

# Iron isotope fractionation by abiotic mechanisms during ore genesis

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Isotopic analysis of ore-forming metals offers the potential for gaining insight into many aspects of ore genetic processes. Biotic and redox factors have been proposed as major controls on the fractionation of Fe isotopes. However, in this study we suggest that significant fractionation of Fe isotopes can occur in the absence of either condition.

Iron-ore samples were taken from underground locations at the Florence Mine, Cumbria, UK. Within the deposit, hematite is the only Fe-bearing phase, occurring in three morphological forms: 1) massive, microcrystalline hematite; 2) reniform/colloform (kidney ore); and 3) euhedral specular. Local Fe-bearing silicate lithologies were sampled at outcrop locations. Solutions were prepared by anion-exchange chromatography. Iron-isotope compositions were analysed using a GV*i IsoProbe* MC-ICP-MS, following a sample-standard bracketing protocol. Long-term analytical  $\delta^{56}\text{Fe}$  reproducibility is  $\pm 0.1\%$  (2s, n=15), based on repeated measurement of industrial, single-element solutions.

Hematite samples have a wide range of  $\delta^{56}\text{Fe}_{\text{IRMM-014}}$  compositions: -1.65 to 0.46‰. This spread is systematic, dependant on both morphotype and sampling location. Massive hematite from proximal to major local faults has  $\delta^{56}\text{Fe}$  values of -0.67 to -0.27‰, whereas samples from increasingly distal locations have values of up to 0.37‰. Kidney and specular varieties show the same spatial variation, but values for these morphotypes are offset to lighter values by  $\sim 0.6\%$  relative to massive samples at the same locations. Silicate samples fall into two main groups: granite  $\delta^{56}\text{Fe} = 0.37\text{-}0.49\%$ ; and sandstone  $\delta^{56}\text{Fe} = 0.18\text{-}0.31\%$ .

Experimental investigation shows that when granite is leached by an aqueous solution the resultant fluid can have a  $\delta^{56}\text{Fe}$  composition of -0.35‰ relative to the original granite. This, coupled with kinetic fractionation during precipitation, can account for the values observed for massive hematite close to the faults. Simple Rayleigh distillation processes then account for the evolving pattern of  $\delta^{56}\text{Fe}$  composition away from the faults, indicating fluid flow direction. Localised hematite dissolution and partial reprecipitation, again involving kinetic Fe fractionation, explains the  $\delta^{56}\text{Fe}$  pattern observed in kidney and specular samples. Consequently, this indicates that these types were formed by post-ore reworking of the earlier, massive ore, and not by a later pulse of ore-fluid. At no stage is there evidence for biological or redox fractionation during emplacement of the ore body.