On processes that lead to enrichment of REEs in marine deposits

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Relatively high concentrations of rare earth elements (REEs) can be found in deep-sea marine clays, polymetallic nodules and cobalt crusts, making them an attractive resource for potential exploitation. Existing studies have highlighted the importance of hydrogenous scavenging of REEs from seawater by iron oxyhydroxide phases [1], and release of REEs from sediment pore waters [2] for high REE concentrations, but the processes that result in high REE concentrations are as yet poorly quantified.

To fill this gap, we have undertaken detailed geochemical and mineralogical studies of deep-sea clays (with a focus on Atlantic waters), cobalt crusts and polymetallic nodules, with emphasis on the less abundant (but economically important) heavy REEs for which few data are available. Sediment samples have been obtained from a transect across the Atlantic Ocean at ~23 ˚N, as well as the deepest parts of the ocean basin (Nares Abyssal Plain and Canary and North America Basins), and crusts and nodules have been obtained from various locations in the Pacific and Atlantic oceans.

Total REE concentrations are highest in red clays deposited away from the mid-ocean ridge and continent. However, total REE concentartions are generally lower (up to 510 ppm) than REE concentrations measured in clays from the Pacific (up to 660 ppm [3]). The REE distribution pattern in the red clays mirrors that of seawater, and they have a pronounced positive cerium anomaly. Total REEs show a positive correlation with iron concentration, except close to the mid-ocean ridge where REEs are low, despite high iron. Some crusts and nodules also exhibit a positive correlation between REE and Fe concentrations, and positive Ce anomalies. These samples would have acquired REEs from seawater; by contrast, nodules that have acquired REEs from sediment pore waters or hydrothermal sources have low REE concentrations and a negative or no Ce anomaly.

This approach provides new insights as to the complex interplay of processes regulating REE enrichment in marine deposits. This is essential for mineral prospecting, and for establishing the footprint of potential mining activities on seafloor and sub-seafloor ecosystems.

[1] Zhang *et al*., (2012). *Journal of Rare Earths*, **30**, 621 [2] Dubinin & Sval'nov (2003), *Lithology and Mineral Resources* **38**, 91-100 [3] Kato *et al*., (2011). *Nature Geoscience*, **8**, 535-539