DEPTH OF ORIGIN OF THE INNER-MOST RINGS IN LUNAR BASINS.

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Introduction: The mineralogical composition of the lunar crust across the entire surface and at a wide range of depths can be inferred from remote sensing observations and numerical impact modeling of complex craters and impact basins. Studies suggest that the composition of the central peaks in complex craters [e.g., 1-4] and that of the inner-most ring of basins [e.g., 5-6] are different. The average composition of central peaks is more mafic than the exposures of nearly pure anorthosite reported on the inner-most rings of basins. These features could be sampling different depths into the lunar crust. However, the depth of origin of the material exposed in the inner-most rings of lunar basins is not well understood. Some estimates derived from remote sensing studies range from ~0.035-0.06D in multi-ring [7] to ~0.15D in peak-ring lunar impact basins [8], where D is the transient crater diameter. In this study, numerical simulations were made to investigate the depth of origin of lunar basins' inner-most rings. Numerical results were then compared with the remote sensing data. The aim was to place a better constraint on the composition of the lunar crust.

Method: The formation of lunar impact basins was modeled using the iSALE-2D hydrocode [9-11], for a range of target properties typical for the Moon at the time of lunar basin formation. Impact simulations used nine different target temperature profiles [12] and three pre-impact crustal thicknesses (30, 45, and 60 km). All impact simulations used projectiles that were 15, 30, 45, 60 or 90-km in size, impacting the Moon at 17 km/s, which yield the entire size range of lunar impact basins (except the South Pole-Aitken basin). The employed methodology was similar to that in our previous work [13-14]. The depth of origin of the inner-most rings was tracked using tracer particles, from its original pre-impact depth to the region of inner-most rings in peak and multi-ring lunar basins.

Results: *Numerical impact modeling* shows that during basin formation, deep-seated material can become exposed on the surface in one of two ways: (i) as part of the ballistic ejecta that is deposited outside the transient crater rim and (ii) as part of the outwardly collapsing central uplift that is thrust up along with the inwardly collapsing transient crater rim. The mean depth of origin of the inner-most rings is approximately $0.2D_{thin}$, where D_{thin} is the diameter of the crustal thinning. (As a rule of thumb, $D_{thin} \approx D$, depending on the target properties.)

Material exposures in this region were separated between the "shallow component" originating from the upper crust (as the crust overturned during the initial ejecta formation) and the "deep component" originating from the lower crust or the upper mantle (associated with the transient crater collapse and uplift of the underlying layers including the mantle). We approximated that the shallow component originates from $0.02D_{thin}$ for 30 km, $0.04D_{thin}$ for 45 km, and $0.09D_{thin}$ for 60-km pre-impact crustal thickness. Similarly, the deep component was approximated to $0.2D_{thin}$ for 30 km, and $0.3D_{thin}$ for 45 and 60-km pre-impact crustal thickness. Their relative abundances predominantly depend on the pre-impact crustal thickness and impact size, but less so on the target temperature gradient. The larger the impact, the more dominant deep component becomes. There is also a small contribution from the impactor (0-10% of the total abundance in the inner-most ring).

Analyses of the Kaguya's Multiband Imager data (at 62 m/pixel) suggested that the most abundant rock type of the inner-most rings in the majority of lunar basins corresponds to anorthosite, which most likely corresponds to the "shallow" crustal contribution. Isolated exposures of mafic rock types (noritic and gabbroic) were found in basins located on the nearside hemisphere and the Moscoviense basin, which could correspond to the "deeper" component of the material excavated during basin formation. In this dataset, no ultramafic exposures were found.

Conclusion: We placed better constraints on the depth of origin of material exposed in basins' inner-most rings using numerical impact modeling. We also compared modeling results with the remote sensing data, which provided a better insight into the composition of the lunar crust.

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