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Subseafloor mineralization related to shallow seawater-hydrothermal circulation in the Longqi hydrothermal field, Southwest Indian Ridge (49.6°E): Evidence from in situ trace element and sulfur isotope compositions of pyrite varieties

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Shallow seawater-hydrothermal circulation plays a crucial role in the subseafloor mineralization of the hydrothermal system. However, its key fluid processes and impacts on the metal mobilization and sulfur cycles in the stockwork mineralization are still poorly understood. We first present the systemic variations in micro-scale trace element and sulfur isotope compositions of pyrite varieties in a stockwork-like sulfide from the Longqi hydrothermal field to constrain the metal transport and deposition and sulfur origins and cycles in the shallow seawater-hydrothermal circulation. Pyrites considered as the dominant sulfides can be clarified into disseminated fine-grained (Py-I), euhedral (Py-II), and subhedral-euhedral (Py-III) varieties based on texture. The wall-rock-derived elements Ti, Cu, Ni, Mg, and Mn and seawater-derived elements Mo, V, and U are concentrated in Py-I within the breccias and related to the fluid-rock reaction and fluid-seawater mixing in the shallow seawater-hydrothermal circulation system. Short-lived shallow circulation results in fluid fluctuation and oscillatory-zoned Py-II with depletion of Co, Ni, Cu, As, and Se in the mantles relative to those in the rims and cores. As the later hydrothermal activity was active, Py-III that was overgrown from Py-II is rich in hydrothermally inherited metals Se, Te, and Co, possibly implying the hydrothermal field is coming into the main mineralization. The sulfur isotope compositions of pyrites range from 4.30 to 9.98‰ (n=37), with distinct $\delta^{34}S$ variations in the individual Py-I crystal (> 1.5 ‰ within a 20 × 20 μm^2 region). This variation is attributed to changes in the relative proportion of sulfur sourced from (i) the shallow-origin reduced seawater via reduction by ferrous iron released from basalt (ii) the reduction of pre-existing anhydrite by later hydrothermal overprinting in the shallow subseafloor. These findings provide evidence for a model to better understand the effect of shallow seawater-hydrothermal circulation on the subseafloor stockwork mineralization of hydrothermal fields.