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Copper isotope evidence for a Cu-rich mantle source of the world-class Jinchuan magmatic Ni-Cu deposit

Yun Zhao[1,2,3], Sheng-Ao Liu[1,*], Chunji Xue[1], and Meng-Lun Li[1]

[1]State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Beijing 100083, China
[2]State Key Laboratory for Mineral Deposits Research, Nanjing University, Nanjing 210023, China
[3]Key Laboratory of Deep-Earth Dynamics of Ministry of Natural Resources, Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China

Abstract

A Cu-rich mantle source may play a key role in generating giant magmatic Ni-Cu deposits worldwide, but evidence for the source's Cu enrichment and its mechanism is still rare. Copper isotopes can provide novel and direct insights into this issue since metasomatism that causes Cu enrichment in the mantle is commonly associated with a huge Cu isotope fractionation. Here we present the first Cu isotopic study on the world-class Jinchuan magmatic Ni–Cu deposit in China, including disseminated, net-textured, and massive sulfides. The disseminated and net-textured sulfides have variable δ^{65}Cu values (+0.36 ± 0.38‰, n = 42), which are higher than those of massive sulfides (−0.44 ± 0.28‰, n = 11). The country rocks have a narrow δ^{65}Cu range of 0.21 to 0.23‰, which is unlikely to have caused the large δ^{65}Cu variations. The absence of a relationship between δ^{65}Cu and whole-rock Cu contents rules out the possibility of surface weathering and diffusion-driven processes. Furthermore, the lack of correlation between δ^{65}Cu and whole-rock Cu/Ni and Pd/Ir ratios excludes large Cu isotopic variations as a result of the progressive evolution of parental magma or sulfide melt. Numerical modeling indicates that the initially segregated sulfide melt has a mean δ^{65}Cu of 0.44 ± 0.22‰ (2SD). Sulfide-liquid fractionation could have contributed to the enrichment of ^{65}Cu in the Cu-rich net-textured sulfides and depletion of ^{65}Cu in massive sulfides, respectively. The fractionated sulfide melts were fragmented and assimilated by new magma pluses, and consequently, the new segregated sulfide melts acquired lighter and more variable δ^{65}Cu values in comparison with the initially accumulated sulfide melts. The estimated Cu isotopic composition of parental magmas for the Jinchuan Ni-Cu deposit is 0.54 ± 0.22‰ (2SD), which is up to ~0.5‰ higher than the mantle value. Copper transportation from oxidized subducted slabs to mantle peridotites and/or dissolution of Cu-bearing sulfides in the mantle caused oxidative breakdown and reprecipitation of sulfides and shifted the hybridized mantle source toward heavy δ^{65}Cu as previously observed in mantle xenoliths. Our study, therefore, suggests that the source's pre-enrichment is a key step in the generation of giant magmatic Ni-Cu deposits.

Keywords: Copper isotopes, initial Cu enrichment, mantle metasomatism, magmatic Ni-Cu deposits