THE CONTRIBUTION OF DYNAMIC TOPOGRAPHY DUE TO LITHOSPHERE COMPRESSION TO THE STRUCTURE OF MOUNTAIN BELTS AND RIDGE BELTS ON VENUS;
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Radar images of the surface of Venus reveal evidence for large-scale compressional deformation [1-3]. Examples of compressional features are mountain belts, found in the highlands, and ridge belts, found in the plains. Previously, compressional folded layer models have been invoked to describe the continuum nature of these features [4-7]. However, these models are characterized by two notable simplifications: First, they assume simpler vertical strength or viscosity stratifications than are likely to describe the Venus lithosphere. Second, the models are valid only for infinitesimal fold amplitudes (<< competent lithospheric layer thickness), and are thus not applicable at finite strains that may characterize highly-deformed structures. In order to develop a more realistic quantitative representation of lithospheric-sale shortening on Venus, we have constructed finite element models of a compressing medium that incorporate general vertical strength distributions and take into account non-Newtonian behavior of the lithosphere. With these models we address aspects of the structure and dynamical evolution of regions on Venus that may have undergone finite amplitude shortening. We also consider the effect of localized lithospheric thickness variations in the development of fold belt morphology.

We used a penalty function approach [8] to calculate deformation due to uniform horizontal shortening of an incompressible viscous medium with an arbitrary vertical viscosity distribution. We assumed a "strength envelope" distribution [*cf.* 9], which contains an upper brittle zone, characterized by a linear increase of strength with depth, and a lower ductile zone, characterized by an exponentially decreasing strength with depth. We assumed a strain rate-dependent viscosity μ of the form

$$\mu = \bar{\mu}(z)\ [1/\varepsilon_{II}]^{1-1/n} \qquad (1)$$

where $\bar{\mu}$ is the reference viscosity, *i.e.* the viscosity at the first time step, ε_{II} is the second invariant of the strain rate tensor and n is the power law exponent of stress. The viscosity was calculated using an incremental procedure [10]. To approximate deformation in the brittle regime we invoked the assumption of perfect plasticity in which $n \to \infty$, while in the ductile creep regime we assumed $n \approx 3$. The geometry of the problem, boundary conditions and model parameters are shown schematically in Figure 1.

Figure 2 shows estimates of the rate of fold growth (q) for three strength stratifications with fixed thickness and strength distribution in the brittle layer and different values of the ductile e-folding thickness ζ. In each case q exceeds the critical value of one, which indicates that all of these models will develop folds when horizontally compressed. As for previous infinitesimal amplitude solutions [5,6], the rate of fold amplitude growth is greater for smaller ζ. Also note that with decreasing ζ, q progressively decreases with increasing horizontal strain, indicating that folds will grow increasingly slowly as deformation progresses.

The topography of deformation features in Ishtar Terra and other highlands likely contains a significant thermal component. However, the topography of ridge belts, which occur in lowland regions, may be almost entirely attributable to dynamic effects associated with deformation. Our models for folding of a lithosphere with a realistic strength stratification and random initial perturbations indicate that surface deformation will develop with topographic highs that alternate with distinctly flattened topographic lows. These models would suggest that if the topography of ridge belts is mainly a consequence of regional compression, and if buoyancy forces are small in comparison to lithospheric strength, then the across-track topography of these structures should be distinctly non-sinusoidal.

The solutions in Figure 2 assume random initial perturbations and no lateral strength variations. However, spatial variations in lithospheric thickness might be expected due to thermal, compositional or mechanical heterogeneities. Simple solutions for compression of a non-Newtonian viscous lithospheric layer with a small, localized thickness variation show significant stress-supported topography (order 1 km). The topography exhibits a pattern which may explain salient morphologic features of certain mountain belts [11]. Similar models adapted to consider finite lithospheric thickness variations may be relevant to the gross morphology of mountain belts on Venus, such as Vesta Rupes and Akna and Freyja Montes that surround Lakshmi Planum.

