DECORRELATION STRETCHES (DCS) OF VISIBLE IMAGES AS A TOOL FOR SEDIMENTARY PROVENANCE INVESTIGATIONS ON EARTH AND MARS. P. Sinha[1], B. Horgan[1], R. Ewing[2], E. Rampe[3], M. Lapotre[4], M. Nachon[2], M. Thorpe[3], A. Rudolph[1], C. Bedford[5], K. Mason[2], E. Champion[2], P. Gray[6], E. Reid[7], M. Faragalli[7], [1]Purdue Univ. (sinha37@purdue.edu), [2]Texas A&M Univ., [3]NASA Johnson Space Center, [4]Stanford Univ., [5]Lunar and Planetary Institute, [6]Duke Univ., [7]Mission Control Space Services.

Introduction: The surface of Mars exhibits vast expanses of mafic sediments and ancient sedimentary rocks [1,2] that record signals of climate and environment [3]. To decipher the paleoenvironments, the sediment sources and transport histories must be constrained, but it is not well known how physical fractionation and aqueous alteration affect mafic sediments during glacial, eolian, and fluvial processes [4-5]. Semi-Autonomous Navigation for Detrital Environments (SAND-E), a NASA Planetary Science and Technology through Analog Research (PSTAR) project, bridges this gap through studies of sediment-grain properties and mineralogy in the glacio-fluvial-eolian landscapes of Iceland. This project also tests the utility of integrating rover-based semi-autonomous terrain analysis and an unmanned aerial system (UAS) simulating NASA's Mars 2020 Helicopter Scout within science workflows.

As part of the SAND-E project, our study aims to evaluate the effectiveness of color analysis applied to visible images to constrain sediment sources and transport pathways in a Mars-analog environment. We test the predictive capabilities of color analysis for characterizing the reflectance properties and mineralogic variability of mafic sediments by correlating color in aerial and rover-based visible imagery with field-based visible/near-infrared (VNIR) spectra and lab-based X-ray diffraction (XRD)-derived mineralogies.

Background: Visible imagery is a common data product in the exploration of planetary surfaces. However, mafic sediments mostly appear homogeneous in true color images at the bedform or larger scales, making the identification of compositional differences with visible images alone difficult. One way to enhance subtle color differences is through decorrelation stretches (DCS) applied to visible bands (red, green, and blue channels) of true color images. During a DCS transformation, the RGB values of pixels are stretched along their principal components and then rotated back into RGB color space to maximize compositional information in the scene and minimize correlations related to surface albedo [6]. Color analysis using DCS has been frequently used on martian visible and thermal images captured from orbit or on the ground by rovers [7-9].

Methods: Field work was conducted in July of 2019 at Skjaldbreidauhraun, a glacio-fluvial-eolian sand plain that is dominated by basaltic minerals and glasses. This region is characterized by eolian and fluvial ripples and dunes, wind-sculpted bedrock, wind-deflated rocky plains, and sand drifts similar to martian landscapes. The fluvial system flows across a glacial outwash plain from a known basaltic source, and was divided into three zones for field work - proximal, medial, and distal.

The scope of our discussion here is restricted to the study at the proximal site which is closest to the Þórisjökull Glacier (Fig. 1). The rover, Argo J-5 developed by Mission Control Space Services, Inc., is equipped with a mast-mounted stereo camera, which acted as rover's vision during the operation, and was supplemented by higher resolution color imaging by commercial handheld cameras [10]. DCS analysis was implemented on in situ images from the rover and handheld cameras, as well as aerial imagery acquired by the UAS and down-sampled to HiRISE resolution (25 cm/pixel), and context images (41 cm/pixel) from a web-based color map provider in Iceland (Loftmynda ehf.) [11]. The DCS was generated in ENVI. During rover operations, color variations in DCS images were used to identify targets whose VNIR reflectance spectra were collected using an ASD QualitySpec Trek handheld spectrometer by field scientists simulating the rover payload.

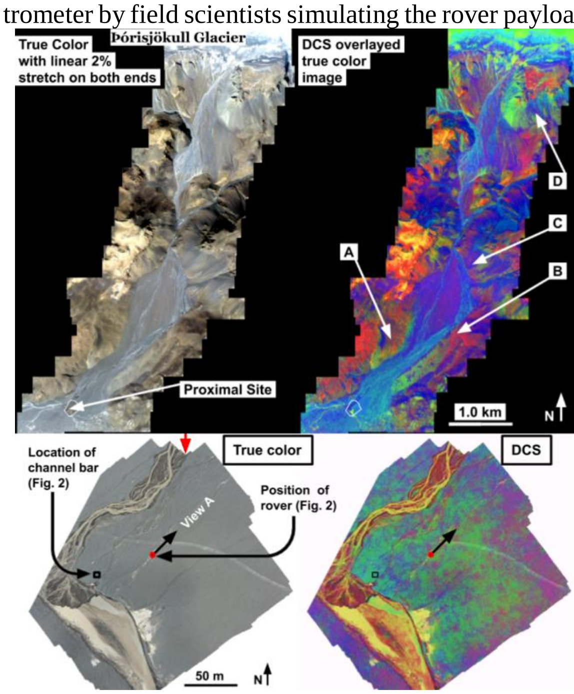

Figure 1: *(Top) True color and DCS of catchment-scale mosaic, showing a river from the glacier running through a series of alluvial fans. A-D label outcrops in Fig. 2. (Bottom) Simulated HiRISE of field site, located where the river intersects a second river, becomes unconfined, and debouches into a broad alluvial plain, creating a small delta at this junction.*

