THE ORIGIN OF SLOPE DEPOSITS IN THE SOUTHERN DRAKENSBERG, EASTERN LESOTHO

Stephanie Christiane Mills

Submitted in fulfilment of the academic requirements for the degree of
Doctor of Philosophy

School of Geography, Archaeology and Environmental Studies
University of the Witwatersrand, Johannesburg

Johannesburg
July 2006

This thesis is dedicated to the memory of my father, Ken Mills (1946-2004).

Declaration

I declare that this thesis is my own, unaided work, except where otherwise acknowledged. It is being submitted for the degree of PhD to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other university.

(Stephanie Mills)

14th day of July 2006

Abstract

The high Drakensberg of southern Africa has received considerable geomorphological interest during recent decades. In particular, there has been an ongoing debate concerning the accuracy of landform interpretations which propagate past glaciation and permafrost. This research examines the macro and micro-sedimentology of various deposits found in eastern Lesotho and compares them with possible geomorphological process origins such as debris flows, debris avalanches, mudflows, mudslides, landslides, solifluction deposits, rock glaciers, pronival ramparts, glacial moraines and fluvial deposits. The results support the contention that four of the deposits are moraines, formed by small glaciers, and one is a debris flow which was initiated by a small glacier. However, two further deposits indicate that localities in close proximity to the linear deposits experienced mass wasting, associated with past periglacial conditions. With the assistance of applying glacier reconstruction methods, modelling hillshade, the provision of new palaeoclimatic extrapolations, and correlation of deposits with contemporary snow patch distribution, it is demonstrated that the valley slope deposits are determined by a past climate that was within the glacial/periglacial equilibrium zone, and was influenced by specific topographic and associated micro-climatic thresholds. It is shown that macro-topographic factors (e.g. slope gradient, aspect etc) and summit altitude are critical factors determining whether slopes were influenced by periglacial (mass wasting) or glacial processes (small niche/cirque glaciers) in adjacent valleys.

Preface

This work stems from the discovery of debris deposits in eastern Lesotho, which display unique morphological characteristics. No work has previously been undertaken on such deposits in the area, which thus offers a great opportunity to add understanding to the Quaternary history of southern Africa. Having lived and been educated all my life in the northern hemisphere, I was unaware of the controversial debate regarding the Quaternary history of southern Africa. This has helped offer a fresh perspective, without any preconceived ideas as to the processes which formed these deposits. The process origins considered for the formation of these deposits were chosen based on the morphology of such process origins and their role in the alpine environment. The initial aim of this research was to ascertain which processes could have formed the deposits located in eastern Lesotho, however through the use of sedimentological analysis and AMS dating, it soon became clear that a serious contender was that of past glacial processes. Given the controversy surrounding such a claim, it was necessary to investigate this further through the use of glacier reconstruction techniques and the influence of solar radiation. These techniques helped further reinforce that small glaciers had been present in the past, however the lack of further deposits on adjacent slopes indicates that glaciers were restricted to only a few areas. Given the recent prolific production of periglacial-related literature for Lesotho, it is hoped that this research will reawaken the interest into past glacial processes, which were first suggested five decades ago.

Sections of this work have been presented at the *SASQUA* conference in Johannesburg, South Africa in 2003, the *Sixth International Conference on Geomorphology* in Zaragoza, Spain in 2005 and the *Geomorphology and Earth System Science* (BGRG) conference in Loughborough, England in 2006. Sections of this work have also been published in *Quaternary International*, 2005.

Acknowledgements

There are many people who have provided assistance with this research project and they are thanked in no particular order. I would first like to thank Colin Bones, without whom I would never have discovered the wonderful country that is South Africa. Colin has supported me both personally and financially and was also indispensable when it came to field work. Although he swore he would never go back to Lesotho and undertake another minute of fieldwork after his first experience, he returned time and time again, and put up with endless hours of horse riding, digging and carrying very heavy soil samples. He has also proved invaluable in terms of proof reading and checking references and has had to put up with my incessant work during the last few months of this research.

