USING CRUSTAL THICKNESS MODELING TO STUDY MARS' CRUSTAL/MANTLE STRUCTURES.
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Introduction: It is known that Mars has intriguing topographic features: the giant volcanic construct Tharsis Rise, containing the Solar System's largest volcano Olympus Mons, the large impact basin Hellas Basin, and the great canyon system Valles Marineris. Aside from these, an even more prominent global feature is the topographic crustal dichotomy [1]. This enigmatic boundary separates the planet into two distinct hemispheres: a Northern Lowlands hemisphere consisting of lower elevation topography and characterized by smooth, resurfaced lava plains, and a Southern Highlands hemisphere consisting of higher elevation topography and characterized by rough, heavily-cratered terrains [1,2].

The gravitational potential signature of Mars can be integrated with topographic data to reveal a lot about the planet's external and internal structures [3]. What we want to know is what are the surface and/or subsurface features that are contributing to the signature and what types of internal/external processes produced them?

Because gravitational potential is non-unique, an infinite number of mass distribution configurations can give the same signature. Factors that control gravity include crustal and mantle densities, crustal thickness, surface topography, Moho topography, and hidden subsurface structures [4]. In order to narrow down the possibilities and pin point the sources that generated specific parts of the signature, a geophysical model is used in studying Mars' gravitational signature, therefore, its crustal and mantle structures.

Modeling: We use a crustal thickness model based on the equations derived in the algorithm of Wieczorek and Phillips [5] using the freely available software archive SHTOOLS (available at http://www.ipgp.fr/~wieczor/SHTOOLS/SHTOOLS.html). The method was originally used to study the Lunar crust, but can be applied to the Martian crust and mantle [6].

The general assumption is that the gravitational potential is explained by variable crustal thickness [5]. Thus, the model computes gravitational potential anomalies that are due to topography (i.e., Bouguer gravity) on a spherical surface. The remaining gravity anomalies are assumed to represent topography at the Moho. Results generated from the crustal thickness model include crustal thickness maps and gravity misfit maps.

In this study, we input a set of parameters and vary the downward continuation filter to observe how the crustal thickness and gravity misfit values change. Specific values are obtained from [3] and [6]: a crustal density ρ_c of 2900 kg/m^3, a mantle density ρ_m of 3500 kg/m^3, and an assumed crustal thickness of 44 km. A minimum amplitude filter is used and degrees l = 10 and l = 50 are selected to show contrast.

Discussion: Figures 1 through 5 show examples of crustal thickness and gravity misfit maps generated from the program when degrees 10 and 50 are chosen for the downward continuation filtering.

Crustal Thickness: Figure 1 show that at low degree (l = 10), the most prominent features are large scale structures such as the Tharsis construct, Hellas Basin, and the thickness contrast between the north and south. The crust is mostly thicker in the Southern Highlands and slightly less thick in the Northern Lowlands with a contrast of about 40 km. When a higher degree is chosen (l = 50, Figure 2), the crust is thicker everywhere and while short-wavelength features become apparent, the same long-wavelength pattern of crustal thickness is still present.

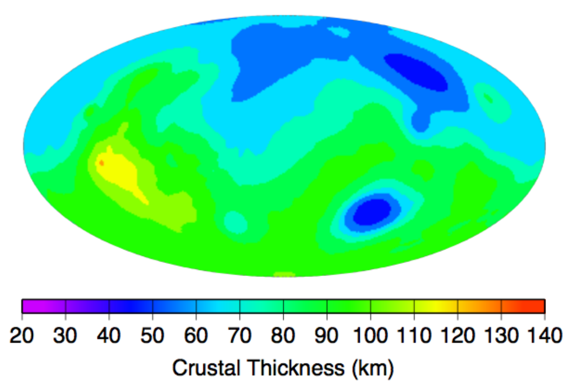

Figure 1. Crustal thickness map, degree 10.

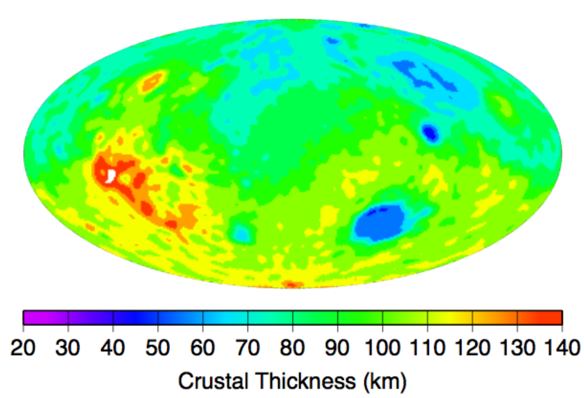

Figure 2. Crustal thickness map, degree 50.

