

SYSTEMATIC STUDY OF DETECTION LIMITS OF HYDRATE AND CARBONATE PHASES IN MIXTURES WITH BASALTIC-LIKE FINE REGOLITH

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Introduction: Although we know more about the surface mineralogy of Mars than of any other planetary body beside Earth [e.g., 1, and references therein], there are still several open questions about its mineralogy and in particular about the genesis and formation of the minerals detected on its surface. The global nature of mineral formation in the presence of liquid water during the first billion years has been a key discovery, but a large number of still open issues makes the study of these mineral deposits a focus of many remote sensing and laboratory studies. In addition, even though there is extensive research related to the analysis of the spectral behaviour of mixtures we still lack a full understanding of the problem.

To investigate the detection limits of hydrate or carbonates phases we are studying the laboratory spectral behaviour of mixtures with basaltic fine regolith as Mars surface analog. On a larger scale, this work is a part of a laboratory effort that seek to provide new laboratory spectral data derived from a systematic study of the spectral behaviour of particulate mixtures that will be useful not only for the investigation of the Martian surface composition but also for the study of other planetary bodies surfaces.

For the purposes of this work we selected two different basaltic samples with grain size $< 50 \mu\text{m}$ (a large set of grainsize is available for further investigation): one pyroxene dominated (basalt A2 [2]) and one olivine-bearing (Py7MM [3; 4]). Basaltic endmembers are mixed with different hydrated minerals of variable grain size.

Measurements are performed at the Planetary Spectroscopy Laboratory (PSL) of the German Aerospace Center (DLR) in Berlin (Germany) [5] and in parallel at S.LAB at INAF-IAPS (Institute for space Astrophysics and Planetology) in Rome (Italy).

Data and methods: The methodology applied in this work is based on two main steps: 1) bidirectional laboratory reflectance measurements in vacuum and in standard terrestrial environments (standard P/T) of samples endmembers and mixtures; 2) laboratory spectral data analysis in the NIR-MIR (from 1 up to $\sim 6 \mu\text{m}$) and in the FIR (between 6 up to $17 \mu\text{m}$).

Sample selection: The suite of samples selected for this work includes pure end-member minerals that belong to the class of minerals detected on the Mars' surface using orbital data [e.g. 1; 6; 7]. The selected bas-

alts (A2 basalt pyroxene dominated; PY7MM Olivine-bearing) are mixed with:

- a dolomite (CIS11C), with some hydration at four different grain sizes: $100 - 125 \mu\text{m}$; $200 - 224 \mu\text{m}$; $300 - 400 \mu\text{m}$; $600 - 710 \mu\text{m}$;
- with a calcite at three different grain sizes: $100 - 125 \mu\text{m}$; $200 - 224 \mu\text{m}$; $300 - 400 \mu\text{m}$;
- Na-carbonate with 2 different level of hydration (a single mole of H_2O and 10 mole of H_2O);
- Hexahydrate with grain size $300 - 400 \mu\text{m}$;
- Epsomite with grain size $300 - 400 \mu\text{m}$;
- Three clays (P17, Pa, argilla varicolori-multicolor clay) with grain size $100 - 125 \mu\text{m}$.

Laboratory measurements: Bidirectional reflectance measurements in vacuum are acquired at PSL by using a Bruker Vertex80V FTIR spectrometer and a Bruker A513 variable-angle accessory that allows bi-conical reflectance measurements for varying viewing geometry with different phase angles. For this work we choose the following angles configuration: i (incidence) = 0° , e (emission) = 30° .

Bidirectional reflectance measurements in standard terrestrial environment are acquired at S.LAB at INAF-IAPS using a goniometer coupled with a FieldspecPro ® in the range between 0.35 and $2.5 \mu\text{m}$.

Laboratory data analysis: In Figure 1 and 2, examples of calibrated bidirectional reflectance measurements are shown for the mixtures of both basalts A2 and Py7MM with epsomite with grain size $300-400 \mu\text{m}$. In the spectra acquired it can be seen how the hydrated component is easily identifiable with some differences between the two basalts. In the spectral range between 1.5 and $6 \mu\text{m}$ and in the mixtures with Py7MM (Figure 1, bottom panel), hydrated features are evident already in the mixture with 20% of epsomite, where the sample is more bright and not shows a $2 \mu\text{m}$ band. In the same spectral range for mixtures with A2 (Figure 1, upper panel), it is interesting to note how the hydrated features starts to be visible only at greater abundances of epsomite (40%). Furthermore it is also interesting to see how, being the sulphate very saturated with water at a length greater than $2.7 \mu\text{m}$, the spectral signature is less varied, but there is still a systematic variation with a clear change between 60% and 80%

of epsomite (the first more similar to the mafic base, the second very similar to the epsomite). Interesting observations can also derive from the study of the spectral range $> 6 \mu\text{m}$.

