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Heavy halogen compositions of lamprophyres derived from metasomatized lithospheric mantle beneath eastern North China Craton

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Abstract

Halogens and other volatiles are widely recycled into the deep mantle by subduction and are key components to metasomatize the sub-continental lithospheric mantle (SCLM). Lamprophyres are well known to be rich in volatiles and are important for understanding the halogen characteristics of the metasomatized SCLM and/or the mobilization of halogens during the ascent of such volatile-rich, low-degree partial melts. The North China Craton (NCC) hosts lamprophyre dikes coeval with extensive thinning of the eastern NCC in the Mesozoic and generated from lithosphere metasomatized by multiple-stage subduction components. Here we report bulk-rock heavy halogens (Cl, Br, and I) of 16 lamprophyres from the eastern NCC. The bulk-rock halogen concentrations are overall very low (Cl = 58–170 μg/g, Br = 285–559 ng/g, and I <5 ng/g), comparable with depleted Mid-Ocean ridge basalts (N-MORBs). Volatile-rich minerals (e.g., amphibole and biotite) are abundant (20–30 vol%) in these lamprophyres, however, electron probe microanalyses (EPMA) data indicate that amphiboles are mainly rich in OH and F but display very low Cl concentrations (0.01–0.04 wt%). The bulk rock and amphibole data consistently indicate low abundances of heavy halogens in the lamprophyres, which is difficult to reconcile with the remarkable enrichment of fluid-mobile large ion lithophile elements such as Ba, Rb, and K. Based on low Cl/Nb and Br/Nb but high Ba/Nb and K/Nb ratios, the low halogen concentrations likely resulted from extensive volatile loss (>90%) during melt ascent. The low Cl concentrations in early-stage amphiboles (Mg# 60–64) further indicate that such loss would have occurred before amphibole crystallization at a depth of ~15 km. We thus propose that crystallization of early olivines and pyroxenes and reaction with surrounding mantle rocks likely induced volatile saturation and exsolution, leading to strong partitioning of the halogens into the exsolved aqueous volatile phases and thus the extensive loss of halogens from the rising melt. These results reveal that significant volatile loss of halogens not only occurs during surficial low-pressure eruption but also at much deeper levels in the crust, as also identified for some kimberlites. Consequently, it would be difficult to constrain the primitive halogen components of the mantle sources via lamprophyres or similar magmas.

Keywords: Halogen, lamprophyres, deep degassing, metasomatized mantle, North China Craton; Experimental Halogens in Honor of Jim Webster