WHY DO MASCON BASINS OCCUR ON THE MOON? S. Karimi and K. Lewis, Johns Hopkins University, Department of Earth and Planetary Sciences, 3400 N Charles St. Baltimore, MD, 21218. saman@jhu.edu

Introduction: Typically, a mass deficit associated with a large crater is expected to show negative free-air gravity anomaly. However, anomalous mass concentrations, or mascons, appear as an apparent mass deficit at the surface that nevertheless shows a large positive free-air anomaly. The characteristic gravity signature of mascons consists of a central positive gravity anomaly ringed by a negative gravity anomaly [1, 2] (Fig. 1). Mascons have been identified most prominently on the moon, and are much less common on other bodies. High-resolution gravity data from the Gravity Recovery and Interior Laboratory (GRAIL) mission has enabled detailed studies of the lunar mascons [1 - 5].

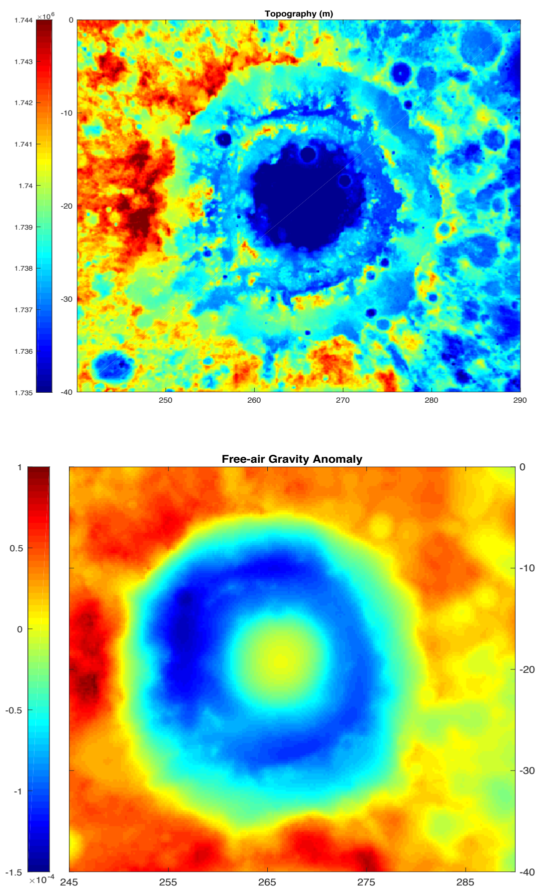

Figure 1. Topography (top) and gravity map (bottom) of Orientale basin on the Moon. This basin shows a prominent mascon behavior with central positive gravity anomaly surrounded by negative gravity.

Since the first mascon observations on the Moon in 1968 [6], there have been debates regarding the origin of mascons as well as their formation mechanisms. *Solomon and Head* (1980) justified the central positive free-air anomaly of mascon basins by the presence of highly dense mare infilling [7]. During the formation of a large impact crater, the underlying mantle uplifts to an isostatic equilibrium level, which is likely due to the collapse of the transient crater [8, 9]. *Wise and Yates (1970)* suggested that the highly dense uplifted mantle material (associated with a large impact crater) is responsible for generating the positive central gravity anomalies [10]. Other studies have proposed magmatic intrusions as a mechanism for producing the positive free-air gravity anomalies [11]. In recent years, *Andrews-Hanna (2013)* suggested that mascon formation is likely due to the flexural uplift of the undercompensated crustal terrains that surround the center of a large impact basin [4]. Regardless of the various formation scenario, it is known that mascon basins exhibit prominent mantle uplifts that have not been relaxed. *Dombard et al. 2013* showed that the majority of large craters on any planetary body initially form mascons, but later relax to an undercompensated state [12].

Several studies have explored relaxation of large impact craters on the surface of planetary bodies such as Mars, Venus, the Moon and Mercury [13-17]. These studies show that several parameters govern the relaxation of the initial mantle uplift: 1) background heat flux, 2) gravitational acceleration, 3) rheology of the crust/mantle, 4) crustal thickness, 5) surface temperatures.

