THE STRUCTURE OF EUROPA'S ICE SHELL: INSIGHTS FROM NUMERICAL MODELING.

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Introduction: Impact craters produced by hypervelocity cosmic collisions are an invaluable tool for studying planetary surfaces. In particular, impact studies could help develop better constraints on the thickness of Europa's ice shell, depth of the subsurface ocean, and the boundary conditions at the interface between the ice and subsurface ocean (warm convective ice vs. a purely conductive shell). The observed impact crater depth-diameter (*d/D*) relationship on the Galilean moons (Europa, Ganymede and Callisto) exhibits three distinct transition regimes [1]. On Europa, these correlate to: simple-to-complex transition (I), anomalous crater dimensions and morphologies (II), and abrupt transition from modified central peak to multi-ring morphologies (III) [1]. Regimes II and III may correspond to the presence of warm convecting ice at depths of 7-8 km and a liquid ocean at 19-25 km, respectively [1]. In this study, we perform numerical modeling of impact cratering on Europa to probe the internal structure. Our study is different from previous modeling studies [2,3] in that we consider the both fully conductive ice shell and warm convective ice regime to discern the boundary conditions at the interface between the ice and the underlying ocean.

Modeling: We model formation of impact craters on Europa using iSALE-2D, a multi-material, multi-rheology shock physics code [4,5]. We use the ANEOS [6] and Tillotson [7] EoS to represent the ocean layer and ice Ih, respectively. We consider a full viscoelastic-plastic (VEP) ice rheology [8], which allows for modeling and full treatment of an ice shell with warm convecting ice. Further model setup details are given in [9]. We model: (1) the fully conductive ice shell over the ocean [2] with implementation of VEP ice rheology, and (2) a conductive-convective layering, where conductive ice overlays a region of convective warm ice. To account for a variety of possible scenarios, we vary both the conductive layer thickness (4–7 km) and the temperature of the warm ice (255–265 K).

Preliminary Results: Fig. 1 shows the *d/D* relation for the observed data [1] (gray circles) and the results from our study. The crater diameters produced by a given impactor size are insensitive to changes in pre-impact thermal structure, however, the depths are significantly different and strongly dependent on the temperature gradient. While the *d/D* trend corresponding to the ice over ocean scenario [2] for an 8 km ice shell is in line with observations, a simple conductive crust overlaying the liquid ocean might not appropriately describe the actual conditions on Europa. Simulations with warm convecting ice indicate that there appears to be a 'Goldie locks' region, roughly corresponding to a warm ice temperature of 265 K and the thermal gradient for a 6 km conductive layer (Fig. 1).

Conclusions: The implementation of the VEP rheology of ice in iSALE has allowed us to consider the formation of Europan craters for a range of possible ice shell structures. Our preliminary results suggest that Europa's crust is likely composed of conductive ice overlying warm convective ice, or at the very least that such a structure can reproduce Europan crater morphologies as well as a completely conductive ice shell.

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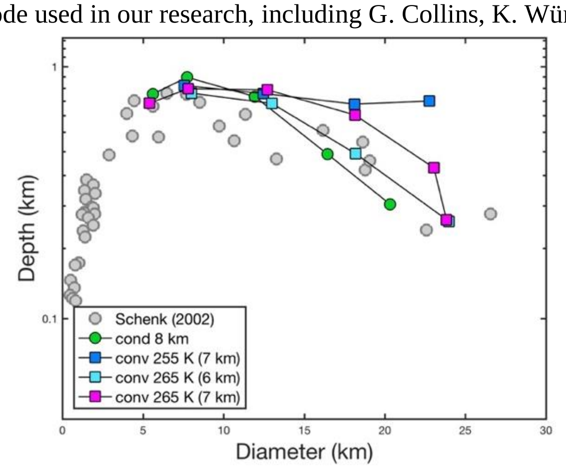

Figure 1: The *d/D* relation for Europan craters. The gray circles are data from [1]. The coloured points represent the simulation results for the ice over ocean (green circles) and various conductive-convective scenarios (squares) in this study (see the legend for details). The projectile radii are R_i = 70 – 405 m, impacting vertically at 15 km/s. We only show the best fit for ice over ocean, where the shell thickness is 8 km.