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Clay Mineralogy and Zonation in the Campana Mahuida Porphyry Cu Deposit, Neuquén, Argentina: Implications for Porphyry Cu Exploration

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Abstract

Analysis of clay mineralogy and illite crystallinity in the clay-size fraction (<2 μm) of 102 whole-rock samples from 33 drill cores of the Campana Mahuida porphyry copper deposit has identified (1) a central chlorite-rich zone superimposed on the potassic core, (2) a peripheral chlorite-rich zone in the outermost propylitic halo, (3) an illite-rich zone within the south and southwestern quadrangles of the phyllic halo that has overprinted the outer potassic core and inner propylitic zone, and (4) a smectite-rich zone within the northeast and northwest quadrangles of the phyllic halo. Lateral and vertical variations in clay mineralogy and illite crystallinity are attributed to alteration and mineralization such that surficial or remotely sensed mineralogy can be used to see through superimposed supergene alteration.

In the chlorite zones, the chlorite octahedral cations vary between 11.62 and 11.99 per $O_{20}(OH)_{16}$ formula unit and the tetrahedral cation composition is between (Si_7Al_1) and $(Si_{4.6}Al_{3.4})$ with an overall composition of $(Al_{2.3-2.85}Mg_{5.8-7.9}Fe^{2+}_{1.5-3.1})(Si_{5.5-5.9}Al_{2.1-2.5})O_{20}(OH)_{16}$. Thus, all are trioctahedral chlorites and, based on $Fe^{2+}/(Fe^{2+} + Mg)$ and Si contents, can be classified as Fe-Al clinochlore and Fe clinochlore. The chlorite zone in the potassic core formed mostly by destruction of hydrothermal biotite during sulfide precipitation as temperature decreased and f_{S_2} increased. The chlorite contains more Mg than the biotite it replaces and has higher $Fe^{2+}/(Fe^{2+} + Mg)$ but lower Al_2O_3 than chlorite formed in the outer propylitic halo.

The phyllic zone that surrounds the potassic core is dominated by illite $(K_{1.25-1.84}Na_{0.0-0.15})(Al_{3.24-3.98}Fe_{0.01-0.35}Mg_{0.06-0.64})(Si_{6.04-6.78}Al_{1.22-2.07})O_{20}(OH)_4$. Illite from the centers and selvages of veins has a composition close to muscovite, whereas disseminated illite in altered protoliths contains more Mg and Fe cations in the octahedral sites, although all belong to the $2M_1$ polytype. This hypogene alteration resulted from fluids with lower pH, temperature, and salinity than fluids responsible for the potassic alteration, propylitic alteration, chlorite formation after biotite, and Cu mineralization. The K content of illite decreases outward from the potassic core and from early, disseminated illite to late crosscutting veinlets.

A smectite-rich zone occurs in the northeast and northwest quadrangles of the phyllic halo. Based on X-ray diffraction analysis and a structural formula of $(Ca,K,Na)_{0.18-1.2}(Al_{2.8-3.8}Fe_{0.11-0.78}Mg_{0.1-1.04}Mn_{0-0.01}Ti_{0-0.07})(Si_{6.9-7.9}Al_{0.1-1.07})O_{20}(OH_4)$, the analyzed smectites are of the aluminum montmorillonite-beidellite dioctahedral series. Smectites from the deepest parts of the porphyry copper system, either from the potassic core or the phyllic halo, are montmorillonite-type smectite, with high total MgO and interlayer cation contents, and are probably hypogene, whereas shallow samples above the potassic core and phyllic halo contain beidellite-type smectite that has the highest FeO_{total} and Al_2O_3 contents. This likely resulted from intense leaching at low temperatures as is typical of a supergene environment.

Illite is widespread in the Campana Mahuida porphyry Cu deposit and in the unaltered Tordillo Formation that hosts the deposit. The Kübler index (illite crystallinity) in the clay-size fraction of fresh sandstone (0.7° 2θ) corresponds to the highest grade of diagenesis, whereas in the altered rocks in the uppermost level of the deposit, the Kübler index ranges from 0.5 to 0.2° 2θ, values that are indicative of high temperature and/or high fluid/rock ratios. Within the deposit, illite crystallinity increases from the outer limit of the phyllic zone toward the center of the deposit, above the potassic core, and with depth, from the leached cap to the hypogene sulfide copper zones. Contours of illite crystallinity from the leached cap roughly delineate the outer limits of the ore zones at depth.

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