GEOLOGIC UNIT DIFFERENCES ARE REFLECTED BY LUNAR REGOLITH DEPTHS

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Introduction: Here we examine the relationship between the individual lunar regolith depth measurements, lunar subsurface structure, and specific lunar geologic units in order to better understand how the lunar surface has evolved at particular locations.

We examine the lunar subsurface as revealed by no-cost, subsurface probes: naturally formed impact craters. Impacts into a surface with a weak layer (regolith) overlying a strong layer (substrate) produce unique crater morphologies that correlate well with the depth of the weak layer ([1, 2], see also Fig. 1). Impact caters both create and reveal the regolith layer.

Knowledge of the regolith depth informs us as to the possible source depth of surface rocks, and hence allows more accurate interpretation of the lunar surface observed via remote sensing. Knowledge of the lunar regolith depth is also important to learning about the impact cratering process. Bart and Melosh [3] found that a layer of regolith covering the lunar surface results in a portion of the high-velocity ejection phase occurring in the fine-grained regolith, reducing the population of large blocks available for ejection at high velocities. Bart and Melsoh [4] also showed that the number of boulders ejected from an impact crater does not correlate with regolith depth.

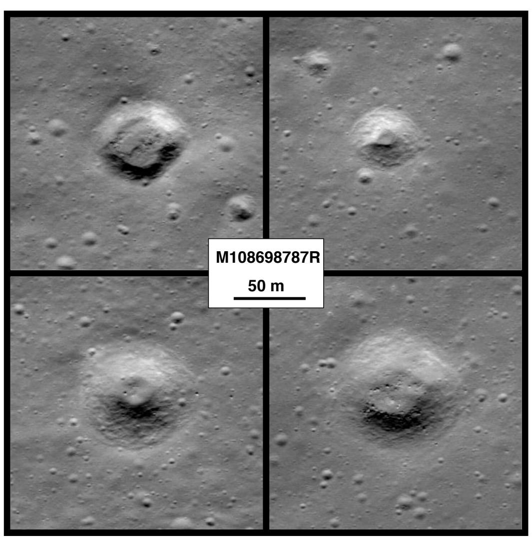

Figure 1: Examples of craters with distinct morphologies indicating impact into regolith. LROC NAC image M108698787R, 56.92°N, 80.63°E, in Mare Humboldtianum.

Crater Morphology Method: To determine regolith depth, we used the results of the study by Quaide and Oberbeck [1]. A series of experimental impacts into both uniform targets and layered targets showed that the morphology of the experimental craters was correlated with the depth of regolith in which they formed. They found that the thickness of the regolith was given by $thickness = (k - D_F/D_A)D_A\tan(\alpha)/2$, where k is an empirically determined constant (0.86) and α is the angle of repose of the material (31°). By measuring D_F and D_A values for many lunar craters, we are able to calculate the regolith depth in each crater's location.

This technique requires meter-scale resolution of small craters for identification of the specific morphologies that indicate regolith depth. The new *Lunar Reconnaissance Orbiter* (LRO) Lunar Reconnaissance Orbiter Camera (LROC) data suits this task, providing images at 50 cm/pixel across the lunar globe.

We examined 143 LROC images and measured the regolith depth as revealed by 10,663 individual craters from 5.2 m to 271.6 m in diameter. The latitudes of the craters studied range from 70.9°S to 60.0°N. Four examples of our measured craters are pictured in Fig. 1.

Global Regolith Depth Averages: While individual measurements may be useful for interpreting local geologic landforms, the average regolith depth provides a regional picture of terrain evolution. Therefore we calculated the median regolith depth in each region. (Oberbeck and Quaide [2] also examined the average regolith depth in the lunar regions they studied.) We group our 143 images into 30 different regions; 14 regions are located on the lunar nearside, and 16 regions are located on the lunar farside. Median regolith depths are all less than 10 m, ranging ranging from 2.5 m in Mare Humorum to 8.7 m near the crater Landau on the farside. The median regolith depths form a distinct pattern, with the thinnest regolith being located in the nearside maria, and most farside and higher latitude regions having thicker regolith.

Individual Regolith Depth Measurements: After considering the average regolith depths, we took a look at individual regolith depth measurements on individual geologic units. The LPI has archived the USGS geologic maps of the nearside of the Moon `http://www.lpi.usra.edu/resources/mapcatalog/usgs/` . We plotted individual regolith depth measurements from thinnest to thickest to display the maximum regolith depths in each region.

