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Instabilities in strain-rate hardening, chemically-weakening rocks: revisiting the mechanism of "dehydration-embrittlement"

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Serpentinized rocks undergoing dehydration generally exhibit a significant weakening due to various mechanisms (e.g., Rutter et al., 2009). We study here on the effects of "intrinsic" weakening mechanisms, such as the production of fine grained dehydration products (as opposed to "extrinsic" effects such as the weakening induced by changes in pore fluid pressures) on the stability of (1) steady slip and (2) homogeneous shear.

General assumptions of rate-hardening and chemically-weakening rheology are used to model the deformation of the reacting rock. In a spring-slider configuration, a linear perturbation analysis provides analytical expressions of the critical stiffness below which unstable slip occurs. In the framework of a frictional constitutive law, numerical tests are performed to study the effects of a non linear reaction kinetics on the evolution of the instability. Slip instabilities can be stopped at relatively small slip rates (only a few orders of magnitude higher than the forcing velocity) when the reactant is fully depleted. The stability analysis of homogeneous shear provides an independent estimate of the thickness of the shear localisation zone due to the reaction weakening, which can be as low as 0.1 m in the case of lizardite dehydration. The potential effect of thermo-chemical pore fluid pressurisation during dehydration is discussed, and shown to be negligible compared to the reaction-weakening effect.

Even though much work is still needed to constrain the particular rheology of reacting rocks as well as the reaction kinetics, the assumptions under which the stability conditions are derived are very general. Hence we argue that the slip instabilities originating from the reaction-weakening process could be a plausible candidate for intermediate depth earthquakes in subduction zones, as an alternative to the "dehydration-embrittlement" mechanism based on the effects of pore fluid pressure.