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Viscous strain softening and its implications on small-scale convection, melting and serpentinisation

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Numerous geodynamical studies have focused on the study of small-scale mantle convection in terms on temperature lateral variations and density changes related to melt retention, melt depletion and solid phase changes. Viscous strain softening is often included in these models to account for the grain-size reduction of deforming rocks in the diffusion creep regime and for lattice-preferred orientations in the dislocation creep regime. As a first order approximation, a linear increase in the pre-exponential factor is used to reduce the effective viscosity. However, at higher temperatures, a small grain size can be unstable over long time scales, leading to a grain growth recovery and a return to the dislocation creep regime. The speed of grain-size recovery scales as an Arrhenius-type process similar to the temperature dependence of diffusion creep itself. Here, we explore the implications of temperature dependent viscous strain softening.

We use a 2D thermo-mechanical code based on MILAMIN with visco-elasto-plastic non-newtonian rheologies to model a compositionally layered and melt-depleted continental lithosphere underlain by an asthenosphere. We observe how different approximations of viscous strain softening influence the flow pattern through the change in the effective viscosity. As a result of these effects on mantle upwelling velocities, partial melting generation and serpentinisation are also affected.