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Controls on the Rarity of Porphyry Cu Deposits in the Archean

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Porphyry Cu deposits are mainly formed in the Phanerozoic and are rare in the Archean. They are closely associated with oxidized S-rich magmas originating mainly from asthenospheric mantle metasomatized by slab-derived fluids in subduction zones. Because of extremely low seawater sulfate concentration and relatively reduced seawater-altered oceanic seafloor, prevention of oxidation of the mantle is hypothesized to have precluded porphyry Cu deposit in the Archean.

To test this hypothesis, we carried out systematic electron probe and μ -XANES analyses on zircon-hosted apatite inclusions from sodium-rich TTG and volcanic rocks and late potassium-rich intrusive rocks formed at 2,750 to 2,670 Ma in southeastern Superior Province, Canada. The main findings include: (1) primary apatite grains from > 2700 Ma pre-modern-subduction volcanic rocks yielded exceptionally low S concentrations except for a few samples yielding high apatite S concentrations but low $S^{6+}/\Sigma S$ ratios. The host volcanic samples yielded elevated La/Yb ratios and zircon Eu/Eu* ratios, suggesting that the operation of immature subduction at >2,700 Ma cannot form oxidized S-rich magmas. (2) Melt S content estimated using the compositions of the primary apatite grains from the intrusive rocks increased sharply upon the onset of the subduction event at ~2,700 Ma, but the apatite $S^{6+}/\Sigma S$ ratios and the magmatic fO_2 values for igneous rocks slightly decrease with increasing zircon $\delta^{18}O$ value (reflecting the increase in crustal assimilation in the source area) and crustal thickness.

These results suggest that the asthenospheric mantle and the derivative magmas may have been oxidized at the onset of the ~2.7 Ga persistent subduction in Superior province, Canada. We conclude that the scarcity of porphyry Cu deposits in Archean cratons may be attributed to (1) the limited operation of persistent subduction at >2.7 Ga and (2) subsequent erosional loss since the surface uplift associated with continental formation.