Transient creep regime during strain localization: a field and numerical perspective

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Ductile shear zones are common features within the lithosphere and accommodate large amount of strain. In extensional settings, for example, low angle dipping mid-crustal shear zone often root at the edge of normal faults and largely participate to the unroofing of deep seated units. Mantle shear zones, also well imaged by seismic profiles and exhumed passive margins, also largely contribute to the thinning of the continental lithosphere. In compressional settings, the deep crust acts as a major shear zone allowing a decoupling between crustal and mantle units, which leads to the stacking of crustal nappes and the subduction of mantle rocks. Most shear zones cannot be explained by the classical rheological layering of the lithosphere, and understanding their formation remains a key issue to better constrain the lithosphere rheology. Different weakening mechanisms have been invoked to explain strain localization: metamorphic reaction, grain size reduction, fluid-rock interaction, melt percolation. Based on various field studies, the relevance and the time-dependence (transient phenomena) of each weakening mechanisms in the crust and in the mantle will be discussed. Classical rheological laws that are extrapolated from laboratory experiments are steady state (time-independent) and can therefore not account for weakening. On these bases, 1D and 2D numerical simulations will show how the kinetics of weakening controls the duration and amplitude of strain localization. A major step forward for the future understanding of the lithosphere rheology will thus be to study in the lab such transient phenomena and to constrain their kinetics.