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Unusual sulfide-rich magmatic apatite crystals from >2.7 Ga Abitibi Greenstone Belt, Canada

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Abstract

Sodic volcano-plutonic terranes in the Archean can be well preserved, but why oxidized S-rich sodic magmas and porphyry-type Cu-Au deposits are so rare remains poorly understood. Here we addressed this issue by measuring the S concentration and $S^{6+}/\Sigma S$ ratio of primary apatite grains in >2.7 Ga felsic volcanic rocks from the well-characterized Neoarchean Abitibi Greenstone Belt of the Superior Province, Canada. Whereas apatite grains in most samples contain low-S concentrations (<0.01 wt%, n = 24), a few apatite samples are S-rich (0.14 ± 0.03 wt%, 1σ) and have low-$S^{6+}/\Sigma S$ ratios (0.56 ± 0.17; 1σ, n = 4). Samples with S-poor apatite have variable whole-rock La/Yb ratios (generally <30) and zircon 10 000*(Eu/Eu*)/Yb ratios of 11 ± 8 (1σ), which may be products of plume-driven or over-thickened crustal melting. In contrast, the samples with S-rich apatite have elevated La/Yb ratios of 49 ± 15 (1σ), zircon 10 000*(Eu/Eu_N*)/Yb ratios of 26 ± 7 (1σ), and zircon $\delta^{18}O$ values of 5.8 ± 0.1 ‰ (1σ), consistent with a deep, hydrous and homogeneous mantle-like source for the melts dominated by amphibole ± garnet fractionation that is reminiscent of subduction-like process. These are the first reported results documenting the predominant accommodation of relatively reduced S in S-rich apatite grains crystallized from terrestrial silicate melts, possibly reflecting slight oxidation associated with the hydration of Neoarchean mantle and crystal fractionation over the magma evolution. The more common S-poor apatite data suggest that suppressed oxidation of the parental sodic magmas led to weak S emission from Earth's interior to its evolving surface, explaining the rarity of porphyry-type Cu deposits in >2.7 Ga Archean sodic volcano-plutonic terranes.

Keywords: Neoarchean, apatite, oxidation state, melt S, porphyry Cu deposit