The Southwest Tilt of Isidis Planitia, Mars.

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Introduction: One of the most prominent features of Mars is the global south to north slope of ~0.036° [1] discovered by analysis of data from the Mars Orbiter Laser Altimeter (MOLA) aboard Mars Global Surveyor. In contrast, Isidis Planitia, the floor of Isidis basin, slopes southwest at an angle of ~0.02° [2]. It has been suggested [3] that deflection of the lithosphere under a load located in Utopia Planitia (NE and adjacent to Isidis basin) could be the cause of this anomalous tilt. In support of this theory, more quantitative models [4,5,6] suggest that in the Terra Cimmeria region, southeast of Isidis basin, a flexural bulge exists in the highlands adjacent to the dichotomy boundary. This bulge is explained by the downward flexure of the lowlands in response to a line load on the lowland side of the dichotomy boundary that has broken the lithosphere. These models compare the current topography of the northern Terra Cimmeria dichotomy boundary area with the universal flexure curve for a line load with a broken plate [7]. However, the source of the inferred line load along the dichotomy boundary is not clear.

Geology: Isidis basin, centered at 87.3° E, 12.5° N, is an ancient multi-ringed impact basin [8,9] straddling the dichotomy boundary. *Frey et al.*, [9] identified two rings: an inner 1100km diameter ring and an outer 1500km diameter ring. Isidis Planitia is entirely within the inner ring. The western section of the rim of Isidis basin appears to be covered either by lava flows from Syrtis Major [10], or cryogenic debris flows [3]. The northeast section of the rim is lower then the rest of the rim, and is continuous with the floor of the basin in profile view (Figure1).

Utopia basin is also an ancient impact basin, now buried beneath Utopia Planitia, which was originally identified by *McGill* [11] based on geological arguments. Its existence has been verified from MOLA altimetry [1]. The apparent center of Utopia basin is at 40° N latitude and 110° E longitude, ~1800km northeast of the rim of Isidis basin. Isidis Planitia is covered with the Isidis Planitia unit, the southwest section of Utopia Planitia is covered by the Vastitas Borealis interior unit and the saddle between Isidis Planitia and Utopia Planitia is covered by the Utopia Planitia 2 unit [12].

Methodology and results: In order for the floor of Isidis basin to be tilted as the result of a flexural bulge, there must be a substantial load adjacent to it in order to displace the lithosphere. Utopia basin adjacent to Isidis basin has a substantial positive gravity anomaly [13,14]. Both *Searls and Philips* [15], and *Banerdt* [16] argue that this anomaly could be due to as much as 20km of fill located in Utopia basin. The main body of the gravity anomaly located in Utopia basin is ~ 1800km in diameter and is located to the south of the center of the basin. The edge of the anomaly is located approximately 800-900km from the highest point between Isidis basin and Utopia basin (Figure 2).

The general equation for the flexure of an elastic plate with no end load is [7]:

$$D[(d^4w(x))/(dx^4)]=q(x)$$

$w(x)$=vertical displacement in m,
$q(x)$=load in m,
D=flexural rigidity.

We used the derivation from *Leverington and Ghent* [17] for a spatially extended asymmetrical load, which was divided into N narrow rectangular loads of varying height, using the following boundary conditions:

$$w(x \longrightarrow \pm \infty) = 0, \quad dw/dx\ (x = x_{Ln}) = 0,$$

and $\rho_w \int_{-\infty}^{\infty} h(x)\,dx = (\rho_m-\rho_w) \int_{-\infty}^{\infty} w(x)dx$,

resulting in:

$$w_n(x)=(\rho_w h_n)/[2(\rho_m-\rho_w)]\lambda \int_a^b e^{-\lambda x}(\cos\lambda x+\sin\lambda x)dx,$$

where $wn(x)$=vertical displacement of the nth rectangle in m, h_n=the load height for the nth rectangle in m, λ=flexural wave length in m ($\lambda=(((\rho m-\rho w)g)/4D)^{1/4}$), ρ_w, ρ_m=density of water and mantle respectively in kg/m^3, a and b=limits of integration from the left and right edges of h_n in m, and L_n=length of nth rectangle in m. We substituted the section of the equation in front of the integral, which calculates the deflection, with the deflection calculated by Banerdt [16] of 10km created by a load height of 20km [15,16]. The limits of integration are the distances from the left and right edges of the gravity anomaly to the left and right edges of rectangles extending into Isidis basin to show the magnitude and extent of the peripheral bulge caused by the load. (In *Leverington and Ghent* [17] the λ variable was omitted from the numerator and has been corrected [18])

Our results show that 10km of deflection can create a 667m high peripheral bulge 800km from the edge of the gravity anomaly.

