FRACTURE MAPPING AND CASSIS IMAGING OF THE EXOMARS2020 LANDING SITE OXIA PLANUM: CHARACTERISING CLAY-RICH SEDIMENTS

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Introduction: Following the 5th workshop of the Landing Site Selection Working Group (LSSWG) [1], characterising the mineralogy and geological history of the selected site Oxia Planum in different ways is essential to maximise the science returns from the mission. This abstract details the analysis of fractures at Oxia as well as colour band ratioing of images obtained by the Colour and Stereo Surface Imaging System (CaSSIS), with Gale Crater used as a point of comparison for both studies [2].

Fractured terrain is common across Mars, appearing in regions dating from the Noachian through to the Amazonian. Analysis of such features could be a useful tool for characterising terrains at landing sites, as the form a fracture network takes varies depending both on the mechanisms which generated it as well as the materials within which the fractures formed [3-5].

CaSSIS, on-board the Trace Gas Orbiter provides ~4.5 m/pixel colour imagery in four bands; NIR, RED, PAN and BLU [2]. This will be used to complement existing HiRISE imagery due to CaSSIS's extra filter and improved colour swath width.

Our key comparison to Oxia is Gale Crater, the site of the MSL rover's mission. It is thought to have once hosted a fluviolacustrine system and possesses several areas with fractured terrains. These include clay-rich units, in particular at Yellowknife Bay and the Murray formation, thought to have formed when the lake was present, and a capping sandstone unit (Stimson) which formed later [6, 7].

*Oxia Planum***:** 18.1 ºN, 335.8 ºE is composed of layered, fine-grained FeMg clay-rich deposits formed during the Noachian epoch, and thought to be overlain by both a later Noachian fluvio-deltaic system and an Amazonian capping unit [8, 9].

Both the clay and capping units at Oxia display extensive fracturing, with these fractures varying in length from being at the limits of resolution of HiRISE imagery (30 cm/pixel) up to the 100 metre scale. The extensive nature of the fractures, as well as their good preservation, makes Oxia an excellent site for fracture analysis.

Oxia's relatively dust-free nature allows colour imagery to be used to characterise the sites lithology [8]. A recent study has utilised HiRISE colour imagery to show that Oxia Planum's clay unit has at least two distinct components to it, one displaying meter scale fracture polygons and being vermiculite-rich, and the other showing decametre scale fracture polygons with spectral signatures of Al-rich clays mixed with Fe/Mg-rich clays [10]. The benefits of CaSSIS imagery make it useful for building upon this study and aiding in characterising Oxia's mineralogical diversity.

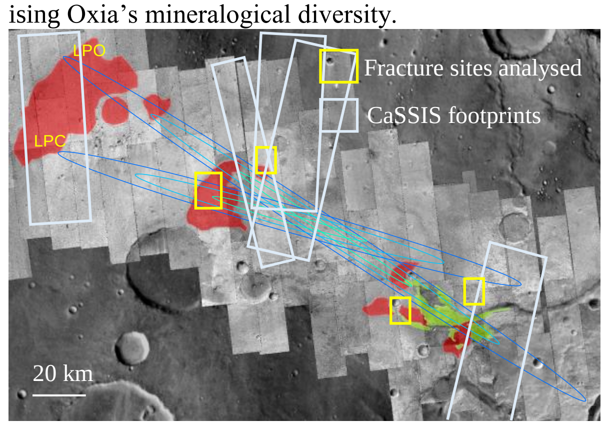

Figure 1. HiRISE coverage of Oxia Planum, with a THEMIS background. The 1-3 sigma ellipses (~104x19 km) are shown in blue, the red areas indicate capping unit within the ellipses whilst the green indicates the possible delta [8]. *Note: LPO is the ellipse if ExoMars launches at the opening of its launch window in 2020, LPC at its close.*

Methods: *Fracture Analysis*. Our fracture analysis involves tracing out a given fracture network in HiRISE imagery using ArcGIS, then using a tool developed at the Open University (UK) to measure metrics of the fractures or the polygons, such as the polygon area, vertex angle, etc.

CaSSIS band ratioing. Band ratios determined from CaSSIS imagery can be used to determine the presence of ferrous (Fe^{2+}) and ferric (Fe^{3+}) mineral-bearing terrains [11]. This is useful in characterising the record of fluid-rock interaction across the area. The band ratios used were RED/PAN, PAN/BLU and PAN/(NIR or RED), and were created using ENVI 5.3. These were then combined into a RGB colour plot.

These combinations are sensitive to ferric minerals for the former two and to ferrous minerals for the latter i.e. red/green areas signifying a greater proportion of ferric iron minerals present compared to ferrous iron minerals, with the reverse being true for blue areas. We have been careful to identify saturated and defective pixels present in the images as these can skew the results.

