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Mobile or not mobile: exploring the linkage between deep mantle composition and early Earth surface mobility

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Numerical models of mantle convection help our understanding of the complex feedback between the plates and deep interior dynamics through space and time. Did the early Earth have plate tectonics, a stagnant lid, or something in between? The surface dynamics of the early Earth remain poorly understood. Current numerical models of mantle convection are constrained by present-day observations, but the behavior of the hotter, early Earth prior to the onset of plate tectonics is less certain. The early Earth may have possessed a large hot magma ocean trapped near the core-mantle boundary after formation during differentiation, and likely containing different elements from the surrounding mantle. We examine how composition-dependent properties in the deep mantle affect convection dynamics and surface mobility in high Rayleigh number models featuring plastic yielding. Our Newtonian models indicate that increased conductivity or decreased viscosity flattens basal topography while also increasing the potential for surface yielding. We vary the viscosity, thermal conductivity, and internal heating in a compositionally distinct basal magma ocean and explore the compositional topography, insulation effects and surface stresses for non-Newtonian rheology. Models are run using a variety of crustal compositions, such as the inclusion of primordial continental material before the onset of plate tectonics. We monitor the surface for plate-like behavior. Since convective vigour is very strong in the early Earth, specialized tracer methods are employed for increased accuracy. In our models, Stokes flow solutions are obtained using a multigrid method specifically designed to handle large viscosity contrasts and non-Newtonian rheology.