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Evolutionary models of the Earth with a grain size-dependent rheology: diffusion versus dislocation creep

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We present a set of 2D numerical simulations of mantle convection considering grain size evolution and a composite visco-plastic rheology including diffusion and dislocation creep. A 1D parameterization allows us to anticipate the stress conditions for the present-day temperature profile in a convection cell. We are therefore able to obtain self-consistent 2D convecion models together with non-equilibrium grain size for present-day conditions, controlling the partitioning between diffusion and dislocation creep.

However, the internal temperature of the mantle is thought to have significantly evolved throughout the history of the Earth. Using a higher internal temperature is usually believed to decrease both viscosity and internal stresses. In our case, a high temperature potentially increases the grain size, which tends to increase the viscosity: the temperature and grain size-dependence of the viscosity are in competition.

We study the evolution of the diffusion-dislocation partitioning throughout the history of the Earth. We report the evolution of grain size and stress over time in our simulations.

Several complex processes are included in our models. Grain size evolution is a sum of grain growth and dynamic recrystallization. All our simulations consider thermochemical convection in a compressible mantle with melting producting basaltic crust and depleted mantle. Close to the surface, melting produces basaltic material which is erupted or intruded at the base of the crust. Phase transitions reset the grain size to a low value, which influences the whole dynamics of the mantle.