INVESTIGATING PHYSICAL AND CHEMICAL WEATHERING OF FLUVIAL AND AEOLIAN SEDIMENTS IN MARS-ANALOG ENVIRONMENTS USING CLOSE-UP IMAGE ANALYSIS.

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Introduction: Results from the NASA *Curiosity* rover show that the ancient (>3 Ga) sedimentary rocks in Gale crater formed by fluvial and lacustrine processes, with aeolian processes dominating the geological record after the river-lake system ended in the Hesperian [2,3]. The sedimentary system in Gale crater contains a mineralogy dominated by basaltic materials, not the quartzofeldspathic minerals that derive most sedimentary rocks on the Earth [4]. There remains a knowledge gap for understanding how basaltic materials are physically and chemically weathered in fluvial and aeolian environments. <u>This research aims to understand how the physical and chemical characteristics of basaltic sediments change as they are transported from source-to-sink in Mars-analog environments utilizing close-up images and X-Ray Diffraction (XRD) analysis.</u> These data were collected as part of the SAND-E mission.

The SAND-E Mission: The Semi-Autonomous Navigation of Detrital Environments (SAND-E) mission seeks to examine the chemical and physical alteration of sediments from source-to-sink in aeolian and fluvial sedimentary systems like those found on Mars [5]. Iceland's cold and wet climate, predominately basaltic crust, and active fluviolacustrine and aeolian sedimentary systems make it a compelling Mars-analog [6]. The Þórisjökull glacio-fluvio-aeolian sedimentary system was selected for the 2019 SAND-E mission field area to study source-to-sink processes in these environments. The field sites were located between 4 tholeiitic volcanoes and samples were gathered from the Proximal site, Medial site and Distal site (Fig. 1).

Methods: To fulfill the research aims of this project, sediment samples acquired during the 2019 SAND-E mission have been analyzed using close-up images and XRD from the Proximal, Medial, and Distal sites. These techniques have been used as they are analogous to those used on the *Curiosity* rover. The sedimentary environment (fluvial or aeolian) for each geological target was identified using the SAND-E rover's Mastcam images. Close-up images of basaltic source rocks were taken using the Olympus Tough TG-6 camera. The close-up images were taken in microscope mode at zero stand-off during the 2019 SAND-E Mission to simulate images taken with the MAHLI camera on *Curiosity*. Changes in sample mineralogy were determined qualitatively by carefully classifying grain textures.

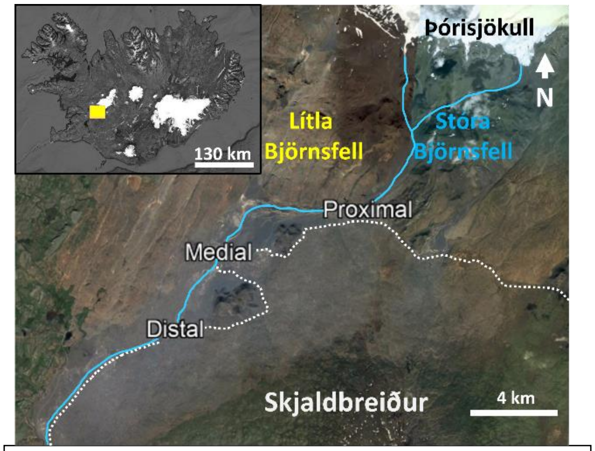

Figure 1. SAND-E 2019 Field Map: Blue line represents the Þórisjökull glacio-fluvio-Aeolian sedimentary system. Yellow square in top image demonstrates the SAND-E 2019 Field Site.
Proximal site = 6.3 km from glacier, Medial site = 11.3 km from glacier, Distal site = 14.4 km from glacier.

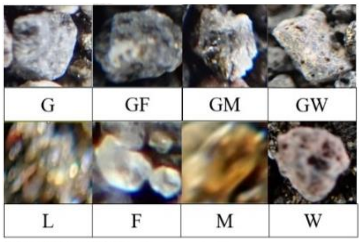

Figure 2: Legend of Mineral Estimate:
G – Glassy (black)
GF - Glassy + Feldspar
GM - Glassy + Mafic
GW - Glassy + Weathered
L - Unknown sediments
F - Feldspar (white)
M - Mafic (green)
W - Weathered (yellow/red)

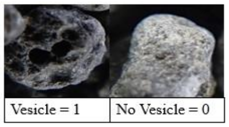

Figure 2.1: Legend on Vesicle classification. #1 means a vesicle was present, #0 means that there was no vesicle.

To quantify mineralogical and physical changes across the close-up images taken at the Proximal, Medial, and Distal field sites, the Gazzi Dickinson method was performed using ImageJ. The Gazzi Dickinson method involves generating a grid of 300 points for each close-up image and classifying the color and texture of each grain located at each grid point. Classifications seen in Fig. 2 were used to characterize the grains. The ImageJ software was also used to measure the intermediate and long axis of the grains and note when a grain contained vesicles (Fig. 2.1).

