USING LARGE QUASI-CIRCULAR DEPRESSIONS TO STUDY THE THERMAL HISTORY OF THE NORTHERN LOWLANDS OF MARS. M. Karimi, A.J. Dombard, Dept. of Earth and Environmental Sciences, University of Illinois at Chicago, 845 W. Taylor St. (MS-186), Chicago, IL 60607 (mkarim5@uic.edu)

Introduction: In order to understand better the geologic processes occurring on the surface of a planet, having a clear perception of the internal heat transfer is necessary. With the exception of the Earth, in situ measurements of the heat flux are uncommon; hence, modeling is key to these unanswered questions. Mars is not exempt from this dilemma; therefore, we take advantage of the sensitivity of Martian lithosphere thickness to the background heat flux and employ modeling in order to study the thermal evolution of Mars. Many workers, such as Karimi et al. [1], Mohit and Phillips [2], McGovern et al. [3, 4, 5], Montesi and Zuber [6] and Comer et al. [7], have studied the thermal evolution of Mars; these studies are generally limited to the Southern Highland or the Tharsis province. In contrast, there has been less effort to study the Northern Lowlands, and a plausible reason for this lack of study could be the lack of the helpful features in that region that lend themselves to modeling.

In this study, we take advantage of large Quasi-Circular Depressions (QCDs), presumably buried impact craters, that are ubiquitous features on the surface of the planet, including in the Lowlands. QCDs cannot be distinguished in images; however, they are detectable in high resolution topography data [8, 9]. Here we constrain the heat flux by simulating the viscoelastic deformation of large QCDs due to lower crustal flow. Studies of Martian crustal thickness revealed that the mantle is uplifted beneath large impacts [10], likely occurring during collapse of the transient crater [11]. Lateral movement of the lower crustal material, inward from the periphery, causes the relaxation of the uplifted crust-mantle boundary (Fig. 1). The entire process is a function of the flow channel thickness and viscosity of the lower crust material [12]; therefore, the process is very sensitive to the background heat flux. We have previously used this technique to explore the thermal evolution of the Southern Highlands. Here, our work will elucidate the thermal evolution of the Northern Lowlands of Mars.

Method: Due to the high resolution of Mars Orbiter Laser Altimeter (MOLA) data, we are able to discern the QCDs on the Northern Lowlands [8]; however, we look for QCDs in a limited size range. We expect these QCDs to be large enough to be resolved in current gravity models, yet small enough to avoid problems that arise when working with very large impacts (e.g., a complex history); therefore, we constrain the size of the QCDs (and the underlying craters) to ~200-600 km in diameter. Among these QCDs, only those that show definitive mantle uplift underneath the impact are good candidates for our study. We have identified 21 QCDs that meet our requirements. Due to the long term burial of QCDs, the regular methods of the constraining age (e.g., crater counting) are not applicable; however, the spatial distribution and size of the QCDs are comparable to those of the craters we used in our study of the Highlands, which were primarily from the mid Noachian. Therefore, we assume that the ages of the QCDs are comparable to those of the craters [9].

Here, we employ the commercially available *Marc* finite element package to investigate the long term deformation of the topography at the surface and subsurface due to lower crustal flow. We apply a 2-layer axisymmetric mesh with a flat surface in order to model the evolution of QCDs. The domains of our meshes are 3 crater radii wide and deep, large enough to minimize the effects of the far edge boundaries. We let the QCDs have the same crust-mantle boundary topography as craters of the same size, and we assume the pre-burial craters are fully compensated isostatically, with the same dimensions we used in our study of craters in the Highlands [1]. In our model, a 45 km crust with a density of 2900 kg m^{-3} lies over the mantle with the density of 3500 kg m^{-3}. The number of elements for the finite element mesh depends upon the size of the QCDs, and is typically of order of 10^4. After building the meshes for these QCDs, we first perform a thermal simulation to constrain the subsurface temperature, piping these results into a mechanical simulation.

Thermal Simulation. We find the steady state conductive thermal equilibrium between a surface temperature of 210 K and a specified basal heat flux, with zero heat flux out the sides. The thermal conductivity of the crust and mantle are 2.5 and 4 W m^{-1} K^{-1}, respectively. We approximate the remnant impact heat by constraining the temperature of the uplifted nodes on the crust-mantle boundary beneath the crater to be that of the undeflected boundary away from the crater. The solution of the thermal simulation is then input in mechanical simulation.

