DECORRELATION STRETCHES (DCS) OF VISIBLE IMAGES AS A TOOL FOR ASSESSING SEDIMENT PROVENANCE ON EARTH AND MARS. P. Sinha[1], B. Horgan[1], A. Rudolph[1], R.C. Ewing[2], E. Rampe[3], M.G.A. Lapôtre[4], M. Nachon[2], M.T. Thorpe[3], C.C. Bedford[5,3], 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, USRA, [6]Duke Univ., [7]Mission Control Space Services.

Introduction: Deciphering paleoenvironments and crustal diversity on Mars requires tracing the sources and transport history of sediments [1,2]. However, it is not well understood how much physical fractionation and chemical alteration may occur along different transport pathways encompassing glacial, eolian, and fluvial environments in basaltic landscapes. Semi-Autonomous Navigation for Detrital Environments (SAND-E), a NASA Planetary Science and Technology through Analog Research (PSTAR) project, aims to study glacio-fluvial-eolian landscapes of Iceland as a Mars analog to advance the science workflows during rover operations and maximize science returns. SAND-E integrates rover-based semi-autonomous terrain analysis and an unmanned aerial system (UAS), simulating NASA's Mars 2020 Perseverance rover and Ingenuity helicopter, while analyzing sediment properties and composition.

This study aims to test the predictive capability of color analysis on visible images to identify mineralogical variability within basaltic sediments along a glacio-fluvio-eolian transport pathway (Fig. 1). Correlating color characteristics of transported sediments with that of the source materials may further help constraining sediment sources as well as the sediment weathering processes. Here, we compare sediment/source rock colors with visible and near-infrared (VNIR; 0.3-2.5 μm) reflectance spectral properties (Figs. 2–3) with XRD-derived bulk mineralogy.

Methods: Field work was conducted in July of 2019 at a glacio-fluvial-eolian sand plain that borders the Skjaldbreiðauhraun postglacial shield flow. The field site contains eolian and fluvial ripples, wind-sculpted bedrock, wind-deflated rocky plains, and sand drifts similar to martian landscapes [7]. Sediment samples were taken from proximal, medial, and distal zones in the outwash plains (Fig. 1). Source rocks were collected from outcrops of exposed bedrock surrounding the valley. VNIR spectra were acquired using an ASD FieldSpec spectrometer. The sediments were sorted by grain-size (<63 μm, 63–125 μm, 125–500 μm, 500 μm–2 mm, and >2 mm). Spectra were also acquired of multiple surfaces and interior of fluvial cobbles. The grain-size segregated sediments and cobbles were imaged using a handheld cellphone camera [9]. Basaltic sediments at the catchment scale appear homogeneous in true color, hence, subtle color differences are enhanced by applying the technique of Decorrelation Stretch (DCS) on visible imagery (red, green, and blue channels).

Color analysis using DCS is extensively used in assessing variability within the images returned by martian orbital and rover assets [3-5]. DCS transforms the limited color differences to expand and utilize the entire color space, thereby, maximizing the compositional information [6]. DCS images of our samples were created using ENVI.

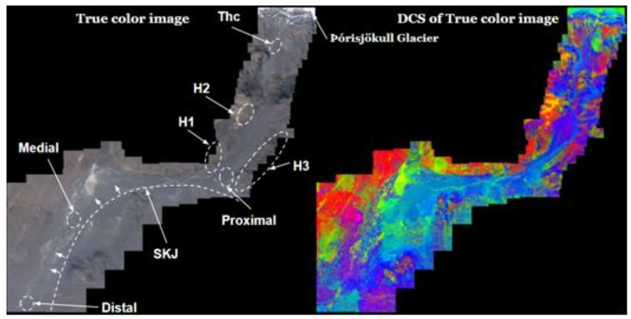

Figure 1: *(left) True color and (right) DCS mosaics showing a glacial river flowing across alluvial fans, lava, and hyaloclastites (Source: [8]).*

