EXPOSURE HISTORY OF THE LUNAR MARE BASALT EETA 87521; S.Vogt, Dept. Earth & Atmospheric Sciences, Purdue Univ., West Lafayette, IN 47907; G.F.Herzog, Dept. Chemistry, Rutgers Univ., New Brunswick, NJ 08903; J.Klein and R. Middleton, Dept. Physics, Univ. Pennsylvania, Philadelphia, PA 19104.

We report first results for the cosmic ray produced radionuclides ^{10}Be and ^{26}Al in the lunar meteorite EETA 87521 and use them to reconstruct the exposure history to cosmic rays.

The contents of the cosmogenic radionuclides ^{10}Be and ^{26}Al are 0.7±0.1 dpm/kg and 3.2±0.2 dpm/kg, respectively. These results are unusually low in comparison to the activities measured for other meteorites whether of lunar (Fig.1 and [1]) or asteroidal origin [2]. A priori, it is not possible to decide from the measured ^{10}Be and ^{26}Al contents whether the low activities are due to a long terrestrial age, a short transit time between Moon and Earth along with a high burial depth on the lunar surface, or a combination of both. The ^{36}Cl concentration of 0.9±0.5 dpm/kg [3] implies a terrestrial age of no longer than 1.5 Ma. Terrestrial ages as long as 1.5 Ma have not been reported for any specimen found in Antarctica. It appears that terrestrial ages of up to 1 Ma are achievable under very particular circumstances [4], suggesting a residence time for EETA 87521 probably shorter than even 1.0 Ma. Maximum ^{10}Be and ^{26}Al concentrations of 1.4 dpm/kg and 13.5 dpm/kg at the time of fall, respectively, are calculated for a terrestrial age of 1.5 Ma. Constraints on the duration of transit time and burial depth on the lunar surface are set by the ^{10}Be contents, as its production is insensitive to SCR effects and less sensitive to depth effects. An upper limit on the transit time of ≤0.15 Ma is derived using a 4π saturation activity of 22 dpm/kg for ^{10}Be and assuming an infinite burial depth on the Moon. A transit time of this magnitude limits the maximum ^{36}Cl contents attainable to ≤6 dpm/kg, which requires a terrestrial age of ≤0.7 Ma in order to decay to the measured content. However, an exposure of ≤0.15 Ma in free space could not possibly have produced the ^{21}Ne concentration measured for EETA 87521 [5] and rules this possibility out. On the other hand, assuming an very brief transit time between Moon and Earth ($T(4\pi)<0.01$ Ma), the ^{10}Be content of about 1.4 dpm/kg leads to a minimum depth on the lunar surface of > 500 g/cm^2. We obtained this result by comparing the ^{10}Be with the those activities measured in the Apollo 15 drill core [6]. In fact, the measured radionuclide contents match those determined in the Apollo 15 drill core at a depth of about 550 g/cm^2 [6,7], suggesting a rather brief transit time and terrestrial age. Similar constraints on the exposure history are required by the measured ^{26}Al/^{10}Be ratio, which closely resembles the one expected at saturation for both 2π and 4π exposure, after adjusting for the different composition of the Apollo 15 core and EETA 87521. In summary, the lunar meteorite EETA 87521 lay buried deeply on the lunar surface (500 - 800 g/cm^2), underwent a rather brief transit time between Moon and Earth (<<0.15 Ma) followed by a brief to moderate terrestrial age (<<0.7 Ma). The analyses of additional cosmogenic radionuclides with varying half lives, such as ^{41}Ca and ^{53}Mn will put further constraints on the exposure history of the lunar meteorite EETA 87521.

