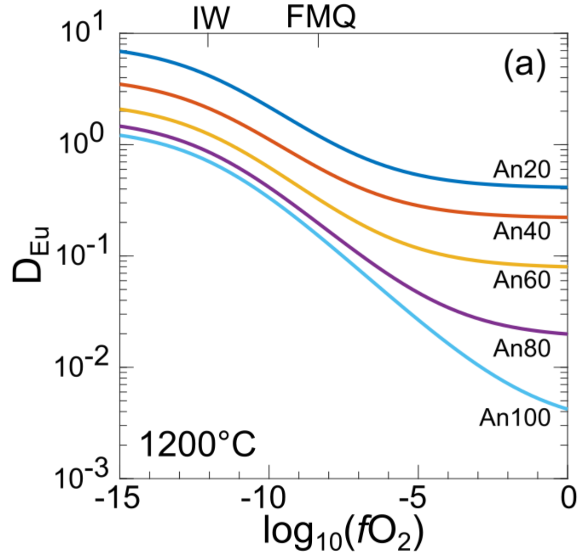
Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.17023

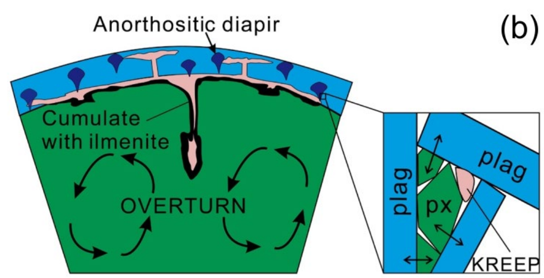
Serial Processing of the Lunar Crust after the Magma Ocean Stage and a Depleted Bulk Moon: Insights from a Europium-in-Plagioclase Partitioning Model

NICHOLAS J DYGERT AND DIAN JI

University of Tennessee

Presenting Author: ndygert1@utk.edu





Positive Eu anomalies ($Eu/(Sm*Gd)^{0.5}>1$, chondrite normalized) are a ubiquitous feature of lunar anorthosites, reflecting preferential substitution of divalent Eu into the plagioclase ring site under reducing conditions relevant to the Moon. Using a temperature (T), composition, and oxygen fugacity (fO_2)-dependent Eu-in-plagioclase-melt partitioning model [1] (Fig. a), we evaluated the significance of Eu anomalies in the context of the lunar magma ocean paradigm, modeling trace element fractionation during solidification of the lunar magma ocean, and comparing the results to anorthositic meteorites and Apollo returned samples [2]. We observe that plagioclase in all lunar anorthites have lesser Eu anomaly magnitudes than anticipated in a magma ocean solidification scenario at lunar-relevant fO_2s. We explored a series of possible explanations, including partial melting of a lunar flotation crust, closed system T and fO_2-dependent subsolidus reequilibration, and subsolidus reequilibration after addition of trapped lunar magma ocean liquid, Mg suite parent liquid, and chondritic components, all of which failed to reproduce the natural samples. Finally, we tested subsolidus reequilibration after addition of a minor KREEPy liquid component, which successfully reproduced Eu anomaly magnitudes and the slopes of the rare earth element (REE) patterns for Apollo samples and lunar meteorites. We ran Monte Carlo simulations testing different bulk Moon trace element patterns, and the T and fO_2 conditions under which subsolidus reequilibration occurred. We find that models assuming a slightly light REE-depleted bulk Moon produce the most successful simulations, at Ts of ~1050-1250°C and fO_2 of ~IW-2, after addition of <1% of a KREEPy liquid component. We propose a Serial Processing model for lunar crustal evolution where a lunar flotation crust experiences an infusion of heat and KREEPy liquid after a cumulate mantle overturn event, inducing subsolidus reequilibration (Fig. b). Hot, low density, reequilibrated anorthositic diapirs buoyantly rise to the lunar surface, where they are eventually sampled. This model reconciles overlapping ages of Mg-suite rocks and lunar anorthosites. A light REE depleted Moon can be explained by a terrestrial differentiation event predating the Moon-forming giant impact.

References

[1] Dygert et al., 2020, GCA 279, 258-280.

[2] Ji and Dygert, 2023, EPSL, 117958.