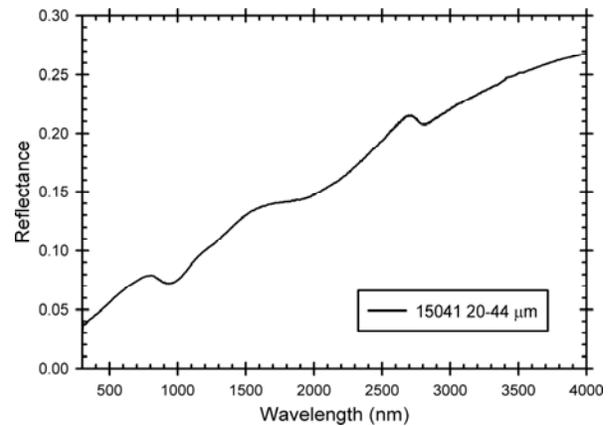


**SPECTROSCOPIC INVESTIGATION OF THE WATER CONTENT OF LUNAR SOIL.** P. J. Isaacson and C. M. Pieters, Dept. of Geological Sciences, Brown University, Providence RI 02912 (Peter\_Isaacson@Brown.edu).

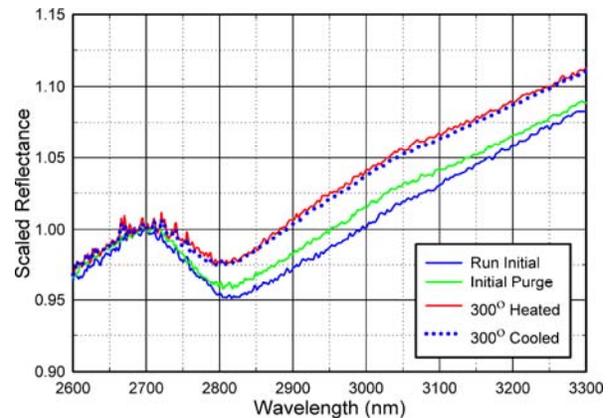
**Introduction:** Small amounts of water have always been detected in spectroscopic analyses of lunar soils in Earth-based laboratories [1]. As seen in Fig. 1, a weak 3  $\mu\text{m}$  feature is apparent in a spectrum of a lunar soil. The 3  $\mu\text{m}$  feature observed in all soils has typically been attributed to water which adsorbed onto the previously dry samples upon exposure to Earth's atmosphere [2]. Weaker 1.4 or 1.9  $\mu\text{m}$  water features are not observed. Possible sources of water in the soil samples include adsorbed terrestrial water [2], solar wind implantation processes [3-6], and meteoritic/cometary sources [7]. Because the weak 3  $\mu\text{m}$  feature is seen in all soils and water is unstable at the collection locations on the Moon [8, 9], the source has been assumed to be terrestrial. However, it has not been demonstrated experimentally that water adsorbed from Earth's atmosphere is solely responsible for the water detected in the samples.

It has been hypothesized that the lunar poles may harbor water-rich deposits [5, 8, 10-13]. A number of lunar missions are scheduled to be launched in the coming years [14-17], many of which have the search for water as a primary mission objective [e.g., 18]. While the stability and form of water is strongly temperature-dependent, it is likely that the distributed polar water, if present, exists in the form of low concentrations of adsorbed water in the regolith. Permanently shadowed craters, however, might have conditions that could maintain solid ice [8]. Nevertheless, it is probable that any water detection will be of very low abundances, perhaps on the order of those attributed to adsorbed water in laboratory investigations. We seek to obtain reliable "ground truth" about the source of the 3  $\mu\text{m}$  water feature in lunar soils, which will aid in investigating the data to be returned by these upcoming missions. We first need a reference soil which lacks the 3  $\mu\text{m}$  feature. To achieve this goal, we have performed heating experiments following the approach of Milliken and Mustard [19], first testing the procedure on terrestrial basalt powder. Other techniques such as UV radiation exposure may also accomplish this goal [e.g., 5], but are beyond the scope of this study.

**Methods:** We investigate a 20-44  $\mu\text{m}$  separate of sample 15041.210, which is part of the Lunar Soil Characterization Consortium [20]. It was chosen as a representative mare basalt soil, and its lack of fines should facilitate easier removal of any adsorbed water [21, 22]. Prior to heating, samples were kept in a purged environment (filtered for  $\text{H}_2\text{O}$  and  $\text{CO}_2$ ) for ~12 hours to drive off loosely-bound water. Samples were



**Fig. 1:** Reflectance spectrum of LSCC soil sample 15041 (purged environment). The broad absorption bands near 1 and 2  $\mu\text{m}$  are due to pyroxene fragments in the soil. The feature near 3  $\mu\text{m}$  is due to water.



