**Numerical and Experimental Investigations of Wetumpka Impact Crater.** L. De Marchi¹, V. Agrawal²,³, and D. T. King, Jr.¹, ¹Geosciences, Auburn University, Auburn University, Auburn, AL 36849; ²Aerospace Engineering, Auburn University, Auburn AL 36849 (vinagr@auburn.edu)

**Introduction:** The Wetumpka impact structure, located in central Alabama USA (32° 31’ N; 86° 10’ W), is a Late Cretaceous crater that was formed in a shallow sea environment [1,2]. The target region was part of the inner Gulf Coastal Plain and was comprised of weathered crystalline rock of the Piedmont metamorphic terrane, which was overlain by poorly consolidated sediments from the Upper Cretaceous Tuscaloosa Group and Eutaw Formation. The water depth at the time of the impact is interpreted to approximately have been 35-100 m [1,3]. Wetumpka is heavily eroded and exhibits unique features such as lack of distinct central peak, absence of resurge gullies, and unique moat-filling sequence. The rims are asymmetric owing to collapse of the southwestern section, and reaching a maximum NE-SW diameter diameter of 7.6 km (Fig. 1) [1,3]. The surficial geology of the crater consists of a deformed, semi-circular, crystalline-rim, composed of Appalachian Piedmont bedrock. The intra-structure region is relatively lower relief area composed by deformed sediments from Tuscaloosa Group and Eutaw Formation, as well as resurge chalk deposits and megablocks from sedimentary and crystalline origin [4].

![Geology of Wetumpka impact crater](image1)

**Figure 1.** Geologic map of Wetumpka crater.

The layer of sea water may have been responsible for Wetumpka’s crater unique features, such as the collapsed rim and the distinctive moat-filling sequence.

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. This study focuses on the short-time scale and aims to understand the effect by water depth, tsunami wave formation, and mechanical parameters of target materials. For this, we are 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 [5,6,7,8]. Current study focuses on iSALE-2D simulations with an axisymmetric approximation of the original impact problem and a resolution of 32 CPPR (cells per projectile radius). Low resolution (9 CPPR) simulations were also per-formed to obtain a rough estimate of different pro-cesses associated with transient crater evolution. Questions to be explored are the formation of tsunami and difference in impact structure based on water layer and target properties. In the model, the target is represented by three layers, granite as bedrock, ~110 m quartzite, 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 and quartzite, while Tillotson equation of state was used for water. Simulations were achieved using Collins’ damage model [7] to account for the volumetric and shear damage, adding porosity properties for the sediment layer, as described in [8]. To compare different impact scenarios, simulations were performed using different seawater depths (65 m and 125 m), while maintaining the impactor and target properties. Parameters such as cohesion, shear damage, strength model, and limiting strength, at intacted and damaged material, were set at different values in 12 distinct simulations. To provide values for material parameters, samples of the crystalline rim were collected and prepared for split-Brazilian (Fig. 2) and compressive tests as per ASTM standards.

![Fractures in 1-in diameter cylinder made from crystalline rim sample after Brazilian test (tensile) was performed.](image2)

**Fig 2.** Fractures in 1-in diameter cylinder made from crystalline rim sample after Brazilian test (tensile) was performed.

**Results and Discussion:** The 9-CPPR simulations were performed to estimate (1) crystalline rim collapse, (2) sedimentary rim collapse, and (3) tsunami
resurge. These results are presented in Figure 3 for 125m initial water depth. Crater depth was also tracked as a function of time for 66m and 132m initial water depth (Fig. 4). A large initial crater excavation was observed for 66m case, and a resurge point of ~430 seconds was noted for 132m case.

Figure 3. Outtakes from 9 CPPR simulations for 125m water depth indicating A) crystalline rim collapse, B) sedimentary rim collapse, C) onset of resurge and D) stable crater filled with water.

For 32 CPPR, a total of 6 distinctly different simulations were performed for each water depth scenario (60 meters and 125 meters) by varying parameters of the sediment layer. At present, simulations are in progress, and outputs of approximately 40 seconds after the impact were acquired so far. Considering the same water depth, the simulations do not show a significant difference considering transient crater diameter, crater depth, and timing of processes such as fall of ejecta curtain, tsunami formation, and collapse of the rim. Comparing different water depth situations, both conditions show a maximum diameter of the transient crater developed by about 13 seconds, with an approximate 4.8 km diameter. At about 25 seconds, the rim starts to collapse and the ejecta curtain starts to fall down on top of the water layer, creating tsunami waves that move outwards. This turbulent flow carries sea floor sediments and blocks of the impacted crystalline basement, which is more abundant in the proximities of the crater. Waves are still active in a distance of ~8km from the crater until where the simulations have reached so far (Fig. 5). The differences in water depth simulations are seen mainly in the crater depth, which reaches its maximum around 20 to 25 seconds, revealing a deeper crater in the deeper scenario, with ~100-150 m of difference. In the short-time scale, the thickness of the sea water layer seems to influence the depth of the transient crater, possibly by acting as an extra force towards the excavation process. Results from mechanical tests on crystalline rim samples are being acquired and interpreted at present.

Figure 5. Density profile at 41.11 sec as predicted by iSALE simulations for initial water depth 125 m. Features shown include the transient crater, overturned rim flap, tsunami waves moving outward, and the falling ejecta curtain.

Another set of 48 CPPR simulations were conducted to estimate pressure distribution at 0.1 seconds. A peak pressure of 48 GPa was noted near the center of the crater at 0.1s for 66m water depth (Fig. 6). Results were similar was 132m water depth.

Figure 6. Vertical pressure profile using 48 CPPR simulations near the crater center for 66m water depth.