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Crystallization of a Model Silicate Moon

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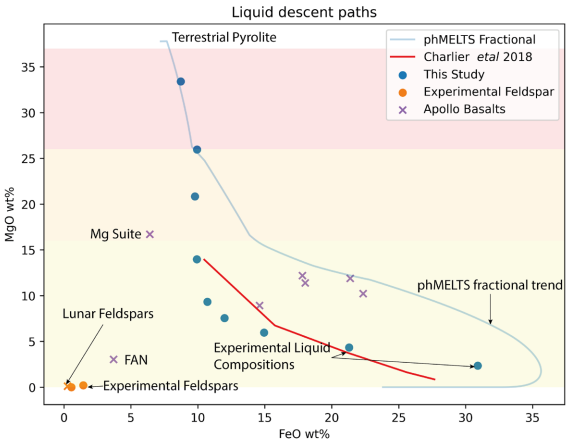

The Moon is almost indistinguishable from the Earth in a number of refractory isotope systems (e.g. W, O, Cr etc.), indicating a close genetic link between the Earth and Moon. Although broadly similar to the terrestrial mantle, the silicate Moon's major element composition appears to differ - the estimated iron content of the silicate Moon (up to 17 wt.% FeO[2]) is higher than Earth's (~8 wt.% FeO). The elevated lunar FeO estimate is based upon interpretations of lunar surface rocks.

Given the genetic link between the Earth and Moon, do lunar surface rocks require a mantle source that is significantly richer in iron? Could the silicate Moon be the same as the terrestrial mantle at the time of the giant impact?

Our experiments investigate a fractionally crystallizing lunar magma ocean of fertile pyrolite composition[1], with volatiles (K and Na) reduced by 67 %. At each step, the melt from the previous experiment was taken as the bulk composition for the next step. Experiments lie between an fO2 of C-CO and IW+1 in graphite capsules and follow the lunar pressure gradient, from 2.5 - 0.5 GPa and 1675 - 850 °C.

The crystal phases produced along the liquid line of descent (fig. 1), when remelted, are able to reproduce the major element compositions of lunar rocks: Explicitly, a lunar mantle, of peridotitic composition, when crystallizing under lunar conditions, is able to reproduce our observations of the surface of the Moon.

On the Moon, the 'Bow-shaped' REE trends require a HREE enriched source; A high-temperature pyroxene is found experimentally to accept HREEs. Forward models of the REE evolution of the Moon suggest further differentiation of late-stage liquids is required to deplete Fe and enrich REEs, in the melt, to recreate the KREEP basalt composition.

Re-mixing and recombination modelling finds that there is no requirement to enrich the Moon in refractory elements to reproduce the Apollo observations.

[1] Mcdonough, W. F. & Sun, S. Chem. Geol. 120, 223–253 (1995)

[2] Jolliff, B. L., Wieczorek, M. A., Shearer, C. K., & Neal, C. R. (2006). New views of the Moon. American Mineralogist, 60.