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Strain shadow “megapores” in mid-crustal ultramylonites - local, transient reservoirs servicing the granular fluid pump?

Florian Fusseis and Craig Allsop
University of Edinburgh, School of Geosciences, Edinburgh, Scotland (florian.fusseis@ed.ac.uk)

Shear zones are important conduits that facilitate the bidirectional migration of fluids and dissolved solids across the middle crust. It is a relatively recent revelation that mylonitic deformation in such shear zones can result in the formation of synkinematic pores that are potentially utilised in long-range fluid migration. The pores definitely influence a shear zone’s hydraulic transport properties on the grain scale, facilitating synkinematic fluid-rock interactions and mass transfer. Our understanding of how exactly various forms of synkinematic porosity integrate with the kinematics and dynamics of shear zones is still growing. Here we show a previously undescribed form of synkinematic porosity in an unweathered, greenschist-facies psammitic ultramylonite from the Cap de Creus Northern Shear Belt (Spain). The sizeable, open pores with volumes > 50k µm3 appear exclusively next to albitic feldspar porphyroclasts, which themselves float in a fine-grained, polymineralic ultramylonitic matrix that likely deformed by grain size-sensitive creep and viscous grain boundary sliding. The pores wrap around their host clasts, occupying asymmetric strain shadows and tailing off into the mylonitic foliation. A detailed analysis using high-resolution backscatter electron imaging and non-invasive synchrotron-based x-ray microtomography confirms that the pores are isolated from each other. We found no evidence for weathering of the samples, or any significant post-mylonitic overprint, unequivocally supporting a synkinematic origin of the pores.

We propose that this strain shadow porosity formed through the rotations of the Ab porphyroclasts, which was governed by the clasts’ shapes and elongation. The ultramylonitic matrix was critical in enabling the formation of pores in the clast’s strain shadows. In the matrix, the individual grains were displaced mostly parallel to the shear direction. As a consequence of clast rotation it can be expected that, in the strain shadows, matrix grains followed diverging movement vectors. As a result, phase boundaries in the YZ plane experienced tensile forces, leading to the opening of pores. We infer that this tensile decoupling among matrix grains established a hydraulic gradient that drained the matrix locally and filled the pores with fluid. The fact that the strain shadow pores remained open in our samples suggests a chemical equilibrium with the fluid. Pore shape and volume will have been subject to continuous modification during ongoing matrix deformation and clast rotation.

This form of synkinematic porosity constitutes a puzzling, yet obvious way to maintain surprisingly large pores in ultramylonites whose transport properties are otherwise likely determined by creep cavitation and the granular fluid pump (Fusseis et al., 2009). We envisage that the strain shadow megapores worked in sync with the granular fluid pump in the ultramylonitic matrix and, while the overall porosity of ultramylonites may be small, locally, substantial fluid reservoirs were available to service fluid-rock interaction and fluid-mediated mass transfer. Our findings add another puzzle piece to our evolving understanding of synkinematic transport properties of mid-crustal ultramylonites and fluid-rock interaction in shear zones at the brittle-to-ductile transition.