STATE OF STRESS IN THE MARTIAN LITHOSPHERE. D. L. Turcotte, *Department of Geology, University of California, Davis, CA 95616, USA, (turcotte@geology.ucdavis.edu)*, R. Shcherbakov, *Department of Physics, University of California, Davis, CA 95616, USA, (roshch@physics.ucdavis.edu)*.

Introduction: The state of stress in and rheology of planetary lithospheres remain poorly understood. The existence of old planetary topography requires long term elastic support. In this paper we present a quantitative analysis of the state of stress associated with the preservation of the Hellas impact basin on Mars. Assuming that the basin is in isostatic equilibrium, the geoid (areoid) anomaly over the basin can be used to infer the state of stress in the elastic lithosphere.

Stress Associated with Compensated Features: The major compensated topographic feature on Mars is the Hellas impact basin. Turcotte et al. [1] studied this feature in some detail. They applied the local correlation between the geoid (areoid) anomaly and topography valid for Airy compensation and found a very good correlation with a crustal thickness $h_c = 90 \pm 10$ km. This approach assumes that the depth of compensation is small compared to the planetary radius. In this paper we show that this approximation leads to less than a 5% error when applied to the Hellas basin on Mars.

The Hellas basin has some 10 km of topographic relief. The maintenance of this relief requires that the lithosphere can sustain relatively high elastic stresses for billions of years. If the Martian lithosphere behaved viscously, the flow would have eliminated the basin.

In the same approximation that the depth of compensation is small compared with the planetary radius as discussed above, the horizontal force (per unit length) F required to maintain the topography is related to the geoid (areoid) anomaly ΔN by [2, eq. 5-170]

$$F = \frac{g}{2\,\pi\,G}\,\Delta N\,, \tag{1}$$

where g is the surface gravity and G is the gravitational constant. For the Hellas basin the maximum geoid (areoid) anomaly is $\Delta N = 200$ m [1]. Taking this value with $g = 3.69$ m s^{-2} and $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}, we find from (1) that $F = 6.50 \times 10^{12}$ N m^{-1}. If this force is carried by a 100 km thick lithosphere the corresponding stress is 65 MPa.

It is of interest to compare this value with values for the earth. Typical geoid anomalies associated with midocean ridges and passive continental margins are in the range $\Delta N = 5 - 10$ m [2, pp. 220–222]. Substituting these values and $g = 9.78\,\mathrm{m\,s^{-2}}$ into (1) gives $F = 1.14 - 2.28 \times 10^{12}\,\mathrm{N\,m^{-1}}$. Both of these features are isostatically compensated so that it is appropriate to apply (1). Typical lithospheric forces (stresses) associated with isostatic features are a factor of 3-6 less on the Earth than is required to support the Hellas basin on Mars.

Willemann and Turcotte [3] explained the gravity-topography correlations over the Tharsis rise using a combination of bending and membrane stresses in a spherical, global elastic lithospheric shell. Using the crustal density $\rho_c = 2960$ kg m^{-3} and crystal thickness $h_c = 90$ km as given by Turcotte et al. [1], Willemann and Turcotte [3] require the thickness of the elastic lithosphere to be $h_e = 100$ km, very close to the value $h_e = 90 \pm 10$ km obtained by Turcotte et al. [1] using spectral techniques. The corresponding maximum deviatoric stress in the elastic shell obtained by Willemann and Turcotte [3] was 600 MPa. This is an order of magnitude larger than the elastic stress required to maintain the Hellas basin as given above.

Stress Relaxation in Planetary Elastic Lithosphere: The ability of planetary lithospheres to maintain elastic behavior for billions of years precludes significant relaxation of the elastic stress at the required stress levels. Nevertheless, it is common practice to model lithospheric deformation using viscous models. The paradox can be understood in terms of damage mechanics [4-7].

Damage mechanics is an empirical approach to the irreversible deformation of solids. Turcotte and Glascoe [8] have shown that a damage mechanics approach to brittle deformation can explain the highly nonlinear viscous behavior of the lithosphere. A yield stress is introduced below which damage cannot occur. The deformation of the lithosphere is associated with repetitive displacements on a hierarchy of faults. The yield stress is, in turn, associated with the dynamic coefficient of friction on the faults. On Earth evidence for a yield stress in the lithosphere comes from induced seismicity. It appears that the earth lithosphere is everywhere on the brink of failure. The loading due to reservoirs behind new dams invariably increases extensive seismicity. This can be attributed to presence of a well defined yield stress in the lithosphere.

In planetary lithosphere, stress relaxes to the yield stress but stress relaxation is not complete. Aftershock sequences are examples of this relaxation process to a yield stress. The ability of Mars to exhibit elastic behavior for billions of years is attributed to a well defined yield stress in the lithosphere. The results given for the Hellas basin in this paper provides a quantification of the yield stress in the Martian lithosphere.

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