References: [1]Campbell, D.B. et al., *Science, 221,* 644-647, 1983. [2]Basilevsky, A.T., et al., *JGR, 91,* D399-D411, 1986. [3]Solomon, S.C. et al., *Science, 252,* 297-312, 1991. [4]Solomon, S.C., and J.W. Head, *JGR, 89,* 6885-6897, 1984. [5]Zuber, M.T., *JGR, 92,* E541-E551, 1987. [6]Zuber, M.T., and E.M. Parmentier, *Icarus, 85,* 290-308, 1990. [7]Banerdt, W.B., and M.P. Golombek, *JGR, 93,* 4759-4772, 1988. [8]Bathe, K.-J., *Finite Element Procedures in Engineering Analysis,* 735 pp., Prentice-Hall, Inc. Englewood Cliffs, 1982. [9]Brace, W.F., and D.L. Kohlstedt, *JGR, 85,* 6248-6252, 1980. [10]Desai, C.S., and Abel, J.F., *Introduction to the Finite Element Method,* 477 pp., Van Nostrand Reinhold, New York, 1972. [11]Parmentier, E.M., *LPSC, XVII,* 648-649, 1986.

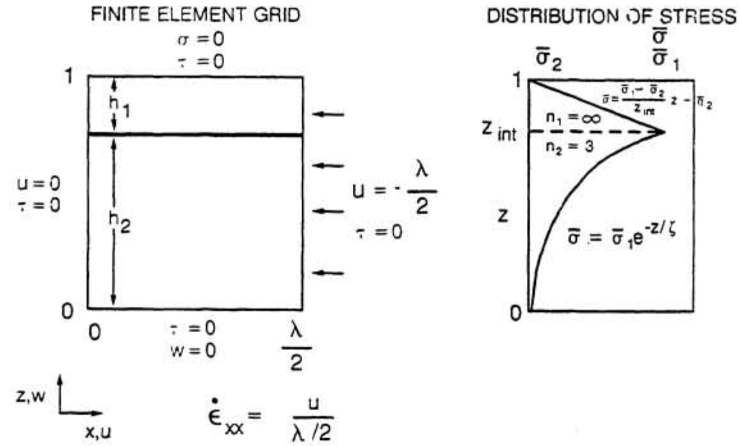

Figure 1. (Left) Geometry, boundary conditions and parameter definitions for the finite element model of a compressing lithosphere. (Right) Assumed distribution of lithospheric stress $\bar{\sigma}$, where $\bar{\sigma}= 2\bar{\mu}\dot{\varepsilon}_{xx}$, $\bar{\mu}$ is the reference viscosity and ε_{xx} is the mean horizontal strain rate.

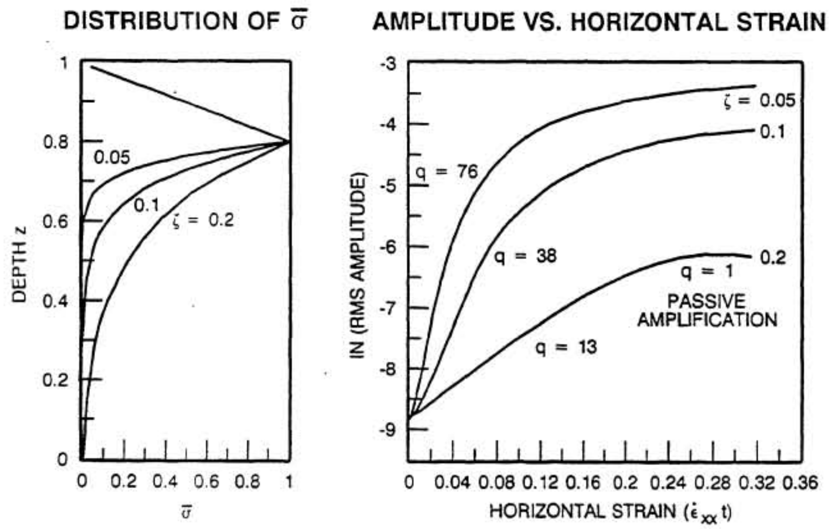

Figure 2. (Right) Relationships between ln(rms amplitude) and mean horizontal strain $\dot{\varepsilon}_{xx}t$ for three lithospheric structures shown on the left. The slopes of the lines (designated by the variable *q*) correspond to the rate at which folds will grow. Parameter values for this calculation are $\bar{\sigma}_1$=100, $\bar{\sigma}_2$=0, z_{int}=0.8, n_1=100, and n_2=3. Values of *q* listed represent those at small strains, where the rates of fold growth are greatest. The slopes of the lines decrease at larger strains, where the rates of fold growth decrease. In the ζ=0.2 case *q*=1 at large strains, indicating that the medium has ceased folding and is instead deforming by passive shortening.