Discussion: Isidis basin could be tilted to the southwest by a peripheral bulge caused by a sediment load in Utopia basin, but the 667m high bulge would create a southwest tilt of 0.032° across the floor of

Isidis basin, somewhat greater then the current tilt of 0.02°.

If Isidis basin were originally tilted to the north, like the rest of the planet, we can subtract the northeast component of the global tilt from the southwest tilt created by the peripheral bulge. If the northerly global tilt was ~0.025°, as it is in the adjacent lowland, then the northeasterly component of this northerly tilt is ~0.018°. When this is subtracted from the 0.032° tilt created by the peripheral bulge, the final southwest tilt is 0.014°, somewhat less than the current 0.02° tilt of the floor of Isidis basin.

Conclusions: We examined several possible models to explain the contrast between the global northern tilt of Mars and the southwest tilt of Isidis Planitia. We found that a peripheral bulge created by a sedimentary or volcanic load in Utopia basin can account for this anomalous tilt. Using a lithospheric flexure model the magnitude and location of such a bulge can be fit to the current topography of Isidis basin.

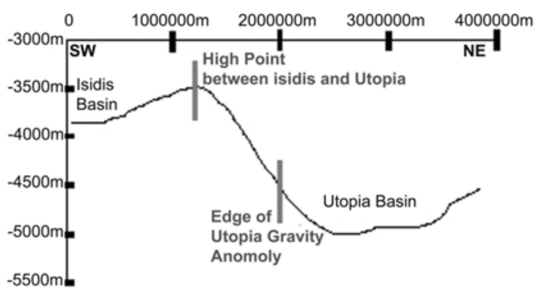

Figure 1 Topographic profile from the southwest edge of Isidis Planitia northeast into Utopia basin showing a continuous slope from the southwest edge of Isidis basin to the high point between the two basins. The profile was constructed from 128px/deg MOLA gridded topography. The geographic location of the profile line is shown in figure 2 by the black line labeled P.

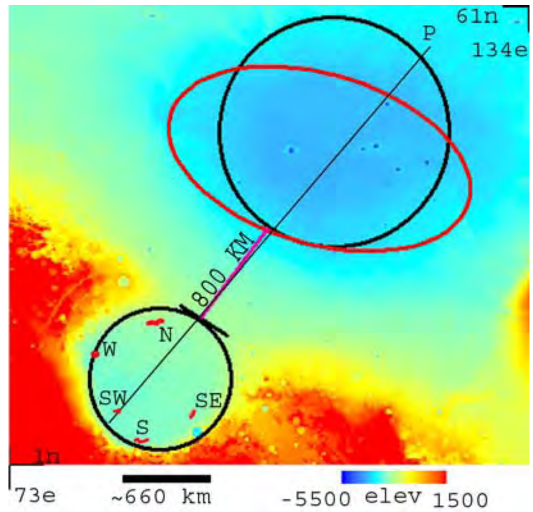

Figure 2 Isidis and Utopia basins; black circles show the central areas of the basins defined from MOLA topography. Red ellipse shows the approximate boundary of the main gravity anomalies within Utopia Planitia from *Smith et al.* [1999]. The black line shows the high point between the two basins. The lavender line shows a distance of ~ 800 km between the edge of Utopia basin gravity anomaly and high point between the two basins. The red lines within Isidis basin and labeled with relative positions are the 5 sections of the Deuteronilus shoreline used for this study. The line labeled P is the profile line from figure 1.

References: [1] Smith, *et al.*, *Science*, **284**, 1495, 1999. [2] Hiesinger and Head, LPS XXXV, #1167, 2004a. [3] Tanaka, et al., *Geology*, **29**, 427, 2001. [4] Watters, *Geology*, **31**(3), 10.1130/0091-7613(2003)031, 2003. [5] Watters, et al., *Workshop on Martian Hemispheres*, #4032, 2004. [6] McGovern and Watters, LPSC XXXV, #2148, 2004. [7] Turcotte and Schubert, John Wiley and Sons, New York, NY, 2001. [8] Wood and Head, LPSC VII, 1976. [9] Frey, et al., LPSC XXX, #1500, 1999. [10] Hiesinger and Head *JGR* **109**, E01004, 10.1029/2003JE002143, 2004b. [11] McGill, *JGR*, **94**, 2759, 1989. [12] Tanaka, et al., U. S.G.S. Sci. Inv. Map SIM-2888, 2005. [13] Sjogren, *Science*, **203**, 1006, 1979. [14] Zuber, *et a.,. Science*, **287**, 1788, 2000. [15] Searls and Phillips, LPSC XXXV, #1822, 2004. [16] Banerdt, , LPSC XXXV, #2043, 2004. [17] Leverington and Ghent, *JGR* **109**, E01005,10.1029/2003JE002141, 2004. [18] Ghent personal communication.