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PRE-DEVONIAN, BRABANTIAN DEFORMATION WITHIN THE SOUTHERN CONDROZ INLIER (RUISSEAU DES CHEVREUILS, DAVE, BELGIUM)

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(4 figures)

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Introduction

The Condroz Inlier is a narrow belt of Lower Palaeozoic rocks, flanked to the south by the Lower Devonian of the Dinant Synclinorium, and to the north by the Middle Devonian of the Namur Synclinorium (Fig. 1). Whereas the former experienced a significant brittle-ductile Variscan deformation, in the latter compressive deformation appears to have been restricted to the local development of thin-skinned reverse faults. Because of this particular position of the Condroz Inlier - approximately coinciding with the Variscan front zone -, and its poor degree of exposure, the structural architecture and the age of deformation have been widely debated (for an overview see Sintubin, 1992; Valcke, 2001). Despite its narrowness, some authors distinguish three, rather ill-constrained, zones within the Condroz Inlier (e.g. Michot, 1980; Verniers et al., 2001): a) a northern part, at Ombret (E), with cleavage (Michot, 1979; Steemans, 1994), b) a central and main part, without cleavage ("Condrusion tectofacies" of Michot, 1979; cf. Michot, 1954; 1969; Maes et al., 1978; Hance et al., 1991), and c) a southern part, at

