

Nanoparticles are the Key to Forming Giant Gold Deposits

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Gold concentrations in gold deposits are several orders of magnitude higher than in most ore-forming fluids, and up to five orders of magnitude more concentrated than in typical crustal rocks. Such high concentrations of gold require vast quantities of fluids to pass through small rock volumes in order to deposit the amount of metal found in even a modest deposit. To remove the gold from the transporting fluid effectively, the entire volume of fluid must undergo whatever process is thought to be responsible for gold deposition, e.g., sulfur oxidation within the rock volume occupied by the gold deposit. Nanoparticulate suspensions, or colloids, present an alternative transport medium to the aqueous ionic gold complexes that are typically considered to have formed gold deposits. Colloidal transport of large gold volumes along with silica nanoparticles is observed in epithermal gold systems, and nanoparticulate gold is present in most deposit types, from orogenic, pyrite-hosted deposits to supergene systems. Despite the widespread acceptance of nanoparticles in deposits with “invisible gold,” colloidal transport is rarely considered as a mechanism to accumulate large volumes of gold. Through a combination of micro- and nanoscale characterization of the crystallographic and chemical variation in gold grains from the Plutonic gold mine, Western Australia, we present the first direct evidence that large, high economic grade, orogenic gold deposits may form from gold nanoparticles.

Electron backscatter diffraction of gold grains from Plutonic gold mine shows that there are micron-scale domains of orientation variation within the grains. These domains are composed of 100-nm nanoparticles of gold that have a strong crystallographic orientation. In between the gold nanoparticles are zoned nanoparticles of platinum-iron alloy. The large gold aggregates also contain 10 micron-scale inclusions of euhedral calcium-aluminium silicate. Nanoscale chemical maps show that the inclusions are composed of silica and gold nanoparticles in a matrix of calcium-iron-aluminium oxide. Only the gold is universally crystalline, but single crystal diffraction patterns consistent with epidote are present in some inclusions, indicating recrystallization of the amorphous oxides. The micro- and nanostructures examined in this study provide direct evidence of orogenic gold being deposited from a polyphase colloidal suspension containing platinum, iron, silica, and gold. Chemical zoning in the iron-platinum alloy nanoparticles indicates that iron and platinum had different diffusion rates during Ostwald ripening of the particles. Full recrystallization of the gold was prevented by the presence of the second-phase nanoparticles, although some postdepositional growth has occurred, possibly linked to varying densities of the alloy nanoparticles. The silica and gold nanoparticles in the oxide inclusions indicate that the two phases were transported together, consistent with experimental data showing silica stabilized colloids are stable at temperatures in excess of 350°C. Given the large quantities of gold that can be transported in relatively small volumes of colloid, this result means that fluid fluxes and formation timescales of orogenic gold deposits may be greatly overestimated.