INVESTIGATING RELATIONSHIPS BETWEEN GEOCHEMISTRY AND PHYSICAL GRAIN CHARACTERISTICS ALONG A GLACIO-FLUVIAL-AEOLIAN SEDIMENT TRANSPORT PATHWAY USING µXRF.

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Introduction: Iceland's basaltic volcanic rocks and glacial, fluvial, and aeolian landscapes resemble those studied on Mars, which makes it an ideal location to study the evolution of basaltic landscapes, the weathering and alteration of basaltic sediments in cold and wet environments, and the generation of a basaltic sedimentary record [1]. The SAND-E: Semi-Autonomous Navigation for Detrital Environments project examines physical and chemical changes in sediments transported through basaltic fluvial and aeolian environments, and tests operational scenarios, which include a drone and a robotic rover instrumented with autonomous terrain analysis software [2]. As part of the SAND-E project, we examined a glacial outwash plain at Skjaldbreiðauhraun, in SW Iceland.

This study uses micro X-ray fluorescence (µXRF) to examine the chemical and physical properties of unconsolidated sediment-size fractions from 710 µm to < 63 µm along a downstream transect from a glacial sourced watershed. µXRF is ideally suited for this task because it maps elemental distributions at sub-grain scales thereby allowing a direct correlation between grainsize, grain shape, and chemistry. It is also a good analog technique for the Mars 2020 mission equipped with the PIXL (Planetary Instrument for X-ray Lithochemistry) that will be deployed at Jezero Crater, Mars [3].

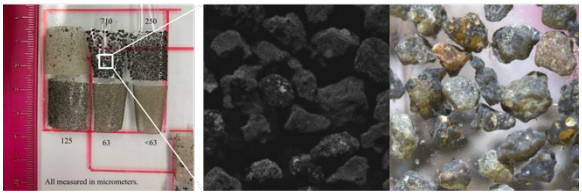
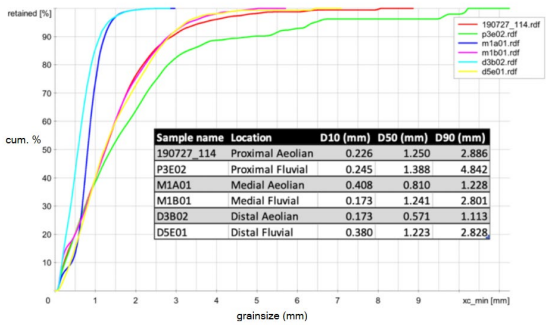


Figure 1: Sediments analyzed in the µXRF. (left) Sediments were sieved and different size fractions placed on tape for analysis in the µXRF. The µXRF scanned a 5.12 by 5.12 mm area of the sample. (middle) Fe element map of the 710 µm fraction. (right) Optical stereo microscope image of sample spatially correlated to the Fe element map.

Methods: Preliminary analysis of six out of 217 sediment samples were analyzed by µXRF for this study. The samples were collected from the þórisjökull glacial runoff system in SW Iceland. Samples were selected based on transport environment and location. Six fluvial and aeolian samples were chosen at distances 6.3 km (proximal), 11.3km (medial), and 14.4 km (distal) to the þórisjökull glacier. Samples were taken from wind ripples and Samples were taken from the bed of a braided river channel.

Samples were sieved to five grainsize separates at 710 µm, 250 µm, 125 µm, 63 µm, and <63 µm. Non-separated bulk samples were analyzed using the CAMSIZER to produce grainsize and shape characteristics, such as sphericity, elongation, and angularity (Fig. 2).



Sample name	Location	D10 (mm)	D50 (mm)	D90 (mm)
190727_114	Proximal Aeolian	0.226	1.250	2.886
P3E02	Proximal Fluvial	0.245	1.388	4.842
M1A01	Medial Aeolian	0.408	0.810	1.228
M1B01	Medial Fluvial	0.173	1.241	2.801
D3B02	Distal Aeolian	0.173	0.571	1.113
D5E01	Distal Fluvial	0.380	1.223	2.828

Figure 2: Cumulative grainsize distribution of six samples in this study. The 10th (d10), 50th (d50) and 90th (d90) percentiles are reported in the table.

Each grainsize separate was analyzed using a µXRF benchtop Horiba XGT7000 µXRF with a 10 µm probe head over a 5.12 x 5.12 mm area generating a 512 x 512-pixel image. Pixel brightness on the maps represents pseudo-intensity, which is the uncalibrated concentration of that element (Fig. 1, middle). Composite color maps show relationships among different elements.

