Itokawa's Orbital Transition from Main Belt to Near-Earth Orbit as Derived from Spectral Ages of Quasi-Circular Depressions on Itokawa. E. Tatsumi[1] (eri@eps.s.u-tokyo.ac.jp), S. Sugita[1], [1]Dept. Earth Planet. Sci., Univ. of Tokyo.

Introduction: Space weathering on S-type asteroids is known to alter the surface spectra, making them redder and darker with continued exposure to space. Microscopic observations of Hayabusa's returned samples from the asteroid Itokawa revealed that they possess an amorphous rim containing npFe, which has been shown to be formed by space weathering [e.g., 1]. Principal component analyses of Itokawa's multi-band spectra obtained by Hayabusa's Asteroid Multi-band Imaging Camera (AMICA) also revealed that space weathering is the dominant process affecting Itokawa's spectral properties [2]. More specifically, the first principal component (PC1) from analysis of Itokawa spectra is consistent with spectral reddening. Using PC1 values we can estimate relative surface exposure age on different regions over Itokawa's surface based on its correlation with space-weathering induced reddening. In this study, we dated quasi-circular depressions [3] on Itokawa based on PC1 values and examined their age distribution. We then discuss Itokawa's orbital evolution based on these crater age distributions.

Spectral dating method: Image data acquired by AMICA with multiple filters (ul, b, v, w, x, p) were used to produce visible spectra across Itokawa's surface. We used images obtained at the Gate Position for global mapping (~2 m/pix resolution), and images obtained at the Home Position (~0.7 m/pix resolution) for regional high-resolution maps. After calibrations [4,5] and conversion to reflectance (I/F), the images were co-registered, especially across filters. Principal component analysis of co-registered Itokawa images display a correlation between the PC1 and spectral reddening [2], which can be explained by the space weathering of silicate-rich materials (Fig. 1). We used the PC1 score as a space-weathering index across Itokawa's surface. Figures 2 and 3 show the global and regional PC1 score maps. These maps indicate large variations in exposure time to the weathering environment over Itokawa's surface. Note that even though the high-resolution datasets were taken only in the b-, v-, w-, p-filters, the reddening trend was still preserved.

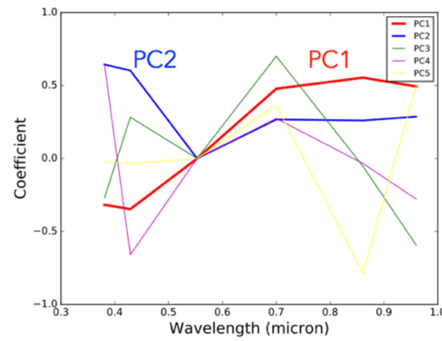

Figure 1 Principal components of visible spectra on the Itokawa surface.

We calculated the PC1 score for a set of ordinary chondrites that were irradiated by laser and ions to simulate space weathering [6,7]. Note that we applied an empirical space weathering variation function [7] derived from ion irradiation experiments on silicate-rich minerals based on the Apply Bridge ion irradiation results. A spectral change along the PC1 axis was observed. Empirically, the shift distances along the PC1 axis is proportional to the logarithm of irradiation energy. Because the irradiation energy is proportional to the surface exposure time, relative exposure time can be estimated from the PC1 score.

Spectral Characteristics of Depressions: Quasi-circular depressions were identified on Itokawa by [3]. Small depressions with more circular shapes are found to produce fresh surfaces due to substrate excavation

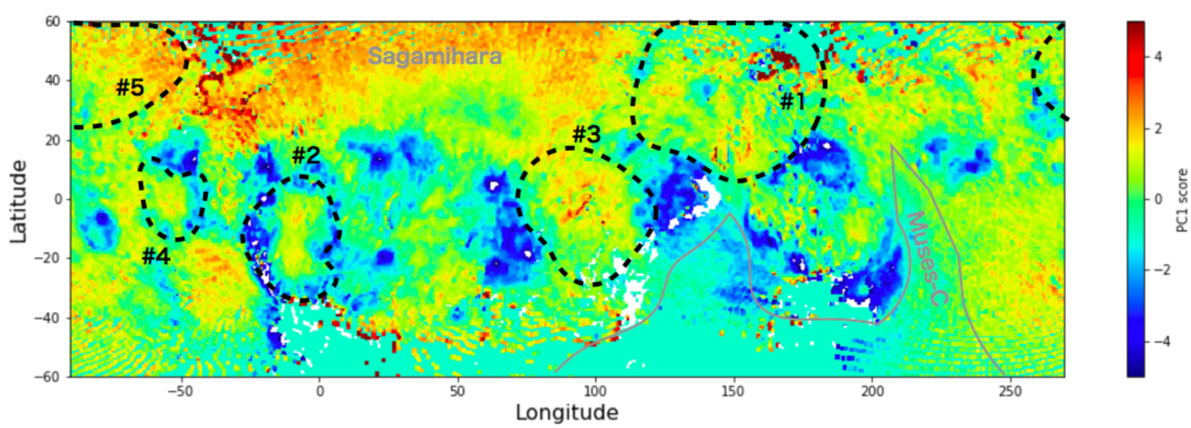

Figure 2 Global PC1 score map of Itokawa. Larger PC1 score indicates longer exposure time. The rims of large quasi-circular depressions are suggested to be relatively fresh. Numbers of depressions were identified by [3].

