FATE OF GLACIOVOLCANIC SEDIMENTS TRANSPORTED BY FLUVIAL AND AEOLIAN PROCESSES IN A COLD CLIMATE MARS-ANALOG ENVIRONMENT.

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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, impact and glacial environments [e.g.,3-6]. Glaciovolcanism is proposed to have occurred on Mars based on unique edifice morphologies [e.g.,7] and palagonite detections [8]. Palagonite and glass can indicate ice-magma interactions however it is not clear how well they are transported in fluvial and aeolian environments. Here we explore glaciovolcanic sediments transported by fluvial and aeolian processes to understand their contribute to modern and ancient sediments investigated by martian surface and rover missions.

This study aims to constrain the dominant influence on the sorting of glaciovolcanic materials in cold and wet climate environments. To do so, we search for spectral trends using visible to near infrared (VNIR; 350-2500 nm) reflectance spectra and thermal infrared (TIR; 1200-400 cm^{-1}) emission spectra. We hypothesize that compositional trends in fluvial and aeolian environments occur primarily due to size- and density-dependent sorting. Under this hypothesis, no additional compositional phases are expected down system, but their relative proportions will vary during transport. We also hypothesize that in a longer transport system we will observe a higher degree of physical breakdown and sorting. We expect that fluvial sediments will display more gradual compositional trends than aeolian as water is able to transport wider variety of materials farther.

These hypotheses can be applied to most basaltic materials transported by fluvial and aeolian activity, we will focus on if they hold true in glaciovolcanic systems. Physical properties of glaciovolcanic materials differ from typical subaerial crystalline lava [9], and we explore the effects of that on their transport in different deposits.

Field Sites: The Semi-Autonomous Navigation for Detrital Environments 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 at two different field transects, Skjaldbreiður and Vatnajökull [7]. Each field transect was sampled at three locations: near the source (proximal), approximately mid-way in the system (medial), and as close to the sink of the system as could be accessed (distal).

Skjaldbreiður. This field transect is ~10 km. The proximal site is near a glacier which sits atop glaciovolcanic and subaerial 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 both fluvial and aeolian activity.

Vatnajökull. This field transect is ~155 km. The proximal site is in a dry river channel near the glacial source with local alluvial input from volcanic outcrops and has both fluvial and aeolian activity. The medial site is slightly away from the main fluvial system for accessibility and is dominated by aeolian activity. The distal site on the terminal delta is fluvially dominated.

Methods: VNIR spectra were acquired of all bulk sediment samples; both VNIR and TIR spectra were acquired of representative sediment samples sieved to 8 grain size bins. VNIR spectra were collected using the ASD FieldSpecPro3 spectrometer. VNIR spectra of expected minerals in a mafic and altered sediment system are dominated by absorptions due to Si-, Fe-, Al-, and Mg-OH bonds, Fe-bearing minerals, and hydration (locations shown in Fig. 1). TIR spectra were acquired using the ASU Mars Space Flight Facility Thermal Emission Spectrometer following procedures similar to [10].

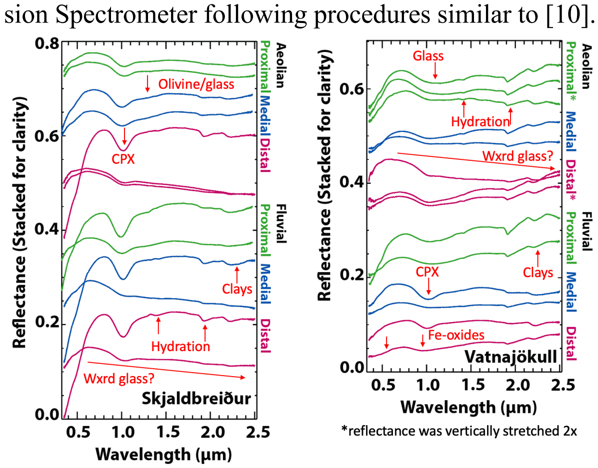

Figure 1: *VNIR laboratory spectra of sediment samples for each site. Prominent absorptions are denoted by red arrows.*

VNIR: Spectra shown in Fig. 1 are representative of aeolian (top) and fluvial (bottom) sediments for both field sites. Skjaldbreiður is dominated by clinopyroxene

(CPX), mixed with olivine or glass, minor hydration, and assemblages of clay minerals and hydrated silica or glass. CPX is more dominant in the fluvial sediments, while mixing with olivine/glass is more common in the aeolian sediments. The blue slope present in some spectra is consistent with either weathered glass [11] or fine-grained igneous rock. Similar spectral features are observed in Vatnajökull, but the field site is dominated by glass rather than CPX, the presence of clays is more consistent, the blue slope is not as readily observed, and possible Fe-oxides are present. There is more spectral variability in the fluvial system in Vatnajökull from proximal to distal, as the glass signatures are reduced and CPX is more dominant in distal sediments.

