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Dynamic differentiation of a magma ocean

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It seems likely that a Magma ocean, after separation of iron from silicate, did freeze from the bottom up, due to the increase of pressure with depth. A scenario can thus arise in which hot material at the bottom of the magma ocean is compositionally light and underlies colder but compositionally denser material. A rapid overturn of this instable configuration has been proposed by several authors. By means of two- and three-dimensional convection models in Cartesian and spherical geometry, we investigated the overturn-scenario and especially the subsequent evolution of the mantle, following the magma ocean period. The numerical models include finite element and finite volume procedures as well as front tracking methods to capture the evolution of chemical heterogeneities Our numerical experiments clearly reveals that an overturning puts the mantle into the diffusive regime, characterized by an unstable thermal, but stable compositional stratification. The formation of layered flow structures is, a typical phenomenon in this regime. In a wide parameter range (thermal/compositional Rayleigh numbers, realistic rheologies and various distribution of internal heat sources) , we observe the overturning followed by a long period of layered convection. Vigorous convection takes place in the upper- and lower mantle, while typically a less vigorous convection layer develops in between. The number of layers and their individual lifetime depends on the particular parameters. However in any case, layered structures develop over a significant time span, such that a profound influence on the chemical evolution seems reasonable to expect.