Copper stable isotopes as tracers of metal-sulphide segregation and impact melting processes on iron meteorite parent bodies

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We report high precision Cu isotope data for magmatic and non-magmatic iron meteorites, for which Fe isotope data are also available. The Cu isotope compositions of metals ($\delta^{65}\text{Cu}_{\text{M}}$) and sulphides ($\delta^{65}\text{Cu}_{\text{FeS}}$) range from -9.30 ‰ to 0.99 ‰ and from -8.90 to 0.63 ‰, respectively. Metal-troilite fractionation factors ($\Delta^{65}\text{Cu}_{\text{M-FeS}} = \delta^{65}\text{Cu}_{\text{M}} - \delta^{65}\text{Cu}_{\text{FeS}}$) are highly variable. In the non-magmatic (IAB, IIICD) irons, $\delta^{65}\text{Cu}_{\text{M}}$ and $\delta^{65}\text{Cu}_{\text{FeS}}$ show broad correlations with published metal Cu concentrations and correlations between $\delta^{65}\text{Cu}_{\text{FeS}}$ and $\Delta^{65}\text{Cu}_{\text{M-FeS}}$ with troilite iron isotope compositions ($\delta^{57}\text{Fe}_{\text{FeS}}$) and metal-troilite iron isotope fractionation factors ($\Delta^{57}\text{Fe}_{\text{M-FeS}}$) are also present. We propose that the range in $\delta^{65}\text{Cu}_{\text{FeS}}$ and $\Delta^{65}\text{Cu}_{\text{M-FeS}}$ displayed by the non-magmatic irons is produced by kinetic stable isotope fractionation accompanying melting and diffusional transport of Cu, where the lighter isotope is preferentially concentrated into FeS. However, this process cannot explain the range in $\delta^{57}\text{Fe}_{\text{FeS}}$ and $\Delta^{57}\text{Fe}_{\text{M-FeS}}$ values as unrealistically large amounts of Fe would need to be transferred. As concluded in an earlier study [1], we suggest that the range in $\Delta^{57}\text{Fe}_{\text{M-FeS}}$ reflects incomplete isotopic equilibrium during cooling, where the irons with the largest $\Delta^{57}\text{Fe}_{\text{M-FeS}}$ values are closest to Fe isotope equilibrium. These irons also display the smallest $\Delta^{65}\text{Cu}_{\text{M-FeS}}$ values. We propose that these irons cooled the most slowly from magmatic temperatures, experienced minimal subsequent thermal perturbations, and are therefore the closest to isotopic equilibrium for both systems. The irons with the smallest $\Delta^{57}\text{Fe}_{\text{M-FeS}}$ and largest $\Delta^{65}\text{Cu}_{\text{M-FeS}}$ values experienced faster cooling such that Fe isotope equilibrium between metal and troilite was not reached, and were subject to later thermal events, which resulted in local melting and diffusional transport of Cu from metal to sulphide. The contrasting thermal histories that can be reconstructed for the IAB and IIICD irons using Cu and Fe isotopes are consistent with models that invoke episodes of impact related breakup and reassembly in the evolution of their parent bodies.

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Formation of Selenium nanospheres accompanying bioremediation of a Uranium-contaminated aquifer

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Removal of selenium from uranium-contaminated groundwater was documented during bioremediation activities at the Department of Energy's Rifle Integrated Field Research Challenge (IFRC) site in Rifle, Colorado. Selenium was removed from groundwater and concentrated in its elemental form [Se (0)] within a mineralized biofilm attached to tubing used to circulate acetate in groundwater. Scanning and transmission electron microscopy revealed close association of spherical Se (0) precipitates and cell surfaces, with selenium aggregates having an average particle diameter of 50-60 nm. While total selenium in groundwater never exceeded 1.2 μM over the three-week treatment period, enrichment of Se (0) within the tubing (1580 μmol m^{-2}) suggests a sorbed reservoir of selenium contributed to that concentrated within the biofilms. We propose that stimulation of iron-reducing microorganisms - as documented by increases in ferrous iron and a *Geobacter*-dominated microbial community - liberated an adsorbed pool of selenium following reductive dissolution of iron oxide sorbents, making it available for reductive immobilization by the tubing-associated, selenium-reducing microorganisms. The selenium removal process appeared to be the result of a mixed microbial community within the biofilm capable of coupling the oxidation of acetate to the reduction of oxygen, nitrate and aqueous selenium species. Phylogenetic analysis of the tubing-associated biomass revealed a community dominated by strains of *Dechloromonas* sp. and *Thaurea* sp., with isolates exhibiting genetic similarity to the latter group having been previously shown to reduce selenate to elemental selenium in laboratory studies. The predominance of *Dechloromonas sp.* in both the tubing biofilms and selenium-amended laboratory enrichment cultures suggests these well known perchlorate-reducing bacteria may also have the ability to reduce selenium or play a previously unrecognized role in the selenium removal process.