Copper isotopes and the role of sulphides during Earth's differentiation

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Copper is moderately volatile and exhibits both siderophile and chalcophile behaviour; it is estimated that 2/3 of terrestrial Cu is in the core [1]. Hence, the Cu isotope composition of the mantle has potentially been affected by volatile loss and core formation, and could provide significant clues to the processes occurring during early Earth history.

To investigate this, δ^{65}Cu estimates for both mantle (BSE) and bulk Earth are required. By analysing a representative suite of peridotites, komatiites and basalts, we have investigated the behaviour of Cu isotopes during mantle melting and magmatic differentiation, and established a BSE δ^{65}Cu [2] value of 0.07 ± 0.11 ‰ (2sd). To constrain bulk Earth δ^{65}Cu, we have utilised previous analyses of chondritic meteorites [3] coupled with new data for enstatite chondrites which gives a range of bulk Earth estimates, from δ^{65}Cu = −0.19 to −0.28 ± 0.10 (2sd). In all cases, BSE is isotopically heavier than bulk Earth.

This suggests that, either, isotopically light Cu was preferentially lost through volatilisation on the proto-Earth, or there is an isotopically light Cu reservoir on Earth. We rule out the former, based on the BSE isotopic composition of the more volatile, lithophile element Zn [3, 4]. Regarding the latter, metal-silicate equilibration of Cu during core formation is an obvious candidate; however, through a series of piston-cylinder experiments, we find that metal is preferentially enriched in the heavier Cu isotope, which would result in a bulk Earth even heavier than chondritic estimates. To solve this conundrum, we posit that isotopically light Cu entered the Earth's core as a sulphide phase, as the final stage of core segregation.

[1] McDonough, ToG, 2003; [2] $\delta^{65}\mathrm{Cu} = [(^{65}\mathrm{Cu}/^{63}\mathrm{Cu}_{sample}) / (^{65}\mathrm{Cu}/^{63}\mathrm{Cu}_{SRM976}) - 1] \times 10^3$; [3] Luck et al., GCA 69, 2005; [4] Chen et al., EPSL 369, 2013.