

REFLECTANCE SPECTRAL PROPERTIES OF RELEVANT MINERALS EXPOSED TO MARS-LIKE SURFACE CONDITIONS.

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Introduction: A suite of 28 hydrous and anhydrous minerals (Tables 1 and 2) were studied at the HOSERLab facility (psf.uwinnipeg.ca) at the University of Winnipeg to determine whether they would be stable and spectrally detectable on Mars. This was done by exposing powdered samples (<45 μm) to Mars-like surface conditions (5 Torr CO_2 , ambient temperature, $\pm\text{UV}$ irradiation) for 66 days in a Mars environment chamber, and periodically measuring their reflectance spectra while in the chamber [1]. This study was undertaken to better understand whether terrestrially stable minerals may or may not be stable on the surface of Mars [2,3]. Previous studies have found that spectral features related to hydration may or may not persist upon exposure to Mars surface-like conditions [1]. Data from this study is integral for the robust identification and interpretation of Martian surface material observed by remote sensing instruments.

Methodology: Samples were powdered by hand and dry sieved to <45 μm particle size and measured as flat matte-surface powders. Reflectance spectra were collected with an ASD FieldSpec Pro HR spectrometer (350-2500 nm), at a viewing geometry of $i=0^\circ$, $e=30^\circ$; 500 spectra were averaged to provide high SNR.

Table 1: Samples that show spectral changes attributable to dehydration.

Sample Name	Mineral	Mineral Group
CRB213	Thermonatrite	Carbonate
CRB214	Trona	Carbonate
HEC102	Hectorite	Phyllosilicate
MON102	Montmorillonite	Phyllosilicate
NON101	Nontronite	Phyllosilicate

Table 2: Samples that showed no spectral changes in terms of dehydration.

Sample Name	Mineral	Mineral Group
CRB506	Cerussite	Carbonate
CHL108	Sylvite	Halide
CHL112	Blue Halite	Halide
JAD004	Nephrite/ actinolite	Inosilicate
CEL101	Celadonite	Mica
ILL105	Illite	Mica/phyllosilicate
MAG121	Magnetite	Oxide
ALB101	Albertite	Organic
ANT101	Anthraxolite	Organic
LCA101E	Lampblack	Organic
KAO101	Kaolinite	Phyllosilicate
HAL001	Halloysite	Phyllosilicate

CLI102	Clinocllore	Phyllosilicate
SRP119	Serpentine	Phyllosilicate
PUM101	Pumpellyite	Sorosilicate
QUA105	Plagioclase	Tectosilicate
KAI101	Kainite	Sulfate
SPT146	Barite	Sulfate
PRH105	Pyrrhotite	Sulfide
MAR101	Marcasite	Sulfide
PPT102	Pyrite	Sulfide
SPH101	Sphalerite	Sulfide
ZEO157	Analcime	Zeolite

Results: Tables 1 and 2 summarize the minerals that did or did not show significant spectral changes upon exposure to Mars surface-like conditions, respectively. Figure 1 shows changes in spectral behaviour of thermonatrite (carbonate; CRB213). The sample shows OH/ H_2O absorption bands at ~ 1500 and 1900 nm. Both bands shows a gradual decrease in intensity (depth) over time, consistent with loss of H_2O .

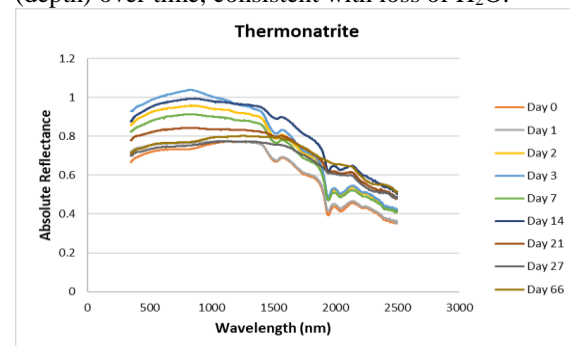


Fig 1. Reflectance spectra of thermonatrite (CRB213); 350-2500 nm, under an atmospheric pressure of 5 Torr (Day 0 was measured at ambient terrestrial pressure).

Figure 2 shows the spectral behaviour of trona (carbonate; CRB214). Its spectra show a reduction in depth of both the 1500 and 1900 nm OH/ H_2O absorption bands after exposure to Mars-like surface conditions, consistent with loss of H_2O over a few days.

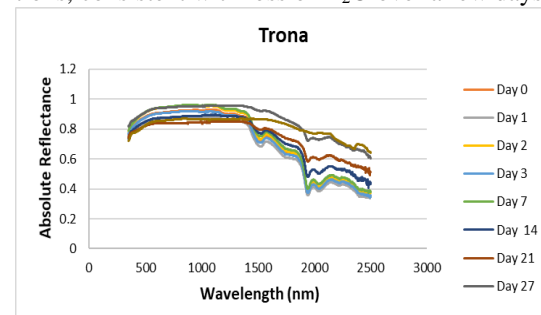


Fig 2. Reflectance spectra of trona (CRB214); same conditions as Figure 1.

