WRINKLE RIDGES, REVERSE FAULTING, AND THE DEPTH PENETRATION OF LITHOSPHERIC STRESS IN LUNAE PLANUM, MARS; *M.T. Zuber*, Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218–2681.

Tectonic features on a planetary surface are commonly used as constraints on models to determine the state of stress at the time the features formed. Quantitative global stress models applied to understand the formation of the Tharsis province on Mars constrained by observed tectonics [1–3] have calculated stresses at the surface of a thin elastic shell and have neglected the role of vertical structure in influencing the predicted pattern of surface deformation. Wrinkle ridges in the Lunae Planum region of Mars form a conentric pattern of regularly spaced features in the eastern and southeastern part of Tharsis and formed due to compressional stresses related to the response of the Martian lithosphere to the Tharsis bulge [1,4,5]. Structurally, the ridges are on the order of 1 km wide, several hundreds of meters high, and are interpreted to be the surface manifestation of reverse faulting in combination with a smaller component of folding [6,7]. The ridges are located in Early Hesperian–aged plains materials that are interpreted to be flood basalts [8] with thicknesses <1 km [9–11]. As observed in the exposures of valley walls in areas such as the Kasei Valles, the surface plains unit is underlain by an unconsolidated impact–generated megaregolith that grades with depth into structurally competent lithospheric basement. The ridges have alternatively been hypothesized to reflect deformation restricted to the surface plains unit ("thin skinned deformation" [12]) and deformation that includes the surface unit, megaregolith and basement lithosphere ("thick skinned deformation" [13,14]). The nature of ridge formation has important implications for the interpretation of geophysical models of the Tharsis region. If the ridges formed normal to the maximum compressive stress direction at the surface, then these features can be used to constrain the state of stress determined in elastic spherical shell models [1–3]. If, however, the ridges nucleated at depth and propagated to te surface, then the orientations of the ridges may have been controlled by a different stress state. Even if ridge–related faults nucleated within the surface plains unit, it is necessary to understand the extent to which vertical mechanical structure affects the near–surface state of stress.

We have adopted a finite element approach to quantify the nature of deformation associated with the development of wrinkle ridges in a vertically–stratified elastic lithosphere. We used the program TECTON [15], which contains a slippery node capability that allowed us to explicitly take into account the presence of reverse faults believed to be associated with the ridges. In this study we focused on the strain field in the vicinity of a single ridge when slip occurs along the fault. We considered two initial model geometries. In the first, the reverse fault was assumed to be in the surface plains unit, and in the second the initial fault was located in lithospheric basement, immediately beneath the weak megaregolith. We are interested in the conditions underwhich strain in the surface layer and basement either penetrates or fails to penetrate through the megaregolth. We thus address the conditions required for an initial basement fault to propagate through the megaregolith to the surface, as well as the effect of the megareolith on the strain tensor in the vicinity of a fault that nucleates in the surface plains unit.

Figure 1a shows the central part of a two–dimensional cartesian finite element grid that treats the surface unit, megaregolith and basement as layers with different Young's moduli. The Young's modulus of the megaregolith layer is assumed to be an order of magnitude less than that of the surface and basement layers. The grid contains a 20° dipping reverse fault that extends through the surface plains layer. The entire grid has 2319 nodes and 2856 elements; 250 m displacement is imposed along the fault. The broad upwarping of the surface is a consequence of elastic flexure of the surface plains layer. Figure 1b is a contour plot showing the second invariant of the strain tensor for a larger portion of grid than shown in Figure 1a. This quantity is a measure of the tendency for strain to concentrate in a particular location. Despite the presence of the weak megaregolith, significant strain is transmitted to lithospheric basement in the area beneath the faulted surface layer.

Figure 2a shows a similar calculation with the reverse fault instead initially located at the top of the lithospheric basement layer, just beneath the megaregolith. In this model the ridge forms due to fault propagation folding in which ridge topography is a consequence of elastic continuum deformation above the fault. Figure 2b contours the second invariant of strain and demonstrates that, despite the presence of the weak megaregolith layer, strain is transmitted to the surface layer.

In both examples, the surface plains unit, megaregolith and lithospheric basement are involved in the deformation, which is a consequence of fault slip presumed to be associated with the development of wrinkle ridges. For the lithospheric structure assumed in these preliminary calculations, the surface layer and basement are coupled sufficiently to allow the transmission of strain so that deformation is not confined to the near–surface as required in thin–skinned deformation models. We are currently investigating parameter sensitivities to further clarify the nature of this coupling, in order to better understand the relationship between wrinkle ridge–related faulting, lithosphere structure, and the style of Tharsis deformation.

