IMPLICATIONS OF THE UTOPIA GRAVITY ANOMALY FOR THE RESURFACING OF THE NORTHERN PLAINS OF MARS. 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: Whereas the surface units of the northern plain of Mars generally exhibit ages ranging from late Hesperian to Amazonian [1], interpretation of precise topographic measurements indicate that the age of the underlying "basement" is early Noachian, or almost as old as the southern highlands [2]. This suggests that widespread but relatively superficial resurfacing has occurred throughout the northern plains since the end of early heavy bombardment. In this abstract I examine some of the possible implications of the subsurface structure inferred for the Utopia basin from gravity data [3, 4] on the nature of this resurfacing.

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 [5-9]. Its diameter (~3000 km) is equivalent to that of the Hellas basin, as is its inferred age (early Noachian). However, whereas Hellas is extremely deep with rough terrain and large slopes, the Utopia basin is a smooth, shallow, almost imperceptible bowl. Conversely, Utopia displays one of the largest (non-Tharsis-related) positive geoid anomalies on Mars, in contrast to a much 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. An obvious source for these differences is in their elevations: Hellas is located in the southern highlands at a rim elevation of about +3 km, 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, it is likely that its floor was the lowest point on the planet at one time. Based on current large-scale topography, which is unlikely to have changed significantly since the late Noachian [10, 11], the Utopia basin would have been the termination point for down-slope drainage from over two-thirds of Mars [8,12].

Thus the nature of the material filling this basin has strong connections to the erosional, sedimentary and/or volcanic processes acting on Mars in the Noachian and Early Hesperian periods. In particular, insofar as the processes which resulted in the filling of Utopia may also have been responsible for burying the rest of the northern plains, it may be able to shed some light on this key aspect of the early history of Mars.

Approach: Recently I used the inferred early correspondence between Hellas and Utopia to investigate Utopia's subsurface structure [3]. I assumed that the present-day topography and geoid (which implies a particular configuration of the crust-mantle boundary) of Hellas is similar to 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.) This obviates the need to explicitly specify the current distribution of anomalous density with depth beneath Hellas, as it is assumed to be the same for both cases. A nominal subsurface structure (characterized by lithosphere and crust thickness, crust and upper mantle density) was specified for a variety of cases and these configurations were then mathematically "filled" with material of a given density until the computed topography and geoid matched those presently observed for Utopia. The loading and deflection were modeled using a thin shell code [10, 13], allowing the modeling of the actual gravity and topography rather than an idealized geometry.

Results: Fig. 1 shows the match between the geoid anomaly computed for a filled Hellas and the observed geoid anomaly for Utopia, confirming the plausibility of the approach. Fig. 2 shows the response of the model to variations in some of the parameters. We find that the most likely fill densities are in the range of 2000-2500 kg/m^3. Comparing this to typical densities of basalts (~2800 kg/m^3) and sedimentary rocks (~2400 kg/m^3), we conclude that the fill is probably sedimentary in nature, with perhaps up to 30% water. However these results are also consistent with a mix of volcanic material intermixed with massive ice deposits.

Discussion: In a typical case the deflection caused by the load is about 10 km, adding to the original topographic hole of 8 km (note that this load column is similar in magnitude to that calculated for the Tharsis plateau [10]). Thus a huge volume of material is involved, ~50 million km^3, roughly half the volume of the surface expression 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 [2]. If all this material were derived from the southern highlands, it would have required an average removal of about 3/4 kilometer from the entire southern hemisphere. Coincidentally, it would have similarly taken about 40 million km^3 to bury the remaining northern plains to a depth of about one kilometer.

Conclusions: The gravity anomaly of Utopia can be explained by filling a Hellas-size basin with sediments and water. This implies a massive erosional source of sediments, of order 50 million km^3. If a similar mechanism were invoked for the resurfacing of the ancient surface of the northern plains, it would require a comparable volume of material. If this material covering the northern plains and filling Utopia includes a few tens of percent water, this might constitute the largest reservoir on Mars today.

References: [1] Tanaka et al., *Mars*, 345, 1992. [2] Frey et al., *GRL* **29**, 1384, 2002. [3] Banerdt, LPSC XXXV, #2043, 2004. [4] Searls and Phillips, LPSC XXXV, #1822, 2004. [5] McGill, *JGR* **94**, 2753, 1989. [6] Thomson and Head, *JGR* **106**, 23,209, 2001. [7] Schultz and Frey, *JGR* **95**, 14,175, 1990. [8] Smith et al., *Science* **284**, 1489, 1999. [9] Frey et al., LPSC XXX, #1500, 1999. [10] Banerdt and Golombek, LPSC XXX, #2038, 2000. [11] Phillips et al., *Science* **291**, 2587, 2001. [12] Banerdt and Vidal, LPSC 31, #1488, 2001. [13] Banerdt, *JGR* **91**, 403, 1986.

