

Thermochemical modelling of chemical segregation in a crystallizing magma ocean

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Despite its control over the primordial thermochemical state of the mantle, the mechanism of solidification of the global magma-ocean (MO) remains controversial. Heterogeneous mantle could result from the settling of crystal grains of bridgmanite (Bg) at the bottom of the magma ocean or at mid lower-mantle depths. The buoyancy of Bg grains in the MO is one of the controlling parameters. Still, chemical segregation does not only require a significant density contrast, but also specific dynamical conditions; turbulent motions in a convecting melt layer can prevent efficient crystal settling. In this work, we use a criterion based on the *Shields* number, which defines the ability of the melt to re-entrain solid grains deposited at the surface of a solid layer, to evaluate the P-T-chemical conditions compatible which Bg segregation in a crystallizing MO.

We calculate *Shields* parameters for a broad range of possible MO properties: -various chemical models for the melt and the bulk silicate Earth (BSE); -solid-melt Fe partition coefficient of 0.1 or 0.25; -Densities of Bg grains and melt computed using the PVT equation of states of several end-members, -Diameter of Bg grain varying from 0.1 to 10 mm; etc.

Calculations show that Bg grains are unlikely to segregate in a mantle of pyrolite composition. Grain segregation is easier in a SiO₂-enriched MO and at shallow depths. Interestingly, absence of major Bg sedimentation would not imply a chemically homogeneous mantle once it is entirely solidified. Instead, a bottom-up MO solidification (NB: solidification is achieved for ~60vol% Bg and ~40 vol% melt) yields a more bridgmanitic lowermost mantle, in agreement with seismic observations. Finally, Bg grains can also segregate upwards in the lowermost mantle when the melt is ultramafic. Such segregation would be compatible with the formation of a primary basal MO. However, segregation of Bg out of an already mafic MO makes it even more mafic and large reservoirs of ultra-mafic melts are not detected in the present day mantle, by either seismic or geochemical investigations. Altogether, homogeneous mantle solidification resulting in a slight SiO₂ vertical gradient appears the most compatible with available geochemical and geophysical observations.