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Origin of heavy sulfur isotope in arc magmas: Insights from apatite in ultramafic cumulates

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Arc magmas generally have higher S contents and higher $\delta^{34}S$ values than mid-ocean ridge basalts. Determining whether the enrichment of S was due to crustal processes or mantle metasomatism is essential for understanding S recycling in subduction zones. We present elemental and S–Sr isotopic compositions of apatite from ultramafic rocks in the Early Permian Dongwanzi intrusion, northern margin of the North China Craton. Based on textural and compositional characteristics, interstitial and cumulus apatite are identified in clinopyroxenite. Interstitial apatite has high Cl, total REE+Y, and Th contents, variable $^{87}Sr/^{86}Sr$ ratios, and low $\delta^{34}S$ values, consistent with crystallization from late-stage trapped melts. In contrast, euhedral cumulus apatite has low Cl and total REE+Y, high $\delta^{34}S$ values (~+7.9 ‰), and low initial $^{87}Sr/^{86}Sr$ ratios (~0.70337), indicative of growth from a primitive magma. Compared to cumulus apatite from clinopyroxenite, most cumulus apatite (Type 1) in hornblendite has high F and total REE+Y contents, but slightly low $\delta^{34}S$ and similar initial $^{87}Sr/^{86}Sr$ ratios, which was attributed to a progressive fractional crystallization from clinopyroxenite to hornblendite. Some cumulus apatite (Type 2) in hornblendite shows extremely low Cl and $\delta^{34}S$ values, but high total REE+Y and initial $^{87}Sr/^{86}Sr$ ratios, recording fluid exsolution related to reduced wall-rock contamination. Using S isotopic data for cumulus apatite in clinopyroxenite, the parental magma has calculated $\delta^{34}S$ values of ~+8.0 ‰, suggesting that sub-arc mantle metasomatism, rather than crustal processes, was responsible for generating the heavy S isotopic signatures of the Dongwanzi intrusion. Our study demonstrates that apatite can record the magmatic S isotope evolution of mafic-ultramafic intrusions.