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Iron isotope fractionation in reduced hydrothermal gold deposits: A case study of the Wulong gold deposit, Liaodong Peninsula, East China

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Abstract

Iron isotope fractionation in hydrothermal systems is a useful diagnostic tool for tracing ore-forming processes. Here, we report on the Fe isotopic compositions of a suite of hydrothermal minerals from ores (pyrite, pyrrhotite, and quartz) from the Wulong gold deposit, Liaodong Peninsula, East China. Pyrites from quartz sulfide ores show a δ^{56}Fe (^{56}Fe/^{54}Fe in the sample relative to IRMM-14) range from +0.11 ± 0.03‰ to +0.78 ± 0.03‰ (2SD), and pyrrhotites from the same vein are isotopically lighter than the pyrites, varying between –0.85 ± 0.01‰ and –0.07 ± 0.00‰. This result is consistent with theoretical predictions of equilibrium fractionation and published mineral compositions. For the first time, to our knowledge, we report the Fe isotopes of hydrothermal quartz that records the isotopic compositions of the ore-forming fluids. Two quartz separates in the quartz-sulfide vein yield δ^{56}Fe values of –0.02 ± 0.02‰ and +0.07 ± 0.07‰. Our Fe isotope fractionation calculations show that pyrrhotite with light Fe isotopes crystallized first from the ore-forming fluids, which indicates a relatively reduced condition for the initial ore-forming fluids. Then the remaining fluids with heavy Fe isotopes precipitated pyrites with positive δ^{56}Fe values, and their mineral crystallization sequence records an increase of oxygen fugacity during mineralization.

Gold deposits in Wulong and Jiaodong share many similar geological characteristics. The pyrites from the Wulong deposit have higher δ^{34}S values (+0.5 to +4.1‰) than the pyrrhotites (–1.2 to +1.2‰). Pyrites from the Jiaodong gold deposits show a wide range of both positive and negative δ^{56}Fe values as well as high δ^{34}S values, whereas those from the Wulong deposit have a relatively narrow range of positive δ^{56}Fe values and near-zero δ^{34}S values. The differences in Fe isotopes may be due to early precipitation of pyrrhotite with light Fe isotopes under a relatively low oxygen fugacity environment in the Wulong deposit, resulting in pyrite precipitated from the remaining fluids with heavy isotopes. The sulfur isotope variations between Wulong and Jiaodong gold deposits reflect differences in their source regions rather than oxygen fugacities. In addition, we have compiled Fe isotopic compositions of pyrites and pyrrhotites from different types of ore deposits to investigate their Fe isotopic behavior in magmatic-hydrothermal systems. Pyrite grains show a wide range of δ^{56}Fe values. Positive pyrite δ^{56}Fe values reflect an equilibrium isotope effect, whereas negative pyrite δ^{56}Fe values may be due to kinetic isotope effects or to a mixture of sedimentary host rocks. Pyrrhotite grains show similar negative δ^{56}Fe values, and they have a strong influence on the Fe isotope systematics in magmatic and hydrothermal systems. Our data show that Fe isotopes can be used to trace precipitation orders of pyrite and pyrrhotite and oxygen fugacity evolution in relatively reduced hydrothermal deposits.

Keywords: Fe isotopes, reduced hydrothermal gold deposits, Wulong gold deposit, Liaodong Peninsula