VISIBLE TO NEAR-INFRARED SPECTROSCOPY AND PHOTOMETRY OF SYNTHETIC COATINGS ON ULTRAMAFIC ROCKS WITH APPLICATIONS FOR MARS.

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Introduction: Jezero crater, Mars, the landing site of NASA's Mars 2020 rover Perseverance, contains the remnants of an ancient river delta, and has experienced a long history of aqueous alteration. The interactions of the crater floor rocks with past water, along with the aeolian processes that dominate the landscape today, give rise to weathering surfaces that obscure the underlying geochemistry of rocks exposed. Perseverance's Mastcam-Z instrument [1] collects visible to near-infrared (VNIR) spectra to investigate the rocks it passes by along its traverse. Among the rocks found in the floor of Jezero crater, the Séítah formation contains ultramafic, olivine-rich rocks with varying degrees of alteration [2]. Weathered Twin Sisters dunites from the Cascade Range in Western WA are good spectral analogs to the Séítah formation [3].

We hypothesize that the VNIR spectra of ultramafic rocks is affected by fine-scale surface roughness as well as coatings of differing compositions. In this study, we will examine the effects of synthetic coatings, specifically silica and ferric coatings, on the VNIR spectra of terrestrial dunites with variable surface textures. We also constrain photometric effects by collecting spectra at multiple viewing geometries. Quantifying spectral changes to ultramafic rocks due to well-characterized coatings will assist in interpreting the complicating effects of coating composition, texture and thickness on VNIR spectra of natural rock coatings and weathering rinds on Earth and Mars.

Methods: We selected a single large clast of Twin Sisters dunite and used a rock saw to cut six sample slabs of equal size, roughly 1.5" x 2". The size was selected to ensure that the spot-size of WWU's TANAGER goniometer [4] would remain entirely on the surface at a range of viewing geometries. We used a lapidary wheel and silicon carbide grit to polish three slabs to 240-grit ("coarse)" and three slabs to 400-grit ("fine"). Of each of these groups of three slabs, one slab will be coated with a silica coating, one slab will be coated with a nanohematite coating, and the third slab will remain uncoated. The result will be six distinct samples, with a range of polish and surface coatings.

Using TANAGER with a Malvern Panalytical ASD FieldSpec 4 Hi-Res Spectrometer, we collected two sets of initial spectra from eight different viewing geometries that include forward-scattering, back-scattering, and specular geometries. To quantify the roughness values of the polished slabs, we used WWU's Tescan Vega-3 scanning electron microscope (SEM) to collect offset images at two resolutions (view fields of 2.00mm and 200µm) and at multiple spots on each sample. We used the Digital Surf MountainsSEM-9 Expert software to create 3-D maps and numerically quantify surface parameters such as roughness and waviness [5]. Here, roughness is derived from a baseline waviness fit over fixed distances of 0.08mm for the 2.00mm view field and 0.008mm for the 200µm view field.

To create the synthetic coatings, we followed the methodology established by [6]. A silica solution was created by diluting a 40% colloidal SiO_2 solution to a concentration of 2.5% to be used for the silica coating. A second batch of 2.5% solution was prepared, and 2% by weight of 30-50µm Fe_2O_3 added to create a nanohematite solution for a ferric coating.

Our first coatings are optically thick. Using an atomizing spray bottle, the coatings were applied while the sample is heated to 200°C until a layer had accumulated on the surface. The next steps are to create the thinnest possible uniform coating on the surfaces of our slabs, with the thicknesses of the coatings checked by looking at a cross-section under SEM.

Results: Preliminary results, prior to application of coatings, consist of primary reconnaissance spectra (Fig. 1) and SEM analyses, including profiles generated from 3-D reconstruction analysis (Fig. 2), magnified imagery, and numerical values for surface parameters (Table 1). These data will be used for comparison to the optically thick coated samples (Fig. 3). Preliminary spectra are mostly consistent across the six slabs. Slight deviations between grit sizes appear, notably that the finer grit samples are slightly more specular than rougher grits. Finer grit samples show a difference in reflectance between similar viewing geometries (e.g., only adjusting azimuth), whereas the rougher grits show more consistent reflectance values for the similar viewing geometries.

SEM analyses allow us visualize the differences in roughness and create profile plots, which deconstruct the topographic surfaces' waveforms into component "roughness" (variation below a scale of 0.08mm) and "waviness" (above a scale of 0.08mm). Numerical analyses show that the finer grit sample is 42% smoother than the coarse grit and has a waviness that is 39% less rough.

Discussion: The rougher grit sample is more backscattering than the finer grit due to more complex surface geometry, whereas the finer grit sample is more specular. In previous studies of synthetic coatings [7], the spectra of coated igneous materials show similar band depths and positions, and a lower overall reflectance, with an increase in overall specularity for silica-coated samples, and a more visible iron absorption feature around 500nm.

