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Intensified bioavailable phosphorus flux induced by the terrestrial ecosystem collapse during the end-Permian mass extinction

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The Permian-Triassic Mass Extinction (PTME), the most severe biodiversity loss in the ocean during Phanerozoic time, has been linked to rapid expansion of oceanic anoxia. Phosphorus (P), as one of the most important nutrients, plays an important role in regulating the ocean's primary productivity and redox state, and the continental input is the predominant external source of bioavailable phosphorus (equivalent to reactive phosphorus, P_{reac}) for the ocean. Thus, multiple proposed mechanisms for the PTME inevitably involve a dramatic increase in terrestrial phosphorus input. However, the direct evidence of continental P_{reac} fluxes is still lacking, which hampers our understanding of the mechanism of oceanic anoxia expansion.

In this study, we report the phosphorus content and chemical speciation, as well as Mg isotopes of sedimentary samples from South China, which were deposited on the paleo-tropics continent during the PETM. The phosphorus speciation was measured using a modified chemical extraction method (SEDEX) and synchrotron X-ray near-edge absorption structure spectroscopy (XANES). Our results suggest that large amounts of P_{reac} were delivered to the ocean near the first pulse of marine extinction, coinciding with the collapse of terrestrial ecosystems at the end-Permian. The Mg isotopic variations indicate that the chemical weathering was intensified prior to the PTME but slightly enhanced during the event, probably with little effects on the phosphorus cycle at low latitude. We propose that enhanced soil erosion due to the ecosystem collapse may contribute to the increased delivery of P_{reac} into the ocean. Further theoretical simulations confirm that the dramatic increase in the delivery of P_{reac} from land could induce life-sustaining anoxic events. We thus conclude that terrestrial ecosystem disturbances may have caused catastrophic pressure on marine ecosystems and further amplified the severity of marine extinctions during the end-Permian.