MEASUREMENTS OF REGOLITH DEPTH FROM A YOUNG MARE SURFACE ON THE MOON.

E. F. M. Atang[1] and G. D. Bart[1], [1]University of Idaho, Department of Physics, 875 Perimeter Dr. MS 0903, Moscow, Idaho, 83843-0903, USA

Introduction: The layer of unconsolidated rock debris that blankets the surface of the Moon is called lunar regolith. The lunar regolith is a mixture of pulverized rock particles, glass-bonded agglutinates, and a variety of mineral and lithic pieces, all generated by impact bombardment [1]. The regolith layer is both formed and exposed by impact craters. Some small impact craters that formed in a target with a strength transition such as regolith over bedrock, have distinct morphologies: flat-floor, central-mound, concentric and normal craters [2]. Several publications have shown that their data support the hypothesis that regolith depth increases with surface age [3-5]. If the assertion that regolith depth correlates with age is correct, we would expect this very young surface to exhibit thinner regolith than in older areas. As we show below, we instead find that the median regolith depth of this young site is similar in depth to the regolith at Mare Tranquillitatis.

Method: Our study area is located between latitudes 38°N to 46°N and longitudes 306°E to 312°E in Northeast of Oceanus Procellarum. In 2003, Hiesinger et al. performed crater counting at this site, which they called P58, and found that the surface has an age of around 1.33 Gy [6]. More recently, Giguere et al. found this site to have an age around 2 Gy [7]. We chose this study site because it is much younger than other mare sites such as Mare Tranquillitatis, for example, with surface ages ranging from 3.4 to 3.8 Gy [6]. This choice of site was to enable us to test whether younger surfaces have thinner regolith.

We selected images from the LROC (Lunar Reconnaissance Orbiter Camera) PDS (Planetary Data System) Archive Interface at http://wms.lroc.asu.edu/lroc [8]. We used JMARS (Java Mission-planning and Analysis for Remote Sensing) [9] to access the LROC images and make diameter measurements. We selected images from a range of latitudes and longitudes across this young mare terrain, to see how the regolith depth varied.

In order to measure regolith depths, we adopted the crater morphology method based on the work by Quaide and Oberbeck [10]. They studied the effects of impacts into layered targets as well as the conditions of formation of different crater types. For flat-bottomed and concentric craters, Quaide and Oberbeck [10] found that there was a relationship between the ratios of apparent crater diameter to surficial layer thickness, D_A/t, and the ratio of the diameter of the flat floor of the crater to the apparent crater diameter, D_F/D_A [10]. Specifically, they found that the surficial layer thickness or thickness of the regolith, t was related to the measurable diameter by

$$t = \frac{1}{2}\left(k - \frac{D_F}{D_A}\right) D_A \tan(\alpha) \quad (1)$$

where k is an empirically determined constant (0.86) dependent on material properties and α is the angle of repose of the material (31°) [3].

We examined the LROC images for small craters (<150 m diameter) with flat floors or interior concentric rings. For each of those craters we found, we measured the diameters of the floor, D_F, as well as apparent crater rim diameters, D_A, for flat-bottomed and concentric craters (Figure 1) and used equation (1) to obtain the regolith depths or thickness.

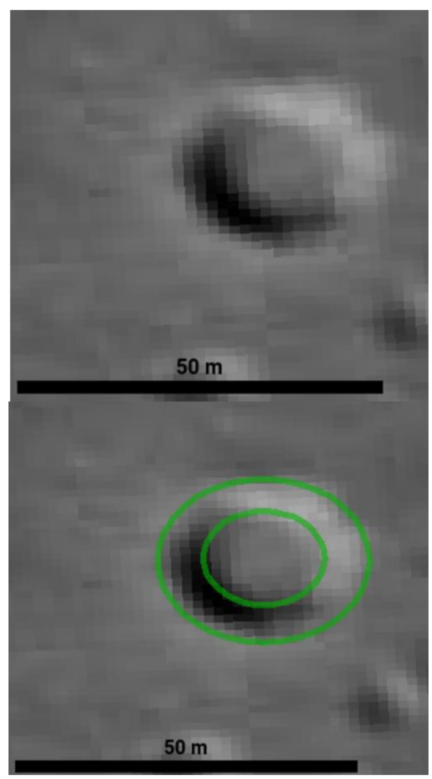

Figure 1: Example of measured flat-bottomed crater from image M1129787408LC. The same crater is shown with and without an outline measuring circle.

