HYDROCODE SIMULATIONS OF WETUMPKA IMPACT CRATER. L. De Marchi[1], V. Agrawal[1,2], and D. T. King, Jr.[1], [1]Geosciences, Auburn University, Auburn University, Auburn, AL 36849 [2]Aerospace Engineering, Auburn University, Auburn AL 36849 (vinagr@auburn.edu)

Introduction: The Wetumpka impact structure is a Late Cretaceous (84.4 ± 1.4 m.y. old) shallow marine crater, which is located in central Alabama USA (32° 31' N; 86° 10' W) [1,2]. The rimmed structure is heavily eroded with a maximum north-south diameter of 7.6 km [1, 3]. Wetumpka's target region is part of the the inner Gulf Coastal Plain and was comprised of weathered crystalline rock of the Piedmont metamorphic terrane, which was overlain by poorly consolidated sediments of the Upper Cretaceous Tuscaloosa Group and Eutaw Formation. The seawater depth at the time of the impact is interpreted to be approximately 35-100 m [1,3]. Wetumpa impact structure exhibits unique features such as lack of distinct central peak, absence of resurge gullies, unique moat-filling sequence, and asymmetric rim. It has been hypothesized that presence of a shallow water layer may have been responsible for such unique features. In the short-time scale, water influences the transient crater formation, whereas in the long-time scale, presence of water leads to tsunami-influenced sediment transport and an aqueous-dominated, moat-filling sequence. Current work focuses on the short-time scale, in order to understand the crater's structure and initial tsunami formation. This study aims to understand the influence of the water depth and target properties on the cratering process by using hydrocode simulations of Wetumpka's crater formation.

Method: The formation of Wetumpka is being simulated by iSALE, an extension of the SALE hydrocode developed to model impact crater formation [4,5,6,7]. Current study focuses on iSALE-2D simulations, limiting the scope to short-time scales and to axisymmetric approximation of the original impact problem. Questions to be explored are the formation of central peak, formation of tsunami, and difference in impact structure based on water layer and target properties. Target model was made of three layers, granite as bedrock, ~ 110 m wet tuff, and topmost water layer of different thickness. A spherical granite impactor of 400m diameter traveling at 20km/sec was considered. This is based on geological estimates of pressures based on shocked quartz planar feature (PDF) analysis [1]. Relying on iSALE-2D database, ANEOS equation of state was used for granite, while Tillotson equation of state was used for water and wet tuff. Simulations were performed using 9 CPPR. To compare different impact scenarios, simulations were performed using different seawater depths (66 m; 88 m; 110 m; and 132 m), while maintaining the impactor and target properties. Simulations were achieved using two different damage models, Ivanov's and Collins' [4,5], adding porosity properties for the sediment layer, as described in [6].

Results and Discussion: Results are presented in Figures 1, 2, 3, 4 and 5. All simulations show a deformed crystalline bedrock with a thin layer of sediment deposited along the crater walls, and a thick layer of sediment layer beyond the crater rim. Results are presented for 66 m water depth, using the Wunneman's porosity model as described in [6], and Collins' damage model [5] to account for the volumetric and shear damage. Previous geological investigations based on field studies and shallow core drilling have indicated that the crater moat's impact filling sequence is (a) impactite sand, which is overlain by (b) a trans-crater slide unit from rim failure of sedimentary strata. This is in turn overlain by (c) a boulder bearing diamictite and (d) a thin resurge chalk deposit from the returning tsunami [3,8]. In contrast to the crater moat area, the central subsurface area sequence is composed of a crystalline megablock breccia in lieu of the impactite sand, but as in the moat area, the trans-crater slide and diamictite lie above this breccia unit [1,3,8].

Results of iSALE modeling (Figs. 1 and 3) in the present study tend to confirm to the geological results in that the central crystalline breccia of the crater center's subsurface conforms to the early central area rebound (2 to 37 sec). The collapse of the rim, first by slide of crystalline materials (37-77 sec) and then by a longer sequence of sedimentary rim collapse (77 to 197 sec). This interval may account for the impactite sand, trans-crater slide, and diamictite emplacment events. Sea water is pushed outward by the tsunami itself and the fall of ejecta, and water returns substantially after 197 sec, which is consistent with the late modification deposit of thin resurge chalk layers in the impact target area.

Quantitatively, simulations at 200 sec predict a stable crater diameter of approximately 5.4 km with 0.85 km depth. Also at 200 sec, a central uplift is absent from the impact structure (Fig. 4). At 50 sec, water rushes outward creating an tsunami of approximately 78 m height, which is traveling at 85m/sec (Fig. 2).

Whereas the crater diameter is underpredicted from the preliminary simulations, these results are qualitatively consistent with the field studies. Tsunami velocity is sufficient to erode coeval chalk deposits from the adjacent shelf, which are found with the crater area as resurge deposits [9].

