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MARTIAN TECTONICS: A REVIEW; R. J. Phillips, Dept. of Geological Sciences, Southern Methodist University, Dallas, TX 75275

Mars appears to play an intermediate role in the tectonic style of the five large bodies of the inner solar system. The tectonic style of Mars is dominated by vertical motion, perhaps more so than any of the terrestrial planets. The imprint of this tectonic activity has left a surface widely faulted even though younger volcanism has masked the expression of tectonism in many places. Geological activity associated with Tharsis and, to a lesser extent, Elysium Provinces is responsible for a significant portion of this faulting (1, 2, 3, 4), while the origin of other features is enigmatic. The tectonic imprint of Tharsis is seen over at least 180 degrees of longitude.

The origin and evolution of the Tharsis and Elysium Provinces, in terms of their great elevation, volcanic activity, and tectonic style has sparked intense debate in the last 15 years in the planetary geosciences community. Central to these discussions are the relative roles of three basic modes of imparting stress to the lithospheric layer; flexural loading, flexural uplift and isostatic loading. These mechanisms predict stress fields that are quite distinct, so that the orientation and type (e.g., graben or wrinkle ridge) of tectonic features mapped on the surface are a guide to the stress mode. In turn, the stress history points to the evolution of the geological feature in question. A caveat in all of this work is that the present-day gravity field and topography must be used to constrain ancient stress fields. This is appropriate if the history of mass movement in the interior has been dominated by vertical motion. Indeed, the fact that the present-day fields can predict ancient structural features suggests that this has largely been the case.

What we are learning is that these different modes of stress have operated at different times in the history of the Tharsis and Elysium Provinces. Thus it becomes crucial to map the tectonic features associated with each stress mode and decipher their relative age of formation. Confounding this task is whether or not there have been distinct centers of faulting (5) that have migrated geographically with time, beyond the spatial resolution of the spherical harmonic stress modeling.

A specific model for the Tharsis Province is as follows (6): The first stage of formation is characterized by flexural uplift. Evidence for this event is found in circumferential graben in the Claritas Fossae region. Following this is an episode of isostatic loading that produced many of the normal faults in the immediate Tharsis region and is probably associated with large-scale volcanic construction. The last major stage is flexural loading, which produced radial graben on the periphery of Tharsis. Major questions concerning this model include: What is the load that caused the flexural failure and what is the mechanism for (essentially) permanent uplift? The former question arises because it is difficult to identify the volcanic load of the correct relative age and magnitude to account for the flexural faulting. Two possibilities are: (a) effective loading due to loss of buoyant isostatic support due to interior cooling and (b) transfer of magma to the surface and the subsequent effects of membrane stress (7). Permanent uplift is a more speculative topic. Possibilities here are:

(a) massive intrusion into the crust (2) and (b) large blow-off of pyroclastic material from an early volatile-rich martian mantle (8), leading to uplift required to maintain mechanical equilibrium.

Analysis of stress models for the Elysium Province suggests that the tectonics of that region have been influenced by flexural uplift and by the stress field associated with Tharsis (4). There is no tectonic evidence for flexural loading, however. There is ample evidence of flexural lithospheric failure on Mars due to local loading, and studies of the location of circumferential graben around large shield volcanoes, for example, have led to estimates of lithospheric thickness (4, 9).

Other tectonic features on Mars have no obvious association with Tharsis or Elysium, and we are challenged to devise plausible models. The role of large impacts in setting a tectonic fabric needs to be evaluated (e.g., 10). We still do not have a plausible model to explain the north-south dichotomy.

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