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Onset of solid state mantle convection and mixing during magma ocean solidification

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The fractional crystallization of a magma ocean can cause the formation of a compositional layering that can play a fundamental role for the subsequent long-term dynamics of the interior, for the evolution of geochemical reservoirs, and for surface tectonics. In order to assess to what extent primordial compositional heterogeneities generated by magma ocean solidification can be preserved, we investigate the solidification of a whole-mantle Martian magma ocean, and in particular the conditions that allow solid state convection to start mixing the mantle before solidification is completed. To this end, we performed 2-D numerical simulations in a cylindrical geometry. We treat the liquid magma ocean in a parametrized way while we self-consistently solve the conservation equations of thermochemical convection in the growing solid cumulates accounting for pressure-, temperature- and, where it applies, melt-dependent viscosity as well as parametrized yield stress to account for plastic yielding. By testing the effects of different cooling rates and convective vigor, we show that for a lifetime of the liquid magma ocean of 1 Myr or longer, the onset of solid state convection prior to complete mantle crystallization is likely and that a significant part of the compositional heterogeneities generated by fractionation can be erased by efficient mantle mixing.