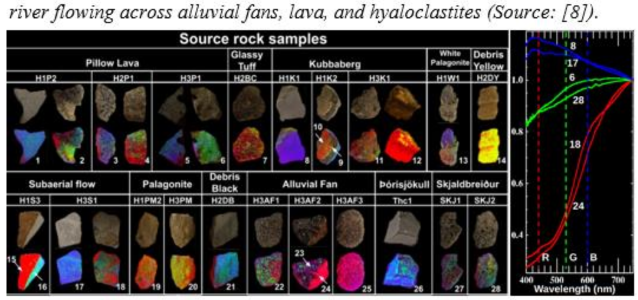

Figure 2: *(Left) True color image and DCS images of source rocks. (Right) VNIR spectra of the source rocks.(Bottom) Visible spectra for each color type normalized by reflectance at 0.75 μm.*

Comparison of DCS with VNIR spectra: Among the source rocks, purple, blue and green colors indicate rocks spectrally dominated by primary minerals (see Fig. 2 for rocks and Fig 3 for its spectra). Pyroxenes typically appear blue in the DCS and display absorption bands at ~1.02 and 2.3 μm (spectra 1, 16, 27) whereas olivine exhibits a broad absorption band beyond 1 μm and typically appears green/purple (spectra 6, 23 28) in the DCS. Yellow represents hydrothermally altered glass (palagonite) with strong hydration bands (spectrum 14). Red represents oxidized samples either with clear hematite signatures (absorption band at 0.86 μm, spectrum 25) or ferric iron associated with other alteration signatures (e.g., spectra 7, 12, 15, 19, 24). The alteration signatures include hydration bands at 1.43, 1.75 (spectrum 4), and 1.93 μm, in combination with hydroxylation (with Si, Al, Fe, Mg) absorption bands at 2.22 μm (spectra 6, 28), 2.27 μm (spectrum 15), and sometimes at 2.09 μm and 2.3 μm (smectite clays, spectra

4,10,11,18). The peak reflectance at visible wavelengths ranges from 0.42-0.84 μm, where lower peaks correspond to spectra dominated by primary minerals. The red/blue ratio (RBR) for spectra dominated by primary minerals is ~1 whereas RBR for glassy/alteration mixtures can reach over ~3 indicating Fe^{3+} phases [10].

DCS images of grain-size segregated sediment samples (Fig. 4) show that coarser grains appear green/blue in color while the finer fraction is red/yellow. Reflectance spectra of finer-grains display a correspondingly high red to blue ratio. The finer fractions still display bands due to primary minerals, and the band center at 1 μm for all grain sizes in sample D4B01 is similar; however, the finer fraction shows hydration and hydroxylation bands at 1.93 and 2.22 μm. These results suggest that altered grains are concentrated in the fine fraction.

