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The geobiological co-evolution of life and surface chemistry on Earth is a fundamental premise that we are only just beginning to understand. Paleo-biogeography, -biodiversity and -ecosystem evolution variably depend on the physical and chemical oceanography through time. Yet, the ocean-atmosphere chemistry is influenced by biological changes. Great progress has been made in understanding and reconstructing the spatial and temporal evolution of paleoclimate. In contrast we have limited understanding of the evolution of ocean chemistry through time. Of particular importance to marine ecosystems are ocean oxygenation and nutrient levels. Here a model of the long term mean nutrient and oxygen levels of the world ocean through the Phanerozoic is presented and accompanied by a review available proxies and implications.

The mean oxygen concentration of the world ocean, and thereby the oceans susceptibility de-oxygenation, is at any point in time dependent on multiple factors. Nutrient levels (dissolved inorganic phosphate (DIP) and/or nitrate etc.) set the marine productivity, ecosystem structure and particle flux to the ocean interior, and thereby the ocean interior oxygen demand. Seeking to understand oxygenation-anoxia in the world ocean it is therefore pertinent to ask what processes control the nutrient inventory and how much it could have changed through the Phanerozoic?

In quantification of nutrient changes through time it is of primary importance to model how sea-level change and shelf-area extent influence the DIP inventory, marine productivity and burial of organic carbon [*Bjerrum et al.*, 2006]. The model of Bjerrum et al. [2006] is update to include explicit resolution of a two layer shelf system. The biogeochemical model explicitly considers the seafloor – surface area distribution of Earth as a function of elevation and the burial efficiency now as a function of siliciclastic sedimentation rate. Based on the model results we find that sea-level rise, on time scales longer than ~100 kyr, results in a significant decreased nutrient inventory of the ocean because of the greater burial efficiency in expanded shelf areas (Figure 1). The reduced nutrient inventory results in decreased productivity which eventually causes oxygenation of the global ocean.

Additional processes can result in changes in the nutrient inventory and thereby the oceans susceptibility to be oxygenated or de-oxygenated. In particular we find that the temperature dependent decay of organic matter in the ocean is quite significant. We evaluate changes such at atmospheric O_2; ocean sulfate concentration; high latitude preformed phosphate and trace nutrient fertilization of other regions with high-nutrient, low-chlorophyll; ocean meridional circulation; and phosphate scavenging associated with sea-floor spreading.

How the DIP inventory may have changed through the Phanerozoic is modeled building on the sensitivity experiments. The phosphate model is coupled to a carbon-sulfur cycle model derived from the family of simple silicate weathering models [*Berner*, 2006; *Wallmann*, 2004]. The nutrient inventory of the world ocean and its base state oxygen concentration is thereby a function of the model derived weathering and temperature changes as well as global sedimentation rates. Even though the model derived oceanic nutrient change has a large uncertainty, a picture emerges of low mean DIP in the Mesozoic in contrast to the increasing levels during the Cenozoic (Figure 2). The modeled very oligotrophic ocean is associated with low productivity of marine organic matter and has a long term mean well oxygenated ocean interior.

References

Berner, R. A. (2006), GEOCARBSULF: A combined model for Phanerozoic atmospheric O-2 and CO2, Geochimica Et Cosmochimica Acta, 70(23), 5653-5664.

Bjerrum, C. J., J. Bendtsen, and J. J. F. Legarth (2006), Modeling organic carbon burial during sea level rise with reference to the Cretaceous, Geochemistry Geophysics Geosystems, 7(Q05008), doi:10.1029/2005GC001032.
Wallmann, K. (2004), Impact of atmospheric CO2 and galactic cosmic radiation on Phanerozoic climate change and the marine d18O record, Geochemistry Geophysics Geosystems, 5, doi:10.1029/2003GC000683.

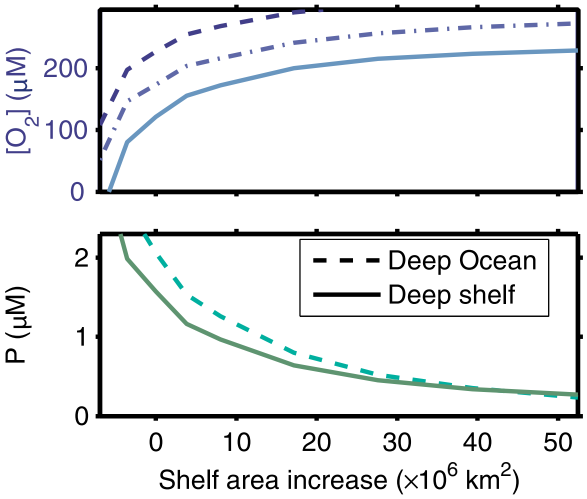

Figure 1. Model phosphate and oxygen concentrations as function of shelf area increase relative to present. The Cretaceous shelf area (~30 to 50 $\times 10^6$ km^2 larger than today) would imply the deep ocean had <0.5 μM PO4, if shelf area was the only thing that was different.

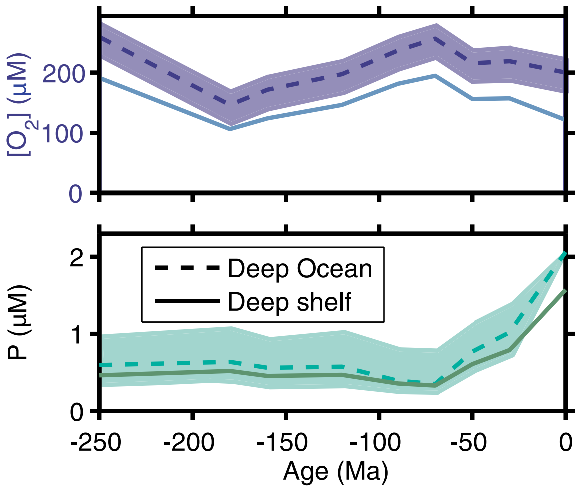

Figure 2. Model phosphate and oxygen concentrations over the last 250 Ma. Note how the long term mean Mesozoic deep ocean perhaps had a significantly reduced phosphate concentration and variably oxygen replete conditions.