

**NOACHIAN CRUST COMPOSITION AND EARLY ALTERATION PROCESSES IN THE VICINITY OF VALLES MARINERIS AS SEEN FROM THE CENTRAL PEAKS OF IMPACT CRATERS.** H. Clenet<sup>1</sup>, C. Quantin<sup>1</sup>, M. Andreani<sup>1</sup>, X. Ceamanos<sup>2</sup>, P. Allemand<sup>1</sup> and P. C. Pinet<sup>3</sup>, <sup>1</sup>Laboratoire de Géologie de Lyon, UMR CNRS 5276, Université Claude Bernard/Ecole Normale Supérieure de Lyon, France; <sup>2</sup>IPAG, UMR CNRS 5274, Université Joseph Fourier, France; <sup>3</sup>IRAP, UMR CNRS 5277, Observatoire Midi-Pyrénées, Université Paul Sabatier, France. (harold.clenet@univ-lyon1.fr).

**Introduction:** Mineralogical composition is essential to further comprehend planetary evolution. As it is linked to mantle properties and crystallization conditions, the chemical composition of each mineral in the primitive crust is related to the igneous processes which have affected the planet. In this respect, detection of mafic minerals and characterization of their respective composition is used to evidence petrological history.

In the present work, we chose to focus on large impact craters central peaks that excavate material from depth [1]. Those rocks are indeed enriched in low-calcium pyroxenes and may represent exposures of Noachian crust [2]. Pyroxenes chemistry give us clues on the crystallization conditions which have existed in the vicinity of Valles Marineris during the first billion years of Mars history.

In a second time, interactions with water have altered those primitive rocks. Resulting mineral assemblages depends on primary composition and on past environmental conditions. Integrated studies including both igneous and aqueous aspects are required to constraint environmental conditions which have prevailed during the early Mars period. Minerals detected in this study could also indicate favourable conditions for past habitability.

**Methodology:** Because of the Fe<sup>2+</sup> electronic transition effect, hyperspectral remote sensing in visible/near-infrared delivers very useful information for characterizing the petrology of igneous rocks. Olivine, orthopyroxene and clinopyroxene have diagnostic absorptions in the 1 $\mu$ m and 2 $\mu$ m wavelength domains and position of their minima are function of the Fe and Ca content [3,4]. In the case of hydrated minerals, vibrational absorption features related to H<sub>2</sub>O and OH are used to identify the different species (e.g. [5]). Overtone shifts can also be observed depending on the mineral chemistry.

Data used in this study were acquired by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) onboard the Mars Reconnaissance Orbiter (MRO) spacecraft. CRISM observations provide visible and near-infrared (VNIR) spectral coverage (0.32–3.92) with a maximum spatial resolution of ~18 m/pixel [6]. CRISM observations were processed as described in [7] to account for atmospheric and photo-

metric contributions. If needed, noise was removed using the despiking and destripping algorithms available under CAT 6.7 for TRR3 datasets [8]. Visible and near-infrared channels were also coregistered in order to use the entire available spectral domain.

To deconvolve hyperspectral data in terms of mafic compositions, we use the Modified Gaussian Model (MGM) originally developed by *Sunshine et al.* [9] and adapted by *Clenet et al.* [10]. An automatic procedure involving different numbers of gaussians, depending on the potential complexity of the mixture, has been implemented on the original MGM approach [10]. The resulting band parameters are used to interpret the spectrum in terms of modal abundances and chemical compositions based on [4,11,12]. Validation processes have been made on both laboratory and natural data [10,13]. Hydrated minerals detection are those made by *Quantin et al.* [1] using summary parameters [14] and spectral ratioing.

**Results:** We here use the position of the pyroxenes absorption center to map variability into each central peak. Local variations can be found, showing no obvious link with morphology or dust coverage. This may instead be related to impact process or to different units in subsurface, as impact crater may have sampled rocks over several kilometers in depth. Craters without local variation of compositions can also be found.

At a regional scale, orthopyroxene chemistry show little variations in terms of Ca and/or Fe content (Figure 1). It seems that a relation with the original depth

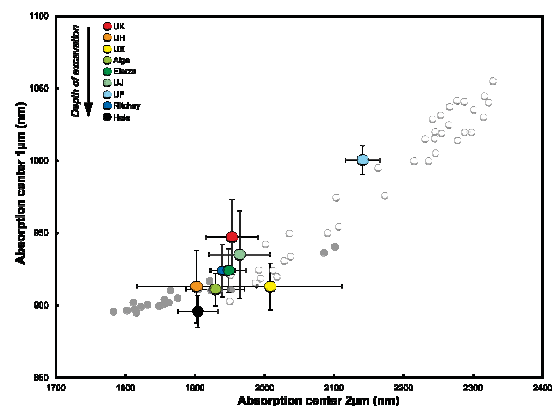


Figure 1: Pyroxene compositions, as determined from MGM results for each central peak, compared to Adams trend [4]

of layers exists. However, the most clinopyroxene-like rocks are found East of the studied area and may represent a change in crust crystallization conditions.