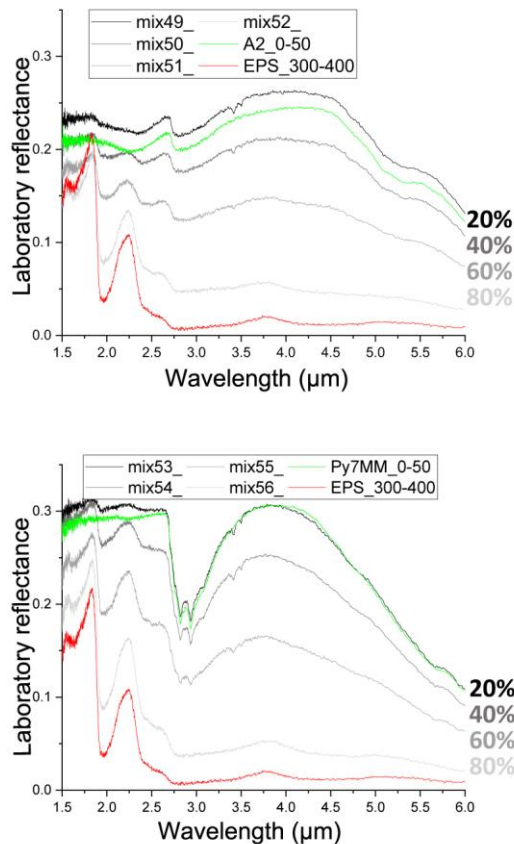


Figure 1. Upper panel: Laboratory reflectance spectra of the samples endmembers and mixtures of basalt A2 with epsomite (300-400 μm) in the spectral range between 1.5 and 6 μm **Bottom panel:** Laboratory reflectance spectra of the samples endmembers and mixtures of basalt Py7MM with epsomite (300-400 μm) in the spectral range between 1.5 and 6 μm .

In Figure 2 (upper and bottom panels), it is possible to see how there is a variation in the set of mixtures and how the evidence of epsomite at lower abundances seems to be clear for mixtures with A2. Another interesting thing is the effect on the Transparency Feature (TF) present in the finer mafic bases, while absent in the sulphate component.

Future developments and implication for the analysis of Martian orbital data: The measurements and data analysis performed in this work are thought in the framework of the interpretation of current and new Martian data. In detail, investigation the spectral behavior of laboratory mixtures in the NIR will be useful for the interpretation of Martian CRISM [8] and

OMEGA[7] orbital data. Moreover new spectral data on their behavior in the MidIR can provide new insights for the interpretation of TES[9], PFS[10] and the new TIRVIM data of the ExoMars 2016 mission[11],

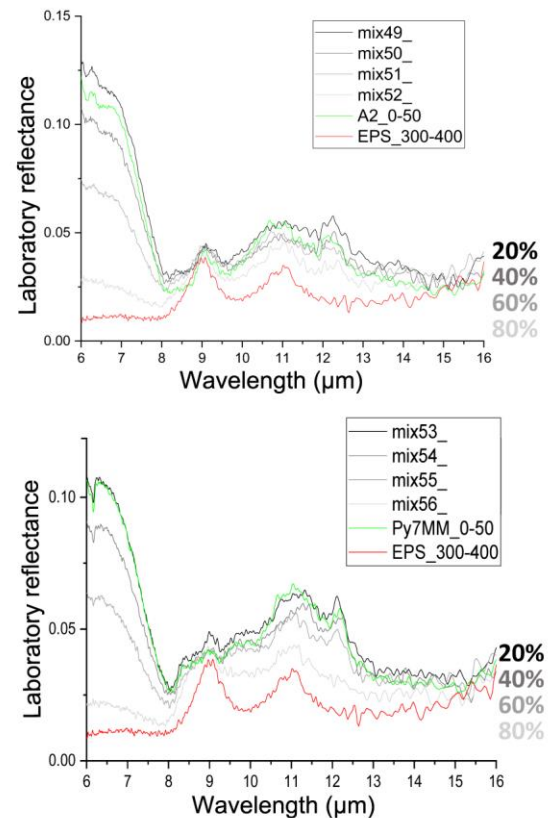


Figure 2. Upper panel: Laboratory reflectance spectra of the samples endmembers and mixtures of basalt A2 with epsomite (300-400 μm) in the spectral range between 6 and 16 μm **Bottom panel:** Laboratory reflectance spectra of the samples endmembers and mixtures of basalt Py7MM with epsomite (300-400 μm) in the spectral range between 6 and 16 μm .

and in preparation for the up-coming in-situ measurements of the ExoMars 2020 rover [12].

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