SIMULATING A Ma_MISS BOREHOLE SURVEY IN THE SUBSURFACE OF OXIA PLANUM

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Introduction: Laboratory measurements were performed on different mineral mixtures representative of Oxia Planum [1] mineralogy with the Ma_MISS (Mars Multispectral Imager for Subsurface Studies) Optical Tool (MOT) [2]. The collected data were used to produce hundreds of simulated spectra that were spatially collocated along the internal surfaces of a simulated cylindrical borehole to simulate a survey capable of providing data that would allow the reconstruction of the stratigraphy of the drilling site.

The Ma_MISS instrument: Ma_MISS is the Visible and Near-Infrared miniaturized spectrometer hosted in the drill system of the ExoMars2022 rover [3] that will characterize the mineralogy and stratigraphy of the excavated borehole wall at different depths (< 2 m) [4]. Ma_MISS has a spectral range of 0.5–2.3 μm, a spectral resolution larger than 20 nm in the IR, a SNR ~100, and a spatial resolution of 120 μm. It will accomplish the following scientific objectives: (1) determine the composition of the subsurface materials; (2) map the distribution of the subsurface H_2O (if present) and of hydrated phases; (3) characterize important optical and physical properties of the materials (e.g., grain size); (4) produce a stratigraphic column that will provide information on the subsurface geology. Ma_MISS will operate periodically during pauses in drilling activity and will produce hyperspectral images of the drill's borehole.

The Ma_MISS Optical Tool: The characterization of the scientific performances of the Ma_MISS instrument was made using the laboratory model at the Institute for Space Astrophysics and Planetology of INAF. The MOT, located within a spare ExoMars2022 drill Tip, hosts a 5 W light source, the optical fibers, and the Optical Head with the dual task of focusing the light on the target and recollecting the scattered light. However, it does not include the flight spectrometer and is therefore coupled with two laboratory spectrometers (Avantes) that allow collecting data in the range 0.5–2.2 μm.

Spectral measurements and spatial data arrangement: Previous studies [5, 6] suggest that the mineralogy of Oxia Planum is dominated by aqueous altered rocks. The widespread presence of Fe/Mg-Al-phyllosilicates and, more generally, of OH-bearing silicates confirms the interaction between water and rocks in the past of Mars. For this reason, we prepared six samples mixing clays of various origins with other mafic minerals to simulate different alteration grades of a hypothetical Martian shallow subsurface. The composition of the samples is reported in the table. 1

	SIM1	SIM2	SIM3	SIM4	SIM5	SIM6
Cap1	•	•	•	•		
NAu1		•				
IMt2	•					
ABas					•	
Fo			•			
En	•					
Feld	•	•	•			
Gy						•

Tab. 1: Sample composition.

To prepare the mixtures SIM1, SIM2, and SIM3 we used the sample Cap1, a natural hydrothermal/pedogenetic clay, consisting mainly of phyllosilicates of Fe, Al, and Mg to which we added, in one case, the Nontronite (NAu1) and in the other the illite-smectite (IMt2) to vary the Al-Mg-Fe ratios in the mixtures. Mg-olivine (Fo) and enstatite (En) have been used in the mixtures as proxies of unaltered mafic silicates. We also used the alkali feldspar (An) to increase/vary the reflectance in the mixtures. The SIM4 sample consists of the natural sample Cap1, while SIM5 is principally constituted by an altered basalt. The only single-mineral sample is SIM6 that is constituted by gypsum that we used to simulate a sulfate-vein across the stratigraphy. All the six samples were measured with a grain size below 100 μm and the resulting spectra are shown in figure 1

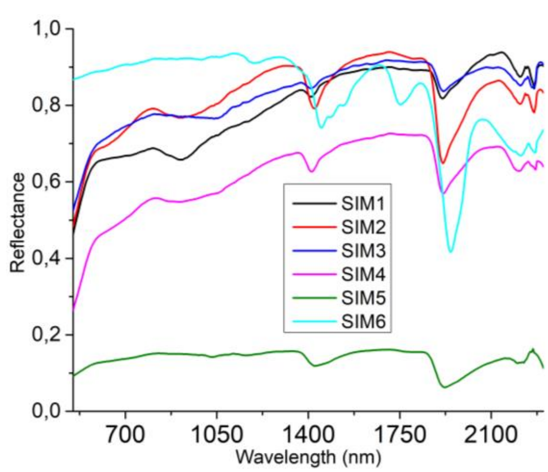

Fig. 1: Ma_MISS spectra of the six samples used in this simulation.