Spectral parameters: The 1 µm iron band of sieved samples were parameterized for band center and shape (Fig. 2). In these samples, we interpret a higher band center as indicating increased glass content and a higher band asymmetry as indicating increased olivine content and thus likely more crystalline lava rather than hyaloclastite. At Skjaldbreiður, crystalline lavas are concentrated in coarser grains, but no trends are observed with distance from the source in either the fluvial or aeolian sediments. At Vatnajökull, there are no clear grain size trends, but the proximal site has a greater abundance of glass while medial and distal have a greater abundance of crystalline minerals.

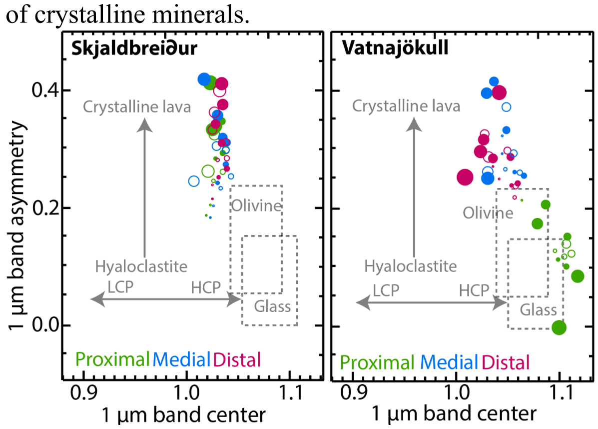

Figure 2: *1-µm band parameters of VNIR spectra. Symbol color represents distance from source and size represents grain size (larger symbol = larger grain size). Filled symbols are fluvial samples and hollow symbols are aeolian samples.*

TIR: Modeled abundance of glass at three grain sizes with distance is shown in Fig. 3 for each field site. In Skjaldbreiður, there is an overall decrease in glass abundance with distance when transported by both fluvial and aeolian processes. The drop in glass abundance is more gradual in the aeolian system. In Vatnajökull, the overall glass abundance is greater than in Skjaldbreiður and is consistent across the fluvial environment, with a slight (<10 wt.%) decrease with distance. In the aeolian environment, glass abundance is similar at proximal and distal, but is reduced at the medial site.

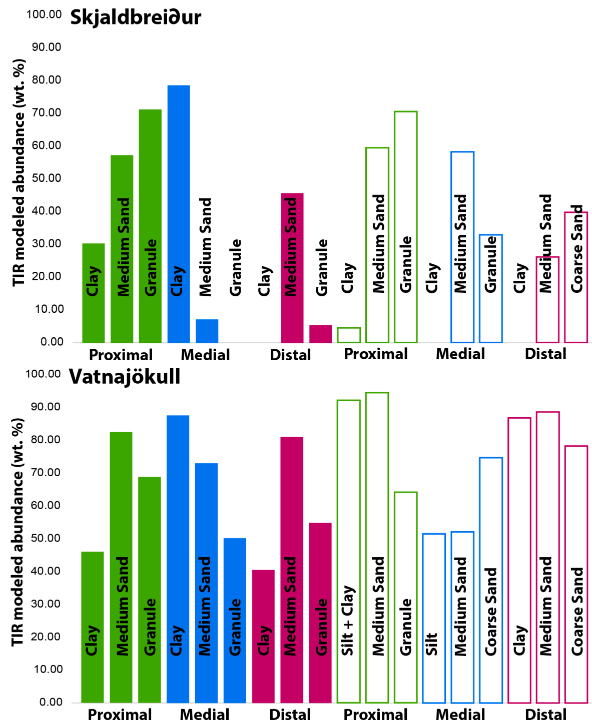

Figure 3: *TIR modeled abundance of glass in sediments from source to sink at different grain sizes. Filled bars are from the fluvial system, hollow bars are from the aeolian.*

Discussion: Overall, the fate of glaciovolcanic materials is dependent more on the physical properties at the source (e.g., glass as part of a fine-grained hyaloclastite matrix as seen in Skjaldbreiður vs. glassy sand grains as seen in Vatnajökull) rather than the process or distance of transport. In VNIR, differences between transport pathways were observed at each field transect, including composition correlating with grain size in Skjaldbreiður while correlating with distance from the source in Vatnajökull. But, when focusing on the abundance of a single component (glass in this case) in TIR, these trends are not as prominent. Further comparison to other primary and secondary components of glaciovolcanic materials will need to be conducted. If glass sourced through glaciovolcanism is common on Mars, we would expect to see some combination of more friable glass materials in finer grained deposits, while glass sand grains would be segregated into coarser deposits.

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 & Space Sci 93-94.* [7] Ghatan & Head (2002) *JGR: Planets, 107.* [8] Ackiss et al. (2018) *Icarus, 311*. [7] Ewing et al., (2017) *PSTAR*. [8] Sinha et al., (2020) *LPSC #2682.* [9] Edwards et al., (2015) *Encyc. of Vol. (II Ed.)*. [10] Ruff et al., (1997) *JGR:Solid Earth, 102.* [11] Henderson et al., (2021) *Earth Space Sci, 8.* [12] Baratoux et al., (2011) *Earth Surf. Process. Landforms, 36.*