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Impact of different weakening parameterizations on crust and lithosphere deformation

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Rocks typically exhibit a decrease in strength with ongoing deformation. This decrease in strength is often related to processes that occur on the grain scale, such as grain size reduction, fluid percolation, interconnection of weak phases etc. Other processes that affect deformation on a larger scale include e.g. shear heating and the formation of oriented fault arrays. In numerical geodynamical models, the weakening behavior is usually accounted for by introducing a simple strain weakening parameterization. However, those parameterizations are mostly ad hoc and do not consider the underlying physical mechanisms that control the amount and transient behavior of the weakening process.

Here, I study the impact of different strain weakening parameterizations on crustal and lithosphere deformation using two dimensional finite element models. Through a parametric study, I show the effect of different parameters that enter the weakening parameterization. As expected, the stress field of the lithosphere and its transient evolution during extension/compression is strongly affected by the shape of the strain weakening parameterization.

Additionally, many physical processes resulting in weakening do in fact no depend on the amount of strain a rock has experienced, but rather on the deformational work that has been used to deform the rock. Treating weakening as a work-dependent property also facilitates conservation of energy. For this reason, I also investigate the effect of employing work-weakening parameterizations in numerical models of lithosphere deformation and highlight differences to conventional strain weakening formulations.