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Nitrogen limitation controlled marine primary productivity across the Ordovician–Silurian Transition: evidence from nitrogen isotopes

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The Ordovician–Silurian transition (OST) represents a profound reorganization of marine ecosystems during one of the Phanerozoic's largest mass extinctions. Although redox fluctuations and climatic perturbations have been intensively studied, the behavior of marine primary producers and their nutrient constraints remain insufficiently resolved. Here we investigate how nitrogen cycling regulated primary productivity across the OST by coupling new bulk nitrogen isotope ($\delta^{15}N_{bulk}$) data from the L203 drill core (South China) with a compilation of globally 17 distributed sections and independently calculated productivity estimates.

Most $\delta^{15}N_{bulk}$ values worldwide cluster between −2‰ and +1‰, markedly lower than modern marine averages (+5‰), indicating pervasive nitrogen deficiency and dominance of biological N_2 fixation in oligotrophic oceans. Under such nitrogen-limited conditions, reconstructed primary productivity shows a consistent inverse relationship with $\delta^{15}N_{bulk}$. Decreasing $\delta^{15}N_{bulk}$ values correspond to intensified nitrogen fixation and expansion of diazotrophic communities, supporting enhanced primary productivity. Conversely, elevated $\delta^{15}N_{bulk}$ reflects either diminished nitrogen fixation or strengthened denitrification associated with expanded anoxia, conditions that restricted planktonic growth. These patterns demonstrate that nitrogen isotopes record shifts in nutrient supply and can quantitatively track productivity changes in N-fixation–dominated systems. Moreover, using the $\delta^{15}N_{bulk}$ data as a proxy of primary productivity, this study reveals the differential mechanisms of organic matter accumulation in the Wufeng and Lungmachi formations, with the former primarily driven by high productivity, and the latter by enhanced preservation under anoxic conditions.

This study establishes a mechanistic linkage between nitrogen cycling, primary productivity, and black shale formation, highlighting nutrient regulation as a key driver of ecological and biogeochemical restructuring during the OST.