

## Restructuring outer neritic foraminiferal assemblages in the aftermath of the Paleocene–Eocene thermal maximum

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**ABSTRACT** – Deep-sea benthic foraminiferal faunas underwent severe extinction during the Paleocene–Eocene thermal maximum (PETM), but less is known about neritic environments. Through taxonomical analysis we document for the first time that recovery of neritic benthic assemblages after the PETM followed a similar pattern in shelf regions in New Jersey (USA) and Egypt. *J. Micropalaeontol.* 31(1): 89–93, February 2012.

**KEYWORDS:** *Paleocene–Eocene thermal maximum, benthic foraminifera, neritic, stratigraphy*

### INTRODUCTION

The early Paleogene climatically dynamic greenhouse world underwent episodes of rapid global warming (hyperthermals), of which the Paleocene–Eocene thermal maximum (PETM) is the best known (Zachos *et al.*, 2008). The associated carbon isotope excursion (CIE; Kennett & Stott, 1991), correlated with global climatic and biotic events (see overview in Sluijs *et al.*, 2007a), now defines the Paleocene–Eocene (P–E) boundary (Dupuis *et al.*, 2003). The base of the CIE is coeval with the extinction of *Gavelinella beccariiiformis* (White, 1928) and associated long-lived, cosmopolitan deep-dwelling foraminiferal taxa, such as *Angulogavelinella avnimelechi* (Reiss, 1952), marking a severe benthic extinction event (BEE) in bathyal and deeper settings (e.g. Thomas & Shackleton, 1996; Thomas, 2007). This event marks the end the ‘Cretaceous fauna’, which survived from the late Cretaceous up to the P–E boundary and the rise of an early–middle Eocene ‘Paleogene fauna’ (Thomas, 2007).

Paleocene benthic foraminiferal faunas were cosmopolitan to a large extent and two principal assemblages can be distinguished. The first is the so-called ‘Midway-type fauna’, typical of continental shelf environments, and the second is the ‘Velasco-type fauna’, representative of continental slope to abyssal environments (Berggren & Aubert, 1975). The BEE has long since been recognized as a major turnover (Tjalsma & Lohmann, 1983) and is applied as the boundary between benthic abyssal Zones AB2 and AB3 and benthic bathyal Zones BB1 and BB2 (Berggren & Miller, 1989). At this level, most of the characteristic ‘Velasco-type’ taxa became extinct, yet the neritic ‘Midway-type’ assemblages remained largely unaffected. In Egypt, the PETM benthic foraminiferal turnover and subsequent recovery was, indeed, less pronounced in shelf faunas although a distinct extinction level corresponds to the onset of the PETM, indicating that the BEE was not exclusively a deep-sea event (e.g. Speijer *et al.*, 1995). We report for the first time that there is a remarkable resemblance in the pattern of benthic foraminiferal recovery in two widely separated shelf areas and the potential stratigraphical application.

### MATERIAL AND METHODS

Samples were obtained from two continuously drilled New Jersey Coastal Plain boreholes at Wilson Lake and Bass River (Fig. 1). The New Jersey Coastal Plain is situated in the northern part of



