FROM GEITAFELL VOLCANO (ICELAND) TO MARS: HYDROTHERMAL ALTERTION OF BASALT TO CONSTRAIN SUBSURFACE FLUID PATHWAYS. J. Semprich, AstrobiologyOU, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK (julia.semprich@open.ac.uk)

Introduction: Hydrothermal systems have the potential to be habitable environments for microbial life in the martian subsurface since they provide suitable temperatures, nutrients and are protected from surface radiation [e.g., 1-3]. Characteristic minerals that are associated with hydrothermal alteration such as prehnite, chlorite, and zeolites have been detected on Mars' surface by visible- to near-infrared spectroscopy from orbit [4-7]. However, their formation conditions such as the amount and composition of hydrothermal fluids and the spatial distribution of alteration minerals remain unknown. This study uses an extinct volcanic hydrothermal system in Iceland as an analog to constrain the mineral and fluid chemistry as well as the extent of hydrothermal alteration. The results will then be combined with geochemical models of hydrothermal alteration and low-grade metamorphism on Mars [e.g., 8-10] to improve our understanding of subsurface fluid-rich environments.

Geology: The Geitafell central volcano, near Hoffell in south-east Iceland is an ideal analog for Mars since it consists primarily of tholeiitic lavas and hyaloclastites with minor rhyolites and intrusive rocks including gabbros [11]. These volcanic units have been exposed to hydrothermal alteration resulting in the precipitation of minerals ranging from zeolite- to greenschist-facies. The high-temperature hydrothermal activity was divided into several major index mineral zones [11]: an epidote zone (~230-300 °C) as well as andradite and actinolite zones (>300 °C). The peak temperature conditions were followed by lower temperature hydrothermal activity. The long lasting hydrothermal activity at varying temperatures resulted in the precipitation of zeolites including laumontite, stilbite, heulandite, and wairakite, prehnite, chlorite, quartz, calcite, celadonite, epidote, talc, actinolite, andradite, and minor amounts of sulfides including pyrite and chalcopyrite. Replacement textures and pseudomorphs indicate a range of hydration, carbonation, oxidation, sulfidization, dehydration, and decarbonation reactions, suggesting variations in fH_2O, fCO_2, fO_2, and fS_2 [11]. A study of fluid inclusions in quartz and calcite from the high-temperature hydrothermal zones determined low salinity for most fluids and temperatures between 255 and 320 °C during the phase of main hydrothermal activity [12].

Figure 1: Large-scale hydrothermal vein system at the contact zone between hyaloclastite and a basaltic dike, Geitafell central volcano. Hammer for scale

Figure 2: Small-scale hydrothermal veins in basaltic host rocks, Geitafell central volcano.

Field work and observations: The main objective of the field work was the sampling of alteration mineralogy, which was observed in large-scale vein systems (Fig. 1), smaller scale hydrothermal veins (Fig. 2), as well as in microscale veining and as vesicle fillings. Samples were collected from all index zones but predominantly of alteration minerals such as zeolites (Fig. 3), prehnite, and calcite that are particularly sensitive to changes in CO_2 and therefore relevant to martian environments.

Discussion: A detailed study of mineral textures and chemistry will be used to distinguish different mineral reactions and hydrothermal events recorded in the samples. These results will then be compared to and integrated into Mars models of low-grade metamorphic phases (Fig. 4) since they will provide important constraints for the alteration mineralogy and identification of fluid pathways not yet otherwise accessible. Fig. 4 shows that small changes of CO_2 in the fluid can change the mineral assemblage from actinolite + zeolites (stilbite and laumontite) + pumpellyite /prehnite to an a assemblage dominated by chlorite, quartz and calcite.

Figure 3: Sample of a basal dike with alteration surface of zeolites and sulfides and secondary alteration of hematite/goethite

Acknowledgements: This study is based on field work funded by. Europlanet 2024RI (under the grant agreement No 871149). Profound thanks go to Geoff Austin for his invaluable assistance in the field at exceptionally short notice.

References: [1] Schulze-Makuch D. et. al. (2007) Icarus, 189, 308-324. [2] Westall F. et al. (2013) *Astrobiology, 13*, 887-897. [3] Osinski G.R. et al. (2013) *Icarus, 224*, 347-363. [4] Ehlmann B.L. et al. (2011) *Clays and Clay Minerals, 59*, 359-377. [5] Carter J. et al. (2013) *JGR, 118*, 831-858. [6] Viviano C.E. et al. (2013) *JGR, 118*, 1858-1872. [7] Ehlmann B.L. and Edwards C.S. (2014) *Ann Rev Earth Planet Sci, 42*, 291-315. [8] Schwenzer S.P. and Kring D.A. (2013), *Icarus, 226*, 487-496. [9] Semprich J. et al. (2019) *JGR, 124*, 681-702. [10] Semprich J. et al. (2022) *MaPS, 57*, 77-104. [11] Friðleifsson G.O. (1983) The Geology and the Alteration History of the Geitafell Central Volcano, Southeast Iceland. PhD thesis. [12] Liotta D. et al. (2020) *J Volcan Geotherm Res, 391*, 106502. [13] Zipfel J. et al. (2011) MaPS, 46, 1-20. [14] Semprich J. et al. (2019) 50th LPSC, Abstract #1437.

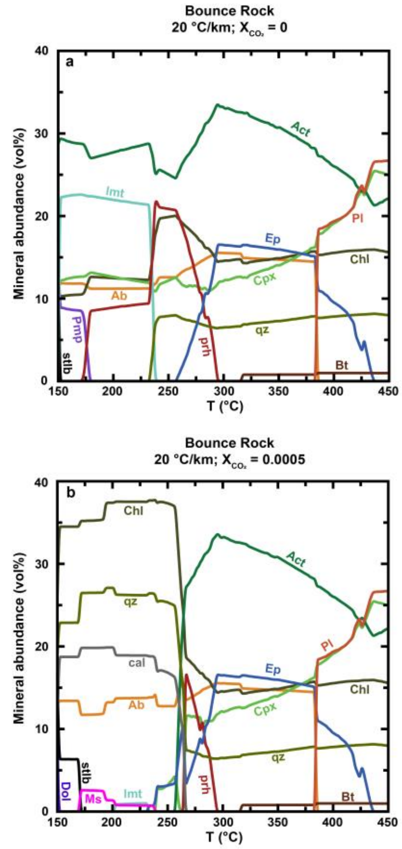

Figure 4: Mineral abundances (vol%) of metamorphic phases on a 20 °C/km geotherm for the composition of Bounce Rock [13] at fluid-saturated conditions with XCO_2 of 0 (a) and 0.0005 (b). Modified after [14]. Mineral abbreviations: Ab = albite; Act = actinolite; Bt = biotite; Chl =chlorite; Cpx = clinopyroxene; cal = calcite; Dol = dolomite; Ep = epidote; lmt = laumontite; Ms = muscovite; Pl = plagioclase; Pmp = pumpellyite; prh = prehnite; qz = quartz; stlb = stilbite.