TOP HYDRATION LAYER NEAR POLES FROM LRO/CRATER: SEARCH FOR TIME-OF-DAY DEPENDENCE. N. A. Schwadron[1], J. K. Wilson[1], A. P. Jordan[1], M. D. Looper[2], N. E. Petro[4], H. E. Spence[1], [1]Space Science Center, University of New Hampshire, Durham, NH (nschwadron@unh.edu), [2]The Aerospace Corporation, Los Angeles, CA, [3]NASA Goddard Space Flight Center, Greenbelt, MD

Introduction: The presence of water on the Moon has been studied intensively for more than half a century [e.g., 1, 2] with volatile accumulation in permanently shaded regions (PSRs) at the poles of the Moon being hypothesized since before the Apollo era [3-5]. The Lunar Prospector Neutron Spectrometer (LP-NS) probed the lunar regolith to depths of ~50 cm, revealing the enhancement of hydrogen (H) or hydrogenous species at very high latitudes where epithermal neutron emission is suppressed [6-9]. The Lunar Exploration Neutron Detector (LEND) on the Lunar Reconnaissance Orbiter (LRO) subsequently provided global maps of lunar neutron fluxes [10]. Additionally, the Moon Mineralogy Mapper (M^3) on Chandrayaan-1, as well as the Deep Impact and Cassini spectrometers, detected absorption features around 2.8-3.0 µm on the lunar surface [2, 11, 12], indicating widely distributed materials containing OH and H_2O, mostly at high latitudes and at several fresh feldspathic craters. Additionally, the LAMP instrument on LRO also detected surface hydration in polar regions as well as towards the equator [18].

Here, we detail a discovery from LRO/CRaTER's observations of the proton albedo showing clear evidence for a surface layer of hydrated material near the poles. To explain CRaTER's observations, the surface layer (at least ~10-20 cm) must contain excessive hydration compared to regolith beneath it. The fact that this layer exists at the surface suggests that it may be subject to thermal effects that depend on time-of-day. We report here on the first search for time-of-day dependence of the surface hydration layer near the poles from CRaTER's proton albedo.

Surface Hydration Layer near Poles from LRO/CRaTER: Schwadron et al. [13] first showed a new technique for detecting hydrated material at the Moon using the energetic proton albedo [14-16]. CRaTER detected a small enhancement in abledo proton flux at higher latitudes (Figure 1), an unexpected and initially counter-intuitive result that turns out to be the precise signature of hydration in a surface layer ~10-20 cm thick.

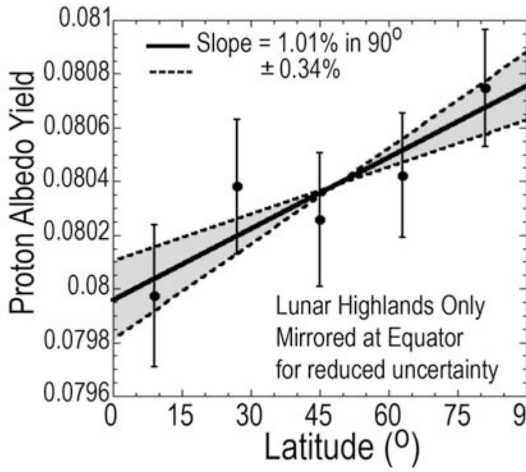

Figure 1. The latitude trend in the proton albedo reveals an enhancement near the poles. The albedo proton data shown here for the highlands only are formed from the albedo proton maps [16], which have been carefully corrected for altitude effects and other sampling biasing. The solid line shows the fit slope using a χ^2 minimization and the dashed lines show the uncertainty limits.

Laboratory measurements clearly show that regolith which is uniformly hydrated to depth should result in *suppression* of albedo protons, which is the opposite of the trend seen by CRaTER. However, hydrated material that is limited to a 10-2 0cm surface layer (Figure 2) can reproduce the trend of higher yields at higher latitudes. Geant4 simulations have shown support for the hypothesis, and the research is still quite active.

