MICROCHEMICAL AND STRUCTURAL EVIDENCE FOR SPACE WEATHERING IN SOILS FROM ASTEROID ITOKAWA.

M. S. Thompson,[1] R. Christoffersen[2,3], and T. J. Zega[1]. [1]Lunar and Planetary Laboratory, Department of Planetary Sciences, University of Arizona, 1629 E. University Blvd, Tucson, AZ 85721, mst@lpl.arizona.edu. [2]Jacobs Technology, Houston, TX 77258-8847, [3]NASA JSC Mail Code KR, Houston, TX 77058.

Introduction: The chemistry, microstructure and optical properties of grains on the surfaces of airless bodies are continuously modified due to their interactions predominantly with solar energetic ions and micrometeorite impacts. Collectively known as space weathering, this phenomenon results in a discrepancy between remotely sensed spectra from asteroids and those acquired directly from meteorites. The return of pristine samples from the asteroid Itokawa provides insight into surface processes on airless bodies and will help in correlating remote sensing data with laboratory analysis of meteorites.

Samples and Methods: We examined Itokawa samples RA-QD02-0042-01 and RA-QD-02-0042-02, ultramicrotomed sections of a singular grain prepared by the Hayabusa sample curation team. We analyzed these slices using a 200 keV JEOL 2010F transmission electron microscope (TEM) at Arizona State University and a 200 keV JEOL 2500SE TEM at NASA JSC. Both field emission TEMs are equipped with energy-dispersive X-ray spectrometers (EDS) and scanning TEM (STEM) detectors.

Results and Discussion: TEM observations reveal that the sectioned grain predominantly consists of a single crystal of low-Ca orthopyroxene, with subsidiary smaller regions of olivine, Fe-Ni sulfide, and Fe-Ni metal. EDS-spectrum imaging and high-resolution TEM (HRTEM) show local, nanocrystalline regions of the outermost 2 to 5 nm of the pyroxene are composed of an Fe-Mg-S-rich and Si- and O-depleted layer that is underlain by a 2- to 5-nm thick amorphous zone enriched in Si. These layers occur in multiple microtome slices and have uniform thicknesses. We also observe localized 'islands' of material on the surface of the pyroxene which HRTEM imaging indicates are amorphous and EDS measurements show are compositionally heterogeneous. A 10- to 60-nm thick partially amorphous zone occurs below the compositionally distinct rim. While this this zone is associated with the compositionally heterogeneous outer layer, it also occurs as a local stand-alone feature on the exterior rim of the grain. Areas of the pyroxene grain rim also exhibit a vesicular texture.

The TEM data indicate a complex history of space weathering for samples RA-QD02-0042-01 and -02. The outermost layer of nanocrystalline material with varied composition is consistent with previously suggested [3-4] chemical and structural processing by solar wind ions, with a possible additional role for impact vapor deposition [3-4]. The amorphous and compositionally distinct islands on the surface of this grain, similar to lunar glasses, suggest formation through vapor deposition via micrometeorite impact events. In comparison, the amorphization and vesiculation textures are likely a product of radiation damage from the solar wind. The depth and degree of amorphization, in conjunction with model calculations, will help provide an upper limit on exposure time for these particles.

References: [1] Hapke B. 2001. *Journal of Geophysical Research- Planets* 106:10039-10073. [2] Pieters C. M. et al. 2000. *Meteoritics and Planetary Science* 35:1101-1107. [3] Noguchi T. et al. 2011. *Science* 333:1121-1125. [4] Noguchi T. et al. 2013. *Meteoritics and Planetary Science.*