**CRUSTAL RECYCLING DUE TO MANTLE FLOW-DRIVEN CRUSTAL THICKENING: A PRELIMINARY ASSESSMENT;** Jeffrey D. Burt, E. M. Parmentier, and James W. Head, Department of Geological Sciences, Brown University, Providence, RI 02912.

**Introduction:** Crustal recycling on Earth occurs at convergent plate boundaries. Magellan mission data indicate there is no global plate tectonic system on Venus (1). A fundamental question for Venus is how crust recycles in the absence of plate tectonics. A second fundamental question is the origin of venusian highland regions. Can crustal thickening associated with mantle downwelling cause plateau-like, compressional highlands (2)? What are the relative roles of thermal buoyancy in the mantle and buoyancy due to the gabbro-eclogite phase change in crust in governing the evolution of highland regions? Studies of the effects of the gabbro-eclogite phase transformation on the isostatic elevation of the compressional mountain belts of Venus predict that compressional crustal thickening in the presence of a shallow thermal gradient may lead to eclogite formation in a crustal root and to possible delamination (3), while low water concentrations in venusian rocks may slow the gabbro-eclogite transformation and allow isostatically balanced mountain belts to reach great elevations (4).

We explore the possibility that large compressional highland terrains could be sites of crustal recycling. If horizontally convergent mantle flow at a downwelling leads to crustal thickening, then the gabbroic crustal root thus formed could deepen sufficiently to transform to eclogite. If the crustal root were to become sufficiently negatively buoyant, an instability would form leading to crustal loss into the mantle and contributing to mantle flow. This may develop into a self-sustaining system which for some span of time may act to gather and recycle crustal material into the mantle. In contrast to (5), who consider crustal recycling linked to thermally driven mantle flow, we examine the influence of crustal buoyancy forces due to the gabbro-eclogite phase transformation.

**Model:** We consider a compositionally buoyant basaltic crust (3000 $kg/m^3$) of thickness Tc overlying a peridotite mantle (3360 $kg/m^3$). Both are assumed to behave as viscous fluids, with the mantle viscosity ten times greater than that of the crust. Assuming the model region is small relative to the region of mantle flow, we model the effects of large scale mantle downwelling and horizontal convergence by imposing a horizontal velocity boundary condition (Vc) on one side of the model while fixing the other. Flow is also driven by buoyancy forces resulting from the topography on both the crust-mantle boundary and on the surface. We calculate flow due to both forces using finite element approximations. Changes in density due to the gabbro-eclogite phase change are determined using a basalt stability field defined in P-T space. Latent heat of reaction effects on the temperature field are included (6), but the effects of heat conduction are not. In our results we look for evidence that eclogitic material has formed in sufficient quantities in the crustal root to enable the resulting buoyancy forces to begin to dominate the material flow. The imposed boundary velocity causes continuous horizontal compression and crustal thickening. With an initially uniform crustal thickness, eclogite would eventually form in a broad region at the base of the crust. We wish to consider instead the behavior of an initial thickened region of crust that might be the remnant of earlier magmatic activity.

We introduce an initial, isostatically balanced, crustal thickness variation and examine how this perturbation evolves. The balance of thinning due to relaxation of crustal thickness variations, and thickening due to horizontal shortening focussed on the relative weakness of the crust in the thicker region, governs crustal thickening. The balance of these effects depends upon the viscosities of the crust and mantle and the magnitude of Vc. Larger viscosities reduce buoyancy-driven flow, allowing the convergence velocity to dominate. We seek to define the conditions, or the range of model parameters, which would allow the gabbro-eclogite transformation to affect this balance and lead to crustal thickening. Thus, we examine the conditions leading to the development of a self-sustaining, eclogite-driven downwelling. In this preliminary study we investigate the role of crustal thickness and convergence velocity in promoting the phase change in, and eclogite-driven flow of, the crustal root.

**Results:** For a 100 km long and 100 km deep model region with a mantle viscosity of $10^{21}$ Pa s, we present preliminary results for different values of Vc and initial Tc. We have chosen a thermal gradient of 4K/km with a surface temperature of 725 K. The convergence velocities used correspond to rates of 1 km/My and 10 km/My.

For Tc=20 km the root of the thickened zone initially lies at 40 km depth. Convergence leads to crustal thickening and deepening of the root, allowing root material to transform to eclogite. Figure 1 shows the crustal thickness ratio between the thick zone and crust away from the initial thickening. Convergence, without the phase change, allows crustal thickness variations to diminish (lower line in Figure 1). When negative buoyancy forces due to eclogite are included, crustal thickness variations still decrease, but more slowly.

