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Mass extinctions, recovery and resilience

Redox-dependent phosphorus cycling sets-off a cascading biogeochemical crisis during the end-Permian

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Multiple indices link the devastating end-Permian mass extinction to the global-scale spread of marine anoxic regions. Recent studies have postulated that the continental influx of nutrients might have played a critical role in eutrophication-induced oxygen depletion and hydrogen-sulfide build-up in the water column. However, advances in geochronological dating schemes and lithium isotope records suggest that the proximal causes, such as volcanic activity and continental weathering pre-date the main extinction pulse. In order to resolve these temporally misaligned signals of environmental deterioration and biotic response, we assess current understanding of local- to global-scale redox changes in marine conditions in conjunction with the fossil record. A primary observation is that a precise reconstruction of ocean redox conditions (i.e. the differentiation between euxinic, ferruginous or oxic conditions) is still largely lacking, which is essential to evaluate the role of redox-dependent sedimentary P retention. By constructing sedimentary P records within the context of local redox conditions across a bathymetric transect, we show that phosphorus might bridge the gap between disparate sedimentological, geochemical and palaeontological observations. This combined approach suggests that phosphorus could have acted as a primer, which pre-conditioned the inner-shelf to an unstable oxygen-restricted state. Only moderate changes in the external forcing were needed to induce an amplification, where phosphorus was extensively recycled under euxinic conditions, increasing productivity and tipping large stretches of the shelf into a reduced state. This killing mechanism also explains why benthic taxa with a high tolerance to low oxygen conditions and a planktotrophic larval stage dominated post-extinction marine communities.