STUDYING THE POSSIBLE VISCOELASTIC DEFORMATION OF THE SOUTH POLAR CRATERS OF VESTA. M. Karimi and 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: Vesta is the second largest member of the Asteroid Belt. Our knowledge of Vesta comes from telescopic observations, from the studies of the HED class of meteorites [1], and recently from the data sent from NASA's Dawn mission. Past Hubble Space Telescope observations provided a coarse image of this body that included a geologic feature on its south pole, which -- due to its size -- was hard to classify. *Thomas et al.* [2] proposed that the south polar feature is a large crater that is anomalously shallow, as determined from a dynamic topographic model using the assumption of constant density. *Kattoum and Dombard* [3] investigated the topography of the south polar crater, assuming the asteroid is differentiated [e.g. 4-6], and proposed a deeper value for the depth of the crater [cf. 2]. The Dawn spacecraft, which orbited Vesta from July 2011 to September 2012, revealed that the south polar feature actually consists of two large craters of similar size, the younger Rheasilvia superimposed on the older Venenia [7, 8]. The structures of these south polar craters are strange, with central peaks whose heights reach the elevation of the surrounding terrain. Though this structural type might be a consequence of a body-scale impact on an asteroid the size of Vesta, this structure is very similar to that of evolved craters on the Saturnian satellites [9]. Many studies have tied the evolution of large craters to the background heat flux and thermal evolution of planets [e.g., 10-13]. Similarly in this study, we investigate the feasibility of the evolution of the south polar craters by simulating the potential for viscoelastic deformation.

Method: The Rheasilvia and Venenia impact basins are ~500 km in diameter [14], large enough to yield global scale deformation. Since these diameters are ~90% of that of Vesta itself [15], we have two approaches to modeling the evolution of the south polar craters based on two different finite element meshes: (1) planar mesh simulations, and (2) spherical mesh simulations. For the planar mesh, the curvature of the asteroid is ignored, while for the spherical mesh, the planetary curvature is included. In our study, we use the commercially available Marc finite element package to investigate the evolution of the south polar craters at the surface and subsurface. We apply a 2-layer axisymmetric mesh to model crust over mantle. For the initial crater shape, we use a rim height of 7 km and an initial depth of 15 km [3]. The shape of the crater depression is a 4th order polynomial, while the rim and ejecta blanket follow an inverse 3rd power law [16]. We consider the initial uplifted mantle topography to follow a Gaussian shape that is narrower than the surface basin [17], with the subsurface and surface topography in isostatic equilibrium at the center of the crater. The same basic topography is considered for the spherical mesh, which is then wrapped around a spherical shell. Many studies have provided various estimates for the thickness of the eucritic/diogenitic crust of Vesta [e.g., 5, 6]; however in order to maximize the effect of any potential lower crustal flow [e.g., 10, 11], we consider the thickest possible crust of 80 km. Previous studies have determined the density value of the crust to be about 2800-2900 kg m^{-3} and the mantle density to be in the range of 3200-3500 kg m^{-3} [3, 18, 19] (though both the crust and mantle may be ~5% porous [19]). We use density values for the crust and mantle in our simulations of 2800 and 3500 kg m^{-3}, respectively. Choosing these values, with the maximum density contrast between the crust and mantle, minimizes the initial mantle uplift, and the subsequent wider flow channel increases the likelihood of lower crustal flow. For the viscous creep behavior of the material, we use the parameters for the flow rules of both wet and dry rheologies [20-22]. In order to eliminate the far edge boundary effects of the planar mesh, the meshes are 3 crater radii wide and deep. Regardless of the shape of the finite element mesh, planar or spherical, the number of the elements is of the order of 10^4.

Thermal Simulation. Since the temperature of the system strongly controls the viscosity of the material, it is necessary to provide the temperature field, as determined by a thermal simulation. For this step, the elements on the side of the mesh are set to exchange no heat flux, the basal elements have an applied heat flux, and the surface temperature is fixed at an average surface temperature of 180 K. Thermal conductivities of the crust and mantle are considered to be 2.5 and 4 W m^{-1} K^{-1}, respectively. In order to approximate impact heat, we constrain the temperature of the uplifted mantle to that of the mantle far from the crater. This action results in isotherm uplift, which serves as a proxy for the thermal anomaly due to impact heat. We run a steady-state, thermally conductive simulation. This thermal solution will be then input into the mechanical simulation.

Mechanical Simulation. For the mechanical simulations, we set the boundary conditions such that the basal nodes are fixed and the nodes on the two sides are free-slip. A vertical gravity load equal to the gravitational acceleration of Vesta, 0.2 m s^{-2}, is applied to every element in the mesh; this load coupled with mass densities appropriate to the crust and mantle produce the gravity force that drives the deformation at the surface and within the subsurface. We use the elastic parameters typical for the crust and mantle materials of the rocky bodies, in which the nominal Young's moduli are 65 and 140 GPa, respectively, and the nominal Poisson's ratio is 0.25 for both the crust and mantle [23]. We run the mechanical simulations over a time frame of 100 Myr, a period during which any deformation might have occurred [10, 11].

Results: We calculate the amount of heat generated by the decay of the radioactive elements in Vesta based on the average concentrations of the heat producing elements in chondritic meteorites at approximately 1 Ga [23], finding an average heat flux in the range of ≤ 4 mW m^{-2}. If we apply this heat flux value for Vesta to our simulations, virtually no deformation occurs for the south polar craters. The results of our simulations with higher heat fluxes up to 10 mW m^{-2} also do not show any appreciable evolution. Our simulations only demonstrate noticeable deformation at the surface and subsurface with an unreasonably high heat flux of more than 25 mW m^{-2} and a wet rheology for the crust and mantle.

Discussion: In this study, we have selected parameters to be the most conducive to lower crustal flow and hence evolution of the craters' topography. We have applied a crustal thickness of 80 km; although, various workers estimate a smaller value for the crustal thickness of Vesta in the range of less than 45 km [7, 8, 24, 25], which we have tested. Plus in our simulations, the surface and subsurface are in isostatic equilibrium at the center point of the crater; a non-isostatic initial state could drive more pronounced deformation. The simulated results with these geometries do not show any significant deformation at the surface and subsurface, nor a remarkable discrepancy when compared to our nominal results. *Schenk et al.* [9] estimated the initial depth of the south polar craters to be 19 ± 6 km; though the depth that we used in this model falls within this scope, we have yet to test this range. Simulations using dry viscous rheologies for the crust and mantle show no appreciable deformation, while simulations with wet rheologies only deform for unreasonably high heat fluxes. In addition, applying higher values for the surface temperature, up to 200 K, does not have significant effect on the final simulated results. Consequently, the evolution of the craters via lower crustal flow at reasonable conditions for Vesta seems unlikely. We conclude that the unusual topography for the Rheasilvia and Venenia Basins is likely attributed to formation of a body-scale impact on a dwarf planet.

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