AN (U-Th)/He GEOCHRONOLOGICAL AGE FOR THE SHALLOW-MARINE WETUMPKA IMPACT STRUCTURE, ALABAMA, USA.

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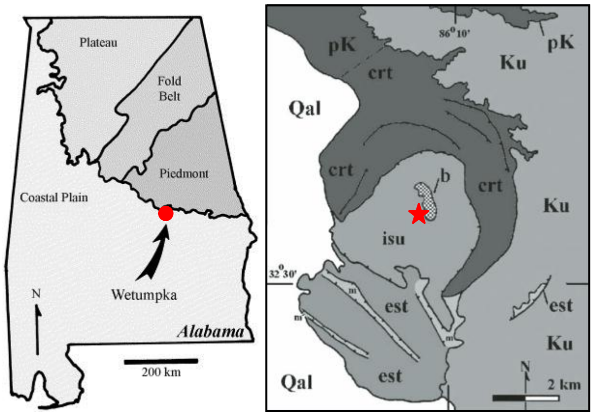
Introduction: Wetumpka is a ~ 7.6 km diameter, marine-target impact structure in the inner coastal plain of Alabama (Fig. 1a; [1-3]). Paleogeographical studies show that the Wetumpka impact occurred in shallow marine water ~ 30-100 m in depth, within ~ 25 km of the local barrier-island shoreline [2-5]. The structure is transitional between a simple, bowl-shaped crater and a complex impact structure.



Figs. 1a & 1b. (a) Location map of the Wetumpka impact structure in Alabama, showing major geological provinces (left; from [2]). (b) Geological map of the Wetumpka structure (right, from [6]). Labels: 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 = impact breccias; and red star = drilling locations of Schroeder and Reeves wells.

The Wetumpka target materials consisted of water, poorly consolidated sediment (comprising three Upper Cretaceous stratigraphic units – chalky ooze, paralic marine sand, and terrestrial clayey sand and gravels), and at the base, a pre-Cretaceous weathered crystalline complex of gneisses and schists (Fig. 1b; [2, 3]).

Neathery [1], who first mapped and described the geology of this structure, suggested that the age of impact was between Late Cretaceous and Pleistocene. Later, an early Campanian stratigraphic age was proposed for the Wetumpka impact structure based on biostratigraphic ages of the youngest layers involved impact deformation (i.e., the lower beds of the Mooreville Chalk [5]. King et al. [6] reviewed the biostratigraphic evidence and estimated that the impact may have been near the local boundary between two planktonic foraminiferal biozones: *Dicarinella asymetrica* range zone and *Globotruncanita elevata* interval zone (regional biozones of [7]). The geochronometric age of this biozone boundary was estimated at ~ 83.5 Ma using the 1988 global synthesis of sequence stratigraphy and biostratigraphy [8].

In this abstract, we present the results of a combined single crystal apatite and zircon (U-Th)/He dating study on five impact breccia samples from drill cores obtained from the crater fill. Our results represent the first radiometric age for the Wetumpka impact event.

Methods and Results: Five samples were obtained from drill cores from two wells (the Schroeder well (#1-98) and the Reeves well (#2-98)) at depths ranging from 107.7-136.9 m. These samples were pestle and mortar crushed, wet sieved, magnetically and heavy liquid-separated to yield heavy mineral fractions of apatite and zircon. The samples mainly consisted of friable, crystalline schist and gneiss clasts of variable size contained within impact breccias/impactites. In all, 4-10 individual zircon and apatite crystals were (U-Th)/He dated from all five samples.

Ultimately, 23 zircon grains gave (U-Th)/He ages ranging from 83.6 to 254.0 Ma, and 24 apatite (U-Th)/He analyses yielded ages ranging from 82.8 to 242.3 Ma. The youngest cluster of ages at 82.8-86.0 consists of 4 apatite and 1 zircon age (Fig. 2).

