Ore metal transport by hydrocarbon vapour in the footwall of the Sudbury Igneous Complex, Canada

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We report hydrocarbon vapour inclusions occurring in quartz-epidote-sulfide alteration veins associated with footwall Cu-Ni-PGE (platinum-group element)-Au sulfide deposits at the Fraser Mine (Sudbury Igneous Complex). Primary inclusions comprised of immiscible CH_4 vapour + brine were trapped during quartz growth at relatively low T (~ 145–315°C) and P < 0.6 kbar, prior to the crystallization of sulfide minerals in the veins. Secondary inclusions contain solid halite and a mixture of light aliphatic hydrocarbons and nitrogen (~ 55 mol% CH_4, 35% C_2H_6, 5% C_3H_8, 5% N_2; by gas chromatography). The secondary inclusions may represent immiscible hydrocarbon vapour + halide melt (mimimum trapping T ~ 710°C) that exsolved from crystallizing sulfide melt postdating early alteration quartz hosting the primary brine-CH_4 assemblage. Alternately, halite may have been precipitated from a halite-saturated hydrocarbon fluid phase at lower T (< 500°C).

Laser ablation ICP-MS microanalysis shows that hydrocarbon vapour, brine and halide melt inclusions contain significant concentrations of Cu (100 µg/g to 1 wt% range), Au, Bi, Ag and Pt (all 0.1-10 µg/g range). Cu:Pt and Cu:Au ratios in the primary hydrocarbon inclusions are up to 4 orders of magnitude lower than in the host alteration veins and adjacent parent massive sulfide ore veins, suggesting either (i) early Cu loss by chalcopyrite precipitation during cooling of the vapour phase or (ii) enhanced Au and Pt solubility relative to Cu at the low temperature of entrapment. Concentration ratios between coexisting primary hydrocarbon vapour and brine inclusions [$C_{\mathrm{hcarb}}/C_{\mathrm{brine}}$] are higher for Cu (0.1 to 100; avg.=10), Au, Bi and Ag (0.1 to 10; avg.=2) than for other elements (Na, Ca, Fe, Mn, Zn, Pb; all < 0.1) indicating that during interaction with the brine, the hydrocarbon vapour was selectively enriched in specific ore metals.

Our study reports the first direct measurements of precious metal concentrations in fluid inclusions from a magmatic Ni-Cu-PGE environment (the Sudbury district) and demonstrates the importance of non-polar solvents for vapour phase transport of ore metals in magmatic Ni-Cu-PGE systems.

Carbonic vapor-dominated fluid systems in orogenic-type Au deposits

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The ore-forming fluids of the majority of orogenic-type gold deposits have compositions in the H_2O-CO_2-NaCl system, with generally low salinities and CO_2/H_2O molar ratios <0.5. In some cases, including the giant Ashanti deposit, Ghana and the Campbell-Red Lake deposit, Canada, the predominant fluid inclusions are carbonic (without detectable H_2O), while aqueous or aqueous + carbonic inclusions are rare. Whether the carbonic inclusions represent the ore-forming fluids or result from post-trapping leakage of water is still a matter of considerable debate.

Microthermometric, Laser-Raman spectroscopic, and gas chromatographic measurements indicate that fluid inclusions from Campbell-Red Lake are predominantly carbonic, composed mainly of CO_2, with minor CH_4 and N_2, and trace amounts of H_2S. Homogenization temperatures of these fluid inclusions vary considerably but in individual fluid inclusion assemblages the range of T_h is relatively narrow, indicating that H_2O depletion in the carbonic inclusions was not due to post-trapping modifications and host mineral deformation.

Fluid phase modeling supports a hypothesis in which the Campbell-Red Lake gold deposit formed from an H_2O-depleted carbonic vapor derived from phase separation of an originally carbonic-enriched hydrothermal fluid. We propose that the gold was preferentially partitioned into the vapor phase during phase separation and transported as H_2S- or hydrocarbon-solvated species to the site of ore-deposition. If correct, this hypothesis will require a re-evaluation of existing models for the formation of orogenic-type gold deposits.