchizonal can be recognised (Dandois, 1981; Huon, 1982). The Havelange Unit, in the hangingwall of the Yvoir-Hun Fault, consists mainly of complex folded competent series of Dinantian age. The anchizonal metamorphism gradually fades out into diagenetic conditions (Dandois, 1981; Huon, 1982). The Godinne Unit consists of competent, upright folded, Lower Devonian series. The Midi-Condroz-Eifel Overthrust Complex, limits this unit to the North. This Variscan Front Complex, in which the Sambre-et-Meuse basement massif is incorporated, furthermore separates the Dinant Allochthon from the Namur Parautochthon (Fig. 1).

3. TEXTURE ANALYSIS

The preferred orientation, or texture, of the platy phyllosilicate grains is determined by an X-ray pole figure analysis, using Ni-filtered CuKa-radiation. The measurements were performed in transmission mode on sections with an optimum thickness of 100 mm (Oertel, 1983). This mode reduces surface effects, which occur during sample preparation of phyllosilicate-rich materials, to a minimum (Oertel, 1978).

The measured intensity decreases dramatically with increasing tilt of the sample in the X-ray beam, mainly due to an increasing absorption. This effectively limits measurements to a tilt of up to 40°. Only incomplete pole figures can therefore be measured directly. Complete pole figures are obtained by combining measurements on two mutually perpendicular sections. Beside a tilt-corrected background subtraction, the measured intensities were corrected for the absorption effect, using an empirical method, similar to that described by O'Brien *et al.* (1987) (Sintubin, 1992). A final normalisation allowed the textures to be described in

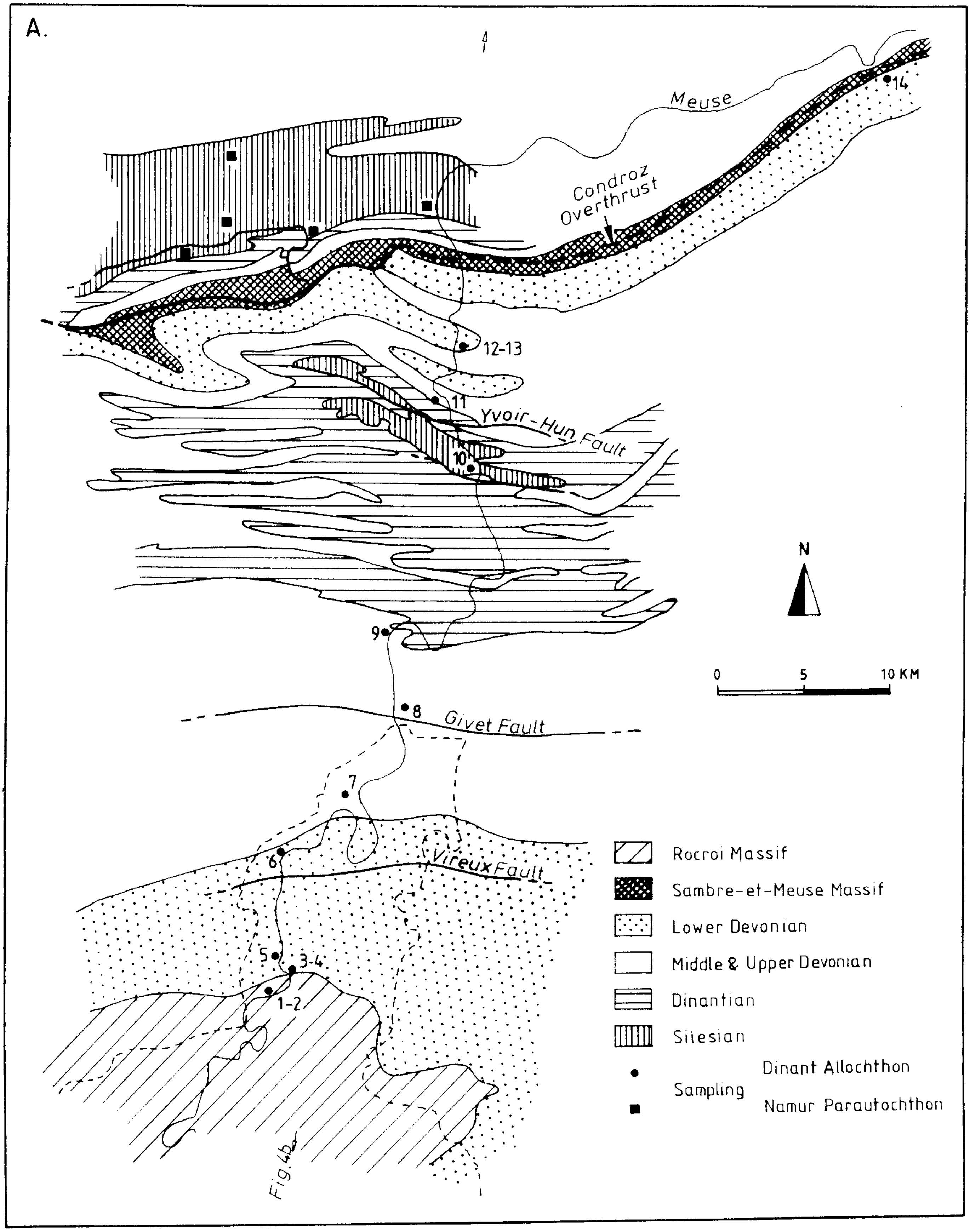

Figure 4. (A) Schematic map of the Meuse River profile with localisation of sampling sites (Tab. 1).

terms of 'multiples of random distribution' (mrd). The resulting pole figures are represented as lower hemisphere equal-area projections. In all samples the (001) mica pole figure (d = 10 Å) was measured. When possible, the (002) chlorite pole figure (d = 7 Å) was also measured.

