Stratigraphy-Controlled Minero-Chemical and Isotopic Imprints for Primary Sulfur Degassing of Lavas in Komatiite-hosted Ni-PGE Ores at Wannaway Deposit, Western Australia

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Escape of volatile components from magmas experiencing primary degassing may leave behind mineralogical as well as crystal-chemical and isotopic imprints in associated ore deposits. Such signatures may be detected and correlated at best when investigated in ore contexts where a polarity can be easily recognized. Archean Ni-rich sulfidic orebodies hosted in komatiite lava flows are ideal for their well-defined succession of stratigraphically correlated facies.

This study focussed on the ore-bearing sequence of the N01 orebody of the Wannaway nickel-sulfide deposit in the Eastern Goldfields Terrane, Yilgarn Craton, Western Australia. This komatiite-hosted deposit underwent regional deformation and metamorphism locally attaining amphibolite facies conditions. However, portions of the mineralized sequence still preserve original, magmatic textures and assemblages. The ore deposit consists of a basal massive sulfide melt accumulation grading to matrix and disseminated upward in the komatiite unit, and in footwall contact with Ni-rich sulfidic metasediments and, subordinately, basalt.

The primary ore mineral assemblage determined outside the tectonically disturbed zones includes Fe sulfide and ubiquitous pentlandite, with minor sphalerite and chalcopyrite, spinels (chromite, magnetite) and accessory PGE-bearing gersdorffite and tellurides, alabandite, PGM irarsite, and rare molybdenite. The ore assemblage shows significant variations across the sequence: the basal massive part is dominated by pyrrhotite, pentlandite, minor chalcopyrite and Zn- and Mn-rich, V-bearing chromite, whereas the transition to the matrix ore facies is marked by sudden disappearance of chromite, crystallization of magnetite and sphalerite and the onset of troilite exsolutions in pyrrhotite. Across the matrix ore facies, the S-poor, metal-rich pyrrhotite with troilite composition gradually becomes the dominant FeS phase intergrown with pentlandite, sphalerite, magnetite, Mn sulfide alabandite and PGM. Post-magmatic, serpentinization-related imprints are marked by texturally distinct growths of late-stage magnetite, pyrrhotite and Ni-sulfides. The compositional modifications in FeS have counterparts in accompanying phases like pentlandite and ubiquitous PGE-rich sulfarsenides and tellurides, which show minor but systematic compositional variations across the sequence. In addition to the gradual sulfur decrease recorded in the dominant Fe sulfide phase, the vanadium distribution in chromite towards the transition massive-matrix ore suggests the progressive instauration of low f_{O2} conditions, which are compatible with the stability of troilite and alabandite.

These minero-chemical features and assemblages are consistent with stratigraphic-related sulfur and oxygen loss from the sulfide melt. This hypothesis was strengthened by the variation in multiple sulphur isotopes on magmatic FeS-pentlandite couples from both orebody and wallrocks. The $\delta^{34}S$-$\Delta^{33}S$ plots comparing both mass-dependent effects on sulfur isotope fractionation and mass-independent Archean footprints show complex yet parallel, equilibrium-related fractionation trends for both pyrrhotite and pentlandite. Uniformly non-zero positive $\Delta^{33}S$ signatures of the magmatic orebody reflect a clear sedimentary source for sulfur and analogous to the footwall sulfidic metasediments. The $\delta^{34}S$ signatures for both pyrrhotite and pentlandite are characterized by a remarkable shift from heavier to lighter compositions up stratigraphy. Such isotopic shift is compatible with primary sulfur loss and degassing in ultramafic lavas via emissions of SO_2.