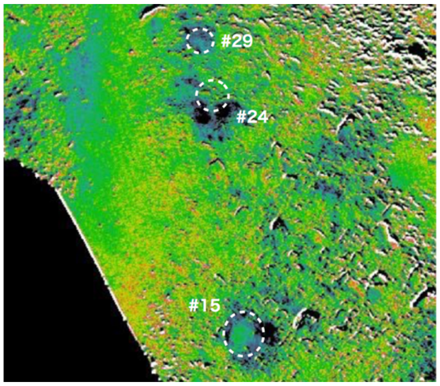

Figure 3 Regional high-resolution (~0.7 m/pix) PC1' map around Muses-C region(ST_2487335302_v.fits).

(Fig. 3). Large quasi-circular depressions on Itokawa display a common spectral feature: a fresher rim with an older floor (Fig. 2). These large depressions also do not correlate with the lowest gravitational potential regions, such as Muses-C or Sagamihara. Thus, the floor materials are most likely from the original production of the depression and do not contain younger materials added later; commensurate with the older spectral properties.

Production Rate of Quasi-Circular Depressions: We measured the PC1 score for each quasi-circular depression listed by [3], thereby evaluating the freshness of each depression. Figure 5 shows the size versus age distribution for these depressions. Large depressions (>100 m) are found to be relatively old. A constant crater production rate would lead to a constant distribution in every time bin. However, there is an apparent deficiency in large depressions in recent age (i.e., relative exposure age < 0.8), suggesting a significant decrease in crater production rate; an old heavy impact epoch and a recent moderate impact epoch.

Discussion: One possible explanation for this impact rate decrease in large sizes is an orbital transition from the asteroid main belt (AMB) to the current near-Earth orbit (NEO). Assuming this transition from the AMB to the NEO occurred at the relative exposure time of ~0.8, the crater accumulation times of two epochs can be calculated based on the crater scaling law for coarse grain targets by [8] and impactor size frequency of the main-belt asteroids and the near-Earth asteroids by [9]. This simple calculation suggests that the old heavy impact epoch may have occured for 3 – 33 Myr and the recent moderate impact epoch for 1 – 25 Myr. The two epochs have comparable time durations in spectral age, which is consistent with the crater chronology. Moreover, the cosmic ray exposure ages (<10 Myr) of the samples suggests similar residence time in NEO [e.g., 10]. These agreements between the space weathering age and other age estimates support the effectiveness of this approach. Furthermore, it is known that the size distribution of projectiles in the AMB is shallower (more larger objects) than that in the NEO [e.g., 11]. The projectile size distribution difference may also contribute to the depletion in large depressions in the NEO. The spectral dating methodology demonstrated in this study is a powerful analysis tool for future missions such as Hayabusa2 and OSIRIS-REx.

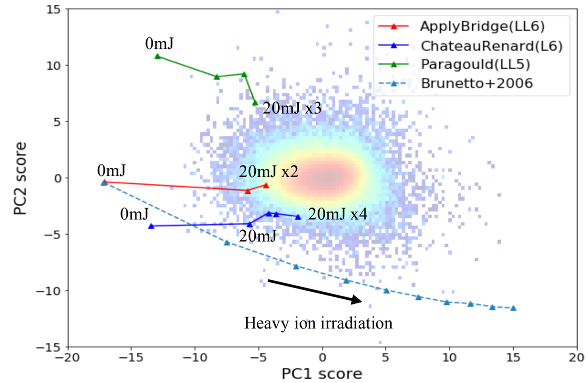

Figure 4 PC1 and PC2 score variations of ordinary chondrites in laser and ion irradiation experiments which simulate space weathering effect [6,7]. The background color shows the distribution of Itokawa surface spectra.

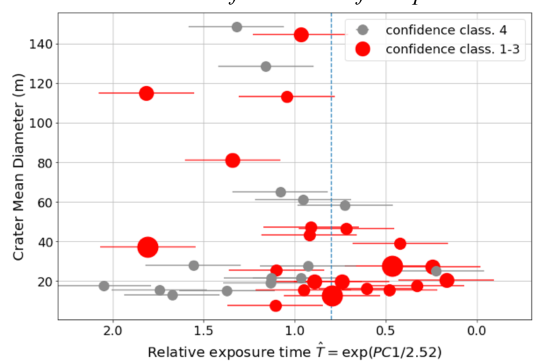

Figure 5 Age and size distribution of quasi-circular depressions listed by [3]. Smaller number confidence classes with red and larger markers indicate more likeliness of impact-induced craters. The large depressions are relatively old and any fresh and large craters cannot be found.

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