

Biological origin of rare earth element and yttrium anomalies: Evidence from the marine bivalve *Mytilus edulis*

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Rare Earth Elements and Yttrium (REY) serve as proxies for (paleo)environmental conditions and biogeochemical processes, yet they have also emerged as (micro)contaminants in surface waters globally. Mussel soft tissues and shells are increasingly utilised as bioarchives for REY, but the mechanisms governing REY fractionation within these organisms remain poorly understood.

We investigate the distribution and fractionation of REY in different compartments of *Mytilus edulis* mussels from Norwegian coastal waters, and in their ambient water and food (plankton). Shale-normalised REY patterns across all compartments exhibit a consistent decreasing pattern from light to heavy REY (LREY to HREY). Compared to ambient seawater, mussels bioaccumulate REY by up to five orders of magnitude, with a preferential uptake of Ce and LREY over HREY. However, REY concentrations in the mussels remain lower than those in their food, exhibiting only minor fractionation, except for a selective uptake of La and Y.

Within the mussel, metabolic REY fractionation in soft tissues is minor. However, vital effects significantly influence REY incorporation into the shell. During biomineralization, Ce is selectively rejected and decoupled most likely due to oxidation and formation of very stable Ce(IV) solution complexes (similar to what has been observed for some siderophore complexes) within the extrapallial fluid (EPF). Strong complexation of HREY in solution limits their incorporation, while preferential uptake of La, Gd, and Y during shell formation may be due to their less stable solution-complexes. Hence, biological processes contribute to REY anomalies in *M. edulis* shells, suggesting that REY anomalies in biogenic carbonates may not solely reflect paleo-redox conditions.