NUMERICAL AND EXPERIMENTAL ANALYSIS OF WETUMPKA IMPACT CRATER, WITH FOCUS ON THE SOUTHERN RIM.

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Introduction: The Wetumpka impact structure, located in central Alabama USA (32° 31' N; 86° 10' W), is a Late Cretaceous simple crater that was formed in a near shore marine environment [1,2]. The water depth at the time of the impact is interpreted to approximately have been 35-100 m [1,3]. Wetumpka's 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 current crater exhibits rims composed of Appalachian Piedmont bedrock, having an asymmetric nature due to collapse of the southwest, ocean-facing, section. The interior area has a lower relief and is composed by deformed sediments and mega-blocks from sedimentary and crystalline target rocks, as well as resurge chalk deposits. [1,3,4]. The crater is elongated and on average is ~5 km in diameter but reaches a maximum NE-SW diameter of 7.6 km (Fig 1).

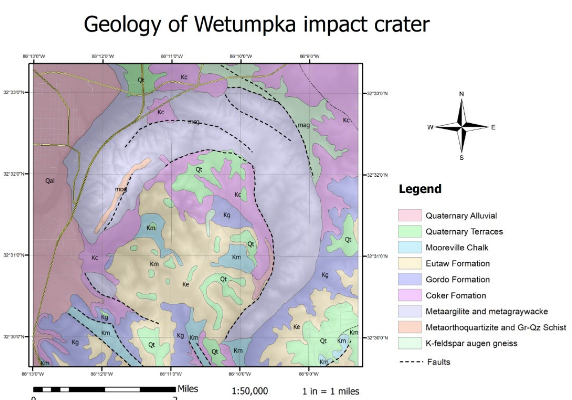

Figure 1. Geologic map of Wetumpka crater.

The layer of sea water may have played an important role on Wetumpka's crater unique features, such as the collapsed rim and the distinctive moat-filling sequence. The water may influence since early stages of crater formation, as transient crater depth and diameter, until late formation stages, as tsunami-influenced sediment transport and an aqueous-dominated, moat-filling sequence. This study aims to understand, from a numerical perspective, the formation of the Wetumpka crater and the effect of different input parameters, such as velocity, water depth, and sediment thickness, on the development and final morphology of the structure, with focus on the southern collapsed rim. 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). Relying on iSALE2D database, different equations of state (EoS) were applied to each target material. The target model consisted of three layers: a) crystalline basement represented by granite; b) the sediment layer, which is represented by the wet tuff, and c) the uppermost sea water layer. A spherical impactor of 400m diameter traveling at 12 and 20km/sec was considered. Simulations were achieved using different water depths (62.5m and 125m) and different sediment thicknesses (100, 200, or 300m), while maintaining the impactor and target properties. 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 provide more realistic values for target material input parameters, samples of the crystalline rim were collected and prepared for split-Brazilian and compressive tests as per ASTM standards.

Fig 2. Left: Fractured 1-inch diameter cylinders made from crystalline rim sample after Brazilian test (tensile) was performed. Right: Fractured 0.5-inch diameter cylinders after compressive test.

Results and Discussion: Tensile and compressive strength values, obtained by split-Brazilian and compressive tests, were used to estimate cohesion (17.12 MPa) and friction angle (0.373) of metamorphic bedrock. These values were then used to set more realist input parameters for the simulations.

A total of 12 different simulations were performed using different combinations of speed, water depth, and sediment thickness. The model that better approximates the field and drill core observations with respect to the southern rim section, show a simple crater formed by a 400m asteroid, impacting at 12km/s on a 62.5-meter water depth sea, with 200 meters of sediment layer overlaying the bedrock. The model exhibits crater depth and diameter consistent with our best understanding of the overall structure. The maximum transient crater size is reached at about 14 seconds, with an approximate 5 km diameter and 1.5 km depth. The rim starts to collapse at about 26 seconds, and the ejecta curtain starts to fall on top of the water layer, creating tsunami waves that move outwards (Fig. 3). The model produced an impact structure with more sedimentary component of the crater rim, which is consistent with the southern rim development and collapse. We observed considerable amounts of sedimentary material within the early modification crater rim moving back into the crater bowl (Fig. 4), which is supported by drill-core findings. One of the cores, located close to eastern rim, reveals inverted stratigraphy of target rocks in the upper ~210m crater filling sequence, suggesting slump of overturned rim flap. The crater filling sequence in the model is also consistent with the gravity analysis predicting higher density material underlying the lower density sedimentary fill [9].

