

EXPERIMENTAL STUDY OF WATER EXCHANGE BETWEEN REGOLITH AND ATMOSPHERE UNDER MARTIAN CONDITIONS: THERMODYNAMICS AND REFLECTANCE SPECTROSCOPY. A. Pommerol¹, B. Schmitt¹, and O. Brissaud¹. ¹Laboratoire de Planétologie de Grenoble, UJF/CNRS, Bât. D de Physique, B.P. 53, 38041 Grenoble Cedex 9, France. (Email: antoine.pommerol@obs.ujf-grenoble.fr).

Introduction: Important exchanges of water between atmosphere and surface are expected on Mars, linked to seasonal and diurnal cycles. To be correctly understood and modeled on the Martian surface, exchange processes (adsorption, diffusion, condensation, phase change...) have first to be extensively studied in the laboratory under conditions representative of the Martian surface. Especially, thermodynamics and kinetics parameters have to be measured for a variety of analog materials. ([1], [2], [3])

Near-infrared reflectance spectroscopy provides extremely valuable information on associations between water and minerals on the Martian surface thanks to successive generations of spectrometers and imaging spectrometers onboard of space missions. Both spatial and temporal variations of condensates and mineral hydration are currently observed and analyzed thanks to the OMEGA and CRISM instruments. Extensive spectral databases are needed to interpret these remote-sensing datasets. When looking at water, it is sometimes crucial to perform spectral measurements under conditions of temperature and pressure representative of the Martian surface. ([4], [5])

Methods: We have designed and built an original experimental facility to analyze various types of associations between water and minerals and study the exchange of water between simulated atmosphere and regolith under Martian conditions (temperature, pressure, relative humidity). A simulation chamber allows the exposure of an analog material to conditions that can be precisely controlled. Pressure and temperature at equilibrium as well as exchange kinetics are measured. Bidirectional reflectance spectra (0.3–4.8 μm) are measured with the LPG spectro-gonio-radiometer ([6]).

Results: We present here preliminary results obtained with the JSC Mars-1 regolith simulant ([7]). Same studies are either already performed or will be performed for other types of Martian regolith analogs including palagonite, basaltic sand, phyllosilicates, sulfates...

In this example, the regolith analog is a relatively smooth and non compacted surface of JSC Mars-1 (depth: 1mm, diameter: 3 cm, mass: 0.7 g). The sample was heated overnight at 180°C under secondary vacuum ($< 10^{-6}$ mbar) to remove part of its moisture. Despite these conditions, the sample spectrum still presents a strong 3 μm band (figure 1). Then, small

known amounts of water vapor were introduced in the chamber in successive steps. Sample temperature was maintained around -35°C. For each hydration step, sample temperature, water vapor pressure and 3 μm band strength were continuously measured. After equilibration, a complete spectrum was measured and equilibrium temperature and water vapor pressure were recorded. Figure 1 presents infrared spectra measured at equilibrium after each hydration step. Inserted in fig. 1, values of Integrated Band Area (between 3 and 4 μm) are plotted versus equilibrium water vapor pressure to form the “spectroscopic adsorption isotherm” at -35°C.

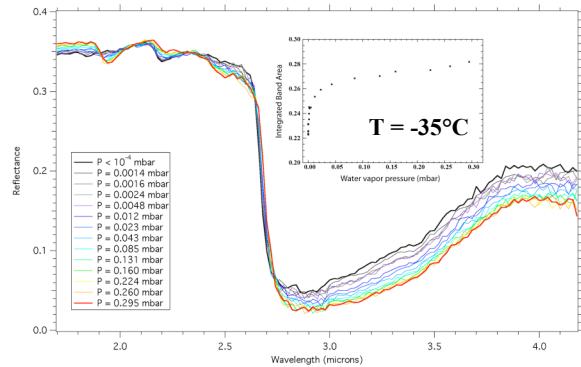


Figure 1: Near-infrared reflectance spectra of the JSC Mars-1 sample equilibrated with water vapor at different pressures. Insert: 3 μm Integrated Band Area (3 - 4 μm) versus water vapor pressure at equilibrium.

Figure 2 presents the water vapor pressure, sample temperature and 3 μm band depth variations during one of the hydration steps (between two of the spectra presented on figure 1). Water is introduced in the simulation chamber from another volume at $t=265$ s. The pressure in the chamber decreases until an equilibrium is reached after a few tens of minutes. In the same time, temperature measured at the bottom of the 1 mm thick sample increases by about 1°C because water adsorption is exothermic. Band depth, measured at 3.26 μm shows a very quick increase during less than two minutes after water injection. Then, band strength shows a very small decrease while pressure and temperature continue to decrease. For other injections of water at either lower or larger pressure, equilibration time is always counted in tens of minutes or hours when looking at pressure and in tens of seconds or minutes when looking at reflectance spectroscopy. The

different kinetics as well as the non monotonic behavior of band strength are due to the small penetration depth of photons in the strong 3 μm absorption band. Thus, only the upper part of the sample is probed by spectroscopy while pressure and temperature vary as a function of the bulk quantity of water adsorbed in the whole sample. Therefore, spectroscopy and thermodynamics used simultaneously provide information about the vertical gradient of hydration inside the sample.

