Variable benthic foraminiferal ecosystem responses to the PETM in shelf environments

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The Paleocene-Eocene thermal maximum (PETM) is characterized by a worldwide 5-8 °C warming of Earth's surface as well as the deep oceans, major global faunal and floral turnovers and large changes in ocean chemistry. In order to establish clear biogeographic patterns of how shallow benthic foraminiferal communities responded to these climate changes, we compare shallow marine ecosystems in three separated regions and provide a synthesis of the short-term biotic responses. These regions are located in Tunisia (Northern and Gafsa Basin), Egypt (Nile Basin) and the North Atlantic Coastal Plain (Salisbury Embayment, United States).

In Egypt, widespread anoxia during PETM peak warming led to the collapse of Paleocene deep shelf communities and a basin-wide downslope migration of pioneering shallow water taxa (*A. aegyptiacus*) during the initial recovery phase. In the shallower Tunisian settings, the PETM is marked by dysoxia, increased water depth and an elevated sedimentation rate. This resulted in the migration of deeper-dwelling species (lagenid and buliminid fauna) at the onset of the PETM, replacing the former shallow water community. At the onset of the PETM in the North Atlantic Coastal Plain, deposition occurred in a basin-wide mud belt, inhabited by opportunistic deep shelf taxa. Increased eutrophication, high sedimentation rates and widespread hypoxia are linked to the establishment of a river-dominated shelf during the PETM. As a result, in shallow and deep shelf settings, diverse Paleocene assemblages were replaced by characteristic river-outflow assemblages (*P. prima*, *A. acutus*, *T. selmensis*), either by upslope migration or increased abundances of these background taxa.

Due to the magnitude and tempo of global warming, the PETM exerted worldwide environmental stress on benthic foraminiferal communities, triggering prominent transient changes in population structure and biodiversity, yet the evolutionary impact was minor compared to the deep-sea extinction event. This implies the existence of refugia on the shelves. In general, stable latest Paleocene benthic foraminiferal assemblages were abruptly replaced by more stress-tolerant faunas, reflecting stressed dysoxic to anoxic eutrophic environments, due to higher nutrient delivery (increased runoff and upwelling) and stratification. These hypoxic conditions occurred in the early stages of the PETM continually or with high frequencies and evolved towards periodic (seasonal?) oxygen depletion during the latter stages of peak warming or initial recovery. The final recovery phase reflects a reoxygenation of the sea floor and a distinctive buliminid bloom (*B. callahani*) occurred at both sides of the Atlantic Ocean. These eutrophic conditions remained stable and continued in the aftermath of the PETM, yet the oxygenation of bottom waters became restored. The PETM sequences thus document a progression of environmental regimes that is somewhat similar in all studied settings, indicating a widespread mutual response to the massive injection of carbon dioxide at the onset of the PETM.