ROCK ABUNDANCE AS A POTENTIAL DISCRIMINATOR OF IMPACT MELT ON LUNAR CENTRAL PEAKS.

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Introduction: The Moon's crust has been penetrated and modified by impacts of all sizes, ranging from micron-sized pits to basins thousands of kilometers in diameter. The depths sampled by these impacts cover the full lunar crustal thickness and may even extend into the mantle, providing a valuable three-dimensional view of lunar stratigraphy. However, the same cratering processes that expose subsurface material also act to obscure the true local composition by contributing to extensive mixing of the surface at all scales and by producing impact melt.

Central peak craters are a particularly useful tool to study crustal composition because their depth of origin is relatively well constrained to 1/10th the crater diameter [2], they are formed from unmelted crustal rock [2], and their steep slopes should retard impact melt pooling and regolith accumulation from later lateral impact mixing. Because of these advantages, remote sensing studies of crater central peak mineralogy, pioneered by Pieters [4] and subsequently extended by many, have provided key insights into the composition of the lunar crust. However, even central peaks are not exempt from the problem of impact melt contamination. Impact melt has been observed on the central peaks of several craters including Tycho, Jackson, Aristillus, and Copernicus (e.g. [5], [6], [7]).

Central peak contamination:

Averaging. The simplest approach to this problem is to average large areas of the full central peak, keeping in mind that there may be some contamination from impact melt or mixing. This is the approach taken by default using relatively low resolution datasets (e.g. [4]). With higher resolution data, histograms of the iron content or modeled mineralogy of the central peak can help to identify outlying compositions that might affect results. Dhingra et al. [5] found the proportion of impact melt on five young central peaks to be relatively small, suggesting that for most central peaks, impact melt may be a negligible contributor to observed composition. However, lateral regolith mixing may be a significant factor, and the central peak of Jackson, which hosts a spectacular impact melt cap, demonstrates that best practices should always include attempts to exclude potentially melt-covered regions.

Geologic mapping. One approach to eliminating potentially mixed or contaminated regions is by careful visual examination and geologic mapping using high spatial resolution imagery. Measurements from the LROC Narrow Angle Camera (NAC) and Kaguya Terrain Camera (TC) provide imagery that allows geologic mapping at scales sufficient to identify key features such as blocks and impact melt pools on central peaks, and authors such as Baker and Head [1] and Dhingra et al. [8] have leveraged these datasets to produce geologic maps of impact melt for individual craters.

Quantitative techniques. However, geologic mapping of individual peaks is time consuming and subjective; for large-scale surveys, a quantitative metric for narrowing data to areas less affected by mixing and contamination is needed in order to ensure only the most reliable spectra are interpreted. Mass wasting provides a mechanism for revealing fresh in-situ material to be analyzed; steep slopes, extreme optical maturity values, and high rock abundance are three possible discriminators for identifying these fresh surfaces for large-scale spectral analyses.

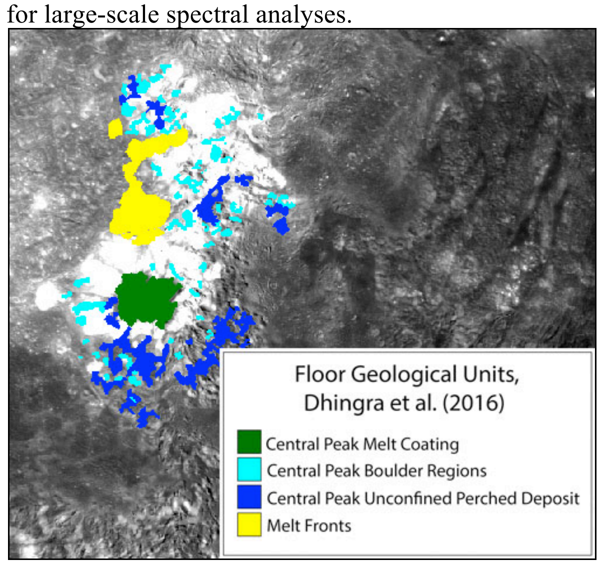

Figure 1. *Central peak geological units of Jackson Crater from Dhingra et al. [8], digitized and overlaid on the Multiband Imager reflectance image at 750 nm for Jackson's central peak and floor region.*