Mechanical Simulation. The nodes at the bottom of the mesh are fixed while the nodes on the sides are free slip. Loading is provided by a uniform gravitational force with an acceleration of 3.7 m s^{-2}. The nominal values for the elastic Young's moduli are 65 and 140 GPa [13] for the crust and mantle, while the Poisson's ratio for both are 0.25. For the viscosity, we employ the parameters consistent with the flow law of a wet Maryland diabase and wet natural peridotite for crust and mantle, respectively [14, 15]. The mechanical simulations are run over a time frame of 100 Myr, which is approximately the diffusion time of the remnant impact heat. In order to keep the running time of the order of weeks, the minimum viscosity is fixed at 10^{21} Pa s^{-1}.

Results: We attempt to find the heat flux that yields final topography on the crust-mantle boundary that best matches the Martian crustal thickness model [10] for each candidate QCD (Fig. 2). This study puts values of the heat flux between ~70 and 100 mW m^{-2}. These values are generally higher than heat fluxes found for craters in the Southern Highlands [1], which range between 45 and 75 mW m^{-2}.

We also test our approximation of a flat surface by comparing against simulations with unburied crater topography on the surface. Deformation of the crust-mantle boundaries in the 2 cases is comparable (displacements within 14%). This agreement is consistent with our previous assessment of the mechanics of the system [1]; because the brittle-ductile interface occurs mid-crust, the surface and crust-mantle boundary are mechanically decoupled. Consequently, our conclusions are not sensitive to when the QCDs were buried. In addition, our simulations do not show any major sensitivity to changes in the surface temperature.

Discussion: In these simulations, we apply a wet rheology for the crust and mantle of the Northern Lowlands. We also test our simulations with parameters consistent with a dry rheology [15, 16], and the results do not show remarkable deformation at the surface or subsurface. Karimi et al. [1] investigated the effects of wet vs. dry rheology for craters in the Southern Highlands and observed negligible deformation for the dry cases. These studies demonstrate that Mars's crust and mantle are likely wet to a certain degree.

Previous study of the viscoelastic behavior of craters [1] has revealed that in the Southern Highlands, mid-Noachian craters closer to the Dichotomy boundary experienced a higher heat flux than those farther from it. Our current results are complementary, with the northward increasing trend of the heat flux in the Southern Highlands continuing into the Northern Lowlands (Fig. 2). This observation further supports the notion that whatever process that formed the Crustal Dichotomy of Mars still possessed a thermal signature in the middle Noachian, with higher heat fluxes in the north, grading away southwards from the Dichotomy boundary.

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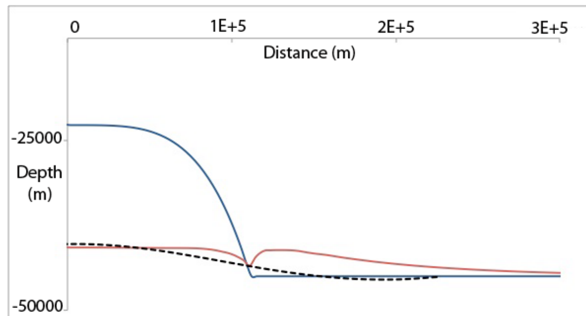

Figure 1. An example that shows the deformation at the crust-mantle boundary for a QCD with a diameter of ~230 km. The blue line is the initial mantle topography, red line is the simulated mantle topography for a basal heat flux of 70 mW m^{-2}, and the dashed line is the current mantle topography.

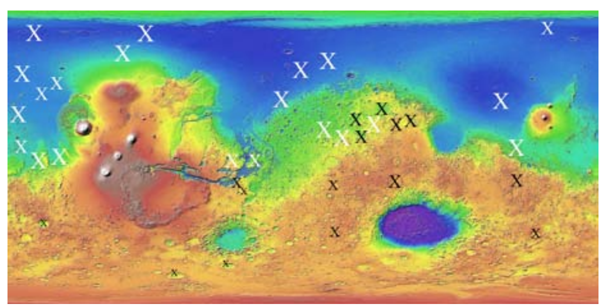

Figure 2. A topographic map of Mars with the locations of the candidate craters [1] (in black) and QCDs (in white). The size of the signs scale with the magnitude of the background heat flux of each impact.