EXTENSIONAL HISTORY OF MARS' THARSIS REGION; **Kenneth L. Tanaka** and **D. John Chadwick**, U.S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, Ariz., 86001

Summary. Graben structures in the outer part of Mars' Tharsis region follow calculated stress patterns that are based on Tharsis topographic and gravity anomalies and flexural response of the lithosphere [1, 2]. However, Tharsis extension is not evenly distributed—most extension is concentrated in the Alba, Tempe, Valles Marineris, and Syria-Thaumasia volcanotectonic provinces [3]. Our preliminary results suggest that the overall extension of Tharsis *produced by loading* is about 8 km (based on the assumption that the Sirenum province exemplifies the overall extension of Tharsis), whereas the *total* circumferential extension of the Tharsis region *estimated thus far* is about 33 km (we have not made an estimate for the Syria-Thaumasia province, and evidence in some other areas may be buried). We conclude that local tectonism, possibly caused by intrusion and passive and active rifting, produced most of the extension in the Tharsis region.

Regional extension. In Sirenum, extension produced by the flexural response to the Tharsis load appears to be the major and perhaps sole cause of graben formation [1, 2]. Because we do not have detailed morphometric data for the Sirenum grabens, we assume that extension is roughly proportional to graben width. This approach is based on work at Alba Patera [4], where the average extension for smaller grabens (<3 km wide) is about 22 m/km of graben width. At Sirenum, 29 grabens (all but one <3 km wide) occur about 2,500 km from the center of Tharsis. These grabens have a total width of 43.5 km, which yields nearly 1 km of extension. Extrapolating to the entire circumference of Tharsis results in 8 km of total extension, or a strain of about 4 to 6 x 10^{-4} (depending on distance from the center of Tharsis).

Extension by province. Of the eight Tharsis provinces (Fig. 1), three—Olympus, Elysium, and Tharsis Montes—are mostly covered by Amazonian rocks. The remaining five appear to have a structural record that is sufficiently preserved for estimates of extension to be made. For these (with the exception of the complex Syria-Thaumasia province) we indicate estimates of extension extracted or inferred from other work. Not surprisingly, the province with the greatest estimated extension is Valles Marineris, where the large grabens in its central area indicate a total extension of at least 16 km (possibly exceeding 30 km, depending on the dip of major graben-bounding faults [5, 6]). Subtracting the extension produced by Tharsis in this province (2 km) and the local strain produced by the passive uplift of Valles Marineris (1 km [5]) results in at least 13 km of extension that must be due to some other mechanism such as active rifting. At Alba Patera, a morphometric analysis of grabens along lat 35° N. [4] indicates that total extension is ~8 km. No comprehensive extensional strain measurements have been made for Tempe Terra. However, visual inspection of southwestern Tempe suggests that its grabens have size and density distributions nearly identical with those of Alba Patera. We therefore assign the same value of extension to Tempe as determined for Alba; both greatly exceed the estimated regional extension (Fig. 1).

Implications for Tharsis extensional history. Most Tharsis faults radiate from its center [7], which demonstrates the influence of regional stress on structural orientations. However, the grabens of the Sirenum province have been dated as Late Hesperian and perhaps Early Amazonian [8], which may indicate that the period in which grabens were produced by flexural response of the Tharsis load began in the Late Hesperian [1]. Also, a few grabens of Early and Middle Amazonian age [7], possibly produced by regional stress, radiate from Tharsis Montes. Elsewhere in Tharsis, most regional extension is not identified because of burial or the dominance of local structure. On broad Lunae Planum, in the northern part of the Valles Marineris province, extensional structures are absent, perhaps due to local compressional stress exerted during the formation of Valles Marineris to the south [2].

Our work indicates that Tharsis can be viewed as a region of warm, weak lithosphere in which mantle plumes or heat sources were concentrated; significant extensional strain developed both locally and regionally due to intrusion and passive and active rifting. Further detailed

morphometric analysis, particularly in the Sirenum and Syria-Thaumasia provinces [9], is necessary for a more precise and complete assessment of Tharsis extensional history.

