ExoMars at Oxia Planum, probing the aqueous-related Noachian environments

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EXOMARS AT OXIA PLANUM, PROBING THE AQUEOUS-RELATED NOACHIAN ENVIRONMENTS.

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Introduction: The European Space Agency (ESA) ExoMars "Rosalind Franklin" rover will launch in 2020, and land in 19 March 2021. The goals of the mission are to search for signs of past and present life on Mars, to investigate the water/geochemical environment as a function of depth in the shallow subsurface, and to characterize the surface environment. To meet these objectives while minimizing landing risks, a five-year landing site selection process has been conducted by ESA, during which eight candidate sites were whittled down to only one: Oxia Planum.

Oxia Planum is a 200-km wide clay-bearing plain located on the south west margin of Arabia Terra and exhibits Noachian terrains that become increasingly eroded towards the crustal dichotomy [1]. At the time of writing, the "Oxia Planum" name is not yet official, but is under review by the International Astronomical Union naming services. The center of the landing ellipse is located in the north part of a clay-bearing plain, which partly overlaps the outlet of Cogoon Vallis drainage system toward the northern plains [2]. The Oxia Planum landing site (Figure 1) bears abundant morphological and mineralogical evidence of long-lived aqueous activity distributed over the landing ellipse, ensuring that the rover will be able to analyze them within its traverse range, which is restricted to be a few kilometers—whereas the landing ellipse is 120 km x 10 km.

Here we show how Oxia Planum was identified using orbital data analysis and detail the diversity of aqueously-altered rocks exposed across the landing site, as well as their potential accessibility by the "Rosalind Franklin" rover.

Orbital data analysis and the identification of Oxia Planum: To identify the best landing site possible for the ExoMars 2020 mission, we used ArcGIS to compile a large set of global data including elevation [3], thermal inertia [4], geological map [5], and mineralogical map [6]. The goal was to highlight areas compliant with the landing engineering constraints, such as latitude, elevation and thermal inertia, as well as areas compliant with scientific criteria, such as surfaces dating from Noachian times and bearing abundant evidence of deposition in aqueous environments. After masking areas of Mars that are non-compliant with engineering constraints, and areas younger than Noachian age, we ended up with just a few places on the borders of Chryse Planitia and Isidis Planitia. Then, we narrowed down our selection to the most extensive areas (as large as 100 km) of hydrated mineral bearing units from the hydrated mineral map [6] which had morphological expressions consistent with sediments. Thus we found Oxia Planum, a new location that has not been studied before.

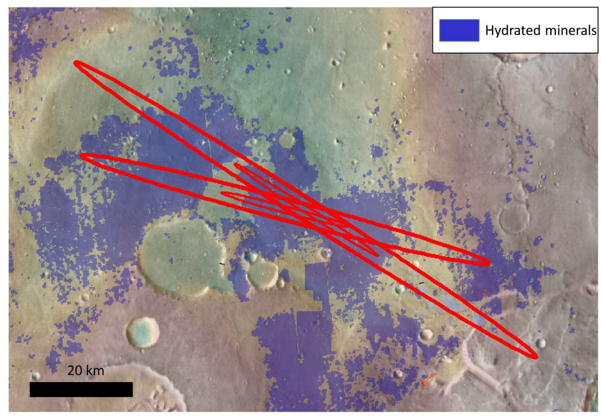

Figure 1: Oxia Planum: background color ramp is Mars Orbiter Laser Altimetry (MOLA) topography on top of Themis IR day-time imagery. The red ellipses represent the 1 and 3 sigma ellipses of both opening and closing launch windows. Hydrated mineral are mapped in blue.

To study the landing site in more detail, we gathered all high resolution available orbital data under GIS: High Resolution Imaging Science Experiment (HiRISE) and Context Camera (CTX) images, elevation data from the MOLA, High Resolution Stereo Camera (HRSC) images and Thermal Emission Imaging System (THEMIS) image mosaics. All data were processed thanks to the MarsSI Application [7]. We performed measurements of layer thickness on HiRISE Digital Terrain Models (DTMs).

Aqueously-altered units in Oxia Planum: The site had a rich geological history, experiencing diverse aqueous episodes, all dated to Noachian times, followed by late volcanic activity [1].

First, the site exhibits a widespread, layered and fractured, clay-bearing unit, which is older than 4 Gy, based on the fact that it straddles a mid-Noachian unit and a late Noachian unit on the global geological map [5]. The stratigraphy exposes at least 50 m of layered clay-bearing deposits. The individual layers resolved by HiRISE DTMs range from 0.7 m to 2-3 m. These deposits drape the current topography at the margin of Chryse Planitia over elevations ranging from -2800 m down to -3100 m. The composition of the hydrated minerals is dominated by Fe/Mg-rich clays with some sporadic detection of Al-rich clays clays [8]. The detailed stratigraphy of the clay-bearing unit is presented in a companion abstract [9]. According to the landing sites ellipses (Figure 1), the probability of landing on the clay-bearing deposits is high. This clay-bearing unit is the main scientific target of the mission.

