COHERENCE ANALYSIS OF LUNAR MARE BASINS

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Clementine GLTM-2 altimetry [1] and GLGM-2 gravity [2] from Clementine and historical tracking provide free-air and Bouguer gravity maps at the lunar surface for wavelengths>200 km. A preliminary study found that lunar topography is not compensated by a single mechanism [3] and maintains significant rigidity over 3 b.y. time scales. Interpretation of these data via flexural isostatic models [4,5,6,7] constrains the flexural rigidity of the lithosphere lie in the range $4 \times 10^{22}$ to $10^{25}$ N m for most nearside basins. These correspond to effective elastic thicknesses of 40 to 120 km. While the coherence method gives relatively robust estimates of lithospheric thickness, interpreting the Bouguer anomaly (BA) in this fashion requires some caution. The uncertainty in the gravity data increases dramatically at short wavelengths, and makes estimation of the relative proportion of subsurface to surface loadings difficult. In addition, most short-wavelength topography results from impact processes that violate the assumption that such loadings are statistically uncorrelated. Nevertheless, coherence analysis can provide a lower bound on lithospheric strength.

Coherence $\gamma^2$ of spherical harmonic coefficients of gravity and topography is generally higher than 0.4 up to degree 50 for bodies with strong lithospheres like Venus, but lunar coherence declines abruptly beyond degree 9 (Fig. 1a). Geoid/topography ratios (Fig. 1b) vary and are negative for degrees 10 and 11. Simple Airy (dashed curves) isostatic models would therefore require negative depths of compensation at wavelengths characteristic of large impact basins (900-1100 km), where geoid and gravity highs often coincide with basin lows. At degrees 20 and higher, a lack of correlation reflects inadequate high-resolution gravity coverage, with low-altitude tracking confined to low latitudes on the near side. While a global study of lithospheric strength is not yet possible, some information may be gleaned from the short-wavelength gravity anomalies over the nearside basins.

**Figure 1.** a: Coherence of gravity and topography  b: Geoid/topography ratio as function of SH degree

**Procedure:** We adopt the flexural model of Forsyth [4] with the flexural rigidity $D$ and the distribution of loads causing flexure as free parameters. The flexural rigidity is interpreted as an effective elastic thickness $T_e$. We assume that compensation occurs at the average depth of the lunar Moho, $z_m$, for each basin [8]. The densities of the crust and mantle are taken to be 2900 and 3400 kg m$^{-3}$ respectively. We further assume the subsurface loading results from topography at the lunar Moho, derived from a global inversion of the BA [3]. Local Bouguer inversions of basins [8] also show that a substantial part of the loading of the lithosphere arises from topography at the Moho. These loads are, in some cases, twice as great as those due to surface topography [8].
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Equal-area gridded topography for 2000-km-square regions centered on each basin is combined with gravity sampled from the spherical harmonic model to yield a BA [8]. Because the power in the gravity field at short wavelengths is sharply reduced by a Kaula-law constraint, it is necessary to upward-continue the gravity field predicted by the topography to an elevation of 50 km. Otherwise, the BA is dominated by the topographic correction and is perfectly coherent at short wavelengths. An additional correction is performed for the anomalous density of mare basalts, following the results of Williams et al. [9]. Topography and gravity are tapered with a Gaussian taper of 1600 km full width and mirrored to minimize edge effects and the effects of surrounding basins. Admittances are estimated as the ratio of the crosspowers of the gravity and topography to the autopower of the topography, while coherence is the ratio of the magnitude of the crosspower squared to the product of the autopowers.

Results: Figure 2 shows the coherence and admittance for Orientale Basin, together with predicted responses for a ratio $f=2$ of subsurface to surface loads and a range of $T_p$. There is a drop in coherence of topography with the BA at wavelengths from 900 to 440 km. At shorter wavelengths, there is almost no power in the gravity field and all the coherence comes from the Bouguer corrections. We interpret the drop in coherence as an estimate of the long-term rigidity of the lunar lithosphere, for an equivalent elastic thickness of 40-80 km. Coherence of older basins such as Imbrium is better fit by thicknesses of 60-120 km. These estimates are consistent with results from tectonic studies [10].

Bouguer admittances reflect the means by which lithospheric loads are compensated by subsurface density variations and supported elastically. Admittances are amplified at wavelengths where flexural response to bottom loads is important. Noise in the topography biases admittance estimates downward, while Bouguer corrections at short wavelengths lead to upward bias. Admittance estimates are unreliable in any case when mixed loading conditions apply [3]. Elastic thicknesses obtained from coherence can be biased downwards [11] by as much as a factor of 2 if the surface and subsurface loadings are strongly correlated ($R=0.6$). Further work will attempt to mitigate the effects of such biases.

Figure 2. a: Admittance in mGal m$^{-1}$ as a function of wavelength b: Coherence (correlation squared).