Texture, Trace Elements, and Sulfur Isotopes of Pyrite from the Zhao'anzhuang Iron Deposit, Southern Margin of North China Craton: Implications for Ore Genesis

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The Zhao'anzhuang iron deposit (160 Mt at ~40% Fe) in the southern margin of the North China Craton, is hosted in an early Paleoproterozoic metavolcanic sequence with intercalations of evaporite-bearing, Mg-rich carbonate, but its genesis remains poorly understood. Here we present trace element and sulfur isotope data for three distinct types of pyrite to provide new insights into ore genesis. These include pre-ore Py1 disseminated within serpentinized olivine in the altered host rock, syn-ore Py2 closely associated with magnetite-apatite ores, and post-ore Py3 veins intersecting iron ores. Py1 has low $\delta^{34}S_{V\text{-}CDT}$ values (3.55~5.37‰), elevated Co (112-2,516 ppm), Ni (27-1,329 ppm), and Se (265-2,458 ppm), and low Cu (29-1,609 ppm), Pb (29-1,647 ppm), and Zn (3.3-17.8 ppm). The trace element compositions and sulfur isotope data of Py1 indicate its precipitation from a high-temperature magmatic-hydrothermal fluid. Py2 has variable Co (11.8-25,951 ppm), Ni (48-27,958 ppm), and Se (<971 ppm) and exhibits distinctly different sulfur isotopes with $\delta^{34}S_{V\text{-}CDT}$ values ranging from 9.84‰ to 16.91‰. These trace element and isotopic signatures are interpreted in terms of the assimilation of evaporites by a magmatic-hydrothermal fluid, with temperature decreasing from the pre- to syn-ore stage. The contents of Co (52.8-1,168 ppm), Ni (198.4-998 ppm), and Se (<86 ppm) are much lower in Py3, which is further enriched in heavy sulfur isotopes with $\delta^{34}S_{V\text{-}CDT}$ of 14.24~23.53‰. This observation indicates continuous assimilation of the evaporites by the ore fluids, whose temperatures progressively decreased. Given the close association of the three pyrite generations with magnetite and other mineral assemblages, we suggest that the Zhao'anzhuang iron deposit is of magmatic-hydrothermal origin and formed through interaction of the magmatically derived fluid with evaporite-rich carbonates. Assimilation of evaporites into the fluid facilitated the oxidation of ferrous iron that led to the precipitation of magnetite, during which process the Py1 and Py2 formed.