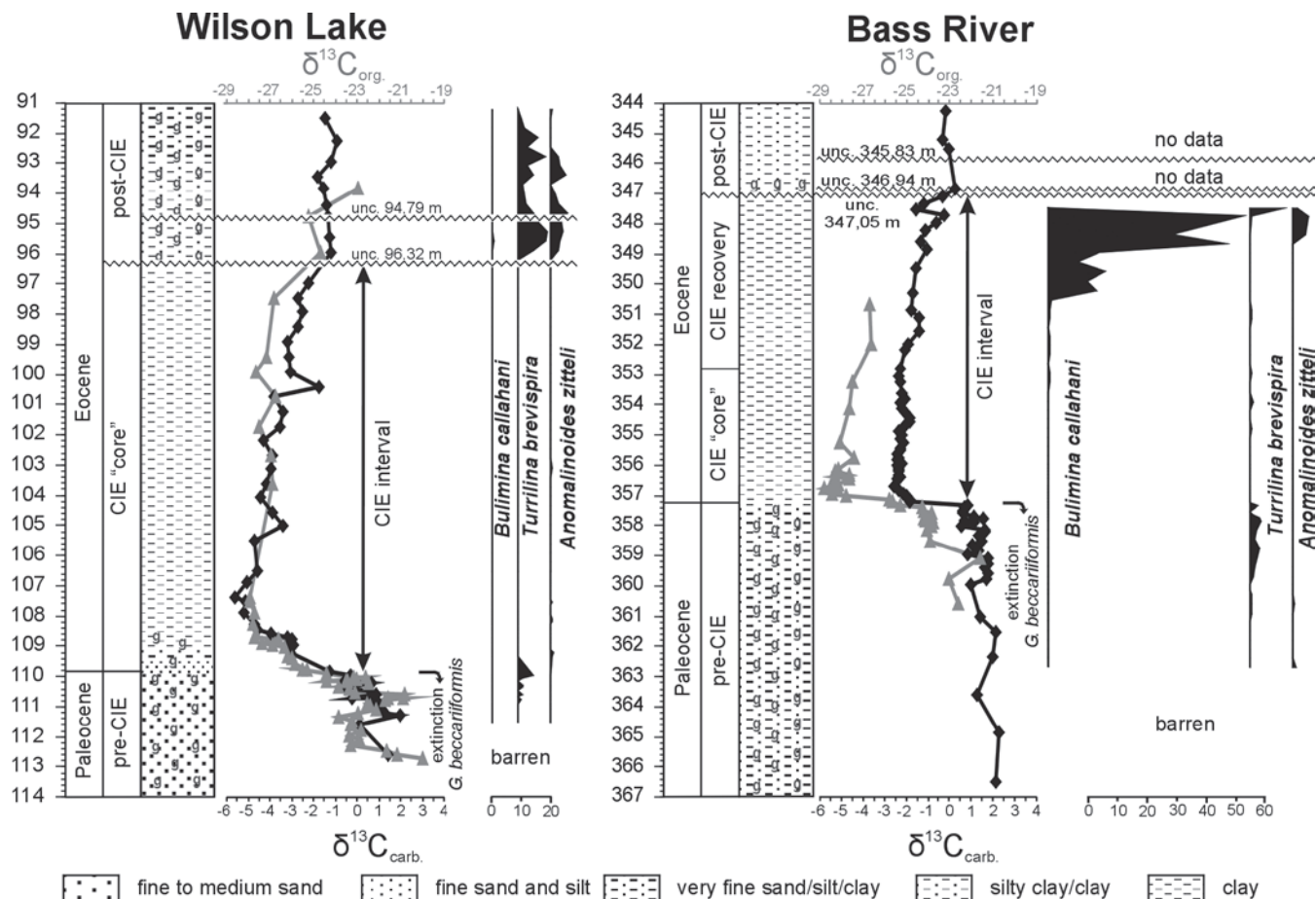
### 55.8 Ma reconstruction

**Fig. 1.** Location the New Jersey Coastal Plain (1) and the Egyptian basin (2). Reconstruction is based upon ODSN Plate Tectonic Reconstruction Service (<http://www.odsn.de/odsn/services/paleomap/paleomap.html>).

the Salisbury Embayment, containing a nearly complete marine record of Paleocene–Eocene boundary sediments (Gibson & Bybell, 1994). Palaeodepth estimations indicate latest Paleocene deep middle neritic (Wilson Lake) to outer neritic (Bass River) settings (unpublished data, P. Stassen). Samples were washed over a 63  $\mu\text{m}$  sieve until completely disaggregated. Benthic foraminiferal frequencies are based upon a representative split of the 63–630  $\mu\text{m}$  fraction. We show relative abundances of three selected taxa (Fig. 2; Pl. 1) and compare these to the distribution patterns of the Egyptian Dababiya section (Fig. 3; Ernst *et al.*, 2006), hosting the GSSP for the P–E boundary (Dupuis *et al.*, 2003). Palaeodepth estimation indicates an outer neritic setting (Ernst *et al.*, 2006). Correlation of the distribution patterns is calibrated using the extinction level of *G. beccariiiformis* and the division of the CIE into a ‘core’ and a recovery phase (Röhl *et al.*, 2007).

### RESULTS AND DISCUSSION

Previous benthic studies were unable to recognize in full extent the similarity between the Atlantic Coastal Plain and Egyptian shelf biota. Detailed comparison between benthic foraminiferal assemblages across the PETM reveals strikingly similar distribution patterns of three benthic species (Pl. 1) – *Bulimina callahani*



