

GEOCHEMISTRY AND MINERALOGY OF CERRO CALIENTE BASALTIC TUFF (ANTARTICA) AFFECTED BY PALAGONITIZATION AND CO₂-RICH FLUIDS AS PLANETARY ANALOGS.

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Introduction: Habitability evaluation of terrestrial bodies as well as biosignature searching includes the understanding of biogeochemical cycles in which the study of analogue environments on Earth become an important working tool. Understand the characteristics of biogeochemical cycles as a whole on terrestrial analogues helps us to determine environmental conditions and constraint the effect they have on nutrient availability. Antarctic environments, where volcanism and glacial activity coexist, are categorized as Mars and Europa analogue sites [1-2].

Here we proposed the Cerro Caliente hill (Deception Island, Antarctica) as a geochemical/mineralogical functional analogue [3] of Mars considering the remote and in situ spectroscopic observations [4]. Recently, it was suggested as terrestrial analogue to Mars due to for the extremophiles detection and related biomarker identification [5]. Indeed, biology in the Cerro Caliente is conditioned by the temperature and circulating fluids within the volcanic rocks, as can be seen in the distribution of the unique microphyte associated to the geothermal activity, which presence categorized the hill as an Antarctic Specially Protected Area (ASP).

Cerro Caliente hill is located in the volcanic active Deception Island, on the shore of Port Foster bay, the sea-flooded part of the island's central collapse caldera. The caldera-forming event [6], which dominates the evolution of the island, has been dated at c. 8,300 years, according to paleomagnetic data [7], and $3,980 \pm 125$ calibrated years Before Present (cal yr BP) based on tephrochronology, sedimentological studies and ¹⁴C dating [8]. Post-caldera eruptive vents have been mostly circumscribed to the caldera rim periphery [9] and a hydrothermal system was established in the Port Foster area [10]. Since then, Cerro Caliente remains as a geothermal anomaly zone with fumarolic activity [11-12].

A hydrothermal alteration band crosses the summit of Cerro Caliente forming hot grounds. Hot CO₂-rich fluids (≤ 100 °C) emerge through a 40 m long fracture, altering lapilli tuff deposits of the Pendulum Cove Formation formed during the last eruptive event of the island [9, 13].

The aim of the research is to study the hydrothermal system of Cerro Caliente to understand planetary geochemical cycles.

Methodology: We analyzed the mineralogy and geochemistry of three 1-2 long-meter drill cores performed at the top of the hill at different thermal regimes: CCBH2 drill core in the central part of the alteration band; CCBH3 and CCBH4, adjacent to this band, but this last one affected by permafrost. The understanding of the interactions between hydrothermalism and cold environments of Cerro Caliente, and their effects over the biogeochemical cycles enable to draw lessons which may be applicable to the environments of Mars and other low-temperature environments.

Petrological and geochemical characterization of these drill cores were carried out by Raman and IR spectroscopy, petrographic microscopy, X-ray diffraction, and ICP-MS. In addition, we performed a geochemical mobility study [14] so as to identify which elements were leached or are enriched in the samples by hydrothermal activity. For this study, elements were classified according to their biological functionality defined in the Astrobiological Periodic Table [15]. The relevance of studying gradients of alteration in different cores in vertical and horizontal directions lies in: a) characterizing mineral assemblages for identification of analog planetary paleoenvironments that could have been influenced by hydrothermal CO₂-H₂O fluids; and b) defining the profile of cationic mobilization in order to evaluate its potential as ecological niche.

Results: The geochemical and mineralogical results are summarized on Table 1. In CCBH2 composition of andesitic basaltic lapilli tuffs have been modified by palagonitization, carbonation and hydration processes. The intensity of alteration is discontinuous along the profile of CCBH2 borehole and decreases transversely from the fracture zone (CCBH2 > CCBH3 > CCBH4). Geochemically, CCBH3 is slightly depleted in SiO₂, Na₂O, K₂O and MgO compared to CCBH4. However, this loss is greater in CCBH2 and increases progressively towards the top of borehole.

