The Deep Structure of Lunar Basins: Implications for Basin Formation and Modification

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We present models for the structure of the crust and upper mantle beneath lunar impact basins from an inversion of gravity and topographic data from the nearside of the moon. All basin models display a thinner crust and an elevated Moho beneath the central basin region compared to surrounding areas, a signature of the processes of basin excavation and mantle uplift during collapse of the transient cavity. There is a general decrease in the magnitude of apparent uplift of mantle material with increasing basin age; we attribute this relation primarily to enhanced rates of ductile flow of crustal material early in lunar history when crustal temperatures were relatively high and the effective elastic lithosphere was thin. The more relaxed topographic and Moho relief associated with older basins on the central nearside may, in particular, be at least partly a consequence of the extensive subsurface heating associated with the formation of the large Procellarum basin. The deep structure of the youngest basins constrains the geometry of the cavity of excavation and the amount of crustal material ejected beyond the basin rim. From the volumes of the topographic basin, of mare basalt fill, and of uplifted mantle material, the volume of crustal material ejected beyond the basin rim for an Orientale-sized event was of the order of 10^7 km^3. A near-constant thickness of nonmare crustal material beneath the central regions of young basins of various diameters and preimpact crustal thicknesses suggests that the transient cavity excavated to at least the base of the crust for the largest basins; significant excavation into the mantle may have been impeded by an abrupt increase in strength at the lunar Moho.

INTRODUCTION

The formation of multiring impact basins has played a major role in the geological evolution of the moon. During the first billion years of lunar history the impact of large projectiles onto the lunar surface resulted in the excavation of basin cavities hundreds of kilometers in diameter [*Wood and Head*, 1976] and the implantation of large quantities of heat into the lunar interior [*O'Keefe and Ahrens*, 1977]. Impact basins also became the focus for volcanic and tectonic activity over a considerable time period following the basin formation events [e.g., *Head*, 1976; *Solomon and Head*, 1979; *Solomon et al.*, 1982]. Important constraints on the processes of basin formation and modification are provided by the present volumes of the topographic basin, of material ejected during basin formation, and of mare basalt fill as well as by the degree of involvement of the mantle in isostatic compensation of basin relief. The topographic volumes of the basins are reasonably well known. Estimates for the volumes of mare basalt and basin ejecta deposits have also been obtained from photogeological studies [e.g., *Moore et al.*, 1974; *Head et al.*, 1975; *DeHon and Waskom*, 1976; *Head*, 1982], but such techniques are generally limited in their ability to resolve the thickness of the deposits. The depth of excavation of several basin-forming events on the moon has also been estimated from the chemistry and mineralogy of ejecta deposits inferred from remote sensing data [*Spudis*, 1982, 1983; *Spudis et al.*, 1984], but such estimates depend critically on the accurate identification of primary ejecta and on assumptions about chemical layering of the lunar crust. In this paper, we apply gravity and topographic data to infer the three-dimensional structure of the crust and upper mantle beneath impact basins on the lunar nearside. With the derived structural models we constrain several of the important geometrical and physical parameters related to the processes of basin formation and modification, and we assess their variations with basin age and size.

Muller and Sjogren [1968] were the first to recognize that the youngest nearside mare basins are characterized by positive gravity anomalies, which they attributed to "mascons." Since that discovery, a number of efforts have been made to model the gravity anomalies over mascon basins with contributions to the anomalous mass placed at the surface [*Conel and Holstrom*, 1968; *Baldwin*, 1968; *Booker et al.*, 1970], at the lunar Moho [e.g., *Wise and Yates*, 1970], or at both locations [e.g., *Hulme*, 1972; *Wood*, 1972; *Bowin et al.*, 1975; *Sjogren and Smith*, 1976]. At least some portion of the anomalous mass contributiong to mascon anomalies resides near the surface [*Phillips et al.*, 1972], but models where mare basalt fill is the sole source of anomalous mass require an unreasonable thickness of mare basalt to fit the measured gravity field [*Thurber and Solomon*, 1978]. While both mare fill and an elevated Moho likely contribute to the observed gravity, the solution for the distribution of anomalous mass between the two locations given only gravity and topographic data requires additional assumptions.

Structural models consistent with gravity and topographic

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