STRUCTURE OF THE WETUMPKA IMPACT CRATER: DRILL-CORE, FIELD DATA, AND NUMERICAL SIMULATION

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Introduction: Wetumpka is a Late Cretaceous marine-target impact structure in the inner Coastal Plain of Alabama USA [1]. The structure is characterized by a wide, horseshoe-shaped crystalline rim, an interior region of broken and disturbed sedimentary formations, and an extra crater terrain on the south-west composed of structurally disturbed target formations (Fig. 1). The extant crater rim spans 270 degrees of arc and is open on the southwest, the same side as the structurally disturbed terrain just noted. The northwest-southeast diameter of the crystalline rim is approximately 5 km.

Setting: The Wetumpka impact occurred in approximately 30 to 100 m deep marine waters of the Gulf of Mexico, which likely shallowed toward the north where the coeval shoreline was located. In reverse stratigraphic order, the target consisted of marine water; poorly consolidated sediment (comprising 30 m of chalky ooze, 30 m of paralic marine sand, and 60 m of terrestrial clayey sand and gravels, and ultimately, weathered crystalline basement dipping to the southwest with about 10 m per kilometer. This is thought to play a role in the cratering and modification [2].

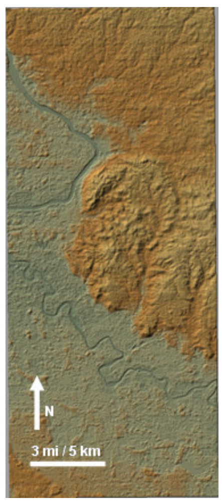

Fig. 1. Setting.

A prerequisite to better understand the processes involved in the formation and modification of the Wetumpka crater is to establish the present erosional level of the crater [2]. The possible existence of basement ejecta at the crystalline rim and its relation with the target sediments within and adjacent to the rim provide crucial information on the erosional level, and thus the size and morphology of the crater. Recently, we performed core drillings at two locations on the crystalline rim [3]. The Eason well on the western rim penetrated 67 m of schist, whereas the Inscoe well on the south-eastern rim penetrated 30 m of schistose ejecta resting upon a few meters of schist [3].

In this study we have complemented drill-core and field-based information with a numerical simulation of the cratering event. The simulation has focused on the formation of the rim and its interaction with the resurging seawater.

Method: Numerical modeling is an important tool in the studies of impact cratering, but good material models are required for reliable results [4]. We used iSALE, a multi-material, multi-rheology extension to the SALE (Simplified Arbitrary Lagrangian Eulerian) hydrocode [5] with several improvements [6-10]. In order to describe the response of a rock to stresses, an elastic-plastic rheologic model (RM) is used. The strength model used in this study was first implemented to the code by [7]. It now includes pressure- and temperature-dependent strength, shear failure, strain softening, brittle and ductile deformation [10].

The non-uniform computational grid of the simulations consists of a central cell region around the impact point, where damage is greater, with a regular mesh (horizontal 240 cells, vertical 180 cells) describing half of the damaged zone (axial symmetry). We increased the mesh size progressively outwards from the central cell region with a 1.05 coefficient multiplier for the mesh extension allowing a larger spatial domain to avoid wave reflection problems at the boundaries [nx (radial)=310 cells, ny=460 cells]. The simulation was conducted with a spherical, 396 m diameter granitic projectile (66 cells radius) with an extended cell zone at top of the projectile. Impact velocity is 20km/s.

The thermodynamic state of the material is calculated using the Tillotson EOS [11] as a function of internal energy and density, in our case using granite and wet tuff parameters [12], and ANEOS [13] for water.

The simulated impact was vertical due to limitations of the code. It is, unfortunately, also not possible to use inclined layers in the target, which may be important at Wetumpka [2]. We chose wet tuff to represent the sedimentary part of the target (120 m) as it for the moment is the best available approximation to the low-strength sediments at Wetumpka.

As we are unable to model an impact into a water layer of varied thickness (i.e., 100 m in one end of the damage zone and 30 m in the other) we used an intermediate water depth of 72 m. However, we are currently running simulations with 30 m and 100 m respectively, which then can give information on the rim development on either of the deep-water or shallow-water sides of the crater.

Results and discussion: The two drill cores of the crystalline rim show that basement ejecta is preserved at least on the south-eastern part of the rim, but also that overturned material may exist on the north-western side [3].

