EXOMARS ROSALIND FRANKLIN ROVER INVESTIGATIONS: ANALYSIS OF PANCAM-SIMULATED DATA FOR ASSESSMENT OF IN SITU HYDRATED MINERALOGY.

C. M. Caudill[1], G. R. Osinski[1], L. L. Tornabene[1], [1]Department of Earth Sciences, University of Western Ontario, London, ON Canada

Introduction: The broad scientific objectives of the ExoMars mission, which includes the Rosalind Franklin rover (RF) and the Trace Gas Orbiter, are based on several goals defined by ESA [1], and the international community, including: the investigation of Martian aqueous geochemical environments, and to characterize the surface environment for geological assessments; preparation for rover ground operations, and; scientific research support to support and help guide active ground operations. PanCam has a mast-mounted instrument capable of precise and expedient detection and discrimination of different types of aqueously-formed clay minerals and other water/hydroxyl-bearing materials [2]; these particular observations are accomplished via near-infrared (near-IR) reflectance spectroscopy [3]. Near-IR spectroscopic observations have not thus far been performed on rover-based in situ geological materials on Mars; the ExoMars rover mission therefore represents a novel and exciting opportunity to acquire observational data on these important mineral markers of the geological history of water, and furthermore ground-truth the comparatively large-scale near-IR spectral observations derived from Mars orbitally-based instruments.

The Oxia Planum ExoMars landing site: ESA's ExoMars Rosalind Franklin (EMRF) rover (now anticipated to launch in 2028) will explore Oxia Planum (335.5ºE, 18.2ºN). Oxia Planum is located on the southern margin of Chryse Planitia and the north western edge of Arabia Terra in Noachia Terra [e.g., 3] The landing ellipse lies at the edge of a shallow basin dominated by a Noachian-aged clay-bearing unit with Fe/Mg spectral signatures and local detections of Al clay minerals [3,4]. The clay-bearing unit has been mapped as a geological marker throughout the circum-Chryse region [4]; this unit has been interpreted to represent the progressive chemical weathering of a layered basaltic composition parent rock based on previous and current regional mapping efforts.

However, the typical alteration associated with the weathering of these rock types (e.g., Mg-rich phlogopite-bearing igneous or metamorphic rocks) yields a series of end-member minerals that are trioctahedral, mixed-layer clay species, commonly interpreted as saponite and vermiculite; [e.g., 5] having formed under oxidative conditions due to the transformation of Fe^{2+} within the clay minerals, the result is a clay with a low Fe^{2+}/Fe^{3+}geochemical ratio [5]. This is in contrast to the crystal-chemistry of the Fe/Mg clay species most commonly observed in Oxia Planum, interpreted as a high Fe^{2+}/Fe^{3+} ratio trioctahedral clay [3,5,6] and therefore may have formed under anoxic conditions. [6] offers a rich terrestrial comparison study of clay-bearing deposits in the Oxia Planum region and conclude that if in fact these clays are a high-Fe saponite and vermiculite, ash-fall deposits, or detrital sedimentary transport and aqueous alteration, are more analogous to the crystal-chemistry and necessary environmental conditions. As a body of work, it is clear that the conditions under which hydrated mineralogy formed within the landing ellipse remains unknown; continuous or discontinuous series of geological events, and the origin of the host material (e.g., deltaic, alluvial, lacustrine, volcanoclastic, impact-related) exhibiting clay signatures remains yet to be determined.

This work builds on operational field test activities undertaken by previous collaborative research with ExoMars PanCam field investigations [7] to discern hydrated mineralogy using Near-IR PanCam-like ground data. In this research, we create PanCam-like spectral band depth (BD) parameters for the assessment of clay and other hydrated mineral composition, abundance, or grain size fluctuations that will be possible to discern. The analysis of hydrated mineralogy in the laboratory and testing of PanCam instrument equivalent wavelengths assists in the development of spectral parameter maps. Therefore, this work seeks to support the PanCam and the larger EMRF team in determining which spectral combination best highlights hydrous minerals for its future surface explorations.

Methods: This work relies on the geological and mineralogical mapping of the Oxia Region [e.g., 3,4], and further identifies and characterizes aqueously-formed minerals (e.g., carbonates, clays, and evaporite-bearing lithologies) as observed from orbitally-derived Near-IR CRISM and OMEGA hyperspectral and CaSSIS multispectral data for Mars. Using the specific "geologic spectral parameters" of PanCam-simulated and geological filters specific to its instruments, this work is developing a well-delineated set of spectral features (e.g., using ENVI/IDL as well as python and open-source remote sensing analytical tools) to provide a tested and trusted output of these minerals and materials as a spectral library that is cross-correlative between ExoMars orbitally-derived spectral data (i.e., CaSSIS) and PanCam-simulated spectral data. In this work, we further analyze the accuracy of geological assessments that can be made from rover-derived spectral data, and ability to establish geological context from that data, by documenting the precision in acquiring the necessary spectral absorption features at adequate band depths to identify molecular bonds indicative of hydrous minerals and mineral suites throughout our analyses of Mars-analogue hydrous minerals and their spectral signatures.

