LABORATORY REFELECTANCE STUDY OF WATER-ICE-REGOLITH MIXTURES FOR MODELING OF LUNAR WATER SCENARIOS. B. P. Blakley[1,2], B. L. Ehlmann[2], R. N. Greenberger[2], V. V. Kachmar[2], E.S. Sosa[2], [1]Pasadena City College, [2]California Institute of Technology Division of Geological and Planetary Sciences. bblakley@caltech.edu

Introduction: Infrared (IR) spectroscopy has shown an OH/H_2O signature in many locations on the surface of the Moon, and further examination of the diagnostic 3-µm absorption feature at higher spectral resolution and range is required to determine if it results from hydrous minerals, molecular water, or water ice [1-3]. Water ice signatures in the IR have, however, been detected in permanently shadowed regions near the lunar poles by diagnostic absorptions at 1.3, 1.5, and 2.0 µm [4-5].

Lunar Trailblazer, a NASA SIMPLEx smallsat mission, will use shortwave-infrared spectroscopy to map the form, distribution, and abundance of water on the Moon [6]. The visible/shortwave-infrared instrument on board, HVM^3, has a spectral range designed to cover the 3-µm absorption band at 10 nm/channel spectral resolution, allowing it to differentiate between OH, molecular H_2O and H_2O-ice [7]. HVM^3's 0.6-3.6 µm spectral range also covers other key absorptions for identification of water ice.

Four potential scenarios of mixtures of water ice and lunar regolith include (1) intimate mixture, (2) a slab of water ice layered on top of regolith, (3) a frost layer on top of regolith, and (4) a mixture of solid water ice and ice-free regolith that can be modeled as a checkerboard (Fig. 1). Within each of these, the grain size of regolith and the grain size of water ice also dictate albedo and band strength. Forward- and reverse-models of these variables can be used to constrain abundances from in situ data [8], however, laboratory confirmation of the models is required.

Methods: In order to measure each scenario of mixtures, we first needed a regolith simulant with no water signature, i.e., a minimal 3-µm feature and no other water related absorptions. Such simulants are challenging to find on Earth where most natural and synthetic materials incorporate OH and H_2O by weathering or atmospheric water vapor interaction. In order to create the simulant, we milled a glassy basaltic sand from Iceland into a fine powder of <60µm grain size. Then, we heated small

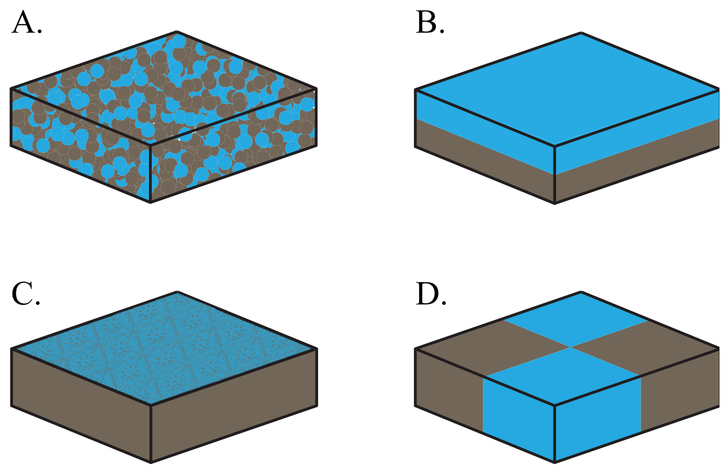


Figure 1. Four potential scenarios of water-ice-regolith mixtures present on the lunar surface: A. Intimate mixture, B. Water ice slab, C. Frost, D. Checkerboard

Figure 2. FTIR Spectra of the milled basaltic sand before and after Loss on Ignition process. The plotted data show that the 3-µm water absorption feature is removed by LOI to make the regolith simulant.

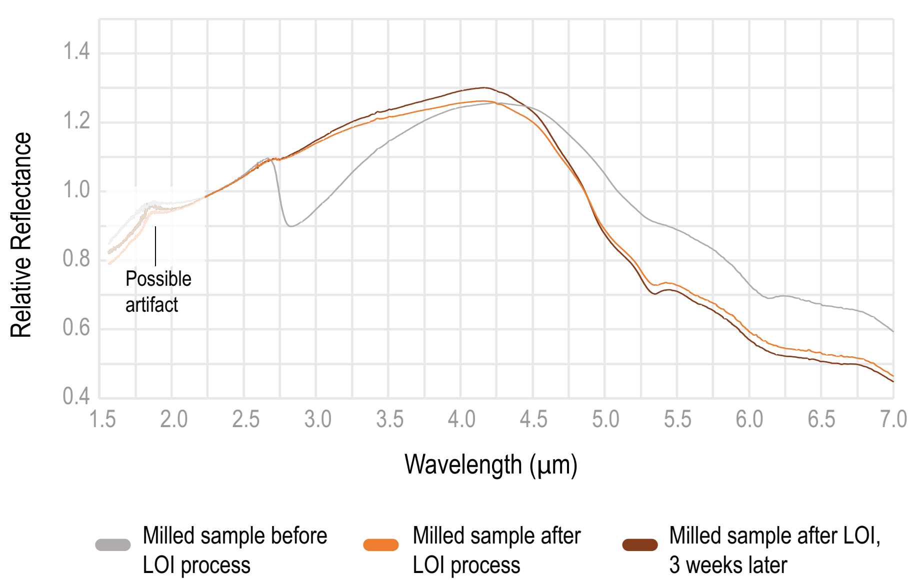
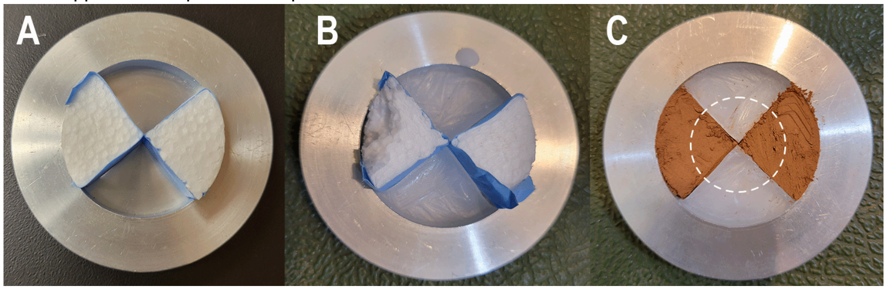


