SPACE WEATHERING OF UREILITES, A MAJOR GROUP OF CARBON-RICH DIFFERENTIATED METEORITES: IMPLICATIONS FOR COMPOSITIONS OF DARK ASTEROIDS. C. A. Goodrich[1], J. Gillis-Davis[2], E. Cloutis[3], D. Applin[3], D. Takir[4], C. Hibbitts[5], R. Christoffersen[6], M. Fries[7], R. Klima[5] and S. Decker[8]. [1]LPI, USRA, Houston, TX 77058 USA (goodrich@lpi.usra.edu); [2]HIGP, U. HI, Honolulu HI USA; [3]Dept. Geogr., U. Winnipeg, Winnipeg, MB Canada; [4]SETI, Mountain View CA USA. [5]JHU/APL, Laurel, MD USA; [6]Jacobs, NASA JSC, Houston TX USA; [7]ARES, NASA JSC, Houston TX USA; [8]Oberwesel Germany.

Dark asteroids (e.g., C-complex, T, and D types) are generally thought to be primitive, volatile-rich bodies, based on their spectral resemblence to carbonaceous chondrite (CC) meteorites [1,2], and as such are the targets of several ongoing or planned missions (OSIRIS-REx, Dawn at Ceres, Hayabusa 2, Lucy). However, not all dark asteroids can be primitive. Ureilites are differentiated meteorites (ultramafic mantle residues) that contain as much carbon as the most carbon-rich carbonaceous chondrites (CCs) [3,4]. Reflectance spectra of ureilites have similarities to those of some CCs [5,6]. Hence, ureilitic asteroids may accidentally be categorized as primitive. In fact, asteroid 2008 TC_3, which fell as the polymict ureilite Almahata Sitta (AhS), had an F-type spectrum (a subtype of the C-complex in Tholen taxonomy) [7]. If AhS had not been recovered, it is likely that 2008 TC_3 would have been assumed to be a primitive, CC-like asteroid.

We have begun simulated space weathering experiments on ureilites, with the goals of predicting UV-VIS-IR spectra of ureilitic asteroids, and identifying features that could distinguish differentiated from primitive dark asteroids. Based on studies of CCs and other C-rich materials [8-12], space weathering could significantly alter ureilite reflectance spectra.

Samples and Methods: We used 3 ureilitic samples (MS-MU-038, -022, -025) from the AhS polymict ureilite 4, 7,13]. The samples were clasts in the breccia, and represent a range of types from #038 (coarse grained, low-shock, olivine-rich, with large graphite crystals) to #025 (highly-shocked, fine-grained with dispersed metal, sulfide and graphite). Space weathering of powdered samples (<75 micron grain size) was simulated by pulsed laser irradiation [8-10,14,15].

Results: Pre-irradiation reflectance spectra of all samples show low albedo (0.08-0.11 % at 0.7 µm) and a steep UVVIS (~0.3-0.6 µm) continuum. MS-MU-038 shows olivine (1.05–1.10 µm) and -022 shows pyroxene (near 1 µm and 2 µm) absorption. MS-MU-025 shows the lowest overall reflectance, with very shallow slope and absorptions, probably due to high shock level and high abundance of dispersed opaques. Raman spectra of #38 show D and G bands indicative of highly crystalline graphite. In response to laser irradiation, VNIR spectra of -038 and -022 became increasingly redder and darker, and lost spectral contrast. The spectrum of -025 became darker, slightly redder, and lost what little spectral contrast it had. Raman graphite peaks in #38 showed disordering of carbon. FE-SEM of irradiated powders (all samples) showed melting/volatilization of grain surfaces and production of micro- and nano-phase Fe metal and sulfide.

Discussion: AhS has a large proportion of highly shocked, fine-grained porous ureilites [13,16], supporting the interpretation that asteroid 2008 TC_3 represents ureilitic regolith [4,16]. Some of those samples have very flat dark spectra similar to C and B asteroids [6] but lacking a 2.7 µm band of hydrated phases. However, one AhS sample is a breccia of C1, ureilitic, and OC materials, and shows a flat, dark spectrum with a strong 2.7 band [16,17]. None of the samples we studied here are of these types, though -025 is the closest Sample -038 is probably an interior mantle sample.

Our results indicate that space weathering causes significant changes in reflectance spectra of ureilites. Comparing VNIR spectra of the irradiated samples with spectral parameters and albedos for SMASS asteroid classes [18,19] shows that with increased laser weathering all 3 samples moved away from C-complex asteroids and toward D, T and some X asteroids. These results suggest that asteroid 2008 TC_3, which had a spectrum resembling C-complex asteroids, was not significantly space-weathered, consistent with [20-22].

From these first results, we infer that non-space weathered ureilitic regolith may resemble C-complex asteroids in VNIR reflectance spectra, but space weathered ureilitic material is more likely to resemble D, T or some X class asteroids. These results could have significant implications for asteroid missions.

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