

Paper Number: 3191

Quantitative characterisation of low temperature hydrothermal alteration of magmatic Ni-Cu-PGE sulfide ores



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Magmatic Ni-Cu-platinum group element (PGE) sulfide deposits are formed when a mafic/ultramafic magma becomes sulphide saturated and an immiscible sulphide liquid separates from the magma. As the sulphide liquid begins to cool, the first phase to crystallise is monosulphide solid solution (mss), into which Ni and the IPGE (iridium-group PGE; Os, Ir, Ru) will partition, at temperatures of ~1000°C [1]. At 900°C, intermediate solid solution (iss) forms from the Cu-rich residual sulfide liquid. The majority of PGEs are incompatible in both mss and iss begin to concentrate with other trace elements, such as Te, Bi, As and form discrete platinum group minerals (PGMs) [1]. Mss and iss recrystallize at low temperature to pyrrhotite (po) - pentlandite (pn) - chalcopyrite (cpy) and subsequently most magmatic Ni-Cu-PGE sulfide contain this relatively consistent primary-magmatic sulfide mineralogy.

Recently, in a number of deposits such as the Grasvalley-Norite-Pyroxenite-Anorthosite (GNPA) member, northern bushveld, South Africa and the Lac Des Iles deposit, Ontario, Canada, another sulfide assemblage has been recognised; pyrite (py) - millerite (mill) - chalcopyrite [2], formed from the low temperature alteration of pyrrhotite to pyrite, and pentlandite to millerite.

A ZEISS SIGMA VP SEM equipped with two Bruker EDS detectors and Mineralogic Mining Automated Mineralogy Analysis Engine is used here to characterise a suite of thin sections, from the GNPA member, representing a continuum of assemblages by fully quantifying the mineralogy of the sulphides.

From this five progressive stages of alteration were identified; (1) primary/fresh Po-Pn-Cpy (2) Po-Py-Pn-Cpy (3) Py-Pn-Cpy (4) Py-Pn-Mill-Cpy and (5) Py-Mill-Cpy. Using mineral chemistry data generated by Mineralogic, we are able to fully quantify the elemental balance through each stage of alteration. Overall there is a net loss of Fe and S, with the amount of Fe in total sulfide decreasing from 54 wt% in stage (1) to 37wt% by the final stage. The resulting Fe is lost to the surrounding silicates. The Ni:Cu ratio increases from around unity to 3:1, indicating some progressive Cu loss, and relative Ni immobility. PGE are found not to be mobilised significantly [3]. As such, the alteration process changes the mineralogy, reduces the volume of the sulfides, but in doing so, also increases the Ni and PGE tenor of the sulfides that remain.

The characterisation of the sulfides using Mineralogic allows for the quantification of this process for the first time, adding to our understanding of this fundamental control on magmatic sulfide mineralogy and demonstrating the wide use of automated mineralogy in ore deposit research.

References:

[1] Holwell D and McDonald I (2010) Platinum Metal Review 54:26-36

[2] Smith J et al. (2011) Applied Earth Science: Transactions of the Institutions of Mining and Metallurgy 120:158-174

[3] Smith J et al. (2014) Min Dep 49:667-692

