

## Hot and Acidic—The Geochemistry of Vent Fluids from Shale-Hosted Massive Sulfide Deposits at Macmillan Pass, Selwyn Basin

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The conduit of hydrothermal upflow (vent complex) is commonly poorly preserved or absent in shale-hosted massive sulfide (SHMS) deposits. Thus, reconstruction of fluid geochemistry is often inhibited by a lack of appropriate samples. In the Macmillan Pass district (Selwyn basin, Yukon), Late Devonian strata host the complete deposit architecture of two SHMS deposits: Tom and Jason. At both deposits, vent complexes are well preserved beneath the overlying strata-bound mineralization, and a suite of samples has been obtained from drill core, intersecting the vent and host rocks (organic-rich mudstone). These samples provide a unique opportunity to constrain key geochemical parameters (temperature, salinity, pH,  $f_{O_2}$ ,  $\Sigma S$ ) that are critical for metal transport and deposition in SHMS systems.

Mineralogical and paragenetic relationships were evaluated using transmitted and reflected light and backscatter electron imaging. In the vent complex, two main paragenetic stages are preserved: (1) disseminated ankerite alteration of the organic-rich mudstone host rock and crosscutting stockwork ankerite veining ( $\pm$  pyrobitumen, pyrite, and quartz) and (2) main-stage massive sulfide (galena-pyrrhotite-pyrite  $\pm$  chalcopyrite-sphalerite) and siderite ( $\pm$  barytocalcite) mineralization. Ankerite mineral separates were analyzed for  $\delta^{13}C_{VPDB}$  and  $\delta^{18}O_{SMOW}$ , and trace and rare earth elements for both ankerite and siderite were analyzed in situ via LA-ICP-MS; together, this formed an approach by which to evaluate fluid chemistry evolution during stages 1 and 2. The major element composition of the mudstone host rock ( $n = 17$ ) is also presented for samples from a mineralized drill hole to assess evidence for hydrothermal alteration.

Covariation ( $r^2 = 0.799$ ) of  $\delta^{18}O$  values (16‰ to 18.2‰) and  $\delta^{13}C$  values (−4.7‰ to −2.1‰) in vein ankerite from the Jason vent is best explained through modeling of fluid-rock interaction between a cooling (300°–235°C) acidic fluid ( $\Sigma CO_2 = H_2CO_3$ ;  $\delta^{13}C_{fluid} = -3\text{‰}$ ,  $\delta^{18}O_{fluid} = 9\text{‰}$ ) and earlier stage 1 ankerite host-rock alteration. A similar process occurred in the Tom vent at lower temperatures (260°–210°C). In host-rock samples from Tom, potassium loss ( $K_2O/Al_2O_3 < 0.2$ ) less than 15 m above and below mineralization provides evidence that the transformation of muscovite to kaolinite buffered the hot, acidic vent fluid.

Ankerite and siderite contain detectable Pb and Zn concentrations (possibly contained in fluid inclusions). The range of Pb (0.1–440 ppm) and Zn (15–249 ppm) concentrations in stage 1 ankerite is consistent with the base metals being transported by a hot (>250°C), acidic (pH < 4.5) fluid with a low sulfur budget ( $\Sigma S \ll 10^{-3}m$ ) and modest salinity ( $\leq 6$  wt % NaCl equiv). Relative to ankerite, siderite contains a lower range in Pb concentrations (0.1–17.7 ppm), but higher Zn concentrations (79–354 ppm); this reflects the partitioning of Pb into galena, which precipitated coevally with siderite, whereas sphalerite precipitation likely occurred later in the stage 2 paragenesis.

Petrographic observations combined with pH- $f_{O_2}$  modeling of the stage 2 mineral assemblage indicate that decreasing temperature and increasing pH were important processes for sulfide deposition in the vent complexes.