DEFORMATION SEQUENCE OF THARSIS AS A GUIDE TO THERMAL EVOLUTION. Roger J. Phillips[1,2] and Matthew P. Golombek[2], [1]Department of Geological Sciences, Southern Methodist University, Dallas, Texas 75275, [2]Lunar and Planetary Institute, Houston, Texas 77058.

Banerdt et al. (1) have proposed a three-stage mechanical model for the evolution of Tharsis based on the relationship of observed grabens and stresses induced in an elastic lithospheric shell by topographic and gravity loads. The hypothesis is that the Tharsis lithosphere proceeded from an isostatic state to a flexural state and finally to a point where the addition of new surface load did not lead to regional lithospheric deformation.

Golombek and Phillips (2) geologically tested the Banerdt et al. (or isostatic-to-flexural, IF) hypothesis by investigating the detailed sequence of fracturing in critical areas of the Tharsis region where the proposed isostatic and flexural stress systems overlap and have not been subsequently covered by younger volcanics. Detailed investigations in the regions of Thaumasia, Tempe Plateau, and Noctis Labyrinthus-Claritas Fossae support the general model that the isostatic state preceded the flexural state.

Banerdt et al. (1) proposed that the IF hypothesis is consistent with the Tharsis lithosphere monitonically increasing in thickness as a function of time and that this is consistent with the expected thermal evolution of Mars. The purpose of this abstract is to initiate a preliminary discussion of possible thermomechanical sequences that are consistent with the proposed model. It should be noted that any scenario is constrained by the observation that the load which induced the flexural deformation is not obvious on the surface. That is, the volcanic units of the Tharsis region that could be responsible for the fracturing do not appear to be of sufficient thickness (3) to lead to shear failure of the lithosphere. Thus, we propose that the flexural failure in the Tharsis region resulted, for the most part, from internal loading of the lithosphere.

A straightforward mechanism to proceed from an isostatic state to a flexural state is by monotonic thickening of the lithosphere, as might be expected as the planet cools. Thin elastic lithospheres tend to support loads more or less isostatically, provided the wavelength of the load is measurably greater than approximately the thickness of the lithosphere. If the Tharsis elevation is built predominately by volcanic construction (4), then the IF hypothesis predicts that early volcanic loads were supported isostatically by a thin lithosphere, which at a later, thicker stage supported new volcanic loads flexurally. A significant fraction of this later igneous activity must be intrusive if it is to satisfy the internal loading constraint discussed above. A possible difficulty with this mechanism is that the deflection for thin lithospheres is large, so that enormous thicknesses of volcanics are necessary to fill the deflection; this deflection is many times greater than the topographic elevation itself (1).

Finnerty and Phillips (5) proposed a mechanism for isostatic volcanic construction of Tharsis that does not require lithospheric deflection. Their idea is that if a source region in the mantle is differentiated, the igneous products that reach the crust from the source region will crystallize in less dense forms than their mantle equivalents. This leads to a net volume increase, manifested in part in the elevation of Tharsis. The configuration is isostatic because there is no mass change in the vertical column beneath Tharsis compared to "normal" mantle and crust.

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Isostatic loading, isostatic uplift, and flexural loading can all be viewed as variations of an open/closed mass system. The initial state is presumed to be normal crust and mantle. A particular "column" of crust and mantle is then subjected to a heat source of unspecified origin, differentiates, and provides igneous products to the crust and surface. If mass is neither added nor subtracted from the column, it remains by definition isostatic, but volcanic construction will take place by the mechanism described by Finnerty and Phillips (5). Mass could be lost, however, by lateral movement out of the column, such as by surface flows, ponding at the base of the crust, or movement through fractures in the crust. The system will remain isostatic by rising to stay in mass balance with normal crust and mantle. For a source region on the order of 200 km in vertical extent, only a few percent of the magmatic differentiate need be lost from the column to provide, say, 10 km of isostatic rise. Hence isostatic uplift most likely played a significant role in the attainment of the elevation of the Tharsis region. On the other hand, net mass added to the system constitutes a true load, which if it is emplaced in the lithosphere will lead to a flexural response. Thus, a second scenario for the IF hypothesis is that Tharsis was initially in a closed state or in a mass-loss state, leading to an increase in elevation under isostatic conditions. Subsequently, new magmatic material entered the Tharsis column to induce a lithospheric load. Either the column went to a state of net mass excess or, if not, the lithosphere had thickened to a point where downward isostatic adjustment was not possible. If part of the isostatic balance was due to thermal buoyancy and if the lithosphere was unable to adjust downward to the cooling of the source region, then the lithosphere would become a flexural load. This is because volume loss from cooling of the source region results in excess mantle mass added to the base of the column.

The thermal evolutionary sequences discussed above are testable by thermomechanical modeling and comparison to relative and estimated absolute age sequences for volcanic stratigraphy and tectonic activity around Tharsis.

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