Cu-PGE vs Cr-PGE mineralization in Alaskan-type mafic-ultramafic intrusions

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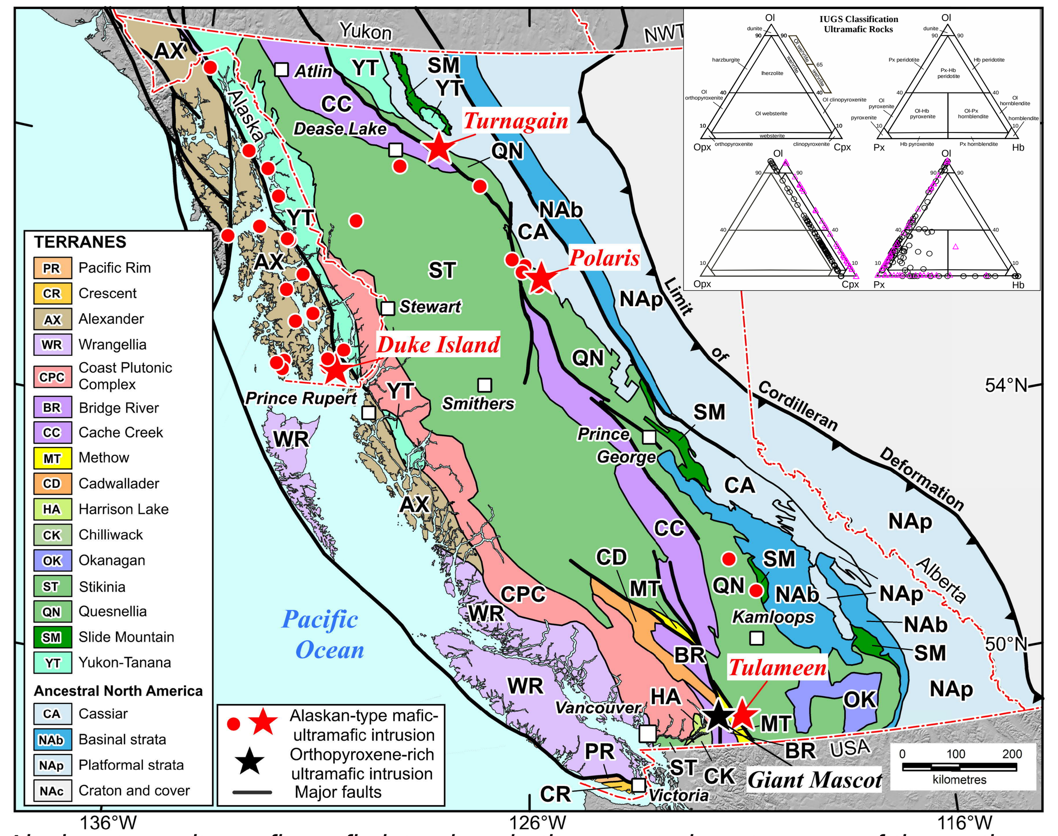
INTRODUCTION

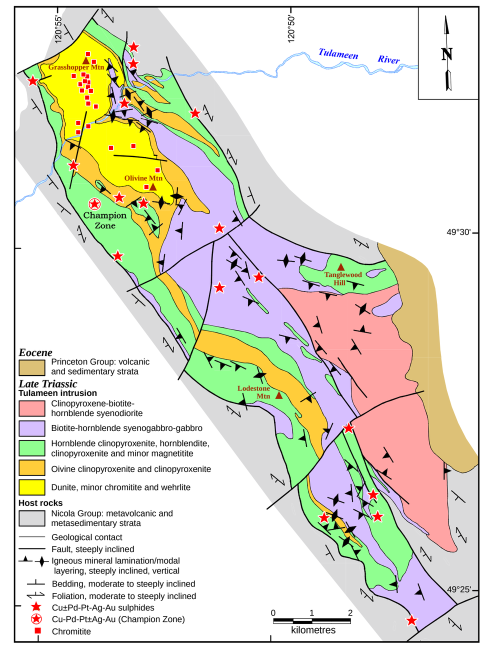
Alaskan-type ultramafic-mafic intrusions in convergent margin settings, distinguished by a lack of orthopyroxene, are well represented in the accreted arc terranes of the northern Cordillera. Although known world-wide for platinum occurrences in lode and commercially exploited placer deposits, four of these intrusions (named below) contain orthomagmatic Ni-Cu-PGE sulphides. The nature and environments of sulphide-PGE and chromite-PGE mineralization at Tulameen and Polaris are described herein.



