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Shear heating induced lithospheric localization: Does it result in subduction?

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Subduction is one of the main features of plate tectonics, yet it remains unclear how subduction started on Earth. Shear heating has been proposed to play an important role in i) creating deep focus as well as intermediate-depth earthquakes (Ogawa 1987) and ii) creating lithospheric-scale shear zones, thus creating a weak decoupling interface that enables subsequent subduction initiation.

To understand the physics of this mechanisms, Kaus and Podladchikov (2006) conducted a scaling analysis for simplified viscoelastoplastic rheologies and found that the boundary between localization and no localization is quite sharp. Crameri and Kaus (2010) and Lu et al. (2011) extended this analysis to more realistic lithospheric setups and demonstrated that shear heating induced lithospheric-scale localization might occur for Earth-like parameters. It is however unclear if a lithospheric-scale shear zones on its own evolves into a subduction zone.

Here, we use numerical models to adress the question of shear heating induced subduction initiation. In the framework of our models, we can identify four different regimes, of which two show subduction initiation. We then develop scaling laws that are able to predict the behaviour of our models, thus providing means to better understand the physics of shear heating induced subduction initiation.

Our results suggest that shear heating induced subduction initiation is more likely to initate in a lithosphere consisting of dry olivine rather than wet olivine. A large plate age does not necessarily increase the potential for subduction initiation, as it increases the potential for convective instabilities to occur.