MINERALOGY AND GEOCHEMISTRY OF AN ICELANDIC FUMAROLE: ANALOG TO MARS HYDROTHERMAL ALTERATION. T.L. Gerard[1], L.J. McHenry, G.L. Carson, and B.I. Cameron[1], [1]UWM Geosciences, 3209 N. Maryland Ave., Milwaukee, WI 53211. , tlgerard@uwm.edu

Introduction: Over the last decade of Mars exploration, planetary scientists have discovered the presence of extensive sulfate and phyllosilicate-rich deposits indicating the acidic weathering of basalts [1,2] in hydrothermal environments at areas such as Gusev Crater, Mawrth Vallis, and Nili Fossae [2-7]. Geochemical and mineralogical evidence can enable scientists to reconstruct the temperature, pH, redox conditions, and salinity of these ancient hydrothermal environments, which in turn will help to determine whether they could have been hospitable to life. Determining the differences between acidic fumarole alteration (less habitable) and more neutral sinter-depositing hot springs (more habitable) aqueous alteration processes on Mars is important for assessing the past habitability. Analyzing the different alteration environments and their resulting mineralogical and geochemical signatures on Earth will provide guidelines for assessing these environments on Mars.

Iceland basalts have a high Fe content similar to Mars [8] that are altering in very active hydrothermal systems under both acid-sulfate and sinter conditions, providing a unique opportunity to determine the geochemical and mineralogical signatures of these processes. Prior research involving Icelandic alteration products as analogs for Martian surface process include [7,9,10], and our study will build upon this prior body of knowledge. This abstract reports preliminary mineralogical and geochemical results from the Krýsuvík hydrothermal area in Iceland.

The Krýsuvík hydrothermal field has been selected because of the high-Fe basalts common in the region [8], the documented presence of oxidizing fumarolic conditions (unlike many Icelandic hydrothermal areas, where reducing conditions are most likely), and the extensive work already done at the site that can be used for comparison [e.g. 11]. While it does not appear to include a near-neutral sinter component for comparison, it provides an excellent opportunity to observe acid-sulfate fumarole-driven alteration in contact with a high-Fe basaltic substrate.

Field Methods: We collected rock, mineral, and water samples from the Seltun area of the Krýsuvík hydrothermal field on the Reykjanes peninsula of southwestern Iceland in 2013. We collected a transect of alteration minerals and rocks with increasing distance from an active fumarole, each associated with an individual temperature measurement. The colors and textures changed dramatically across the several meter scale of this single outcrop, likely indicating mineralogical differences. Water was collected from the outlet stream from a nearby acidic hot pool. While in the field, a Hydrolab sonde was used to collect water temperature, pH, and other parameters.

Figure 1: Gerard and Carson collecting a mineral transect at an active fumarole at Krýsuvík, Iceland.

Lab Methods: Mineral and rock samples were hand ground without heat or liquid for analyze using a Bruker D8 Focus X-ray Diffractometer (XRD) in order to determine the mineral phases. Future work will include X-ray fluorescence (XRF) to determine major and minor element composition, Scanning Electron Microscopy (SEM) to determine element distributions, fine-scale textures, and for the analysis of coatings, along with water chemistry.

Water Results: At the time of collection, the Krýsuvík water sample had a temperature of 32.6°C. A water sample was allowed to cool and then measured later in the day using the Hydrolab sonde, yielding a pH of 3.89, ORP of -177 mV, Sp Cond of 187 uS/cm, salinity of 0.08 ppt, and TDS of 0.1 g/l. LDO is not reported since the sample had some time to equilibrate prior to analysis. A field-filtered water sample awaits further laboratory analysis.

Mineral Results: The XRD results of our mineralogical transect across an active, warm fumarole are presented in Table 1. The temperature ranged from 99.1°C at the vent to 10.0°C at the edge of the alteration apron. It was not possible to measures the pH as there was not enough gas; however, the stream flowing through the area was 32.6°C with a pH of 3.89 and a bubbling pool up the hill from this fumarole had a pH of 2.3 and a temperature of 40°C where most easily accessible. The minerals observed at the fumarole consists of elemental sulfur at the vent and sulfates, clay, and amorphous phases elsewhere, suggesting alteration under acid-sulfate conditions. Sample K-13-12 was collected in contact with the stream and consists of an amorphous material rather than sulfates.

A wide range of Fe, Mg, Ca, Al, and mixed sulfates was observed, with most individual sulfate minerals appearing in only one or two samples.

Some trends can be observed between the temperatures and the minerals present. Amorphous phases were only identified in the cooler samples and were absent above 49°C. Sulfides were also absent in the hottest samples, though elemental sulfur was present in samples ranging in temperature from 42 to 99°C. Clay (halloysite) was only observed in the coldest sample, away from the main transect.

Table 1: XRD results for Krýsuvík

	K-13-0	K-13-1	K-13-2	K-13-3	K-13-4	K-13-5	K-13-6	K-13-7	K-13-8	K-13-12
Temperature (°C)	68	55	99	99	30	49	42	77	20	33
Distance (cm)	150	140	10	0	120	80	-	-	-	-
amorphous					XXX	XX	XX		XXX	XXX
quartz		+								
halloysite									X	
feldspar				+		+				
sulfur	XX		XXX	XXX		XXX	XX	XX		
Fe sulfide	XXX						XX			
hematite		XXX								
anatase	+	X	+	X	X				X	
anhydrite			+							
gypsum									+	
rhomboclase				+			X			
quenstedtite					+					
alunogen								+		
rostite			+							
milosevichite								+		
epsomite			+					+		
halotrichite								+		
tamarugite		X								

Discussion: The range of soluble sulfates observed in this deposit, and the apparent temperature control on the nature of the alteration minerals observed, makes this a good site to help constrain the conditions surface hydrothermal alteration. It is especially interesting that amorphous (likely silica) phases appear to be limited to areas of lower temperature. Further analysis by SEM will ascertain the nature of this amorphous material, and determine textural relationships between the various phases. Comparison to other sites across Iceland (Hengill, Reykjanes, Krafla, Landmannalaugar, etc.) will further help identify specific temperature, pH, and other controls on basalt alteration under fumarolic conditions.

Mars Comparison: Iceland provides an analog for alteration under acid-sulfate conditions and near neutral sinter conditions. The presence of a wide range of soluble sulfate salts, including rhomboclase and other Fe sulfates along with epsomite and mixed sulfates, could serve as a useful comparison for the unusual and in some cases poorly constrained sulfate assemblages observed by the MER Sprit and Opportunity rovers on Mars. Acid-sulfate fumarolic alteration has been invoked as an explanation for various geochemical and mineralogical features within the Columbia Hills [e.g. 5], as has more neutral sinter deposition [e.g. 12]. Further geochemical and mineralogical analysis will provide further information on unique signatures for the different alteration conditions, which could than be applied to the geochemical data on Mars.

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References:

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