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Evolution of Magmatic-Hydrothermal Systems Forming Porphyry Copper Deposits: Results of Quartz Solubility Modeling

Thomas Monecke[1], James T. Reynolds[1, 2]
1. Colorado School of Mines, Golden, CO, USA, 2. Fluid Inc., Denver, CO, USA

Quartz solubility calculations in the H_2O-NaCl system were conducted to explain the occurrence of consistent crosscutting relationships between different vein types in porphyry deposits. The model predicts that high-temperature (≳500°C) ‘A’ vein quartz associated with potassic alteration of the wall rocks precipitates as a result of cooling of the magmatic-hydrothermal fluids. In shallow (≲1.5 km) deposits, rapid decompression may form ‘banded’ quartz veins. During continued cooling of the magmatic-hydrothermal system, ‘B’ vein quartz is formed at intermediate temperatures (≳375-500°C). The fluid inclusion inventory of this quartz suggests formation at fluctuating pressure conditions, marking the lithostatic to hydrostatic transition, and the change of wall-rock behavior from ductile to brittle. Textural evidence from many porphyry veins suggests that hypogene sulfide minerals present in ‘A’ and ‘B’ veins postdate the quartz, and contacts between quartz and sulfide minerals commonly show dissolution textures. Hypogene sulfide minerals in ‘C’ veins form at conditions of retrograde quartz solubility, explaining why mineralized 'paint' veins contain little to no quartz. The quartz solubility calculations suggest that ‘C’ vein formation occurs at temperatures ~375–450°C from low-salinity, single-phase fluids escaping from the lithostatic to the hydrostatic environment. In many deposits, these veins are associated with chlorite, chlorite-K-feldspar, or chlorite-sericite alteration. Late quartz is formed during continued cooling of the hydrothermal fluids at ≲375°C within the single-phase field of the H_2O-NaCl system. This process is responsible for the formation of quartz in ‘D’ veins and later base-metal-bearing ‘E’ veins, which are associated with phyllic, advanced argillic, or argillic alteration. An integrated study of the fluid inclusion inventory and cathodoluminescence properties of stockwork vein samples from deposits such as Cöpler in Turkey, Erdenetiin Ovoo in Mongolia, Santa Rita in New Mexico, and Yulong in China confirms the predictions made from quartz solubility modeling.