Carbon release, transient global warming, and productivity feedback during the Paleocene-Eocene Thermal Maximum (PETM) and related hyperthermal events

Peter SCHULTE

GeoZentrum Nordbayern, Universität Erlangen, Schloßgarten 5, D-91054 Erlangen, Germany, schulte@geol.uni-erlangen.de

The Paleocene-Eocene Thermal Maximum (PETM), ~55.5 Myr ago, was a geologically brief (~170 kyr) episode of globally elevated temperatures that occurred superimposed on the long-term late Paleocene and early Eocene warming trend. The PETM was marked by a 5-8°C global warming, ocean acidification, rapid sea-level fluctuations, an enhanced hydrological cycle, and a major biotic response on land and in the oceans (Bowen et al. 2006; Sluijs et al. 2008; 2009; Zachos et al. 2005). In addition, the PETM is associated with a prominent negative 2-3 ‰ $\delta^{13}C$ carbon isotope excursion ("CIE"; Kennett and Stott 1991; Koch et al. 1992). The CIE can only be explained by a massive (>1500 Gt) injection of isotopically light CO_2 and/or CH_4 into the ocean-atmosphere carbon pool (Dickens et al. 1995). The PETM has been studied extensively since its discovery in 1991 because it may serve as a deep-time analogue for current global warming. In addition, several events that appear similar to the PETM in nature, but of smaller magnitude, were identified to have occurred during the Paleocene and the early Eocene (e.g., Nicolo et al., 2007; Speijer, 2005). Although the research carried out in the last 15 years has provided new constraints that improved our understanding of PETM carbon cycle and climate change, the source and the mechanisms that caused the carbon input still remains enigmatic.

The currently favored hypothesis to explain the carbon release are (i) large-scale dissociation of oceanic methane hydrate on continental margins (e.g., Dickens et al. 1995) and (ii) sill emplacement in organic-rich sediments, followed by metamorphism and venting that took place in the Northwest Atlantic (Planke et al., 2009). However, by calculating the mass balance of carbon input through the magnitude of the CIE, Pagani et al. (2006) suggested that CO_2 released from methane hydrates or by oxidation of terrestrial and/or marine organic carbon would both require extremely large carbon inputs to explain the warming. Thus carbon from these sources could only have caused the PETM if the climate sensitivity to CO_2 was much higher than currently assumed. In consequence, the PETM either resulted from an enormous input of CO_2 for which currently no satisfying explanation exists, or climate sensitivity to CO_2 was extremely high and possibly enhanced by yet unidentified climate feedbacks.

Beside ongoing investigations related to the source of the carbon, recent work has focused on the importance of high productivity during the peak phase of the PETM, suggesting that shelf areas may have acted as large carbon sinks due to increased weathering and sea level rise (John et al., 2008; Schulte et al., 2009 subm.). Other questions of interest include the role of the additional Paleocene and Eocene hyperthermal events (Speijer & Wagner 2002, Nicolo et al., 2007) as well as the relevance of eustatic sea-level changes during these hyperthermals (Sluijs et al., 2008).

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