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Intrusion sequence, vein evolution and timing of mineralization at Encuentro porphyry Cu-Au-Mo deposit, Chile

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The Encuentro porphyry Cu-Au-Mo deposit is part of the middle Eocene to early Oligocene porphyry copper belt of northern Chile. New core logging observations, together with geologically constrained U-Pb and Re-Os geochronology documents the intrusion sequence, and the timing of Cu-Au and Cu-Mo mineralization. A sequence of five porphyry dikes (Eep-1 to Eep-5) of dacitic composition are synchronous with and genetically related to mineralization. The Encuentro porphyry Cu-bearing dikes span from 42.3 ± 0.7 Ma to 41.2 ± 0.8 Ma, based on U-Pb zircon ages via LA-ICP-MS. The earliest intrusion (Eep-1) contains the highest Cu and Au grades; the metal content decreases systematically from oldest to youngest porphyry phases. Each porphyry intrusion developed a similar sequence of veins: (1) biotite, (2) early dark micaceous halos (EDM), and (3) A-type quartz-K feldspar-anhydrite veins (A1 to A5). In each sequence, biotite veins and EDM halos are cut by A-quartz veins. Cu-bearing sulfides are present in all these veins; however, A-type quartz veins contribute most of the Cu-Au and are the most voluminous vein type in the deposit (up to 56 vol.%, averaging 5 vol.% in rocks with >0.3 wt.% Cu). A-type veins are most abundant within and surrounding the upper parts of the porphyry dikes, and display a concentric distribution that correlates well with the Cu and Au ore shells. Cathodoluminescence (CL) images in A-quartz veins reveal that Cu-bearing sulfides precipitated simultaneously with early bright- and to grey-CL quartz that mainly display mosaic and euhedral growth textures.

Other veins also stable with K-silicate alteration, such as (4) B-type quartz-chalcopyrite±molybdenite, (5) quartz-anhydrite-molybdenite ± Cu-sulfides (QAM), and (6) magnetite±chalcopyrite veins, postdate all porphyry intrusions, and offset earlier biotite veins, EDM halos, and A-quartz veins. QAM veins and to a lesser extent B-type veins contribute the bulk of molybdenum mineralization in the deposit. Six Re-Os ages of molybdenite in different veins types range from 41.3 ± 0.2 Ma to 40.9 ± 0.2 Ma. These dates are consistent with cross-cutting vein relationships and also with the 41.2 Ma age of the youngest porphyry (Eep-5). Hence, most of the Mo mineralization likely occurred as a protracted single event immediately following the emplacement of porphyry phase Eep-5.

Late veins such as (7) chalcopyrite-pyrite±sericite veins, (8) chlorite-sericite-chalcopyrite±pyrite veins, and (9) D-type sericite-pyrite±chalcopyrite veins, are all part of the sericitic alteration. They show a zonal arrangement, where chalcopyrite-pyrite veins are dominant in the core of the deposit, and are outwardly surrounded by chlorite-sericite vein zone, which are surrounded by D-type sericite-pyrite veins occupying the most distal parts of the system. Their spatial distribution and similar mineral assemblages suggest that these veins were likely originated from the same fluid. Changes in mineral ratios and development of wider quartz-sericite selvages towards distal areas were caused by decrease in pH, as a consequence of cooling and acid dissociation. A late hydrothermal breccia with a tourmaline matrix and associated with tourmaline-

pyrite±chalcopyrite veins was emplaced in the eastern part of the deposit. These veins offset and re-open previous emplaced veins.