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Deccan volcanism induced high-stress environment during the Cretaceous–Paleogene transition at Zumaia, Spain: Evidence from magnetic, mineralogical and biostratigraphic records

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ABSTRACT

We conducted detailed rock magnetic, mineralogical and geochemical (mercury) analyses spanning the Cretaceous–Paleogene boundary (KPB) at Zumaia, Spain, to unravel the signature of Deccan-induced climate and environmental changes in the marine sedimentary record. Our biostratigraphic results show that Zumaia is not complete, and lacks the typical boundary clay, zone P0 and the base of zone P1a(1) in the basal Danian. Presence of an unusual ∼1m-thick interval spanning the KPB is characterized by very low detrital magnetite and magnetosome (biogenic magnetite) contents and by the occurrence of akaganéite, a very rare mineral on Earth in oxidizing, acidic and hyper-chlorinated environments compatible with volcanic settings. These benchmarks correlate with higher abundance of the opportunist *Guembelitria cretacea* species. Detrital magnetite depletion is not linked to significant lithological changes, suggesting that iron oxide dissolution by acidification is the most probable explanation. The concomitant decrease in magnetosomes, produced by magnetotactic bacteria at the anoxic–oxic boundary, is interpreted as the result of changes in seawater chemistry induced by surficial ocean acidification. Mercury peaks up to 20–50 ppb are common during the last 100 kyr of the Maastrichtian (zone CF1) but only one significant anomaly is present in the early Danian, which is likely due to the missing interval. Absence of correlation between mercury content ($R^2 = 0.009$) and total organic carbon ($R^2 = 0.006$) suggest that the former originated from the Deccan Traps eruptions. No clear relation between the stratigraphic position of the mercury peaks and the magnetite-depleted interval is observed, although the frequency of the mercury peaks tends to increase close to the KPg boundary. In contrast to Bidart (France) and Gubbio (Italy), where magnetite depletion and akaganéite feature within a ∼50cm-thick interval located 5 cm below the KPg boundary, the same benchmarks are observed in a 1m-thick interval encompassing the KPg boundary at Zumaia. Results reinforce the synchronism of the major eruptions of the Deccan Traps Magmatic Province with the Cretaceous–Paleogene (KPg) mass extinction and provide new clues to better correlate the Deccan imprint of the global sedimentary record.

1. Introduction

Recent advances in U–Pb and Ar–Ar radiometric dating have improved constraints for the onset and duration of the entire Deccan Magmatic Province (Renne et al., 2015; Schoene et al., 2015). More than 3000 m of continental flood basalts, representing more than 1.1 million of km^3 in volume, erupted within ca. 750,000 years, spanning Chron 29r and encompassing the Cretaceous–Paleogene boundary (KPB), the mass extinction and the Chicxulub impact (Schoene et al., 2015). The KPB mass extinction has been documented by planktic foraminifera assemblages within

