An emerging link between low sulfate oceans and large igneous province driven mass extinction?

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Sulfate plays a key role in Earth's carbon cycle where it acts as the most important oxidant for organic carbon after oxygen. Mass extinction intervals are commonly linked to carbon cycle instability by rapid carbon isotope fluctuations. Part of this volatility could be linked to lower oceanic sulfate concentrations and the resulting changes in carbon cycle operation.

The rate of change of seawater-sulfate isotopic composition gives an indication of sulfate concentration. Carbonate-associated sulfate (CAS) across the Permo-Triassic and early Toarcian mass extinction intervals displays rapid rates of isotopic change (5-14‰ Ma^{-1} and 60-350‰ Ma^{-1} respectively) consistent with low marine sulfate concentrations [1,2]. New bivalve shell CAS records from a high latitude Cretaceous-Palaeogene section also record similar high rates of variability (2-16‰ Ma^{-1}) establishing a tentative link between low sulfate, mass extinction and large igneous province eruption.

Estimates of sulfate concentration from CAS isotopic change sit uneasily with records of sulfate concentration derived from halite fluid inclusions, particularly for the late Permian, but also for the other intervals. If the CAS data represent a good estimate of sulfate concentration, they establish low sulfate as a potential contributing factor for volcanic climate change driven mass extinction. In this case the discrepancy with fluid inclusion data constrain the magnitude of sulfate drawdown of intervening evaporite deposition episodes. Alternatively, there may be a systematic difference in the way each proxy derives sulfate concentrations.

[1] Bottrell, & Newton, *Earth-Sci. Rev.*, 2006. **75**: p. 59-83. [2] Newton, *et al Geology*, 2011. **39**: p. 7-10.