EXPOSURE HISTORIES OF LUNAR METEORITES. K. Nishiizumi[1], [1]Space Sciences Laboratory, University of California, Berkeley, CA 94720-7450, USA. (kuni@ssl.berkeley.edu).

Introduction:

Most lunar meteorites have complex cosmic ray exposure histories, having been exposed both at some depth on the lunar surface (2π irradiation) before their ejection and as small bodies in space (4π irradiation) during transport from the Moon to the Earth. These exposures were then followed by residence on Earth's surface, a time commonly referred to as the terrestrial residence time. In addition to their complement of galactic cosmic ray (GCR) produced nuclides some lunar and Martian meteorites contain nuclides produced by solar cosmic rays (SCR). Unraveling the complex history of these objects requires the measurement of at least four cosmogenic nuclides. The specific goals of these measurements are to constrain or set limits on the following shielding or exposure parameters: (1) the depth of the sample at the time of ejection from the Moon; (2) the transit time (4π exposure age) from ejection off the lunar surface to the time of capture by the Earth; (3) and the terrestrial residence time. The sum of the transit time and residence time yield an ejection age. The ejection age in conjunction with the sample depth on the Moon can then be used to model impact and ejection mechanisms. To investigate the complex exposure histories of lunar meteorites, we measured cosmogenic radionuclides, ^{41}Ca (half-life = 1.04×10^5 yr), ^{36}Cl (3.01×10^5 yr), ^{26}Al (7.05×10^5 yr), ^{10}Be (1.5×10^6 yr), and ^{53}Mn (3.7×10^6 yr) in each lunar meteorite [e. g. 1].

Discussion:

Figure 1 shows the ejection ages and terrestrial ages of 24 (18 individual) lunar meteorites. Most results were obtained from our cosmogenic radionuclide measurements. Figure 2 shows lunar meteorite transition times. Meteorite names in italic indicate ejection depths greater than 1,000 g/cm^2.

The transition time of lunar meteorites have been predicted by Monte Carlo simulations [2-3]. Numerical simulations modeling the dynamical evolution of lunar impact ejecta have also been performed and can be used to explain the distribution of transition times for lunar meteorites [4]. In general, the model predictions agree with our measurements that indicate that the majority of lunar meteorites are captured by the Earth less than 1 Myr after ejection. All meteorites having exposure ages greater than 0.5 Myr were ejected from greater depths within the lunar surface. These meteorites may in general have higher launch velocities than those lunar meteorites ejected from shallower depths. Accordingly, they are more likely to escape the Earth-Moon system and reside in a heliocentric orbit.

When sufficient sample was available, we measured detailed depth profiles for all the measured cosmogenic nuclides. These depth profiles included samples taken on a transect from the fusion crust to the interior. To date, at least 6 lunar meteorites, Calcalong Creek, MAC 88105, NWA 032, NWA 482, QUE 93069, and Y-791197 show SCR produced ^{26}Al at the near surface of meteorites. Presence of ^{26}Al indicates minimal ablation during atmospheric entry, presumably the result of either low entry velocity or low entry angle. The dynamical evolution model predicts lunar meteorite entry velocities at the top of the atmosphere just above the Earth's escape velocity of 11.2 km/s [4]. This entry velocity is lower than that of ordinary meteorites. The presence of SCR-produced ^{26}Al is apparent not correlated with exposure ages or ejection depths.

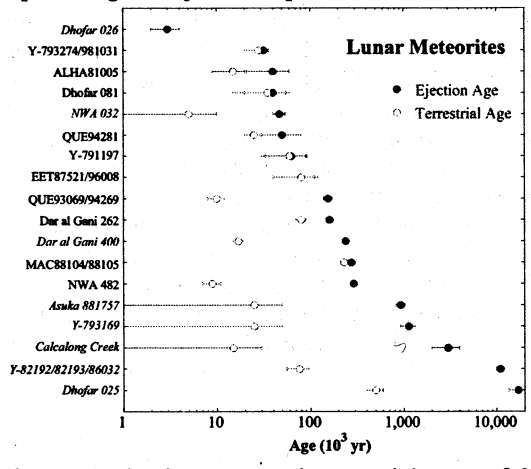

Figure 1. Ejection ages and terrestrial ages of 24 lunar meteorites. Meteorites in *italic* indicate the ejection depth >1,000 g/cm^2.

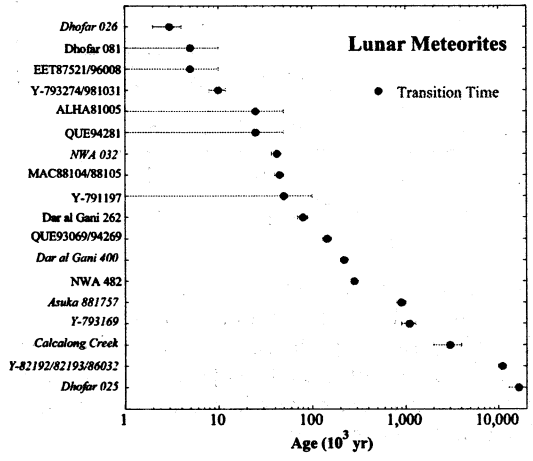

Figure 2. Transition time of 24 lunar meteorites. Meteorites in *italic* indicate the ejection depth >1,000 g/cm^2.

References: [1] Nishiizumi K. *et al.* (1991) *GCA 55*, 3149-3155. [2] Arnold J.R. (1965) *Ap. J. 141*, 1536-1547. [3] Wetherill G.W. (1968) *Science 159*, 79-82. [4] Gladman B.J. *et al.* (1995) *Icarus 118*, 302-321.

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