HiRISE BAND RATIOS AND CRISM SPECTRAL RESULTS AT HARGRAVES CRATER.
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Introduction: Impact craters, found on all planetary surfaces, offer a wealth of knowledge about the interiors of planetary bodies. The excavation of material via cratering processes provides access to subsurface materials. Impact ejecta deposits, consisting of material excavated and displaced beyond the rim of the transient crater, inform on the original stratigraphy below the surface. The understanding of the subsurface layers gained from studying the organization of materials in ejecta blankets can be tied to the regional stratigraphy and help elucidate the relative timing of nearby events.

Using the Mars Reconnaissance Orbiter (MRO) spacecraft, there have been major advances in the study of impact craters on Mars. The CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) and HiRISE (High Resolution Imaging Science Experiment) instruments allow scientists to tie spectral signatures to small-scale (meter-scale) features. These abilities enable high-resolution study of the composition of ejecta blankets, and thus deeper understanding of the impact cratering processes and crustal interior of Mars.

To fully utilize the capabilities of CRISM and HiRISE, study sites on Mars exhibiting exposed bedrock and dust-free surfaces are preferable, providing the most accurate spectral information. For this reason, Hargraves Crater is an ideal study location for the connections between ejecta blanket materials and target stratigraphy. Hargraves Crater is uniquely well preserved, but well exposed, with little net deposition [1, 2]. This study presents cursory results tying ejecta materials to spectral signatures.

Geologic Setting: Hargraves Crater is located in the Sorties Major region of Mars, near Nili Fossae. It has a diameter of ~68 km and the surrounding terrain is Noachian in age. The crater is well preserved, but exposes the ejecta deposits from the crater, unlike many other well-preserved Martian craters. At Hargraves Crater, previous studies have indicated the presence of at least two exposed layers of ejecta [2]. However, the exposure of the clast rich ejecta at Hargraves, similar to the Bunte Breccia at the Ries [2, 3], is unique and correspondingly, the focus of this study.

Two areas around Hargraves crater have adequate CRISM coverage for the analysis done in this study. One area is distally northwest of the crater, while the second area is west of the crater near the Nili Fossae landform known as the “trough.” The second location is less distal to the crater. This abstract presents cursory results from the distal northwest location.

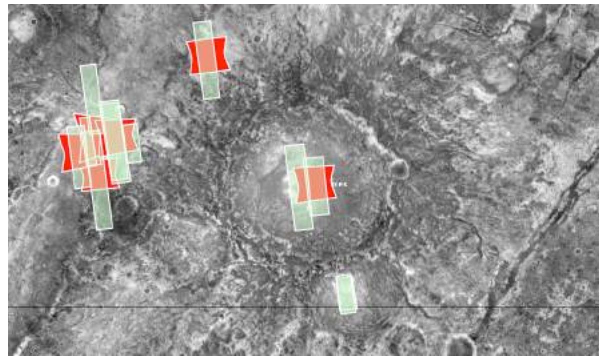

Figure 1. Red shapes indicate locations of relevant CRSIM coverage, while green stamps indicate relevant HiRISE coverage. Hargraves crater is located in the center of the image.

Methods: The HiRISE instrument aboard MRO provides the high resolution (~25-50 cm/pixel) images used in this study. By viewing a composite image of three band ratios of the color-strip data from HiRISE images, we can highlight particular features, including the exposed clast-rich ejecta. The exposed ejecta provide good targets for spectral investigation. Though lower resolution (~18 m/pixel), targeted observations from the CRISM instrument, also aboard MRO, allow for spectra to be extracted from each of these spots by overlaying the HiRISE band ratios and correlating them with CRISM-defined spectral units. The spectra from these units can then be analyzed to draw conclusions about the compositions of different parts of the ejecta blanket, relationships with regional stratigraphy, as well as the relationship between different HiRISE band ratios and different compositions.

Results: The HiRISE band ratios used for this analysis (NIR/BGR, RED/BGR and RED/NIR in RGB) highlight ferric versus ferrous differences in the spectral signatures of the ejecta blanket and were devised after [4, 5]. The colors present in the Hargraves ratio images are generally a bright yellow, a more muted orange, a bright blue, a muted darker purple tone, and speckled purple orange overlap (Fig. 2 middle).

Figure 2 shows a composite spectral parameter image composed of (BD2290, OLINDEX3, LCPINDEX2) [see 6]. The composite is intended to highlight the main spectral contributions to the study

