MODELS OF THERMAL/CHEMICAL BOUNDARY LAYER CONVECTION: POTENTIAL APPLICATION TO VENUS.

A.Lenardic and W.M.Kaula, UCLA Dept. of Earth and Space Sciences, Los Angeles, CA 90024

N94-16348

Introduction: The upper boundary layer of Venus is comprised of at least two distinct chemical components, mantle and crust. Fluid dynamical models of convection within Venus' mantle have been primarily of the thermal boundary layer type. Models assessing the ability of convective mantle flows to deform the crust have been undertaken, but models exploring the effects of a variable thickness crust on mantle convection have been largely lacking. A Venusian crust of variable thickness could couple back into, and alter, the mantle flow patterns that helped create it, leading to deformation mechanisms not predicted by purely thermal boundary layer convection models. We explore this possibility through a finite element model of thermal/chemical boundary layer convection. Model results suggest that a crust of variable thickness can serve as a mantle flow driver by perturbing lateral temperature gradients in the upper mantle. Resulting mantle flow is driven by the combination of free convection and nonuniform crustal distribution. This combination can lead to a flow instability manifest in the occurrence of episodic mantle lithosphere subduction initiated at the periphery of a crustal plateau. The ability of a light, near surface, chemical layer to potentially alter mantle flow patterns suggests that mantle convection and the creation and/or deformation of such a chemical layer may be highly nonseperable problems on time scales of 10^8 years.

Models and Discussion: We employ a 2-D finite element code [1], modified to treat multi-component flow problems [2]. We model a system comprised of a thin layer of chemically light material, meant to mimic crust, imposed within the upper thermal boundary layer of a deep layer of heavier, thermally convecting material, meant to mimic mantle. Isoviscous and temperature and composition dependent newtonian rheologies are investigated.

For the type of system we model, the crust can potentially thicken above mantle downwellings: zones of near surface convergence [3]. Once a crust of spatially varied thickness has been established it can serve as a driver for flow in the mantle [4,5,6,7,8]. Mantle flow associated with crustal thickness variations results from the modification of horizontal temperature gradients in the upper most mantle by one or more of the following effects: 1) lower thermal conductivity in the crust vs. mantle; 2) higher density of heat producing elements in the crust; 3) crustal thickness approaching the unperturbed thermal boundary layer thickness. For a mantle marginally stable against convective instability due to vertical temperature gradients, horizontal temperature gradients due to crustal thickening can cause an instability characterized by traveling or standing wave solutions for the crust/mantle interface [7]. For an unstable mantle, system evolution can be characterized as the nonlinear superposition of flow due to free convection in the mantle and flow driven by horizontal temperature gradients due to a nonuniform distribution of a light chemical component in the upper thermal boundary layer [5]. When the light component is deformable crust, as in the case of our models, crustal deformation and mantle flow become tightly coupled (i.e., crustal deformation resulting from flow in the mantle leads to spatial and temporal redistribution of crustal thickness, which feeds back into the mantle altering the flow via the introduction of horizontal temperature variations dependent on the shape of the crust/mantle interface, which in turn affects subsequent deformation, etc.). The interconnection of mantle flow drivers in such a system allows for deformation mechanisms unique to thermal/chemical boundary layer convection. A specific mechanism is associated with an upper boundary layer instability that has some similarity to lithospheric subduction [9]. This instability can be episodic in nature; delay intervals are characterized by heating of the mantle and relative stagnation of flow while instability intervals involve bursts in flow velocities and significant increases in surface heat flux.

Conclusion: Thermal/chemical boundary layer convection models show how nonuniform crustal thickness can alter convective flows in the mantle, the strongest alteration involving complete flow reversal. Strong time dependence occurs at Rayleigh numbers for which thermal boundary layer models predict largely steady state flow in the mantle, i.e., relatively fixed convection cells. Model results suggest that, on the time scale of mantle overturn, crustal deformation and mantle convection can not be treated as separable problems (this statement also applies to the interaction of a residuum layer with mantle convection). The models further elucidate various flow and deformation mechanisms unique to thermal/chemical boundary layer systems. The relevance of these mechanisms to the evolution of Venus awaits more thorough comparisons of various model predictions to geophysical observations. What seems certain is that differentiated terrestrial planets possessing thermal/chemical boundary layers will evolve differently from hypothetical planets possessing purely thermal boundary layers. As such, further fully dynamic convection models allowing for thermal/chemical boundary layers are in order.

