# A GRAVITY ANALYSIS OF THE SUBSURFACE STRUCTURE OF THE UTOPIA IMPACT BASIN:

W. B. Banerdt, Jet Propulsion Laboratory, California Institute of Technology (M.S. 183-501, 4800 Oak Grove Drive, Pasadena, CA 91109; bruce.banerdt@jpl.nasa.gov).

**Introduction:** The large, shallow, circular depression in Utopia Planitia has been identified as a huge impact basin, based on both geological evidence and detailed analysis of MOLA topography [1-5]. Its diameter (~3000 km) is equivalent to that of the Hellas basin, as is its inferred age (early Noachian). However, there the similarity ends. Their appearance, both surficially and geophysically, are virtually polar opposites. Whereas Hellas is extremely deep with rough terrain and large slopes, high-precision MOLA measurements were required to unambiguously define the smooth, shallow, almost imperceptible bowl of the Utopia basin. Conversely, Utopia displays one of the largest (non-Tharsis-related) positive geoid anomalies on Mars [Fig. 1(a)], in contrast to a more subdued negative anomaly over Hellas.

As these two features presumably formed roughly contemporaneously by similar mechanisms, it is reasonable to assume that they were originally quite similar, and that their differences are due largely to different paths of subsequent modification. The obvious source for these differences is in their elevations: Hellas is located in the southern highlands at a rim elevation of about 3km, whereas Utopia is in the low-lying northern plains, at an average elevation of –4 km. Thus Utopia has been in an especially gravitationally favorable position to be subjected to infilling, for example, by lava flows, sedimentation, or water. In fact, its floor was almost certainly the lowest point on the planet at one time, and it would have been the termination point for down-slope drainage from over two-thirds of Mars [6]. Thus the nature of the material filling this basin has strong connections to the sedimentary and/or volcanic processes acting on Mars in the Noachian and Early Hesperian periods. In particular, it may be able to shed some light on amount and persistence of water on early Mars in general and in the Utopia basin in particular [5,7-10].

**Approach:** In this study I will use the inferred early correspondence between Hellas and Utopia to investigate Utopia's subsurface structure. The approach is similar to a preliminary study presented by Zuber et al. [12]. I assume the present-day topography and geoid (which implies a particular configuration of the crust-mantle boundary) of Hellas is the same as that of Utopia shortly after its formation. (The geoid representation of the gravity field was chosen because of its sensitivity to the longer wavelengths associated with these features.) It is not necessary to explicitly specify the current distribution of anomalous density with depth beneath Hellas; it is assumed to be the same for both cases, and only the variations need be modeled. This starting configuration can then be modified using plausible physical mechnisms until the computed topography and geoid match those presently observed for Utopia. This provides insight into the present structure beneath Utopia and the processes that might have been responsible for causing it.

The loading and deflection are modeled using a thin shell code [13,14]. This allows me to model the actual gravity and topography rather than an idealized geometry, and to efficiently run a large number of cases to explore the parameter space of lithosphere and crust thicknesses, crust and fill densities.

**Results:** Fig. 1(b) shows an example in which the set of parameters chosen provide a good match between the computed and the observed anomaly, confirming the plausibility of the approach. In this typical case a deflection of 10 km was caused by the load, adding to the original topographic hole of six km. Thus a huge volume of material is involved, ~50m $km^3$, roughly half the volume of the Tharsis plateau. Note that this filling must have occurred relatively early, as many subtle craters have been identified in the basin interior which could not have been that deeply buried [15].

Fig. 2 shows the response of the model to variations in some of the parameters. It can be seen that a very thin crust (<35 km) and a relatively thick lithosphere (>75 km, unless the fill is all volcanic) are favored; there is little sensitivity to crustal density. The most likely fill densities are in the range corresponding to sedimentary rocks, although they are also consistent with a mix of denser material with massive ice deposits.

**References:** [1] McGill, *JGR* **94**, 2753, 1989. [2] Thomson and Head, *JGR* **106**, 23,209, 2001. [3] Schultz and Frey, *JGR* **95**, 14,175, 1990. [4] Smith et al., *Science* **284**, 1489, 1999. [5] Frey et al., LPSC XXX, #1500, 1999. [6] Banerdt and Vidal, LPSC 31, #1488, 2001. [7] Chapman, *Icarus* **109**, 393, 1994. [8] Clifford and Parker, *Icarus* **154**, 40, 2001. [9] McGill, *GRL* **28**, 411, 2001. [10] Buczkowski and McGill, *GRL* **29**, 1155, 2002. [11] Boyce et al., LPSC XXXIV, #1967, 2003. [12] Zuber et al., *Science* **287**, 1788, 2001. [13] Banerdt, *JGR* **91**, 403, 1986. [14] Banerdt and Golombek, LPSC XXX, #2038, 2000. [15] Frey et al., *GRL* **29**, 1384, 2002.

