COMPARING THE INFLUENCE OF TRANSPORT VS. ALTERATION ON THE COMPOSITION OF COLD CLIMATE MARS-ANALOG SEDIMENTS. A. Rudolph[1], B. Horgan[1], P. Sinha[1], R. Ewing[2], E. Rampe[3], M. Lapôtre[4], M. Thorpe[3], C. Bedford[3,5], L. Berger[2], M. Hasson[4], K. Mason[2], M. Nachon[2], E. Champion[2], P. Gray[6], E. Reid[7], M. Faragalli[7], [1]Purdue Univ. (rudolph4@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: The Mars Science Laboratory (MSL) and Mars 2020 missions aim to understand the ancient geologic environments in Gale and Jezero craters, respectively [1,2]. Observations of sedimentary deposits and their composition suggest that the two craters have been geologically dynamic regions that received sediment input from a combination of lacustrine, fluvial, aeolian, volcanic, and glacial environments [e.g., 3-6]. Do compositional variations observed in these environments reflect differences in source area or changes in sediment due to fractionation and alteration that occur along sediment transport pathways? Here we explore this broad question through studies of compositional changes in analog environments in Iceland.

During two field seasons in 2019 and 2021, the Semi-Autonomous Navigation for Detrital Environments (SAND-E) team examined how physical and geochemical sediment properties vary with distance from their source along fluvial and aeolian transport pathways in a cold climate regime [7]. Mars-like volcanic source rocks and cold-climate sedimentary environments make Iceland an ideal martian-analog site.

This study aims to constrain the dominant influence on compositional variability in cold and wet climate environments between chemical alteration and physical sediment sorting. To do so, we search for spectral trends using visible to near infrared (VNIR; 350-2500 nm) reflectance spectra along two source-to-sink transects. We hypothesize that compositional trends in fluvial and aeolian environments occur primarily due to size- and density-dependent sorting. Under our hypothesis, finer-grained sediments should contain a greater concentration of alteration materials. We also hypothesize that fluvial sediments will display a more gradual compositional trend with transport distance than aeolian.

Field Sites: Two field areas (Skjaldbreidauhraun in 2019 and Vatnajökull in 2021; Fig. 1) were studied from source-to-sink. At each field area, three sites were focused on to study spatial variability of each system, one that was near the source (proximal), one approximately mid-way in the system (medial), and one as close to the sink of the system as could be accessed (distal).

2019 Field Area. The 2019 field transect is ~10 km. The proximal site is near a glacier which sits atop glacial and intraglacial volcanic deposits and is dominated by an alluvial system extending from the glacier. The medial site is adjacent to a large shield volcano, and the medial and distal sites show fluvial and aeolian activity.

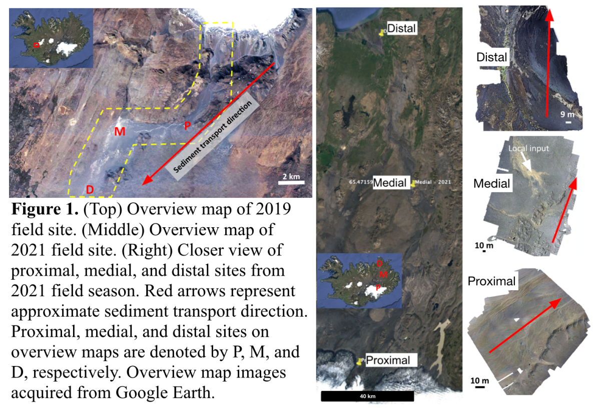

Figure 1. (Top) Overview map of 2019 field site. (Middle) Overview map of 2021 field site. (Right) Closer view of proximal, medial, and distal sites from 2021 field season. Red arrows represent approximate sediment transport direction. Proximal, medial, and distal sites on overview maps are denoted by P, M, and D, respectively. Overview map images acquired from Google Earth.

2021 Field Area. The 2021 field transect is ~155 km. The proximal site, in a dry river channel near the glaciovolcanic source, has both fluvial and aeolian activity. The medial site, slightly away from the main system for accessibility, is dominated by aeolian activity. The distal site, on the terminal delta, is fluvially dominated.

Methods: VNIR spectra from 2019 samples were analyzed using the ASD FieldSpecPro3 spectrometer. 2021 samples have not been analyzed in the lab, so field spectra collected using the ASD QualitySpec Trek spectrometer are used here to constrain spectral trends. Field spectra exhibit significant and variable hydration while lab spectra were taken on air-dried sediment samples. Example VNIR spectra of expected minerals in a mafic and altered sediment system are dominated by a few key absorptions due to Si-, Fe-, Al-, and Mg-OH bonds, Fe-bearing minerals, and hydration (Fig. 2).

2019 Spectra: Preliminary analyses for the 2019 spectra can be found in [8]. Spectra shown in Figure 3 are representative of spectral variability observed across the 2019 field sites. All five spectra have a narrow band centered at 1 µm consistent with clinopyroxene. The depth of this absorption decreases in spectra that have a broad shoulder at 1.1-1.3 µm, consistent with olivine or glass. The broad 2 µm absorption expected in pyroxene is also present in some spectra. Hydration is indicated by a shallow absorption at 1.9 µm and sometimes a weak absorption at 1.4 µm. Absorptions at 2.2 and 2.3 µm, observed in all spectra, are consistent with assemblages of Fe/Mg/Al clay minerals and/or hydrated silica/glass [9]. A blue slope >0.7 µm is consistent with weathered glass [10] or fine-grained igneous rock. The three field sites show no significant changes in the spectra, which are consistent with basaltic sediments with minor chemical alteration.