Results and Discussion: Fluvial sediments followed the expected patterns in size decrease from Proximal (0.11 cm) to Distal (0.08 cm). Small sphericity changes can be attributed to the short transportation distance from which the sediments were sampled, as well

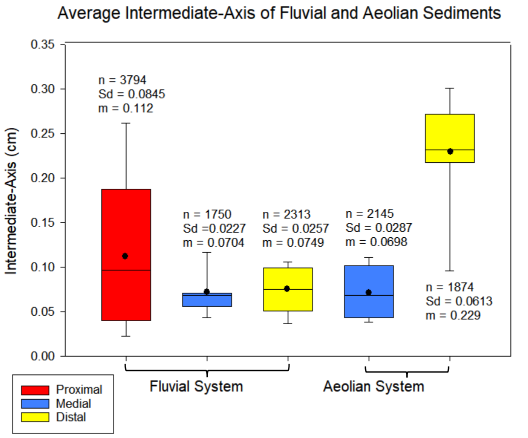

Figure 3: Box plots demonstrating change in intermediate axis size from Proximal to Distal in both systems.

as smaller grain-sized sediments being more resistant to physical weathering [7].

Aeolian sediment seen on the right columns, increased in size from Medial (0.07 cm) to Distal (0.23 cm). They also demonstrated a greater vesicle abundance in the coarser grain size fraction (Fig. 4). Correlating these two characteristics, we can interpret that the more vesicles, the less density a grain has, making it easier to transport farther from its source. Aeolian sediments also show a parallel shift in mineralogy from Medial to Distal in the aeolian transport (Fig. 5), demonstrating a disappearance of crystalline mafic material between the two locations.

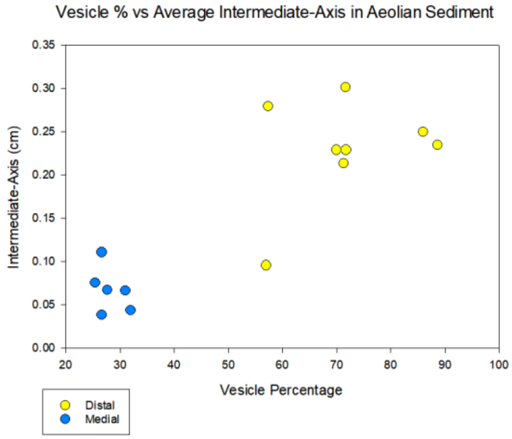

Figure 4: Scatterplot correlating average Medium-axis increase with respect to vesicle percentages in Aeolian transport system. Dots demonstrate 300 point averages from each MAHLI-style image of the Medial and Distal aeolian sites.

The difference in vesicle abundance could be interpreted as Medial and Distal Aeolian grains being from different sources [8]. Vesicles form due to the outgassing of volatiles from lava during an eruption [9]. As the source rocks of the SAND-E 2019 field site are largely glaciovolcanic, it would indicate that these grains primarily formed in the later stages of the eruption, where the eruption penetrates the top of the ice cap [9]. This idea is further seen through the movement in mineralogy of the aeolian grains, which indicates a different source of grains from each site due to the lack of mineral transport evolution present

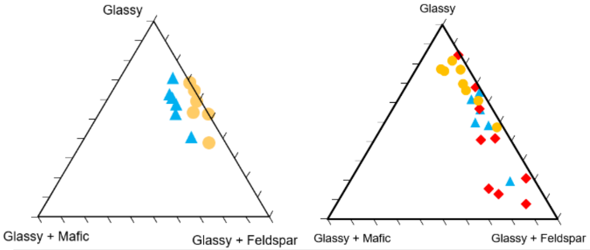

Figure 5: Ternary Diagrams of Aeolian (left) and Fluvial (right) Systems. ◆ Proximal ▲ Medial ● Distal

Gazzi Dickenson Method advantages and disadvantages: Picture analysis of grains presented many advantages and limitations. This surface-level examination made tracking grains' evolution through transportation in their respective system easier. It was also easier to account for rock textures and vesicle abundance. However, this method's accuracy depended on the images' quality and failed to see fine-grained minerals. XRD was also performed in some of the samples to test the benefits of the method. The XRD analysis demonstrated accurate mineralogical data of all grains regardless of size. However, XRD analysis does not distinguish between polymineralic and monomineralic grains. Utilizing both of these methods we were able to determine the physical and chemical changes of sediments in fluvial and aeolian systems. The fluvial system demonstrated the expected patterns while the aeolian system demonstrated a possible different source production of the grains in the area of study. Because of this, we propose implementing both the Gazzi Dickenson and XRD analysis to create an accurate and in-depth breakdown of the changes that grains undergo throughout their transportation systems.

References: [1] Grotzinger et al., (2012) *Space Sci Rev 170, 5-56*. [2] C.C. Bedford. et al. (2019) *Geochimica et Cosmochimica Acta. 246, 234-266*. [3] Bandfield et al (2004) *Journal of Geophysical Research: Planets 109*. [4] Thorpe et al (2021) *Journal of Geophysical Research 126*. [5] Cornwall et al (2015) *Icarus 256, 13-21. [7]* Mangold et al (2011) *Earth and Planetary Science Letters 310, 233-243*. [7] Mason et al (2020) *LPSC 2020*, Abstract #2720 [8] Bedford et al (2022) [9] Moles et al (2019) *GeoScienceWorld 47, 577-580*