LIFE CYCLE OF VENUSIAN CORONAE Daniel M. Janes and Steven W. Squyres, Center for Radiophysics and Space Research, Cornell University, Ithaca, NY 14853

Coronae are large circular topographic and tectonic features on the surface of Venus. They are believed to result from the uplift of the surface over a rising mantle diapir and the subsequent relaxation of the raised topography [1,2]. To date modeling of the formation and evolution of these features has involved many simplifying assumptions which may result in inadequate representation of all the forces and dynamics involved. For example, models of uplift have assumed either a purely viscous rheology [3] or have modeled the dynamics of the diapir rise by examining static models of the diapir at some depth [2]. Similarly, models of the relaxation phase have assumed that the complexities of a stratified, visco-elastic, non-Newtonian rheology can be modeled using linearized viscous modeling [2,3]. We address these simplifications by developing two models. The first includes an elastic lithosphere and follows the deformation of the diapir as it rises through the mantle and interacts with the overlying lithosphere. The second treats the relaxation of the upraised topography and includes non-Newtonian viscosity, as well as elastic and isostatic support.

In the diapir uplift model, the diapir is treated as a swarm of point masses, spread uniformly through the volume of the diapir, the mantle as a constant viscosity fluid, and the lithosphere as an elastic shell. We then use mantle velocity formulations [4] to determine the distance moved by points within both the diapir and the mantle over some small timescale and reposition the points that constitute the diapir accordingly. Examples of results from this model are shown below. Fig. 1a shows a 100-km radius diapir at a depth of 1100 km below the base of the lithosphere and the flow field that it sets up in the mantle. Our results indicate that a spherical diapir of this size rising from depth under these conditions will begin to spread laterally at a depth of approximately 800 km. In the example shown, the mantle has a Newtonian viscosity of 10^{21} Pa s and the diapir is 60 kg/m less dense than the mantle. Fig. 1b shows changes in the topography of the surface of a 5 km thick lithosphere overlying the diapir as the diapir rises. Uplift becomes higher and more narrowly concentrated with time, reaching its maximum height after approximately 100 My. At later times, the uplift becomes broader and somewhat less pronounced as the diapir flattens out against the base of the lithosphere. These results also show that a depression begins to form outboard of the central uplift at about the time of maximum central uplift because mantle and diapir material flows out and down as the diapir flattens. Formation of the moat surrounding most coronae, therefore, may be partly a consequence of initial uplift rather than being entirely due to later relaxation. The timescale for the diapir to rise from this depth and flatten out against the underside of the lithosphere is approximately 100 My. One important finding of our work to date is that only a relatively limited set of model parameters appear capable of fitting the topography and tectonics associated with the resulting radially-fractured domes [5].

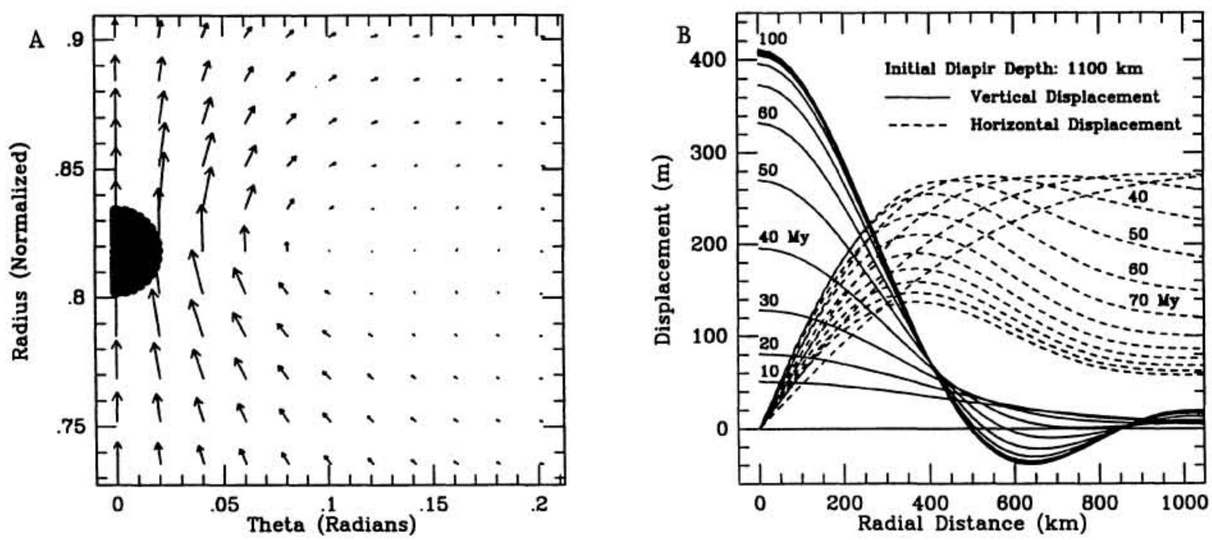

Fig. 1. a) Flow field in the mantle due to a 100 km radius diapir at a depth of 1100 km. b) Surface displacements through time as the diapir rises.

