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Does the Neodymium Oceanic Residence Time Paradox Really Exist?

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The rare earth elements (REE) and neodymium (Nd) isotopes have been widely used as tracers and chronometers in many fields, and much excellent research has been done in this area. However, for decades, a major apparent enigma in geochemistry and oceanography has been the "Nd paradox", in which Nd isotopic heterogeneity between ocean basins indicates a short oceanic residence time, less than the oceanic mixing time (~1200y), whereas residence times based on dissolved Nd river fluxes are much longer, ~7000y, (e.g. [1]). As a result, research has focused on additional REE fluxes to the oceans, and other ocean boundary sources, including groundwater, aeolian, and sedimentary have been found.

However, other explanations haven't been explored thoroughly. First, based on the few systematic studies of REE and iron in oceanic colloids, it's possible that a significant amount of REE in seawater isn’t truly dissolved, and that the typical REE seawater concentration, measured after filtration through a ~200 or 400 nm filter followed by acidification, is an upper limit on the truly dissolved component. Second, any exchange of REE between particles and seawater could easily add to the flux. Recent laboratory mixing experiments (e.g. [2]) have shown a small but significant release of REE (~0.004%) from Mississippi River sediment to Gulf of America seawater, which could certainly happen within the seawater column as well as shelf sediments. Using that value along with a typical Nd concentration for seawater and estimates of the river water suspended flux to the oceans (e.g. [1]), the Nd oceanic residence time is <~100y.

Consequently, the traditional oceanic residence time concept may not be helpful for the REE, where the truly dissolved component is very small, heterogeneous, and likely modified by the presence of and/or exchange with small seawater particles. In summary, there are undoubtedly many enigmas related to the oceanic REE geochemical cycle, but the Nd oceanic residence time paradox probably isn't one of them.

References:

[1] Goldstein, S.J. and Jacobsen, S.B.,1988. https://doi.org/10.1016/0012-821X(88)90031-3

[2] Adebayo, S.B. et al., 2022. https://doi.org/10.1016/j.gca.2022.08.024