Phosphate-sulphide-carbonate immiscibility as transport for metals in the mantle

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Given the chalcophile nature of metals such as the platinum-group elements (PGE), Se, Te, Re, Cu and Au, the mobility of these metals is intimately linked with that of sulphur. But how are sulphides mobilised in the mantle? Is this purely dependent upon partial melting and metasomatism, or can these be 'fluxed'? If so, what effect does this have on their composition? We use a case study of spinel lherzolite mantle xenoliths from Loch Roag (NW Scotland) to exemplify the complex processes governing base metal sulphide (BMS) mobility and composition.

We identify two populations of co-existing BMS within a single spinel lherzolite xenolith and that can also be recognised more widely in the peridotite xenolith suites of Northern Scotland (margin of the North Atlantic Craton) as a whole. Both populations consist of a mixture of Fe-Ni-Cu sulphides, but with different BMS textures, petrographic setting (i.e., location within the xenolith in terms of 'interstitial' or within feldspar-spinel symplectites, as demonstrated by X-ray Computed Microtomography) and *in situ* trace element composition. Group A BMS are interstitial, coarse, metasomatic, with low concentrations of total PGE (< 40 ppm) and high $(Re/Os)_N$ (ranging 1 to 400). Group B BMS strictly occur within symplectites of spinel and feldspar, are finer and rounded droplets, with micron-scale PtS, high overall total PGE concentrations (15-800 ppm) and low $(Re/Os)_N$ ranging 0.04 to 2. Group B BMS are sometimes observed to coexist with apatite and with rounded micron-scale Ca-carbonate inclusions (indicative of phosphate-sulphide-carbonate immiscibility). Carbonate-phosphate metasomatism may be important in fluxing sulphide minerals wholesale (regardless of the whether they were metasomatic or residual in the source) to form PGE-rich sulphide liquids. Although the precise mechanism remains obscure, there is growing evidence that a carbonatite-phosphate association with high-tenor PGE sulphides may be important in crustal mineralisation processes for mantle-derived magmas [e.g., 1].

[1] Holwell et al., 2017, *Ore Geology Reviews*, dx.doi.org/10.1016/j.oregeorev.2017.02.034