THE DEEP STRUCTURE OF LUNAR BASINS: IMPLICATIONS FOR EXCAVATED CAVITY VOLUMES. Steven R. Bratt and Sean C. Solomon, Dept. of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge MA 02139; James W. Head, Dept. of Geological Sciences, Brown University, Providence, RI 02912; and Clifford H. Thurber, Dept. of Earth and Space Sciences, State University of New York, Stony Brook, NY 11794.

Introduction. The formation of large impact basins has modified substantially the structure of the surface [1] and subsurface [2] of the moon and terrestrial planets. Photogeologic studies have provided estimates for the radius and present depth of major lunar basins and, with greater uncertainty, for the volume of material ejected beyond the basin rim [3-5]. Current information on the deep structure of impact basins, however, is incomplete. A better understanding of the crustal and upper mantle geometry under impact basins would give insight into questions on (1) the formation and volume of the original excavated cavity, (2) the uplift of sub-basin material during collapse of the cavity, and (3) the heating of the sub-basin region by uplift of crustal and mantle isotherms [6]. In this study, we utilize observed gravity and surface topography from the lunar near-side plus seismic constraints on lunar crustal thickness to develop models for the deep structure of impact basins. We then use these models to investigate the excavated cavity volumes for basin-scale impacts.

Crustal and Upper Mantle Structure Models. We follow the procedure of Thurber and Solomon [7] in constructing models of the crust and upper mantle of the lunar near-side. We assume that Airy compensation dominates and that the density contrast ($\Delta\rho$) between crustal (ρ_c=2.9 g/cm^3) and mare or mantle material is 0.5g/cm^3. To restrict the range of possible models, we use the seismic constraint that the crustal thickness in the area of the Apollo 12 and 14 landing sites is about 55 km [8]. An additional assumption about either the thickness of mare fill or the degree of pre-mare isostatic compensation is necessary to determine a single model for the structure under mare basins. Evidence suggests that the mass deficiency and anomalous heat associated with basin formation, in conjunction with a young, thin lunar crust, may have allowed rapid and possibly complete isostatic compensation of the basin long before the emplacement of mare basalts [7,9,10]. Unless the pre-mare compensation is nearly complete, unreasonably large thicknesses of mare basalt are required to fit gravity and topographic data [7]. A map of Moho depths, under the assumption of complete isostatic adjustment of pre-mare topography, is shown in Figure 1. Uplift of the lunar Moho under major basins is several tens of kilometers above that determined seismically in the central near side of the moon. A cross section of the deep structure of the Serenitatis basin according to this model is shown in Figure 2.

Implications for Early Basin Geometry. Photogeologic evidence from the Orientale basin indicates that cavity wall collapse and sub-cavity uplift occurred approximately contemporaneously with the return of ejected impact melt and solid debris to the basin interior [10]. If little or no ejecta fell back into the excavated volume (V_{ex}), that volume could be approximated by the sum of the volume (V_{up}) of mantle uplifted above the ambient Moho depth and the volume (V_{ba}) of the presently observed basin minus the mare fill. Using the structure model depicted in Figure 2, ignoring ejecta fall back, and assuming that the pre-basin Moho depth was the same as that beneath the adjacent terrain, we estimate the excavated volume of the Serenitatis basin to be about 11x10^6 km^3. Previous estimates of the excavated cavity volume for basins the size of Serenitatis or Orientale range from 0.4x10^6 km^3 [3] to 12x10^6 km^3 [11].

© Lunar and Planetary Institute • Provided by the NASA Astrophysics Data System

The effect of considering an ejecta component in the cavity interior is to cause our estimate of V_{ex} to be low by an amount close to $V_{ej}(1 + \rho_c/\Delta\rho)$, where V_{ej} is the volume of ejecta within the basin. This relation holds if the ejecta within the basin is of uniform density (ρ_c) and thickness. If we use the estimated thickness of the ejecta at the basin rim, 1.5 km [5], as an approximation to the ejecta cover within Serenitatis, the previously calculated V_{ex} would be an underestimate by $3 \times 10^6 km^3$. More information about ejecta distribution would permit better estimates of the original excavated cavity volume.

Mantle uplift presently observed under older basins (e.g., Tranquillitatis) is not as pronounced as that beneath younger structures. Solomon et al. [9] argue that viscous relaxation of surface topography and Moho relief for pre-Nectarian basins on the lunar near-side can explain this observation. The effect of such relaxation on estimates for excavated cavity volumes is again to cause our estimates to be low.

Conclusions. We have developed crustal structure models for large basins on the lunar near side using seismic constraints and assumptions about early lunar isostasy based on geologic observation. Models such as that in Figure 2 provide an estimate for the extent of mantle uplift associated with transient cavity collapse and a lower bound on the volume of the excavated cavity for the major basins.

References: [1] C.A. Wood and J.W. Head, Proc. Lunar Sci. Conf. 7th, 3629, 1976; [2] D.U. Wise and M.T. Yates, JGR, 75, 261, 1970; [3] J.W. Head et al., Proc. Lunar Sci. Conf. 6th, 2805, 1975; [4] R.S. Pike, GRL, 7, 291, 1974; [5] T.R. McGetchin et al., Earth Planet. Sci. Lett., 20, 226, 1973; [6] S.R. Bratt et al., Lunar Planet. Sci. XII, 109, 1981; [7] C.H. Thurber and S.C. Solomon, Proc. Lunar Planet. Sci. Conf. 9th, 3481, 1978; [8] M.N. Toksoz et al., Rev. Geophys. Space Phys., 12, 539, 1974; [9] S.C. Solomon et al., JGR, in press, 1982; [10] J.W. Head, Moon, 11, 327, 1974; [11] W.M. Kaula et al., Proc. Lunar Sci. Conf. 5th, 3049, 1974.

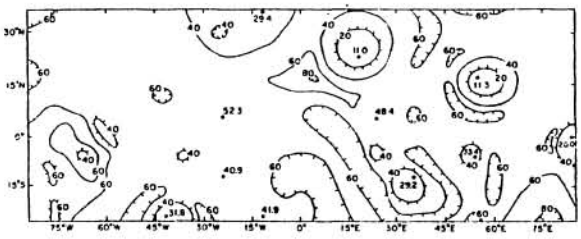

Figure 1. Depth to lunar mantle, assuming that pre-mare topography is isostatically compensated. Contour interval is 20 km.

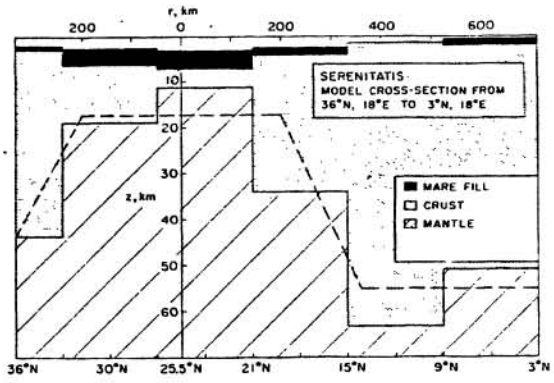

Figure 2. Cross section of the deep structure of the Serenitatis basin, from the model in Figure 1.

© Lunar and Planetary Institute • Provided by the NASA Astrophysics Data System