IMPLICATIONS OF FLEXURAL FLANKS AT THE VALLES MARINERIS, MARS.

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Introduction: The presence or absence of flexural flanks at the Valles Marineris (VM), Mars, have strong implications for the properties of the lithosphere, information which is critical for models of compensation state and formation of the troughs [1]. Two hypotheses are favored for the formation of the VM, tectonic extension or subsurface withdrawal potentially related to dike emplacement [3-7]; in either case, the formation of the large troughs at the VM requires a flexural response [8]. After discussing preliminary models of flexure for VM from released Mars Global Surveyor (MGS) Mars Orbiting Laser Altimeter (MOLA) topography, this abstract considers the implications of flexure for gravity modeling and the lithosphere at VM. With future MGS topography and gravity data, and constraints on T_e from this study, significantly better gravity modeling can be done to understand the state of the lithosphere at VM.

Background: Observations based on Viking topography suggest that there is little, if any flank uplift at the edges of the chasma [9,1]; currently released MOLA data further supports this observation. Three possibilities exist to explain the current observation: 1) the lithospheric elastic thickness is large ($T_e > 200$ km) [9], 2) erosion has removed the flexural flanks for most of the troughs [1], or 3) dynamic processes have prevented the formation of, or removed, the flanks. Previous data and a preliminary look at MOLA tracks across the VM are most consistent with possibility 1, though MOLA data may reveal flanks at some locations, favoring 2.

Constraints on the state of flexural compensation at the VM have been derived from two methods, the relationship between gravity and topography (admittance), and deflection of the topographic profile by surface loading [1,9].

Gravity. Gravity modeling results indicate that T_e and crustal thickness H are inversely related; T_e is less than 30 km, H is 30-80 km, and heat flux $q > 20$ mW m^{-2} [1]. These estimates account for the estimated error at VM in topography of +/- 1 km, and in the gravity of +/- 70 mgal; significantly tighter constraints will result when MGS topography (error less than a few meters) and gravity (error less than a few tens of mgal), become available.

Flexure. Flexural models of the chasmata have only been compared to the regional topography high at VM due to the lack of clear flanks near the trough rims [9]. The topography of the entire topography high is generally concave down, consistent with an unbroken elastic plate, and results in $T_e > 200$ km for the eastern troughs; the western troughs are not consistent with flexural deformation [9]. However, the crustal high may in fact be due to crustal thickening, not flexure [1]. Collected but unreleased MOLA profiles of the VM may reveal local flexure at trough rims resulting from low values of T_e, and consistent with trough morphology as a whole, as well as previous gravity results. Nonetheless, global evidence for flexure of the lithosphere on Mars is limited, and may be a result of regionally thick elastic lithosphere.

Data: Topographic profiles are extracted from the released MOLA data, and have errors on the order of meters. As new profiles become available, they will be incorporated into this analysis. Admittance calculations will use gridded topography generated from individual MOLA tracks, and be compared to MGS gravity solutions. Preliminary results based on available tracks are discussed here.

Method: *Flexure.* Flexural topography for the VM

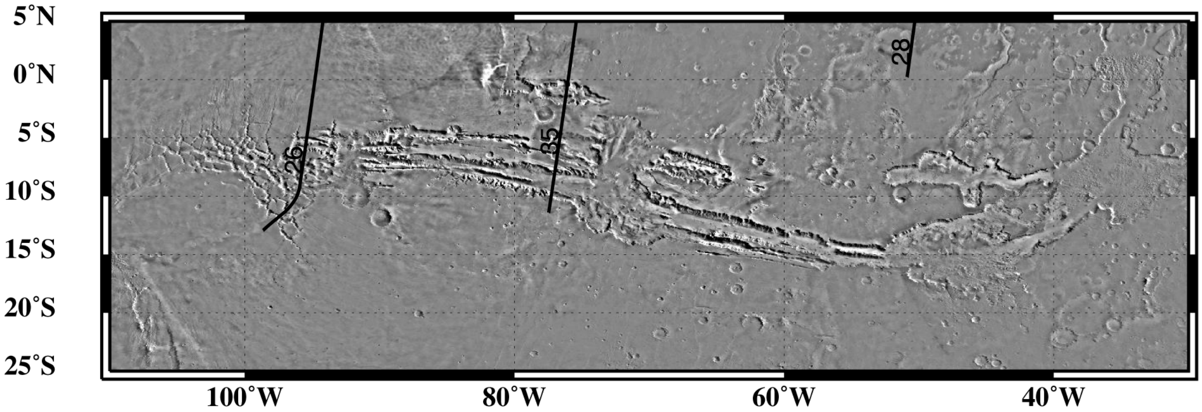

Figure 1: Currently released ground hit MOLA tracks crossing the Valles Marineris. Topography shown in Fig. 2. Over 500 orbits have now crossed the VM region.

falls into two broad categories, broken plate (concave up topography) and unbroken plate (concave down topography). Flexural topography w due to a broken plate is [8]:

$$w = \frac{V\alpha^3}{4D} e^{-x/\alpha} \cos\left(\frac{x}{\alpha}\right) \qquad (1)$$

where V is the applied load, D is the flexural rigidity $ET_e^3 / 12\left(1-\nu^2\right)$, E is the Young's modulus, ν is the Poisson's ratio, α is the flexural parameter $\left(4D/\rho_c g\right)^{1/4}$, ρ_c is the density of the crust, g is gravity, and x is distance from the trough axis.

