IDENTIFYING THE PRODUCTS OF VOLCANO-ICE INTERACTION IN BASALTIC SEDIMENTS IN ICELAND AND THEIR IMPLICATIONS FOR MARS.

C. C. Bedford[1,2], E. B. Rampe[2], M. T. Thorpe[2], R. Ewing[3], B. Horgan[4], M. Nachon[3], M. Lapotre[5], P. Sinha[4], K. Mason[3], E. Champion[3], E. Reid[6], [1]Lunar and Planetary Institute, USRA, Houston, Texas (cbedford@lpi.usra.edu), [2] Astromaterials Research and Exploration Science, NASA Johnson Space Center, Houston, Texas, [3]Texas A&M, College Station, Texas, [4]Purdue University, [5]Stanford University, [6]Mission Control Space Services.

Introduction: Geomorphological features representative of possible volcano-ice interactions have been identified on the Martian surface [1–3], with volcano-ice interactions suggested to have caused episodic flooding on ancient Mars [2] and generated aqueous environments potentially suitable for life [4]. The capability to identify the eroded products of volcano-ice interactions in sedimentary systems using geochemical and mineralogical instruments deployed on the current Mars Science Laboratory mission and future Mars 2020 mission could aid in determining the extent to which volcano-ice interactions contributed sediments to catchments on ancient Mars.

In June 2019, The SAND-E: Semi-Autonomous Navigation of Detrital Environments analog mission to Iceland investigated three field sites of varying distances to the sediment source (Fig. 1) along a basaltic glacial-fluvial-aeolian sedimentary system analogous to Mars to examine changes in the physical and chemical properties of sediments along a transport pathway from their source rocks. The SAND-E mission was conducted in SW Iceland at Skjaldbreiðauhraun using Mars2020 techniques such as X-ray fluorescence (XRF) and visible/near-infrared (VNIR) spectroscopy in the field. The source rocks formed as a result of both subglacial and subaerial volcanism. Our aim is to investigate how sediments eroded from these subglacial and subaerial volcanoes are sorted and deposited in fluvial and aeolian sedimentary systems within our Mars analog environment to inform current and future Mars missions.

Methods: Over 50 hand samples were collected from four volcanoes and the Þórisjokull Glacier outwash fan (Fig. 1). Three volcanic mounds distinguished in the field according to color and geological contacts (V1, V2, V3) are largely composed of pillow basalt and palagonite tuff, which indicate eruption in a subglacial environment. Two of the subglacial volcanoes (V1 & V3) have a flat capping unit indicative of the eruption penetrating the overlying ice cap [5]. One volcano (Skjaldbreiður) that formed to the south of the SAND-E field site is a typical subaerial shield volcano (Fig. 1). The weathered exteriors and fresh interiors of the source rock samples were analyzed to compare to the sediments investigated at the three field sites.

Geochemical data for SAND-E sediment and source rock samples were acquired using a hand-held Olympus Vanta XRF Spectrometer. XRF targets of sediments conducted in the field were classified by a visual assessment of the dominant grain size - pebble, sand, and mud - using images taken during analysis. To generate a representative source rock geochemistry of the area, a multivariate density contour analysis was done for all hand sample interior and exterior analyses using MatLab 2019 similar to those used on Mars [6]. We included exterior analyses in the density contour plots because weathered sediments are also likely to be incorporated and sorted within sedimentary systems.

When an XRF sediment target was analyzed in the field, the sediment was collected for X-ray diffraction (XRD) analysis using a Rigaku MiniFlex 6G at the NASA Johnson Space Center. Lab-based XRD analyses were similarly conducted on the bulk source rock samples. Petrography of thin sections of select hand samples was obtained to evaluate petrogenetic relationships among phases in the samples.

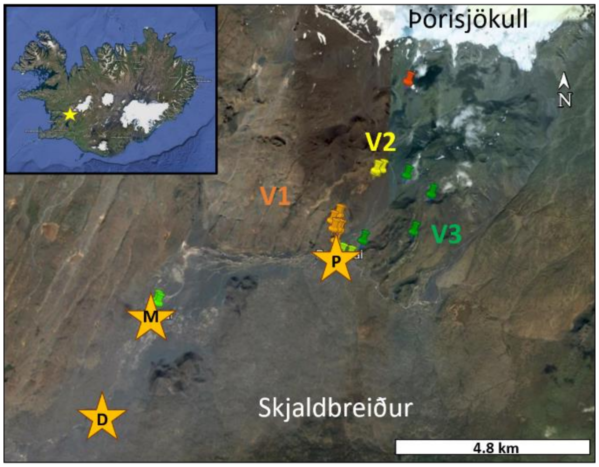

Figure 1: Map of the three SAND-E field sites Proximal (6.3 km), Medial (11.3 km), and Distal (14.4 km) shown as stars with P, M, and D respectively, with annotations showing the sampling sites (pins) of the three subglacial volcanic mounds V1, V2, and V3, and the subaerial Skjaldbreiður volcano lava field.

Results and Discussion: *Source rocks:* The source rocks include two dominant basaltic endmembers: olivine-phyric (V1) and plagioclase-phyric (V2, V3 and Skjaldbreiður). Each of these endmembers can be distinguished in a decorrelation stretch of the field site [7] and includes samples that are either palagonite tuff or variably glassy (pillow basalt and kubbaberg), and crystalline (subaerial flow) depending on their morphology.

