ANDESITIC PLINIAN ERUPTIONS AT MT. RUAPEHU (NEW ZEALAND): FROM LITHOFACIES TO ERUPTION DYNAMICS

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

Doctor of Philosophy

in

Earth Science

at Massey University (Palmerston North, Manawatu)

New Zealand

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2012

Mt. Ruapehu is Te Whare Toka o Paerangi (The House of Stone of Paerangi, Ngāti Rangi ancestor), Matua te Mana (The Powerful One; "Mana" means prestige and enduring, spiritual power) in Ngāti Rangi maori culture. The Waikato-iti stream, in the Rangipō Desert, is Te Onetapu (sacred place) where Ngāti Rangi people rise their "karakia" to the volcano, their ancestor.

Dedicated to the Ngāti Rangi Iwi on behalf of all the indigenous communities living around active volcanoes in the world, who constantly teach us about the unfolding of life, the dynamic interdependence between people and the environment, and how to integrate all sources of knowledge to consciously and truly build sustainable communities

He Ruruku: Mai ara rā!

Mai ara rā! Mai ara rā!
Mai ara rā te Tupua!
Mai ara rā te Tawhito!

Tēnei au
Tēnei au te rangahau ana, ki te ao, ki te pō
Kia Ranginui e tū iho nei,
Kia Papatuānuku e takoto ake nei.

Mai ara rā, mai whea ra tōku ahunga mai?
Tāhuri whakataumaha, huri whakamāmā
E te Kāhui Maunga ko wai ra koe?

Inā, Matua Te Mana te aunahi pīataata mātahi
Pikimai Rawea te kai-kukume ake matua whenua rō wai

Te rongo nei ia hīhī,
Te rongo nei ia hāhā me huka tātairango.
Tina, tina toko te manawa ora, he manawa ora!

Ko te Roi-a-Rangi mo Rua-te-Tipua
Ko te Roi-a-Rangi nō Nukuhau e
Te pātukituki ka tū whakahirahira Kāhui Maunga mā.

Ko toka pokohiwi ka hora maru tapu, e Ngā Turi-o-Murimotu
Te ahi kā o Paerangi i te Whare Toka
Te puta mai te Kāhui-o-Rangi, te Kāhui-a-Rua
Tōna hekenga mai i Te Wai-ā-Moe ki Paretetaitonga
Ko te ara hekenga, ko te ara hokinga mo ngā uri kōtuku
Ka tuku, ka tuku atu i ngā hau kaha ia Parakakariki, ia Mouwhakaarahia

Hei tohu, hei whakaatu ki te ao!
Whiti, whano, hara mai te toki!
Haumia! Hui e!
Taiki e![1]

[1] Karakia (i.e. prayer) offered by Ngati Rangi Iwi to Mt. Ruapehu, their ancestor. Provided by Che Wilson, Ohakune 2011, Aotearoa.

ABSTRACT

A new detailed stratigraphy was developed for a sequence of pyroclastic deposits including the largest known eruptions associated with Mt. Ruapehu, deposited in the period ~27-10 ka BP cal. From the largest Plinian eruption deposits in this sequence, subtle lithofacies variations within componentry, pumice textures and sedimentary features were used to identify a systematic change in eruptive conditions over time. Early eruptions involved steady eruption columns, while younger eruptions involved unsteady, collapsing columns. Isopach and Isopleth (pumice and lithic) mapping of most widespread and distinctive units show that the largest explosive eruptions known from this volcano attained peak column heights between 22 and 37 km, with mass discharge rates reaching 10^7-10^8 kg/s.

To characterise the conditions controlling the style of Plinian eruptions at this andesitic volcano, and to explain the systematic variation in column stability over time, five key units were sampled in detail, exemplifying the major contrasting lithofacies. The sampled tephras underwent grain-size analysis, along with quantification of componentry, porosimetry and density on particles of a range of size classes, as well as 2D and 3D microtextural analyses of juvenile pumice clasts to define vesicularity and crystallinity. In addition, physiochemical factors such as melt-evolution and volatile-contents were determined by analysing bulk pumice, glass-inclusions and residual glasses with electron microprobe and FTIR-spectroscopy.