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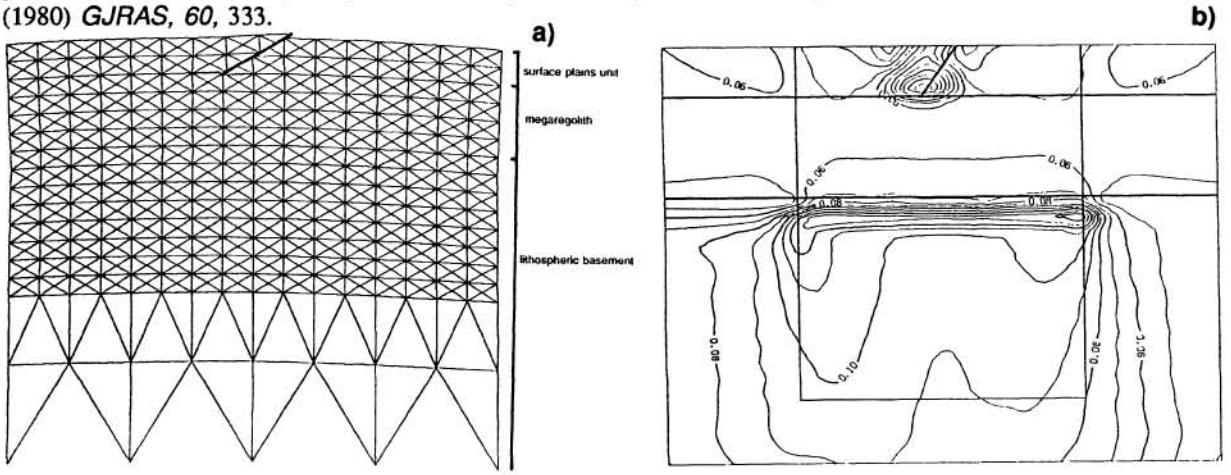

Figure 1. (a) Deformation grid and *(b)* contours of second invariant of strain tensor for a horizontally shortening model Martian lithosphere with a 20°–dipping reverse fault with 250–m displacement. The fault is located in the surface plains unit. The megaregolith is characterized by a Young's modulus an order of magnitude less than the surface plains unit and basement. Note the transmission of strain through the megaregolith to basement.

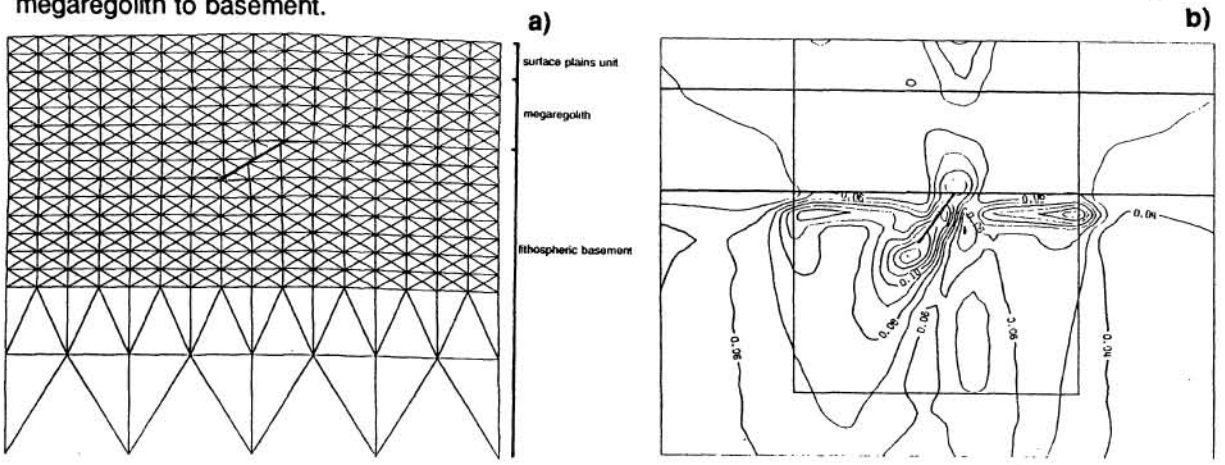

Figure 2. Same as above, except the fault is located at the top of the lithospheric basement layer. Note the transmission of strain through the megaregolith to the surface layer.