The kinematic interpretation of the pole figures is based on the March model (March, 1932), which proposes a unique relationship between the normalised (00l) pole density distribution and the finite strain ellipsoid (Fig. 5). However, the application of this simple strain/texture relationship is subject to a series of constraints: 1) the orientation distribution must be unimodal with at least orthorhombic symmetry; 2) the deformation of matrix and marker grains has to be homogeneous; 3) the volume has to be constant; 4) the total deformation is measured; 5) the initial orientation distribution of the marker grains must be random; and 6) the marker grains must behave passively. Although few phyllosilicate-rich materials comply with these conditions, reasonable correlations with independent strain markers (Oertel, 1970; Tullis & Wood, 1975; Oertel *et al.*, 1989) show that the March values can still be considered as acceptable estimates of the real strains.

While the qualitative interpretation of the phyllosilicate pole figures is based on the orientation distribution symmetry and on its geometric relationship with the mesoscopic structural elements (Sintubin, 1994a) (Fig. 6), the quantitative interpretation is based solely on the degree of preferred orientation. This degree of preferred orientation seems however not only dependent on the strain,

Table 1. Sampling localities and stratigraphical position of samples.

Sample Nr.	Topographic Map (1/25000)	Stratigraphical Position	description of sampling locality
1	63(1-2) Moulin Manteau - Moulin de Chestion	Devillium	R.N. 51 - Anc. Carrières des Rochettes
2	63(1-2) Moulin Manteau - Moulin de Chestion	Devillium	R.N. 51 - Anc. Carrières des Rochettes
3	58(5-6) Olloy-sur-Viroin - Treignes	Lochkovian - Haybes Formation	Rocher-à-Fépin, east bank of Meuse River
4	58(5-6) Olloy-sur-Viroin - Treignes	Lochkovian - Haybes Formation	Rocher-à-Fépin, east bank of Meuse River
5	58(5-6) Olloy-sur-Viroin - Treignes	Lochkovian - Oignies Formation	R.N. 51 - Moulin de Fetrogne
6	58(5-6) Olloy-sur-Viroin - Treignes	Emsian - Chooz Formation	D47 - in front of "Hauts-fourneaux de Vireux-Molhain"
7	58(3-4) Agimont - Beauraing	Eifelian	R.N. 51 - Les Bonniers
8	58(3-4) Agimont -Beauraing	Famennian	east bank of Meuse river, North of bridge at Heer-Agimont
9	53(7-8) Hastière-Lavaux - Dinant	Famennian	N17 - Hermeton-sur-Meuse
10	53(3-4) Bioul - Yvoir	Namurian	N17 - North of Carrière Watrisse, South of Alhnée
11	53(3-4) Bioul - Yvoir	Famennian	N17 - South of Hun
12	53(3-4) Bioul - Yvoir	Emsian	N47 - in valley of Ruisseau du Fonds d'Hastroi
13	53(3-4) Bioul - Yvoir	Emsian	N47 - in valley of Ruisseau du Fonds d'Hastroi
14	48(3-4) Huy - Nadrin	Lochkovian - Fooz Formation	railway station of Huy-Statte

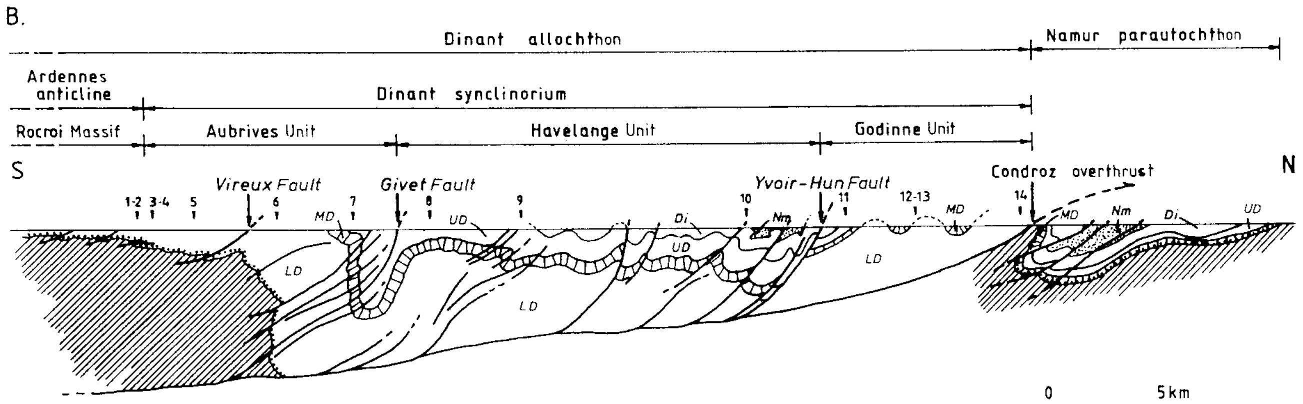

Figure 4. (B) Meuse River Profile (after Raoult & Meilliez, 1986) with localisation of sampling sites (LD = Lower Devonian; MD = Middle Devonian; UD = Upper Devonian; Di = Dinantian; Nm = Namurian).

but is also influenced by lithological parameters (Sintubin, 1994b/c). The latter influence is reflected in the systematic intensity difference between mica and chlorite textures, as well as in the negative correlation between quartz content and degree of preferred orientation (Fig. 11). Because of this complex interaction between strain, lithology and degree of preferred orientation, the following discussion emphasises on the qualitative characteristics of the phyllosilicate textures.

4. MEUSE RIVER PROFILE: FABRICS AND TEXTURES

In the different structural units, described previously, pelitic material was sampled and analysed. The sample sites (Fig. 4; Tab. 1), between Fumay and Namur, were selected in such a manner that a comparison with the results of Piqué *et al.* (1984) was possible. The selection was moreover determined by the requirement to have pelitic material with a minimal lithological variation.

