

Epithermal Au-Ag-Te Mineralization, Acupan, Baguio District, Philippines: Numerical Simulations of Mineral Deposition

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Abstract

In this study, we discuss the effects of cooling, boiling, fluid mixing, and water-rock interaction on a low-sulfidation chloride water. Our water composition is derived from fluid inclusion and mineralogical studies of the Acupan gold mine, a large gold-silver-tellurium-bearing low-sulfidation epithermal deposit in the Philippines. Our numerical modeling results show that a single mineralizing water (300°C, 0.5 wt % NaCl + KCl, 0.41 m CO₂) will evolve along different reaction pathways in response to different physicochemical processes, and that these pathways are difficult to predict intuitively in many cases. Acidity and redox can evolve dramatically and in different directions, with boiling resulting in oxidation and pH increase, cooling resulting in pH decrease at a relatively constant sulfate/sulfide ratio, and mixing with sulfate-bearing ground waters causing oxidation and acidification.

Based on the correlation of predicted and observed ore and gangue minerals, boiling is concluded to have resulted in the deposition of most of the precious and base metals at Acupan. Continuous boiling, boiling with intermittent gas loss, and throttling probably all occurred at various times during the evolution of the hydrothermal system. The loss of gases during boiling (e.g., H₂S, H₂Te, Te₂) enhanced electrum and base metal sulfide deposition and inhibited the precipitation of hessite and calaverite. Mixing of low-temperature ground waters with the high-temperature chloride water resulted in mineral assemblages that are similar to those observed in shallow levels of the mine and in deep-level, late-stage barren vein fill. Mixing with ground water could account for the observed transition from adularia-carbonate vein assemblages in deep mine levels to sericite-bearing assemblages in shallow levels. Late-stage anhydrite could have formed via mixing with or heating of near-surface ground waters.

We predict tellurium to be transported preferentially in a gas phase. Because tellurium solubilities are predicted to be low in auriferous chloride waters, telluride and native tellurium deposition in low-sulfidation environments may result from condensation of magmatically derived H₂Te_(g) and Te_{2(g)} into deep-level chloride waters. The minor amount of tellurium that dissolves into chloride waters will be deposited effectively by cooling or fluid mixing. Aqueous tellurium will partition strongly into the gas phase in boiling low-sulfidation systems and could precipitate via condensation into lower temperature ground waters. This could lead to vertical zonation of electrum and tellurium-bearing minerals, which may be of significance to mineral exploration.