Modeling the Internal Structure of Mars Using Normal Mode Relaxation Theory. T. M. Pithawala[1], R. R. Ghent[1], and B.G. Bills[2]. [1]University of Toronto (Earth Sciences Centre, 22 Russell St., Toronto, ON, Canada M5S 3B1 taronish.pithawala@utoronto.ca), [2]Jet Propulsion Laboratory, Pasadena, CA, United States.

Introduction: We seek to resolve an apparent paradox between two sets of observations, which seem to suggest quite different thermal structures for the deep interior of Mars. The orbit of Phobos is observed to be accelerating alongtrack at a rate of (273.4 ± 1.2) 10^{-5} deg/yr^2, which implies that the orbit is shrinking at (4.03 ± 0.03) cm/yr, and losing energy at a rate of 3.42 MW [1]. The most likely sink for that energy is tidal dissipation within Mars, seemingly requiring a warm interior. However, SHARAD observations show little to no lithospheric deflection under the polar caps [2]. Static support of the gravity and topography of Mars requires a thick elastic lithosphere, indicating a relatively cool (and therefore stiff) mantle.

Method: We use normal mode relaxation theory as described by Sabadini and Vermeersen [3] to calculate second-degree tidal Love number (k_2) for a given model. We use tidal forcing due to Phobos as the perturbing force and investigate spherical axisymmetric layered viscoelastic models. We seek models that: satisfy the Martian moment of inertia (MOI = 0.365 [4]) and bulk density (3395 kg/m^3 [5]), can support large-scale topography via a thick elastic lithosphere, and yield the observed tidal dissipation rate as well as previously calculated $k_2 \sim 0.15$ [1,4,5].

Models: Models incorporate four layers: a core, a mantle, a weak layer, and an elastic lithosphere. Layer viscosities (η) are written in terms of Maxwell relaxation time (τ - time required for viscous strain to equal initial elastic strain) and are related to a constant rigidity (μ).

$$\tau = \eta/\mu \qquad (1)$$

Two model families investigate end-member states of the core (inviscid and elastic). An inviscid layer is modeled with a near-zero relaxation time, whereas an elastic layer is modeled with a near-infinite relaxation time.

Table 1: Model constants

Planetary Radius (R)	3 397 000 m
Bulk Density	3395 kg/m^3 [5]
Mean Moment	0.365 [4]
Phobos Synodic Rate	~ 778 deg/day [1]
Solar Synodic Rate	~ -350 deg/day [1]
Rigidity	10^{11} Pa [1]
Core Density	6700 kg/m^3 [4]
Core Radius	0.461R ~ 1560 km
Inviscid Core Relaxation Time	$\tau = 10^{-20}$ s
Elastic Core Relaxation Time	$\tau = 10^{20}$ s
Lithospheric Density	2900 kg/m^3
Lithospheric Thickness	300 km [2]
Elastic Lithosphere Relaxation Time	$\tau = 10^{20}$ s

The Weak Layer: In our search for models that satisfy the aforementioned conditions, we began with simple two- and three-layer models. We found that a soft layer (relaxation time ~ 10^3 – 10^5 seconds) is required to exist somewhere in the planet to dissipate the observed 3.2 MW of tidal energy. It is not plausible that, for the case of two or three layer models, a whole Martian mantle can have such a low relaxation time. Thus we investigate four-layer models that incorporate a single thin layer with the requisite low relaxation time. We place this layer either above the core, or beneath the elastic lithosphere.

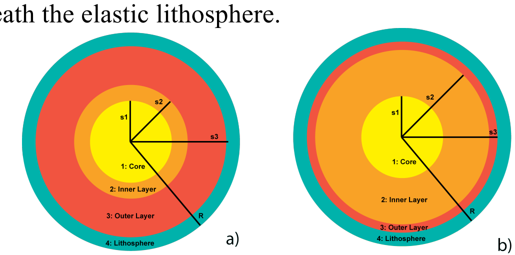

Figure 1: a) weak layer (2) above core; b) weak layer (3) beneath lithosphere

Results: We find that k_2 >0.1 can result from an elastic core with a soft outer layer. This layer can be thin (~200km) and thus does not violate the expectation that a thick elastic lithosphere is underlain by a mantle with a relatively stiff bulk viscosity. Also, we find a larger family of solutions for an inviscid core, with the weak layer (as thin as 40km) either above the core or beneath the lithosphere. These models satisfy the observed dissipation (3.42 MW) as well as constraints on MOI, density, and k_2.

References: [1] Bills, B. G. et al. (2005) *J.Geophys.Res,* **110**. [2] Philips, R. et al. (2008) *Science.,* **320**(5880), 1182-1185. [3] Sabadini, R. and Vermeersen, B. (2004) *Global Dynamics of the Earth*. Kluwer Academic Publishers. [4] Khan, A. and Connolly, J. A. D. (2008) *J. Geophys. Res.,* **113, E07003**. [5] Yoder, C. F. et al. (2003) *Science* **300**, 299