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Tectonic controls on Ni and Cu contents of primary mantle-derived magmas for the formation of magmatic sulfide deposits

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Abstract

We have modeled the genesis of primary mantle-derived magma to explore the controls exerted on its Ni-Cu ore potential by water content, pressure, and mantle potential temperature (T_p). During decompression melting, Ni concentration in primary magma decreases with an increasing degree of melting, which is in contradiction to long-held understanding obtained from previous isobaric melting models. Pressure exerts a first-order control on the ore potential of primary plume-derived melt, such that plumes rising beneath thick lithosphere with melting paths terminating at relatively high pressure generate Ni-rich melts. Additionally, as plumes with higher T_p produce more Ni-rich melt at a higher pressure, the magmatism related to hotter plume-centers may have the greatest ore potential. On the other hand, the strong dependence of Cu behavior upon the presence or absence of residual sulfide is partly countered in decompression melting. Significant influences of mantle-contained water on Ni and Cu partitioning are restricted to low-degree melting. While release of H_2O in lithosphere delamination may trigger voluminous magmatism, the Ni concentration in the melt is far lower than in melt generated from plumes. Furthermore, if isobaric melting dominates when the subcontinental lithospheric mantle (SCLM) is heated by underlying hotter plumes, the plume-lithosphere interaction plays no active role in the Ni ore potential of primary magma because derived melt volumes are relatively small. In subduction zones, flux-melting of the mantle wedge tends to generate cool Ni-poor melts, however hot subduction zones may produce magmas with increased metal concentrations. Overall, the anticipated ranges of Ni contents in primary melts are strongly controlled by tectonic setting, with a range of 100–300 ppm in subduction zones, 230–450 ppm in mid-ocean ridges, and 500–1300 ppm in plume suites. There are only minor differences in the Cu concentrations of primitive magmas generated from diverse tectonic settings, despite the variations in Cu partitioning behaviors.

Keywords: Mantle partial melting, Ni and Cu partitioning behaviors, tectonic settings, ore potential of primary magma, forward model; Planetary Processes as Revealed by Sulfides and Chalcophile Elements