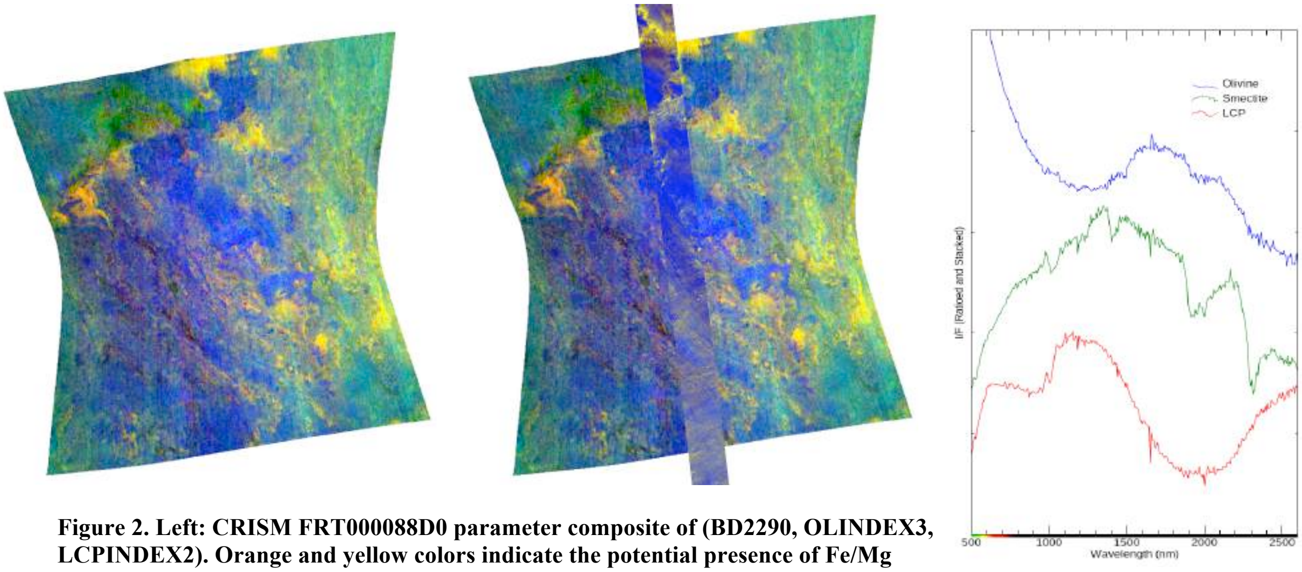

Figure 2. Left: CRISM FRT000088D0 parameter composite of (BD2290, OLINDEX3, LCPINDEX2). Orange and yellow colors indicate the potential presence of Fe/Mg smectite. Blues indicate potential low calcium pyroxene, and greens indicate potential olivine. Middle: The ratioed HiRISE image PSP_005921_2020 is overlain to show correlation between ratios and spectral parameter colors. Right: Preliminary ratioed spectra from left most figure image.

site, showing Fe/Mg smectite, olivine, and low calcium pyroxene as red, green, and blue respectively.

In the analysis completed of the northwest Hargraves Crater ejecta deposit, bright yellow HiRISE ratio signatures have corresponded with some low-calcium pyroxene signatures as well as some iron oxides. This conclusion corroborates the ferric iron signature suggested by the yellow color of the HiRISE band ratio.

The bright blue areas of the HiRISE image correlate most strongly with more ferrous signatures such as those for olivine and pyroxene and correlate with blue and green areas of the CRISM parameter composite. Preliminary spectra from the image support the presence of olivine and low calcium pyroxene (Fig. 2).

The orange areas and the speckled orange and purple areas of the HiRISE ratio image correlate more strongly with signatures suggesting Fe/Mg smectites (Fig. 2). Spectral absorptions at 1900 nm and 2300 nm in preliminary spectra support this observation. 1900 and 2300 nm absorptions in the olivine spectra and a 1000 nm absorption in unratioed Fe/Mg smectite spectra suggest low calcium pyroxene or olivine may be potential protoliths for the smectite phyllosilicates. The composite spectral image shows yellow and orange colors at these areas, which suggests a combination of red and green, or smectite and olivine, again suggesting a potential olivine or pyroxene contribution, or at least a 1000 nm absorption.

Discussion: The results shown here corroborate current understanding of the stratigraphy in the Nili Fossae area. A local olivine rich unit appears to overlay low calcium pyroxene in proximity to Fe/Mg smectites and is exposed at the surface [7]. Much of this exposure is likely related to numerous impact ejecta events within the area, likely including the Isidis basin. The presence of Fe/Mg smectite and iron oxide confirms suggestions of alteration on a large scale, which includes the target materials sampled by Hargraves Crater. These results also confirm the belief that the more yellow band ratio coloring (i.e. ferric dominance in the VNIR) can be tied primarily to altered units with the darker blue colors correlating more closely with unaltered material and with impact melt deposits.

Conclusions: At this preliminary stage, the results of linking the HiRISE band-ratio images with CRISM data suggest good correlation between the two and supports that HiRISE band-ratios support the extension of CRISM compositional mapping at the scale of HiRISE. The presence of Fe/Mg smectites and other alteration products align closely with proposed stratigraphic relationships for the Nili Fossae region. Forthcoming efforts to examine other outcrops of Hargraves Crater ejecta will continue to place sections of the ejecta within known stratigraphic relationships.

References: [1] McEwen AS et al. (2010) *Icarus, 205(1), 2-37*. [2] Sacks LE et al. (2019) *LPSC L, 2904.* [3] Hörz F (1983) *Reviews of Geophysics, 21(8), 1667-1725.* [4] Delamere WA et al. (2010) *Icarus, 205(1), 38-52.* [5] Tornabene LL et al. (2018) *SSR, 214(1), 18*. [6] Viviano-Beck CE et al. (2014) *JGR: Planets, 119, 1403-1431*. [7] Ehlmann BL and Mustard JF (2012) *Geophys. Res. Lett., 39, L11202.*