MEASURING STABILITY OF HYDRATED MINERALS EXPOSED TO MARS SURFACE CONDITIONS.
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Introduction: The Perseverance rover is investigating Jezero crater to study past habitability and potential biosignatures [1]. Carbonates and phyllosilicates have been detected in Jezero crater by Perseverance’s instruments [1, 2, 3, 4]. These materials and others can exist across a range of hydration states. A key goal of the mission is to determine the state of hydration of minerals preserved within the rocks.

There are various pathways to mineral dehydration, such as changes to the atmosphere via temperature, relative humidity (RH), pressure, solar UV irradiation or solar radiant heat [5, 6, 7]. On Mars, these factors can cause hydrated minerals to become unstable [8, 9, 10]. A potential problem in studying the hydration state of pristine minerals measured by Perseverance is that minerals can dehydrate in the time period after an abrasion patch is created and before measurements are made. Due to rover operational limitations, this period is usually one to several days.

Based on Mars environment chamber experiments, laboratory data show that minerals can dehydrate within one day of exposure to Mars-like surface conditions. Spectral features related to hydration may or may not persist upon exposure to a martian environment [8, 9, 10]. Here we report on a further series of laboratory measurements of relevant mineral samples that address this dehydration issue and its spectral detectability on Mars.

Methods: Following previous laboratory experiments [8, 9, 10], 27 powdered (<45 µm) samples were exposed in an atmospheric controlled chamber with Mars-like surface conditions (5 Torr, constant flow of dry CO2, ambient temperature, ±UV irradiation) and periodically measured for approximately 66 days in a simulated martian environment. Reflectance spectra were collected with an Analytical Spectral Device FieldSpec Pro HR spectrometer (0.35-2.50 µm), at a viewing geometry of i=0°, e=30°. The samples were measured before and after, and periodically during the experiment.

Results: Four samples in the phyllosilicate (Figs. 1-3) and Na carbonate (Fig. 4) groups show dehydration after exposure to martian surface conditions. Band depth calculations were applied to the 1900 nm (OH stretch and H-O-H bend) absorption band to constrain the relative signature of H2O lost, as this band exhibited the most spectral changes over the experimental run.

The hectorite (HEC102; phyllosilicate) sample spectra (Fig. 1) shows 1400 nm and 1900 nm OH/H2O absorption bands, and a 2300 nm Mg/Fe phyllosilicate band. The 1400 nm band shows little change in depth, while the 1900 nm band exhibits a rapid increase in depth after Day 0, consistent with rapid loss of H2O. The band depth for Day 0 is 21.9% and shows a reduction in band depth to 3.47% by Day 66. The largest reduction in water is on Day 1, immediately after exposure to martian conditions, showing a 17.25% decrease.

The montmorillonite (MON102; phyllosilicate) sample spectra (Fig. 2) shows the 1400 nm, 1900 nm, and 2300 nm absorption bands. The 1400 nm absorption band shows little change after exposure to Mars conditions, while the 1900 nm absorption band exhibits loss of H2O at a rapid rate. The band depth for Day 0 is 7.73% and decreases to 1.65% by Day 66. The highest drop in H2O is on Day 1 at 6.08%.

Figure 1. Reflectance spectra of hectorite (HEC102) at a wavelength range of 350-2500 nm, under an atmospheric pressure of 5 Torr (Day 0 was measured at ambient terrestrial pressure). Percentages in the legend show band depth calculations for loss of the 1900 nm hydration band. Ideal formula: Na0.3(Mg, Li)2Si2O5(OH)2·nH2O

Figure 2. Reflectance spectra of montmorillonite (MON102) with calculated hydration band depths. Same environmental conditions as Figure 1. Ideal formula: (Na,Ca)0.3(Al, Mg)2Si2O5(OH)2·nH2O

The nontronite (NON101; phyllosilicate) sample spectra (Fig. 3) shows the 1000 nm Fe2+ absorption
band, and the 1400 nm, 1900 nm, and the 2300 nm absorption bands. The spectra again show a decrease in the 1900 nm band, with a calculated band depth of 11.69% on Day 0 and decreases to 1.33% by Day 66. At 1900 nm, after an initial decrease by Day 1 of 9.25%, there is little further change in depth.

The trona (CRB214; Na carbonate) sample spectra (Fig. 4) shows 1500 nm (OH), 1900 nm, and 2300 nm (carbonate) absorption bands. Its spectra show a reduction in depth of both the 1500 nm and 1900 nm (OH/H₂O overtones) absorption bands after exposure to Mars-like surface conditions, exhibiting gradual dehydration. There is overall loss in hydration with 26.55% on Day 0 and 1.23% on Day 66. There is only a 0.43% reduction in hydration on Day 1.

![Nontronite](image1)

**Figure 3.** Reflectance spectra of nontronite (NON101) with calculated hydration band depths. Same environmental conditions as Figure 1. Ideal formula: Na₀.₀Fe²⁺(Si,Al)₄O₁₂(OH)₂·nH₂O

![Trona](image2)

**Figure 4.** Reflectance spectra of trona (CRB214) with calculated hydration band depths. Same environmental conditions as Figure 1. Ideal formula: Na₂(CO₃)·(HCO₃)·2(H₂O)

**Application to Mars:** The martian subsurface is exposed by the Perseverance rover using a rock abrading tool that removes surface weathering, dust coatings, and rinds [11]. After the surface abrasion occurs, dust removal is performed by the Gas Dust Removal Tool (gDRT) [11]. The gDRT ensures that the flat surface of the abrasion patch is clear of any dust particles post abrasion [11]. Abraded surfaces on Mars expose alteration minerals to current martian conditions that could rapidly alter minerals. The lab experiments suggest that these changes could occur on Mars immediately after abrasion before Perseverance’s instruments can make their first measurements. Obtaining several data points as a function of time (observations on a multi-sol cadence) could allow an extrapolation of hydration levels to the time the abrasion patch was created.

SuperCam is a remote-science instrument that includes visible (0.40-0.85 µm) and near-infrared (1.3-2.6 µm) (VISIR) reflectance spectroscopy in its payload [12]. Like the laboratory experiments that measure the hydration band in the IR, SuperCam includes this spectral region which could provide direct measurements of the 1900 nm band on martian materials. Calculating this hydration band using Mars data can validate measurable changes to hydrated minerals due to abrasion and dehydration. The Scanning Habitable Environments for Raman and Luminescence for Organics & Chemicals (SHERLOC) is a proximity instrument with a deep ultraviolet (DUV) Raman and fluorescence spectrometer [13]. Dehydration can be measured by observing changes in the hydration/mineral peaks in SHERLOC Raman spectra. Both instruments can measure hydration on Mars by measuring spectral variability.

**Discussion and Conclusion:** The laboratory results of phyllosilicates and a Na carbonate suggest that changes occur to some hydrated mineral species after exposure to Mars surface conditions. There is a more gradual decrease in dehydration for the carbonate sample compared to the rapid dehydration rates of the phyllosilicates. We see initial changes to the 1900 nm H₂O bands first, with little to no changes to the 1400/1500 nm OH bands, consistent with previous studies.

In essence, performing direct dehydration experiments on Mars can provide important information for understanding long-term preservation of rock interiors and past martian environment conditions.

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**References:**