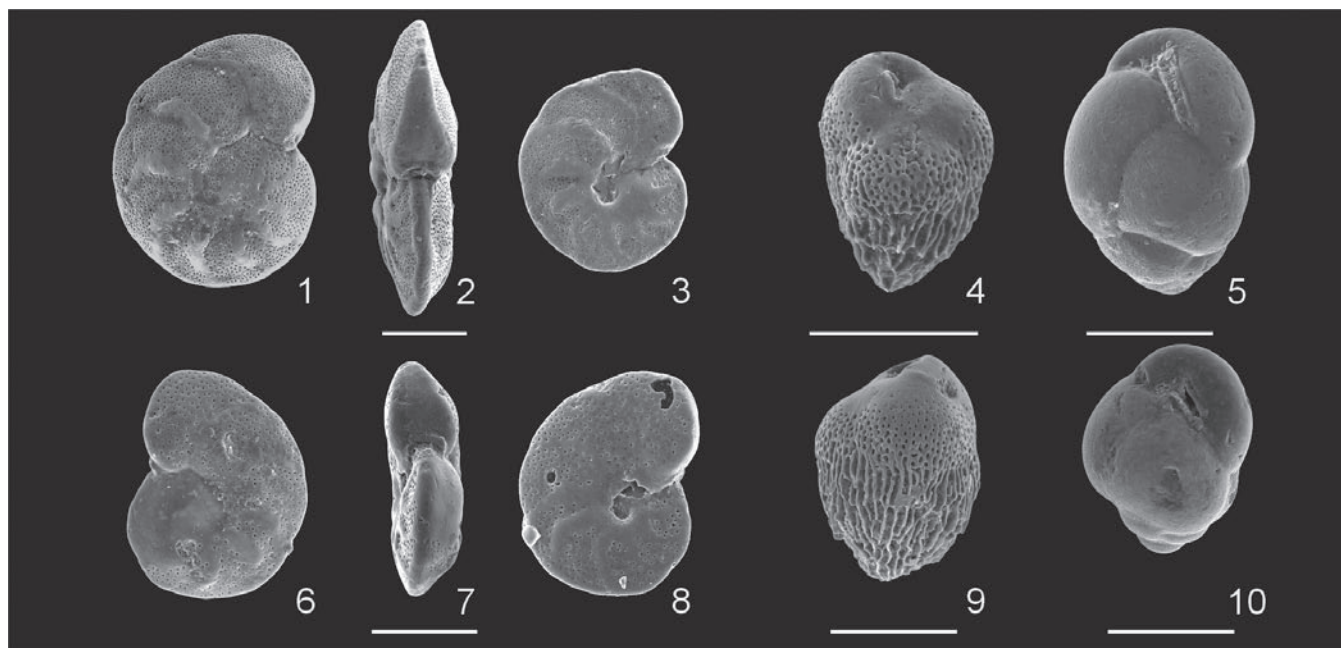
**Fig. 2.** The P–E boundary at Wilson Lake and Bass River with carbon isotope record (Zachos *et al.*, 2006; Sluijs *et al.*, 2007b; John *et al.*, 2008) and distribution of the three benthic taxa (63–630  $\mu\text{m}$  fraction).

Galloway & Morrey, 1931, *Turritina brevispira* ten Dam, 1944 and *Anomalinoidea zitteli* (Leroy, 1953), which are rare to common in the uppermost Paleocene in both regions. They were absent during the CIE ‘core’, corresponding to the peak environmental perturbation and became common to abundant components of Eocene benthic assemblages during the CIE recovery, with *B. callahani*, in particular, blooming. This buliminid remained dominant in post-PETM Egyptian outer neritic environments (Speijer *et al.*, 2000), whereas it disappeared in the post-PETM interval at Wilson Lake (deep middle neritic). *Turritina brevispira* and *A. zitteli* remained common to abundant throughout the remainder of the lower Eocene (NP10) at Wilson Lake and in Egyptian settings (Speijer & Schmitz, 1998). Similar behaviour of *T. brevispira* is also observed in the deep sea (Thomas & Shackleton, 1996).

Zonation of the Paleocene–Eocene boundary by means of planktic organisms has resulted in well-calibrated stratigraphical frameworks (Aubry *et al.*, 2007). Similar application using benthic foraminifera has been hampered by inadequate taxonomy and their relatively longer stratigraphical ranges. In addition, benthic foraminiferal turnovers may merely reflect regional environmental changes or facies control rather than evolutionary phenomena. This often results in diachronous ranges; nevertheless certain species

may be applicable in stratigraphical correlations. Our observed biotic shifts in shelf ecosystems occurred simultaneously and may have persisted over time. The (temporal) bloom of *B. callahani* probably represents merely a palaeoecological signal (buliminid bloom in response to high organic flux; Ernst *et al.*, 2006), but the lowest common occurrences of *T. brevispira* and *A. zitteli* seem to be applicable as neritic stratigraphical markers for the P–E boundary. As these species inhabited the outer parts of the shelf (>75 m water depth and up to bathyal settings; Speijer & Schmitz, 1998), they can be stratigraphically applied in outer shelf and deeper sedimentary sequences.