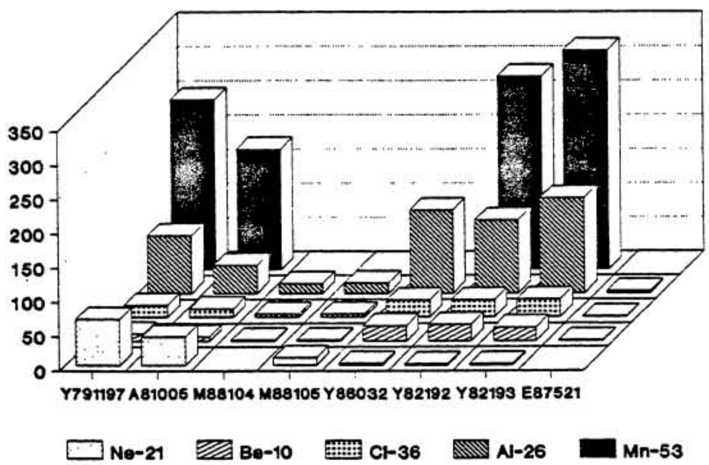

Figure 1: Cosmogenic nuclide contents in lunar meteorites. Activities of radionuclides are in dpm/(kg bulk material) and dpm/(kg Fe+Ni) for ^{53}Mn; Concentrations of ^{21}Ne are 10^{-8} cc/g STP (for refs. see [1] and [3]).

S.Vogt et al., Exposure History Of The Lunar Mare Basalt EETA 87521

To what extent do cosmogenic nuclides enable us to identify pairing of lunar meteorites? Specimens belonging to a *paired fall*, fragments of the same meteoroid, have to obey a sum rule: T(ter.) + T(4π) + T(2π) = constant, except under extraordinary circumstances. Sizable effects of depth on the production rates of cosmogenic radionuclides are to anticipate, during 2π and 4π irradiation, for larger meteoroids ("R" > 15 cm). Thus, in order to pair specimens we would anticipate quite similar quantities of cosmogenic nuclides for fragments of small meteorites (see [8]); such is the case for MAC 88104/5 and Yamato 82192/3 & 86032. Petrographic differences between the four lunar mare basalts (EETA 87521, Yamato 793169, Yamato 793274 and Asuka-31) and the four anorthositic breccias (ALHA 81005, MAC 88104/5, Yamato 791197 and Yamato 82192/3 & 86032) also indicate that pairing of them with each other seems very unlikely [9].

A more complex situation arises in attempting to distinguish *paired ejecta*, distinctive fragments from the same impact event. They should obey a sum rule of the form: T(4π) + T(ter.) = constant, where the duration of 4π exposure and terrestrial age need not to be similar. Beyond that, however, their parameters of exposure need not agree. Mineralogy and composition can help in identifying paired ejecta but may be less helpful in ruling it out, because a large event on the Moon could conceivably eject several different kinds of material. The impact that produced the triad of Yamato meteorites (Y 82192/3 and Y 86032, with T(4π) + T(ter.) > 0.1 Ma) clearly predates the events that ejected the other lunar meteorites analyzed so far. The other four lunar meteorites (ALHA 81005, MAC 88104/5, Y 791197 and possibly EETA 87521, with T(4π) + T(ter.) <0.5 Ma) seem to originate in either three (ALHA 81005 and Y 791197 might be paired ejecta) or four impact events on the Moon.

Beyond the question of how many impact events produced the lunar meteorites collected in Antarctica, the number of lunar meteorites found on Earth seems surprisingly large. Four of the five lunar meteorites analyzed for their cosmogenic nuclide contents were ejected less than 0.5 Ma ago. Thus, a minimum estimate of the frequency with which lunar meteorites arrive on Earth is 8 Ma^{-1}, assuming one meteorite arrives per impact event. As all lunar meteorites were collected in an area of about 1000 km^2, we can anticipate the recovery of more lunar meteorites in Antarctica and perhaps other areas as well, provided the survival time of the meteorites is long.

Refs.: [1] Vogt S. et al. (1989) 15th Symp. Antarct. Meteorites, NIPR, 207; [2] Nishiizumi K. (1987) Nucl. Tracks. Radiat. Meas. 13, 209; [3] Nishiizumi K. et al. (1991) this volume; [4] Nishiizumi K. et al. (1989) EPSL; [5] Eugster O. (1991) this volume; [6] Nishiizumi K. et al. (1984) Earth Planet. Sci. Lett. 70, 157; [7] Nishiizumi K. et al. (1984) Earth Planet. Sci. Lett. 70, 164; [8] Melosh J. (1988) Impact Cratering, Oxford Univ. Press, pp. 256; [9] Lindstrom M.M. and Martinez R.R. (1990) 15th Symp. Antarct. Meteorites, NIPR, 114.