MECHANICS OF UTOPIA BASIN ON MARS. M. L. Searls and R. J. Phillips. Dept. of Earth and Planetary Sciences & McDonnell Center for the Space Sciences, Washington University, Saint Louis, MO 63130 USA (searls@levee.wustl.edu)

Introduction: Utopia was first recognized as an impact basin based on the lack of evidence of buried topography and on the existence of a gravity high associated with the basin [1]. Utopia is located in the northern lowlands of Mars and is marked by a 1-3 km surface depression with a diameter of ~3200 km [2]. With a free-air gravity high of 350 mGal, Utopia basin shows the classical signs of mascon loading [3]. Here we use gravity and topography data to analyze the mechanical configuration of the basin, focusing particularly on the amount of basin fill material.

Conceptual Model: When analyzing the source of this gravity high we are faced with a fundamental non-uniqueness problem. For example, a positive free-air gravity anomaly could be due to uplift of the crust-mantle boundary, basin fill, a subsurface density variation, or any combination of the above. In this study we adopt a two-stage model in which we combine uplift of the Martian crust-mantle boundary and infilling of the original basin to describe the positive gravity anomaly.

The formation of the Utopia mascon is divided into two stages:

Stage 1. The Utopia impact occurred early in the evolution Mars [2] when the planet had a very high temperature gradient [4]. The resulting thin elastic lithosphere allowed for rapid compensation of the unfilled basin.

If the basin is in complete Airy isostasy, then Moho relief in a Cartesian framework can be expressed as a crustal perturbation $\delta c = \rho_c O / \Delta \rho$ (where ρ_c, O, and $\Delta \rho$ are the crustal density, original basin topography, and Moho density contrast, respectively). As the dominant wavelengths of Utopia are comparable to planetary radius, some of the basin will be supported by membrane stresses [5]. The degree of compensation, C_l, [5], provides a measure of the fraction of the load that is in mass balance, taking membrane support by an elastic spherical shell into account. Therefore, to achieve mechanical equilibrium for Utopia basin before infilling occurred, we need to incorporate the degree of compensation, C_l: $\delta c_{lmi} = C_l \rho_c O_{lmi} / \Delta \rho$, where C_l ($0 \leq C_l \leq 1$) approaches unity (and simple isostasy) for short wavelengths and thin/weak shells.

An analysis of Hellas, a somewhat younger basin, provides justification for the pre-fill isostatic assumption. The lack of a large scale free-air gravity anomaly over Hellas indicates that it is very close to isostatic equilibrium, while Utopia's gravity high indicates that it is not [3]. Further, admittance analysis [6] indicates that Hellas, early in its history, was supported by an effective elastic lithosphere of about 10 km, and this implies negligible contributions from bending stresses. Both basins formed early in Martian history; however, unlike Utopia basin, Hellas remained unfilled [7]. Since Hellas is isostatically compensated, it is reasonable to assume that Utopia was also compensated before infilling occurred.

Stage 2. The influx of sediments and volcanics that occurred mostly during the Hesperian period has greatly subdued the surface expression of the original Utopia impact basin [2]. The loading of the basin results in a downward deflection of the lithosphere. The basin fill and associated lithospheric flexure are not isostatically compensated (hence the large positive free-air gravity anomaly). We attribute this lack of compensation to the thickening of elastic lithosphere due to the secular cooling of the planet [4].

Physical Model: Based on the spherical harmonic thin shell model described in [8], we derive a system of six equations that allows us to explore the mechanics of mascon loading in a novel way: *i*) the pre-fill Moho is specified, and it is subject to further deformation due to basin filling, and *ii*) the geometry of basin fill is constrained. Given a handful of parameters, the geometry and loading of a mascon basin can easily be determined. Specifically, we solve for the amount of lithospheric flexure, the original basin shape before infilling, the amount of fill within the basin, the vertical load, and the horizontal load potential. In this analysis, topography [7] and gravity [9] (expanded to degree and order 50) are used as boundary conditions.

Results: Our preliminary calculations show that ~20 km of fill with an associated ~11 km of downward lithospheric deflection beneath Utopia is required to satisfy the observed topography and geoid. Similar to Hellas basin, the pre-fill Utopia basin is characterized by a depression ~10 km deep (Figure 1).

An exploration of the parameter space was made in an attempt to understand the relationships between the parameters and the output. We have examined how the assumed crustal thickness, elastic thickness, Young's modulus, and the density of the fill affect the mechanics of the basin.

The depth of the basin before infilling is not extremely sensitive to changes in the parameter space. However, the downward deflection of the lithosphere

and the depth of the fill material are affected by changes in elastic thickness, Young's modulus and the density of the fill. Figure 2 demonstrates the relationship between the elastic thickness and maximum amount of infilling of the basin.

