GEODYNAMIC ORIGINS OF THE THARSIS AND ELYSIUM VOLCANISM J. P. Murphy[1] and S. D. King[2], [1]Virginia Tech Department of Geosciences, Blacksburg, VA [jmurph16@vt.edu], [2]Virginia Tech Department of Geosciences, Blacksburg, VA [sdk@vt.edu].

Introduction: Mars has two major centers of volcanic activity: Tharsis and Elysium. The origin of the Tharsis rise is generally ascribed to one or more long-lived mantle plumes [1-5]. While most of the rise was emplaced by the end of the Noachian and the large volcanic shields in the Hesperian, the region has remained volcanically active for most of the planet's history [6-8], and as recently as 2.4 million years ago [7]. The relatively recent volcanic activity and modeled long-term stability of convection in the Martian mantle indicates that mantle melting is still occurring in the present day [3, 4, 9]. Elysium likewise shows evidence for billions of years of volcanic activity [10]. Using 3D geodynamic models of the Martian mantle, our goal is to explain the volcanism in both provinces and the difference in magnitude between them.

The Tharsis rise straddles the dichotomy boundary between the thicker crust of the southern highlands and the thinner crust of the northern lowlands [11]. Overall the highlands have a ~26 km thicker crust than the lowlands [11-13]; however, the contrast in crustal thickness does not exactly match the topographic boundary of the dichotomy [12]. The origin of the dichotomy is still highly uncertain. It may be of internal origin, for example the result of degree-1 mantle convection [14, 15], or from a giant impact [16-18]. A hybrid origin from degree-1 mantle convection caused by the giant impact has also been proposed [19]. Others have considered a causal link between the dichotomy and Tharsis [5, 20-24]. One proposed mechanism for this link is that Tharsis is the result of small-scale edge-driven convection at the dichotomy boundary [21].

Modeling: We investigate the origin and evolution of Martian volcanism and evaluate the potential for small-scale convection at the dichotomy boundary to have produced the Tharsis and Elysium volcanism along and north of the boundary. To do this we construct and analyze 3D spherical shell models of solid-state convection in the Martian mantle using a modified version of the finite element code CitcomS [25-27], which is designed to solve problems in thermochemical convection in planetary mantles. Modifications include a cooling core boundary condition, decaying internal heating, crustal enrichment of HPE, the dichotomy, and melting. In addition to a simplified degree-1 hemispherical dichotomy, we consider a realistic dichotomy geometry derived from elevation and gravity data., with Tharsis removed using the method of [16] and [28].

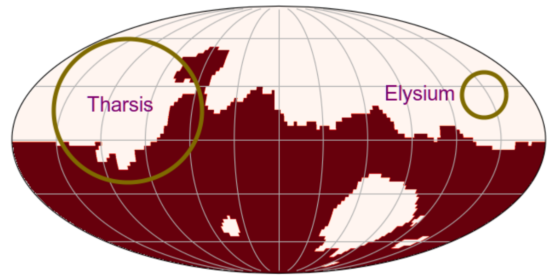

Figure 1: Our dichotomy with Tharsis removed using the method of [20] and [31].

The melt fraction field X is calculated using the formulation of [29] for dry peridotite. The melt production rate is

$$\dot{M} = \frac{DX}{Dt} = \frac{\partial X}{\partial t} + \mathbf{u} \cdot \nabla X$$

where t is time and **u** is the mantle velocity.

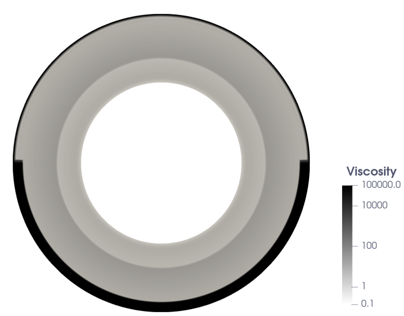

Figure 2: Initial non-dimensional viscosity structure (reference viscosity 10^{21} Pa·s) of one of our models, showing a degree-1 dichotomy (thick southern hemisphere lithosphere) and a mid-mantle viscosity jump.

Preliminary Results and Discussion: Our modeling indicates that a realistic initial step in crustal or lithospheric thickness (i.e., not too thick) associated with the dichotomy boundary is not sufficient to maintain small-scale convection for the billions of years needed to explain the Tharsis volcanism. Alternatively, some models, in response to the dichotomy and mid-mantle viscosity contrast (Figure 2), produce a plume that rises up in the middle of the southern hemisphere and migrates toward the equator (Figure 3). This plume migration would be consistent with the region of thickened southern hemisphere crust identified by [13] as analogous to the path of thickened crust associated with the terrestrial Snake River-Yellowstone hot spot track.

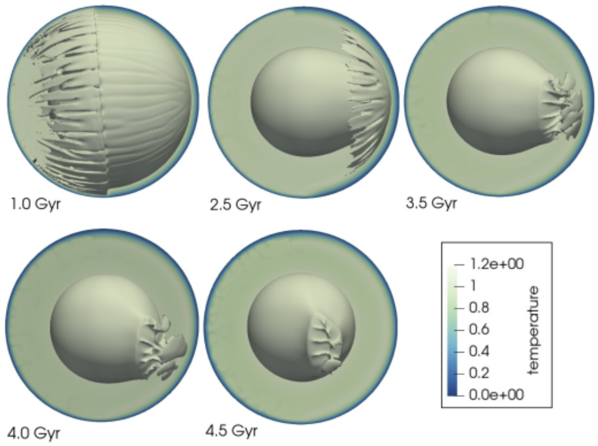

Figure 3: Evolution and migration of a single large plume (degree-1 convection). The lithosphere (1000× reference viscosity) is 350 km thick and there is a 10× viscosity increase at 1000 km depth. The Rayleigh number is 2.08×10^5.

The quantity and timing of melt production appears to be highly sensitive to the initial mantle temperature profile. It is difficult to continue producing small amounts of melt for over up to the present day. If the mantle starts out too hot, a layer of partial melt, leading to continued high melt productivity, persists for billions of years. If the mantle is starts out cooler, no melt is produced after 1-2 billion years.

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