Thin-Skinned Gravity-Driven Deformation on Venus. S. Smrekar and R. J. Phillips, Dept. of Geol. Sci., Southern Methodist Univ., Dallas, TX 75275.

Gravity spreading may provide an alternative to terrestrial-style plate tectonic forces as a cause of intense horizontal deformation of the venusian crust (e.g. 1). The conditions of high temperature, low erosion rate and elevated terrain all favor thin-skinned gravitationally driven deformation. In contrast to the whole lithosphere viscous relaxation models of Binschadler and Parmentier (2), this study examines the potential for the translation of a layer with an inclined surface slope above a detachment, analogous to fold-and-thrust belts on Earth.

BACKGROUND. Mechanisms for decollement development are undoubtedly more limited on Venus than on Earth. Estimates of water content of the crust (3) and erosion rates (4) indicate that high pore pressures or soft sedimentary rocks are probably not likely on Venus. Instead, a high temperature, low viscosity region near the base of a crust is considered the most likely possibility for the development of a ductile shear zone. Thus rheology is a key issue in deciding whether gravity alone can drive thrust belt deformation. Compositional, and thus rheological, data for Venus come from several Soviet lander experiments which indicate a basaltic composition (5).

MODEL. We use the two-dimensional equations of equilibrium for plane stress to describe the forces acting on a region with an inclined surface slope. The lateral density contrast due to a surface slope provides a driving force. For simplicity, we assume that the basal slope is the same as the surface slope. Shear stress is zero at the surface, and a no slip (zero velocity) lower boundary condition, corresponding to the boundary between the crust and a more rigid mantle, is used to calculate the velocity profile in a column of crust. A diabase flow law (6), corresponding to a basaltic composition, is used, along with a linear thermal gradient. By making the assumption that the wavelengths of the surface and basal undulations are large compared to the layer thickness, the changes in stress parallel to the down-surface slope direction can be neglected. This is equivalent to assuming internal deformation due to extension and compression is negligible. The resulting model allows only translation of the upper, rigid portion of the crust above a ductile zone near the base, with the downslope velocity asymptotically approaching a maximum at the surface.

To evaluate the potential for crustal mobility and ductile shear zone development, the velocity profile in a column of crust of a given thickness was found by numerical integration. Figure 1a shows the resulting surface velocity (the maximum velocity) for a surface slope of 2 deg and a range of thermal gradients and crustal thicknesses. For the purposes of evaluating whether or not the model predicts significant deformation over geologic time, a reasonable minimum velocity to consider might be 0.1 cm/yr (1 km/my), corresponding to the minimum velocity of shortening suggested for thrust development in the Canadian Rockies (7). The model predicts that for $dT/dz = 15$ K/km and a surface slope = 2 deg, a crustal thickness $\approx$15 km is required to produce a surface velocity of 0.1 cm/yr. With a higher $dT/dz = 25$ K/km, a crustal thickness of 11 km is necessary. On average, a change in surface slope of 1 deg produces a 2-5 km shift in the crustal thickness required to provide a certain velocity. Higher slopes result in smaller thickness values, lower slopes in larger ones. The parameters used here agree well with available estimates of surface slope (8) and crustal thickness (9). Based on global heat flux estimates, dT/dz for venus is likely to vary between 15 and 25 K/km (10,11).

Smrekar, S. and R. J. Phillips

Strain rate data for the same parameters are shown in Figure 1b. As one less boundary condition is required to solve for the first derivative of velocity, no lower boundary condition is specified. The figure simply shows the depth and thermal gradient at which a gravitationally induced stress produces a given strain rate. Regions where 'geologically significant' strain rates (10^{-13} s^{-1}) occur are at approximately the same depths (or crustal thicknesses) and thermal gradients that produced surface velocities of 0.1 cm/yr. Such a strain rate can be used to define a transition to very ductile behavior; numerous terrestrial decollements have been observed to occur along exhumed brittle-ductile transitions (e.g. 12).