References cited. [1] Banerdt, W.B., et al., 1992, *Mars*, UA Press, Tucson, ch. 8, p. 249-297. [2] Tanaka, K.L., et al., 1991, *JGR 96,* 15,617-15,633. [3] Tanaka, K.L., and Dohm, J.M., 1989, *LPI Tech. Rept. 89-04*, p. 79-81. [4] Plescia, J.B., 1991, *JGR 96,* 18,883-18,895. [5] Chadwick, J. and Lucchitta, B.K., *this volume.* [6] Schultz, R.A., 1991, *JGR 96,* 22,777-22,792. [7] Scott, D.H., and Dohm, J.M., *PLPSC 20,* 487-501. [8] Tanaka, K.L., and Chapman, M.G., *JGR 95,* 14,315-14,323. [9] Tanaka, K.L., and Dohm, J.M., *this volume.*

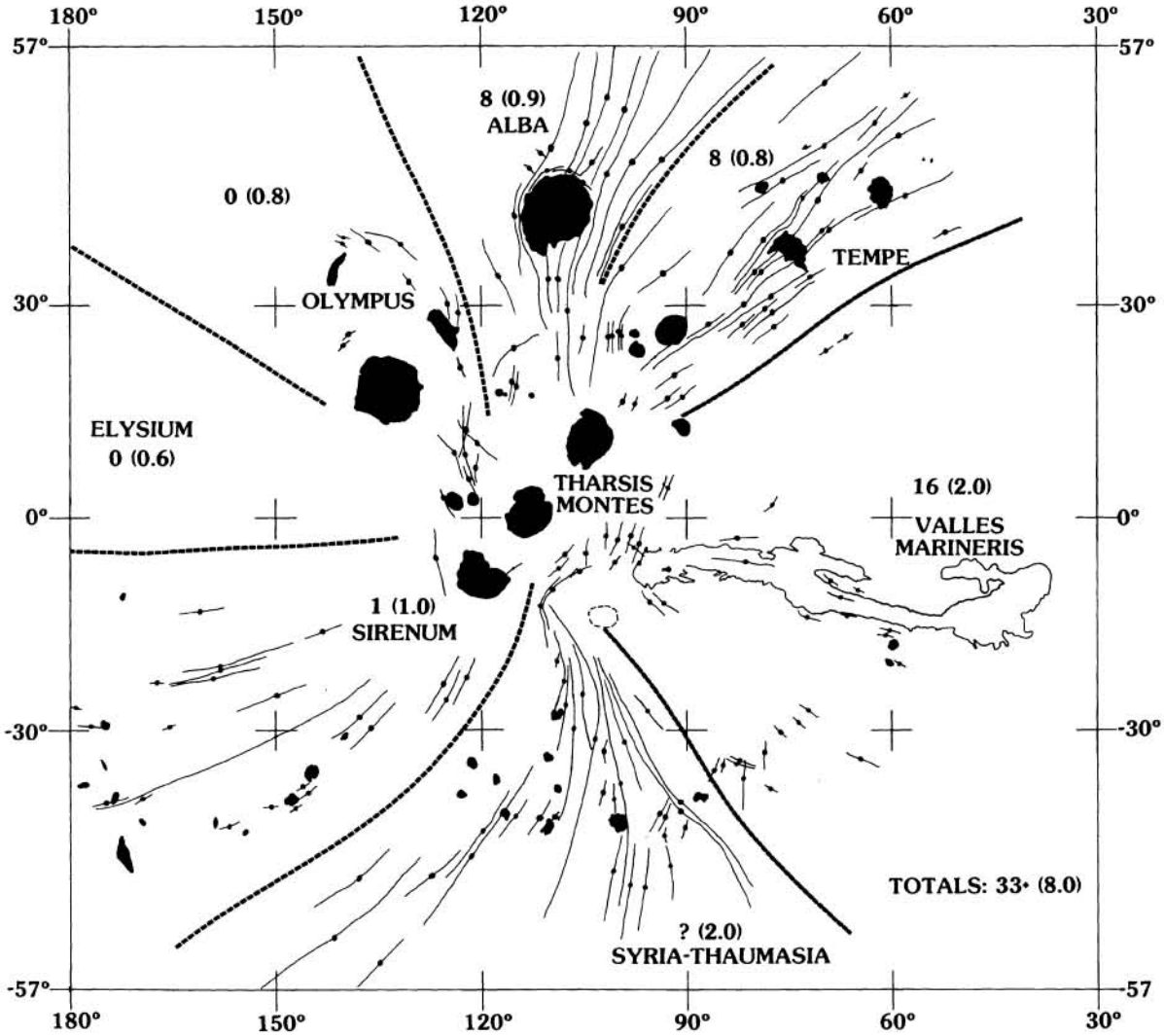

Figure 1. Map of the Tharsis region of Mars showing individual volcanotectonic provinces (modified from [3]). Heavy dashed lines separate the seven provinces radiating from the eighth, Tharsis Montes. Solid areas are volcanoes; lines with balls are grabens. Solid line outlines Valles Marineris trough system. Compare estimated circumferential extensional strain in each province (in km) with model-based regional calculations of extensional strains (in parentheses).