**LARGE IMPACT CRATER FORMATION ON THE MOON: COMPARING NUMERICAL MODELS WITH GRAIL-DERIVED CRUSTAL THICKNESS PROFILES**

G. S. Collins[1], M. A. Wieczorek[2] and K. Miljković[2], [1]Impact and Astromaterials Research Centre, Dept. Earth Science & Eng., Imperial College, London, UK (g.collins@imperial.ac.uk), [2]Univ Paris Diderot, Sorbonne Paris Cité, Institut de Physique du Globe de Paris, France.

**Introduction:** The well-imaged record of impact craters on the Moon provides arguably the best test for numerical models of crater formation. However, previous numerical modeling studies have shown that the Moon's crater size-morphology progression can be matched with different model assumptions about target rheology [1,2]. In an effort to resolve this ambiguity, here we use gravity and crustal thickness anomalies measured by GRAIL [3], which provide new constraints on crustal deformation beneath large lunar craters, as an additional test of models of crater formation.

**Methods:** Numerical impact simulations, using the iSALE shock physics code [4-6], were performed for typical impact conditions on the Moon. Simulations assumed an impact velocity of 15 km/s, and a surface gravity of 1.63 m/s$^2$, a simplified two-layer target with a crustal thickness of 30-60 km and a range in impactor diameter from 0.1-50 km. The 2D, axial symmetry of the numerical models enforced an assumption of vertical impact. In all simulations the impactor and target mantle were modeled using a material model for dunite; the crust was modelled using a material model for grantite. Equation of state tables generated using ANEOS were used to describe the thermodynamic state of both materials, while material strength was modeled using the approach described in [5]. In some simulations, dilatancy (porosity increase during shear failure) was accounted for using a recently developed algorithm [7]. To facilitate late stage collapse of the craters, the block-oscillation model was used [e.g., 1]. A single choice of block model scaling constants was sought to produce a simulated crater morphology and crustal thickness structure for each impactor diameter that best matched observations (e.g., [8]; see Fig. 1).

For comparison with numerical models, azimuthal averages of surface topography, crust-mantle interface, and Bouguer gravity were calculated as a function of distance from the center of ~50 of the largest lunar craters. The crustal thickness profiles were derived from recent crustal thickness models [3], which take into account lateral variations in crustal density as constrained by orbital remote sensing data. The crustal thickness models were constructed by removing the gravity contribution of the surface topography (as mapped by the laser altimeter LOLA onboard LRO) from the observed GRAIL free-air gravity; the remaining signal was then interpreted as relief along the crust-mantle interface and inverted using standard techniques [9].

**Results:** Numerical impact simulations with consistent block-model scaling constants are able to reproduce several key observations, including: (a) the simple-to-complex transition diameter; (b) the central peak to peak-ring crater transition diameter; (c) the depth-to-diameter trend up to a crater diameter of ~300 km; (d) the peak-ring vs. rim diameter ratio [8]. Crater depth is over-estimated in the models for craters larger than 300 km diameter, which may be explained by post-impact visco-elastic modification of large basins [10]. The numerical simulations predict a central region of thinned crust, overlying mantle uplift, surrounded by a ring of thickened crust and depressed mantle, in qualitative agreement with crustal thickness models derived from GRAIL gravity. However, the crustal thickness in the basin centre and the mantle uplift diameter in the simulations tends to be less than is observed (Fig. 1).

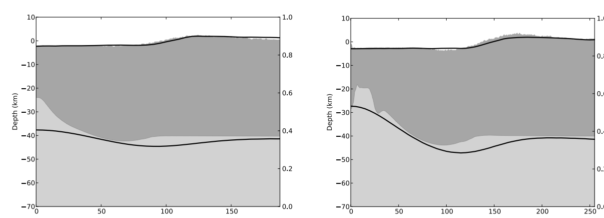


**Figure 1** Comparison of simulated final crater profiles for a 17.5-km (left) and 25-km (right) diameter impactor with azimuthally averaged topography and crustal thickness profiles across d'Alembert (left) and Mendeleev (right) basins.

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