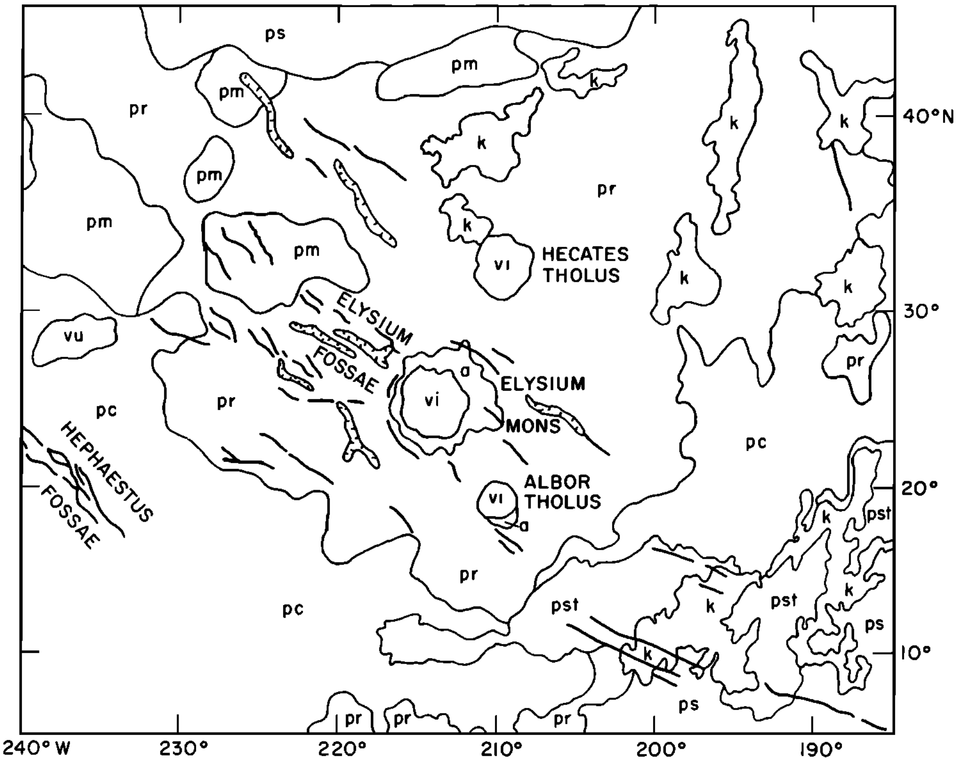

Fig. 6. Geologic map of the Elysium province of Mars, simplified from *Scott and Carr* [1978]. Symbols for tectonic features and abbreviations for geologic units are as in Figure 1. Curvilinear scarps or collapse depressions are shown with inward facing tick marks.

beneath young seafloor [e.g., *Parsons and Sclater*, 1977]. Thermal uplift has similarly been offered as an explanation for the Tharsis rise.

For several reasons, however, heating and thermal expansion are not likely to provide the primary mechanism for the topographic anomaly of Tharsis. Uplift strictly by thermal expansion is essentially an isostatic process, with the elevated topography compensated by the lower density of the underlying mantle [e.g., *Parsons and Sclater*, 1977]. The present gravity anomaly over Tharsis cannot be matched by a model involving only isostatic rise of an otherwise unmodified Martian crust [*Phillips and Saunders*, 1975]; rather a subsurface excess mass is indicated, due either to crustal thinning or to emplacement within the crust of igneous rocks of greater density than the surrounding crustal material [*Sleep and Phillips*, 1979].

If the present Tharsis topographic rise is supported by an underlying mantle of anomalously low density, the required contrast in density with respect to normal mantle may be too large to be strictly a thermal effect. Although the specific density contrast is a function of such details of the model as the thicknesses of the crust and the thermal lithosphere, the lateral contrast is 0.3 g/cm^3 in the model of *Sleep and Phillips* [1979]. Assuming a coefficient of volumetric thermal expansion of $3 \times 10^{-5}\,°C^{-1}$, such a density difference would require a horizontal contrast in the average temperature of the uppermost 300 km of mantle of about 3000°C, a factor of 5 greater than the difference in average temperature in the uppermost 100–150 km of oceanic mantle between midocean ridges and old oceanic lithosphere on earth [*Parsons and Sclater*, 1977], and surely far in excess of that likely to be sustained for billions of years in the mantle of Mars.

Any model for the origin and evolution of the Tharsis province should be considered as well for the Elysium region, the other large volcanic province on Mars [*Carr*, 1973; *Malin*, 1977]. As with the Tharsis region, the Elysium province includes both a topographic rise and a broad positive free-air gravity anomaly [*Sjogren*, 1979]. A series of volcanic plains units spans the province, which also includes several constructs (Figure 6). A number of extensional fractures, many with a northwest-southeast trend, occur within the region. On the basis of crater densities, however, the Elysium province ceased to be volcanically active considerably before the time of the most recent volcanic activity of Tharsis. The Elysium plains are more densely cratered than the Tharsis plains [*Malin*, 1977], and the Elysium volcanic constructs have surfaces older than those of the Tharsis shields [*Plescia and Saunders*, 1979*b*]. While the time of last volcanic activity in Elysium is poorly constrained, the ages of the surfaces of the Elysium volcanoes are similar and are at least 1.0 b.y. according to current competing crater chronologies [*Plescia and Saunders*, 1979*b*]. Despite this great length of time since cessation of volcanism, time during which any thermal anomaly beneath Elysium should have substantially decayed, the topographic rise and the broad gravity anomaly of the Elysium province have persisted. A principally thermal mechanism for the origin of the present topographic rise of Elysium is therefore unlikely.

This discussion does not rule out a limited contribution by thermal expansion to the topographic rise of Tharsis, particularly during the early history of the region. A rough guide to the possible magnitude of this contribution is given by the topographic relief of midocean ridges on earth; in the ab-