At degree 50, an interesting feature also become more visible: an apparent connection between the thickest regions: the South Pole, the Tharsis swell, and Alba Patera, a shield volcano north of Tharsis. These form a path that is analogous to hotspot tracks on Earth. Zhong [7] and Sramek and Zhong [8] suggest that the Tharsis region may be the product of a plume that has migrated from the Martian South Pole to its current position near the topographic dichotomy. The region of thickened crust is consistent with this proposed plume path (Figure 3).

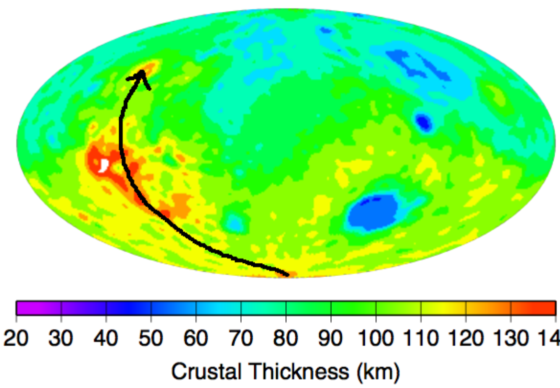

Figure 3. Crustal thickness map, degree 50, with possible plume migration track.

Gravity Misfit: At degree 10 (Figure 4), the largest gravity misfits are dominant around large structures such as Alba Patera, Tharsis, Hellas, and Isidis Basins and have a greater contrast range. At degree 50 (Figure 5), large misfits with corresponding structures fade off, giving way to more noticeable smaller structures and smaller misfit values (10's as opposed to 100's of mgals). What is striking about both figures are the void areas centered on the maps. This area could be the remnant of a large impact basin with ejecta materials forming the small topography surrounding it, similar to the Hellas Basin and its surrounding materials. This speculation requires further studies.

Future Work: Preliminary work is currently underway that will lead to subsequent experiments: incorporation of isostacy, a degree-1 structure, and a mantle plume in the program code. These effects should give insight into possible mechanisms and processes that may have produced the topographic dichotomy or specific structures such as the Tharsis construct. Possible past tectonics, global impact, and interior processes such as mantle plumes can also help us understand the interior thermal evolution of Mars.

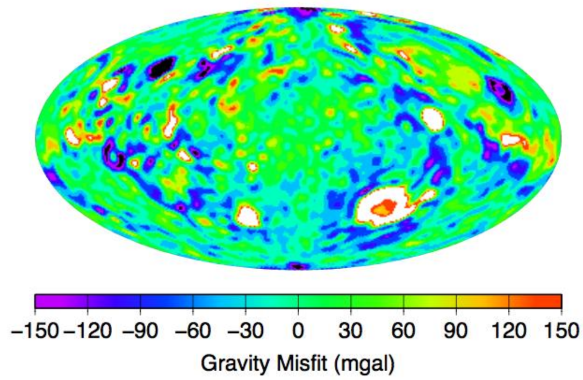

Figure 4. Gravity misfit map, degree 10.

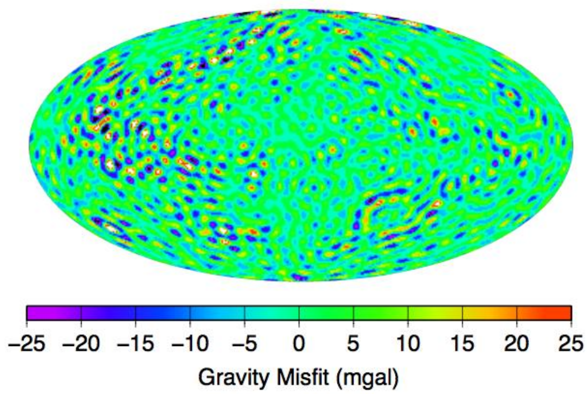

Figure 5. Gravity misfit map, degree 50.

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