# CAN WEAK CRUST EXPLAIN THE CORRELATION OF GEOID AND TOPOGRAPHY ON VENUS?

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The effect on geoid and topography of low viscosity crust overlying a steady-state convecting mantle is estimated under the assumption that the shear between crust and mantle does not alter the mantle flow. The weak crustal layer can change the sign of the geoid to topography ratio (admittance). The positive long wavelength admittance for Venus is consistent with a weak crust overlying a mantle with a viscosity that increases strongly with depth.

The accepted interpretation of the strong positive correlation of geoid and topography on Venus, is that the convecting mantle of Venus has a constant viscosity with depth [1-4]. According to these workers, topography results from vertical normal stresses caused by mantle convection and highlands occur where mantle upwells. For topography to be supported by normal stress, the time scale for crustal flow must be long compared to the time scale for changes in the pattern of mantle flow. Because the high surface temperature of Venus may cause the crust to have a low viscosity, this assumption may be false. Topography should then be dominated by shear coupling between the crust and mantle.

In the absence of a crustal layer convection in a constant viscosity layer gives rise to a geoid anomaly that correlates positively with surface topography. When the viscosity in the layer increases with depth by several orders of magnitude the surface topography and geoid anomaly become anti correlated [5].

Consider that mantle convection in the absence of crust produces a 100 meter variation in geoid height $\Delta N$. In the case of a constant mantle viscosity the geoid high is above the mantle upwelling and in the case of strongly depth dependent mantle viscosity the geoid high is above the downwelling. Next, consider a low density, low viscosity crustal layer overlying a steady-state mantle convection cell. Convective normal stresses deflect the crust-mantle boundary, but do not affect the surface in steady-state, as noted in [6]. If the top of the mantle cell moves with a horizontal velocity of $u_p$ and is of lateral dimension L, then shear stresses cause a difference in elevation between the surface above the mantle downwelling and over the upwelling of:

$$\Delta w = \frac{\partial w}{\partial x} L = \frac{3 u_p \mu L}{g \rho_c h^2}$$

where g is the acceleration of gravity, w is topography. h, $\rho_c$ and $\mu$ are the thickness, density and viscosity of the crust, respectively. In the limit that the crust is invicid the surface topography conforms to the geoid. Topographic differences should be the sum of the topography related to geoid variations and due to shear coupling as given above.

Assume that the stresses within the crust are small enough to have a negligible effect on the pattern and rate of mantle convection. Then the geoid anomaly $\Delta N$ will be the combination of that due to convection in the absence of a crustal layer and that due to the topography and crustal thickness variations caused by the shear coupling between the mantle and crust.

Figure 1 shows the steady state topography for a range of conditions of shear coupling between crust and mantle for the two cases of mantle viscosity. Note the parameter on the horizontal axis is proportional to the elevation difference resulting from shear coupling. Figure 2 shows the same variation of the geoid height difference across the convecting cell. The admittance defined as the ration of geoid to topography is shown in Figure 3.

Correlation of Geoid and Topography on Venus
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For Venus the observed admittance at long wavelength is of order 0.02-0.04 [2]. For the weak crust model, the sign of the admittance is positive and of magnitude 0.1 only for the model with a mantle viscosity that increases with depth. For convection cells on the order of 1000-5000 km and a crust of order 10 km thick the crustal viscosity would be in the range of $10^{17}$ to $10^{18}$ Pa s to give the observed admittance and elevation differences.

This model of a weak crust for Venus suggests that the mantle of Venus may have a similar viscosity structure as the Earth. Also all highlands must be underlain by mantle downwellings. Previously, [7] I showed that this kind of model might lead to low surface slopes in the lowlands and higher slopes in highlands due to thermal differences in the crust mantle system. Temporal variations in the rate of mantle convection can lead to either dominantly compressive or extensional features in highlands.

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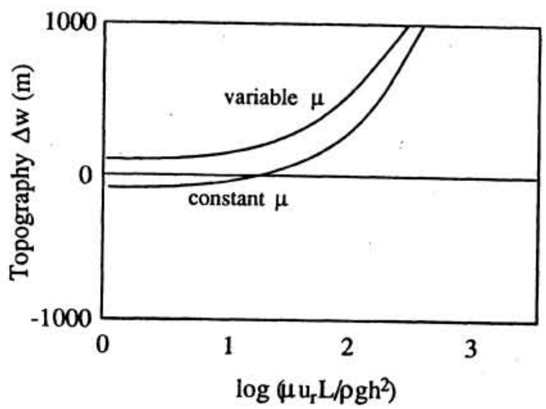


Figure 1

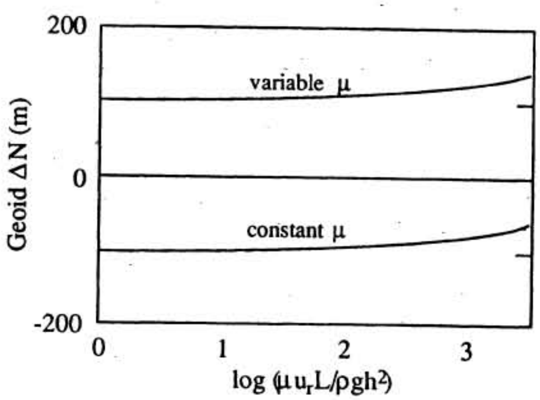


Figure 2

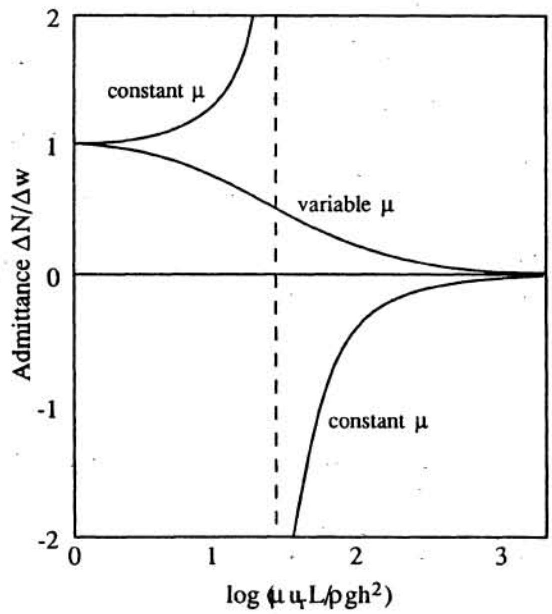


Figure 3