WATER RETENTION IN MATURE AND IMMATURE LUNAR REGOLITH Abigail Flom[1,2] and Georgiana Kramer[2], [1]Deparment of Physics and Space Sceinces, Florida Institute of Technology,150 W University Blvd, Melbourne, FL 32901 (aflom2015@my.fit.edu), and [2]Lunar and Planetary Institute

Introduction A common view of the Moon abruptly changed when water was detected in lunar regolith by multiple remote sensing instruments: EPOXI, Cassini Visual and Infrared Mapping Spectrometer (VIMS), and the Moon Mineralogy Mapper (M^3) [1, 2, 3]. The study of this surface water and how it is retained has important implications for understanding how the Solar System and the Moon were formed as well as potential for use as a resource in space missions.

This study looks at how the amount of surface water changes over time in lunar regolith. This is done by comparing abundance of surficial water and/or hydroxyl (HOH/OH) between mature regolith (that has been exposed to weathering processes on the surface) and immature regolith (which has been mostly unaffected by these processes). The comparison between these two regoliths tests two differing hypotheses for the retention of water in the regolith. Although they are opposing hypotheses, they both are based on the axioms that HOH/OH is being formed due to hydrogen atoms from the solar wind interacting with oxygen in lunar minerals, and that the glassy component of the regolith increases with maturity. The first hypothesis states that HOH/OH (also referred to as water) is formed when positively charged solar wind hydrogen ions are adsorbed by the negatively charged exposed oxygen atoms on freshly fractured mineral surfaces. Over time, weathered glassy coatings are formed on lunar soil grains with increased exposure to the space environment. This neutralizes the surface charge, reducing the ability of the surface material to capture hydrogen ions as efficiently. This hypothesis predicts that mature regolith will have lower HOH/OH compared to immature regolith. The second hypothesis states that the regolith would be better able to retain water in the vesicles of a glassy coating (mature regolith) and predicts that mature regolith will have higher HOH/OH compared to immature regolith.

Methods The ejecta of small, recently formed impact craters provide a source of immature regolith to sample. These impacts throw up unweathered regolith to the surface where it can be detected by remote sensing instruments. These impactors need to be small, so that they don't tap too far into the surface bedrock and expose a different composition altogether [4]. The maturity and composition of the material can then be checked by using the material's spectra and Clementine color-ratio maps.

The spectral data used for this study was acquired by the M^3 on Chandrayaan-1. In this data, the presence of HOH/OH is identified by an absorption feature near 3 microns [1]. The absorption grows deeper with increasing OH/HOH, so it can be used to determine the relative amounts of HOH/OH present. It is known that there are some problems with the thermal correction on the M^3 data set available on the PDS, which affects the 3 micron absorption being studied. To fix this, the data was processed through a new thermal correction based on a surface roughness model [4].

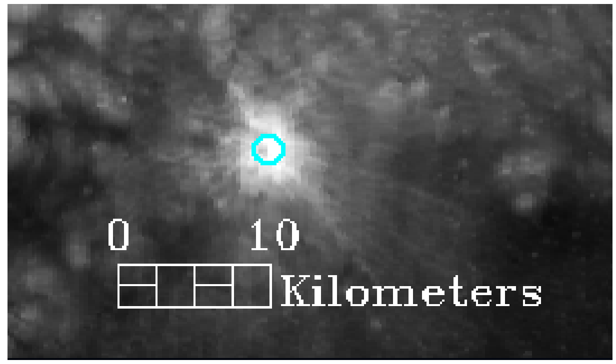

Figure 1: *Example Crisium Crater: The Blue circle indicates from where the spectra were pulled. A yellow box in Figure two shows its location in Crisium*

The resulting multi-spectral image cubes were then viewed in ENvironment for Visualizing Images (ENVI) and small fresh craters were identified. From there, the spectra from the ejecta of the craters were gathered using Small Crater Rims and Ejecta Probing (SCREP) [5]. This algorithm takes the spectra from pixels just outside the crater rim (see Figure 1), where the impact has exposed the deepest excavated layer [6]. The pixels are averaged to obtain a single spectrum representative of the immature material and the standard deviation between these pixels at each wavelength is treated as the error in the pulled spectrum. The mature spectra are taken by averaging pixels from areas in the material outside the fresh crater ejecta.

Comparisons between the immature regolith and their mature counterparts use band depth to define the relative strength of the absorption features. The more HOH/OH present, the deeper the absorption feature is and the greater the value of the band depth. The band depth parameter (B) defines the distance between the reflectance value (R) and the continuum (C) of the spectrum and is calculated using this formula: $B = 1 - \frac{R(\lambda)}{C}$ In this case the continuum was chosen by fitting a line to points known to be unaffected by absorption or emission.

