Textural and isotopic evidence for metallic nanoparticles in bonanza epithermal ores

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Detailed petrographic investigations of mid-Miocene bonanza epithermal ores (Yellowstone Hotspot-related: Sleeper, DeLamar, National, Buckskin National, Midas, Hollister-Ivanhoe, etc.) of the northern Great Basin (NGB) and from Koryu and Hishikari deposits, Japan, exhibit similar geochemical and textural features: 1) distinctly banded nature of ore at the hand sample scale; 2) simple mineralogy consisting of electrum, chalcopyrite and naumannite (or aguilarite); 3) quartz (sometimes doubly terminated), opal, adularia, clays and calcite as common gangue minerals; and 4) ore textures suggesting aggregation of solid nanoparticles of ore minerals. Two principal textures are recognized pointing to metallic nanoparticles in the ore: A) radial symmetrical fractal dendrites that grew outward from vein walls by apparent aggregation of nanoparticles; and B) physical transport (“sluice-box”) textures where nanoparticles are deposited in “low-velocity” zones on the lee side of perturbations in vein walls. In early papers describing these textures from the Sleeper deposit (Saunders, 1990, 1994; and Saunders and Schoenly, 1995), we assumed nanoparticles (colloids) nucleated and were deposited in a zone of boiling, leading to these “disequilibrium” textures. However detailed Pb- and Re-Os-isotopic investigations of ore minerals (Kamenov et al., 2007; Saunders et al., 2011) also indicated a primitive magmatic source for ore metals. Similarly, new Cu- and S-isotope data (this paper; Saunders et al., in prep.) from these bonanza ores also indicate a magmatic source of these ore-forming constituents. Cu- and S-isotope data were collected from chalcopyrite and gold-silver phases from highest-grade bands in the ores, and thus should be representative of bonanza ore-forming solutions. These data lead to the following conundrum: If >95% of water in the ore-forming fluids is composed of heated meteoric waters based on O-H isotope data on numerous deposits in this class, then how can a magmatic isotopic signature be preserved by the ore-forming minerals? One possibility is that metals and sulfur are transported to the epithermal environment (and mix with the shallow geothermal waters) in low density magmatic “vapors” which contribute magma-sources metals but little water. But would nucleation of crystals directly in the shallow epithermal setting preserve magmatic isotopic signatures? Perhaps, but it seems more likely to us that such a scenario would not necessarily preserve magmatic isotopic signatures. Instead, we propose that low-D magmatic fluids perhaps cooled enough to reach saturation with ore minerals deeper than the epithermal environment, where they nucleated metallic nanoparticles that were then transported up to the epithermal environment. In the process, magmatic Cu-, Pb, and S-isotopic signatures were preserved and ores formed by particle aggregation along vein walls.