THIN AND THICK-SKINNED DEFORMATION IN THE THARSIS REGION OF MARS.

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The ridge system of the Tharsis Plateau is a dominant structural form only equaled by the radial fracture system. The structural interpretation of the ridges are: 1) folds formed by regional or local compressional stress [Watters and Maxwell, 1983; Watters and Maxwell, 1985a]; 2) the surface manifestation of reverse or thrust faults [Plescia and Golombek, 1986]; or 3) folds with thrust faulting developing as a result of fold geometry [Watters and Maxwell, 1985b]. Watters and Maxwell [1986] suggest that the compressional events that generated the ridges occurred after the emplacement of the ridged plains volcanic units, but before the episode of faulting that generated the majority of the observed ridge-fault crosscutting relationships on the ridged plains [Watters and Maxwell, 1983] and that it did not continue beyond the emplacement of the Syria Planum Formation or the basal units of the Tharsis Montes Formation.

Models for the origin of the regional stresses involving a combination of isostatic uplift and flexural loading have been proposed by Banerdt et al. [1982] and Sleep and Phillips [1985]. One important aspect of these models is that the stresses are calculated for the surface of a spherical lithosphere. This requires that stress be transmitted through the lithosphere to the free surface. If the Tharsis ridges are the result of compressional stress from isostatic uplift then they are the result of full lithospheric compression involving deformation of the basement as well as surface units.

Compressional deformation of terrestrial oceanic lithosphere has been observed in the interior of the Indo-Australian plate. Topographic undulations observed seismically and with Seasat altimeter profiles have been interpreted as lithospheric folds, resulting from horizontal compression associated with continental collision. These features have an average or dominant wavelength of 200 km and amplitudes that approach 3 km. The thickness of the lithosphere in the region of the folds is estimated to be 40-50 km [McAdoo and Sandwell, 1985]. The ratio of the dominant wavelength to the deformed plate thickness (L_d/T) for these lithospheric folds is about 4. The L_d/T of the lithospheric folds are within the range of L_d/T of folds in sedimentary rocks reported by Currie et al. [1962] and the open folds of the Appalachians of Pennsylvania. The wavelength to thickness ratio for these folds range from > 2 to < 40 (indicated on figure 1).

The significance of the L_d/T ratio in characterizing folds is found in plate bending theory, and the relationship of ratio to the bending moment is largely a function of the rheology. The solution to the differential equation for the buckling of a plate resting on a weaker substrate is a sinusoidal deflection curve, and thus, the plate buckles in the shape of a sine wave. However, this need not be the form of the final structure. Deformation may begin with the development of low amplitude deflections where the anticlines serve as sites of 1) localized deformation resulting from cataclastic flow; or 2) fault nucleation and gross fracturing (i.e. thrust faults). These mechanisms will result in non-sinusoidally shaped, but regularly spaced structures.

The relationship of L_d/T can be used to estimate the wavelength of deformation for a known plate thickness or the plate thickness for an observed wavelength. The lithospheric thickness on Mars has been estimated to be between 100 to 400 km [see Banerdt et al., 1982]. Assuming a lithospheric thickness of 100 km, a L_d/T of 4, and solving for L_d:

$$L_d = 4T \tag{1}$$

lithospheric folds in the Tharsis region would have a dominant wavelength of 400 km. Roth et al. [1980], using radar altimetry data, generated a three-dimensional reconstruction of the topography covering a portion of the Coprates region (figure 2). This topography indicates the presence of three parallel N-S trending undulations in SE Coprates spaced at roughly 400 km with amplitudes approaching 3 km. These features may be analogous to the topographic undulations observed in the interior of the Indo-Australian plate. If the long wavelength, low amplitude features in Coprates are interpreted to be lithospheric folds, then applying equation (1), the thickness of the deformed lithosphere is on the order of 100 km. These long wavelength ridges may be the result of full lithospheric compression resulting from the lithospheric stresses predicted in the models by Banerdt et al. [1982] and Sleep and Phillips [1985].

The wavelength predicted by equation (1) can also be compared with measured spacings of compressional ridges on volcanic plains units. Regularly spaced ridges in SW Coprates are generally NE trending with an average spacing of approximately 60 km. Compressional features with spacings of 60 km would involve a deformed layer with a thickness of approximately 15 km. This suggests that the plains ridges in SW Coprates are the result of thin-skinned deformation of the upper 15 km of the crust. Thus, it appears that there are two distinct levels of compressional deformation in the Tharsis region.