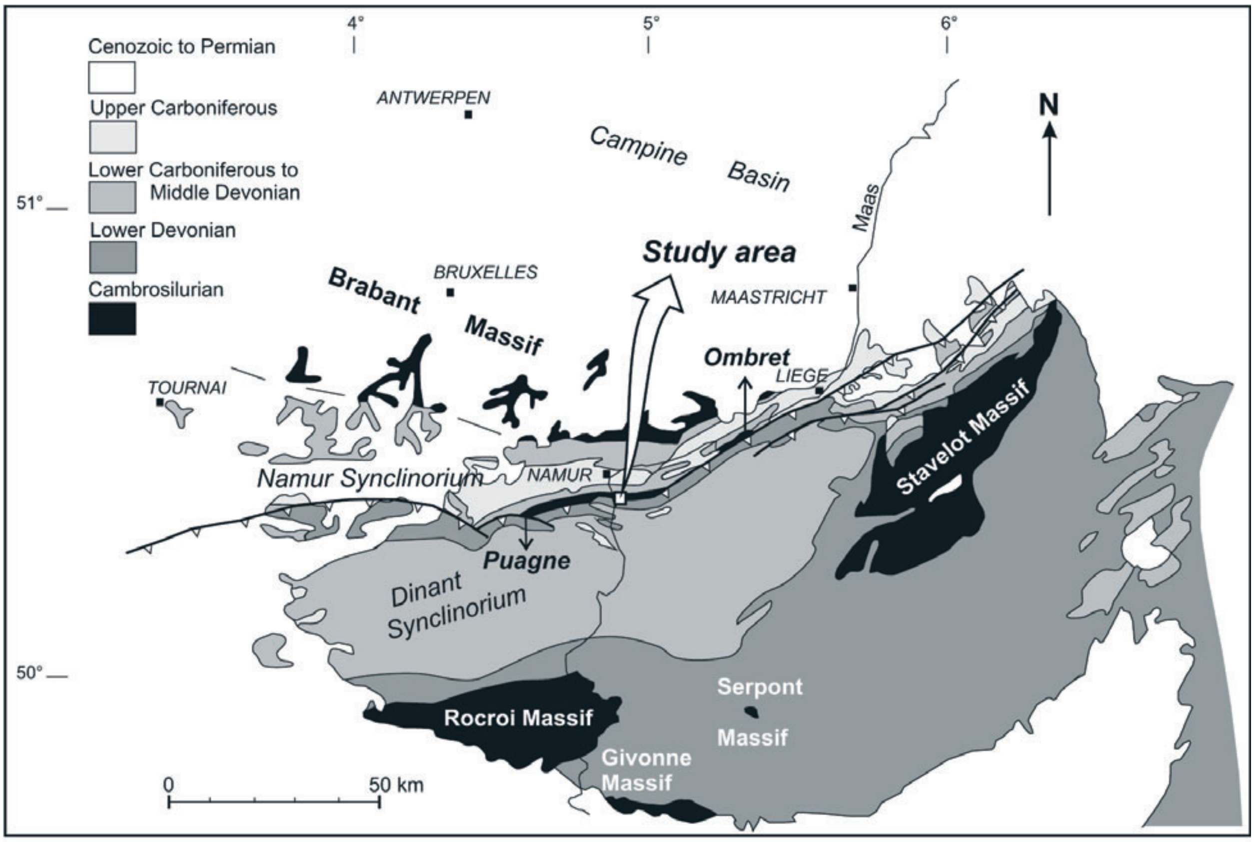

Figure 1: Simplified geological map of Belgium showing the position of the study area within the Condroz Inlier along the Variscan Front zone (modified after Fielitz & Mansy, 1999).

Puagne (W) and Fond d'Oxhe (E), again with cleavage (e.g. Fourmarier, 1939; Steemans, 1994). Because of the relative position of these three zones, the cleavage in the northern part is sometimes considered as a result of the pre-Devonian, Brabantian deformation event (Valcke, 2001; Valcke & Debacker, 2002), whereas the cleavage in the southern part is often attributed to the Variscan deformation (e.g. Fourmarier, 1939; Michot, 1979).

The present study focuses on the Ruisseau des Chevreuils, situated in the SW-part of the central Condroz Inlier, directly to the SE of Dave. Along this brook, outcrops occur of the recently defined and biostratigraphically dated upper Darriwilian to lower Sandbian Chevreuils Formation (Vanmeirhaeghe, 2006). These outcrops can be combined to a discontinuous, ~300 m long NNW-SSE-trending section. To the southeast, the section continues for at least another 100 m across the Lower Devonian Fooz Formation of the Dinant Synclinorium. According to several authors (e.g. Fourmarier, 1939; Michot, 1944), the (unexposed) contact between the conglomerates and sandstones of the Fooz Formation and the Ordovician of the Condroz Inlier is formed by an important reverse fault (Faille du Midi).

Structural outcrop observations

Most of the Lower Palaeozoic in the Ruisseau des Chevreuils is only poorly deformed. The deposits generally have gentle to moderate bedding dips, with quite variable strikes, and, although locally reflecting gentle, dm- to m-scale fold structures, do not show any macroscopically recognisable fold-related cleavage. In fact, the only pervasive fabric is a bedding-parallel compaction fabric, and much, if not all, of the internal deformation of the rocks appears to be due to the abundant bioturbations and, in certain levels, to (non-biogenic) soft-sediment deformation (e.g. slump folds).

However, between 75 and 125 m to the NNW of the (fault-?; e.g. Fourmarier, 1939) limit with the Lower Devonian, the Lower Palaeozoic is affected by a poorly to well-developed, gently to moderately NE-dipping cleavage. In several outcrops, asymmetric, south-verging folds are observed, to which the cleavage shows an axial planar relationship (Fig. 2). Moreover, in the fine-grained beds, the cleavage shows a divergent fanning with a symmetrical disposition with respect to the fold axial surface. In addition, contrasting cleavage refraction patterns are observed

