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The Azorean fumarolic fields as an analog for Mars hydrothermal alteration

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1. Introduction

Hydrothermal environments have long been presumed to exist on Mars based on orbital detections of hydrated minerals, terrestrial analogs studies, and Martian meteorites analyses (e.g., [1] and references therein). The first definitive evidence for volcanic hydrothermalism on Mars is the in situ detection of amorphous silica-rich outcrops (>90% wt opal-A) by the Mars Exploration Rover Spirit, which have been tentatively interpreted as either acid sulfate leaching in fumarolic environments or direct precipitation from hot springs [1,2]. Such hydrothermal spots may have created suitable environments for life and should be a prime target in the search for biosignatures on Mars. The present project focuses on the alteration at the fumarolic fields of the Azorean islands, Portugal, as an analog to some early Martian environments.

2. Geologic Context

The nine Azorean Islands located in the Atlantic Ocean at the triple junction of the Eurasian, North American and Nubian tectonic plates, are thought to originate from the combination of the mid-oceanic ridge activity and a hotspot. They are characterized by the occurrence of frequent seismic activity and volcanic eruptions [3]. In addition to fissural volcanism, large polygenetic volcanoes are also present and sometimes display fumarolic and hydrothermal activity in their calderas and/or along their flanks [4]. Volcanoes and lava flows in the Azores have basaltic to trachytic compositions, which are roughly similar to the Martian surface composition [5,6] (Table 1). Three hydrothermal fumarolic fields emitting various gas species at Furnas Volcano on São Miguel Island (two sites: village and lake) and at Pico Alto Volcano, on Terceira Island, were visited in September 2017. Several fumarolic emissions (Figure 1) and relatively pristine outcrops were sampled for gases, biomaterials, rocks and water (when available) at each site. Bedrock at Pico Alto is made of peri-alkaline lavas (comendites), and is characterized by the presence of riebeckite. Its composition slightly differs from the Furnas Volcano bedrock (Table 1), which is less crystalline and shows traces of phlogopite. Bedrock samples at Furnas are also more porous and show pumice textures. Gas compositions were typical of hydrothermal environments and were found to be roughly similar between the various vents within the same volcano and on the different islands; fumarole temperatures range between 97 and 100 °C. Gas emissions include H_2O and CO_2 as major components with H_2S, H_2, CH_4, CO, Ar, O_2 and N_2 as minor species [7,8]. Water ponds which are present at Furnas, however, show a wide range of temperatures, pH (from 2 to 8) and compositions.

Table 1: Bedrock samples bulk composition at Pico Alto (lava) and Furnas (pumice) volcanoes.

(wt %)	Pico Alto	Furnas
SiO_2	63.94	60.88
Al_2O_3	10.99	16.58
Fe_2O_3	9.14	3.86
MnO	0.27	0.26
MgO	0.18	0.32
CaO	0.46	0.74
Na_2O	6.54	7.74
K_2O	4.32	5.49
TiO_2	0.56	0.46
Total major oxides	98.75	98.42
S	0.02	0.01

Figure 1: Fumarolic vents at Pico Alto (left) and Furnas (right) Volcanoes.

3. Alteration Patterns

Characterization of the collected rock samples performed by in situ VNIR spectroscopy (ASDinc TerraSpec 4), and laboratory XRD and ICP-OES analyses revealed a variety of mineralogical assemblages and alteration patterns on the two islands (Figure 1). At Pico Alto, alteration products include alunite - jarosite, kaolinite, montmorillonite, amorphous silica and hematite, which is responsible for the reddish color of the site. At Furnas, mineralogical assemblages around vents are dominated by aluminum hydroxy-sulfates such as alunite, alunogen, and alum-K, associated to traces of goldichite and copiapite. Mudpots are dominated by amorphous silica. Walls at a distance show surficial alteration into alunite (characterized by yellow tones) and minor jarosite (orange tones). Similar observations were made at two distinct sites, located within Furnas village and at Furnas lake. Clays were not detected at Furnas. Although VNIR spectroscopy is more sensitive to the presence of coatings, its results are in accordance with XRD analyses.

4. Discussion and Perspectives

Despite roughly similar fluid compositions and temperatures, various mineralogical assemblages are observed at Pico Alto and Furnas. Whereas Pico Alto shows the presence of Al-rich clays and hematite, Furnas Volcano is dominated by amorphous silica and sulfates. Both assemblages are observed on Mars, where various hydrated minerals have been detected; however their context is often difficult to infer (e.g., [9,10]). Subtle differences in bedrock compositions are observed, but the bedrock texture and porosity (lava versus pumice) and the surface proximity of the water table could also explain the differences in the resulting alteration patterns. Understanding the context of formation of those alteration minerals and cataloging their occurrences is key to reconstructing Mars paleo-environments; and the first step towards sample-return and astrobiology missions. Future work also includes both defining the microbial communities present at the different vents and hot springs and isolating and characterizing novel thermophilic microbes in the Azores.

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