The numerical simulation shows how the target water is pushed away from the expanding crater by the shoving-effect of the deposition of the ejecta curtain. This causes a tsunami-like wave travelling away from the crater. When the water comes back to the crater site the elevated rim stands as a wall preventing a resurge into the crater. However, as can be seen in Figures 2 and 3, much of the crater rim consists of material from the poorly consolidated sedimentary target. This provides an unstable foundation for the overturned, more dense basement material. However, the overturned flap formed by denser (i.e., relatively strong) basement material (Figs. 2 and 3) is narrow and the crystalline-blended ejecta is rather thin (Fig 2). In the modeled 75-m target water depth case it is likely that the rim, at least its upper parts, rather soon would collapse and, possibly, open up for a resurge of seawater and megablock slumping of the weakened poorly consolidated sediments outside the crater. This is consistent with the observed opening in the southern part of the rim, the chaotic zone of the extrastructure terrain, and the slumped megablock infill [2]. The forthcoming simulations of 30 m and 100 m water depth options will give further insight in the variations in rim development and hopefully provide answers to the enigma of the yet absent/undiscovered resurge deposits we would expect to find inside the crater.

Conclusions: Drill core and field data show that the erosional level of the Wetumpka crater is not deeper than the polymict ejecta, which is preserved at the rim. Numerical simulation shows, however, that the rim would have a relatively small part developed in the more stable basement rocks. In the upper range of the water depths suggested for the target water sea (i.e. southern side of the crater), collapse of the rim is expected, which likely would open up for extensive slumping of extrastructure sediments as well as resurge of seawater.

References: [1]King, D.T., Jr. et al. (2002) *EPSL 202*, 451-459; [2]King D.T., Jr. et al. (2006) *Met.. Plan. Sci. 41*, 1625-1631; [3]King, D.T., Jr. et al. (2007) LPS XXXVIII, abs. 2178; [4]Pierazzo E. and Collins G. (2003) In *Submarine Craters and Ejecta-Crater Correlation*, 323-340; [5]Amsden A.A. et al. (1980) *Los Alamos National Laboratory Report* LA-8095; [6] Melosh H.J et al. (1992) *J. Geophys. Res.* 97, 14735-*14759*; [7]Ivanov B.A. et al. (1997). *Intl. Jour. Impact Eng. 17*, 375-386; [8]Wünneman K. and Lange M.A. (2002). *Deep-Sea Res. II 49*, 969-981; [9]Wünneman K. and Ivanov B.A. (2003) *Planet. Space Sci. 51*, 831-845; [10]Collins G.S. et al. (2004) *Met. Plan. Sci. 39*, 217-231; [11]Tillotson J.M. (1962) General Atomic Report #GA-3216. San Diego, California: Advanced Research Project Agency, 141p; [12]Allen R.T. (1967) Spec. Nuclear Eff. Lab. - Defense Atomic. Support Agency: DA49-146-XZ-462 16 p; [13]Thompson S. and Lauson H.S. (1972) Sandia National Laboratory, Albuquerque NM 87115, Report SC-RR-71 0714

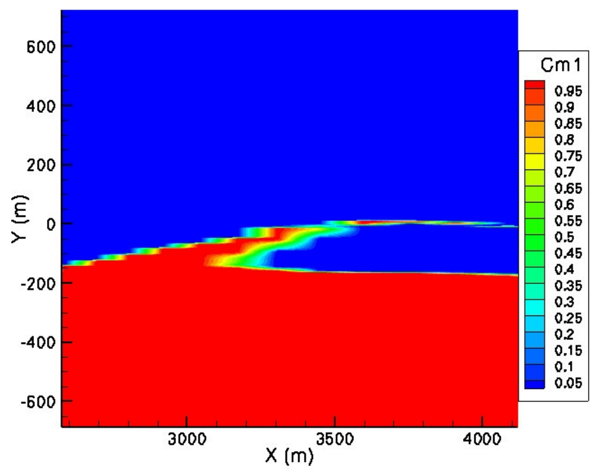

Fig. 2. Relative amount of basement material (granite) at the crater rim (e.g., 0.95 means 95% granite and 5% other material). X-axis shows distance from crater center (to the left).

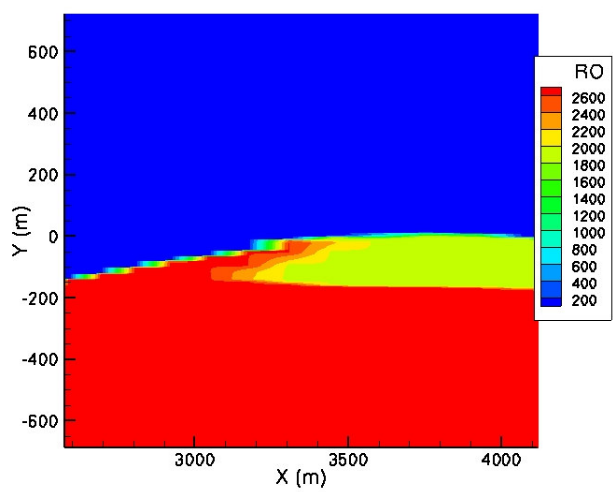

Fig. 3. Density in kg/m^3 of materials in the same frame as in Fig. 2. X-axis shows distance from crater center.