

IMPACT-REACTIVATION OF A HYDROTHERMAL SYSTEM AT VARGEÃO DOME, BRAZIL

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Introduction: Impact-generated hydrothermal systems (IGHS) are a widely available potential habitat for early life on Mars [1,2]. Analog impact structures in basaltic target terrain on Earth can provide a better understanding of the thermochemical evolution and potential for life within these systems [3,4]. Out of the four impact structures on Earth in dominantly basaltic target terrain, the Vargeão Dome in Southern Brazil is of particular interest, because of its exposure and abundance of hydrothermally altered material [4–6].

This study focuses on the evolution of two vein-forming hydrothermal alteration stages [5] within Vargeão Dome. Each stage is studied in detail using optical microscopy, scanning-electron microscopy, Raman spectroscopy, and thermodynamic modelling. Impact-features and textural relationships are used to separate pre-impact from impact-related alteration, and ultimately draw conclusions on the viability of these systems on Mars.

Methods: Samples were systematically collected throughout the Vargeão Dome impact structure, prepared into standard, 30 µm thin sections, studied optically, carbon-coated, and analyzed using a JEOL JCM-6000 benchtop SEM. Subsequently, Raman spectroscopy was performed using a Nd:YAG 532 nm laser and a Renishaw InVia Spectrometer. Thermodynamic reaction path modelling was performed using PHREEQC to obtain limits on the thermochemical stability of each of the minerals in the hydrothermal alteration sequence.

Results: The presence of two types of veins was confirmed in Vargeão Dome: white and red veins. White veins consist mainly of quartz, with anhydrite inclusions and/or chabazite and celadonite. They locally include other zeolites (heulandite, stellerite, erionite, and gismondine). Within the white veins, possible planar deformation features and Mn-rich shatter cone deposits [7] occur. Red veins show more variation, but always contain mineral fragments within either newly deposited oxides, or a fine-grained oxide-rich matrix. The fragments consist mainly of pyroxene and plagioclase, as found in the host basalt, as well as chabazite and quartz as found in the white veins. Oxides in the matrix consist of hematite and goethite, in roughly equal amounts. Red veins appear to be superimposed upon white veins since, in places, they cannibalize the pathway of white veins (Fig. 1). Thermodynamic models indicate temperatures up to ~ 120°C for the white veins, whereas goethite in the red veins indicates temperatures <40°C.

Discussion: Shatter cone deposits and planar deformation features in white veins place the related hydrothermal event before the impact. Red veins may have resulted from impact-induced friction on pre-existing fault planes, which would explain that red veins cut into white veins, as well as the occurrence of chabazite- and quartz fragments within red veins. Goethite in combination with hematite indicates that considerable post-impact hydrothermal activity took place at temperatures <40°C, implying a limited temperature-increase that could largely be explained through an uplifted geotherm related to the ~1 km uplift experienced in the centre of the structure. If similar processes occur on Mars, there is potential for (re-)flourishing of life in craters with a pre-existing hydrothermal system and a >20 km diameter (comparable to a ~10 km-sized crater on Earth [2]), needed to achieve a sufficient temperature increase.

Conclusion: Red veins with mineral fragments in Vargeão Dome have likely been formed through impact-related reactivation of a fossil hydrothermal system present as white veins. However, the temperature increase in the impact-generated hydrothermal system was likely limited, implying that for Mars, increased potential for life is only found in impact craters larger than ~20 km diameter containing a pre-impact fossil hydrothermal system.

References:

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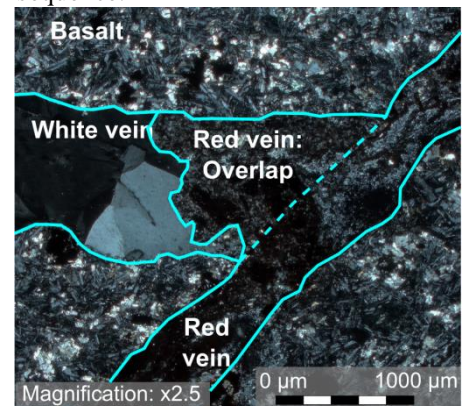


Fig. 1 Photomicrograph (XPL) showing the vein relation between white and red veins. Red veins are not straight, but instead are superimposed upon other veins