NET ROTATION OF LITHOSPHERE FOR ONE-PLATE PLANETS AND ITS IMPLICATIONS FOR FORMATION AND EVOLUTION OF THARSIS RISE. Shijie Zhong, Department of Physics, University of Colorado at Boulder, Boulder, Colorado 80309, USA, szhong@colorado.edu.

Introduction: Crustal dichotomy and Tharsis Rise are the two most important geological features on Mars. Their formations in the first 0.8 Ga of Martian history dictate the tectonic and thermal evolution of the planet [1-3]. A number of observations suggest that the time span between formations of crustal dichotomy and Tharsis is relatively short and is probably between 200 Ma and 500 Ma [2-5], implying a possible link between these two events. Indeed, crustal dichotomy and Tharsis Rise share some important common features. Both the dichotomy and Tharsis are most likely caused by volcanic and magmatic activities in the early history of Mars [2,3,6]. Both of them display a predominately hemispherically asymmetric structure. However, there are also important differences. While the thickened crust of crustal dichotomy is centered near the south pole, the center of Tharsis is nearly 90° away at the equator. Furthermore, surface geophysical and tectonic observations suggest that the volcanic center of Tharsis may have migrated from the Thaumasia region (~40oS) equator. Furthermore, surface geophysical and tectonic observations suggest that the volcanic center of Tharsis may have migrated from the Thaumasia region (~40oS) of the southern hemisphere to the current location from the Early Noachian to the Late Noachian [7-9].

A number of studies have addressed various aspects of Tharsis formation and its possible links to crustal dichotomy. 1) Considering crustal dichotomy as a pre-existing feature and exploring its insulating effects on subsequent mantle dynamics, both numerical and laboratory studies have shown that while mantle plumes exist in different regions of the mantle, more plumes are generated in the mantle below the insulating surface (i.e., the thickened crust) [10,11]. However, these studies did not answer why Tharsis is largely centered at the dichotomy boundary and why the Tharsis volcanism only occurs in one hemisphere (i.e., a hemispherically asymmetric structure). 2) A solid-solid phase transition from spinel to post-spinel, if existing in the Martian mantle, may produce degree-1 convection (i.e., one-plume convection) on a time-scale of several Ga that was used to explain the Tharsis’ hemispherically asymmetric feature [12]. This model did not address any possible link of Tharsis to crustal dichotomy. Furthermore, the time scale of several Ga needed to produce degree-1 convection in this model is much too long to reconcile with the inferred Noachian age of Tharsis [4]. A recent study [13] shows that this phase change mechanism fails to produce degree-1 convection if either temperature-dependent viscosity or more realistic convective vigor (i.e., Rayleigh number) is used. (3) Mantle convection with a weak asthenosphere produces degree-1 convection for realistic temperature dependent rheology and on time-scales comparable with that inferred from observations [13,14]. Although this mechanism was originally proposed for explaining crustal dichotomy, it is general enough to be applicable to the formation of Tharsis. However, the possible link between crustal dichotomy and Tharsis has not been explored in this model.

In this study, I present a new mechanism of net rotation of lithosphere that links the formation of Tharsis to crustal dichotomy and explains all the basic features of Tharsis.

Models: My model is motivated to explain the northward migration of Tharsis volcanic center from the thickened crust of the southern hemisphere and the final location of Tharsis at the dichotomy boundary. My hypothesis is that there is a relative motion between an one-plume structure responsible for Tharsis volcanism and the overriding lithosphere, similar to how the Hawaiian volcanic chain on the Earth is generated. However, Mars is an one-plate planet with no plate tectonics at least since the pre-Noachian time [2-3] and Martian mantle convection is in a stagnant-lid regime [2-3,15]. I propose that the net rotation of lithosphere with respect to the mantle (i.e., degree-1 toroidal motion), as a unique mode of mantle convection can occur for one-plate planets, as with this mode of convection, the lithospheric shell rotates as a whole relative to the mantle with no need for internal deformation of lithosphere which is prohibited in stagnant-lid convection. Net rotation of lithosphere exists in Earth’s plate motion and can be generated most effectively in mantle convection with lateral variations in lithospheric thickness including continental keels [16]. Therefore, the objective of my modeling is to examine the role of lithospheric thickness variation in causing net rotation of lithosphere for one-plate planets.

My modeling consists of two steps. The first is to generate degree-1 convection with one-plume structure via a weak asthenosphere [13,14]. The second step is to explore the interaction of degree-1 convection with lithosphere with laterally varying thickness. If the thickened crust of crustal dichotomy is caused by additional melting in endogenic processes, either via degree-1 mantle convection [13,14] or overturn of magma ocean residue [17], the melt residue should be significantly thicker below the thickened crust (i.e., the southern hemisphere). Since the viscosity of the melt residue is likely to increase by a factor of ~100 or more
due to dewatering effects [18,19], it is expected that the viscous lithosphere in the southern hemisphere is significantly thicker than that in the northern hemisphere which should have more uniform lithospheric thickness given the uniform crustal thickness there. Considering that the plumes tend to form below the thickened crust of crustal dichotomy [10,11], I place the one-plume structure below the thickened crust (i.e., the hemisphere with thickened lithosphere).

**Results:** Step one modeling is similar to that in [13] and produces degree-1 convection with a weak asthenosphere (Fig. 1a). Such degree-1 convection does not contain any net rotation of lithosphere and is very stable in its configuration. In step two, I introduce hemispherically asymmetric lithospheric thickness variations such that the plume from step one modeling is centered below the thickened lithosphere but with 20° offset from the center of the thickened lithosphere or crust, for modeling purpose. Significant net rotation of lithosphere with respect to the mantle or the one-plume structure starts as soon as step two modeling begins. The separation between the center of the one-plume structure and the center of thickened lithosphere or crust increases steadily with time (Figs. 1b and 2) until the plume is near the dichotomy boundary where lithospheric thickness variations vanish. The rate of net rotation of lithosphere is sensitive to the asthenospheric viscosity. The smaller the asthenospheric viscosity, the faster the net rotation of lithosphere (Fig. 2).

**Conclusions and Discussions:** I demonstrate that the dynamic interaction between degree-1 convection and lithospheric thickness variations that results from the formation of crustal dichotomy due to melting may cause large net rotation of lithosphere with respect to the one-plume structure, thus explaining the basic observations of Tharsis including: 1) the hemispherical asymmetry of Tharsis volcanism, 2) the northward migration of Tharsis volcanic centers from the thickened crust of the southern hemisphere, and 3) the final dichotomy-boundary location of Tharsis. This new model offers a physical mechanism to unify the formation of both crustal dichotomy and Tharsis. The large net rotation of lithosphere revealed in my model challenges the basic tenet of planetary mantle dynamics for one-plate planets that lithosphere is stagnant with no large-scale motion with respect to the underlying mantle.