THE UNIQUE AND DIVERSE RECORD OF NOACHIAN AQUEOUS ACTIVITY IN OXIA PLANUM, MARS

C. Quantin-Nataf[1], P.Thollot[1], J. Carter[2], L. Mandon[1], E. Dehouck[1] Laboratoire de Géologie de Lyon Terre, Planètes, Environnement (CNRS-ENSLyon-Université lyon1), 2 rue Raphaël Dubois 69622 Villeurbanne Cedex, France, 2 Institut d'Astrophysique Spatial, Université Paris 11-Orsay, France, cathy.quantin@univ-lyon1.fr

Introduction: Oxia Planum is a 200 km wide clay-bearing plain located at the margin of Chryse Planitia, 350 kilometers southwest of Mawrth Vallis [1]. Based on near-infrared, nadir-pointed OMEGA data at a 2.5 km/pixel scale as well as CRISM multispectral data at 200 m/pixel, the regional compositional mapping of the region has revealed wide deposits of Mg/Fe phyllosilicates around the margin of Chryse Planitia, in particular in Oxia and Mawrth vallis region [2, 3]. Oxia planum is at lower elevation compared to Mawrth Vallis. The plain is also at the outlet of Cogoon Vallis drainage System toward the northern plains [1].

Oxia planum has been proposed and selected along with Mawrth Vallis as the two final landing sites for ESA's Exomars Mission as this site bears abundant morphological and mineralogical evidence of long-lived aqueous activity. These evidences are distributed over the landing ellipse, ensuring that the rover will analyze them within its traverse range, which is restricted to a few kilometers while the landing ellipse is 120 km wide [1]. More than 80% of the landing ellipse of Oxia planum expose phyllosilicates signatures linked to light-toned layered rocks [2]. In addition, a deltaic fan is observed at the top of the layered clay-rich formation, suggesting sub-aqueous episodes post-dating the altered layered formation [1]. These two distinct aqueous-related deposits have been then capped by a later, amazonian-aged volcanic unit and the entire region has known intense erosion since these events [1].

To decipher when the aqueous activity occurred at Oxia Planum, and how long it was sustained, we investigate here the stratigraphic relationships and the crater size distributions of the aqueous-related geological units of Oxia Planum.

Method: Using the MarsSI application [4], we have gathered all available orbital data in the studied region into a Geographic Information System (GIS): High Resolution Imaging Science Experiment (HiRISE) and Context Camera (CTX) images, Mars Orbiter Laser Altimetry (MOLA), High Resolution Stereo Camera (HRSC) images and Thermal Emission Imaging System image mosaic (THEMIS). We performed measurements of layer thickness on HiRISE Digital Terrain Models (DTMs). For crater statistics analyses and age determination, we used Cratertools software [5].

The Clay rich unit: The clay rich unit of Oxia planum overlaps terrains mapped as mid and late Noachian by [6]. But detailed stratigraphic investigations reveal that a mid-noachian volcanic unit, stratigraphically on the top of the clay rich unit, has filled a depression between Oxia and Mawrth Vallis region, suggesting that the layered clay rich deposits of both Oxia and Mawrth Vallis region are mid-noachian or older.

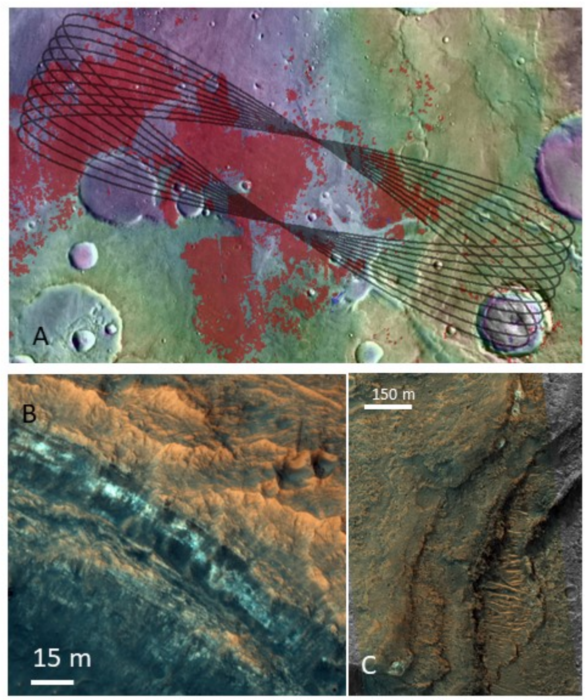

Fig.1: The clay-rich unit. A] Different possible landing ellipses for a landing in 2020 of Exomars rover over the phyllosilicate detections mapped by [2] in red. The ellipse is 120 km long. B] HiRISE color enlargement of the rim of an impact crater exposing the metric clay rich layers. C] HiRISE color enlargement of a valley wall exposing clay rich layers.

The clay rich unit is layered with thickness of the layers ranging from 0.7 m to 2-3 m as measured on HiRISE DTMs. The total thickness of this layered sequence is more than 50 m but probably less than 100 m (Figure 1). The entire clay rich unit is overlapping the pre-existing topography like in Mawrth Vallis with elevations ranging from -2800 m down to -3100 m. The age returned from crater counts on this clay rich formation is older than 4 Gy. The composition is dominated by Mg/Fe clays with some sporadic detection of Al clays [2]. Evidence for a pedogenetic sequence a-la Mawrth Vallis in Oxia is still equivocal in the current state of our analysis [2].

