Geophysical Research Abstracts, Vol. 8, 07320, 2006
SRef-ID: 1607-7962/gra/EGU06-A-07320

Fluid-rock interaction and strain localization at midcrustal depths

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Midcrustal shear zones, formed in an extensional setting, are commonly seen as zones of pervasive fluid flows, as suggested by isotopic analysis and the formation of a large amount of veins. Ductile strain localization is often coeval with such fluid flows and required important fluid-rock interaction. The objective of this study is to propose a new rheological model for midcrustal rocks that accounts for fluid-rocks interactions. This rheological model could be described by two successive events. First, an incremental and instantaneous fluid influx is triggered by fracturing at midcrustal depths (detected by a Mohr-Coulomb criterion), leading to the instantaneous evolution of the pore fluid pressure from lithostatic towards hydrostatic. Second, a progressive consumption of available fluids by fluid-rock ineractions (metamorphic reaction, mineral precipitation). This second event is supposed to weaken the material. The onset and timing of weakening depend together on a kinetic parameter φ and on strain rate$\dot{\varepsilon}$. During the transient evolution, the viscosity of the midcrust is progressively reduced from a value close to Dry Quartz (strength of the midcrust without fluid-rock interaction) towards a lower value typical of Wet Quartz. A 1D numerical simulation is then proposed to document the role of this rheological model in explaining strain localization at midcrustal depths. The lower ductile crust sustains simple shearing at a velocity V. Starting from a steady state; the shearing velocity V is increased linearly with time and then kept constant, defining a transient regime. Fracturing, fluid influxes and fluid-rock interactions (leading to weakening) are triggered during this transient evolution. An increase of strain rate by three orders is observed at the brittle-ductile

transition. The onset and timing of strain localization are dictated by the value of the fluid-rock interaction kinetics $\varphi\dot{\varepsilon}$. Aginimum value of $2.10^{-13}\mathrm{s}^{-1}$ is required for localization to occur; the greater φ, the shorter the time necessary for localization. A positive feed-back between strain localization and fluid-rock interaction is observed, since the increase in strain rate enhances the kinetics of fluid consumption. Transient fluid fluxes are put forward in the lower crust thanks to this model.

On these bases, we propose that fluid-rock interaction at midcrustal depths can lead to a significant decrease of the viscosity at that depths and thus trigger strain localization. The brittle-ductile transition can thus now be defined by the depths where fluid-rocks interaction occurs in a two steps phenomena: 1- the fracturing of the "strong" midcrustal rocks that induces fluid fluxes and 2- the progressive consumption of the available fluids that tends to soften the midcrustal rocks.