# The application of U-series systematics in understanding the rates and timescales of magmatic processes at a composite andesite volcano, Mount Ruapehu, New Zealand

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The application of U-Th disequilibria in investigating the timescales of recent magmatic processes is now well established. Processes which fractionate U and Th, and hence disturb secular equilibrium are detectable for ~350 ka. Whilst there appears to be an increased understanding of the behaviour of these isotopes in young arc rocks from ocean-ocean collision zones (e.g. Elliott et al., 1997; Turner et al., 1997), early work on continental arcs has demonstrated that the additional complexity of magma ascent through and residence in continental crust can make interpretation of U-Th data difficult (e.g. Volpe, 1992). This work is a detailed, high-precision study of a single volcano over at least 100 ka, looking at how U-Th data can aid investigation of magma fluxes and crustal residence times over a significant time span.

Mount Ruapehu is a composite andesite cone, with a history of volcanism for at least 250–300 ka. It forms the most southerly and largest volcanic edifice in the Taupo Volcanic Zone (TVZ), a zone of extension, high heat flow and volcanism related to the westward subduction of the Pacific Plate beneath the Indian Plate along the Hikurangi Margin. The volcano lies approximately 175 km behind the Hikurangi Trough, and 100 km above the subducting slab. The present day surface geology is dominated by sector collapse structures and glacier-related erosion, which has exposed a number of excellent vertical sequences on which this study concentrates.

Compositionally, Ruapehu has been remarkably consistent throughout its known eruptive history. Lavas range from 53–63 wt.% $SiO_2$, but analysed material from this study and others (Graham and Hackett, 1987) is largely dominated by andesitic compositions (55–60 wt.% $SiO_2$). U-Th isotope data has been obtained for samples from four eruptions this century (1945, 1971, 1995 and 1996), older samples belonging to coherent sequences from the Whangaehu and Ohinepango valleys (Tukino, eastern Ruapehu), and from three parasitic cones.

All of the lavas analysed show uranium excesses of 3–12%, and have relatively constant U/Th ratios of ~0.26 – 0.30. The data for each set of contemporaneous samples plot along well constrained linear arrays (Fig. 1), with each array having a similar range in $(^{238}U/^{232}Th)$, but different $(^{230}Th/^{232}Th)$. The arrays are progressively closer to the equiline with increasing eruption age from a rough stratigraphy based on field evidence. Three explanations can be proposed to explain these arrays, (i) mixing with an assimilant or magma, (ii) crystallisation induced fractionation of U and Th, and/or (iii) source related variations.

Significant fractionation of U and Th during crystallisation is most likely to reflect crystallisation of an accessory phase such as apatite or zircon. There is no geochemical or petrographic evidence for such a phase, and no correlation exists between U/Th ratio and indexes of fractionation such as Mg number or Zr. Both $P_2O_5$ and Zr behave incompatibly throughout the full range of erupted compositions.

Traditional petrogenetic models for Ruapehu require that assimilation has played an important role in generating some of the observed geochemical signatures (Graham et al., 1992). Mixing may also have taken place between rhyolitic magmas which dominate the central TVZ and more primitive basaltic or basaltic andesite compositions. On the $(^{230}Th/^{232}Th)-(^{238}U/^{232}Th)$ diagram, both crustal and rhyolitic components plot on the equiline near the extrapolation of the data arrays from this study. Trace element data suggests however, that mixing between primitive Ruapehu compositions and rhyolites from Taupo (the nearest rhyolite centre) would not produce the trends observed (Fig. 2). Radiogenic isotopes have commonly been used to identify assimilation trends between primitive basaltic melts and local Torlesse basement. However, U/Th ratio does not vary in any coherent fashion with either Sr
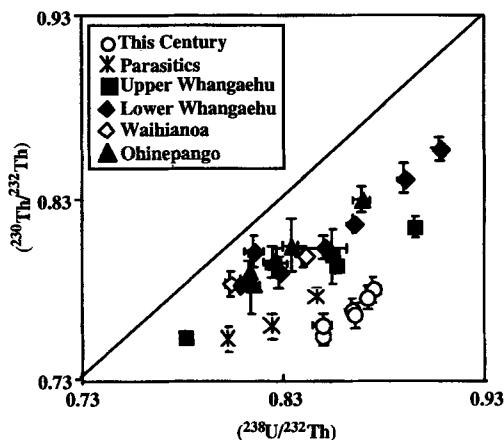
FIG. 1.



FIG. 2.

or Nd isotopes, and so at present there is no evidence that crustal contamination has significantly affected U-Th isotopes.

The lack of correlation between assimilation tracers and U-Th systematics implies that the observed variations are related to source processes. Treating the linear data arrays as pseudo-isochrons yields ages of $64 \pm 8$ ka, $147 \pm 17$ ka and $162 \pm 6$ ka for the recent eruptions, lower Whangaehu and Ohinepango sequences respectively. By using the age from the array of data for eruptions this century as an average total transport and residence time, approximate eruption ages for the older sequences can be calculated. This yields approximate eruption ages of 85 ka and 98 ka for the Whangaehu and Ohinepango sections. If estimated wedge transport times of ~30-50 ka from intra-oceanic arcs (Elli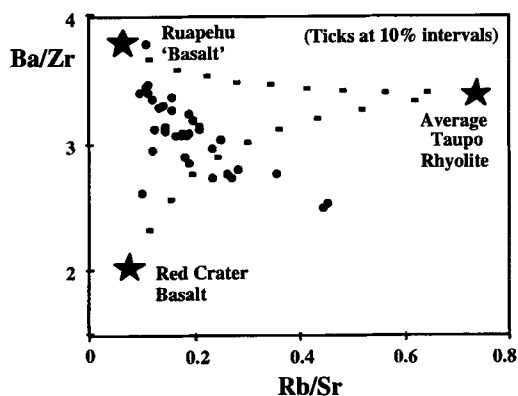ott *et al.*, 1997; Turner *et al.*, 1997) are assumed to be relatively constant regardless of tectonic setting, crustal residence times of 15-35 ka are implied from the total transport and residence time.

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