PLANETARY RESPONSE OF THICK LITHOSPHERES TO LOADING. D.M. Janes and H.J. Melosh, Lunar and Planetary Laboratory, University of Arizona

Studies of the lithospheric tectonics of one-plate planets have used flat plate (1) and thin shell (2) approximations or inverted for stress states given additional topographic and gravitational data (3) to determine lithospheric thicknesses and stress histories in a number of applications. We have developed an exact analytical model to determine the stress state in a spherical lithosphere of finite thickness (4). For a superposed load, here modeled as a Gaussian distribution, the stress state is a function of four dimensionless parameters: LTH/R_p, the ratio of lithospheric thickness to planetary radius; q, the ratio of isostatic to flexural response; σ, the characteristic width of the load in radians; and θ, the angular distance from the load center (Fig. 1). For a superposed load, the four required boundary conditions are: 1,2) shear stresses at the base and surface of the lithosphere are zero, 3) vertical stress at the lithosphere surface is that due to the overlying load and 4) the load and isostatic restoring forces are in equilibrium at the base of the lithosphere. The parameter, q, cannot be known exactly for most planetary bodies, but can be closely approximated. The tectonics of loading are relatively insensitive to q, being far more dependent on the width of the load (σ).

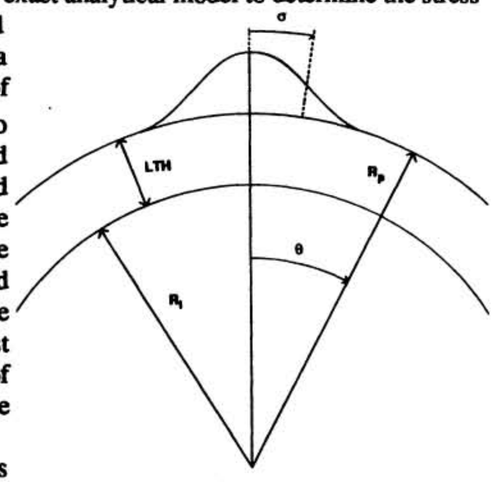
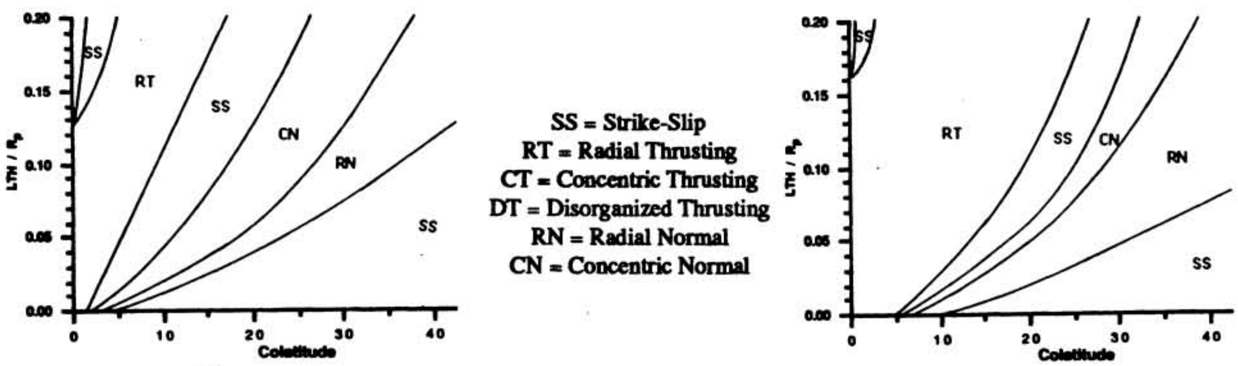


Fig. 1: Load Model Parameters

NARROW LOADS. The current study reproduces the stresses and tectonic patterns derived from flat-plate approximations when σ is small ($\leq \pi/32$). Surface stresses derived from the model are converted into maps of predicted fault types as functions of angular distance from the load center and lithospheric thickness for a given σ and q. Fig. 2 shows the surface tectonics for a load of $\sigma = \pi/64$, and two values of q: a) 1.11 (Mars) and b) 0.28×10^{-2} (Miranda). These two planets represent the extremes of q among single-plate solar system bodies.



(a) Fig.2: Fault Types For: a) Mars and b) Miranda for $\sigma = \pi/64$ (b)

These concentric regions of fault types can be generalized as tectonic provinces surrounding the load center (Fig. 3). The major difference between the two cases is the magnitude of the stresses. For the smaller q (lower shell rigidity), greater deflection of the lithosphere is required to balance the load stress at the base, resulting in greater induced radial and hoop stresses.

BROAD LOADS. For broader loads that cover a significant degree of curvature on the planet, the results are sharply different from those obtained by a flat-plate approximation. Again using Mars and Miranda as the two type examples, the tectonics produced by a broad load with $\sigma = \pi/8$ are given in Figs. 4a and b. These tectonic fields are shown graphically in Fig. 5 which differs considerably from the narrow load examples. In particular, the narrow load ('Flat-Plate') response produces radial thrusts and concentric graben while the broad load ('Shell') response produces neither of these features but instead results in radial thrusting. Again, the exact radial distances at which the transition

