EPSC Abstracts
Vol. 10, EPSC2015-531, 2015
European Planetary Science Congress 2015


# Thicknesses of Mare Basalts from Gravity and Topograhy

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## 1. Introduction

Mare basalts are derived from partial melting of the lunar interior and are mostly located on the near side of the Moon [1, 2]. Their iron-rich composition gives rise to their dark color, but also causes their density to be substantially higher than normal crustal rocks.

The total volume of mare basalts can provide crucial information about the Moon's thermal evolution and volcanic activity. Unfortunately, the thicknesses of the mare are only poorly constrained. Here we use gravity data from NASA's GRAIL mission to investigate the thickness of mare basalts.

## 2. Method

Besserer et al. [3] have developed a method for constraining the depth dependence of density below the surface by use of an "effective density" spectrum, which relates the free-air gravity and the gravity predicted from unit-density topography:

$$g_{lm} = \rho_{eff}(l) b_{lm} + \nu_{lm}$$

Here $g$ and $b$ refer to the observed (free-air) gravity and Bouguer correction of unit density topography [4], respectively, and $\nu$ is the noise which is assumed to be uncorrelated with topography. From this equation an unbiassed estimate of the effective density spectra can be calculated as,

$$\rho_{eff}(l) = \frac{S_{gb}(l)}{S_{bb}(l)}$$

Localized estimates of the effective density spectrum, obtained from a multitaper spectral analysis [5], are then compared to an analytical model that depends on the subsurface density model.

### 2.1 Subsurface density model

We construct a theoretical subsurface density model which contains a constant density mare basalt layer of thickness $t_b$, and an underlying highland crust whose density increases with depth. For the basalt density, we use the pore-free grain density predicted from remote sensing data [6] with a porosity of 12%, while for the density gradient in the underlying highlands crust we use the average value from the work of Besserer [3]. The basalt thickness $t_b$, density and the uppermost density of the highlands crust $\rho_o$ are free parameters.

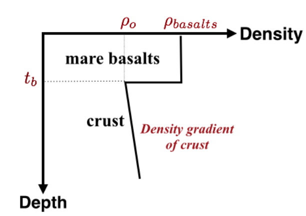


Figure 1: Theoretical density model that contains a constant density mare basalt layer overlying the highlands crust.

### 2.2 Localized multitaper spectral analysis

When calculating the localized effective density spectrum, we used 30 orthogonal windows localized to a spherical cap with an angular radius of 15 degrees and a spectral bandwidth of $L_w = 58$. These are the same windows used by Besserer et al. [3], and only the spherical harmonic degree range of 250-550, was considerer in order to neglect the effects of lithospheric flexure and lateral variations in crustal thickness. Example effective density spectra in Fig. 3 show that this function is sensitive to both the mare thickness and density of the upper crust.

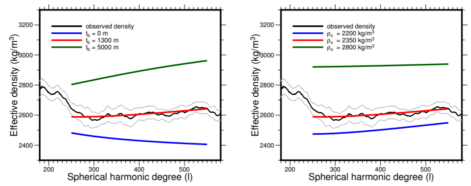


Figure 2: Theoretical effective density spectra for various basalt thicknesses (left) and various upper crustal densities beneath the basalts (right). In the first case, the upper crustal density and density gradient were set to 2340 kg $m^{-3}$ and 21 kg $m^{-3}$ $km^{-1}$, respectively, and in the second case the mare basalt thickness was set to 1300 m. The example spectra corresponds to 26$^o$N 129$^o$W. Gray lines denote the 1-$\sigma$ uncertainty from the multitaper spectrum analysis.

# 3. Results

As the presence of highland materials with the localization windows would bias the calculated effective densities, only those locations where 75% of the window is covered by mare basalts are shown in our results.

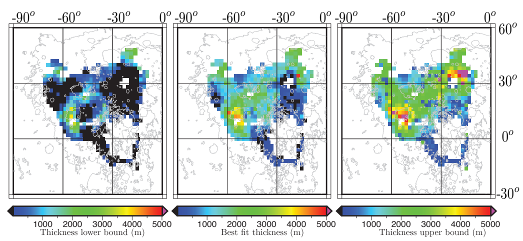


Figure 3: 1-$\sigma$ lower bound (left), best fit (middle) and 1-$\sigma$ upper bound (right) of the mare basalt thickness. The lower and upper bounds are determined by use of the possible distribution of reduced $\chi^2$ from 1000 Monte carlo simulations.

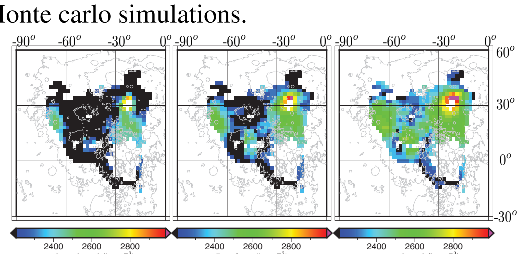

Figure 4: 1-$\sigma$ lower bound (left), best fit (middle) and 1-$\sigma$ upper bound (right) of uppermost highlands crustal density.

# 4. Summary and Conclusions

Our results show that mare basalts are thickest near Marius Hills, which is a prominent, long-lived volcanic complex in Oceanus Procellarum. In general, our basalt thicknesses are somewhat larger than those obtained using the techniques of flooded craters, the composition of impact crater ejecta, and radar sounding. [7, 8, 9]

# Acknowledgements

This work is supported by a CSC (China Scholarship Council) doctoral fellowship.

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