TOPOGRAPHIC RELAXATION IN A SPHERICAL, VISCOELASTIC PLANET: IMPLICATIONS FOR LONG-WAVELENGTH TOPOGRAPHY AND COMPENSATION OF LUNAR BASINS. M. T. Zuber and S. Zhong, Department of Earth and Planetary Sciences, Code 54-511, Massachussetts Institute of Technology, Cambridge MA 02139, USA (zuber@mit.edu, szhong@rayleigh.mit.edu).

Introduction: Topography and gravity anomalies on planets including the Earth and the Moon have significant power at long wavelengths. The long wavelength anomalies can be either supported statically by the elastic strength of lithosphere or maintained dynamically through planetary mantle convection. The capacity of elastic lithosphere to support topography increases sharply with decreasing planetary radius due to membrane stresses, according to models of a thin elastic shell [1]. Although these simple models reveal important insights into the origin of long wavelength topography, the assumption that the elastic shell overlies an invisid fluid interior in thin elastic shell models has two drawbacks. First, the models are static with no time scales. Second, since the rheology of major constituents of terrestrial planets, silicates, is thermally activated, it is unlikely that a sharp rheological boundary can exist within the lithosphere. Particularly, the different compensation states of lunar basins suggest that thermal history is important for the topographic relaxation [2].

Models: We have developed analytic models of topographic relaxation in a spherical geometry for a multi-layer viscoelastic medium with a layer of crust overlying the mantle. The viscosity in our models can be related to temperature with a rheological equation for silicates. The planetary radial temperature profile within the surface conductive thermal boundary layer can be estimated from either surface age with a half-space cooling model or measured heat flow. We solve the time evolution of topography at the crust-mantle boundary (Moho) and the surface for a given initial topography at these boundaries with a Laplacian transform technique [3]. In the limits (*i.e.,* a highly viscous layer overlying a weak layer in our viscoelastic models) where a thin elastic shell model is valid, our models yield the same results as those from the thin elastic shell models for spherical harmonic loads [1] and disc loads [4].

Results and Discussions: We find that for a dry olivine rheology, a 100 myr old planetary surface for Earth-like planets can only support long-wavelength non-isostatic topography anomalies for about 1 myr before the crust reaches approximately an isostatic state. However, the same age surface with the same rheology can support > 35 and 65% long-wavelength topography, including degree 2, over 4 billion years for Mars and Moon-like planetary radii, respectively (Fig. 1). The older the surface, the longer it takes to relax the topography. Other forms of rheology do not change our results significantly.

Since the relaxation times are the same for internal loads, our results also suggest that for relatively small planets, mantle buoyancy is unlikely to produce significant dynamic topography even at degree 2, and even if active mantle convection is present. This has significant implications for the interpretation of long wavelength topography and gravity anomalies on the Moon and Mars.

We also consider the relaxation of lunar basins on a very young surface (100 myr) for dry olivine rheology. Our results show that most non-isostatic anomalies can be supported over the entire lunar history (Fig. 2), though lateral variations in viscosity, such as might be associated with major impacts, could cause locally variable relaxation. Results suggest that the existence of lunar mascons cannot be used as a constraint on lunar viscosity at a depth greater than tens of kilometers, as has been done in the past [5].

References: [1] Turcotte D. et al. (1982) *JGR, 90,* 1151–1154. [2] Zuber M. T. et al. (1994) *Science, 266,* 1839–1843. [3] Zhong S. (1997) *JGR, 102,* 15287–15299. [4] Brotchie J. F. and Silvester R. (1969) *JGR, 74,* 5240–5252. [5] Arkani-Hamed J. (1973) *Moon, 6,* 112–124.

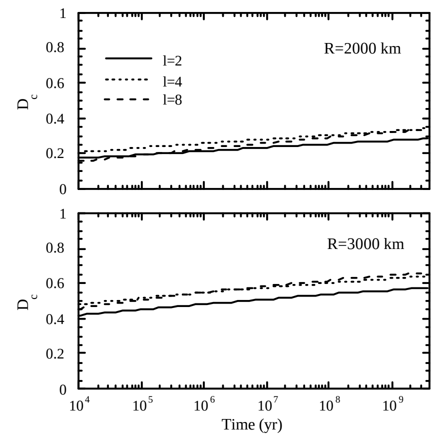

Fig. 1. Time evolution of degree of compensation (D_c = mass anomaly at Moho/mass anomaly at surface) for three different spherical harmonics l = 2, 4, and 8 for planets with different radii.

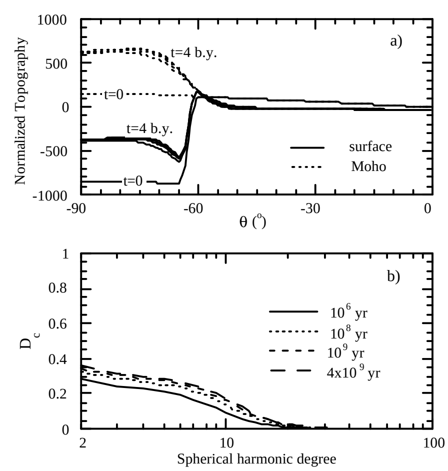

Fig. 2. **(a)** Time evolution of topography for a lunar basin of azimuthal radius of 30°. **(b)** D_c at different times for 2^2l^2100.