ROCK ABUNDANCE AND SURFACE AGES IN THE LUNAR MARIA. J. T. Haber[1], P. O. Hayne[2], C. M. Elder[3], [1]Cornell University, Ithaca, NY (jth254@cornell.edu), [2]University of Colorado, Boulder, CO, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

Introduction: The Moon does not have a significant atmosphere, and its small size implies that its interior cooled quickly [1]. Most volcanism on the Moon occurred at least 1 billion years ago [2]. Since this time, the main process modifying the lunar surface has been bombardment by meteorites, which break down bedrock and rocks of all sizes into smaller rocks and eventually, regolith. However, the details of rock breakdown and regolith formation are poorly understood. Rocks currently on the surface are part-way through the process of being broken down. Here, we investigated differences in the rock abundance of maria units, defined and dated through crater counting by [2] to quantify the rate of regolith formation and rock breakdown.

Younger surfaces are expected to be covered by a thinner layer of regolith, because they have been exposed to impact bombardment for a shorter period of time. Individual impacts are more likely to penetrate the thin regolith on top of the lunar maria and eject fragments of bedrock than impacts onto the older highlands, where the regolith layer has grown thicker and surface rock abundance is lower [2-3].

This study attempts to quantify the relationship between surface age and Diviner rock abundance in the lunar maria. Bandfield et al. (2011) [4] mapped the lunar rock abundance using nighttime multispectral infrared observations from the Lunar Reconnaissance Orbiter Diviner Lunar Radiometer Experiment to detect subpixel anisothermalality caused by warm rocks. They found a clear enhancement in rock abundance in the lunar maria compared to the highlands, consistent with their younger age. Hiesinger et al. (2010) [2] determined the ages of different maria units by crater counting. Here, we attempt to quantify the correlation between rock abundance and surface age on the Moon. Such a correlation could constrain the rate of rock breakdown and regolith formation, and potentially enable surface age estimates using rock abundance alone.

Methods: Heisinger et al. (2010) [2] defined 665 unique lava flows by identifying spectrally homogenous regions using Clementine data and used crater counting to determine the age of each flow. Diviner rock abundance is the fraction of the surface covered by rocks 1 m in diameter or larger, mapped at a resolution of 128 pixels per degree [4]. We used these two data sets to generate histograms of the number of Diviner pixels with a given value of rock abundance (as in [5]) for each of the 665 regions outlined by [2]. While [5] used the 95th percentile to quantify changes in rock abundance around Copernican craters, in our study we found that both the 95th percentile and the median rock abundance were representative of the rock population so we used the latter in our analysis, for simplicity. We then determined the relationship between the median rock abundance and the surface age as reported by [2].

Results: Figure 1 shows the median rock abundance for each of the 665 regions. Hiesinger et al. (2010) [2] used crater counting to date 290 of these regions, and found ages ranging from 1.2 to 3.8 billion years old. For this subset, we find that the median rock abundance within each unit is negatively correlated with the unit's age, with a correlation coefficient of ρ=-0.424. We fit a linear function to this data and find that, $R = 0.000733t - 0.00639$ (Equation 1) where R represents Diviner rock abundance and t is age in billions of years. Thus, in general, rock abundance decreases with age. Figure 1 shows that rock abundance is also correlated with location; in particular, parts of Oceanus Procellarum and Mare Humorum are realtively rockier and Mare Australe in the southeast is relatively rock poor.

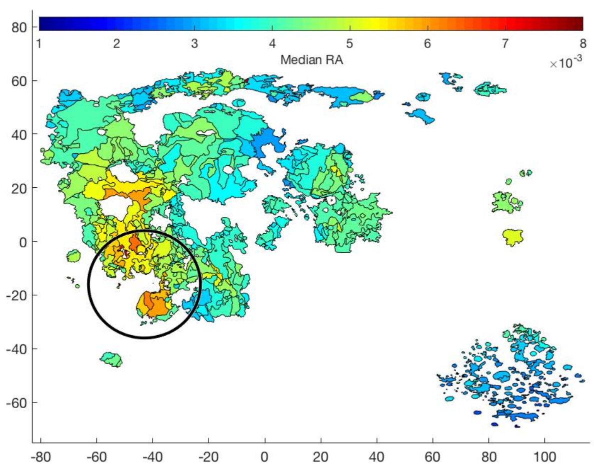

Figure 1: Median Diviner rock abundance of regions mapped by [2]. A particularly rocky area in the southwest is circled in black. The high concentration of rocks in these mare units is unexpected, given their crater-retention ages of ~2.0-3.5 Ga.

