THE COMPOSITION OF THE LUNAR CRUST: AN IN-DEPTH REMOTE SENSING VIEW.
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Introduction: The mineralogical composition of the lunar crust across the entire surface and at a wide range of depths has been inferred from remote sensing observations of complex craters and impact basins on the Moon. Results from recent studies suggest a difference in composition between the rock population of basin rings and central peaks. Hawke et al. [1] found that major portions of the inner ring of many impact basins are composed of pure anorthosite. Cheek et al. [2] conducted the first comprehensive survey of the mineralogy of an impact basins and confirmed that the inner most ring of Orientale is dominated by nearly pure anorthosite. Exposures of olivine and low-calcium pyroxene have also been reported in association with some basins [e.g., 3,4]. Central peaks seem to be on average more mafic than anorthosite; only 2 of the 34 central peaks studied by Lemelin et al. [5] have an average composition corresponding to anorthosite. A possible explanation for this apparent discrepancy is that central peaks and basin rings sample material at different depths into the lunar crust. However, this is difficult to assess because the depth of origin of the material exposed on the basins' inner most ring is not well understood. Another explanation is that the compositions reported for basin rings are simply not representative of all basins, or of the rings as a whole.

To better constrain the composition of the lunar crust with depth, we (1) conduct a comprehensive study of the mineralogy of the inner most ring of 13 basins, and compare their mineralogy to that of the central peaks studied by Lemelin et al. [5], and we (2) use iSALE-2D hydrocode models to better constrain the depth of origin of the material exposed by the basin's inner most ring.

Methods: We define the inner most ring material as the USGS "circumbasin materials" or "basin materials" [6] located on or within the diameter of the inner most ring of Neumann et al. [7]. We determine the composition of the inner most ring of these basins at ~62 m/pixel for all immature exposures (OMAT>0.2 [8]), using Multiband Imager data (750-1550nm, MAP level 02 [9]) and Hapke's radiative transfer equations. We construct a spectral lookup table of the reflectance spectra of 6601 mixtures of olivine, low-calcium pyroxene, high-calcium pyroxene and plagioclase, at 7 amounts of submicroscopic iron (SMFe), an Mg# (Mg/Mg+Fe) of 65, and a grain size of 17μm. We also model the reflectance spectra of these mixtures for a grain size of 200 μm for plagioclase to account for the band depth observed in the Multiband Imager data [10], for a total of 92,414 spectra. We compare the modeled spectra that contained ±2 wt% FeO of a given pixel [5], and assign the composition to the best spectral match (in terms of correlation and absolute difference in continuum removed reflectance). We model the depth of origin of the material exposed by the innermost ring by simulating impacts for a variety of impactor sizes and crustal thicknesses with iSALE-2D. As the spatial sampling of these models does not allow direct detection of the rings, we use the top 10 km of the region of crustal thinning (a zone that includes the inner ring) as a proxy.

Results: The average composition of the inner most ring of 11 basins corresponds to anorthositic rock types (≥77.5 wt.% plagioclase), and the most abundant rock type is anorthosite (≥90 wt.% plagioclase) in 9 basins. We find isolated exposures of more mafic rock types in the near side basins and Moscoviense, but no ultramafic outcrops at the scale of the MI data. iSALE-2D modeling suggest that the top 10 km region of crustal thinning exposes material originating principally from two mean depths: a "shallow component" from the crust, and a "deep component" from the lower crust or the upper mantle. Using the average plagioclase content we modeled for each basin, and assuming that the crust contains 100 wt% plagioclase allows us to place constraints on the abundance of the shallow component present on the basins's inner most ring more specifically. We find that the shallow component largely dominates the ring material. The isolated exposures of more mafic rock types we find might correspond to mantle material exposed by the deep component. Overall, the average composition of the basins' inner most ring appear to be more anorthositic than the average composition of the central peaks studied by Lemelin et al. [5], although the more mafic central peaks are located in the South Pole Aitken basin, which we did not sample in our basin population.

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