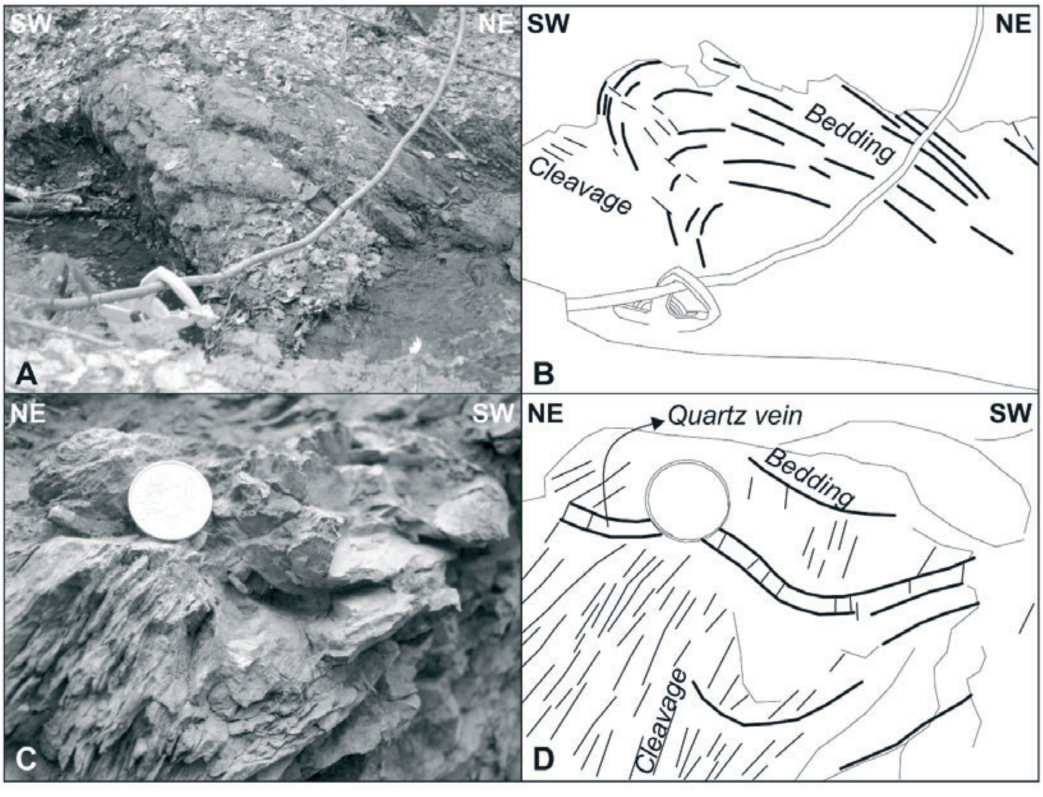

Figure 2: South-verging syn-cleavage folds within the Chevreuils Formation in the Ruisseau des Chevreuils outcrop section (Dave). A) Gently NE-dipping, strongly asymmetric close to tight antiform within a bioturbated sandstone level (outcrop 13 of Vanmeirhaeghe, 2006; tape measure for scale); B) Sketch of (A), highlighting bedding and cleavage; C) NE-dipping, asymmetric, open fold train affecting a bedding-parallel quartz vein (outcrop 17 of Vanmeirhaeghe, 2006; 50 eurocent coin for scale); D) Sketch of (C), highlighting bedding, cleavage and folded quartz vein. Note the axial planar cleavage, the divergent cleavage fanning and the cleavage refraction patterns.

