

Magma oxygen fugacity of mafic-ultramafic intrusions in convergent margin settings: Insights for the role of magma oxidation states on magmatic Ni-Cu sulfide mineralization

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ABSTRACT

Oxygen fugacities (f_{O_2}) of mantle-derived mafic magmas have important controls on the sulfur status and solubility of the magmas, which are key factors to the formation of magmatic Ni-Cu sulfide deposits, particularly those in convergent margin settings. To investigate the f_{O_2} of mafic magmas related to Ni-Cu sulfide deposits in convergent margin settings, we obtained the magma f_{O_2} of several Ni-Cu sulfide-bearing mafic-ultramafic intrusions in the Central Asian Orogenic Belt (CAOB), North China, based on the olivine-spinel oxygen barometer and the modeling of V partitioning between olivine and melt. We also calculated the mantle f_{O_2} on the basis of V/Sc ratios of primary magmas of these intrusions.

Ni-Cu sulfide-bearing mafic-ultramafic intrusions in the CAOB include arc-related Silurian-Carboniferous ones and post-collisional Permian-Triassic ones. Arc-related intrusions formed before the closure of the paleo-Asian ocean and include the Jinbulake, Heishan, Kuwei, and Erbutu intrusions. Post-collisional intrusions were emplaced in extensional settings after the closure of the paleo-Asian ocean and include the Kalatongke, Baixintan, Huangshandong, Huangshan, Poyi, Poshi, Tulaergen, and Hongqiling No. 7 intrusions. It is clear that the magma f_{O_2} values of all these intrusions in both settings range mostly from FMQ+0.5 (FMQ means fayalite-magnetite-quartz oxygen buffer) to FMQ+3 and are generally elevated with the fractionation of magmas, much higher than that of MORBs (FMQ-1 to FMQ+0.5). However, the mantle f_{O_2} values of these intrusions vary from ~FMQ to ~FMQ+1.0, just slightly higher than that of mid-ocean ridge basalts (MORBs) (\leq FMQ). This slight difference is interpreted as the intrusions in the CAOB may have been derived from the metasomatized mantle wedges where only minor slab-derived, oxidized components were involved. Therefore, the high-magma f_{O_2} values of most Ni-Cu sulfide-bearing mafic-ultramafic intrusions in the CAOB were attributed to the fractionation of magmas derived from the slightly oxidized metasomatized mantle. In addition, the intrusions that host economic Ni-Cu sulfide deposits in the CAOB usually have magma f_{O_2} of $>$ FMQ+1.0 and sulfides with mantle-like $\delta^{34}\text{S}$ values (-1.0 to $+1.1\%$), indicating that the oxidized mafic magmas may be able to dissolve enough mantle-derived sulfur to form economic Ni-Cu sulfide deposits. Oxidized mafic magmas derived from metasomatized mantle sources may be an important feature of major orogenic belts.

Keywords: Mafic-ultramafic intrusion, magmatic Ni-Cu sulfide mineralization, magma oxygen fugacity, Central Asian orogenic belt, convergent margin setting