MINERALOGY, AQUEOUS ALTERATION AND BIOSIGNATURE PRESERVATION POTENTIAL OF BEDROCK DEPOSITS AT OXIA PLANUM, EXOMARS 2022 LANDING SITE AS INFERRED FROM SPECTRAL STUDY OF TERRESTRIAL ANALOGUES.

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Introduction: Oxia Planum is the landing site for the ExoMars2022 rover. It is a wide, Noachian-age, phyllosilicate-bearing plain located between Mawrth and Ares Valles. The bedrock phyllosilicate deposits at Oxia Planum are Fe,Mg-rich and one of the largest exposures of this type on Mars, with a thickness of more than 10 m [1]. When characterized in the near infrared by CRISM and OMEGA instruments, the bedrock deposits exhibit absorptions that suggest the presence of Fe,Mg-rich phyllosilicates with significant amounts of Fe^{2+} in octahedral sites (i.e., trioctahedral) [2]. The spectra are best matched by saponite or vermiculite, but an accurate spectral match is lacking. Because precise mineral composition of the bedrock is not fully understood, limited conclusions can be drawn regarding the aqueous evolution and habitability potential of Oxia. To fill this gap, and to better prepare for in-situ analyses by the ExoMars2022 rover, we performed a survey of potential terrestrial analogue rocks. We have identified terrestrial deposits of Fe-rich, trioctahedral vermiculite and from spectral comparisons with the Martian substrate we suggest aqueous processes that could form Oxia bedrock clays.

Survey of Fe-rich vermiculite deposits: Analogues from two terrestrial sites were obtained: (1) vermiculitized chlorite-schists from Blue Spur, Otago, New Zealand and [3] (2) basaltic tuffs and pyroclastics from Granby, Massachusetts, USA, with Fe-rich clays filling amygdales [4]. Both analogues have been added to a newly built Planetary Terrestrial Analogue Library (PTAL) rock collection and spectral library.

Blue Spur conglomerate. Deposits in Blue Spur formed by erosion and deposition of greenschist-facies quartzo-feldspathic schists rich in Fe-rich chlorite. Due to rapid erosion and non-oxidizing or mild oxidative conditions [3] chlorite remained unoxidized when buried. Later interactions with groundwater caused formation of trioctahedral vermiculite and progressive alteration of deposit led to illitization and kaolinitization For our purposes we have collected samples of pristine schist clasts, greenish (unoxidized) vermiculitized material and pale, illitized clasts [3].

Granby basaltic tuff. The Granby Tuff consists of basalt flows and pyroclastic units. In places it contains zones of vesicular basalts that have amygdales filled with calcite and dark-brown clays. The clays filling the amygdales are of apparent hydrothermal origin, that is precipitated in gas vesicles from solutions generated by hydrothermal alteration of the basaltic tuff. The clays were reported to be either saponite or vermiculite [4].

Methods: The samples were characterized by X-ray diffraction to understand their chemistry and structure and by NIR spectroscopy in order to provide further structural details and to assess the match to Oxia Planum bedrock clays. XRD was performed on bulk rock samples as well as for separated clay fraction

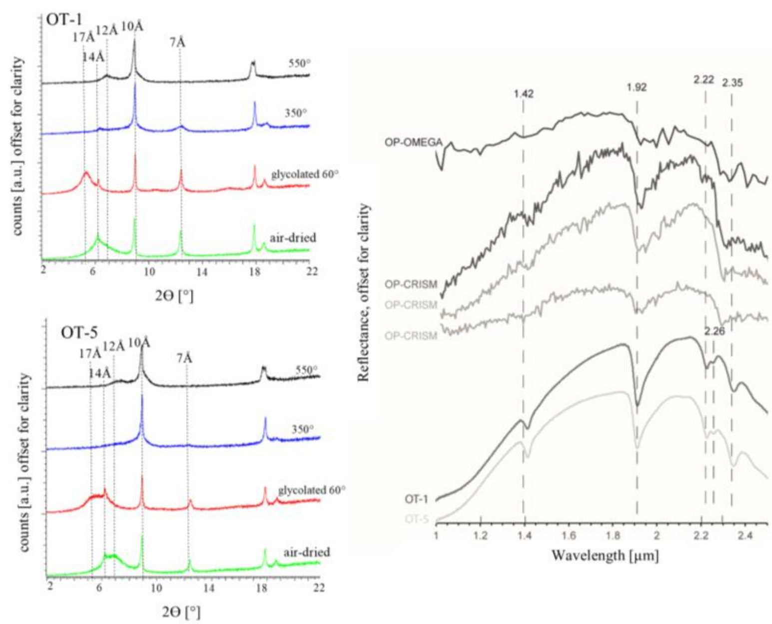

Fig. 1. Examples of XRD and NIR results for selected Otago samples and comparison to Oxia bedrock deposits.OT-1 – a sample with trioctahedral vermiculite and no illite. OT-5 – an illitized, dioctahedral vermiculite-bearing sample.

minerals. Near Infrared (NIR) spectra for each sample were collected using a reflectance spectrometer in the near-infrared (0.8–4.2 μm) mode. Analysis was performed on powdered samples, under ambient temperature and pressure conditions.

