Sr isotope and trace element evidence in lunar granulite NWA 3163 for a lunar upheaval in the Moon at 4.35 Ga

C.L. MCLEOD[1], A.D. BRANDON[2]*

[1]Geology and Environmental Sciences, Miami University, Oxford, OH, 45056, USA.
[2]Earth and Atmospheric Sciences, University of Houston, Houston, TX, 77204, USA (*email: abrandon@uh.edu)

Recently obtained geochronological evidence from lunar ferroan anorthosite 60025 has led to a proposal that the Moon-forming giant impact between Earth and a Mars-sized object occurred from around 4.42 to 4.34 Ga [1]. This time window is significantly later than previous estimates of ≥ 4.5 Ga. While this late age is inconsistent with some published older ages for lunar crustal rocks, it has been suggested that these previously published older ages may be in error [2]. Alternatively, the event recorded during this time window could have been the result of a lunar upheaval following earlier Moon formation.

A record of a global-wide lunar event at this time is also consistent with the ^{142}Nd-^{143}Nd systematics of lunar basalts that give a mantle source closure age of *ca*. 4.35 Ga [3]. This age overlaps with the prominent peak of 4.345 Ga for U-Pb in lunar zircons. These ages are consistent with either scenario. New Sr isotope data and in-situ trace element data on lunar felsic granulite NWA 3163 is presented here to examine this issue. The ^{87}Sr/^{86}Sr isotopes for 3 fractions of NWA 3163 have an average of 0.699282±7 (2σ). The calculated source model Sr T_{RD} age is 4.34±0.057 Ga, and overlaps with the lunar basalt mantle source closure age, and the peak in lunar zircon ages. The REE concentrations in plagioclase and pyroxene from NWA 3163 indicate that they were derived from melts that were more LREE-enriched than melts derived from a primordial magma ocean. Hence, taken together, the NWA 3163 Sr model age and its mineral trace element compositions support a reworking event at *ca*. 4.35 Ga in the Moon. The convergence of lunar ages, in combination with evidence from Earth rocks, for example, a minimum source Sm/Nd fractionation age from ^{142}Nd-^{143}Nd systematics of 4.50 Ga for Isua, Greenland rocks, [4] indicates that the ca. 4.35 Ga age represents a lunar upheaval in an already formed Moon. Possible mechanisms for a 4.35 Ga lunar upheaval will be discussed.

[1] Borg (2011) *Nature* **477**, 70-73. [2] Borg et al. (2015) *MAPS* **50**, 715-732. [3] McLeod et al. (2014) *EPSL* **396**, 179-189. [4] Bennett et al. (2007) *Science* **318**, 1907-1910.