A MODEL FOR THE SHAPE OF OVERTHRUST ZONES ON VENUS.

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Introduction: Several regions have been identified on Venus as the location of possible large-scale underthrusting and crustal imbrication [1,2,3]. These regions are characterized by a steep scarp with up to 3 km of relief flanked by an inboard high rim characterized by ridges and valleys that trend subparallel to the scarp, beyond which the topography may level off or exhibit a steady increase. On the outboard side, a narrow trough or foredeep and outer flanking high run parallel to the scarp. A profile showing this situation in Itzpapalotl Tessera is shown in Fig. 1. The outboard topographic features observed may be modelled as the result of the flexure of an elastic plate [4], but a similar analysis is insufficient to account for the topographic features of the scarp and its inboard components. Instead, a model utilizing a Newtonian rheology for accretionary wedges may be able to account for the topography of the scarp and its inboard components. In this abstract, we introduce such a model and compare its results to a observed topographic profile on Venus.

Model Description: Our approach follows that of Emerman and Turcotte [5], who considered the shape of terrestrial accretionary wedges. In their study, the accretionary sediments were modelled as a Newtonian fluid, with a planar base parallel to the sea surface, and with no sediment transport into the wedge [5]. We have modified this model to include: 1) a dipping, planar basal detachment (a non-zero angle of underthrusting); and 2) a finite thickness accreting layer which correponds to material above the detachment that becomes incorporated into the wedge. On Earth this layer would correspond to accreting sediments, but on Venus, where the distribution of erosional soils appears minimal [6], this layer is more likely to correspond to deformed and 'sutured' volcanic or basaltic crustal material that is added to the mountain range, as suggested by Head [1] for Itzpapalotl Tessera. The geometry of our model is shown in Figure 2. For this geometry, the wedge is sufficiently thin to allow the replacement of the Navier-Stokes equations by the lubrication equations [5]. The solution of these equations determines the shape of the wedge over time as:

$$\boxed{\frac{\partial \zeta}{\partial t} \approx w_0 + \frac{\partial}{\partial x}\left[U\zeta + \frac{\rho g}{3\eta}\zeta^2 (\zeta + \theta)\left(\frac{\partial \zeta}{\partial x} + \beta\right)\right]} \tag{1}$$

The variables and constants are defined as follows: ζ is the thickness of the wedge, w_0 is the flow of material across the base of the wedge, U is the rate of underthrusting, ρ is the crustal density, η is the viscosity of the wedge materials, θ is the slip parameter (a measure of the relative strength of the detachment surface), and β is the angle of underthrusting. Emerman and Turcotte [5] consider the steady-state case in which: no material flows into the wedge, neither across the base (w_0=0), nor from the front; there is no slip (θ=0); and the angle of underthrusting, β, is 0. Like Emerman and Turcotte [5], we will examine the steady-state case with no flow through the base, no slip, but with a layer of thickness, ζ_0, and an angle of underthrusting, β (Fig. 2). The steady-state solution is such that $\partial\zeta/\partial x = 0$ and $\zeta = \zeta_0$ beyond the toe of the wedge. In the Emerman and Turcotte model [5], the wedge thickness at the toe goes to 0 and the slope is infinite. With a finite ζ_0 the steady state solution has a finite maximum slope near the toe of the wedge. With these conditions it is then possible to rewrite eq. (1) into a non-dimesionalized form that also gives the true surface slope, α:

$$\boxed{-\alpha \approx \left(\frac{\partial \zeta}{\partial x} + \beta\right) \approx a\,\frac{1-y}{y^3} + \frac{\beta}{y^3}}, \text{ where } a = \frac{3\eta U}{\Delta\rho g \zeta_0^2}, \text{ and } y = \frac{\zeta}{\zeta_0}. \tag{2}$$

Wedge profiles may be generated by using eq. (2) in conjunction with the geometry of Fig. 2 and some assumptions based on observations. In Itzpapalotl Tessera the steady rise of the plateau abruptly steepens at Freyja Montes at a height of approximately 4 km (point C, Fig. 2). We estimate the underthrusting angle, β, by assuming Airy isostasy at Freyja Montes with a crust of 3.0 g/cc over a mantle of 3.4 g/cc. In our geometry (Fig. 2) it is unecessary to know the original crustal thickness, C_0, since β can be determined by considering only the crustal thickness necessary to balance 4 km of topography and the horizontal distance to the trench (the crustal thickness at the trench greater than C_0 is considered negligible, point A, Fig. 2). From this we determine that $\beta \approx 0.13$ (7.5°). From eq. (2) we find that the maximum surface slope, α_{max}, occurs at $y \approx 3/2$.

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This value of y corresponds to point B in Fig. 2, and we can use this combined with β and $\alpha_{max} \approx 0.1$ (observed on the scarp, Fig. 1) in eq. (2) to find that $a \approx 1.0$. For typical values on Venus (ρ=3.0 g/cc, g=900 cm/ss, U=1 cm/yr) such layers with ζ_0= 1 and 10 km correspond to viscosities of 10^{22} and 10^{20} poise, respectively.

Preliminary Model Results and Future Considerations: The steady state model provides a good fit to the profile across Itzpapalotl Tessera using values of ζ_0= 2 km and β =7.5° (Figure 3). This would place the detachment surface well within the estimated thickness of the Venus crust and/or elastic lithosphere (15 km) determined in previous studies [4,7]. The marginal high adjacent to the scarp is not completely modelled in this analysis. It is suspected that this region may represent the location of underplating (w_0) as either a steady-state or transient phenomenon. Future work will incorporate these considerations into the model.

References: 1) Head, J.W. (1988) *LPSC* XIX, 467, and *Geology*, in press. 2) Vorder Bruegge, R.W. & J.W. Head, (1989) *LPSC* XX, 1162. 3) Head, J. & J. Burt, (1990) this volume. 4) Solomon, S.C. & J.W. Head, (1989) *LPSC* XX, 1032. 5) Emerman, S.H. & D.L. Turcotte, (1983) *EPSL*, **63**, 379. 6) Bindschadler, D.L. & J.W. Head, (1989) *Icarus*, **77**, 3. 7) Solomon, S.C. & J.W. Head, (1984) *J.G.R.*, **89**, 6885; Zuber, M.T. (1987) *J.G.R.*, **92**, E541; Grimm, R.E. & S.C. Solomon, (1988) *J.G.R.*, **93**, 11,911.

Figures: 1) Venera 16 topographic profile of 12/28/83 across Itzpapalotl Tessera with features indicated. 2) Geometry of fluid model for wedge accretion. Various parameters described in text. 3) Comparison of model results for various detachment depths.