Integrated Structural-Geophysical-Geomechanical Models of Landslides in Seismic Regions

Presented by
Anne-Sophie Mreyen

Supervisor
Dr. Hans-Balder Havenith
Co-Supervisor
Dr. Frédéric Nguyen

A dissertation submitted in partial fulfillment of
the requirements for the degree of Doctor of Sciences

University of Liege
Department of Geology
Georisk & Environment Group

December 2020

Members of the Doctoral Jury

Dr. Alain Demoulin University of Liège, Belgium	*President*
Dr. Hans-Balder Havenith University of Liège, Belgium	*Supervisor, Secretary*
Dr. Frédéric Nguyen University of Liège, Belgium	*Co-Supervisor*
Prof. Tomàs Fernandez-Steeger Technical University of Berlin, Germany	
Dr. Céline Bourdeau Gustave Eiffel University, France	
Dr. Mihai Micu Romanian Academy, Romania	
Prof. Xuanmei Fan Chengdu University of Technology, China	

ABSTRACT

Slopes in hilly or mountainous regions can present complex morphologies due to erosional, gravitational and seismotectonic processes. In seismically active regions, mountain ranges are usually characterised by numerous slope failures in the form of shallow to deep-seated landslides; yet, their origin is often not clearly established and must not necessarily be seismic.

This thesis investigates deep-seated landslides of unknown origin (and age) that hint at a probable co-seismic development in regard to their regional seismotectonic context, site-related structural and geological setting, and distinct geomorphological shape. Such investigations include the reconnaissance of surface as well as subsurface structures with a variety of methods; here, we analyse landslide surfaces with satellite imagery, through geomorphological observations and structural measurements, while multiple geophysical techniques are used to reveal subsurface structures and to infer geotechnical properties of the ground.

The work is focused on two study areas presenting rather ancient slope failures: the seismogenic Hockai Fault Zone in East-Belgium, with the *Bévercé* and the *Pays de Herve* landslides, and the seismic Vrancea-Buzau region in the Carpathian Mountains of Romania, with the *Eagle's Lake* and *Balta* landslides. A third study area, the Longmenshan Fault Zone in Central China with the *Daguangbao* and the *Qinglincun* landslides, is used as reference site to discuss landslides actually triggered by a recent earthquake, i.e. the 2008 Wenchuan event, and highlights mechanisms leading to co-seismic slope failure.

A decisive approach of this work is the integration of the collected data into 3D geomodels of the respective sites; these allow to link the geophysical subsurface information to observed surface structures, as well as to assess landslide dimensions and to estimate the volume of landslide debris still in place. For two study areas, the Bévercé and Balta landslides, we present a numerical back-analysis with distinct element modelling in the 2D and 3D domain, respectively, to further comprehend mechanisms influencing the genesis and development of slope collapses possibly induced by earthquakes. These computations are based on geomodelled pre-failure slope shapes, structural settings derived from field measurements and geotechnical properties inferred from geophysical measurements. For both sites, numerical computations indicate the necessity of ground acceleration to achieve similar failure patterns as observed in their actual post-failure state.

At last, we introduce conclusive key elements that link the observed markers deduced from the field measurements and numerical analyses to distinctive processes that are crucial components to comprehend the development of slope failures in seismic regions. The larger interest beyond the direct scope of this study is the deeper comprehension of regional seismotectonic processes that were active in the past to allow for better constrained seismic hazard evaluations in the future.

Contents