Bulk compositions of these tephras vary from basaltic-andesite to andesite (56-62 wt.%, SiO_2), and had minimum pre-eruptive H_2O contents of 4-5 wt.%. The evolution of eruption behaviour over time was not correlated to any progressive change in bulk geochemical properties, but instead resulted from variations in physical processes within the conduit. Ascending magmas experienced heterogeneous bubble nucleation, and later-erupted units showed increasing degrees of rheological heterogeneities developed across the conduit. Differences between units were due to changes in the magma decompression rates, the degree of bubble-crystal-melt interactions and bubble shearing, as well as the composition of the residual melt. Conditions that led to the most variable physical states of the magma reaching the fragmentation level resulted in the highest variability in pumice textures, the greatest range in styles of fragmentation, and the most unstable eruption columns.

A new model describing the pre-eruptive magma storage region, conduit processes, magma fragmentation, and pyroclastic dispersal during Plinian eruptions at Mt. Ruapehu is proposed. This hypothesises that eruption column unsteadiness and collapse occurs when magma shear reaches extreme levels along the conduit under conditions of low isolated porosity (<3 vol.%). This situation also generates the worst-case hazard scenarios expected for Ruapehu, eruptions, where Plinian columns of over 30 km may produce widespread tephra fall, as well as partially collapse to generate pyroclastic density currents of over 15 km runout.

ACKNOWLEDGMENTS

This thesis would not have been possible without the guidance and the help of several people who, in one way or another, contributed and extended their valuable assistance in the preparation and completion of this study. I would first like to acknowledge my first teacher of Volcanology, Héctor Cepeda, for keeping alive from afar my passion for volcanoes and question our role as scientists within any local community. He also dragged my attention to explore this side of the world, Aotearoa (New Zealand). Professor Claus Siebe (UNAM-Mexico), who encouraged me to come and continue my studies in Volcanology, suggesting without hesitation Professor Shane Cronin as my supervisor. My utmost gratitude goes to Professor Shane Cronin who continuously motivated me and supported me along the difficult PhD process, providing excellent guidance, lessons, discussions and encouragement, together with his patience with my "Colombian English" and exhaustive final edition. He, together with my other co-supervisors, Drs. Alan Palmer and Karoly Németh, and Associate Professor Ian Smith, helped me to keep up every day's motivation in the research. I will always be grateful to Alan Palmer for all his assistance and guidance during the extensive field-work and data collection phases of this study. Dr. R.B. Stewart (Massey University), Dr. Ben Kennedy (Canterbury University), and Dr. Katherine Cashman (University of Oregon, U.S.A.) are greatly thanked for the examination of this thesis, all the comments, discussions, and suggestions that significantly improved the final version.

Some of the most difficult tasks of this project would definitely not have been possible without the teachings, hospitality and guidance of Dr. Heather Wright (USGS, California, USA). During and after the X-ray synchrotron analyses at California, she always found time to discuss and review my ideas until outputs were reached that we could trust. Also, Dr. C. Ian Schipper (ISTO-CNRS, Orléans, France), who arrived at the precise moment to rescue me from the frustrating sample preparation for FTIR measurements and taught me that patience, persistence, and having fun are the best ingredients to be successful in any lab procedure.

This study was financed by the New Zealand Foundation for Research Science and Technology, (now the Ministry of Science and Innovation, NZ Natural Hazards Research Platform) programme, "Living with Volcanic Risk" and by a Massey University Doctoral Research Scholarship. I am also grateful for the support of the Tongariro Natural History Society through a Memorial Award. H. Keys, J. Johnson (Department of Conservation), and the Range Control staff of the NZ National Army camp at Waiouru are thanked for allowing access to the Tongariro National Park and Army land.

