STATE OF STRESS AND ERUPTION CHARACTERISTICS OF MARTIAN VOLCANOES. Patrick J. McGovern and Sean C. Solomon, Dept. of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139.

Introduction. The growth of a large volcano exerts a load on a planetary lithosphere that can give rise to flexural deformation and faulting. Lithospheric stress, in turn, can influence the state of stress within the volcano and thus the characteristics of eruptions and the deformation and growth of the construct. Previous studies of the stress state within and beneath terrestrial volcanoes have been of two main types: (1) models of plate flexural stresses in isolation [1,2], or (2) finite element models of volcanic bodies with rigid lower boundary conditions [3,4]. We seek a model which couples the stress and displacement fields of both the plate and volcano structures, in order to understand the behavior of Martian volcanoes and the relationship of eruption styles to evolving local and regional stress.

Method. We use the finite element code TECTON, written by H.J. Melosh and A. Rafesky [5,6], to construct axisymmetric models of volcanoes resting on an elastic lithospheric plate overlying a viscoelastic asthenosphere. This code can model buoyancy forces supporting the plate, thus allowing a proper representation of plate flexure. Several values of the ratio of volcano size to lithospheric thickness were considered. The thickness of the strong upper lithosphere was taken from flexure models [7]. The viscoelastic layer was taken to extend to a sufficient depth so that a rigid lower boundary has no significant influence on the results. The code first calculates elastic deformations and stresses and then determines the time-dependent viscous deformations and stresses. Time in the model scales as the Maxwell time in the asthenosphere.

Results. The deviatoric stress field (principal stress directions) resulting from the elastic deformation induced by a volcano 20 km in height and 400 km in diameter on a strong lithosphere 40 km thick (parameters appropriate to Ascraeus Mons) is shown in Fig. 1. The stress field after the plate has flexed under the volcanic load is shown in Fig. 2. We note two effects of plate flexure with increasing time: (1) the deviatoric stresses in the surface region grow quite large; and (2) the area where the principal compressive direction is parallel to the surface extends progressively deeper, eventually reaching into the crust beneath the construct. Also, at large times, the boundary between the area of rotated stress directions and the underlying area of 'normal' stress orientations (compression axis vertical) is a region of low deviatoric stress. We find that plate deflections and stresses within the lithosphere are in qualitative agreement with those of flexural models [7].

Discussion. The above effects of flexure on the volcano stress field may have important implications for the history of volcanic events. It has been suggested [1] that time-dependent flexural stresses at the top of the elastic lithosphere beneath the Hawaiian volcanic chain control the history of eruptions at individual volcanoes, with eruptions ceasing during intervals when the two principal horizontal stress deviators are compressive and of significant magnitude. Applied to our model, this would imply that at early times after an interval of significant shield-building eruptions, the horizontal stress deviators within and beneath the volcano are tensional, so magma ascent to high-level chambers within the construct is favored. At later times, the stress directions in and beneath the volcano rotate such that the most compressive axis is nearly horizontal, so high-level magma bodies and summit eruptions would not be expected unless the ascending magma is significantly overpressured. In contrast, given that magma propagates through conduits oriented perpendicular to the least compressive stress, the stress orientations shown in Fig. 2 imply that flank eruptions are preferred at this stage of development. The young ages of the volcanic units surrounding Olympus Mons and Tharsis Montes are consistent with such an evolution in eruptive style [8].

Conclusions. These initial models suggest that the state of stress during volcano growth and lithospheric flexure can have an important influence on volcano evolution on Mars. Further models are planned to examine the roles of magma chamber overpressure and evacuation and near-surface faulting on the stress orientations presented here.

References. [1] U.S. ten Brink and T.M. Brocher, *JGR, 92,* 13687, 1987; [2] C.H. Thurber and A.E. Gripp, *JGR, 93,* 4721, 1988; [3] L. Chevallier and W.J. Verwoerd, *JGR, 93,* 4182 1988; [4] J.H. Dieterich, *JGR, 93*, 4258, 1988; [5] H.J. Melosh and A. Rafesky, *GJRAS, 60*, 333, 1980; [6] H.J. Melosh and A. Rafesky, *JGR, 88,* 515, 1983; [7] R.P. Comer et al., *Rev. Geophys., 23*, 61, 1985; [8] D.H. Scott and K.L. Tanaka, *Icarus, 45*, 304, 1981.

