Radar Scattering and Block Size Properties of Lunar Crater Ejecta From Mini-RF and LROC NAC Data

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Summary Block abundances around lunar craters are measured on LROC images and compared with CPR values derived from the Mini-RF SAR images. CPR tends to increase with increasing blockiness, but the correlation is not simple.

Introduction A major objective of the Mini-RF experiment is to distinguish lunar surfaces that may contain water/ice deposits [1,2]. Better understanding of the backscattering properties of craters of varying age and size is crucial for interpreting data received from the Mini-RF. The Mini-RF transmits a circularly polarized RF electromagnetic energy and coherently receives orthogonal linear polarization echoes [1]. The Mini-RF maps in two separate bands (λ=12.6 and 4.5 cm) at a high resolution mode of 30 m/pixel [1]. Given the variables mentioned, the four stokes parameters are reconstructed. The Circular Polarization Ratio (CPR) is calculated for the purposes of understanding subsurface and surface roughness. The CPR is determined from reflections acquired from the ratio of power of the transmitted radio wave in same sense to the reflected radio wave in the opposite sense [1]. Ice in the permanently shadowed regions (PSRs) would be transparent to radar, but the inclusions of materials and imperfections would cause the radio wave to reflect multiple times [3], enhancing the number of same sense reflections and increasing the CPR. In addition, ice also displays the coherent backscatter opposition effect (CBOE), an interferrometric addition of same sense backscatter that further increases the CPR of ice targets [7]. High CPR values also correlate to multiple reflections and are typically associated with very rough surfaces [3]. The average dry lunar surface has a CPR in the range of 0.2-0.4 at 48° incidence [3]. The purpose of this study is to begin to quantify degrees of surface wavelength-scale roughness with CPR and to understand how such surface roughness is created and gradually destroyed by erosion on the lunar surface. Another goal is to identify and isolate the possible causes of high CPR within the shadowed areas of anomalous polar craters [3]. All the studied craters are non-polar, so that we can see into their interiors in NAC images. The idea is to understand what controls blockiness in these craters so that we can rule out rocks (and rule in ice) for the anomalous polar dark ones [3].

Method We have selected a sample of a dozen craters with diameters ranging from 3 to 71 km, covered by both Mini-RF radar and NAC high resolution images. Blocks were identified in the LROC images and the number of blocks on the surface were counted with concurrent measurement of CPR values for the same areas. Because the resolution of the LROC Narrow Angle Camera images (0.5 m/pixel) is coarser than the decimeter-scale (~10 cm) blocks to which Mini-RF diffuse backscatter is sensitive, we estimated the density of decimeter-scale rocks by fitting a power-law curve [4, 5] to the observed distribution and extrapolating that function to the smaller scales. Although we now believe that there is good reason to suspect that function is incorrect [8], we are still studying that possibility for future analyses.

Estimated block densities were compared to Mini-RF CPR data for the same area. Each crater was divided into four representative areas: floor, wall, rim, and continuous ejecta (Fig. 1) and separate block counts were performed for each area. Because we cannot see 10-cm blocks in even the best images, we made linear least-squares fits to the semi-log plots and estimated the approximate abundance of smaller rocks, recognizing that such extrapolation is only approximate. Previous studies have suggested that the block distributions follow a power law [4, 5] (Fig. 2), although we suggest elsewhere that this assumption may be an oversimplification [8].
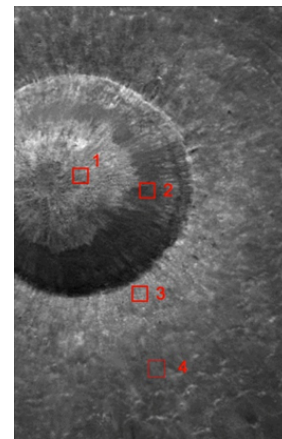

Figure 1. NAC image of the lunar crater Linné showing approximate locations of the areas defined for analysis.

The Mini-RF CPR data was registered with the NAC images and these same defined areas were analyzed for CPR values and their variation (Fig. 3). All measured areas show a skewed Gaussian distribution, for which we calculated mean CPR values and standard deviations. These values were compared with block densities to determine if any systematic relationships exist (Fig. 4).
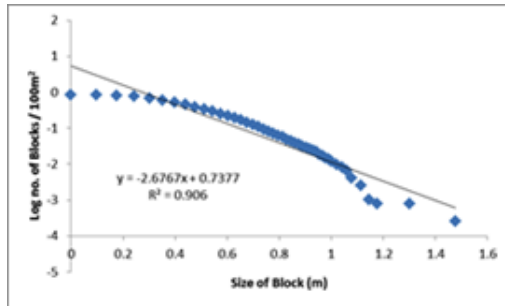

Figure 2. Block size-frequency data for area 1 of the crater Linné. Decimeter-sized rock density is estimated from density of meter-scale and larger blocks.
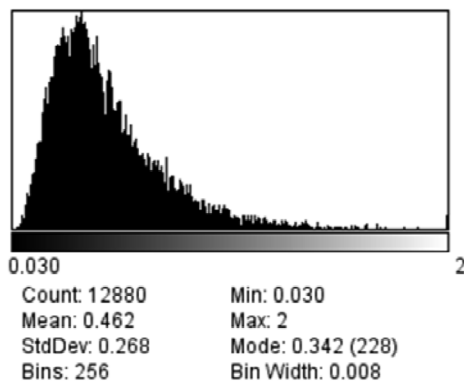

Figure 3. Histogram of CPR data from crater east of Lassel C

Results There should be a correlation between the measured blockiness of crater ejecta and CPR, with rougher and younger surfaces having higher CPR than older, more block-poor surfaces [3]. Our initial results show a weak correlation between CPR values and inferred block abundance; the trend in Fig. 4 has a positive but shallow slope and the correlation is not strong. This plot implies that CPR values are not increasing concurrently with block abundance and may be controlled at least in part by other, more complex factors. Our current sample size is probably too restricted in both crater size and range of degradation to adequately portray all the possible geological occurrences of crater blocks.
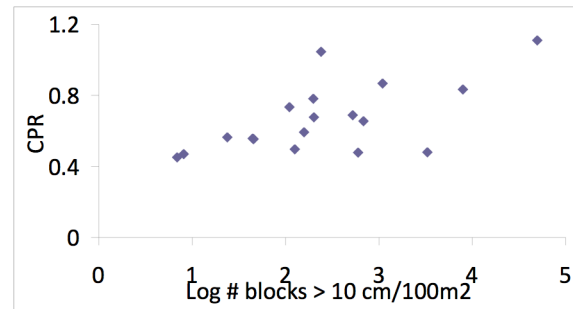

Figure 4. Mean CPR values as a function of estimated decimeter-scale block density for craters and areas analyzed by this study. Error bars on the mean values are smaller than the symbols. There is a general increase in mean CPR with block density. Despite some scatter, the correlation coefficient of 0.62 is statistically significant at the 5% level.

Conclusions A dozen craters of varying age, diameter, and geological setting were analyzed for block abundance and radar backscatter. CPR values vary widely and do not closely correspond with the degree of blockiness as expected, although there does appear to be a weak correlation of high CPR with high block density. Our tentative interpretation is that we must estimate the degree of decimeter-scale surface roughness from meter-scale images using a function different [8] from the traditional power law function used to describe crater ejecta fragment sizes [4,5]. We intend to re-analyze these and additional areas using the new function to better estimate decimeter sized block densities.

References

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