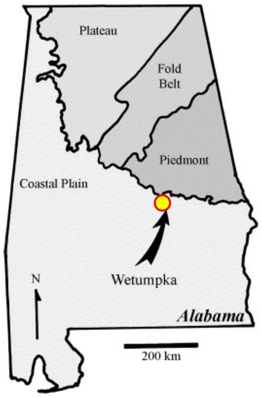
WETUMPKA IMPACT STRUCTURE (ALABAMA) – A GRAVITY MODEL.

E. A. Robbins[1], L. W. Wolf[1], and D. T. King, Jr.[1], [1]Geology Office, Auburn University, Auburn, Alabama 36849 [robbinsea@auburn.edu].

Introduction: The Wetumpka impact structure (Fig. 1) is a Late Cretaceous marine target impact feature located in central Alabama [1, 2, 3]. The total structural diameter is ~ 7.6 km, but the inner crystalline rim has a diameter of ~ 5 km. Wetumpka's submarine target formations includes (in reverse age order): a few m of lower Mooreville Chalk, the clastic paralic Eutaw Formation, the clastic fluvial Tuscaloosa Formation, and basal weathered crystalline Piedmont metamorphic rocks. Wetumpka impact structure consists of three surficial terrains (Fig. 2), including crystalline rim (crt), interior (intracrater sediments and broken formations, ist), and exterior (structurally disturbed target formations, est).

This project utilizes high-resolution gravity data to explore the subsurface geology and structure of the crater. Gravity modeling shows that simple geologic layering cannot explain the observed gravity lows near the impact site. A simplified model based on previous studies [1, 2, 3, 4, 5] adequately explains the extra and crater-rim terrains, but cannot explain the variances in gravity data observed within the crater's central area. An alternative, more complex geologic model accounts for these variations by incorporating a feature representing a central uplift of the underlying Piedmont metamorphic rocks. Densities consistent with a zone of thick sedimentary in-fill and brecciated rocks explains the gravity low within the crater. This research proposes that a significant uplift of the Piedmont metamorphic basement occurred in response to the impact and created a large space for sedimentary infill in the crater bowl.

Background: In the 1990s, a single east-to-west gravity survey transect was conducted by Wolf et al. [5]. The surveyed transect bisects the Wetumpka impact structure and transverses the intra-crater terrain, and the crater rim (Fig. 2). Results from the gravity profile in [5] show a strong eastward gravity gradient of ~ -1.0 to -1.5 mGal/km. A regional gravity trend was subtracted from the observed gravity data to highlight minor differences in gravity associated with the impact region. The residual gravity values along the east-west profile show a small increase in gravity (~ 0.5 mGal) associated with the extra-crater terrain and serves as a base line for gravity data comparison. High gravity values (2 to 4 mGal) are associated with the crater rim, whereas gravity lows (-3 to -6 mGal) generally correspond to the intra-crater terrain. An anomolous gravity high of approximately 2 mGal (above adjacent readings) occurs near the center of the intra-crater terrain and is consistent with findings of other impact structures. Thus, the maximun change in gravity associated with the Wetumpka impact structure is aproximately 10 mGal [5], indicating a stong denisty contrast in this portion of the crater. Although Wolf et al. [5] noted the gravity data were consistent with other crater interpretations, no further gravity modeling was done.



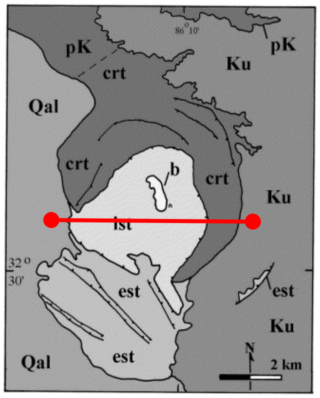


Fig. 1. Location map (left) of the Wetumpka impact structure in Alabama (yellow dot), showing major geological provinces (modified from [2]).

Fig. 2. Geological map of the Wetumpka structure (right), showing approximate location of gravity profile line of this study (red line; see [5] for details). Map symbols: crt = crystalline-rim terrain; ist = intra-structure terrain; est = extra-structure terrain; Ku = Upper Cretaceous undeformed units; pK = pre-Cretaceous crystalline units unaffected by the impact structure; b = central impact breccias (modified from [2]).

Methods: The observed gravity data used in this study were collected at 105 stations along a profile that bisects the Wetumpka impact structure [5]. Gravity values were obtained using a LaCoste-Romberg gravimeter at closely spaced intervals (~ 100 m) along the roughly 6-km transect. Several other readings were taken to establish regional gravity trend. The length and spacing of the gravity data provide a comprehensive coverage of the three geologic terrains associated with the impact and highlight minor changes in gravity. The observed gravity data from the Wetumpka transect were reduced using a standard procedure. A looping procedure was utilized to correct for instrument and tidal drift.

Results: We present two models as results.