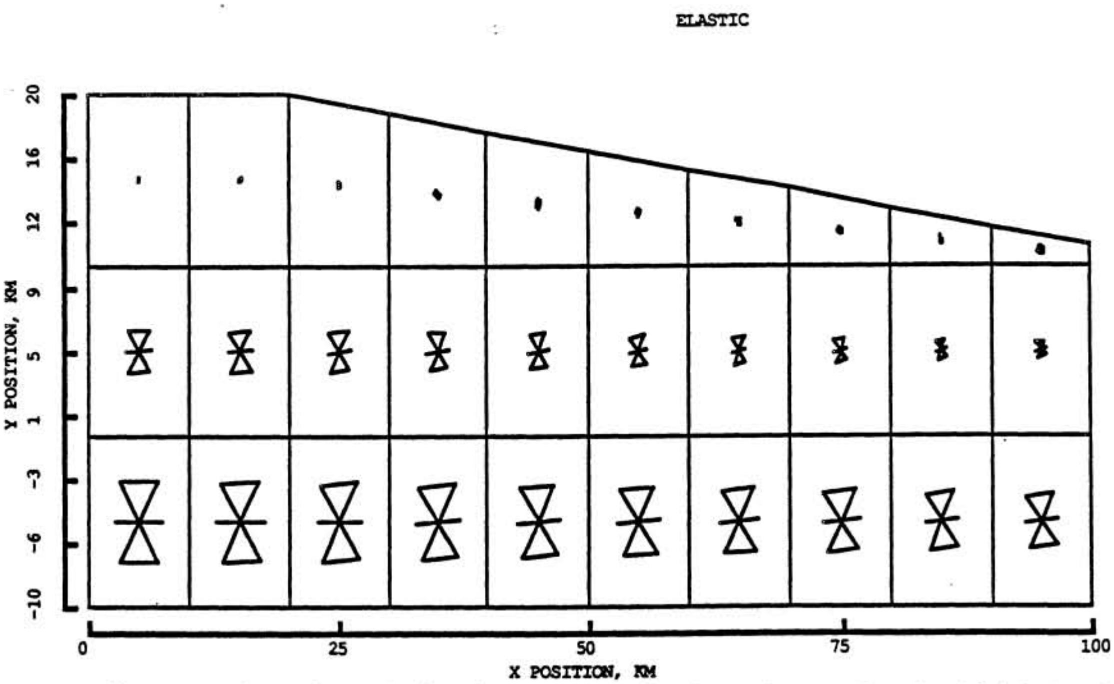

Figure 1. Close-up view of the deviatoric stress field in the volcano after the initial elastic deformation. An hourglass shape denotes the principal axis of compression, a bar denotes the principal axis of tension; the size of each symbol is proportional to deviatoric stress magnitude. The axis of rotational symmetry is x=0.

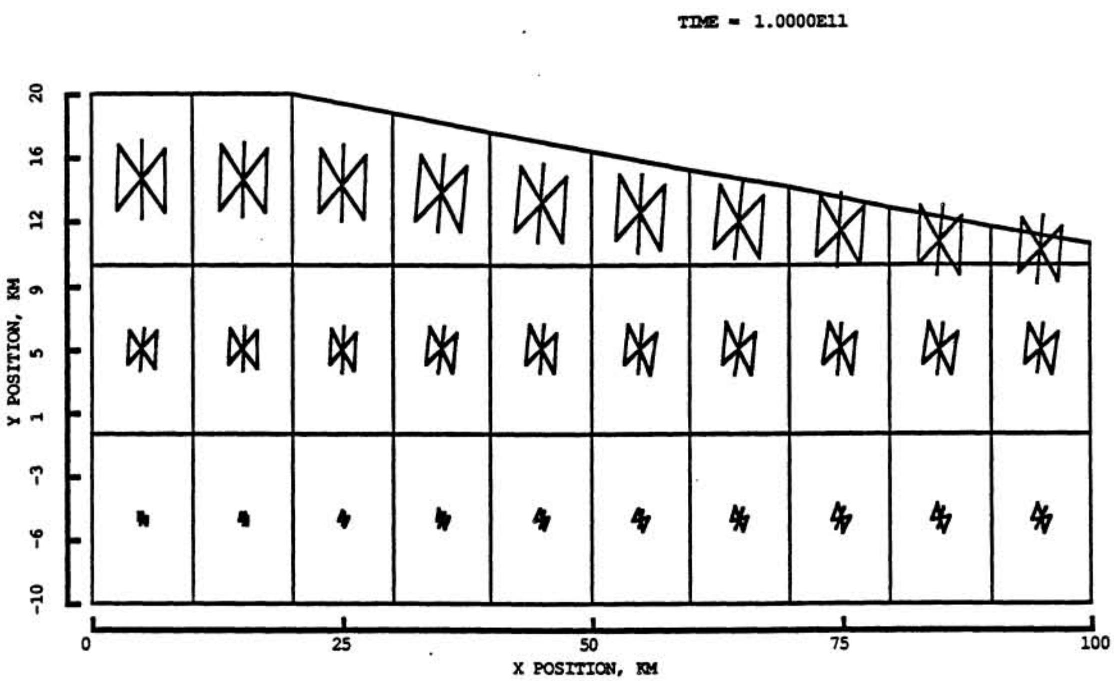

Figure 2. Deviatoric stress field in the volcano after flexure. The time elapsed is on the order of 100 Maxwell times. Rotation of the stress axes extends downward to the top layer of the plate (below y=0).