SURFACE EXPOSURE AGES OF SPACE-WEATHERED GRAINS FROM ASTEROID 25143 ITOKAWA. L. P. Keller[1], E. L. Berger[2] and R. Christoffersen[3]. [1]ARES, Code XI3, NASA/JSC, Houston, TX 77058 (Lindsay.P.Keller@nasa.gov). [2] Geocontrol Systems, Jacobs JETS contract, NASA/JSC, Houston, TX 77058.

Introduction: Space weathering processes such as solar wind ion irradiation and micrometeorite impacts are widely known to alter the properties of regolith materials exposed on airless bodies. The rates of space weathering processes however, are poorly constrained for asteroid regoliths, with recent estimates ranging over many orders of magnitude [e.g., 1, 2]. The return of surface samples by JAXA's Hayabusa mission to asteroid 25143 Itokawa, and their laboratory analysis provides "ground truth" to anchor the timescales for space weathering processes on airless bodies.

Materials and Methods: Itokawa particles RAQD02-0211 (0211) and RA-QD02-0125 (0125) were allocated by JAXA; particle RA-QD02-0192 (0192) was allocated by NASA. Multiple electron transparent thin sections of each of these samples were prepared via a hybrid ultramicrotomy-focused ion beam (FIB) technique using an ultramicrotome and a FEI Quanta 3D dual-beam FIB-SEM [3]. Transmission electron microscope (TEM) analyses were acquired with a JEOL 2500SE 200kV field emission STEM.

Results: Itokawa particles 0211, 0192, and 0125 are all olivine-rich (Fo_{70}) and contain minor Fe-sulfides. They have continuous solar wind damaged rims that are structurally disordered, nanocrystalline, and compositionally similar to the cores of the grains. All three particles have adhering mineral grains and melt particles, as well as solar flare particle tracks (tracks). Compared to lunar soil grains with a similar exposure history, the Itokawa grains are notable for a relative lack of abundant melt spherules and vapor deposits. Interestingly, the track densities and rim thicknesses vary across all three particles. Particle 0211 exhibits a track density gradient across the grain that correlates with the rim thickness. The widest solar wind damaged rim (~80 nm) is on the side of the particle with the highest track density (3.4×10^9 tracks/cm^2), while the thinnest rim (~40 nm) is on the opposite side of the particle (track density: 9.2×10^8 tracks/cm^2). Particle 0192 also shows a track density gradient (2.9×10^9 to 1.1×10^9 tracks/cm^2) and has similar rim widths to particle 0211. Particle 0125 shows a track density of 1.1×10^9 tracks/cm^2) and a solar wind damaged rim thickness of ~50 nm. Applying the track production rate calibration of [4] to the Itokawa particles gives surface exposure ages of ~80,000 years for 0211, ~70,000 years for 0192, and ~25,000 years for 0125.

Discussion: Based on the solar flare particle track production rate in olivine at 1AU, the Itokawa grains recorded solar flare tracks over timescales of $<10^5$ years. Interestingly, the preservation of well-defined solar flare track gradients in all three particles indicates that they maintained a relatively stable orientation at mm to cm depths for $\sim10^4-10^5$ years in the Itokawa regolith. Plots of track density vs. depth for the particles showing track gradients reveal no changes or breaks in slope suggesting the particles experienced little or no erosion of their surfaces.

Over timescales of a few 10^3 years, interaction with the solar wind produces ion-damaged rims on the outer ~100 nm of grains that are exposed on the uppermost surface of lunar and asteroidal regoliths. The damaged rims on Itokawa grains are predicted to become amorphous and reach a steady state thickness of 80−100 nm within a few thousand years [5]. As the rims are not amorphous and portions are thinner than 60−70 nm, this suggests their direct exposure to the sun was less than $\sim10^3$ years. Although rims are generally continuous around the grain circumference, their thickness varies in a manner suggesting different sides of the grain had different solar wind exposure times. This indicates the Itokawa regolith was sufficiently dynamic for the grains to rotate, but not so dynamic that the grains become lost to space.

Conclusions: Space weathering of regolith particles on airless bodies results in a number of morphological changes, including cosmic ray exposure tracks, solar flare particle tracks and solar wind damaged rims. Each of these space weathering effects yields information about particle histories at different depths and over multiple timescales. Together, they give us information about the regolith dynamics on asteroid Itokawa. The presence of track gradients in the particles indicates that the regolith in the Muses-C region on Itokawa was relatively stable at mm to cm-depths for the last $\sim10^5$ years, implying little overturn. We conclude that only late in their history ($<10^3$ years) were the particles directly exposed to the solar wind. The continuous nature of the damaged rims on the Itokawa particles however, requires grain movement on the uppermost surface of Itokawa in order to expose all sides of the particles to the solar wind.

References: [1] Willman, M. *et al.* (2010) *Icarus*, 208, 758. [2] Vernazza, P. *et al.* (2009) *Nature*, 458, 993. [3] Berger, E. L. & Keller, L. P. (2015) *Microscopy Today*, 23, 18. [4] Berger, E. L. & Keller, L. P. (2015) *LPS XLVI*, #1543. [5] Christoffersen, R. & Keller, L. P. (2015) *LPS XLVI*, #2084.