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Thermo-mechanical and analytical models of slab detachment: calibration of an effective slab flow law

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In order to study the dynamics of slab detachment, we have been developing 2D thermo-mechanical models of continental collision. In numerical models, the deformation of the mantle is usually modelled using a complex composite olivine rheology. These composite rheology takes into account the effects of viscous (diffusion-dislocation creep) and plastic (Mohr-Coulomb, Peierls) deformation. The non-Newtonian rheological components allow for strain localisation and eventually lead to slab detachment. The parameters governing these flow laws are calibrated from laboratory experiment of olivine deformation.

In Duretz et al. (2010), we showed that, using the same rheological description, slab detachment can happen at various depths (40-400 km), leading to a wide range of geodynamic (eduction, plate decoupling, extension) and topographic evolution. These different end-members are related to the activation of different rheological mechanisms within the slab and therefore display different slab necking dynamics.

Schmalholz (2011) presents the application of an analytical solution of necking in a layer to slab detachment. This 1D solution can predict the necking in a layer of power-law fluid under its own buoyancy and is governed by the layer thickness, the necking time, and the stress exponent. We compile all our slab detachment data computed with the geodynamic code (I2VIS, Gerya and Yuen, 2003) and express it in terms of neck thickness versus necking time. We observe that our numerical data well reproduces the necking evolution predicted with the analytical solution. The modelled detachment events are characterized by a narrow range of characteristic necking time (0.8-2.5 My) despite the variety of rheological mechanism involved. We propose that a simple power law rheology, characterized by an effective stress exponent, may be use to describe the rheology of the slab during slab detachment.

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Gerya, T. V., Yuen, D. A., 2003. Charaterictics-based marker method with conservative finite-difference schemes for modeling geological fows with strongly variable transport properties. Physics of the Earth and Planetary Interiors 140 (4), 293-318.