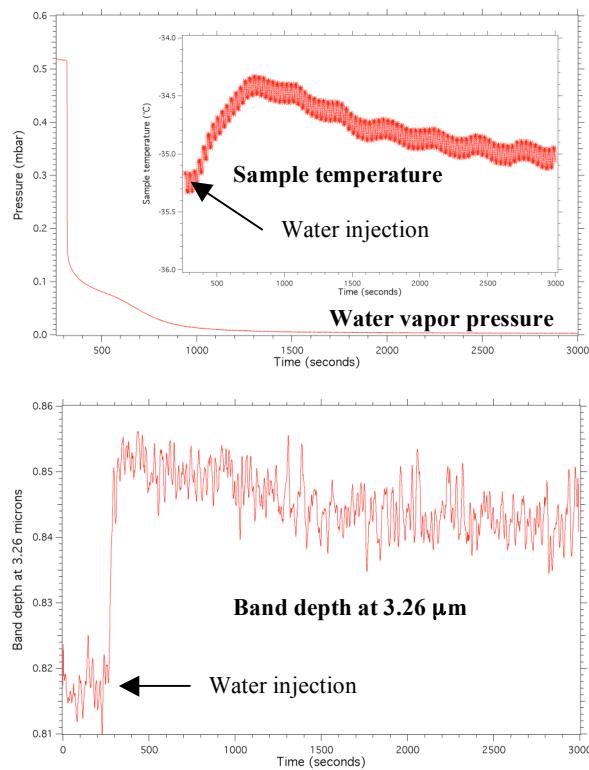


Figure 2: Water vapor pressure, sample temperature and hydration band depth evolutions during hydration. Water is injected in the sample at $t=265$ s.

We also simulated cyclic variations of environmental conditions with different periods. An example is provided on figure 3 with a period of 8 hours. The 3 μm hydration band depth oscillates as a response to cyclic variations of atmospheric water pressure.

Conclusion: We have developed an original experimental facility to measure reflectance spectra of materials under conditions representative of the Martian surface. We use this facility to study the exchange of water between simulated atmosphere and surface both from spectroscopic and thermodynamic points of view. We measure water adsorption isotherms for various analog materials at low temperature and relative humidity and build a spectral database of these analogs with different hydration states. Exchange kinetics are studied through the response of materials to

water vapor instantaneous variations or periodic variations of the environmental conditions.

Results on JSC Mars-1 at low temperature (-35°C) indicate that fast kinetics have to be considered when looking at hydration from a “reflectance spectroscopy” point of view (case of OMEGA and CRISM instruments). As the 3 μm hydration band is very strong, photons penetration depth is extremely reduced so that the soil thickness probed by reflectance spectroscopy equilibrates with atmosphere very fast.

The shape of the spectroscopic adsorption isotherm at -35°C of the JSC Mars-1 material (presented in figure 1) indicates that water content and thus hydration band strength are susceptible to strongly vary as a response to variations of relative humidity in the partial pressure range to be considered for the Martian surface (around 10^{-3} mbar).

All results so far indicate that usual analog materials for the Martian surface adsorb sizeable amounts of water under ambient Martian surface conditions. The amount of water in the regolith will vary as a response to temperature and atmospheric water vapor pressure variations. Near-infrared reflectance spectroscopy reveals the hydration state of the upper part of the surface that is always at thermodynamics equilibrium with atmosphere whereas the hydration state of the subsurface under this sub-millimeter thick layer may be different.

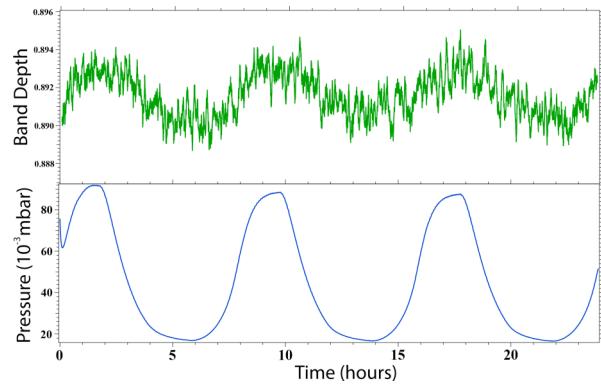


Figure 3: A periodic variation of water vapor pressure is imposed to the JSC-1 sample (period: 8 hours). JSC Mars-1 adsorbs and desorbs water as water vapor pressure varies as this is shown by the cyclic variation of the 3 μm hydration band strength.

- References:**
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