



Stable Fe isotope variation within a hematite ore-body and related Fe source rocks

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The West Cumbrian hematite deposits are hosted in Dinantian limestone and form a belt running to the west and north-west of the major Lake District batholith, NW England. Hematite is the only major iron-bearing phase, and occurs in three morphological forms: 1) massive hematite, formed by metasomatic replacement of the host limestone; 2) reniform/colloform hematite ("kidney ore"); and 3) euhedral crystalline, specular hematite. The latter two appear to be synchronous phases, with one or both forming in void space within the earlier, massive form. Ore samples were taken at various locations underground at Florence Mine, Egremont, including examples of all three morphological varieties. Putative Fe-source lithologies were sampled at surface outcrop locations, including samples from the overlying Permo-Triassic red-bed sandstone formations, and underlying basement granite and other igneous lithologies.

Samples were purified using anion-exchange chromatography. Iron-isotope compositions were analysed using a GVi IsoProbe MC-ICP-MS at the Natural History Museum, London, following a sample-standard bracketing protocol. Long-term analytical $\delta^{56}\text{FeIRMM-014}$ reproducibility is ± 0.1 permil (2s, $n = 15$), based on repeated measurement of industrial, single-element solutions. Relative to local major fault structures, early, massive hematite samples from proximal locations give $\delta^{56}\text{FeIRMM-014}$ values of -0.67 to -0.24 permil, whereas more distal locations have values of 0.24 to 0.37 permil. Later phases mirror this variation pattern, however values in these samples show a displacement of ~ 0.6 permil towards lighter values, relative to massive hematite taken from the same location. This pattern is observed both within the main Florence-Beckermet ore body and in minor, associated ore-bodies. Permo-Trias sediment samples display a range in $\delta^{56}\text{FeIRMM-014}$ values of 0.18 - 0.31 permil, while basement granite samples have values of 0.37 - 0.49 permil.

Quantitative dissolution of Fe-oxide grain coatings within the red-bed facies results in fluids with Fe-isotope compositions identical to the source. However, previous work suggests that aqueous alteration of igneous minerals results in fluids with Fe-isotope compositions lighter than the source. A leached granite Fe-source would best account for the relatively light compositions noted at the more proximal locations, with Rayleigh distillation fractionation driving values towards heavier compositions as fluids moved outward from the principal fluid conduit. Development of kidney and specular hematite is heterogeneous through the deposit, with percentages varying from <5 to >30% of total hematite at any individual location. The observed pattern of Fe-isotope composition distribution suggests that the later phases derive their Fe content from localised dissolution and reprecipitation of the earlier, massive hematite body, rather than being formed from a second pulse of Fe-enriched brine.