Identifying impact melt: Taking two central peak craters (Jackson and Tycho), we identify impact melt regions using the geologic maps of Dhingra et al. [8] (Fig. 1) as "truth," and test how well each of our three quantitative metrics (LOLA/TC slope, Diviner rock abundance, OMAT) discriminates these regions. We then examine the variation in spectral parameters and modeled mineral composition using Kaguya Multiband Imager data between 1) all central peak pixels, and 2) pixels limited to fresh or unmixed areas as identified by our three parameters. A significant difference in mineral composition between the two regions would imply that average central peak mineralogy may not be an appropriate proxy for crustal composition at depth.

Rock abundance: We isolated the regions of Jackson's central peak mapped as impact melt by Dhingra et al. [8] and found that the rock abundance of these regions is very low, with average rock fractions near 0.03, in contrast to the rest of the central peak, which has an average rock abundance of 0.056 and a much broader rock abundance distribution (Fig. 2, 3).

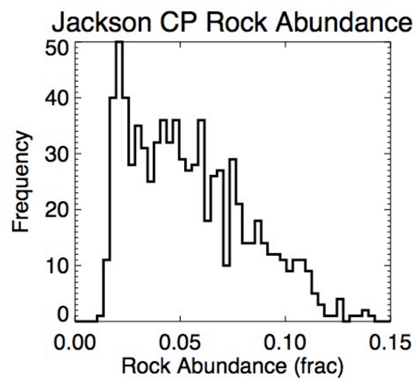

Figure 2. *Histogram showing the distribution of Diviner rock abundance for Jackson's central peak.*

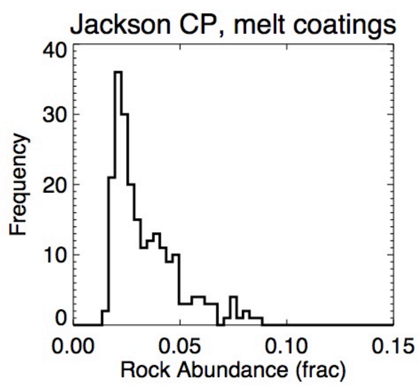

Figure 3. *Histogram showing the distribution of Diviner rock abundance for the impact melt cap map on Jackson's central peak mapped by Dhingra et al. [8]. Rock abundances are much lower for the impact melt cap than for the rest of the central peak.*

We then performed a "blind" thresholding test, dividing the central peak into regions with high and low rock abundances, iterating through thresholds from 0 to 0.15 rock fraction. We calculated average iron abundance and modeled mineralogy based on the central peak maps of Lemelin et al. [9] using Multiband Imager data, downsampled to 128 ppd to match the rock abundance dataset. We find that a rock abundance threshold of 0.05 isolates the same regions mapped as impact melt by Dhingra et al. [8]. Consistent with previous work ([6], [7]), we also find that the regions identified as impact melt have higher iron (avg. FeO 4.8%) and lower modeled plagioclase content (avg. plagioclase 78.8%) than the rest of the very plagioclase-rich central peak (avg. FeO 1.9%, avg. plagioclase 89.7%).

This conclusion is consistent with the work of Bandfield et al. [10][11], who observed that impact melts are low in rocks or even rock-free in the Diviner rock abundance dataset, and hypothesized that impact melts rapidly form a thin layer of regolith cover, masking rocky surfaces beneath from detection by Diviner.

Ongoing work: While rock abundance appears to be an effective discriminator of impact melt for Jackson Crater, we are continuing work to understand whether, and how, it can be applied to other craters. At Tycho, an extremely young and anomalously rocky crater, rock abundance does not appear to identify impact melt regions. Older craters have much lower rock abundances than Jackson and Tycho ([10], [12]), and regolith development throughout the central peak might mask the anomalously rock-free signature of impact melt regions. Ongoing work includes an effort to map impact melt on older central peaks and compare melt rock abundance distributions with average central peak values for these more weathered craters.

Another issue for compositional analyses of central peaks is lateral mixing of regolith from later small impacts. We are currently investigating approaches to eliminate potentially mixed regions in order to further limit analyses to the regions of the central peak most likely to reflect the original composition of the crust at depth.

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