

TECTONIC FEATURES DUE TO GRAVITATIONAL RELAXATION OF TOPOGRAPHY; D.L. Bindshadler and E.M. Parmentier, Dept. of Geological Sciences, Brown University, Providence, RI 02912.

Pioneer Venus (PV) altimetry data (1,2) reveal a number of topographically high regions on Venus, ranging in form from the gentle dome of Beta Regio to the steep, asymmetric topography of Maxwell Montes. These high regions are also characterized by a range of tectonic structures: from rift structures in Beta (3,4) to compressional foldbelts in Maxwell, Akna, and Freyja Montes (5,6) to patterns of intersecting ridges in the parquet terrain (7-9). As on Earth, mechanisms such as horizontal compression and extension, constructional volcanism, and dynamic processes in the interior are all candidates for producing high topography. In contrast to Earth, erosion rates on Venus are extremely slow and erosion much less efficient (9,10). Gravitational relaxation should be a much more significant mechanism for reducing relief on Venus because of both the low erosion rates and the present high surface temperature (11). While numerous studies have discussed gravitational relaxation of topography, none have examined its relationship to tectonic features. We examine such relationships, with the further goal of better understanding some of the tectonic structures observed on the surface of Venus by radar imaging.

Horizontal surface deformation resulting from the gravitational relaxation of topography is treated using the approximation that surface slopes are small. Viscous flow within the substrate is produced by the load of relaxing topography which can be represented as the superposition of Fourier harmonics in the horizontal (x) direction. Each Fourier component of topography will relax at a rate that is dependent on its wavelength and independent of the other harmonics. We first consider two models in which the topographic surface is shear stress free. Because horizontal velocity does not vanish, horizontal strains will accumulate as surface topography relaxes. The strain rate $\dot{\epsilon}_{xx} = \partial w / \partial x$ at the surface can be calculated from the horizontal velocity induced by the topographic load. Figure 1 shows the effect of variations in viscosity with depth for a simple layered structure in which a layer of viscosity μ_1 overlies a halfspace of viscosity μ_2 . Vertical surface velocity w is taken as positive downward and horizontal strain rate as positive in extension. Relaxing topographic highs and lows correspond to positive and negative w , respectively. The ratio of $\dot{\epsilon}_{xx}$ to w is expressed in Figure 1 as a non-dimensional transfer function between horizontal strain rate and vertical surface velocity at a range of topographic wavelengths. For viscosity increasing with depth ($\mu_1 < \mu_2$, for example, weak crust overlying a strong mantle), horizontal strain is compressive in topographic lows and extensional on highs, as is commonly assumed. However, if the viscosity decreases with depth, compression will occur on topographic highs and extension in lows.

Figure 2 shows the effect of a discontinuity in density (e.g. a crust-mantle boundary) at depth h for a layer of viscosity μ overlying an inviscid halfspace (12). The transfer function between $\dot{\epsilon}_{xx}$ and w is plotted for a range of wavelengths and for varying degrees of initial isostatic compensation c . For no isostatic compensation of topography ($c=0$), the horizontal strain rate is initially compressive on topographic highs and extensional in lows. For partially compensated initial conditions ($c=0.5$), $\dot{\epsilon}_{xx}$ varies from extensional on highs at shorter wavelengths to compressive on highs at longer wavelengths. For complete initial compensation ($c=1$), horizontal strains are never compressive on topographic highs and the transfer function approaches 2.0 in the thin layer or long wavelength limit. This model is characterized by two relaxation times, the shorter representing the time to achieve isostatic compensation and the longer the time to relax remaining topography. Thus the curves $c=0$ and $c=0.5$ represent only initial values of the transfer function; these curves will approach the $c=1$ curve before topography has completely relaxed. This has implications for the tectonic history of topographic features on Venus. If a topographic load is emplaced more quickly than isostatic compensation can be reached, the topographically high region would first undergo compressive and later extensional deformation as isostatic conditions were approached.

The final model considers the effect of a brittle-elastic surface layer which acts as a stress guide. In such a case, the top of the viscous layer is no longer shear stress free. As in the model of Figure 2, we consider an isostatically compensated, low density layer. Figure 3 shows a topographic plateau and the shear stresses at the base of the brittle layer due to its relaxation. Shear stresses are confined to the margins of the topographic plateau, where slopes are steep; but horizontal normal stress is transmitted into the interior by the brittle surface layer. Horizontal normal stress is simply proportional to the topography δ . The plateau in Figure 3 approximates the form of Tellus Regio, a large region of parquet terrain (7). Mapping of Tellus has shown that some of the youngest tectonic features are extensional and occur in the highest topography, while compressive ridges are found on the flanks of the plateau (13). Work is currently in progress to more fully assess the consequences of these models for tectonic features.

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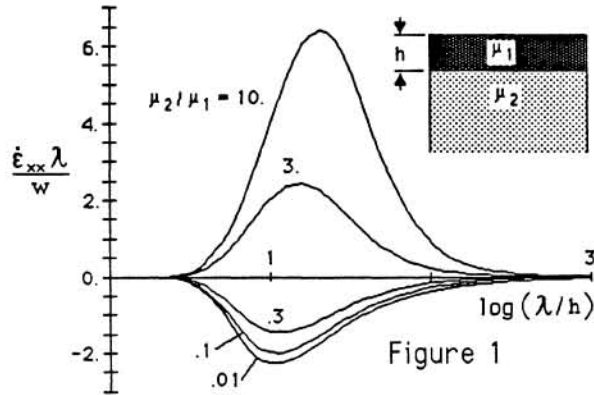


Figure 1. Transfer function between horizontal strain rate $\dot{\epsilon}_{xx}$ and vertical velocity w due to relaxation of topographic harmonics of wavelength λ . For viscosity increasing with depth ($\mu_1 < \mu_2$), horizontal extension occurs on highs and compression in lows. However, if $\mu_1 > \mu_2$, this relationship between $\dot{\epsilon}_{xx}$ and topography is reversed.

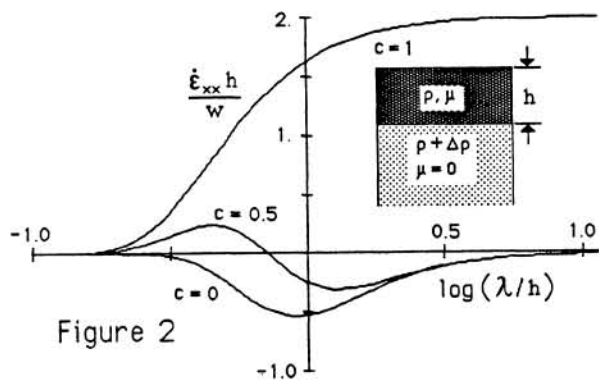


Figure 2. Transfer function between $\dot{\epsilon}_{xx}$ and w at varying wavelengths for a simple density stratification and varying degrees of isostatic compensation c of surface topography. For an uncompensated surface load, horizontal strain rates are compressional in topographic highs and extensional in lows. As isostatic conditions are approached ($c=0.5, 1$), $\dot{\epsilon}_{xx}$ becomes extensional on highs and compressional in lows.

Figure 3. Shear stresses at the base of a brittle elastic layer due to relaxation of a topographic plateau. Although shear stresses are confined to the steep margins of the plateau, the brittle layer acts as a stress guide, transmitting horizontal normal stresses into the interior. Normal stresses are proportional to topography δ .

