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Magmatic volatiles and platinum-group element mineralization in the Stillwater layered intrusion, U.S.A.

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Abstract

The activity of volatile-rich fluids may be important in the evolution of basaltic magmatic systems and associated precious metal ore formation. There is evidence for Cl-rich fluids within the Stillwater Complex (Montana, U.S.A.), which have been linked to platinum and palladium mineralization in the economically important Johns-Manville (J-M) Reef ore body. We present the first data set for heavy halogens (Cl, Br, and I) and natural noble gas isotopes in bulk rock and mineral separates from the Peridotite Zone and the Olivine-Bearing Zone I of the Stillwater Complex, including samples from the J-M Reef and G Chromitite bodies. Our data reveal concentrations of 4 to 13 500 ppm for Cl, 26 ppb to 360 ppm for Br, and <1 ppb to 9 ppm I over the whole sample set. Cl, Br, and I correlate well with each other implying a shared process and/or distribution in mineral species. Br/Cl and I/Cl ratios span a range from 0.3 to 35 × 10^{-3} and 5 to 900 × 10^{-6} by weight, respectively, encompassing MORB-like to more enriched compositions, particularly for Br/Cl. High-Br/Cl ratios compared to MORB in some Stillwater samples suggest fractionation of halogens during the exsolution of a volatile-rich fluid to explain the most Br-enriched samples. More generally, the presence of minerals such as scapolite, hornblende, and apatite in the most halogen-enriched samples suggests that the halogen-bearing fluids were derived from the cooling of the intrusion rather than late-stage (low-temperature) metamorphism. The combined halogen abundance and noble gas isotope data set imply that crustal contamination may have played a limited role in the crystallization of pegmatoids and the G Chromitite but is not required to account for the halogen budget of the J-M Reef. High-halogen contents in the sulfide-bearing J-M Reef and associated lithologies are consistent with the influence of fluid-related activity during platinum-group element (PGE)-Reef formation, lending weight to the hydromagmatic model for mineralization in the Stillwater intrusion. Our new data also imply chalcophile tendencies of Br and I over Cl in sulfides in natural systems, hinting at the importance of sulfide liquid interaction with halogen-rich fluids in the formation of sulfide-hosted precious metal ore deposits.

Keywords: Halogens, platinum-group elements, Stillwater intrusion, metasomatism, J-M Reef; Experimental Halogens in Honor of James Webster