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Upper Maastrichtian ammonite biostratigraphy of the Gulf Coastal Plain (Mississippi Embayment, southern USA)

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ABSTRACT

The Cretaceous outcrop belt of the Mississippi Embayment in the Gulf Coastal Plain (GCP) spans the Cretaceous/Paleogene (K/Pg) boundary. A detailed reconstruction of this time interval is critical for understanding the nature of biotic and environmental changes preceding the end-Cretaceous Mass Extinction event and for deciphering the likely extinction mechanism (i.e., bolide impact versus volcanism). Eight sections encompassing the K/Pg succession across the Mississippi Embayment were analyzed using biostratigraphic sampling of ammonites, dinoflagellates, and nannofossils. An upper Maastrichtian ammonite zonation is proposed as follows, from oldest to youngest: *Discoscaphites conradi* Zone, *D. minardi* Zone, and *D. iris* Zone. Our study documents that the ammonite zonation established in the Atlantic Coastal Plain (ACP) extends to the GCP. This zonation is integrated with nannofossil and dinoflagellate biostratigraphy to provide a framework to more accurately determine the age relationships in this region. We demonstrate that ammonites and dinoflagellates are more reliable stratigraphic indicators in this area than nannofossils because age-diagnostic nannofossils are not consistently present within the upper Maastrichtian in the GCP. This biostratigraphic framework has the potential to become a useful tool for correlation of strata both within the GCP and between the GCP, Western Interior, and ACP. The presence of the uppermost Maastrichtian ammonite *D. iris*, calcareous nannofossil *Micula prinsii*, and dinoflagellates *Palynodinium grallator* and *Disphaerogena carposphaeropsis* suggests that the K/Pg succession in the GCP is nearly complete. Consequently, the GCP is an excellent setting for investigating fine scale temporal changes across the K/Pg boundary and ultimately elucidating the mechanisms causing extinction.

1. Introduction

The end-Cretaceous (K/Pg) Mass Extinction qualifies as one of the "Big Five" extinction events in the Phanerozoic Era, when over 70% of marine species became extinct worldwide (e.g., Sepkoski, 1981; Jablonski and Raup, 1995). This led to a major global ecological reorganization in both the terrestrial and marine realms (e.g., Bambach et al., 2002; Labandeira et al., 2002; D'Hondt, 2005; Fastovsky and Sheehan, 2005). In the marine setting, ammonoids, inoceramids, and rudists became extinct, while planktic foraminifera and coccolithophorids were nearly wiped out (e.g., Jablonski and Raup, 1995; D'Hondt, 2005; Molina et al., 2006; Hönisch et al., 2012). These events have generally been attributed to an extraterrestrial bolide impact along the Yucatan Peninsula with the worst effects experienced in the vicinity of the impact (Alvarez et al., 1980; Schulte et al., 2010). Although much research supports this explanation, the ultimate extinction mechanism is still under debate. Critics of the impact

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theory posit that climate change related to the outpouring of the Deccan flood basalts in India caused the Cretaceous/Paleogene (K/Pg) extinction (Archibald et al., 2010; Keller, 2012).

An accurate and high-resolution biostratigraphic zonation of upper Maastrichtian strata across the Gulf Coastal Plain (GCP) of North America is essential for understanding the nature of the events and biotic changes preceding the K/Pg boundary. In contrast to well-resolved upper Maastrichtian microfossil biostratigraphy in the GCP (Moshkovitz and Habib, 1993; Habib et al., 1996; Mancini et al., 1996; Puckett, 2005; Mancini and Puckett, 2005), macrofossil biostratigraphy has received little attention. The currently used macrofossil biostratigraphic zones are the *Haustator bilira* Assemblage Zone (Sohl, 1977) and the *Exogyra costata* Assemblage Zone (Stephenson, 1914; Sohl and Koch, 1986). However, these zones are long ranging, encompassing the entire upper Maastrichtian, which limits their utility for fine scale correlation of upper Maastrichtian strata.

Ammonites are widely used elsewhere as biostratigraphic markers due to their rapid rates of evolution, abundance, and broad distribution (Kennedy and Cobban, 1976; Page, 1996; Kröger et al., 2011; Monnet et al., 2011; Ritterbush et al., 2014). Cobban and Kennedy (1995) made an initial attempt to reconstruct an ammonite biozonation for the upper Maastrichtian GCP, where they proposed two zones: a lower *Discoscaphites iris* Zone, followed by a higher *D. conradi* Zone. However, at the time of publication, the authors were not confident that their zonation was definitive. This zonation differs from that of the ammonite biozonation proposed by Landman et al. (2004a) for the upper Maastrichtian of the Atlantic Coastal Plain (ACP) in which the *D. iris* Zone is the highest zone of the upper Maastrichtian.

