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Forward Mechanical Modeling of Rima Ariadaeus, the Moon

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Lunar graben are long, narrow troughs up to several hundreds of kilometers long and exhibit two morphologies in map-view: linear and arcuate. Both linear and arcuate graben are commonly found in the highlands adjacent to the lunar basins on the nearside. A well-known example of a linear graben on the nearside is Rima Ariadaeus (6.5º N, 12.7º E), located south of Mare Serenitatis, and is approximately 200 km long, 4.5 km wide, and has a relief of $\sim$350 m.

Graben produced by purely tectonic stresses can be distinguished from dike-induced graben by the detection of the subtle yet diagnostic topographic signature. The rock on either side of the dike is displaced outward and upward, forming the characteristic topographic swells. In contrast, the surface topography produced by slip along two inwardly dipping normal faults ($i.e.$, graben) is elevated and concave-up in the footwall and decays more rapidly with distance from the fault than the topographic swells resulting from dike inflation in the subsurface. In order to differentiate between these possible formation mechanisms, more accurate knowledge of the three-dimensional structure must be obtained by methods such as forward mechanical modeling of fault topography.

To test the purely tectonic model, the forward mechanical dislocation program COULOMB was used to calculate surface displacements to determine important fault parameters, determined once a good fit to the topography is obtained. In these models, a fault is idealized as a rectangular plane with the sense of slip ($i.e.$, normal, thrust, strike-slip, or oblique), magnitude of displacement, fault dip angle and direction, depth of faulting, fault separation, and fault length specified. Modeled faults are considered here to be planar at depth as observational evidence, such as graben wall geometry, argues against listric faulting. The initial displacement magnitude is estimated from the relief of the scarp and adjusted based on model output. Final model parameters were determined based on visual fits to the shape of the footwall between observed (measured LOLA) and predicted (modeled) topography, as the shape of the footwall uplift is characteristic of normal fault topography, and depth of the graben. A Young's modulus E of 100 GPa and Poisson's ratio ν of 0.25 are assumed for the anorthositic rock mass that comprises the upper surface of the area between Maria Vaporum and Tranquillitatis transected by Rima Ariadaeus.

Topographic profiles were derived from gridded LRO LOLA data (1024 ppd; $\sim$30 m/px). The mean topography was calculated by stacking and averaging nine individual profiles taken near the center of the structure and the regional topographic slope was removed. The best-fit parameters from the model indicate that the northern fault dips at 75°, accommodates 350 m of displacement, and extends to a depth of 3.5 km; the southern fault dips at 55°, accommodates 450 m of displacement, and extends to a depth of 4.2 km. The depth of faulting is consistent with previous work which assumed that the depth of faulting was controlled by the thickness of the megaregolith. The depth of faulting may indicate that the stresses responsible for forming the faults have arisen locally and imply an origin related to impact basins and maria in the vicinity. Future work consists of modeling the topography assuming dike intrusion at depth and a combination faulting and dike intrusion to test other possible formation scenarios for Rima Ariadaeus.