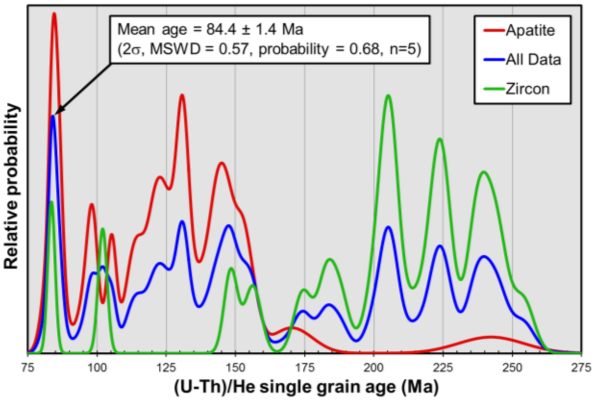


Fig. 2. Probability density plots of (U-Th)/He apatite (n=23), zircon (n=24) and combined (n=47) ages from five Wetumpka drill core samples.

Four apatite and one zircon (U-Th)/He analyses yielded the youngest ages that clustered in the range of

82.8 to 86.0 Ma (Fig. 2). These five ages provided a mean age of **84.4 ± 1.4** Ma (2σ internal errors, MSWD = 0.57; probability = 0.68) using Isoplot 3.7 [9].

Discussion: The 23 (U-Th)/He zircon ages and 24 (U-Th)/He apatite ages are all younger than the ^{40}Ar-^{39}Ar white mica ~ 300 Ma regional Appalachian basement deformation age [10]. Some of the older (U-Th)/He ages could reflect regional cooling ages, but the younger range of ages reflects partial to complete resetting of the (U-Th)/He zircon and apatite ages, most probably during the Wetumpka impact event. The Wetumpka impact event was not high enough in temperature, shocking pressure, or duration to cause the complete loss of radiogenic ^{4}He in all the zircon and apatite grains, as evidenced by the large range of (U-Th)/He ages (82.8-254.0 Ma) recorded in the 47 grains.

The combined apatite and zircon (U-Th)/He age of **84.4 ± 1.4** Ma is near the stratigraphic estimate of King et al. [6] and is also within error of the latest stratigraphic age of 83.5 ± 0.7 Ma for the Upper Cretaceous Campanian-Santonian boundary [11, 12]. As both the apatite and zircon analyses give the same youngest age, the mean age likely reflects the age of the formation for the Wetumpka impact structure. If these young ages had been the result of any other reheating and/or cooling event, the distinctly different closure temperatures for these two minerals would not have yielded this overlapping young age cluster.

Conclusions: The (U-Th)/He dating technique is proving to be a potentially powerful tool for dating large, e.g., 100-km diameter Manicouagan [13, 14], medium impact structures (e.g., 40-km diameter Lake Saint Martin [15], and small (e.g., 350-m diameter Monturaqui [16, 17].

Small and low-energy impact structures are extremely difficult to age-date using conventional geochronological techniques (e.g., U-Pb, Rb-Sr and ^{40}Ar-^{39}Ar), which generally rely on high-temperature impact and post-impact events to reset most commonly applied isotopic geochronometers. However, the (U-Th)/He apatite and zircon geothermometers have the combined unique properties of (1) low-temperature closure temperatures, and (2) fast He diffusivity [18, 19]. This results in rapid and more effective resetting of the (U-Th)/He grain ages during impact than might be expected for more commonly utilized chronometers. Although the (U-Th)/He dating technique does not provide the same precision as other geochronometers, nevertheless it can still yield accurate impact ages, with a typical 2σ error precision of ~ 6-10% [20], and in many cases the precision can be better.

From a total of 47 (U-Th)/He analysed zircon and apatite grains, five grains (one zircon and four apatites) gave the youngest cluster of ages, yielding a mean (U-Th)/He age of **84.4 ± 1.4** Ma (2σ). This **84.4 ± 1.4** Ma geochronological age is within error of the previous Wetumpka stratigraphic age estimate and the Campanian-Santonian stratigraphic boundary age previously suggested for Wetumpka, and represents the first radiometric age obtained for this impact structure.

The successful geochronological dating of the ~ 7.6 km diameter Wetumpka impact structure has additionally highlighted the viability of the (U-Th)/He dating technique to date lower energy (e.g., marine) impact structures.

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