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The origin of Na at Popocatépetl volcano in the Trans-Mexican Volcanic Belt

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Understanding the origin of major-element oxides in primary arc magma is fundamental to arc-trench mass-balance calculations. An evaluation of moderately mafic magmas with Mg# [=molar [Mg/(Mg+Fe^{2+})] >55 from global arc-front composite volcanoes shows an inverse correlation between bulk-rock CaO and Na_2O across oceanic and continental arcs [1]. In analogy with the melting systematics of mid-ocean ridge basalts (MORB), this array was interpreted to reflect different extents of melting in the mantle wedge, which is modulated by lithospheric thickness. Primary mantle melts beneath thicker continental lithosphere have higher Na_2O and lower CaO than those formed beneath the thinner lithosphere of oceanic arcs [2]. However, this 'melting model' is irreconcilable with evidence that arc Na_2O is part of the slab flux, and especially so at arc-front volcanoes where the bulk of melt erupts. We address this contradiction in the Trans-Mexican Volcanic Belt (TMVB), which is the 'thick-lithosphere' end member of the global array. We compare high-Mg# magmas from the voluminous composite volcano Popocatépetl (several hundreds of km^3 erupted volume) with small-volume (<1 km^3) arc-front monogenetic magmas, which display a broad spectrum of mantle-derived magmas. Despite a similar thick lithosphere, the TMVB magmas form an inverse trend in CaO vs. Na_2O space that overlaps with the upper half of the global Na_2O-CaO trend. Results from data inversion suggest that between ~10-70% of the arc Na_2O is slab-derived, with the slab-derived Na flux highest at Popocatépetl, where the ambient mantle is depleted in incompatible elements by previous melt extraction. However, on the global spectrum array, the Na_2O in TMVB magmas with the lowest slab-added Na_2O are still about ~2x to 3x higher at lower CaO than the high-Mg# oceanic arc magmas at the other end of the array. Thus, the slab flux only overprints and enhances the underlying melting systematic global Na-Ca array. Ultimately, mass-flux calculations must take into account the strongly varying contributions from slab and mantle sources within single arcs.

[1] Plank and Langmuir (1988) ESPL 90: 349–370 [2] Turner and Langmuir (2022) J Pet 63(3)