FORMATION OF MULTIRING BASINS ON EUROPA. E. A. Silber[1], B. C. Johnson[1], [1]Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI, USA, 06912 (Elizabeth_Silber@Brown.edu).

Introduction: Impact craters are a ubiquitous geological feature on solid planetary surfaces. The final size and morphology of an impact crater depend on both the projectile (e.g. size, velocity) and target properties (e.g., composition, thermal gradient) [1,2]. Thus, impact structures could reveal clues about planetary surface properties and conditions at depth. Europa, one of the Galilean moons of Jupiter, exhibits a wide variety of crater morphologies [3], including two multiring basins, Tyre (*D* ~38 km) and Callanish (*D* ~33 km) (Fig. 1). The concentric rings (fault scarps and graben) are thought to form during the collapse of a much smaller transient crater [4,5]. During the collapse, the weaker and warmer material (ductile ice and/or water) at depth flows inward, dragging along the much stronger overlying ice lid towards the crater center, thereby forming faults [5].

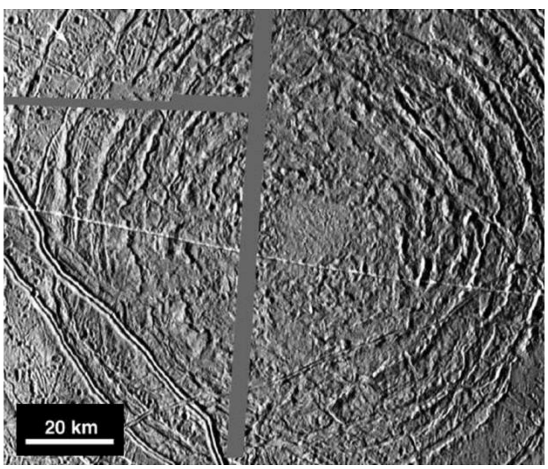

Figure 1: The image of Tyre, the multiring basin on Europa. The image was taken by the Solid State Imaging (SSI) system on NASA's Galileo spacecraft (Credit: NASA).

While it has been established that Europa hosts a global ocean, the thickness and structure of its ice shell remain poorly constrained [6]. A recent numerical modeling study demonstrated that crater sizes and morphologies of smaller Europan craters (*D* < 25 km) could form on both thick (conductive-convective) and thin (conductive) ice shell overlying ocean [2]. However, modeling formation of multiring structures, such as Tyre (Fig. 1) and Callanish, could offer clues and better constraints as to the thickness of Europa's ice shell at the time of their formation.

Estimates of radial strain based on graben widths, expressed as: $\varepsilon(r) = \Sigma\Delta r/(r+\Sigma\Delta r)$, for Tyre show values of ~1% for the innermost graben [7]. Strain of this magnitude is consistent with ring formation during crater collapse rather than through post-impact relaxation [7]. Numerical simulations aimed at modeling formation of the Orientale multiring basin [8] on the Moon showed that iSALE-2D shock physics code [9,10] is capable of representing the formation of basin rings. In iSALE-2D, rather than being directly resolved, the faults manifest as regions of highly localized strain.

Modeling: In this study, we use iSALE-2D [9,10] and build upon the results of [2] to model formation of multiring basins on Europa; Tyre and Callanish. Our aim is to resolve the formation of the concentric rings associated with multiring basins. We model formation of multiring basins as icy projectiles with radius (R_i) of 900 m impacting at 15 km/s a 2-layered target, consisting of ice over ocean. The icy layer (ice shell) is comprised of the conductive ice lid overlying warm convective ice (Fig. 2). We vary the thickness of the ice shell from 10 – 30 km, which is broadly consistent with that reported by [3]. The model inputs are the same as those described by [2 and references therein]. The initial conditions, such as the conductive lid thickness and temperature of the warm convective ice, are from [2]. The cell size is set to 50 m, with the high-resolution zone extending to 100 km laterally, to maximize the spatial parameter space [7].

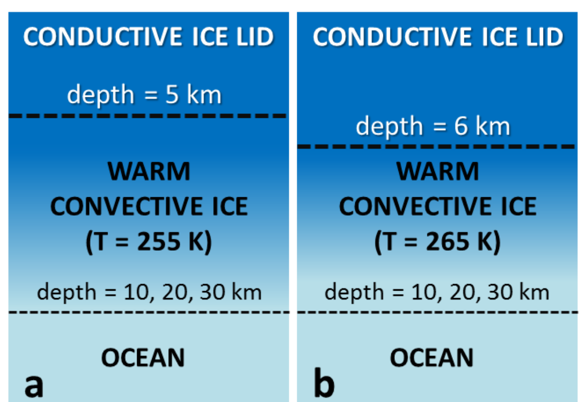

Figure 2: Diagram showing the conductive-convective setups based on the modeling results reported by [2]. (a) A 5 km thick conductive lid overlaying warm convective ice at T = 255 K. (b) A 6 km thick conductive lid overlaying warm convective ice at T = 265 K. The total thickness of the ice shell (including the conductive lid and warm convective ice) is varied from 10 – 30 km. The diagram is not to scale.

