Fluid inclusions in high sulphidation gold deposits: what can we learn from them about conditions of ore deposition?

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Popular ore deposit models (e.g. Hedenquist and Lowenstern, 1994) require that high sulphidation gold deposits form at temperatures below 300°C. However, stable isotope data consistently link these ores with high proportions of magmatic fluids. This presents a paradox, in that magmatic fluids by their nature are high temperature.

In their classic paper, Bethke et al. (2005) said that; “A number of planes of inclusions with large vapour bubbles were seen but not measured because of the difficulty in determining temperatures of homogenisation to vapour on small inclusions. Thus, vapour-rich inclusions are much more abundant than they appear to be from Table 2.” This highlights the problem we have with vapour-rich fluid inclusions. Because we cannot measure them accurately, should we ignore them? Analogously, since liquid-rich inclusions are easy to measure should we measure them with impunity?

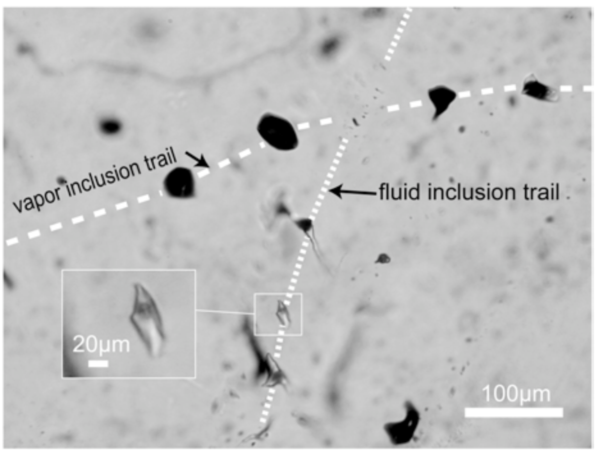

Fig. 1. Crosscutting trails of secondary vapour and secondary fluid inclusions in sulphosalt-ore stage quartz from the Summitville Au-Ag-Cu deposit, Colorado.

We have separated euhedral quartz crystals from sulphosalt “feeder-zone” ores from the El Indio Au-Ag-Cu deposit, Chile; and the Summitville Au-Ag-Cu deposit, Colorado in order to characterise the fluid inclusions present during enargite-gold deposition. These euhedral ~200 µm crystals either grow into vugs in the sulphosalt ore, or are encased by sulphosalts.

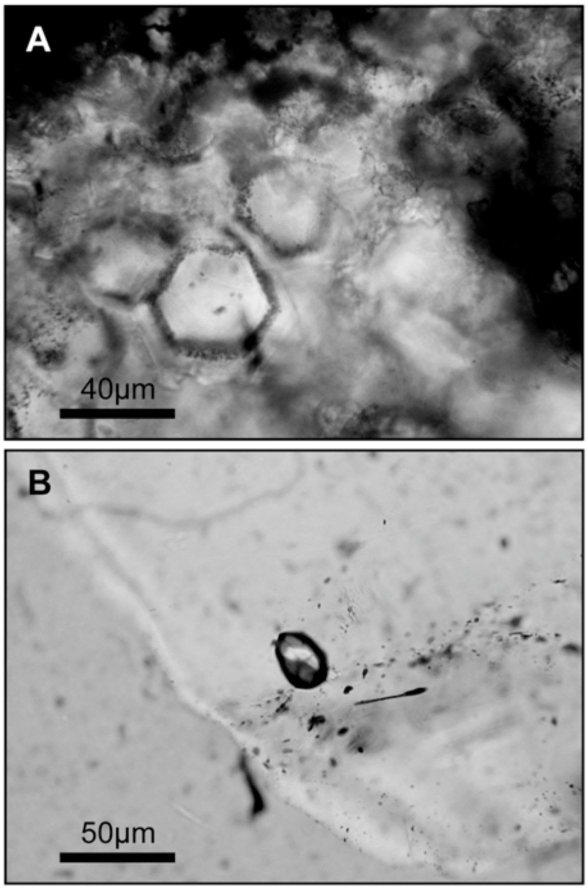

Fig. 2. Fluid and vapour inclusions in sulphosalt-ore stage quartz from the Summitville Au-Ag-Cu deposit, Colorado: (A) primary inclusions (<1 µm) mantling growth bands in euhedral quartz; (B) An isolated low-density vapour inclusion in quartz.

All the high-density fluid inclusions (those that homogenise to the liquid) found in these crystals are secondary, occurring in multiple generations of healed fractures. Low-density (vapour) vapour-rich inclusions are present as both primary and secondary inclusions.

We interpret the well-formed, isolated vapour inclusions as pre-dating the higher density (liquid) fluid inclusions because they are spherical, concentrated in the middle of quartz crystals and are not along healed fracture planes (Fig. 2B). Yet the preponderance of high-density (liquid-rich) inclusions is somehow interpreted as playing a more significant role than the rarer, vapour-rich fluid inclusions by most workers (e.g. Hedenquist et al., 1998). Yet, these may be the only direct evidence of the original magmatic fluid.

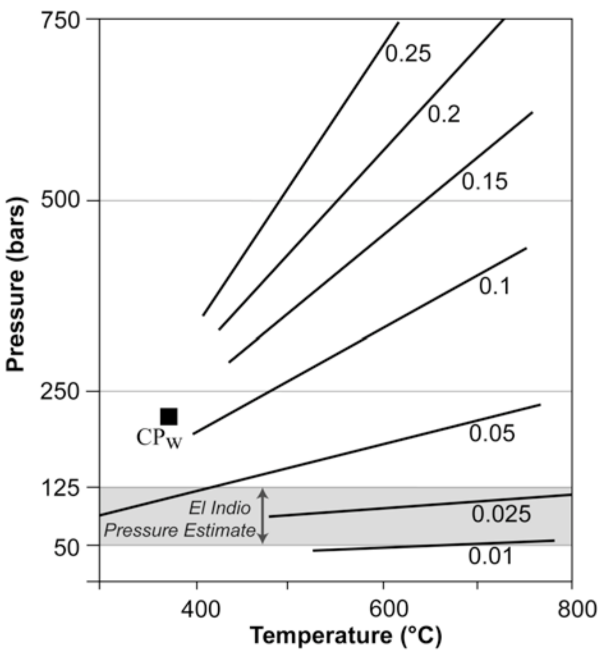

Fig. 3. A pressure-temperature plot of low-density water isochors (from the Steam Tables). Gray strip represents pressure estimates for deposition of the El Indio Au-Ag-Cu deposit. CP_w denotes the critical point of pure water.

El Indio, Chile formed as a sequence of veins at about 650 – 1150 meters below the surface of a dacitic volcanic complex (Jannas et al., 1999). Stable isotope data indicate a dominance of magmatic fluid and there is an absence of significant brecciation indicating that vein fluid pressure was greater than hydrostatic; giving pressures between 50 and 125 bars. Visual estimates of vapour-rich fluid inclusion densities from El Indio (such as those shown in Fig. 1) and Summitville are so low (inclusions appear empty) that quantitative measurement is impossible, but densities less than 0.05 g/cc are the norm. Isochoric plots of low-density isochors (Fig. 3) intersect the pressures appropriate for El Indio deposition at temperatures significantly above 300 °C. For instance, vapour inclusions of 0.01 g/cc would have been trapped at temperatures above 600 °C, consistent with independent estimates based on sulphosalt stability data (Henley and Mavrogenes, in review).

Fluid inclusion studies are not popularity contests where the most abundant win, as is often claimed, but should focus on independently linking fluid inclusion generations to specific geological events.

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