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Trace fossil evidence suggests widespread dwarfism in response to the end-Cretaceous mass extinction: Braggs, Alabama and Brazos River, Texas

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ABSTRACT

As a proxy for the body size of the tracemaker, burrow diameter provides information on fundamental characteristics such as organism biology and behavior. Furthermore, changes in this endobenthic parameter provide insight into the timing and recovery of burrowing organisms in response to large-scale processes operating in ancient trophic systems. We herein report a decrease in burrow size in *Thalassinoides*-dominated ichnoassemblages across the Cretaceous–Paleogene (K–Pg) boundary in well studied shallow-marine sections along the Brazos River and Cottonmouth Creek, Texas and at Braggs, Alabama. At the Cottonmouth Creek and Brazos River localities, *Thalassinoides* isp. occurring above the previously reported negative $\delta^{13}C$ shift and the first occurrence of unequivocal Danian planktonic foraminifera are 17% smaller in short-axis diameter and 22% smaller when diameters are corrected for sediment compaction (mean K = 27.15 ± 7.12 mm, mean Pg = 21.13 ± 6.88 mm; n = 53) than those excavated and filled prior to deposition of a hummocky cross-bedded, ejecta-bearing sandstone complex commonly interpreted as the Chicxulub 'event deposit'. Across the K–Pg boundary at Braggs, diameters (D_{Th}) of simple maze *Thalassinoides* structures from similar, recurring depositional facies abruptly decrease by 22% (mean K = 13.08 ± 1.86 mm, mean Pg = 10.21 ± 1.87 mm; n = 26). The Cretaceous and Paleogene burrows were preserved in beds of similar lithology, suggesting that the reduction in size is not attributed to sedimentological factors. At both localities, up-section trends in D_{Th} are statistically significant ($\alpha < 0.05$, equal variance t-test, non-parametric Mann–Whitney U test). A reduction in D_{Th} above the K–Pg boundary reflects dwarfing within the post-extinction endobenthic community. These ichnological trends are similar to those recently documented at more impact-distal sites along the New Jersey Coastal Plain. Dwarfing during the early recovery stages of the end-Cretaceous mass extinction, as recorded by trace fossils, was widespread and occurred within siliciclastic, carbonate, and glauconite-producing depositional environments. Since this ichnological signal in shallow marine successions appears to be a general phenomenon across the crisis interval, trace-fossil analysis provides a potential *in-situ* field method for constraining and correlating the stratigraphic position of the event, particularly in the absence of other macroscopic, microscopic, and geochemical indicators.

1. Introduction

Most major mass extinctions during the Phanerozoic resulted in a decrease in burrow diameter (Bottjer and Droser, 1994; Twitchett and Barras, 2004; Morrow and Hasiotis, 2007; Twitchett, 2007). As a proxy for tracemaker body size, burrow diameter provides information on fundamental characteristics such as organism biology and behavior (Twitchett and Barras, 2004; Morrow and Hasiotis, 2007; Twitchett, 2007). In continental environments, the PETM is marked by a decrease in burrow diameter of soil fauna (Smith et al., 2009). Similarly, in marine settings, such as the Pilot Basin sequences of western Utah, the late Devonian extinction was marked by a reduction in burrow size, as well as ichnodiversity and tier depth during the extinction, survival, and early recovery stages (Morrow and Hasiotis, 2007). A reduction in burrow size was also documented beginning at the Permian–Triassic boundary and extending into the mid-Early Triassic (Twitchett and Wignall, 1996; Twitchett, 1999; Fraiser and Bottjer, 2000; Twitchett et al., 2001, 2004; Pruss and Bottjer, 2004; Twitchett and Barras, 2004; Pruss et al., 2005). The end-Triassic mass extinction was marked by a reduction in burrow size and tier depth as a response to potential widespread reduction in oxygen levels (Twitchett and Barras, 2004). Qualitative observations indicate ichnodiversity and burrow size are reduced at the Cretaceous–Paleogene (K–Pg) boundary in the lower Danian Fish Clay beds of Denmark (Ekdale and Bromley, 1984).

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More recently, a significant decrease in *Thalassinoides* isp. burrow diameter (D_{Th}) was documented at the K–Pg boundary along the Atlantic Coastal Plain at several sites in New Jersey (Wiest, 2014). *Thalassinoides* trace fossils are unlined, three-dimensional box-work of branching burrows interconnected by vertical shafts, which occur in deep marine turbidites and shallow marine environments. The *Thalassinoides* trace fossil may have several potential tracemakers, however they are generally thought to represent dwelling/feeding structures created by decapod crustaceans, primarily thalassinid shrimp (Myrow, 1995). Until now it remains unclear if this reduction in *Thalassinoides* size at the K–Pg boundary along the Atlantic Coastal Plain is a regional signal to the large-scale environmental perturbation, or a widespread response. In this paper we present new ichnological evidence for abrupt dwarfing from two Chicxulub impact-proximal sites along the Gulf Coastal Plain (Braggs, Alabama, and Brazos River, Texas), which indicates the widespread nature of the facies-independent endobenthic response to the K–Pg event and thus serves as a potential stratigraphic correlation tool.

