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Iron Isotopic Tracing of Iron Cycling and Its Controls in Yangtze Estuary Sediments

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Iron (Fe) is an essential trace element that limits marine primary productivity and regulates oceanic carbon cycling. Recent studies identify marginal sea sediments as a significant Fe source to the ocean via early diagenetic remobilization [1,2]. However, the complex interplay of redox conditions, sedimentary dynamics, and mineral–water interactions in river-dominated estuaries makes it challenging to disentangle the relative controls on Fe mobilization and preservation. The Yangtze Estuary, characterized by intense bioturbation, seasonal hypoxia, and dynamic redox fluctuations, provides an ideal natural laboratory to address this knowledge gap. Here, we combine Fe isotope geochemistry with sequential extraction and porewater analysis to investigate how these processes govern Fe cycling and isotopic signatures in such active marginal settings.

Systematic sampling of sediments and porewaters across the estuary and adjacent shelf was conducted. Elemental concentrations, Fe fractions, and Fe isotopes collectively reveal that reductive dissolution drives benthic Fe release. These fluxes correlate negatively with bottom-water oxygen, indicating that hypoxia enhances Fe mobilization. Coupled sedimentary Fe–K–Si relationships, increasing non-reactive Fe fractions with depth, and parallel dissolved Fe–Si profiles—all implicate clay minerals in Fe retention and transport.

Spatially, sedimentary Fe content and δ^{56}Fe increase offshore alongside reactive Fe fractions, suggesting that reductive dissolution - reoxidation and clay adsorption jointly control Fe mobilization and preservation, with diminishing adsorption offshore. The relationship between Fe flux and isotope composition shows greater porewater δ^{56}Fe variability under low-flux conditions, reflecting multiple transformation pathways; under high-flux conditions, reductive dissolution emerges as the dominant process.

This study demonstrates that estuarine Fe cycling integrates redox conditions, sedimentary dynamics, and mineral–water interactions, providing isotopic constraints on Fe sources, sinks, and ecological effects in marginal seas.

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