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Stable cerium (Ce) isotopes in hydrogenetic Fe–Mn crusts track Pacific oxygen-deficient zone dynamics over the past ~80 Myr

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Dissolved oxygen in the ocean is declining today, but the long-term history of marine redox structure, especially the spatial dynamics of suboxic oxygen-deficient zones (ODZs), remains poorly constrained. Here, we evaluate stable Ce isotopes ($^{142}Ce/^{140}Ce$, expressed as $\delta^{142}Ce$) as a novel redox-sensitive tracer of ODZ variability by generating the first $\delta^{142}Ce$ records from two hydrogenetic ferromanganese crusts, including CJ01 from the central North Pacific and MDD53 from the western North Pacific, spanning the past ~80 Myr. To separate redox-driven $\delta^{142}Ce$ variability from non-redox influences, we compare our data with paired stable Nd isotopes ($^{146}Nd/^{144}Nd$, expressed as $\delta^{146}Nd$) measured in the same samples, together with published radiogenic Nd and Pb isotope records that constrain water-mass sources and material provenance.

Both crusts record resolvable $\delta^{142}Ce$ variability (CJ01: -0.021 to 0.175‰; MDD53: -0.001 to 0.156‰). The CJ01 record shows a gradual increase from ~0‰ at ~80 Ma to ~0.15‰ by ~45 Ma, followed by relatively stable values thereafter. In contrast, MDD53 exhibits a ~0.1‰ decrease from ~80 Ma to ~50 Ma, followed by a subsequent increase to values similar to those recorded by CJ01. These isotopic variations cannot be attributed to changes in detrital contents, phosphatization, mineralogical shifts, or growth-rate effects. Instead, they are best interpreted to reflect secular changes in seawater $\delta^{142}Ce$. The long-term increase in $\delta^{142}Ce$ observed in both crusts reflect progressive contraction of Pacific ODZs since ~80 Ma, whereas the contrasting early trajectories between CJ01 and MDD53 capture the spatial heterogeneity in ODZ extent, providing new insights into the dynamics of ODZ contraction in the Pacific through time. Our results establish $\delta^{142}Ce$ in hydrogenetic Fe–Mn crusts as a sensitive, regionally responsive archive of suboxic variability over Cenozoic timescales.