The PETM and ETM2: Reset buttons for benthic ecosystem evolution?

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D'haenens S.[1], Bornemann A.[2], Speijer R.P.[1]

→ simon.dhaenens@ees.kuleuven.be

1 Department of Earth and Environmental Sciences, KU Leuven, Belgium

2 Institut für Geophysik und Geologie, Universität Leipzig, Germany

Ever since its discovery, the Paleocene-Eocene Thermal Maximum (~PETM; 55.8 Ma) has intrigued micropaleontologists. This geologically brief global warming event - possibly caused by the dissociation of ^{12}C-rich methane hydrates – drove the extinction of ~30-50% of all deep-sea benthic foraminifera. As such, the PETM can be considered as a "reset" button in the evolution of benthic ecosystems, eliminating certain taxa (e.g. *Gavelinella*) – for reasons actually still unknown - and subsequently propelling other taxa (e.g. *Nuttallides*) as common components in the Eocene. This particular transition from the "Cretaceous fauna" to the Paleogene fauna was kick-started by the PETM, yet the fully mature Eocene fauna only developed in the course of the Early Eocene.

With the recent discovery of several other global hyperthermal events in Eocene sedimentary sequences, a number of questions arise. What role – if any – did these hyperthermals have in shaping Paleogene deep-sea benthic communities? Did they exert a noticeable effect on the (disrupted post-PETM) deep-sea benthic ecosystem on short time scales or did they also produce more longer-lasting effects?

To answer these questions, we investigated latest Paleocene to early Eocene (NP9-NP12) pelagic deposits of DSDP Site 401 (North Atlantic Ocean). In this interval, lithological changes and stable isotope records reveal the presence of the PETM and Eocene Thermal Maximum 2 (ETM2). Using a detailed quantitative benthic foraminiferal record for this interval, we were able to 1) compare the faunal patterns of the PETM with those of ETM2 and 2) assess these patterns in a longer-term perspective. Our dataset confirms the extinction of several Paleocene species at the onset of the PETM, although at ~15-20%, the extinction rate is significantly lower than the global average. The PETM itself shows a marked increase in *Nuttallides umbonifera*, *Tappanina selmensis*, *Bulimina tuxpamensis* and several abyssaminid taxa. This perturbed assemblage is quickly replaced by an *Epistominella minuta*/*Bulimina* cf. *simplex* assemblage, which is associated with an expanded and clay-enriched sequence. Near the top of Biozone NP10, the clay content decreases and the assemblage subtly changes: *Cibicidoides eocaenus* and *Bulimina virginiana* become common up to ETM2. Just like the PETM, ETM2 is dominated by *N. umbonifera*, but more striking is that directly following it, the assemblage permanently changes: *C. eocaenus*, *E. minuta*, *B. virginiana* and *Brizalina carinata* truly dominate, while previously common *B. tuxpamensis*, *Bolivina huneri* and other minor components virtually disappear from the record.

Differences in magnitude aside, the ETM2 resembles the PETM: a similar excursion fauna characterizes both events and they both initiate a permanent change in an otherwise relatively stable benthic foraminiferal assemblage. Hence, we suggest that hyperthermal events are transient climatic/paleoceanographic perturbations, partially "resetting" benthic ecosystem evolution, creating a stepwise developmental pattern. Whether the punctuated changes at DSDP Site 401 are truly representative of Eocene deep-sea foraminiferal evolution remains to be seen, as global benthic records encompassing Eocene hyperthermals are still in development at the moment.