The role of percolation on the volution of lunar magma ocean and its consequence for the mantle overturn

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The mantle overturn model by Hess and parmentier (1995) has been widely accepted, which well explains the later magma activity in the mare basalts and possibly the dctonomy the Moon. The model requires effectve accumulation of the residual melts enriched in incompatible elments during the magma ocean crystalliation just below the anorthosite crust, and they have evaluated the time scale of the development of the graviational instability.

The accumulation of the incompatible elements-enriched layer, however, is not guranteed if percolation process was highly effective that erases the density reversal. In order to evaluate the evolution of the density of the lunar magma ocean, we have developed a new physical and chemial model that desribes the chemical evolution of the magma ocean as a function of several physical parameters. The crystallization model is based on Sakai et al (2014) and the percolation process in the cumulate layer were taken into consideration.

The density of the magma ocean decrease from ~3150 to ~2929 [kg m-3] with the progress of crystallization, and then increases to ~3100 [kg m-3] after appearance and floatation of anorthite, though the exact numbers vary depending of the parameters. The viscosity of the magma ocena increases from ~5 to ~500 [Pa s] till the appearance of anorthite, which slightly decreases after anorthite crystallization.

By using the density and visosity parameters, we have evaluated the percolation time, which is defined to be the time for the growth of the density instability between the overlying magma ocean and the trapped melt in the underlying cumulate layer. The results show that the percolation time shows extremely large dependence on the grain size; the percolation time is unrealistically long if the grain size is smaller than 10um. If the grain size is larger than 1cm, the percolation time is short enough to grow the density instability. Thus, the density reversal that was achieved by differentiation was effectively resolved during crystalliation of the magma ocean if the grain size of olivine and pyroxene was larger than ~100 micron, that is, the residual melt layer enriched in incompatible elements, Fe, and Ti beneath the anorthosite crust is not expected to form.