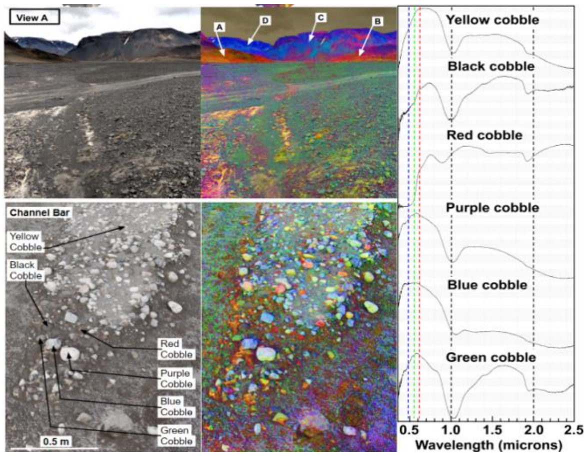

Figure 2: *(Top) True color and DCS of rover's view A, (bottom) cobbles within rover's workspace, (right) VNIR spectra.*

DCS Images: DCS images are shown in Figs. 1-2. Variations in intensity of the same color in the DCS images may result from grain-size and textural effects. A caveat of the technique is that the intensity of colors within shadowed areas is sharply reduced. Furthermore, non-lithic materials such as ice tended to appear bright green. Vegetation/moss also appear green (likely olivine-rich) clasts, leading to potential confusion when seen through the rover's eyes. However, some variations in color intensities at visible wavelengths are clearly related to compositional differences, as these wavelengths are highly sensitive to iron redox states, iron-bearing minerals, and their crystallinity [12-15].

DCS of aerial images also show color differences associated with different source units. At the catchment-scale in Fig. 1 (top), the valley appears more purple/blue than the adjacent red/orange/yellow capping units. More local variability is evident within the valley in the DCS of the UAS image of the field site shown in Fig. 1 (bottom). The dark sediments within the braided channel and delta system appear red, and light-toned sediments appear yellow, suggesting a correlation with composition, grain size, and/or water content. The rest of the area is a patchwork of green, blue, and purple. Fig. 2 (top) is a perspective view from the rover looking upstream in the valley, and the colors of the lithic units correlate with the colors of regions A, B, C, and D in the aerial image shown in Fig. 1. Finally, Fig. 2 (bottom) shows an example rover workspace atop a river bar. DCS over the bar reveals significant color variation in the cobbles, some of which appear to directly correlate with colors observed in regional and local DCS images.

Comparison to VNIR spectra: VNIR spectra of streambed cobbles are shown in Fig. 2. The dotted RGB reference lines show the visible wavelengths which determine the color variability in the DCS. Clear differences are observed in the position of the peak between 0.5-0.7 µm with yellow, black, and red cobbles peaking at higher wavelengths. Red cobbles show a hematite absorption at 0.86 µm. These wavelength variations are likely due to differences in Fe/Ti oxide mineralogy, Fe redox state, and elemental substitutions in Fe-bearing minerals [12-15]. However, they are correlated with spectral variations at longer wavelengths. Absorption bands around 1 and 2 µm are due to mafic minerals (mostly pyroxenes and some olivine). The band center at 1 µm in particular varies between 1.00-1.05 µm, consistent with olivine and pyroxene, and blue cobbles exhibit a shoulder at 1.3 µm likely due to olivine or glass. Comparison of these spectral properties to source rock spectra and sediment spectra as well as bulk mineralogy and chemistry of both rocks and sediments from XRD and X-ray fluorescence (XRF) will allow us to better interpret the relationship between DCS colors of sediments and source rock units.

Discussion: The ridges around the valley in Fig. 1 (top) are more red due to hematite as in the red cobbles, which suggests in situ oxidation of bedrock units of varying primary composition. Yellow in the DCS corresponds to palagonitized bedrock/cobbles. Blue and green dominated areas are consistent with unaltered lavas of variable mafic compositions. Sands on the valley floor are dominated by blue/green while the channels are red/yellow, perhaps suggesting that altered red/yellow material is more easily weathered to small grain sizes and transported through the braided river system compared to blue/green lava units. VNIR spectra show no signs of additional alteration in sediments under the transport conditions up to the proximal site.

Conclusions: Preliminary results demonstrate that DCS applied to visible images can help to identify compositional endmembers based on color in rocks and sediments, and that endmember cobbles are representative of materials sourced from surrounding units. Visible wavelength orbital, aerial, and rover-based observations can be useful for detecting subtle spectral differences that are potentially indicative of significant compositional differences. Results from the study will be useful in developing a scientific framework for provenance study of a mafic detrital environment on Mars.

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