Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.30044

Investigating boron isotopic variability in the magnet production chain

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The traceability of raw materials through the value chain for magnets is crucial for ensuring sustainable sourcing, ethical production, and the optimization of high-performance applications. Permanent magnets, particularly rare-earth-based ones, primarily consist of Nd-Pr alloys (ca. 28–33%), Fe (65–70%), and B (~1%), with additional elements such as Dy, Co, Cu, Al, Ti, and Ga. The supply chain begins with the extraction of rare-earth ores, followed by beneficiation, separation, and refining processes that yield high-purity oxides. These oxides are then converted into metals or metal alloys and manufactured into magnets, which are widely used in applications such as electric vehicles, wind turbines, and electronic devices.

We have obtained samples from different stages of the magnet value chain, spanning from concentrates to the alloy, ribbon, powder and the final magnet product. Isotopic compositions of Nd and B were measured across these samples. This abstract focuses on the results of the B isotopes.

Boron (^{10}B and ^{11}B) has unique geochemical properties. It is primarily bonded with oxygen, forming boron-oxygen complexes. Boron in aqueous phase exists in two structural forms: tetrahedral ($B(OH)_4^-$) and trigonal ($B(OH)_3$), depending on the environment. The isotopic ratios of boron in terrestrial materials typically vary between -40 and +60, with magmatic rocks generally exhibiting values close to 0. These variations are influenced by the geochemical processes and environmental conditions in which boron is present.

Boron is added to the magnet alloy in the form of FeB. In our studies, the origin of B remains unknown; however, the values for the commercial ribbons and products along the value chain show very low variability in B isotopic signatures, ranging between -2 and 0. No strong fractionation of B occurs during the production of the magnet, despite the melting process involved, suggesting that B could be a potential tracer between the concentrates and the final product. However, the variability of B isotopic signatures between different magnets and concentrates still needs to be verified, as no significant variability was observed between three different ribbons used in the production of magnets from three different producers. This study is part of the EU-funded MaDiTraCe.