MARTIAN TECTONICS: WHY THE GLOBAL DICHOTOMY AND THE THARSIS UPLIFT; D.L. Turcotte, Department of Geological Sciences, Cornell University, Ithaca, NY 14853

Two of the major tectonic features on Mars are the global crustal dichotomy and the Tharsis uplift. One explanation for the dichotomy is that hemispheric subduction occurred during the early evolution of Mars. The lithosphere in the northern hemisphere was subducted one or more times removing the primordial crust. As the planet cooled and the global lithosphere stabilized, heat was lost by continuous volcanism in one region, the Tharsis uplift. This volcanic construct can be best explained by pressure release melting in an ascending limb of a global mantle convection system.

The Magellan Mission provided a wealth of new data concerning the geology and internal geophysics of Venus. The planetary community is now turning its attention again to Mars. Planned orbiter and lander missions are necessary to provide the required data base for an improved understanding of the evolution of this planet. Two of the major tectonic features of Mars are the global crustal dichotomy and the Tharsis uplift. Both must be associated with the extraction of heat from the interior of Mars. Because of its small size, heat is lost more efficiently and the lithosphere has greater global stability on Mars than on the Earth or Venus.

First consider the global crustal dichotomy. There is an approximately hemispherical dichotomy between the ancient southern highlands and the younger northern plains. The systematic difference in elevation requires the ancient southern crust to be thicker than the crust beneath the northern plains. The heavily crated southern uplands probably record the terminal bombardment of the inner solar system and thus date from 3.9 to 4.0 Ga. Presumably the entire planet had a similar thick crust at that time.

A dominant question concerning Mars is how this primitive early northern crust was removed. A number of hypotheses have been proposed including:

1) One or more giant impacts [1, 2]. This hypothesis cannot be ruled out, but it seems fortuitous that the collison(s) remove(d) essentially one hemisphere of crust.

2) Thinning of the northern crust by mantle convection processes, i.e. crustal erosion [3-5]. This mechanism must be regarded as plausible, however, crustal erosion has not been demonstrated to be an effective mechanism for crustal thinning on other planetary bodies.

3) Hemispheric subduction and/or delamination of the Martian lithosphere. This mechanism for crustal tinning is the dominant process on the Earth, and is likely to also be the dominate process on Venus. Sleep [6] has argued that plate tectonics has been active in the northern plains; this would only be possible if the original crust and lithosphere had been eliminated.

The analogy between Mars and the moon is quite striking with the lunar far side resembling the southern highlands and the lunar nearside resembling the northern plains. In the case of the moon there is clearly old cratered surface on the nearside along with major impact basins. But the lunar nearside crust is systematically thinner than the farside resulting in a center-of-figure, center-of-mass offset similar to that on Mars.

It has been proposed that episodic global subduction events have occurred on Venus [7]. Turcotte [8] further argued that a planet without continents could not have uniformatarian plate tectonics, but would rather have episodic subduction events. The soft continents of the Earth are required to provide the deformation associated with the temperal evolution of plate tectonics.

In analogy with Venus, I would suggest that episodic subduction events occurred during the early evolution of Mars when heat loss was large. Because of the smaller diameter of Mars the spherical rigidity of its lithosphere is greater. Based on the ping-pong ball analogy suggested by Frank [9], hemispheric subduction would be likely to be favored over global subduction on the smaller body. Once hemispheric subduction is accepted then plains volcanism similar to that on Venus (and possibly back arc basins on Earth) would follow naturally. This could take the form of a transient episode of plate tectonics as suggested by Sleep [6]. Episodic subduction is a form of mantle convection and would be effective in removing heat from the interior of Mars.

As the internal heat generation within Mars has decayed in time, the required heat loss to the surface decreased. As a result a global lithosphere stabilized preventing further episodes of hemispheric subduction. Since the thickness of a lithosphere on a planet y_L scales inversely with its radius r, $y_L \sim r^{-1}$, and since the spherical structure adds rigidity; it is not surprising that a stable, thick lithosphere developed relatively early in the evolution of the planet. Subsequently heat loss from the interior of Mars has been responsible for the formation of the Tharsis uplift. This is basically a massive volcanic construct that is statically supported by a thick elastic lithosphere [10 - 12]. The localized volcanism can best be explained in ascending convection in a low-order mode of mantle convection. The localization of volcanism over a long period of time in the Tharsis region is evidence that the mantle flow was focused by this surface feature. Otherwise it would be expected that the center of volcanism would wander over the surface of the planet.

An alternative hypothesis is that plume associated volcanism occurred nearly uniformly on Mars, but outside the Tharsis uplift the volcanism underplated the lithosphere rather than penetrating the lithosphere to form the surface construct. An initial Tharsis structure could have been responsible for tensional stresses that allowed the subsequent penetration of magmas.

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