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Author(s):
Hanley, Jacob; Mungall, James; Pettke, Thomas; Spooner, Edward; Bray, Colin

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

JACOB HANLEY\textsuperscript{1}, JAMES MUNGALL\textsuperscript{1}, THOMAS PETTKE\textsuperscript{2}, EDWARD SPOONER\textsuperscript{1} AND COLIN BRAY\textsuperscript{1}

\textsuperscript{1}Dept. of Geology, Univ. Toronto, 22 Russell Street, Toronto, M5S 3B1, Canada (hanley@geology.utoronto.ca)
\textsuperscript{2}Dept. Earth Sciences, ETHZ, CH-8092, Zurich, Switzerland

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\textsubscript{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\textsubscript{4}, 35\% C\textsubscript{2}H\textsubscript{6}, 5\% C\textsubscript{3}H\textsubscript{8}, 5\% N\textsubscript{2}; by gas chromatography). The secondary inclusions may represent immiscible hydrocarbon vapour + halide melt (minimum trapping $T$ ~ 710°C) that exsolved from crystallizing sulfide melt postdating early alteration quartz hosting the primary brine-CH\textsubscript{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 [$C_{\text{vapour}}/C_{\text{brine}}$] 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.