Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.31375

Geochemical and Isotopic Constraints on Sulfide Deposition at the Rainbow Hydrothermal Field

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The Rainbow hydrothermal field (RHF), located along the Mid-Atlantic Ridge (MAR), hosts a variety of hydrothermal chimneys, characterized by vent activity ranging from focused to diffuse flow, with dispersed inactive structures. These structures accommodate Cu- and Zn-rich sulfide deposits hosted in mafic and ultramafic rocks. This study presents new findings regarding the metal distribution, sulfur isotopic composition, and depositional processes that control Rainbow's chimney mineralization. Cu-rich deposits exhibit high Fe and Cu concentrations, indicative of focused high-temperature venting, whereas Zn-rich deposits are associated with lower-temperature diffuse flow and seawater mixing. Anomalously high Au values were identified (average = 5.02 ppm), with a maximum of 12.9 ppm recorded in a chimney with diffuse venting and evident oxidation, located within a sulfide mound where serpentinized ultramafic rocks were identified. This vent chimney also exhibited the highest concentrations of Cu (344,000 ppm) and Ni (1,180 ppm). *In situ* sulfur isotope analysis ($\delta^{34}S$) of Cu-sulfides and sphalerite revealed values ranging from -2.77‰ to 3.82‰ (mean ± sd = 1.696 ± 1.835‰). Cu-rich samples show the most positive $\delta^{34}S$ values, while sphalerite-rich samples exhibit the lowest. Less active or inactive vents tend to have higher $\delta^{34}S$ values, likely due to prolonged exposure to cold seawater and oxidation, emphasizing post-depositional alteration processes. These results highlight the role of fluid-seawater interactions, redox conditions, and host rock composition in controlling mineral precipitation and the evolution of RHF sulfide deposits.

This work was supported by the Macao Science and Technology Development Fund Project (FDCT -0041/2021/A1) and by the Portuguese Fundação para a Ciência e Tecnelegia FCT, I.P./MCTES through national funds (PIDDAC): UID/50019/2025 and LA/P/0068/2020 (https://doi.org/10.54499/LA/P/0068/2020)