Life in the Deep-Sea during Eocene Hyperthermal Events

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The Paleocene-Eocene Thermal Maximum and other early Eocene hyperthermals were short-lived (10^4–10^5 years) episodes of exceptionally warm climate, linked to emission of large amounts of iso-topically depleted carbon into the ocean-atmosphere system. During these episodes there was severe dissolution of carbonate on the seafloor, and there is evidence for low oxygen conditions at least in parts of the world's oceans. The hyperthermal events were of varying intensity, with deep-sea temperatures increasing by 5–6°C during the PETM, about 4°C during Eocene Thermal Maximum 2 (ETM2 or Elmo,1.8 myr after the PETM) and about 2.5°C during Eocene Thermal Maximum 3 (ETM3 or X event, 3.2 myr after the PETM). Benthic foraminiferal assemblages were studied along a depth transect (1500–3600 m) on Walvis Ridge (SE Atlantic) across these three hyperthermal events. Severe dissolution associated with the PETM allowed no preservation of carbonate along the full depth transect during the most intense part of that event. Dissolution persisted over a shorter period at the shallower site, and was less intense during later hyperthermals. Globally deep-sea benthic foraminifera suffered severe extinction during the PETM but not during later hyperthermals, which occurred before the faunal diversity recovered. During all hyperthermals, benthic assemblages are characterized by low-diversity and dominance of relatively small and thin-walled specimens (as e.g. the epifaunal *Nuttallides truempyi*), although at least one infaunal species (*Oridorsalis umbonatus*) shows increased wall thickness during the PETM. Benthic foraminiferal accumulation rates and relative abundance of species indicate a lower supply of food to the seafloor at Walvis Ridge during all three hyperthermals, possibly because of decreased open-ocean productivity during periods of warming and increased ocean stratification. Benthic assemblage data from above the dissolution interval of the PETM indicate that an Oxygen Minimum Zone expanded downwards over the shallower site in the earlier and later stages of the main Carbon Isotope Excursion (CIE) associated with the PETM. Benthic foraminifera were present throughout the CIE associated with ETM-2 at the deepest site, but absent to very rare in a few samples from the shallowest site. Assemblages show a similar, but less extreme pattern than that during the PETM, with development of low-oxygen conditions during the earliest and latest stages of the event. There is no evidence in the benthic assemblages from ETM-3 that OMZs expanded to the depth transect. We thus see evidence for ocean acidification in the SE Atlantic during all three early Eocene hyperthermal events, but for development of low oxygen conditions only during warm events with an estimated deep-sea warming of more than 2.5°C.