Results: We found that the median regolith depths in the study area is 4.0 m. 97% of the craters indicated regolith depths between about 2-14 m. Out of the 3268 craters we counted, only six had regolith depth greater than 15 m. The histogram (Figure 2) displays regolith depth measurements for all of the images that we studied. The modal regolith depth is between 3.0 m to 4.0 m.

Figure 3 shows a map view of our study area. We chose nine non-overlapping LROC images in Oceanus Procellarum. The circles represent individual small craters that were measured in the images while the color bar shows the regolith depths calculated at each of the crater locations. The preponderance of blue and green dots reflects the result observed in the histogram that most regolith depth measurements were in the 2-7 meter range.

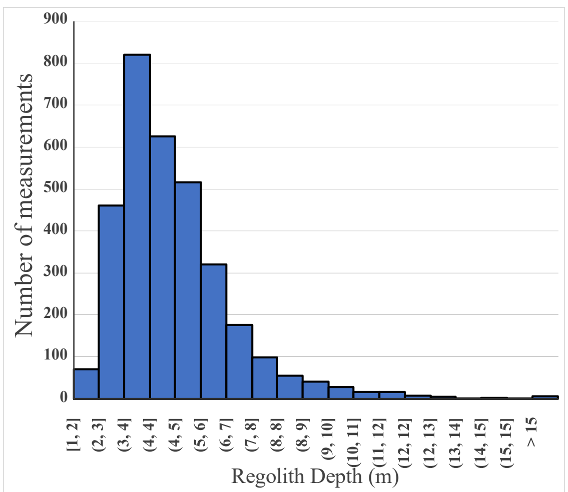

Figure 2: Variation of regolith depth across the study area.

Discussion and Conclusions: We found that the median regolith depth is 4.0 m from a young mare region of the Moon, northeast Oceanus Procellarum. We found that the median regolith depth in the region is similar to those found in older aged mare regions. Mare Tranquillitatis and Mare Orientale have median regolith depths of 4.4 m and 4.5 m respectively [3], comparable to median regolith depth we measured at site P58 in Northeast Oceanus Procellarum. The regolith depths are similar although both Mare Tranquillitatis (3.6 Gy [6]) and Mare Orientale (3.8 Gy [6]) are much older than our study site (1.33 Gy or 2 Gy) [6,7]. Regolith does not appear to be significantly thinner despite being on younger surface.

We plan to expand this regolith depth study on a wide range of surface ages. Ultimately, we would like to have regolith depth estimates for regions dated between 1-4 Gy.

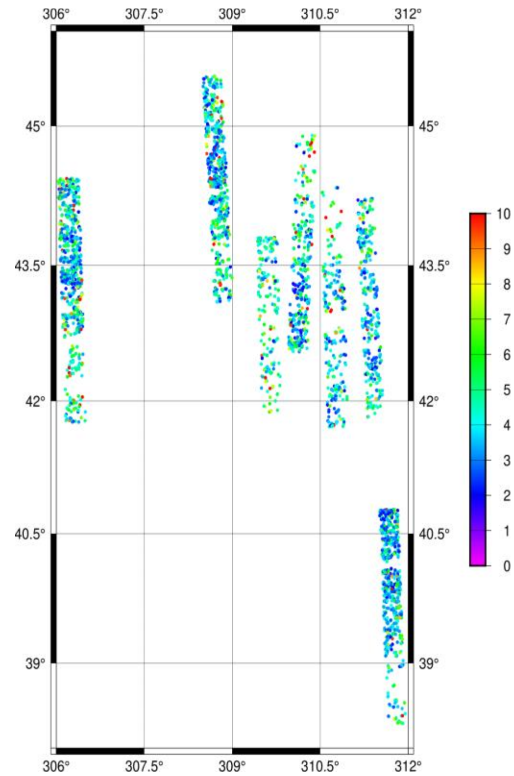

Figure 3: Map view of the regolith measurements from nine LROC Images from Oceanus Procellarum between latitudes 38°N and 46°N and longitudes 306°E and 312°E.

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