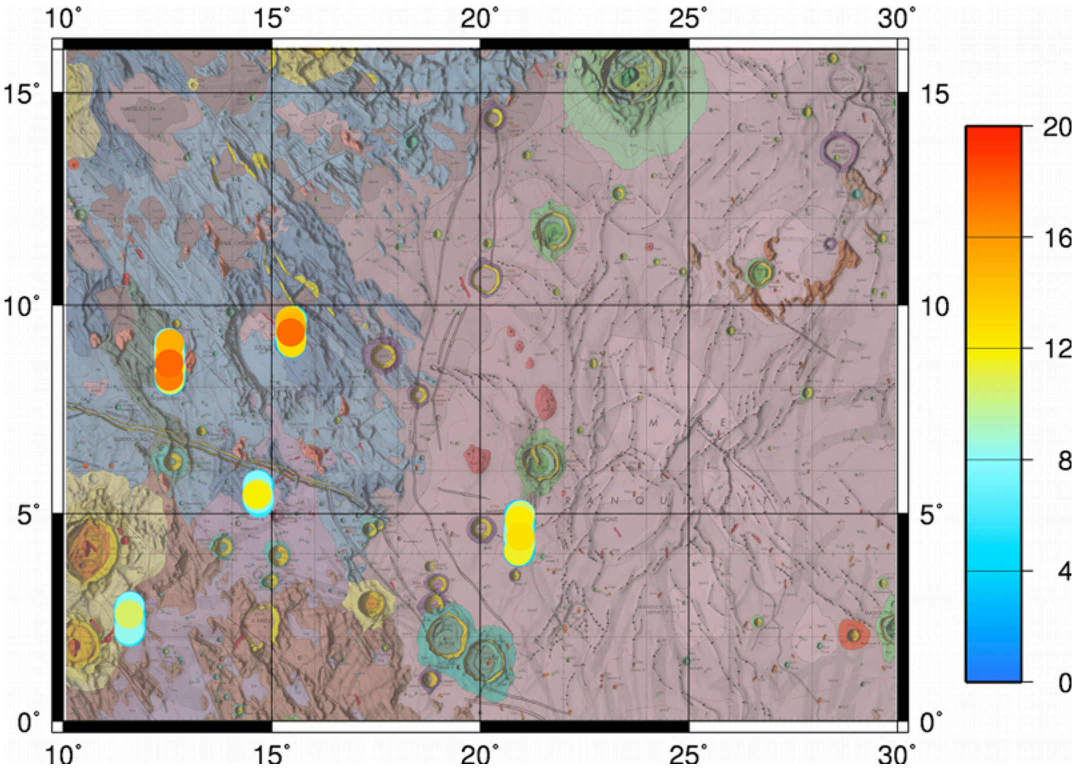

Figure 2: Julius Caesar (and Mare Tranquilitatis) region of the Moon. Background is USGS geologic map I-510. Colored dots are individual regolith depth measurements, with the maximum values plotted last, and thus their dots somewhat cover those of the thinner depths.

We then superimposed the maps of our data on the USGS geologic maps (Fig. 2). Our preliminary results show that the maximum regolith depth in each region correlates with the geologic unit on which it is found.

We first examine the case of the Julius Caesar region of the Moon (Fig. 2). (Julius Caesar is a crater just west of Mare Tranquilitatis.) Here we find that the maximum regolith depth on the Imbrium basin ejecta (the Ifh/Ifs blue units) is about 20 m, significantly larger than the maximum depths (15 m) within Mare Tranquilitatis itself (the Ipm pink unit), the Cayley Formation (12 m, the Ica purple unit), or the Terra material (10 m, the It rust-colored unit). It is interesting to consider whether we might be observing other strength transitions within the target material related to the deposition or formation of the units, in addition to a strength transition associated with regolith formation.

Conclusions: We find that on both the lunar farside and in nearside, non-mare regions, the regolith depth is twice as deep as it is within the lunar maria. We find that median regolith depths in the mare regions are typically 2-4 m, whereas median regolith depths on the farside and non-mare nearside areas are typically 6-8 m.

Furthermore, we find that individual regolith depth measurements correlate with specific lunar geologic units. Because our "regolith depth" measurements are really measurements to the depth of a subsurface strength transition, these differences may indicate processes of deposition or formation of the geologic unit in addition to (or instead of) strictly reflecting the regolith depth on some particular units. Further study of our individual measurements will result in a better understanding of the lunar subsurface on these scales.

Understanding the current state of the lunar regolith is important for understanding the context and history of collected samples, as well as understanding of the impact history of the Moon and its connection to the formation of the regolith.

References: [1] W. L. Quaide, et al. (1968) *J Geophys Res* 73(16):5247. [2] V. R. Oberbeck, et al. (1968) *Icarus* 9:446. [3] G. D. Bart, et al. (2010) *Journal of Geophysical Research (Planets)* 115:E08004 . [4] G. Bart, et al. (2010) *Icarus* 209:337 .