Fluid and Metal Sourcing Related to Native Silver Deposits in the Batopilas Mining District, Chihuahua, Mexico

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Introduction

The historic Batopilas Mining District of southwestern Chihuahua, Mexico has proven to be a major supplier of the world's silver, producing more than 300 million ounces (Wilson & Panczner, 1986). Recent exploration has facilitated reexamination of the geologic features and origin of this district, for which some preliminary results to constrain fluid and metal sourcing are reported here. Application of modern mineralogical identification methods, such as energy dispersive spectrum (EDS) and electron backscatter diffraction pattern (EBSD) analyses, have provided insight on major, minor and trace minerals present at Batopilas. Better understanding of the source of metals and fluids can be achieved by combining new geologic information (Lyons, 2008) with sulfur and lead isotopic analyses of Batopilas samples. In addition, the utilization of reconnaissance fluid inclusion data (Wilkerson et al., 1988), as another method of constraining fluid sourcing, can act as a check on isotopic data.

Mineralogy and paragenesis

Ore bodies consist of high-grade silver in the forms of native silver, silver sulfide (predominantly acanthite), and silver arsenides (predominantly proustite) hosted dominantly in calcite veins. Calcite, sphalerite and galena precipitated in veins between 4 centimeters and 5 meters wide and 100s of meters long. Multiple generations of quartz have been observed with an early generation most likely associated with silicification along vein boundaries, and a second generation within vein interiors that pre-dates a late-stage of subhedral sphalerite, galena and silver-bearing minerals. Arsenopyrite and proustite post-date and replace galena and pre-date native silver mineralization. Acanthite seems to form as the result of a late-stage, S-rich fluid altering native silver.

Sulfur isotope analyses

The $\delta^{34}S$ values from galena, sphalerite, and pyrite are -8.12 to -1.55, -5.55 to -0.05, -5.12 to +2.69, showing a relatively narrow and generally negative range. From the data it can be observed that two phases of sulfide precipitation occurred. This could imply a mixing event and altered fluid and metal sourcing with progressive sulfide generations.

Fractionation temperatures of 227+/-63 °C can be calculated using averages for $\delta^{34}S$ values of galena and sphalerite (Ohmoto & Rye, 1979). These temperatures overlap fluid inclusion homogenization temperatures determined by Wilkerson et al. (1988).

Lead isotope analyses

Galena lead isotopic values show two distinct signatures. The core samples represent stratabound polymetallic sulfides, and have $^{206/204}Pb$, $^{207/204}Pb$, and $^{208/204}Pb$ values of 18.742 and 18.747, 15.611 and 15.618, and 38.512 and 38.535 respectively. For vein samples the corresponding $^{206/204}Pb$, $^{207/204}Pb$, and $^{208/204}Pb$ values range from 18.799 to 18.817, 15.623 to 15.639, and 38.603 to 38.655.

Fluid inclusion analyses

Fluid homogenization temperatures range from 224 to 412.5 °C for quartz-pyrite veinlets occurring in the silver zone. Calcite and sphalerite fluid inclusions directly associated with silver mineralization give a range of 102.3 to 257.3 °C. NaCl equivalent salinities of fluid inclusions in quartz range from 7.6 to 13% and from 4.9 to 20% for inclusions in calcite and sphalerite. These fluid inclusion data have been interpreted to indicate an epithermal origin for fluids associated with the intrusion of the adjacent Tahonas granodiorite (Wilkerson et al., 1988). However, these salinities are substantially higher than those found in typical epithermal fluids, suggesting a more complex origin.

Work in progress

To better constrain the data and attempt to constrain fluid evolution, fluid inclusion data will be collected from zoned sphalerites; inclusions as large as 120 μm have been identified. In addition further measurements will be made from calcite and quartz as the presence of multiple generations of these minerals has been confirmed. The potential exists for sampling of fluid inclusions from proustite, which could provide insight into the fluids precipitating material just prior to native silver mineralization.