Additionally, the bathyal benthic foraminiferal biozonation into a Paleocene Zone BB1 (*G. beccariiiformis* and *A. avnimelechi* assemblage) and an Eocene Zone BB2 (*T. brevispira*, *B. callahani* and *Nuttallides truempyi* (Nuttall, 1930) assemblage) can be extrapolated towards outer neritic settings with an upper Paleocene assemblage (*G. beccariiiformis* and *A. avnimelechi*) and a lower Eocene assemblage (*B. callahani*, *A. zitteli* and *T. brevispira*). This indicates also that the composition of the Paleocene ‘Midway-type’ fauna was affected by environmental changes during the PETM. These three characteristic species were already present during the latest Paleocene and became more frequent after the elimination of Paleocene taxa.



**Explanation of Plate 1.**

figs 1–3. *Anomalinooides zitteli* (Dababiya 4.25 m): 1, spiral view; 2, apertural view; 3, umbilical view. fig. 4. *Bulimina callahani* (Dababiya 5.65 m). fig. 5. *Turrilina brevispira* (Dababiya 4.75 m). figs 6–8. *Anomalinooides zitteli* (Wilson Lake 96.04 m): 6, spiral view; 7, apertural view; 8, umbilical view. fig. 9. *Bulimina callahani* (Bass River 349.32 m). fig. 10. *Turrilina brevispira* (Wilson Lake 96.04 m). Scale bar represents 100 µm. Figured specimens are deposited in the Department of Earth & Environmental Sciences, K.U. Leuven.

## CONCLUSIONS

Our taxonomical comparison reveals similar distribution patterns of *Bulimina callahani*, *Turrilina brevispira* and *Anomalinooides zitteli* across the PETM between the study areas. The recognition of this biotic shift can be used to track the Paleocene–Eocene boundary in the deeper parts of the shelves surrounding the Atlantic Ocean and the Tethys and possibly elsewhere too.

## SYSTEMATIC DESCRIPTION

We adopted species concepts of Leroy (1953), Speijer (1994) and Ernst *et al.* (2006) for the Tethys. The works of Olsson (1960) and Charletta (unpublished thesis, Rutgers University) on the Paleocene and Eocene New Jersey Coastal Plain faunas, respectively, are used for taxonomical comparison. Unfortunately, more recent publications lack detailed taxonomical documentation (e.g. Olsson & Wise, 1987; Browning *et al.*, 1997; Harris *et al.*, 2010).

Family **Heterolepidae** Gonzáles-Donoso, 1969  
Genus *Anomalinooides* Brotzen, 1942

*Anomalinooides zitteli* (Leroy, 1953)  
(Pl. 1, figs 1–3, 6–8)

non 1948 *Cibicides simplex* Brotzen: 83, pl. 13, figs 4–5.  
1953 *Cibicides zitteli* Leroy: 25, pl. 6, figs 20–22.  
1960 *Cibicides simplex* Brotzen; Olsson: 53, pl. 12, figs 7–9.  
1994 *Anomalinooides zitteli* (Leroy); Speijer: 166, pl. 7, fig. 1.  
2006 *Anomalinooides zitteli* (Leroy); Ernst *et al.*, pl. 2, figs o–p.

**Remarks.** This species is characterized by a compressed evolute test with strongly curved limbate sutures on both sides. *Cibicides simplex* (Brotzen, 1948) displays slightly depressed sutures on the spiral side and may have a rounded periphery, whereas the New Jersey specimen depicted by Olsson (1960) has a distinctive narrow keel at the periphery and limbate sutures.