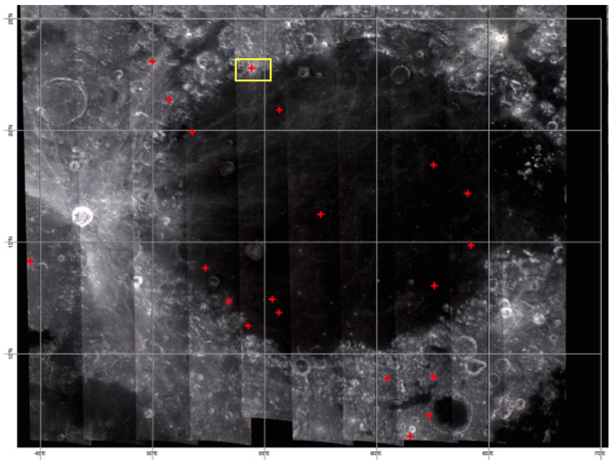

Figure 2: *Map of Regions Sampled in Crisium*

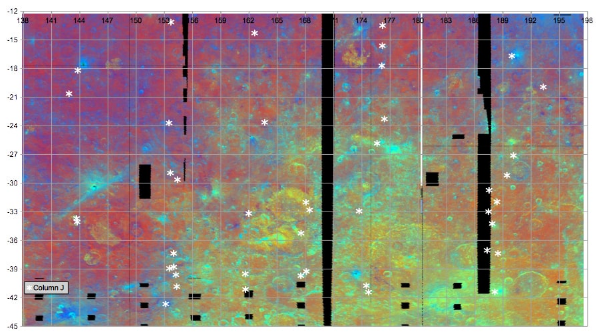

Figure 3: *Clementine Color-Ratio Map of Regions Sampled in South Pole Aitken*

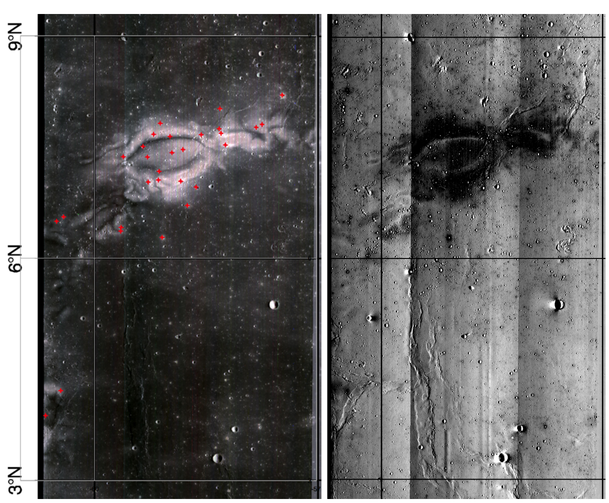

Figure 4: *Left: Map of Regions Sampled in Reiner Gamma, Right: Map of HOH/OH with brightness corresponding to more water*

Results and Discussion The craters sampled in Crisium (Fig. 2) and South Pole Aitken (Fig. 3) showed deeper band depths in the mature spectra than in the immature spectra. This trend was shown in both the mare and highland compositional regions. It is known that the absorption features look relatively deeper in brighter samples versus darker samples with the same water content [7], however, the mature soil was found to have relatively deeper absorption features than the fresh material - the opposite trend expected were it only an albedo effect. This suggests the trend toward increasing HOH/OH with maturity may be stronger than currently seen.

In addition freshly excavated regolith, there are also samples of immature regolith on the surface that have been sheltered from weathering affects. Lunar swirls (Fig. 4) are an example of such a location, because they have magnetic fields that inhibit the solar winds ability to reach the surface and therefore also prevent the regolith from maturing in that area [8, 9]. The Reiner Gamma swirl was examined in order to check how results from a region of unusual space weathering compares to ”typical weathering” locations As can be seen in the 3 μm band depth (HOH/OH abundance) map (right image in Fig. 4), there is a more HOH/OH in the surrounding optically mature material than is present on the optically immature swirl, which is consistent with the results from the crater ejecta analyses from ”typical” weathering locations.

Conclusions The trend for greater band depth in mature regolith aligns with the predictions of the second hypothesis. This suggests that the dominant form of retention of HOH/OH in lunar regolith is entrapment in the glassy vesicles as the regolith matures. This work is still in progress. We will continue to analyze more locations, representing different terrains and at different latitudes.

References

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