Lastly, peaks of pressure (Fig. 5) and temperature near the center of the crater are consistent with shock petrological studies.

References: [1] King D.T. Jr. et al. (2002) *EPSL 202*, 541-549. [2] Wartho J.-A. et al. (2012) *MAPS 47*, 1243-1255. [3] King and Ormö (2011) *GSA SP 483*, 287-300. [4] King D. T. Jr. et al. (2006) MAPS 41, 1625–1631. [5] Melosh H.J. et al. (1992) *JGR 97*, no. E9, 14735-14759. [6] Ivanov B.A. et al. (1997) *Int. J. Impact Eng. 20*, 411-430. [7] Collins G. et al. (2004) *MAPS 39*, 217-231. [8] Wunnemann K. et al. (2006) *Icarus 180*, 514-527. [9] Robbins E. A. et al. (2011) 42nd LPSC, abstract #2732.

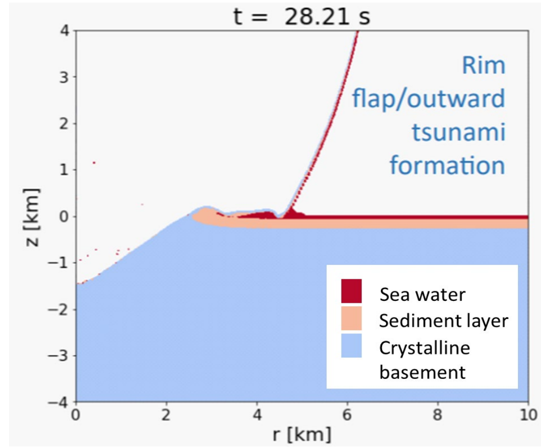

Fig. 3. Density profile at 28.21 seconds as predicted by iSALE, showing rim flap formation and consequent formation of outward moving tsunami waves.

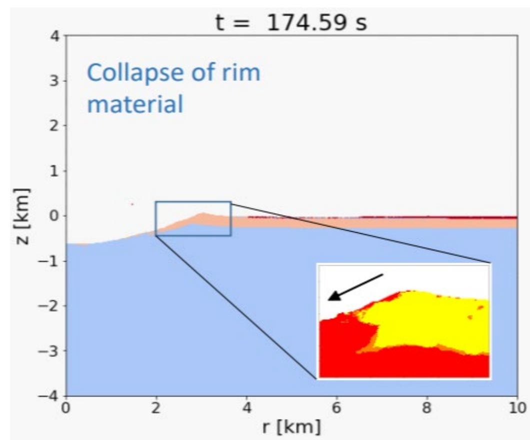

Fig 4. Density profile at 174.59 seconds, showing sedimentary material from rims moving back into the crater. Inset figure shows the direction of the velocity in the x direction. Red and yellow represent the horizontal component of the velocity in the negative and positive X-direction respectively.

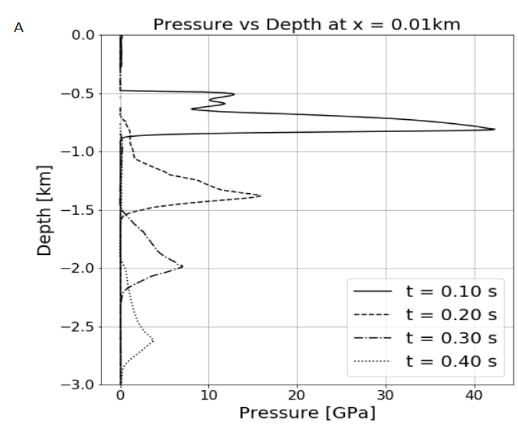

Fig. 5. Evolution of pressure by depth near the center of the crater at 0.1, 0.2, 0.3 and 0.4 seconds.