A Model-Data Comparison of OAE1a and the PETM: How does rapid global warming contribute to ocean anoxia

The Oceanic Anoxic Events (OAEs) of the Mesozoic reflect major perturbations of the global carbon cycle during greenhouse conditions (Jenkyns, 2010) and are accompanied by enhanced accumulation of organic rich sediments (black shales), which form important targets for petroleum exploration. One of the largest OAEs of the Mesozoic, OAE 1a, occurred in the early Aptian (~120 Ma). OAE 1a is related to major perturbations of biogeochemical cycles and intensified and expanded oxygen minimum zones with widespread anoxia and euxinia. Although classically not considered an OAE, the Paleocene Eocene Thermal Maximum (PETM) shares many features with Mesozoic OAEs, in particular a strong negative carbon isotope excursion indicative of a rapid injection of CO2 into the ocean-atmosphere system.

Although the concept of the OAEs was introduced more than 35 years ago (Schlanger & Jenkyns, 1976), the precise trigger mechanism(s) for OAEs remain unclear. There is a growing body of evidence from various geochemical proxies (δ18O, Mg/Ca from planktonic foraminifera and organic-based TEX86) that indicate an association of OAEs with ocean warming (Voigt et al., 2006; Bailey et al., 2003; Forster et al., 2007). However, the exact timing and temporal patterns are relatively complicated and not well constrained. As a result the relationship between perturbations of the carbon cycle, ocean warming, and anoxia is unclear. In addition, the precise geographical extent of ocean anoxia is unclear and appears quite variable. For example, anoxia during the PETM appears restricted to continental shelves (Tremolada et al., 2007), while Cretaceous OAEs affected at least 50% of the ocean (Monteiro et al., 2012). In order to fill these important gaps in our knowledge it is essential to investigate OAEs further.

Using sediment records from around the world (e.g. ODP Sites 866, DSDP Site 398, etc) we will use organic geochemical proxies to gain a mechanistic understanding of the processes and mechanisms that occurred during OAEs. A multidisciplinary analytical approach will be used, using lipid biomarkers (e.g. methylhopanes, Isorenieratene, etc.) and compound specific carbon isotopic compositions to identify and monitor (changes in) the depositional environment during OEAs. The analysis of compound specific carbon and hydrogen isotopes will also illuminate the interplay between the carbon and hydrological cycles during OAEs. These biomarker results will be combined with model results of GENIE, a model of intermediate complexity and extremely suitable to study OAEs (Monteiro et al., 2012; Weber, 2010) and to achieve a high resolution comparison between different aspects of OAE1a and PETM.

The results of this project will be critical for petroleum exploration, and our understanding of poorly oxygenated oceans, which are important in the context of the predicted decrease in oxygenation of the world ocean and expansion of oxygen minimum zones due to global warming.

References:

Bailey, T. R., Y. Rosenthal, J. M. McArthur, B. van de Schootbrugge, and M. F. Thirlwall (2003), Paleoceanographic changes of the Late Pliensbachian–Early Toarcian interval: A possible link to the genesis of an oceanic anoxic event, Earth Planet. Sci. Lett., 212, 307–320.

Forster, A., S. Schouten, K. Moriya, P. A. Wilson, and J. S. Sinninghe Damsté (2007), Tropical warming and intermittent cooling during the Cenomanian/Turonian oceanic anoxic event 2: Sea surface temperature records from the equatorial Atlantic, Paleoceanography, 22, PA1219.

Jenkyns, H.C., 2010. Geochemistry of oceanic anoxic events. Geochem. Geophys. Geosyst. 11 (3), Q03004. doi: 10.1029/2009gc002788

Monteiro, F.M., Pancost, R.D., Ridgwell, A., Donnadieu, Y., 2012. Nutrients as the dominant control on the spread of anoxia and euxinia across the Cenomanian-Turonian oceanic anoxic event (OAE2): Model-data comparison. Paleoceanography 27 (4), PA4209. doi: 10.1029/2012pa002351

Schlanger, S.O., Jenkyns, H.C., 1976. Cretaceous oceanic anoxic events: causes and consequences. Geologie En Mijnbouw 55 (3-4), 179-184.

Tremolada, F., E. Erba, and T. J. Bralower (2007), A review of calcareous nannofossil changes during the early Aptian oceanic anoxic event 1a and the Paleocene-Eocene Thermal Maximum, in Large Ecosystem Perturbations, edited by S. Monechi, R. Coccioni, and R. R. Rampino, spec. Pap. Geol. Soc. Am., 424, 87-96.
Voigt, S., A. S. Gale, and T. Voigt (2006), Sea-level change, carbon cycling and palaeoclimate during the Late Cenomanian of northwest Europe; an integrated palaeoenvironmental analysis, Cretaceous Res., 27, 836–858.
Weber, S. L. (2010), The utility of Earth system Models of Intermediate Complexity (EMICs), Wiley Interdisciplinary Reviews: Climate Change, 1, 155–303.