The olivine-phyric endmember has high MgO (17.7 ± 0.2 wt%), Ni (716 ± 40 ppm) and Cr (1616 ± 215 ppm), with low SiO_2 (45.1 ± 0.4 wt%) and TiO_2 (0.6 ± 0.03 wt%) and contains abundant olivine phenocrysts with plagioclase, pyroxenes and olivine in its groundmass. The palagonite tuff from the olivine-phyric endmember is orange with abundant glassy clasts and is enriched in TiO_2, FeO, and Sr, and depleted in Al_2O_3 relative to the crystalline and glassy hand specimens (Fig. 2).

The plagioclase-phyric endmember contains large glomerocrysts of plagioclase feldspar with occasional olivine phenocrysts, is highly vesicular, and has relatively high abundances of TiO_2 (1.5 ± 0.2 wt%), Al_2O_3 (19.2 ± 1.1 wt%), Sr (180 ± 18 ppm), and Mn (1302 ± 76 ppm) in comparison to the olivine-phyric endmember. Two types of palagonite tuff exists for the plagioclase-phyric endmember. V3 palagonite tuff is orange and shares similar element enrichments and depletions in comparison to glassy and crystalline samples as the OP palagonite tuff. The palagonite tuff from V2 is bright yellow with very few sideromelane clasts. The yellow palagonite tuff has geochemical trends showing strong enrichments in Al_2O_3, TiO_2 and FeO compared to the glassy/crystalline samples from the same volcano. The yellow palagonite geochemistry is therefore distinct to that of the other palagonite tuff from V1 and V3.

No phyllosilicates were detected in VNIR or bulk XRD for any source rock, however XRD Rietveld refinements show a larger abundance of amorphous material in all palagonite tuff samples.

Sediments and implications for Mars: Sediments analyzed among the three field sites, particularly between the Proximal and Distal sites, show variations in geochemistry indicative of sediment sorting and/or changes in sediment source between the olivine-phyric and plagioclase-phyric endmembers (Fig. 2). XRF analyses of sand and pebble grain size fractions overlap at the Proximal site, with a range in compositions between the olivine-phyric and plagioclase-phryic endmembers (Fig. 2). At the Medial and Distal sites, the compositions of the sand and pebble grain size fractions separate, with more pebbles being derived from the local plagioclase-phyric Skjaldbreiður lava flows (Fig. 2). The sand grain size fraction instead becomes more uniform in composition and is more similar to the olivine-phyric endmember. Bulk XRD data of the three field sites also show an increase in the mafic:felsic mineral abundances and an increase of the amorphous component from the Proximal to the Distal field site [8]. Therefore, mineral sorting has likely transported and concentrated sands from the olivine-phyric endmember's crystalline, glassy and palagonite tuff units between the Proximal and Distal sites. This is likely due to the friable palagonite tuff and rounder shape of the olivine grains relative to the elongate feldspar grains being more efficiently transported by saltation and suspension away from the Proximal site [9]. Pebbles appear to be derived from the more local, plagioclase-phyric bedrock of the Skjaldbreiður lava flows at the Medial and Distal sites (Fig. 2). As such, we would expect to best identify the products of glaciovolcanism on Mars in distal sands of a glacio-fluvial-aeolian system; however the geochemistry and mineralogy of the local bedrock is best preserved in pebble sized sediments.

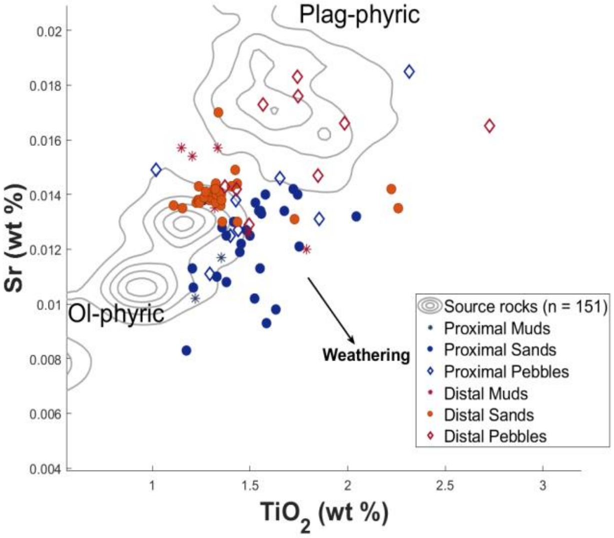

Figure 2: Geochemical plots of Sr against TiO_2 for the source rock and field Proximal and Distal XRF data. Source rock data are shown as density contours with respective endmembers labelled as Ol-phyric and Plag-phyric. Scatter data for the mud, sand, and pebble grain sizes are shown as asterisks, circles and diamonds respectively.

References: [1] Martínez-Alonso S. et al. (2011) doi:10.1016/j.icarus.2011.01.004. [2] Ghatan G. J. and Head J. W. (2002) doi:10.1029/2001JE001519 [3] Ackiss et al. (2018) doi: [4] Cousins C. R. et al. (2013) doi: 10.1016/j.jvolgeores.2013.02.009. [5] Jakobsson S. P. and Gudmundsson M. T. (2009) *Jökull* no. 58 pp179-196. [6] Bedford C. C. et al. (2019) doi:10.1016/j.gca.2018.11.031. [7] Sinha P. et al. (2020) this conference. [8] Rampe E. B. et al. (2020) this conference. [9] Mangold et al. (2011) doi:10.1016/j.epsl.2011.07.025.