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Strontium and multiple sulfur isotopic constraints on Volcanogenic Massive Sulfide (VMS) deposits in the Oman ophiolite

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We present a Sr and multiple-sulfur isotopic study on the Shinas and Mandoos VMS deposits in the Samail Ophiolite. Sequential S-extraction for monosulfides-AVS, disulfides-CRS and soluble sulfates was performed on whole-rock powders.

Mandoos is a large deposit (8Mt @ Cu, Zn =1.8, 0.6wt%, Au=0.18g/t) formed during quiescence between regional V1-V2 volcanic stages. Shinas is a small, higher-grade orebody (0.8Mt @ Cu, Zn=2.6, 0.4wt%, Au=0.72g/t) resulting of short-lived hydrothermal activity during late V2. Mandoos ores preserve pristine hydrothermal textures overlying an incipient stockwork, indicating it developed mainly above seafloor, through mound growth and collapse. Shinas' deep stockwork is hosted in multi-phased breccias, formed under hydraulic overpressure conditions, with a transient mound growth stage.

Shinas has a narrow $\delta^{34}S$ span (+2.1 to +4.1‰), within the range of Seafloor Massive Sulfide-SMS deposits hosted in fast-spreading, sedimented-starved ridges. Mandoos wider $\delta^{34}S$ range (-1.1 to +5.4‰) overlaps with SMS in slow-spreading ridges. A distal domain in the Mandoos orebody has negative $d^{34}S_{CRS}$ (-1.1 to -0.8‰) that correlate with increasing In/Cu, Se/S, Ni contents, and low $^{87}Sr/^{86}Sr$ (0.703932) suggesting contributions from a metal-rich, S-light magmatic-hydrothermal phase, although late biogenic reworking cannot be excluded.

Excluding one ore (0.708128), $^{87}Sr/^{86}Sr$ ratios at Mandoos are lower (<0.706018) than at Shinas where $^{87}Sr/^{86}Sr$ in the stockwork increases steeply upward (0.705430-0.708128) indicating increasing water/rock ratios during mixing of hydrothermal fluids and seawater. Sulfates have $_{\delta}^{34}S$ within the range of sulfides indicating they result of post-hydrothermal abiotic oxidation.

$\delta^{33}S^*_{CRS}$ are mostly negative (-0.031 to 0.06‰, Average=-0.013±0.01) as reported for Samail lower crust and Troodos, being unclear if these reflect a primary mantle anomaly. $\delta^{34}S_{CRS}$-$\delta^{33}S^*_{CRS}$ relationships for Shinas develop a steeply negative slope consistent with mixing and incomplete isotopic homogenization of a basaltic-S dominated, deep hydrothermal fluid with SO_4 during upflow. Correlation lines with different slopes for Mandoos suggest multi-phased fluid inputs during its protracted hydrothermal history.

The cover lavas of both deposits exhibit elevated $^{87}Sr/^{86}Sr$ (0.704094-0.706860) and depleted sulfide-sulfur contents (<34-292 ppm), reflecting leaching and oxidation during oceanic metasomatism. Secondary pyrite $\delta^{34}S$ (Mandoos: -0.1 to +1‰; Shinas: +0.1 to 2.5‰) implies recrystallization of primary sulfides incorporated mostly basaltic sulfur.