
Over 3% of the surface of Mars is covered by smooth plains material characterized by landforms analogous to mare wrinkle ridges. Although the exact nature of these ridged plains materials has not been directly determined, indirect evidence suggests they are the result of flood volcanism (1,2,3). The origin of wrinkle ridges is also not agreed upon, and recent debates have focused on the role of buckling and reverse or thrust faulting (3,4,5). However, the general consensus is that wrinkle ridges are tectonic in origin resulting from horizontal compressive stresses.

The largest known occurrence of wrinkle ridges on the terrestrial planets, observed within a distinct physiographic province, is on the Tharsis Plateau of Mars (6). The average spacing, evaluated in six provinces of the Tharsis ridge system, is 30 km (2,934 measurements), equal to the average spacing of the crosscutting wrinkle ridges of Hesperia Planum (7). There have been a number of buckling models proposed to explain the periodic nature of the wrinkle ridges (8,9,10,11,12) and some recent debate as to whether the lithosphere is involved in the deformation (thick-skinned) or not (thin-skinned). One reason for considering models that do not require wrinkle ridges be rooted in the lithosphere is the unlikelihood that stresses penetrating both the crust and lithosphere were involved in the deformation of ridged plains units well distant from Tharsis, particularly the many relatively small, isolated areas of ridged plains material that occupy topographic lows within intercrater plains.

In the models evaluated in this study, it is assumed that the ridged plains material behaves as both a single member and a multilayer with frictionless contacts, resting on a mechanically weak megaregolith substrate of finite thickness that has buckled at a critical wavelength of folding. The basement does not directly participate in the deformation that results in the ridges, thus no assumption of whole or partial lithosphere deformation is necessary to explain the periodic spacing. Free slip between layers is assumed in the possible existence of mechanically weak interbeds in the ridged plains sequence separating groups of flows. Interbeds separating groups or units of flows are not uncommon within mare basalts on the Moon or in terrestrial continental flood basalt sequences (13,14,15) and may contribute to the localization of buckling (16). The rheologic behavior of the ridged plains and megaregolith are approximated by a linear elastic and linear viscous material. The models are examined for a range in: 1) the strength contrast between the ridged plains material and the underlying megaregolith of 100, 1,000 and 5,000; 2) thickness of the ridged plains material of 250 to 3,500 m; 3) thickness of the megaregolith of 1,000 to 5,000 m; and 4) number of layers (n) of 1 to 12. For the elastic case, wavelengths consistent with many of the observed spacings are obtained at critical stresses below the yield-strength of a basalt-like material for n > 5. For n = 8, wavelengths range from 27 to 42 km for thicknesses of the ridged plains material ranging from 1,900 to 3,500 m over a range in thickness of the substrate of 1,000 to 5,000 m and ratio in Young’s modulus of 1,000 to 5,000. The cases of n = 1 (i.e., a single member) through 5 do not yield admissible wavelengths. At the upper limit of the model parameters, the average thickness of the ridged plains necessary to account
WRINKLE RIDGES ON MARS: Watters, T. R.

for the minimum average spacing of the ridges (20 km) is roughly 1,700 m. If the ridge spacing is the result of elastic buckling, the relatively high contrast in Young's modulus required (≥ 1,000) is only possible if there were high pore-fluid pressure within the megaregolith at the time of deformation that reduced the effect of the overburden.

Over the same range in values of the parameters, viscous buckling is much less restricted than the elastic case. The observed wavelengths can be accounted for over almost the entire range of viscosity contrast, ridged plains material thickness and substrate thickness for either a single layer or a multilayer. The minimum average spacing of the ridges can be explained with a single layer (n = 1) at the lower limit of the estimated thickness of the ridged plains material (250 m), at the upper limit of the substrate thickness and viscosity contrast. In addition, viscous buckling is viable if the megaregolith were dry, water-rich or ice-rich at the time of deformation.

References Cited: