Dendritic ore minerals in the Buckskin National and Fire Creek bonanza-style low-sulfidation epithermal deposits, Nevada

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Background

- Low-sulfidation epithermal deposits form within hundreds of meters of the surface to less than 2 km at temperatures below 300 °C.
- The deposits are dominated by meteoric water with only minor amounts of magmatic fluid.
- Ore-forming fluids are near neutral-pH and principally composed of NaCl, H₂S, and CO₂.
- Ore-forming processes are significantly related to adiabatic boiling of hydrothermal fluids.
- Ore deposits formed in low-sulfidation system usually exhibit open-space or cavity-filling veins and stockworks as well as breccias.
- Precious metals (Au and Ag) can occur in banded silica veins at bonanza grades (e.g. >10’s g/t).
- Due to the associated alteration, they are also called “Adularia-Sericite Epithermal Gold-Silver” deposits.

(Corbett, 2013)
• The Buckskin National and Fire Creek deposits are typical bonanza-style low-sulfidation epithermal precious metal deposits located in the northern Great Basin, northern Nevada.

• Both deposits formed in middle Miocene related with bimodal rhyolitic-basaltic magmatism derived by the Northern Nevada Rifting.

• Saunders et al. (2008) and Hames et al. (2009) suggested that precious metals were initially derived from partial melting of fertile mantle to produce basalts enriched in Au.

• The Bell vein in the Buckskin National deposit produced around 24,000 ounces of gold and 300,000 ounces of silver from 34,000 tons of ore between 1906 and 1941.

• The recent total ore reserves at Fire Creek are currently around 228,000 tons averaging 20.13 g/t of Au and 19.56 g/t of Ag. The inferred resources are 1,142,000 tons with grades of 12.96 g/t of Au and 13.13 g/t of Ag.

(Modified from Leavitt et al., 2004)

(Saunders et al., 2008)
Epithermal veins exhibit crustiform-colloform banded textures along with recrystallization textures, and pseudoblabded quartz after calcite.

Gangue minerals include quartz, calcite, chalcedony, adularia, and clay minerals.

Ore minerals are typically composed of Ag-Se-S phase minerals and electrum in specific colloform banded quartz veins as well as minor amounts of Hg in associated sinters formed at the paleosurfaces overlying these veins.

Previous studies (Saunders, 1994; Hedenquist et al., 2000; Simmons et al., 2005) suggested that the ore-depositing processes within banded silica veins are influenced by either boiling or flashing of the hydrothermal fluid within the conduit.
Objectives

- To observe textural characteristics and elemental information of ore minerals found in the bonanza-style epithermal veins

- To better understand the textural relationship between ore minerals and quartz in low-sulfidation epithermal veins

- To be able to establish an ore-forming process, which effectively produces bonanza-style epithermal deposits
Methodology

• Petrographic study (two dimensions)
  • Polished thin sections
  • Transmitted light microscope

• Topography of ore minerals (three dimensions)
  • Hydrofluoric acid (HF) experiment
  • Gold coated samples on the aluminum stub
  • TESCAN MIRA3 LMH FE-SEM

• Elemental Information
  • Bruker XFlash®6130 silicon drift detector
  • Energy-dispersive x-ray spectrometry (EDS)
  • 2D Micro X-ray Fluorescent by M4 TORNADO
Buckskin National

**Ore-bearing**
- Mosaic-colloform quartz
- Breccia-like bands

**Barren**
- Plumose quartz
- Euhedral comb quartz
- Pseudobladed quartz
- Chalcedonic quartz
- Coarse-grained mosaic quartz
Buckskin National

Ore minerals have small pits showing a fractal pattern

Multi-branching tree-like forms

[SE image at magnification of 500x, 20.0 kV, and WD of 9.8 mm]

[SE image at magnification of 11.5 kx, 15 kV, and WD of 10.59 mm]
Fire Creek

Ore-bearing
- Microcrystalline-colloform quartz
- Rhombic adularia bands

Barren
- Plumose quartz
- Comb quartz
- Zonal quartz
- Chalcedonic quartz
- Late platy calcite
Fire Creek

Negative crystal shape cutting through the dendrites

Naumannite grains

[SE image at magnification of 2.08 kx, 15 kV, and WD of 7.62 mm]

[SE image at magnification of 3.14 kx, 15 kV, and WD of 7.30 mm]
## Elemental Information

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>wt% Ag</th>
<th>wt% Se</th>
<th>wt% S</th>
<th>Mineral Name</th>
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<tbody>
<tr>
<td>BN-1</td>
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M4 maps

Buckskin National

Fire Creek
Discussions

- Comparison with electrum dendrites from the Sleeper deposit
- Relict microsphere in colloform banded epithermal veins
- Relationship to textural characteristics of silica sinters in modern geothermal system
The naumannite dendrites from BN and FC deposits are similar to electrum dendrites in a matrix of very fine-grained silica found in the Sleeper deposit (Saunders, 1994).

The formation of ore dendrites are probably results of coagulation and aggregation of colloidal particles within the boiled hydrothermal fluids (Saunders, 1990 & 1994).

Mosaic quartz within ore dendrites are result of (re)crystallization of noncrystalline silica precursor (Lovering, 1972; Oehler, 1976; Saunders, 1990; Moncada et al., 2012).

Electrum Dendrites

[SEM image at magnification of 204 x, 15 kV, and WD of 11.98 mm]

[SEM image at magnification of 944 x, 15 kV, and WD of 11.83 mm]
Relict Microspheres in Epithermal Veins

10-micron-sized relict microspheres found in ore-bearing vein sample of the Buckskin National deposit.

Relict microspheres are associated with naumannite occurring in ore-rich bands in the Fire Creek deposit.
Taksavasu et al. (2018) compared the textures of banded silica epithermal veins with those of modern silica sinters.

Silica sinters at the Wairakei geothermal power plant, New Zealand, are composed of opal-A, which rapidly deposited from cooling geothermal liquids flashed to atmosphere.

Textural characteristics of the sinters commonly show silicified filamentous microbes encrusted by fused silica microspheres, which are similar to the relict microspheres observed in the colloform bands of epithermal veins.

Relict microspheres observed in the ore-bearing quartz in banded epithermal veins are interpreted to result from intense boiling of the hydrothermal fluids creating silica supersaturation and the deposition of amorphous silica.
Conclusions

- Highest grade ores in this study generally contain sulfur-rich naumannite dendrites in the Buckskin National, and naumannite dendrites in the Fire Creek, which are found in colloform quartz.

- Dendritic pattern of ore minerals in colloform bands should be a result of the coagulation and aggregation of gold/silver and silica colloids during phase separation of hydrothermal fluids.

- Small negative shapes of euhedral quartz in the dendrites are likely formed by recrystallization of noncrystalline silica precursor.

- Relict microspheres preserved in the ore-rich bands in combination with fractal pattern of ore dendrites could be key evidences for the occurrence of intense boiling (flashing) of hydrothermal fluids, allowing the formation of bonanza-style ore deposits.

(Modified from Driesner and Heinrich, 2007; Moncada et al., 2012; Monecke et al., 2014)
References

Thank you

Question Time!
Silica scaling from the Wairakei Geothermal Power plant, NZ

(Taksavasu et al., 2018)
Ag-Se-S phase minerals

- Acanthite (Ag\textsubscript{2}S)
- Naumannite (Ag\textsubscript{2}Se)
- Aguilarite (Ag\textsubscript{4}SSe)