Carbon and oxygen isotopes will be analyzed in order to better constrain the source of carbonate material for the various generations of calcite. Strontium isotopes analyses will also be conducted to better constrain the source and mixing of fluids, specifically to determine the contribution of sedimentary brine fluids versus fluids of magmatic origin.

References

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Wilson, W., Panczner, C., 1986, Batopilas: famous mineral localities: the Batopilas district, Chihuahua, Mexico: The Mineralogical Record, p. 61-80.

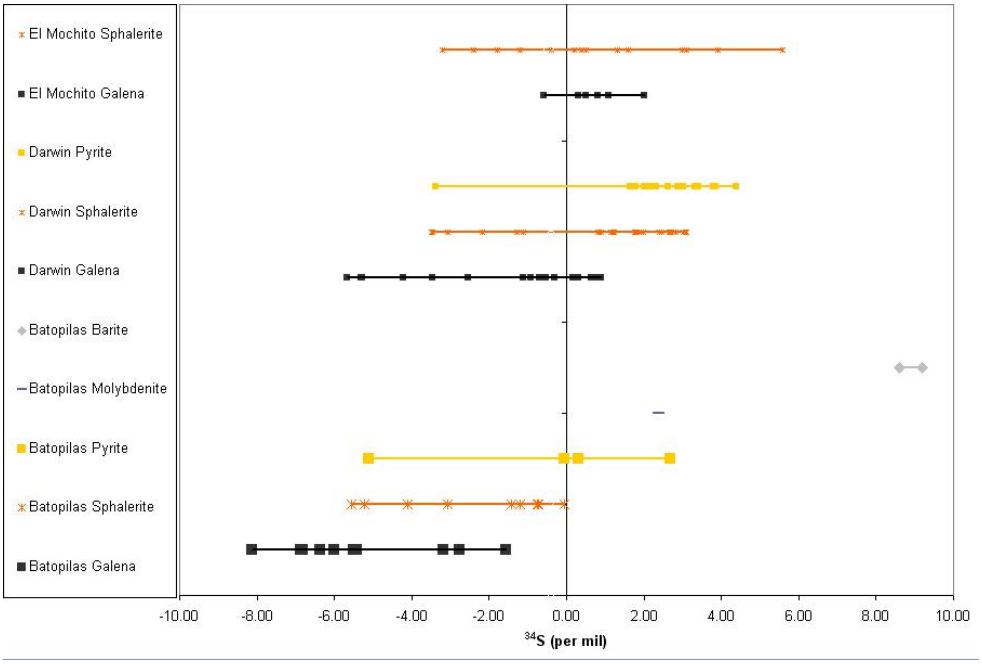
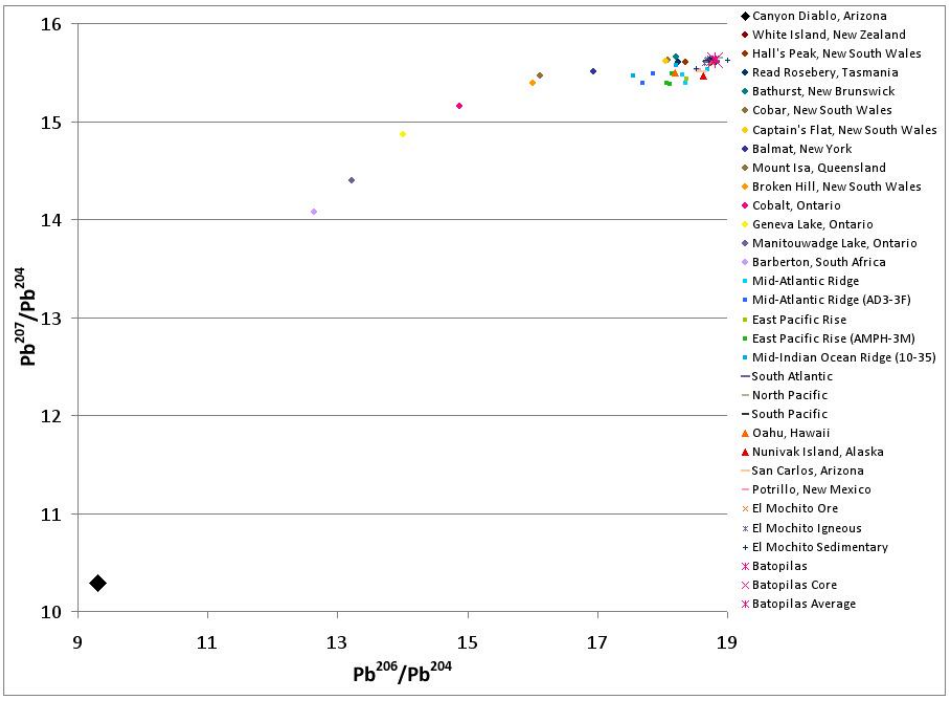
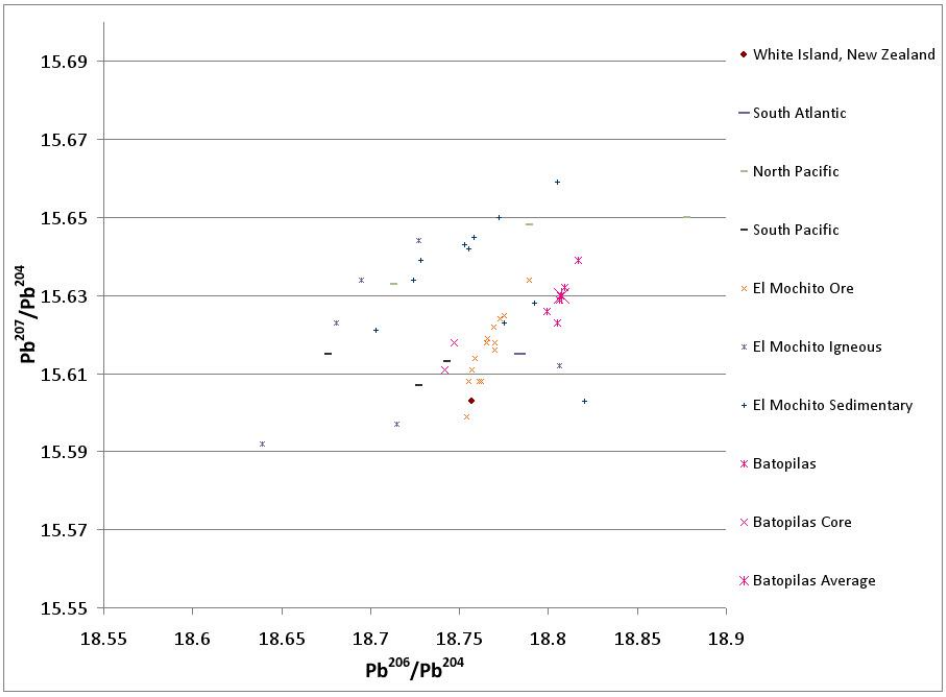


