INVESTIGATING IMPACT BASIN FORMATION ON EUROPA'S SEAFLOOR. A. B. Cunje[1] and A. J. Dombard[1], [1]Dept. of Earth & Environmental Sciences, University of Illinois at Chicago, Chicago, IL, 60607 (acunje2@uic.edu, adombard@uic.edu).

Introduction: Europa, one of Jupiter's Galilean moons, is of particular interest because of uncertainties regarding its interior structure, its lightly cratered icy surface, and, most importantly, its potential to host life in its subsurface ocean [e.g., 1]. Impact craters and basins can provide insight into the age and properties of their target surface and subsurface [e.g., 2], and we investigate their formation on Europa to provide insight into its layered interior structure. While the Moon, Ganymede, and Callisto feature large impact basins hundreds to a thousand km in diameter, resulting from large impactors up to 100 km in diameter, Europa features no craters larger than the 44 km Tyre crater [3]. If Europa similarly encountered a large impactor in its history, then persistent activity in Europa's ice shell should have erased any surface basin long ago, but the scale of basin-sized impacts means that a signature of the impact could have been recorded on the silicate interior below the ocean. Basin-scale impacts on the Moon have been shown to create transient craters that extend hundreds of kilometers deep [4], and a similar impactor on Europa would likely disrupt the subsurface ocean floor and generate impact topography that could remain well preserved [5]. Studies modeling marine impacts on Earth environments have indicated that impact topography on a seafloor is likely to be generated in conditions where the diameter of the impactor is at least 1/10th the thickness of the ocean layer [6]. With a maximum estimated ocean size of 200 km for Europa, impactors at least 20 km in diameter could be expected to modify the seafloor. While previous works have modeled smaller impacts to determine the properties of Europa's outer ice shell [e.g., 7-10], this work uses hydrocode simulations to investigate the impact basin formation process through the ice shell, to the seafloor.

Impact Modeling: We use iSALE-2D, a multi-material, multi-rheology shock physics code [11, 12] to simulate basin-scale impacts. We simulate a vertical impact on a 2D, axisymmetric space of either planetary scale or an infinite half-space, considering only vertical impacts. The planetary scale collision occurs in a differentiated body with central gravity. The impactors are tens of kilometers in diameter, with a diameter of 50 km used as the median in the suite of simulations. We implement a standard impact velocity of 15 km s^{-1} that is less than the predicted average impact velocity of 26 km s^{-1} [3] but saves computation time and is consistent with previous impact modeling work on Europa [7-10]. Simulations run for a model time of ~2 – 4 hr, by which point, significant movement ceases.

We utilize a variable internal structure with ranges for the thickness of Europa's compositional layers that are consistent with currently estimated values [13]. Our Europa is composed of a solid water ice outer shell ranging from 5 – 50 km in thickness, a subsurface water ocean varying from 100 – 200 km in thickness, and a silicate mantle/interior with the possibility of a differentiated basaltic crust 10 – 30 km thick overlying a dunite interior. We implement conductive thermal profiles for the ice shell, capped convective profiles for the interior, and hold the ocean temperature constant. iSALE-2D is only currently able to represent three unique material compositions in one simulation and is therefore unable to represent fully the predicted 4 or 5 layered materials of the interior if an iron core is included. We use different "Scenarios" to examine the range of possible basin formation processes.

We define a control "Scenario 0" made of only two essential layers of the water ocean and rocky dunite interior that are present in all simulations. Two other three-layer scenarios highlight the contributions of the interfaces of the other expected material layers: Scenario 1 is composed of the outer solid water ice shell overlying the liquid water ocean, with the dunite interior. Scenario 2 omits the thin ice shell layer, consisting of the water ocean, a thin basaltic crustal seafloor, and the dunite interior. Scenario 1 highlights the contribution of the ice shell to the impact process, while Scenario 2 examines the effects caused by a seafloor crust. Each Scenario is broken down into three size classes to examine the variation in thickness of each layer. "Small" and "large" scenarios examine the thinner and thicker ranges of the expected outer layers such as the ice shell, ocean layer, or seafloor crust. We also investigate the effect of impactor material based on a scenario's material limitation, with uniform impactors composed of either ice, water, or dunite.

Following previous works [e.g., 7-10, 14], we implement the ANEOS and Tillotson [15] equations of state to represent the solid ice shell, ocean layer, and silicate interior, as well the strength and damage models for the ice shell and the block model of acoustic fluidization [16].

