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Vanadium isotope fractionation in the mantle: constraints from peridotites and pyroxenites

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Decoding isotopic records of mantle rocks and mantle-derived magmas is crucial to understanding mantle heterogeneity on both local and globle scale. Metal stable isotopes have garnered significant attention, offering unique insights into crustal recycling and melt migration processes. The vanadium (V) isotope system emerge as a particularly promising tracer, due to the incompatible and redox-sensitive behavior of the V. However, whether and how V isotope systems could be fractionated in the terrestrial mantle remains unclear. Especially, there is insufficient study that fully addressed the fractionation of V isotopes during interaction of host mantle with migrating melts and fluids.

Here, we present comprehensive study targeting V isotope fractionation in response to mantle melting, melt-peridotite interaction, and metasomatism. We measured V isotope ratios for peridotites and pyroxenites worldwide, including the Balmuccia (BM) and Baldissero (BD) massifs in the Italian Alps, and Zhimafang in Dabie-Sulu orogen of China, as well as for xenoliths in basalts from Tariat (Mongolia), Tok (Siberia), and Panshishan and Tashan in eastern China. These samples are grouped, according to their origin, as follows: Group 1 fertile to moderately melt-depleted, unmetasomatised lherzolites; Group 2a strongly melt-depleted peridotites (harzburgites, dunites) and associated vein pyroxenites from the Italian Alps; Group 2b samples are three composite xenoliths (pyroxenite veins in peridotites) from Tariat; Group 3 strongly metasomatised peridotites from Tok and Zhimafang.

We find a a moderate range of V isotopic compositions in Group 1 peridotites, indicating V isotope can fractionate during partial melting. However, the $\delta^{51}V$ values in Group 2a peridotites show a limited range, possibly involving minor redistribution of V between residual peridotites and parental melts of pyroxenite veins. Surprisingly, Group 2b composite xenoliths show contrasted V isotope between peridotite hosts and pyroxenite veins, likely reflecting diffusion-driven kinetic V isotope fractionation during melt intrusion and the formation of the pyroxenites. The $\delta^{51}V$ values in Group 3 peridotites fall in the range of Group 1 rocks, indicate no equilibrium melt-rock reaction processes. Our V newly reported V isotope data display a larger range than previous study estimated. We highlight mantle melting and melt-peridotite interaction in shaping mantle V isotope heterogeneity.