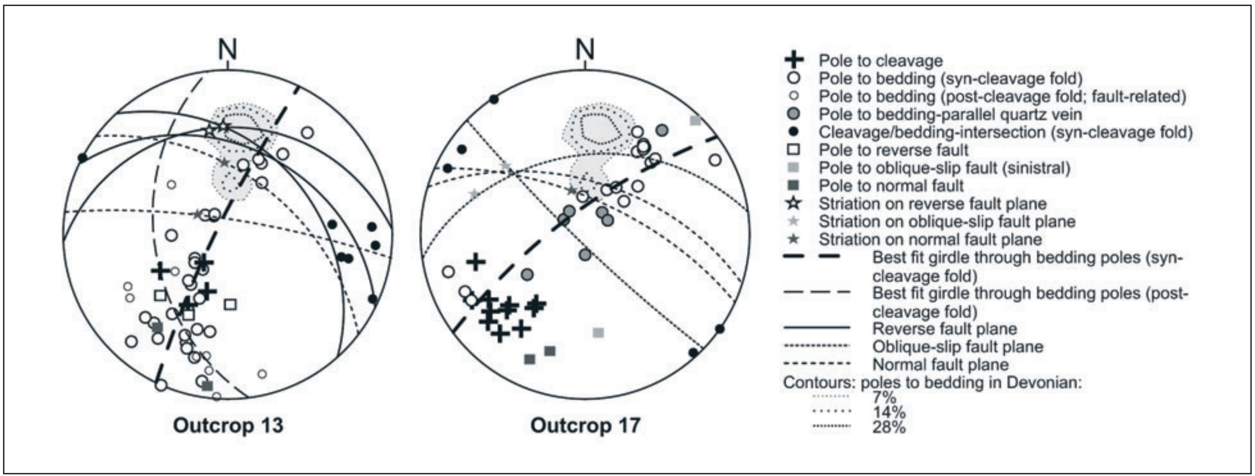

Figure 3: Lower-hemisphere equal area projections of bedding, cleavage, cleavage/bedding intersection and fault data of outcrops 13 (cf. fig. 2A & 2B) and 17 (cf. fig. 2C & 2D) of Vanmeirhaeghe (2006). For comparison, contours of poles to bedding in the Devonian of the Dinant Synclinorium are added (grey-shaded contours in background; outcrops 1 & 2 of Vanmeirhaeghe, 2006).

on opposite fold limbs. These cleavage/fold relationships (axial planar cleavage, divergent fanning, and contrasting refraction patterns on opposite fold limbs) indicate that folding and cleavage development are cogenetic (Figs 2 & 3). In one outcrop (outcrop 17 of Vanmeirhaeghe, 2006), a folded bedding-parallel, pre-cleavage quartz vein occurs, showing a similar asymmetry and cleavage/fold relationship as the other syn-cleavage folds (Figs 2 & 3). This quartz vein reflects a bedding-orthogonal extension and a bedding-parallel shortening prior to folding and cleavage development.

Apart from their mere presence, also the NW-SE-trend of the cleavage and the south-verging folds is unexpected, as it is markedly oblique to the overlying Devonian and to the general trend of the Condroz Inlier (E-W) (Fig. 3). Towards the north and towards the south, cleavage becomes less obvious or disappears altogether.

Throughout the section numerous faults occur. Where observed, these faults all deform cleavage and hence post-date cleavage. Some of the reverse faults (N-dipping) can be related geometrically -and probably also genetically- to the syn-cleavage folds (Fig. 3). Many of the S-dipping reverse faults, however, as well as the normal and the oblique-slip faults, all cross-cutting cleavage and related structures (folds and N-dipping reverse faults), do not show any geometrical relationship with the syn-cleavage deformation. Therefore, these faults are not likely to have formed during the same deformation event as cleavage.

Discussion and conclusion

Taken together, a) the irregular distribution and intensity of the cleavage fabric, b) the comparably irregular distribution of the south-verging, syn-cleavage folds and c) the unexpected predominantly NW-SE-trend of the cleavage, fold hinge lines and cleavage/bedding intersection, seemingly reflect a "higher-strain zone" in otherwise almost undeformed Lower Palaeozoic rocks.

Because of a) the obliquity of the structural grain in the Lower Palaeozoic of the Ruisseau des Chevreuils with respect to the Lower Devonian deposits and b) the south-verging asymmetry of the syn-cleavage folds, the N-dipping cleavage, the associated south-verging folds and the suggested "higher-strain zone" are all attributed to the Brabantian (formerly called "Caledonian"; cf. Debacker, 2001; Verniers *et al.*, 2002) deformation event. The presence of a "Caledonian" deformation event in the Condroz Inlier has already been proposed previously in order to explain the folded and tilted beds (Fourmarier, 1931, 1939; Michot, 1928, 1934, 1954, 1979). However, the present study for the first time actually demonstrates the presence of a Brabantian ("Caledonian") cleavage and related folds in the central part of the Condroz Inlier. Hence, both the northern part (e.g. Ombret; Valcke, 2001; Valcke & Debacker, 2002) and the central part of the Condroz Inlier (this study) experienced a Brabantian deformation event. According to the present observations, the Chevreuils Formation in the Ruisseau des Chevreuils section appears to have experienced Brabantian cleavage development prior to the deposition of the Lochkovian Fooz Formation. This inferred deformation age is fully compatible with the long deformation age interval proposed for the Brabantian deformation event in the Brabant Massif (Debacker et al., 2005).