In addition, the landing ellipse is at the outlet of a large catchment area [10] at the front of which can still be identified remnants of an ancient sediment fan system (Figure 2A) [2].The valleys that feed into the fan-system appear at first glance to be a poorly developed system, but detailed analysis reveals that the valley system is highly eroded and overlain by large late Noachian and early Hesperian impact craters, implying a Noachian age for the valley-fan system. The fan is ~ 10 km long, and lies on top of, and thus post-dates, the clay-bearing unit. The fan is layered and about 80 m thick. The flat surface and the overlapping divergent finger-like terminations argue for a deltaic structure, rather than an aerial alluvial fan. The delta-fan is composed of hydrated silica-rich deposits, attesting to ponding of liquid water [8]. The delta-fan only covers a small part of the 3-sigma landing ellipse of the opening launch window. The chance to land on or near it is thus very low, but the delta fan signals the presence of a standing body of water that would have covered almost the entire landing ellipse after the time of clay-bearing unit formation. Furthermore, distal deposits associated with the delta-fan, but not recognizable from orbit may be distributed more widely throughout the ellipse.

From the delta-fan downward to Chryse Planitia, we observe scattered rounded buttes (figure 2B) ranging from hundred meters to kilometers in scale, more abundant approaching Chryse Planitia. They have a clear low thermal inertia signature and show inverted lineations that may be indurated structures; for example, mineralized veins. No clear signature of hydrated minerals has been found so far, but the CRISM coverage is incomplete. The buttes lie on top of the clay-clay-bearing unit, suggesting that they post-date it. Similarly to the delta-fan, these remnant buttes are younger than the clay-bearing layers, but no clear stratigraphic relationship allows us to link these remnant buttes to the remnant delta-fan observed upstream in Oxia Planum. Similar buttes of low thermal inertia material are ubiquitously observed on the margin of Chryse Planitia at the outlet of Mawrth Vallis and in the region of the Hypanis delta [11]. The buttes are interesting secondary scientific targets for the ExoMars rover, and are scattered widely within the landing ellipses, so should be reachable with a <5 km drive from landing anywhere in the ellipse.

Lastly, the region exposes a dark resistant unit, with no sign of alteration mineralogy, that unconformably overlies other adjacent units within the region. Evidence argues for this being a volcanic unit that would have covered a paleo-surface composed of the eroded deposits described above. The volcanic unit is observed today as erosional remnants, demonstrating intense and long-lived erosion processes over this region's entire history.

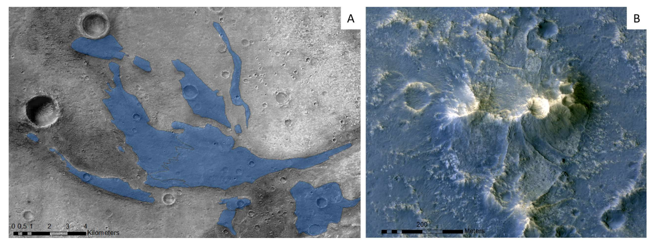

Figure 2: A] Map of the delta fan deposits at the outlet of Cogoon Vallis, B] HiRISE close-up of a remnant rounded butte.

Discussion/conclusion: Oxia Planum exhibits outcrops of Noachian clay-bearing sedimentary rocks over hundreds of kilometers of terrain. The site also hosted a standing body of water during the Noachian, leading to the formation of a delta fan enriched in hydrated silica. Hence, this site has recorded at least two clearly distinct aqueous environments and contexts, both during the Noachian: 1) the alteration of 50 to 100 m depth of layered deposits, and 2) the fluvio-deltaic system post-dating the earlier the clay-rich layered unit. The intense erosion undergone by then by Oxia Planum region has exposed these two types of Noachian sediments, making it a perfect site for exploration. Deciphering the formation environments of such diverse Noachian altered rocks would fulfill the goals of the ExoMars Rover.

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References: :[1] Quantin-Nataf et al., 2019 [2] Molina et al., 2017 [3] Smith et al., 2001 [4] Putzig et al., 2005 [5] Tanaka et al., 2014 [6] Carter et al., 2013 [7] Quantin-Nataf et al., PSS, 2018 [8] Carter et al., 2019 [9] Mandon et al ; 2019 this issue [10] Fawdon et al., 2019. [11] Fawdon et al., EPSL, 2018