Starting from the laboratory measurements of the six samples, we mathematically generated hundreds of spectra that we ideally arranged on the inner surface of a 250 mm deep borehole wall (Figure 2). In particular, the spectra were spatially arranged as if the Ma_MISS instrument was acquiring data by operating:

- 6 Ring acquisitions (with $\Delta Z = 50$ mm) of 360 spots with $\Delta\theta = 1°$;
- 8 Column acquisitions (with $\Delta\theta = 45°$) of 250 spots with $\Delta Z = 1$ mm;

Where ΔZ is the depth spacing, and $\Delta\theta$ is the angular spacing.

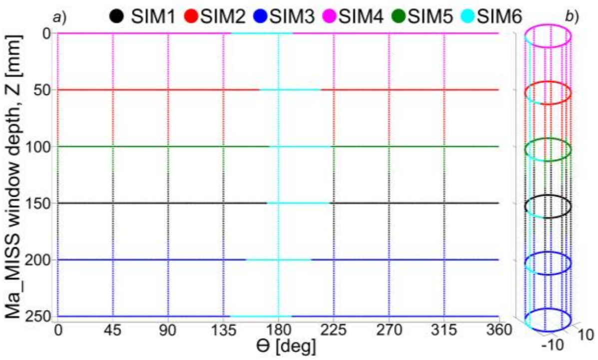

Fig. 2: Diagram of the measurement spots arrangement in a 250 mm depth borehole wall; a) 2D scheme; b) 3D cylindrical view.

This data arrangement simulates a real profile of aqueous alteration that changes from the top, where a higher degree of leaching in the upper part of the stratigraphy (with Al-bearing clays) is present, to the bottom, where a few mafic minerals are mixed with Fe/Mg clays as relics of the magmatic mother rock. Moreover, we arranged the spectroscopic data of the gypsum in a sub-vertical direction like a post-depositional vein of sulphates that cuts the stratigraphy to simulate the circulation of fluids.

Discussion: In this work, we reconstructed a fictitious stratigraphy starting from real spectral data with the aim of simulating a putative investigation that Ma_MISS will be able to carry out in the Oxia Planum subsurface. The purposes of this exercise can be multiple: 1) plan the distribution of the measurement spots in the drilling hole; 2) evaluate the minimum number of spots necessary to characterize a given stratigraphy; 3) find the best way of representing the data that will be acquired during the scientific phase of the mission. In figure 3 we show an example of a synthetic color plot. The color of each point was derived from its reflectance spectrum by using, as RGB components, the reflectance values at three specific wavelengths: 700 nm for the red, 550 nm for green, and 500 nm for blue. This provides a representation of the borehole wall which looks somewhat like the way the human eye would see it. In addition, as a preliminary output, we used a biharmonic interpolation to fill the borehole wall areas where the data were not collected, the result is shown in figure 3b.

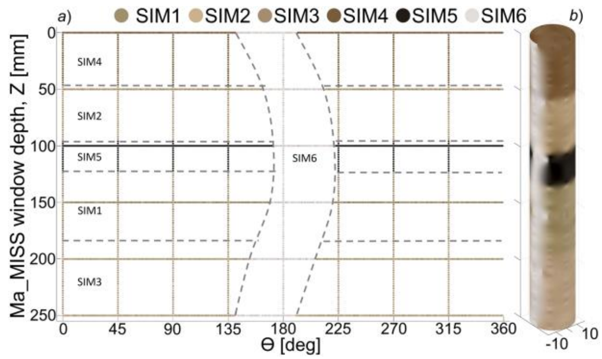

Fig. 3: Schematic view of the measurement spots arrangement with the reconstructed stratigraphy; a) 2D scheme with dashed lines representing the contacts between the interpreted strata; b) RGB image of the borehole wall in a 3D cylindrical view.

Conclusions and future work: The obtained results are just one of the many possibilities of data representation. It will be possible to generate other output images from different spectral characteristics, e.g., using wavelengths in the infrared range to highlight different hydration or oxidation states of the subsurface layers. We are now working on the production of a complete borehole survey by using only acquired data (without mathematically generated spectra) to testing an actual borehole scan and reconstructing the wall stratigraphy.

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References:[1] Quantin-Nataf, C. et al., (2021) Astrobiology, 345-366. [2] De Angelis S. et al. (this conference). [3] Vago J.L. et al. (2017): Astrobiology, 17, 6, 7. [4] De Sanctis M.C. et al. (2017): Astrobiology, 17, 6, 7. [5] Carter J. et al. al (2016) #2064, 47th LPSC, Houston, TX. [6] Mandon L. et al. Astrobiology, 464-480.