Plate evolution after the magma ocean period: Influence of a compositionally enriched basal layer

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Abstract

Early periods of Earth's history are still of great interest for the evolution of plate tectonics. For instance, neither the transition from the magma ocean to mobile lithospheric plates nor the nature of Archean plate tectonics itself is well known. As a remnant of the magma ocean period, a compositionally dense layer at the core-mantle boundary is assumed to interact with the convective flow of the Earth's mantle. Since plate motions are strongly coupled to the convection of mantle material, stabilizing effects of compositionally dense material have a profound impact on plate tectonics and will be of major importance for its evolution.

To investigate the influence of a dense basal layer on the onset and evolution of plate tectonics, we use a numerical approach employing thermo-chemical mantle convection models. Considering different possible scenarios of the post magma ocean period we analyze the influence of different parameters, i.e. the density contrast between the dense basal material and the ambient mantle, the thickness of the enriched layer and the initial temperature. The outcome reveals that these parameters strongly control the onset time of plate tectonics, which basically depends on the initiation mechanism. We find scenarios where plate motions are considerably delayed due to the influence of an enriched layer, while other cases exhibit scenarios with an early onset of plate tectonics. Since plate breakup for early onset scenarios is induced in a top-down manner, thus primarily triggered by subduction events, plate motions are largely unaffected by dense material at the bottom of the system.

Besides, phenomena like regionally confined plate movements or a temporal decoupling of the compositionally dense layer from the convective bulk indicate that early plate tectonics is strongly intermittent. Such intermittencies yield the assumption that the style of plate tectonics in the Archean fundamentally differs from the one observed on modern Earth.