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Mineralogy and Trace Element Composition of Sulfides from Porphyry-Stage and Minor Late Polymetallic Mineralization in the Gaby District, Northern Chile

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Metal precipitation in porphyry systems involves multiple hydrothermal events forming a continuum of porphyry-style alteration and mineralization commonly overprinted by a late polymetallic stage. Textural variations and trace element content of major sulfides remain largely unexplored in porphyry systems, despite their significant potential for understanding ore-forming processes. Chalcopyrite, bornite, pyrite, and sphalerite composition from both porphyry mineralization and a minor polymetallic stage, as well as supergene chalcocite, are investigated in the Gaby district (northern Chile) using optical microscopy, automated mineralogy (QEMSCAN), electron microprobe, and laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS). Copper mineralization is developed in a suite of Eocene porphyries intruding a Carboniferous-Permian volcano-sedimentary sequence and a Permo-Triassic plutonic complex. An early stage of copper introduction, coeval with potassic alteration, occurs in veinlets and disseminations with chalcopyrite, bornite, molybdenite, and minor pyrite intergrown with K-feldspar and secondary biotite. A second stage of copper precipitation is paragenetically associated with white mica alteration. Chalcopyrite, molybdenite, and locally pyrite intergrown with white mica and chlorite, form a dominantly disseminated mineral association, commonly overprinting the potassic alteration. Sulfides occur also in early halo veinlets that partly reopen previous structures. Traces of luzonite formed at the expense of high-temperature Cu-Fe sulfides are also observed. Polymetallic intermediate-sulfidation mineral associations are sporadically observed at Gaby, consisting of Fe-poor (<0.4 wt% Fe) sphalerite, galena, chalcopyrite, tennantite-tetrahedrite, pyrite, locally wittichenite, and native gold, intergrown with early Ca-Mg-Fe carbonates, minor rhodochrosite, late siderite and Mn-poor calcite, and traces of kaolinite. Secondary chalcocite is formed during supergene processes and can be detected down to >500 m from the present-day surface. LA-ICP-MS results indicate higher In content (5-20 ppm) in porphyry-stage chalcopyrite compared to the polymetallic veins and high Co content (up to 2 wt. %) in pyrite from polymetallic veins in volcanic rocks.