Acta Mineralogica-Petrographica, Abstract Series 2, Szeged, 2003

USING FLUID INCLUSIONS TO CONSTRAIN ORE FLUID PROPERTIES AT THE GOLDSTRIKE CARLIN-TYPE GOLD SYSTEM, NEVADA, USA

LUBBEN, J. D.[1], HENKELMAN, C.[1], CLINE, J. S.[1]
[1] University of Nevada Las, Vegas, 4505 Maryland Parkway, Box 454010, Las Vegas, NV 89154.
E-mail: j_lubben27@hotmail.com

Introduction

Nevada hosts the majority of the world's Carlin-type gold systems. These large low- to high-grade sedimentary rock hosted disseminated gold systems are responsible for Nevada's position as one of the world's major gold-producing districts.

Carlin-type gold mineralization consists of submicron gold contained within fine pyrite grains or pyrite rims that overgrow older generations of pyrite and marcasite. Silicification is a primary hydrothermal alteration process in Carlin-type gold deposits and quartz, usually in the form of jasperoid and drusy quartz, precipitated (Bakken, Einaudi, 1986); (Arehart, 1996); (Hofstra, Cline, 2000). The presence of jasperoid and drusy quartz crystals indicates that ore fluids saturated in silica cooled, and the jasperoid replaced carbonate host rocks.

Ore fluid origin in Carlin-type gold deposits remains enigmatic. Previous research indicates that ore fluids in several deposits have a meteoric origin (Kuehn, Rose, 1992); (Emsbo et al., 1999). However, ore fluids responsible for deposits along the Getchell trend have been linked to a deep-seated magmatic or metamorphic origin (Cline et al., 1996); (Groff et al., 1997); (Cline, Hofstra, 2000); (Cline et al., 2002). Previous fluid inclusion studies indicate that ore fluid temperatures ranged from 180°C to 240°C (Cline, Hofstra, 2000); (Hofstra, Cline, 2000).

Ore fluid conditions, components, and sources at the Goldstrike deposit, the largest Carlin-type gold system in the world, have not been examined. To improve our knowledge of ore fluids in this major system, chemical, textural, isotopic, and fluid inclusion characteristics in ore-stage quartz associated with gold-bearing pyrite, and in pre-ore and post-ore quartz spatially associated with ore but related to other events, were examined. Petrographic and paragenetic studies on samples collected from different ore zones in the Goldstrike system have identified jasperoid and drusy quartz that are spatially, temporally, and genetically associated with gold. By analyzing fluid inclusions within ore stage quartz, important information about ore fluid temperature, composition, and source can be derived. The ability to distinguish different generations of quartz and recognize ore quartz will provide a new exploration tool for these systems.

