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Mass wasting and hiatuses during the Cretaceous-Tertiary transition in the North Atlantic: Relationship to the Chicxulub impact?

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ABSTRACT

Deep-sea sections in the North Atlantic are claimed to contain the most complete sedimentary records and ultimate proof that the Chicxulub impact is Cretaceous-Tertiary boundary (KTB) in age and caused the mass extinction. A multi-disciplinary study of North Atlantic DSDP Sites 384, 386 and 398, based on high-resolution planktonic foraminiferal biostratigraphy, carbon and oxygen stable isotopes, clay and whole-rock mineralogy and granulometry reveals the age, stratigraphic completeness and nature of sedimentary disturbances. Results show a major hiatus across the KTB at Site 384 with Zones CF1, P0 and P1a missing, spanning at least ~540 ky, similar to other North Atlantic and Caribbean localities associated with tectonic activity and Gulf Stream erosion. At Sites 386 and 398, discrete intervals of disturbed sediments with mm-to-cm-thick spherule layers have previously been interpreted as the result of impact-generated earthquakes at the KTB destabilizing continental margins prior to settling of impact spherules. However, improved age control based on planktonic foraminifera indicates spherule deposition in the early Danian Zone P1a(2) (upper *Parvularugoglobigerina eugubina* Zone) more than 100 ky after the KTB. At Site 386, two intervals of white chalk contain very small (<63 μm) early Danian Zone P1a(2) assemblages (65%) and common reworked Cretaceous (35%) species. In contrast, the in situ red-brown and green abyssal clays of this core are devoid of carbonate. In addition, high calcite, mica and kaolinite and upward-fining are observed in the chalks, indicating downslope transport from shallow waters and sediment winnowing via distal turbidites. At Site 398, convoluted red to tan sediments with early Danian and reworked Cretaceous species represent slumping of shallow water sediments as suggested by dominance of mica and low smectite compared to in situ deposition. We conclude that mass wasting was likely the result of earthquakes associated with increased tectonic activity in the Caribbean and the Iberian Peninsula during the early Danian well after the Chicxulub impact.

1. Introduction

For more than 30 years, a bolide impact (Chicxulub) on the Yucatan Peninsula has been popularly accepted as the direct and sole cause for the Cretaceous-Tertiary boundary (KTB, also known as KPg for Cretaceous-Paleogene) mass extinction 66 Ma ago (e.g., Alvarez et al., 1980; review in Schulte et al., 2010). This conclusion is largely based on the claim of complete and continuous sedimentation with a thin impact spherule layer precisely at the KTB in various deep-sea sections of the North Atlantic (Bass River, New Jersey, Blake Nose ODP Site 1049, Demerara Rise ODP Site 1259), providing the ultimate proof that the Chicxulub impact is KTB in age (Olsson et al., 1997; Norris et al., 1998, 1999; Martinez-Ruiz et al., 2001; MacLeod et al., 2007). Mass wasting deposits in some North Atlantic deep-sea sections (Bermuda Rise DSDP Site 386, Vigo Seamount DSDP Site 398) are interpreted as additional supporting evidence of the effects of the Chicxulub impact, such as downslope displacement and reworking of Cretaceous sediments just prior to spherule deposition followed by reportedly undisturbed Danian sediments (Klaus et al., 2000; Norris et al., 2000; Norris and Firth, 2002).

The underlying assumptions in these studies are that the Chicxulub impact occurred precisely at the KTB, the spherules represent primary impact fallout and the sections are complete. However, high-resolution quantitative faunal analysis from North Atlantic and Caribbean sites (Bass River, Sites 999, 1001, 1049, 1050, 1259) revealed a major KTB hiatus and impact spherules reworked within early Danian Zone P1a deposits (Keller et al., 2013), similar to earlier observations reported from Cuba, Haiti, Belize, Guatemala and SE Mexico, along with multiple Platinum Group Elements (PGE: Ir, Pd, Pt) anomalies (Stinnesbeck et al., 1997; Keller et al., 2001, 2003a, 2013; Stüben et al., 2002, 2005; Keller, 2008). This pattern of erosion was attributed to intensified Gulf Stream current circulation during times of significant

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climate and sea-level changes (Keller et al., 1993, 2003a,b, 2013; Watkins and Self-Trail, 2005). In contrast, in the more complete sequences of NE Mexico and Texas, thick impact spherule layers are interbedded in late Maastrichtian Zone CF1 sediments up to 9 m below the KTB, an interval that is generally missing in the North Atlantic due to erosion (Adatte et al., 1996; Keller et al., 2002a,b,c, 2003b, 2011a; Schulte et al., 2003).

Within this context, the mass wasting deposits described from the North Atlantic and their relationship, if any, to the Chicxulub impact are intriguing. As evident from earlier studies, impact spherules are easily reworked and frequently redeposited in lower Danian sediments. Therefore, the sole presence of impact spherules does not represent primary deposition and is not indicative of the age of the impact. High-resolution quantitative planktonic foraminiferal biostratigraphy is critical to determine the age and completeness of the sedimentary record.

Mass wasting along the North Atlantic slope could have resulted from earthquakes associated with Chicxulub impact or from tectonic activity, which was particularly active in the Caribbean and the Iberian Peninsula during the late Cretaceous to early Paleogene (e.g., Malfait and Dinkelman, 1972; Boillot and Capdevilla, 1977; Réhault and Mauffrey, 1979; Pindell and Dewey, 1982; Duncan and Hargraves, 1984; Burke, 1988; Pindell and Barrett, 1990; Meschede and Frisch, 1998; Pindell and Kennan, 2001). To date, the North Atlantic margin collapse, though attributed to the Chicxulub impact by some workers, remains little understood particularly with respect to the age of the disturbance, the location of the KTB, the stratigraphic position of impact spherules, and the roles of the Chicxulub impact and tectonic activity.