Preliminary Results: Here we report the preliminary results for the setup shown in Fig. 2b. The apparent faulting, represented by the total plastic strain (Fig. 3), more readily forms in a 10 km thick ice shell as opposed to the 20 km ice shell. The 10 km thick ice shell also produces more numerous faults as a function of radial distance (Fig. 3a). These early results are in line with the “thin” lithosphere results as reported for the Valhalla basin [11]. As measured from the center of the crater outward, the first largest fault forms at a distance of ~30 km, which is more consistent with Callanish than Tyre [7]. The radial strain is several factors smaller than that reported by [7], but that is likely due to the impact size being too small. Larger impactors may be required to reproduce the observed structure of Tyre and Callanish. Nevertheless, these preliminary results demonstrate that iSALE-2D can resolve the faults at resolutions implemented in this work.

Future work: Simulations with larger projectile sizes for both setups shown in Fig. 2 are currently underway. We will also model the outcome for the fully conductive 8 km thick ice shell over ocean [2] and compare to the conductive-convective shell. While the preliminary results do not include tensile failure consideration in iSALE, it will be included in future simulations. This might change the preliminary results we noted here. Future work might also include exploring a broader parameter space. We aim to expand our work to the formation of multiring basins on Ganymede and Callisto.

References: [1] Melosh H. J. (1989) Oxford University Press, NY, 253 p. [2] Silber E. A. and Johnson B.C. (2017) *JGR-Planets*, doi: 10.1002/2017JE005456 [3] Schenk P. (2002) *Nature*, 417, 419-421. [4] Melosh H. J. (1982) *J. Geophys. Res*., 87, 1880-1890. [5] McKinnon W.B. and Melosh H. J. (1980) *Icarus*, 44, 454-471. [6] Nimmo, F. and M. Manga (2009) The University of Arizona Press USA, pp. 382-404. [7] Singer K. N. et al. (2013) *LPSC XLIV*, 2179. [8] Johnson B. C. et al. (2016) *Science*, 354(6311), 441-443. [9] Wünnemann K. et al. (2006) *Icarus, 180*, 514–527. [10] Collins G. S. et al. (2004) *Meteorit. Planet. Sci.*, *39*, 217–231. [11] Johnson B. C. et al. (2013) *LPSC XLIV*, 1302.

Acknowledgements: We gratefully acknowledge the developers of iSALE-2D (www.isale-code.de), the simulation code used in our research, including G. Collins, K. Wünnemann, D. Elbeshausen, B. Ivanov and J. Melosh. EAS gratefully acknowledges the Natural Sciences and Engineering Research Council of Canada (NSERC) Postdoctoral Fellowship program for supporting this project.

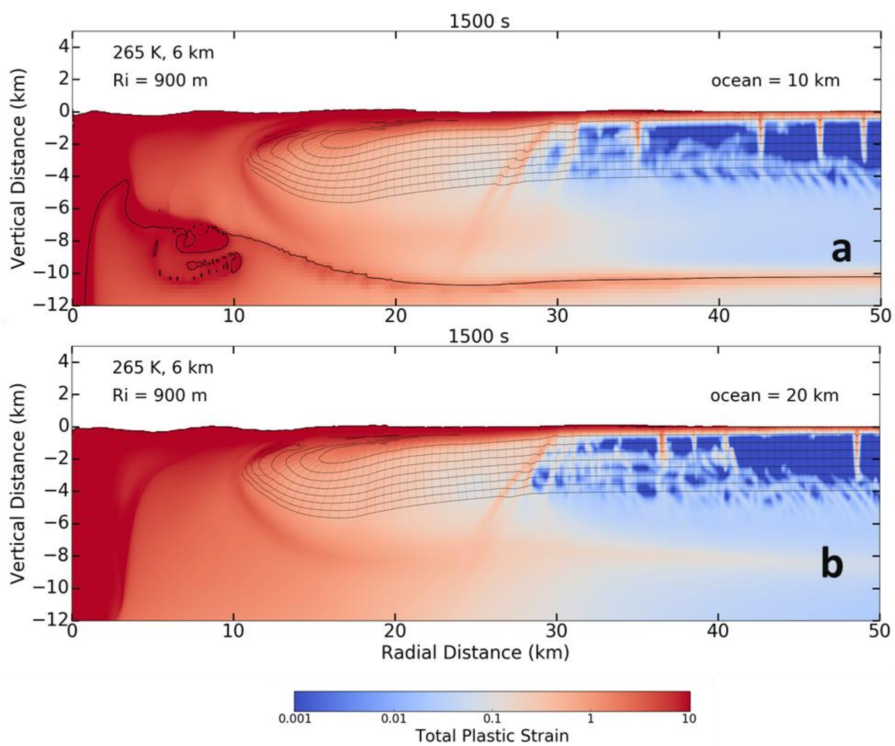

Figure 3: The impact into the (a) 10 km thick ice shell and (b) 20 km thick ice shell, 1500 seconds after the impact. The material is colored according to its total plastic strain. The origin is point of impact. The grid lines represent the size of the high-resolution zone, where the cell size is 50 m. The impactor radius is 900 m. Although the impactor size might not be sufficiently large to produce a Tyre-like basin, the early results suggest that a thick ice shell (>20 km) might not accurately represent the conditions on Europa. However, additional simulations with larger impactor sizes, and varying setups are needed before firm conclusions can be made.