SPACE WEATHERING RATES IN LUNAR SOILS. L. P. Keller[1] and S. Zhang[2]. [1]ARES, Code XI3, NASA/JSC, Houston, TX 77058 (Lindsay.P.Keller@nasa.gov). [2]Texas Materials Instit., U. Texas, Austin, TX 78712.

Introduction: Lunar soil grains record the combined effects of several regolith processes related to their impact and irradiation history. In fine size fractions of mature soils, pristine (unaltered) surfaces are rare, most silicate surfaces are amorphous (except for olivine) and contain variable amounts of nanophase Fe metal inclusions. It is these fine size fractions of lunar soils that dominate the bulk optical properties of a soil. The silicate surfaces are not all the same, and include high-T melts, solar wind amorphized/damaged crystals and impact-generated vapor deposits. A major unanswered question is the rate at which space weathering effects are acquired in lunar regolith materials. Here we use the accumulation of solar flare particle tracks in individual lunar grains to estimate their exposure age – we then use transmission electron microscope techniques to measure the space weathered rim thickness and composition to determine its formation process.

Materials and Methods: We analyzed <20µm anorthite grains in microtome thin sections from several different soils showing a range of maturity: 67701, 10084, 71501 and 62231. The microtome thin sections were analyzed using a JEOL 2500SE scanning and transmission electron microscope (STEM) equipped with a Thermo-Noran thin window energy-dispersive X-ray (EDX) spectrometer. We used the recent calibration of the solar flare track production rate in lunar anorthite and olivine to estimate exposure ages [1].

Results and Discussion: We focus here on anorthite which displays two physically and chemically distinct grain rim types. *Solar wind damaged rims* are amorphous, lack inclusions, and are compositionally similar to the host grain. The *vapor-deposited rims* on anorthite are also amorphous, but are compositionally different from the host, and have inclusions of nanophase Fe metal throughout their width. Previous work has shown that the two rim types are equi-abundant in mature soils [2], but it is also common to observe vapor-deposited material on top of a solar wind damaged layer. Over 90% of the grains we measured have solar flare track exposure ages <10 My.

The width of *vapor-deposited rims* on anorthite shows no correlation with exposure age suggesting that the deposition occurred in a single or only a few events during the grain's lifetime (Fig. 1). The width of *solar wind amorphized rims* on anorthite increases as a smooth function of exposure age until it reaches a steady-state at ~180 nm after ~20 My (Fig. 1). Solar wind damage can only accumulate if the grain has a direct line of sight to the Sun, whereas solar flare particles can penetrate mm of regolith. Thus, tracks can accumulate while the particle is not directly exposed at the lunar surface. To assess whether the track density accurately predicts surface exposure, we measured the amorphized rim width and track density in anorthite from the surface of rock 64455 [1] that was never buried, and has a well constrained surface exposure age of 2 My based on isotopic measurements [3]. The 60-70 nm rim width from 64455 plots within error of the well-defined trend for solar wind amorphized rims in Fig. 1, indicating that the measured solar flare track densities are accurately reflecting the surface exposure of the grains.

Conclusions: Space weathering effects (both vapor-deposited rims and solar wind amorphized rims) accumulate in 10^6-10^7 y in mature lunar soils based on observed solar flare track densities in individual space-weathered grains. This result however, is 2-3 orders of magnitude longer than the rapid (~10^3-10^4 y) development of amorphized layers predicted by numerical models [4, 5]. The source of this discrepancy is not known.

References: [1] Berger, E. L. and Keller, L. P. (2015) *LPS XLVI*, #1543. [2] Keller, L. P. and McKay, D.S. (1997) *GCA* 61, 2331. [3] Blanford, G. E. *et al*. (1975) *PLPSC 6th*, 3557. [4] Loeffler, M. J. *et al*. (2009) *JGR-Planets* 144, 3003. [5] Christoffersen, R. & Keller, L. P. (2015) *LPS XLVI*, #2084.

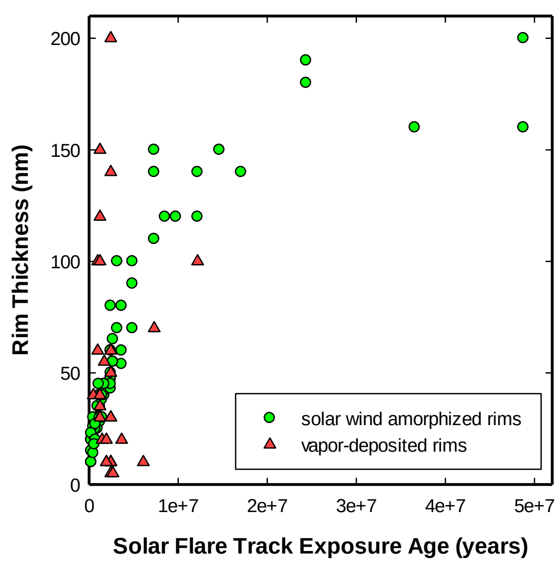

Figure 1. A plot of rim thickness versus solar flare track exposure age for solar wind amorphized and vapor-deposited rims on lunar anorthite.