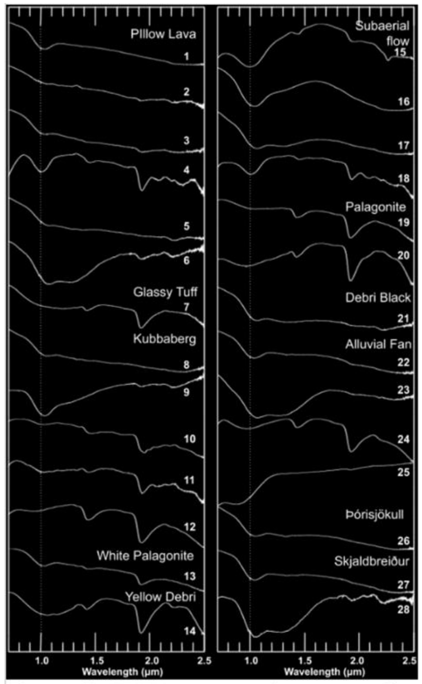

Figure 3: *VNIR spectra of source rocks.*

Origin of sediment and transport pathways: Exposed basaltic bedrock and hyaloclastite mounds around the Þórisjökull interglacial volcanic is the primary source of sediment/cobbles in the valley up to the proximal site because of river's hydraulic action. Further downstream, the river cuts through the Skjaldbreiður lava flow, which contributes additional-pebble-to-boulder-sized material to an overall sandy outwash plain. Lithic materials from Þórisjökull interglacial volcanic and Skjaldbreiður lava flow contain pyroxene and olivine as dominant primary minerals (spectra 1,6,9,27,28) which are also abundant in the distal sediment (Fig. 4). Geochemical plots comparing abundances of Zr and Sr based on XRF measurements show that medial and distal sites derive more pebbles from Skjaldbreiður lava flow [11]. XRD results measure abundances of plagioclase between 35–60% [12], which goes undetected in VNIR range due to spectral dominance by mafics. In Fig. 1, we see that the DCS of exposed bedrock surrounding the outwash plain shows all colors but the valley/outwash plain is dominated primarily by blue along with purple and green. Some of the color variability within the outwash plain is likely due to differences in the local surface density of coarser and finer particles. Based on our analysis of color variations with grain size (Fig. 3), this is because sediment color is dominated by coarser materials whose spectral properties are dominated by primary minerals (olivine and pyroxene), while red and yellow colors corresponding to altered materials (such as hyaloclastite tuff from interglacial volcanoes) are only apparent in the fine grained fraction. The coarse-grained fraction is likely dominated by relatively unaltered materials both because finer-grained, aqueously altered materials (e.g., hyaloclastite tuff) are more friable and thus break down into finer grains more quickly, and because these fine-grained materials are preferentially transported down the transport pathway by the river or winds, leaving behind coarser and more resistant mineral grains. Bulk XRD data suggests that the above transport process causes an increase in amorphous content from the proximal to the distal site [11].

Conclusions: The observed correlation between mineralogy and color has the potential to enhance mapping, analyzing, and targeting during mission tactical cycles. DCS images used in tandem with spectral and other data sets can be used to optimize rover's traverse to targets of higher scientific merit, thereby, reducing redundancy in selection of similar targets. In addition, DCS of high-resolution color data can help extend mineralogical interpretations from coarser resolution or limited sampling hyperspectral datasets.

References: [1] Siebach et al. (2017) *JGR 122* 295-328. [2] Lapotre et al. (2017) *JGR 122* 2489-2509. [3] Farrand et al. (2014) *JGR 119* 2349-2369. [4] Rogers et al. (2005) JGR *110*(E5). [5] Horgan et al. (2019) LPSC, #1424. [6] Gilespie et al. (1987) *Rem. Sen. Envi. 20* 209-235. [7] Ewing et al. (2020) LPSC, #2857. [8] Chandler M et al. (2016) *JM 12* 904-916. [9] Amiri & Fairchild (2017) *JOSAA 34* 1224-1235. [10] Morris et al. 1985. [11] Bedford et al. (2020) AGU Fall. [12] Rampe et al. (2020) LPSC, #2365.

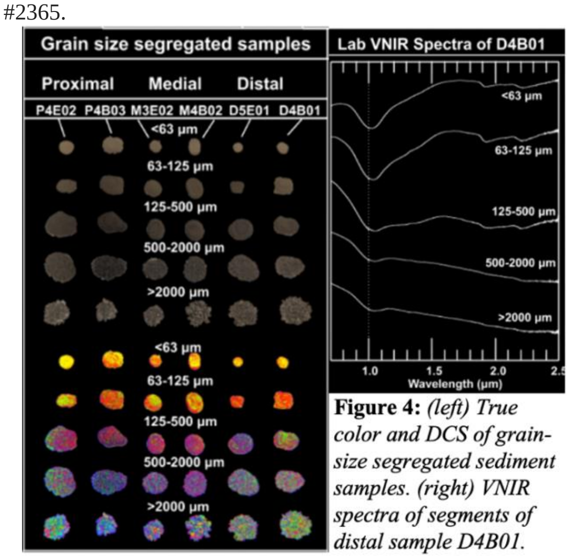

Figure 4: *(left) True color and DCS of grain-size segregated sediment samples. (right) VNIR spectra of segments of distal sample D4B01.*