THE EVOLUTIONARY HISTORY OF ITOKAWA: WHAT CAN WE LEARN FROM MEASURMENTS OF INDIVIDUAL GRAINS?

K. Nishiizumi[1] and M. W. Caffee[2], [1]Space Sciences Laboratory, University of California, Berkeley, CA 94720-7450, USA (e-mail: kuni@ssl.berkeley.edu), [2]Department of Physics and Astronomy, Purdue University, West Lafayette, IN 47907-2036, USA (mcaffee@Purdue.edu).

Introduction: Although the recovered samples were much smaller than in the original plan, there have been many important studies since Hayabusa returned Itokawa surface samples. One of the most interesting findings, especially related to our study, are the high concentrations of solar He, Ne, and Ar components indicating that Itokawa samples were exposed to the solar winds (SW), similar to the lunar soils. The residence time on the surface of Itokawa was calculated to be on the order of tens of Myr, based on the cosmogenic ^{21}Ne concentration [e.g., 1-5]. Additionally, the ^{21}Ne cosmic ray exposure (CRE) ages scatter from <1 to ≥20 Myr for each grain, even though all samples originated from a similar depth on the surface. The ^{10}Be and ^{26}Al concentrations in one Itokawa particle indicates solar cosmic ray (SCR) exposure in addition to galactic cosmic ray (GCR) exposure at a near surface location for more than a few Myr [6]. Our ultimate goal is to understand the evolutionary history of asteroidal regolith and to obtain surface erosion rates, or escape rates of dust from Itokawa. The means available is the measurement of cosmogenic nuclides in surface materials taken from Itokawa. The scarcity of samples requires us to use individual samples, so a key step is understanding cosmogenic nuclide records in individual Itokawa grains.

Approach and Previous Studies: The important questions for our ultimate goals are (1) why do individual Itokawa particles collected from the same location on the surface of the asteroid display such a wide range of noble gas CRE ages and (2) what is the real surface exposure age or erosion rate of the Itokawa surface. Noble gas measurements provide integrated CRE durations but alone do not provide irradiation depth or the timing of cosmic ray irradiation. An exception is SW implanted noble gas, which does indicate exposure at the surface. The key issue is whether the CRE histories of individual Itokawa particles represent the average evolutional history of Itokawa surface or do they indicate independent histories for each particle that may be different from the average history of the surface. To answer these questions and investigate the evolutionary histories of the Itokawa asteroid surface, in relation to the lunar surface, we measured cosmogenic radionuclides in individual lunar surface grains.

Cosmogenic radionuclide depth profiles of lunar surface bulk soils show smooth profiles [e.g., 7], but each rocklet in the same soil shows a very different exposure history [e.g., 8]. All previous studies of lunar surface regolith mixing were based on measurements of ^{53}Mn and ^{26}Al in 50-100 mg of bulk soils. To study the gardening processes on a grain-by-grain basis, the ^{53}Mn activities in individual rock fragments or "rocklets" from core 60010 were measured [9]. The rocklets ranged in size from 2 to 4 mm or 8 to 26 mg. The ^{53}Mn activities in the individual rocklets show wide scatter compared to the bulk soil, suggesting that in many cases the rocklets have a different exposure history than the surrounding soil. Subsequent measurements of ^{53}Mn, ^{26}Al, and ^{10}Be in 18 individual rocklets taken from lunar core 15011 show even greater effects than those measured in the 60010 samples [8]. These results show that individual rocklets and bulk soils have different regolith histories.

Results: To further investigate movement of individual lunar surface grains in relation to Itokawa surface materials, we picked 10 lunar fine grains (18-157 μg) from the same depth (0-5 mm) of surface soil 15008,207 and 10 grains (126-566 μg) from the same depth (0-5 mm) of surface soil 76001,385. The individual masses of these grains are nearly 3 orders of magnitude smaller than those of previous radionuclide measurements in rocklets of core 15011 and 60010 but 10-100 times larger than individual large Itokawa grains. In both cores, the measured ^{10}Be activities in 20-30 % of the individual lunar grains differ dramatically from those of the bulk soils, from which the individual grains were extracted. The deviations of ^{10}Be concentrations in individual grains from the bulk value are not correlated to the size of the grains and much larger than expected for both cores. The measured ^{26}Al activities of nearly half of individual grains were far differed from that of bulk soil for both cores. Those lunar grains were moved much deeper depth interval than collected sample interval of 0-5 mm within much shorter (<1 Myr) interval. We don't know yet why so many individual grains show such wide scatter in exposure history compared to that of individual rocklets. We must next extend these measurements to individual lunar grains that are similar in size to the Itokawa particles to understand the history of Itokawa surface materials. It would be beneficial to measure cosmogenic nuclides in combined grains of Itokawa samples as a complement to our measurements of individual grains.

Acknowledgements*:* This work was supported by NASA Cosmochemistry and LARS programs.

References: [1] Nagao K. et al. (2011) Science, 333, 1128-1131. [2] Nagao K. et al. (2013) LPSC, XLIV, #1976. [3] Busemann H. et al. (2014) Meteorit. Planet. Sci., 49, S1, #5362. [4] Busemann H. et al. (2015) LPSC XLVI, #2113. [5] Meier M. M. M. et al. (2014) LPSC, XLV, #1247. [6] Nishiizumi K. et al. (2015) LPSC,. XLVI, #2499. [7] Langevin Y. et al. (1982) JGR, 87, 6681-6691. [8] Nishiizumi K. et al. (1985) LPS, XVI, 620-621. [9] Nishiizumi K. et al. (1980) LPS, XI, 818-820.