Alaskan-type ultramafic-mafic intrusions in the accreted arc terranes of the northern Cordillera. Orthomagmatic sulphide mineralization is known at Duke Island, Turnagain and Polaris (Ni-Cu-PGE) and Tulameen (Cu-PGE); chromite-PGE mineralization occurs at Polaris and Tulameen.

TULAMEEN

The Late Triassic Tulameen ultramafic-mafic intrusion (below) is a classically zoned Alaskan-type body with a dunite(-chromitite) core and hornblende clinopyroxenite rim. Chromitites in the core host PGE mineralization, mainly Pt-Fe(-Cu-Ni) alloys; Cu-PGE(-Ag-Au) orthomagmatic sulphides are hosted in peripheral hornblende clinopyroxenites and are well exposed in the Champion zone.

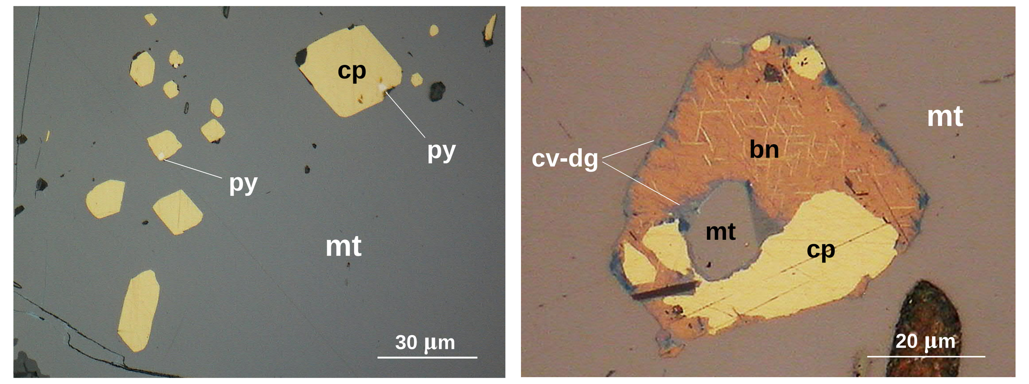


Tulameen sulphides

Magmatic sulphides in the Champion zone are hosted by hornblende clinopyroxenite, hornblendite, and magnetitite. The principal Cu-Fe sulphides (<2 vol. %) are chalcopyrite and lesser bornite, minor pyrite and rare pyrrhotite, sphalerite, acanthite(?), and platinum group minerals (PGM). Whole-rock abundances of PGE attain 1.9 g/t Pd+Pt with Pd/Pt~1.5.

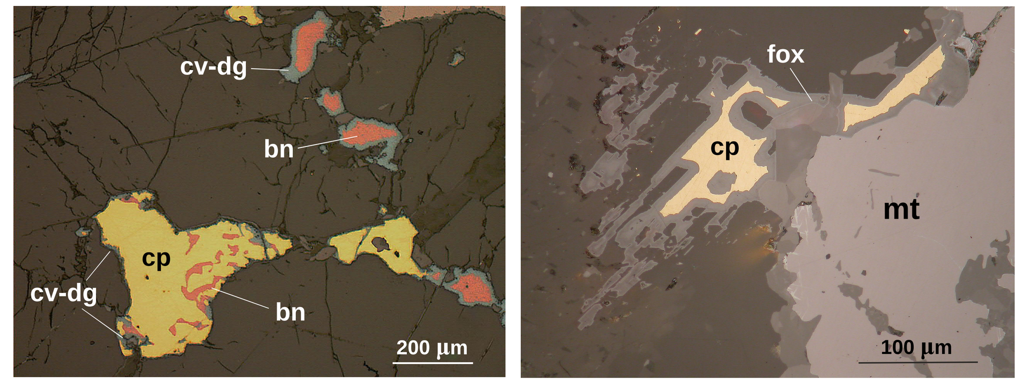
Four main textural associations are illustrated below: 1) magmatic inclusions (<50 µm) in hornblende, magnetite, and clinopyroxene; 2) interstitial sulphides; 3) sulphides recrystallized during greenschist metamorphism; and 4) a late, localized pyrite overprint.