Future Work: Ongoing work includes conducting a second series of spectroscopy and SEM data collection to quantify the changes resulting from the synthetic coating application. We will also include a third grit size to have rough, fine, and intermediate data sets. In addition, we will be using dunite sands to conduct the similar analyses for sediments coated in silica and ferric coatings, complementing the work of [6], which is investigating two-phase particulate mixtures of dunites and Fe-oxides.

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References: [1] Bell J. F. et al. (2021) *SSR, 217.* [2] Farley K. A. et al. (2022) *Science, 377.* [3] Curtis S. A. et al. (2022) *WWU Graduate School Collection, 1118.* [4] Rice M. S et al. (2022) *LPSC, 2750.* [5] Duflot L. E. et al. (2022) *LPSC, 2368.* [6] Hoza K. et al. (2019) *WWU Graduate School Collection, 921.* [7] Lapo K. E. et al. (2023) *LPSC, this issue.*

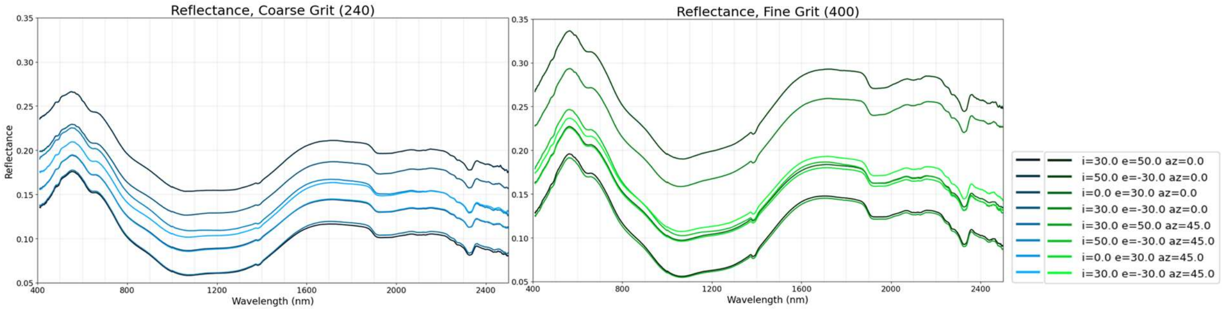

Figure 1: VNIR reflectance spectra of samples at varying viewing geometries prior to application of synthetic coatings: 240-grit ("coarse)" in the left plot, 400-grit ("fine") in the right plot.

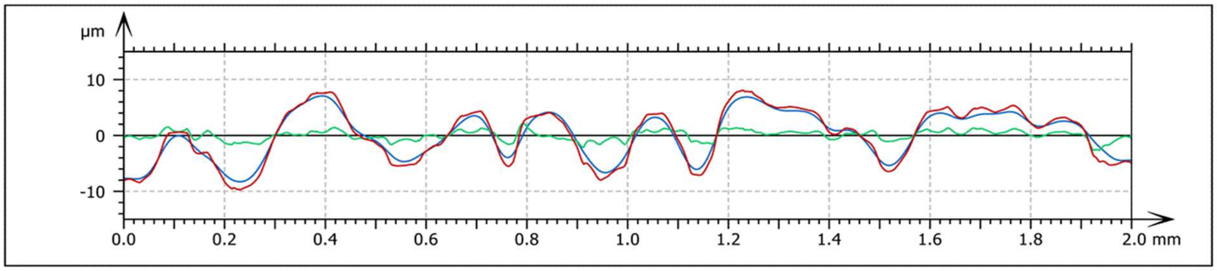

Figure 2: Surface texture plot of a coarse sample, with profile (red); roughness (green), measuring relative smoothness below a scale of 0.08mm; and waviness (blue), measuring relative smoothness above a scale of 0.08mm.

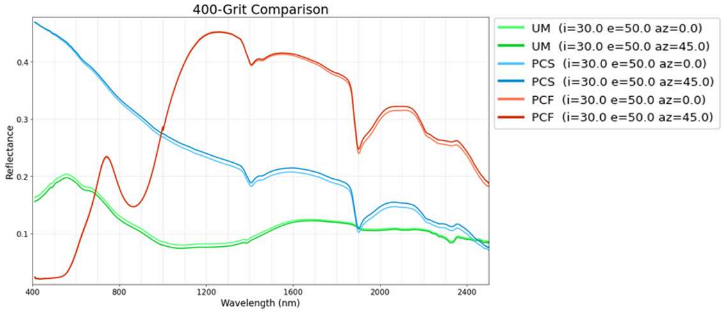

Figure 3 (left): A comparison of coated optically-thick coated samples at 400-grit: unaltered dunite in green, silica coated dunite in blue, and nanohematite coated dunite in red. For each coating, a standard viewing geometry of i=30 and e=50 was chosen, with two azimuth values at az=0 and az-45.

Table 1 (right): Numerical values for surface parameters from SEM analysis, prior to application of synthetic coatings.

	Coarse Grit (240)	Fine Frit (400)
Maximum Height	5.070µm	2.059µm
Mean Roughness	2.558µm	1.481µm
Mean Waviness	4.974µm	1.988µm