

SALT AND WATER MIGRATION EXPERIMENTS AND IMPLICATIONS FOR MARS DURICRUST FORMATION. J. L. Miller¹, C. A. Hibbitts², and M. T. Mellon³, ¹Johns Hopkins University Department of Earth & Planetary Sciences (jmill250@jhu.edu), ²Johns Hopkins University Applied Physics Laboratory, ³Cornell Center for Astrophysics & Planetary Science

Introduction: Duricrusts are weakly cohesive surface regolith materials that are widely observed on Mars, and commonly present with a higher concentration of salts compared to unconsolidated regolith¹⁻³. On Earth, they often form in arid regions as water precipitates dissolved salts to cement grains. However, Mars currently lacks such abundant liquid surface water.

To investigate duricrust formation on Mars, we designed experiments to simulate salt and water migration in wet, salty soils in desiccating conditions over a range of temperatures. We measured reflectance spectra in the 350 to 2500 nm (visible to near-infrared) range, focusing on overall spectral slope (an indicator of grain size) and the shape of the water absorption band at 1950 nm (diagnostic of the presence of adsorbed or structural water). We also measured changes in salt concentrations in the prepared samples and investigated correlations between salt concentration and reflectance spectra, which may be useful in remote sensing applications and interpreting environments. We test the hypothesis that hydration could be a proxy for hydrophilic salts, like MgSO₄ and to a lesser extent CaSO₄, and possibly even be an indicator for less hydrating salts such as MgCl₂.

Experiments: We performed two series of desiccation experiments to examine different characteristics of salt and water migration: 1) ~0.25 cm thick “thin discs” to focus on changes in surfaces, 2) 2 cm tall, 2 cm diameter “cylinders” to examine changes in salt at depth. We prepared the Mars simulant from Birch Hill loess (silt-dominated soil with minimal organics, clays, and salts) combined with one of three salts identified at Viking and Phoenix landing sites⁴⁻⁵: MgCl₂ (1 wt%), MgSO₄ (10 wt%), and CaSO₄ (10 wt%).

These salt-doped loesses were wetted, mixed, then prepared as “thin discs” by spreading the paste (~2 cm diameter x ~0.25 cm thick) onto aluminum foil sheets, and as “cylinders” by packing paste into 2 cm tall acrylic tubes open at both the top and bottom and placing the tubes onto a Pyrex tray. Samples were then subjected to a constant temperature (-196 °C, -20 °C, 20 °C, 80 °C, or 150 °C) and desiccated. Subfreezing samples were rapidly frozen (in liquid nitrogen at -196 °C) or slowly frozen (in a freezer at -20 °C) then desiccated at -20 °C for one week. Ambient samples (20 °C) were desiccated for 1 week (thin discs) or 4 weeks (cylinders) in a nitrogen purge. Heated samples were desiccated at

80 °C (thin discs for 2 hours, cylinders for 4 hours) and 150 °C (2 hours).

After desiccation, we noted changes in surface appearances (Fig. 1a), and obtained reflectance spectra for the surfaces of the thin disc samples (Fig. 1b-c). We horizontally cut the desiccated cylinders into 0.5 cm thick sections, and measured salt concentrations and reflectance spectra of each section (0.0, 0.5, 1.0, and 1.5 cm).

Desiccation Effects: In the thin disc experiments, the MgSO₄-sample surfaces showed white surface salt crusts at all temperatures, which cement loess grains to cause steepened spectral slopes at elevated temperatures. MgCl₂ and CaSO₄ samples do not feature such prominent salt crusts, and spectral slopes are flatter (Fig. 1b). The normalized 1950 nm water absorption bands change with temperature (Fig. 1c). In MgCl₂, the 1 – 2 micron slope flattens and slightly deepens at both tem-

