Hydrothermal alteration patterns of the Ticlioporphyry Cu-Au prospect, Miocene Morocochadistrict, central Peru: surface spatial distributionmineralogy and geochemistry

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Abstract

The Morococha mining district is part of the Miocene polymetallic belt of central Peruand hosts various types of ore bodies – porphyries, skarns, replacement bodies (mantos) andpolymetallic veins. The geology of the district comprises volcanic sequences of the PermianMitu Group, overlain by Triassic to Jurassic carbonates of the Pucará Group, including basaltflowintercalations such as the Montero Basalt, and, mainly in the western part, by Cretaceouscarbonate sedimentary sequences. The magmatic activity began at 14.1 Ma with theemplacement of the Anticona diorite intrusion that covers a large area in the western part ofMorococha district. During Late Miocene (7-9 Ma) a serie of porphyry intrusions (diorites,granodiorites to quartz-monzonites in composition) intruded the different sedimentary sequencesas well as the Anticona diorite. Most of these intrusions are barren, but some of them sharefeatures with typical porphyry Cu systems. The Ticlio Cu-Au porphyry is an atypical porphyryin the district, where epithermal polymetallic mineralization (Ag, Zn and Pb) is predominantin the peripheral part and where Cu-Mo porphyries systems are dominant in the district suchas Toromocho and Codiciada.The Ticlio Cu-Au porphyry is a single granodiorite intrusion that intruded sedimentarylayers as well as the Anticona intrusion during the Late Miocene. The Ticlio intrusion islocated in the westernmost part of Morococha district. The studied area represents about 2.5km^2 and field works gave the possibility to map this region.The geology of the area consists of Cretaceous dolomitic limestones, the Ticlio intrusivestock in the central part with xenoliths of basalt on the eastern fringe of the intrusion and theAnticona diorite intrusion that delimits the eastern part of the studied area. Different systems offracturation in time offset the area. The first system displays a NE-SW orientation whereas the lastsystem of fracturation shows a NW-SE trend. Dike and aplitic dike, which are altered, crosscut theTiclio intrusion. Based on the crosscutting relationships the aplitic dike could be syn-mineralization.Dike that offsets the Anticona intrusion could be post-mineralization.According to the alteration map, the studied area is overprinted by different zones ofalteration. Potassic alteration that is characterized mainly by secondary feldspars, biotites,quartz and magnetite is dominant in the central part of the system where quartz-magnetiteveins form the stockwork. In the southern Ticlio intrusion, the density of veining is strongerto the SE that is accompanied by increasing in the intensity of the potassic alteration. This isinterpreted as the focus of the upwelling fluids. The second stage of the alteration ischaracterized by chlorite-epidote and the late stage of the alteration is illustrated by thesericitic alteration that occurs on the rim of the Ticlio porphyry and developed about 100’000years after the emplacement of the Ticlio intrusion.This study also discusses the mineralogy and whole-rock geochemistry on the igneousrocks as well as whole-rock geochemistry and elemental mass balance of the hydrothermalalteration zones within Ticlio porphyry copper-gold deposit.Whole-rock analyses display high-K calc-alkaline affinity and indicate magmatic arcsignature with a subducted slab component. Microscope observations and electronmicroprobe analyses of phenocrysts of plagioclase suggest mixing process in the magmachamber.The rare earth elements are often considered to be immobile, unaffected by the leachingand geochemical redistribution processes that characterize hydrothermal alteration. However,recent studies on the REE contents of hydrothermal fluids and hydrothermally altered rockshave shown that, under particular conditions, REE can be

mobilized by hydrothermalalteration. Chondrite-normalized REE plots of altered rock together with mass balancecalculations were used to understand the interactions between fluids and rock and to5characterize REE behavior in the different alteration zones. Potassic alteration is accompaniedby enrichment in K, Si and depletion in Fe, Sr, Ba. These changes attended replacement ofplagioclase and amphibole by K-feldspars and biotite respectively. The copper is introducedmost probably during this stage of alteration because of the gain in Cu. Gold could beintroduced at the same time. In contrast, phyllic alteration displays strong depletion in Mg,Ca, Na, Fe Sr and Ba that reflect sericitization of alkali feldspars and destruction offerromagnesian minerals. The addition of Si is consistent with silicification that is a majorfeature of phyllic alteration. This hydrothermal alteration is accompanied by strong depletionin heavy rare earth elements (HREE). This latter involves acid leaching during the waningstage of the hydrothermal system. In general, major elements and some minor trace elementsdecrease from the least altered rock to the late alteration. Moreover, depletion in MREEaccompanied by depletion in P_2O_5 indicates that apatite do not resist at the phyllic alteration.The Ticlio porphyry shares similar features of typical porphyry systems. Actually,hydrothermal zoned alteration patterns stockwork and skarn characterize the Ticlio stock.Microscopy observations mass balance calculations and REE patterns indicate a saline andoxidizing hydrothermal fluids with an evolution in its acidity that is typical for the porphyrysystem.Finally, gold occurs as inclusion within the chalcopyrite presents in the xenoliths ofbasalt that display higher concentration values of gold and copper compared to the leastaltered and altered rocks of the Ticlio intrusion. Therefore, this area is not propitious for aneventual prospection due to the low grade of gold and copper and the small volume of theTiclio porphyry deposit.