2. Geologic setting

2.1. Braggs, Alabama

The Upper Cretaceous (Maastrichtian) and Lower Paleogene (Danian) strata along State Highway 263 between Braggs and Greenville, Alabama (Fig. 1; 32° 0′ 19″ N, 86° 45′ 1″ W) consist of slightly southward-dipping, interbedded calcareous mudstone, sandstone and sandy limestone sequences which were deposited in a shallow marine paleoenvironment (Copeland and Mancini, 1986; Jones et al., 1987; Donovan et al., 1988; Savrda, 1993). The exposed Upper Cretaceous sedimentary sequence is represented by the upper portion of the Prairie Bluff Formation and the lowermost 1 m of the Pine Barren Member of the Clayton Formation (Fig. 2). The formational contact is an erosional unconformity at the base of an indurated sandy limestone bed (Fig. 2, Bed 3; Copeland and Mancini, 1986). Jones et al. (1987), Donovan et al. (1988), Bryan and Jones (1989), and Zachos et al. (1989) placed the K–Pg boundary approximately 1 m above the formational contact, between Beds 5 and 6 (Fig. 2). This boundary, which occurs during magnetochron 29R, was established solely based on calcareous nanoplankton (Jones et al., 1987; Channell and Dobson, 1989). However, Habib et al. (1992) reported Danian nanoplankton in Bed 4 and placed the K–Pg boundary at the formational contact between Beds 2 and 3. Likewise, Olsson and Liu (1993) assigned the period boundary to the top of the Prairie Bluff Chalk because Paleocene planktonic and benthic foraminiferal species were observed in Bed 3, although rare and poorly preserved. Iridium peaks (≤0.7 ppb) have been reported within Bed 2 and at the top of Beds 5 and 9 (Donovan et al., 1988). Still, the K–Pg boundary section at Braggs is likely incomplete because neither the negative shift in $\delta^{13}C$, nor the latest Maastrichtian/earliest Danian index foraminifera are present (Cepek et al., 1968; Gibson et al., 1982; Donovan et al., 1988; Zachos et al., 1989; Habib et al., 1992).

2.2. Brazos River & Cottonmouth Creek, Texas

The Cottonmouth Creek site, located on a tributary of the Brazos River just south of the FM-413 Bridge in Falls County, Texas (Fig. 1; 31° 6′ 57″ N, 96° 49′ 57″ W), contains exceptional exposures of the K–Pg succession (Keller et al., 2007; Hart et al. 2012; Keller, 2012). Units A1 and A3 (Fig. 3) are Latest Maastrichtian in age, dark gray, weakly-bedded claystone separated by a thin layer of yellow cheto smectite (A2), which Hart et al. (2012) interpreted as weathered volcanic ash. These units comprise the upper portion of the Corsicana Formation and were deposited in a low-oxygen, shallow marine paleoenvironment (Keller et al., 2007). Overlying Unit A3, across an erosional unconformity, is a hummocky, cross-bedded sandstone (Unit HCS) with multiple fining

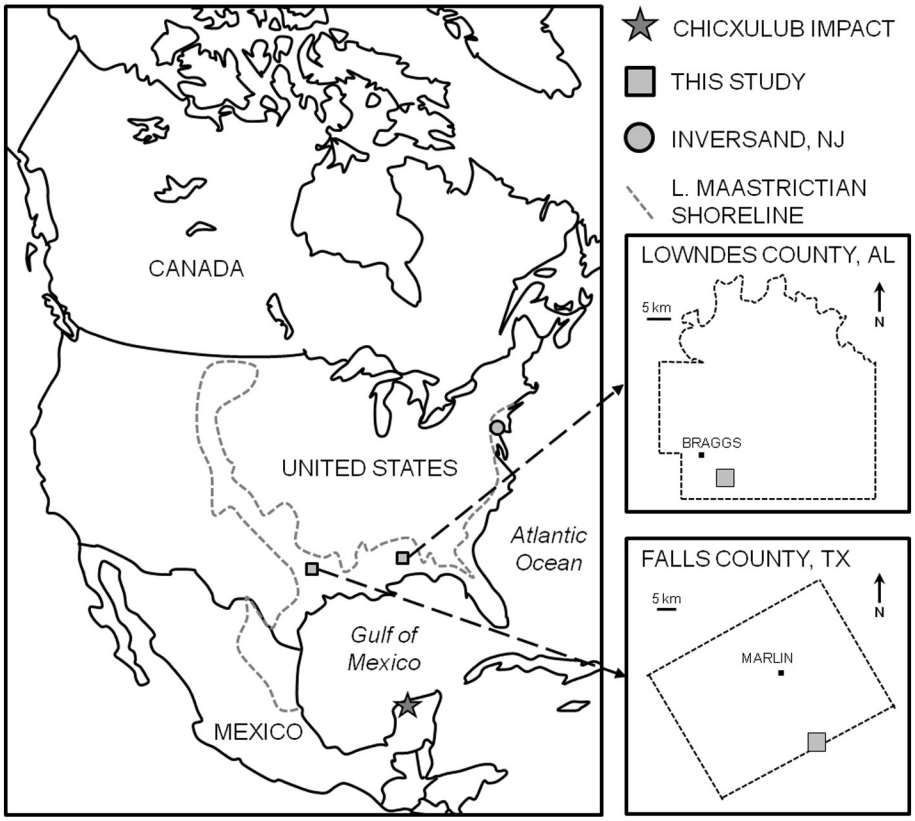

Fig. 1. Location map for studied K–Pg boundary sections. Squares = Brazos River (TX) and Braggs (AL) sections (this study); circle = Inversand Quarry, Sewell, NJ.