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Source and evolution of ore fluids of the Daqiao sediment-hosted gold deposit, western Qinling orogen, China: revealed from in situ sulfur isotope analysis of sulfides

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The newly-discovered Daqiao gold deposit (140 t ore averaging at 3-4 g/t Au) in western Qinling orogen, central China, is hosted in clastic rocks of the Triassic Daheba Formation that are intensively silicified and brecciated. Gold mineralization is preferentially localized in dilational hinges of anticlines and interlayered fracture zones within the host rocks. Ore bodies consist of silicified breccias that are overprinted with minor quartz-carbonate-sulfide stockworks. Gold is predominantly hosted in fine-grained pyrite and marcasite, typically showing textural and compositional zoning. Numerous felsic dikes intrude the Triassic sedimentary rocks in the mine and surrounding areas, with some having sericitic alteration and subeconomic gold mineralization. Laser ablation MC-ICPMS sulfur isotope analyses of the sulfides show $\delta^{34}\text{S}$ ranges from -31.31‰ to 21.98‰. Stage 1 diagenetic pyrite is porous and has $\delta^{34}\text{S}$ mostly between -0.06‰ and 21.98‰ (mean of 7.5‰; n=9), with two exceptions at -6.94‰ and -25.29‰. Stage 2 pyrite in hydrothermal breccias is euhedral and has $\delta^{34}\text{S}$ values of -1.15‰ to 8.66‰ (mean 3.99‰; n=36), consistent with values of coexisting tabular marcasite (-1.22‰ to 11.36‰ with a mean of 2.84‰; n=32). Stage 3 colloidal pyrite (0.2-136.7 ppm Au) in the main gold mineralization stage has $\delta^{34}\text{S}$ of -13.87‰ to -0.69‰ (mean -6.79‰; n=36), whereas the associated fine-grained marcasite (22.5 ppm Au) has values of -21.08‰ to -5.22‰ (mean -11.63‰; n=4). Stage 4 coarse-grained pyrite in calcite-ankerite-sulfide veins has extremely low $\delta^{34}\text{S}$ ranging from -31.31‰ to -17.90‰, with a mean of -25.17‰ (n=9).

Formation of stage 1 diagenetic pyrite is attributed to bacterial reduction of seawater sulfates in the host rocks ($\delta^{34}\text{S}$ =15-25‰). Stage 2 sulfides with average $\delta^{34}\text{S}$ of 2.84‰ to 3.99‰ may have precipitated from a fluid with a deep-seated source for sulfur. Whether this source is related to regional prograde metamorphism or magmatism remains unresolved. The negative $\delta^{34}\text{S}$ (-6.79‰-11.63‰) of stage 3 auriferous sulfides either is a result of fluid oxidation in the process of mineralization or reflect introduction of an external fluid with sulfur derived from metamorphic devolatilization of Paleozoic marine sequences containing abundant carbonaceous materials (e.g., black shales). The wide presence of hydrothermal breccias in the mine is interpreted to be a result of fluid overpressurization and resultant hydraulic fracturing/brecciation and fluid unmixing that caused fluid oxidation and sulfur isotopic fractionation. The extreme negative $\delta^{34}\text{S}$ of stage 4 (-31.31‰ to -17.90‰) may be an integrated effect of continuous fluid oxidation and input of metamorphic derived sulfur from Paleozoic black shales that are widely distributed in the western Qinling orogen.

