A SEDIMENTOLOGICAL AND GEOCHEMICAL APPROACH TO UNDERSTANDING CYCLES OF STRATOVOLCANO GROWTH AND COLLAPSE AT MT. TARANAKI, 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

Anke Verena Zernack

2008

***Frontispiece*. Mt. Taranaki viewed from the beach.**

ABSTRACT

The long-term behaviour of andesitic stratovolcanoes is characterised by a repetition of edifice growth and collapse phases. This cyclic pattern may represent a natural frequency at varying timescales in the growth dynamics of stratovolcanoes, but is often difficult to identify because of long cycle-timescales, coupled with incomplete stratigraphic records.

The volcaniclastic ring-plain succession surrounding the 2 518 m Mt. Taranaki, New Zealand, comprises a wide variety of distinctive volcanic mass-flow lithofacies with sedimentary and lithology characteristics that can be related to recurring volcanic cycles over >190 ka. Debris-flow and monolithologic hyperconcentrated-flow deposits record edifice growth phases while polylithologic debris-avalanche and associated cohesive debris-flow units were emplaced by collapse. Major edifice failures at Mt. Taranaki occurred on-average every 10 ka, with five events recognised over the last 30 ka, a time interval for which stratigraphic records are more complete. The unstable nature of Mt. Taranaki mainly results from its weak internal composite structure including abundant saturated pyroclastic deposits and breccia layers, along with its growth on a weakly indurated and tectonically fractured basement of Tertiary mudstones and sandstones. As the edifice repeatedly grew beyond a critical stable height or profile, large-scale collapses were triggered by intrusions preceding magmatic activity, major eruptions, or significant regional tectonic fault movements.

Clasts within debris-avalanche deposits were used as a series of windows into the composition of previous successive proto-Mt Taranaki edifices in order to examine magmatic controls on their failure. The diversity of lithologies and their geochemical characteristics are similar throughout the history of the volcano, with the oldest sample suites displaying a slightly broader range of compositions including more primitive rock types. The evolution to a narrower range and higher-silica compositions was accompanied by an increase in K_2O. This shows that later melts progressively interacted with underplated amphibolitic material at the base of the crust. These gradual changes imply a long-term stability of the magmatic system. The preservation of similar internal conditions during the volcano's evolution, hence suggests that external processes were the main driving force behind its cyclic growth and collapse behaviour and resulting sedimentation pattern.

ACKNOWLEDGEMENTS

This research would not have been possible without assistance of my chief-supervisor Assoc. Prof. Shane Cronin. He suggested my research project and helped me receive a Massey and DAAD doctoral scholarship as well as other financial assistance during the course of my PhD. I would also like to thank him for helpful discussions and new ideas during my PhD. I appreciate his thorough reviews of my thesis, papers and conference abstracts.

I also wish to thank my co-supervisors Prof. Vince Neall and Dr. Bob Stewart (Massey University) and Prof Richard Price (Waikato University) for their fruitful discussions over the last four years. Vince first introduced me to Taranaki and I furthermore want to thank him for the thorough revision of a major part of my thesis and helpful criticism. Bob and Richard's help with finding the most interesting rock samples and their huge physical effort to trim them down with a sledge hammer to reasonable sizes is also greatly acknowledged, as is their guidance regarding the geochemical and analytical work afterwards. In addition, Richard organised for me to re-visit Australian National University (ANU), Canberra, for the second part of ICP-MS analyses and also arranged a stay at the University of Melbourne for isotope analysis.

I am grateful to Assoc. Prof. Ian Smith (University of Auckland) for arranging the use of the XRF and EMP equipment in Auckland as well as at ANU, Canberra for the first visit to the ICP-MS.

I would like to thank some of the people of the Soil and Earth Sciences Group. Bob Toes and Ian Furkert introduced me to the labs at the start of my PhD and helped me out during sample preparation. Mike Bretherton was there whenever my computer decided to stop working. Thanks also to Moira Hubbard who helped out with administrative and stationary problems.

At Auckland University I would especially like to thank Dr. Ritchie Sims who not only provided outstanding assistance during the use of the microprobe, but also always made me love. Thanks for all those Family Guy episodes and GBs of music, which made probing a lot more enjoyable. Mr. John Wilmhurst is thanked for his assistance in XRF analysis and sample preparation.

Roland Maas is gratefully acknowledged for his help during sample preparation and subsequent analyses of isotope sample. He made me feel at home at Melbourne University and his good sense of humour made working easy. Thanks to John Woodhead who analysed some of my samples after I left. And a big thanks also to Jo "Tiger" Whelan who invited me to stay with her during my visit to Melbourne. She helped me get around in town and in the lab.

Thanks also to the technician and scientists at ANU, Canberra, (and Ian Smith) for help during long nights of ICP-MS analyses.

I am also grateful to all the farmers of Taranaki who allowed me to access their land and especially the Dorn family of Pihama who invited me to stay with them, introduced me to other farmers and showed me important access ways to the numerous beaches I visited during my field studies.

I furthermore want to thank fellow postgraduate students, Dr. Katherine Holt, Dr. Michael Turner, Dr. Thomas Platz and Anja Moebis for sharing our "PhD experience", listening and helping each other out during harder times.

My PhD was supported by a Massey Doctoral Scholarship and a complementary DAAD (German Academic Exchange Service) Doctoral Stipend. I would also like to thank the George Mason Trust for an additional scholarship and Education New Zealand for a New Zealand Postgraduate Study Abroad Award, which allowed me to attend the 17th International Sedimentological Congress in Fukuoka, Japan. I gratefully acknowledge FRST (MAUX0401 "Learning to live with Volcanic risk") for field and laboratory financial support and INR for a Supplementary Scholarship.

I am very grateful to my parents who have supported me all my life and encouraged me during hard years of MSc as well as PhD study, even from the other side of the globe.

Last but most important, I would like to thank my fiancé Jonathan Procter, who has supported me for the last four years in everything I did. He was my field buddy during summer field work, my drinking buddy after hard work of study and he always had an open ear for discussions as well as my complaints. I am very thankful for his help with printing the final version of this thesis. I am very grateful for his support, patience and love during the last months.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES