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Thermal distribution and metal-silicate partitioning resulting from planetary core formation in a magma ocean

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It has been long known that the formation of the core transforms gravitational energy into heat and is able to heat up the whole Earth by about 2000 K. However, the distribution of this energy within the Earth is still debated and depends on the core formation process considered. Iron rain in the surface magma ocean is supposed to be the first mechanism of separation for large planets,iron then coalesces to form a pond at the base of the magma ocean.

A simple estimate of the metal-silicate partition from the P-T condition at the base of the magma ocean, which must coincide with between silicate liquidus and solidus by a single-stage model, is inconsistent with Earth's core-mantle partition. P-T conditions where silicate equilibrated with metal are far beyond the liquidus or solidus temperature for about 700K [Wade and Wood 2005]. Although the base of the magma ocean must be placed between the liquidus and solidus temperature, temperature in the middle of the magma ocean would be higher than the liquidus because of the release of gravitational energy.

In this study, we made 1D numerical calculations of the whole magma ocean using a parameterization based on a direct numerical simulation of a 10cm-scale emulsion of liquid iron in liquid silicates. The maximum temperature is obtained at the boundary between the metal pond (or the core if the whole planet is liquid) and the silicate layer. Therefore, the metal pond is thermally stable and the remaining silicate magma ocean is thermally unstable. Then we estimated the depth of the magma ocean as more than 2000km by chemical distribution.

Keywords: magma ocean, core mantle partitioning