REGOLITH FORMATION ON YOUNG LUNAR VOLCANIC FEATURES.

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Introduction: [1] identified 70 irregular mare patches (IMPs) on the Moon. These small topographic anomalies (100-5,000 m maximum dimension) have irregular morphologies and textures. Several formation mechanisms have been suggested for Ina, the most studied IMP, including: caldera collapse followed by small extrusions of lava [2]; patches of regolith removed by recent out-gassing [3]; or lava flow inflation [4]. Crater distributions indicate that the IMPs are younger than 100 million years, possibly as young as 18 Myr in the case of Sosigenes [1]. Such recent volcanism has important implications for our understanding of the Moon's thermal evolution. Furthermore, if they are as young as implied by crater distributions, IMPs may be among the best places on the Moon to study the earliest stages of regolith formation and evolution.

Here, we present preliminary observations from the Lunar Reconnaissance Orbiter (LRO) Diviner thermal radiometer of the four largest IMPs: Sosigenes, Ina, Cauchy-5, and Maskelyne. We investigated how the Diviner derived rock abundance and regolith properties of the IMPs constrain their formation and evolution.

Data and Methods: We use Diviner data collected at local times of 1930 to 0530 from channels 6, 7, and 8, which have full width half max band passes of 13-23, 25-41, and 50-100 μm respectively. Rocks and fine-grained regolith have different thermal inertias, so they have different nighttime temperatures.

Rock abundance: Warmer sub-pixel surfaces increase measured brightness temperatures more strongly at shorter wavelengths, so warm rocks are detectable by spectral slopes in the nighttime Diviner data. This allowed [5] to calculate the abundance of rocks greater than ~1 m on the Lunar surface. [6] showed that in crater ejecta, this measured rock abundance decreases with time as the large boulders thrown out by the impact are broken into regolith. [5, 6] found that regolith typically has a low measured mean rock abundance of 0.004-0.006 (i.e., 0.4-0.6% of each pixel is covered by rock at the surface) and has little global variation. We compare the measured rock abundance of the four largest IMPs to the surrounding terrain.

Regolith thickness: The different thermal inertias of rock and regolith could potentially also be used to detect layering. A thin (<10 cm) layer of regolith overlying a layer of rock would initially have the same temperature as areas where the regolith is thick. However, over the course of the lunar night, the buried rock would slow further cooling of the regolith, keeping it warmer than areas with thick regolith.

Results: The terrains surrounding Ina, Cauchy-5, and Maskelyne have rock abundance distributions similar to that of the regolith discussed in [6]. They are close to normal distributions and have mean and median rock abundance values ~0.004 (Figure 1, right column). Ina, Cauchy-5, and Maskelyne have a higher mean rock abundance than the surrounding regolith and their rock abundance distributions are slightly skewed toward higher rock fractions (Figure 1, center column). However, the mean measured rock abundance is less than 0.01 meaning that less than 1% of the surface is covered in rocks. The 95th percentile value ($RA_{95/5}$), used to represent a population maximum in [6], is also relatively low compared to the rocky ejecta considered by [6].

Sosigenes, the largest IMP, has a higher mean, median, and 95th percentile measured rock abundance than Ina, Cauchy-5, and Maskelyne. This is because Sosigenes is within a topographic depression, and the steep slopes have a higher rock abundance due to mass wasting. Future work will exclude the slopes and compare the interior of the depression to the background regolith.

The change in brightness temperature of the IMPs over the course of the lunar night is similar to that of their surrounding terrain. This suggests that the regolith is thick enough to mask the signature of any underlying rock.

Discussion and Conclusion: Analysis of IMPs, using Lunar Reconnaissance Orbiter Camera (LROC) images suggest that they were formed by recent basaltic lava flows and lava flow inflation [1, 4]. We would expect fresh lava flows to have a high rock abundance compared to the average lunar regolith. However, we find that the measured rock abundance is only slightly higher than the lunar average and much lower than the ejecta of ~100 Myr-old craters that penetrate the regolith. Furthermore, we see no evidence for layering, so the regolith must be >10 cm thick. This suggests that either the IMPs are older than crater distributions suggest, or that regolith develops more rapidly on lava flows than on blocky ejecta blankets.

Future Work: The irregular mare patches dated by [1] have ages comparable to some young impact craters on the Moon. We will also compare the rock abundance distributions of impact melt associated with young craters to those of the irregular mare patches to study the formation of regolith and possible differences in the rock abundance of impact melt and volcanic features.

Current Diviner targeting efforts to increase coverage over the course of the lunar night may allow us to take advantage of the different cooling rates of different sized rocks to estimate the rock size frequency distribution of the IMPs. Given the volcanic origin and suggested young age of the IMP's, we expect that they may have a rock size frequency distribution unique compared to the old cratered surfaces that dominate the Moon.