In addition, there has been debate regarding the completeness of the uppermost Maastrichtian sequence in the GCP. Based on analysis of foraminifera and ostracods, some authors have suggested that there is a hiatus of up to three million years at the top of the Maastrichtian in the Owl Creek Formation and Prairie Bluff Chalk in the northeastern part of the GCP (e.g., Mancini et al., 1989; Smith, 1997; Puckett, 2005). Still other authors (Bryan and Jones, 1989; Habib et al., 1992; Moshkovitz and Habib, 1993; Olsson and Liu, 1993; Habib et al., 1996; Hart et al., 2013; Dastas et al., 2014) have argued that the sequence is nearly complete based on the presence of the uppermost Maastrichtian calcareous nannofossils, dinoflagellates, and foraminifera.

Our study re-evaluates the biozonation proposed by Cobban and Kennedy (1995) and establishes a refined upper Maastrichtian ammonite biozonation in the GCP using high-resolution biostratigraphic sampling of three ammonites *D. iris* (Conrad, 1858), *D. minardi* (Landman et al., 2004a), and *D. conradi* (Morton, 1834) integrated with nannofossil and dinoflagellate biostratigraphy at several sites in Mississippi, Missouri, Arkansas, and Alabama. Our results provide, for the first time, the formal definition of three ammonite zones in the GCP. Application of this biostratigraphy then enables evaluation of the duration of the putative hiatus at the K/Pg boundary in the GCP.

2. Geologic setting

Overall, the Mississippi Embayment is characterized as a shallow marine basin. In the Cretaceous, the south-central portion of the North American Plate drifted over the Bermuda plume causing uplift and subsequent subsidence of the Mississippi Embayment (VanArsdale, 2009). As a result, the Mississippi Embayment formed a trough-like basin dipping southwestward stretching from Louisiana into southern Illinois during the Late Cretaceous (Pryor, 1960; Ebersol, 2009) (Fig. 1). This part of the GCP has experienced minimal tectonic activity in the past 80 Ma providing an excellent geologic setting for examining biostratigraphic ranges of marine fossils (Puckett, 2005; VanArsdale, 2009). Throughout the study area, upper Maastrichtian deposits of the Prairie Bluff Chalk, Owl Creek Formation, and Arkadelphia Formation overlie lower Maastrichtian strata of the Ripley Formation, McNairy Sand, and Nacatoch Formation, respectively. The Upper Cretaceous is disconformably overlain by Paleocene strata of the Clayton Formation.

The influence of fluvio-deltaic and marginal marine sediments in the northeastern part of the Embayment resulted in the deposition of a siliciclastic-dominated succession represented by the Owl Creek Formation (Pryor, 1960; Mancini, 1995; Mancini et al., 1996). Mineralogical, faunal, and sedimentological analysis suggests a nearshore, shallow marine depositional environment for this formation (Pryor, 1960; Mancini et al., 1996; Oboh-Ikuenobe et al., 2012; Sessa et al., 2015). The Owl Creek Formation extends from southeastern Missouri to northeastern Mississippi and transitions into a mixed carbonate and siliciclastic sequence deposited as the Prairie Bluff Chalk in east-central Mississippi and the Arkadelphia Formation in Arkansas (Stephenson, 1955; Mancini, 1995; Kennedy and Cobban, 2000) (Fig. 1).

Based on biofacies distribution, Sohl and Koch (1986) interpreted the depositional environment of the Prairie Bluff Chalk as offshore continental shelf. Puckett (1992) proposed a middle to outer neritic depositional environment for the Prairie Bluff Chalk using ostracod assemblages as paleoenvironmental indicators. Charles C. Smith (personal communication, 2015) suggested an inner to middle neritic setting for the Prairie Bluff Chalk deposited along a broad shallow shelf. This interpretation is based on the predominance of benthic versus planktonic foraminifera, as well as the presence of nannofossil ooze. In addition, gas and oil explorations reveal that the Prairie Bluff shelf was very broad and gently dipping, with no shelf break. The Arkadelphia Formation has been interpreted by Pitakpaivan and Hazel (1994) as an inner sublittoral depositional environment with no influence of fresh water based on the ostracod assemblage and chondrichthyan remains (Becker et al., 2006).

3. Material and methods

The results of this study are based on samples collected in situ at eight sites along the Upper Cretaceous outcrop belt in Mississippi, Alabama, Arkansas, and Missouri (Fig. 1). Sedimentological and taphonomic features were documented at each of the studied sections. Fossil specimens were collected at stratigraphic intervals with 5 cm precision. The number of fossils represents collections over four field seasons (the years of 2011–2014). Biozones were determined following the definition of interval zones of Salvador (1994). The lower boundary of each interval zone was defined by the lowest occurrence of the index taxon; the highest boundary was defined by the lowest occurrence of the index taxon of the next succeeding zone. These data were integrated with analysis of co-occurring dinoflagellate and calcareous nannofossil assemblages. The ammonites were identified using morphological characteristics described by Landman et al. (2004a, 2007) and Cobban and Kennedy (1995). All collected material is reposited in the American Museum of Natural History, New York (AMNH).

4. Description of localities

4.1. **Owl Creek type locality, Tippah County, Mississippi (34.748611°N, 88.911667°W). AMNH loc. #3460**

Lithology.—The stream-cut at the type locality of the Owl Creek Formation exposes the sedimentary sequence of the upper