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PGE-Ni-Cu deposit formation in a deep-crustal ultramafic conduit system. The Seiland Igneous Province, North Norway

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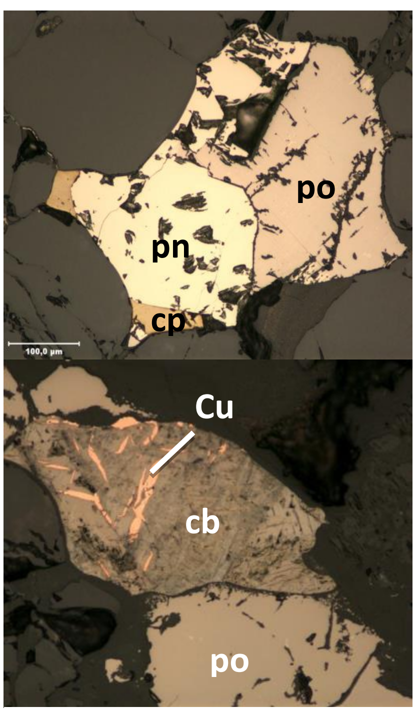
The Seiland Igneous Province (SIP) consists of >5,000 km^{2}of mafic, ultramafic and alkaline melts that were emplaced into the lower continental crust (25-35 km depth) in <10 Ma (570-560 Ma) during mantle plume upwelling. We argue that the SIP was the deep-seated conduit system of a large igneous province (LIP), making the region a key location in which to study the ascent, emplacement and modification of dense mantle melts enroute to more shallow igneous systems. It is also an ideal location for the study of ore-deposit forming events in open ultramafic conduit systems dominated by repetitive recharge of mafic-ultramafic melts. Loci of the main conduit system features ultramafic complexes of which, the Reinfjord Complex is an excellent example.



Sulphide aggregates with pyrrhotite (po), pentlandite (pn) chalcopyrite (cp), cubanite (cb) and native copper(Cu).

The picritic to komatiitic (16-22 wt% MgO) melts of the Reinfjord Complex were emplaced into gabbros in three major pulses punctuated by several smaller recharge events. The first two pulses, the lower and upper layered series (LLS + ULS) comprises modally layered ol – cpx ±opx cumulates. The final phase, the central series (CS), comprises dunitic cumulates in the centre of the intrusion. The CS intruded into a crystal-melt mush of the ULS. A replenishment event in the CS is associated with two reef deposits of 5 and 7 metres thickness, respectively, and separated by 20 metres of dunite. The reefs contain 1.2-1.6 wt% total sulphides dominated by pyrrhotite, pentlandite and chalcopyrite (top figure). The lower occurrence (5 m) is a PGE-reef with 0.8 ppm of total Pt+Pd+Au+Os and 0.27 wt. % Ni. The upper Cu-Ni reef carries 0.38 wt% Ni and 0.12 wt% Cu and only traces of PGE. Analysis of the entire chondrite normalised PGE spectrum provides a trough pattern with positive Os, Pt and Pd, Au patterns. In-situ, ion-probe, sulfur-isotope analysis yielded juvenile values for all sulphide deposits in the UM complex and the country rock gabbros, however, with conspicuous variations amongst the

individual deposits. The PGE-reef yielded a $\delta^{34}S$ value of -0.40 ‰, the Cu-Ni reef, -4.56 ‰, contact deposits gave +0.02 ‰, and gabbro sulphides gave an average of +2.19 ‰. Finally, sulphides in the country rock gneisses yielded a value of +9.09 ‰. Accordingly, the reef deposits did not achieve their sulphur by *local* country rock contamination. It may also be concluded that the source of sulphur for the PGE-reef is distinctively different from that of the Cu-Ni reef only 20 m's higher up! Detailed studies showed that the Au-rich parts of the PGE-reef were decoupled from the Pt-Pd-Os enriched parts. The Au rich parts were associated with stringers and clusters of Ca-Mg carbonates, amphibole, phlogopite, rutile and apatite. Probably this volatile-rich assemblage formed when alkaline carbonatitic melts infiltrated the reefs and selectively remobilised Au previously present in the PGE-reef. Alkaline melt infiltration also altered chalcopyrite to native copper + cubanite (bottom figure). The PGM's are dominated by Pt-Pd tellurides and Au-Cu ±Ag alloys and a rare Os-Ir-Ru phase was also identified.
What arguably makes the Reinfjord reefs an unusual type of Cu-Ni-PGE deposit is; i) the great thickness of the reefs with low total sulphides; ii) clear separation of a PGE-Ni-rich and a Ni-Cu-rich PGE-poor reef; iii) selective remobilization of Au by infiltrating volatile-rich alkaline melts iii) strongly contrasting S-isotope signatures over only 20 metres of cumulates; iv) the strong trough shaped PGE-pattern and v) setting in a pure dunite formed from UM parental melts.