Conditions for Global Oceanic Anoxia/Euxinia Obtained from a one-dimensional Marine Biogeochemical Cycle Model

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Depositions of organic rich marine sediments called 'black shale' have occurred intermittently during the Phanerozoic. The depositional events indicating extreme anoxic bottom water conditions are called 'Ocean Anoxic Events' (OAEs). Occurrences of global oceanic anoxia/euxinia are accompanied by remarkable variation of the marine biogeochemical cycles. Previous studied have proposed several oxygen-depleted mechanisms, such as (1) ocean stagnation, (2) high primary productivity in the surface ocean, (3) low oxygen solubility due to warming, (4) low atmospheric oxygen concentration, and (5) sea-level change. There is however a possibility that widespread anoxia may have been caused by combination of these factors. We therefore need to examine the effects of these mechanisms on the ocean redox state quantitatively.

We systematically investigated the conditions for occurrence of anoxia/euxinia in the ocean with respect to ocean ventilation rate, phosphorus riverine input rate, and sea surface temperature (SST) using a vertical one-dimensional biogeochemical cycle model. In addition to the biogeochemical processes iunder the oxic ocean condition, the model includes those under the anoxic ocean condition, such as decomposition processes of particulate organic matter due to nitrate and sulfate, oxidation processes of ammonium and hydrogen sulfide in an aerobic water column. We also consider redox-dependent phosphorus burial processes in the model.

We obtained the physical conditions for ocean anoxic events quantitatively. Because of the characteristic behaviors of marine phosphorus cycle under the anoxic ocean condition, the primary production can be enhanced in spite of stagnant ocean circulation. It is revealed that the positive feedback loop between oxygen concentration, phosphorus regeneration, and primary productivity ('anoxia-productivity feedback') plays an important role in controlling the oceanic redox conditions.