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# Osmium isotope perturbations during the Pliensbachian–Toarcian (Early Jurassic): Relationships between volcanism, weathering, and climate change

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The Mesozoic Era marked a time of greenhouse conditions on Earth, punctuated by a number of abrupt perturbations to the carbon cycle, such as Ocean Anoxic Events (OAEs). OAEs are typically marked in the stratigraphic record by the appearance of organic-rich shales, and excursions in carbon-isotope ratios registered in carbonates and organic matter. A range of geochemical evidence indicates changes to global temperatures, typically featuring abrupt warming possibly caused by $CO_2$ emissions resulting from Large Igneous Province (LIP) volcanism. A warmer atmosphere is thought to have led to changes in the global hydrological cycle, which would likely have enhanced global weathering rates. The Toarcian OAE (T-OAE) is inferred, from osmium isotope ratios in organic-rich mudrocks from Yorkshire and western North America, to have been a time of such increased weathering rates. However, it is likely that the sediments at these locations were deposited in relatively hydrographically restricted environments, potentially more susceptible to the influence of local input; consequently, they may not offer the best representation of the global seawater Os-isotope composition at that time.

In this study, we have measured the osmium isotope composition of siciliclastic mudrocks in a core from the Mochras borehole (Llanbedr Farm, Cardigan Bay Basin, Wales), which constitutes a sedimentary record for a fully open-marine seaway that connected Tethys to the Boreal ocean during the Toarcian. We analysed samples from strata including both the T-OAE and preceding Pliensbachian–Toarcian boundary (Pl–To), both of which record multiple geochemical excursions and records of elevated extinction amongst benthic fauna. We find that the latest Pliensbachian records seawater 187Os/188Os of ~0.35–0.4, rising to ~0.5 at the Pl–To boundary, before a further rise to ~0.7 during the T-OAE. We conclude that such increases in radiogenic Os flux to the ocean system resulted from enhanced continental weathering, and note that both excursions coincide with negative excursions in $\delta$13C (indicating a massive release of isotopically light carbon to the atmosphere) and positive excursions in Hg/TOC (indicating enhanced volcanic activity associated with the Karoo–Ferrar LIP). These concurrent changes suggest that carbon–emissions related to the Karoo–Ferrar may have aided climate warming, leading to the enhanced weathering and marine anoxia recorded in Toarcian strata. Additionally, we record a potential lag in the recovery of 187Os/188Os compared to $\delta$13C; such a lag would support previous hypotheses that enhanced weathering contributed towards draw-down of excess atmospheric carbon, alleviating the Toarcian warming. Finally, our recording of a second (stratigraphically lower) excursion in Os isotopes, coincident with previously recorded excursions, indicates that major climate change during the Toarcian in fact began, albeit to a lesser degree, at the Pl–To boundary, rather than being restricted solely to the T-OAE.