THE RELATIONSHIP BETWEEN SURFACE TECTONIC STYLE AND MANTLE CONVECTION: EARTH AND VENUS; Stuart A. Weinstein and Peter Olson, Department of Earth and Planetary Sciences, The Johns Hopkins University, Baltimore, MD 21218

Radar images from Magellan and previous spacecraft show that there is a great difference between the styles of tectonics on the surfaces of Earth and Venus. On Earth, most of the surface deformation is confined to narrow zones, at plate boundaries, whose length scales are generally less than 100 km. The deformed regions of the Venusian surface are typically much broader with length scales of several hundred kilometers. Good examples of broad areas of deformation on Venus are the Tessera and Aphrodite Terra regions of Venus which have length scales on the order of 1000 km. In addition, based on the analyses of cross-strike discontinuities in Aphrodite Terra, the Earth's surface appears to be at least an order of magnitude more mobile than the surface of Venus. The goal of our study is to explain how such a great difference in surface tectonics can exist between planets which are physically very similar.

We examine a fully dynamic model for the interaction of a planetary lithosphere with a convecting mantle in an attempt to explain why the large difference in tectonic styles between Earth and Venus exists. Our model consists of a thin non-Newtonian lithosphere atop a Newtonian viscous mantle. The non-Newtonian lithosphere has a simple power law rheology characterized by a power law index n and a stiffness constant μ_p. The non-Newtonian lithosphere is deformed by the basal shear stresses produced by convection in the Newtonian mantle. The dynamics of the entire system is governed by three parameters: n, μ_p and the Rayleigh number Ra. We have conducted a systematic numerical investigation of this model in an attempt to understand the conditions needed for the creation of mobile, rigid plates that characterize deformation of the Earth's surface as well as the conditions needed to generate a style of deformation similar to that observed on Venus.

We have investigated steady, single cell configurations for Ra in the range $1 \times 10^4 \leq Ra \leq 5 \times 10^6$ and power law indices in the range $3 \leq n \leq 19$. μ_p is varied from 10^6 to 10^{85}. The results demonstrate that the non-Newtonian lithosphere has four regimes of behavior in the parameter space of n, μ_p and Ra. These four regimes have the following characteristics: (1) The lithosphere moves slowly with respect to the underlying flow and has broad zones of deformation, (2) Same as (1) except that the zones of deformation are narrow, (3) The lithosphere moves at velocities close to those of the underlying flow and has narrow zones of deformation, (4) Same as (3) except that the zones of deformation are broad.

The style of surface tectonics on Earth falls into regime (3) and that of Venus appears to correspond to regime (1). If the lithospheres of Venus and Earth have similar properties, excepting that the lithosphere of Venus is possibly weaker due to the fact it is warmer and perhaps thinner, the only way to change from regime (3) to regime (1) in the context of our model is to lower Ra. Therefore, based on the results of our model, we conclude that convection in the mantle of Venus may be characterized by a significantly lower value of Ra than convection in the Earth's mantle.