VISCOUS RELAXATION OF LUNAR BASIN TOPOGRAPHY: EVIDENCE FOR HEMISPHERICAL ASYMMETRY IN PRE-NECTARIAN CRUSTAL TEMPERATURE. Sean C. Solomon and Robert P. Comer, Dept. of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge MA 02139; James W. Head, Dept. of Geological Sciences, Brown University, Providence, RI 02912.

Introduction. As part of an ongoing effort to understand the properties and processes that affect the formation and evolution of impact basins [1-3], we evaluate the hypothesis that viscous relaxation has acted to modify the topographic relief of ancient lunar basins due to elevated temperatures at shallow depth. We begin by developing a simple mathematical model for viscous relaxation of topographic relief on planetary surfaces. We then apply this model to pre-Nectarian impact basins on the Moon and examine the consequences for a nearside-farside heterogeneity in crustal temperatures.

Analysis. For features as large as impact basins, the uniform halfspace model commonly used to model viscous relaxation of lunar craters [e.g., 4] fails to account for two features of importance to the relaxation problem: (i) viscosity, primarily a function of temperature, decreases with depth in the outer regions of planets; and (ii) topographic relief at long wavelengths is partially to completely compensated by corresponding variations at depth in crustal thickness or density. We have therefore solved [5] the viscous relaxation problem for an analytical model that retains both of these features: the model is a uniform layer of viscosity η, density ρ and mean thickness H overlying an inviscid halfspace of greater density ρ_m. Initial surface topography is partially to completely compensated by corresponding relief at the base of the layer (i.e., crust). For this problem, there are two time constants for relaxation. Initial topographic relief relaxes quickly, according to the smaller time constant, to an isostatic state at long wavelengths; thereafter there is a much slower relaxation, according to the second time constant, of both surface topography and its compensation at depth [5].

Application to the Moon. We have applied this formulation for viscous relaxation to the problem of topographic modification of large lunar basins formed sufficiently early in the Moon's history so that near-surface temperatures were high and significant viscous flow occurred in the crust in response to topographic stress. To use the model, we need both the present topographic profile of an ancient basin and an estimate of the profile after basin formation but before the onset of subsequent modification processes. For the latter we use the topographic profile of the Orientale basin [6], because Orientale has not been modified by the emplacement of ejecta from younger basins [7], the volume of mare basalt fill is small [8], and the geologically long-term modification to early basin structure cannot have been substantial [8]. Based on the analysis of gravity anomalies over present lunar basins partially filled with mare basalt, we must account for the fact that the initial (pre-mare) topographic relief of the basin was at least partially compensated by crustal thickness variations [9, 10].

We first apply the viscous relaxation model to the pre-Nectarian Tranquillitatis basin. Wilhelms and McCauley [11] show a single ancient basin for Tranquillitatis, marked by a major ring structure of about 340 km radius and remnants of an outer ring. Identifying the major ring structure as analogous to the outer Rook Mountains of Orientale gives these two basins closely similar horizontal dimensions. Figure 1 shows a comparison of the present topographic profile of Tranquillitatis, after removing the mare basalt fill [12], with the profile predicted by viscous relaxation of an initial topography similar to that preserved in Orientale. The two profiles compare favorably except in detail, and support the hypothesis that viscous relaxation

was an important modifier of pre-Nectarian basins on the lunar nearside.

In contrast, the large topographic relief indicated by Apollo laser altimetry for the larger and older South Pole-Aitken basin [13] on the southern farside is inconsistent with significant viscous relaxation since basin formation. This result requires a mean crustal viscosity at least a factor of 10 higher on the backside than on the nearside over the time interval during which viscous relaxation was important for nearside basins. Cooler crustal temperatures for the backside are indicated for this time period. A nearside-farside asymmetry in temperature may have originated with the process of differentiation that produced the offset of lunar centers [13], and would have been maintained by the concentration of late-stage basin-forming impacts and mare volcanism on the nearside.

Conclusions. The hypothesis that viscous relaxation of topographic relief was an imortant modification process for pre-Nectarian basins on the lunar nearside is consistent with observed topography. In contrast, this process was not as important for a larger contemporaneous basin on the farside. It is likely that the lunar farside was characterized by higher effective viscosities and cooler average temperatures than the nearside in pre-Nectarian times.

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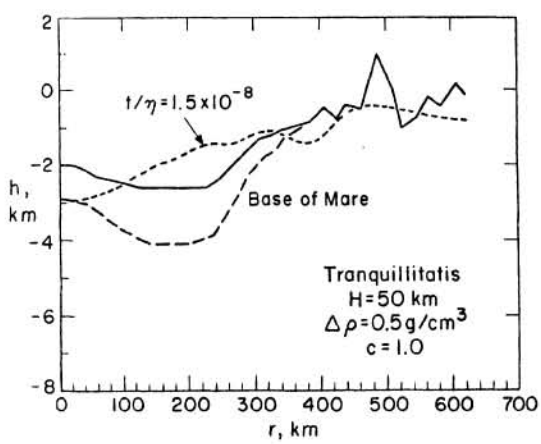

Figure 1. Topographic profile for Tranquillitatis compared with the predicted profile assuming viscous relaxation of an initial basin similar to that of Orientale. Topographic profile, from LM60, extends SW from basin center [11]; the base of the mare basalt is from [12]. The Lamont region, containing a small mascon, may have subsided relative to the rest of the basin by as much as 1.5 km [14]. The model has ρ=2.9 g/cm^3, ρ_m=3.4 g/cm^3, H=50km, and complete initial compensation. The quantity η is approximately the lowest effective viscosity of the sub-basin crust and t is the time interval over which viscosity was similar to that value.