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In-Situ Multiple Sulfur Isotopes of the Archean Hongtoushan Cu-Zn-Au Deposit (North China Craton): Tracing Ore Sources and Predicting Deposit Scale and Metal Grades

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The Hongtoushan Cu-Zn-Au deposit, the oldest and largest known Archean volcanogenic massive sulfide (VMS) deposit in China, offers critical insights into Precambrian metallogenic processes. This study presents in-situ multiple sulfur isotope analyses ($\delta^{34}S$, $\Delta^{33}S$) of pyrite, pyrrhotite, and chalcopyrite from the ~2.55 Ga Hongtoushan ore system. Measured $\delta^{34}S$ values vary slightly among sulfide phases (pyrite: +0.94‰; pyrrhotite: +0.60‰; chalcopyrite: +0.57‰), while $\Delta^{33}S$ values cluster near zero (pyrite: –0.07‰; pyrrhotite: –0.02‰; chalcopyrite: –0.05‰). These isotopic signatures indicate a predominantly magmatic sulfur source with minor seawater sulfate contributions (2.5–3.5%), as evidenced by subtle negative mass-independent sulfur isotope fractionation.

Building on the Chen et al. (2015) model linking $\Delta^{33}S$ values to Archean VMS deposit tonnage [1], our data suggest significant untapped mineralization potential at Hongtoushan. Notably, we challenge the Sharman et al. (2015) paradigm that exclusively associates near-zero $\Delta^{33}S$ values with high-Au-grade systems [2], demonstrating that low-Au-grade Archean VMS deposits can exhibit comparable isotopic signatures. Furthermore, Cu grades show an inverse correlation with $\Delta^{33}S$ values: enhanced seawater influx (marked by more negative $\Delta^{33}S$) correlates with elevated Cu concentrations, likely due to rapid hydrothermal cooling facilitating efficient metal leaching.

These findings refine genetic models for Archean VMS deposits and establish sulfur isotopes as predictive tools for assessing deposit size, Cu grade, and Au endowment. This approach provides a novel framework for targeting exploration in ancient terranes, with implications for both academic research and resource evaluation.

References

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