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The Toarcian Sulfur Cycle: Recent Progress

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The early Toarcian oceanic anoxic event (TOAE) is marked by evidence for perturbations in global element cycles and a second order mass extinction [1] driven by warming linked to the eruption of the Karoo-Ferrar large igneous province. Many carbon isotope records exist for this time period, but the closely linked sulfur cycle is far less well constrained.

Early work presented carbonate associated sulfate-$\delta^{34}S$ records from several locations in the European Epicontinental Sea and a single record from Tibet. These all show a positive excursion across the TOAE, but the Tibetan record is of a much greater magnitude [2,3]. New work on additional Tibetan sections suggests that this difference represents genuine heterogeneity in the isotopic composition of seawater sulfate during the TOAE [4] and raises questions about how this can be sustained. A feature of all records is a rapid change to more positive isotope compositions during the event, indicating an increase in pyrite burial in an ocean with much lower sulfate than modern. Whilst the isotopic heterogeneity represented by these records complicates the use of the 'rate method' for calculating seawater sulfate concentrations, modelling of the ubiquitous feature of sustained positive values for around 6 million years after the event, suggests that sulfate and/or calcium was maintained at low enough concentrations to halt gypsum deposition for much of this time.

New records of pyrite-$\delta^{34}S$ from shallow and deep settings in Japan [5] and a shelf location in the UK indicate an increase in the pyrite-$\delta^{34}S$ of the burial flux during the event, driven by increased sedimentation rates in shallow settings, and an increased flux of organic matter in the deep ocean. These suggest that, whilst the global average isotopic enrichment between buried pyrite and ocean sulfate may have become smaller, it didn't drop below 40‰ providing further constraints on sulfate concentration.

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