**Fig. 2:** Selected spectra from a heating sequence. Spectra have been atmospherically corrected and scaled to a common wavelength at 2700 nm. Initial and Purged spectra were collected prior to any heating steps; the 300° spectra were collected following the 300° heating step. Temperatures are given in °C.

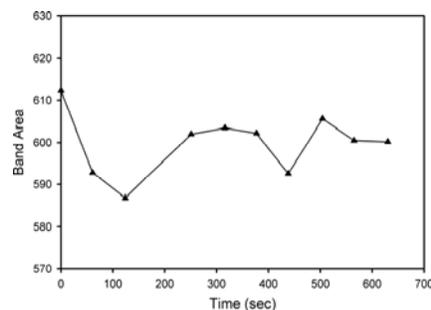
then heated for one hour at specified temperatures, and then immediately measured in the FTIR spectrometer. Prior to the next heating step, samples were allowed to cool in a purged environment for at least 2 hours. Temperatures were increased in 50°C increments, from 150° to 300°. The resulting spectra were scaled to a common wavelength on the short wavelength edge of the 3  $\mu\text{m}$  band. The scaled spectra were fitted with a linear continuum over the absorption feature. The difference between continuum and spectrum was summed to calculate a band area parameter.

It is possible for water to reabsorb onto the sample as it cools over the duration of the FTIR measurement. We collected spectra continuously throughout one cool-

ing period and monitored the change in band area. Similar heating and readsorption experiments were performed on the terrestrial basalt to provide constraints on the relevant timescales.

Transferring samples from the furnace to the spectrometer requires momentarily breaking purge. This causes transient atmospheric features to appear in subsequent spectra. We performed atmospheric corrections by dividing affected spectra by the best fit from a series of atmospheric spectra obtained by a similar "cooling period" sequence with the reference standard. The high frequency residual atmospheric features are a potential source of error, and are one focus of error analyses.

**Results:** Comparison of spectra of the unpurged, purged, and heated sample shows sequential removal of water. Purging removed small amounts of loosely held water, while heating drove off additional water. An example of this sequence is shown in Fig. 2. Some readsorption may have been detected over the duration of the FTIR measurement, but was small compared to

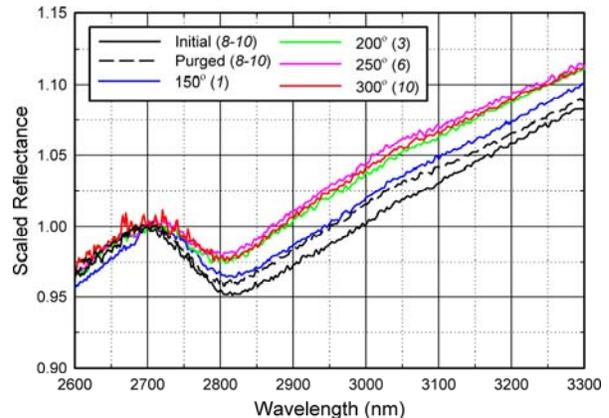


**Fig. 3:** 3 μm band areas calculated during the readsorption sequence. Major readsorption is not observed; the band area variations are small relative to overall band area.

Results of these heating steps show that the water bands generally remain similar over all moderate heating temperatures. As shown in Fig. 4, the 150°C runs appear to produce stronger bands, but all other spectra exhibit water bands which are similar within the current limits of our precision. Water appears to be retained in the soils even after heating to 300°C.

**Interpretations:** The water seen in this soil is quite resistant to removal. Indeed, the water is resistant to temperatures more extreme than those found on the surface of the Moon [23]. It appears that the lowest heating increment is able to remove some of the water that is not removed by purging, and that subsequent heating steps remove slightly more. However, at the present time, we are unable to pinpoint reliably the source of the water. If the water is indeed adsorbed from the terrestrial atmosphere, it is far more resistant than loosely adsorbed contaminants. Early studies suggest that exposure of lunar samples to water vapor

causes significant alteration by the creation of a pore system which is stable to temperatures of up to 700-800°C [2]. Our data are consistent with this result, as the water in our sample is not all loosely-held on the surface. Our soils may have some internal water reservoir in addition to loosely adsorbed surface water, but the characteristics of this reservoir are currently unclear.



**Fig. 4:** Scaled spectra of heated soils. Examples of unpurged (initial) and purged spectra are shown for reference. Italicized numbers correspond to the sequence in which the heating runs were conducted. All heated spectra are similar apart from the 150° runs, which show stronger bands.

**Conclusions/Summary:** To aid in the search for lunar water with remote sensors, we investigate the 3 μm water feature in lunar soils. Heating experiments were performed in an attempt to remove loosely-held water from lunar soil. Significant water was detected after heating, indicating a more resistant water source than previously anticipated. The ultimate provenance of this water is unclear, but the existence of a reservoir in addition to loosely-held surface adsorbed water is confirmed.

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