Astrobiological implications: The volcanic environment with hydrothermal activity of Cerro

Caliente might have been developed in an analog way on early Mars, based on the high number of pyroclastic deposits with basaltic composition [16] and the suggestion of a globalized low-temperature palagonitization [17]. This hydrothermal condition demands high water/rock ratio, and could be present, for instance, in a cold and icy Late Noachian Mars based on the identification of the palagonite assemblage in the Sisyphi Montes [18]. Cerro Caliente case serve as model for identification of mineral assemblages formed as a result of hydrothermal alteration by palagonitization, and calcite impregnation from CO₂-rich fluids. Thus, a mineral assemblage composed of Fe-Mg smectites, such as nontronite and saponite, zeolites and palagonite could be interpreted as a Martian geomarker for the in situ alteration of pyroclastic fall deposits.

Geochemically, it is found that most of the elements that are depleted in CCBH2 have a functional role for life, for example, some of these metals are biological catalyst [19]. Hydrothermal alteration generates a geochemical disequilibrium, becoming a source of chemical energy [20] and essential elements for life. In addition, it constitutes the entrance via for elements to biogeochemical cycles. However, its potential character with regards to habitability would be restricted to distribution and magnitude (type and intensity) of alteration and physical properties of rock.

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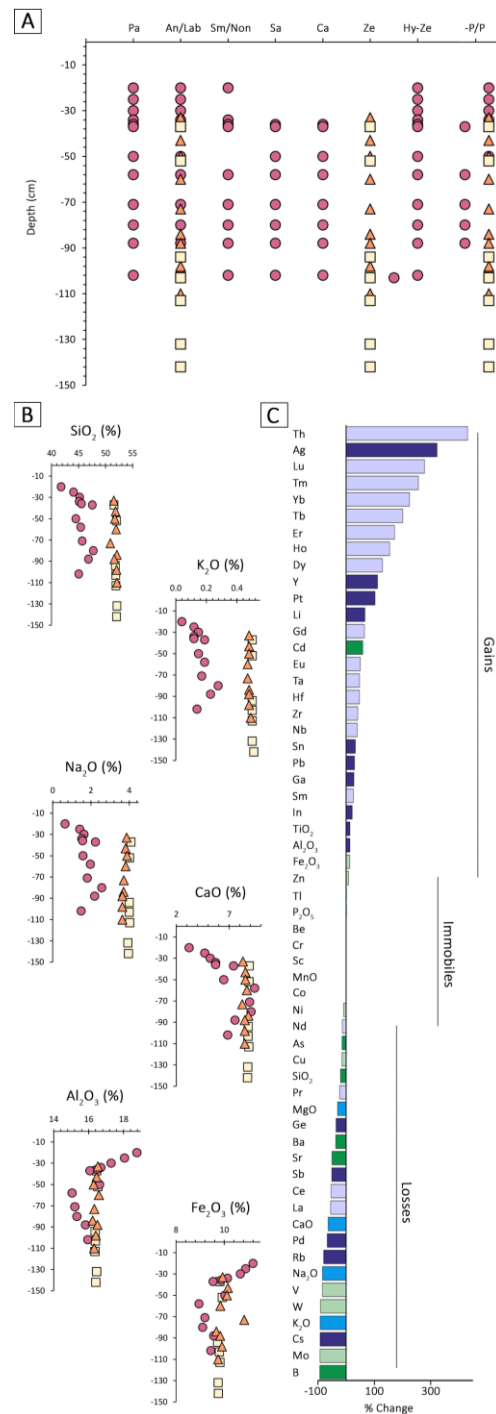


Table 1. A) Summary of minerals identified in samples of CCBH2 (circles), CCBH3 (triangles) and CCBH4 (squares): palagonite (Pa), andesine/labradorite (An/Lab), other smectite or nontronite (Sm/Non), saponite (Sa), calcite (Ca), zeolites (Ze), hydrated zeolites (Hy-Ze), loss porosity (-P) regarding porosity (P) observed in CCBH4. B) Depth profiles of element oxide contents. C) Chemical changes of altered rock CCBH2 at the 20 cm depth compared to the least altered rock CCBH4. Colors denote the biological use of elements defined in the Astrobiological Periodic Table.