The fluvio-deltaic system: The landing ellipse is at the outlet of a large catchment area of more than 28 000 km^2 (Figure 2). The drainage system seems to be not well developed but detailed analysis reveals that the valley system is highly eroded and overlapped by large late noachian and early hesperian impact craters hiding the initial state of this valley network. Furthermore, many valleys like Cogoon valley have been further filled by material with a high thermal inertia that we interpret as volcanic material. At the outlet of this drainage basin, a 10 km long fan-shaped feature is observed (Figure 2B). The fan is clearly on top of the clay rich unit. The fan is layered (Figure 2C) and about 80 m thick. The flat surface, the overlapping divergent Finger-like terminations argue for a deltaic system rather than an aerial alluvial fan (Figure 2B).

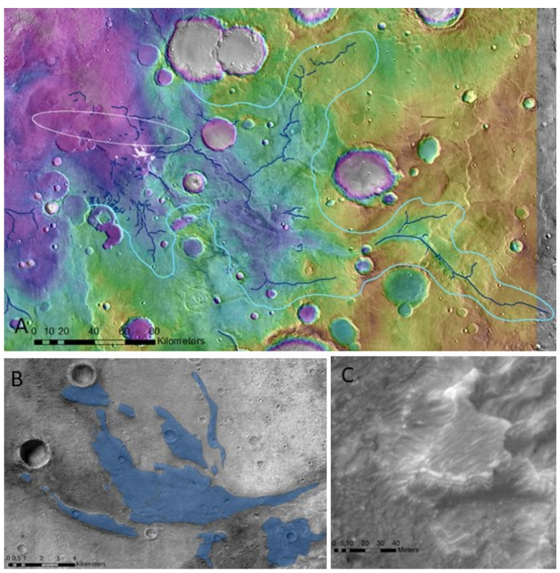

Figure 2: A]Global view of the fluvial morphologies and the large catchment area upstream Oxia Planum landing site ellipse. Light blue underlines the catchment area. Blue denotes the valleys and in white is mapped the delta-fan. B] Map of the delta fan deposits at the outlet of Cogoon Vallis, C] HiRISE close-up of the layered deposits of the delta fan.

The thermal inertia signature of this delta fan highlights a fine grain formation. These observations argue for a standing body of water that would have covered almost the entire landing ellipse. Another possible delta-fan is also observed at the same elevation as the main delta fan and at the outlet of another valley. Down to the deltaic deposit, younger valleys eroding the delta-fan are observed arguing for a late stage of fluvial activity probably correlated with a lower level of the standing body of water. The age of the fluvial activity of the main catchment area has been retrieved by relative stratigraphy and by a buffered crater counting. The fluvial activity would not be older than mid-noachian and would be older than 3.9 Gy. Oxia Planum landing ellipse is located in a basin of a noachian fluvio-deltaic system. Currently open to the northern lowlands by a shallow pass, the basin might have been closed in the Noachian. In term of mineralogy, the delta-fan layers are uniquely enriched in Opaline-silica attesting to water-rock interactions [2].

Discussion: Oxia Planum clay rich widespread layers are mid-noachian or older. Then, later but still in the Noachian, the region has hosted a fluvio-deltaic system. There is no evidence of activity later than during the Noachian in this fluvio-deltaic system. Large late noachian craters post-date the fluvial activity attesting to the pristine nature of this fluvial system. Evidence of fluvial activity is reported at other locations around Chryse Planitia but none of them have their deltaic deposits preserved. Usually, the expected fan deposits at the outlet of noachian valleys, like e.g. Mawrth Vallis, are probably buried below the hesperian volcanic filling of Chryse Planitia [6]. The particular geography of Oxia Planum would have preserved the noachian deltaic deposits from the low land hesperian lava flow capping seen further north. Oxia Planum would be a unique recorder of Chryse Planitia noachian fluvio-deltaic processes.

Conclusion: Oxia Planum exhibits outcrops of Noachian phyllosilicates over hundreds of kilometers of terrain. The site also hosted during Noachian times a standing body of water leading to the formation of a delta fan enriched in hydrated silicates. Hence, this site recorded at least two clearly distinct aqueous environments and contexts, both during the Noachian: 1) the clay-forming alteration of the 50 to 100 m of layered deposits and 2) the fluvio-deltaic system post-dating the wide-spread clay-rich layered unit. The ancient age of Oxia Planum is in contrast with the more recent site being explored by Curiosity. Deciphering the formation environments for such diverse and ancient noachian altered rocks would fulfill the goals of the ExoMars Rover mission.

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References: :[1] Quantin-Nataf et al., The 4th Exomars Landing Site Selection Workshop, 2017 [2] Carter et al., LPSC, 2016; [3] Carter et al., JGR, 2013 [4] Quantin-Nataf et al., PSS, 2018 [5] Kneissl et al., PSS, 2011. [6] Tanaka et al., 2014.