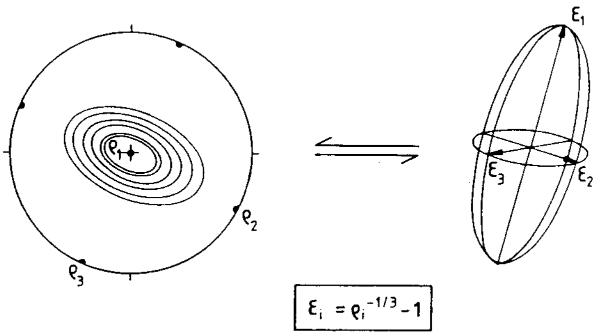

Figure 5. March model (March, 1932): analytical relationship between the orientation distribution of platy marker grains, expressed as a normalised density distribution (ri), and the finite strain ellipsoid (ei).

4.1. ROCROI MASSIF

In the northernmost part of the Rocroi Massif the overturned series exhibit a parallelism between bedding and cleavage. The Devillian slates (RM1 & RM2) (Fig. 4) are characterised by a very fine grained continuous cleavage fabric (Powell, 1979). In sample RM2, however, the cleavage fabric is disturbed by coarser quartz grains. Both mica and chlorite pole figures (Fig. 7) show an orthorhombic symmetry. The pole figure maximum coincides with the cleavage pole, while the short axis of the orientation distribution is parallel to the stretching lineation, observed on the cleavage planes in sample RM1. These geometrical elements are indicative for a deformation pole figure pattern, which is characteristic for an apparent flattening regime (Sintubin, 1994a) (Figs. 6 & 8). The lower degree of preferred orientation in sample RM2 is the reflection of the disturbing influence of the coarser quartz grains on the preferred orientation of the phyllosilicates in the cleavage fabric.

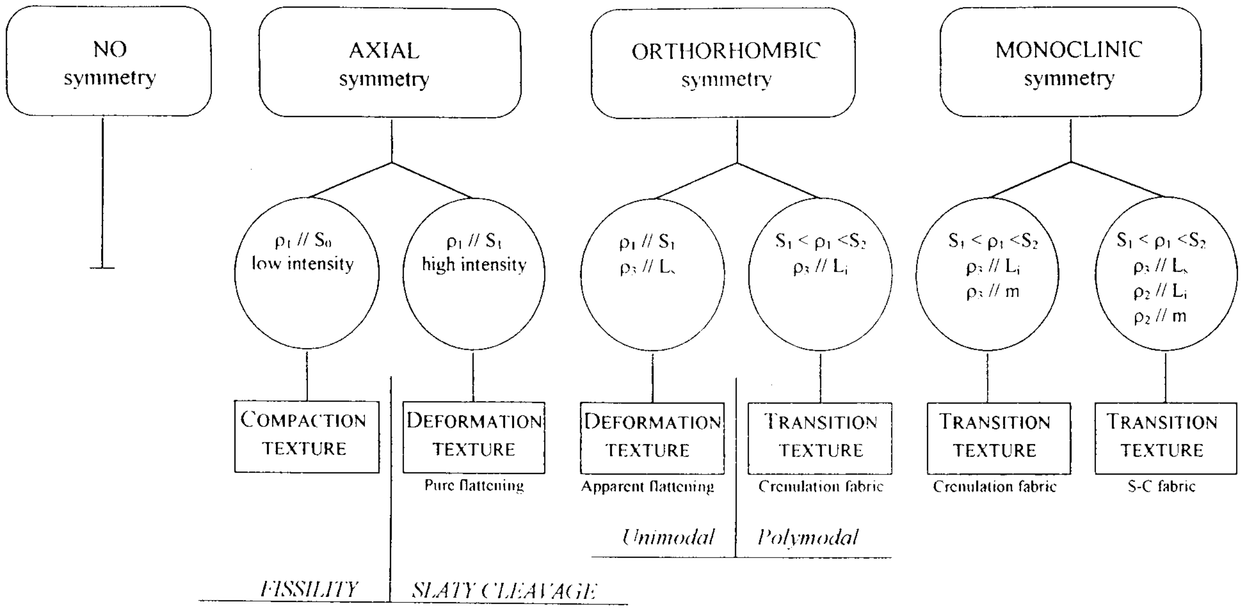

Figure 6. Flow chart for the classification of different pole figure patterns, based on degree of preferred orientation, symmetry of orientation distribution, and its geometric relationship with the structural elements (S0 = bedding pole; S1 = primary cleavage pole; S2 secondary cleavage pole; Li = intersection lineation; Ls = stretching lineation; m = pole of mirror plane; ri = orientation pole density) (after Sintubin, 1994a).

4.2. AUBRIVES UNIT

The slates (AU3 & AU4), sampled in the overturned Haybes Formation (Lochkovian), just North of the unconformity with the Rocroi Massif (Fig. 4), show a slaty cleavage development oblique to the bedding. The fine grained phyllosilicate fabric is characterised by a dense spaced cleavage, which behaves anastomosing with regard to coarser quartz-rich lenses. No chlorite is present. The pole figure pattern (Fig. 7) is similar to that observed in both Devillian slates. The bedding is not reflected in the phyllosilicate texture.

The claystone (AU5) of the Oignies Formation (Lochkovian) shows an irregular pencil cleavage. The phyllosilicate fabric is characterised by a weak spaced cleavage (spacing of 10 mm), materialised by irregular film of mica. The fabric in the microlithons does not show any parallelism with neither bedding nor cleavage. No texture could be obtained.

A shaly sample (AU6) from the overturned Chooz Formation (Emsian), in the footwall of the Vireux Fault (Fig. 4), is characterised by a fine grained, bedding-parallel, continuous phyllosilicate fabric. At 20° to the bedding a dense spaced cleavage (spacing 10 mm) is materialised by very fine opaque films. In quartz-rich laminae the cleavage is refracted. Mica and chlorite textures not only differ in intensity but also in pattern (Fig. 7). The mica texture shows an orthorhombic symmetry. The symmetry plane, which contains both bedding and cleavage pole, coincides with the intermediate axis of the orientation distribution. This transition pole figure pattern (Fig. 6) is considered as the result of a summation over different orientation populations (Sintubin, 1994a) (Fig. 9B). The chlorite texture, on the other hand, is axially symmetric. The maximum pole density coincides with the bedding pole. Contrary to the mica texture, the slaty cleavage development is not reflected in the chlorite texture.

