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# Hydrothermal Fluid Evolution within the Cadillac Tectonic Zone, Abitibi Greenstone Belt, Canada: Relationship to Auriferous Fluids in Adjacent Second- and Third-Order Shear Zones

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## Abstract

The Cadillac tectonic zone in the Abitibi greenstone belt, Canada, is spatially associated with world-class gold deposits that are hosted in second- and third-order faults. Five types of hydrothermal quartz veins with distinct structural timing are distinguished in the Cadillac tectonic zone in the Val d'Or camp and are related to $D_2$ steep-reverse faulting and $D_3$ oblique-transcurrent movement.

Fluid inclusions in gold-bearing and barren hydrothermal quartz veins in the transcrustal Cadillac tectonic zone record the progressive evolution of the hydrothermal fluids within the Cadillac tectonic zone. Oldest $H_2O$-$CO_2$-$CH_4$-NaCl fluid inclusions, which predate gold mineralization, are superseded by gold-associated, dominantly carbonic $CO_2$-$CH_4$ ± $H_2O$ ± NaCl fluid inclusions. On the basis of variable phase ratios and similar total homogenization temperatures in contemporaneous fluid inclusions trails, the oldest $H_2O$-$CO_2$-$CH_4$-NaCl fluids are interpreted to have undergone phase separation. The $CH_4$ content increases from the older ($X_{CH_4}$ = 0.03–0.24) to the younger ($X_{CH_4}$ = 0.15–0.71) fluid inclusions, and the salinity is low to moderate in the older fluid inclusions (mean ± $1\sigma$ = 7.2 ± 6.2 wt % NaCl equiv) and increases in the younger fluid inclusions (mean ± $1\sigma$ = 16.2 ± 6.0 wt % NaCl equiv). Trails of late-stage $CO_2$-$CH_4$-$N_2$ ± $H_2O$ and $CH_4$ ± $C_2H_6$ ± $C_3H_8$ fluid inclusions crosscut earlier carbonic-aqueous fluid inclusion trails. In all veins, the texturally latest fluid inclusions occur in trails that crosscut earlier fluid inclusion trails and quartz deformation bands and are composed of $H_2O$-NaCl-$CaCl_2$. Postentrapment modifications are considered unlikely for most fluid inclusions in the Cadillac tectonic zone.

The hydrothermal fluids in the Cadillac tectonic zone were compared with those in second- and third-order fault zones in the world-class Sigma deposit to evaluate whether the two fluid systems are of similar derivation. Carbonic aqueous fluids that deposited quartz in veins and some gold in the Cadillac tectonic zone are distinct from those that are hosted in structures of similar timing at Sigma. Cadillac fluids have higher $CO_2$ content and marginally higher salinity (0.6–15.3 wt % NaCl equiv and 1–10 wt % NaCl equiv in the Cadillac tectonic zone and at Sigma, respectively) but contain similar amounts of $CH_4$. The high-salinity aqueous inclusions at Sigma, which are interpreted to represent the unmixed $H_2O$-rich end member of a combined $CO_2$-$CH_4$-$H_2O$-NaCl fluid, are absent in the Cadillac tectonic zone. Veins of $D_3$ timing, which contain a high $CH_4$ component in the Cadillac tectonic zone (to 70 mole %), have not been documented at Sigma.

The magnitude of the hydrothermal quartz vein field and the homogeneity of quartz vein mineralogy and textures in the Val d'Or camp strongly suggest that the fluids that precipitated auriferous quartz veins in second- and third-order shear zones were not locally derived. It is suggested that ore-bearing fluids ascended along the Cadillac tectonic zone and infiltrated the second- and third-order fault network. An unknown amount of metamorphic $H_2O$ from the greenstone belt probably mixed with these fluids. Differences in the fluid composition in the Cadillac tectonic zone and those in second- and third-order shear zones are explained by phase-separation with preferential vapor loss into the upper portions of the Cadillac tectonic zone and by in situ phase separation without vapor loss during ore deposition at Sigma. Methane enrichment in the late fluids in the Cadillac tectonic zone was most likely controlled by an increased fluid interaction with reduced carbon in sedimentary rocks, but increasing mantle outgassing and cooling of an $f_{O_2}$-buffered ascending fluid may also have contributed to the $CH_4$ budget. The youngest aqueous brines in the Cadillac tectonic zone are similar to fluids in late fracture fillings and to Canadian Shield basement brines.