Magmatic inclusions



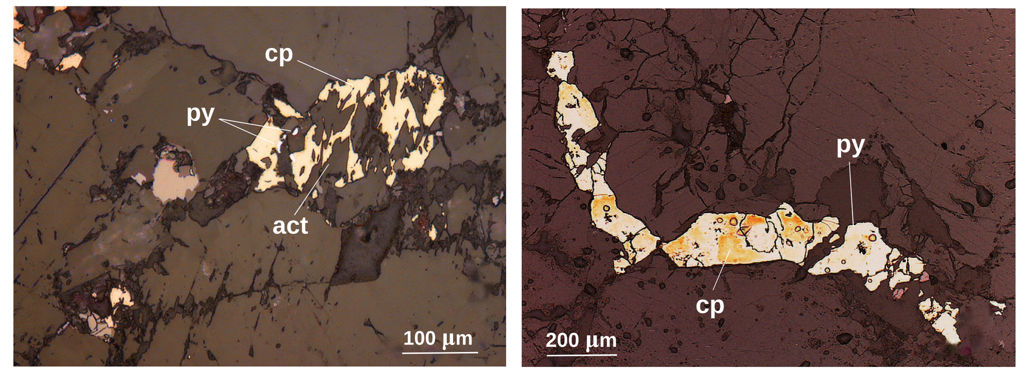
Magnetite(mt)-hosted inclusions of chalcopyrite(cp)-pyrite(py) in hornblende clinopyroxenite (left); and chalcopyrite-magnetite-bornite(bn) altered to covellite-digenite (cv-dg) in hornblende (right).

Interstitial sulphides



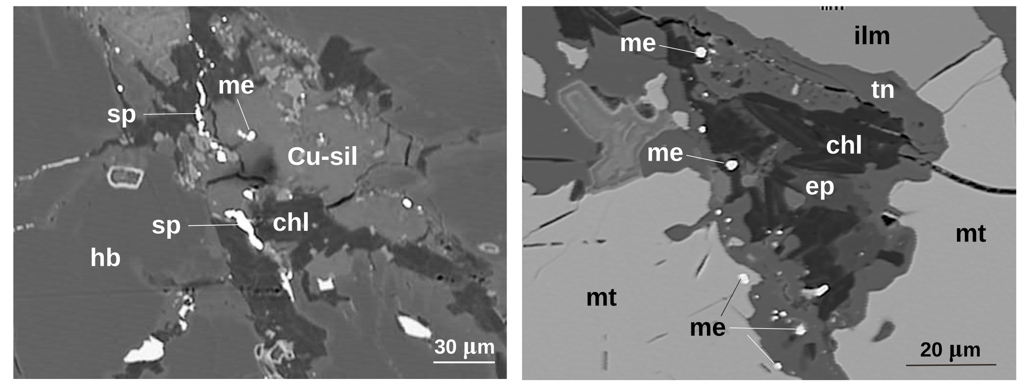
Bornite and chalcopyrite with vermiform bornite exsolution and covellite-digenite rim in hornblende (left); relict chalcopyrite extensively altered to Fe-oxyhydroxide(fox) in hornblende clinopyroxenite (right).

Recrystallized & hydrothermal sulphides



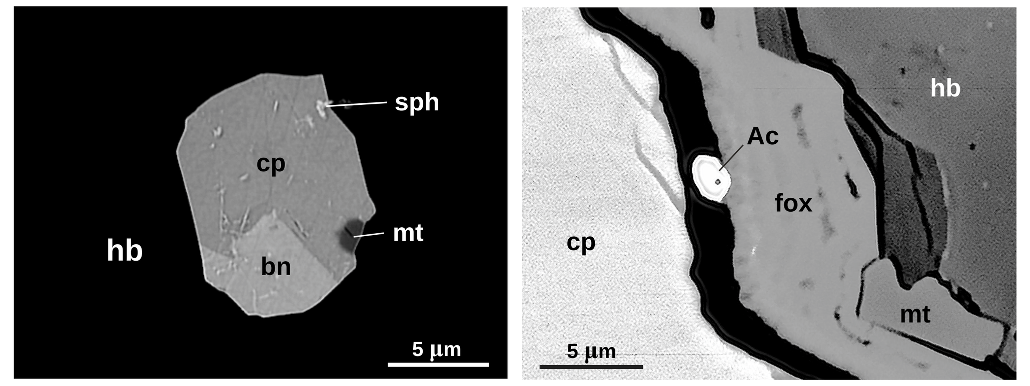
Chalcopyrite and minor pyrite intergrown with oriented laths of actinolite(act) in hornblendite (left); late hydrothermal pyrite replacing interstitial chalcopyrite in hornblende clinopyroxenite (right).

