Stress Models, Global Contraction, and Surface Faults on Mars. L. L. Dimitrova[1], W. E. Holt[1], A. J. Haines[2] and R. A. Schultz[3], [1]Department of Geosciences, Stony Brook University, Stony Brook, NY 11794 (Lada.Dimitrova@stonybrook.edu, William.Holt@stonybrook.edu), [2]Department of Earth Sciences, University of Cambridge, UK (ajh50@cam.ac.uk), [2]Department Department of Geological Sciences and Engineering, University of Nevada, Reno, NV (schultz@mines.unr.edu).

Introduction: A planet's evolution is recorded, in part, in the surficial expression of the tectonic features observed today. Theoretical models of deformation mechanisms can be compared to the surficial expression of the tectonic features observed today and interpreted in terms of major tectonic events, thus allowing us insights into the internal structure and processes on Mars. Previous workers hypothesized a period of global contraction during the late Noachian into the Hesperian [1, 2]. In this study we evaluate the contribution of global contraction as recorded by a global fault data set in the presence of a lithospheric stress field associated with horizontal GPE gradients and estimate the associated radius decrease.

Background: Recently, two different models of the lithospheric stress have been employed to explain the majority of the faulting in and around Tharsis. [3] calculated the deflection of the lithosphere due to the Tharsis load alone while satisfying the long wavelength signal of present day topography and gravity. The resulting extensional component of the surface stresses and strains is consistent with normal faulting on pre-existing faults radial to Tharsis and away from the load; however, the faulting extending from northern Claritas Fossae north to Tantalus and Alba Fossae is not well explained by the flexure model, which predicts zero extension there, where the density of normal faults is high [4].

An alternative model ([5]), based on stresses associated with gravitational potential energy (GPE) differences, has been shown to fit (~70%) of the normal faults in Tharsis. This fit implies that possibly the normal faults in and around Tharsis formed early in the Martian history when elastic thicknesses as well as membrane and flexural stresses were small, and viscous rather than elastic processes dominated.

[6] also showed that very small pertubations in crustal or mantle densities (2-4%) and vertical displacements (<200m) sicne the time of faulting are sufficient to explain the global dataset of both normal and reverse faulting from [7].

Further studies of loading models have invoked additional stresses associated with global planetary contraction to fit reverse faults concentric to Tharsis [1, 2], strike-slip faults southwest of Tharsis [8], and reverse faults concentric to Utopia [9].

Methods & Results: As in [5], we perform a Kostrov moment tensor summation to estimate the total strain tensor associated with the fault segments of [7]. We assume a uniform amount of slip for each fault as a first approximation. We use an objective inner product measure [5] to estimate the misfit of the GPE associated model of stress to the calculated strain (Fig. 1).

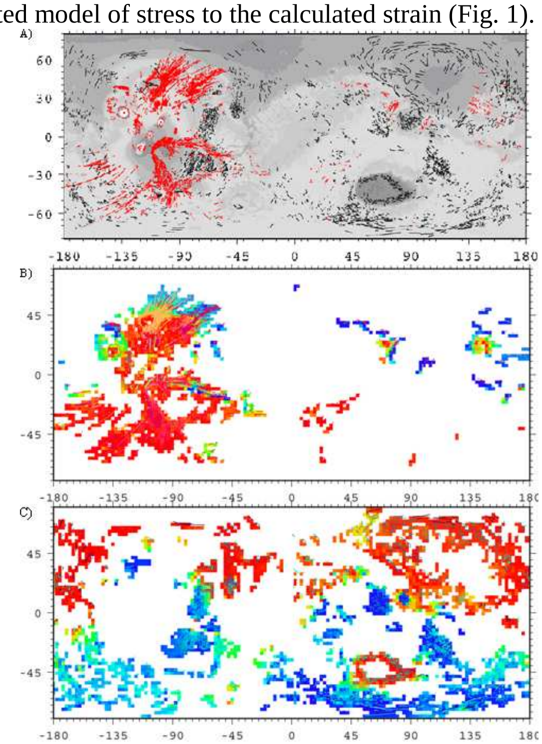

Figure 1. A) Normal (in red) and reverse (in black) faults from [7]. The misfit between the strain associated with B) the normal faults and C) the reverse faults and the GPE stress solution of [5]. Red means a very good fit, while green and blue mean a poor fit.

The GPE model fits normal faults in high elevations and reverse faults in low elevations but fails to fit the few normal faults in the northern hemisphere and the many reverse faults in the southern hemisphere (with the exception of those associated with Hellas Plantia).

The global contraction is represented as uniform horizontal compressive stresses. We solve for the magnitude of this compressional stress such that the resultant stress field, when added to the GPE associated stress field, minimizes the surface integral of the misfit to the reverse fault strain or the combined normal and reverse fault strain.

For each of the two cases, we show in Fig. 2 the resultant vertically integrated global stress field and the misfit overlaid on the faults. Stresses associated with global contraction can fit most of the reverse faults alone but not both normal and reverse faults. In fact, global contraction stresses degrade the fit to the normal faults in the southern periphery of Tharsis, while significantly improving the fit to the reverse faults only in Sabaea Terra and Lunae Planum, i.e., not altering the misfit to the majority of the reverse faults.

