THE POTENTIAL FOR CRATER RELAXATION ON VENUS. S. Karimi[1], A.J. Dombard[1], S. E. Smrekar[2]. [1]Dept. of Earth and Environmental Sciences, University of Illinois at Chicago, 845 W. Taylor St. (MS 186), Chicago IL, 60607. [2]Jet Propulsion Lab, Pasadena, CA, 91109 (mkarim5@uic.edu).

Introduction: A planet's internal heat transfer drives geologic activity on the surface. Among the various geologic phenomena on Venus (e.g., volcanism, tectonism, Aeolian processes, etc.), volcanism is believed to have played the main role in shaping its surface [e.g., 1-6]. Topographic relaxation, however, has not been studied extensively. Numerous works have explored crater relaxation on the surface of such planetary bodies as Mars, the Moon, and icy satellites in order to have an insight into their structural and thermal histories [e.g., 7-14]. Unlike the Moon and Mars, the surface of Venus is not highly cratered, and as a result, only a few studies have explored the relaxation of Venusian craters [e.g., 2, 12, 15]. Geometric analyses of Venusian craters showed that they are systematically shallow [6, 16]. Comprehensive works on Venusian craters demonstrated that the dark-floored craters are more shallow than bright-floored craters [6, 17, 18], consistent with the interpretation that dark-floored craters are volcanically flooded. Studies that benefited from high resolution stereo-derived topography [6, 18] and analyzed images of the surface [19], concluded that substantial crater relaxation on Venus is unlikely and that the shallowness of these craters is due to volcanic infilling, even the bright-floored ones. Using a gravity-driven relaxation model, *Grimm and Solomon* [2] also concluded that Venusian craters seem to maintain their pristine shape without any significant relaxation.

This conclusion, however, may need revision. Previously, we examined the relaxation of Mead Basin using the finite element method and applying a viscoelastic rheology [12, 15]. This study found that lower crustal flow is efficient in reducing the topography at the surface and subsurface (i.e., the crust-mantle boundary) of Mead, and that relaxation plays a more important role than presumed. However, we know that relaxation is generally a more efficient phenomenon for larger scale features. Consequently, it is not directly obvious whether relaxation would occur for other craters on Venus that are much smaller than Mead. Here, in light of our study of Mead Basin relaxation, we expand our scope and test the extent of the crater relaxation on Venus.

A previous relaxation study [2] applied the current surface temperature of 740 K and concluded that crater relaxation was unlikely on Venus. More recent Venusian climate studies, however, suggested that massive release of volcanic gases could cause large variations in average surface temperature over time scales of 10-100 Myr [e.g., 20, 21]. The long-term diffusion of very high surface temperatures into the subsurface could have weakened the lithosphere, thus leading to a higher rate of relaxation. This phenomenon provides another justification for revisiting relaxation on Venus under the effects of the very high surface temperatures (~110 K more than the current surface temperature). Furthermore, our recent implementation of relaxation modeling [10, 12-15, 22] incorporates a more complex rheology than the previously conducted one [2]. Thus, we investigate the effects of a higher surface temperature on the development of the lower crustal flow, subsequent relaxation, and shallowing of Venusian craters.

Topographic relaxation is a result of viscous flow within the crust and mantle and thus is strongly correlated with the water content of the material. Previously, we have tested the relaxation of Mead Basin for the appropriate rheology [12, 15] and concluded that the crust and mantle in the vicinity of Mead seem to be anhydrous. Here, we aim to extend our rheology examination by testing the rheological parameters of Venus for various size craters.

Methodology: Using the finite element method, we investigate the potential relaxation of Venusian craters. We also simulate crater relaxation under various rheological parameters and determine the appropriate rheology of the Venus's interior. Our methodology is similar to that described in our previous studies [e.g., 10, 12-15, 22]. We use an axisymmetric mesh of one radial plane with two layers of crust over mantle. Using previous studies [e.g., 6, 17] that explored the geometric properties of Venusian craters (e.g., depth and rim height), we determine the initial shape of fresh craters. After building the finite element mesh, we run thermal and mechanical simulations. The thermal solution finds the steady state equilibrium among the thermal boundary conditions (e.g., various surface temperatures, background heat fluxes, etc.) and is piped into mechanical simulation. In the mechanical simulation, we apply gravity loading and rheological parameters to the crust and mantle (e.g., hydrous and anhydrous [23, 24, 25]), and we run it over the time frame of 100 Myr, sufficiently long to capture any lower crustal flow.

Results: We simulate the potential viscoelastic relaxation of Venusian craters under various thermal and rheological conditions. Craters > 50 km in diameter show noticeable relaxation when the surface temperature is 850 K (Fig. 1). Furthermore, simulations using the lower current surface temperature see some degree of relaxation. As expected, relaxation increases with increasing background heat flux. Additionally, the results of our simulations using hydrous rheologies for the crust and mantle show an almost complete relaxation of the topography at the surface and subsurface (Fig. 1). Application of anhydrous rheology, however, yields the topography at the surface more consistent with the topography observed on Venus.

Discussion: The viscosity of the material and its water content contribute greatly to the relaxation phenomenon. In turn, the rheological behavior of the material during relaxation can give us insight into the water content of the crust and mantle. By applying both hydrous and anhydrous rheologies [23-25], we determine that a wet rheology does not seem to be suitable for the Venus's interior. When an hydrous rheology is applied, the results of our simulations show an almost completely flattened crater – a result that is inconsistent with current crater topographies (Fig. 1). Applying an anhydrous rheology, instead, results in more modest amounts of shallowing that is in line with the observed topography for the craters. Based on these results, the Venus's interior is drier than that of our planet, a finding that is consistent with our work on Mead [12, 15].

Application of high surface temperature and high background heat flux (> 70 mW m^{-2}) leads to a strong relaxation. This finding indicates that concurrent occurrence of high surface temperatures and high background heat flux is unlikely, or high surface temperatures could not last long on Venus (< 10 Myr), in contrast with atmospheric models [21].

In our study, we have shown that crater relaxation is a feasible phenomenon for shallowing the Venusian craters. While volcanism is believed to form and modify the majority of the Venus's surface, this study demonstrates the potential of the relaxation in helping to shape the surface of Venus.

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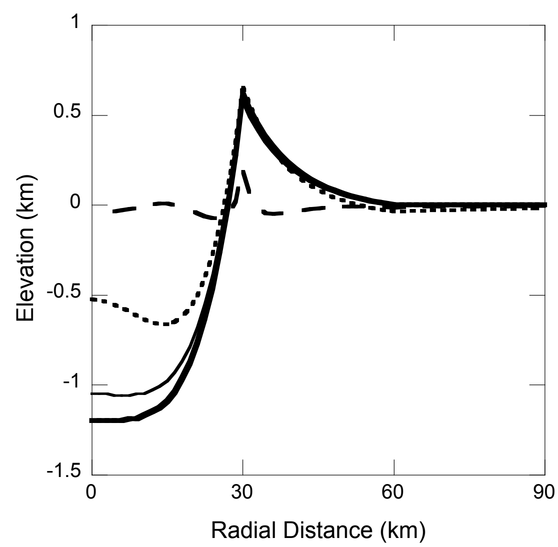

Figure 1. Results of the simulations for a crater 60 km in diameter and a background heat flux of 40 mW m^{-2}. The bold black line shows the initial surface topography. Dashed line shows the simulated result for an hydrous rheology and surface temperature of 740 K. Dotted and thin lines show the simulated results for the surface temperature of 850 and 740, respectively (with an anhydrous rheology). The thickness of the crust is 30 km.