Finally, a calcareous shale (AU7) (Eifelian) shows signs of a weak bedding-parallel preferred orientation, due to coarse detrital phyllosilicate grains. The phyllosilicate texture reflects this bedding-parallel fabric (Fig. 7).

4.3. HAVELANGE UNIT

In the southern part of this unit (Fig. 4) the two Famennian samples show a different cleavage fabric. Sample HU8 is very similar to sample AU6. A continuous, fine grained, phyllosilicate fabric developed parallel to the bedding. At 30° to the bedding a dense spaced cleavage is observed. The pole figure pattern (Fig. 7) is characterised by an intermediate position of the pole figure maximum between bedding and cleavage pole, although not exactly within the symmetry plane containing both poles. Both the specific position of the pole figure maximum and the symmetry of the orientation population indicates an equal importance of both bedding-parallel and cleavage-parallel orientation populations.

Sample HU9, on the other hand, shows an anastomosing spaced cleavage (spacing 50 mm) with rather randomly oriented microlithons, which consist of quartz grains and distorted mica-chlorite aggregates. This weak cleavage fabric developed perpendicular to the bedding. The heterogeneity of the fabric did not allow a proper texture determination.

Finally, in the Anhée Syncline, situated in the direct hangingwall of the Yvoir-Hun fault (Fig. 4), a Namurian shale (HU10) is characterised by a pronounced fissility. The bedding-parallel phyllosilicate fabric is continuous. The mica texture (Fig. 7), which is characterised by an axial symmetry around the bedding pole, is exclusively the result of a compaction strain (Sintubin, 1994a) (Fig. 6).

4.4. GODINNE UNIT

In this unit the southern limbs of the Godinne and Lustin anticlines were sampled (Fig. 4). A micaceous sandstone (GU11) of Famennian age shows a bedding-parallel cleavage, caused by the preferred orientation of coarse phyllosilicate grains, parallel to the bedding. Low phyllosilicate concentration did not allow a reliable texture determination.

In the southern limb of the Lustin Anticline (Fig. 4), Emsian shales (GU12 & GU13) show different cleavage fabrics. Sample GU12 is similar to samples AU6 and HU8. At an angle of 35° of the fine grained, bedding-parallel, continuous phyllosilicate fabric a dense spaced cleavage developed. Again, a transition pole figure patterns (Figs. 7 & 9B), with a certain asymmetry (Sintubin, 1994a), is observed.

Sample GU13 show pronounced bedding-parallel cleavage planes with a clear lineation. The phyllosilicate fabric is continuous. A rather exceptional pole figure pattern (Fig. 7) is measured, which is very similar to that measured in the Devillian slates in the Rocroi Massif (RM1 & RM2). The orthorhombic symmetry, as well as the geometric relation between texture and lineation, indicates a partially tectonic origin of the bedding-parallel cleavage fabric (Fig. 6).

