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**SPECIAL COLLECTION: OLIVINE**

# Nickel variability in Hawaiian olivine: Evaluating the relative contributions from mantle and crustal processes

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## ABSTRACT

Olivine in Hawaiian tholeiitic lavas have high NiO at given forsterite (Fo) contents (e.g., 0.25–0.60 wt% at $Fo_{88}$) compared to MORB (e.g., 0.10–0.28 wt% at $Fo_{88}$). This difference is commonly related to source variables such as depth and temperature of melting and/or lithology. Hawaiian olivine NiO contents are also highly variable and can range from 0.25–0.60 wt% at a given Fo. Here we examine the effects of crustal processes (fractional crystallization, magma mixing, diffusive re-equilibration) on the Ni content in olivine from Hawaiian basalts. Olivine compositions for five major Hawaiian volcanoes can be subdivided at $\geq Fo_{88}$ into high-Ni (0.25–0.60 wt% NiO; Ko‘olau, Mauna Loa, and Mauna Kea) and low-Ni (0.25–0.45 wt% NiO; Kīlauea and Lō‘ihi), groups that are unrelated to major isotopic trends (e.g., Loa and Kea). Within each group, individual volcanoes show up to 2.5× variation in olivine NiO contents at a given Fo. Whole-rock Ni contents from Ko‘olau, Mauna Loa, Mauna Kea, and Kīlauea lavas overlap significantly and do not correlate with differences in olivine NiO contents. However, inter-volcano variations in parental melt polymerization (NBO/T) and nickel partition coefficients ($D_{Ni}^{Ol/melt}$), caused by variable melt $SiO_2$, correlate with observed differences in olivine NiO at $Fo_{90}$, indicating that an olivine-free source lithology does not produce the inter-volcano groups. Additionally, large intra-volcano variations in olivine NiO can occur with minimal variation in lava $SiO_2$ and NBO/T. Minor variations in parental melt NiO contents (0.09–0.11 wt%) account for the observed range of NiO in $\geq Fo_{88}$ olivine. High-precision electron microprobe analyses of olivine from Kīlauea eruptions (1500–2010 C.E.) show that the primary controls on $<Fo_{88}$ olivine NiO contents are fractional crystallization, magma mixing, and diffusive re-equilibration. Core-rim transects of normally zoned olivine crystals reveal marked differences in Fo and NiO zoning patterns that cannot be related solely to fractional crystallization. These Fo-NiO profiles usually occur in olivine with $<Fo_{88}$ and are common in mixed magmas, although they are not restricted to lavas with obvious petrographic signs of mixing. Three-dimensional numerical diffusion models show that diffusive re-equilibration decouples the growth zoning signatures of faster diffusing Fe-Mg (Fo) from the somewhat slower Ni. This diffusive “decoupling” overprints the chemical relationships of Fe-Mg, Ni, and Mn inherited from crystal growth and influences the calculated fraction of pyroxenite-derived melt (Xpx). Sections of numerical olivine that have been affected by diffusive re-equilibration indicate that larger phenocrysts (800 μm along *c*-axis) are >50% more likely to preserve original Xpx compared to smaller phenocrysts (400 μm along *c*-axis) which rarely (6%) recover original Xpx. Sections that are parallel or sub-parallel to the *c*-axis and/or pass near the core of the crystal best preserve growth signatures. Thus, diffusive re-equilibration, crystal size, and sectioning effects can strongly influence the characterization of mantle source lithologies for Hawaiian volcanoes.

**Keywords:** Olivine, nickel, Kīlauea, Hawai‘i, magma mixing, diffusion, pyroxenite