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Origin of Massive Calcite Veins in the Golden Cross Low-Sulfidation, Epithermal Au-Ag Deposit, New Zealand

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Abstract

At Golden Cross, andesitic lavas and volcaniclastic rocks host epithermal veins that formed in the shallow part (<500 m depth) of a hydrothermal system. Calcite is a trace mineral in precious metal-bearing quartz veins and a common replacement mineral in the surrounding intensely altered host rocks. Late barren calcite veins crosscut the precious metal-bearing quartz-sulfide veins and were a significant source of dilution in the underground workings of the mine; where large, they also posed significant problems for ground control. These veins range up to 10 m in width and contain more than 99 percent calcite, predominantly as massive coarse crystals, with only trace amounts of quartz, pyrite, and clays.

Fluid inclusion data indicate that much of the late barren calcite formed between 160° and 220°C, overlapping the temperature range of fluid inclusions from the precious metal-bearing quartz-sulfide veins. Ice melting temperatures range from 0.0° to –1.1° C. Slight vapor bubble expansion during crushing of a few calcite-hosted fluid inclusions indicates the presence of dissolved carbon dioxide. These results indicate that the hydrothermal solutions responsible for late calcite deposition were very dilute (<2 NaCl wt percent equiv) and contained up to approximately 2.5 wt percent dissolved carbon dioxide. The best interpretation of the steep T_h vs. T_m cooling trend is carbon dioxide gas loss through phase separation combined with variable amounts of mixing.

The $\delta^{18}O$ composition of calcite from the altered country rock and late veins ranges from 3.4 to 15.4 per mil, with the bulk of the data corresponding to equilibrium $\delta^{18}O$ water compositions of –2 to –6 per mil; this range of compositions is 0 to = 2 per mil lower than the ™$_{18}$O compositions for the waters in equilibrium with quartz from precious metal bearing quartz-sulfide veins. The $\delta^{13}C$ composition of calcite ranges from –3.1 to –9.0 per mil. The equilibrium $\delta^{13}C$ compositions of carbon dioxide for most of these data fall between –7 and –9 per mil.

Electron microprobe analyses indicate that calcite contains less than 10 mole percent combined Mn, Mg, and Fe. Replacement calcite and veinlet calcite show greater substitution by these elements compared to calcite in massive veins, which is nearly pure. The minor element compositions of calcite appear to be primarily controlled by solution composition, and these constituents may be locally derived from the country rock.

Using the knowledge from active geothermal systems of the Taupo Volcanic Zone as a framework for interpretation, we propose that the late massive calcite veins were deposited from downward-moving, CO_2-rich, steam-heated water. This water was heated and locally reached vapor saturation as it descended into the former upflow zone of the hydrothermal system during waning activity. The reverse solubility of calcite accounts for the selective deposition of calcite over all other common hydrothermal phases, and condensation of steam into local ground water accounts for the slightly lower ™$_{18}$O water values. From this we suggest that, for some low-sulfidation epithermal prospects, the occurrence of barren calcite veins may be indicative of CO_2-rich, steam-heated waters that formed as a result of boiling.