High-precision tephrostratigraphy: Tracking the time-varying eruption pulse of Mt. Taranaki, North Island, New Zealand

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Mt. Taranaki and the Ahukawakawa Swamp viewed from the Pouakai Tarns, North Island, New Zealand. (December 2014)

Abstract

In this research it was proposed that a more robust record of volcanic activity for Mt. Taranaki (New Zealand) could be derived from tephras (pyroclastic fall deposits) within cores from several lakes and peatlands across a 120^{o} arc, NE-SE of the volcano, covering a range of prevailing down-wind directions. These data were integrated with previous tephrochronology studies to construct one of the longest and most complete volcanic eruption history records ever developed for an andesitic stratovolcano. Using 44 new radiocarbon dates, electron microprobe analysis of glass shard and titanomagnetite chemical composition, along with whole-rock chemistry, a chrono- and chemostratigraphy was established. The new record identifies at least 272 tephra-producing eruptions over the last 30 cal ka BP. Six chemo-stratigraphic groups were identified: A (0.5 – 3 cal ka BP), B (3 – 4 cal ka BP), C (4 – 9.5 cal ka BP), D (9.5 – 14 cal ka BP), E (14 – 17.5 cal ka BP), and F (23.5 – 30 cal ka BP). These were used to resolve previous stratigraphic uncertainties at upper-flank (proximal) and ring-plain (medial) sites. Several well-known "marker tephras" are now recognized as being ~2000 years older than previously determined (e.g., Waipuku, Tariki, and Mangatoki Tephra units) with the prominent Korito Tephra stratigraphically positioned above the Taupo-derived Stent Tephra. Further, new markers were identified, including the Kokowai Tephra unit (~4.7 cal ka BP), at a beach-cliff exposure, 40-km north-east of the volcano. Once age-models were established for each tephra, units were matched between sites using statistical methods. Initial statistical integration showed that the immediate past high-resolution tephrochronological record suffered from a distinctive "old-carbon" effect on its ages (Lake Rotokare). This had biased the most recent probabilistic forecasting and generated artificially high probability estimates (52-59% eruption chance over the next 50 years). Once the Rotokare record was excluded and chemostratigraphy constraints were applied, a reliable multi-site tephra record could be built only for the last ~14 ka BP. The new data confirms a highly skewed distribution of mainly (98% of cases) short intervals between eruptions (mode of ~9 years and average interval ~65 years). Long intervals (up to 580 years) as seen in earlier records were reduced to 2% of the record, but can now be considered real, rather than missing data.

The new data confirm a cyclic pattern of varying eruption frequency (with a five-fold range in annual frequency) on a period of ~1000-1500 years. The new time-varying frequency estimates suggest a lower probability for a new eruption at Mt. Taranaki over the next 50 years of 33-42%. The newly established chemostratigraphy was further used to investigate time-related compositional changes. Whole-lapilli analyses highlighted that a specific very evolved Ca-rich and Fe-poor composition was only found within the easterly and south-easterly depositional sites. This was explained by eruption of a stratified magma reservoir, which holds greater modal proportions of plagioclase and lower proportions of pyroxene within low-density, gas-rich upper conduit regions. During the most explosive phases of eruptions, when plumes reach the stratospheric jet-stream, the lowest-density pumice is thus dispersed by high-level stable westerly winds. Further, two distinct evolutional trends were seen in the long and new tephrochronological record; from 17.5 to 3 cal ka BP and <3 cal ka BP; with whole-lapilli, glass, and titanomagnetite compositions overall evolving over time. The former compositional trend indicates a crystallising and cooling magma source in the deep crust, with multiple, spatially separated magma source regions forming, each generating magmas (i.e., magma batches) with unique titanomagnetite compositions. This trend is interrupted by a distinct shift towards less-evolved compositions and the initiation of a second parasitic vent (Fanthams Peak at the southern flank of Mt. Taranaki).

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Table of contents

List of tables

List of figures