THE NATURE OF LUNAR ISOSTASY. Michael M. Sori[1] and Maria T. Zuber[1]. [1]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, USA (mms18@mit.edu).

Introduction: One way planetary topography can be supported is isostatic compensation, in which overburden pressure of rock is balanced at some depth. The regions of the Moon that are not associated with maria or basins are generally isostatically compensated [1], an observation that was made when the first detailed lunar gravity maps were constructed [2] and has held with each subsequently more precise data set [e.g., 3].

There are two models of isostasy commonly considered. In the Airy isostasy model [4], crustal thickness is varied such that overburden pressures are equal at some depth of compensation. The crust is a layer of uniform density overlaying a mantle of higher uniform density. The Pratt isostasy model [5] instead invokes laterally variable density and constant crustal thickness, again producing constant pressure at a compensating depth. The models can be thought of as end members in a continuum of possible compensation mechanisms; it is possible for both Pratt and Airy isostasy to be operating in the same local region. Drawing inspiration from previous work [6], we investigate the importance of Pratt isostasy on the Moon by searching for negative correlations between elevation and density.

Methods: Solomon [6] searched for the characteristic negative correlation between surface elevation and crustal density associated with Pratt isostasy by calculating densities from Apollo 15 and 16 experimental results that measured surface chemistry and normative mineralogy. Here, we take measurements from two recent spacecraft missions. Observations from the Gravity Recovery and Interior Laboratory (GRAIL) mission [7] have provided the most accurate and highest resolved gravity data of any planetary body to date using inter-satellite ranging [8]. Data from the Lunar Orbiter Laser Altimeter (LOLA) instrument [9] aboard the Lunar Reconnaissance Orbiter (LRO) mission [10] are providing the most accurate and spatially dense topographic map of the Moon. Calculations of crustal density have been made by minimizing the correlation between topography and Bouguer gravity anomaly [11], yielding an average bulk density of the lunar highlands of 2550 kg m^{-3}. Grain density is estimated by [11] from surface elemental abundances derived from gamma-ray spectroscopy [12] in combination with empirical relations between grain densities and FeO and TiO_2 concentrations [13].

A key assumption in investigating the role of Pratt isostasy by looking at the relationship between crustal density and topography is that the density one observes near the surface is representative of the underlying crustal column. We justify that assumption here by noting that calculation of the effective density of the lunar crust as a function of spherical harmonic degree considered results in a linear trend [14], supporting the notion of a single-layer crust.

Results: We make scatter plots of crustal density as a function of elevation. One such scatter plot, for the South Pole-Aitken basin, is shown in Figure 1. Points are sampled in a grid every ~8 km. For each scatter plot, we make a least-squared fit to the data and calculate the associated R^2 value.

We take moving circular windows across global topographic and density maps of the Moon and sample elevation and density in a grid with spacing ~8 km in those windows. Maps of the resulting R^2 values of the associated scatter plots are shown in Figure 2. The higher the R^2 value, the more likely Pratt isostasy is important.

Discussion: The portions of lunar crust that show strongly negative correlation between topography and grain density near the border of Oceanus Procellarum are likely simply due to the tendency of maria to be preferentially located in regions of low elevation. The Pratt model may be a relevant contributing mechanism to the isostatic compensation of the South Pole-Aitken basin and select portions of the lunar highlands. We do not see evidence for Pratt isostasy being a major component of isostasy for the farside highlands in general.

If Pratt isostasy is important in certain regions of the Moon's crust, how does it originate? Intrusions of magma from the lunar mantle to dikes could contribute to Pratt isostasy [6], but we have investigated regions near the vertical tabular igneous intrusions found in a recent study based on GRAIL data [15] and do not find a strong negative correlation between density and elevation. Pratt isostasy can also result from variable degrees of impact melting, which we believe may be a plausible relevant factor on the Moon, as it could explain the negative density-elevation correlation we find in the planet's largest confirmed impact structure, the South Pole-Aitken basin.

Important ongoing work involves consideration of admittance, a quantity that relates topography and gravity. Admittance is defined as the ratio of the cross-power of topography with gravity to the power of topography, for a given spherical harmonic degree *n*. The admittance expected from a strict Airy model as shown by [16], is:

$$Z_A(k) = 2\pi G\rho e^{kH}\left(1 - e^{-kt}\right)$$

H is the elevation, ρ is the crustal density, *t* is the mean crustal thickness, and *k* is the wavenumber. The admittance expected from a strict Pratt model [16] is:

$$Z_P(k) = 2\pi G\rho e^{kH}\left(1 - \frac{1 - e^{-kH}}{kH}\right)$$

We are modeling admittances to compare with observed admittances derived from GRAIL and LOLA data. Comparison of observed admittances with Pratt or Airy modeled admittances will shed further light onto the nature of lunar isostasy.

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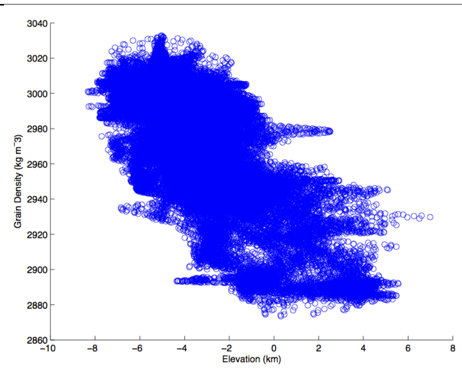

Figure 1: Scatter plot of grain density as a function of elevation in the SP-A basin. Data points are sampled every ~8km in a grid in the basin. A least-squared best-fit line fits the data with an R^2 value of ~0.47, indicating a moderate correlation and lending support to the idea that Pratt isostasy may be a contributing mechanism. Note that the SP-A basin was found to be mostly compensated by [3].

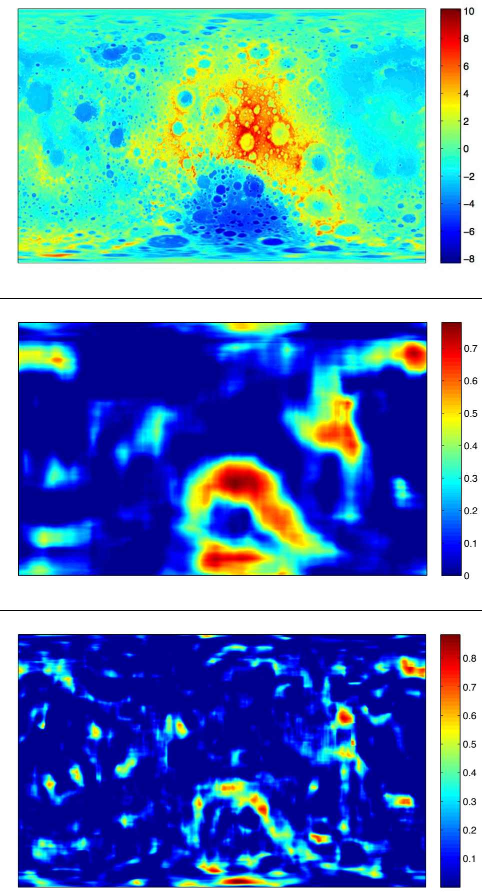

Figure 2: Maps showing LOLA-derived topography in km (top) and the R^2 values of lines that are fit in a least-squared sense to grain density as a function of elevation (middle, bottom). Data points for grain density and elevation are sampled in a grid with spacing ~8 km in a moving window with radius ~450 km (middle) and ~180 km (bottom). The R^2 values are only plotted here when the correlation between density and elevation is negative; otherwise, the map displays a value of zero. Maps are cylindrical projections centered on the lunar farside.