



Chemical consequences of perovskite fractionation from an ultramafic liquid with application to the evolving composition of a basal magma ocean

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Heterogeneity in the present day mantle is evidenced by seismology and geochemistry, with significant heterogeneity apparent in the lowermost mantle, just above the core-mantle boundary. Origins of this structure are hypothesized to be related to the initial solidification of a deep magma ocean. In particular, in a scenario where solidification begins mid-mantle, a resulting basal magma ocean could be long-lived and geochemically isolated, with the final crystallization products accumulating at the core mantle boundary. The geochemical makeup of the basal magma ocean products depends on fractionation of elements (major, minor, trace) by Mg-perovskite (MgPv), the dominant lower mantle mineral. Here we compile a comprehensive database of elemental partitioning by MgPv from published experimental studies and use it to generate a set of parameterized partition coefficients (f[melt composition]). Partition coefficients are then applied to a crystallization model. Uncertainty bounds are calculated from monte carlo methods. Partitioning of minor and trace elements (i.e. Fe, REE, HFSE, U+Th) depend significantly on melt composition, particularly Al and Ca content, due to charge coupled substitution and site size effects. After accounting for these effects through our parameterized partition coefficients, we present the resulting evolution of the melt and solid (MgPv) phases during magma ocean crystallization. Using a simple model of fractional crystallization, the chemical evolution is calculated until the liquid becomes saturated in a second solid phase (likely ferropericlase). The co-saturation point is uncertain but is estimated to be at ~50% crystallization of the magma ocean. During crystallization of MgPv, the melt phase becomes enriched in Fe, leading to compositionally denser products in the later stages of crystallization. The enrichment in Fe, however, is less extreme than predicted by recent experimental work (e.g. Nomura et al., 2011), bringing into question whether a basal magma ocean is an expected consequence of a whole mantle magma ocean. The melt also becomes enriched in heat producing elements (U+Th) and REE, but not to the degree predicted using earlier experimentally derived partition coefficients for MgPv (e.g. Corgne et al., 2005). Divergence from experimental partition coefficients is the result of compositional effects related to using a peridotitic (directly applicable to a magma ocean) liquid composition. Finally, we estimate the radiogenic heat production within the evolving solid and melt for various crystallization scenarios covering a range of plausible magma ocean crystallization time-scales.