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Offset PGE reefs revisited: equilibrium and diffusive partitioning in action

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Offset reefs are a subdivision of magmatic sulfide deposits defined as layered intrusion-hosted, precious-metal enriched, stratiform disseminated sulfide accumulations. Examples include the Platinova Reef of the Skaergaard intrusion, the Ferguson Reef of the Munni Munni Complex, the Main Sulfide Zone of the Great Dyke of Zimbabwe and the PGE-enriched layers of the Sonju Lake intrusion, the Rincon del Tigre complex and the Stella Intrusion. In all these deposits, the peaks in PGE lie immediately *below* a sharp increase in the volume of sulfide, the latter of which coincides with the major Au peak (Figure 1). This similarity exists notwithstanding substantial difference in detail, such as the multiple sub-layers within the Platinova package, and a wide variability in thickness (a few metres at Munni Munni, several tens of metres at Rincon del Tigre), and a magnetite association in some cases (Stella and Rincon del Tigre) but not others (Munni Munni and the Great Dyke). On this basis, there must be a set of underlying processes that have operated in all of these intrusions, and the notion that any one of these (e.g. Skaergaard) is the product of a unique set of processes is unlikely.

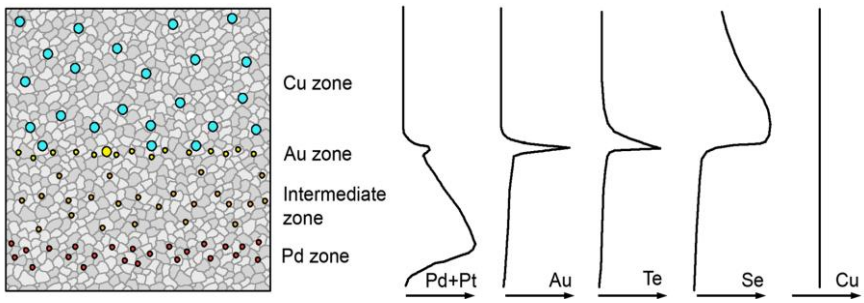

Figure 1: Example of the relative enrichment in sulfide of various chalcophile elements in the Platinova Reef of the Skaergaard Intrusion. The Cu zone sees a significant increase in sulfide abundance [1]

The stratigraphic transition to higher volumes of sulfide essentially preserves the onset of chamber-wide sulfide saturation. The very small size of the sulfide droplets as they nucleate means that those formed in the crystal mush at the floor will be trapped, as microdroplets in situ, *without* growing or coalescing significantly. Droplets in the main part of the chamber have the ability to grow from the convecting magma and accumulate at the floor. The transition to higher volume, PM-poor Cu sulfides seen in all the aforementioned deposits thus marks the point where the first arrival of this wave of chamber-derived sulfides hits the floor. It also appears to coincide with the main Au peak, which in all such deposits coincides with an increase in the volume of sulfide, before the main Cu peak. New data from Skaergaard [1] shows that there is also a Te peak immediately above the Au peak, and a Se peak immediately above the Te peak, at the base of the Cu peak, such that it shows a sequence of peaks in Pt+Pd>Au>Te>Se>Cu, upwards over a thickness of a few metres.

The consistent sequence of PGE, Au, Te, Se and Cu peaks is entirely consistent with relative $D_{sul/sil}$ values and offset reefs have been modelled in several examples by sequential fractional segregation of sulfide. Mungall [2] obtained a highly refined fit for the Munni Munni profile by including terms for diffusivity as well, but the order of magnitude and order of peaks was substantially the same as that obtained when

using partition coefficients only. As such, offset reefs are formed from the onset of sulfide saturation in a magma chamber, with small volumes of sulfide being enriched in chalcophile elements sequentially in order of $D_{sul/sil}$ value *and* relative diffusivites. This consistent relationships across a number of deposits argues against hydrothermal models for individual deposits.

References:

[1] Holwell DA et al (2015) Contrib Mineral Petrol 170:53

[2] Mungall JE (2002) J Petrol 43:749-768