Small-volume volcanism associated with polygenetic volcanoes, Taupo Volcanic Zone, New Zealand

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

Doctor of Philosophy

in

Earth Science

at Massey University, Palmerston North, New Zealand

Szabolcs Kósik

2018

Panoramic view of the west shore of Lake Taupo with three lava domes from the Motuoapa Peninsula

"Each volcano is an independent machine—nay, each vent and monticule is for the time being engaged in its own peculiar business, cooking as it were its special dish, which in due time is to be separately served. We have instances of vents within hailing distance of each other pouring out totally different kinds of lava, neither sympathizing with the other in any discernible manner nor influencing other in any appreciable degree."

Clarence Edward Dutton

Abstract

In the past 350 ky, the Taupo Volcanic Zone (TVZ) has been the most productive silicic volcanic region in the world, with 12 silicic large-volume (35-2200 km^3 DRE) caldera-forming eruptions and hundreds of predominantly silicic smaller-volume eruptions. These spatially and temporally scattered small-volume events are characterised by relatively short-lasting single eruptive episodes that may have been strongly influenced by location-specific environmental factors. The aim of this study is to evaluate the volcanic hazards associated with the activity of these small-volume volcanoes using two different approaches. At the local scale, possible eruption scenarios were defined through three example localities (Ohakune, Motuoapa, Puketerata) that are characterised by different chemical compositions, eruption styles, as well as distinct environmental conditions representative of the entire TVZ. At the field scale, evaluation of small-volume activity was focused on the spatio-temporal and volumetric distribution of vents and their relationship to the structural elements of the TVZ. The most common small-volume eruptions form lava domes that were originally thought to be rarely associated with explosive activity. In contrast, this study shows that dome emplacement is often accompanied by explosive activity. However, the associated pyroclastic deposits are characterised by a low preservation potential. The most likely scenario for future eruptions is a rhyolitic eruption with an initial phreatomagmatic phase followed by the effusive emplacement of lava with or without associated explosive activity. Based on the average eruptive volumes (0.2-0.3 km^3) of single TVZ events and typical eruption rates of dome-forming activity (2-5 m^3/s), future eruptions are expected to last for several months to a few years. TVZ-scale spatio-temporal analysis of eruptive vents indicates that small-volume volcanism is not entirely limited to active calderas. Instead, frequent fissural activity indicates a strong linkage to the fault system of the TVZ. The temporal and volumetric pattern of small-volume volcanism displays a sudden increase of activity at 45 ka, producing at least 130 km^3 of volcanic material to date. The random occurrence, great variability of eruption styles, small but significant volumes, prolonged duration and relatively high frequency of small-volume volcanism pose a significant threat within the entire TVZ, which New Zealand will have to face in the near future.

Acknowledgements

This thesis is the result of 3.5 years-long research at Massey University, New Zealand that I started in April 2014. I am grateful to many people who have worked with or assisted me throughout the maze of the PhD to complete this thesis.

First of all, I am thankful to my chief supervisor, Károly Németh, for our scientific discussions as well as guidance and support in the world of research and beyond. I am also thankful for the contributions and support of my co-supervisors, Jonathan Procter, Georg Zellmer and Shane Cronin. Many thanks to Kate Arentsen for administrative, organizational, and proof reading support. I would like to acknowledge my co-authors, Gábor Kereszturi, Mark Bebbington, Robert Stewart (Massey University), Nobuo Geshi (Geological Survey of Japan), and Jaroslav Lexa (Earth Science Institute, Slovak Academy of Sciences) for their support and contributions to manuscripts or presentations. I also acknowledge the field assistance of many colleagues and friends, such as Braden Walsh, Ermanno Brosch, István Hajdu, Boglarka Németh (Massey University) and Takeshi Hasegawa (Ibaraki University, Japan). I acknowledge Anja Moebis and the staff of the Manawatu Microscopy and Imaging Centre (Matthew Savoian, Niki Minards, and Jordan Taylor) for their priceless technical support. Special thanks go to staff, former and present PhD students of Volcanic Risk Solutions for discussions in various research and non-research-related topics that make university life colourful, Javier Agustin-Flores, Maricar Arpa, Eric Breard, Magret Damaschke, Martha Gabriela Gómez-Vasconcelos (aka Gaby Gómez), Charline Lormand, Gert Lube, Stuart Mead, Adam Neather, Andrea Todde, Rafael Torres-Orozco, Manuela Tost, Marija Voloschina, and Aliz Zemeny and others already mentioned.

I would like to express my gratitude to the Institute of Agriculture and Environment, Massey University for the financial support. I also acknowledge the support of Massey Foundation and Massey University Doctoral Completion Grants for the last months of my studentship. Many thanks to the IAVCEI Commission on Collapse Calderas and Geological Society of New Zealand for their support helping me attend conferences during my study.

LiDAR data in this thesis was provided by Waikato Regional Council, Hamilton and Horizons Regional Council, Palmerston North; the National Institute of Water and Atmospheric Research (NIWA) supplied bathymetry maps of New Zealand lakes.

This is an excellent opportunity to acknowledge the people who helped me to get this far. I would like to thank my two mentors, Róbert Győri (Eötvös Loránd University, Hungary) and István János Kovács (Geological and Geophysical Institute of Hungary) for encouraging me to start a research career at the beginning of my university studies in Hungary. A special recognition goes to my former supervisor, Dávid Karátson (Eötvös Loránd University, Hungary), who endeared me to volcanology and did the most for my research career before coming to New Zealand.

I wish to thank my parents for their help in achieving my life goals and efforts to make me an open minded competent person.

Last but not least I would like to express the greatest thanks to my family. Without the unconditional love and support of my fiancée Zsuzsa it would not have been easy to get so far, while our newborn son, Titusz, inspires me to continue this journey and look for new challenges. This thesis is dedicated to the two of you!

Table of contents

List of figures

List of tables