MINERALOGY OF FUMAROLIC DEPOSITS FROM ICELAND AS ANALOGS FOR ANCIENT HYDROTHERMAL SYSTEMS ON MARS: ROLE OF TEMPERATURE.

M. R. El-Maarry[1], S. R. Black[1], B. M. Hynek[1] , L. J. McHenry[2]. [1]Laboratory for Atmospheric and Space Physics, University of Colorado, 3665 Discovery Drive, CO 80303, USA (Mohamed.el-maarry@lasp.colordao.edu). [2]Department of Geosciences, Univeristy of Wisconsin-Milwaukee

Introduction: Mars has experienced intensive volcanic and impact activities early in its history (more than 3 Gyr ago), which incidentally coincided with similarly extensive hydrologic activity and abundant surface water on a global scale [e.g., 1]. These activities constitute the main ingredients for hydrothermal systems whether they were magmatic-driven, or impact-generated [e.g., 2–6]. There are many mineralogical indicators from orbit, and from rovers on the ground that suggest Mars had ancient hydrothermal systems. On Earth, such systems may harbor certain life-forms, which could potentially indicate that similar systems on early Mars may have offered the habitat and essential ingredients for life. Therefore, a better understanding of analogous hydrothermal systems on Earth is essential for constraining the conditions at ancient Martian systems.

Hydrothermal systems in Iceland provide excellent analogous sites for Mars because of the similar Fe-rich lavas, as well as the prevalent fumarolic settings and acidic conditions [e.g., 7, 8]. These systems create mineral assemblages that have been suggested as analogues for various locations in Meridiani and Gusev, which may have experienced extensive acid-sulfate weathering of basalts under hydrothermal conditions especially in a hot spring or fumarol setting [e.g., 9, 10]. However, it is important to understand the conditions that drive the production of certain alteration assemblages from a given parent material to better constrain the conditions in these ancient environments. To that end, we investigate weathered samples that have been acquired in a recent field trip to Iceland in August 2016 to specifically understand the role of temperature in creating different mineral assemblages.

Study site and methods: Samples were acquired during a field campaign to Iceland in August 2016, which included the Námafjall geothermal field. This field is located in Northeastern Iceland, east of Lake Mytvatn. The area is known for its fumarolic and mud pot settings and highly acidic conditions, and has been a target of recent investigations [e.g. 7, 8, 11, 12]. The main primary rocks in the area encompass late Holocene basalts and older (Pleistocene) altered hyaloclastites.

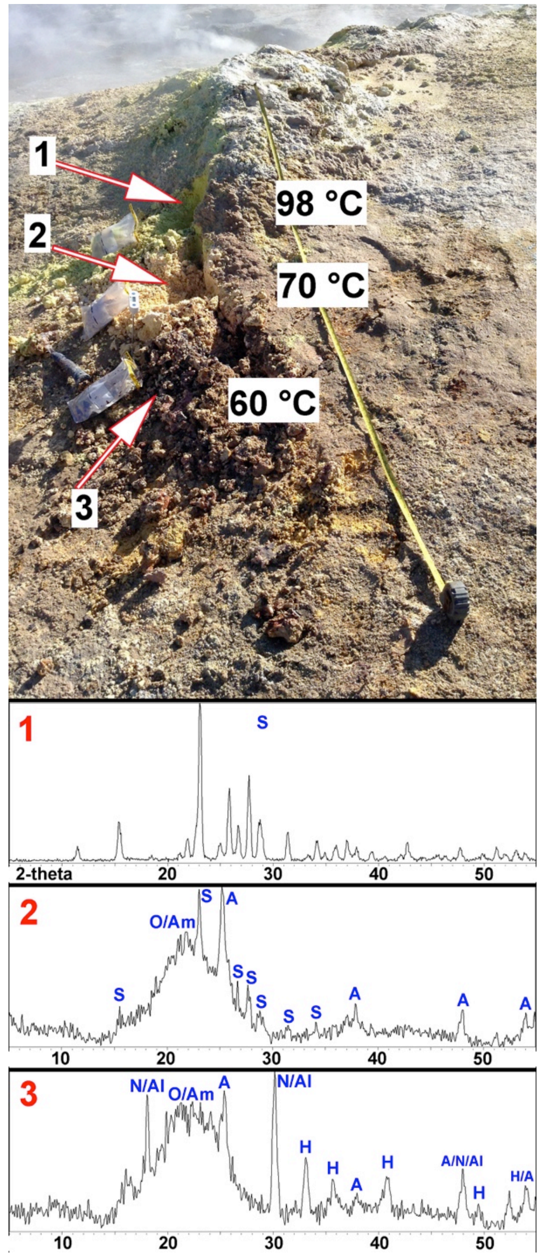

Fig. 1. One of the locations in Námafjall, Iceland, where a series of samples were collected at varied-distances from a fumarole. The arrows mark the samples and their corresponding XRD difractograms are shown below. The letters correspond to sulfur (S), anatase (A), hematite (H), opal/amorphous silica (O/Am), and (natro)-alunite (N/Al).