Platinum group minerals



Back-scattered electron images of vermiform platinum arsenide (sperrylite, sp) and granular palladium antimonide (mertieite, me) associated with chlorite(chl) and copper silicate(Cu-sil) in hornblendite (left); and mertieite with chlorite-epidote(ep)-titanite(tn) in magnetite(mt)-ilmenite(ilm) hornblendite (right).

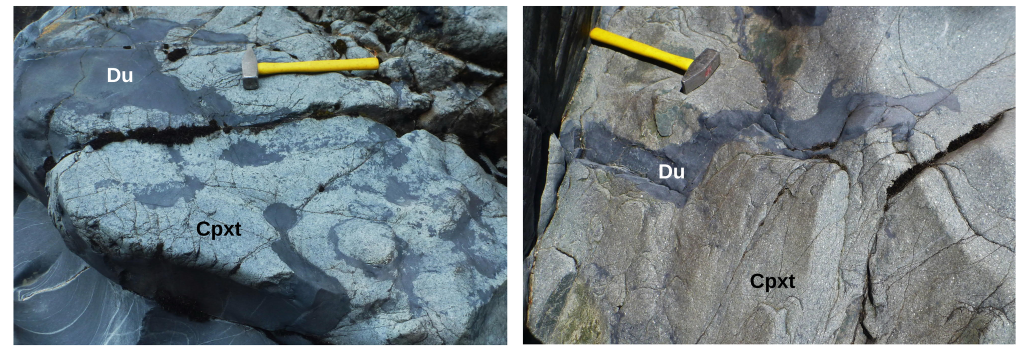
Other rare minerals



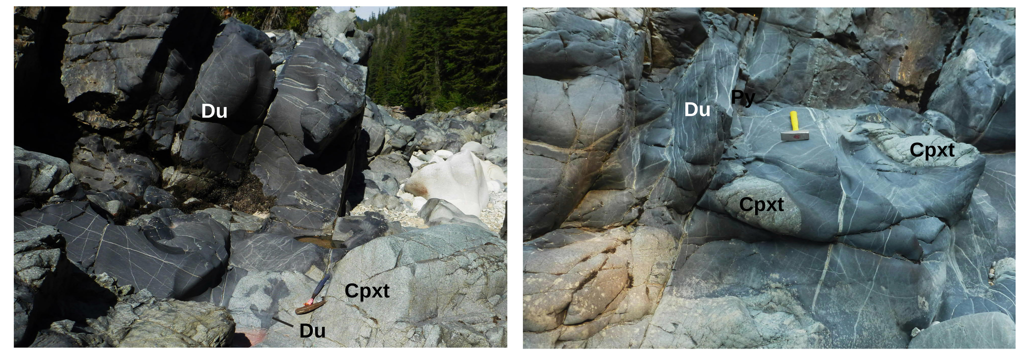
Back-scattered electron images of composite inclusion of chalcopyrite(cp)-bornite(bn)-magnetite(mt) and trace sphalerite(sph) in hornblende in magnetite hornblendite (left); silver mineral (?acanthite(Ac)) at margin of chalcopyrite altered to Fe-oxyhydroxide in magnetite hornblendite (right).

Magmatic avalanche deposits

Plastically deformed inclusions of dunite in olivine clinopyroxenite exposed in the Tulameen river bed at the eastern margin of the dunite core are interpreted as avalanches of pre-existing hot cumulates triggered by magma recharge event(s).