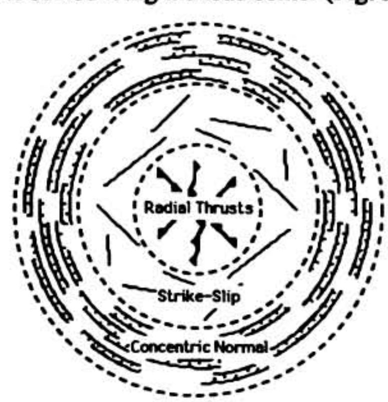
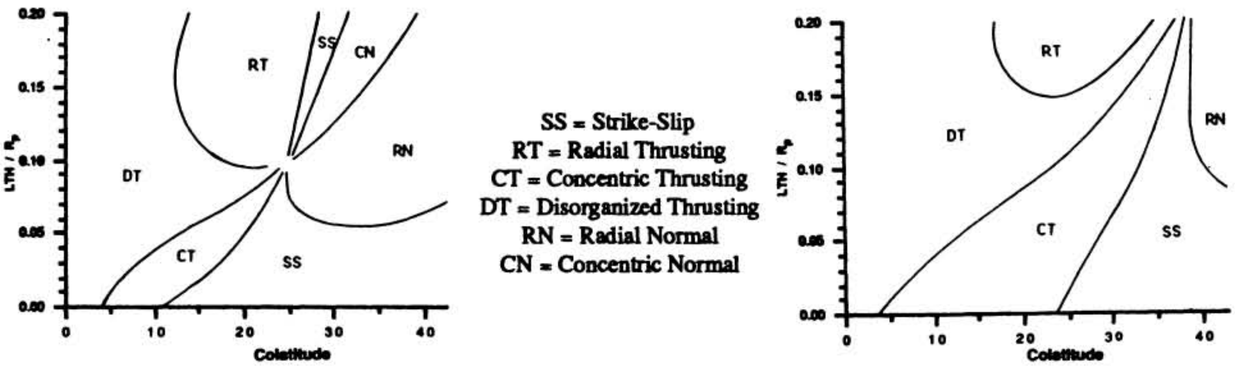


Fig.3: Narrow Load Tectonic Pattern

TRANSITION. The transition between narrow and broad load responses can be seen in Fig. 4a. The singularity is a point of isotropic stress at the planetary surface. As the load width narrows, the isotropic singularity

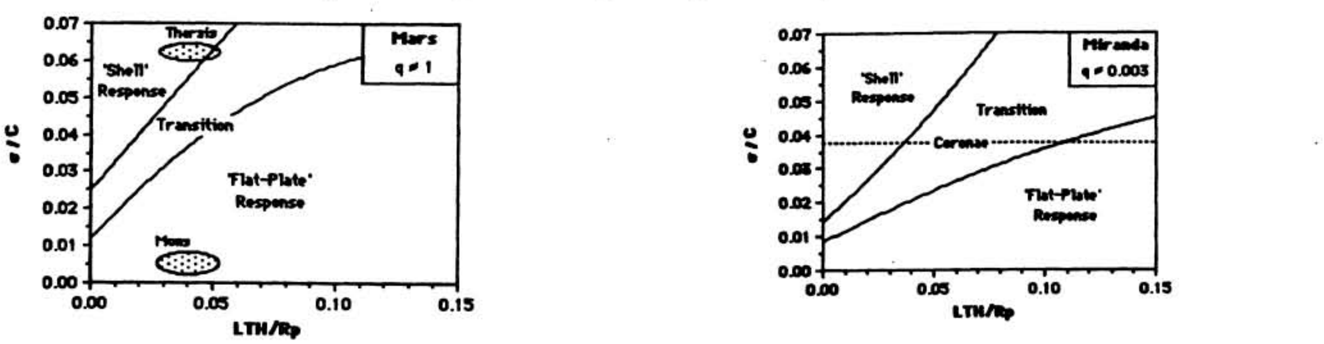


(a) Fig.4: Fault Types For: a) Mars and b) Miranda for $\sigma = \pi/8$ (b)

and the changeover from wide to narrow load responses occurs in thinner lithospheres. The response type can be plotted as a function of width and lithospheric thickness (Fig. 6a and b).

APPLICATIONS. Generally, q, σ and the tectonic response field are known for a given planet and load, while the lithospheric thickness at the time of loading is to be determined. A previous study (1), using a flat-plate approximation, demonstrated that lithospheric thicknesses can be determined from tectonic fields produced by lunar mascon loading. This study is in general agreement with those results. However, taking the finite width of the load into account results in a moderate lowering of the estimated lithospheric thickness. As Figures 4a and b show, two of the more intriguing features in the solar system straddle the transition between narrow load ('Flat-Plate') response and broad load ('Shell') response. If the Coronae of Miranda were initially surface loads, then the tectonics produced should be a very sensitive indicator of the lithospheric thickness at the time of their formation. The case of the Tharsis Rise on Mars is complicated by a long history of increasing load size in the Tharsis region and by having to determine the relative contributions to the stress field by mantle upwelling and the load. This study demonstrates that no model attempting to determine the history of this region solely on the basis of current Mars data can succeed, as Tharsis has passed through various response regimes during its construction.

Fig. 5: Broad Load Tectonic Pattern



(a) Fig. 6: Tectonic Response Fields For a) Mars and b) Miranda (b)

References: (1) Melosh, H.J., The Tectonics of Mascon Loading, *Proc. Lunar Planet. Sci. Conf. 9th*, 3513-3525, (1978); (2) Comer, R.P., S.C. Solomon and J.W. Head, Mars: Thickness of the Lithosphere From the Tectonic Response to Volcanic Loads, *Rev. of Geophys.*, **23**, No. 1, 61-92, (1985); (3) Banerdt, W.B., R.J. Phillips, N.H. Sleep, and R.S. Saunders, Thick Shell Tectonics on One-Plate Planets: Applications to Mars, *JGR*, **87**, No. B12, 9723-9733, (1982); (4) Janes, D.M. and H.J. Melosh, Sinker Tectonics: An Approach to the Surface of Miranda, *JGR*, 93, No. B4, 3127-3143, (1988)