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New petrological, geochemical, and geochronological perspectives on andesite-dacite magma genesis at Ruapehu volcano, New Zealand

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Abstract

Time–composition relationships in eruptive sequences at composite volcanoes can show how the ongoing intrusion of magmas progressively affects the lithosphere at continental convergent margins. Here, new whole-rock and microanalytical major and trace element data from andesite-dacite lava flows are integrated with previous studies and existing isotopic data, and placed within the framework of a high-resolution chronostratigraphy for Ruapehu volcano (southern Taupo Volcanic Zone, New Zealand). The geochemical evolution of lavas erupted over the ~200 kyr lifetime of the exposed edifice reflects variable degrees of fractionation and systematic changes in the type of crustal assimilation in the Ruapehu magma system. Lavas erupted from ~200–150 ka have previously been distinguished from those erupted <150 ka based on Sr-Nd isotopic characteristics, which indicate that the oldest lavas were sourced from magmas that assimilated oceanic crust. Such source rocks underlie the regionally widespread Mesozoic meta-sedimentary greywacke-argillite basement, which was conversely assimilated by <150 ka magmas. New results from this work reveal that since 150 ka, an upper limit of magma differentiation occurred from ~50–35 ka. High K_2O (~6 wt%) and Rb contents (~270 ppm) in melt inclusions, interstitial glass, and glass from in situ quenched melts of partially fused crustal xenoliths are reported for andesite-dacite lavas erupted during this period. In addition to crystal fractionation, selective partial melting and assimilation of K- and Rb-rich mineral phases (e.g., biotite, K-feldspar) that are significant components of the meta-sedimentary basement rocks is inferred to explain these geochemical characteristics. These processes coincided also with the effusion of high-MgO andesite-dacite lavas that display petrological evidence for mixing between andesite-dacite and more mafic magmas. An influx of hotter mafic magma into the system explains why the extent of crustal assimilation recorded by Ruapehu lavas peaked during the ~50–35 ka eruptive period. From 26 ka to the present, andesite lavas have reverted to more mafic compositions with less potassic melt inclusion and whole-rock compositions when compared to the ~50–35 ka lavas. We suggest that the younger lavas assimilated less-enriched melts because fertile phases had been preferentially extracted from the crustal column during earlier magmatism. This scenario of bottom-up heating of the lithosphere and exhaustion of fertile phases due to the progressive intrusion of magma explains the geochemical evolution of Ruapehu lavas. This model may be applicable to other long-lived composite volcanoes of the circum-Pacific continental arcs.

Keywords: Ruapehu, andesite, dacite, petrogenesis, arc magma, crustal contamination, high-Mg andesite; Dynamics of Magmatic Processes