Results: Bulk grain size analysis shows that the median grainsize of these aeolian samples is finer than the fluvial, though variability exists in the system (e.g., [4]), Furthermore, the sediment size fines farther from the glacial source area (Fig. 2). The fluvial samples are more poorly sorted than the aeolian samples, as indicated by the less steep cumulative distribution curve (Fig. 2).

The µXRF color maps were used to determine where are concentrated in specific grains. In Figure 3, Fe (displayed in yellow) stands out as bright patches on the grains. Certain areas of the grains contain higher concentrations of Ca (blue). Mg (red) does not appear strongly in these grains. This lack of Mg is unexpected due to the high concentration of Mg in the sediments

and sediment source rocks [6] which could be due to the insensitivity of the XRF to lighter elements.

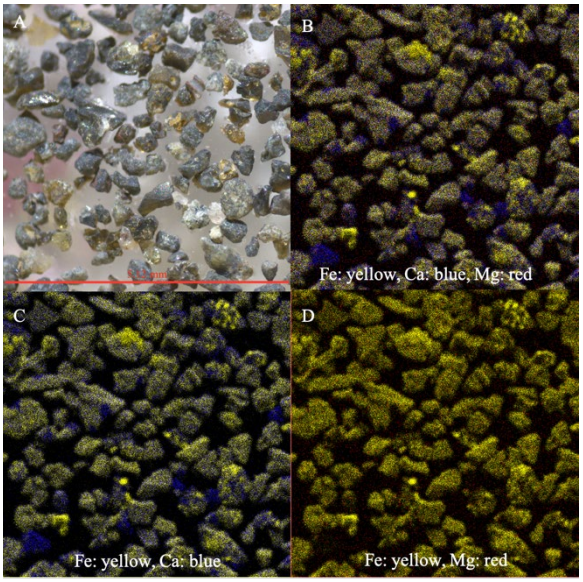


Figure 3: The 250 µm sample is shown with a high-resolution camera on the ZEISS Stemi508 microscope (A). The color maps are produced from µXRF (B,C,D). Map B is the combination of maps C and D.

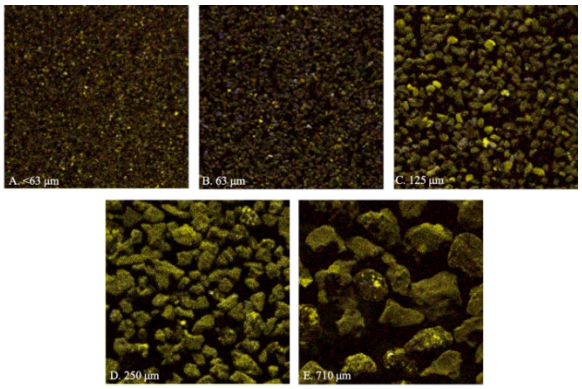


Figure 4: µXRF color maps (16-bit images) of five grain sizes of the proximal aeolian sample. Fe is yellow, Ti is blue, and Mg is red. All maps are 5.12 mm by 5.12 mm.

Figure 4 shows the elemental variability of each grainsize fraction within one aeolian sample. In all 5 maps, the Fe signal is strong and, similar to Fig. 3, presents as bright patches on the grains, however the Mg and Ti signal is weak. Ti has similar overall abundance to Mg, but as indicated by the brightness is slightly more concentrated in some grains rather than others.

Discussion and Conclusions: Relationships between geochemistry and physical characteristics can be made with µXRF scans and manual measurements. The high intensity of FE, Mg, Ca, and Ti are typical of basaltic minerals like those found in this system [see 6 for XRD analysis]. The patchy presentation of the Fe may be due to multimineralic grains or surficial weathering products. In some grains, the Fe patches correlate to the vesicles in the grains.

Future work will develop a method to effectively correlate µXRF elemental abundances to individual particle grain characteristics. This would be useful determining grain-scale physical and chemical processes affecting sedimentary particles within the system. Further, such methods could be applied to future PIXL Mars2020 rover data.

References: [1] Mangold N. et al. (2011) Earth and Planetary Science Letters 310.3-4: 233-243. [2] Ewing et al. (2019), SAND-E: Semi-Autonomous Navigation for Detrital Environments First Results, AGU Fall Meeting Abstract EP24A-05 [3] Allwood A. et al. (2013) AGU Fall Meeting Abstracts, P51F-1786. [4] Mason et al. *this meeting.* [5] Bedford et al. *this meeting*. [6] Rampe et al. *this meeting.*