Geophysical Research Abstracts,
Vol. 10, EGU2008-A-01977, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-01977
EGU General Assembly 2008

Net rotation of lithosphere-shell driven by one-plume convection – A unified model for crustal dichotomy and Tharsis on Mars

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A number of observational evidences suggest that the time span between formations of crustal dichotomy and Tharsis is relatively short and is probably between 200 Ma and 500 Ma, implying a possible link between these two events. Various formation mechanisms have been proposed for either the crustal dichotomy or Tharsis, but none was attempted to interpret both the dichotomy and Tharsis in a single framework. Zhong and Zuber [2001] suggested that a degree-1 mantle convection with one upwelling plume can be dynamically generated with a weak asthenosphere and that such a degree-1 convection may explain the crustal dichotomy. Recent 3-D modeling studies show that the one-plume structure can be generated rapidly in 150 Ma but is stable for several Ga [Roberts and Zhong, 2006]. While the stable plume explains the long-lived Tharsis volcanisms, the center of Tharsis is at the dichotomy boundary or nearly 90 degree away from the center of the southern hemisphere and the dichotomy-producing plume.

Here we propose a new mechanism that unifies the formations of both crustal dichotomy and Tharsis. The basic physics is that one-plume convection can cause a lithospheric shell with variable thickness to rotate relative to the plume. The lithospheric thickness variations are the key to this mechanism. The lithosphere below the thickened crust of the southern hemisphere is expected to be thicker than that in the northern hemisphere. This is because the melting in the southern hemisphere needed to produce the thicker crust there should lead to thicker melt residue with much larger

viscosity due to de-watering effects. We propose that the one-plume structure produced the thickened crust in the southern hemisphere, and also left a thicker melt residue and viscous lithosphere above the plume there. The plume then started to migrate away from the center of the southern hemisphere due to its relative rotation with respect to the lithosphere. The same plume eventually stabilized at the dichotomy boundary and produced Tharsis as lithospheric thickness becomes more uniform at the dichotomy boundary and also as mantle viscosity increases with time due to cooling. This proposal is consistent with the observation that Tharsis formation first appeared at possibly 40S and migrated to the dichotomy boundary. Our numerical models using CitcomS support this mechanism.