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Gold Concentrations in Springs at Waiotapu, New Zealand: Implications for Precious Metal Deposition in Geothermal Systems

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Abstract

Gold and silver from a selection of springs at Waiotapu, New Zealand, was preconcentrated onto activated charcoal and analyzed by ICP-MS. The measured gold concentrations were combined with field and laboratory analyses of other components, thermodynamic data and geochemical modeling software to calculate the gold saturation index in each spring, assuming that reduced sulfur ligands largely control gold solubility. The springs that were selected for analysis have elevated concentrations of components that are residually enriched by boiling, so their composition is strongly related to that of the geothermal reservoir. Therefore, these analyses provide information about geochemical processes that operate beneath the springs as well as those at work within the springs. Previous geochemical investigations at Waiotapu indicated that dissolved gold concentrations are elevated within Champagne Pool and in precipitates surrounding this spring. Therefore, it is likely that the reservoir fluid that feeds springs at Waiotapu also contains dissolved gold.

Champagne Pool has the highest gold concentration measured in this study, 109 ngL^{-1} dissolved and 362 ngL^{-1} total. This spring is slightly undersaturated with gold in solution, but the total concentration is higher than the solubility of Au(s). Undersaturation with respect to Au(s) is consistent with deposition of gold by adsorption and concentration within an As- and Sb-sulfide precipitate that forms around Champagne Pool and is similar in magnitude to that expected from modeling of gold adsorption onto As- and Sb-sulfide precipitates.

Elevated Au concentrations of gold (40–90 ngL^{-1}) at two sites downstream from Champagne Pool indicate that deposition of gold within Champagne Pool is inefficient. The two downstream sites are substantially oversaturated with respect to reduced S-Au species; however, assumptions used in solubility calculations are unlikely to be valid at these sites because the oxidation state of the fluids after discharge was not determined. Despite uncertainty in the saturation index calculated at these sites, the elevated concentrations of gold and apparent oversaturation indicate that gold is transported by other ligands, such as polysulfides and thiosulfates or as colloidal particles downstream from Champagne Pool.

Several springs at Waiotapu with moderate concentrations of dissolved reduced sulfur (1–6 mgL^{-1}) have very low dissolved concentrations of gold and are substantially undersaturated with respect to Au(s). Deposition of gold by precipitation requires loss of reduced sulfur ligands through processes such as boiling, oxidation, acidification or sulfide precipitation. Therefore, the low concentrations of gold in springs that contain substantial reduced sulfur indicates that gold is deposited by processes that can cause substantial undersaturation of Au(s), such as adsorption, coprecipitation, or both. Deposition of gold by adsorption or coprecipitation is consistent with the occurrence of gold as impurities in epithermal sulfide minerals. These results do not rule out direct precipitation of Au(s) at Waiotapu but indicate that other depositional mechanisms could also be important in the geothermal system beneath the springs.

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