AN OLIVINE OCEAN IN THE NORTHERN PLAINS OF MARS.

A. Ody[1], C. Quantin[1], F. Poulet[2].
[1]Laboratoire de Géologie de Lyon, 69622 Villeurbanne, France. [2]Université Paris-Sud, 91405 Orsay cedex, France

Introduction: Numerous surface analyses of the northern plains of Mars have shown that this region was underlain by a Noachian basement and has undergone a complex history including volcanism, sedimentary deposition and secondary modification by climate change. However, despite these analyses the origin and the evolution of this region are still debated. Were these plains formed by a giant impact? Were these plains once covered by an ocean? Are these plains filled by a large quantity of lavas? Craters of different sizes present in the Northern plains excavate underling material and are such powerful windows into the past history of this region. A detailed analyse of the mineralogy of these impact craters give us insight into the 3D geology of the northern plains. This type of study was made by [1] in the region of Acidalia and Chryse Planitia using the imaging spectrometer CRISM/MRO and shows that these regions were underlined by basaltic material (mainly olivine with few clinopyroxene) obscured by weathering rinds and/or a sedimentary layer. Here, we present the extension of this study to the Utopia Planitia region with OMEGA and CRISM data.

Method: Pyroxene and olivine can be globally detected and mapped thanks to the imaging spectrometer OMEGA/MEx. Pyroxene is mapped using the pyroxene global map published in [2]. Detection of olivine in the northern plains is challenged by the huge blue slope which characterize spectra of this region and which highly diminish the 1µm olivine absorption band [e.g. 3]. In order to highlight small increase in the 1µm band depth compared to a typical spectrum of this region, we compute here the difference between the calculated olivine spectral parameter [2] for each pixel and the median value of the OMEGA cube. We then mapped only values which are larger than 0.03*the median value. However, these detections are to take with caution because high dusty region shows a lower blue slope than medium spectra of the northern plain and thus, the presence of dust can contaminate olivine detection and lead to false positive. In order to confirm these detections and to analyze in more detailed the distribution of olivine and pyroxene associated to the northern plains craters, we use here the CRISM/MRO imaging spectrometer. CRISM acquired spectrum in the near infrared [1 and 2.5µm] with a spatial resolution ranging from 18 to 36m/pixel for the "targeted" observations which is better adapted to the study of crater ejectas than OMEGA. Pyroxene and olivine mineral are detected thank to spectral parameter adapted from the OMEGA spectral parameter [2] and from [1] for olivine. As for the OMEGA olivine detections, only spectral parameter higher than 0.01*the medium value of the criterion on the cube was mapped. Available targeted CRISM observations are analysed for craters showing OMEGA olivine detections. Detections are mapped on CTX or HiRISE high resolution imagery data to assess their geological context.

Results: Figure 1 shows the OMEGA olivine and pyroxene map of the Utopia Planitia. We clearly see that pyroxene weak signatures are detected all over this region as already pointed out by [3] and [2]. OMEGA olivine weak detections are visible on most crater ejectas of different sizes. Red point represents craters that were analysed with CRISM data. Point size is proportional to crater diameter ranging from 6 to 52km. All these craters show clear CRISM olivine detections.

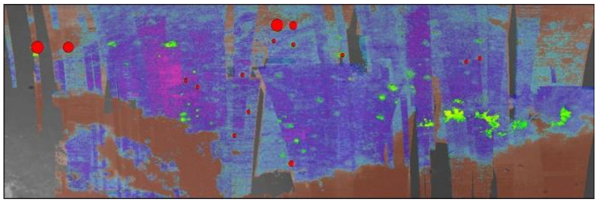

Figure 1. *Map of the Utopia Planitia region with the dust OMEGA global map in red color, pyroxene OMEGA global map in blue color and olivine OMEGA detections in green-yellow color. Points represent craters analyzed with CRISM, with point size proportional to crater diameter. OMEGA olivine detections that are clearly correlated to dust have been removed.*

For small craters (diameter < 15km) olivine is associated to the crater rim, wall and to the inner thick and blocky ejectas (Figure 2) as well as in dunes in the crater floor for some of them. The central peak as well as the floor of these craters is no more visible because of the filling of the crater probably by ice. Distribution of the olivine signatures over the ejecta is not homogenous and is mainly associated to exposed blocky material which was partially obscured by a mantling unit, likely composed of dust and/or fine particules. These olivine signatures are mainly associated to a weaker pyroxene 2µm absorption band which seems more presents in wall and rim than in ejectas. Pure pyroxene signatures are rarely detected associated to these small craters and their context (dust vs exposure) is not clear yet. Some of these small craters also show a second distal thiner lobated ejecta blanket which does not show any recognizable spectral signatures.

