
G7
Magmatic Origins of Carlin-type Gold Indicated by NanoSIMS Sulfur Isotope and Trace Element Depth Profiling

Elizabeth A. Holley[1], Anne Fulton[1], Christie E. Jilly-Rehak[2], Michael J. Pribil[3], Craig A. Johnson[3]
1. Colorado School of Mines, Golden, CO, USA, 2. Stanford Nano Shared Facilities, Stanford, CA, USA, 3. Geology, Geochemistry, and Geophysics Science Center, U.S. Geological Survey, Denver, CO, USA

Nevada's Carlin-type deposits represent the largest gold accumulation in the northern hemisphere, but throughout 55 years of mining, their origins have been disputed. Did meteoric fluids scavenge and then redeposit the gold while circulating through the sedimentary host rock package? Or did the gold come from magmatic fluids during the southwest sweep of calc-alkaline magmatism through the region in the Eocene?

"Invisible" Carlin-type gold occurs most commonly in solid solution within micron to submicron-scale hydrothermal arsenian pyrite rims, overgrowing older sedimentary or magmatic pyrite grains. The lack of abundant alteration minerals and the small size of the ore grains have made it difficult to study the processes responsible for mineralization. Sulfur isotopes have long been considered the key to fingerprinting the source of the gold, but previous quantitative studies lacked the spatial resolution necessary to distinguish between the isotopic signatures of precursor pyrite and the thin, gold-rich hydrothermal pyrite overgrowths. We leverage advances in nano-scale secondary ion mass spectrometry (NanoSIMS) and laser ablation multi-collector inductively coupled plasma mass spectrometry (LA-MC-ICPMS) to produce and validate sub-micron, quantitative, standardized $\delta^{34}S$ and trace element data from five Carlin-type gold deposits in Nevada, as well as unaltered magmatic pyrites from Eocene dikes on the Carlin Trend.

At the Carlin, Getchell, and Turquoise Ridge deposits, ore pyrite is hosted in carbonaceous, realgar and orpiment-bearing limey mudstones and dolomitic limestones that have been decarbonatized during alteration. Most of the Au-poor precursor pyrite is isotopically heavy (22.0 to 54.4‰ $\delta^{34}S_{VCDT}$), consistent with formation during diagenesis of carbonaceous, iron-poor sediments beneath a marine basin that may have been closed. At Deep Star, the Au-poor cores of the ore grains are isotopically moderate (6.5 to 6.9‰) Jurassic pyrite from the hornfels aureole of the Goldstrike stock, similar to the mean $\delta^{34}S$ of Jurassic magmatic sulfur in the Great Basin. Unaltered Eocene magmatic pyrites hosted in dikes at Beast, Deep Star, and Betze Post contain minor Au and show variable $\delta^{34}S$ (7.9 to 15.2‰), within the range of Eocene magmatic sulfur in the Great Basin.

In the hydrothermal arsenian pyrite overgrowths, $\delta^{34}S$ varies systematically with Au. Submicron-scale zones with low Au concentrations show $\delta^{34}S$ values similar to the precursor pyrite hosting the overgrowths. In contrast, submicron-scale zones with high Au concentrations show $\delta^{34}S$ values as low as 4.2‰ at Deep Star, 2.5‰ at Carlin, 2.1‰ at Beast, 1.7‰ at Getchell, and 1.2‰ at Turquoise Ridge. These values are similar to those of porphyry-related sulfide minerals in the Battle Mountain district, the nearest location of definitively magmatic-hydrothermal Eocene mineralization.

We propose a model for Carlin-type gold formation wherein the gold was sourced from Eocene magmas isotopically and compositionally similar to the Beast dike. Fluids exsolving from the cooling magma bodies became enriched in Au. Fluid circulation in the magmatic-hydrothermal environment resulted in variable degrees of mixing with other sulfur sources in the host rock package. When these compositionally-evolving fluids ascended into favorable lithologic horizons, they precipitated the hydrothermal pyrite in sequential nano-scale zones on existing pyrite.