CRUSTAL STRUCTURE OF LARGE IMPACT BASINS ON THE MOON;

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The early bombardment of the lunar surface dramatically redistributed the newly-formed crust. In order to investigate lunar crustal structure and its implications for the early evolution of the Moon, we have examined Bouguer gravity and isostatic compensation mechanisms using the altimetry from the Clementine lidar and a gravity field derived from Clementine, Lunar Orbiters 2-5, and Apollo subsatellite tracking data [1]. In a previous study we computed a global crustal thickness map by downward continuation of Bouguer gravity to the lunar moho [1]. In the present study we perform more detailed regional modeling of several major impact basins on the lunar near and far sides. We find that typical lunar basins have a central peak of upwarped mantle and are often surrounded by a ring of thickened and/or lighter crust.

Approach. We calculated crustal thicknesses from a global Bouguer gravity map derived from the GLGM-1 and GLTM-1 global gravity and topographic models [1]. For both gravity and topography we evaluated the spherical harmonic models to produce a 2°x2° (60 km x 60 km) grid. In the global crustal thickness map we assumed a reference value of 64 km in order to match the thickness of 56 km at the Apollo 12 and 14 sites [2, 3]. We also assumed a constant density crust (ρ_c=2800 kg m^{-3}) and mantle (ρ_m=3300 kg m^{-3}). In our regional models of individual basins we corrected for the gravitational attraction of mare fill (ρ_f=3300 kg m^{-3}).

Our approach for calculating the crustal thickness beneath lunar basins differs from a previous study by Bratt et al. [4], who inverted Apollo-era Bouguer gravity data to obtain crustal thicknesses beneath the major near side basins. Their inversion simultaneously solved for both crustal and mare thickness. In order to solve for these two unknowns, the following assumptions were invoked: (1) topography in mare areas was Airy compensated before the emplacement of mare basalts; and (2) no compensation of maria has occurred since their emplacement. On the basis of higher quality and more spatially extensive data provided by Clementine, we have found mare basins to exhibit a wide range of compensation states [1]. As a consequence we do not feel that assumption (1) necessarily holds in a general sense. We thus make use of published mare thickness compilations fill [5, 6, 7, 8] to correct for the attraction of mare and solve for crustal thickness alone.

Results. Interpretations of lunar gravity during the Apollo era [4, 9] recognized that the near side mascon basins -- Crisium, Imbrium, Nectaris, Serenitatis, Humorum, Smythii, Grimaldi -- were due at least in part to upwarping of the moho [10, 11], as well as to mare basalt fill that was denser than highland crust [12]. The structure of the far side basins may now be resolved, and results show that while far side crust is thicker overall, significant thinning takes place under basins such as Mendel-Rydberg, Hertzprung, Moscoviense, and South Pole-Aitken. Figure 1 shows that all resolvable lunar basins exhibit varying degrees of crustal thinning, likely the consequence of excavation and mantle rebound associated with impact [4, 13]. For the near side mascons, approximately 80%, on average, of the subsurface mass excess indicated by the gravity is a consequence of upwarped moho, and 20% is due to the presence of mare materials. On the far side, where extruded mare is much less abundant, almost the entire mass excess is a consequence of crustal thinning. This conclusion holds for plausible variations in crustal and mantle density.

The massive South Pole-Aitken basin is surrounded by a crescent of thickened crust, with its thickest region comprising the far side highlands. A similar, but smaller pattern describes the younger (3.8 BY) Orientale basin. Other prominent basins on the lunar far side appear to have thinned the crust, but do not reach the extremes of thinning seen on these two, or on the near side basins, even after correcting for the effects of mare flooding.

Downward continuation is inherently unstable, and requires the truncation or attenuation of short-wavelength anomalies, resulting in exaggerated moho topography. Stable inversion for crustal structure may be performed [14] that minimizes the extremes in crustal thickness while providing an adequate fit to the gravity data. Such "minimum structure" models provide minimum constraints on the combined variation of crustal thickness and/or density and mantle structure. Application of this technique to our data confirms the pattern of excavation produced by giant impacts.

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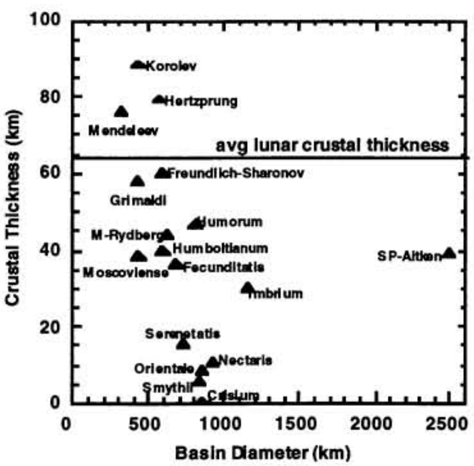

Figure 1. Crustal thickness vs basin diameter for major nearside and farside lunar basins. Crustal thicknesses have been corrected for the gravitational attraction of mare fill. The average thickness of the lunar crust is shown for comparison.