**THE RELATIONSHIP BETWEEN REGOLITH THICKNESS AND TIME AS INFERRED FROM COLD-SPOT CRATERS.** A. E. Rincon[1], C. M. Elder[2], and B. Douglass[3] [1]University of California Berkeley, ashley.rincon@berkeley.edu, [2]Jet Propulsion Laboratory, California Institute of Technology, [3]University of Colorado Boulder

**Introduction:** Regolith is a layer of fragmental debris on the Moon's surface, which formed through billions of years of meteoroid bombardment [1]. The canonical model of regolith development is predicated on the idea that older surfaces will generally have endured a higher number of impacts and would therefore have a thicker regolith layer. Many attempts have been made to constrain the thickness of lunar regolith over specific regions using remote sensing [e.g. 2] and in situ [e.g. 3] techniques. However, a detailed understanding of the variability of regolith thickness remains largely undetermined.

Here we investigate the blockiness of the ejecta blankets of a recently discovered class of geologically young craters, cold-spot craters. The presence or absence of blocks in ejecta blankets has long been used to estimate variability in regolith thickness [e.g. 4, 2]. However, recent work has shown that blocks on the Moon break down within a few hundred million years [5], which may have caused previous crater ejecta studies to overestimate regolith thickness [6, 7].

Cold-spot craters (Figure 1) are surrounded by an annulus of low-thermal inertia material (cold at night) extending ~10-100 crater radii [8]. The proximal ejecta blanket is unaffected by the low-thermal inertia material and is often rocky [6]. The low-thermal inertia signature of these craters fades in less than 1 Myr [8], which allows us to presume pristine ejecta. Here we investigate how regolith thickness varies with surface age by classifying 375 cold-spot craters in the lunar maria as blocky or block-free and comparing the frequency of blocky craters in geologic units of different ages using the units defined and dated by [9].

**Methods:** We considered all cold-spot craters from [8] that occur within a unit dated by [9] and had suitable coverage by the Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC). This resulted in a list of 375 craters. To ensure that we were sensitive to the same size boulders at each crater, we resampled all NAC images to a resolution of 1.5 meters per pixel. We only considered images with an incidence angle between 25 and 80 degrees. This range represents a balance between using comparable lighting conditions and ensuring coverage for the majority of cold-spot craters in the maria. At each crater with NAC coverage within these constraints (see example in figure 1), we measured the crater diameter and counted the blocks observed within one-crater radius of the crater rim. We only counted blocks >3 m along their long axis. We classified each crater as having no blocks, 1-3 (a few) blocks, and greater than 3 (many) blocks. The middle category is to account for the possibility of a stray block not excavated by impact that formed the cold-spot crater.

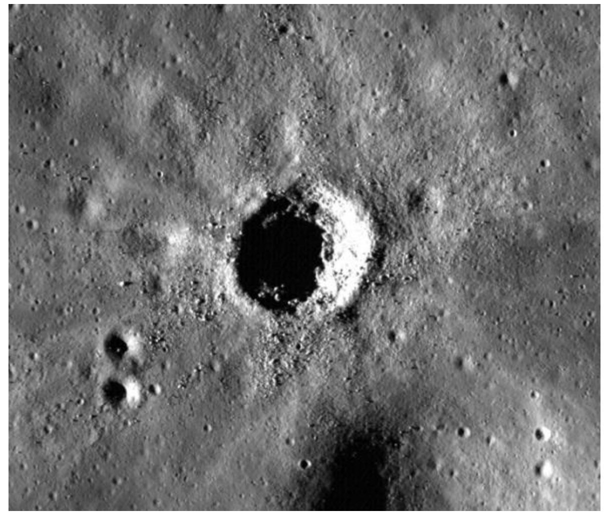

Figure 1. A cold-spot crater with a diameter of 239 m located at 6.40282ºN, 11.12768ºW (LROC NAC).

Based on the canonical model of regolith development, we expected cold-spot craters in younger units to excavate more blocks than cold-spot craters in older units, which have had more time to develop a thick layer of regolith. To test this hypothesis, we separated the craters into three bins based on the age of the unit in which they occur. Most of the mare basalts were emplaced >3 Gya, so in order to have a similar number of craters in each age bin we divided the craters into unit age ranges: 1-2.8 Ga, 2.9-3.3 Ga, and >3.4 Ga. We then compared the sizes of craters that excavated blocks in units of different ages.

