Goldschmidt 2021 Abstract
https://doi.org/10.7185/gold2021.6160

High temperature (>800°C) brine phase present during the formation of Northern Bushveld magmatic sulfide Cu-Ni-PGE deposits

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The role of volatiles in the development of layered intrusion-hosted magmatic sulfide deposits is still poorly understood. We present petrological and fluid inclusion evidence that an aqueous brine phase was present during the formation of the Aurora, Waterberg PTM and Troctolite Unit Ni-Cu-PGE mineralisation from the northern Bushveld Complex where magmatic sulfide deposits are hosted in leucocratic rocks of the Main Zone and the Upper Zone. This brine phase was present while the system was at least partially molten and we present direct evidence of brine – sulfide melt interaction.

Fluid inclusions were identified in cumulate magmatic silicates (feldspar, olivine, and pyroxene) in all three deposits. These comprise brine and vapour inclusions which do not crosscut crystal boundaries and terminate against peritectic reaction rims. Optical microscopy and confocal Raman spectroscopy show that the brine inclusions contain multiple daughter minerals (including halite and carbonates), 10-15% vapour and 15-25% liquid water; whereas vapour inclusions contain CH_4 and N_2. Microthermometry shows that brine inclusions homogenise to liquid by vapour disappearance between 819 – 1000°C in the Aurora deposit (n=281), between 877 – 994°C in Waterberg (n=256), and between 860 – 942°C in the Troctolite Unit (n=428). Halite dissolves between 521 – 697°C, giving salinities of 61-87 wt.% NaCl equivalent.

At the estimated trapping temperatures of these brines (895 – 1028°C, corrected for an assumed trapping pressure of 150 MPa) sulfides would be partially molten. Examples of co-eval interaction and entrapment of brine and Cu-rich sulfide melt are observed in all deposits, implying this was a common factor during their development. The PGE in the Aurora project and the T zone at Waterberg are hosted in platinum group minerals (PGM) that are spatially removed from magmatic sulfides and hosted in late silicates such as quartz, suggesting PGE remobilisation by hydrothermal processes. The petrological similarity between inclusions in all Main Zone deposits suggests the high temperature fluids had a similar origin, either from late magmatic degassing or possibly from volatiles released from assimilated dolomite country rock. The results of this study have important implications for northern Bushveld Ni-Cu-PGE deposits, and layered intrusion-hosted deposits more generally.