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Understanding the largest-scale explosive volcanism at Mt. Taranaki, New Zealand

A thesis presented in partial fulfilment of the requirements for the degree of

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“In solitude we find ourselves, defeat our ego, discover our worst, our best, love, real life and real friends.” Photo: Sharks Tooth from the summit of Mt. Taranaki, Jul/2016.

Dedicated to my mother - the strongest person I’ve ever met, and to my beloved adopted sisters and brothers
Abstract

Over the last 5000 years B.P., at least 53 explosive eruption episodes occurred at Mt. Taranaki, (western North Island, New Zealand) from either the summit-crater (2500 m), or a satellite vent on Fanthams Peak (1966 m). These eruptions are represented in well-preserved pyroclastic successions on the upper volcano flanks. At least 16 episodes produced deposits with lithostratigraphic characteristics comparable to those of the last sub-Plinian eruption at AD 1655, suggesting an average recurrence of one Plinian/sub-Plinian eruption episode every 300 years. Several large-scale mafic-intermediate (~48-60 wt.% SiO₂) eruption episodes sourced from the two vents were studied in detail to determine the “maximum” intensity, magnitude and eruptive styles from this volcano. These episodes comprised climactic phases with sustained and steady, 14-29 km-high eruption columns, often starting and ending with unsteady pulsating, oscillating and collapsing plumes. The columns erupted 0.1-0.5 km³ DRE at mass and volume discharge rates of 10⁷-10⁸ kg/s and 10³-10⁴ m³/s, respectively, indicating magnitudes of 4.1-5.1. The unsteady initial, pre- and post-climactic eruptive phases were dominated by dome-collapse, column-collapse and lateral-blast pyroclastic density currents (PDCs), with run-out distances of 3-19 km and volumes of up to 0.02 km³ DRE. The steadiest phases were associated with eruption of rheologically homogeneous magmas producing homogenous pumice textures. Unsteady phases produced density and porosity pumice gradients by magma stalling in upper conduit levels. Three eruption onset scenarios were developed from this work: a) initial closed-conduit decompression by vent unroofing and dome-collapse, b) transient open and clogged conduits produced by repeated plugging-and-bursting of chilled or gas-depleted magma, and c) rapid conduit opening with more mafic eruptives. In all scenarios, the climactic phases are comparable, with pyroclastic fallouts
covering 1500-2500 km$^2$. The most violent phases of these events, however, are lateral-blast PDCs that could reach a broad arc between 14-19 km from source. This reappraisal of the hazardscape at Mt. Taranaki integrates many new details that enable a more realistic hazard management and provides a range of findings that can be applied to other similar andesitic volcanoes prior to reawakening.
Acknowledgements

The first time I heard about New Zealand was in 2009 during an outstanding poster presentation about Mt. Ruapehu at the Jorullo conference in Mexico, by PhD student Natalia Pardo. The next thing I discovered was an incredibly beautiful, almost perfect cone-shaped stratovolcano, confusingly named both Taranaki and Egmont. This I wished to climb if I ever had the chance to go for any reason to the other side of the world. A few years later I emailed Shane Cronin inquiring about PhD opportunities and he replied by asking if I would be interested in working on explosive volcanism at Mt. Taranaki - I felt that I had just won the lottery. Doing fieldwork in this volcano has been challenging, slow, and at times frustrating due to the multiple obstacles posed by topography and vegetation and the very intricate stratigraphy. Disentangling a little part of such complexity whilst walking on its slopes has been extremely rewarding, and I would never choose differently, even if I could.

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A Tectonic setting of the North Island (NI) of New Zealand (modified from King and Thrasher 1996; Henrys et al. 2003; Sherburn and White 2006). CEFZ Cape Egmont Fault Zone, R Mount Ruapehu, SI South Island, TVL Taranaki Volcanic Lineament (yellow line), TVZ Taupo Volcanic Zone. B Zoomed area of the TVL. The latter comprises four <1.75 Ma and NNW-SSE migrating andesitic volcanoes (Neall 1979) or their eroded volcanic edifice-remnants: Kaitake, Pouakai and Mt. Taranaki (and the satellite cone of Fanthams Peak – topped by Syne Hut). C Zoomed transect of the proximal eastern flanks of Mt. Taranaki and the type sections of this study (points A to Y, Appendix 5.1). Digital profile modified from Google Images (2017). D 10 cm-thick isopachs of fall deposits produced during <5 ka Plinian (white ellipses) and sub-Plinian (grey ellipses) eruptive episodes at Mt. Taranaki (modified from Torres-Orozco et al. 2017b, Table 5.2). Red circles indicate the position of the summit crater and the Fanthams Peak vent. Coordinate system of all insets: NZGD 2000 New Zealand Transverse Mercator.

