

# Hydrothermal Alteration and Fluid Chemistry of the Endako Porphyry Molybdenum Deposit, British Columbia

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## Abstract

Hydrothermal alteration and fluid chemistry data of the early Cretaceous Endako porphyry molybdenum deposit, British Columbia, provide new information on the hydrothermal fluids associated with low-fluorine molybdenite mineralization. Molybdenite mineralization and hydrothermal alteration occur as early quartz  $\pm$  molybdenite stockwork veins with K feldspar-bearing selvages and paragenetically later quartz-molybdenite ribbon veins with sericite-bearing selvages. Late hydrothermal alteration is associated with the development of kaolinite and postore (Tertiary age) calcite veins.

Fluid inclusions in early-formed quartz  $\pm$  molybdenite stockwork veins with K feldspar-bearing alteration assemblages are dominated by moderate-salinity (5 to 15 wt % NaCl equiv), liquid-rich (type 1) and rare high-salinity (30 to 45 wt % NaCl equiv), halite-bearing (type 3) fluid inclusions. Type 1 and type 3 fluid inclusions in early veins homogenize between 390° and 430°C and 375° and 420°C, respectively. Secondary fluid inclusions (type 2) of low salinity (1 to 5 wt % NaCl equiv) in these early veins are minor, and homogenize between 130° and 285°C. Fluid inclusions in quartz-molybdenite ribbon veins with sericite-bearing alteration assemblages are dominated by moderate-salinity, liquid-rich (type 1) inclusions, with minor type 2 fluid inclusions. Type 1 fluid inclusions of ribbon veins homogenize between 360° and 400°C. Fluid inclusions in postore calcite veins are of only type 2 fluid inclusions, which homogenize at 209°C.

Hydrothermal fluids recorded by type 1 and type 3 fluid inclusions in early veins were trapped under lithostatic to hydrostatic conditions between 0.3 and less than or equal to 2.0 kbar, and 360° and 560°C. Postore fluids recorded by type 2 fluid inclusions were trapped under conditions less than or equal to 0.5 kbar, and between 190° and 300°C.

Quartz stockwork and ribbon veins possess  $\delta^{18}\text{O}$  values of  $8.4 \pm 0.2$  ( $n = 9$ ) and  $8.4 \pm 0.6$  ( $n = 13$ ), respectively. Hydrothermal K feldspar and biotite from K feldspar alteration assemblages possess  $\delta^{18}\text{O}$  values of  $6.8 \pm 0.4$  ( $n = 7$ ) and  $3.5 \pm 0.8$  ( $n = 8$ ), respectively. Oxygen isotope geothermometry of quartz-biotite and quartz-K feldspar pairs from K feldspar alteration assemblages yield temperatures between 200° and 490°C, which is similar to the trapping temperatures of hydrothermal fluids determined from fluid inclusion studies associated with molybdenite mineralization, the development of kaolinite, and calcite veins. The oxygen isotope temperatures of the quartz-biotite and quartz-K feldspar pairs suggest that K feldspar and biotite either record the approximate  $^{18}\text{O}$  composition of hydrothermal fluids associated with K feldspar alteration or have undergone  $^{18}\text{O}$  exchange with late-stage hydrothermal fluids. Hydrogen isotope composition of quartz stockwork and ribbon veins fluid inclusion waters range between  $-105$  and  $-173$  per mil.

Solute chemistry studies of fluid inclusion waters indicate that ore-forming fluids from Endako have low Br/Cl and Br/Na ratios, and high I/Cl and I/Br ratios in comparison to Porgera (epithermal), Babine Lake (porphyry Cu), and St. Austell, Capitan Pluton (vein) deposits associated with magmatic processes. Na/K ratios of fluid inclusion waters yield temperatures (308° to 429°C) similar to those determined from type 1 and type 3 fluid inclusions and stable isotope thermometry.

Results from fluid inclusion and solute chemistry studies indicate the involvement of hydrothermal fluids exsolved from a crystallizing melt in the formation of the Endako molybdenum deposit. However, oxygen and hydrogen isotope values deviate from the generally accepted magmatic compositions, which suggests the early involvement of meteoric water in the ore-forming fluids and ore genesis.