Hydrothermal alteration of phosphorus-rich basaltic glass: A potential source of phosphates on Mars and Enceladus

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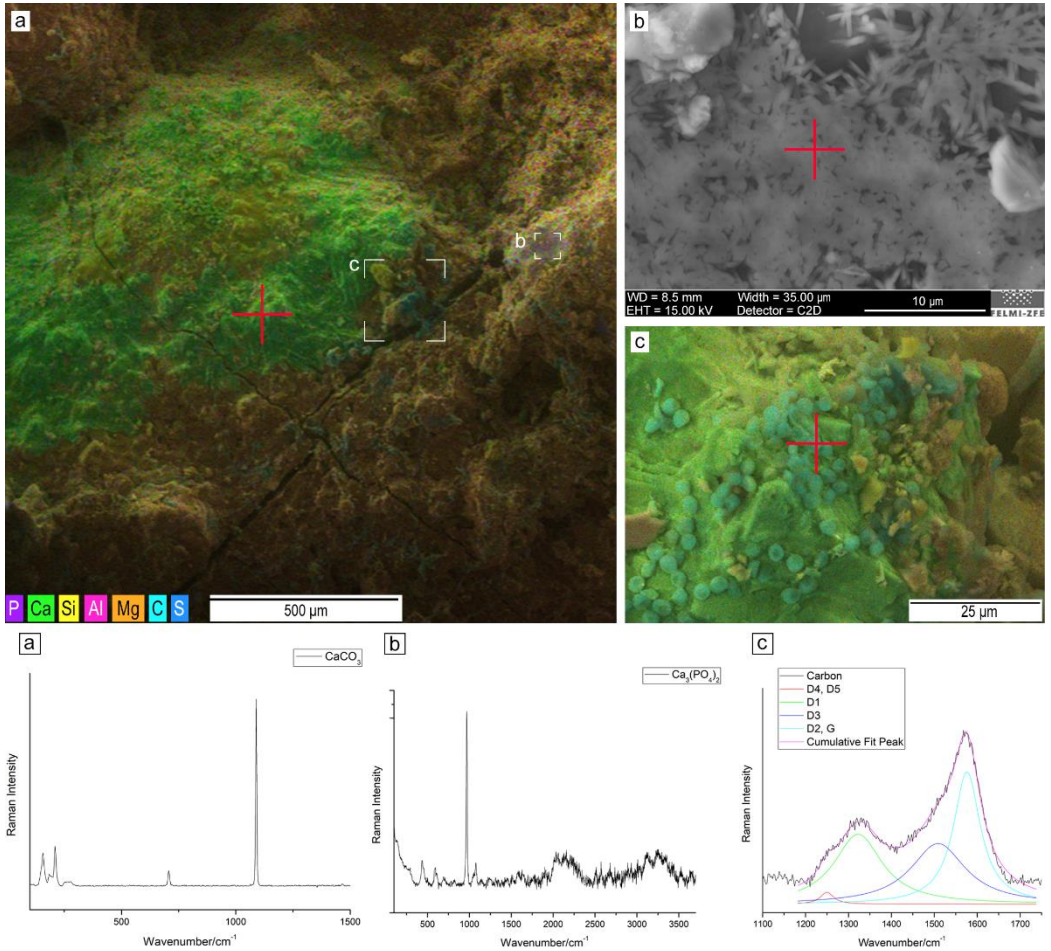

Figure. (a) The EDX map shows the distribution of calcium (green), phosphorous (purple) and carbonaceous (light blue) minerals. (b) SE image and Raman spectrum of tricalcium phosphate. (c) SE image and Raman spectrum of microbial shaped carbon. Red crosses refer to the acquisition point of Raman measurement in SE image.

On the Antarctic Deception Island, Cerro Caliente stands out for the band of geothermal alteration crowning its summit. Located on the shores of Irizar Lake, opposite the Argentina scientific base, it has attracted the attention of the astrobiological community as an analogue of Martian glaciovolcanic environments. At this site, the secondary hydrothermal mineralogy composed of palagonite, carbonate, phyllosilicates and zeolites, along with geochemical signatures derived from the hydrothermal alteration of basaltic glassy tuff by hot CO_2-rich fluids, provide valuable clues about the habitability potential of similar environments that may have developed on Mars. Furthermore, the hypothetical content of basaltic glass within the unconsolidated silicate cores of ocean worlds opens up the possibility to extending this analogy to Enceladus. We characterised the hydrothermal system of Cerro Caliente by describing the secondary mineral assemblages and tracking the chemical mobility through the analysis of three drill-core samples dug from the central part of alteration band (CCBH2), and from adjacent permafrost-affected areas (CCBH3 and CCBH4).

Geochemical analysis showed that basaltic tuff was primarily rich in phosphorus, and that hydrothermal alteration through palagonitization favoured the release of elements essential for life in sample CCBH2. In contrast, in samples CCBH3 and CCBH4, permafrost conditions reduced permeability, limiting hydrothermal activity. Electron microscope images of CCBH2 were particularly revealing. Although phosphorus appeared to be as immobile element, we identified tricalcium phosphate needle-like crystals, suggesting that phosphorus was released by the hydrothermal activity into the biogeochemical cycle and subsequently sequestered as phosphate under alkaline conditions. Therefore, the chemical exchanges occurring at Cerro Caliente provide an alternative hypothesis to explain the origin of phosphate grains detected in Enceladus´ plumes. In addition, Raman spectroscopy identified carbonate as aragonite, with a spectral signature indicating the sorption of organic matter. This is consisted with the presence of coccus-like objects observed on its surface, whose Raman spectra corresponded to carbonaceous material. Lipid biomarker analysis further supported this interpretation, indicating active bacterial processes in the central part of the alteration band.

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