Consequences of the nucleation barrier on lunar core evolution

Sara Gutierrez,[1] Steven A. Hauck II[1]

[1] *Earth, Environmental, and Planetary Sciences Department, Case Western Reserve University, Cleveland, OH 44106*
sara.gutierrez@case.edu

Abstract. The Moon's unique magnetic field history — characterized by a short, high intensity period followed by a long-lasting, weak period — is an indicator of its interior evolution. The exact driver(s) of the Moon's paleomagnetic field have not been determined[1]. Recent work has also outlined the previously ignored nucleation energy barrier's hindrance of solids forming in the Earth's core[2,3]. To overcome the thermodynamic barrier, a homogenous liquid must be supercooled an additional ~.32$T_{melting}$ below the liquidus, or alternatively, an appropriate substrate be present for heterogeneous nucleation to commence. Lunar solid core formation has been described by bottom-up or top-down crystallization regimes solely determined by composition: a homogenous metal liquid solidifying either at the center of the planet or the core mantle boundary (CMB)[4] . Due to the nucleation barrier, the liquid may experience supercooling before a substrate initiates heterogeneous nucleation. As well, because the temperature profile for Lunar pressure conditions is so steep, relatively little supercooling would supersaturate the entire core, making it so a core thermodynamically inclined to crystallize bottom-up, could as easily start forming solids at the CMB. The solidification from a supercooled condition would lead to fast growth of an inner core[1]. For an Fe –S core this would initially produce a dendritic, porous core that would undergo both composition and growth on rapid timescales. Constraining the timing, size, and energy release associated with the growth of a solid inner core is key to understanding the Lunar geodynamo history. We present the possible outcomes for the various crystallization regimes, complicated by the nucleation barrier, and explore what these results mean for the texture of the Lunar deep interior and magnetic field history.

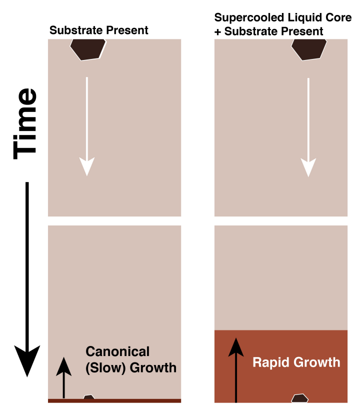

Figure 1. Bottom-up solidification for a partially supercooled core will be delayed and quickened compared to canonical growth.

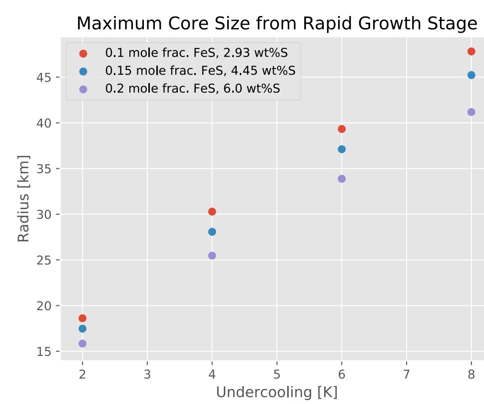

Figure 2. Inner core resulting from rapid growth and compaction due to bottom-up crystallization from a supercooled state.

[1] Tikoo S. M. et al. (2017) *Sci. Adv.* 3, e1700207.
[2] Huguet L. et al. (2018) *EPSL*, 487, 9.
[3] Davies C.J. et al. (2019) *EPSL,* 507, 1.
[4] Liu J. et al. (2020) *EPSL,* 530, 115834.