A dynamic biological pump controlled the global redox landscape during the end-Permian extinction

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Numerous hypotheses link the evolution of the biological pump to major transitions in marine redox chemistry and ecosystem structure. Predictive models of the biological pump have generally been presented in a too simplified, static fashion and thus seriously limit the ability to simulate the true functioning of the pump under dynamic environmental conditions. To address these limitations, we developed a numerical model for the biological pump that dynamically responds to environmental conditions by incorporating organic matter sulfurization, temperature-dependent remineralization and organic carbon burial feedbacks. We present model simulations for the Permian/Triassic transition, an interval where ocean redox changes, mass extinction and changes in the biological pump intersect due to a major global warming event induced by the emplacement of the Siberian Traps large igneous province. Simulated marine redox variations are able to reproduce spatially explicit observations from the geological record and the extent of seafloor anoxia inferred from uranium isotopes. The dynamic model predicts a shallow, temperature-sensitive chemocline separating a thin layer of oxygenated surface waters from sulfidic waters below. Further upward excursion of the chemocline due to rapid climate warming could have severely stressed the marine ecosystem by significantly restricting the habitable area. We therefore provide the first mechanistic explanation for the hypothesis that shoaling of sulfidic waters may not only have been an important killing mechanism during the mass extinction but may have been critical for the delayed Early Triassic biotic recovery.