Figure 3 shows a change in spectral behaviour of hectorite (phyllosilicate; HEC102). Its spectrum shows 1400 and 1900 nm OH/H₂O absorption bands. The 1400 nm (likely) OH absorption band shows little change in depth, while the 1900 nm H₂O band exhibits a decrease in depth after Day 0, consistent with rapid loss of H₂O.

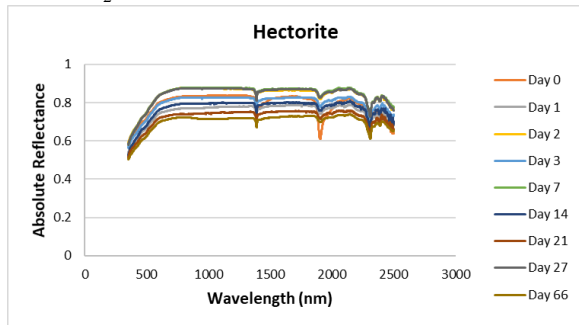


Fig 3. Reflectance spectra of hectorite (HEC102); same conditions as Figure 1.

Figure 4 shows the changes in spectral behaviour of montmorillonite (phyllosilicate; MON102). The sample spectra show 1400 and 1900 nm OH/H₂O absorption bands. The 1400 nm OH/H₂O adsorption band shows little change after exposure to Mars conditions, while the 1900 nm H₂O absorption bands exhibits loss of H₂O at a rapid rate (rapid decrease in band depth).

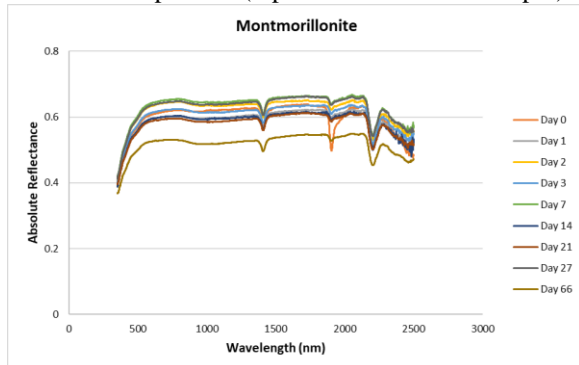


Fig 4. Reflectance spectra of montmorillonite (MON102); same conditions as Figure 1.

Figure 5 shows changes in spectral behaviour of nontronite (phyllosilicate; NON101). The spectra again show 1400 and 1900 nm OH/H₂O absorption bands. There are consistent shallow OH/H₂O adsorption bands at 1400 nm on all days, except for day 66 which shows a shallower band depth. At 1900 nm, after an initial decrease by Day 1, there is little further change in depth.

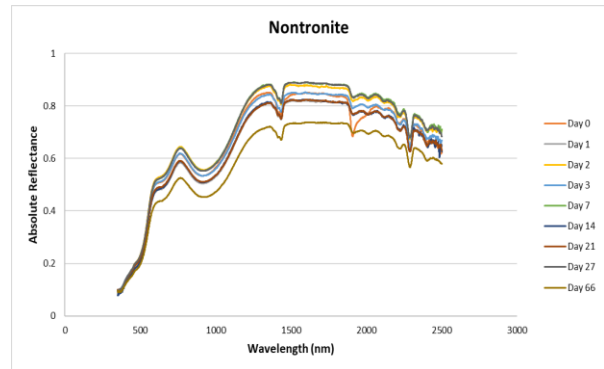


Fig 5. Reflectance spectra of nontronite (NON101); same conditions as Figure 1.

Discussion: The results indicate that after a short period of time upon exposure to Mars-like surface conditions, measurable spectral changes in the OH/H₂O absorption bands can take place. The reflectance spectra of the five hydrous minerals discussed above all showed loss of H₂O as measured by the depth of the absorption band near 1900 nm immediately after exposure, and over the duration of 66 days, decreasing in intensity. However, not all minerals had the same OH/H₂O absorption bands: the carbonate's bands were much shallower than the phyllosilicates at 1500 nm. The 1900 nm band became shallower faster, and became shallower than the 1400 and 1500 nm bands which is consistent with the minerals losing H₂O rather than, or preferentially over, OH. Although all five hydrous minerals were exposed to the same simulated Mars environment, not all minerals reacted the same spectrally in terms of rate and magnitude of change in H₂O-associated absorption bands.

Conclusion: Several hydrated carbonates and phyllosilicates, when exposed to Mars-like surface conditions, can dehydrate gradually or rapidly, while others are unaffected. If OH/H₂O is integral to them, this implies that some minerals may transform to other (less hydrated or dehydrated) species. This is significant for detection of minerals where their identification is based on OH/H₂O-related absorption features. This study supports the need for empirical studies of mineral stability relevant to the surface of Mars because not all hydrated minerals show spectral changes, and those that do, do not always show the same spectral changes.

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References:

- [1] Cloutis E. A. et al. (2007) *Geophys. Res. Lett.* 34(20), L20202. [2] Poitras J. T. et al. (2018) *Icarus*, 306, 50-73. [3] Bandfield J. L. et al. (2013) *Icarus*. 226(2), 1489-1498. & Bishop J. L. et al. (2005) *Am. Mineral.* 90(7), 1100-1107.