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Strain localisation in the continental lithosphere, a scale-dependent process

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Strain localisation in continents is a general question tackled by specialists of various disciplines in Earth Sciences. Field geologists working at regional scale are able to describe the succession of events leading to the formation of large strain zones that accommodate large displacement within plate boundaries. On the other end of the spectrum, laboratory experiments provide numbers that quantitatively describe the rheology of rock material at the scale of a few mm and at deformation rates up to 8-10 orders of magnitude faster than in nature. Extrapolating from the scale of the experiment to the scale of the continental lithosphere is a considerable leap across 8-10 orders of magnitude both in space and time. It is however quite obvious that different processes are at work for each scale considered. At the scale of a grain aggregate diffusion within individual grains, dislocation or grain boundary sliding, depending on temperature and fluid conditions, are of primary importance. But at the scale of a mountain belt, a major detachment or a strike-slip shear zone that have accommodated tens or hundreds of kilometres of relative displacement, other parameters will take over such as structural softening and the heterogeneity of the crust inherited from past tectonic events that have juxtaposed rock units of very different compositions and induced a strong orientation of rocks. Once the deformation is localised along major shear zones, grain size reduction, interaction between rocks and fluids and metamorphic reactions and other small-scale processes tend to further localise the strain. Because the crust is colder and more lithologically complex this heterogeneity is likely much more prominent in the crust than in the mantle and then the relative importance of "small-scale" and "large-scale" parameters will be very different in the crust and in the mantle. Thus, depending upon the relative thickness of the crust and mantle in the deforming lithosphere, the role of each mechanism will have more or less important consequences on strain localisation. This complexity sometimes leads to disregard of experimental parameters in large-scale thermo-mechanical models and to use instead ad hoc "large-scale" numbers that better fit the observed geological history. The goal of the ERC RHEOLITH project is to associate to each tectonic process the relevant rheological parameters depending upon the scale considered, in an attempt to elaborate a generalized "Preliminary Rheology Model Set for Lithosphere" (PReMSL), which will cover the entire time and spatial scale range of deformation.