This study set out to examine the potential causes of the western North Atlantic margin disturbance based on DSDP Sites 384 and 386 and comparison with DSDP Site 398 off the coast of Portugal (Fig. 1). The main objective is to gain a better understanding of the nature of these disturbances based on improved age control and faunal and mineralogical data. We hypothesize that the Chicxulub impact is the likely cause if impact spherules are precisely at the KTB and continuous sedimentation can be demonstrated. However, if sedimentation is discontinuous due to hiatuses and impact spherules are reworked above the KTB, then tectonic activity must be considered. Our investigation concentrates on (1) high-resolution quantitative planktonic foraminiferal biostratigraphy to assess the age and depositional environment, (2) carbon and oxygen stable isotope analysis as additional tool for stratigraphic correlation and environmental information, (3) whole-rock and clay mineralogy to evaluate the origin of sediments, and (4) granulometric analysis to assess the sedimentary processes involved. DSDP Sites 384, 386 and 398 were chosen because they are considered among the most complete KTB sections and/or representative of mass wasting deposits associated with the Chicxulub impact (Thierstein and Okada, 1979; Norris et al., 2000; Norris and Firth, 2002).

2. Locations and materials

DSDP Site 384 is located at a water depth of 3909 m in the western North Atlantic on the J-Anomaly Ridge where it emerges above the Sohm Abyssal Plain and the continental rise south of the Grand Banks (Fig. 1, Table 1). The high carbonate content (~90%) marks deposition well above the carbonate compensation depth (CCD) (Tucholke and Vogt, 1979). Upper Maastrichtian and lower Danian sediments (core sections 12-6 to 13-6) consist of tan to white, mottled and weakly laminated nannofossil chalk and ooze (Fig. 2). The KTB was identified at 167.93 m below the surface (mbsf) (in core-section 13-3, 33 cm) at a lithologic change from tan to gray chalk (Berggren et al., 2000) (Fig. 2).

DSDP Site 386 was drilled at a water depth of 4782 m on the central Bermuda Rise in the western North Atlantic, about 140 km south-southeast off Bermuda (Fig. 1, Table 1). Sediments in core-sections 35-3 to 35-5 generally consist of red-brown abyssal clay and silt, except for two discrete white chalk beds (upper chalk: 636.65–637.80 mbsf; lower chalk: 638.05–638.95 mbsf) that are separated by 15-cm-thick green clay (637.90–638.05 mbsf) with a 5-cm-thick altered impact glass spherule layer on top (Fig. 2). The red-brown and green clays are laminated. The base of each chalk bed is also laminated followed by mottled, weakly laminated to structureless sediments at the top (Fig. 2). Norris et al. (2000) placed the KTB at the top of the upper chalk bed at 636.68 mbsf (core-section 35-4, 18 cm) (an early Danian age was determined for the chalk beds in this study, Fig. 2). Paleodepth reconstruction places Site 386 below the CCD (Tucholke and Vogt, 1979). Chalk deposition is interpreted as the result of either a drastic drop in the CCD in the late Maastrichtian (e.g., Tucholke and Vogt, 1979; Barrera and Savin, 1999) or mass wasting from shallower depths (Norris et al., 2000; Norris and Firth, 2002).

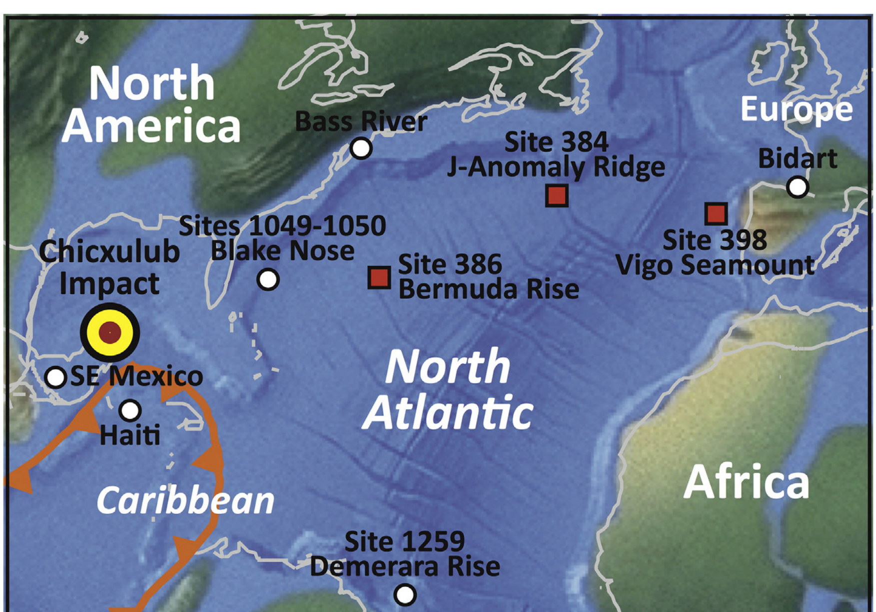

Fig. 1. Paleogeography and paleolocations during the KT transition of North Atlantic sites analyzed in this study (DSDP Sites 384, 386 and 398) and sites used for comparison (Bass River, New Jersey; ODP Sites 1049–1050, 1259; Beloc, Haiti; Bochil and Guayal, SE Mexico; Bidart, France). Paleomap modified after Scotese (2000).