The hypothesis of an excess of albedo protons from a hydrated layer near the surface can be understood in terms of two steps: (1) GCRs penetrate the regolith, producing a large upward secondary flux of neutrons and protons through nuclear evaporation of subsurface atoms heavier than H; (2) The collisions between upward neutrons and H in the hydrated layer causes forward scattering of the H (protons), leading to an enhancement of albedo protons. The process requires H to be most abundant near the surface. If H were distributed uniformly throughout the regolith, this would suppress the flux of secondary protons via forward scattering of incident GCRs.

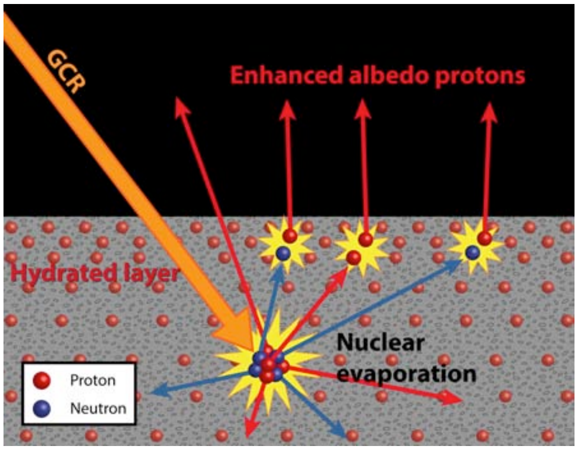

Figure 2. Illustration of the effects of a hydrated layer of lunar regolith. The nuclear evaporation process from deep in the regolith produces abundant secondary particles in all directions. The highest flux of secondary particles near the surface will be neutrons of up to ~100 MeV [15]. If a neutron collides with a hydrogen nucleus near the surface, the collision would yield an additional "tertiary" proton. In general, the interaction of secondaries from deeper in the regolith with the hydrated layer would create an excess of albedo protons.

The Search for Time-of-Day Dependence of the Hydration Layer: The same collisional process that enhances the lunar proton albedo from the surface hydration layer should result in an additional observational signature. Knock-on collisions between grazing-angle GCRs and hydrogen atoms in the hydrated layer will produce an enhancement of grazing-angle albedo protons at low elevation angles, and would be detectable when CRaTER's field of view is pointed near the lunar horizon/limb. CRaTER collected 35 hours of horizon observations in May and November of 2015 in the longitude range covering Oceanus Procellarum (300°-340°), and the data shows a significant enhancement of lunar albedo protons at grazing angles relative to nadir, suggesting that in this region we are seeing the low-elevation enhancement that would be expected from knock-on collisions with GCRs.

Given the large dependence of the lunar albedo proton flux on ejection angle, we are encouraged to look for features within the 35 hours of horizon-viewing data collected so far, and plan to acquire additional data in future observations. We will report on our first effort to find time-of-day dependence in the albedo protons from the hydration layer.

Conclusions: Observations from LRO's CRaTER instrument have proven to be critical for Planetary Science, in addition to the important contributions to better understand the radiation environment at the Moon. New modes of observations by CRaTER, as well as the discovery of a new measurement that probes lunar surface hydration over large areas, have shown the value of continued CRaTER measurements. In the future CRaTER will make new, off-nadir measurements to further determine diurnal variability of hydration over the upper 10-20 cm of the regolith. For the first time, CRaTER probes a unique near-surface regolith hydration layer, which is thinner than measured by Neutron instruments (*e.g.,* LEND, LP-ND), and thicker than what is measured by NIR and UV spectrometers (*e.g.,* M^3, LAMP). By integrating results for hydration and its variability over these three thicknesses, we will improve our understanding of lunar volatile mobility, as well as how volatiles on airless bodies migrate. The CRaTER science team is eager to explore this new paradigm further with unique targeted observations, thereby continuing to make substantial contributions to Planetary Science.

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