ported by a globally thick lithosphere. This model invokes geological processes that are evident at smaller scales in a number of areas on Mars and does not require special chemical or dynamical characteristics to persist in the mantle beneath the Tharsis province for billions of years. The model—which may be applicable as well to the Elysium province—is capable of accounting for the extended history of volcanic and tectonic activity in the Tharsis area, the general distribution of tectonic features, and the presently observed topographic and gravity anomalies.

It should be repeated that even though most of the topographic rise of Tharsis is attributed here to volcanic construction and most of the fracture-producing stress is attributed to the response of the lithosphere to loading, it is likely that some type of uplift mechanism may have also played a contributing role in the evolution of the region. A thinner elastic lithosphere in the central areas of Tharsis and Elysium implies steeper near-surface thermal gradients and therefore a contribution from thermal expansion to the Tharsis and Elysium topographic rises over at least some portions of the history of each province. Further, extraction from the Martian mantle of the large volumes of lava required to build the topographic rises of Tharsis and Elysium will have altered the density of the residual source regions [*Finnerty and Phillips*, 1981], also contributing some amount of uplift for an uncertain length of time.

It is vital at this stage in our understanding of the tectonic and volcanic history of Mars to test as fully as possible the competing models for the evolution of the Tharsis province, including the model proposed in this paper. Several profitable lines of further investigation can be identified. It will be important to build upon the work of *Wise et al.* [1979*a*], *Frey* [1979], *Plescia and Saunders* [1979*a*], and *Scott and Tanaka* [1980, 1981*a*] to determine in detail the relative ages of all major tectonic features and volcanic units. Particularly significant will be ages of the mare-type ridges in ridged plains units (Figure 4) and in areas where ridges and graben are both present [e.g., *Watters and Maxwell*, 1981; *Sharpton and Head*, 1982]. Since ridges and graben cannot be produced by shear failure in one location by the same stress field, a time-dependent stress field is required. The time dependence may be associated with the evolution of Tharsis [e.g., *Banerdt et al.*, this issue] or may be contributed by a superposed time-variable global stress field, such as that associated with planetary thermal stress [*Solomon*, 1978; *Solomon and Head*, 1980*a*].

To predict the stress field due to loading at the time of formation of prominent fracture systems, it will be necessary to remove the contributions of younger loads to the present topographic and gravity anomalies. The work on estimating the thicknesses of individual volcanic units from the rim heights of partially buried craters [*Plescia and Saunders*, 1980; *De Hon*, 1981] or from the dimensions of partially buried volcanoes [*Pike and Clow*, 1981] will be especially valuable in this effort. Once the history of the Tharsis load is estimated, then further stress calculations of the sort reported by *Willemann and Turcotte* [this issue] and *Banerdt et al.* [this issue] should be carried out to test proposed models for Tharsis against the tectonic features formed between times of major changes in the load distribution. It may be necessary to include the effects of lithospheric heterogeneity (Figure 7) in these calculations. Because the Elysium province may share many aspects of its history with the Tharsis province, these tests should be carried out for the Elysium region as well.

The themes of lithospheric heterogeneity, volcanic loading, and vertical tectonics have general validity throughout the terrestrial planets [*Head and Solomon*, 1981]. Only the large horizontal scale and extended duration of activity distinguish Tharsis from most other regions of volcanism and faulting on the moon and Mars and in intraplate areas on earth. An interesting question left to further investigations is whether the physical model for Tharsis proposed here can sharpen the hypotheses for the origin and evolution of such similarly large-scale volcanic and tectonic provinces on other bodies as Oceanus Procellarum on the moon [*Head et al.*, 1980] or Beta Regio on Venus [*McGill et al.*, 1981].

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