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Grain size reduction as a weakening mechanism in 3D-numerical models: Is it sufficient to initiate and stabilise transform faults?

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Is it sufficient to initiate and stabilise transform faults?

Transform faults are conservative plate boundaries since they do not produce or consume any crust. Instead, they accommodate motion via strike-slip movement. In nature, these highly localised, ductile shear zones show a great amount of grain size reduction up to ultra-mylonites. Various studies concluded that grain size reduction can lead to a progressive localisation of strain (Jaroslow et al., 1996, Jin et al., 1998, Warren and Hirth, 2006).

In numerical models, transform faults are difficult to reproduce, as mantle convection simulations tend to produce poloidal rather than toroidal motion. In order to obtain toroidal motion in numerical models a strain weakening mechanism is necessary. So far, in transform fault modelling ad hoc strain weakening has been applied to reproduce the observed weakening phenomena (e.g. Hieronymus, 2004, Choi et al., 2008, Gerya, 2010a), but without including a physics-based weakening mechanism. However, also numerical studies suggest grain size reduction to be a potential candidate for weakening (e.g. Kameyama et al., 1997). In order to utilise a more realistic weakening we incorporate grain size reduction due to dynamic recrystallisation in the ductile regime.

We investigate the effect of grain size reduction occurring at transform faults using a 3D-numerical model with a composite rheology (diffusion and dislocation creep). Viscosity is therefore pressure-, temperature- and grain size-dependent. Instead of imposing ad hoc strain weakening, we let the model evolve self-consistently and allow for a gradually developing strain weakening and strain localisation due to grain size reduction.

Our results show that weakening purely by grain size reduction can localise strain strong sufficiently to initiate a transform fault. However the stability and longevity of the transform faults highly depends on the amount of grain damage, the thickness of the brittle crust and to a smaller extent on the velocity of the spreading centres. Our most stable transform faults arise when the crust is thick and when we use a temperature-dependent grain damage parameter. Yet, so far all transform faults are only stable for a maximum of around 1.5 Myr.