NOACHIAN INTERCRATER PLAINS BEDROCK UNITS SHOW VARIABLE OLIVINE ENRICHMENT.

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Introduction: Intercrater plains located within Martian Noachian cratered highlands terrain likely represent ancient resurfaced impact basins [1]. Intercrater plains commonly host high thermal inertia units, indicating lithified or partially-lithified surface materials ('bedrock') [2]. Visible/near-infrared olivine parameter images and false color THEMIS thermal infrared images suggest many intercrater plains host olivine-enriched bedrock relative to their surroundings [3,4].

However, quantitative spectral analysis has only been performed on a few bedrock units. These units have ~10-15% olivine enrichments over the surrounding materials [eg. 5, 6]. It is unknown whether all bedrock units show this same level of olivine enrichment, as spectral parameter values and false color images do not provide quantitative olivine abundance estimates.

Olivine-enriched source regions for bedrock material have not been detected, leading intercrater basin bedrock units to be interpreted as volcanic in origin. However, most intercrater plains bedrock units lack quantitative olivine data, meaning units with lower levels of olivine enrichment may also be present. This data is necessary to interpret petrogenic origin(s) and assess means of preferential olivine enrichment.

This work quantified the spectral differences between bedrock and basin fill sources ('surroundings', typically gently sloped, non-bedrock surfaces surrounding massifs) for most intercrater plains regions. We determined whether these differences could be modeled as simple mixtures of surrounding materials and olivine. These spectral models were then used to interpret the general mineralogic variability among bedrock units. Finally, we discuss non-igneous processes that could produce the observed olivine enrichments.

Methodology: Intercrater plains bedrock units > 15 km in the longest diameter were previously delineated by [7]; those units were the focus of this work.

We used THEMIS multispectral images for spectral characterization. THEMIS false color composites were used to define regions of interest (ROIs) for bedrock and surrounding units. Single THEMIS image scenes were used to retrieve atmospherically-corrected surface emissivity spectra [8] of each bedrock-surroundings pair. In some cases, bedrock units contained two false color surface units. Both units were compared to the non-bedrock surroundings in these situations.

We developed a 'spectral distinctness' parameter to quantify the spectral differences between bedrock and its surroundings. First, we determine whether the ROIs are statistically distinct in each THEMIS band between bands 4-9. This was done by adjusting the emissivity spectra of each unit pair to a constant depth before comparing the set of emissivity values in each THEMIS band with Welch's T-test [9] set at a confidence level of 99.5%. Then, the absolute difference of means from statistically distinct bands were summed to provide a spectral distinction score.

We also determined whether the bedrock spectra could be modeled as simple mixtures of the surrounding surface materials and olivine (Fo_{68} [10]) at THEMIS spectral resolution. Least squares minimization over the 7.93 µm – 12.57 µm spectral range (corresponding to THEMIS bands 3-9) determined the olivine addition needed to fit the observed spectrum. Model fit was assessed visually and by RMS error [11].

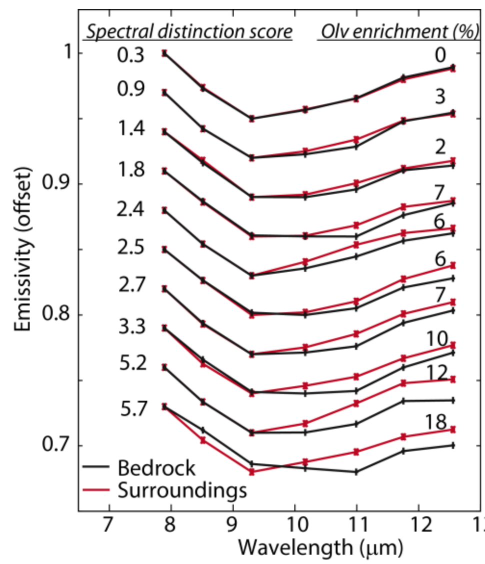

Figure 1 Bedrock and surrounding spectral pairs with their corresponding spectral distinction scores. The olivine enrichment relative to surrounding materials is shown on the right.

We selected 10 bedrock spectra that were well-modeled by olivine addition to understand how spectral distinction scores correspond to relative differences in mineralogy. These spectra and the corresponding modeled olivine enrichments are displayed in **Fig. 1**. Higher scores generally correspond to greater olivine enrichment, but there is not a 1:1 correlation as olivine is likely not the sole contributor to spectral differences.

Results: Intercrater plains commonly host more than one bedrock unit. Spectral analysis was performed on 76 bedrock regions (containing 111 bedrock units) in Noachis, Tyrrhena, and Cimmeria Terra, as well as the NW Hellas Basin rim. We found that all bedrock units are statistically distinct from their surroundings, but spectral distinction varies greatly. Our results are shown in **Fig. 2**.

