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Constraints for a solid inner core in the Earth's Moon

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Since Apollo it has been debated whether or not the Moon has a core and whether or not that core would be fluid, solid or partly solid. Various geophysical data have been interpreted to suggest a small core with a radius of about 300km and with at least a molten outer core. The present state of the core is important in view of the absence of a lunar self-sustained magnetic field and in light of the evidence (not undisputed, however) for an early magnetic field that caused the remanent magnetization of part of the lunar crust. In earlier publications (Konrad and Spohn, Adv. Space Res. 19, 1997 and Spohn et al., Icarus, 149, 2001) we had argued for an entirely fluid lunar core at present as the most straightforward explanation for the lunar magnetic history. The early field would have been produced by a thermal dynamo that would have ceased to operate after about 500 Ma of lunar cooling. Failure of cooling to inner core solidification and the absence of a dynamo driven by inner core freezing would explain the absence of a present field.

Recent reanalysis of Apollo seismic data (Weber et al, 2010) did not only determine the size of the lunar core more accurately but also suggested the presence of a solid inner and a fluid outer core. Moreover, recent reanalysis of lunar rock suggested that the lunar mantle may not be as dry as had been assumed. In order to constrain under which circumstances a solid inner core can form, we calculated a suite of three dimensional thermal evolution models of the Moon. The lunar mantle was modeled as an internally and bottom heated, isochemical fluid in a spherical shell. The principle of this convection model is widely accepted and is used for thermal evolution models of terrestrial planets. We solved the dimensionless hydrodynamical equations of mass, momentum and energy conservation. Assuming the lunar core to consist of iron and some weight percent of a of lighter alloying component a solid inner core forms as soon as the core adiabat intersects with the liquidus temperature of the core alloy. We systematically varied the core thermal parameters and the rheological parameters of the mantle from a dry to a wet rheology and included the thermal effects of a regolith layer. Preliminary results show that stagnant lid convection as well as the thermal effects of the regolith layer tend to keep the core warm and prevent freezing. A wet rheology will tend towards more efficient cooling and allow an inner core. The observation of an inner core and its size can be used as an indirect constraint on the mantle rheology and composition. The problem of the present-day absence of a dynamo will be discussed.