**EXPLORING THE SOURCE OF THE LUNAR LINEAR GRAVITY ANOMALIES.** W. Liang[1] and J. C. Andrews-Hanna[1], [1]Lunar and Planetary Laboratory, University of Arizona (wl463@lpl.arizona.edu)

**Introduction:** The GRAIL Bouguer gravity gradients reveal, on both the lunar near and farsides, a large number of randomly oriented linear gravity anomalies (LGAs) with no surface expression in other datasets [1]. These linear anomalies have been proposed to be dike-like structures that formed very early in lunar history, possibly during a period of global expansion. However, the dimensions of the source bodies are much greater than typical dikes, with widths of order 10 km and widths approaching the heights. While simple dike-like bodies can fit the gravity data, other geometries may as well, with different implications for the origin and implications of the structures.

In this study, we use localized Bouguer power spectra of one of the largest LGAs combined with a Monte Carlo model to explore the nature of the source bodies. Localized power spectra of most of the LGAs, as well as the nearside PKT border anomalies, do not rise above the background despite being distinct in map view [2]. In contrast, the localized power spectrum of a 350 km long LGA (Fig. 1, FN) located in the northern farside highlands at ~66ºN rises significantly above the power of the background northern highlands (Fig. 1, FBG). We investigate the nature of the source body for the FN anomaly using a Markov chain Monte Carlo algorithm to fit the top depths and dimensions of three possible cross-sectional shapes for the subsurface intrusions: an elliptical dike-like body, a triangular prism similar to the Great Dyke of Zimbabwe, and a T-shaped prism representing a hybrid dike-sill structure.

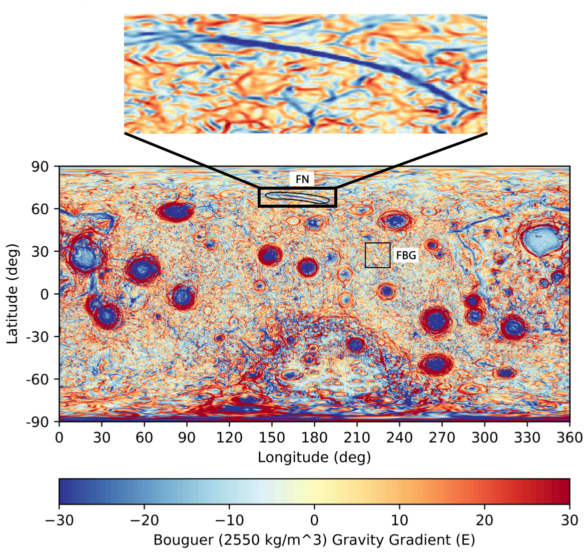


**Figure 1.** Bouguer gravity gradient calculated for a surface density of 2550 kg/m$^3$ for the entire Moon (bottom) and an area surrounding the FN anomaly (top).

**Model:** In the MCMC models, the elliptical cross-section density anomaly represents the shape of a typical dike and consisted of 1000 rectangular prisms of constant lengths (parallel to the strike of the anomaly) and widths (horizontal dimension perpendicular to the strike of the anomaly), but with varying heights (vertical dimension) to provide an elliptical cross-section. The triangular density anomalies were chosen to represent the shape of the Great Dyke of Zimbabwe [3], which is perhaps the best terrestrial analog to the scale of the LGAs. The Great Dyke is a layered intrusion formed from a series of interconnected magma chambers fed by an underlying dike, formed in an extensional tectonic setting associated with nearby greenstone belts. The T-shaped density anomalies were chosen to represent the possibility of a sill formed on top of a dike [4]. Such a scenario could arise from a decrease in buoyancy within the intrusive network resulting from the decrease in density in the upper crust, from an increase in the rigidity or fracture toughness of the rock at shallower depths, or from a decrease in the extensional stress near the surface. The T-shaped anomalies were represented as a combination two regular rectangular prisms, with the bottom prism extending to the base of the crust at a depth of 50 km.

Both the elliptical anomalies and the triangular anomalies were characterized by the depth to the top of the anomaly, depth to the base of the anomaly, and width of the anomaly. T-shaped anomalies were characterized by the depth to the top of the anomaly, the depth to the transition between the two prisms, the width of the top prism, and the width of the bottom prism. The width of the T top prism was constrained to be always greater than the width of the T bottom prism. The length of all prisms was set to 350 km, such that the ends did not have any impact on the gravity profile at the midpoint. The misfit was defined as the summed squared difference (SSD) of the modeled and observed gravity power spectra.

**Model Results:** The models return a consistent best-fit (and mean ±1-σ ranges) top depth of 11-15 km (14-18 ± 3-4 km) across all three shapes. The spectral method is more sensitive to and better constrains the top depth than the previous spatial approach, which constrained the top depth to a wider range of 8 to 32 km [1]. On the other hand, the range of the best-fit and mean results for height and width were larger across the elliptical and triangular structures, with heights and widths ranging from 18-37 km and 11-35 km, respectively.

