EGU24-103, updated on 21 Jul 2024
https://doi.org/10.5194/egusphere-egu24-103
EGU General Assembly 2024

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

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Redox state of parental magma would have undergone significant changes from partial melting in the mantle to emplacement in the shallow crust, which might play a critical role in the genesis of magmatic Ni-Cu sulfide deposits in convergent tectonic settings. In this study, we present mineralogy, petrology, and fO_2 calculations of the Xiarihamu Ni-Cu deposit and the Shitoukengde non-mineralized intrusion in the East Kunlun orogenic belt. Olivine-spinel pairs in different magmatic stages were chosen to estimate the magma fO_2 (olivine-spinel oxybarometer), track the changes in oxygen fugacity during magmatic evolution, and reveal its influence on the metallogenic mechanism of the Ni-Cu sulfide deposit. Spinel $Fe^{3+}/\Sigma Fe$ ratios determined by a secondary standard calibration method using electron microprobe. Those ratios of the Xiarihamu Ni-Cu deposit vary from 0.32±0.09 to 0.12±0.01, corresponding to magma fO_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 fO_2 varying from ΔQFM-1.3±0.3 to ΔQFM+1.0±0.5. A positive correlation between fO_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 fO_2. The high fO_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 fO_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 fO_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 reduction processes from mantle source to shallow crust play an important role in the genesis of magmatic Ni-Cu sulfide deposits.