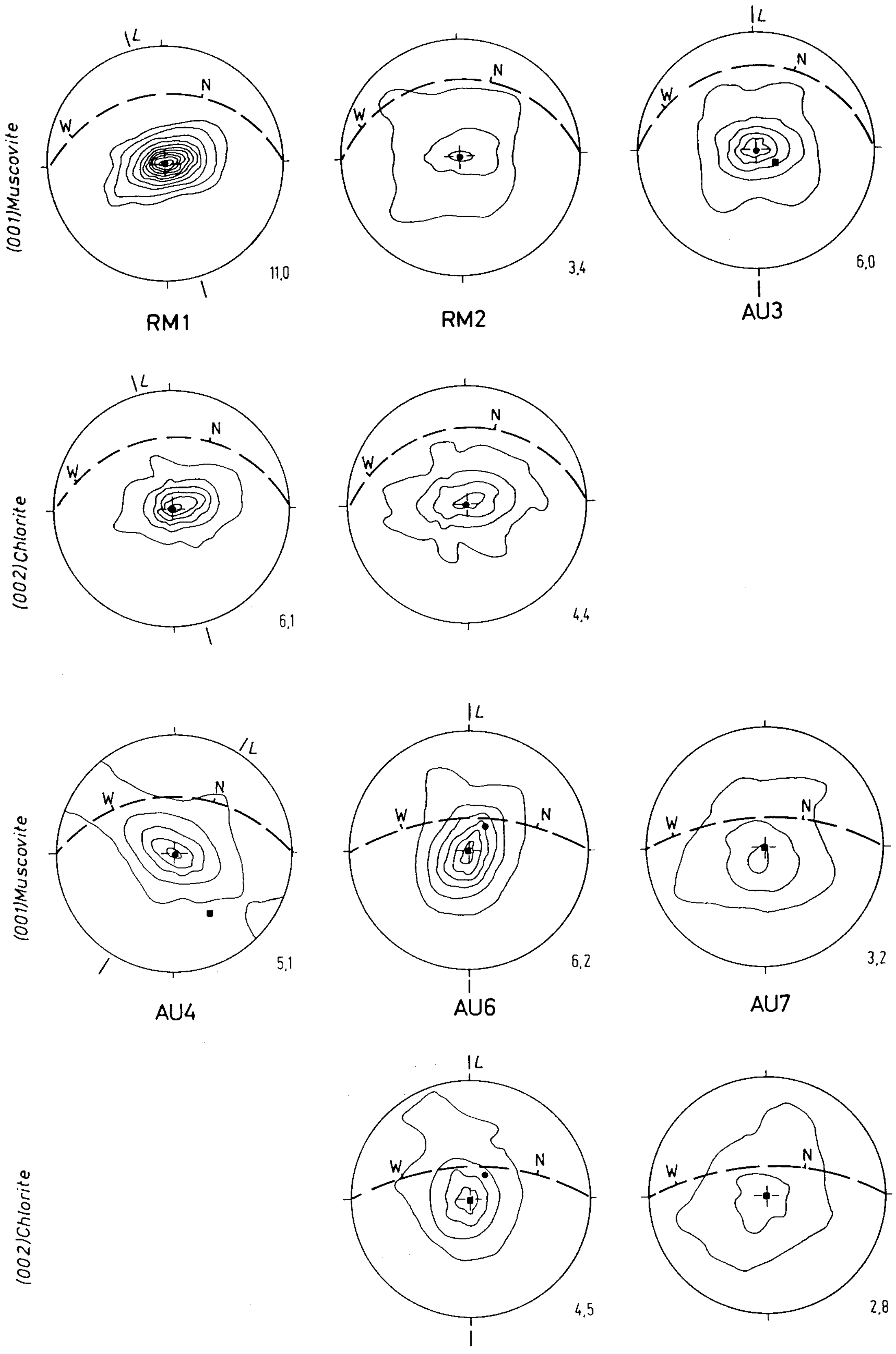

Figure 7. (001) Mica and (002) chlorite pole figures from the Rocroi Massif (RM), the Aubrives (AU), Havelange (HU) and Godinne Units (GU) (lower hemisphere equal-area projections; contour lines = intervals of 1 mrd; n = bedding pole; l = cleavage pole; L = lineation; dashed great circle = geographical reference plane), with indication of the degree of preferred orientation.

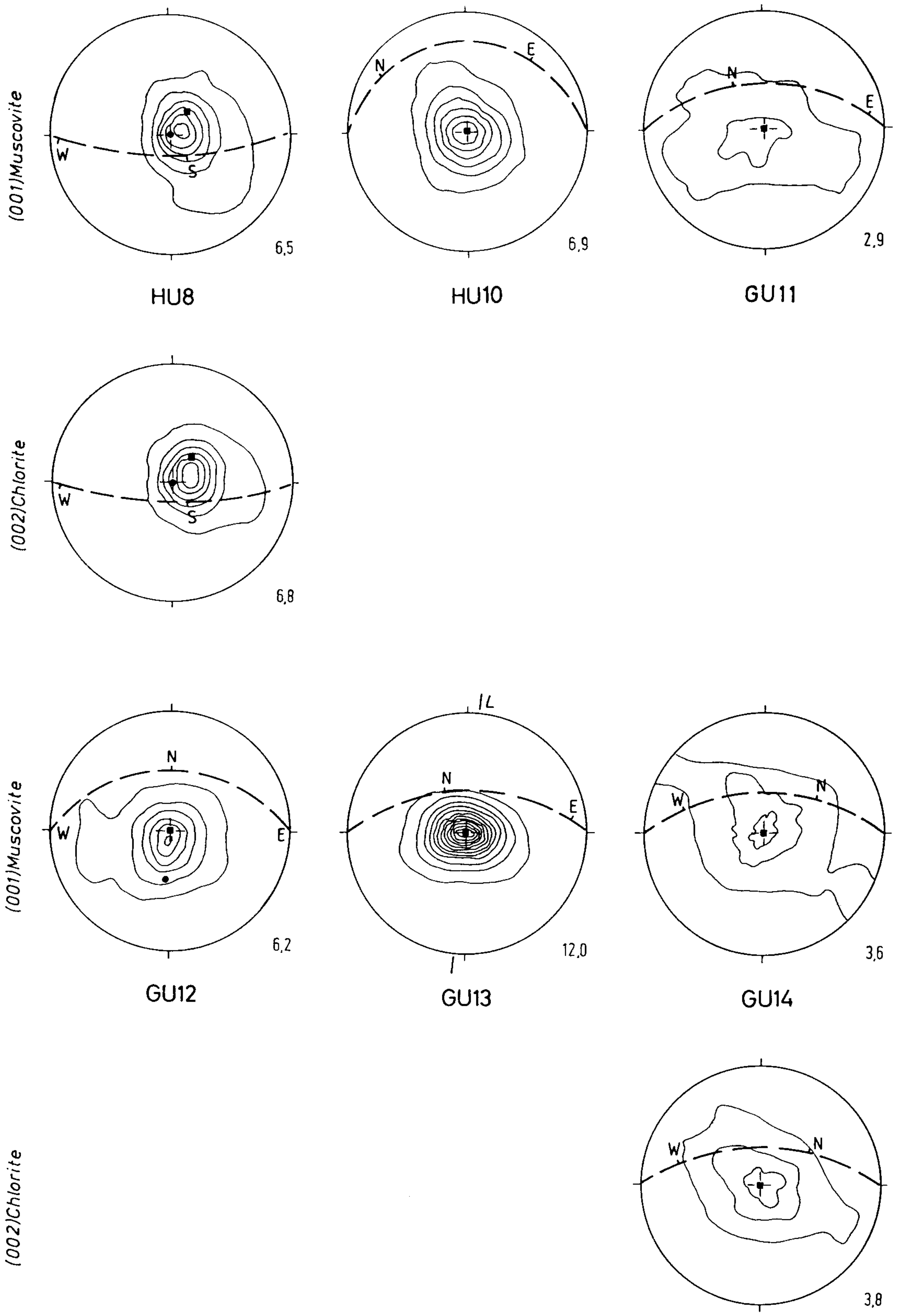
(001)Muscovite
N
E
W
S
6,5
HU8
6,9
HU10
2,9
GU11
(002)Chlorite
W
S
6,8
(001)Muscovite
N
W
E
6,2
GU12
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Figure 7. (002)

