

Gold Enrichment Mechanism in Mid-ocean Ridge Hydrothermal Systems: Examples From the Longqi and Yuhuang Hydrothermal Field on the Ultraslow-spreading Ridge

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Seafloor massive sulfide (SMS) deposits form at submarine hydrothermal vent sites. To date, more than 700 hydrothermal systems have been discovered on the seafloor, over half of which are associated with metal sulfide mineralization. SMS deposits formed in oceanic arc settings generally have higher Au contents than those formed in mid-ocean ridge (MOR) settings. This may reflect the greater Au endowment of felsic magmas in oceanic arc settings. In mid-ocean ridge (MOR) settings, gold grades in SMS deposits are negatively correlated with spreading rate. Although previous studies have addressed the distribution of gold in sulfides from ultramafic-hosted hydrothermal fields, enrichment mechanisms in mafic-hosted systems along ultra-slow spreading ridges remain poorly understood. The basalt-hosted Longqi and Yuhuang hydrothermal fields, located on the ultra-slow spreading Southwest Indian Ridge, offer an opportunity to investigate such processes. The dominant sulfide minerals in these fields include pyrite, marcasite, sphalerite, chalcopyrite, and isocubanite. Abundant native gold nanoparticles are observed in early-stage pyrite, which is characterized by elevated Mo, V, Sn, and Pb, and lower As, Co/Ni, and Se/Tl ratios. Furthermore, the $\delta^{34}\text{S}$ values of these pyrites also vary significantly. Compilation of sulfur isotope data from 41 basalt-hosted hydrothermal fields reveals wide $\delta^{34}\text{S}$ variations in slow and ultra-slow spreading MORs, reflecting diverse sulfur sources (e.g., leaching of MORB, thermochemical reduction of seawater sulfate, magmatic degassing, microbial activity), variable fluid-basalt interaction, and redox conditions (CH_4/CO_2 ratios). Prolonged fluid-rock interaction and specific chimney types, such as beehive structures, may promote higher gold grades. Additionally, low H_2S concentrations could be a key factor contributing to gold enrichment in basalt-hosted SMS deposits along ultra-slow spreading ridges. The study of modern SMS deposits not only contributes to the improvement of the metallogenic theory, but also has significant implications for guiding the exploration of ancient VMS deposits.