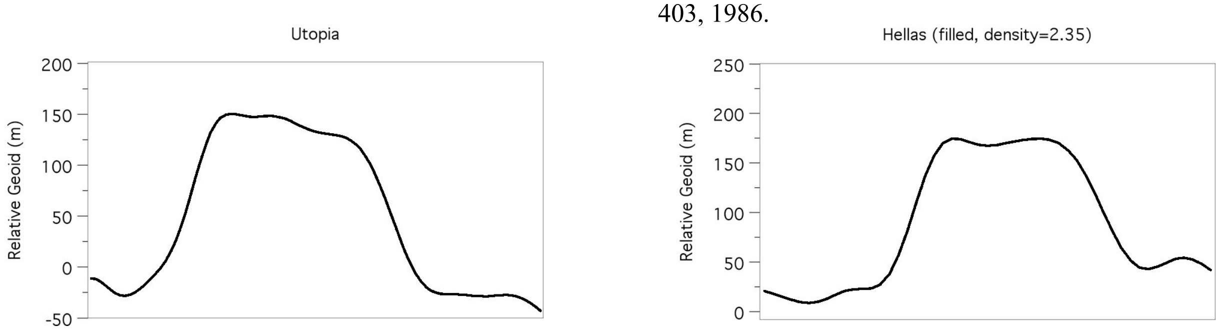

Figure 1. Comparison of observed geoid over Utopia Planitia (left) and calculated geoid anomaly for the Hellas basin (right) with the currently observed topography filled with material (allowing for flexural response) until level. These representations are complete for harmonic degrees 5-50. The assumed 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 both form and amplitude.

2(a) **2(b)**

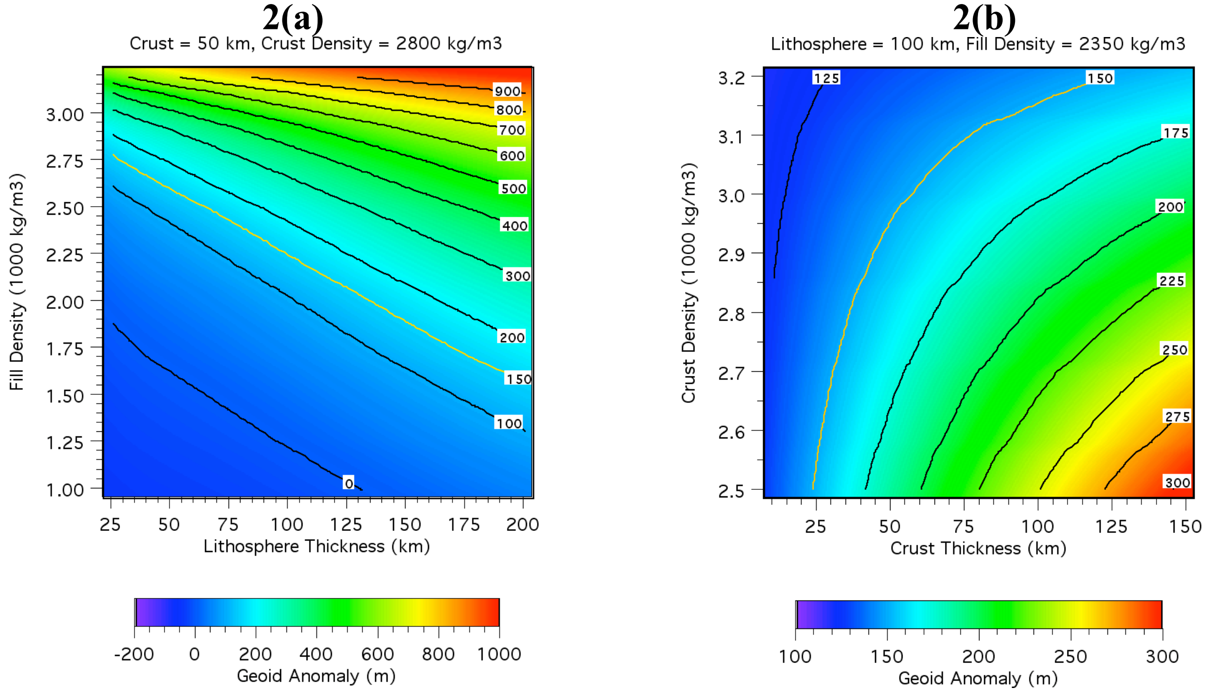

Figure 2. (a) Variation of the amplitude of the computed geoid anomaly with lithosphere thickness and fill density. Crustal thickness and density are held constant. The colored 150 m contour indicates the region of the parameter space corresponding to the observed Utopia anomaly. (b) Geoid anomaly variation with crustal thickness and density, holding lithosphere thickness and fill density constant.