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Carbonate barium isotopes uncover the spatio-temporal evolution of primary productivity in the Tethys Ocean during the Toarcian Oceanic Anoxic Event

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The early Toarcian Oceanic Anoxic Event (T-OAE) or Jenkyns Event was a major hyperthermal episode of the Phanerozoic Aeon, characterized by a marked negative carbon-isotope ($\delta^{13}C$) excursion (N-CIE) in biospheric carbon reservoirs that typically intersects an overarching positive trend. This warming event was accompanied by oceanic deoxygenation and widespread deposition of organic-carbon (OC) rich deposits. However, how marine primary productivity varied spatio-temporally in response to climatic warming, and interacted with OC burial and oceanic deoxygenation, remains poorly constrained. Here, we reconstruct primary productivity in the Tethys Ocean during the T-OAE N-CIE interval using barium isotopes of marine bulk carbonates ($\delta^{138}Ba_{carb}$) from China (Nianduo, a shallow-water carbonate-platform environment) and Italy (Dogna, a basinal pelagic environment). Despite widely differing paleo-depths, both sites are characterized by positive shifts in $\delta^{138}Ba_{carb}$ at the N-CIE onset. This excursion suggests a coeval supra-regional increase in biogenic barite formation associated with increased export production in the Tethys Ocean, and thus an overarching pattern of productivity-driven OC enrichment. At Nianduo, export production continuously increased due to increased weathering-driven terrestrial nutrient inputs and culminated at the end of the N-CIE onset interval, as indicated by maximum $\delta^{138}Ba_{carb}$. At Dogna, a negative shift in $\delta^{138}Ba_{carb}$ follows the initial positive shift, interpreted as a result of efficient anoxia-driven barite dissolution. A subsequent positive shift in $\delta^{138}Ba_{carb}$ to the middle of the N-CIE recovery phase at Dogna suggests a protracted increase in export production in the pelagic surface ocean relative to the shallow-water Nianduo section. Based on redox and nutrient data, we propose that formation of bottom-water anoxia/euxinia at Dogna could have effectively enhanced the recycling of sedimentary phosphorus that, combined with deeper water upwelling and potential aeolian fertilization linked to volcanogenic emissions, substantially fueled pelagic productivity over a protracted period, contributing to OC burial. Our study highlights that pelagic environments that have been previously understudied might have been an additional and important carbon sink, which could have played a significant role in regulating the T-OAE carbon-cycle perturbations and oceanic deoxygenation.