Results: We show a subset of results in Fig. 1 and 2, with the former showing the pre-impact state, and the latter showing the end state. Immediately following the strike of a 50 km impactor, a large transient crater ~150 km wide and deep forms, resulting in a central uplift of the silicate interior by just under 100 km before gravitational collapse. The extent of damaged solid interior can be observed in Fig. 2 and broadly outlines the extent of the deflected surface from its original pre-impact position. Basin profile depths reach only a fraction of their diameter, ~5 – 10 km, with some showcasing long wavelength topography with central uplifts. Diameters are ~800 km for the medium ocean thickness Scenario 0, with additions of the outer ice shell and basaltic crust ultimately reducing the extent of the deformation to diameters of ~600 km. Half-space scenarios explore the effect of planetary curvature. Other simulations include thinner ocean and ice shell layers and increased impactor size and velocity, all of which result in relatively more pronounced basin geometries, with the converse properties consistently showing reduced basin sizes and shorter times before material ceases movement.

Discussion and Ongoing Work: Our results indicate that crater topography is likely to be found on the seafloor for sufficiently large impactors, though the combination of effects of multiple layers such as the ice shell and basaltic crust could further reduce expected basin dimensions. The suite of results will be expanded to include a third scenario able to represent the differentiated iron core from the dunite mantle to examine antipodal deformation and other effects. We will also determine the minimum impactor diameter that causes deflection of the seafloor interface. Recent work showed that carbon dioxide clathrate hydrates could blanket the seafloor if the ocean was amply gas infused; however, the given 500 m equilibrium thickness of this layer [17] is less than our highest 2 km/cell resolution models, so we do not include it as a scenario. Last, we will predict the gravity anomaly of a large impact basin preserved on Europa's seafloor, which has implications for future gravity studies at Europa [e.g., 5].

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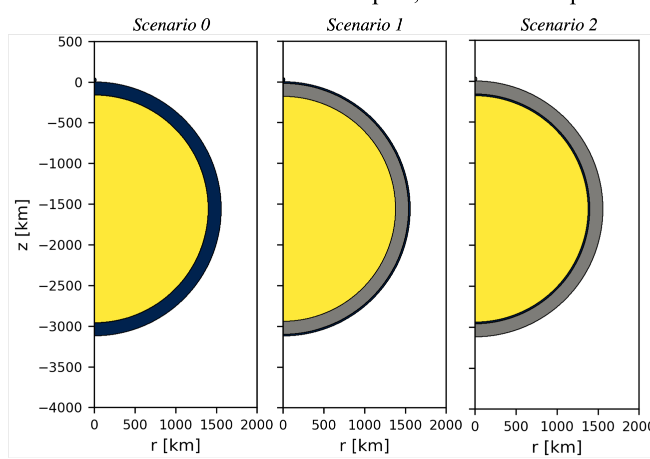

Figure 1: Planetary scale simulation setups for our 3 scenarios, with a 50 km impactor. The dark color is interior layer of interest: ocean, ice shell, and basaltic crust for Scenarios 0, 1, 2. The dunite interior is shown in yellow for all scenarios.

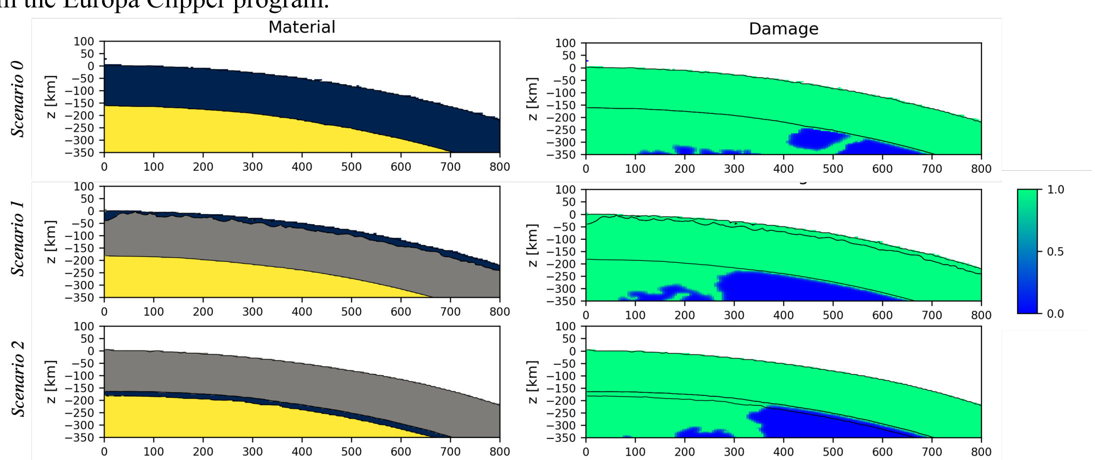

Figure 2: Simulation results at 4 hrs after collision for three scenarios outlined in Fig.1. Medium thickness layers are shown: 160 km ocean (Scenario 0); 20 km thick ice shell with 160 km ocean (Scenario 1); 20 km thick basalt crust with 160 km ocean (Scenario 2).