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Tracing sulfur recycling in the mantle: high-precision δ^{34}s constraints from pyroxenite-hosted sulfides

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Recycled pyroxenites represent a major component of mantle heterogeneity, providing key insights into crust–mantle recycling. We present in situ sulfur isotope data for garnet clinopyroxenites from the External Ligurian (EL) mantle sequences (Northern Apennines, Italy), together with selected samples from the Ronda (Spain) and Beni Bousera (Morocco) orogenic massifs. In situ δ^{34}S measurements were obtained by SIMS on primary Fe–Ni–Cu base-metal sulfides (BMS). Our study aims to integrate these data into pyroxenite petrogenetic models, to advance our understanding of deep sulfur cycling in the inner Earth.

Previous studies indicate that the EL pyroxenites originated from MORB-like gabbroic precursors with a long residence time in the mantle (> 1 Ga [1]). The Ronda and Beni Bousera massifs exhibit a spectrum of pyroxenite lithologies, including corundum-bearing garnet clinopyroxenites and UHP garnet clinopyroxenites with graphitized diamond pseudomorphs. Their wide range of Sr–Nd–Hf–Pb–O isotopic compositions reflect MOR-type crustal precursors variably overprinted by seafloor hydrothermal alteration and mixing with pelagic sediments, with additional involvement of recycled EMII-like lower continental crust for the diamond-bearing varieties [2]. Overall, these pyroxenites record ancient recycling events (2.2–2.8 Ga).

The EL garnet clinopyroxenites have δ^{34}S values from −2.84 to +0.83 ‰ (VCDT), partially overlapping the depleted mantle range. Ronda and Beni Bousera samples show a broader spectrum of δ^{34}S (−4.46 to +0.96 ‰) extending to significantly negative values. These variations indicate multiple sulfur sources and recycling processes, including preservation of hydrothermally altered oceanic crust signatures and interaction with sedimentary components. The observed negative δ^{34}S values in diamond-bearing garnet clinopyroxenites, may be due to either a lower crustal source or marine sediment-derived sulfides.

Our results suggest that recycling of oceanic and, possibly, lower continental crust introduces isotopically negative sulfur into the mantle, where it may be stored within pyroxenitic domains. The recycling of isotopically heterogeneous materials represents a key mechanism generating sulfur isotope variability in the mantle and may account for the inferred non-chondritic sulfur isotope composition of the depleted mantle.

[1] Montanini, Luguet, van Acken, Tribuzio, Schuth, Nowell (2025), GCA,402, 217-233.

[2] Varas Reus, Garrido, Marchesi, Bosch, Hidas (2018), GCA, 232, 303-328.