HIGH-RESOLUTION CHARACTERIZATION OF THE CLAY-BEARING UNIT AT OXIA PLANUM, THE EXOMARS 2020 LANDING SITE. L. Mandon\textsuperscript{1}, A. Parkes Bowen\textsuperscript{2}, C. Quantin-Nataf\textsuperscript{3}, J. C. Bridges\textsuperscript{4}, J. Carter\textsuperscript{1}, L. Pan\textsuperscript{1}, P. Beck\textsuperscript{5}, E. Dehouck\textsuperscript{1}, M. Volat\textsuperscript{1}, N. Thomas\textsuperscript{5}, G. Cremonese\textsuperscript{6}, L. L. Tornabene\textsuperscript{1}. \textsuperscript{1}Université de Lyon, LGTPE, France, \textsuperscript{2}Space Research Centre, University of Leicester, United Kingdom, \textsuperscript{3}Institut d’Astrophysique Spatiale, CNRS/Paris-Sud University, France, \textsuperscript{4}Université Grenoble-Alpes, IPAG, France, \textsuperscript{5}Die Universität Bern, Switzerland, \textsuperscript{6}Istituto Nazionale di Astrofisica, Padova, Italy, \textsuperscript{7}Centre for Planetary Science and Exploration, University of Western Ontario, Canada. lucia.mandon@univ-lyon1.fr

Introduction: In 2021, the Rosalind Franklin rover of the ESA/Roscosmos ExoMars 2020 mission will start investigating extensive Noachian terrains on Mars. The landing site is Oxia Planum \cite{1}. The site exhibits evidence of aqueous processes during the Noachian, with a wide (~2500 km\textsuperscript{2}) stratified and fractured clay-bearing unit as well as deltaic deposits lying on top of the clay-bearing unit \cite{2, 3}. Detailed investigation into the origin and potential habitability of the Noachian aged clay-bearing unit using a suite of analytical instruments is one of the main science objectives of the mission. We investigate the stratigraphy of the fractured clay-bearing unit using visible and near-infrared orbital datasets. This allows us to discuss the possible formation scenarios for the clay-bearing unit and provide new guidelines for future \textit{in situ} exploration by the ExoMars rover.

Datasets and processing: We used HiRISE color products to map exposures of the fractured clay-bearing unit and to assess its variability using high resolution texture and color criteria. The spectral variability of the unit was investigated using CRISM data in the near-infrared (1.0 to 2.6 µm) and processed using the MarsSI application \cite{4}. We also used CaSSIS data to help determine the presence of ferric and ferrous-bearing materials. In order to mitigate atmospheric scattering effects, we applied the Dark Object Subtraction method \cite{5} to the CaSSIS images.

Results: Stratigraphy of the fractured clay-bearing unit. At high resolution, the unit exhibits textural and color variations (Fig. 1). We identified a first member with meter to decameter-sized polygons and an orange hue on the HiRISE color images. A second member is identifiable and consists of a 10-20 meters-thick unit with decameter-sized polygons and a blue hue on HiRISE color products. This second member is observed in different parts of the ellipse and always lies on top of the main “orange member”. The relative difference of color in HiRISE color products between the two members may be explained by a variation of dust cover, leading to more bluish layers when they are dustier. However, larger polygons and hence lower crack densities are observed on blue terrains compared to orange terrains, showing that the dust fill factor is lower on blue terrains. This observation, in addition to the correlation between color and polygon size, and the consistency of the stratigraphic relationship between the orange and blue terrains make it unlikely that variations of the dust cover might be solely responsible for the observed difference of color in HiRISE images.

![Figure 1. High resolution morphologies and color variations of the clay-bearing unit](image)

We identified a possible third member of the fractured layered unit, a few meters-thick layer that appears blue in HiRISE, with a more massive aspect and wide fractures. So far, this layer is observed only locally in the eastern part of the landing ellipse on the top of the upper blue member and immediately below the deltaic deposit identified by \cite{3}.

