A REVIEW OF EXPERIMENTAL STUDIES SIMULATING LUNAR MAGMA OCEAN SOLIDIFICATION. D. S. Draper and T. C. Prissel, 1Astromaterials Research Office. NASA Johnson Space Center, 2101 NASA Parkway, Mail Code XI3, Houston TX 77058, david.draper@nasa.gov. 2Department of Earth & Planetary Sciences, Rutgers University, 610 Taylor Rd., Piscataway, NJ 08854.

Introduction: Lunar magma ocean (LMO) crystallization is a guiding paradigm for understanding the thermal and magmatic evolution of the Moon. Important inferences arose from numerical crystallization models [1, 2], and more recently, petrologic experiments duplicating the entire process of LMO solidification. The experiments provide extensive, internally-consistent datasets that cover the likely range of LMO compositions and crystallization histories, enable important inferences about lunar evolution, and provide needed inputs to numerical LMO models and understanding of post-LMO magmatism. Here we review key aspects of and results from these experiments.

Types of crystallization, range of starting compositions: Some studies (e.g. [3-5]) experimentally simulated the numerical model of [1], which features initial equilibrium crystallization followed by fractional crystallization of the LMO. Others simulated fractional crystallization operating from the outset of solidification (e.g. [6-8]) as suggested by later models (e.g. [2]). Compositions used include Taylor Whole Moon (TWM) [9], with ~6 wt% Al₂O₃ and Mg# = 84; a depleted Lunar Primitive Upper Mantle (LPUM) [10,11] with ~4 wt% Al₂O₃ and Mg# = 90; and a composition derived via inversion of lunar seismic data [12] with 4.5 wt% Al₂O₃ and Mg# = 86. TWM includes an enrichment of ~50% in refractory elements (e.g. Al, Th) relative to Earth [13], whereas LPUM represents no refractory element enrichment. The Snyder model [1] used a composition with 5 wt.% Al₂O₃ and Mg# 82.

Summary of results: Whether a two-stage or fully fractional process, LMO crystallization produces cumulate piles (Fig. 1) with denser, more Fe-rich material at the top and less dense, more magnesian material at the base. Thus cumulative overturn is likely, as predicted by numerical models. Reconciling these results with the production of a plagioclase-rich crust of similar thickness to that inferred by the GRAIL mission [14] is complicated by uncertainties in bulk lunar Na₂O and water contents (not every experimental or numerical study included Na₂O, and only Lin et al. [4, 5] set out to evaluate to role of water). Experimentally-determined residual liquids show broad similarities with the Snyder [1] model for MgO and Mg#, and less so for TiO₂ contents. In contrast, measured SiO₂ and Al₂O₃ decrease with crystallization instead of increasing as predicted, and vice versa for CaO and FeO. The last liquids produced have many features that have been ascribed to KREEP, both in terms of phase equilibria and major element contents, and with respect to REE contents inferred from applying relevant partitioning data. These results provide a springboard for future, more focused experimental and numerical simulations of LMO crystallization.