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Research paper

Stable seafloor conditions, sea level and food supply during the latest Maastrichtian at Brazos River, Texas

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ABSTRACT

The Cretaceous/Paleogene (K/Pg) boundary extinction event is inextricably linked to the Chicxulub impact. Environmental changes like sea level changes and changes in food supply prior to or after the impact could however have contributed to the biotic turnover. In this study, benthic foraminifera from two cores from the Brazos River area in Texas are quantitatively analyzed in order to reconstruct environmental changes across the K/Pg boundary. Cluster analysis as well as non-metric multidimensional scaling reveals three distinct benthic foraminiferal assemblages: an upper Maastrichtian assemblage, a post-impact assemblage, and a lower Danian assemblage. The rather uniform upper Maastrichtian assemblage at Brazos River, composed of e.g. *Clavulinoides midwayensis*, *Gavelinella dumblei*, *Cibicidoides harperi*, *Gyroidinoides aequilateralis* and *Bulimina kickapooensis*, indicates a stable paleodepth of about 75–100 m up to the K/Pg boundary. Food supply indicators such as percentage Buliminaceae and foraminiferal numbers suggest a relatively low and stable food supply during this interval. Environmental disruption caused by the Chicxulub impact led to the settlement of a typical pioneer assemblage, characterized by endobenthic morphotypes such as *Ammobaculites* spp. and *Pseudouvigerina naheolensis*. During the early Danian, the typical Midway-type benthic foraminiferal shelf fauna (e.g. *Alabamina midwayensis*, *Anomalinoides acutus*, *Gyroidinoides subangulatus*, *Praebulimina carseyae* and *Cibicidoides alleni*) developed, indicating a paleodepth of 75–100 m. No clear water depth changes can be derived from the benthic foraminiferal record during this interval, although the sedimentary record suggests a shallowing followed by a transgressive pulse in Zone P1a. Food supply indicators suggest a lower food supply in the early Danian than during the upper Maastrichtian. Because of the stability of the late Maastrichtian environment we conclude that environmental disruption caused by the impact was most likely the principal cause of the benthic foraminiferal turnover across the K/Pg boundary observed at Brazos River.

1. Introduction

The Cretaceous/Paleogene (K/Pg) boundary marks one of the largest extinctions in the Phanerozoic, and is inextricably connected to the Chicxulub impact (Alvarez et al., 1980; Smit and Hertogen, 1980; Schulte et al., 2010). Total diversity of the fossilized marine genera declined by ~47% from the upper Maastrichtian to the lower Danian (Sepkoski, 1996), and over 90% of planktic foraminifera species went extinct (e.g. Smit, 1982; D'Hondt et al., 1996; Molina et al., 1998). Extinction rates varied largely among genera, however. Where planktic foraminifera almost went extinct completely, global extinction of benthic foraminifera across the K/Pg boundary is quite low (Culver, 2003), where it should be noted that benthic foraminifera can locally show considerable extinction patterns and assemblage changes (e.g. Olsson et al., 1996, 2002; Speijer and van der Zwaan, 1996; Alegret et al., 2003; Alegret, 2007).

Although the Chicxulub impact is commonly believed to have been the major cause of the mass extinction event at the K/Pg boundary, additional causes have been suggested to have contributed to the mass extinction. Perhaps the most important contributor is the CO_2 mantle degassing of the Deccan Traps (e.g. Duncan and Pyle, 1988; Schoene et al., 2015) which presumably caused significant temperature rises during the late Maastrichtian that would have stressed ecosystems already before the impact (e.g. Keller, 2001; Keller et al., 2011).

In addition to the Deccan Traps degassing, sea level changes prior to or at the K/Pg boundary have been suggested to have contributed to the biotic turnover at the K/Pg boundary (e.g. Brinkhuis and Zachariasse, 1988; Keller and Stinnesbeck, 1996; Hallam and Wignall, 1999; O'Dea et al., 2011). For instance, marine regression reduces the amount of continental shelf habitats, whereas transgression may lead to anoxia on the shelf. Both effects could have contributed to extinction at the K/Pg boundary (Hallam and Wignall, 1999).

