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FORMATION OF FOLD AND THRUST BELTS ON VENUS DUE TO HORIZONTAL SHORTENING OF A LATERALLY HETEROGENEOUS LITHOSPHERE; *M.T. Zuber*[1,2], *E.M. Parmentier*[3], and *G.A. Neumann*[1], [1]Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218, [2]Laboratory for Terrestrial Physics, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, [3]Department of Geological Sciences, Brown University, Providence, RI 02912.

An outstanding question relevant to understanding the tectonics of Venus is the mechanism of formation of fold and thrust belts, such as the mountain belts that surround Lakshmi Planum in western Ishtar Terra (*cf.* Figure 1). These structures are typically long (hundreds of km) and narrow (many tens of km), and are often located at the margins of relatively high (km-scale) topographic rises [1-5]. Previous studies have attempted to explain fold and thrust belts in various areas of Venus in the context of viscous [6] and brittle [7,8] wedge theory. However, while wedge theory can explain the change in elevation from the rise to the adjacent lowland, it fails to account for a fundamental aspect of the deformation, *i.e.*, the topographic high at the edge of the rise. In this study we quantitatively explore the hypothesis that fold and thrust belt morphology on Venus can alternatively be explained by horizontal shortening of a lithosphere that is laterally heterogeneous, due either to a change in thickness of the lithosphere or the crust. Lateral heterogeneities in lithosphere structure may arise in response to thermal thinning or extensive faulting, while variations in crustal thickness may arise due to either spatially variable melting of mantle material or by horizontal shortening of the crust. In a variable thickness lithosphere or crust that is horizontally shortened, deformation will tend to localize in the vicinity of thickness heterogeneity, resulting in a higher component of dynamic topography there as compared to elsewhere in the shortening lithosphere. This mechanism may thus provide a simple explanation for the topographic high at the edge of the rise.

To investigate the pattern of deformation, we invoke a finite element approach. We have developed a finite element program that calculates incompressible Newtonian viscous fluid flow using the penalty method [9], and modified it to treat non-Newtonian flow problems [10-12]. We incorporated the strain rate dependence of viscosity by implementing a simple incremental procedure [13] to re-calculate the viscosity $\mu(z,t)$ at each time step. The viscosity takes the form

$$\mu=\mu_0[1/\dot{\varepsilon}_2]^{(1-1/n)}$$

where $\mu_0(z,t=0)$ is the reference viscosity (viscosity at the first time step), z is depth, t is time, $\dot{\varepsilon}_2$ is the second invariant of strain rate tensor, and n is the power law exponent of stress in the stress-strain rate relationship. To simulate the rheology of the lithosphere in the ductile creep regime we used a power law exponent of ~3, while in the brittle regime we invoked the assumption of perfect plasticity in which $n \to \infty$ to approximate a material that deforms by pervasive faulting. In the model the viscosity was constrained to have an upper bound defined by the brittle or ductile strength [14].

We assume that a uniform viscosity layer of thickness h_1 initially contains a thickness perturbation of amplitude Δh and half-width ΔL. We also assume a vertical thermal profile in which the lithosphere cools as a simple half space. For both models we incorporated a strength envelope distribution of lithosphere viscosity, to take into account variation of strength with depth indicated by rock mechanics experiments [*cf.* 15]. For both models, the initial topography of the medium is isostatically compensated and is assumed to shorten at a constant horizontal velocity u. The effect of buoyancy forces in resisting topographic amplification associated with shortening is included via a dimensionless parameter $S=\rho g L^2/\mu_0 u$, where L is the horizontal length scale. Both Cartesian and axisymmetric geometries were explored, where the latter is relevant to the formation of fringing mountain belts at the periphery of the Lakshmi Planum plateau.

Figure 2 shows model profiles for the variable thickness lithosphere model assuming a Cartesian geometry for strains of 0, 0.03 and 0.05. Here it was assumed that the lithosphere was thinned by a factor of 2. The predicted topography is consistent with the general pattern observed across many fold and thrust belts on Venus, such as in the Akna Montes region (Figure 1), both in terms of the change in elevation between the topographic rise and lowland, and the elevation and width of topographic high at the edge of the rise. In this model 80% of the topography associated with the topographic rise is supported by stresses in the lithosphere.

Mountain belt-fringed plateaus with similar patterns of long wavelength topography are also found on Earth. Prominent examples include the Himalayas at the southern edge of the Tibetan plateau, and the Andes at the western margin of the Altiplano. Mechanisms for the formation of these terrestrial counterparts include lithosphere shortening related to subduction [16], marginal plateau erosion and isostatic uplift [17], and lithospheric shortening not necessarily associated with subduction [18]. Of these mechanisms, subduction may not occur on Venus and mechanical erosion certainly is not important there. It is thus appropriate to question whether similar topographic patterns can be produced by entirely different mechanisms or whether the absence of the first two mechanisms on Venus might point to horizontal shortening of a laterally heterogeneous lithosphere as a mechanism for the formation of fold and thrust belts on both planets.