I also thank Alastair McDowell for his training and aid during the CT-scanning at Lawrence Berkeley National Laboratory (Berkeley, California). Dr. C. Ian Schipper for scanning the samples at ISTO-CNR (University of Orléans, France), along with Dr. Alan Burgisser and ERC grant 202844 under the European FP7, for providing the facilities within this micro-CT laboratory. Dr. Anja Moebis, for helping with the complex FTIR sample preparation, and together with Professor Bob Stewart and Dr. C.I. Schipper, for discussing and developing the corresponding methodology at Massey University. Drs. Anja Moebis and Clel Wallace, thank you for teaching me how to deal with the serious mission of thin sectioning pumice and polishing. Mr. Doug Hopcroft and Dr. Jianyu Chen are gratefully acknowledged for their collaboration with the Scanning Electron and Confocal microscopes. A very special acknowledgment goes to Ritchie Sims, at University of Auckland, who made every second of the tedious microprobe analysis fun and enriching. His help and friendship were always there. I am extremely grateful to Ian Furkert, Bob Toes, Matthew Irwin, and Mike Bretherton for bringing all their best energy and enthusiasm while assisting me in the different laboratory procedures. It was very important to be surrounded by their kindness and smiles, which made the long journeys in the lab peaceful and joyful. I also thank them for making me stop sometimes and forcing me to go home.

Dr. R.B. Stewart, Dr. G. Lube, and Dr. J. Procter, as well as Professors V. Neall, and M. Bebbington, for their helpful lessons and discussion. All the PhD-students, friends and staff of Volcanic Risk Solutions of Massey University were extremely helpful and supportive. I am very grateful to Dr. Marco Brenna, Dr. Gert Lube, Ms. Emma Phillips, Dr. Jon Procter, and Dr. Ting Wang for their support in the field. Thanks to Marco, Ting, and Gert for being always there in my moments of panic, especially with software and calculations. This project could not have achieved the desired progress without the efficiency, promptness, and help of Dr. Kate Arentsen, who dealt with most of the exhaustive logistics. She, and Dr. A. Moebis greatly contributed to the final edition and formatting. My gratitude goes also to Moira Hubbard and Liza Haarhoff for all their assistance and kindness with administrative issues during the PhD.

Chapter reviews by Dr. Claus Siebe (UNAM-Mexico), Dr. Guido Giordano (Italy), Dr. Roberto Sulpizio (Italy), an anonymous reviewer, Dr. Setsuya Nakada, and Dr. James White, were gratefully received and proved extremely useful for improving the quality of the resulting manuscripts. The final publications are available at www.springerlink.com.

Warm and special gratitude to my "kiwi brother", Andy Dolling, for being so present and filling my soul with joy, poetry, and music, needed to survive the PhD. Through the ukulele and drums he always found a way to keep me singing, creating, and smiling even in the most difficult moments. Along with him, all my friends in Whanganui, Mike and Loraine Dolling, Ron Riddel and Saray Torres, Chika and Richie Janutka, and David Griffiths who became a beautiful and supportive family in this country. Niji, Kiwa, and Kaho Janutka, thank you all for remind me to keep my inner child alive and strong, even while doing a PhD.

Vilma Rodríguez, German Molano, and Alvaro Martínez, for helping me to keep connected with my roots, my dreams, my reasons, my questions. They have been a wonderful example and reference; a grounding point, guiding me in my own personal search within this hybrid Colombian personality dancing between arts, science, and social justice. Erica Lattughi and Matiu Te Huki, for opening a new perspective of freedom and possibilities, nurturing my will to choose our own path and work with love for our dreams. Erica, Jen Hyde, and Korty Wilson, for supporting and helping me to contribute to the real, physical, daily world by reinforcing the meaning of community and sustainable living while we conduct scientific research. Jaime Dorner and Marisol Vargas, for opening the paths of theatre, allowing me to keep vibrant the creative artistic world, contributing to balance the scientific days and to keep exploring the depths, multiplicity, and possibilities of the human being. I also thank my first friends and flatmates, Sadia Tahir and Mazidah Abdul Rahman, who created a beautiful and supportive connection between women from different countries and cultures arriving to a common place, Te Papaioea (Palmerston North). Also to newer friends in this town, including Angela and Gabor Kereszturi, as well as my wonderful flat-mate, friend, and supportive shoulder, Javier Agustín-Flores. Thank you all for listening and sharing.

Last, but not least, my thanks to my wonderful, missed family in Colombia and overseas, for giving me strength, believing in my dream, and letting me fly with my own wings.