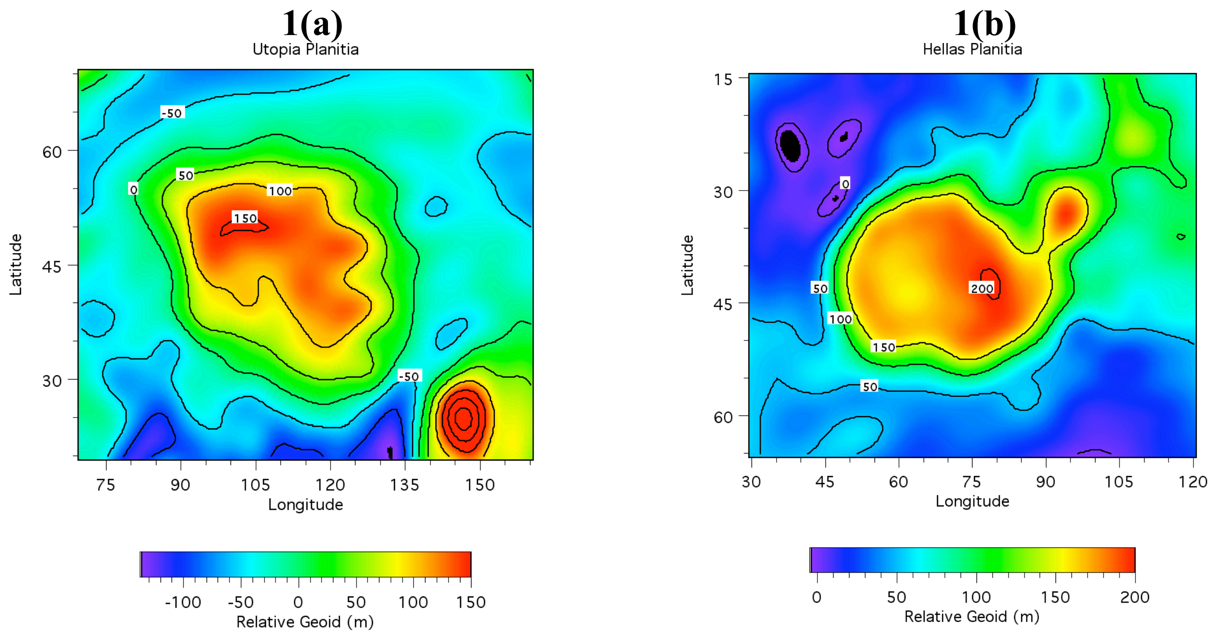


Figure 1. (a) Observed geoid over Utopia Planitia, complete for harmonic degrees 5-50. The anomaly is centered at about 45N, 110E, and its total amplitude is nearly 200 m. The positive feature to the lower right is Elysium Mons. (b) An example of the computed geoid anomaly for the Hellas basin with the currently observed topography filled with material (while allowing for flexural response) until level. The starting geoid anomaly is about –100 m. The assumed parameters in this case were: lithosphere thickness 100 km, crustal thickness 50 km, crust and mantle density 2800 and 3400 kg/m$^3$, respectively, and fill density 2350 kg/m$^3$. Note the similarity in size and amplitude to (a).

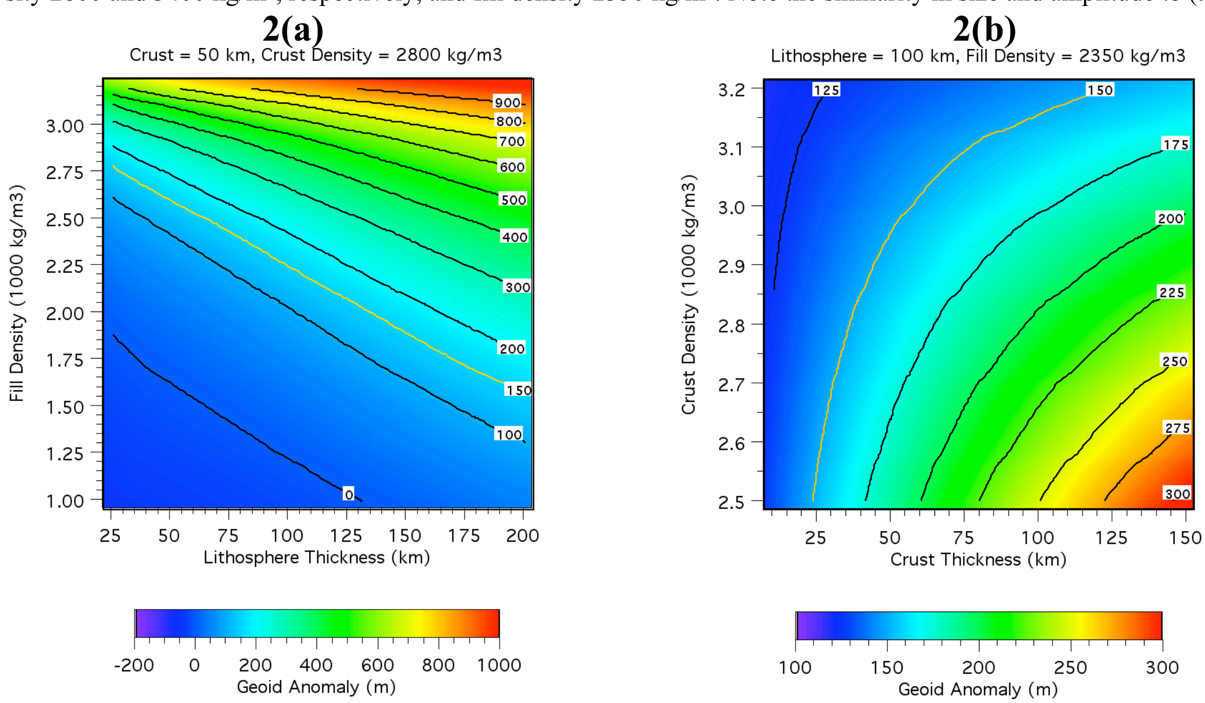


Figure 2. (a) Variation of the amplitude of the computed geoid anomaly with lithosphere thickness and fill density. Crustal thickness and density are held constant. The colored 150 m contour indicates the region of the parameter space corresponding to the observed Utopia anomaly. Fill density ranges from that of ice to shergottite and the lithosphere thickness range incorporates most estimates for Mars. (b) Geoid anomaly variation with crustal thickness and density, holding lithosphere thickness and fill density constant. Note the more restricted range of reasonable densities and thicknesses, and the smaller variation of anomaly amplitude compared to (a).