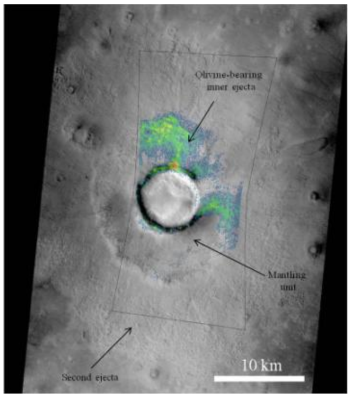

Figure 2. *Example of olivine CRISM detection (from blue to red, HRL0000A543) over CTX image in a small crater (6 km) in Utopia Planitia (53.9°N,76.6°N).*

In large craters (diameter > 20km) olivine and pyroxene signatures are more distinct and both are clearly present in wall, rim and ejecta. Among the studied large craters, only two central peaks are visible and both show clear olivine signatures while the presence of pyroxene is less clear.

In order to better understand the geometry of the olivine-bearing material we have reported the excavation depth of each olivine exposures as a function of their localization in the crater (figure 3 left). For olivine found in wall and rim, we supposed that the excavation depth is about 0, for olivine found in ejecta and central peak, we calculate the maximum excavation depth in function of the crater diameter following the method used in [4]: ED=0.1*D for ejecta $ED=0.25*Dq^{0.15}*D^{0.85}$ for central peak (Dq is the simple-complex transition diameter (10km)).

The elevations of the excavated layers are then calculated by subtracting the excavation depth to the elevation of the crater (figure 3 right). Figure 3 shows that most of olivine signatures are excavated from 0 to about 1 km under the surface which correspond to olivine excavated by small craters (<11km). Olivine found in central peak of large craters is excavated until 10km below the surface corresponding to an elevation of -14km.

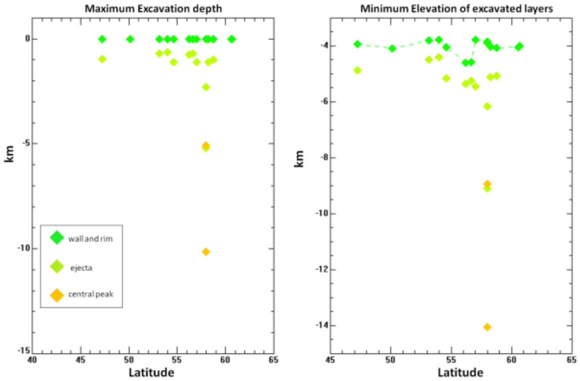

Figure 3. *Maximum excavation depth (left) and minimum elevation of the excavated layer (right) for all craters studied in this work. Green dashed line in the left panel represents the surface elevation.*

Discussion and conclusion: the presence of clear olivine signatures associates to wall, rim and inner ejecta of small craters in Utopia Planitia indicates the presence of an olivine-bearing layer just below the surface in this region. The blocky morphology of the olivine-enriched ejecta suggests that this layer is formed by rocky material in agreement with lavas. Figure 3 shows that the olivine-bearing layer is at least 1 km deep which is in agreement with geological studies suggesting that the northern plains was filled by about 1km of lavas during the early hesperian [5]. These observations confirm that the olivine-enriched basaltic layer detected in Chryse and Acidalia planitia [1] extended until Utopia Planitia and likely in the whole northern plains. This layer could be formed by volcanic infilling as those which have likely filled craters and depression in the southern highlands and which also show an olivine-bearing composition [6]. The distal lobated and thinner ejecta blankets observed for small crater also suggest that this olivine-bearing layer is buried below a shallow olivine- pyroxene-poor layer, likely sediments or mantling unit [1]. Olivine detected associated to wall and rim of large craters (>20km) are likely excavated from the same layer than those excavated by small craters. The fact that olivine and pyroxene signatures are more apart in rim and wall of large craters could suggest that these both minerals originate from different layers as seen in Chryse Planitia by [1] where a thin pyroxene-bearing layer over the olivine-bearing layer is reported. Olivine rich units excavated as deep as 10 km below the surface as seen in large impact craters, may attest of a distinct deeper olivine-bearing unit. Extending this study to more craters of different size and to different region would help us to better understand the relationship between material excavated from small and large crater and to better reconstruct the 3D stratigraphy of this region.

References: [1] Salvator et al. (2010) JGR 115 E07005. [2] Ody et al., (2012), *JGR*, 117, E00J14. [3] Poulet et al. (2007) JGR, 112,E08S02. [4] Bultel et al. (2014), *submitted to JGR.* [5] Head et al. (2002) JGR 107,E1. [6] Ody et al., (2013), *JGR*, vol 118, 234–262.

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