References: [1] Braden, S. E. et al. (2014) *Nature Geoscience, 7*, 787-791. [2] El-Baz, F. (1973) *NASA SP-330, 30*, 13-17. [3] Schultz, P. H. et al. (2006) *Nature, 444*, 184-186. [4] Garry, W. B. et al. (2012) *JGR*, *117*, E00H31. [5] Bandfield J. L. et al. (2011) *JGR*, *116,* E00H02. [6] Ghent R. R. et al. (2014) *Geology*, *42*, no. 12, 1059-1062.

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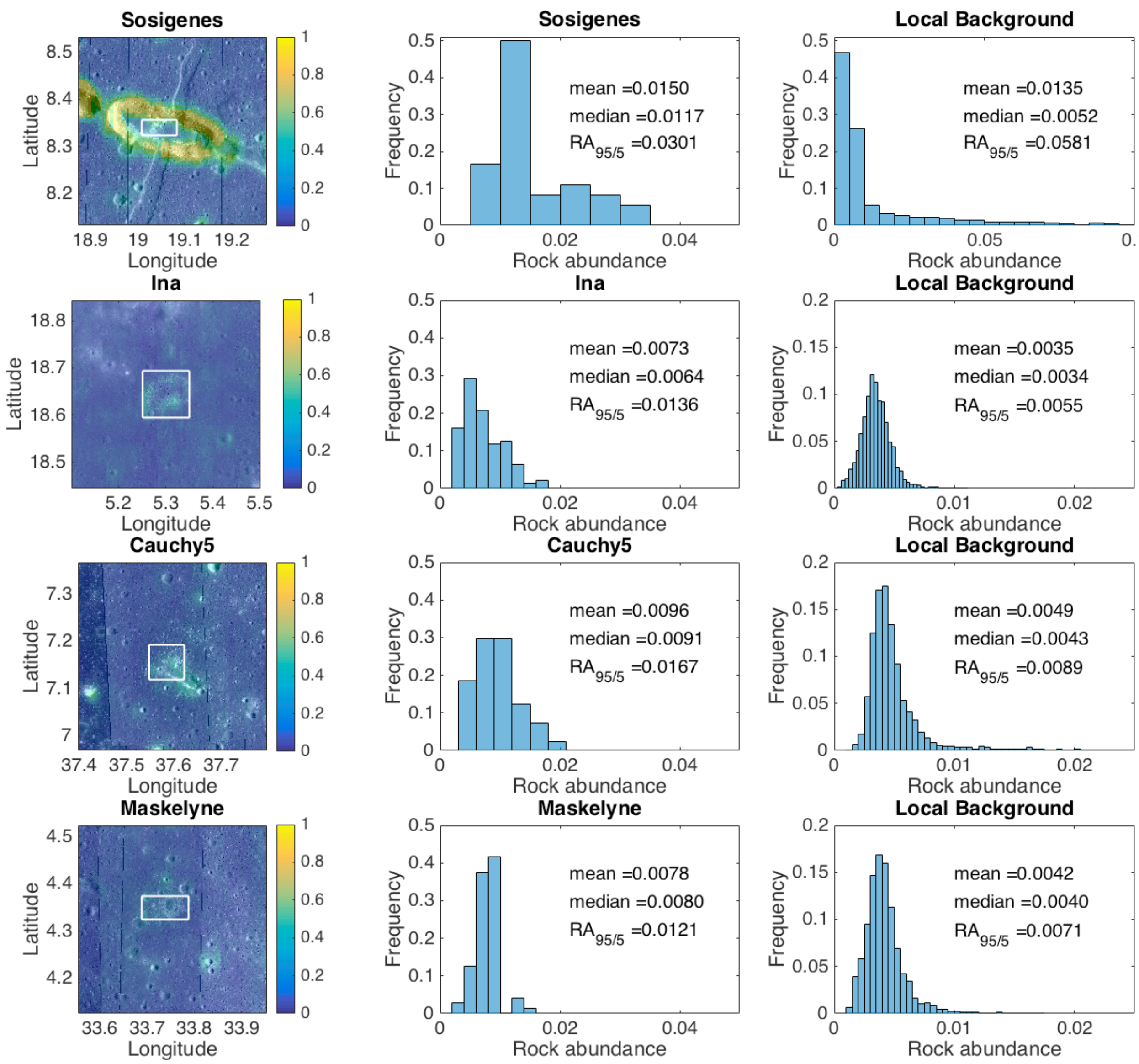

Figure 1. Map of the abundance of surface rocks larger than ~1 m overlain on LROC images (left column); histograms of the measured rock abundance of the feature (center column); and histograms of the measured rock abundance in the regolith surrounding the feature (right column) for Sosigenes (first row), Ina (second row), Cauchy-5 (third row), and Maskelyne (fourth row).