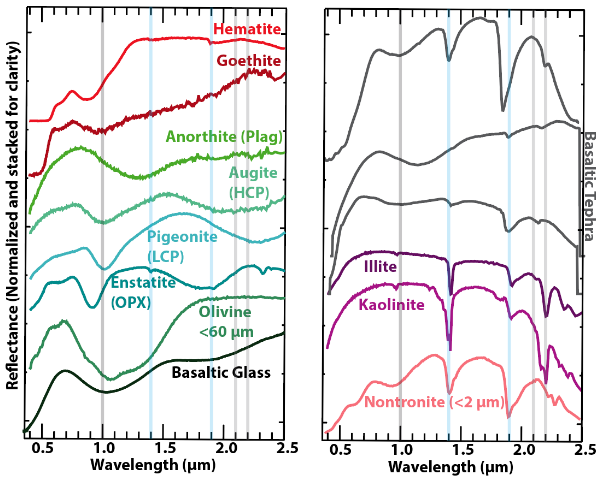

Figure 2: VNIR laboratory spectra of expected materials. Locations of prominent absorptions are denoted by gray and blue vertical lines.

2021 Spectra: Spectra shown in Figure 3 are representative of the spectral variability across the 2021 field sites. Deep and narrow hydration features, observed at 1.4 and 1.9 µm, are mostly attributed to the surface wetness. We expect these features to be less prominent in air-dried samples. Spectra with a broad and shallow ban centered 1.08-1.15 µm are consistent with glass, likely hyaloclastite from subglacial eruptions, and those with a narrower band closer to 1 µm are consistent with pyroxene, consistent with more crystalline intraglacial lavas. Spectra consistent with Fe-oxides exhibit a shallow absorption at ~0.65 µm and a narrow absorption between 0.85-0.95 µm [9], likely due to syneruptive oxidation. Additional absorptions at 2.2 and 2.3 µm are consistent with clay minerals and/or hydrated silica/glass [9], most likely indicating palagonite in subglacial volcanism. Some spectra have a shallow blue slope like the 2019 field season spectra, consistent with weathered glass or fine-grained igneous rock.

Sediments from proximal and medial have slightly different spectral properties while distal spectra appear to be a mixture of the two. Proximal fluvial and aeolian sediments are consistent with pyroxene, glass, olivine, Fe-oxides/clays, and glass-rich tephra which is consistent with glacial hyaloclastites that have experienced chemical alteration. Aeolian sediments at the medial site are more pyroxene-dominated, differing from proximal by a lack of spectra that are consistent with Fe-oxides/clays. This site is consistent with sediments derived from crystalline (intraglacial) basalt that have experienced little chemical alteration. Typical aeolian sands on the widespread jökulhlaup plains of Iceland are dominated by glassy hyaloclastites [11], so these crystalline sediments likely have a local source.

Discussion and Future Work: Initial interpretations on the driving force behind spectral variability is

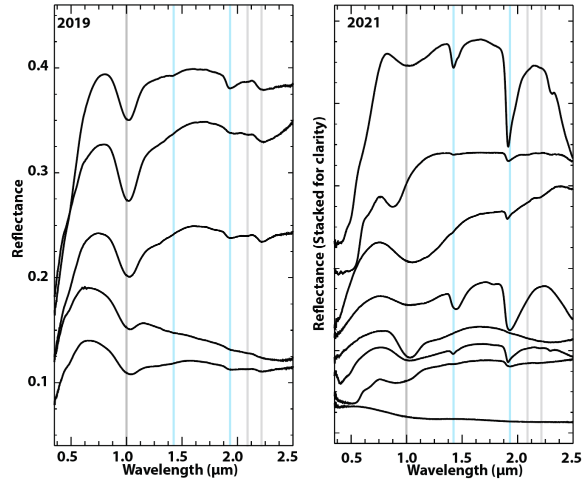

Figure 3: Representative spectra from the field seasons. Locations of prominent absorptions are denoted by gray and blue vertical lines.

that it is due to sorting more so than alteration. In both field areas, sediments with spectral properties of the distal sites, including those due to alteration, are detected in the proximal, medial, or both sites. There are no spectral signatures present that suggest additional or enhanced alteration at the distal sites. Detailed analysis of spectral properties and their frequency and comparison to quantitative mineralogy from XRD and thermal-IR spectra will help constrain if sediments of a specific composition are transported farther or not, and whether or not the composition or proportion of crystalline and amorphous alteration phases changes.

Overall, the 2021 field season is more spectrally diverse than the 2019 field season. This diversity is partially due to the larger scale of the 2021 transect that is impacted by not only the primary sediment source, but localized system inputs. If we see a similar wide range of compositions in martian systems, that system could also be representative of larger-scale systems with multiple inputs rather than a small-scale source-to-sink regime like what was observed in our 2019 field season.

Our next steps will be to analyze air-dried 2021 samples and sieve sediments to search for trends correlated with grain size. Then we will separate spectra by field site to narrow down variability with source distance.

References: [1] Grotzinger et al., (2012) *Space Sci Rev, 170.* [2] Farley et al., (2020) *Space Sci Rev, 216.* [3] Grotzinger et al., (2015) *Science, 350.* [4] Fraeman et al., (2016) *JGR: Planets*, *121*. [5] Morris et al., (2016) *Proc Nat. Acad Sci, 113.* [6] Fairen et al., (2014) *Plan and Space Sci 93-94.* [7] Ewing et al., (2017) *PSTAR*. [8] Sinha et al., (2020) *LPSC #2682.* [9] Hunt (1977) *Geophysics 42.* [10] Henderson et al., (2021) *Earth Space Sci, 8.* [11] Baratoux et al., (2011) *Earth Surf. Process. Landforms, 36.*