Furthermore, the collapse of the pelagic food web just after the K/Pg impact resulted in a diminished food supply towards the seafloor across the K/Pg boundary (e.g. D'Hondt, 2005). This decrease in export productivity is believed to have been moderate, regional, and insufficient to

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explain marine mass extinction (Alegret et al., 2012), but is often suggested to have caused the temporary early Danian changes in deep-sea benthic foraminiferal community structures at numerous locations (e.g. Speijer and van der Zwaan, 1996; Alegret et al., 2001, 2002; Culver, 2003). It is furthermore suggested that not only food quantity, but also food quality changes across the boundary influenced benthic foraminiferal communities (Thomas, 2007).

This study aims to clarify to what extent sea level changes, changes in food supply to the seafloor and changes in oxygenation of the seafloor, before and after the K/Pg boundary impact could have contributed to the end-Cretaceous mass extinction. Benthic foraminifera are excellently suited to reveal changes in food supply and oxygenation as well as sea level changes especially in neritic environments (e.g. Olsson and Nyong, 1984; Corliss and Chen, 1988; Jorissen et al., 1995; Van der Zwaan et al., 1999; Sen Gupta, 2002; Murray, 2006). In addition, unlike planktic foraminifera and calcareous nannofossils, benthic foraminifera did not go massively extinct across the boundary. Therefore, in this study, benthic foraminifera are used to reconstruct possible environmental changes across the K/Pg boundary in a virtually continuous K/Pg transition at the shallow sea Brazos River area, Texas, relatively close to the Chicxulub impact crater. Some, mostly qualitative, benthic foraminiferal research was already performed at this site (e.g. Schulte et al., 2006; Hart et al., 2011), showing a clear transition from an upper Maastrichtian benthic foraminiferal assemblage towards a new Midway-type lower Danian assemblage. This study provides a more elaborate quantitative analysis and ecological interpretation of the benthic foraminiferal assemblages across the K/Pg boundary.

2. Regional setting

Paleogeographically, the Brazos River area is located on the shallow shelf of the northern part of the Gulf of Mexico (Fig. 1) (Scotese, 2012; Scotese and Dreher, 2012). This region underwent nearly continuous and predominantly siliclastic sedimentation during the late Cretaceous and early Paleogene (Davidoff and Yancey, 1993). Sedimentation rates were higher than the increase of accommodation space on the continental shelf, resulting in an outward prograding shelf margin and an overall shallowing trend from the latest Cretaceous to the early Eocene (Davidoff and Yancey, 1993). Variations in sediment supply as well as eustatic sea level modified the progradation of the Paleogene shelf margin substantially, however (Galloway, 1989).

The late Maastrichtian Corsicana Formation of the Brazos River succession consists of gray silty claystones and mudstones with concretions. Some benthic foraminifera as well as some mollusk debris are preserved as aragonite. Shell debris is present throughout the formation. The top 0.5 m of the Corsicana Formation is a bioturbated claystone with burrow fills. In some places the soft, shell rich claystone contains >20 cm diameter clasts of intact claystone and marlstone, possibly due to reworking (Hart et al., 2011) or current drag and earthquakes (Schulte et al., 2006).

The overlying Paleogene Littig Member of the Kincaid Formation has an anomalous sandstone unit at its base. The thickness of this basal unit is variable depending on location (Gale, 2006; Hart et al., 2012). Where complete, the basal unit consists of a reworked, shell rich, mudstone clast bearing mudstone (Yancey and Liu, 2013) that shows no lamination (Schulte et al., 2006). On top of these mudstones, a complex of upward fining, spherule bearing, cross bedded, hummocky sandstones is present (Schulte et al., 2006; Yancey and Liu, 2013). Above this sandstone-complex, again mudstones are deposited (Hart et al., 2011).