Figure 2 (a-c) shows a model beginning with a thicker crust (Tc=40 km) having a root already lying within the eclogite stability region. Flow due to negative buoyancy forces in the dense crustal root becomes significant relative to convergence flow (Vc=1 km/My). The sequence of figures illustrates how flow driven at first by convergence becomes dominated by negative buoyancy, increasing the rate of crustal thickening. Figure 2d shows the importance of the phase change in enhancing the crustal thickness variation. Without the phase change, shown by the descending curve, the thickness variation dissipates, while the reverse is true when the phase change is included.

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**Discussion:** This preliminary work illustrates the manner in which mantle-driven crustal thickening could lead to the formation of a negatively-buoyant crustal root. For an initially thick crust, the body forces in a dense eclogitic root will enhance the crustal thickening effects of convergence. Continuing convergence and thickening increases the amount of eclogite. Flow due to the growing buoyancy forces of the root will eventually become significant relative to convergence-driven flow and lead to the instability of the root and the descent and recycling of root material. This scenario may be appropriate to areas where anomalously thick crust has been created by means such as magmatism and later cooling brings the root within the eclogite stability field.

For a thin crust, the initial zone of thickening relaxes. Continued convergence will cause thickening over a broad region. The wavelength of an eventual instability may not be related to the size of the initial zone of excess crustal thickness. Instead, the instability wavelength will be determined by the relative thicknesses of the basalt and eclogite layers and the mantle and crustal viscosities. It is important to recall that these preliminary models do not yet include the effects of heat conduction or crustal radioactivity, both of which will tend to heat regions of thickening crust therefore inhibiting eclogite formation. Including these effects is the next step in our modelling studies.

**References:** 1) Solomon, S.C., et al., JGR, 97, 13199-13255, 1992. 2) Bindschadler, D.L., and E.M. Parmentier, JGR, 95, 21329-21344, 1990. 3) Vorder Bruegge, R.W., and J.W. Head, Geology 19, 885-888, 1991. 4) Namiki, N., and S.C. Solomon, JGR, 98, 15025-15032, 1993. 5) Lenardic, A., W.M. Kaula, and D.L. Bindschadler, JGR, 98, 18697-18706, 1993. 6) Turcotte, D.L. and G. Schubert, JGR, 76, 7980-7987, 1971.

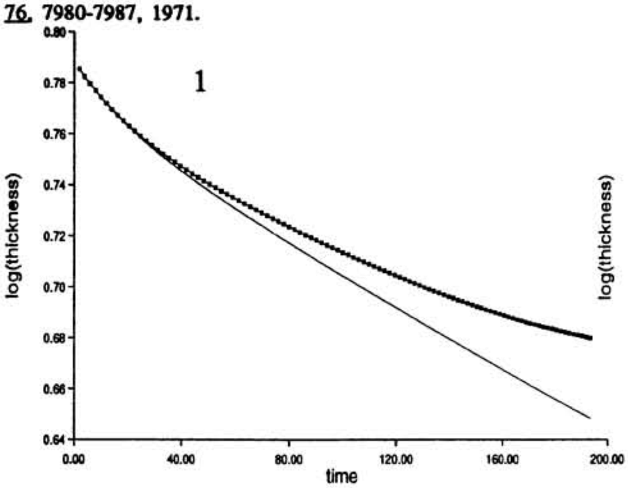


Figure 1. Log of crustal thickness ratio vs time for Tc=20 km. Dotted line shows the model including the phase change while solid line shows results without the phase change.

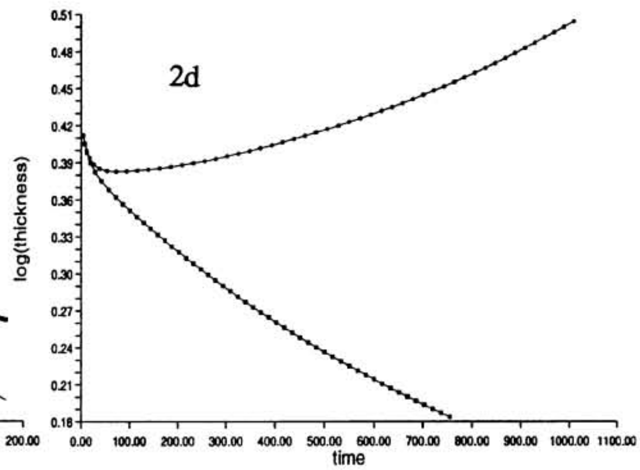


Figure 2. Model evolution for Tc=40 km. Light tone is mantle, medium is gabbro, and darkest is eclogite. Flow is shown by lines segments. Timesteps correspond to times of: a) 250, b) 750, and c) 1100 on the scale of figure 2d. 2d shows the log crustal thickness ratio vs time.