SEG 2017 Conference

Hydrothermal fluid origins of carbonate-hosted Pb-Zn deposits of the Sanjiang thrust belt, Tibet：Indications from noble gases and halogens

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The Sanjiang metallogenic belt includes a variety of economically important carbonate-hosted Pb-Zn deposits that share some similarities with classic Mississippi Valley-type (MVT) ore deposits but are hosted within a thrust belt rather than an orogenic foreland. This study aims to clarify the origin of mineralizing fluids responsible for this style of mineralization.

Fluid inclusions trapped in ore-stage carbonate and fluorite from these deposits have salinities of ~6 – 28 wt. % NaCl equivalent and homogenization temperatures of 70 – 370 °C that extend to much higher values than are typical of MVT deposits. The majority of ore-stage samples have fluid inclusion molar Br/Cl ratios of between seawater (1.5×10^{-3}) and $(2.86 \pm 0.04) \times 10^{-3}$, but low salinity fluid inclusions in late-calcite have lower Br/Cl of less than $(0.55 \pm 0.01) \times 10^{-3}$. In contrast, fluid inclusion molar I/Cl ratios are uniformly greater than the seawater value of $\sim 0.8 \times 10^{-6}$ and extend from $(2.1 \pm 1.1) \times 10^{-6}$ to $(506 \pm 12) \times 10^{-6}$. This range of Br/Cl and I/Cl values is similar to what has been reported for fluid inclusions in other MVT districts and together with the fluid salinity implies the ore-forming fluids had a dominant origin from basinal brines (e.g. sedimentary formation waters) formed by the subaerial evaporation of seawater; all the fluids were influenced by addition of organic Br and I derived from the sedimentary host rocks and some fluids were locally modified by interaction with evaporites producing low Br/Cl ratios.

The fluid inclusions have $^{40}Ar/^{36}Ar$ ratios of up to 441 that are higher than the atmospheric value of 296 and typical of carbonate sedimentary rocks. The fluid inclusions have high concentrations of atmospheric ^{36}Ar and variable $^{129}Xe/^{36}Ar$ and $^{84}Kr/^{36}Ar$ ratios that are outside the range expected from mixing air and air-saturated water. These data are likely to reflect a complex fluid history involving acquisition of atmospheric (^{36}Ar, ^{84}Kr, ^{129}Xe) and radiogenic (e.g. $^{40}Ar^*$) noble gases trapped in sedimentary rocks and fractionation of these gases between water and hydrocarbons. The $^{3}He/^{4}He$ ratios of fluorite fluid inclusions range from a typical crustal value of 0.061 ± 0.004 to values of >0.7 Ra, indicating a minor component of mantle-derived ^{3}He. The fluids with the highest $^{3}He/^{4}He$ also have $^{4}He/^{40}Ar^*$ close to the mantle value suggesting the ^{3}He could have been introduced by a volumetrically minor fluid of either magmatic or deep metamorphic origin ($^{40}Ar^*$ = radiogenic ^{40}Ar).

The new halogen and noble gas data are consistent with a model in which regional Pb-Zn mineralization formed by mixing two modified basinal brines that were transported through independent aquifers and fluid pathways to the sites of mineralization. A low temperature brine contained organic Br, I and H_2S, and a high temperature metal-rich brine (>370 °C) that included a volumetrically minor magmato-metamorphic component was channeled up deeply penetrating thrust structures.