FORMATION OF EQUATORIAL GRABEN FOLLOWING THE RHEASILVIA IMPACT ON ASTEROID 4 VESTA. T. J. Bowling[1], B. C. Johnson[2], and H. J. Melosh[1,2], [1]Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, 550 Stadium Mall Drive, West Lafayette, IN, 47907 (tbowling@purdue.edu); [2]Department of Physics, Purdue University, 525 Northwestern Avenue, West Lafayette, IN, 47907.

Introduction: The geologically recent (~1 Gya) Rheasilvia impact basin on 4 Vesta is nearly equal in size to the diameter of the asteroid [1, 2]. The stress wave produced by an impact of this size is capable of deforming the surface of a body at considerable distance from the basin itself. The Dawn spacecraft has observed a set of troughs thought to be related to the Rheasilvia impact. These troughs lie ~60-100° from, and form planes orthogonal to, the basin center [1]. The spatial relationship between crater and troughs suggests that they are related, with the troughs being a distal effect of the impact itself. Furthermore, a second, older set of troughs were observed in the northern hemisphere of Vesta, and have a similar spatial relationship to the older, slightly smaller Venenia impact basin [1]. Further analysis of the faults that bound these troughs suggest that they are in fact graben systems and accommodate several kilometers of extension [3].

While it seems obvious that these graben are related to the Rheasilvia impact, it is unclear exactly what mechanism is responsible for their formation. One possibility is that they are the result of long term deformation related to the collapse of Rheasilvia basin. On the other hand, they could have opened as a result of localized impact induced stresses (as has been suggested for the origin of Ithaca Chasma on Tethys [4]), opening concurrently with the transient crater and before the arrival of impact ejecta. If this is the case, we must be able to explain why the Rheasilvia impact created a fresh set of graben instead of re-activating the pre-existing system formed by the earlier Venenia impact. In other words, we must understand what kind of strains are induced by the passage of the impact stress wave as well as how these strains were concentrated only in one region of the body, where the graben system is found. To better understand this issue, we perform numerical modeling of the Rheasilvia impact event. We directly calculate the strains induced by the impact stress wave to gain insight into where strains are localized and what mode of deformation should be expected.

Numerical Modeling: The Rheasilvia impact was simulated using the iSALE shock physics code [5-7]. Our simulations are run in two dimensions with cylindrical symmetry on an Eulerian (fixed cell) computational mesh with 400 meter resolution, sufficient to resolve the deformation in the near surface of the target. The impactor is treated as a 37 kilometer diameter dunite body striking at 5.5 km s^{-1}. Impact parameters were determined by fitting the observed topography of the Rheasilvia basin to impact model output [8]. The target is treated as a spherical body with a basalt crust, a dunite mantle, and a ductile iron core. The thermodynamics of each material are addressed using the ANEOS equation of state. Massless tracer particles are distributed throughout the mesh and follow material flow. By treating each tracer as the node of a quadrilateral element we can calculate individual strain tensor components as a function of time. This provides insight into what types of deformation should be expected in different regions of the target.

Results: The dominant mode of strain in the target's crust following the passage of the impact stress wave is shear, or in target centered spherical coordinates, $\varepsilon_{r\theta}$. Shear strains on the order of 5% are found throughout much of the target's crust. This is likely a result of spallation in the near surface and basal shearing at the crust-mantle boundary. Shearing of this magnitude is capable of deforming the surface on its own, perhaps producing half graben systems. However, the presence of strong shear throughout much of the crust cannot explain why graben related to Rheasilvia basin are found only near the equator of Vesta. Strains along equal lines of longitude $\varepsilon_{\theta\theta}$, however, show a strong localization of extension near the target's equator. Strains within this locus are on the order of ~1-2%, consistent with strains of ~1-5% based on observation [3], and are of the correct mode to produce graben of the observed orientation. This suggests that the equatorial graben on Vesta opened immediately following the Rheasilvia impact, before the arrival of ejecta from the basin.

Two important parameters controlling the magnitude and localization of extensional stresses in the target body are porosity and core strength. As the impact stress wave passes through the target's mantle and crust, pore space is crushed out. This saps energy from the wave and greatly reduces the amount of deformation. If the mantle porosity is set at 5%, similar to estimates based on radiometric tracking of the Dawn spacecraft [1], the amount of extensional strain in the region where graben are found is insufficient to match observation. However, this result may be an effect of the strength of the porous material used (the strength above which pore space begins to be crushed out), and warrants further investigation.

The presence of a ductile core seems to be responsible for localizing extensional strains in the region where graben are observed. While the strength of Vesta's core is currently unknown, the strength of meteoritic iron has been shown to be dependent on the amount of nickel and carbon in the alloy [9]. In addition, the strength of metals is dependent on accumulated strain [10], and it is possible that previous impacts, such as the one that formed the Venenia basin, could have served to harden Vesta's core. When a 'strong' core rheology is implemented, one in which much of the core deforms elastically as the impact stress wave passes, strains are no longer localized. The dependence of strain localization on core strength and strain magnitude on mantle porosity, coupled with two sets of independently produced graben, can perhaps provide a window into the chemical and mechanical composition of Vesta's core, the material properties of its mantle, and the asteroid's impact history.

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Acknowledgements: We gratefully acknowledge the developers of iSALE, including Gareth Collins, Kai Wünnemann, Boris Ivanov, Jay Melosh, and Dirk Elbeshausen. We would also like to thank the Dawn science team for feedback and advice on this project. This research was supported by NASA grant PGG NNX10AU88G..

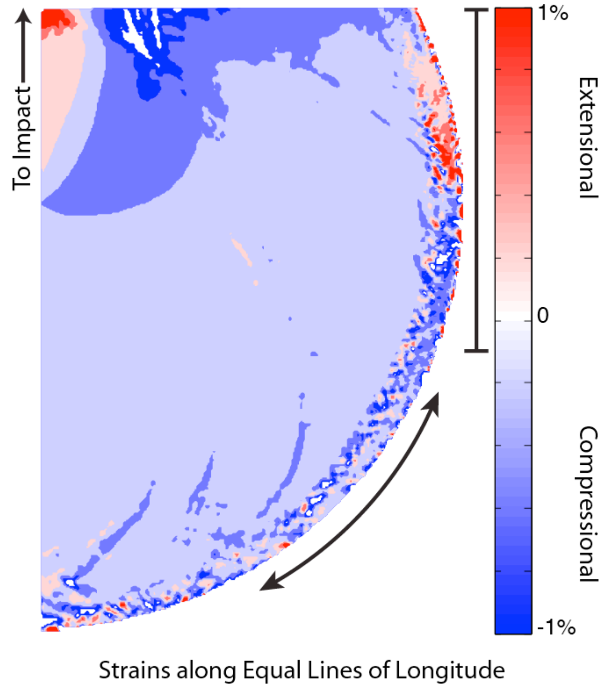

Figure 1: Strain component $\varepsilon_{\theta\theta}$ in the Vesta-like target body 500 seconds after impact. The image shows a cross section of Vesta from 60 degrees away from the impact point (upper right) to the antipode (bottom). This simulation was run with a mantle porosity of 2% and a crust porosity of 5%. The strength of the mantle before crushing of pore space begins is ~500 MPa. The initial compressive strength of the core was 170 MPa. The black arrow in the bottom of the figure gives a sense of the direction of extension. The black bar gives a sense of the region in which Rheasilvia related graben are found