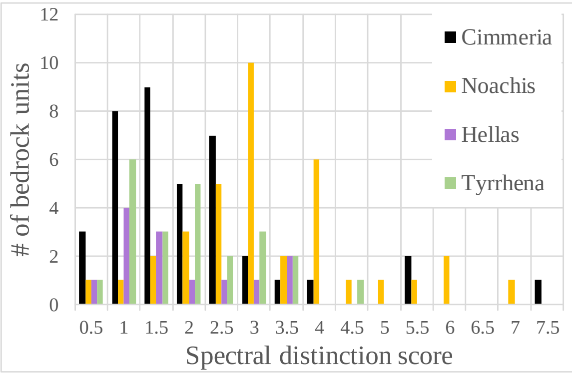

Figure 2 Graph of spectral distinction scores grouped by score and region. Units in Cimmeria Terra (black) generally show lower scores than those in Noachis Terra (yellow).

Most bedrock units (68%) are well-modeled by the addition of olivine to the surrounding materials. The majority score < 3.5, corresponding to olivine enrichments < 10%. The highest score (5.7) corresponds to ~18% olivine enrichment. Some bedrock units cannot be modeled by olivine addition. The highest distinction score (7.5) is a putative chloride unit described by [12]. Others units have spectral characteristics associated with high silica, olivine-depleted surfaces.

There appear to be regional trends in olivine enrichment (**Fig. 2**). Most bedrock units in Noachis Terra show 6-10% model enrichments. Units in Cimmeria Terra generally show < 6% model enrichments. The Tyrrhena Terra and NW Hellas Basin regions had too few measured units for meaningful comparison.

Discussion: Previous studies invoked igneous processes to explain high (10-15%) olivine enrichment compared to apparently olivine-poor surroundings. However, we find most bedrock units show < 10% enrichments, increasing the plausibility that sedimentary surface processes could also produce the real or apparent olivine enrichments. We review a few such processes in the geologic context of intercrater plains.

Preferential accumulation of dust in the highlands may obscure olivine-enriched sediment sources. Martian global dust is spectrally bland [e.g. 13,14], and dust cover may alter the spectral signal of the underlying surface. Local differences in regolith properties may be one mechanism for this preferential dust accumulation. If the highlands consist of mechanically competent basement rock, blocky regolith developed from that rock might efficiently trap dust [15]. In contrast, basin bedrock may consist of friable sedimentary material that is less likely to produce blocky ejecta and more easily cleared of comminution products. Counterintuitively, the spectral character of the highlands may be better expressed within intercrater basins.

Fractionation may occur during sediment delivery into basins. Olivine is among the most resistant basaltic minerals to mechanical breakdown during fluvial transport [16]. Lithic comminution also increases free crystal abundance downstream. Thus, olivine crystals could accumulate in fluvial sands and sandstones.

Aeolian processes may also sort sediments already present within intercrater basins. Observations of the Bagnold Dunes in Gale Crater by MSL Curiosity show that the coarse fraction of dune sands are olivine-enriched relative to inactive ripple sheets observed along the traverse [17]. Density sorting, grinding and subsequent removal of mechanically weaker minerals, and destruction of olivine alteration rims may cause this enrichment. Large round grains (apparently olivine) also form armored dune surfaces, which may superficially enrich the surface composition.

Multiple non-igneous processes could create the observed (generally < 10%) olivine-enriched surfaces. Multiple units within individual intercrater plains display variable olivine enrichments, which may reflect changes in the intensity or effectiveness of these processes over time. Thus, using bedrock units to reconstruct regional histories may necessitate basin-by-basin analyses of surface processes, such as dust mantling, depositional context, and erosion rate.

References: [1] Irwin R.P. and Howard A.D. (2002) *JGR*, *107*, 10-1-10-23 [2] Edwards C.S. et al. (2009) *JGR*, *114*, E11001[3] Ody A. et al. (2013) *JGR: Planets*, *118*, 234-262 [4] Loizeau D. et al. (2012) *Icarus*, *219*, 476-497 [5] Rogers A. D. et al. (2009) *Icarus*, *200*, 446-462 [6] Rogers A. D. and Fergason R. L. (2011), *JGR: Planets*, *116*, E08005 [7] Cowart J.C. and Rogers A.D. (2017) *LPS XLVIII*, Abstract #1547 [8] Bandfield J.L. et al. (2004) *JGR: Planets*, *109*, E10008 [9] Welch B.L. (1947) *Biometrika*, *34*, 28-35 [10] Koeppen W.C. and Hamilton V.E. (2008) *JGR: Planets*, *113*, E05001 [11] Ramsey M.S. and Christensen P.R. (1998) *JGR: Solid Earth*, *103*, 577-596 [12] Osterloo M.M. et al. (2008) *Science*, 319, 1651-1654 [13] Bandfield J.L. and Smith M.D. (2003) *Icarus*, *161*, 47-65 [14] Hamilton V.E. et al. (2005) *JGR*, *110*, E12006 [15] Golombek M.P. et al. (2006), *JGR*, *111*, E02S07 [16] Davies D.K. et al. (1974) *Fluvial Sedimentology*, 61-84 [17] Cousin et al. (2017), *JGR: Planets*, *122*, 2144-2162