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Post-magmatic modification of heavy halogens in mantle-derived rocks

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Halogens play a crucial role in Earth's long-term geochemical evolution [1]. The lithospheric mantle serves as an important halogen reservoir, and mantle-derived rocks are commonly used to infer mantle compositions. However, due to their fluid-mobile and volatile nature, Cl, Br, and I in these rocks are susceptible to post-magmatic modification. The mechanisms of modifications and their impact on halogen compositions remain unclear. To address this, we investigate halogen systematics in mantle-derived peridotites, pyroxenites, and lamprophyres.

Peridotites and pyroxenites from the Balmuccia and Baldissero peridotite massifs (Ivrea-Verbano Zone, Italy) represent fragments of non-metasomatized, depleted lithospheric mantle. However, these rocks exhibit highly variable halogen concentrations (Cl: <30–244 μg/g; Br: <0.10–0.94 μg/g; I: <0.015–0.12 μg/g), with some samples exceeding depleted and even primitive mantle estimates. This enrichment is attributed to post-magmatic fluid percolation during exhumation, as indicated by the presence of widespread secondary fluid inclusions and elevated Ba/Nb ratios relative to MORB [2].

Lamprophyres, originating from a metasomatized lithospheric mantle source, are generally used to record mantle compositions. However, lamprophyres from the eastern North China Craton exhibit unexpectedly low halogen concentrations (Cl: 58–170 μg/g; Br: 0.28–0.55 μg/g; I: <0.005 μg/g), comparable to MORB, despite their volatile-rich mineralogy. Recalculation based on halogen/K ratios suggests that >90% of the halogens were lost from the primary melts. This depletion is likely due to fluid exsolution during magma ascent, with halogens preferentially partitioning into the fluid phase [3].

These findings underscore the role of post-magmatic processes, particularly degassing and fluid percolation, in modifying Cl, Br, and I concentrations in mantle-derived rocks. As a result, these rocks may not reliably preserve the heavy halogen signature of their mantle source. In contrast, fluorine (F) is less mobile and thus less susceptible to post-magmatic modification, suggesting that it may better retain mantle volatile signatures. Future studies integrating F with Cl, Br, and I analyses could provide further insights into the halogen distribution in the mantle and the variable behavior of halogens during magmatic and post-magmatic processes.

[1] Barnes et al. (2018) Springer; [2] Zheng et al. (2024) CG; [3] Zheng et al. (2023) AM.