EPSC Abstracts
Vol. 8, EPSC2013-652, 2013
European Planetary Science Congress 2013

Evidences of hydrothermal processes from phyllosilicates and carbonates assemblages in Martian crustal outcrops.

B. Bultel(1), C. Quantin(1), M. Andreani(1), and H. Clenet(1,2).
(1) Laboratoire de Géologie de Lyon (Laboratoire de Géologie de Lyon, Bâtiment Géode 2 Rue Raphael DUBOIS 69622 VILLEURBANNE CEDEX. (2) École Polytechnique Fédérale de Lausanne. benjamin.bultel@univ-lyon1.fr, cathy.quantin-nataf@univ-lyon1.fr.

Abstract

Evidence for putative hydrothermal processes of the Martian crust is one of the most important inputs from recent observations as regard to life emergence on the red planet. The present paper documented hypothermal induced minerals detected in crustal outcrops between Hellas and Isidis basins. The results reveal high temperature CO_2 rich fluid interactions with rocks before 3.75Gy inside the Martian crust.

1. Introduction

Previous detections of putative hydrothermal phases lie in crustal outcrops such as deep canyon [i.e. 1, 2] or deep impact crater [i.e. 3]. The deepest crust and/or the early crust of Mars possibly experience hydrothermalism processes [4]. The Fe/Mg smectite are the most frequent phases, others detections are smectites, micaceous phases, chlorites and more sporadically serpentine and carbonates [5, 6]

As we suspect that the early crust of Mars is ultramafic and that the early atmosphere may have been rich in CO_2 [7, 8], serpentinization and carbonation are suspect to be more ubiquitous [9, 10, 11] than the few detections of serpentine and carbonates reported for now.

We perform a systematic analysis of the crustal outcrops imaged by CRISM targeted between Hellas and Isidis basins. We used a new method to remove CRISM noise and to automatically highlight the carbonates, chlorites and serpentines in a CRISM data cube. Our results in term of mineralogical assemblage as well as geographic distribution, outcrop exposure age and crustal cross section raise a discussion about the high temperature water-rock interactions in these parts of the Martian crust.

2. Data and Method

CRISM data are pre-processed with the CRISM Analysis Toolkit (CAT) [12] for correction from the photometric angle, the atmosphere contribution and the noise (spatial stripes and spectral spikes). Despite these processing, the noise as well as the atmospheric contribution is not completely removed. We so develop a personal pipeline to remove noise of CRISM data combining mobile average, mobile median and sharpening-median filters [13]. Our pre-process also includes a ratio of each spectra of the CRISM cube by an average spectrum of the cube to remove the residual contribution of the atmosphere and the average dust contribution.

In first approximation, the discrimination between phyllosilicates and carbonates can be made by investigate the combinations of absorptions in the the 2.3-2.5 μm domain [14, 15]. We develop a statistical tool running under IDL language to detect if there is any absorption around 2.3 μm and 2.5 μm, to remove the continuum, to determine the center of the absorption and to count the number of pixel for each possible combination. An example is presented in figure 1. Detail of this method is presented in [13].

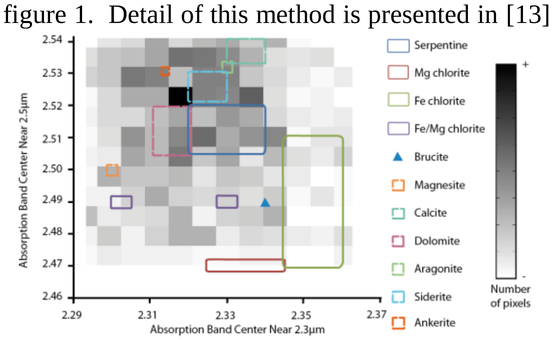

Figure 1: Example of a pixel count with a combination of absorption centered near 2.3 and near 2.5μm in a single data cube. Location phyllosilicates and carbonates from library are from [14, 16, 17, 18]. The gray scale represents the number of pixels.

3. Result

In 27 of the studied CRISM cubes, we detected the following mineral species: smectites, chlorites, serpentines and carbonates. Example of these four groups of alteration minerals is shown in figure 2.

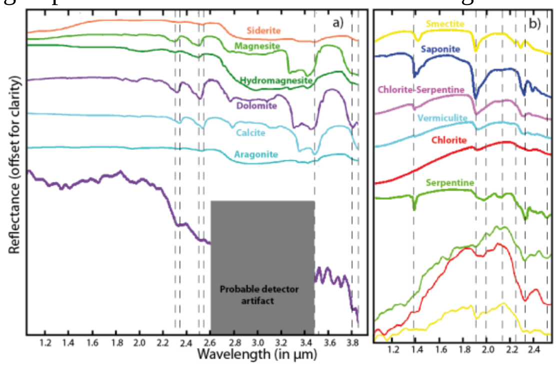

Figure 2: a) Spectra of carbonates from RELAB library in the upper part; spectra identified as dolomite from CRISM data. b) Spectra of phyllosilicates from RELAB library in the upper part; spectra identified as serpentine (green), chlorite (red) and smectite (yellow) from CRISM data.

We especially pay attention to the mineralogical assemblages. As presented in figure 1, these different groups of alteration minerals are observed in same data cube and some time in same outcrop. The figure 1 for instance highlights the presence of serpentine, dolomite and siderite. In the whole area, we identify the following assemblages: chlorite-carbonates (10 cubes), chlorite-serpentine (7 cubes), chlorite-serpentine-carbonates (6 cubes) and smectite-chlorite-serpentine-carbonates (4 cubes).

We then generate a database of the detected mineral assemblage and their observation context. All the detections lie in impact crater contexts where rocks have been exhumed from depth (ejectas, uplifted ramparts and central peak). We analyze the mineralogical assemblages according to the diameter of the impact crater. Assuming that the hydrated minerals predate the impact craters, we also analyze the distribution of the assemblage according to the pre-impact depth of the exposed rocks. It seems that a relationship exists with the pre-impact depth: assemblages with smectite are restricted to the upper part of the crust while assemblages with carbonates, serpentine and chlorite are more widely distributed in the crustal cross section.

We also determine the ages of the studied impact craters using the small crater population and crater counting techniques [19]. The ages of the studied craters range from 500 My to 3.75 Gy. There is no obvious relationship between the ages of the crater and the exposed mineralogy.

4. Discussion

Our results on impact crater raise a discussion about the origin of the alteration: it is either due to impact-induced hydrothermal process [20] or the alteration predates the impact. The lack of correlation between the observed assemblages and the age the outcrop as well as the presence of alteration phases in the ejectas argues for an older and exhumed alteration. In such case, the alteration is older than 3.75Gy, the age of our oldest impact. Our results are so new elements to better constrain the environmental conditions of the early Martian crust such as the amount of water and/or the gradient of pressure and temperature. Serpentinization and carbonation, suggested by the assemblages reported here, would be an evidence of low water/rock ratio and high temperature fluid/rocks interactions in presence of CO_2. These environments are extremely favorable for life emergence.

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Acknowledgements

The research leading to these results has received funding from the European Research Council under the European Union's Seventh Framework Program (FP7/2007-2013)/ERC Grant agreement n° 280168.