Influence of rotation on iron and silicate particles in an early Magma Ocean

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During its evolution the Earth most likely experienced a 'Giant Impact' in which a Mars size body hit the early planet. Today it seems widely accepted that the origin of the Moon is a result of this Giant Impact. Another consequence of such an impact would be the formation of a 'Deep Magma Ocean', i.e. a layer of molten material, extending to a depth of about 1000 km. Transport of heat and matter in a vigorously convecting Magma Ocean plays a key-role for the further evolution and differentiation of the Earth. The sinking of iron droplets in the convecting Magma Ocean probably provides an effective mechanism leading to the separation of metallic and silicate material. Dense material would finally pond at the bottom of the magma ocean. An instability of this dense material (Rayleigh-Taylor Instability) could lead to a rapid formation of the Earth's Core. Further, the dynamics of a Magma Ocean under the influence of dense silicate crystals is interesting to study, since it leads to a better understanding of layer formation in the later Earth's mantle.

We employed a 3D Cartesian numerical model, in order to study the sinking of heavy particles in a vigorously convecting environment. Differently from most approaches we have included the effect of rotation on the flow dynamics While a significant role of rotation can be ruled out for the today's Earth's mantle, due to the high viscosity of the mantle material, this is not the case for a Magma Ocean.

Our numerical model is based on a Finite Volume discretization. The finite size crystals are simulated by tracer particles using a position grid for the tracers being much finer than the numerical grid used to solve the fluid equations. The basic idea of the tracer algorithm used in this study is to divide the movement of particles into a part advected with the fluid and another part describing the settling of the particles due to Stokes sinking.

First results show, that the rotation of the fluid has little influence on the settling of iron particles in magma in a wide range of Rossby numbers ranging from Ro=10 to Ro=0.001. In this range settling is a rapid process which strongly disturbs the formation of typical structures in rotating fluids.

Numerical experiments on silicate crystals show a much more differentiated behavior in the presents of rotation. First the settling timescale depends on the Rossby number and has it's minimal value between Ro=1 and Ro=0.1, which is most likely the domain for the Rossby number in the Magma Ocean. Second the particles in this domain are not completely settled, so that some stay in suspension. A active interaction between settled and suspended tracers is possible in this case.

Though many aspects of the role of heavy particles in convection, under the influence of rotation, further need to be investigated, we feel that our numerical experiments indicate that rotation played a significant role at in the early history of the Earth.