

Formation of Continental Intraplate Basalts with Coexistence of Alkaline and Tholeiitic Suites and Their Geochemical Transition from Upwelling of Fractured Oceanic Slabs

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Abstract

Intraplate basalts, exhibiting a continuous geochemical spectrum from alkaline to tholeiitic compositions, are extensively distributed along the continental margins of eastern and southeastern Eurasia, where subducted oceanic slabs are stagnant in the mantle transition zone (MTZ). The genetic relationship between the coexistence of alkaline and tholeiitic magmatism, the alkaline-tholeiitic transition, and upper mantle dynamics remains enigmatic. We present Sr, Nd, Mg, and Fe isotopic data, combined with major and trace elemental compositions, for the Late Cenozoic Buon Ma Thuot (BMT) and Pleiku (PLK) basalts from southern Vietnam to investigate these mantle processes. Changes in Mg and Fe isotopic values of these basalts are associated with their alkaline-tholeiitic transition. Besides higher MgO, TiO₂, CaO/Al₂O₃, and lower SiO₂, alkaline basalts exhibit lower $\delta^{26}\text{Mg}$ (−0.32‰ to −0.43‰) and higher $\delta^{57}\text{Fe}$ values (+0.16‰ to +0.37‰) than tholeiitic basalts (i.e. $\delta^{57}\text{Fe}$ varies from +0.09‰ to +0.21‰), which resemble normal mid-ocean ridge basalts. Trace element ratios and Sr and Nd isotopes of the studied basalts vary spatially. BMT basalts display Ce/Pb (18.4–24.2) and Nb/Th (9.80–11.3) ratios akin to those of oceanic crust, coupled with elevated positive Sr anomalies ($\text{Sr}/\text{Sr}^* = 1.10\text{--}1.56$) and constant low $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, indicating the presence of recycled lower oceanic crust in their mantle source. In contrast, the mantle source of PLK basalts appears to incorporate more recycled sediments, as indicated by their lower Ce/Pb (13.0–23.1) and Nb/Th (7.16–9.43) ratios, along with elevated $^{87}\text{Sr}/^{86}\text{Sr}$ ratios and decreased ϵ_{Nd} values. The alkaline-tholeiitic transition in both BMT and PLK basalts arises from differences in their source lithologies and melting processes. Spatial geochemical variations can be further ascribed to the small-scale lateral heterogeneity of the mantle, which arises from the recycling of various segments of subducted slabs. Given that BMT basalts erupted prior to PLK basalts, and considering the geophysical evidence (such as receiver function investigations and *P*-wave velocity models) indicating slab edges and mantle upwelling in the MTZ, we suggest that the observed geochemical variations in intraplate basalts are primarily driven by the upward flow of fractured oceanic slabs, facilitated by slab tearing processes occurring within the MTZ.

Keywords alkaline basalt, tholeiitic basalt, intraplate basalt, slab tearing, mantle heterogeneity

Introduction

Intraplate basalts are widely distributed along the continental margins of eastern and southeastern Eurasia, where subducted oceanic slabs are stagnant within the mantle transition zone (MTZ) (Huang & Zhao, 2006; Li *et al.*, 2017; Xu *et al.*, 2018, 2020; Zhao *et al.*, 2021). These continental intraplate basalts are characterized by both alkaline and

tholeiitic eruptions with variable isotopic compositions that overlap the isotopic trends observed in global ocean island basalts (OIB) (Zou *et al.*, 2000; Xu *et al.*, 2018; Hanyu & Chen, 2021). However, in contrast to plume-derived OIB, these continental intraplate basalts are hardly attributed to mantle plume activities directly. Alternatively, slab decarbonation and dehydration from the MTZ (identified by basalt geochemistry—e.g. light Mg and heavy Zn isotopes (Li *et al.*, 2017;

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