A FINITE ELEMENT MODEL OF CRUSTAL DEFORMATION ON VENUS.

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Introduction: Quantitative insufficiency of plate-tectonic models (1) coupled with the apparent lack of an asthenosphere (2) have lead to the hypothesis that the surface tectonics of Venus are much more determined by bulk mantle flow rather than by a lithospheric boundary layer (3). It has also been recognized that stresses generated by mantle flow could lead to crustal thinning and thickening (4). In an effort to further quantify these ideas we have developed a numerical model of crustal deformation driven by thermal mantle convection. The forward nature of the model leads to predictions which can be compared to topography, gravity, and radar images in an effort to discern the mode of tectonic deformation that has shaped the surface of the planet.

Model: The finite element model, based on ConMan developed by Raefsky et.al. (5), uses a double diffusive convection approximation which parameterises the effects of compositional and thermal density variations through chemical and thermal Rayleigh numbers. Model behavior is governed by these two Rayleigh numbers, boundary conditions, and initial conditions such as the volume of crustal material or heating mode. The simplest model is isoviscous and consists of an initially undeformed low density crustal layer set atop a high density convecting mantle heated from below. Figure 1 shows three stages of model evolution. The upwelling region shows an initial, dome-like, extensional uplift, followed by increasing extension and decreasing upper boundary layer thickness as crustal material is swept aside and the upwelling comes to the surface. Downwelling regions display a more complex evolution: 1)an initial compressional depression forms; 2)it is replaced by a dome-like uplift with interior extension and a band of outward sweeping mild compression; and 3)finally an elevated plateau-like region bordered by concentrated zones of high compression forms and is dynamically maintained. Downwelling regions also show an increase in upper thermal boundary layer thickness as crustal material converges and piles up over the thermal downflows. Stages 1) and 2) match well with analytic results (4), while stage three is beyond the analytic limit due to the fact that it is a result of significant lateral as well as vertical compositional variation.

It has been suggested that a layer of low density residuum mantle would keep mantle convection from manifesting itself at the surface of Venus (6). We find this not to be the case for residuum density as low as 0.7 mantle density. Mantle flow sweeps away the residuum just as it sweeps the crust, leading to the formation of thickened crust underlain by a layer of residuum over downwellings. A similar mix of upper mantle lateral chemical hetrogeneities has been suggested for the Archean Earth (7).

Conclusion: The model of crustal deformation driven by thermal mantle convection obtains results similar to most of the major tectonic features on Venus. Regions such as Beta are probably dynamic uplifts caused by upwelling mantle material. These regions should be broad zones of crustal generation. Ishtar has been suggested to be a long lived downwelling displaying concentrated zones of peripheral compression (9), and possibly underlain by a deep residuum root. If Ishtar is indeed such a cratonic complex it could have significant implication for crustal recycling (10). The complex tectonic history infered for regions of tessera can be explained if these regions represent downwellings now in a state of collapse (11). The correlation of model results to data suggests that the tectonic signature of Venus is determined by the ability of bulk mantle flow to generate time evolving lateral material variations through the direct coupling of convective stresses to upper surface layers.

Venus appears to differ from the Earth in the way its surface layers respond to mantle convection. On Earth the existence of an asthenosphere leads to a sharp distinction between a strong upper boundary layer and a weak interior: thence plate-tectonics. But

Venus Crustal Deformation Model
Lenardic, A., et. al.

on Venus, the high gravity:topography admittance ratio indicates that there is no asthenosphere, possibly due to the absence of water (12), and hence its tectonic evolution is dominated by the bulk flow of its deep interior.

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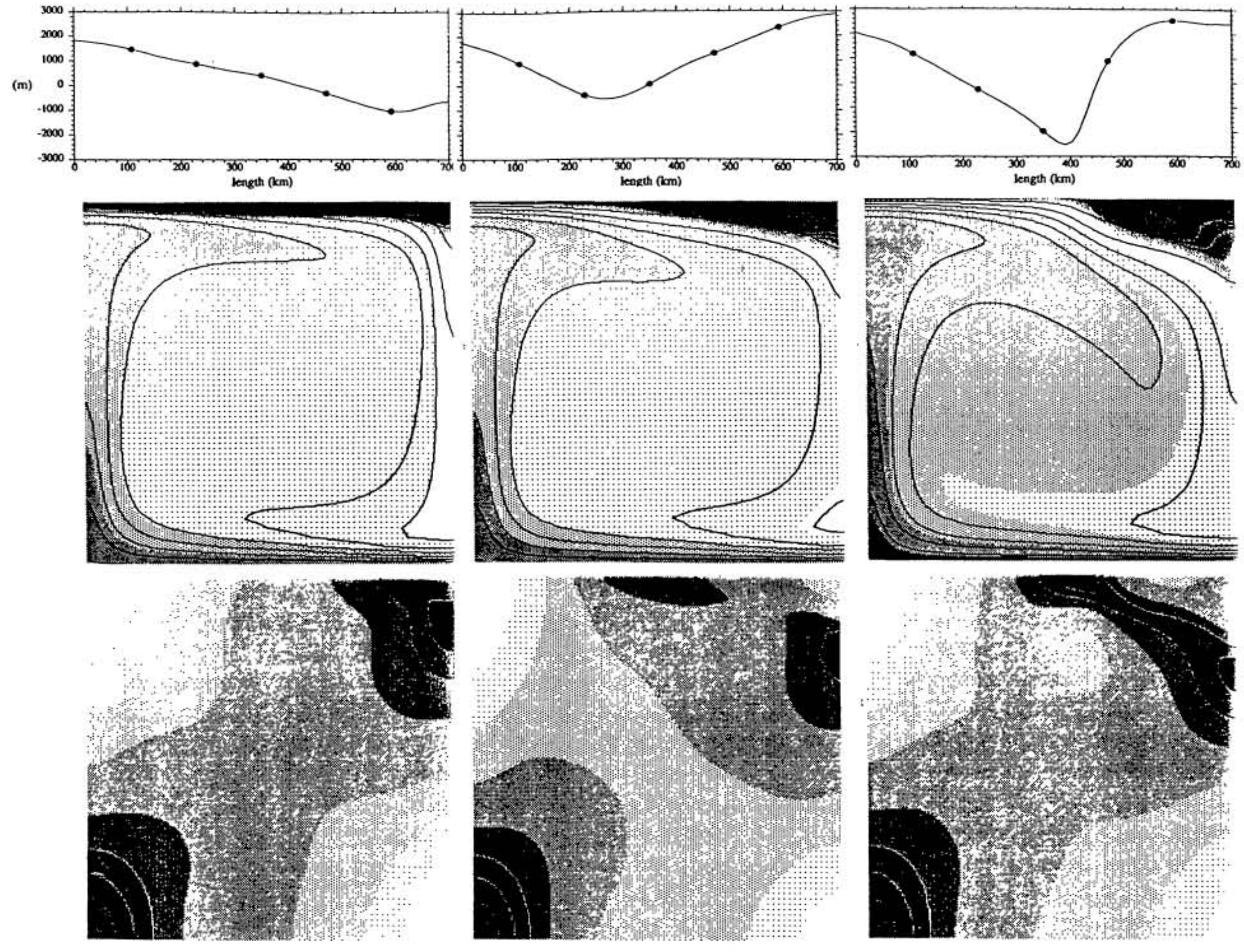

Figure 1

topography, temperature contours over a shaded plot of density (dark regions representing lowest density), and the horizontal component of the strain rate tensor (dark regions represent compression, light regions extension) at times of .01, .05, and .25 Gyr.