SOURCE TO SINK INVESTIGATIONS OF PRESTAHNÚKUR VOLCANO, ICELAND: ANALOG FOR GALE CRATER, MARS. R.V. Patterson1,2, C.C. Bedford3, P.D. Casbeer2, 1University of Houston Department of Earth and Atmospheric Sciences (rubypatterson1@gmail.com), 2NASA JSC-JETS II, 3Purdue University.

Introduction: Prestahnúkur volcano in the Western Volcanic Zone of Iceland was used as an environmental Mars analog for Gale Crater to investigate possible volcanic formation scenarios of tridymite and cristobalite, as well as their transportation and deposition in Mars-relevant sedimentary systems. Prestahnúkur is a rhyolitic subglacial volcano surrounded by purely basaltic volcanic terrain [1, 2]. The glaciovolcanic edifice of Prestahnúkur contains a diversity of morphologies (pillow, hyaloclastite, and sill intrusions) that reflect different conditions as the volcano erupted through the ice cap [1].

Several detections of high-temperature silica polymorphs have been made in Gale crater, of particular note is the Buckskin drill hole which contained ~14 wt. % tridymite, ~2 wt. % cristobalite, and ~39 wt. % opal-A and/or high-SiO2 glass and opal-CT [3, 4]. These detections sparked several hypotheses for Buckskin’s formation and evolution on a predominately basaltic planet [5-8]. The presence of tridymite, cristobalite, or other SiO2 polymorphs could indicate several formation mechanisms: evolved volcanism [e.g., 5], hydrothermalism [e.g., 6], physical grain segregation of an evolved volcanic source [e.g., 7], or alteration by glacial activity [e.g., 8]. To characterize how silicic materials are incorporated into sedimentary environments within a primarily basaltic provenance, sediment samples were collected from varying distances from Prestahnúkur along two fluvial systems (Fig. 1). The main objectives for the field campaign were to (1) sample the volcanic edifice and two source-to-sink sediment pathways, (2) investigate the geochemical components and mineralogy within each sample in-situ and in a laboratory setting, (3) investigate how silica is generated and preserved in basaltic terrains, and (4) draw comparisons to the Buckskin drilled sample to better understand silica genesis and preservation on Mars.

Methods:

Field methods. Hand samples were collected from the Prestahnúkur volcanic edifice (white stars in Fig. 1) any time a morphology change was observed. Two source-to-sink systems were sampled at an interval of 0.2 miles from the base of Prestahnúkur, across the glacial floodplain, ending at a low velocity fluvial sediment ‘sink.’ Images, GPS coordinates, and written descriptions were recorded.

Laboratory Analysis. A multi-pronged analytical approach was deployed at NASA Johnson Space Center to study the hand samples and sediments collected from the field. A PanalyticalX’Pert pro MPD Diffractometer, using Co-Kα radiation at 45 kV and 40 mA, was used to characterize the mineralogy of powdered hand and sediment samples. The analyses ranged from 2° to 80° at a 0.0167° step size. The Rietveld refinement [e.g., 9] method was used for quantitative crystalline phase estimation with a 20 wt. % corundum internal standard for estimating X-ray amorphous content.

X-ray fluorescence (XRF) was performed using an Olympus Vanta M Series handheld instrument to determine elemental abundance on powdered hand and sediment samples.

Size fraction analyses were performed on sediment samples using a Microtrac Bluewave particle size analyzer with water as the carrier fluid.

Figure 1. Map view of Prestahnúkur Volcano (lighter terrain on eastern side of image) depicting locations of collected hand samples (white stars), sampling locations for two source-to-sink sediment systems (red- system ‘S’; blue- system ‘Th’). Each sampling location is 0.2 mi apart. E-W extent of map is ~3 miles.

Results:

System ‘S’ (northern flank of Prestahnúkur). Average particle sizes range from large cobbles (~10 cm diameter) to fine sand at proximal sampling sites to fine silt at the lacustrine sink. XRD analyses revealed three of the samples (S1 (Fig. 2), S2, and S6) contained a similar mineral assemblage to that of the Buckskin mudstone [3, 4], including tridymite and amorphous glass materials. Common mineral assemblages for all samples in System ‘S’ includes plagioclase feldspars (e.g., labradorite, bytownite, etc.) and clinopyroxenes (e.g., diopside, augite, etc.).
One sample, S7, located little more than halfway to the ‘sink’ in this sediment pathway, was found to contain ~3 wt. % cristobalite.

The X-ray amorphous content of each sample collected ranged from ~25 to ~62 wt. % of the total sample. A rough decreasing trend of total X-ray amorphous content is observed with increasing distance from Prestahnúkur.

XRF data show several trends: a decrease of K and Na with increasing distance from the source, and an increase of Ba with increasing distance from source. These trends support the notion of silica-rich sediments from Prestahnúkur mixing with the pre-existing basaltic sediments along the glacial outwash plain.

Conclusions: Mineralogy assemblages and abundances in the two most proximal samples within our silica-rich source-to-sink sediment pathway ‘S’ were similar to the mineralogy identified at Buckskin (e.g., rhyolitic glass, tridymite, etc.). The identification and relative abundance of high-T SiO₂ polymorph cristobalite in sample S7 (~3 wt. %) is also similar to the ~2 wt. % cristobalite identified within Buckskin [3]. These findings support the hypothesis for high-T silica to form in an evolved volcano on Mars and be concentrated in the sediments.

The mineralogical and geochemical data at Prestahnúkur suggest that fluvial transport of silica-rich volcanogenic materials could have preserved the mineral assemblage and relative abundances observed in the Buckskin mudstone.

The large fraction of each Prestahnúkur sample found to be X-ray amorphous (~25 to ~62 wt. %) is comparable to the ~60 wt. % X-ray amorphous materials within the Buckskin sample [3]. Rhyolitic glass was abundant throughout the morphological units, which may have contributed significantly to this finding.

It should be noted Prestahnúkur is known to host warm springs along the northern flank of the volcanic edifice [2], which is subjected to weathering by glacial meltwater with diurnal flow fluctuations. We believe all tridymite found within our samples to be orthorhombic (versus monoclinic found in Buckskin [4]), which could have been produced through hydrothermal activity in these warm springs. The high abundance of amorphous silica in all of the Prestahnúkur samples may be reflective of the proximity of the warm springs in addition to the omnipresent rhyolitic glass on Prestahnúkur.

Future Work:
Data analyses is currently being performed on the basaltic sediment pathway ‘Th’ which flanks the southern border of Prestahnúkur. Results from this system will be presented at LPSC.

In depth thin section analyses will be performed on each of the hand samples collected from the volcanic edifice. Scanning electron microscopy (SEM) will be performed to map the abundance of silica polymorphs within the epoxy-mounted samples. Spot analyses of these siliceous pockets within hand samples will be performed using SEM and Raman spectroscopy to determine the exact mineralogy contributing to the silica-rich sediments being produced at Prestahnúkur.

Laser-induced breakdown spectroscopy (LIBS) was also deployed in the field as a means of tracing geochemical components from Prestahnúkur. These data will be analyzed and presented in future publications related to this work.

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