In analyzing the results, the effect of Tharsis must also be taken into account [10]. The antipodal gravity high due to the Tharsis loading could lead to an over-estimation of amount of fill and flexure in Utopia.

Tectonics: Subsidence due to loading of the lithosphere within a mascon can result in the formation of tectonic features such as arcuate grabens and wrinkle ridges, e.g., [2], [11]. Utopia basin is no exception. Thomson and Head mapped a series of circumferential grabens and radial wrinkle ridges within the Utopia region [2].

Our suite of equations allows us to solve for the vertical load and the horizontal load potential. With this information, the stress field associated with the load can be computed [8]. A comparison of the calculated stress field with the observed tectonic features can provide constraints on the parameters values of this model. Calculating the stress field is an integral part of the modeling of Utopia and will be explored in the future.

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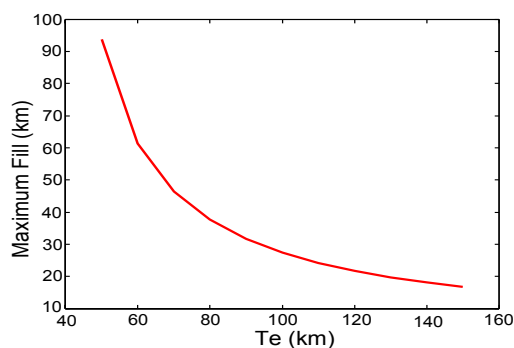

Figure 2. Dependence of the maximum amount of basin fill on the thickness of the elastic lithosphere, T_e. Models parameters as in Figure 1.
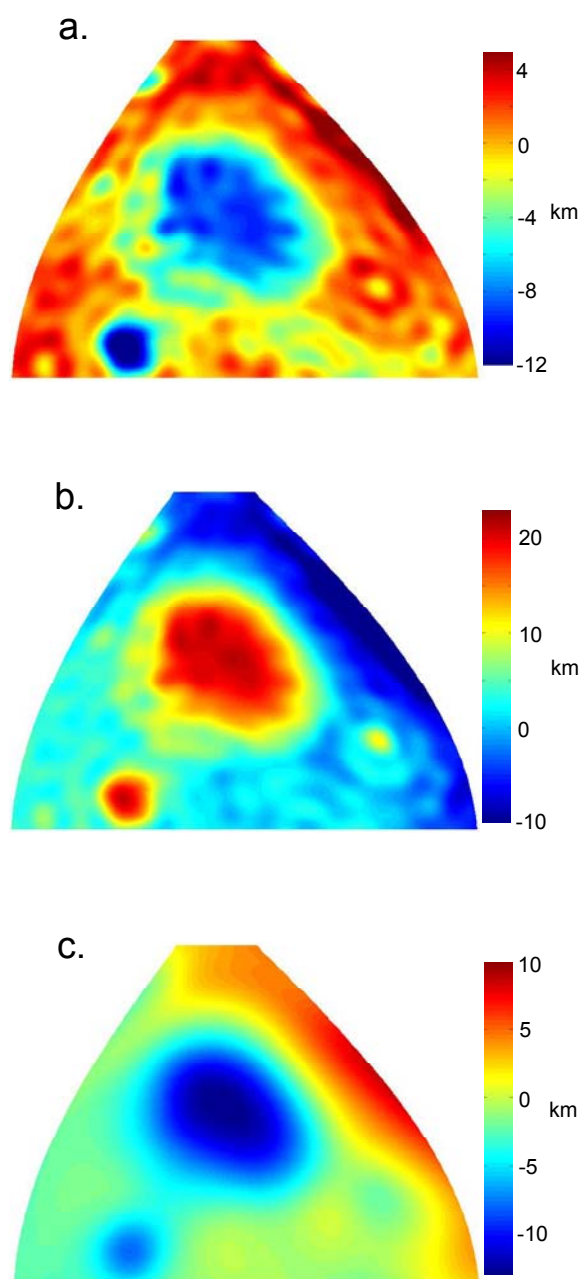

Figure 1. Modeled (a) pre-fill basin shape, (b) depth of fill, and (c) lithospheric flexure of Utopia Basin (sinusoidal projection from latitude 5° to 80° and longitude 60°E to 165°E). For these calculations, the following parameter values were used: an elastic thickness of 120 km, a crustal thickness of 60 km, a Young's modulus of 1.25×10^{11} Pa, a crustal density of 2900 kg/m^3, a mantle density of 3500 kg/m^3, a Poisson's ratio of 0.25, and a fill density of 2500 kg/m^3.