

Regional paleoenvironmental features modulated T-OAE global effects (Toarcian, Early Jurassic): aqueous molybdenum drawdown

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Anoxic conditions, recorded as black shale deposits, were widely developed on the seafloor during the Toarcian (Early Jurassic). This event, known as the Toarcian Oceanic Anoxic Event (T-OAE), was characterized by massive release of volcanogenic CO₂ from the Karoo-Ferrar large igneous provinces, global warming, sea-level rise, and a second-order mass extinction among marine invertebrates. This event also resulted in perturbations to geochemical cycles, being marked by a negative excursion in isotopic carbon, and marked changes in trace metals. In particular, molybdenum (Mo), which is taken up by organic fraction of sediment in quantity only under euxinic conditions (*i.e.*, anoxic, free H₂S), should show elevated total organic carbon (TOC)-normalized concentrations in anoxic facies. However, Mo/TOC ratios declined significantly in T-OAE sediments despite the existence of widespread anoxia. Two hypotheses have been proposed to explain this phenomenon: the “global model”, which proposes a generalized Mo drawdown in the Toarcian ocean; and the “local model”, which argues for hydrographic restriction (interruption of water exchange with the open ocean) and, thus, Mo drawdown in local basins. Within this context, our study compares Mo, TOC, and sedimentological data from twenty sections representing Toarcian oceanic basins globally. A case-by-case analysis of the studied settings clarifies Mo behavior during the T-OAE, revealing that low Mo in some SW Tethyan and Panthalassic sections is due to a well-oxygenated setting (pelagic/hemipelagic and ramp carbonates) inhibiting Mo fixation. On the contrary, several shallow basins in the NW and E Tethys regions (epicontinental intrashelves troughs and barrier/lagoon settings) exhibit high Mo and TOC combined with low Mo/TOC, reflecting accumulation in a euxinic and hydrographically restricted setting. Notably, open-marine Panthalassic settings can exhibit high Mo and TOC contents accumulated under unrestricted and intermittent euxinic bottomwaters. Compared to modern (*e.g.*, Black Sea) and Mesozoic (Cenomanian-Turonian Anoxic Event; OAE2) analogs, the T-OAE black shales exhibit markedly lower Mo/TOC, indicating global aqueous Mo starvation during the

early Toarcian. Therefore, locally high rates of Mo accumulation in shallow-restricted settings, and in deep, open-marine paleoenvironments, played a major role modulating the global expression of the T-OAE, characterized by widespread Mo_{aq} drawdown during the Toarcian.