THE ROLE OF CRUSTAL INSTABILITY IN CRUSTAL RECYCLING ON VENUS;

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INTRODUCTION: The apparent surface age of Venus, established through study of the impact cratering record, and the lack of global plate tectonics, establishes a need for mechanisms of crustal recycling and resurfacing. Proposed resurfacing models include episodic plate tectonics [1] and periodic accumulation and catastrophic loss of a depleted mantle layer [2]. Vertically accumulated crust on a one-plate Venus may be limited in thickness by the gabbro-eclogite phase change. This implies a simple recycling mechanism in which crustal material either converts to, or is accreted as, eclogite, then is lost by sinking into the mantle. The manner in which this would occur, the scale of the eclogitic bodies lost, and the efficiency of the mechanism are unconstrained.

Crustal accumulation accompanied by mantle flow-driven deformation should create an uneven distribution of crustal thickness. Deep roots of anamolously thick regions could be subject to the phase change, leading to their eclogitization and the onset of instability. The size of the anomalous region, both vertically and horizontally, will determine the rate of growth of the instability. Once initiated, the growing negative diapir could drive flow in the crust and mantle and result in the formation of unique surface topographic and tectonic features. In order to recognize the characteristic surface expression of eclogite-driven diapirism and crustal recycling, modelling of diapir growth is necessary. This we have undertaken using a finite element model for crustal and mantle flow driven by buoyancy forces.

MODEL: The model assumes a viscous layering of gabbroic crust over a peridotite mantle. Buoyancy forces due to layer topography and material density drive flow. Density changes due to the gabbro-eclogite phase change are determined using a pressure-temperature defined basalt stability field. The phase change is assumed to occur instantaneously. Thermal effects on the phase change, including those due to heat diffusion, radioactive heat production, and heat evolved in the phase change, are also determined. Structurally, the model incorporates a strong upper and weak lower crust, a strong upper mantle, and a layer of depleted mantle. In this preliminary investigation variation of parameters of layer thicknesses, layer strengths, and the initial width of the crustal thickness perturbation are studied. Flow is calculated using a Lagrangian finite element method in an axisymmetric geometry. As an initial condition a zone of anomalously thickened crust is assumed, having a root deep enough to contain sufficient eclogite to result in net negative buoyancy.

RESULTS: This study has focused on the characteristics of the surface evidence of the instability. In general, the growth of the instability creates a broad topographic depression as the eclogitic root affects the isostatic balance. Predicted surface deformation includes compression (radial) within the depression and extension, beginning on the depression rim, and diminishing with distance away from the rim. Crustal thickness, layer strengths, and horizontal scale influence the depression depth. Depressions are deeper for greater crustal thickness and greater zone width. Thicker crust allows more rapid flow of material into the instability, adding directly to the growing eclogite body and the negative buoyancy that depresses the surface isostatically. Depression depth increases with zone width probably because of more rapid development of the instability. The relative thicknesses and strengths of the upper and lower crust also influence depression depth. When the upper crust is thicker than the lower crust, lower crustal flow is diminished, which would be expected to slow the growth of the instability and result in shallower depressions. However, lower crustal flow may also be important in providing gabbroic material to the zone above the phase change depth, thus partially compensating for the negatively buoyant root. The result is that a thick strong upper crust leads to deeper depressions than a thick lower crust. The compensating affect of lower crustal flow is more important when the strength contrast between the upper and lower crust is larger. A thin strong upper crust in combination with a thick very weak lower crust produces slightly positive topography instead of a depression.

DISCUSSION: The results of this model indicate that the surface evidence of crustal instability growth includes the development of a broad depression within which compressional deformation is expected and which will be flanked by extensional tectonics diminishing with distance away from the depression. The depth of the depression is influenced by factors of crustal thickness, zone width, and layer strengths and thicknesses. High topography, such as the formation of plateaus, is not expected over diapirs, though depressions range in depth and the instability may be marked by slightly raised topography for some parameter values. Since the Venus crust and mantle may contain little water, the strength characteristics of dry materials may be most appropriate [3]. In this case, a weak lower crust is not expected to exist, and the growth of the instability would be slowed by the lack of lower crustal flow. However, the surface expression of the instability would still include development of a depression as well as the compression and extension described above.

The dry conditions of Venus may also make the phase change occur slowly, since volumetric diffusion may dominate ion transport rather than grain boundary diffusion [4,5]. We do not expect this to change the fundamental character of the surface expression of instability growth. The slowed phase change may limit the size that an eclogitic root can reach before sinking into the mantle, thus the horizontal scale of the topographic depression may be smaller than in the instantaneous phase change case.

These calculations are limited by deformation of the finite element grid. Development of the instability can be followed for early stages as the root begins to descend and form a drop-like shape. Later stages of instability growth are expected to resemble the early development except for the stage at which the root detaches from the crust. Descent of a detached root may continue the mantle and crustal flow pattern of earlier stages, but diminishing in strength with time as the root body deepens. Relaxation of topography and counterflow may follow unless delamination leaves sufficient eclogitic root to trigger further diapirism.

Further investigation will attempt to better define the favored scales of instabilities, as well as the timescales of development. We will also seek to define the evolution of surface deformation and tectonics.

REFERENCES: [1] D.L. Turcotte, [2] E.M. Parmentier and P. Hess, *GRL, 19*, 2015-2019, 1992. [3]S.J. Mackwell et al., *LPSC XXV*, 817-818, 1994. [4] N. Namiki and S.C. Solomon, *JGR, 98*, 15025-15032, 1993. [5] T.J. Ahrens and G. Schubert, *Rev. Geophys., 13*, 383-400, 1975.