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Abbreviation	Meaning
Locations and Stratigraphic Units	
Fm.	Formation
TVZ	Taupo Volcanic Zone
TgVC	Tongariro Volcanic Centre
CL	Crater Lake
Rhyolitic tephras (Okatania Caldera):	
Ok	Okareka Tephra
Rw	Rerewhakaaitu Tephra
Wh	Waiohau tephra
Mt. Ruapehu andesitic tephras:	
HP	Hokey Pokey Eruptive Unit
Mgt	Mangatoetoenui Eruptive Unit
Sw	Shawcroft Eruptive Unit
Oru	Oruamatua Eruptive Unit
Ak	Akurangi Eruptive Unit
Okp-Ph	Okupata-Pourahu Eruptive Unit
L-	Lower
M-	Middle
U-	Upper
Mt. Tongariro andesitic tephras:	
Pk	Pahoka Tephra
Rt	Rotoaira lapilli
LA	Lithofacies Association
PDC	Pyroclastic density current
cal yr BP	Calibrated years before present
ka BP cal.	kilo-annum before present (calibrated)
Eruption parameters	
V	Tephra volume [km^3]
Vp	Proximal tephra volume [km^3]
Vt	Total tephra volume [km^3]
T	Deposit thickness [cm]
T_0	Extrapolated thickness at the vent [cm]
A	Area [km^2]
A_{ip}	Break-in-slope distance [km]
k	slope
H_b	Eruption column neutral buoyancy level [km]
H_t	Eruption column total height [km]
b_c	Clast half-distance
b_t	Thickness half-distance
D	Fragmentation Index of Walker (1973)
Q	Volume discharge rate [m^3/s]
MDR	Mass discharge rate [kg/s]
M	Eruption magnitude
Sh	Shape factor
Grain-size parameters	
M	Mode
Md	Median
σ_G	Graphic standard deviation
S_{Kg}	Graphic asymmetry
Mz	Mean
σ_i	Inclusive standard deviation
S_{ki}	Inclusive graphic asymmetry
K_g	Kurtosis
Density and porosity parameters	
δ_{bulk}	Bulk density [$g \cdot cm^{-3}$]
δ_{skel}	Skeletal density [$g \cdot cm^{-3}$]
δ_{sol}	Solid density [$g \cdot cm^{-3}$]
φ_{bulk}	Bulk porosity [vol.%]
φ_{conn}	Connected porosity [vol.%]
φ_{iso}	Isolated porosity [vol.%]
Textural parameters	
N_v	Vesicle number density [cm^{-3}]
nv	vesicle number density per size class [cm^{-3}]
N_x	Mafic crystals number density [cm^{-3}]
VVD	Vesicle volume distribution
CVVD	Cumulative vesicle volume distribution
VSD	Vesicle size distribution
CVSD	Cumulative vesicle size distribution
CVD	Mafic crystals volume distribution
CCVD	Mafic crystals Cumulative volume distribution
CSD	Mafic crystals size distribution
CCSD	Mafic crystals Cumulative size distribution
Mt	Magnetite
Pl	Plagioclase
Px	Pyroxene
Cpx	Clinopyroxene
Opx	Orthopyroxene
Mt	Magnetite
Ox	Oxides
Gx	Glomerocryst
Others	
ε	Molar absorptivity coefficient [Liters/(mol x cm^{-2})]
LOI	Water from loss on ignition
ΔP	Decompression rate
ΔP_{SS}	Supersaturation pressure
Pc	Closure pressure
GT	Growth rate in a given timescale
n_o	Number of initial nuclei
L	Dominant diameter
Ves	Vesicle
Qz-Ab-Or	Quartz-Albite-Orthoclase

Techniques and equipment	
SEM	Scaning Electron Microscope
BSE	Back-scatter electron image
μ-CT	X-ray microtomography
FTIR	Fourier Transform infra-red
EMPA	Electron Microprobe
XRF	X-ray fluorescence spectrometry
LA-ICP-MS	Laser Ablation Inductively Coupled Mass Spectrometry
Institutions	
LBNL	Lawrence Berkeley National Laboratory at Berkeley (CA, USA)
ISTO	Institut des Sciences de la Terre d'Orléans l'Université d'Orléans (France)