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Role of mineralogical and chemical changes on shear zone nucleation: an example from the Neves area (Tauern Window, Eastern Alps, Italy)

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Several studies have proposed a model for shear zone nucleation in granitoids, in which an initial anisotropy, frequently a brittle structure or a compositional heterogeneity, is required to localize and initiate the ductile shearing in granitoids. This model is referred as an inherited-localization model. This brittle precursor is also the loci of intense fluid-rock interactions that induce mineral and chemical transformations that control the behavior of shear zone. However, Oliot et al. (2010, 2014) suggest that brittle precursors are not necessary required to initiate the ductile shearing in granites. Indeed, the early recrystallization of metastable phases (like plagioclase) into a fine-grained metamorphic assemblage, stable at the P-T-fluid conditions of the deformation, might induce local weakening required for strain localization and shear zone nucleation. We will define this model as the metamorphic-localization model.

In both models, shear zone nucleation appears to be associated with metamorphic reactions, fluid flow and mass transfer. The goal of this contribution is to document and quantify the mineralogical and chemical changes involved during the process of shear zone nucleation in granitoids, and to discuss their role. Answering these questions requires to study shear zones in which petrological and microstructural evidences of the deformation have not been obliterated by subsequent ductile deformation. One of the best example is located in the Neves area (Tauern Window, Eastern Alps, Italy) where a Variscan granodiorite is affected by an Alpine amphibolite facies deformation strongly localized on precursor fractures. The studied samples are mm to cm-wide shear zones with distinct mineralogical evolution. In the undeformed granodiorite, the mineralogical assemblage consists of quartz, K-feldspar, biotite and a fine-grained assemblage of albite, epidote and white mica developed at the expense of the metastable magmatic plagioclase. In addition to the breakdown of biotite and K-feldspar into chlorite and phengite, the most noticeable metamorphic reaction is the crystallization of garnet on former plagioclase site. Shape, grain size and chemical zoning of garnet evolve continuously along the strain gradient. The highest strained zone is characterized by the crystallization of Fe- and Ti-oxide while albite and epidote are no more present. The interior of the ultramylonitic shear zone is later reactivated under brittle conditions with the formation of a dense micro-scale network of fractures, which are filled with K-feldspar and epidote. To quantify the chemical mass transfer associated with these reactions, quantified high resolution X-ray mapping has been performed along the strain gradient. In addition, the evolution of chemical zoning of garnet as a function of the strain is used to estimate the P-T conditions of the deformation and model the amount of chemical mass transfer.

Although macroscopic field observations clearly suggest that shear zones nucleate on pre-existing brittle fractures, there is no microscopic evidence of cataclasis or shear fracture. Micro-scale observations suggest that the earliest stages of shear zone formation are characterized by large metasomatic recrystallization. These chemical and microstructural changes induce local variations in time and space of the viscosity that will control the subsequent development of the shear zone. For instance the late brittle reactivation in the ultramylonitic shear zone core might be due to a relative hardening induced by garnet crystallization.