VENUS MAGMATIC AND TECTONIC EVOLUTION; R.J. Phillips[1] and V. L. Hansen[2]; 1. McDonnell Center for the Space Sciences and Department of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130. 2. Department of Geological Sciences, SMU, Dallas, TX 75275.

Introduction. Two years beyond the initial mapping by the Magellan spacecraft, hypotheses for the magmatic and tectonic evolution of Venus have become refined and focussed. In this abstract we present our view of these processes, attempting to synthesize aspects of a model for the tectonic and magmatic behavior of the planet. The ideas presented should be taken collectively as an hypothesis subject to further testing. The quintessence of our model is that shear and buoyancy forces in the upper boundary layer of mantle convection give rise to a spatially and temporally complex pattern of strain in a one-plate Venusian lithosphere and modulate the timing and occurrence of magmatism on a global basis.

Boundary Layer Phenomena. Sources of magmatism and tectonism are related to boundary layers within the mantle. The ones with reasonable certainty we presume to exist are at the base of the mantle associated with core heat flux (lower boundary layer) and beneath the mechanical lithosphere (upper boundary layer). The former is responsible for major plumes that create topographic rises. The latter is responsible for storing significant potential energy related to both internal heating and heat flux from the core. Because internal mantle heating should be energetically more important than core heat flux, tectonic deformation of the lithosphere should be controlled dominantly by actions in the upper boundary layer. Since Venus lacks an asthenosphere, boundary layer flow stresses couple directly into the lithosphere [1].

Plumes transfer both buoyant and shear forces to the overlying lithosphere and are responsible for broad topographic rises, associated rifting, and large partial melting events leading to residual crustal plateaus [2]. Flow in the upper boundary layer provides shear forces as well as large buoyancy forces supplied by the downwellings associated with return flow to the mantle. This can be enhanced by detached lithosphere containing significant eclogite.

The surface of Venus does not participate in the flow of the upper boundary layer, and major tectonic plate boundaries do not exist. Topographic analogies of coronal trenches with terrestrial subduction zones [3,4] have led to hypotheses regarding the recycling of the Venusian lithosphere. However, geological predictions of the subduction model are not borne out by observation [5]. For example, pre-trench radial structures emanating from corona centers are found in places to be continuous across putative plate boundaries.

In-plane tectonic force supplied by the boundary layer to the overlying lithosphere is estimated from long-wavelength gravity data to be in places at least 5×10^{12} N/m [6]. This is equivalent, approximately, to the buoyant energy in a 100–km length of a 100–km–thick boundary layer if the average temperature contrast of the boundary layer with the convecting mantle "core" is 500 K. This magnitude of in-plane force will lead to significant crustal deformation: ductile flow in the lower crust and brittle failure in the upper crust. The tectonic style of mountain belts suggests that deformational forces are supplied largely from below and are not related to plate boundary phenomena as on Earth [7].

Widespread Magmatism. The global occurrence of dark-floored craters provides evidence that volcanism has been widespread in space and time on Venus [8]. Given the random global distribution of impact craters, this suggests that partial melt has been widely available in the Venusian interior. This in turn implies that passive magmatism is an important process on Venus. By the term "passive" we mean that partial melts or incipient partial melting conditions have existed widely in the subsurface at relatively shallow depths (certainly less than 100 kilometers) and that volcanism results when tectonic conditions permit access of

magmas to the surface, either directly or by pressure release partial melting of upwardly mobile subsolidus material.

Forces supplied by the upper boundary layer, and to a lesser extent plumes rising from the core-mantle boundary, give rise to a complex, time-varying history of strain in the lithosphere. Where the lithosphere is placed in significant tension, volcanism occurs at the surface and is associated with broad, diffuse regions of mantle upwelling. Volcanism is thus widespread, despite the fact that at present constructional volcanism is concentrated regionally [9]. Volumetrically, topographically subtler plains volcanism dominates, and, because of the strain modulation of the lithosphere, during any geological episode volcanism is active in only a limited number of regions on the planet. However, over longer periods ($\sim$ 1 Ga) volcanism has taken place in almost every region.

It is widely held that the volcanotectonic coronae are the direct result of active mantle plumes and that coronae and topographic rises are part of a size-continuum of the same process: plumes formed at the core-mantle boundary [e.g., 10]. In this view, chains of coronae can give rise to rifts. We adopt an alternative view given by Tackley and his colleagues [11,12]. Deep mantle plumes are not a universal explanation for Venusian volcanic features extending over a broad range of sizes. The formation of coronae involves Rayleigh-Taylor melt instabilities forming at depths of incipient partial melting. Such instabilities are initiated by vertical velocity perturbations, which are provided by horizontal lithospheric extensional events that are regional in nature and initiated from time to time in the global strain regime of the lithosphere. Thus coronae formation follows rifting in a passive manner.

Origin of topography and its support. Topography on Venus arises from crustal thickening, from thermal isostasy, and from dynamic support by mantle convection. Significant crustal thickening takes place by large-scale partial melting associated with lower boundary layer plumes, and, if subsolidus crustal flow takes place on geologically reasonable time scales, with downwelling of the upper boundary layer leading to shear thickening of the lithosphere [13]. These mechanisms lead to crustal plateaus, examples of which include Ovda, Thetis, Alpha, and Tellus regiones. Thickening of the crust results also from upwellings in combination with lateral variations in lithospheric rheology [14,15], as might be expected for the strength contrast of crustal plateaus with their surroundings. Isostatic support by thickened crust is responsible for at least partial support of many features.

Conclusions. Venus is different from Earth because of the strong effect of the upper convecting boundary layer on the overlying lithosphere [1]. The lack of divergent plate boundaries means that magmatism and tectonism are controlled by a distributed strain regime in the lithosphere [16], which in turn is largely influenced by the upper boundary layer of mantle convection.

References. [1] R.J. Phillips, *Geophys. Res. Lett.* **13**, 1141; (1986); [2] R.J. Phillips *et al.*, *Science* **252**, 288 (1991); [3] D. McKenzie *et al.*, *J. Geophys. Res.* **97**, 13,533 (1992); [4] D.T. Sandwell and G. Schubert, *Science* **257**, 766 (1992); [5] V.L. Hansen and R.J. Phillips, *Science*, submitted (1992); [6] R.J. Phillips, *J. Geophys. Res.* **95**, 1301 (1990); [7] V.L. Hansen and R.J. Phillips, this volume (1993); [8] R.J. Phillips *et al.*, *J. Geophys. Res.* **97**, 15,923 (1992); [9] J.W. Head *et al.*, *J. Geophys. Res.* **97**, 13,153 (1992); [10] E.R. Stofan *et al.*, *J. Geophys. Res.* **97**, 13,347 (1992); [11] P.J. Tackley and D.J. Stevenson, *EOS* **72**, 287 (1991); [12] P.J. Tackley, D.J. Stevenson, and D.R. Scott, in Papers Presented to the International Colloquium on Venus, LPI Contribution No. 789, 123 (1992); [13] A. Lenardic, W.M. Kaula, and D.L. Bindschadler, *J. Geophys. Res.*, submitted (1992); [14] A.A. Pronin, *Geotectonics* **20**, 271 (1986); [15] R.E. Grimm and R.J. Phillips, *J. Geophys. Res.* **96**, 8305 (1991); [16] R.E. Grimm and S.C. Solomon, *J. Geophys. Res.* **94**, 12,103 (1989).