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A reactive transport model that simulates how rainwater infiltration and chemical weathering impact the evolution of rare earth element fractionation patterns in the critical zone

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Interest in the rare earth elements (REE) is rising because of their importance in manufacturing micro-electronics, hybrid and fully electric automobiles, medical imaging, permanent magnets, and in wind power generation, among other uses. Because of their ubiquity in the emerging “green economy”, the REEs are likely to become significant environmental contaminants in the future. Of the REEs, the heavy REEs (HREE, i.e., Tb, Dy, Ho, Er, Tm, Yb, Lu) are cosmically less abundant, and hence, commonly of higher economic value than the light REEs (LREE, La, Ce, Pr, Nd, Sm, Eu, Gd). A primary source of the HREEs are ion-adsorption deposits, which are chiefly located in southeast China. These deposits appear to form by low-temperature chemical weathering reactions between meteoric waters and minerals within metaluminous to peraluminous granitoids. The precise biogeochemical processes that form these important deposits have not been completely identified, and the specific geochemical reactions that mobilize, sequester, and fractionate the REEs have not been quantitatively demonstrated. Here, we present a reactive transport model that couples the 1-D advective-dispersive flow equation to an aqueous and surface complexation model for the REEs. Generalized kinetic rate laws for mineral dissolution and precipitation are also included in the model. We investigate the evolution of REE fractionation patterns in groundwaters from a well-studied aquifer using the reactive transport model to gain insights into these processes. The model shows how reactive transport of the REEs affects their fractionation patterns along flow paths, as the composition of groundwater evolves with geochemical reactions in aquifers.