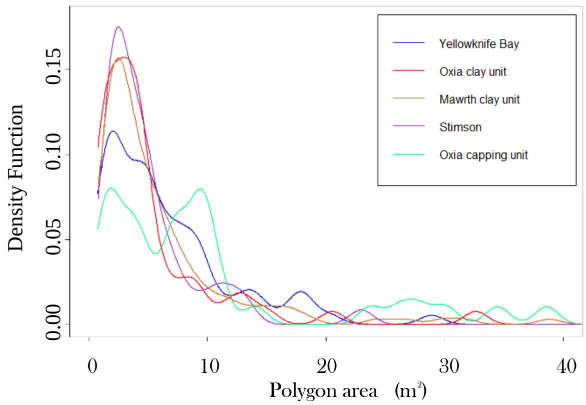

Figure 2. Kernel density plot comparing polygon area of fracture networks. Yellowknife Bay and Stimson are, respectively, clay and sandstone units from Gale Crater, whilst Mawrth was the other finalist potential landing site alongside Oxia Planum [1]. *Density function varies depending on the number of data points within a bin width (1 m^2) of a given point on the distribution.*

Results: *Fracture Analysis***.** The results obtained thus far indicate that there are notable similarities between the mudstones at Gale Crater [6, 7] and those at Oxia Planum, with the distribution in polygon area (Fig 2) showing a relatively narrow peak at around 2-3 m^2, before tailing off at 15-20 m^2. This contrasts significantly with fractures within the Oxia capping unit, though the Stimson sandstone capping unit from Gale crater is not easily distinguishable.

The polygon vertex angles show less of a distinct difference between the clay and non-clay units. Most of the distributions show a peak at ~90-120° with a smaller one at 180°, this latter peak representing where a fracture joins another but without passing through it, forming a T-junction. This second peak is not present in the Stimson sandstone or Oxia clay unit, which could indicate that the fractures within these units have been subject to alteration after the cracks formed, as repeated cycles of fracture formation and closing, e.g. repeated desiccation and wetting, favours Y-intersections (i.e. vertex angles of 120°) compared to T-junctions, (which show up as 90°/180° peaks) that are favoured by single fracture formation events [12]

CaSSIS band ratioing. Of the three sets of CaSSIS images currently available of Oxia, each demonstrates large colour variations in each band ratio. Fig 3(b) is a good example of this colour diversity, with the Oxia clay unit in this region clearly showing two distinct areas; one more yellow/green and therefore likely richer in ferric-rich minerals compared to ferrous-rich minerals, and another which is distinctly blue and therefore more ferrous-rich than ferric-rich.

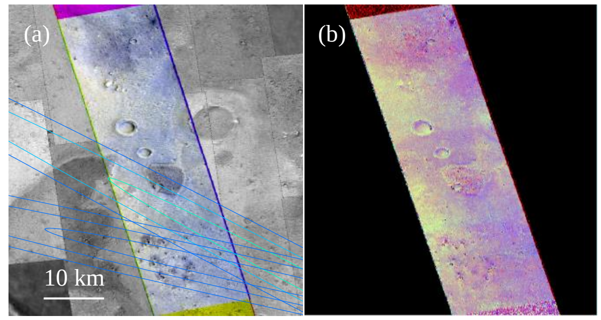

Figure 3(a) RGB CaSSIS image (image ID; MY34_001934_162_0), filters arranged as follows; R: RED, G: PAN, B: BLU, (b) Band ratio RGB composite of CaSSIS image in 3(a), with the band ratios arranged as follows R: RED/PAN, G: PAN/BLU, B: PAN/RED, with R and G representing a higher portion of ferric to ferrous iron (the yellow-green areas) and B the reverse (the bluer areas).

Discussion: *Fracture Analysis*. The similar range of values and distribution for the polygon area and vertex angle indicate the Oxia FeMg clay-rich units are broadly similar to those at Yellowknife Bay, likely being fine-grained with similar bedding thicknesses. However, the uniform polygon area distribution for Oxia, along with a lack of a 180° vertex angle peak suggests that the fractures within the Oxia clay unit are more likely to have undergone a cycle of fracture formation and closing e.g. by repeated cycles of desiccation fracturing then wetting and closing. This contrasts with the fractures at Yellowknife Bay, with their metrics suggesting a single period of fracture formation e.g. a single cycle of desiccation.

CaSSIS band ratioing. The images so far constructed suggest significant variation in ferric and ferrous minerals across Oxia Planum. Ferrous mineral content appears higher in the clay units closer to the centre of the ellipses compared to areas in or near the South-East of the ellipse, which seem to have a higher proportion of ferric minerals. These areas so far do not appear to be related to the vermiculite-rich and Al-clay rich units highlighted previously [10], which indicates that the Oxia Planum clay unit may be more mineralogically diverse than previously thought.

References: [1] Loizeau D. et. al. (2019), *this conference*, [2] Thomas N. et. al (2017) *SSR, 212:*1897-1944, [3] Tang C-S. at. al. (2011) *Geoderma, 166(1):*111-118, [4] Plummer P. S. et. al. (1981) *JSR, 51:*1147-1156, [5] Goehring L. et. al. (2010) *Soft Matter, 6:*3562-3567, [6] Grotzinger J. P. et. al. (2014) *Science, 343:*6169, [7] Yen A. S. et. al. (2017) *EPSL, 471:*186-198, [8] Quantin C. et.al (2017) *ExoMars LSSW#4*, [9] Quantin C. et al. (2015) *EPSC 2015*, 704, [10] Quantin et al. (2018) *5th ExoMars landing site workshop*, [11] Tornabene L. L. et. al. (2018) *SSR, 214:*18, [12] Goehring L. (2011), *Phil. Trans. R. S.* 371