SPECTRAL REFLECTANCE PROPERTIES OF <5 µm POWDER ON CARBONECEOUS CHONDRITES.

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Introduction: The surfaces of extraterrestrial bodies have shown particle size distributions dominated by fine grained particles (<50 µm) [1]. Understanding the compositional and physical properties associated with the lithosphere of planetary surfaces is a fundamental requirement for interpreting the petrogenesis of these bodies [2]. Asteroids are also remnants of the earliest building blocks of the terrestrial planets and hence can provide insights into early solar system processes. This study focuses on improving our ability to spectroscopically characterize carbonaceous chondrite-like asteroids, which are an important source of volatiles and organic matter found on Earth [3]. In this study, we examined the spectral characteristics of <5 µm powder coatings on bare meteorite slabs, in order to better understand how we can recognize surfaces with a fine-grained regolith overlying more intact bedrock. This research is relevant to interpreting spectroscopic data from the OSIRIS-REx and Hayabusa-2 sample return mission to presumed carbonaceous asteroids Bennu and Ryugu, respectively.

Methodlogy: Reflectance spectra of three different carbonaceous meteorites were acquired for this study (Table 1.). Reflectance spectra were measured at HOSERLAB (psf.uwinnipeg.ca) using an Analytical Spectral Devices (ASD) Labspec 4 reflectance spectrometer. It obtains data from 350 nm to 2500 nm with ~3-6 nm spectral resolution. Reflectance spectra were measured at i=30° and e=0° relative to a near perfect reflector (Spectralon®), and a total of 500 spectra were collected and averaged to improve the signal to noise ratio.

The sample saw cut powders (<5 µm) utilized in this study were obtained from the Royal Ontario Museum, and were produced during the initial dry cutting of the samples using a diamond wire saw. The dust coating on the slabs was prepared by sieving <5 µm powder samples through an air fall chamber to uniformly distribute the powder onto the meteorite slab. Quantification of the <5 µm powder coating was measured with a Bruker A 670 HYPERION infrared microscope with a 15X magnification objective.

Table 1. Samples utilized in this study.

Meteorite	Sample size
Moss (CO3.6)	Slab, <5 µm
NWA 801 (CR2)	Slab, <5 µm
SaU 290 (CH3)	Slab, <5 µm

Results: Figure 1 shows the spectral variability of the type CO3 meteorite Moss as a result of applying low density <5 µm Moss powder onto the Moss slab using an air fall chamber. All the spectra obtained are relatively dark (<17%). The absolute reflectance of each sample at 560 nm wavelength was 0.134 for the pure <5 µm saw cut Moss powder, 0.138 for the Moss slab, 0.126 for the 71.82 µm thick powder coating, 0.122 for the 114.59 µm thick powder coating and 0.117 for the 162.45 µm thick powder coating, indicating a decrease in absolute reflectivity as a result of the accumulation of <5 µm powder on the slab. The slab showed the highest reflectance and may be attributed to surface scattering or bright mineral inclusions located at the analyzed spot on the slab. The spectral slope as indicated by the 700/2500 nm reflectance ratio shows a blue slope for the Moss slab, and a reddening of slopes as a result of <5 µm powder accumulation. The reflectance spectra show weak absorption bands near 1050 nm and 2000 nm, which are associated with olivine and calcium-aluminum rich inclusions, respectively.

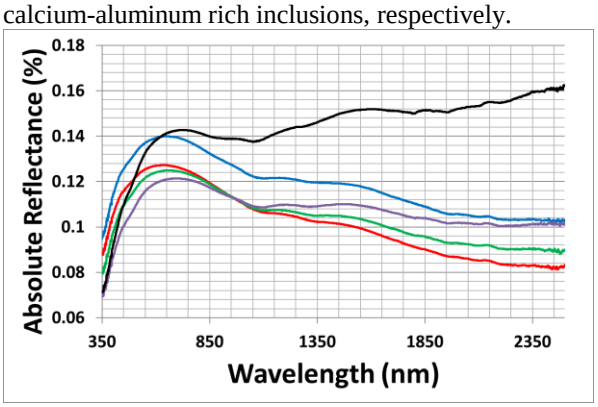

Fig 1. Reflectance spectra of Moss slab (blue), Moss slab with 71.82 µm thick >5 µm powder coating (red), Moss slab with 114.59 µm thick >5 µm powder coating (green), Moss slab with 162.45 µm thick >5 µm powder coating (purple) and the pure <5 µm saw cut powder (black).

Figure 2 shows the spectral variability of type CR2 meteorite NWA 801 as a function of <5 µm saw cut powder. The absolute reflectance for all the spectra was between 2 - 22%. The reflectance of each spectra at the 560 nm wavelength was 0.089 for the slab, 0.084 for 107.73 µm thick <5 µm powder coating, 0.091 for 147.06 µm thick <5 µm powder coating, 0.091 for 174.42 µm thick <5 µm powder coating, 0.086 for

242.8 µm thick <5 µm powder coating and 0.104 for the pure <5 µm powder. The absolute reflectance at 560 nm shows non-linear variability. The reflectance ratio (700/2500 nm) shows increasing red slope attributable to the presence of fine grained powder. The bare slab exhibits the bluest sloped spectrum while the pure powder sample displays the reddest sloped spectra. Absorption bands are present in all spectra at 1000 nm and 1900 nm.

