Freie Universität Berlin

GFZ
Helmholtz-Zentrum
Potsdam

A seismological study of gravitational mass movements based on lab-scale experiments

Master's thesis
in the Department of Earth Sciences
at Freie Universität Berlin

by Zahra Amirzada
May 2015

assessed by
Prof. Dr. Onno Oncken & Prof. Dr. Niels Hovius
from Geoforschungszentrum Potsdam

I hereby certify that the work presented in this thesis has been composed independently without use of any sources or auxiliary means other than mentioned.

Zahra Amirzada *Berlin, 1st of May 2015*

Abstract

Seismological monitoring of gravitational mass movements is considered an emerging field in earth and environmental sciences, allowing for the remote detection and quantification of slope processes by distant seismometers (Burtin et al. (2013); Petley (2013)). The method includes the possibility to invert seismic signals for a suite of aspects of event dynamics and for details of the fragmentation process. For a sound interpretation of these ground movement signals in nature, knowledge of the seismic source and of the energy transfer to the detector is paramount. Since most events however lack direct observations by other methods (e.g. cameras), the source–signal relationship often remains obscure. In order to shed light on the source–signal relationship in the context of monitoring gravitational rock movements, we started controlled laboratory experiments using analogue models. The idea of applying seismological monitoring techniques on a lab–scale opens for new and perhaps improved ways of characterizing natural events by their corresponding seismograms. Initial benchmark tests are carried out involving a controlled source i.e. a ballistic steel ball vertically impacting a horizontal glass base. These tests intend to calibrate and verify the monitoring method by relating a set of seismic metrics to the energy released during impact and deriving the respective scaling laws. Subsequently, the method is applied to models of dynamically fragmenting gravitational rock movements (Haug et al. (2014)). For this purpose a material was developed that fails in a brittle manner at lab–scale conditions. Experiments are performed by releasing the material down a slope and monitoring with a digital camera at a frequency of 50 and 250 Hz. The results from previous experiments illustrate the dynamic propertied of samples as a function of shear strength or cohesion (Haug et al. (2014)). By application of the scaling law to the experimental data, we attempt to estimate the impact energy during analogue experiments, potentially allowing for qualitative and quantitative information about the underlying mechanisms and the energy budget of the system. We find that the degree of fragmentation of a sample not only influences the mobility of experiments, but also their corresponding seismic signals and that the amount of energy consumed by fragmentation plays a more significant role in the energy budget of gravitational mass movements than has previously been assumed.

Acknowledgment

Many thanks to Dr. Matthias Rosenau and Oystein Thorden Haug for guidance and support along the way and for showing me how interesting the world of research can be. I left every meeting with many new ideas, motivation, helpful advice and good spirit. Thanks for always having an open door and a lot of patience. I thank Prof. Dr. Onno Oncken for giving me the opportunity to work on my thesis in the department of lithosphere dynamics at GFZ and for assessing my work together with Prof. Dr. Niels Hovius. Further gratitude is owed to Dr. Arnaud Burtin for Matlab support and for taking the time to answer any of my questions as well as to Prof. Dr. Frank Riedel for giving me the choice to decide on any field of work and for some inspiring talks.

Contents