Fibrous vein microstructure: Experimental and numerical simulation

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Abstract
Syntectonic veins containing calcite or quartz grains with a pronounced fibrous morphology are thought to be formed by multiple crack-seal events, with the fibres growing parallel to the opening trajectory of the crack. This assumption provides a unique tool for structural geologists to analyse progressive deformation in rocks, although Cox (1987) and Williams and Urai (1989) have shown, that the long axis of the crystals do not always grow parallel to the opening direction. Urai et al. (1991) presented a model to explain the formation of fibrous morphologies, and predicted that, depending on the boundary conditions, fibres may or may not track the opening trajectory of the crack. We have further tested this model by simulations of natural antitaxial fibrous veins. Results show good agreement with observed morphology.

Introduction
One of the aims in structural geology is the reconstruction of the deformation history for small volumes of rock from the geometry and orientation of fabric elements (Lister & Williams, 1983). Such data can then be used for regional kinematic analysis. Methods for determination of finite strain and volume change are well established but deformation history is not so easily reconstructed. On the one hand progressive deformation overprints older structures, on the other hand all data must be retrieved from the final rock fabric. One of the few tools used in such analyses makes use of syntectonic fibrous veins (Beach, 1977; Ramsay & Huber 1983; Passchier & Trouw, 1995). Syntectonic veins and pressure fringes containing mineral (calcite or quartz) grains with a pronounced fibrous morphology are common in rocks at low metamorphic grades and high fluid pressure (at higher temperatures the fibrous morphology becomes thermodynamically instable and will be destroyed by recrystallization). Fibrous veins are exposed often together with veins of more equant, blocky infill morphologies. Such crystal morphologies are not expected for crystals growing from hydrothermal solution, and explaining their genesis has been attempted by several workers since the pioneering work of Taber (1916, 1918) and Mügge (1919, 1928, 1930). The key process leading to the fibrous morphologies is thought to be the crack-seal process (Ramsay 1980) and/or diffusional processes (Bons & Jessel 1997, Durney & Ramsay 1973, Taber 1916, 1918 A striking feature of many vein fibres is their markedly curved shape, without the crystal lattice having the corresponding curvature. This led Durney & Ramsay (1973) to propose that the curvature in these fibres was developed during crystal growth, with the fibre long axis of the fibrous crystal extending parallel to the opening vector. This means that fibrous veins have a unique capability to record progressive deformation histories. Therefore curved fibres have rapidly become an important tool for structural geologists (Ramsay & Huber 1983, Beutner & Diegel 1985; Ellis 1986; Passchier & Urai 1988, Fisher et al. 1994). Less attention has been paid to testing the tracking hypothesis itself, in spite of the classic Durney and Ramsay (1973) paper, where some exceptions were already noted in the cases of some fibres in pressure fringes and in ‘stretched crystals’. This point was further corroborated by Cox & Etheridge (1983) and Cox (1987) who showed examples of veins where fibres clearly did not track the opening direction.

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