Spectral variability of the layered fractured unit. From CRISM data, the lower “orange” member is associated with a spectrum whose overall shape and absorption band positions are consistent with Fe/Mg-rich phyllosilicate, the closest match being vermiculite or Fe-rich saponite \cite{2}. The upper “blue” member of the clay-bearing unit shows similar absorption bands typical of Fe/Mg phyllosilicate but with shallower bands. However, the spectrum shows a wide absorption band centered at 1 µm. This band witnesses an enrichment in Fe, either explained by a mixture with mafic mineral such as olivine or a mixture with oxide or a transition toward a phyllosilicate more enriched in Fe. The third identified member exposed below the deltaic deposits is associated with a large 1 µm absorption band typical of olivine spectra. Some spectra on this unit have the tight absorption bands at 1.9 and 2.3 µm of hydrated minerals.

CaSSIS 3 points spectra are consistent with CRISM mineralogical detections for the lower and upper members. The dip in the NIR band for the CaSSIS data is less
than what would be expected for the olivine-bearing member. This is interpreted to be caused by high atmospheric opacity (>1.0) when the image was taken. The ferric-bearing surfaces highlighted within the CaSSIS ratioed products correlate well with the CRISM clay-bearing surfaces detections, this is potentially caused by the presence of iron oxides in the clay-bearing unit [2].

Variation over the landing area. Outcrops of the fractured clay-bearing unit are widespread within the ellipse, even more so than estimated by the previous spectral map of [2] (Fig. 2). The lower and upper members often coexist at the kilometer scale. Outcrops associated with the lower member are located within the Fe/Mg-rich phyllosilicate spectral detections of [2], and outcrops located outside of these detections are more often associated with the upper member (Fig. 2). Notably for the aims of the mission to analyze clay-rich rocks, the lower member, corresponding to the most intense spectral signature of alteration, is well exposed in the landing area including in the center of the landing ellipse.

Figure 2. Distribution of the different clay-bearing subunits in the ExoMars landing area, as seen on HiRISE color data

Discussion: The variability of polygonal patterns in the different subunits correlates with the spectral variability. Two scenario can be proposed: either the difference in the fracture pattern leads to difference in olivine-rich sand accumulation that may explain the spectral difference, or the bulk mineralogy of the members is different, leading to different rheology and consequently different fracturing pattern. As noted previously, the cracks density is lower in the upper member, which corresponds with the most likely scenario being a true compositional mixture of clay minerals and olivine in the spectral variation in these two members. Therefore, we favor the scenario where the bulk rock composition of the upper blue member is a compositional mixture of clay minerals and olivine. We have noticed that the abortion bands linked to hydrated minerals are less deep from the bottom to the upper part of the stratigraphy. Assuming the spectral signature corresponds to the bulk mineralogy, the Noachian fractured unit at Oxia Planum may have recorded a gradual transition of conditions during its deposition and/or alteration. Carter et al. [2] favored a pedogenic/lacustrine/groundwater alteration scenario for the formation of the clay minerals. If the unit was emplaced as a primary deposit (e.g. volcanic, impactoclastic or aeolian) and was subsequently altered, the change of composition would record a decline in the weathering rate, or an increase in the deposition rate of volcanic or sedimentary materials over time. This would form alteration minerals in the early stacks, covered by rocks with primary, poorly altered minerals corresponding to the latest deposition of layered sediments. If the fractured unit was formed by material deposition in a subaqueous environment, it could involve: some intermittent immersion, a decrease of the altered continental inputs, or an increase of igneous materials, potentially linked with local volcanic activity.

The center (where the probability to land is the highest) of the landing ellipse exposes the portion of the clay-bearing unit stratigraphy that exhibits the clearest spectral signals of clay minerals, which are the primary scientific target of the mission. Their spectral signature, a close match to vermiculite or saponite, is representative of the widespread Fe/Mg-rich clay-bearing deposits common across much of Mars [6]. For this reason, landing in the center or western part of the ellipse would allow investigations that can give insights into the global Martian alteration history. Landing in the eastern part of the landing area would provide a lower probability of access to the bedrock with the strongest signature of clay minerals, but would still be valuable since the clay-bearing unit is exposed there as well. Future mapping efforts of the 1-sigma landing ellipse at HiRISE resolution by the ExoMars working group will bring up new details on the high resolution variability of the Oxia Planum site.

Acknowledgments: CaSSIS is a project of the Univ. of Bern and funded through the Swiss Space Office via ESA’s PRODEX program. The CaSSIS instrument hardware development was also supported by ISA (ASI-INAF agreement no. I/018/12/0), INAF / Astronomical Observatory of Padova and the Space Research Center in Warsaw. Support from SGF, the Univ. of Arizona and NASA are also gratefully acknowledged.