# REGOLITH MIXING OF LUNAR METEORITES.

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**Introduction:** Most lunar meteorites have very short transfer times from the Moon to Earth ($10^3$-$10^6$ yr). Therefore, the cosmogenic radionuclide concentrations in lunar meteorites reveal their ejection depth from the lunar surface, i.e., the shielding depth during the last ~5 Myr [1]. The cosmogenic noble gas concentrations reflect their exposure history in the lunar regolith, which typically lasted $10^8$-$10^9$ yr [2]. These regolith ages depend on the average shielding depth, which is not well constrained. The average shielding depth of lunar meteorites, as derived from several noble gas ratios [2], is often different from the ejection depth. It is not clear if this discrepancy is due to uncertainties in the average shielding depth or represents temporal variations in shielding depth due to regolith mixing processes. We will address this question by using neutron capture effects on Samarium as an additional shielding parameter.

**Methodology**. Due to the large neutron-capture cross sections of $^{149}$Sm (41,000b), the $^{150}$Sm/$^{149}$Sm ratio increases as a function of thermal neutron dose. Deviations of the measured $^{150}$Sm/$^{149}$Sm ratio from the average solar system value are expressed as $\varepsilon Sm = 10^4 * [(^{150}Sm/^{149}Sm)_m/(^{150}Sm/^{149}Sm)_0 - 1]$. Since the depth profiles of neutron capture products and spallogenic nuclides (such as $^{21}$Ne, $^{38}$Ar, $^{83}$Kr and $^{126}$Xe) are very different [3,4], the combination of the two products is very sensitive to depth. We measured the Sm isotopic composition of five lunar meteorites with known ejections depths [1]: ALH 81005 (165 g cm$^{-2}$), MAC 88105 (380), QUE 93069 (75), QUE 94281 (295) and LAP 02205 (700). The $^{150}$Sm/$^{149}$Sm ratios in four of these (except LAP) show large neutron capture effects, ranging from εSm = 94 (QUE 94) to εSm = 237 (QUE 93) [5]. Since cosmogenic $^{21}$Ne in lunar samples suffers from diffusive losses, we used the measured $^{126}$Xe concentrations [6-8] as the spallogenic component. Based on $^{126}$Xe/εSm ratios, we derive average shielding depths of 100-140 g cm$^{-2}$ and regolith exposure ages of 500-1100 Myr. These ages are generally similar to those in [2], although the age of ALH 81005 is ~60% higher.

**Discussion**: The ejection depth of 110 g cm$^{-2}$ for QUE 93069 is similar (within error) to its average irradiation depth, suggesting that this meteorite came from a regolith that was relatively stable for the last ~1 Gyr. However, the ejection depths for the other three lunar meteorites are 65-275 g cm$^{-2}$ deeper than their average irradiation depths. This indicates that these samples have experienced one or more burial (deposition) events in the last 10-100 Myr. It is not clear yet if the relatively constant irradiation depth of 100-140 g cm$^{-2}$ for all four lunar meteorites is due to sample bias or reflects continuous regolith mixing in the top few meter of the lunar surface [e.g., 9].

**References:** [1] Nishiizumi K. and Caffee M. W. 2010. *MAPS* 45:A152. [2] Lorenzetti S. et al. 2005. *MAPS* 40:315-327. [3] Lingenfelter R. E. et al. 1972. *EPSL* 16:355-369. [4] Hohenberg C. M. et al. 1978. *Proc. Lunar Planet. Sci. Conf.* 9:2311-2344. [5] Welten K. C. et al. 2013. 44th *Lunar Planet Sci. Conf.*, #2933. [6] Eugster O. et al. 1991. GCA 55:3139-3148. [7] Eugster O. et al. 1986. *EPSL* 78:139-147. [8] Polnau E. and Eugster O. 1998. *MAPS* 33:313-319. [9] Langevin Y. and Arnold J. R. 1977. *Ann. Rev. Earth Planet. Sci*. 5:449-489.