Figure 3. Checkerboard mixture preparation and test sample. A. First, Styrofoam pieces were cut to size and placed into an aluminum sample holder. B. Second, water was poured into the mold and left to freeze. C. Lastly, regolith simulant was poured into the open areas left by the Styrofoam. Dotted line shows approximate spot size of spectrometer.



portions of the sample to 1100°C for ~3 hours in a process to induce Loss on Ignition (LOI) of volatiles. FTIR spectra before and after the LOI process show that the sample has been dewatered (Fig. 2). To ensure that the simulant could be made in bulk quantities and stored in desiccant, spectra were also taken after 3 weeks, showing that the samples acquired no water signature.

The first mixture we created in the lab was the checkerboard model. Using styrofoam ice molds, we created two slabs of ice, each one-quarter the size of the sample holder. Placing the slabs corner-to-corner in the sample holder, we then filled in the empty areas with the regolith simulant, filling in the field of view of the spectrometer (Fig. 3). Samples were prepared and stored at a temperature of -15°C.

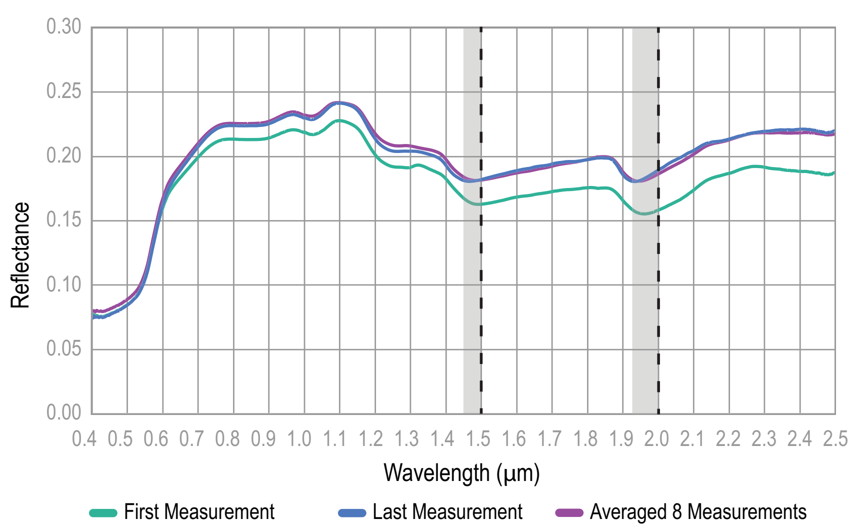
Measurements of each sample were acquired with an ASD spectrometer with a spectral range of 0.4-2.5 µm in a refrigerated room, approximately 4°C. Eight measurements were taken of the sample using the ASD's contact probe, turning the sample ~45˚ between each measurement.

The slab mixture was created in a similar manner as the checkerboard mixture; ice was prepared in the aluminum dish, then removed and placed on top of the regolith simulant in the same sample holder. Measurements of this mixture are forthcoming.

Initial Results and Future Work: Initial measurements were taken of the checkerboard mixture with an ASD field spectrometer within a cold environment to prevent melting (Figure 4). Spectra show diagnostic water-ice absorption bands at 1.3 and 1.5 µm, and a blend of absorption bands by liquid water and water ice from 1.9-2.0 µm. This shows we were able to successfully acquire test data from the checkerboard mixture; however, we are continuing to optimize measurement conditions to prevent melting and sublimation.

Further measurements will be taken with an FTIR spectrometer in a cryochamber, in order to obtain the 3-µm region of interest. Both instruments will also be used to obtain spectra of the three other mixtures. Methods to create the intimate mixture and frost layered samples are currently in development.

Figure 4. ASD spectra of the checkerboard mixture. Average of 8 measurements acquired with a contact probe, each taken after a 45˚ turn from the previous measurement. Further optimization of measurement conditions is needed to prevent melting and sublimation: dashed lines mark 1.5, 2.0 µm water-ice absorption bands; absorptions shift shortward with melting.



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References: [1] R. N. Clark et al. (2009) *Science, 326,* 562-564. [2] J. M. Sunshine et al. (2009) *Science, 326,* 565-568. [3] C. M Pieters et al. (2009) *Science, 326,* 568-572. [4] A. Colaprete. et al. (2010) *Science, 330,* 463–468. [5] S. Li et al. (2018) *Proceedings of the National Academy of Sciences, 115,* 8907–8912. [6] B. L. Ehlmann et al. (2022) *2022 IEEE Aerospace Conference (AERO), 2022*, 1-14. [7] H. A. Bender et al. (2022) *Proceedings of SPIE, 12235,* 1223503. [8] V. V. Kachmar et al. (2023) this conf., Abstract #1398