Epithermal-Carlin Transition: Evidence for Magmatic Input to Carlin-type Deposits

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ABSTRACT: New trace element and ion probe (SIMS) analyses provide strong evidence for a magmatic input to Carlin-type gold deposits. Average abundances and relative enrichments of Ba, As, Se, Sb, Hg, Au and Te in the Twin Creeks, Getchell, and Screamer Carlin-type deposits (Nevada, USA) and the Moore and Monte Negro high-sulfidation deposits in the Pueblo Viejo district (Dominican Republic) are very similar. SIMS analyses of gold-bearing arsenian pyrite from the Screamer Carlin-type deposit yield $\delta^{34}S$ values of 0 to 7 permil for ore-related sulfur, which are almost identical to those obtained for ore-related sulfur in high-sulfidation deposits. These similarities suggest that the mineralizing fluid in Carlin-type deposits derived most of its ore elements from magmas and that the differences between Carlin and high-sulfidation gold deposits probably reflect largely differences in their host rocks.

New trace element and ion probe (SIMS) analyses suggest that Carlin-type gold deposits are geochemically similar to high-sulfidation epithermal gold type deposits and therefore that a significant fraction of their contained metals and sulfur came from an igneous source. Average trace element abundances compiled from large numbers of samples in the Twin Creeks, Screamer, and Getchell Carlin-type deposits (Nevada, USA) (Cail & Cline, 2001; Kesler et al. 2003a) show similarities to each other and to high-sulfidation deposits, including the Moore and Monte Negro deposits in the Pueblo Viejo district (Dominican Republic), for which most complete trace element data are available (Kesler et al. 2003b). Average trace element abundances are best compared by ratioing them against a standard such as the average trace element composition of intermediate igneous rocks, which is the method used here (Fig. 1). Viewed in this way, Ba is depleted or barely enriched relative to average intermediate igneous rocks. Te is strongly enriched and, in fact, appears to be more enriched than gold in both types of deposits, although there is some uncertainty about the average abundance of Te in intermediate igneous rocks. As, Sb, and Hg are relatively strongly enriched in all deposits, and Ag, and Se are not strongly enriched (although data for Se are available for only two deposits). Relative abundance patterns in all deposits are similar for most elements with the notable exception of Hg, which is more enriched in Carlin-type deposits, especially Getchell. This difference probably reflects that fact that high-sulfidation fluids boiled, whereas those in Carlin-type deposits probably did not. Note in this regard that Hg abundances are lowest and most similar to high-sulfidation systems at Twin Creeks, where the presence of adularia might indicate local boiling.

New and unpublished ion probe (SIMS) analyses from the Screamer section of the Betze-Post Carlin-type deposit, the largest such deposit in the world, provide further support for similarities between high-sulfidation epithermal deposits and Carlin-type deposits. Previous studies have concluded that gold-bearing arsenian pyrite in most Carlin-type deposits formed from sulfide sulfur that has $\delta^{34}S$ values as high as 20 permil and is largely of sedimentary origin (Hofstra & Cline 2000). However, most of these studies were made by analysis of mineral separates consisting of pre-ore diagenetic pyrite with thin overgrowths of gold-bearing arsenian pyrite rather than pure, ore-related pyrite, indicating that they contained sulfur from both pre-ore and ore-related sources. Our SIMS spot analyses of thin ore-related arsenian pyrite overgrowths at Screamer yield $\delta^{34}S$ values of 0 to 7 permil, which are much lower. The

only two SIMS studies of sulfur isotope compositions in Carlin-type deposits that

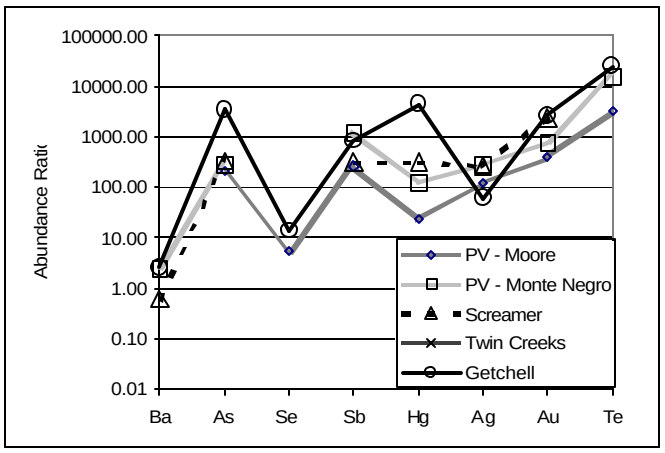

Figure 1. Comparison of average trace element contents of Carlin-type and high-sulfidation-type precious metal deposits (ratioed against average abundance in intermediate igneous rock).

have been published previously, including one in the Post area at the eastern end of the Betze-Post deposit (Arehart et al. 1993), have also obtained values in this range along with other values as high as 22 permil. Reinterpretation of these values in the light of results from Screamer and studies of the sulfur isotope composition of Paleozoic country rocks in Nevada suggests that the original composition of sulfur in Carlin-type deposits is near 0 permil and that it was driven to higher values largely by contamination from sulfur in surrounding Paleozoic country rocks.

Variations in the degree of contamination of original magmas and their hydrothermal solutions would have produced a range of sulfur isotope compositions in Carlin-type deposits. Variations within individual deposits probably reflect passage of later magmas or hydrothermal fluids that were shielded from wallrock contamination by earlier material.

If this scenario is correct, sulfide sulfur in Carlin-type deposits is probably of mixed magmatic–wallrock origin, but the wallrock source does not indicate direct involvement of hydrothermal solutions of sedimentary origin. Rather, the dominant process delivering sulfur and mineralizing fluids to Carlin-type systems was separation of fluids from a magmatic source. In view of the strong similarity in metal and sulfur isotope compositions of Carlin and high-sulfidation epithermal systems, they are likely to have had similar magmatic sources and to differ in detail largely because Carlin-type systems formed dominantly in carbonate wallrocks.

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