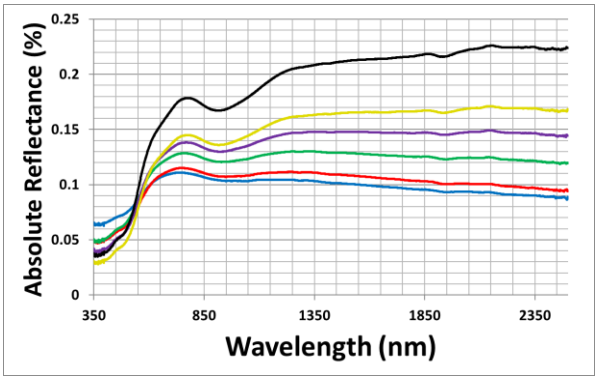

Fig 2. Reflectance spectra of NWA 801 slab (blue), NWA 801 slab with 107.73 µm thick <5 µm powder coating (red), NWA 801 slab with 147.06 µm thick <5 µm powder coating (green), NWA 801 slab with 174.42 µm thick <5 µm powder coating (purple), NWA 801 slab with 242.82 µm thick <5 µm powder coating (yellow) and the pure <5 µm NWA 801 saw cut powder (black).

Figure 3 shows variations in the reflectance spectra of type CH3 meteorite SaU 290 attributed to the presence of <5 µm fine grained powder. In all cases, the spectra are relatively dark (<18%). The absolute reflectance of each spectrum at 560 nm shows a linear increase in reflectivity attributed to an increase in the amount of powder on the slab surface. The reflectance ratio (700/2500 nm) indicates a reddening of spectral slope as a function of accumulated <5 µm powder. Weak absorption bands are present in all spectra near 900 that are likely attributable to pyroxene.

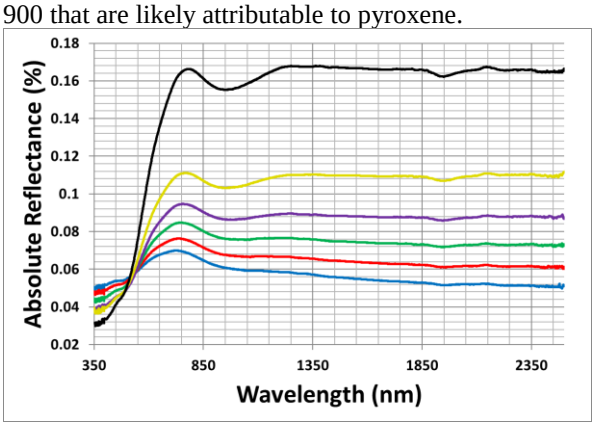

Fig 3. Reflectance spectra of SaU 290 slab (blue), SaU 290 slab with 56.43 µm thick <5 µm powder coating (red), SaU 290 slab with 95.76 µm thick <5 µm powder coating (green), SaU 290 slab with 162.45 µm thick <5 µm powder coating (purple), SaU 290 slab with 196.65 µm thick <5 µm powder coating (yellow) and the pure <5 µm SaU 290 saw cut powder (black).

Disscussion: The reflectance spectra of the three carbonaceous chondrites show variations due to the presence of <5 µm powder. The Moss samples absolute reflectance at 560 nm shows an inverse relationship to NWA 801 and SaU 290, with the accumulation of powder resulting in a decrease in absolute reflectance. This may be due to differences in metal:silicate ratios between the slab and powder or surface texture effects on the slab. The NWA 801 samples absolute reflectance at 560 nm shows a non-linear relationship with dust coating thickness. The cause of non-linearity in 560 nm reflectance is not yet determined. The SaU 290 samples' absolute reflectance at 560 nm shows increases with an increasing amount of powder. The absolute reflectance for NWA 801 and SaU 290 shows that the powder coating was more akin to the pure <5 µm powder than to the slab [4], with the degree of similarity increasing as powder thickness increases, as expected. At ~200 µm powder coating thickness, the differences between the coated slab and pure powder are minor. In all three samples, the spectra show increasing absolute reflectance at the longer wavelengths with increasing powder coating thickness.

Previous experiments have looked at the variations of spectral slopes of carbonaceous chondrites attributed to space weathering, and have shown both reddening and bluing of spectra [5]. Increasing blue slopes are commonly associated with increasing particle size with removal of the smallest grains [6]. Therefore, the smallest grains are necessary to produce a red slope. The samples used in this study show an apparent reddening of spectral slope relative to the bare slab, which can be attributed to the accumulation of the <5 µm powder.

Conclusion: This study demonstrates how fine-grained dust can affect the spectral reflectance properties of carbonaceous chondrites. Further work will determine how variations in other physical properties of a dark asteroidal surface can be uniquely recognized

References: [1] Mustard J.F. and Hays J.E. (1997), *Icarus*, 125, 145-163. [2] Pompilio et al. (2007), *Journal of Geophysical Research*, 112. [3] Clark et al. (2011), *Icarus*, 216, 462-475. [4] Morris et al. (2001), *LPS XXXII*. [5] Binzel et al. (2015), *Icarus*, 256, 22-29. [6] Cloutis et al. (2013), *LPS*, 44.