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Modeling biogeochemical cycles and climate during oceanic anoxic events

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Atmosphere-ocean-system has been oxygen-rich conditions for much of the Phanerozoic Eon. However, widespread black shale depositional intervals termed oceanic anoxic events (OAEs) occurred sporadically under warm climate conditions (e.g., the mid-Cretaceous). Several lines of evidence suggest that mid-Cretaceous OAEs are linked to extensive volcanism. However there is no consensus as to the identity of underlying mechanism of OAEs, although some causal mechanisms have been suggested; such as ocean stagnation, enhanced biological productivity in the surface oceans, and an oxygen solubility decrease due to global warming. To simulate the oceanic redox state and global climate variation during OAEs quantitatively, we developed an atmosphere-ocean biogeochemical cycle model that involves geochemical cycles of carbon; several chemical reactions in an oxic-anoxic-sulfidic water column (such as denitrification, nitrification, sulfate reduction); and redox-dependent phosphorus (P) regeneration in surface sediments for paleoceanographic applications. This model includes the total dissolved inorganic carbon (DIC), d^{13}C of DIC, total alkalinity (Alk), oxygen (O_2), phosphate (PO_4), nitrate (NO_3), ammonium (NH_4), sulfate (SO_4), and hydrogen sulfide (H_2S) as dissolved chemical components of seawater, and can calculate the variation of atmospheric partial pressure of carbon dioxide. To explore the conditions for occurrence of OAE, we examined the effect of the massive CO_2 release event on biogeochemical cycles. The systematic sensitivity experiments of oceanic redox states indicate that (1) enhanced P input rate is an important mechanism for widespread anoxia via expansion of oxygen minimum zone and coastal deoxygenation, resulting in massive P efflux from surface sediments, (2) oceanic anoxia is easily achieved in case of low ocean circulation rate, but those are not enough to achieve global anoxia/euxinia by itself, and (3) high sea-level conditions act as a buffer against oceanic eutrophication (and OAEs) supporting the results of Bjerrum et al (2006). We will also present the discussions of required CO_2 input rate for global OAEs.

Keywords: oceanic anoxic events, biogeochemical cycles, phosphorus cycle, anoxia/euxinia