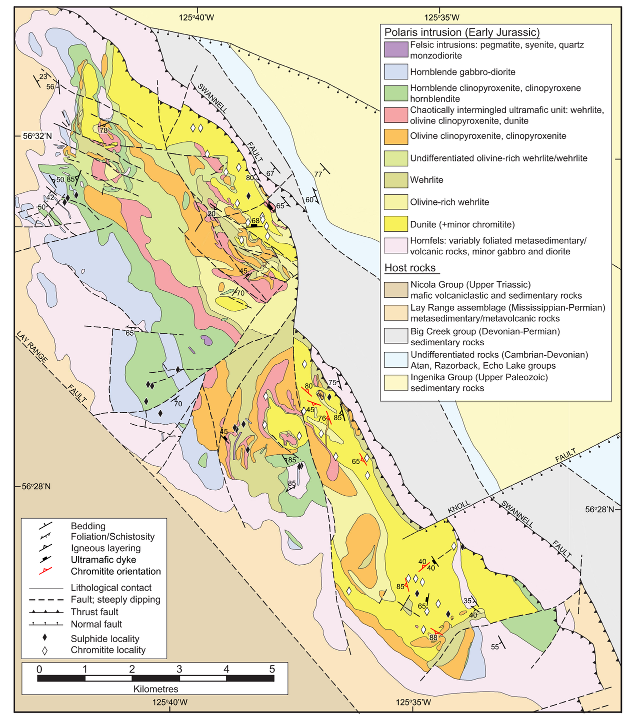
Disaggregated to bulbous (left) and elongate (right) dunite inclusions (Du) in olivine clinopyroxenite (Cpxt).



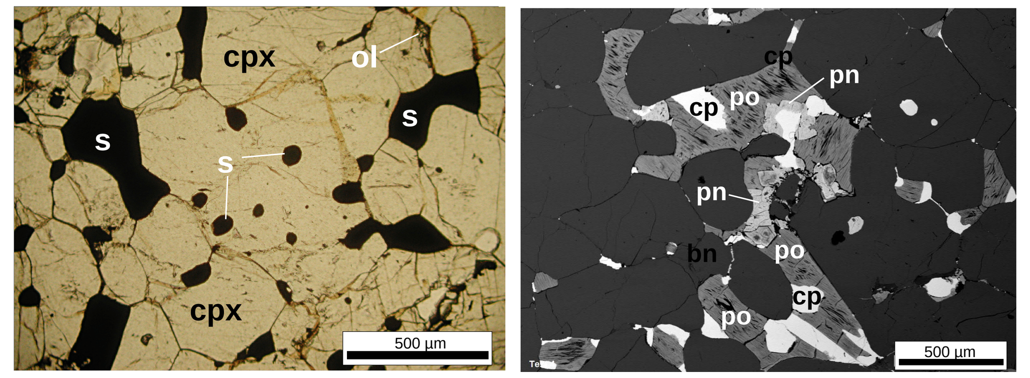
Dunite (Du) inclusions up to 15 m across (left) locally enclosing olivine clinopyroxenite (Cpxt) (right).

POLARIS

The Early Jurassic Polaris intrusion (below) is a zoned, sill-like body with dunite(-chromitite) cumulates prevalent near the base (east) and more evolved hornblende-bearing rocks towards the roof (west). Zones of intermingled ultramafic cumulates, minor breccias and dikes represent remobilized cumulates in variable thermal/rheological states, features that may reflect magma recharge processes like those inferred for Tulameen. (Ni-)Cu-PGE sulphides occur in the more evolved ultramafic and mafic rocks, and comprise mainly pyrrhotite and chalcopyrite with minor pentlandite, pyrite, and rare bornite.

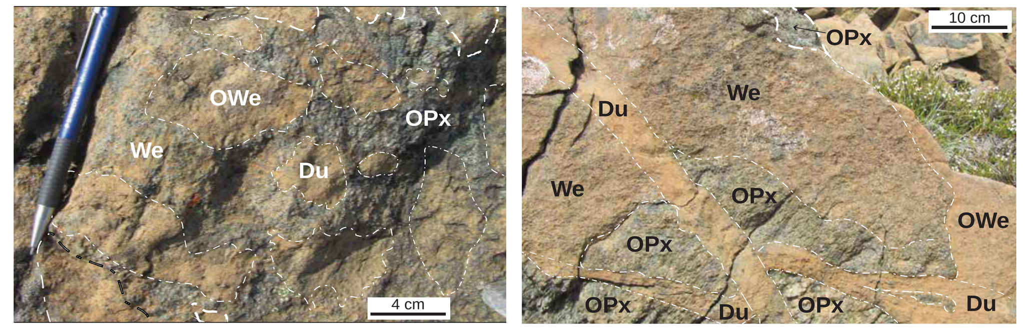


Polaris sulphides



Crystallized sulphide melt trapped in clinopyroxene (cpx) and interstitially in olivine(ol)-bearing clinopyroxenite (left; plane-polarized transmitted light); interstitial sulphides (pyrrhotite(po)-chalcopyrite(cp)-pentlandite(pn)) in olivine clinopyroxenite (right; backscattered electron image).