In this study, we comparatively explore the likelihood of formation and evolution of mascon basins on the surface of the terrestrial planets – the Moon, Mars, Mercury and Venus. We analyze the role of above parameters in viscoelastic relaxation of large craters in detail. In doing so, we seek to constrain the conditions at which the highly dense mantle uplift underneath a large impact maintains its initial shape and does not undergo relaxation over geologic timescales. Here, we aim to find a response to the following question – "*why does the lunar crust host the majority of mascon basins?*"

Methodology: We simulate the evolution of a 300-km crater on Mars, the Moon, Mercury and Venus. We model relaxation at both the surface and subsurface for a total model time of 100 Myr, and analyze the results. We test the role of each of the above parameters that can potentially affect the evolution of a large crater. To model the relaxation of surface and subsurface topography associated with a large crater, we use the Marc-Mentat finite element package and we follow the same approach as described in [14].

Thermal and Mechanical Simulation: We initialize our model by running a thermal simulation which modulates the thermal structure by finding the equilibrium between various boundary conditions such as surface temperature, background heat flux and remnant impact heat. The results of the thermal simulation are then input into the mechanical simulation, where we set the mechanical parameters of the crust and mantle including rheology (in particular, hydrous or anhydrous) and density.

Results: We explored the effects of the parameters that play significant role in the formation/progression of lower crustal flow. We comparatively determined their effects in maintaining the topography (surface and subsurface) at the desired states and investigated the formation/evolution of mascon basins. Our models show that under certain conditions lower crustal flow is efficient in relaxing the highly dense mantle topography underlying the basin, such that the lithosphere cannot maintain the mascon structure.

In line with expectations, we find that colder thermal states (low background heat flux and/or low surface temperatures) lead to a less efficient relaxation of mantle topography. Similarly, our simulations show that for planetary bodies with a smaller gravitational acceleration, a lesser amount of relaxation at the surface and subsurface is expected. Additionally, we find that a thinner crust leads to cooler temperatures in the basal crust, and thus, inhibits mantle relaxation. Simulations in which anhydrous rheologies were applied for the crust and mantle experienced less relaxation, compared hydrous rheologies.

Discussion and Conclusion: Our study shows that a planet on which the development of lower crustal flow is not efficient can maintain a mascon long after a large impact. This study explored the conditions at which the formation of lower crustal flow and, therefore, mantle relaxation is inhibited. For instance, under identical conditions, a simulation with smaller gravitational acceleration goes through lesser relaxation (Fig. 2), which in turn assists the mantle uplift to preserve its topography (and to form a mascon basin). Gravitational acceleration of the Moon is the smallest among the Solar System's inner planetary bodies. Similarly, our study shows that for a planetary body with a colder thermal state, the likelihood of mascon formation is higher. The thermal budget of a planetary body is a function of planetary mass, and the Moon is the least massive body among the studied planetary bodies. Furthermore, the rheology of the crust and mantle also plays a crucial role in determining whether lower crustal flow can efficiently relax a mantle uplift. Our results demonstrate that planetary bodies with anhydrous rheology, again including the Moon, have a higher likelihood of forming mascon basins.

Our analysis demonstrates that the Moon, due to its relatively cold thermal state, anhydrous rheology and low gravitational acceleration, inhibits the efficient relaxation of surface/subsurface topography. A confluence of these factors make the lunar crust especially suited to the formation of mascon basins among the terrestrial bodies. Conversely, large craters on Mars, Venus and Mercury undergo much faster relaxation than the Moon, and thus, the likelihood of mascon formation on those bodies is relatively smaller.

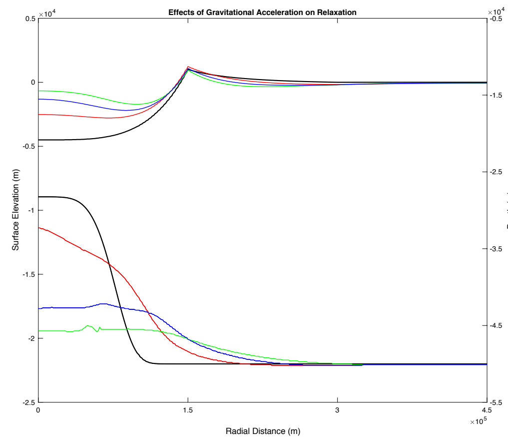

Figure 2. Results of the simulations for three different values of local gravitational acceleration. Black lines show the initial topography at the surface and subsurface for a 300 km impact. Red, blue, and green lines show the simulated topography for gravitational acceleration of the Moon, Mars/Mercury, and Venus respectively under otherwise identical conditions.

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