Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.31005

Geochemical fingerprinting of permanent magnet along the value chain using high precision Nd isotopic analysis

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The transition towards a carbon-neutral economy may drastically increase our dependence on metals [1]. Permanent magnets play an important role in this transition, as they are intensively used in wind turbine generators and electric vehicles [2]. The rare earth supply chain involves more than a hundred actors and keep track of the material during the different steps of production is a real challenge. Many initiatives have been taken in order to bring more transparency in the complex network of the permanent magnet supply chain, but the actual certification methods suffer from a lack of reliable control over the different data collected. The MaDiTraCe project funded by the European Union aims at developing high-performance analytical methods for critical raw material traceability. The present work focuses on Nd isotopic analysis as a geochemical tool for the traceability of permanent magnets. The objective of this study is to investigate whether the initial Nd isotopic composition of the rare earth ore is preserved throughout the different steps of magnet manufacturing, by measuring samples from the entire value chain.

Rare earth ores, targeted ores and concentrates from all over the world were collected, as well as permanent magnets. Metallic samples from the value chain were provided by the Permanent Magnet Platform (CEA, Grenoble, France). Isotopic analyses were performed using both MC-ICP-MS (Ghent University, A&MS group, Belgium) and TIMS (BRGM, France) for inter-lab cross-validation. Several isolation protocols were tested and optimized in order to be able to address the complex variety of the different samples. The isotope ratio obtained using TIMS and MC-ICP-MS are very close to each other, validating the two approaches for accurate and precise isotopic analysis. The eight magnet samples display an average ε^{143}Nd of – 18.50 (±0.79, 2sd). The results for the value chain samples don't show significant isotopic fractionation between the samples, suggesting that no isotopic fractionation occurs during magnet manufacturing, despite the complex metallurgical processes involved. These results provide new insights into Nd isotopic analysis as a possible tool for permanent magnet source tracking.

[1] Pitron (2018), Liens Libèrent.
[2] Depraiter, Goutte (2023), Resources Policy 86, part B.