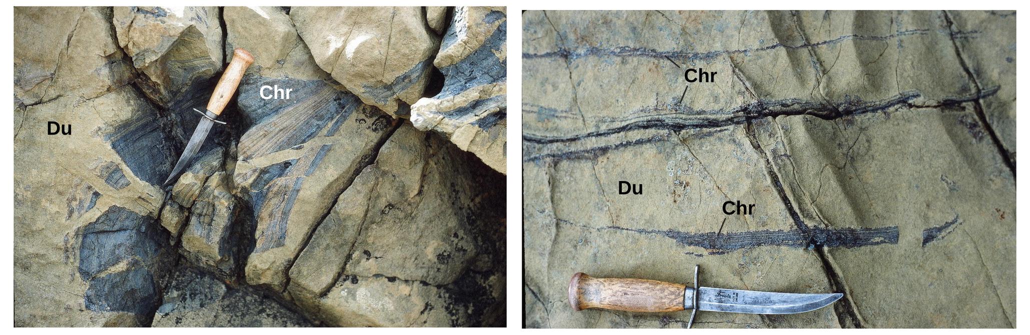
Remobilized cumulates



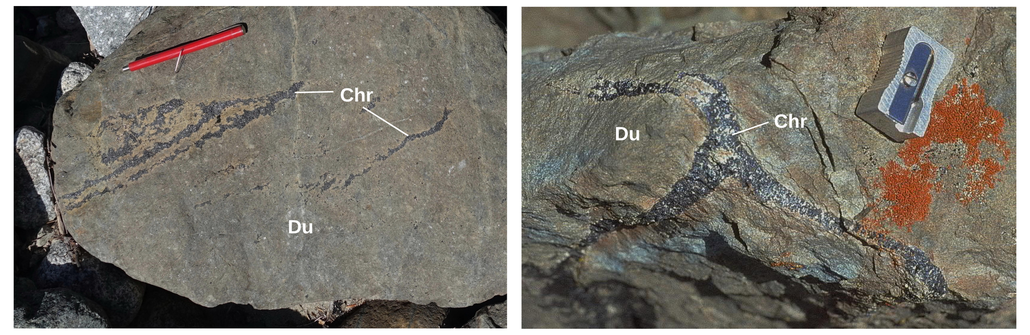
Fragments of dunite(Du)-olivine wehrlite(OWe) with diffuse boundaries set in wehrlite(We)-olivine clinopyroxenite(OPx) matrix (left); olivine clinopyroxenite blocks in wehrlite cut by/intermingled with dunite (right).

CHROMITITE

Chromitites in the Tulameen and Polaris intrusions are primarily hosted by dunite and are invariably remobilized. Their platinum abundances reach 9.3 g/t Pt (Pt/Pd ~127) but are heterogeneous.



***Polaris:** remobilized, semi-coherent block of layered chromitite (Chr) in dunite (Du) cut by late dunite dikes (left); chromitite schlieren in dunite cut by dunite dike (right).*

