Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.20762

Unraveling the Molybdenum (Mo) Cycle at the Subduction Interface: A case study from the Ligurian Alps

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Heavy Mo isotope compositions in arc lavas have been interpreted to have resulted from the reactive flow of serpentinite-derived fluids through subducted crustal rocks under oxidizing conditions, while light Mo is retained in the residual subducted oceanic rocks[1] (in phases like rutile, ilmenite). However, the effect of high-pressure (HP) metamorphism and metasomatism on Mo systematics remains enigmatic. This study attempts to a) distinguish Mo systematics among exhumed Fe-Ti metagabbros and serpentinites from the Voltri Massif of the Ligurian Alps and b) evaluate the (re)distribution of Mo and its isotopes formed by HP fluid-mediated mass transfer by analyzing a metasomatic reaction zone between juxtaposed serpentinite and metagabbro, wherein serpentinite-derived fluids have been suggested to have infiltrated a large hm-scale metagabbroic body.[2] We present both the variability within and correlations between Mo isotopes, [Mo], [fluid-mobile elements; FMEs], and $Fe^{3+}/\Sigma Fe_{total}$.

Overall, metagabbros (n = 36) across the Voltri Massif exhibit a range of [Mo] (0.07 to 4.4 µg/g; avg. = 1.0 µg/g) and $\delta^{98/95}$Mo (-0.36‰ to 0.93‰; avg. = -0.08‰), comparable to MORB[1] (6.1 µg/g and -0.16‰, respectively). Serpentinites (n = 12) exhibit a range of [Mo] (0.01 to 1.9 µg/g; avg. = 0.45 µg/g) and $\delta^{98/95}$Mo (-0.39‰ to 0.49‰; avg. = 0.05‰), displaying overall higher [Mo] and lower $\delta^{98/95}$Mo, compared to oceanic serpentinized peridotite[3] (0.11 µg/g and 1.1‰).

For the aforementioned reaction zone, systematic trends in [Mo], [FMEs], $Fe^{3+}/\Sigma Fe_{total}$, and $\delta^{98/95}$Mo exist. Metagabbros at the core of the gabbro body maintain MORB-like [Mo] and $\delta^{98/95}$Mo values and low [FMEs], remaining largely unaltered by metasomatism. Metagabbros proximal to the contact with the serpentinite display lower [Mo], $Fe^{3+}/\Sigma Fe_{total}$, and $\delta^{98/95}$Mo. Notably, samples at an intermediate distance from the contact (~0.5 m) display elevated $\delta^{98/95}$Mo, [FMEs] and $Fe^{3+}/\Sigma Fe_{total}$.

We suggest fluid-mediated mass transfer between serpentinite and crustal rocks as a possible mechanism for generating isotopically heavy Mo that can be delivered to the source of arc magmas. This study helps bridge the gap in understanding the fate of Mo in subduction zones.

[1]Chen, et al. 2019, Nat. Comm.
[2]Codillo et al., 2022, G[3]
[3]Rojas-Kolomiets et al., 2023, EPSL