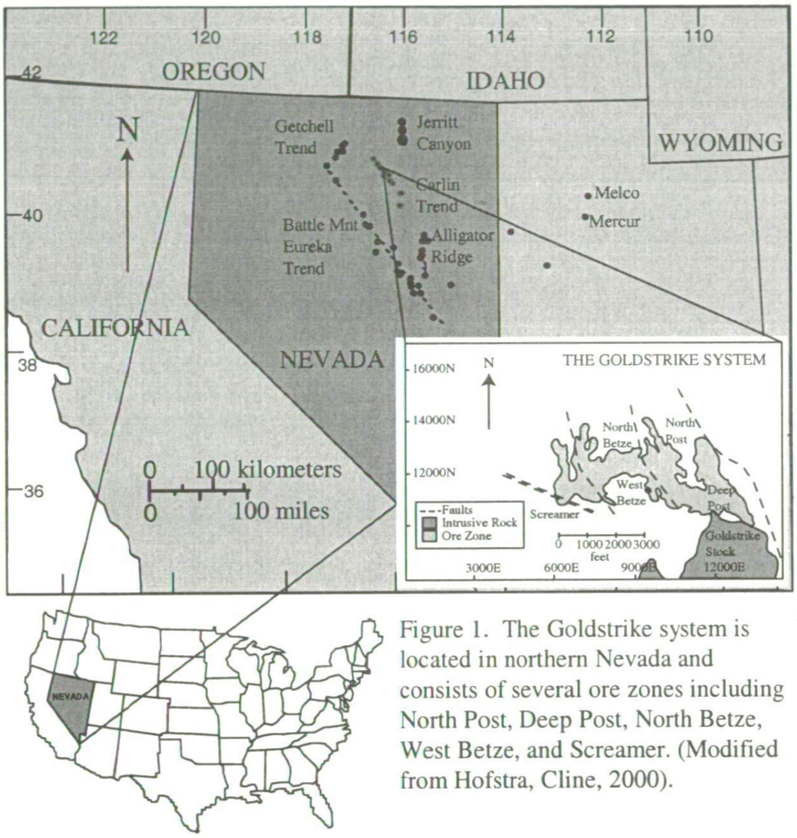

Figure 1. The Goldstrike system is located in northern Nevada and consists of several ore zones including North Post, Deep Post, North Betze, West Betze, and Screamer. (Modified from Hofstra, Cline, 2000).

Paragenetic sequence

Paragenetic studies identified gold-bearing pyrite grains, and then determined the relative timing of other gangue minerals including ore-stage quartz. Discrete types of pyrite were distinguished based on size, morphology, color, and geologic association. Ore-stage pyrite grains, identified initially by morphology, were confirmed to be gold-bearing by electron microprobe analysis (EMPA). Various stages of quartz were identified by integrating petrographic studies with fluid inclusion, oxygen isotope, and cathodoluminescence studies, and spatial association with gold-bearing pyrite.

Cathodoluminescence (CL) analyses were important in that they distinguished generations of quartz that exhibit different intensities of luminosity. CL stratigraphies were developed and, along with petrography, permit various stages of quartz to be correlated between samples from different localities. Ore stage jasperoid quartz does not luminesce and was overgrown by drusy quartz that also does not luminesce. The drusy quartz crystals encompass gold-bearing pyrite grains at their base and appear to be late-ore stage (Lubben et al., 2003). These observations indicate that ore-stage quartz is manifested by both jasperoid replacement of limestone and open-space deposition of drusy quartz. Multiple generations of post-ore drusy quartz overgrow ore and late-ore quartz and exhibit luminescence of varying intensities (Lubben et al., 2003). Preliminary EMPA indicates that decreasing trace Al in quartz corresponds with increasing intensity of luminosity (Lubben et al., 2003).

In-situ ion probe oxygen isotope analyses with analytical spots 10 to 15 micrometers in diameter were obtained. Analyses yield different ranges of $\delta^{18}O$ values for different generations of quartz and have contributed to refining the paragenesis. $\delta^{18}O$ values range from 17.8‰ to 19.3‰ for pre-ore quartz, 11.0‰ to 15.6‰ for ore stage quartz, 3.2‰ to 7.9‰ for late-ore-stage quartz, and 9.2‰ to 12.7‰ for post-ore quartz.

Microthermometry

Primary and secondary fluid inclusion assemblages have been identified in multiple generations of quartz. Ore stage quartz contains sparse two-phase primary fluid inclusion assemblages in jasperoid and in youngest late ore-stage drusy quartz. Primary inclusion assemblages exhibit consistent liquid-vapor ratios (approximately 5 volume percent vapor) and occur within growth zones in quartz crystals. Microthermometry was conducted on primary inclusion assemblages in ore-stage jasperoid and yielded a homogenization temperature range of 160°C to 240°C and ice melting temperatures from -2.3°C to -2.5°C. Based on these ice melting temperatures, a salinity range of 3.9wt% to 4.2wt% NaCl equivalent was calculated. Microthermometry was also conducted on secondary fluid inclusion assemblages in pre-ore quartz grains. These quartz grains were transported and incorporated within a debris flow, which was later silicified. Microthermometry conducted on these inclusion assemblages yield a homogenization temperature range of 170°C to 250°C and an ice-melt temperature range of -2.5°C to -2.9°C. Based on these ice-melt temperatures, a salinity range of 4.2wt% to 4.8wt% NaCl equivalent was calculated. Based on the similarities in data, these secondary inclusions may have trapped ore-stage fluids.

