Strain localization in the brittle and semi-brittle regimes and its consequences in terms of rock physical properties and anisotropy.

Alexandre Schubnel

Lassonde Institute, University of Toronto

Deformation in the Earth's crust can be very complex. Natural deformation mechanisms can be physical processes such as microcrack propagation, dislocation slip or phase transitions. They can also be chemical processes such as cementation or physico-chemical processes such as pressure-solution mechanisms. Therefore, the complexity of the variation in the mechanical and transport properties of rocks does not only arise from the complexity of each mechanism taking place during deformation, but also results from the coupling between them. The understanding of the variation in volume of the rocks in the crust is of interest in many research fields. Indeed, the Earth's crust is a elastic medium saturated with fluids of different nature (magma, CO_2, water and oils) that are of vital interest in geology (fault mechanics, volcanism, hydrothermalism, metamorphism), ecology (water resources pollution and preservation) and in the industry (nuclear waste storage, oil and gas extraction).

Since the early works of Rudnicki and Rice [1975], theory of strain localization has for a long time been focused on dilatant materials. Such materials have been extensively investigated experimentally, and crack propagation models are generally satisfying to explain the observed shear enhanced dilatant strain that takes place in the brittle regime. On the other hand, it has recently been shown by various authors (Wong et al., (1997], Issen [2000], Bésuelle, [2001]) that shear-enhanced compaction could localize as well. Thus, the strain inside a shear band can be dilatant or compactant, and therefore pure compaction and dilatation bands are an extreme case. Two major consequences can be drawn for these results: (1) in porous rocks deforming non-homogenously, fluid flow cannot be understood before a rigorous mechanical analysis is performed; (2) in crystalline rocks, metamorphism and phase transitions can induce a substantial variation in volume due to mean stress, and therefore metamorphic reactions should localize in presence of shear stress. This is in particular the case of rocks deforming naturally inside both the upper and the lower crust.

During this seminar, I will present a series of experimental results on three different set of rocks (granite, carbonates and sandstones) in order to illustrate the complexity of strain localization when several deformation micromechanisms are in competition, and its consequences on both elastic and hydraulic properties.