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Olivine Trace Elements Constrain a Mantle Origin of Calc-Alkaline Magmas in the Trans-Mexican Volcanic Belt

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Cr-spinel-bearing olivines that crystallize on the liquidus of mantle melts preserve information in their major and trace element composition about the composition, temperature, oxygen fugacity, and possibly water concentration of the mantle melts, providing unique constraints on the melts' origin and formation. This information is particularly valuable in hybrid arc magmas, where Cr-spinel-bearing olivines are often the only remnants of mafic mantle melts in the evolved hybrid calc-alkaline melts that build arc-front composite volcanoes. To understand the trace element signature of olivines in arc magmas, we analyzed Li, Na, Al, P, Ca, Sc, Ti, V, Cr, Mn, Co, Ni, Cu, Zn, Ga, Y, Zr, and Yb in forsteritic olivines from high-Mg# [= molar $Mg/(Mg+Fe^{2+})$] arc magmas erupting at several monogenetic volcanoes, and one composite volcano, Popocatépetl, in the Trans-Mexican Volcanic Melt (TMVB).

Al-in-olivine thermometry shows that hydrous calc-alkaline mantle melts are cooler and more silicic than melts from mid-ocean ridge and within-plate settings [1]. This predicts different olivine trace-element patterns, given the sensitivity of olivine partition coefficients to melt temperature and composition. Indeed, trace element patterns of olivines in calc-alkaline TMVB magmas are systematically fractionated relative to those in hotter TMVB rear-arc and OIB-type arc-front basalts, which originate from mantle not or minimally modified by slab flux. Quantitative modeling of olivine trace elements, for which partition coefficients are sufficiently well known, shows that trace-element fractionation in calc-alkaline arc olivines must be further enhanced by ‘subduction processing’ of the mantle wedge, by the reactive recycling of silicic slab components, and multiple melt extractions. Importantly, our study confirms the existence of high-Ni component melts, formed by melt-rock reaction processes, that produce high-Ni olivines, as well as source depletion from previous melt extraction, which lowers olivine Ca, Yb, Y, and Ti. Overall, the olivine trace element data confirm that the high-Mg#, FeO-poor calc-alkaline arc magmas are primary mantle melts and are not produced by crustal differentiation.

[1] Straub SM, Batanova V, Sobolev A, Gómez-Tuena A, Espinasa-Perena R, Bindeman IN, Stuart FM, Widom E, Iizuka Y (2025) J Pet 66(11)