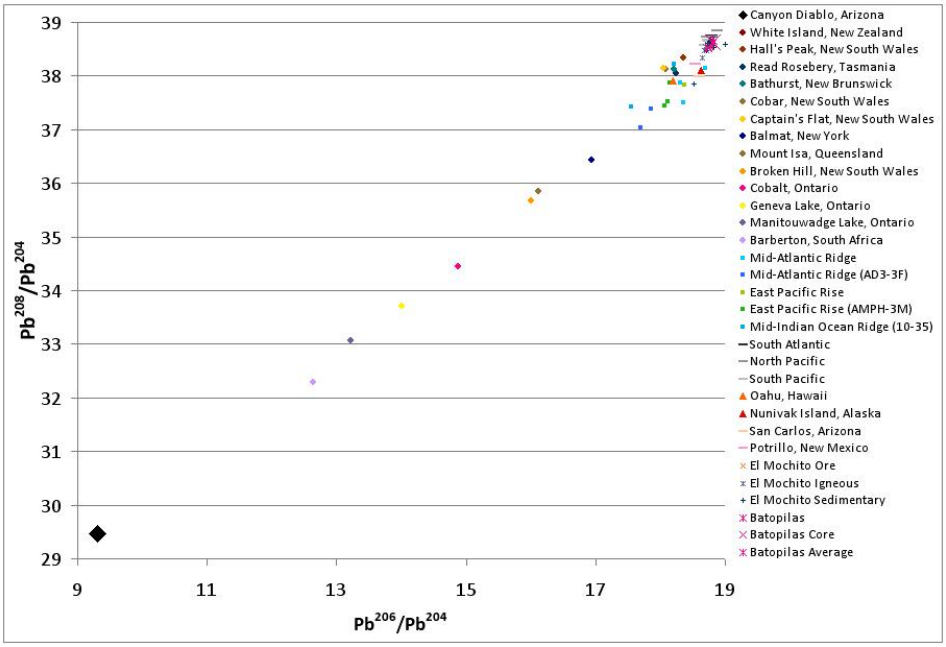
Fig. 1. Range of $\delta^{34}S$ for sulfide minerals from various deposit types (adapted from Figure 1 of Rye & Ohmoto, 1974, references therein, and Table 2 of Ault & Williams-Jones, 2004)