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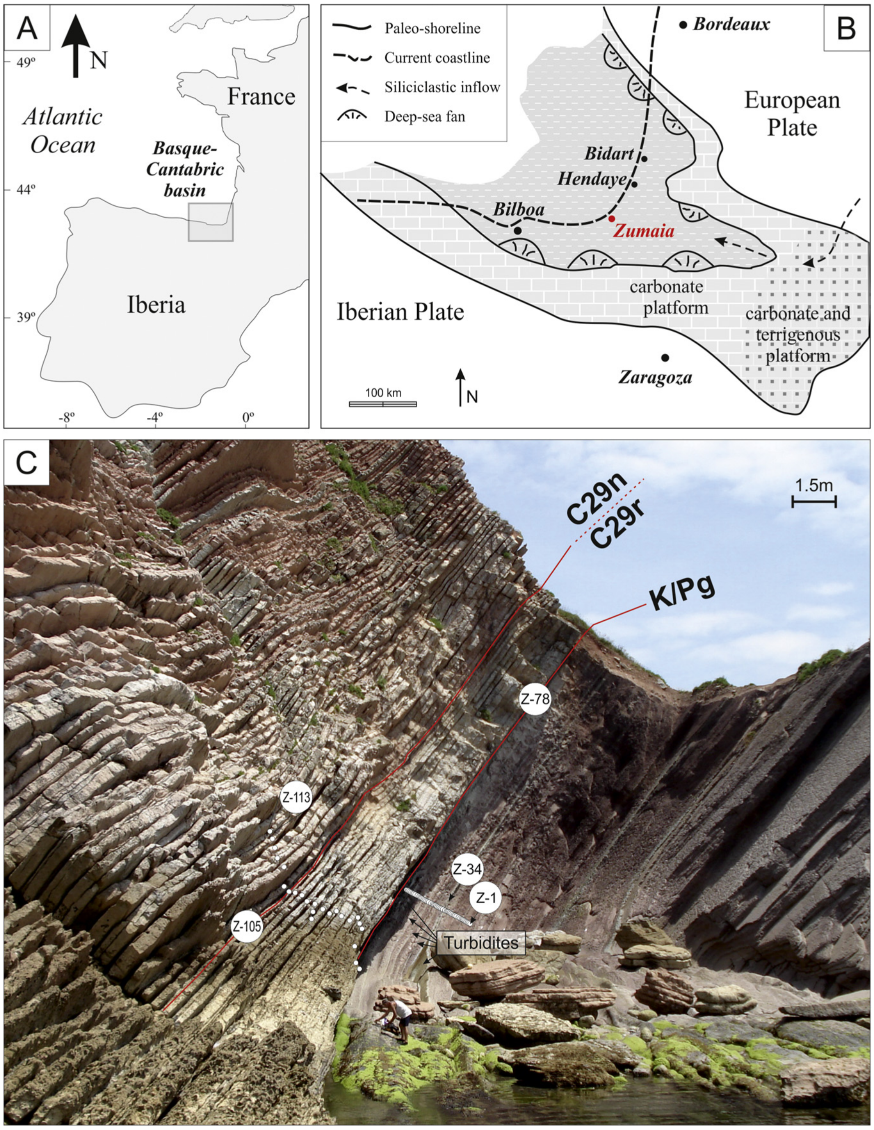

Fig. 1. A) Location of the Basque-Cantabric basin and studied area. B) Paleoenvironmental context of the Zumaia section (modified from Pujalte et al., 1995). C) Field photograph of the Zumaia section and location of the collected samples. Position of the KPg and 29r/29n chron boundaries (from Dinares-Turell et al., 2003) are also shown.

Deccan lava flows of the Krishna-Godavari Basin of eastern India (Keller et al., 2012). The cumulative effect of these huge and rapid volcanic eruptions may have led to global climate and environmental changes by the injection of stratospheric acid aerosols, leading to widespread global climate change, ozone depletion, acid rain, and surficial ocean acidification (Punekar et al., 2016; Self et al., 2008). However, the global climate and environmental effects of the Deccan Trapps and their contribution to the KPg mass extinction in remote sections is still under debate. Even when the stratigraphic position of the impact is well marked in marine sediments by the iridium and platinum-group element anomalies, as well as the presence of shocked quartz, the sedimentary imprint of global changes induced by large igneous province volcanism is still challenging. Furthermore, the critical global effects induced by the Deccan are not expected to occur at the onset of the first eruptions, but at the time when increased eruption rates and volumes reached a critical threshold, starting to affect climate, the environment and life on Earth. Indirect sedimentary benchmarks such as iron oxides and mercury may help identify this critical threshold in the sedimentary record (Burgess et al., 2017).

Here, we investigate the Zumaia section of northwestern Spain, a well-exposed uppermost Cretaceous to Paleogene section that has been proposed as a reference for the Cretaceous–Paleogene geological time-scale calibration based on orbital cyclicity (Batenburg et al., 2014, 2012; Dinares-Turell et al., 2003; Husson et al., 2011; Kuiper et al., 2008; Westerhold et al., 2008). Results presented in this study provide new data to better calibrate the sedimentary signature of the Deccan-induced paleoenvironmental changes and its relative chronology with the KPB mass extinction.

2. Geological settings and sampling

The Zumaia section crops out at the Itzurun beach (42°18.00′N/2°15.30′W) in northwestern Spain (Fig. 1). Hemipelagic sediments were deposited in the E–W trending Basque-Cantabric basin spanning the Cretaceous–Paleogene boundary (KPB). Danian sediments consist of pink limestones alternating with thin clay layers. Maastrichtian sediments consist of reddish (and sporadically grey) marls intercalated with sandy turbidites (Fig. 2). The KPg boundary clay layer is not present at Zumaia, making this boundary event problematic. The lithological boundary between the Maastrichtian and the Danian is marked by a level of secondary calcite. Biostratigraphic and magnetostratigraphic constraints are provided by Pujalte et al. (1995), Dinares-Turell et al. (2003) and