In our models, as water depth is increased from 66 m (3 cells) to 132 m (6 cells), in each instance, the crater rim and internal crater-filling processes appear to be substantially the same. A small, transient central hump rises but rapidly collapses and is does not develop as a true central peak. The crater rim in each instance collapses as noted previously, the thin crystalline part slides back into the crater moat first and then the sedimentary section slides back over an interval of about 100 sec. The differences in the water depth simulations are seen mainly in the depth of the outgoing wave and its origins. In progressively deeper water scenarios, the wave has larger amplitudes and appears to be enhanced and amplified by the fall of the ejecta curtain, which appears to be 'pushed' outward by the fall of ejecta into the surrounding ocean (Fig. 5).

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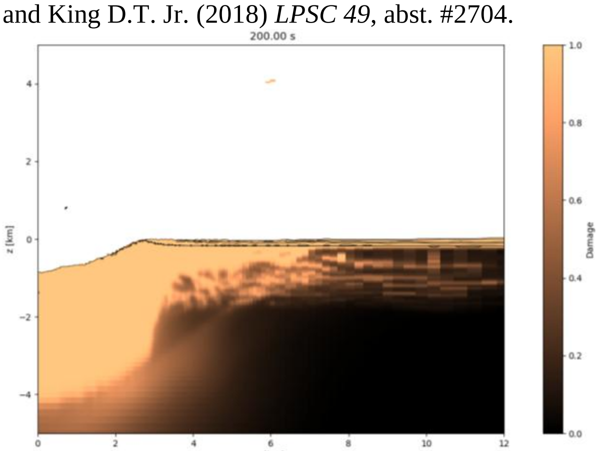

Fig. 1: Damage profile at 200 sec for the Wetumpka crater.

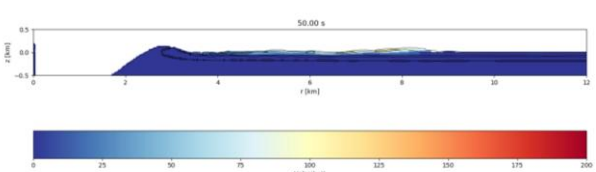

Fig. 2: Zoomed plot depicting formation of outward tsunami at 50 sec. Velocity at the head of the tsunami front is around 85m/sec.

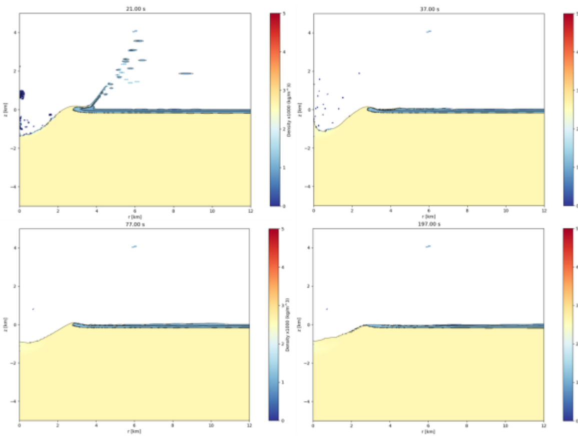

Fig. 3: Density profile at 21 sec (top-left), 37 sec (top-right), 77 sec (bottom-left), and 197 sec (bottom-right) depicting various stages of crater evolution.

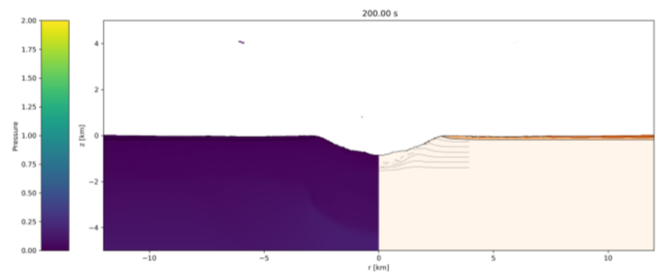

Fig. 4: Crater shape at 200 sec as predicted by iSALE simulations for initial water depth 66 m.

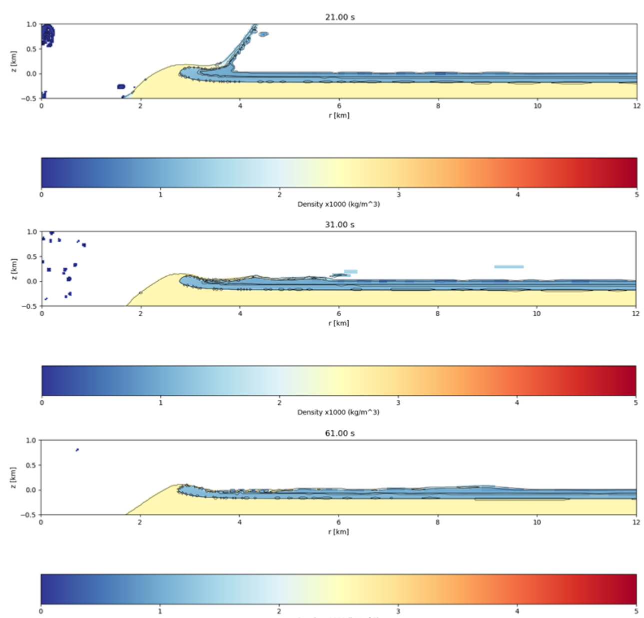

Fig 5: Zoomed plot of density at 21 sec (top), 31 sec (mid), and 61sec (bottom) showing the pushing effect, driving the tsunami.