16
15
14
13
12
11
10
9
11
13
15
17
19
Pb207/Pb204
Pb206/Pb204
Canyon Diablo, Arizona
White Island, New Zealand
Hall's Peak, New South Wales
Read Rosebery, Tasmania
Bathurst, New Brunswick
Cobar, New South Wales
Captain's Flat, New South Wales
Balmat, New York
Mount Isa, Queensland
Broken Hill, New South Wales
Cobalt, Ontario
Geneva Lake, Ontario
Manitouwadge Lake, Ontario
Barberton, South Africa
Mid-Atlantic Ridge
Mid-Atlantic Ridge (AD3-3F)
East Pacific Rise
East Pacific Rise (AMPH-3M)
Mid-Indian Ocean Ridge (10-35)
South Atlantic
North Pacific
South Pacific
Oahu, Hawaii
Nunivak Island, Alaska
San Carlos, Arizona
Potrillo, New Mexico
El Mochito Ore
El Mochito Igneous
El Mochito Sedimentary
Batopilas
Batopilas Core
Batopilas Average

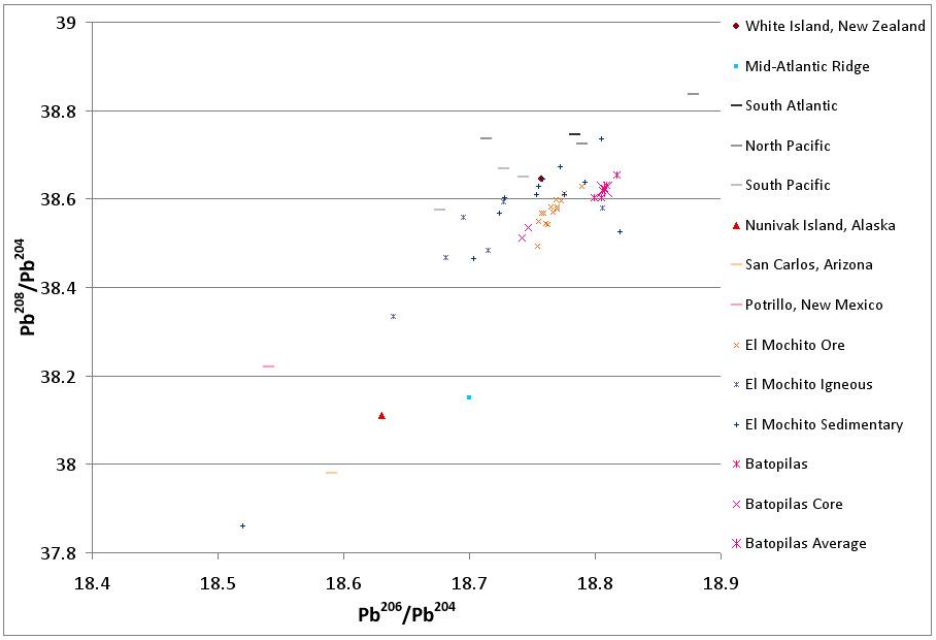
(a)