Model 1. The first model (Fig. 3) represents a simplified cross-section of the Wetumpka impact based on

[4]). The first layer (yellow) represents a thin veneer of Quaternary sediments and Cretaceous sedimentary sequences, including the Tuscaloosa Group, the Eutaw Formation, and the Mooreville Chalk. It reaches a maximum thickness of 60 m on the far western and eastern flanks of the cross-section and pinches out near the rim of the crater. The density assigned to this sedimentary layer is 1.77 g/cm^3. The orange layer represents the interior broken unit (crater fill) within the impact structure. The lithology of this layer is chaotically oriented Tuscaloosa Group and Eutaw Formation sediments, which have an assigned density of 2.1 g/cm^3. This layer extends down to a depth of approximately 300 m near the center of the crater. The blue layer represents a brecciated unit of the intra-crater terrain and has an assigned density of 2.6 g/cm^3. The brecciated unit corresponds to the broken Emuckfaw Group seen locally and extends down to a depth of ~ 950 m. The gray layer represents the Appalachian Piedmont basement and has an assigned density of 2.7 g/cm^3. The structure of the crater is nearly symmetrical with the exception of a slight central uplift (~ 350 m) near the center of the impact site.

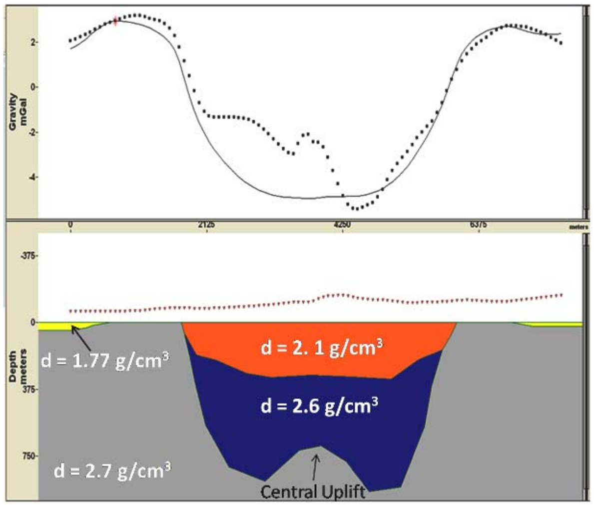


Fig. 3. Model 1 - Simple model based on [3, 4]. The yellow layer represents unconsolidated Quaternary sediments and Cretaceous sedimentary units. The orange unit represents slumped sedimentary target units and unconsolidated crater in-fill. The blue layer represents a brecciated unit formed within the basement rocks by the impact. The gray unit represents Piedmont rocks and continental basement. A small central uplift of the basement is also incorporated into this model. Density values representative of the lithologies are denoted. Dots indicate surface elevation. Model does not extend to the surface due to gravity corrections. Upper graph: Black dots indicate observed gravity. Black line indicates modeled gravity.

Model 2. An alternative model containing the same lithologies but with a very different overall structure based on [6] is shown in Fig. 3. As in the simplified model, the extra-crater terrain consists of Quaternary and Cretaceous sedimentary units (yellow) unconformably overlapping Appalachian Piedmont rocks (gray). Within the crater, the thickness of the sedimentary fill varies significantly from west to east. In the western portion of the crater, the crater fill or broken unit averages approximately 200 m thick. However, to the west, the crater-filling unit increases significantly in overall thickness. Within the crater, the brecciated unit extends to a depth of 900 m. In this model, the brecciated unit crops out at the surface near the crater center, reflecting the findings of [7]. Beneath the brecciated unit, the Piedmont rocks show a pronounced uplift at a depth of 400 m (Fig. 3). The densities assumed for all layers in this model are the same as those in the simplified model.

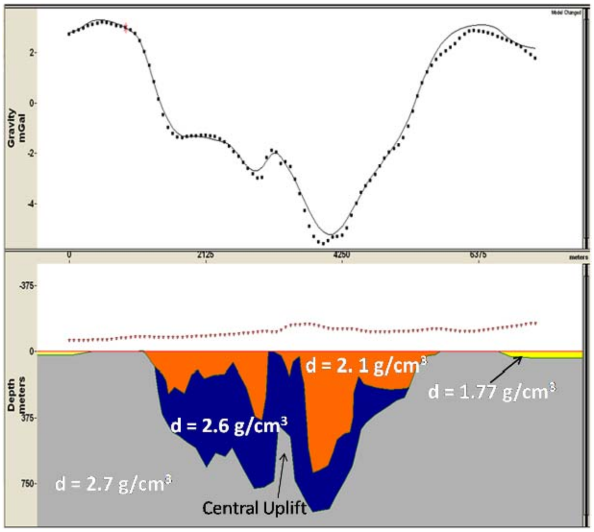


Fig. 4. Model 2 - More complex model shows an overall better agreement with the observed gravity (see upper graph). Same format and scale as Fig. 3. The variations in gravity within the crater are explained by a higher central uplift of dense rocks. Conversely, places of lower gravity within the crater are explained by thicker low density sediments.

References: [1] King Jr. D. T. et al. (2002) *EPSL 202*, 541-549. [2] King Jr. D. T. et al. (2003) *Cratering in marine environments and on ice*, Springer-Verlag, Berlin, 97-113. [3] King Jr. D. T. et al. (2006) *MAPS 41*, 1625-1631. [4] Johnson R. C. (2007) *Auburn Univ. Master's thesis.* [5] Wolf L. W. et al. (1997) *Ala. Geol. Soc. Guidebook, 34c*. [6] Neathery T. L. et al. (1976) *GSA Bull. 87*, 567-573. [7] Nelson A. I. (2000) *Auburn Univ. Master's thesis.*