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Volcanically modulated micronutrient cycles in the mid–Proterozoic ocean

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Volcanic forcing of nutrient influxes into the ocean has been proposed as a driver in punctuating a pervasively sluggish oceanic productivity during the mid–Proterozoic, but direct evidence linking these events remains rare. Here we investigated high-resolution zinc isotopic systematics in the well-studied Xiamaling Formation from North China Craton (NCC), where synchrony of mid-Proterozoic volcanism and deposition of organic-rich sediments has been documented. Coeval negative δ^{66}Zn excursions and enrichments in sedimentary zinc concentrations are observed during periods of either NCC volcanism or large igneous provinces, followed by positive δ^{66}Zn excursions and concomitant high and/or muted zinc enrichments. The decrease of δ^{66}Zn toward continental range can be most likely explained by volcanism-induced intensification of continental weathering, which delivered greater terrestrial-derived Zn fluxes to the ocean. Following the culmination of volcanism, gradual increase in δ^{66}Zn indicates a mechanistic linkage between oceanic nutrification and an elevation in marine primary productivity, stimulating the drawdown of organic-derived zinc from the seawater inventory due to enhanced organic carbon burial. These feedback loops help reconcile the major mafic magmatic events (1800−800 Ma) and concurrent widespread deposition of black shales in the Nuna supercontinent, wherein volcanism-dependent micronutrient feedback may pace the evolution of Earth's surficial system over billion-year timescales.