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Quantification of the spatial enhancement of ocean anoxia during Mesozoic OAEs using Mo and U isotope signatures

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Throughout the Phanerozoic, the oceans have been considered to be oxygenated. Nevertheless, episodes of depleted oxygen conditions in the oceans have been recorded. These episodes, known as oceanic anoxic events (OAEs) [1], are characterized by the widespread deposition of organic-rich sediments, e.g., black shales, of regional or even global extent. The Mesozoic greenhouse world becomes particularly important, having witnessed several of these OAEs. We focused on two Mesozoic OAEs, the mid-Cretaceous OAE2 and the early Jurassic Toarcian OAE (T-OAE); both with a possibly global extension [2-3]. Here, combining Mo- and U-isotope signatures with redox sensitive trace metal concentrations in modern and ancient organic-rich sediments, we present an approach to determining the expansion of oceanic anoxia during the OAE2 and the T-OAE, compared to modern oxygenated conditions. We observed a systematic shift of $\approx$0.6‰ and 0.2‰ towards lighter Mo and U isotope compositions respectively, between modern (Black Sea) and OAE black shales. Black shales deposited before and after OAE2 display a similar U isotope composition as modern Black shales. However, the Mo-isotope compositions of black shales from above and below the OAE2 interval are even lighter than those from the OAE2 black shales. The Mo isotope composition of these samples is likely affected by changes in the local redox conditions from euxinic to anoxic/non-euxinic [4] resulting in Mo isotope fractionation towards lighter compositions. We modeled the increase of Mo and U removal to anoxic and/or euxinic sinks during both OAEs by combining the observed isotopic offsets with previous results [5-6] and applying mass balance constraints. According to our model, we obtained an enhancement in seafloor anoxia of up to about 60% during the OAEs, compared to 10% at present day. Such an increase translates to $\sim$1-2.5% anoxic and/or euxinic environments during both OAEs and may represent a global increase of reducing environments in the oceans if assuming unrestricted connection of the sample localities to the world ocean. According to our U isotope results, seafloor anoxia during the T-OAE may have been even more enhanced than during OAE2, oppositely in direction to what is indicated by Mo isotope signatures. However, as indicated by a positive trend of U isotopes and U/Al, T-OAE samples may be affected by mixing with a detrital component, which may affect U- slightly more than Mo isotope signatures.

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