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Thermodynamics of the Formation of a Basal Magma Ocean : a two-phase model

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In a recent paper Labrosse et al. (2007) have proposed that the sparse ultra low velocity zone observed at the base of the Earth's mantle, and generally interpreted as patches of dense partial melt (Williams & Garnero, 1996), could be the vestiges of a basal magma ocean once overlying the core mantle boundary.

To investigate the physical mechanisms involved in the formation of such a basal magma ocean, we have designed a 1D spherical two-phase flow model describing the early mantle of the Earth as a mixture of melt and viscously deforming solid matrix. More specifically our model takes into account the compressibility of melt with depth and the melting/solidification of the matrix via a source term coupling the mass conservation equations.

Because of its compressibility the melt eventually becomes denser than the surrounding matrix. Consequently, above this critical density cross-over depth, the melt is percolating upwards to form a magma ocean at the surface while symmetrically below this depth it is migrating downward to form a basal reservoir. Meanwhile the rocky matrix deforms as well inducing compaction and thermal adjustment. Knowing the temperature of fusion of the rocky matrix, we can compute the temporal evolution of temperature and thus observe episodes of re-melting/re-solidification of the mantle.

Our models demonstrate that melt percolation within a partially molten mantle is a likely process to form two magma oceans: one at the surface and one at the Core Mantle Boundary that may be labeled Basal Magma Ocean.

Reference

Labrosse S., Hernlund J.W. and Coltice N., A crystallizing dense magma ocean at the base of the Earth's mantle, Nature, 450 (7171): 866-869, 2007

Williams Q. and Garnero E.J., Seismic evidence for partial melt at the base of the Earth's mantle, Science, 273:1528-1530, 1996