

Sulfide liquid evolution is recorded by iron isotopes in the Cu–PGE mineralization of the Eastern Gabbro, Coldwell Complex, Canada

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Despite the fact that metal stable isotopes are not expected to exhibit large equilibrium fractionations at magmatic temperatures, Fe isotope compositions of base-metal sulfides (BMS) are increasingly being used to characterize the processes that generate and modify Ni–Cu–platinum-group element (PGE) deposits. In the Cu–PGE mineralization of the Eastern Gabbro of the Coldwell Complex, Canada, variations in $\delta^{56}\text{Fe}$ of up to $\sim 1.8\text{‰}$ are observed in BMS. The $\delta^{56}\text{Fe}$ composition of pyrrhotite (-1.48‰ to -0.16‰) is consistently negative and exhibits no variation with style of mineralization, whereas the $\delta^{56}\text{Fe}$ composition of chalcopyrite (-0.65‰ to 1.11‰) is largely positive (except for the W Horizon) and decreases systematically from Footwall Zone, Main Zone \approx Four Dams \approx Sally, to W Horizon. Source heterogeneity, sulfide segregation, variations in R factor, crustal contamination, hydrothermal fluids, and redox reactions have been ruled out as having had a significant effect on the Fe isotope composition of both pyrrhotite and chalcopyrite. The pyrrhotite/chalcopyrite ratio in these mineralized zones generally mirrors the $\delta^{56}\text{Fe}$ of chalcopyrite. Because pyrrhotite preferentially sequesters ^{54}Fe and crystallizes before chalcopyrite, the inverse correlation between the $\delta^{56}\text{Fe}$ composition of chalcopyrite and the pyrrhotite/chalcopyrite ratio of the mineralized zones likely results from the amount of monosulfide solid solution (MSS) that crystallized prior to intermediate solid solution (ISS). This would have controlled the $\delta^{56}\text{Fe}$ of the residual Cu-rich liquid from which ISS crystallized (i.e., the more MSS that crystallizes prior to the crystallization of ISS, the heavier the Fe isotope composition of chalcopyrite). The similarity in $\delta^{56}\text{Fe}$ of chalcopyrite in the W Horizon to magmatic pyrrhotite, and the presence of a pyrrhotite-poor and bornite-rich assemblage suggests that only limited MSS crystallized; this is likely the result of oxidation of the sulfide liquid early on in its evolution. These conclusions demonstrate that the Fe isotope composition of the two most common BMS in Ni–Cu–PGE systems — pyrrhotite and chalcopyrite — are not controlled by mineralizing processes, but rather by the evolution of the sulfide liquid.