Discussion: Variations in rock abundance that correlate with location rather than age could be due to the size and location of some of these regions. Many of the regions that do not have ages assigned by crater counts [2] are much smaller than the dated regions. The rock abundances in smaller regions may be more strongly affected by anomalies such as a few very rocky craters that

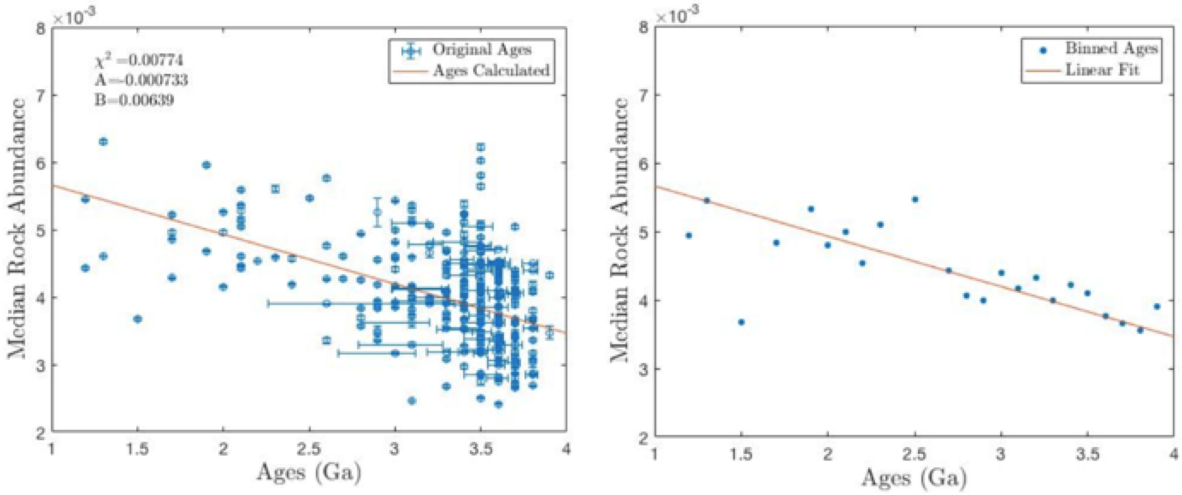

Figure 2: Median rock abundance vs. age with errors in ages reported by Hiesinger et al. (2010) [2] on the left and the same values binned by age on the right. There is an apparent correlation between rock abundance and age as shown by the line of best fit in red. The relationship is clearer when the regions are binned by age in the right plot.

skew the results. The location may also have some effect on the correlation as many of the regions without ages assigned appear to be much less rocky and are concentrated in the the southeast region of the Moon, Mare Australe, away from larger lava flows.

The units roughly circled in Figure 1 are unusually rocky for their age as determined by crater counting. This rockiness was not only observed in the Diviner products, but also in radar observations [6]. This suggests that something besides regolith development has affected the rock abundance in these units. More analysis is needed to determine why these regions are rockier than expected.

While the general trend is that rocks are broken down into regolith over time as revealed by the negative correlation found in this study, the process of regolith formation and evolution involves several sources and sinks. We generalize rock breakdown as a process in which a coherent rock surface generated by a lava flow is broken apart into smaller and smaller fragments by micrometeorite impacts. This process builds up a layer of regolith on top of the coherent rock. Subsequent impacts may penetrate through this regolith layer and excavate rocks from under the regolith layer or form new rocks through impact melt. Rocky ejecta from a large impact may be the culprit for the very rocky area circled in Figure 1. Once on the surface, rocky ejecta is buried by other impacts ejecting regolith and/or broken down by some combination of impacts and thermal fatigue. This breakdown of individual surface rocks may temporarily increase surface rock coverage if a single large rock is broken into multiple smaller rocks that cover a larger fraction of the surface.

Conclusions: The correlation between surface age and Diviner rock abundance is apparent in Figure 2, with a correlation coefficient of -0.424. From the line of best fit, the median rock abundance (area fraction) decreases by 0.000733 every billion years (the average Diviner rock abundance in the maria ranges from 0.004-0.006 [5]). This rate likely represents a complicated relationship between the excavation of rocks and the breakdown and/or burial of rocks. Future work may seek to use these observational results to contrain models of rock breakdown and regolith formation, on the Moon and other planetary bodies.

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