MINERALOGICAL EXAMINATION OF A SEAWATER INFLUENCED HYDROTHERMAL AREA ON THE REYKJANES PENINSULA, ICELAND.

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Introduction: Iceland is uniquely situated atop an active mid-ocean ridge and a mantle plume, resulting in a wide variety of volcanic and hydrothermal activity. The Reykjanes Peninsula of the southwestern tip of Iceland is located directly atop the Western Zone of the Icelandic Neovolcanic Zone [1], has been subject to numerous volcanic episodes, and currently has several extensive hydrothermal fields [2]. While most geothermal waters in Iceland are freshwater dominated, the influence of heated seawater can be observed at hydrothermal sites on the Reykjanes Peninsula, increasing westward [3]. The focus of this study is Gunnuhver, near the southwestern tip of the peninsula (Figure 1). We will assess how the surface hydrothermal mineral assemblage at this site differs from others in the region, which are less influenced by seawater.

Figure 1: Map of Reykjanes Peninsula, showing locations of Gunnuhver and Krýsuvík hydrothermal areas.

The mineralogical and geochemical patterns produced when high-iron basalts interact with varied hydrothermal fluids can help reconstruct the conditions under which Martian hydrothermal deposits may have formed. Gunnuhver represents a unique environment that could help provide context to unusual Martian hydrothermal deposits.

Methods: We visited the Reykjanes Peninsula in August of 2016, and collected surface precipitates and altered soils from a fumarole in the Gunnuhver geothermal field (table 1, figure 2), along with water from a hot spring (figure 3) and a fresh basalt nearby. The water was tested onsite for temperature and pH. A Hydrolab sonde was used to measure temperature, pH, salinity, oxidation/reduction potential, total dissolved solids, and specific conductivity. Collected samples were analyzed using X-Ray Diffraction (XRD) to determine the mineralogy. XRD samples were hand ground using an agate mortar and pestle, using no heat or water. Random powders were analyzed using a Bruker D8 Focus XRD. X-Ray Fluorescence (XRF) samples were powdered using a shatterbox and fused using an M4 fluxer and analyzed for major and minor elements using a Bruker S4 Pioneer WD-XRF (methods of [4], data not reported here).

Table 1: Sample descriptions and locations

Sample ID	Type of sample	Description	Depth (cm)	T (°C)
IR1601	Precipitate	Yellow, crinkly	Surface	84.8
IR1602	Precipitate	White	Surface	80.4
IR1603	Soil	Bright red mud	Surface, North side	38.7
IR1604	Soil	Light grey mud	Beneath 03, 5 cm thick	90.6
IR1605	Soil	Brick red mud	Beneath 04, 15 cm thick	97
IR1606	Soil	Darker grey w/ depth	Beneath 07, 12 cm depth	74.6
IR1607	Soil	Beige/tan	Surface, South side, 2-3 cm	65.6

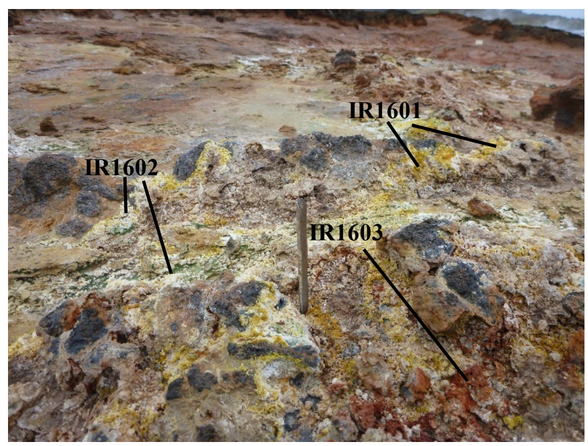

Figure 2: The sampled fumarole in the Gunnuhver geothermal field, with sulfate mineral precipitates encrusting rocks around the fumarole.

Hydrolab Results: The water sample collected at one of Gunnuhver's hot springs (figure 3) has a high salinity compared to Krýsuvík, a hydrothermal field further east on the Reykjanes Peninsula where seawater is less involved [5] (Table 2). These conditions show a saline, acidic environment, influenced by seawater in close proximity to Gunnuhver.

Table 2: Hydrolab results (Krýsuvík data from [5]).

Locality	T (°C)	Salinity	ORP (mV)	pH	SpCond (mS/cm)
Krýsuvík	32.6	0.08 ppt	-177	3.89	0.19
Gunnuhver	81.7	14.14 psu	385.4	2.86	23.4

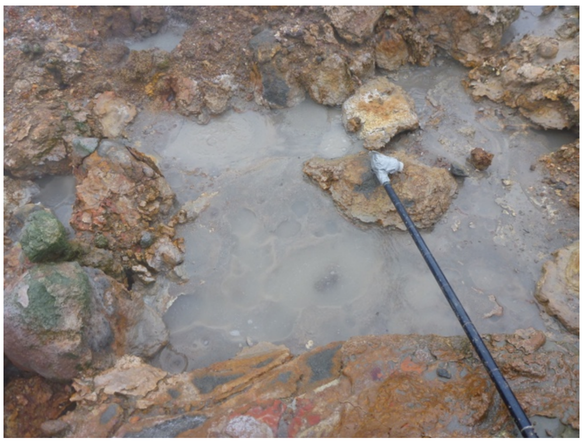

Figure 3: acid hot spring (water sample).

XRD results: XRD results reveal abundant sulfur-bearing minerals in most samples collected from this site, including both sulfate and sulfide phases. Several samples contain abundant ammonium aluminum sulfates. Clays, especially kaolinite, were common throughout the samples. Table 3 shows the minerals present in the samples.

Table 3: XRD results from Gunnuhver. P = Precipitate, S = Soil

	IR1601	IR1602	IR1603	IR1604	IR1605	IR1606	IR1607
	P	P	S	S	S	S	S
Amorph. Silica		X					
Pyrite					X	XXX	
Hematite			XX		XX		
Kaolinite			XXX	XX	XX	XX	XXX
Tschermigite	XXX	XX					
Tamarugite	XXX						
Gypsum	XX	XX					
Rhomboclase	XX						
Boehmite				XXX			
Ammonioalunite		XXX					
Anatase				+			XX
Montmorillonite			X				

Discussion: The mineral assemblage determined by XRD agrees with the Hydrolab results. The rhomboclase present in the precipitate points to an oxidizing environment at the surface. The ammonium aluminum sulfates indicate alteration of volcanic material by sulfuric acid [6]. Altered soil samples indicate more reducing conditions with increasing depth, shown by a greater abundance of pyrite with depth. The abundance of tamarugite, a sodium sulfate, in a surface precipitate samples is potentially consistent with seawater interaction; this mineral is rare at Krýsuvík. The ammonium in tschermigite and ammonioalunite could possibly be related to seawater input as well.

When compared with Krýsuvík, several differences are apparent. While both Gunnuhver and Krýsuvík have oxidizing environments [7], Gunnuhver has formed significantly more clays, unlike Krýsuvík, which has more native sulfur, iron sulfide, amorphous silica, and varied sulfates. Furthermore, the prescence of sodium sulfates and ammonium aluminum sulfates sets Gunnuhver further apart from its neighbor. The seawater input should serve to make the pH of Gunnuhver more basic; its acidity could be due to increased sulfate concentrations.

Mars Comparison: Mars has a wide variety of hydrothermal areas, and the abundance of high-Fe basalts makes Iceland very useful in Martian analogues. With that in mind, Gunnuhver is a unique terrestrial hydrothermal area influenced by seawater. Should one of the rovers, present or future, ever encounter deposits such as these, we would have greater insight as to how they have formed.

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