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Fluid-rock interactions during the initiation and widening of a shear zone: an example from the Roffna metarhyolite (Eastern Central Alps)

Jean-Charles Poilvet (1), Philippe Goncalves (1), Emilien Oliot (2), and Didier Marquer (1)

(1) Lab. Chrono-environnement, University of Franche-Comté, Besançon, France, (2) Ecole et Observatoire des Sciences de la Terre, University of Strasbourg, Strasbourg, France

The formation of shear zones in a homogeneous granitic host-rock may be subdivided into two distinct stages: (1) nucleation on a new or pre-existing brittle structure and (2) lateral widening during ductile deformation (e.g. Mancktelow & Pennacchioni, 2005). During these two stages, the presence of pressure, temperature and chemical potential gradients across the shear zone will induce mass transfer either by fluid infiltration and/or diffusion in a static pore fluid. With material transport, metasomatic reactions produce new assemblages, textures and microstructures that affect the rheology of the shear zone and therefore its behavior. A shear zone developed in a magmatic host-rock is probably the case where the mineralogical changes are the most dramatic, and therefore the easiest to characterize, because deformation and fluid infiltration affect magmatic assemblages that are metastable at the P-T conditions of deformation.

The ability of predicting the mineralogical and geochemical evolution during syn-deformation fluid-rock interactions is critical to either estimate PT conditions of deformation or better understand the processes of shear zone formation. The goal of this contribution is to determine the effects of the fluid-rock interactions, and more generally the role chemical processes, on the formation of the shear zone. A major difficulty is that with increasing deformation, the mineralogical and textural evidences of fluid-rock interactions are continuously overprinted, which prevent discussions on the precursor stages. The only way to overcome this difficulty is to study a suite of shear zones at different stages of formation, from the precursor to the most mature ductile shear zone, that were developed in the same host-rock and P-T conditions. The Roffna metarhyolite from the Suretta nappe (eastern central Alps) provides the unique opportunity to study shear zones at different stages of development.

The Roffna ryolite is an early Permian massif that intruded a Variscan basement at 268 Ma (Marquer et al., 1998) and was affected by Alpine tectonics under blueschist facies conditions (450 °C, 1 GPa) at ca 45 Ma (Challandes N. et al., 2003). The Alpine ductile deformation is characterized by a network of precursor brittle fractures and shear zones from millimetre to plurimetre width. A detailed petrologic study (X-ray mapping and textural analysis) combind with thermodynamic modeling have been performed on different stages of shear zone development. We show that the first brittle increment of deformation and the ductile widening occur under the same blueschist facies conditions. This isobaric/isothermal coeval development of brittle and ductile structures challenges the temperature-dependent concept of brittle-ductile transition. Furthermore, it appears that chemical mass transfer and metamorphic reactions occur since the first increment of brittle deformation suggesting that fluid-rock interactions are not restricted to mature and highly permeable shear zones. We also suggest that the widening of the shear zone is driven and controlled by the kinetics of the equilibration of the metastable host-rock at the P-T-fluid conditions of the deformation. Using a suite of PT and chemical potential computed phase diagrams, we are able to model the reaction path involved during the equilibration process from the host rock to the highest strained zone.