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Controlling factors in REE-rich mud formation based on an ocean-sediment Nd mass balance model: Implication for highly REE-rich mud formation

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Deep-sea sediments highly enriched in rare-earth elements (REEs), termed "REE-rich mud," have recently attracted attention as a potential mineral resource for industrially critical metals [1]. Previous studies of the geochemistry and mineralogy of REE-rich mud have suggested that the sedimentation rate is key for the formation of REE-rich mud, and, therefore, that Earth system dynamics affecting pelagic sedimentation rates control the formation, ore grade, and distribution of REE-rich mud on a geological time scale [2]. However, the environmental factors controlling the formation of REE-rich mud and their secular variations have never been studied systematically nor quantitatively. In this study, to investigate the dominant factors promoting the formation of REE-rich mud in the Pacific Ocean, we constructed a new multi-box neodymium (Nd) mass balance model that considers interactions between the ocean and seafloor sediments [3]. Sensitivity analysis revealed that sedimentation rate and REE flux from continental margin to the ocean significantly impact REE contents in REE-rich mud. Long-term simulations through the Cenozoic demonstrated that dust fluxes dominantly control the secular trend of REE contents in REE-rich mud. The calculated REE content range is consistent with the range observed in data previously reported for North and South Pacific REE-rich mud. However, our model could not reproduce the highly REE-rich mud with >3,000 ppm of total REE that is observed in some areas. This result implies that such REE peaks reflect regional or local processes, as previously proposed [4]. Furthermore, numerical experiments considering the effect of biogenic calcium phosphates (BCP), a predominant REE host in deep-sea sediments, showed that a significant excess supply of REE to the sediment is necessary to generate the highly REE-rich mud.

[1] Kato et al. (2011) *Nat. Geosci.* **4,** 535-539. [2] Yasukawa et al. (2016) *Sci. Rep.* **6,** 29603. [3] Matsunami et al. (2024) *Ore. Geol. Rev.* **175**, 106338. [4] Ohta et al. (2020) *Sci. Rep.* **10**, 9896.