LIFE CYCLE OF CORONAE: Janes, D.M. and Squyres, S.W.

We examine the relaxation of topographic highs from diapiric uplift using the finite element code TECTON, which permits a significantly more detailed treatment of the relaxation problem than is afforded by analytical modeling. Our modeling includes an estimate of the initial stresses present in the mantle, crust and load, eliminating the unrealistic elastic deformation present in many applications of TECTON. We have also developed a protocol for the application of restoring forces. For thick crusts and steep geothermal gradients, the lower portion of the crust can behave as a viscous fluid over relatively short timescales. This requires that buoyancy forces be applied not at the mantle/crust boundary, but rather at the viscous/elastic boundaries in both the crust and mantle. We extend the finite element grid to sufficient depth and width that mantle flow during relaxation is fully accounted for and elastic edge effects are eliminated.

An example of the results from this modeling is shown in Fig. 2. The case shown is for a 1 km high plateau load on a 5 km thick crust. The near surface temperature gradient is 15K/km. The plateau relaxes to produce the central elevated basin, the high standing rim, and the peripheral moat that are seen in a typical corona. For stress dependent, non-Newtonian rheologies, relaxation occurs at a very rapid rate initially, with most of the relaxation taking place in as little as 10,000 to 100,000 years. This timescale is much shorter than the expected cooling time for the diapir [3] so that the relaxation time will be governed by cooling and loss of thermal buoyancy rather than by the viscosity of the mantle or crust. The end state of the relaxation model occurs when the topography is in equilibrium, supported by any residual thermal or compositional buoyancy of the diapir, isostatic forces, and elastic stresses. No further relaxation will occur and, in the absence of erosion or constructional volcanism (especially flows filling the peripheral moat), the topography will remain unchanged.

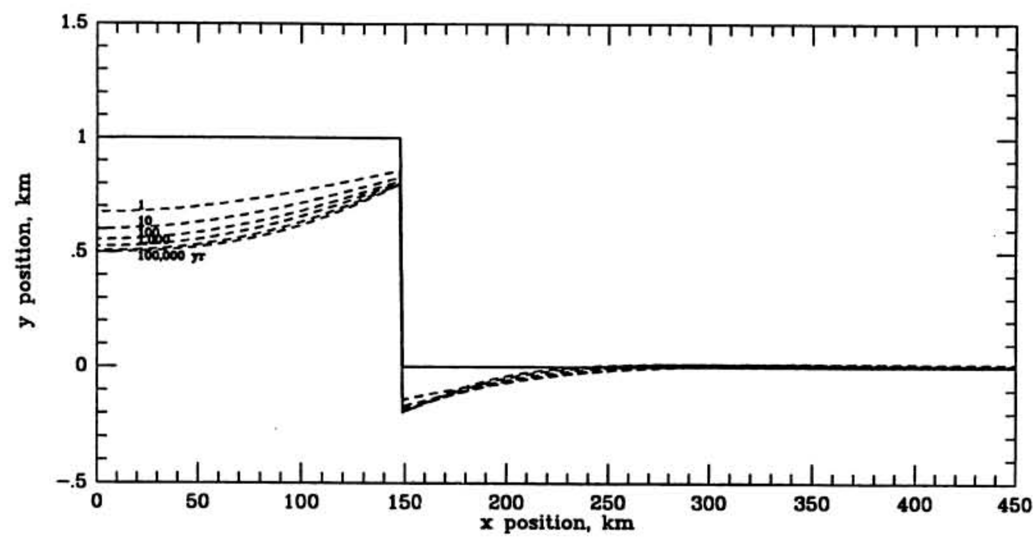

Fig. 2. Topographic profiles through time of a relaxing plateau-shaped load.

The results of the two models indicate that most of the life cycle of coronae should be taken up by the rise of the diapir through the mantle and by the static end state of equilibrium. The transition from an uplifted radially fractured dome and a relaxed corona should occur rapidly with the total time for relaxation dependent on the time needed for the diapir to cool and lose buoyancy. During most of the diapir rise time, surface manifestations are minimal so that continuous formation of coronae over the last several 100 My should result in a current surface marked by a few recently formed radially fractured domes with many more coronae which have relaxed to equilibrium as was observed by Magellan [6].

References 1) Barsukov, V.L., et al., *J. Geophys. Res.*, 91, D378–D398, 1984. 2) Janes, D.M., et al., *J. Geophys. Res.*, 97, 16055–16067, 1992. 3) Stofan, E.R., et al., *J. Geophys. Res.*, 96, 20933–20946, 1991. 4) Janes, D.M. and H.J. Melosh, *J. Geophys. Res.*, 93, 3127–3143, 1988. 5) Janes, D.M. and S.W. Squyres, *GRL*, in press. 6) Stofan, E.R., et al., *J. Geophys. Res.*, 97, 13347–13378, 1992.