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Proximal lithofacies transitions of the 4700-4600 cal BP Kokowai (Kw1-Kw8). KA Kapuni-A, KB Kapuni-B, Ko Korito. Sections indicated on top of each profile (A-Y, Fig. 5.1). Yellow lines on photographs indicate lower and uppermost bed-set contacts. Lithofacies codes (Table 5.3) indicated to the right of each profile and inside white boxes on pictures. FA fine-ash, CA coarse-ash, FL fine-lapilli, CL coarse-lapilli, B block/bombs. Scale on pictures represented by a black bar or a scraper (32.5 cm-long).

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Proximal lithofacies transitions of the 3800 to 3500 cal BP Kapuni-A (KA: KA1-KA2), Kapuni-B (KB: KB1-KB4) and Korito (Ko: Ko1-Ko8). Kw Kokowai, Uig Upper Inglewood. Sections indicated on top of each profile (A-Y, Fig. 5.1). Yellow lines on photographs indicate lower and uppermost bed-set contacts. See Fig. 5.2 for more details. The scale on pictures is represented by a black bar or a scraper (32.5 cm-long).

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Proximal lithofacies transitions of the 3300 cal BP Upper Inglewood (Uig1-Uig7). Sections indicated on top of each profile (A-Y, Fig. 5.1). Yellow lines on photographs indicate lower and uppermost bed-set contacts. See Fig. 5.2 for more details. The scale on pictures is represented by a black bar, a long (32.5 cm-long) or a small scraper (20 cm-long), or a 10 cm-long scale.

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Proximal lithofacies transitions of 3000-2600 cal BP members Manganui-A (MA: MA1-MA3), Manganui-B (MB), Manganui-C (MC), Manganui-D (MD: MD1-MD3) and Manganui-E (ME) of the Manganui Formation (Torres-Orozco et al. 2017a; b). Uig Upper Inglewood, DF debris flow. Sections are indicated on top of each profile (A-X, Fig. 5.1). Yellow lines on photographs indicate lower and uppermost bed-set contacts. See Fig. 5.2 for more details. The scale on pictures is represented by a black bar, and a long (32.5 cm-long) or a small scraper (20 cm-long).

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A Example of landscape elements that integrate the present-day micro-topography of the upper eastern flanks of Mt. Taranaki. The gradient of deposit confinement is indicated (modified from Schwarzkopf et al. 2005). B Profile of the general lateral transitions, relative to landscape, of deposits corresponding to each lithofacies association. Dotted white line indicates section not represented (not rep.) in the profile. Proximal (P-lateral) and proximal-medial (M-lateral) lateral lithofacies transitions relative to a reference incision-channel (i) are sketched. Digital image modified from Google Images (2017).
Hazard maps indicating the possible distribution of different types of eruptive activity, throughout distinct eruptive phases, during a future Plinian eruption at Mt. Taranaki. Insets A to D correspond to opening, pre- or post-climactic eruptive phases. A dome-collapse block-and-ash flows, B blast type PDCs and lithic-rich surges, C column-collapse PDCs, D fallout, ballistics, and lava flow distributions. Insets E to G correspond to climactic eruptive phases. E blast type PDCs, F fallout, ballistics and lava flow distributions, G column-collapse PDCs. Inset H represents possible distributions of channel-confined lahars and small-scale landslides during any eruptive phase. Coordinate system of all insets: NZGD 2000 New Zealand Transverse Mercator.

Volcanic hazard scenarios for Plinian eruptions at Mt Taranaki’s summit-crater and Fanthams Peak vent. A-F Scenario I: initial eruptive phases of close-conduits and conduit-decompression by vent unroofing and dome collapse. G-K Scenario II: transient open and clogged conduits by repeated plugging-and-bursting of gas-depleted or chilled magma. L-O Scenario III: rapid progression into steady phases by open-conduits. The possible upper conduit dynamics for each scenario were sketched based on data and interpretations of Torres-Orozco et al. (2017a; b).

Event-tree sequence of the volcanic scenarios expected at Mt. Taranaki during a possible Plinian eruptive episode (magnitudes 4 to 5), produced at either the summit crater, or a satellite vent. For any vent, the eruptive sequence progresses from an opening and pre-climactic phase (1), throughout a climactic phase (2), to a post-climactic phase (3). Vent and/or conduit conditions (A to H) may direct into different processes and events (i.e., Scenarios I to III). Dotted lines indicate subsequent, alternative directions. Run-out distances simplified from Fig. 5.7.