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Reactive-transport modeling of the early diagenesis of Neodymium and its radiogenic isotope in deep-sea sediments: the roles of authigenesis, silicate weathering and reverse weathering

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The Rare Earth Element (REE) neodymium (Nd) has wide geochemical applications in studying Earth surface processes. Its radiogenic isotope composition (ε_{Nd}) has been used to trace continental and marine weathering, as well as modern and past ocean circulation. However, the modern oceanic budget of Nd is unbalanced if only riverine and dust inputs are considered. The sediment-porewater system is now implicated as perhaps the dominant source of Nd to the ocean, and the discovery of large benthic Nd fluxes from deep-sea sediments is not consistent with the traditional view that deep-sea sediments act only as sinks of trace metals. Studies of sedimentary Nd sources have hypothesized processes regulating the diagenetic cycle of Nd, but no quantitative tests has been made.

Here we present the first reactive-transport model of Nd and ε_{Nd} in marine sediments. Using this model, we study the early diagenetic Nd cycle at a deep site on the Oregon margin at ~3000 m water depth. This site has the highest benthic flux yet measured (~30 pmol/cm^2/yr), and pore water ε_{Nd} is more radiogenic than bottom water. We quantify the roles of authigenesis, silicate weathering and reverse weathering on the diagenetic Nd cycle. We show that the pore water Nd profile can be explained mostly by Fe/Mn oxide reduction and authigenic phosphate formation. The modelled benthic Nd flux agrees well with observations. We also find that although silicate weathering has relatively minor impact on the pore water Nd concentrations and benthic flux, it is necessary to explain the radiogenic pore water ε_{Nd} profile. Among the silicate minerals present in sediments in the study region, we find that weathering of volcanic minerals such as basalt glass and clinopyroxene can explain the pore water ε_{Nd} data, while weathering of plagioclase and chlorite cannot. This reflects a difference in mineral reactivity in terms of mineral abundance, dissolution rate and saturation state. We further show that reverse weathering influences the Nd cycle *indirectly* because authigenic clay formation drives silicate weathering. Our model is thus the first step towards a quantitative resolution of the Nd budget imbalance and interpretation of paleo-authigenic ε_{Nd} records.