Accepted Manuscript

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PII: S0012-8252(18)30329-5
DOI: doi:10.1016/j.earscirev.2018.08.002
Reference: EARTH 2677

To appear in: *Earth-Science Reviews*

Received date: 28 May 2018
Revised date: 7 August 2018
Accepted date: 7 August 2018

Please cite this article as: Florian Scholz , Identifying oxygen minimum zone-type biogeochemical cycling in Earth history using inorganic geochemical proxies. Earth (2018), doi:10.1016/j.earscirev.2018.08.002

Identifying oxygen minimum zone-type biogeochemical cycling in Earth history using inorganic geochemical proxies

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Abstract

Because of anthropogenic global warming, the world ocean is currently losing oxygen. This trend called ocean deoxygenation is particularly pronounced in low-latitude upwelling-related oxygen minimum zones (OMZs). In these areas, the temperature-related oxygen drawdown is additionally modulated by biogeochemical feedback mechanisms between sedimentary iron (Fe) and phosphorus release, water column nitrogen cycling and primary productivity. Similar feedbacks were likely active during past periods of global warming and ocean deoxygenation. However, their integrated role in amplifying or mitigating climate change-driven ocean anoxia has not been evaluated in a systematic fashion. Moreover, many studies on past (de)oxygenation events emphasize anoxic-sulfidic (i.e., euxinic) basins such as the Black Sea rather than upwelling-related OMZs as modern analogue systems.

In this review, I summarize the current state of knowledge on biogeochemical processes in the water column and sediments of OMZs. Nitrate-reducing (i.e., nitrogenous) to weakly sulfidic conditions in the water column and Fe-reducing (i.e., ferruginous) to sulfidic conditions in the surface sediment are identified as key-features of anoxic OMZs in the modern ocean. A toolbox of paleo-redox proxies is proposed that can be used to identify OMZ-type biogeochemical cycling in the geological record. By using a generalized model of sedimentary Fe release and trapping, I demonstrate that the extent of Fe mobilization and transport in modern OMZs is comparable to that inferred for the euxinic Black Sea and ferruginous water columns in Earth history. Based on this result, I suggest that many sedimentary Fe enrichments in the geological record are broadly consistent with OMZ-type redox conditions in the water column and surface sediment, especially if enhanced chemical weathering and reactive Fe supply to the ocean during past periods of global warming are taken into account. Future studies on paleo-(de)oxygenation events with a combined focus on Fe, sulfur and nitrogen cycling may reveal that OMZ-type redox conditions were an important feature of the ocean through Earth's history.