References: [1] Campbell, D.A. (1983) *Science, 221,* 664-667. [2] Crumpler, L.S., et al. (1986) *Geology, 14,* 1031-1034. [3] Head, J.W. (1990) *Geology, 18,* 99-102. [4] Solomon, S.C., et al. (1991) *Science, 252,* 297-312. [5] Solomon, S.C., et al. (1992) *J. Geophys. Res., 97,* 13,199-13,256. [6] Vorder Bruegge, R.W., and R.C. Fletcher, (1991) *LPSC, XIX.* [7] Suppe, J., and C. Conners (1992) *J. Geophys. Res.* [8] Williams, C.A., et al. (1993) submitted to *J. Geophys. Res.* [9] Bathe, K.-J. (1982) *Finite Element Procedures in Engineering Analysis,* 735 pp., Prentice-Hall, Inc., Englewood Cliffs. [10] Zuber, M.T. and E.M. Parmentier (1992a) *Workshop on Mountain Belts on Venus and Earth,* 49-50, Lunar Planet. Inst., Houston, 49-51. [11] Zuber, M.T. and E.M. Parmentier (1992b) *Lunar Planet. Sci. Conf. XXIII,* 1595-1596, Lunar Planet. Inst., Houston. [12] Zuber, M.T. and E.M. Parmentier (1993) *EOS Trans. Am Geophys. Un., 74,* 546. [13] Desai, C.S., and J.F. Abel (1972) *Introduction to the Finite Element Method,* 477 pp., Van Nostrand Reinhold Co., New York. [14] Chen, Y., and J.W. Morgan (1990) *J. Geophys. Res., 95,* 17,583-17,604. [15] Zuber, M.T. (1987) *J. Geophys. Res., 92,* E541-E551. [16] Wdowinski, and R.J. O'Connell (1991) *J. Geophys. Res., 96*, 12,245-12,255. [17] Masek, J., et al. (1993) submitted to *J. Geophys. Res.* [18] Karner, G.D., and A.B. Watts (1983) *J. Geophys. Res., 88,* 10,449-10,377.

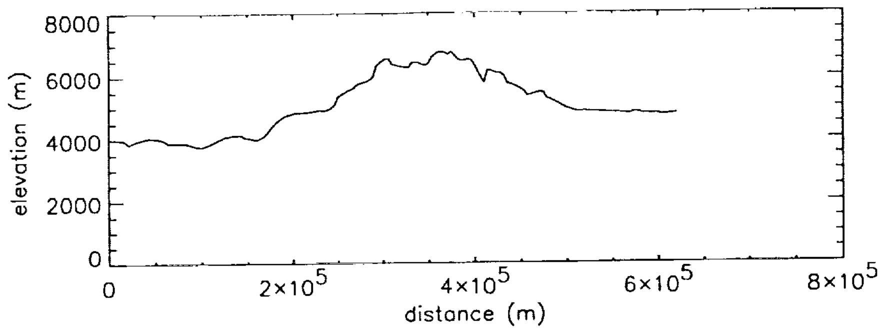

Figure 1. Magellan topographic profile of fold and thrust belt in the Akna Montes region of Venus (long=317°, lon=71°). In this area there is a 1 km elevation difference between the lowland on the left and the topographic rise on the far right. Over 2 km of topography is associated with the high at the edge of the rise.

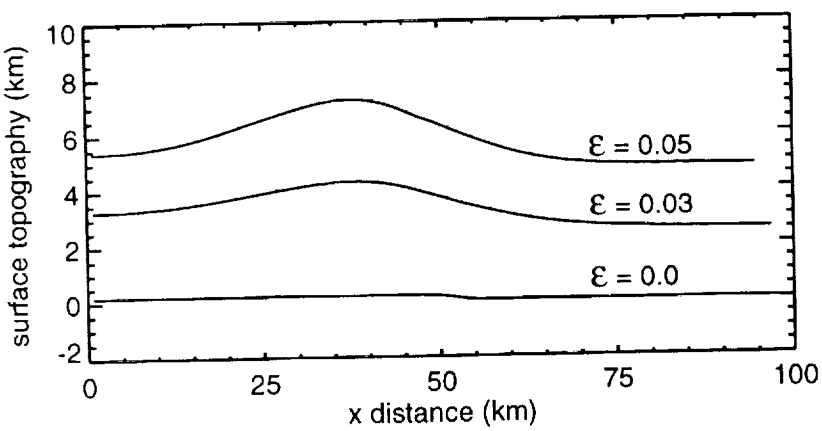

Figure 2. Topographic profiles for variable thickness lithosphere model for strains of 0, 0.03, and 0.05.