µXRF INVESTIGATION OF RELATIONSHIPS BETWEEN GEOCHEMISTRY AND PHYSICAL GRAIN CHARACTERISTICS IN A GLACIO-FLUVIAL-AEOLIAN CATCHMENT IN ICELAND.

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Introduction: Iceland's basaltic volcanic rocks, cool and wet climate, and fluvial and aeolian volcaniclastic sedimentary environments offer a unique opportunity to study physical and chemical changes to sediments along their transport pathways in a Mars-analog environment [1, 2]. Specifically, studying these changes can provide insights on how to evaluate the significance of weathering, alteration, and grain sorting in similar present and past environments on Mars.

This project uses micro X-ray fluorescence (µXRF) to investigate how sediment geochemistry, grain size, and grain shape evolve along a glacio-fluvial-aeolian transport pathway with the aim to determine the propensity of minerals derived from volcanic source rocks to sort and weather during transport. We studied the Skjaldbreiðauhraun glacial outwash plain in SW Iceland, which sits at the base of Þórisjökull. The glacier caps intraglacial volcanic sequences which contribute the sediments to the outwash plain in addition to material derived from the postglacial Skjaldbreiður shield volcano which is situated further downstream. This area was used as the operations site for the SAND-E: Semi-Autonomous Navigation for Detrital Environments project – a campaign-scale analog project that uses an autonomous rover and unmanned aerial system to investigate physical and chemical changes in sediment along a sediment transport pathway [3].

Methods: µXRF is a non-destructive technique to analyze minor and major geochemical concentrations in geological samples [4]. A µXRF instrument, PIXL (Planetary Instrument for X-ray Lithochemistry), will be deployed on the Mars2020 *Perseverance* rover [5]. We analyzed fluvial and aeolian samples from an 8 km transect that began proximal to the glacier and source material. Each sample is approximately 1 km apart along the transect. Samples were selected to capture the average fluvial and aeolian sediment at each location. Each sample was sieved into five grainsize separates at 710-1000 µ, 250-710 µ, 125-250 µ, 63-125 µ, and <63 µ in order to determine trends within each separate. To prepare each sample for µXRF, each grainsize separate was placed on a piece of glass (Fig. 1).

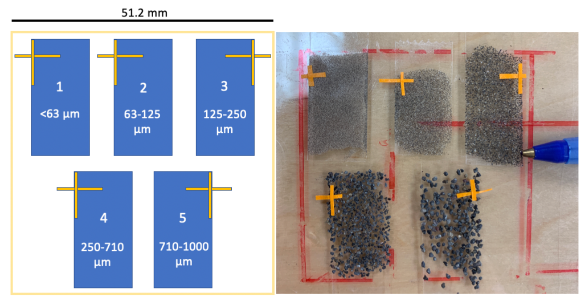

Figure 1. A schematic of sediment sample layout is shown on the left for preparation of sand for µXRF analysis. Sand was evenly dispersed on tape, represented by the blue rectangles. Orange crosses are Ti tape used for correlation of the scan to the optical microscope images. There are 5 different grain size bins each classified by a number from finest (1) to coarsest (5). The right shows the medial fluvial sample ready for µXRF analysis. Pen tip is included for scale.

Scans of fluvial sediments, sampled at the medial and distal sites, were acquired. The scans were taken at 10 µ and 100 µ using a Horiba XGT-7000. The 100 µ compare to the capability of PIXL [5]. The 10 µ scans provide detailed images of elemental data with spatial resolutions sufficient to characterize individual particles to a scale of ~40 µ. These scans are produced with 4 accumulations, whereas the 100 µ scans are produced with 8 accumulations. The 100 µ are used to obtain semi-quantitative elemental abundance data because of the high accuracy due to the high number of accumulations. To measure particle size and shape, we referenced µXRF images to optical microscope images using a ZEISS Stemi 508 microscope.

Results: Color maps and scatter plots were generated from the µXRF data. Qualitative color maps help pinpoint elemental trends found on a sub-grain scale. Semi-quantitative results were generated by utilizing the mean gray scale values in each element of each grain size fraction in µXRF scan and creating scatter plots.

µXRF Color Maps. We used Fe, Ca, Ti and Mn to generate color maps of our 5 grainsize fractions. Findings show multimineralic and monomineralic grains in the coarser grain sizes of 125-1000 µm (Fig. 3), whereas the finer fractions (<125 µm) possess an abundance of monomineralic grains.

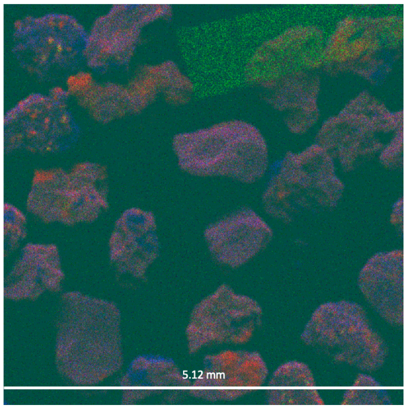

Figure 2. 10-micron color map of medial fluvial sample, grain size 710-1000 µm, showing Fe (R), Ca (B), Ti (G). The large green rectangle in the upper right-hand corner is Ti tape.

