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Environmental perturbation in the southern Tethys across the Paleocene/Eocene boundary (Dababiya, Egypt): Foraminiferal and clay mineral records

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Abstract

Foraminiferal and clay mineral records were studied in the upper Paleocene to lower Eocene Dababiya section (Egypt). This section hosts the GSSP for the Paleocene/Eocene boundary and as such provides an expanded and relatively continuous record across the Paleocene/Eocene Thermal Maximum (PETM). Deposition of illite–smectite clay minerals is interpreted as a result of warm and arid conditions in the southern Tethys during the latest Paleocene. Benthic foraminiferal assemblages are indicative of seasonal variation of oxygen and food levels at the seafloor. A sea-level fall occurred in the latest Paleocene, followed by a rise in the earliest Eocene. Foraminiferal diversity and densities decreased strongly at the P/E boundary, coinciding with the level of global extinction of benthic foraminifera (BEE) and start of the Carbon Isotope Excursion (CIE) and PETM. In the lower CIE, the seafloor of the stratified basin remained (nearly) permanently anoxic and azoic. A sudden increase in mixed clay minerals (kaolinite and others) suggests that warm and perennial humid conditions prevailed on the continent. High levels of TOC and phosphathic concretions in the middle CIE are evidence for increased organic fluxes to the sea floor, related to upwelling and to augmented continental runoff. Low densities of opportunistic taxa appeared, indicating occasional ephemeral oxygenation and repopulation of the benthic environment. The planktic community diversified, although conditions remained poor for deep-dwelling taxa. An increase in illite–smectite dominated clay association is considered to mark the return of a seasonal signature on climatic conditions. During the late CIE environmental conditions changed to seasonally fluctuating mesotrophic conditions and diverse and rich benthic and planktic foraminiferal communities developed. Post-CIE planktic faunas consisted of both deep and shallow-dwelling taxa and buliminid-dominated benthic assemblages reflect fluctuating mesotrophic conditions.

The frequent environmental perturbations during the CIE/PETM at Dababiya provided a rather specialized group of foraminiferal taxa (i.e., *Anomalinoides aegyptiacus*) the opportunity to repopulate, survive and subsequently dominate by a hypothesized capacity to switch to an alternative life strategy (population dynamics, habitat shift) or different metabolic pathway. The faunal record of Dababiya provides insight into the cause and development of the BEE: various severe global changes during the PETM (e.g., ocean circulation, $CaCO_3$-dissolution, productivity and temperature changes) disturbed a wide range of environments on a geologically brief timescale, explaining together the geographically and temporally variable character of the

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BEE. This allowed a number of specific but different foraminiferal assemblages composed of stress-tolerant and opportunistic taxa to be successful during and after the periods of environmental perturbations associated with the PETM.

Keywords: foraminifera; clay mineralogy; PETM; Dababiya; Egypt; Paleocene; Eocene

1. Introduction

The transition from the Paleocene to the Eocene is characterized by a number of exceptional events, collectively known as the Paleocene/Eocene Thermal Maximum (PETM), a transient period of global warmth at 55 Ma (Kennett and Stott, 1991; Zachos et al., 1993). A global drop in δ^{13}C values of up to 2–3‰, known as the Carbon Isotope Excursion (CIE), marks the onset of the PETM during which within a few thousand years global temperatures rose by 5–8 °C, (Kennett and Stott, 1991; Zachos et al., 1993; Koch et al., 1995; Corfield and Norris, 1998; Jenkyns, 2003). The PETM is the best-studied period in the Earth's pre-Quaternary history, in which rapid climate change took place, and it is thought to be a good analogue for climatic changes the Earth is facing today (Dickens, 1999). Study of the PETM enables an assessment of the interaction between geosphere and biosphere during rapidly occurring climatic perturbations and provides insight into the return to background conditions (Bains et al., 2000; Schmitz, 2000).

The release of a massive amount of methane from gas hydrates from the seafloor is generally held responsible for the dramatic climate change during the PETM (Dickens et al., 1995; Katz et al., 1999; Dickens, 2004). The strong negative shift in δ^{13}C (CIE) is presently explainable only by the release of very light methane (~ −60‰ ^{13}C), although the trigger for the release of methane is still a point of debate (e.g., Eldholm and Thomas, 1993; Dickens et al., 1995; Kent et al., 2003; Svensen et al., 2004; Cramer and Kent, 2005).

The effect of globally rising temperatures on ocean productivity during the PETM is an issue of debate. Several oceanic records suggest widespread oligotrophy (Kelly et al., 1996; Bralower, 2002), although most continental margin records and some open ocean records suggest an increase in productivity (e.g., Crouch et al., 2001; Speijer and Wagner, 2002; Gavrilov et al., 2003; Stoll and Bains, 2003).

A global increase in kaolinite during the PETM (Robert and Kennett, 1992) is interpreted as a period of global warm and perennial humid conditions (Robert and Chamley, 1991). However, within the Tethyan realm clay mineral records give evidence for differentiated climate zones (Bolle et al., 2000a; Bolle and Adatte, 2001). Lower Paleocene sediments from Tunisia, Spain, Israel and Egypt contain abundant kaolinite, considered to point at warm and perennial humid conditions (Bolle and Adatte, 2001). Along the southern margins of the Tethys however, conditions became progressively drier from the late Paleocene to Eocene, indicated by the increased deposition and formation of minerals such as palygorskite and sepiolite (Bolle and Adatte, 2001; Shoval, 2004). During the PETM the southern margins of the Tethys were arid with high evaporation rates (Bolle et al., 2000b; Shoval, 2004; Khormali et al., 2005), although warm and humid conditions may have persisted on the African continental hinterland (Bolle and Adatte, 2001). However, the paleoenvironmental interpretation of clay minerals is not always straightforward and has shown to potentially yield complex and mixed signals, for instance because of the attribution of weathered minerals from different climate zones in the drainage area of rivers (Thiry, 2000). Therefore, paleoenvironmental implications based on clay minerals should be made carefully and preferably in combination with other proxies, as done in this paper.

The climate change triggered many faunal and floral radiations and migrations in both continental and marine settings (Kelly et al., 1998; Clyde and Gingerich, 1998; Aubry, 1998; Oreshkina and Oberhänsli, 2003; Speijer and Morsi, 2002). In the deep-sea, however, a major extinction took place among the benthic foraminifera (Tjalsma and Lohmann, 1983; Kennett and Stott, 1995; Thomas, 1998; Thomas et al., 2000). This benthic foraminiferal extinction event (BEE) yielded high extinction rates of ~40% and locally up to 65% in the deep-sea (Beckmann, 1960; Thomas, 1990; Kaiho, 1994). In the southern Tethys, the extinction event was similarly severe at upper bathyal sites in Sinai (Egypt) and in southern Israel (Speijer, 1995), but it had less impact at middle to outer neritic depths where estimated extinction rates range up to 25% (Speijer et al., 1995, 1996). Paleocene benthic foraminiferal faunas were to a