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Mantle mixing efficiency during Archean Earth

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The present-day rate of mantle mixing in Earth may be different than it was during the Archean. Changes in the convective style between two-layered and one-layered mantle convection can have global consequences due to a transition between heterogeneous mantle composition and efficient mixing. In the Archean, mantle temperatures exceeded present-day values by $\sim$150-200 degrees, which affected the phase transition from upper to lower mantle, such that the mantle may have been separated into two convecting layers. We do not know how strong the layering effect was in the past or if it existed already after the magma ocean stage. Therefore, we investigate how parameters like temperature, pressure and composition influence the phase transition Clapeyron slopes and hence mantle convection.

In our geodynamic mantle evolution models we locally determine material-dependent thermodynamic parameters (e.g. density, thermal expansion coefficient, and specific heat capacity) for different initial temperature profiles, ranging from adiabatic profiles close to the melting temperature to non-adiabatic profiles assuming a magma ocean overturn after the solidification stage. For this we trace the variations in local composition (e.g. from primordial to depleted mantle) within the Mg-Fe-Si-O-Al-Ca-Na system. For the assumed higher temperature regime in the Archaean, we find that the Clapeyron slope was larger than today, leading to less efficient mixing between the upper and lower mantle. We quantify the mixing efficiency of the mantle over time, and determine the amount of primordial mantle from the lower mantle that can be mixed into the upper, depleted mantle over time and compare our model scenarios to the geological record.