[*Phillips and Saunders*, 1975], membrane stresses in the spherical lithospheric shell of Mars dominate the stress field [*Turcotte et al.*, 1981; *Willemann and Turcotte*, 1981]. Lithospheric uplift at the scale of Tharsis leads to membrane stresses of different geometry and sign than the associated bending stresses, and predictions of lithospheric stress based on the lithospheric uplift model are at variance with the observed tectonic features in the Tharsis region [*Willemann and Turcotte*, this issue; *Banerdt et al.*, this issue].

In the calculations of *Willemann and Turcotte* [this issue], the Martian lithosphere is modeled as a thin elastic shell subjected to loads applied from above or below. Tharsis is approximated by a circularly symmetric structure, zonal spherical harmonics are superposed to represent the applied load, and stresses are calculated at the top of the shell beneath the base of the load. Willemann and Turcotte find that if the Tharsis region exerts a radially inward load on the Martian lithosphere, with the magnitude of the load and the thickness of the elastic lithosphere constrained by the amplitudes of the topographic and gravity anomalies over Tharsis, then the calculated stress field would predict extensional fractures radiating from the center of Tharsis over a substantial distance range, consistent with the observed distribution of tectonic features. Uplift of the elastic lithosphere from below, however, would lead to the opposite pattern of stresses, including the prediction of radial compressive features, contrary to observations. A loading model is preferable to a lithospheric uplift model, therefore, as an explanation of the radial extensional fractures of the Tharsis region.

In the calculations of *Banerdt et al.* [this issue], the Martian lithosphere is modeled as a thick elastic shell subject to specified boundary conditions. With this formulation, stresses can be calculated everywhere on the Martian surface as well as within the volume of material constituting the lithospheric load. The topography and gravitational potential associated with Tharsis are represented by the corresponding spherical harmonics of degree and order 4 and below. Three models have been considered: (1) lithospheric uplift in response to a distribution of upward forces, (2) the 'isostatic' model of *Sleep and Phillips* [1979], and (3) a 'flexural' model in which the Tharsis topographic rise exerts a downward load on the elastic lithosphere of Mars. Trajectories for the maximum and minimum horizontal stress at the Martian surface for the flexural model were also shown by *Phillips and Ivins* [1979] and by *Phillips and Lambeck* [1980]. Because these trajectories in the Tharsis area were shown to be broadly orthogonal to mare-type ridges and extensional fractures, respectively, this manner of presentation apparently contributed to the mistaken impression [*Arvidson et al.*, 1980; *Carr*, 1981; *Watters and Maxwell*, 1981] that a single stress model for Tharsis could produce ridges and extensional fractures at similar distance ranges from the center of the topographic rise and, in some regions, could produce generally orthogonal ridges and fractures in the same region. Compressional and extensional tectonic features cannot, of course, be produced by shear failure of the lithosphere [e.g., *Anderson*, 1951] at one location by a single fixed stress field, and the stress trajectories of *Banerdt et al.* [this issue] which display the relative magnitudes of the three principal stresses in a single figure should not lead to such confusion in the future.

Banerdt et al. [this issue] find that the predicted surface stresses for the uplift model show virtually no correspondence to observed tectonic features, in agreement with the conclusion of *Willemann and Turcotte* [this issue]. Both the isostatic and the flexural models are found to predict stresses which match subsets of the observed tectonic features: stresses from the isostatic model provided the best fit for faults within 40° of arc (about 2400 km) from the center of the Tharsis rise, whereas those from the flexural model yielded the best match for tectonic features at greater distance. *Banerdt et al.* [this issue] have suggested that the two models are each appropriate to a different period of Tharsis history.

Many of the details of the stress models of *Willemann and Turcotte* [this issue] and of *Banerdt et al.* [this issue] can be questioned on a number of grounds. The assumption of circular symmetry made by Willeman and Turcotte and the assumption of only long-wavelength anomalies made by Banerdt and co-workers may be oversimplifications, but these approximations should not introduce serious errors for the long-wavelength components of regional stress. The new determinations of topographic heights by earth-based radar [*Simpson et al.*, 1982; *Downs et al.*, this issue] will require that the stress calculations be redone to account for the downward revisions in the elevation of the northern Tharsis rise. A more serious problem is that in both calculations the present topography and gravity are used to constrain models of the stress field that produced ancient tectonic features. The present topography and gravity may be appropriate for modeling the youngest faulting in Tharsis, particularly since the present regional slope directions agree with those determined from the directions of the youngest major lava flows [*Mouginis-Mark et al.*, 1982], but are not necessarily appropriate for the extensive fracturing that predated the emplacement of the Tharsis plains and most or all of the cratered plains as well as the construction of the large shields. The cratered and Tharsis plains units may together contribute several kilometers to the present topographic relief of the central Tharsis rise [*Plescia and Saunders*, 1980; *De Hon*, 1981]. The excess masses associated only with the four largest shield volcanoes [*Sjogren*, 1979] may constitute as much as 25% of the total excess mass of the Tharsis province [*Reasenberg*, 1977]. Thus these contributions to the topography and gravity must be removed before calculating stresses for comparison with the oldest tectonic features. The time-dependent stress models of *Banerdt et al.* [this issue] deserve particular scrutiny; even if the present gravity and topography are approximately correct for one of their preferred models, they are not likely to be valid constraints for the second model presumably appropriate to an earlier period of Tharsis history.

Despite these criticisms of details, the essential conclusion of two independent sets of calculations remains: the stresses predicted by the lithospheric uplift model for the origin of Tharsis do not lead to radially oriented extensional fractures as is observed. Downward loading of the lithosphere by the Tharsis rise is required to account for the distribution of many of these fractures, while an isostatic model may be a preferable explanation for other tectonic features.

Thermal effects. Because of thermal expansion, higher mantle temperatures generally result in more elevated surface topography. The best examples of this process on earth are midocean ridges, which stand several kilometers above the level of the ocean basins because of the much higher temperatures in the uppermost 100–150 km of the mantle