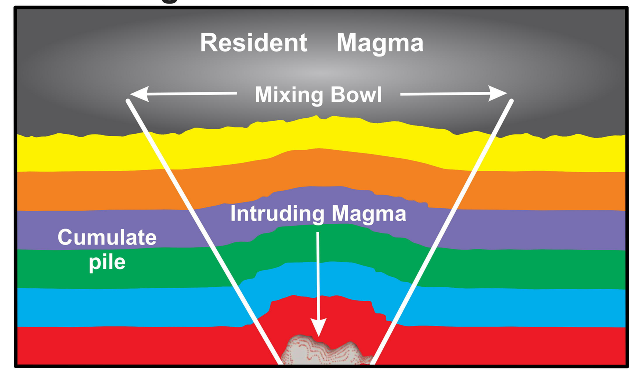


***Tulameen:** remobilized and deformed chromitite (Chr) schlieren in the dunite (Du) core of the intrusion.*

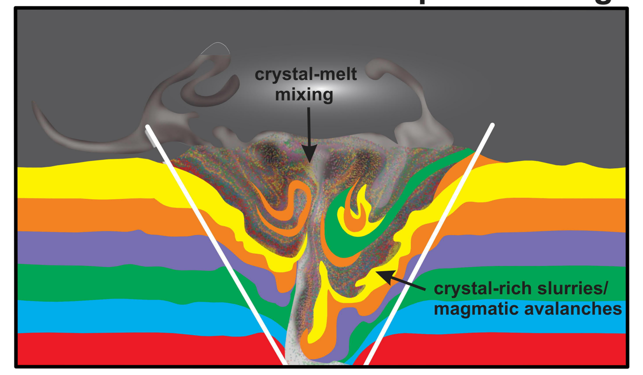
Magma Recharge Model

The disaggregation, reworking and redeposition of pre-existing ultramafic cumulates in Alaskan-type intrusions resemble some key features of a simulated magma chamber recharge model (below). An olivine cumulate mush is intruded by a new influx of basaltic magma which induces a viscoplastic response and defines an uplifted region - the "mixing bowl". Hydrogranular dynamics create a well-mixed fluidized region of disrupted cumulates (e.g., chromitite-dunite) in the core of the mixing bowl, and generate slumping of cumulates (e.g., dunite-clinopyroxenite) along the unstable sidewalls.

Initial magma influx



Advanced cumulate disruption/mixing



(after Schleicher and Bergantz, 2017).

Cr-PGE vs Cu-PGE ENVIRONMENTS

The textural features taken as evidence for remobilization of hot, variably consolidated ultramafic cumulates at Tulameen and Polaris are common to many other Alaskan-type intrusions. Formation of the dunite core involves episodic recycling of early formed chromitite-olivine cumulates and their redeposition in deposits of mixed age and heritage. Peripheral, syn-magmatic avalanche deposits and coherent zones of intermingled ultramafic cumulates reflect gravitationally driven movement downslope in the cooler sidewall environment.

Low-volume, disseminated (Ni-)Cu-PGE sulphides at Tulameen and Polaris are restricted to the more evolved clinopyroxene-rich cumulates. In both cases, the first appearance of sulphides is closely linked to magnetite crystallization in evolving parental magmas. Magnetite fractionation depletes residual silicate liquids in ferrous and ferric iron thereby promoting sulphide saturation and segregation of an immiscible sulphide melt. Thus, this intrinsic process induces formation of magmatic sulphides, obviating the need for wallrock contamination.

EXPLORATION TARGETING

Exploration challenges include:

> low-volume (Ni-)Cu-PGE sulphide mineralization requires intensive geochemical sampling of the more favourable rock types: magnetite and hornblendite at Tulameen; olivine clinopyroxenite at Polaris.

> chromitites with significant PGE-alloy mineralization are typically remobilized; placer concentrations are better targets unless chromitite bodies with lateral continuity can be identified.

REFERENCES

Nixon, G.T., Scoates, J.S., Milidragovic, D., Nott, J., Manor, M.J., and Kjarsgaard, I.M., 2020. Convergent margin Ni-Cu-PGE-Cr ore systems: U-Pb petrochronology and environments of Cu-PGE versus Cr-PGE mineralization in Alaskan-type intrusions. *In* Targeted Geoscience Initiative 5: Advances in the understanding of Canadian Ni-Cu-PGE and Cr ore systems - examples from the Mid-Continent Rift, the Circum-Superior Belt, the Archean Superior Province, and Cordilleran Alaskan-type intrusions, Geological Survey of Canada, Open File 8722, 197-218. http://doi.org/10.4095/326897

Schleicher, J.M., and Bergantz, G.W., 2017. The mechanics and temporal evolution of an open-system magmatic intrusion into a crystal-rich magma. Journal of Petrology, 58, 1059-1072.

ACKNOWLEDGMENTS

Funding for this study was provided by Natural Resources Canada's Targeted Geoscience Initiative Program (TGI-5) under the Ni-Cu-PGE-Cr subprogram's 'Convergent margin Ni-Cu-PGE-Cr ore systems: temporal and magmatic evolution' project; the British Columbia Geological Survey; and a NSERC Discovery Grant to James Scoates.

RECOMMENDED CITATION

Nixon, G.T., Scoates, J.S., Milidragovic, D., Nott, J., Manor, M.J., Spence, D.W. and Kjarsgaard, I.M., 2021. Cu-PGE vs Cr-PGE mineralization in Alaskan-type ultramafic-mafic intrusions. British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey, GeoFile 2021-07 (poster).