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The nickel output to abyssal pelagic manganese oxides: a balanced elemental and isotope budget for the oceans

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The development of nickel (Ni) isotopes as a chemical tracer of past ocean environments requires a sound understanding of the modern oceanic budget. Our current understanding of this budget implies a large elemental and isotope imbalance between inputs to and outputs from the dissolved pool of the ocean [e.g. 1]. This imbalance is mainly caused by the dominant oxic sink of Ni to manganese (Mn) oxide-rich sediments. Though the Ni isotope composition of Fe-Mn crusts has previously been used as proxy for the Ni isotope composition of these sediments, crusts and nodules represent a very small part of the total Mn oxide output [2]. Instead, Mn oxide microparticle supply to pelagic and hemi-pelagic sediments dominates the removal of Mn to sediments [2], but there are very few isotope data for such samples.

Here we present the first extensive Ni concentration and isotope dataset from fully oxic Mn-rich pelagic sediments, from 6 different sites across the open Pacific and 10 sites in the Indian Ocean. We also present data for one hemi-pelagic site representing suboxic Mn-rich sediments of the California Margin. All the analysed sediments are isotopically lighter than seawater (δ^{60}Ni = +1.33; [3]). The Ni isotope compositions of fully oxic abyssal sediments range from +0.26 to +1.08‰, whereas the organic-rich Californian Margin sediments are lighter at around -0.08‰.

We show that the Ni isotopes of nearly all Mn-rich sediments and deposits analysed to date are correlated with Co/Mn ratios, suggesting that they are controlled by accumulation rate, progressive incorporation of Ni into the metal oxide structure and isotopic re-equilibration between the solid and aqueous phase. We present a new mass balance calculation producing a budget that can be simultaneously balanced for both amounts and isotope compositions of Ni. This result provides a strong basis for the application of Ni isotopes as records of the evolution of the metal sink from the oxic oceans through Earth history.

[1] Little et al. (2020) *Earth Planet. Sci. Lett.*, 547, 116461.

[2] Uramoto et al. (2019) *Nat. Commun. Geochem.*, 10(1), 1-10.

[3] Lemaitre et al. (2022) *Earth Planet. Sci. Lett.*, 584, 117513.