Otago vermiculite mineralogy and NIR characterization: The XRD patterns of oriented clay fraction separates (Fig. 1) reveal under treatment characteristic trends that suggest the presence of chlorite in pristine material, trioctahedral vermiculite in greenish samples that underwent alteration in anoxic conditions, and interstratified illite-vermiculite in more oxidized samples.

NIR spectroscopy analysis of Otago samples tends to indicate that the nature and overall Fe content of the is broadly similar to the phyllosilicates at Oxia. Furthermore, illitization of the vermiculite seen spectrally in Otago is likely limited for Oxia (Fig. 2). This means that vermiculite at Oxia is a rather pure, one-phase mineral that underwent only minor (if any) post-depositional alterations toward illite.

Granby clays mineralogy and NIR characterization: The XRD patterns of the oriented clay fraction separates reveal the presence of well crystallized, trioctahedral vermiculite and various amounts of saponite in different samples (Fig. 2).

In NIR spectroscopy, Granby samples show quite a good spectral match to Oxia and indicate that saponite, present in Granby, is absent from Oxia spectra. Oxia deposits are likely pure vermiculite rather than a mixture of saponite and vermiculite (Fig. 2). Additionally, other spectral features suggest that the Granby clays have a different Fe/Mg ratios than minerals of Oxia Planum, or a different (plausibly lower) oxidation state of Fe in the clay structure.

Implications for aqueous alteration at Oxia Planum: Rocks containing Fe^{2+}-rich vermiculite, locally with octahedral Al and (oxidized) Fe^{3+}, are likely the main component of bedrock phyllosilicates at Oxia Planum. In terms of clay structure and its di- versus trioctahedral nature, Oxia deposits are matched best by a vermiculite-saponite from hydrothermally-derived settings (Granby Tuffs), although the contribution of saponite must be minor at Oxia. Comparison of Otago vermiculite to Oxia shows high Fe content in Oxia and a similar oxidation state. Spectral inconsistencies between Otago and Oxia related to presence of Al in the clay structure allow us to conclude that Oxia bedrock deposits were not oxidized nor illitized after formation.

Plausible environments of Oxia's bedrock deposit formation are: (1) igneous-hydrothermal, for instance deposition as ash-fall deposits or (2) alteration of chlorite in anoxic, reducing conditions. In both scenarios, post-depositional alteration must have been negligible to prevent oxidation of vermiculite and its transformation to illite.

Biosignature preservation potential: Trioctahedral vermiculite has high potential to store organic matter [5]. Both scenarios of deposits formation at Oxia, that we present based on mineralogical analogies with terrestrial deposits, are advantageous for retaining organic matter during deposition. Furthermore, non-oxidizing conditions after deposition that we infer enhance the likelihood of the preservation of organic matter, if such matter was present during the Noachian on Mars.

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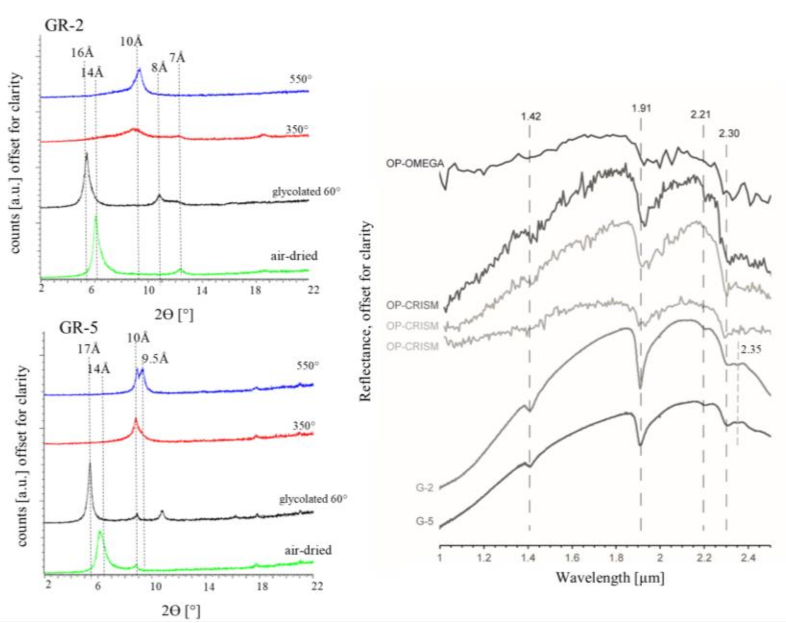

Fig. 2. XRD and NIR results for example Granby samples and comparison to Oxia bedrock deposits. GR-2 – a sample with trioctahedral, well crystallized, pure vermiculite, GR-5 – well-crystallized vermiculite mixed with saponite.