THE MATURELY, IMMATURE ORIENTALE IMPACT BASIN. J. T. S. Cahill, D. J. Lawrence, O. Delen, A. Stickle, and R.K. Raney, [1]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, (Joshua.Cahill@jhuapl.edu).

Introduction: The Moon is consistently bombarded by large and small projectiles that weather its surface. This includes micrometeorites, cosmic and solar rays, and solar wind implantation and sputtering in a process known as space weathering. Based on data from the Clementine spacecraft, several studies [2, 4, 5] have shown that the degree of this process imparted upon the lunar surface can be estimated in the near-infrared with the optical maturity parameter (OMAT; **Fig. 1a**). However, near-infrared spectroscopy only gives us a perspective of how space weathering affects the upper microns of the lunar surface. As informative as the OMAT parameter has proven to be, it does not inform us to the degree space weathering imparted upon shallow subsurface materials (<1.5 m).

Recently, studies of data sets from Lunar Prospector (LP) and Lunar Reconnaissance Orbiter (LRO) that are sensitive to a greater depth of the lunar regolith are beginning to report measures of space weathering. These include the thermal infrared, radar, and neutron spectroscopy data sets [1, 6, 7]. Some aspects of each of these data sets are directly comparable to OMAT estimates. For example, a study by *Lawrence et al.* [1] shows evidence that LP-measured epithermal neutron counts in the lunar highlands (defined here as areas with <3.5 ppm thorium) correlate relatively well with 750 nm albedo, OMAT, and the Diviner Christensen Feature (CF). From these data, *Lawrence et al.* [1] was able to determine and map hydrogen abundances in the lunar highlands (**Fig. 1b**). Because these abundances are correlated with previous determinations of space weathering (for non-polar contexts) *Lawrence et al.* [1] has interpreted these abundances to be driven and maintained by H-implantation into the upper ~10 cm of the lunar regolith by solar wind. In this context, areas of high H abundances are interpreted to be more mature, while areas of depleted H abundances are interpreted to be immature (e.g., Tycho).

One of the peculiarities of *Lawrence et al.* [1]'s lunar H-maps are the regions depleted in hydrogen. While Tycho is shown to consist of H-depleted material, consistent with OMAT maps showing it to be immature, other H-depleted regions conflict with previous interpretations discerned by OMAT maps. Orientale basin is the most prominent example, shown to be H-depleted despite a relatively mature upper regolith that is consistent with a relative old age date determination (at least ~3.5 Ga; **Fig. 2**). Here, in an effort to better understand how the lunar regolith is weathered not only on the surface, but within the upper ~1 m of regolith, we more fully characterize the Orientale region relative to other H-depleted regions. We do this by examining the similarities and differences between neutron, radar, near-, and thermal- infrared observations.

Data Products: Each of the data products measures a unique quality about the regolith. Therefore, areas where they differ offer just as much or more information about the regolith as areas where they agree. LP neutron counts are sensitive to the presence of hydrogen on the lunar surface in a variety of forms. However, here we are interested in the non-polar highlands from which is most likely solar wind implanted hydrogen. LP neutron counts and H-maps used here are the same reported in *Lawrence et al.* [1]. Also examined are Mini-RF circular polarization ratio (CPR) maps of *Cahill et al.* [8]. Mini-RF is a synthetic aperture radar (SAR) onboard LRO that collected global S-band (12.6 cm) maps which are sensitive to 1-2 meters vertically. A relevant product derived from Stokes parameters for this study is CPR defined as the same sense relative to the opposite sense polarized return, SC/OC. Values of CPR serve as quantitative estimates of surface roughness and composition. LRO's Diviner rock abundance (RA) and CF maps were derived by [9, 10], and OMAT maps are derived with the methodology of *Lucey et al.* [4].

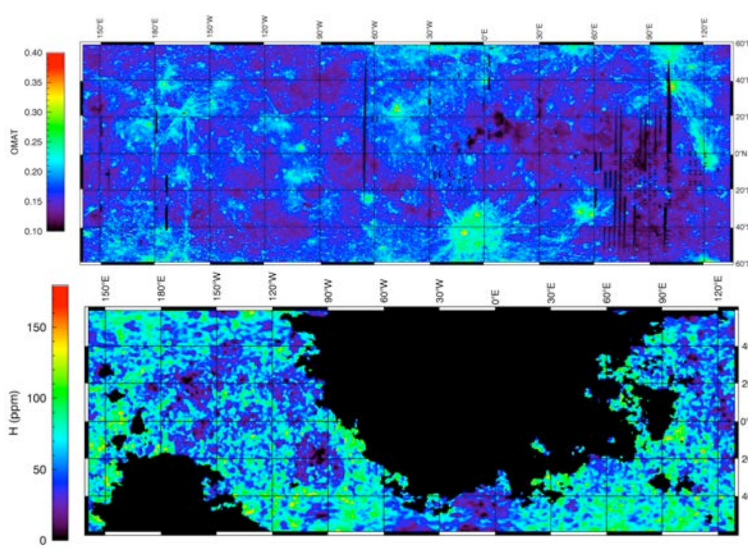

Figure 1*: Global lunar (top) Clementine-derived OMAT and (bottom) Lunar Prospector-derived Hydrogen abundance map [1-3]; 2 ppd.*

