

Basal magma ocean crystallisation combined with core exchange

R.G. TRØNNES^{1,2}, C.E. MOHN², B. GRØMER²

¹Natural History Museum, Univ. of Oslo

²Centre for Earth Evolution and Dynamics, Univ. of Oslo

At pressures exceeding 80 GPa, the elevated Fe/Mg-ratios of peridotite melts coexisting with extremely Fe-poor bridgmanite (bm) imply a bm-melt density crossover at 1700-1900 km depth [1-3]. A resulting basal magma ocean (BMO) would have been thermally insulated by the overlying mantle, which solidified rapidly upwards from the neutral buoyancy level. The BMO solidified from the top towards the core-mantle boundary. Limited secular cooling of the Earth since 2.5-3.0 Ga and a peridotite solidus within 200 K of the outer core temperature, indicate that the complete solidification of the BMO might have taken at least 2 Gy [3,4]. The crystallisation of MgSiO₃-rich bm as the first liquidus phase would be extended by chemical core-BMO exchange. Floating silica crystals from the core would dissolve in the BMO and Fe-oxide components from the BMO would dissolve in the core, inhibiting rapidly increasing Fe/Mg and (Fe+Mg)/Si ratios in the BMO melt.

Core-BMO exchange in large terrestrial planets results from high initial core temperatures, at which the equilibrium $2\text{Fe}^{\text{core}} + \text{SiO}_2^{\text{BMO}} = \text{Si}^{\text{core}} + 2\text{FeO}^{\text{BMO}}$ is displaced towards the products. During subsequent cooling, the equilibrium is reversed towards the left side reactants [3,5], resulting in a Si-saturated and O-undersaturated core.

Protracted crystallisation and accumulation of bm would increase the Ca, Na and Al contents in the BMO, leading to precipitation of Ca-perovskite (cpv) and the Al-Na-rich Ca-ferrite phase. Our density calculations show that the latter would be incorporated in relatively early bm cumulates in the central BMO region, while dense cpv would sink and dissolve in the melt. At a late stage, cpv would be incorporated in Fe-rich bm cumulates, forming dense piles, enriched in incompatible trace elements. Rapid early Earth rotation would facilitate a degree-2 convection regime in which late-stage dense cumulates within a thin residual BMO could be swept into two equatorial and antipodal piles [3,6]. The early Mg-dominated, high-viscosity bm cumulates would be convectively aggregated into large refractory blobs or bridgmanite-enriched ancient mantle structures, BEAMS [7].

[1] Tateno et al. (2014) *JGR* **123**,4684. [2] Petitgirard et al. (2015) *PNAS* **112**,14186. [3] Trønnes et al. (2018) *Tectonophys.* 10.021. [4] Labrosse et al. (2007) *Nature* **450**,866. [5] Laneuville et al. (2018) *PEPI* **276**,86. [6] Maas & Hansen (2019) *EPSL* **513**,81. [7] Ballmer et al. (2017) *Nat. Geosci.* **10**,326.