These simple models suggest that, for reasonable parameters, the stress due to an inclined surface slope can create a shear stress within or along the base of a crustal layer of sufficient magnitude to induce extensive ductile deformation and possible detachment of the layer. For a diabase rheology, a crustal thickness of about 20 km is required to produce deformation. A websterite "crust" would deform only at much larger (at least a factor of two) depths. Conversely, a weaker rheology than diabase would develop a detachment at shallower depths.

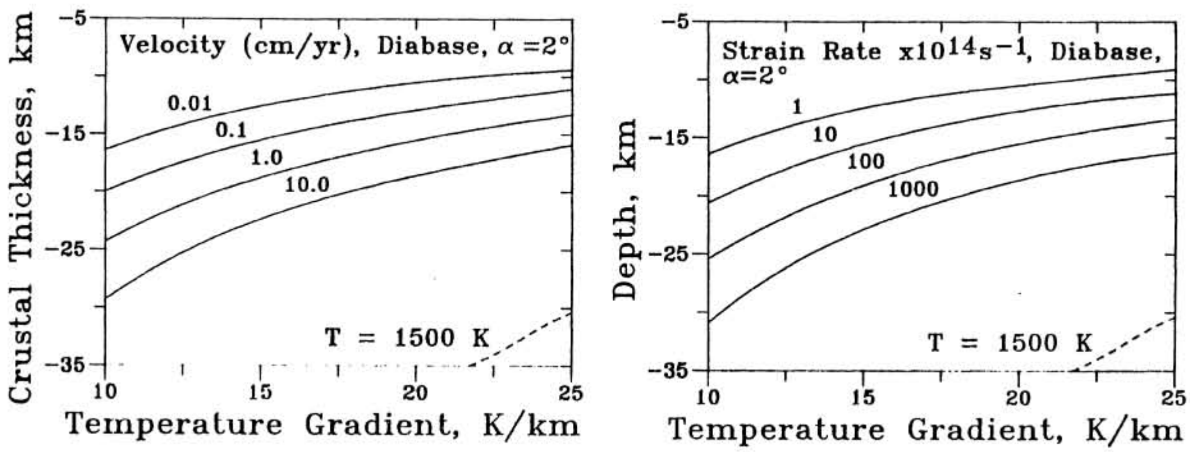

Figure 1.

Figure 1. (a) Surface velocity. Crustal thickness represents the depth at which the velocity is set to zero (the crust-mantle boundary). The dotted line indicates where temperature = 1500 K. (b) Strain rate normalized to 10^{-14} s^{-1} (no crustal thickness specified). Curves for 10^{-14}, 10^{-13}, 10^{-12}, and 10^{-11} are shown.

References: (1) Basilevsky, A. T., et al., *PLPSC 16th, J. Geophys. Res., 91*, D399-D411, 1986; (2) Binschadler, D. L., and E. M. Parmetier, *Lunar Planet. Sci. XVIII*, 75-76, 1987; (3) McGill, G. E., et al., in *Venus*, eds. D. M. Hunten, L. Colin, T. M. Donahue, and V. I. Moroz, Univ. of Arizona Press, 69-130, 1983; (4) Barsukov, V. L., et al., *Geochem. Internat., 29*, 135-143, 1985; (5) Surkov, Y. A., et al., *Proc. 14th Lunar Planet. Sci Conf, J. Geophys. Res., 89*, B393-B402, 1984; (6) Shelton, G. and J. Tullis, EOS, 62, 396, 1981; (7) Elliot, D., *J. Geophys. Res., 81*, 949-963, 1976; (8) Sharpton, V. L., and J. W. Head, J. Geophys. Res., 90, 3733-3740, 1985; (9) Zuber, M. T., *PLPSC 17th.*, in *J. Geophys. Res.*, 92, E541-E551, 1987; (10) Solomon, S. C., and J. W. Head, *J. Geophys. Res., 87*, 9236-9246, 1982.; (11) Phillips, R. J., and M. C. Malin, *Ann. Rev. Earth Planet. Sci., 12*, 411-443, 1984; (12) Hatcher, R. D., and R. T. Williams, *Geol. Soc. Am. Bull., 97*, 975-985, 1986.