
Duration of the thermal lunar overturn

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Abstract

The observed variation in lunar crustal thickness between the nearside (20-30km) and the farside (50-60km) cannot be explained by the classical scenario of the Lunar Magma Ocean (LMO) crystallization involving anorthite flotation. We investigate whether thermal instabilities developing within the lunar cumulates could arise before the completion of LMO solidification and contribute to this dichotomy. The possibility of flow through the LMO–cumulates interface by melting and crystallisation makes the development of the convective instability faster and leads to larger scale modes of convection. We investigate the onset and duration of a thermal overturn in the lunar cumulates using a combination of linear stability analysis (LSA) and direct numerical simulations (DNS), accounting for a flow-through LMO–cumulates boundary. LSA enables exploration of a wide parameter space relevant to lunar conditions, but is limited to growth rates and dominant convective modes. DNS, in contrast, provides access to the full spatial and temporal evolution of the instabilities, although over a restricted parameter range. We show that DNS results can be extrapolated using LSA, allowing us to constrain the onset and duration of the lunar thermal overturn. Our results show that a thermal overturn can initiate well before the final stage of LMO solidification and persist over timescales ranging from several hundred or thousand years to tens of millions of years. The dominant convective mode corresponds to a spherical harmonic of degree one. Such an early thermal convection in the cumulates could influence crustal growth and stabilization, potentially contributing to the lunar crustal dichotomy, and may also have implications for the generation of an early lunar dynamo when considering the thermal evolution of the core.

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