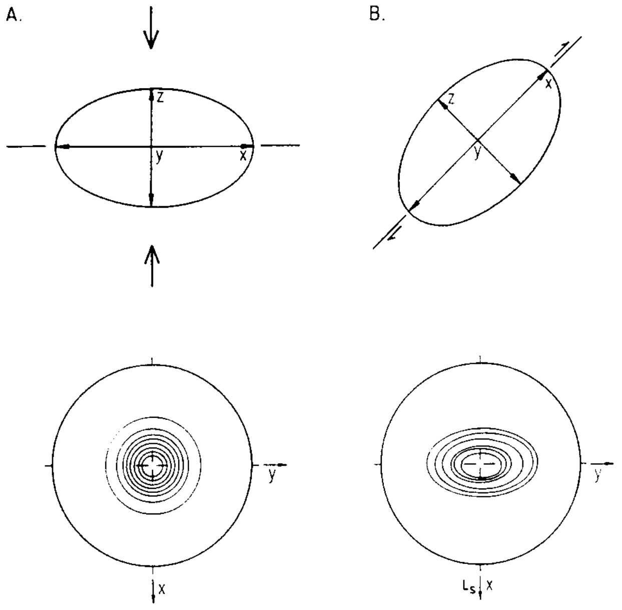

Figure 8. (A) Axially symmetric pole figure pattern, reflecting a pure compressional strain(x=y>z); (B) orthorhombic pole figure pattern, reflecting a compressional strain with significant extension in the flattening plane (x>y>z) (after Sintubin, 1994b).

A micaceous sandstone (GU14) from the Fooz Formation (Lochkovian), sampled in the Hoyoux valley just South of the Sambre-et-Meuse Massif (Fig. 4), shows a bedding-parallel preferred orientation of the phyllosilicates. Only a weak texture is observed (Fig. 7).

4.5. NAMUR PARAUTOCHTHON

At different sites in the Namur Parautochthon (Fig. 4) silty shales of Silesian age are sampled. These shales all show an irregular bedding-parallel cleavage. The phyllosilicate fabric is weak. Coarse mica grains, as well as fine phyllosilicate-rich laminae, are oriented parallel with the bedding. No secondary phyllosilicate fabrics are observed. Textures are weak and reflect the bedding-parallel fabric.

5. DISCUSSION

In the pelitic material, sampled across the Dinant Allochthon, different pole figure patterns, reflecting the different stages in the cleavage development (Fig. 10), are recognised.

An exclusively sedimentary fabric is observed in the micaceous sandstones in the Godinne Unit (GU11 & GU14) and in the calcareous shale in the Aubrives Unit (AU7), as well as in all silty shales in the Namur Parautochthon. Detrital mica grains and fine grained phyllosilicate-rich laminae form a bedding-parallel phyllosilicate fabric. No texture information can be obtained, because of low phyllosilicate concentration.

The Namurian shale in the Anhée Syncline (HU10) shows a typical compaction texture (Sintubin, 1994a). The compaction strain is estimated at 62% (Oertel & Curtis, 1972). Very similar results are found in the Westphalian and Zechstein shales in the Campine Basin (Sintubin, 1994c) and in the Ordovician and Silurian shales in the Sambre-et-Meuse Massif (Sintubin, 1994d). This compaction value is relatively high because it reflects the fabric evolution from the deposition of the flocculated clay particles on (Sintubin *et al.*, submitted).

Both in the Oignies shale (AU5) and the Famennian shale (HU9) the development of a secondary cleavage, oblique to the bedding, is initiated. The development of such a pencil cleavage primarily involves the destruction of the existing bedding-parallel phyllosilicate fabric. Incipient cleavage domains are formed, but do not dominate the fabric. Statistically this phyllosilicate fabric lacks any preferred orientation, so that no texture can be measured.

The next stage in the cleavage development is reflected in the transition pole figure pattern, observed in the Emsian shales (AU6 & GU12) and in the Famennian shale (HU8). The continuous phyllosilicate fabric is still parallel to the bedding. At an angle to the bedding a spaced secondary cleavage fabric, reflected in fine grained phyllosilicate-rich cleavage domains, is developing. This bimodal nature of the fabric results in the transition pole figure pattern. The relative importance of the two orientation populations and their mutual geometrical relationship eventually determines the symmetry and the orientation of the pole figure pattern (Sintubin, 1994a) (Fig. 9).

The final stage of the slaty cleavage development is reached when the phyllosilicate fabric is completely recrystallised, which is the case on both sides of the northern unconformity of the Rocroi Massif (RM1, RM2, AU3 & AU4). The characteristic pole figure pattern implies a cleavage development in a deformation regime, generating a substantial extensional component in the cleavage plane (Fig. 8B). The same pole figure pattern is observed across the whole Rocroi Massif (Rathore & Hugon, 1987). The identity of the textures on both sides of the unconformity furthermore implies a Variscan origin of the cleavage fabric. The strong fabric of the Devillian slates is therefore probably caused by a