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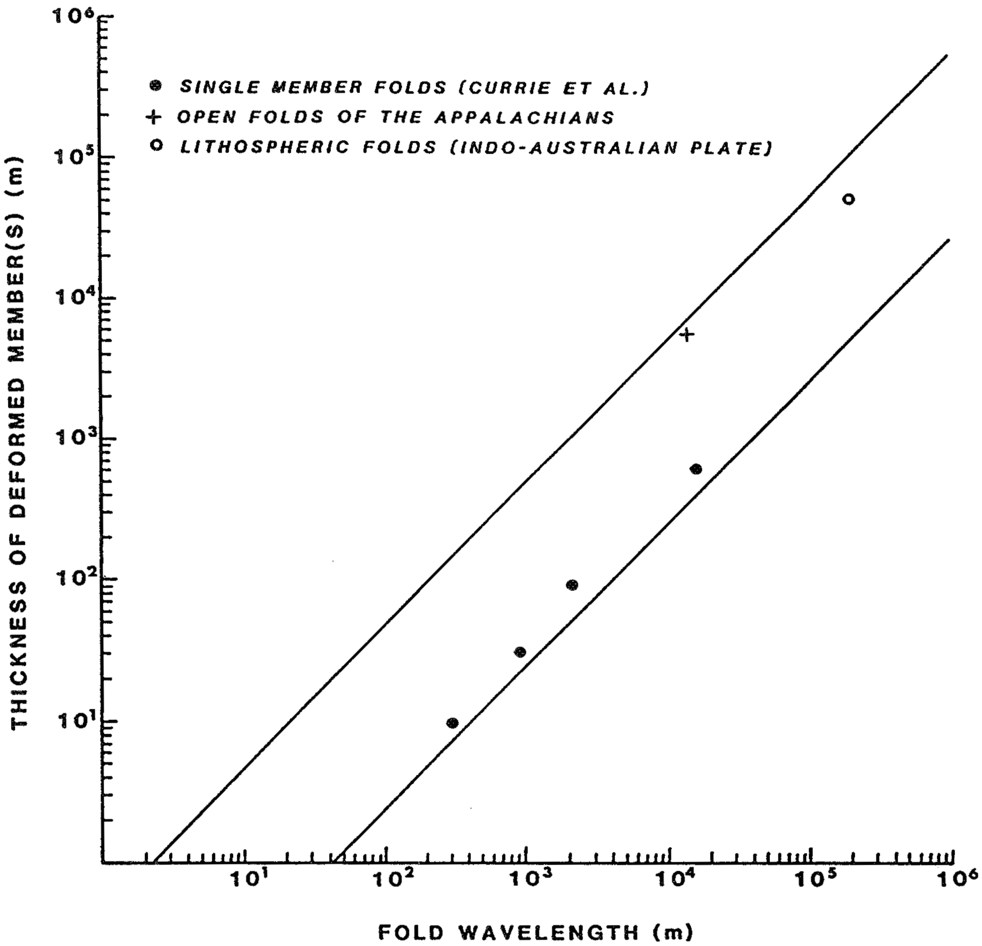

FIGURE 1.

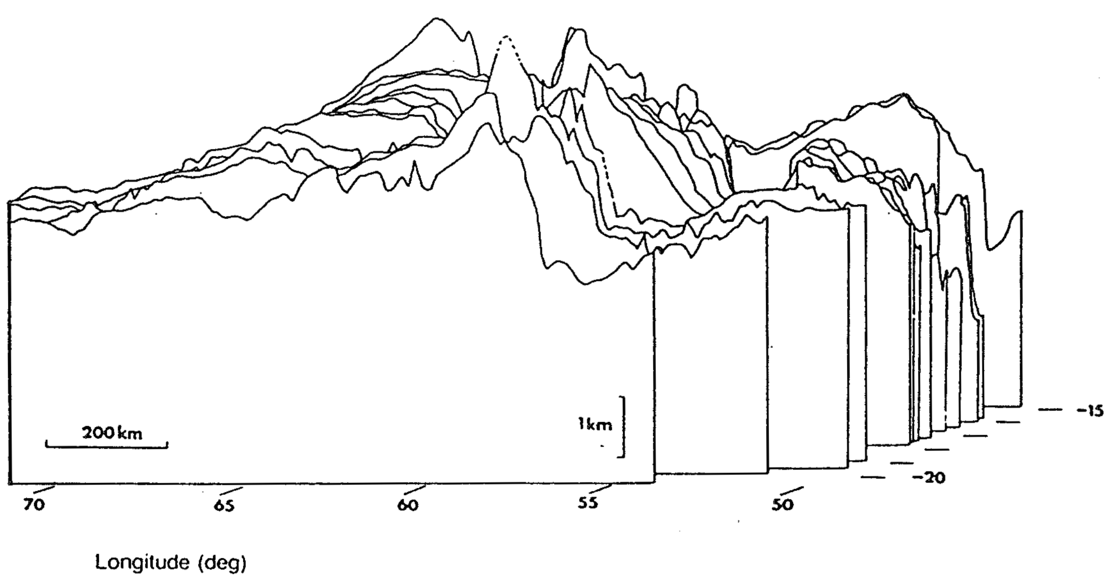

FIGURE 2.