Results and Discussion: The assessment of the accuracy of geological interpretations are heavy based on the accuracy of the spectral parameters of the instruments acquiring ground data during rover operations. Our work begins with a laboratory analysis of the clay minerals to confirm the presence of different compositional units assessed for the PanCam-like parameter maps. Decorrelation stretches are used to highlight spectral differences, which identifying potential science target locations that the PanCam team may encounter during rover operations. PanCam-like spectra will then be extracted from simulated regions of interest (ROI), assuming a working distance of 4 m and ROIs containing 50 pixels covering ~1.2 by 1.2 cm, comparable to an assumed FOV parameter of 1 cm. Beyond producing BD parameters and spectral parameter products that will support ongoing development of hardware and software for PanCam spectroscopy, this work will support the Science Team in using this data for training to target hydrated minerals and other materials with PanCam during eventual operations. Ultimately, this work seeks to improve the detection and characterization of science targets through the PanCam spectral filter subsets by developing spectral "fingerprinting" for identifying specific minerals (e.g., clay minerals, sulfates, carbonates) that are consistent with near-IR PanCam-like observations.

This work has assessed data and spectral parameters acquired with the PanCam-like (Aberystwyth University PanCam Emulator 3, "AUPE3") [7] RGB data, PanCam WAC-like spectral parameter maps, and PanCam HRC-like textural and grain size data in ENVI/IDL to defined spectral parameters. The work builds on parameter maps from other previously-acquired hyperspectral imaging of field outcrops and laboratory samples using the Headwall Photonics co-boresighted system custom-built for the California Institute of Technology. [8] From this, preliminary results include the computations of BD parameters to create image maps of particular mineral compositions (e.g., Table 1) calculated with center wavelength and continuum points and stretched so that the deepest absorption features corresponding to each mineral-proxy parameter.

The example parameters in Table 1 are based on the absorptions and spectral features of thus-far interpreted Oxia bedrock clay-bearing deposits (high Fe^{2+} Fe/Mg rich clay minerals, Al clay minerals, and tentative observations of carbonates mixed with clay minerals. [e.g., 2,3,4]

Table 1. Example Band depth (BD) PanCam parameters that will be used to highlight hydrous minerals like clay mineral species and carbonates.

Parameter	Formula
BD2340	1-R2.34/Continuum (2.286 - 2.352) *C-O combination in carbonates; wavelengths optimized for carbonates*
BD2300	1-R2.30/Continuum (2.16 - 2.34) *Fe/Mg-OH combination bands; e.g. Fe/Mg clay minerals*
BD2210	1-R2.20/Continuum (2.13 - 2.27) *Al-OH, Al/Fe-OH, Al/Mg-OH modes, or Si-OH; e.g., Al-clay minerals or hydrated silica*

Such a spectral library is key to enabling cross-spatial-scale synergy, as it will allow a quick-reference of geographically-contextualized and well-characterized hydrated minerals that will be targeted in the specific range of the full PanCam suite.

Conclusions and Future Work: The PanCam instrument suite is capable of providing rover-scale morphological and mineralogical context and detecting minerals and rocks as geochemical and environmental indicators of past aqueous—and potentially habitable—conditions. The presence of extensive clay minerals in the ancient Noachian terrains of Mars is often used to invoke past climatic conditions that were warmer and supported surface-stable liquid water. As the origin of clay minerals on Mars is the subject of ongoing debate, our ultimate goal is to carry out detailed field and laboratory investigations will assess the composition, texture, and setting of clay minerals that were impact-generated and compare those to the clay minerals identified orbitally in the Oxia Region RF rover landing site from which the PanCam proxy spectral parameters were created.

Future work builds on our detailed study and analysis of the field analogue site well-preserved Ries impact structure, Germany to provide context and baseline laboratory analyses for the clay mineral composition of impact-related materials and aid in interpreting the provenance of clay mineral-bearing materials on the surface of Mars.

References: [1] Vago J., et al. (2018) *LSSWG, ESA.* [2] Clark, R.N., et al. (1990) *JGR,* 95:12653–12680. [3] Mandon, L., et al (2021) *Astrobiology* 21:464–480. [4] Quantin-Nataf C. et al. (2021) *Astrobiology* 21, 345-366. [5] Michalski J.R., et al. (2015) *Earth Planet Sci Lett*. 427:215–225. [6] Krzesińska et al. (2021) *Astrobiology* 21(8):997-1016. [7] Allender, E. J., et al. (2020) *Earth and Space Sci.*7,4 e2019EA000692. [8] Caudill, C.M. (2020) *Western Thesis Rep.* 6935.