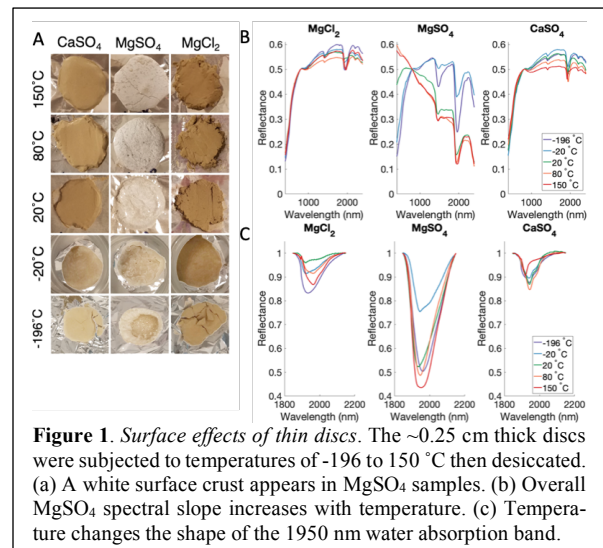


Figure 1. Surface effects of thin discs. The ~0.25 cm thick discs were subjected to temperatures of -196 to 150 °C then desiccated. (a) A white surface crust appears in MgSO₄ samples. (b) Overall MgSO₄ spectral slope increases with temperature. (c) Temperature changes the shape of the 1950 nm water absorption band.

perature extremes, indicating hydration. In MgSO₄, the normalized band depth and shape is largely invariant except at -20 °C where it shallows and narrows, signaling loss of hydration, but the spectral slope greatly increases at higher temperature possibly signaling increasing grain size. In CaSO₄, this band narrows at 150 °C, signaling dehydration relative to lower temperatures.

In the cylinder experiments, spectral slope increased with temperature for MgSO₄ and white salt crusts formed at the surfaces which became thicker and more opaque as temperature increased (Fig. 1). The 1950 nm water absorption band changed shape with temperature. In the MgCl₂ samples, it remained unchanged across

depths at subfreezing temperatures, was relatively deep and broad at 20 and 80 °C at the surface, signaling hydration, then narrow again but still deep (hydrated) at all depths at 150 °C (Fig. 2). In MgSO_4 , the band gradually

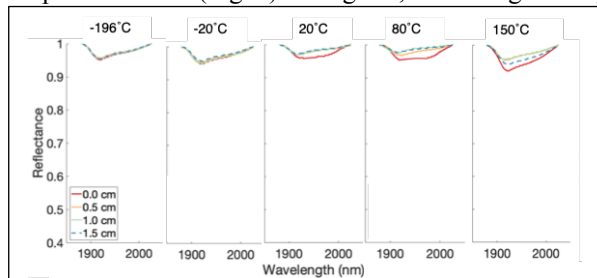


Figure 2. Desiccation effects on the 1950 nm water absorption band in MgCl_2 cylinder experiments. The 2 cm cylinders were subjected to temperatures of -196 to 150 °C then desiccated. A gradual broadening and flattening occurs at the surfaces at 20 and 80 °C, signaling a hydration at moderate temperatures.

deepened at the sample surface as temperature increased, indicating increasing hydration, and a shoulder appeared at the sample surface and 1.5 cm depth at 150 °C (Fig. 3). In CaSO_4 , this band retained shape across

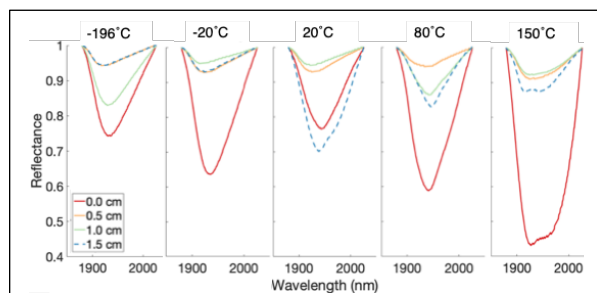


Figure 3. Desiccation effects on the 1950 nm water absorption band in MgSO_4 cylinder experiments. The 2 cm cylinders were subjected to temperatures of -196 to 150 °C then desiccated. A gradual deepening of the surface occurs with increasing temperature. A shoulder appears at 150 °C, indicating dehydration.

depths at subfreezing temperatures but the band area decreased as temperature increased, first at depth and also for the surface at the highest temperature, indicating gradual dehydration (Fig. 4).