Judging from the degree of metamorphism, the Condroz Inlier and the SW-part of the Brabant Massif did not experience such a high overburden as the main part of the Brabant Massif (e.g. Hance et al., 1991; Steemans, 1994; Fielitz & Mansy, 1999; Van Grootel et al., 1997; cf. Debacker et al., 2005). In terms of burial metamorphism, this suggests a much smaller sediment thickness

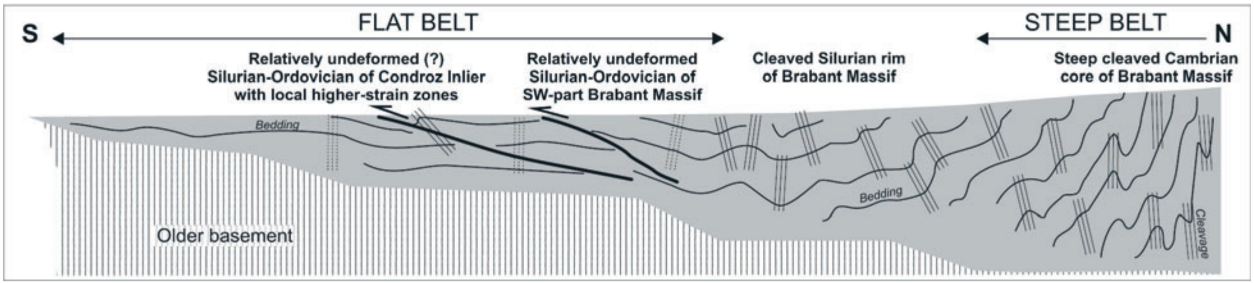

Figure 4: Schematic section from the (thick) central part of the Brabant Massif towards the (thin) Condroz Inlier, demonstrating the transition from a steep belt towards a flat belt, typical for many orogens (not to scale).

and hence a much lower subsidence for the former areas as compared to the latter area. This is fully compatible with lithostratigraphic and sedimentological data of the Ordovician and Silurian (see overview in Verniers et al., 2002 and detailed work of Vanmeirhaeghe, 2006). These considerations, combined with the very low degree of Brabantian deformation in the Condroz Inlier and the SW-part of the Brabant Massif, lead Verniers et al. (2002) to consider the Condroz Inlier and the SW-part of the Brabant Massif as shelf areas of the Brabant Basin during the Late Ordovician and Silurian. The Brabantian deformation style observed in the northern part (Valcke, 2001; Valcke & Debacker, 2001) and the central part of the Condroz Inlier (this work) is compatible with this idea. As shown schematically on Fig. 4, the (Brabantian) inversion of the Brabant Basin gave rise to a steep belt in the thick, central part of the Brabant Massif, characterised by a pervasive, steep fabric (e.g. Sintubin, 1999; Debacker, 2001; Sintubin & Everaerts, 2002; Debacker et al., 2005). Towards the south, deformation became less intense and less pervasive, ultimately giving rise to a flat belt in the thin deposits of the Condroz Inlier and the SW-part of the Brabant Massif (the shelf areas), characterised by a virtually absent to localised, non-pervasive, strongly asymmetric deformation style (cf. Sintubin, 1999; Debacker, 2001; Debacker et al., 2005). Likely, this localised, strongly asymmetric, thin-skinned deformation was accompanied by south-vergent thrusts and/or shear zones, rooting down towards the north on the interface with the older underlying basement or originating within the more strongly deformed parts.

As pointed out, the NW-SE-trending (Brabantian) structural grain within this part of the Condroz Inlier is oblique to the overlying Lower Devonian and to the shape of the inlier (~E-W-trend). Or, in the study area, the structural grain of the Lower Palaeozoic is not reflected by the shape of the inlier. The latter essentially results from the Variscan Orogeny whereas the former is a result of the Brabantian deformation event, likely with a Variscan overprint. Keeping this in mind, also in other outcrop areas of the Condroz Inlier in which an obliquity is observed between the internal structural grain on the one hand, and the shape of the inlier and the main Variscan structures on the other hand, an influence of the Brabantian deformation event may be expected.

Acknowledgements

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