Scatter plots. Ti, an immobile element during chemical weathering, was used to normalize the elements of each scan for comparison. Scatter plots show that the Fe/Ti ratio decreases in the finer grain size fractions (Fig. 3, A). Mn/Ti (Fig. 3, C) and Ca/Ti (not shown) have similar abundance trends across all grain sizes, as well as along the traverse. The finest and coarsest fraction in the medial fluvial sample have the highest element ratio value, and the 125-250 µm grain-size fraction has the lowest for Mn/Ti and Ca/Ti. The distal fluvial for Mn/Ti and Ca/Ti sample has an increasing element ratio value with increasing grain size (Fig. 3, C). Al/Ti (not shown) and Si/Ti (Fig. 3, B) have similar abundance trends in which the 63-125 µm grain-size fraction deviates from the increasing trend with increasing grain size. The majority of distal fluvial samples have less element ratio variability than medial fluvial samples.

Discussion and Conclusion: In both the medial and distal sites, the lower Fe/Ti concentrations in finer grain-size fractions may indicate increased weathering in the fines. Distal fluvial samples have less elemental variability than medial fluvial samples leading the conclusion that there is decreasing geochemical variability with increasing distance from the source, possibly signaling proximal particle sorting toward more uniform grain and elemental distribution.

Although the variation in Fe appears to correlate with that of Ti, we cannot eliminate variations in Ti from physical sorting or the addition of different source material. The Si/Ti and Al/Ti element ratio values decrease in the 63-125 µm grain-size fraction for both medial and distal samples, which could indicate that grains rich in these elements are preferentially weathered or physically sorted into the fine grain fraction relative to other grains. The Mn/Ti and Ca/Ti element ratio values increase with increasing grain size in the distal samples, but not in the medial, which may indicate local input of coarse grains.

Finally, multimineral grains were found in abundance in the coarsest grain sizes (125-1000 µm) and monomineralic grains were found in abundance in the finer fractions, possibly indicating that multimineralic grains break down into their monomineralic components during transport, contributing individual mineral phases as single grains to the finer fraction.

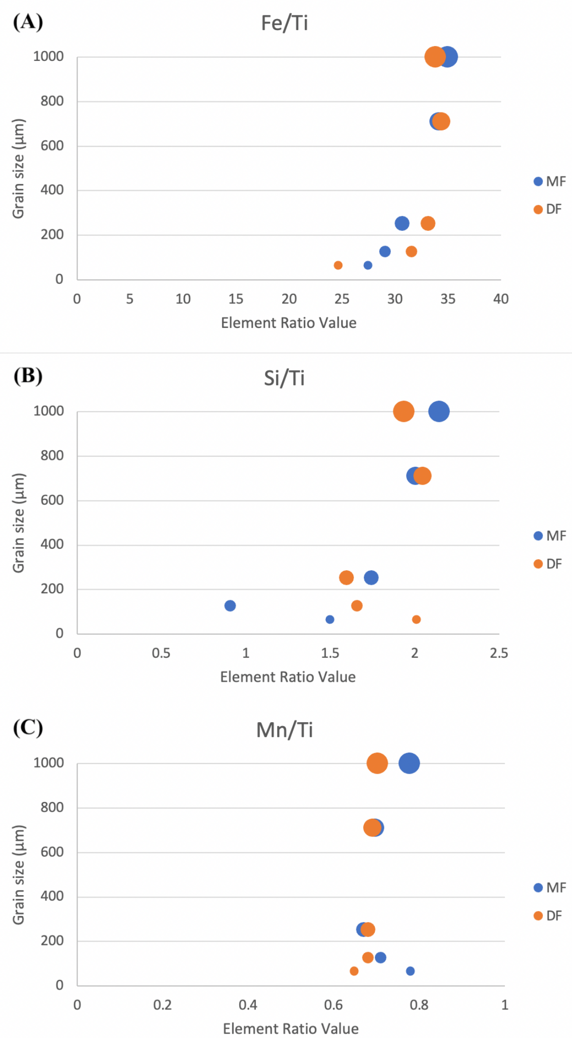

Figure 3. Grain size (µm) vs. element ratio value plots of Fe/Ti (A), Si/Ti (B), and Mn/Ti (C) containing both medial fluvial and distal fluvial samples.

References: [1] Mangold N. et al. (2011) *Earth and Planetary Science Letters, 310,* 233-243. [2] Thorpe M. et al. (2021) *JGR-planets*. [3] Ewing R. C. et al. (2019) *AGU Fall Meeting Abstract* EP24A-05. [4] Flude S. et al. (2017) *Mineralogical Magazine*, *81*(4), 923-948. [5] Allwood A.C. (2020) *Space Science Reviews,* 216.8, 1-132.