American Mineralogist, Volume 107, pages 1968–1981, 2022

Oxygen-fugacity evolution of magmatic Ni-Cu sulfide deposits in East Kunlun: Insights from Cr-spinel composition

Lihui Jia[1,*], Yi Chen[1,2,*], Bin Su[1], Qian Mao[1], and Di Zhang[1]

[1]State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
[2]University of Chinese Academy of Sciences, Beijing 100049, China

Abstract

In this study, we use Cr-spinel as an efficient indicator to evaluate the oxygen fugacity evolution of the Xiarihamu Ni-Cu deposit and the Shitoukengde non-mineralized intrusion. Oxygen fugacity is calculated using an olivine-spinel oxybarometer, with spinel $Fe^{3+}/\Sigma Fe$ ratios determined by a secondary standard calibration method using an electron microprobe. Cr-spinel $Fe^{3+}/\Sigma Fe$ ratios of the Xiarihamu Ni-Cu deposit vary from 0.32 ± 0.09 to 0.12 ± 0.01, corresponding to magma f_{O_2} values ranging from ΔQFM+2.2 ± 1.0 to ΔQFM-0.6 ± 0.2. By contrast, those of the Shitoukengde mafic-ultramafic intrusion increase from 0.07 ± 0.02 to 0.23 ± 0.04, corresponding to magma f_{O_2} varying from ΔQFM-1.3 ± 0.3 to ΔQFM+1.0 ± 0.5. A positive correlation between f_{O_2} and Cr-spinel $Fe^{3+}/\Sigma Fe$ ratios suggests that the Cr-spinel $Fe^{3+}/\Sigma Fe$ ratios can be used as an indicator for magma f_{O_2}. The high f_{O_2} (QFM+2.2) of the harzburgite in the Xiarihamu Ni-Cu deposit suggests that the most primitive magma was characterized by relatively oxidized conditions, and then became reduced during magmatic evolution, causing S saturation and sulfide segregation to form the Xiarihamu Ni-Cu deposit. The evolution trend of the magma f_{O_2} can be reasonably explained by metasomatism in mantle source by subduction-related fluid and addition of external reduced sulfur from country gneisses (1.08–1.14 wt% S) during crustal processes. Conversely, the primitive magma of the Shitoukengde intrusion was reduced and gradually became oxidized (from QFM-1.3 to QFM+1.0) during crystallization. Fractional crystallization of large amounts of Cr-spinel can reasonably explain the increasing magma f_{O_2} during magmatic evolution, which would hamper sulfide precipitation in the Shitoukengde intrusion. We propose that the temporal evolution of oxygen fugacity of the mantle-derived magma can be used as one of the indicators for evaluating metallogenic potential of Ni-Cu sulfide deposits and the reduction processes from mantle source to shallow crust play an important role in the genesis of magmatic Ni-Cu sulfide deposits.

Keywords: Oxygen fugacity, Cr-spinel, ultramafic rocks, Ni-Cu sulfide deposit, East Kunlun