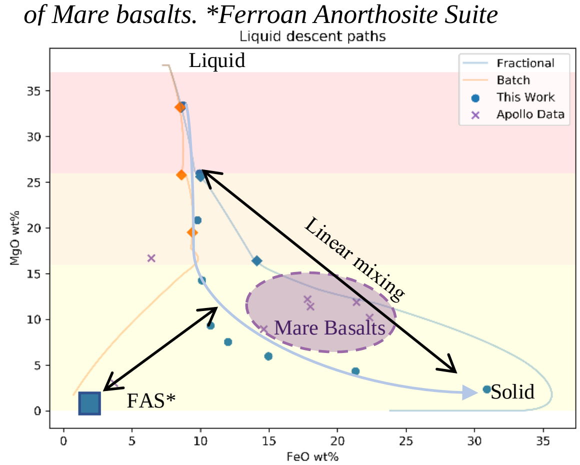
Crystallization of a Model Silicate Moon. E. Baker[1] (edward.baker@seh.ox.ac.uk), Dr. J Wade[1] and Prof. B Wood[1]. 1 (Department of Earth Sciences, University of Oxford)

The Moon is almost indistinguishable from the Earth across a range of refractory isotope systems (e.g. W, O, Cr etc), which suggests a close genetic link with the Earth [1], [2]. Although broadly similar to the terrestrial mantle, the silicate Moon's major element chemistry appears to differ in one key respect - the reported silicate Moon's iron content (up to 17wt% FeO) may be notably higher that the Earth (8wt%FeO). These elevated lunar FeO contents are, however, primarily based upon interpretations of the lunar surface rocks, and in particular the melting and crystallisation history of the silicate Moon.

Given the established genetic link between silicate Earth and Moon, do lunar surface rocks really require a mantle source that is significantly richer in iron? Or is the silicate Moon merely a snapshot of the terrestrial mantle?

My experiments investigate a fractionally crystallizing lunar magma ocean of fertile pyrolytic composition. Starting with McDonough and Sun (1995)[3] primitive mantle, with volatile elements (e.g. K and Na) reduced by 2/3rds. Experiments started at 85% liquid with 15% Olivine removed from primitive composition. At each step the melt from the previous experiment is the bulk composition for the next step. For long duration experiments, graphite lined Pt capsules were used to prevent CaF_2 ingress. Experiments lie between fO_2 of C-CO and IW+1.5 and follow the lunar pressure gradient, from 2.5GPa, 1675ºC for the primitive melts to 0.5GPa, 850ºC for evolved melts.

*Figure 1: Fractional and Batch models used phMELTS. Mineral stability fields are taken from MELTS too. My experimental line of descent differs from that modelled and enables the mixing of late and early fractions to produce the bulk rock compositions of Mare basalts. *Ferroan Anorthosite Suite*



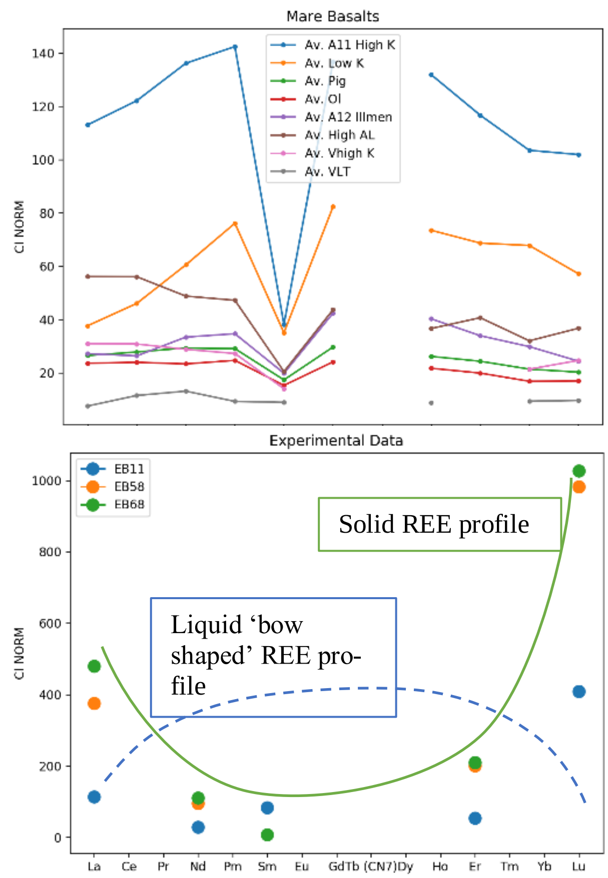


Figure 2a: Rare Earth Element plots for Mare basalts.
Figure 2b: My experiments show an enrichment of the solid phases in Heavy REEs. Data from LA-ICPMS.

Data from [4]

In major element space my experimental crystallization has shown that linear mixing of early and late stages can reproduce much of the bulk rock geochemistry of the Mare basalts.

Mare basalts have a characteristic 'Bow' Shaped rare earth element trend, depletion in both heavy and light rare earth elements. KREEP, rich in LREEs can be the sink for the light REEs. On the Moon, the lower pressure precludes the formation of Garnet; another sink is therefore needed to explain the depletion of the HREEs.

A high temperature pyroxenoid phase in the early stages of the crystallization is able to accept large amounts of the HREEs. I propose this as the sink for the HREEs.

The complete fractionation curve, when re-mixed, is able to explain the bulk of the major and rare earth element observations of the surface of the Moon. It is possible to have vigorous mixing between the Earth and Impactor, explaining the Major element, and Isotopic composition of the Apollo Basalts.

[1] E. D. Young, I. E. Kohl, P. H. Warren, D. C. Rubie, S. A. Jacobson, and A. Morbidelli, "Oxygen isotopic evidence for vigorous mixing during the Moon-forming giant impact," *Science (80-.).*, vol. 351, no. 6272, pp. 493–496, Jan. 2016, doi: 10.1126/science.aad0525.

[2] H. S. C. O'Neill, "The origin of the moon and the early history of the earth-A chemical model. Part 1: The moon," *Geochim. Cosmochim. Acta*, vol. 55, no. 4, pp. 1135–1157, 1991, doi: 10.1016/0016-7037(91)90168-5.

[3] W. F. Mcdonough and S. -s. Sun, "The composition of the Earth," *Chem. Geol.*, vol. 120, pp. 223–253, 1995.

[4] G. H. HEIKEN, D. T. VANIMAN, and B. M. FRENCH, "Lunar Sourcebook," *Cambridge Univ. Press*, p. 778, 1991, doi: 10.1017/CBO9781107415324.004.