IAPETUS

NERC DOCTORAL TRAINING

Identifying slow deformation processes preceding dynamic failure by combining microseismic monitoring of an active rockfall at Madonna del Sasso (VB), Italy and rock deformation laboratory experiments

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Host partner: Soil&Rock Physics Laboratory, British Geological Survey, Environmental Science Center, Keyworth

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Key Words	**rock slope instability; microseismic monitoring; rock deformation; laboratory experiment; slow deformation**

Overview

The project is aimed at developing innovative strategies for forecasting dynamic ruptures by monitoring an unstable patch of the Madonna del Sasso, Verbania, Italy rock mass, prone to the development of rock falls and repeated failure episodes, preceded by clear and long lasting episodes of slow deformation. The identification of characteristic signs of impending failure is possible because of the installation of a "site specific" microseismic monitoring (1-200kHz) system for acoustic emission/microseismic (AE/MS), integrated with a conventional monitoring for seismic detection (1-10Hz) and ground deformation monitoring strainmeters, geophones and accelerometers as a result of a collaborative project supported from University of Turin, ARPA, Piemonte and SEIS-UK (Fig. 1).

The installation of the monitoring network has been accompanied by a detailed geophysical characterization of the test site in order to establish the best nodes position and internal characteristics of the monitored rock mass. In this respect both in-hole and surface seismic geophysical tests have been undertaken, allowing to provide fundamental parameters for a correct definition of the velocity field of the rock mass. Following this preliminary analysis the first 4 stations of the network have been installed and data from the monitoring network can be analyzed in order to correctly locate micro seismic sources. In this respect the project is aimed at testing and evaluating different source location algorithms and develop new stable methodologies in order to come up with the best solution comparably to the available field data. Studies related to the frequency content of the micro-tremors detected by the network will also be undertaken and their possible correlation with the stiffness and stability constraints and rock bridges that keep the rock mass in its stable

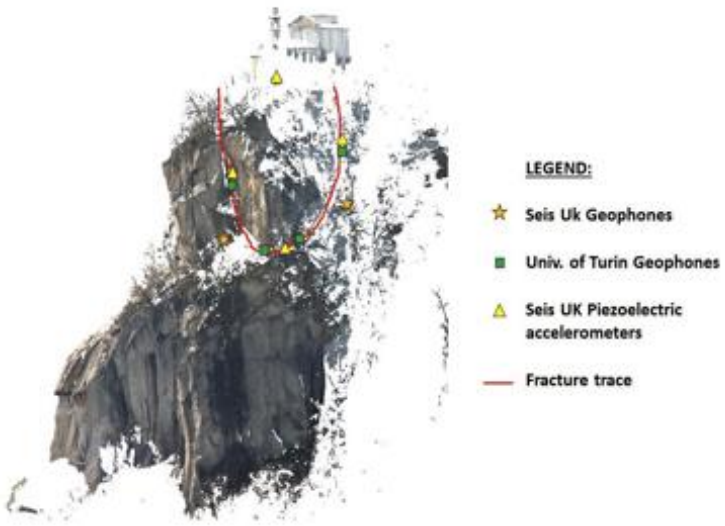

Fig. 1 – Microseismic monitoring of the instable patch at Madonna del Sasso, Verbania, Italy

configuration will be investigated. It will be finally evaluated the correlation of these characteristics of the signals with the climatic conditions and freezing cycles.

Core aims:
The main objective aims to identify slow deformation/pre-failure mechanisms (slow cracks nucleation, growth and propagation) and related physical parameters (AE, strain and seismic structure) during real-time stress controlled rock deformation laboratory experiments. Rock physical and mechanical characterization along with rock deformation laboratory experiments during which the evolution of related physical parameters under simulated conditions of stress and fluid content will be studied in order to identify the processes responsible for the mechanical instability. Indeed changes in micro-fracturing activity, and physical properties prior to the ultimate fracture of rock samples control the preparation process of the rupture. Rock failure will produce localized slip surfaces along which competing weakening and strengthening mechanisms will determine the evolution from low slip rates of few mm/s to large slip rates of m/s, leading to a large scale rockfall. This project will produce better constraints on the processes, which control the different stage of rockfall events, from their nucleation (relevant to understanding of precursory phenomena) to their propagation.

Research Questions:
During the PhD the student will investigate the following questions: (1) What are the characteristic slow deformation signals and accelerating patterns before impending failure? (2) What are the relationships between the mechanical processes and the geophysical signatures of interest for monitoring the slow deformation ? (3) How can we transfer knowledge between multiscale signs of slow deformation from the laboratory to the field ?

Methodology
Field studies 1) identify and describe (e.g. geometry, finite thickness, grain size, etc.) zones of localised slip; 2) measure the amount of slip associated with individual sliding events; 3) collect samples from the slip zones and surrounding rocks suitable for microstructural and mineralogical analyses and laboratory friction experiments. Seismological observations 1) identify and discriminate characteristic seismic signals recorded throughout frequency and spectra analysis; 2) Relate locations and seismic features to the deforming event of the rock mass. Deformation experiments will be carried out on samples with different stages of alteration/damage. Physical (density, porosity, microseismicity, permeability) and mechanical (elastic moduli, strength and friction) will be measured throughout state-of-the-art experimental apparata. Microstructural observations (optical microscopy, SEM) will be carried out on thin sections obtained from suitable experimental and natural samples.

Timeline
The activity in the first year of the PhD will be devoted to bibliographic research, field excursions, sample collection, seismic data (microseismicity) reduction, laboratory training and perfecting of sample preparation procedures, and preliminary tests. The second year will be devoted to experimental activity both on triaxial and friction experiments, analysis of lab microseismicity and post-experimental microstructure and interpretation of experimental observations in terms of processes. Third year will be devoted in small part to further experimental activity, but mainly, to the interpretation, extrapolation of results to the field and writing of publications and PhD thesis.

Training & Skills
The PhD student will derive very significant benefits from this project; he/she will be involved in a cutting-edge, multidisciplinary project. The student will be trained in different disciplinary fields as geophysics, field monitoring techniques, rockfall mechanics and laboratory mechanical experiments. Importantly, he or she will learn to use high pressure rock deformation apparatuses and techniques which are widespread not only in the world of academic research but also that of technical expertise and industry. In addition, he or she will develop skills to undertake microscopic analysis of rock formations and the interpretation of the deformation microstructures.

References & Further Reading
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