Upper mantle sulphides as 'time capsules' for critical metals

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Geodynamic models suggest the age and stability of the subcontinental lithospheric mantle (SCLM) may control long-term storage and release of chalcophile critical metals (PGE, Re, Co, and Au). We investigate the mineralogy and trace element composition of sulphides from North Atlantic Craton (NAC) and Kaapvaal mantle xenoliths. In Northern Scotland multiple populations of base metal sulphides co-exist within individual xenoliths. Sulphides are situated in distinct petrographic settings, each with distinctive textures, PGM phases (e.g., cooperite (PtS)) and trace elements. $(Re/Os)_N$ ratios are characteristic to each population, providing a rare opportunity for geochronology on a sulphide-by-sulphide basis. This highlights that the precious metal budget of magmas that chemically or physically interacted with the SCLM, particularly at craton margins, depends on complex S budget controls relating to the age and situation of each sulphide group. For example, we note a temporal control on Pt/Pd ratios of basaltic lava suites from the North Atlantic Igneous Province: The oldest lavas (e.g., Scotland and West Greenland) have broadly chondritic Pt/Pd (~ 1.9) whereas the youngest lavas (e.g., Iceland) have the lowest Pt/Pd (~ 0.4). This correlates with the changing geodynamic environment of the (proto)-Icelandic plume through time and could reflect the availability of lithospheric mantle Pt-rich sulphides for entrainment in ascending plume magmas.

In Southern Africa, the geodynamic setting and source(s) of magmas that fed the Bushveld Complex remain unresolved – not least the controls on Pt/Pd ratio between northern and southern portions of the complex. These are separated by a major lithospheric lineament and might reflect interplay between a mantle plume event and significant SCLM melting (or 'resetting'). As demonstrated by the NAC, we suggest that sulphide populations in the Kaapvaal SCLM keel are capable of recording numerous magmatic and metasomatic events for protracted periods, documenting transient S-bearing (chalcophile-controlling) episodes. Hence the shallowest portions of this keel should record the Bushveld magmatic perturbation, either revealing the SCLM as a major magmatic source or as a largely 'passive' lithospheric region.