Common minerals identified in previous studies include kaolinite, smectites (beidellite and nontronite), native sulfur, pyrite, halloysite, calcite, gypsum (mainly as veins cross-cutting the lavas and hyaloclastites), pyrite, anatase, alunogen, rhomboclase, and zeolites in addition to amorphous silica [13–15, 8, 11]. Fumaroles in the area are generally structurally controlled, and a number of them were investigated. Samples were acquired with increasing distance from the fumaroles to better understand the influence of temperature on the resulting alteration phases. The samples were transported back to the lab, dried, and their XRD and VNIR properties were measured using the TerraSpec 4 high resolution reflectance spectrometer from ASD Inc., and the Terra field-portable X-Ray Diffraction spectrometer from Olympus, which are considered as analog instruments to OMEGA and CRISM, the orbital spectrometers, and the CheMin instrument on MSL, respectively.

Results: Fig. 1 shows the results from one of the investigated sites. The three samples were acquired ~40, 85, and 120 cm from the fumarole pit. Sample 1 (Fig. 1) is dominated by native sulfur and a minor (~10%) component of amorphous materials. Sample 2 still shows a significant amount of native sulfur (~60%) along with anatase and opaline/amorphous silica. Sample 3 displays higher variety due to the lower ambient temperature and is mainly dominated by iron oxides (hematite), anatase, (natro-)/alunite, and opaline/amorphous silica. A second sequence of samples at another fumarole nearby (~15 m-away) ~18, 80, and 125 cm from the pit corresponding to local temperatures of ~90, 70, and 30 °C, respectively, displays native sulfur and alunite in the first zone, and kaolinite, anatase, alunite and amorphous silica in the second. The third zone is more noisy in the XRD but is indicative of amorphous silica and kaolinite.

VNIR spectra (Fig. 2) for the presented samples are mostly consistent with the XRD data, but additionally indicate the presence of opal in most samples and indicate the presence of hematite in the third outer zone of the second sample, just like the one shown in Fig. 1, which is ambiguous at best in the XRD data. The lack of signatures for pyrite and smectites, commonly identified minerals in the area, could be attributed to highly oxidizing conditions near the surface where the samples were taken, and high acidic conditions, respectively (no direct pH measuremnts are available but a stream a few meters away from the samples had a pH of <2). We plan to continue our analysis by looking at additional samples and investigating them further with SEM to better understand their alteration history.

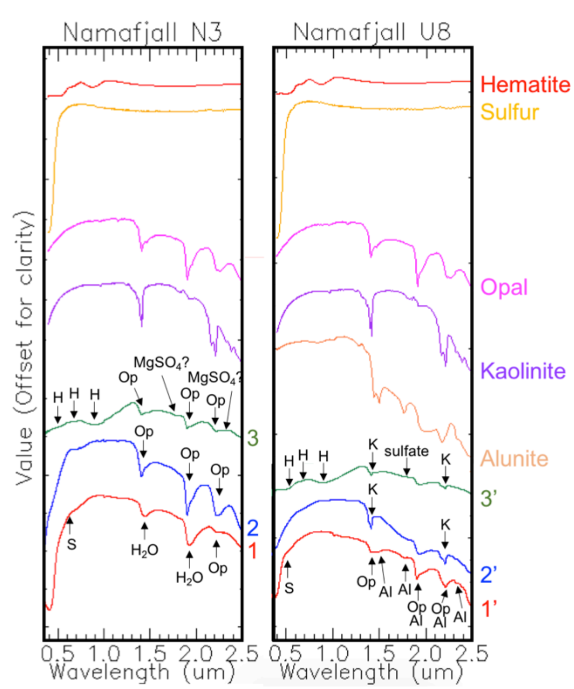

Fig. 2. VNIR spectra for the fumarole shown in Fig. 1 (left) and another fumarole ~15 m-away (right). The letters correspond to sulfur (S), opal (Op), hematite (H), kaolinite (K), and alunite (Al).

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