CRYSTALLIZATION OF A MAGMA OCEAN

C-E Boukaré[1], Y. Ricard[2]
[1]*Laboratoire de Géologie, Université Lyon1, Villeurbanne, France*
[2]*Laboratoire de Géologie, Ecole Normale Supérieure, Lyon, France*

Key words Convection, magma ocean, crystallization.

The Earth mantle was significantly molten just after the accretion of our planet by the heat dissipation due to large impacts and by the segregation of the core. The mineralogical observations and thermodynamics models of solid-liquid equilibrium of silicates show that several type of crystallization may have happened at different depths in the mantle [1]. Solids were probably formed at the surface and in the middle of the lower mantle, leaving two possible magma oceans, a shallow one and an abyssal one. In the deep magma ocean, the liquid phase, richer in iron was likely gravitationally stable. In the shallow magma ocean, the solid phase formed near the surface was initially denser and sank through the magma to settle and compact at depth. However due to its enrichment in iron, the magma became eventually denser and at the end of crystallization the upper magma ocean might have undergone overturns (i.e. Rayleigh-Taylor instability) or a period were light solids were compacting under the lithosphere.

To understand these complex dynamics, we develop a two phase numerical code that can handle simultaneously the convection in each phase and in the slurry, and the compaction or decompaction of the two phases. The mathematical basis of the code akin to what we have used in [2-3] will be presented. Although our code can only run in a parameter range (Rayleigh number, viscosity contrast between phases, Prandlt number) very far from what would be realistic, we think it already provides a rich dynamics that illustrates what could have happened. We first study the simple situations of solidification where the melting curve is such that only a single magma ocean is expected (at depth or near the surface) but where the liquid phase can be either denser or lighter than the solid phase. We show situations in which the crystallization front is gravitationally stable and situations were the newly formed solid can "snow" across the magma in a regime that can be punctuated by large overturns. More complex cases where two magma oceans are present will also be presented and discussed.

References

[1] C.E. Boukaré, Y. Ricard and G. Fiquet, *Thermodynamics of the MgO–FeO–SiO2 system up to 140 GPa: Application to the crystallization of Earth's magma ocean*, J. Geophys. Res. **120**, 6085–6101, doi:10.1002/2015JB011929, 2015.

[2] Bercovici D. and Y. Ricard, *Energetics of a two phase model of lithospheric damage, shear localization and plate-boundary formation*, Geophys. J. Int., 152, 581-596, 2003.

[3] O. Sramek, Y. Ricard, and F. Dubuffet, *A multi-phase model of core formation*, Geophys. J. Inter., 181,198-220, 2010.