Several people have helped me with fieldwork and made the time more enjoyable. Thank you very much Christine Deschamps and Joel LeBaron for your tireless help in the field, friendship and advise throughout. They put up with 12 hours on a horse to get to one of my sites, which was not a particularly enjoyable experience and days camping in the freezing cold, so thanks guys. Thank you also to Nicolas Mulder and Emily Craven for their help in the field on separate occasions. Thank you also to Nicolas for providing the contemporary snow patch distribution diagrams which were used in this research.

Many people have also provided their time, energy and expertise to help me in the laboratory. Thanks to Thandiswe Nsimbi for his help in enabling me to have access to the soils lab and in helping me whenever the sieving machine broke down. Due to the lack of equipment at Wits I contacted my old university (Royal Holloway University of London) in order to beg them to let me have the use of their soils lab. Huge thanks to Adrian Palmer for helping me with the sedigraph machine and the manufacturing of the thin sections. Adrian dedicated a lot of his time in supervising me during the manufacturing process and also allowed me the use of microscopes during endless hours and days of analysis. Adrian proved indispensable, when on moving back to the UK the thin sections along with my hand luggage were stolen. Thanks to the insurance pay out he was able to re-do all my thin sections when I just didn’t have the time nor the courage. Many thanks to Stefan Woodborne and staff at the QUADRU, CSIR for discussions and providing the AMS dates. Thank you also to Devlyn Hardwick for her advice regarding the DEM and to Eric Hallot for creating it. Statistical analysis would have been much more difficult had it not been for Richard Smerin's help, which was much appreciated.

Scientific advice on the various aspects of my thesis has been provided by several people. I would first like to thank Simon Carr for all his help and advice regarding the glacier reconstruction work. Simon gave up his time to take me through the process step by step, along with his postgraduate student, Chris Coleman. Thanks also for checking that I had undertaken the process correctly and also on the advice regarding several aspects of my PhD. Thanks also to Jim Rose for all his advice regarding the Sehonghong deposits. Jaap Van der Meer gave up time for discussion and looked through my thin sections and advised me on references I should look at. Correspondence by email was also invaluable and I would like to thank Colin Thorn for his advice regarding snow patches, Richard Shakesby for his advice regarding pronival ramparts, Wishart Mitchell for his advice regarding snow blow and Pascal Bertran and John Menzies for their advice on the micromorphology of debris flows. Thank you also to Colin Lewis for his advice regarding the Sehonghong deposits and Richard Washington for his advice regarding past climatic processes.

Many people have helped towards the end of this research so I would like to apologise to my friends for roping them into this, but at least they have a better understanding of what I have been doing for the last few years. Thank you to Naomi Davies for checking my references and to Deana Rouse and Helen Cameron for proof reading a few chapters. Thank you also to Claire Munson for proof reading some chapters and for all her support and friendship over the years. I would also like to thank my family for their moral support and for coming out to visit so many times in South Africa so that it didn't seem we were too far away from home. Thanks to my dad as I'm sure it was his passion for geography that first awakened mine. I'm just sorry that he wasn't able to see me complete this PhD but his support in the beginning was instrumental.

Finally, but by no means least I would like to thank my supervisor, Stefan Grab. Thank you for providing the funding for the AMS dates, without which this thesis would have had much less of a standing in stating that glaciers existed during the Last

Glacial Maximum (LGM). Stefan believed in me and encouraged me throughout and was the inspiration behind this project. Thank you for going through my thesis with a fine tooth comb, for putting me in touch with others, suggesting various references I should read and for developing my writing skills into what they are now. Thank you also for encouraging me to present my work at various conferences and for all your help with the article that we published.

Contents

CHAPTER 3: Environmental and Geomorphic Setting

CHAPTER 4: Methodology

CHAPTER 5: Tsatsa-La-Mangaung Results

CHAPTER 6: Sekhokong Results

CHAPTER 7: Leqooa Valley Results

CHAPTER 8: Sehonghong Results

CHAPTER 9: Discussion

CHAPTER 10: Glacier Reconstruction

CHAPTER 11: Conclusion

List of Figures

List of Tables