15.69
15.67
15.65
15.63
15.61
15.59
15.57
15.55
18.55
18.6
18.65
18.7
18.75
18.8
18.85
18.9
Pb207/Pb204
Pb206/Pb204
White Island, New Zealand
South Atlantic
North Pacific
South Pacific
El Mochito Ore
El Mochito Igneous
El Mochito Sedimentary
Batopilas
Batopilas Core
Batopilas Average

(b)



(c)



(d)

Fig. 2. Pb isotope values of various ore deposits and source rocks (adapted from Table 1 of Doe & Stacey, 1974, references therein, and Table 2 of Ault & Williams-Jones, 2004). (a) $^{207/204}$Pb vs $^{206/204}$Pb values plotted for ore deposits and source rocks approaching single-stage evolution. (b) Zoom-in on Batopilas and similar Pb isotopic values. (c) $^{208/204}$Pb vs $^{206/204}$Pb values plotted for ore deposits and source rocks approaching single-stage evolution. (d) Zoom-in on Batopilas and similar Pb isotopic values.

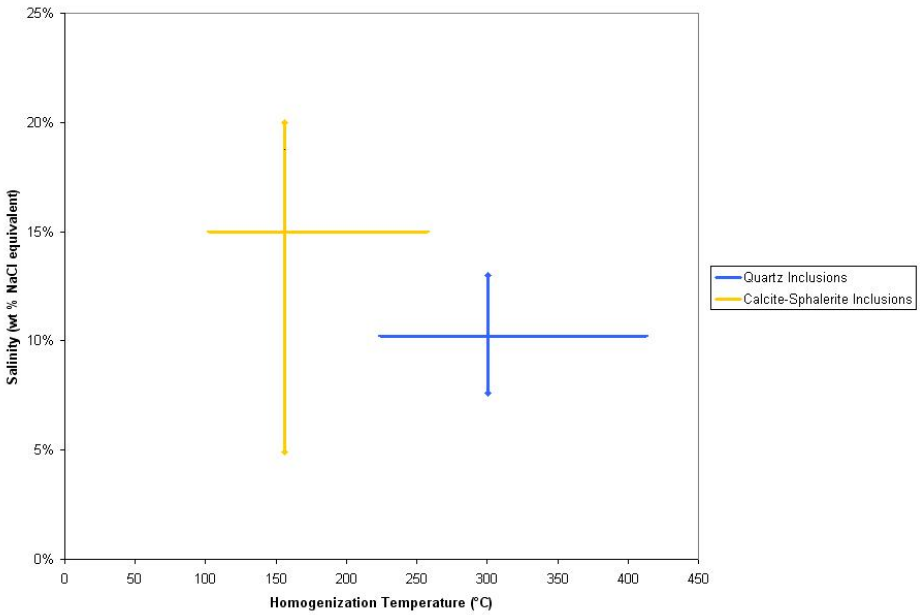


Fig. 3. Fluid inclusion homogenization and ice melting temperature ranges and averages for Batopilas, Chihuahua, Mexico (adapted from Table 1 of Wilkerson et al., 1988); cross-points show average salinity and temperature based on available data.