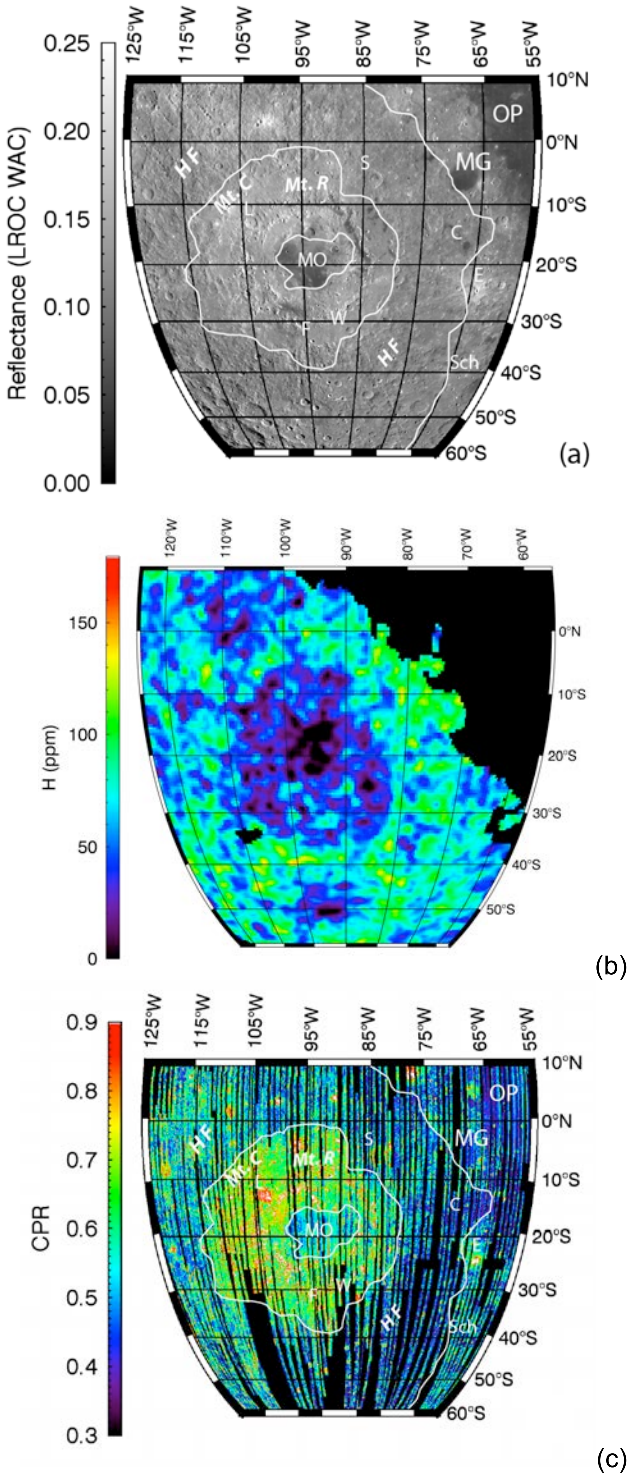

Figure 2*: Orientale impact basin in (a) LROC WAC monochrome, (b) Lunar Prospector derived Hydrogen, and (c) Mini-RF derived CPR maps at 2 ppd.*

Discussion: OMAT maps of Orientale show it to be mature albeit not the most mature region on the Moon; this is generally consistent with Orientale's interpreted age (~3.7 Ga) although still considered one of the youngest basins. Radar is used as a proxy for maturity as *Neish et al.* [7] demonstrated by directly comparing CPR and OMAT of crater ejecta. However, in the context of Orientale, OMAT and radar backscatter characteristics disagree. *Cahill et al.* [8] noted the prominence of Orientale in S-band CPR and *m-chi* data products and suggested the reason for these characteristics may be buried subsurface material with immature characteristics not exhibited at the surface. Orientale shows little to no RA concentrations on the surface while also exhibiting higher *m-chi* double bounce and volume scattering characteristics than its surroundings and the bulk of the lunar surface.

At first glance, H-maps and CPR maps agree in terms of Orientale being highly immature. H-maps suggest depleted average hydrogen abundances (<35 ppm) for Orientale highlands material. Although the spatial distribution of high CPR and H-depleted terrain is similar, high CPR material extends further from the center of Orientale. LP neutron and Mini-RF overlap somewhat in regolith sampling cross section sampling the upper ~10 cm (LP) to 10 cm to 1.5 m (Mini-RF).

Summary and Ongoing Work: Our view of lunar highlands measures of regolith maturity has been expanded with LP and LRO Mini-RF and Diviner instrument observations. This is supported globally in many locations with large-scale regions showing hydrogen, RA, CF, CPR, and *m-chi* measures relatively consistent with near-infrared measures (i.e., OMAT) of maturity. However, there are differences and the variations in the spatial distribution and intensity of these measures imply that there is additional information about lunar space weathering contributions recorded within the same regolith that are yet to be fully discerned, disentangled, and understood. In the context of Orientale, these differences may imply depth of sampling effects specific to the measurement technique and/or physical (e.g., regolith versus impact melt) and compositional (e.g., anorthositic versus pure anorthosite materials) characteristics specific to Orientale materials. Ultimately, these results are peculiar given the age (~3.7 Ga) of Orientale and yet to be fully resolved.

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