MORE SPECULATIONS ON THE ORIGIN OF THARSIS RISE. S. D. King[1], [1]Virginia Tech Geosciences, 4044 Derring Hall, Blacksburg, VA 24061 (sdk@vt.edu).

Introduction: Mars has two striking global-scale geologic features: the crustal dichotomy, a systematic elevation difference between the northern and southern hemispheres, and Tharis rise, a region of thick volcanic crust covering almost 25% of the surface of the planet. Tharsis rise formed near the edge of the crustal dichotomy and the spatial association between these features has lead to speculation that the processes forming them are related [1-4]. I present calculations of convection in a 3D spherical-shell geometry with temperature-dependent rheology and an imposed hemispheric dichotomy in the near surface viscosity to approximate the crustal dichotomy. For sufficiently thick viscous hemispheres, small-scale convection develops along the dichotomy boundary and the melt generated by this flow is sufficient to create Tharsis rise, providing a natural explanation for the spatial association between Tharsis rise and the crustal dichotomy.

The crustal dichotomy is separates the smooth, low elevation northern hemisphere from the heavily cratered, higher elevation southern hemisphere and is among the oldest features on Mars. While both endogenic and exogenic origins have been debated [5-7], the crustal dichotomy was in place by the early Noachian (i.e., 4.0 Ga) [8]. At this early time in martian history, the lithosphere would have been significantly thinner than today and the difference in crustal thickness [9] could have played a significant role in the planform of mantle convection [1].

The lithosphere beneath the southern martian highlands may be similar to the deep cratonic roots beneath the Archean cratons on Earth, which extend to depths of 250~km or greater [10]. While the formation of cratonic roots on Earth remains the subject of debate, the subcratonic lithosphere must be both more buoyant and viscous, possibly due to dehydration, to remain stable for 2.5-3.0 Gyr [10]. Small-scale convection may be responsible for some areas of intra-plate volcanism on Earth [11-12] particularly where volcanism occurs within 600-1000~km of a craton boundary [13]. A similar small-scale convective flow at the crustal dichotomy boundary could provide the upwelling velocity necessary to generate the melt that formed Tharsis rise.

The Tharsis province is a nearly-circular, 2,000-km diameter swell rising almost 10 km above the surface. At least one of the volcanoes on the Tharsis swell, Arsia Mons, may have been active within the last 10-40 Myr [14-15]; however, the majority of the volcanic material was in place by the end of the Noachian, within approximately 200-500 Myr after the formation of the crustal dichotomy.

A mantle plume has been proposed to provide the heat necessary to generate the melt that formed Tharsis swell [16-18]. Both a deep-mantle endothermic phase transformation and a viscosity increase in the mid-mantle have been shown to produce a single upwelling plume (i.e., degree-1 convection) [19-20]. Whether or not there is an endothermic phase transformation at the base of the mantle exists is largely controlled by the size of the martian core [17]. Tank experiments with a step change in the thickness of the viscous surface layer to simulate the effect of a thick and thin lithosphere find that a stable upwelling plume forms under the center of the thick lithosphere [1] and not near the boundary between the thick and thin surface layer. A large stable plume develops under the *thin* hemispherical cap in spherical convection models with a temperature and pressure dependent viscosity (Fig. 1).

I consider a series of convection calculations with a thick viscous cap covering one hemisphere to test the hypothesis that small-scale convection driven by a step change in thickness in the martian lithosphere would generate sufficient melt to produce Tharsis rise. I use the finite element code CitcomS [21-22] to solve the equations for 3D spherical, incompressible, convection with a wet olivine-based temperature-dependent rheology [23] and a core-mantle boundary radius of 0.41 times the planetary radius, giving a silicate mantle thickness of 2000 km. The calculations begin from a uniformly hot mantle and convection evolves for at least 500 million years. I vary the Rayleigh number between 10^6-10^9 and use an internal heat generation. To simulate the effect of a thick viscous root under the southern martian highlands, I impose a viscosity increase of 1000 over one hemisphere of the spherical shell and vary the thickness of this high-viscosity layer from 170-340 km.

Results: I compare the isothermal surfaces and melt from spherical calculations with a uniform stagnant lid and a hemispherical viscous dichotomy. Both calculations use temperature-dependent rheology and are in the stagnant-lid convection regime with a high viscosity lid resulting from the thermal boundary layer even without the imposition of a high viscosity over one hemisphere.

The thick high-viscosity hemisphere extends to 340 km depth, or $1/10^{th}$ of the planetary radius. For the calculation with the uniform lid, the planform is the

degree 1 upwelling structure consistent with previous stagnant lid convection calculations [19-20].
In contrast, the calculation with the viscosity dichotomy there is a significant difference in the convective planform of the two hemispheres with small-scale convection in the form of long rolls aligned perpendicular to the step in viscosity developing within the first 100 million years. Beneath the thin hemisphere an upwelling plume forms (Fig. 1), in contrast to the planform found in tank models with variable lithosphere thickness [1]. Time-dependent small-scale structure developes at the lithosphere boundary and melt forms in the upwelling limbs of the small-scale roles near the step in the lithosphere. This result is similar to the form of small-scale convection has been observed in 2D Cartesian calculations [11-12]; however the structure of the small-scale flow along the strike of the viscosity step can not be investigated in 2D. The wavelength of these small-scale rolls is a function of Rayleigh number with wavelengths decreasing with increasing Rayleigh number.

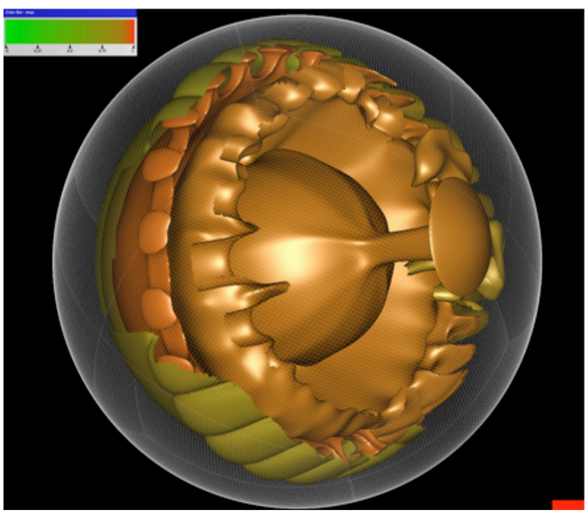

Figure 1. Isotherms from a temperature-dependent, internally heated convection model showing a single upwelling plume beneath the thin hemosphere with small-scale convection along the lithospheric step. The Rayleigh number is 10^8 and the thick viscous hemisphere (far) is 340 km thick.

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