For an unbroken plate topography w is [8]:

$$w = \frac{V\alpha^3}{8D} e^{-x/\alpha} \left[\cos\left(\frac{x}{\alpha}\right) + \sin\left(\frac{x}{\alpha}\right)\right] \qquad (2)$$

The topography predicted by these equations as a function of T_e can then be fit to MOLA topography.

Admittance. As the MGS MOLA topography and MGS gravity solutions become available, admittance and, given sufficient resolution, coherence solutions for crustal thickness and T_e can be determined using the standard method of *Forsyth* [10]. These results can then be further constrained by the results of this flexural study.

Preliminary results: Concave up topography, if it exists, may occur on a small scale on the trough rims, requiring a broken plate model to have a small T_e. If T_e is small enough, sufficient rim material may have been removed by erosion to effectively hide flank uplift. Erosion of 10 km of rim requires $T_e < .5$ km, while 50 km of erosion requires a slightly more plausible $T_e < 5$ km, consistent with gravitational models [1]. Alternatively, the region may represent an unbroken plate with concave down topography. The only obvious concave down topography consists of the entire crustal high. As noted previously, such a broad high requires $T_e > 200$ km [9], in disagreement with previous gravity results [1]; it seems unlikely that the new MGS gravity will support a 10x increase in T_e.

Another approach is to estimate the amount of displacement from the missing mass of the VM. An estimate of the upwards force resulting from the missing linear (2D) mass for MOLA track ap00035n, assuming a crust of basalt and a line load, is ~10^{13} N, similar to the line load force applied by the Hawaiian islands on the Pacific plate [8]. The peak uplift versus T_e (Fig. 3) suggests that a large elastic thickness is more consistent with observed uplift, as Te < 5 km results in a large rim uplift.

Conclusion: We predict that MOLA profiles of the VM will validate one of two hypotheses for T_e: 1) that small flank uplifts are observed at some rim locations, indicative of small T_e, large uplift, and erosion, or 2) that no flanks will be observed, requiring large T_e and significant revision of current gravity models. In either case, new MGS gravity and topography data will improve our understanding of lithospheric structure at the Valles Marineris.

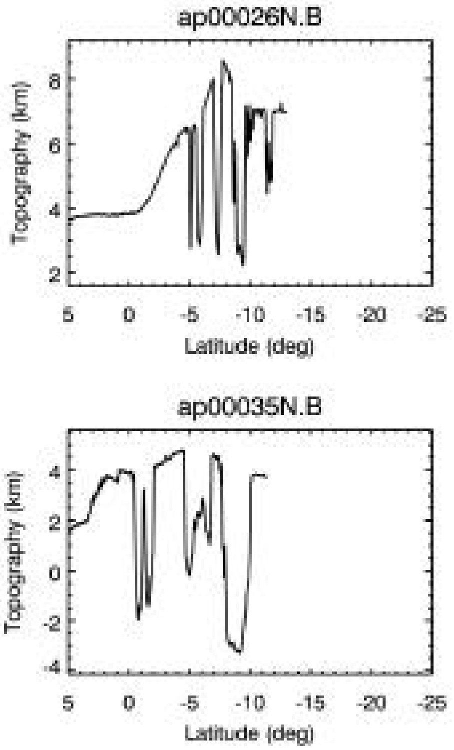

Figure 2: Topographic profiles from MOLA tracks; the top profile crosses Noctis Labyrinthus, the lower profile Ius/Melas, Candor, and Hebes chasma. Note lack of flexural flanks at trough rims.

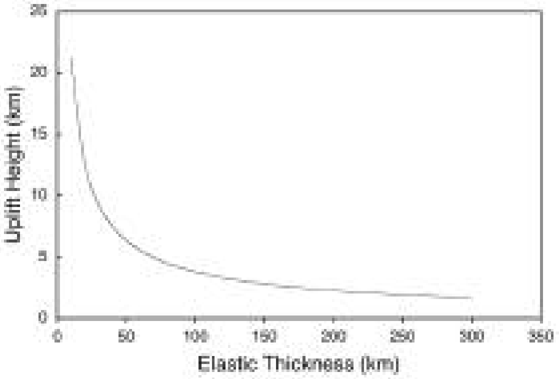

Figure 3: Peak uplift versus T_e, assuming missing load of 10^{13} N for VM troughs.

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