

Hydrothermal Alteration and Hydrologic Evolution of the Golden Cross Epithermal Au-Ag Deposit, New Zealand

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Abstract

Golden Cross, located in the Coromandel peninsula, New Zealand, is a classic example of a volcanic rock-hosted, low-sulfidation epithermal gold-silver deposit. Gold and silver ore is confined to the Empire vein system and shallow-level stockwork. The veins are hosted by Miocene to early Pliocene andesites and dacites of the Waipupu Formation and the Waiharakeke Dacite that are unconformably overlain by the postore Whakamoehau Andesite.

Hydrothermal alteration minerals display distinct spatial and temporal zonation around veins, as defined along three cross sections (1,000 m long \times 450 m deep), located 200 m apart, which transect the Empire vein system. Along these sections replacement quartz, chlorite, and pyrite are ubiquitous with the abundance of quartz veinlets increasing toward major veins. Replacement adularia envelops the Empire vein system and shallow stockwork in each section. It is coextensive with, and is variably replaced by, illite that progressively grades upward and laterally into a zone of interstratified illite-smectite that mantles the deposit. Replacement calcite and minor siderite formed contemporaneously with, and also overprint, the above minerals, whereas late barren calcite veins crosscut mineralized quartz veins. Kaolinite \pm pyrite veinlets, together with rare, very local alunite, formed during late-stage hydrothermal activity.

Clay mineral zonation is well developed. Illite occurs at depth and close to the veins, grading outward and upward into illite-smectite, with minor smectite occurring \sim 600 m east of the Empire vein system. This overall zonation reflects paleothermal gradients of \sim 150°C on the periphery to $>$ 220°C near the veins, consistent with the observed T_h range of 150° to 240°C for fluid inclusions in quartz, platy calcite, and late barren calcite veins. Final ice-melting temperatures for inclusions mostly range from 0.0° to -1.4°C , corresponding to apparent salinities of less than 2.4 wt percent NaCl equiv. Ice-melting temperatures combined with vapor bubble expansion on crushing indicate the presence of dissolved CO_2 in some platy calcite and late-stage barren calcite. The CO_2 content is estimated to range from 0.35 to 3.5 wt percent, with the lower limit set by fluid inclusion vapor expansion during crushing and the upper limit by the absence of any observable clathrates. Depth estimates based on inclusions in platy calcite suggest that the shallow-level stockwork zone formed about 100 m below the paleowater table under hydrostatic conditions.

Veins and alteration minerals at Golden Cross formed in the shallow part ($<$ 400 m) of a hydrothermal system analogous to geothermal systems in the nearby Taupo Volcanic Zone. The assemblage of quartz, adularia, chlorite, illite, calcite, and pyrite reflects the upflow of near-neutral pH to weakly alkaline chloride waters. Contemporaneously, steam-heated CO_2 -rich waters formed on the margins and reacted with the wall rock to form the assemblage of calcite, siderite, smectite, illite-smectite, and kaolinite. Eventual thermal collapse and invasion of these peripheral CO_2 -rich waters into the former upflow zone produced late-stage barren calcite veins and an overprint of clay-carbonate alteration minerals. At the same time, localized steam-heated acid-sulfate waters, generated above the water table, descended to form the late overprint of kaolinite, pyrite, and alunite.