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δ^{142}Ce minus δ^{146}Nd value as a redox indicator in Earth's surface environments

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Stable Ce isotope ratios are considered potential indicators for tracing the redox state of Earth's surface; however, their quantitative relationship remains undefined. Here, we investigated the influences of both redox and non-redox processes on stable Ce isotope fractionation in a terrestrial environment by analyzing the weathering products, selective soil chemical extracts, and parent materials of a typical basaltic profile formed in Hainan Island, South China. During redox processes, the preferential enrichment of the heavier ^{142}Ce in the tetravalent Ce and/or the inheritance of the heavier isotope signature from the soluble led to the crystalline Fe-Mn (hydro)oxide phases having the highest $\delta^{142/140}$Ce values (up to +0.184 ± 0.040‰). This phenomenon is likely governed by the oxidative adsorption of Mn oxides, while Fe-oxides appear to be less important. In addition, distinct Mn concentrations are important in the $\tau_{Th,Ce}$ and $\delta^{142/140}$Ce values but did not correlate with Ce anomalies, indicating that the Mn (hydro)oxides $\delta^{142/140}$Ce values may be more reliable than Ce/Ce* in quantitatively tracing redox conditions. Regarding non-redox processes, we discussed the impact mechanisms, including external input, pH, organic matter complexation, adsorption/co-precipitation of the poorly crystalline Fe-Mn oxide, and the formation of clay minerals on stable Ce isotopic fractionation. Results indicated that Fe-Mn-Al oxides preferentially enriched the heavier ^{142}Ce, while the formation of kaolinite preferentially incorporated the lighter ^{140}Ce. However, the impact of external input, pH, organic matter complexation, and clay mineral adsorption on stable Ce isotopes appeared to be limited. Furthermore, $\delta^{142/140}$Ce values displayed a positive correlation with $\delta^{146/144}$Nd in both the 0.5 mol L^{-1} HCl leachates and residual phases, suggesting that stable Ce and Nd isotopes behave similarly during non-redox processes. To isolate the signal of stable Ce isotopes in response to redox conditions, we proposed that $\delta^{142/140}$Ce minus $\delta^{146/144}$Nd could serve as a quantitative proxy for tracing redox fluctuations in terrestrial environments.