GRAVITY, BULK DENSITY, AND CRATER MORPHOMETRY OF THE LUNAR MEGAREGOLITH.

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Introduction: The relationship between GRAIL gravity and lunar topography at short wavelengths can be explained by the impact structures visible on the present-day Moon surface. Using conventional crater morphometry models in conjunction with published GRAIL results, we show, using a simple two-layer gravity model, that the short-wavelength GRAIL response is consistent with a lateral negative density contrast between the impact zones associated with the currently visible craters and the surrounding more compacted megaregolith. By this hypothesis, the average bulk density of the lunar megaregolith crust is about 2225 kg/m^3, much lower than the commonly accepted value of 2560 kg/m^3. The impact zones associated with the currently visible craters are bulked up by brecciation and fragmentation resulting in a density contrast of -101 kg/m^3 compared to the surrounding megaregolith crust.

The Bouguer reduction density of the lunar highlands is 2560 kg/m^3 [1]. This value has been presumed to represent the bulk density of lunar megaregolith crust, an important result used to constrain seismic, thermodynamic and petrological models of the lunar interior [2]. However, this interpretation of the Bouguer reduction density is inappropriate on the Moon where the topography is dominated by impact structures with mass deficiencies.

Method: Important constraints on lunar impact models are provided by 1185 measurements of the GRAIL residual Bouguer anomalies over complex craters in the lunar highlands [3]. These anomalies were found to be generally negative and to scale inversely with crater diameter (D) from 27 km to 93 km. This pronounced negative trend in the residual Bouguer anomalies with D over the lunar highlands can be modeled by conventional crater morphometry in conjunction with the known size-frequency distribution of complex craters. To simulate the lunar highlands, we used the catalog based on LOLA data [4] of complex craters with D in the 20-140 km range. A total of 5055 craters were included and were distributed randomly across a simulated plane.

The two-layer crater structure employed (Figure1) consists of an upper layer of density ρ_1 bounded above by the lunar surface and bounded below by the parabolic-shaped base topography of the impact zone; the lower layer of density ρ_0 is bounded above by either the base of the impact zone or the lunar surface. Conventional power-law crater morphometry was used to model the crater surface features with an adjustment made for degradation [5]. The proportional scaling factor T/D, where T is the maximum thickness of the impact zone, was left as a free parameter. Using forward gravity modeling, the theoretical residual Bouguer anomalies for the modeled crater structures were calculated as a function of D given trial parameters ρ_0, ρ_1, and T/D for comparison with the observed negative trend in Bouguer residual anomalies with D, under the constraint provided by the observed Bouguer reduction density of 2560 kg/m^3 established by the GRAIL mission.

Conclusion: Short-wavelength GRAIL gravity observations, including the Bouguer reduction density and the pattern of residual Bouguer anomalies over complex craters, can be explained a lateral density contrast of -101 kg/m^3 between the currently visible impact zones and the surrounding more compacted megaregolith. The modeled bulk density of the lunar megaregolith crust (2225 kg/m^3) and that of the impact zones (2124 kg/m^3) are each much lower than the presumed crustal bulk density found by simply minimizing the correlation between gravity and topography.
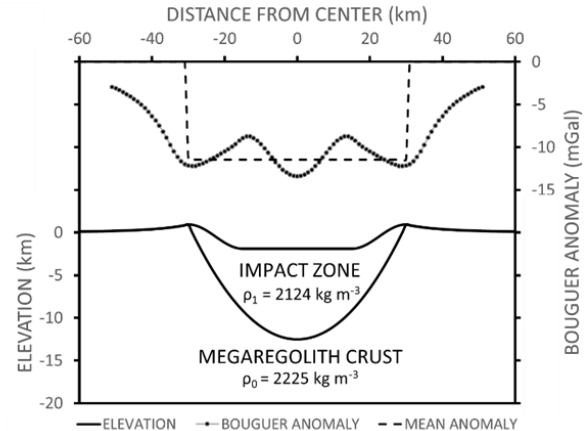

Figure 1 The crater morphology, simple Bouguer anomaly, and the mean residual Bouguer anomaly averaged over the entire crater area for an impact structure of diameter 60 km [6].

References:
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