In the case of alteration products, smectite, hydrated glass and putative serpentine have been detected in the observed central peaks. Serpentine seems to be associated with pyroxenes showing higher Ca and/or Fe content. One particular crater, Unnamed crater J in Eos Chasma, have a unit which exhibits characteristic absorption features with three main absorptions (red spectrum in Fig. 2). This indicates carbonate rather than serpentine. Carbonates have probably formed in a hydrothermal system, either during the emplacement of the mafic unit or in relation with the impact process. This implies relatively high temperature fluids percolating through fractures and potential H<sub>2</sub> emission, which represent favourable conditions for life to emerge (e.g. [15,16]).

**Conclusions:** Our results in impact craters central peak show orthopyroxene dominant mineralogies associated to the old Noachian crust. Small variations of chemistry within outcrops exists but the main variation seems to be related to spatially distinct areas. Investigations are ongoing on additional central peaks, as well

as rock exposures in the walls of Valles Marineris.

Alteration products associated to crustal outcrops indicates a particular relationship. Ongoing studies may indicate whether the igneous compositions or the past environments has controlled the observed variations. New observations on unnamed crater J may confirm the potential habitability of the past hydrothermal system.

**References:** [1] Quantin C. et al. (2012), *Icarus*, submitted. [2] Mustard J. F., et al. (2005), *Science* 307, 1594-1597. [3] Burns R. G. (1993), *Cambridge Univ. Press, NY*. [4] Adams J. B. (1974), *JGR* 79, 4829-4836. [5] Clark R. N. et al. (1990), *JGR* 95, 12653-12680. [6] Murchie S. et al. (2007) *JGR* 112, E05S03. [7] Ehlmann B. et al. (2009), *JGR* 114, E00D08. [8] Parente M. et al. (2008), *LPSC 39<sup>th</sup>*, #2528. [9] Sunshine J. M. et al. (1990), *JGR* 95, 6955. [10] Clenet H. et al. (2011), *Icarus* 213, 404-422. [11] Sunshine J. M. and Pieters C. M. (1993), *JGR* 98, 9075. [12] Sunshine J. M. and Pieters C. M. (1998), *JGR* 103, 13675. [13] Clenet H. et al. (2008), *LPSC XXXIX*, #1918. [14] Pelkey S.M. et al., *JGR* 112, E08S14. [15] Ehlmann B. E. et al., (2010), *GRL* 37, L06201. [16] Ménez B. et al., (2012), *Nature Geoscience* 5, 133-137.

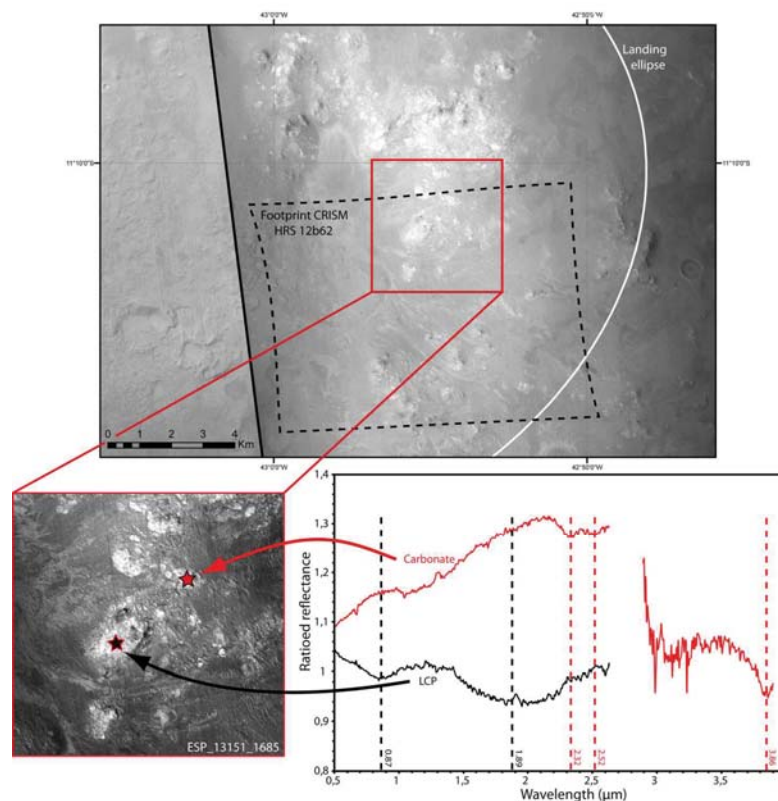


Figure 2: Spectra from the CRISM low resolution product HRS12b62 on high resolution imagery background (CTX and HiRISE) of the central peak at an unnamed crater on Eos Mensa. Two units can be found north of CRISM image. Spectral features indicate the presence of low-calcium pyroxenes and carbonates.