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Strain localisation in the crust: impact of out-of-balance thermodynamics.

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Many numerical codes used to model long-term tectonic processes have been coupled explicitly with thermodynamic tabulated dataset in order to determine the effective density and sometime rheology of rocks as a function of pressure and temperature. This explicit coupling introduces major non-linearities in the rheology of the crust and large variation in density. The main assumptions behind this coupling are that the chemistry of rock does not evolve with time and that at every stage of the deformation, rocks are always at thermo-dynamic equilibrium.

This last assumption is very questionable because if this was indeed the case, no high-grade metamorphic rocks should be present at the surface of Earth.

The metamorphic reactions imply important mass transfers and occurrence of non-hydrostatic fluid pressure gradients during deformation and rock exhumation. These phenomena are associated with fluids circulation, which are affected by dynamic porosity and dynamic permeability that in-turn are the functions of strain rate and of degree of metamorphism. They are known to have a considerable influence on the effective mechanical properties of the rocks within shear zones.

In this paper we present and argue a parameterization that permits to account for out of equilibrium thermodynamics in large-scale numerical codes. Our target problem is the exhumation of high-grade metamorphic rocks during extension. The observed P-T-t paths indicate that during extension, rocks experience initial decompression, followed by a phase of reheating and ending, almost systematically, by retrograde phase, in which temperature and pressure diminish with increasing deformation. The occurrence of retrograde reactions implies that at some stages the water re-enters the dehydrated parts of the system, resulting in rheological (re)-softening. Without an input of water, metamorphic reactions should not occur and the rocks must preserve their dry (i.e. Strong) rheologies.

In a first part, we will describe and argue for a parametrisation of porosity and permeability, which encompasses first order geological observations in both ductile and brittle crust. In a second part we will describe how out of equilibium thermodynamic is accounted and related to the presence and absence of water. The third part will be devoted to the impact of this out of equilibrium thermodynamics on the mode of continental rifting and particulary on the localisation of strain on large crustal detachment zones.