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How to create mylonitic shear zones in the presence of shear heating

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Lithospheric-scale shear zones are commonly defined as regions inhomogeneous and localized deformation. Strain softening has been demonstrated to be necessary for localization in those shear zones, but there is still debate about the physical cause of this softening. Here, we investigate the interplay between two mechanisms that have been suggested to have a significant impact on lithospheric localization: shear heating and grain size reduction.
Shear heating has been suggested to play an important role in i) creating deep focus as well as intermediate-depth earthquakes (Ogawa (1987), Kelemen and Hirth (2007)) and ii) creating lithospheric-scale shear zones, thus creating a weak decoupling interface that enables subsequent subduction initiation (Kaus and Podlatchikov (2006), Crameri and Kaus (2010)).
As natural shear zones typically have a significantly reduced grain size, it has been put forward that grain size reduction provides the necessary strain softening to localize deformation. As grain size reduces, the dominant deformation mechanism switches from dislocation to diffusion creep, thus requiring less stress to deform the rock. Usually, the equilibrium grain size is thought to follow a piezometric relationship, thus indicating the stress under which a shear zone deformed. Recent work (Austin and Evans (2007), Rozel et al. (2011)) suggests that the equilibrium grain size is not dependent on stress, but rather on the deformational work.
In our study, we employ the grain size evolution law of Rozel et al. and use 1D viscoelastic numerical models of simple shear deformation to investigate the influence of both weakening mechanisms and their interaction for a variety of boundary conditions. We find that grain size reduction in pure olivine does not localize very efficiently, as grain size very rapidly reaches a steady state. Even when a fraction of the deformational work is used by grain size reduction processes, shear heating is found to localize very efficiently (Kaus & Podlatchikov (2005), Braeck et al. (2009)) and the significant temperature increase induced by shear heating severely affects the grain size in the shear zone. Generally, we find that the elevated temperature inside the shear zone results in a larger grain size inside the shear zone compared to the surrounding rock matrix. This finding is not compatible with field observations, where shear zones are usually characterized by small grain sizes. This indicates that further mechanisms are needed to keep either the grain size small (e.g. pinning by secondary phases (Herwegh et. al (2011), Bercovici and Ricard (2012)) or to limit the temperature increase inside the shear zone.