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Lead in the Getchell-Turquoise Ridge Carlin-Type Gold Deposits from the Perspective of Potential Igneous and Sedimentary Rock Sources in Northern Nevada: Implications for Fluid and Metal Sources*

R. M. Tosdal,†
Mineral Deposit Research Unit, University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z4

J. S. Cline,
University of Nevada, 4505 Maryland Parkway, Las Vegas, Nevada 89104

C. Mark Fanning,
Research School of Earth Sciences, Australian National University, Canberra, A.C.T. 0200, Australia

and J. L. Wooden
U. S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025

Abstract

Lead isotope compositions of bulk mineral samples (fluorite, orpiment, and realgar) determined using conventional techniques and of ore-stage arsenian pyrite using the Sensitive High Resolution Ion-Microprobe (SHRIMP) in the Getchell and Turquoise Ridge Carlin-type gold deposits (Osgood Mountains) require contribution from two different Pb sources. One Pb source dominates the ore stage. It has a limited Pb isotope range characterized by $^{208}Pb/^{206}Pb$ values of 2.000 to 2.005 and $^{207}Pb/^{206}Pb$ valuesof 0.8031 to 0.8075, as recorded by 10-μm-diameter spot SHRIMP analyses of ore-stage arsenian pyrite. These values approximately correspond to $^{206}Pb/^{204}Pb$ of 19.3 to 19.6, $^{207}Pb/^{204}Pb$ of 15.65 to 15.75, and $^{208}Pb/^{204}Pb$ of 39.2 to 39.5. This Pb source is isotopically similar to that in average Neoproterozoic and Cambrian clastic rocks but not to any potential magmatic sources. Whether those clastic rocks provided Pb to the ore fluid cannot be unequivocally proven because their Pb isotope compositions over the same range as in ore-stage arsenian pyrite are similar to those of Ordovician to Devonian siliciclastic and calcareous rocks. The Pb source in the calcareous rocks most likely is largely detrital minerals, since that detritus was derived from the same sources as the detritus in the Neoproterozoic and Cambrian clastic rocks. The second Pb source is characterized by a large range of $^{206}Pb/^{204}Pb$ values (18–34) with a limited range of $^{208}Pb/^{204}Pb$ values (38.1–39.5), indicating low but variable Th/U and high and variable U/Pb values. The second Pb source dominates late and postore-stage minerals but is also found in preore sulfide minerals. These Pb isotope characteristics typify Ordovician to Devonian siliciclastic and calcareous rocks around the Carlin trend in northeast Nevada. Petrologically similar rocks host the Getchell and Turquoise Ridge deposits. Lead from the second source was either contributed from the host sedimentary rock sequences or brought into the hydrothermal system by oxidized ground water as the system collapsed. Late ore- and postore-stage sulfide minerals (pyrite, orpiment, and stibnite) from the Betze-Post and Meikle deposits in the Carlin trend and from the Jerritt Canyon mining district have Pb isotope characteristics similar to those determined in Getchell and Turquoise Ridge. This observation suggests that the Pb isotope compositions of their ore fluids may be similar to those at Getchell and Turquoise Ridge.

Two models can explain the Pb isotope compositions of the ore-stage arsenian pyrite versus the late ore or postore sulfide minerals. In either model, Pb from the Ordovician to Devonian siliciclastic and calcareous rock source enters the hydrothermal system late in the ore stage but not to any extent during the main stage of ore deposition. In one model, ore-stage Pb was derived from a source with Pb isotope compositions similar to those of the Neoproterozoic and Cambrian clastic sequence, transported as part of the ore fluid and then deposited in the ore-stage arsenian pyrite and fluorite. The second model is based on the observation that the Pb isotope characteristics of the ore-stage minerals also are found in some Ordovician to Devonian calcareous and siliciclastic rocks. Hence, ore-stage Pb could have been derived locally and simply concentrated during the ore stage. Critical to the second model is the removal of all high $^{206}Pb/^{204}Pb$ (>20) material during alteration. It also requires the retention of only the low $^{206}Pb/^{204}Pb$ component of the Ordovician to Devonian sedimentary rocks. This critical step is possible only if the high $^{206}Pb/^{204}Pb$ values are contained in readily dissolvable mineral phases, whereas the low $^{206}Pb/^{204}Pb$ values are found only in refractory minerals that released Pb during a final alteration stage just prior deposition of auriferous arsenian pyrite.

Distinguishing between Pb transported with the ore fluid or inherited from the site of mineral deposition is not straightforward; however, it is simpler to explain the Pb isotope compositions of ore-stage arsenian pyrite

*Mineral Deposit Research Unit, University of British Columbia, contribution 160.
† Corresponding author: e-mail, rtosdal@eos.ubc.ca

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and fluorite in two different but spatially related Carlin-type deposits (Getchell and Turquoise Ridge) with different host rocks by input of Pb with the ore fluid. Once the limited Pb in the hydrothermal fluid was exhausted by incorporation in ore-stage arsenian pyrite or other ore-stage minerals, Pb from the second source, the Ordovician to Devonian sedimentary rock sequences, became available for incorporation in some but not all of the late-stage sulfide minerals.