The T-shape model returned best-fit results that represented a range of possible structures. In multiple MCMC restarts, the models converged on two distinctly different geometries. The first geometry had similar widths for the top and bottom prisms and combined heights that are larger than the widths, which is more similar to typical dike-like intrusions. The second geometry involved a thin but wide sill-like top prism (best-fit heights of 0.7-1 km, widths of 133-152 km) and a bottom prism similar in scale to the other models (best-fit widths ~10 km).

**Table 1.** Mean (±1 $\sigma$) height and width for the three assumed cross-sectional geometries. The T-shaped width results refer to the widths of only the top prism.

| | Height (km) | Width (km) |
|---|---|---|
| elliptical | 18.9 (±7.97) | 24.1 (±9.47) |
| triangular | 19.3 (±7.51) | 33.9 (±13.3) |
| T (T-shaped) | 35.2 (±4.19) | 294 (±133) |

Generally, the solutions for the three prism types returned similar RMS misfits, which were all ~4 times lower than the background variability. The dike-like T geometry had a low misfit (~0.137), followed by the elliptical cross-section (~0.142) and then the triangular cross-section (~0.158). The T-shape model has a larger number of free parameters and thus was expected to provide a better fit to the multiple slopes within the power spectrum, though this adds to the non-uniqueness of the solution. The second class of T-shape solutions, the sill-on-top-of-a-dike geometry resulted in much lower misfits (~0.05) than the rest of the solutions. This lower misfit came about because the model was better able to match the shape of the power spectrum, with a prominent inflection at degree 140 separating a steeper power spectrum at lower degrees from a gentler spectrum at higher degrees (Fig. 3, T4). In contrast, elliptical, triangular, and dike-like T geometries under-predict the power spectrum at lower degrees and over-predict at middle degrees. Nevertheless, the elliptical and triangular models (Ell 3, Tri 2, T 3) were all able to fit to within a factor of 2 from the observed spectrum.

**Conclusions:** While most linear gravity anomalies do not have power spectra that are distinct from their surroundings, the most prominent anomaly in the northern farside clearly rises above the background. This distinctive power spectrum allows us to use power spectral methods to investigate the source of the anomaly. The MCMC models were able to better constrain the top depths in comparison to previous studies, but a large variability exists for the height and the widths. While both the elliptical and triangular prisms provided reasonable matches to the power spectrum, the T-shaped

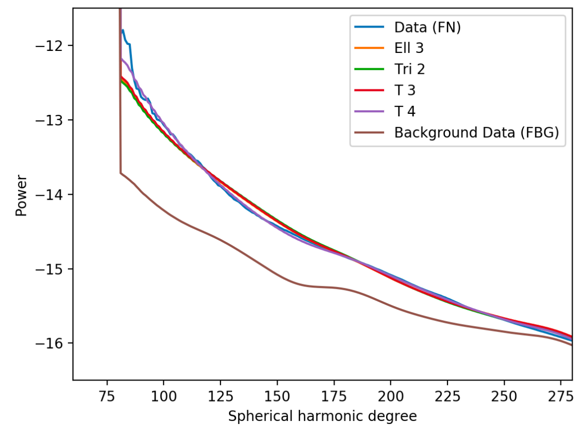


**Figure 3.** Synthetic power spectra of the best-fit elliptical (Ell 3), triangular (Tri 2), dike-like T (T 3), and dike-sill hybrid T (T 4) prisms compared to the FN spectrum.

dike-sill hybrid solution provided a much better fit the observed spectrum. Our results support the interpretation of large intrusive bodies in the subsurface [1], though they can be fit by dike-like, triangular, or dike-sill hybrid structures. It is noteworthy that the elevation difference between the near- and farsides of the Moon is roughly 10 km, which is similar to the modeled top depth of the subsurface structures of 11-15 km, suggesting that similar processes could results in intrusive activity on the far side and extrusive activity on the nearside.

Dikes, dike-sill hybrids, and the Great Dyke are all volcano-tectonic structures that occur on the Earth, and are thought to be present on other major solid bodies as well. Large chains of collapse pits extending from Valles Marineris on Mars may have formed above similar structures, but are not resolved in the gravity data on that planet. Thus, a better understanding of the lunar LGAs may contribute to our understanding of similar scale intrusive bodies on the Earth and Mars. All of the model structures are consistent with an extensional stress regime at depth at the time of formation, possibly associated with an early period of interior warming and expansion due to thermal equilibration after solidification of a shallow magma ocean [5] or interior warming associated with sinking cumulates enriched in heat-producing elements [6].

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