**Results & Discussion:** We do not see a significant difference in the number of blocky craters in units of different ages. Figure 2 shows the percentage of blocky craters as a function of crater size for three different ranges of unit ages. A small fraction of the craters between 75 and 125 m in diameter have blocky ejecta for units in each age range considered. All craters larger than 175 m in diameter excavated blocks in units between 1 and 2.8 Ga, which may suggest slightly thinner regolith in those units. However, there were only two block-free craters larger than 175 m in diameter in

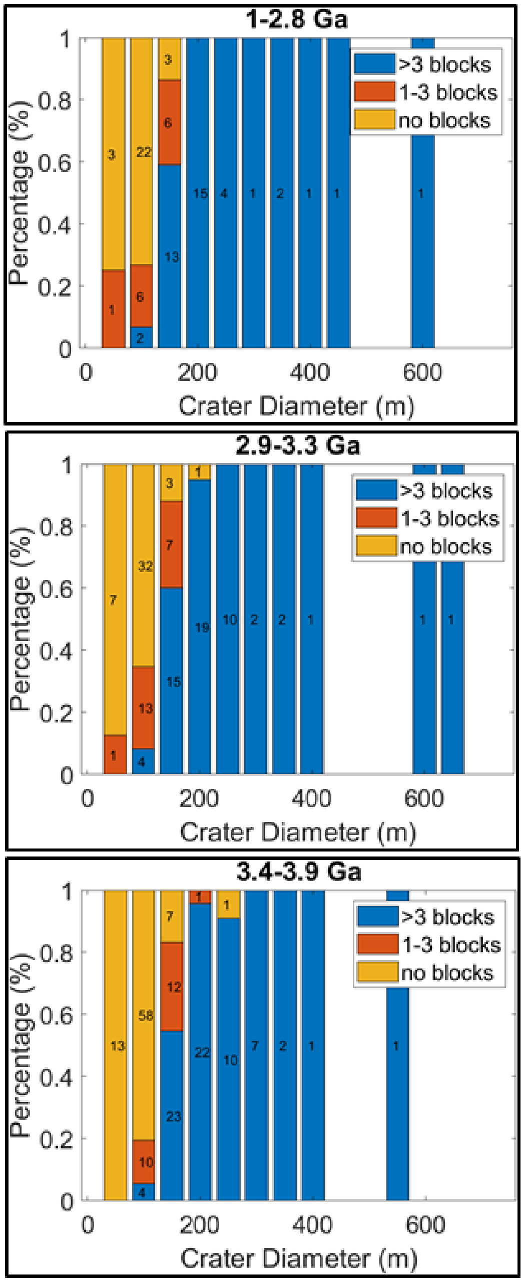


Figure 2. The distribution of craters with different block abundances versus crater diameter for units of ages 1-2.8 Ga (top), 2.9-3.3 Ga (center), and 3.4-3.9 Ga (bottom). The colors signify the percentages of craters with zero blocks (yellow), 1-3 blocks (red), and greater than 3 blocks (blue). The number of craters in each bin is indicated by the numbers overlaying the

units older than 2.8 Ga, so we do not consider this difference to be significant. Overall, we do not see a significant difference in the size-frequency distribution of blocky craters with unit age.

These results are inconsistent with the canonical model of regolith development in which a layer of regolith gradually thickens over time. This model would predict that smaller impacts are capable of excavating blocks in geologically young units. However, recent work [10] suggested that different eruption types would produce a wide range of initial conditions, which would affect the rate of regolith development resulting in variability in the thickness of regolith on units of similar age. Our results are more consistent with this new conception of regolith development than with the canonical model.

Alternatively, it may be easier to excavate blocks from older lava flows, which may already be more fragmented [11]. It is also possible that the relationship between excavation depth and final crater diameter is complicated and could depend on multiple factors including target properties, impact angle, impactor density, etc. Our observations could also be of limited use at small craters since the size of the largest excavated block scales with crater diameter, and the largest blocks at our smallest craters may be below our detection limit [12]. However, this limitation is not related to surface age in any way, so it affects each set of craters equally. Furthermore, we do observe a block at two craters in our smallest size range.

**Conclusions:** Surface age does not appear to have a significant effect on regolith thickness in the lunar maria based on the blockiness of ejecta blankets of craters <1 Myr old. This result is unexpected based on the long-standing model that regolith thickens gradually over time. However, it seems consistent with recent work [10] that argued that the development of regolith is sensitive to initial conditions, which could vary based on the dynamics of each individual eruption.

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