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Quantifying the impact of metamorphic reactions on strain localization in the mantle

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Metamorphic reactions are most often considered as a passive record of changes in pressure, temperature and fluid conditions that rocks experience. In that way, they provide key constraints on the tectonic evolution of the crust and the mantle. However, natural examples show that metamorphism can also modify the strength of rocks and affect the strain localization in ductile shear zones. Hence, metamorphic reactions have an active role in tectonics by inducing softening and/or hardening depending on the involved reactions. Quantifying the mechanical effect of such metamorphic reactions is, therefore, a crucial task for determining both the strength distribution in the lithosphere and its evolution.
However, the estimate of the effective strength of such polyphase rocks remains still an open issue. Some flow laws (determined experimentally) already exist for monophase aggregates and polyphase rocks for rheologically important materials. They provide good constraints on lithology-controlled lithospheric strength variations. Unfortunately, since the whole range of mineralogical and chemical rock compositions cannot be experimentally tested, the variations of strength due to in metamorphism reaction cannot be systematically and fully characterized.
In order to tackle this issue, we here present the results of a study coupling thermodynamical and mechanical modeling that allows us to predict the mechanical impact of metamorphic reactions on the strength of the mantle. Thermodynamic modeling (using Theriak-Domino) is used for calculating the mineralogical composition of a typical peridotite as a function of pressure, temperature and water content. The calculated modes and flow laws parameters for monophase aggregates are then used as input of the Minimized Power Geometric model for predicting the polyphase aggregate strength. Our results are then used to quantify the strength evolution of the mantle as a function of pressure, temperature and water content in two characteristic tectonic contexts by following P-T evolutions underwent by the lithospheric mantle in both subduction zones and rifts. The mechanical consequences of metamorphic reactions at the convergent and divergent plate boundaries are finally discussed.