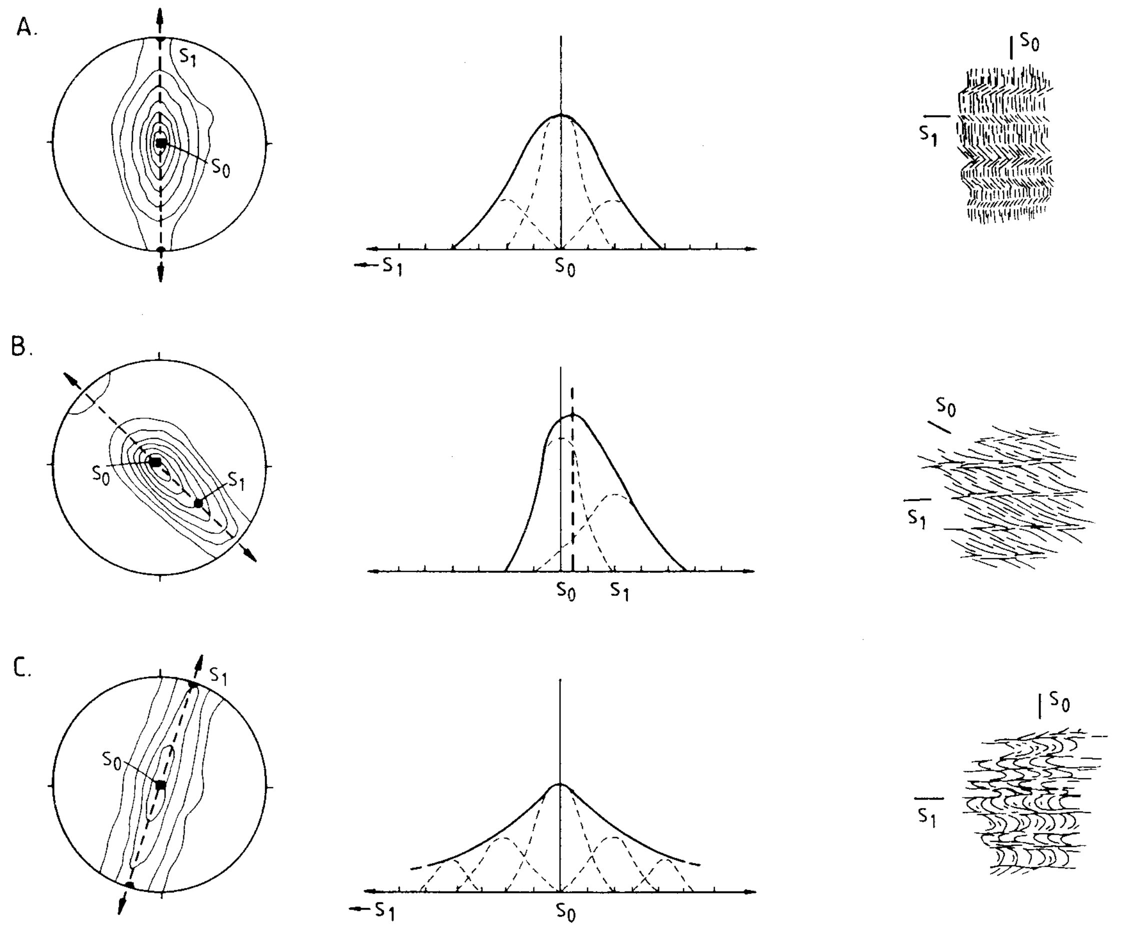

Figure 9. The composition of the transition pole figure pattern for crenulation fabrics (pole figure, pole figure profile, fabric): (A) incomplete girdle pattern with orthorhombic symmetry; (B) incomplete girdle pattern with monoclinic symmetry; (C) complete girdle pattern with orthorhombic symmetry (S0 = bedding pole, S1 = cleavage pole) (Sintubin, 1994a).

superposition of the Variscan cleavage on an pre-existing bedding-parallel phyllosilicate fabric, caused by compaction or a Caledonian deformation.

A similar pole figure pattern is observed in the Emsian shale in the southern limb of the Lustin Anticline (GU13), which definitively implies a partially tectonic origin of this bedding-parallel cleavage fabric.

The presence of the different pole figure patterns, reflecting all stages of the cleavage development, clearly proves that the Dinant Allochthon can definitively not be considered a homogeneous schistose domain. The distribution of the pole figure patterns is moreover not determined stratigraphically nor spatially. A gradient, as proposed by Piqué *et al.* (1984), seems not reflected in the spatial distribution of the pole figure patterns.

Only on both sides of the unconformity of the Rocroi Massif the pole figure pattern can be related directly to the metamorphism, associated with the Variscan deformation. To the North this cleavage development rapidly decreases in intensity, as becomes already apparent when considering the total absence of any pervasive cleavage fabric in the Oignies shale (AU5).

In stead of the metamorphism, which determines the development of a pervasive cleavage along the axis of the Ardennes Anticline, the cleavage development towards the front of the Dinant Allochthon seems rather controlled by lithological characteristics and local strain conditions.

The lithological control is on the one hand expressed in the negative correlation between degree of preferred orientation and quartz content (Fig. 11). The presence of equant quartz grains indeed inhibit the development of a perfect alignment of the phyllosilicate grains. Also the systematic intensity difference between mica and chlorite textures is explained by a concentration difference of both minerals in the fabric (Sintubin, 1994b). Sample AU6 is rather exceptional in this respect because of the difference in pole figure pattern. While the mica texture reflects the bimodal nature of the fabric, the chlorite texture only represents the primary fabric.