[**1**]King, S.D. et al., *Phys. Earth Planet. Inter.*, *59,* 195-207, 1990. [**2**]Lenardic, A., and W.M. Kaula, *J. Geophys. Res.*, *97,* accepted, 1992. [**3**]Bindschadler, D.L., and E.M. Parmentier, *J. Geophys. Res.* *95,* 21,329-21,344, 1990. [4]Pekeris, C.L., *Roy. Astron. Soc. Geophys. Suppl.*, *3,* 343-367, 1935. [**5**]Elder, J., *Nature*, *214,* 657-660, 1967. [**6**]Howard, L.N., et al., *Geophys. Fluid Dynamics*, *1,* 123-142, 1970. [**7**]Busse, F.H., *Geophys.J. R. astr. Soc.*, *52,* 1-12, 1978. [**8**]Gurnis, M., *Nature*, *332,* 695-699, 1991. [**9**]Lenardic, A., et al., *Geophys. Res. Lett.*, *18,* 2209-2212, 1991.

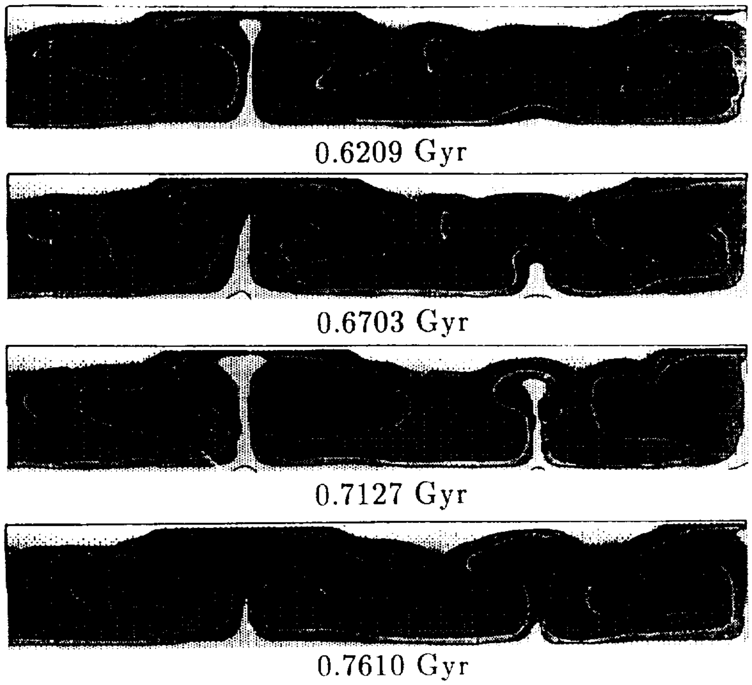

Fig. 1: Density field frames (light indicates lowest density, i.e., crustal material, and dark highest density, i.e., mantle lithosphere) from a 6x1, isoviscous, model, the initial conditions of which had a thin, uniform, crustal layer embedded within the upper thermal boundary layer of the convecting mantle layer. Thermal Rayleigh number, defined for pure bottom heating, is 10^5; reference crust and mantle densities are 2900 and $3300kg/m^3$; system depth is $700km$; initial crustal depth is $28km$, and the thermal conductivity of the crust is one fourth that of the mantle, i.e., results of this model are akin to the crustal thickness instability investigated analytically by Busse [7]. Dimensional time below each frame is from the initial start time of the model. The top portion of the frames is slightly stretched for ease of visualization. Note how the region of thick crust, slightly to the right of center, which formed over a mantle downwelling, alters the convective flow in the mantle by damping heat flux out of the mantle and, as a result, leads to a mantle upwelling below itself. In the absence of a thin, nonuniform, crustal layer, the convective cells in the mantle layer remain fixed in space and in number.