Ferruginous conditions and the collapse of the early Cretaceous seawater sulphate reservoir

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Oceanic anoxic events (OAEs) are intervals of widespread global ocean anoxia and are linked to dynamics in the global carbon cycle, climatic anonmalies and biological crises. OAEs thus represent some of the most dramatic perturbations to the Earth system over the last 200 million years. Little is known, however, of the precise chemical composition of seawater during these events and this confounds models that aim to mechanistically connect ocean anoxia to the corresponding ecological and climactic effects. Here we show using Fe-speciation analyses that during OAE1a, some 120 Ma ago, the oceans were anoxic and Fe-rich (ferruginous) for more than 1 million years. While reminiscent of the ferruginous oceans of the Precambrian eons, ferruginous conditions are rare in the Phanerozoic eon due to generally high sulphate concentrations in seawater. Using geochemical models tightly tethered to the geologic record and calibrated based on modern marine ecosystems and low sulphate ferruginous analogues, we show that development of ferruginous conditions during OAE1a requires seawater sulphate concentrations less than 5 μM—three orders of magnitude lower than previous estimates of early Cretaceous seawater suphate concentration. Such low seawater sulphate concentrations imply a reorganization of Earth surface redox budgets at a previously unrecognized scale.