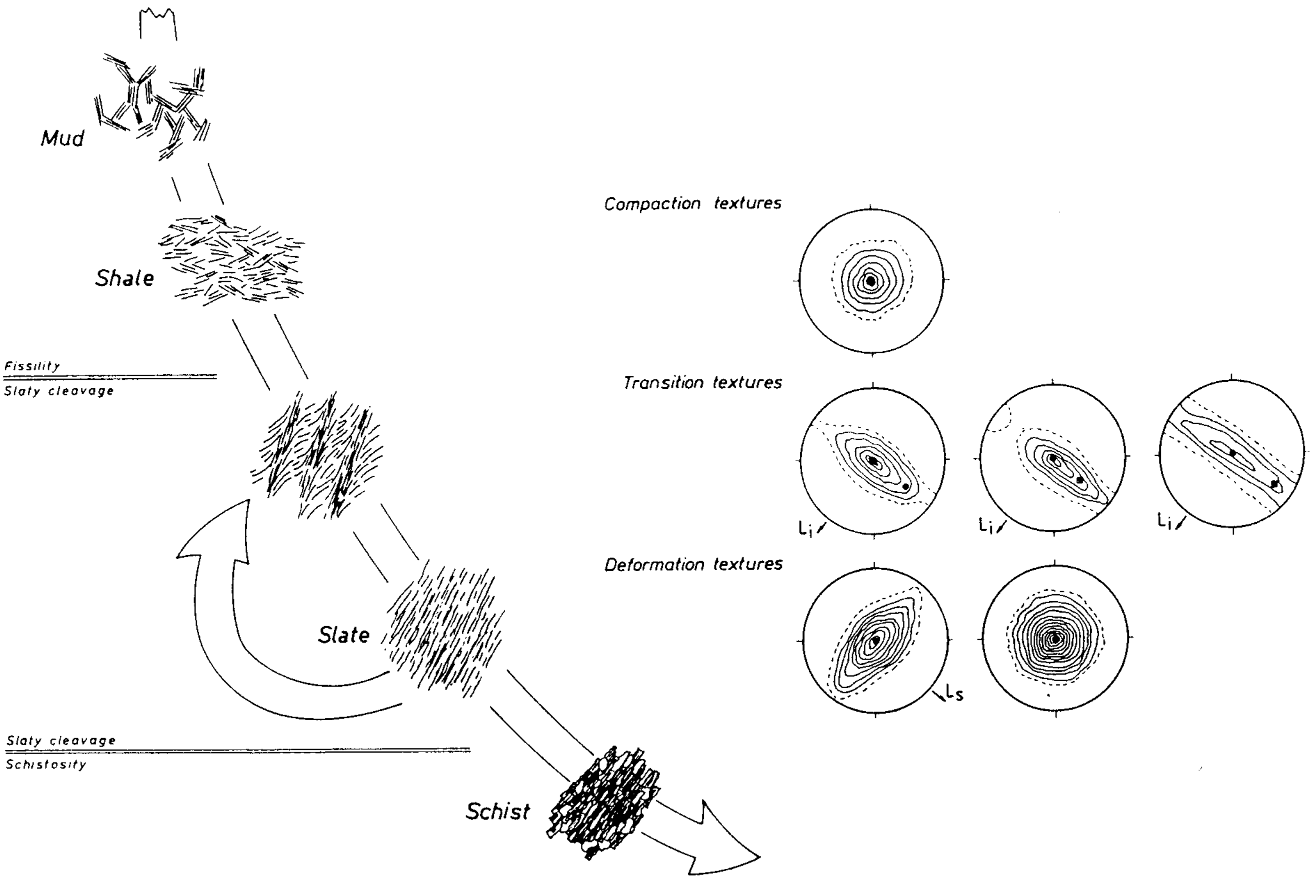

Figure 10. Relationship between the fabric development and the texture development during burial and tectonic history of pelitic rocks (n = primary cleavage pole (S0 or S1); I = secondary cleavage pole (S1 or S2); Ls = stretching lineation; Li = intersection lineation) (Sintubin, 1994a).

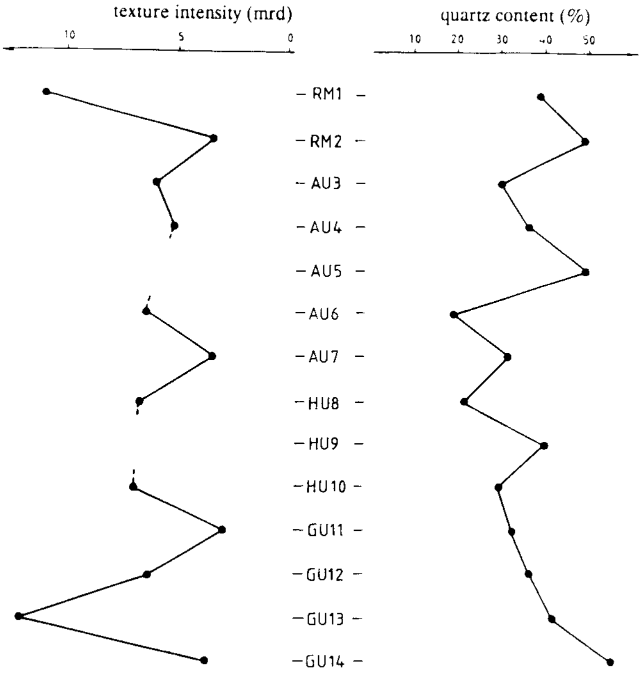

Figure 11. Correlation between the intensity of the mica textures and the quartz content, determined by the gravimetric technique of Trostel & Wyne (1940).

The cleavage development does not seem to involve chlorite.

Local strain condition also seem to influence the cleavage evolution. This is on the one hand obvious when considering the structural position of the Emsian (AU6) and Famennian shale (HU8), both characterised by a transition pole figure pattern, in the footwall of major faults, the Vireux Fault, respectively the Givet-Philippeville Fault. The importance of the localised strain conditions is even more obvious in the southern limb of the Lustin Anticline, where both transition texture (sample GU12) and deformation texture (sample GU13) imply an intense deformation. The southern limb of this anticline clearly underwent a significant semi-ductile deformation (cf. Hugon, 1983), similar to the deformation in the Devillian slates. It can be assumed that the pelitic horizons acted as localised shear zones. This observation may eventually very well answer the question of the abnormally high illite crystallinity, observed in these formations (Dandois, 1981). Shear heating can in our opinion be considered responsible for both the high illite crystallinity and the deformation texture.

6. CONCLUSION

This quantitative texture analysis clearly shows that the Dinant Allochthon can not be considered as a domain, characterised by a uniform cleavage development. Moreover, the gradient, as proposed by Piqué *et al.* (1984), seems not reflected in the presented evolution in pole figure pattern.

Only along the northern unconformity of the Rocroi Massif the cleavage development can be related directly to the Variscan metamorphism. To the North, towards the Variscan Front, it is shown that the cleavage evolution is primarily controlled by lithology and local strain conditions.

As demonstrated in the southern limb of the Lustin Anticline, the distinction of the pole figure patterns enables an additional specification of the deformation regime, in which the cleavage fabric developed. This specific contribution of the texture analysis transcends the possibilities of a qualitative fabric analysis.

Finally, I believe that the classical subdivision of the Variscan thrust-and-fold belt in schistose and aschistose domains can not be retained. The presence or absence of a cleavage can in our opinion no longer be used as a valid criterion to determine the structural affinity in the Variscan fold-and-thrust belt. The cleavage evolution is indeed far more complex.

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