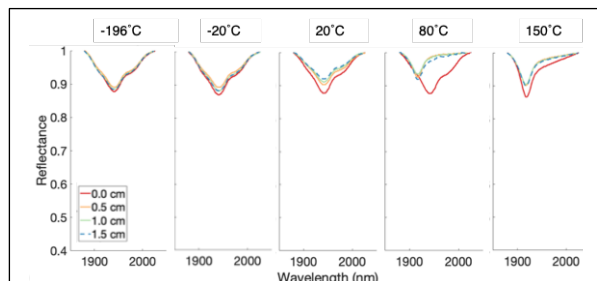


Figure 4. Desiccation effects on the 1950 nm water absorption band in CaSO_4 cylinder experiments. The 2 cm cylinders were subjected to temperatures of -196 to 150 °C then desiccated. The 1950 nm band gradually loses the shoulder with increasing temperatures, indicating a gradual dehydration.

Salt Migration and Hydration: We calculated the area of each band at 1950 nm, then plotted it against the measured salt concentrations for each of the four horizontal sections for each cylinder experiment (Fig. 5).

Band areas correlate well with salt concentrations in subsurface sections (solid symbols), especially at lower temperatures and for CaSO_4 , the weakest migrator of the three salts. However, at higher temperatures, at the uppermost surfaces (open symbols) and for MgSO_4 , the strongest migrator of the three salts, band areas do not correlate well with salt concentrations.

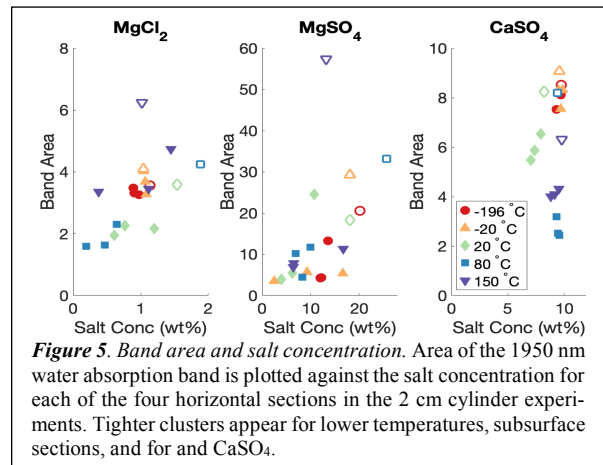


Figure 5. Band area and salt concentration. Area of the 1950 nm water absorption band is plotted against the salt concentration for each of the four horizontal sections in the 2 cm cylinder experiments. Tighter clusters appear for lower temperatures, subsurface sections, and for CaSO_4 .

Conclusions: In our experiments, migration ($\text{MgSO}_4 > \text{MgCl}_2 > \text{CaSO}_4$) and hydration ($\text{CaSO}_4 > \text{MgCl}_2 > \text{MgSO}_4$), are controlled by water migration in two phases: 1) adsorbed phase capable of salt transport to change salt concentration and hydration states (MgSO_4 and MgCl_2) or 2) vapor phase removed from soil without salt transport but hydration may occur (CaSO_4). Adsorbed water migration may cause deepening in the 1950 nm water band as it drives more salts to increase salt abundance. However, this band deepening may also arise from more water sites available in the salt structure, or fewer water molecules at weak sites.

The thin disc experiments focus on surficial changes and corresponding surface spectra analogous to data from missions limited to planetary surface analysis. The cylinder experiments showcase salt migration at depth and corresponding changes in spectra, and are useful in interpreting data from sampling at depth. These results highlight the shortcomings of surficial data, caution against interpreting underlying geologic histories solely from surficial data, and motivate future planetary missions to include subsurface multi-sampling capabilities.

References: [1] Moore, H.J. et al. (1987) *USGS Prof. Paper*. [2] Golombek, M.P. et al. (2008) *Cambridge UP*. [3] Jakosky, B.M. & Christensen, P.R. (1986) *JGR*. [4] Clark, B.C., & Van Hart, D.C. (1981) *Icarus*. [5] Hecht, M.H. et al. (2009) *Science*.