Conclusions

Fluid inclusion assemblages in quartz associated with gold mineralization have been identified using petrography integrated with chemical, isotopic, and cathodoluminescence studies. These studies have determined that ore-stage quartz consists of both non-luminescing jasperoid and non-luminescing drusy quartz. These stages of quartz are followed by quartz that exhibits a range of luminosities. Microthermometric analyses of fluid inclusion assemblages in ore-stage quartz indicates precipitation temperatures of 160°C to 240°C from fluids that have a salinity of 3.9wt% to 4.2wt%. These studies show that ore fluids deposited gold, pyrite, and quartz at the Goldstrike system at temperatures similar to temperatures of gold deposition in other Carlin-type gold systems. Analytical work is continuing with the goal of determining the hydrogen and oxygen isotope signatures of inclusion fluids, to identify ore fluid source.

References

AREHART, G. B. (1996): Characteristics and origin of sediment-hosted disseminated gold deposits: A review: Ore Geology Reviews, **11**, 383-403.

BAKKEN, B. M., EINAUDI, M. T. (1986): Spatial and temporal relations between wall rock alteration and gold mineralization, Main pit, Carlin Gold Mine, Nevada, U.S.A.: Macdonald, A.J., ed., Gold '86: Willowdale, ON, Canada, Konsult International, 388-403.

CLINE, J. S., HOFSTRA, A. H. (2000): Ore-fluid evolution at the Getchell Carlin-type gold deposit, Nevada, U.S.A.: European Journal of Mineralogy, **12**, 195-212.

CLINE, J. S., HOFSTRA, A. H., LANDIS, G. P., RYE, R. O. (1996): Stable isotope and fluid inclusion evidence for a deep sourced ore fluid at the Getchell Carlin-type gold deposit, Nevada [ext. abs.]: Pan-American Current Research on Fluid Inclusions, Sixth Biennial, Madison, Wisconsin, May 30-June 1, 1996, Programs and abstracts, 33-35.

CLINE, J. S., STUART, F. M., HOFSTRA, A. H., TRETBAR, D. R., RICIPUTI, L., PREMO, W. (2002) He, Nd, and stable isotope constraints on Carlin-type ore fluid components, Getchell, NV, USA: Geological Society of America Abstracts with Programs, **34**, 141.

EMSBO, P., HUTCHINSON, R. W., HOFSTRA, A. H., VOLK, J. A., BETTLES, K. H., BASCHUK, G. J., JOHNSON, C. A. (1999): Syngenetic Au on the Carlin trend: Implications for Carlin-type deposits: Geology, **27**, 59-62.

GROFF, J. A., HEIZLER, M. T., MCINTOSH, W. C., NORMAN, D. I. (1997): $^{40}Ar/^{39}Ar$ dating and mineral paragenesis for Carlin-type gold deposits along the Getchell trend, Nevada: Evidence for Cretaceous and Tertiary gold mineralization: Economic Geology, **92**, 601-622.

HOFSTRA, A. H., CLINE, J. S. (2000): Characteristics and models for Carlin-type gold deposits: Vikre, P., Thompson, T.B., Bettles, K., Christensen, O., and Parratt, R. eds., Society of Economic Geology Reviews, **13**, 163-220.

KUEHN, C. A., ROSE, A. W. (1992): Geology and geochemistry of wall-rock alteration at the Carlin-type gold deposit, Nevada: Economic Geology, **87**, 1697-1721.

LUBBEN, J. D., HENKELMAN, C., CLINE, J. S. (2003): Chemistry, textures, and fluid inclusions in quartz: Clues to ore fluid sources at the North Betze ore zone, Goldstrike Carlin-type gold system, northern Carlin trend, Nevada: Geological Society of America Abstracts with Programs, **35**, (in press).