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Strain localization in models and nature: bridging the gaps.

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Mechanisms of strain localization and their role in tectonic evolution are still largely debated. Indeed, the laboratory data on strain localization processes are not abundant, they do not cover the entire range of possible mechanisms and have to be extrapolated, sometimes with greatest uncertainties, to geological scales while the observations of localization processes at outcrop scale are scarce, not always representative, and usually are difficult to quantify. Numerical thermo-mechanical models allow us to investigate the relative importance of some of the localization processes whether they are hypothesized or observed at laboratory or outcrop scale. The numerical models can test different observationally or analytically derived laws in terms of their applicability to natural scales and tectonic processes. The models are limited, however, in their capacity of reproduction of physical mechanisms, and necessary simplify the softening laws leading to “numerical” localization. Numerical strain localization is also limited by grid resolution and the ability of specific numerical codes to handle large strains and the complexity of the associated physical phenomena. Hence, multiple iterations between observations and models are needed to elucidate the causes of strain localization in nature. We here investigate the relative impact of different weakening laws on localization of deformation using large-strain thermo-mechanical models. We test using several “generic” rifting and collision settings, the implications of structural softening, tectonic heritage, shear heating, friction angle and cohesion softening, ductile softening (mimicking grain-size reduction) as well as of a number of other mechanisms such as fluid-assisted phase changes. The results suggest that different mechanisms of strain localization may interfere in nature, yet it most cases it is not evident to establish quantifiable links between the laboratory data and the best-fitting parameters of the effective softening laws that allow to reproduce large scale tectonic evolution. For example, one of most effective and widely used mechanisms of “numerical” strain localization is friction angle softening. Yet, namely this law appears to be most difficult to justify from physical and observational grounds.