Impact of oceanic anoxia and high pCO_2 on the marine nitrogen cycle during the Early Cretaceous

F. M. MONTEIRO[1*], B. D. A. NAAFS[2], M. B. HIGGINS[34], R. D. PANCOST[2], A. PEARSON[3] AND A. RIDGWELL[15]

[1]School of Geographical Sciences, University of Bristol, Bristol, UK (*F.Monteiro@bristol.ac.uk)
[2]Organic Geochemistry Unit, School of Chemistry and the Cabot Institute, University of Bristol, Bristol, UK
[3]Department of Earth and Planetary Sciences, Harvard University, Cambridge, USA
[4]ExxonMobil Research & Engineering, Annandale, USA
[5]Department of Earth Sciences, University of California, Riverside, Riverside, CA, USA

Oceanic anoxic events (OAEs) reflect the most dramatic changes in ocean state of the last 250 Ma. It is generally accepted that the marine nitrogen (N)-cycle operated fundamentally different during OAEs. However, the precise response of the marine N-cycle to periods of widespread anoxia and high pCO_2 is subject to debate and poorly constrained. Using an (organic geochemical) data – model comparison here we provide detailed insights into the response of the marine N-cycle to one of the largest OAEs of the Mesozoic, Aptian OAE 1a (~120 Ma).

Our results demonstrate that given an increase in oceanic phosphorous inventory and pCO_2 associated with OAE 1a, the spread of anoxia would have led to intense denitrification and limited nitrification, causing large parts of the ocean to become nitrate depleted. Large oxygen minimum zones (OMZs) that are rich in ammonium (NH_4^+) would have developed, with upwelling of these NH_4^+-rich waters at the equator and high latitudes allowing NH_4^+-assimilation to become an important pathway to supply fixed-N to the photic zone. At the same time rates of N_2-fixation are also higher due to upwelling of waters with a low N:P ratio. The precise balance between N_2-fixation and NH_4^+-assimilation depends on the extent of oceanic anoxia, but both processes are crucial to sustain the high levels of primary productivity during OAEs. Our results highlight the impact of widespread anoxia in a high pCO_2 world on the marine N-cycle. These N-cycle changes had a profound impact on the OAE's marine ecosystems and emission of N_2O to the atmosphere (potentially reinforcing the initial weathering/phosphate feedback).