Thus, global contraction is a possible mechanism for predicting the reverse faults alone globally. If global contraction stress, in addition to the GPE associated ones, is responsible for the reverse faulting in southern, or all of, Mars, then the radius change ∂R resulting in the calculated global contraction stress is given by

$$\delta R = R\left[1-\sqrt{\frac{1}{1+\varepsilon}}\right], \quad \text{with} \quad \varepsilon = \frac{\sigma}{2\mu h}$$

where R is the planet's radius, ε is the horizontal strain, h is the lithospheric thickness, σ is the vertically integrated stress from global contraction, and μ is the shear modulus[1]. For the reverse faults, the vertically integrated global contraction stress required, $-0.7*10^{12}\ N/m$, for values of μ ranging between $4*10^{10}\ Pa$ and $8*10^{10}\ Pa$ translates to a very small radius decrease of $0.07km$ to $0.37km$, consistent with those of [10]. The ages of the various faults will be considered to determine if global contraction could have indeed occurred.

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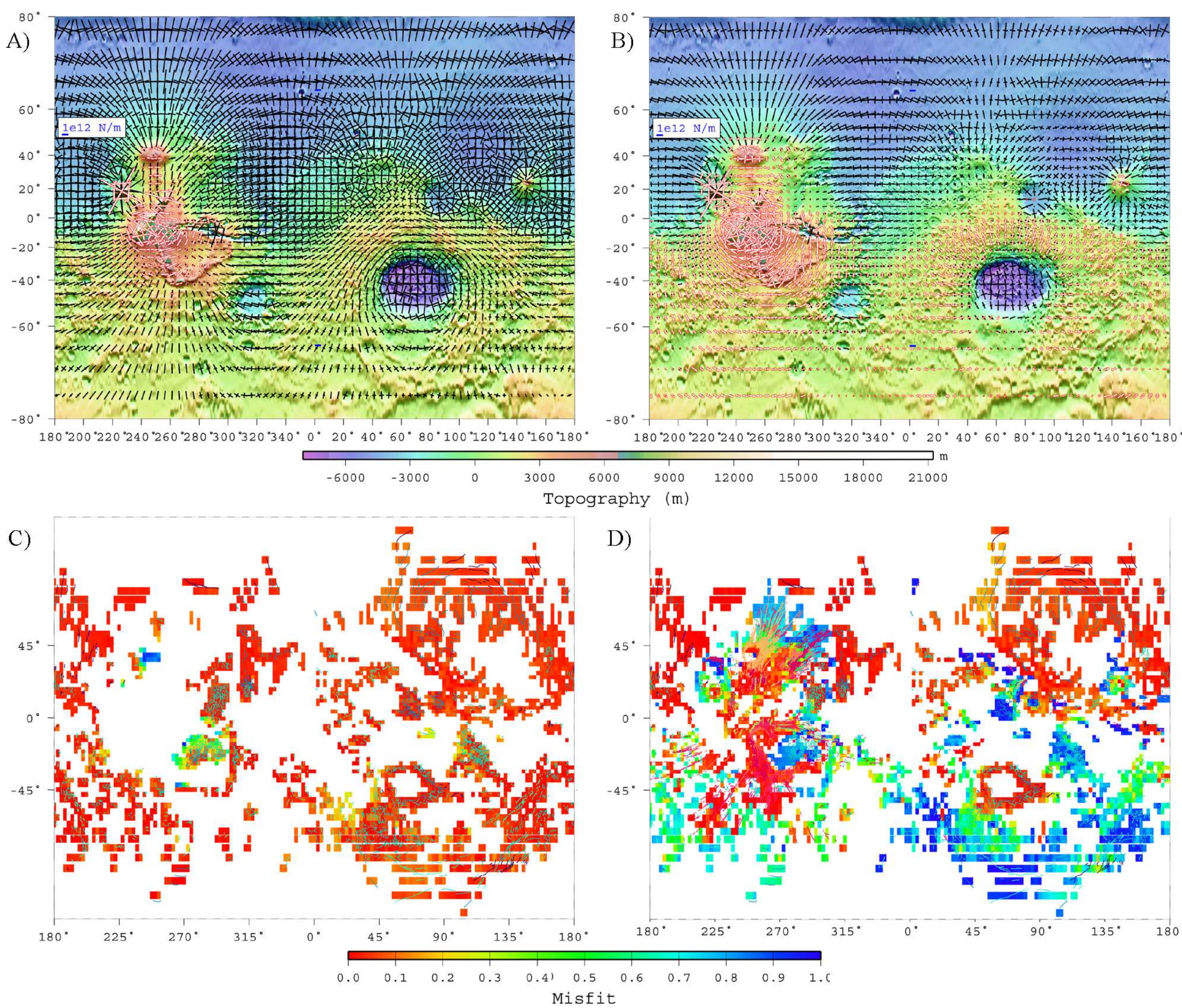

Figure 2. The combined GPE and global contraction stresses for the inversion to A) the reverse faults and B) the normal and reverse faults. The misfit to the faults is shown in panels C) and D) respectively.