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New Horizons in Magmatic Cu-Ni-PGE Sulfide Exploration: Expanding the Search Space to Alkaline Systems

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Magmatic Ni-Cu-PGE sulfide deposits are classically hosted in mafic-ultramafic complexes formed from magmas that are the product of moderate to high degrees (10-25%) of mantle melting. Such ores typically have Ni/Cu ratios around 1-20, with deposits formed from the most MgO-rich magmas generated from the highest degrees of melting, komatiites, being the most Ni rich. However, there is an increasing recognition of magmatic sulfide occurrences in alkaline ultramafic systems, generated from lower (<10%) mantle melting. A key consequence of the lower degree of partial melting in such systems is that the melts formed are more volatile rich, as components such as H_2O and CO_2 are incompatible. Thus, the lower the partial melt, the more volatile-rich the magma. This also impacts on the metal budget. Impartial or incongruent melting of mantle sulfide will liberate elements such as Cu, Au, and Te preferentially over Ni, Co, and some of the PGEs, which will remain in any residual mantle sulfide.

Consequently, magmatic sulfides in alkaline systems are typically hosted by ultramafic rocks that contain hydrous and volatile phases like amphibole, phlogopite, apatite, and carbonate. There is a continuum in composition from carbonatite-phoscorite, through shonkinites and alkalic ultramafics to thoeliites. The volatile content decreases through this continuum, and the metal ratios change, with initially high Cu/Ni, Au/PGE, and Te/PGE, which reduce to a more conventional Ni-Cu-PGE assemblage in volatile-poor tholeiitic melts. Thus this "alkalic DNA" is characterised by sulfides that are Cu dominant over Ni and have elevated Au concentrations and abundant telluride minerals as part of the assemblage. Notably, sulfides are often intimately associated with carbonate that suggest CO_2 played a critical role in buoyant transport from the mantle into the crust.

The alkaline magmatic sulfide systems can be observed throughout the lithosphere, from lower crustal pipes and intrusions (e.g., in the Ivrea Zone, Italy) where sulfide and carbonate are hosted by amphibole-rich ultramafic rocks. In mid-crustal conduits and alkaline-mafic-carbonatite complexes (e.g., Mordor Complex, Australia), sulfides are associate with carbonate as large blebs. Notably, upper crustal expression of these systems are not, however, ultramafic-mafic intrusions, but evolved alkaline intrusions that can be host to Cu-Au-Te-(Pd)-rich porphyry deposits and Au-Te epithermal systems.

Whilst the upper crustal porphyry-epithermal deposits can be giants (e.g., Cripple Creek), the question remains as to whether such systems can generate significant magmatic sulfide orebodies in the mid to lower crust. We propose that the Cu-Au-Te-rich orebodies of the Curaça Valley, Brazil; the Okiep district, South Africa; and the Mbesa prospect, Tanzania are all mid-crustal expressions of the accumulation of magmatic sulfides from such systems and form a continuum towards classic, volatile-poor, Ni-Cu-PGE deposits. As such, exploration targeting in regions of alkaline mafic-ultramafic and carbonatitic magmatism has the potential to broaden and open up new search spaces for more Cu-Au-Te-rich magmatic sulfide deposits in settings that do not necessarily conform to the conventional model for Ni-Cu-PGE deposits.