Olivine in the Polaris Alaskan-type Intrusion of North-central British Columbia: Implications for the Magmatic Evolution of Primitive Arc Magmas and for Convergent Margin Ni-Cu-PGE Ore-forming Systems

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Abstract

The Jurassic Polaris Alaskan-type ultramafic-mafic intrusion is a 14 km by 3 km sill-like intrusion hosted by sedimentary and volcanic rocks of the Lay Range Assemblage in the Quesnel terrane of north-central British Columbia. Olivine, the dominant mineral in the intrusion, displays a wide range of textures and compositions that reflect different environments of crystallization. Olivine compositions (n = 326) determined by electronprobe microanalysis (EPMA) span a range of forsterite contents (Fo_{94-79}), with the most Mg-rich olivine present in chromitite, due to subsolidus exchange with chromite, and most Mg-poor olivine present in olivine clinopyroxenite. Nickel concentrations in olivine vary significantly from 3108 ppm Ni at Fo_{89} to 275 ppm Ni at $Fo_{81.}$ The lack of systematic Fo-Ni-Mn zonation from core-to-rim in Polaris olivine is indicative of pervasive diffusion and re-equilibration at high temperatures. The Mg-rich compositions of olivine in dunite, olivine wehrlite, and werhlite ($Fo_{87.5-92}$) are evidence for the involvement of primitive, mantle wedge-derived parent magmas that experienced little fractionation prior to emplacement in the crust. The Fo-Ni relationships of olivine are consistent with a fractional crystallization control from dunite-olivine werhlite-wehrlite ($Fo_{87.5-92}$, 1605-3108 ppm Ni) through magnetite-rich olivine clinopyroxenite (Fo_{79-84}, 275-550 ppm Ni), whereas Ni-rich olivine in magnetite-poor olivine clinopyroxene ($Fo_{81.5-84}$, 1305-2090 ppm Ni) is accounted for by mixing between fractionated and primitive magmas. Outcrop-scale field relationships (i.e., chaotic mixing, ultramafic dikes, chromitite schlieren) in the Polaris intrusion support the operation of periodic recharge and mixing processes. Polaris olivine is distinguished by extremely low Ca concentrations (<1000 ppm, and mostly <500 ppm) compared to olivine from volcanic rocks globally, including those from subduction zone environments. Low-Ca olivine is also typical of ultramafic-mafic plutonic rocks in general (e.g., Skaergaard, Kiglapait, Bushveld, Duke Island) and may be related to pervasive diffusional loss of Ca from olivine to interstitial melt. The shallow emplacement depth of the Polaris intrusion (~12 km) requires that ascent of primitive, unfractionated magmas was relatively rapid from the mantle wedge source to maintain the observed Mg-rich olivine compositions. The Polaris intrusion shares common petrogenetic characteristics with mafic-ultramafic ore-forming conduit systems in other settings, highlighting the similarities between extensional and convergent margin Ni-Cu-PGE ore-forming systems.