Family **Buliminidae** Jones, 1875  
Genus *Bulimina* d’Orbigny, 1826

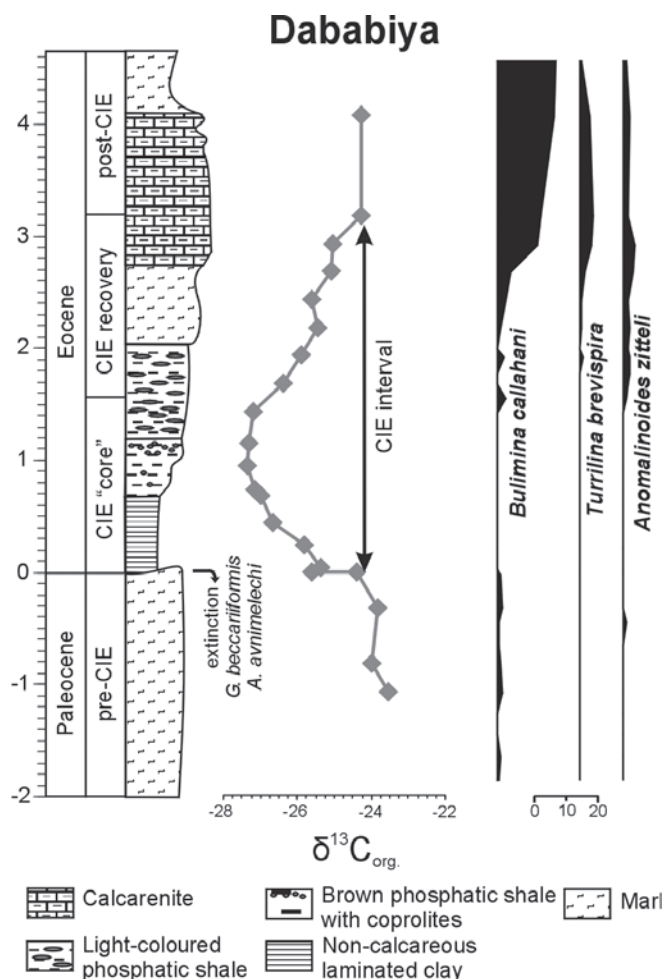
*Bulimina callahani* Galloway & Morrey, 1931  
(Pl. 1, figs 4, 9)

1931 *Bulimina callahani* Galloway & Morrey: 350, pl. 40, fig. 6.  
1953 *Bulimina rugifera* Glaessner; Leroy, 21, pl. 6, figs 13–14.  
1994 *Bulimina callahani* Galloway & Morrey; Speijer, 152, pl. 3, fig. 3.  
2006 *Bulimina callahani* Galloway & Morrey; Ernst *et al.*, pl. 2, fig. j.

**Remarks.** This species displays the characteristic, thin, closely spaced, irregular and branching costae, extending from the initial part up to the last whorl. The upper part is smooth and almost without pores.

Family **Turrilinae** Cushman, 1927  
Genus *Turrilina* Andreae, 1884

*Turrilina brevispira* ten Dam, 1944  
(Pl. 1, fig. 5)



**Fig. 3.** The P–E boundary at Dababiya with carbon isotope record (Dupuis *et al.*, 2003) and distribution of the discussed benthic taxa (63–630  $\mu\text{m}$  fraction) (modified after Ernst *et al.*, 2006).

non 1939 *Bulimina robertsi* Howe & Ellis in Howe: 63, pl. 8, figs 32–33.

1944 *Turritina brevispira* ten Dam: 110, pl. 3, fig. 14.

1953 *Bulimina esnaensis* LeRoy: 20, pl. 6, figs 11–12.

1994 *Turritina brevispira* ten Dam; Speijer, 150, pl. 3, fig. 4.

2006 *Turritina brevispira* ten Dam; Ernst *et al.*, pl. 2, fig. v.

**Remarks.** This species can be recognized easily based upon the slit-like aperture with a short perpendicular extension up the infolded apertural face and its glossy appearance due to the smooth surface and very fine pores. *Turritina brevispira* and *T. robertsi* strongly resemble each other, but are distinguishable on the basis of the numbers of chambers in the last whorl (respectively 3 and 4). *Turritina robertsi* is thought to have evolved from *T. brevispira* during the middle Eocene (Revets, 1987).

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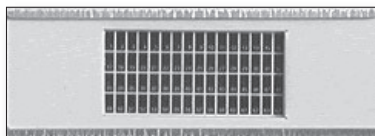
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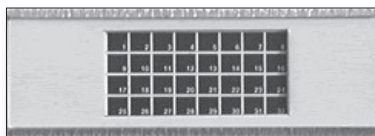
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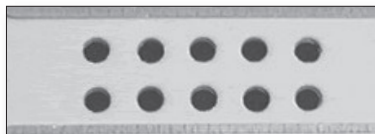
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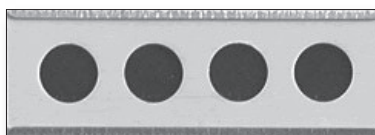
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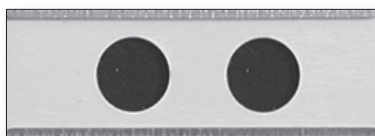
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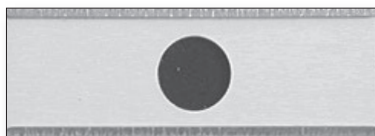
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