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Experimental evidence of YREE enrichment through FeOOH breakdown and redox interactions in simulated phosphorite deposits.

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One model for YREE fractionation and enrichment in phosphorite deposits posits that these processes are influenced by iron oxyhydroxide breakdown and redox-driven interactions. To explore these mechanisms, we conducted batch experiments at 80°C and pH 4.5 using four systems: Type (1) goethite-only, Type (2) hydroxyapatite-only, Type (3) a 50:50 goethite-hydroxyapatite mixture, and Type (4) a pyrite-hydroxyapatite-goethite mixture (~25% goethite, 10 g pyrite). Results indicated distinct mineralogical and redox controls on YREE behavior. Goethite retained LREEs (La–Nd), while hydroxyapatite showed strong MREE (Sm–Dy) affinity, likely through phosphate interactions. The mixed system balanced LREE retention from goethite with MREE and HREE incorporation from hydroxyapatite. The pyrite-containing system exhibited the highest MREE enrichment (Gd/Gd* ~2.35), with Yb/Nd ~1.94, La/Yb ~1.21, La/Sm ~0.87, Gd/Yb ~1.75, Ce/Ce* ~1.63, Eu/Eu* ~0.92, and MREE/MREE* ~1.58, reflecting strong Y retention under reducing conditions (Y/Ho ~1.78).

Redox-sensitive anomalies highlighted these trends: Ce oxidation and Eu reduction indicated oxidative scavenging and reductive retention, with Y enrichment most pronounced in the pyrite system. This supports the hypothesis that redox-active conditions promote YREE complexation and fractionation. Pyrite-driven redox reactions influenced MREE sorption and modulated LREE and HREE mobility. Additionally, our data shows that YREE retention is influenced not only by redox conditions but also by mineral surface properties and structural incorporation into phosphate lattices, consistent with competitive sorption mechanisms.

These findings align with previous studies on Y fractionation under low-oxygen conditions through Fe oxyhydroxide sorption and phosphate competition, including substitution mechanisms in apatite. Our results underscore the significance of mineralogical composition variability, redox dynamics, and co-competition in YREE cycling within phosphorite deposits. This study provides detailed insights into early diagenetic enrichment processes, the role of redox in YREE mobility, and practical applications for improving resource exploration strategies. By highlighting YREE retention mechanisms, we aim to enhance geochemical modeling accuracy for predicting YREE behavior in sedimentary systems and provide a framework for future studies on diagenetic YREE enrichment.