The Brazos K/Pg outcrop area is situated between Waco and Hearne along the Brazos River in south-central Texas (Fig. 1). The Brazos cores investigated in this study were drilled close to each other at the western bank of the river. Their location is about 370 m downstream from the Texas Highway 413 Bridge, which is located near the crossing between Texas Highway 413 and 1373 (Schulte et al., 2006).

3. Material and methods

Schulte et al. (2006) describe the stratigraphy of Brazos Core 1 and Brazos Core 2 in detail. Together, Brazos Core 1 and Brazos Core 2 constitute an expanded succession of 14.5 m of the uppermost Maastrichtian and lower Danian. There is no evidence for significant hiatuses from the sedimentological and paleontological record (Schulte et al., 2006). Although the marker for the uppermost Maastrichtian biozone (CC26b, *M. prinsii*) is missing in these cores and is very rare in the area (Jiang and Gartner, 1986; Schulte et al., 2006), the presence of *P. hantkeninoides* (a planktic foraminifer) in uppermost Maastrichtian material from these cores (Mai et al., 2003) and nearby Brazos River locations (Hart et al., 2012) shows that the uppermost Maastrichtian is biostratigraphically complete at the Brazos River area. The lowermost Danian record is considered to be complete and expanded in the Brazos area. Both the planktic foraminiferal as well as the nannofossil record show all biozones and subzones (Schulte et al., 2006). However, an unconformity within Subzone P1a indicates a small hiatus between lithological units I and J.

In total, 38 samples from Brazos Core 1 and Brazos Core 2 (Schulte et al., 2006) were processed for foraminiferal studies at Karlsruhe University after methods given by Pardo et al. (1996). Both cores cover the K/Pg boundary. Brazos Core 1 mainly covers the lower Danian sequence, whereas Brazos Core 2 mainly represents upper Maastrichtian sediments. The benthic foraminiferal number (BFN) represents the number of benthic foraminifera per gram dry sediment and the foraminiferal number (FN) consists of the total number of foraminifera (planktic and benthic) per gram dry sediment. Both were calculated

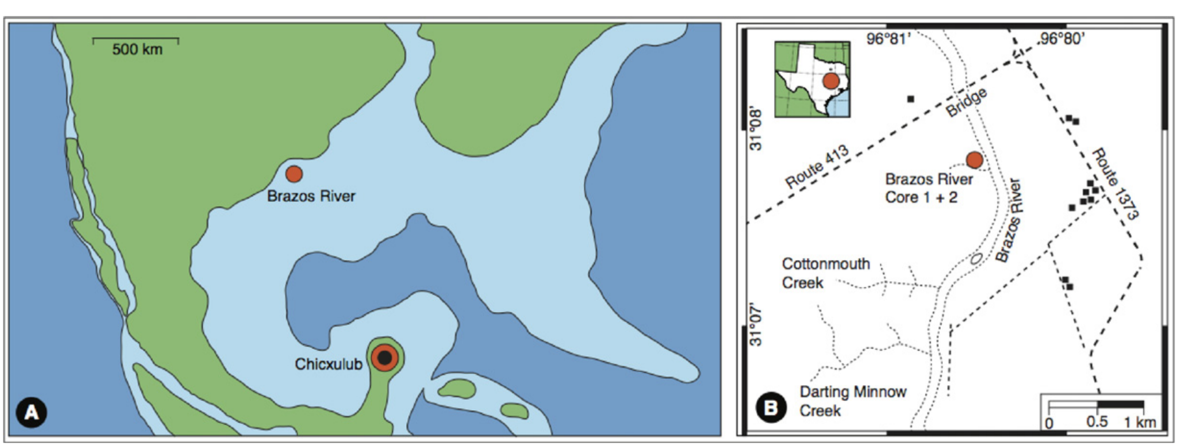

Fig. 1. A: Approximate paleogeographic location of Brazos River, Texas on the North American shallow shelf. Also the location of the Chicxulub impact crater is indicated. Map after Scotese and Dreher (2012). B: Location of Brazos River outcrop area, where Brazos Core 1 and 2 (which were used in this study) were taken. After Schulte et al. (2006).