TRIGGERING OF INSTABILITIES IN MATERIALS AND GEOSYSTEMS
(TRIGS)

SPECIFIC TARGETED RESEARCH OR INNOVATION PROJECT
SIXTH FRAMEWORK PROGRAMME
NEW AND EMERGING SCIENCE AND TECHNOLOGY
PATHFINDER

Introduction:

Materials from the laboratory to geological scales respond to perturbations in a complex nonlinear fashion. In particular, the response to finite perturbations which cause failure (triggering) is an important, yet poorly understood, issue. Causes of failure may either be exogenous (precipitations, pore pressure, seismic waves, or in the materials context, mechanical perturbations) or endogenous (chemomechanical deterioration, creep deformation, microcracking and microplasticity). The multiplicity of mechanisms makes it difficult to understand and forecast failure of materials, structures and devices, or the triggering of natural hazards such as landslides, snow avalanches and earthquakes. In either case one has to analyze the response of a complex material system, involving a wide range of scales in time and space. In particular, bridging the lengthscales is at the heart of understanding materials failure and implies a theory of size and scale effects. To achieve this, methodologies from materials and earth sciences must be integrated into the more general perspective of complexity. In particular, the TRIGS project will combine the investigation of triggering mechanisms through the statistical analysis of catalogs and field measurements, with laboratory experiments, multiscale materials simulations and non-equilibrium statistical models and theories. This requires a transfer of knowledge across different disciplines which are traditionally separated. Tools developed for complex systems will be applied to materials and geoscience problems, multiscale materials modeling will be adapted to geomaterials, and experimental data and field observations will be fed back to assess the performance of theoretical models. The TRIGS project represents a joint European initiative for developing complex systems theory into an integrated methodological framework for the analysis of complex behaviour in materials failure from the atomic and nanoscale up to the geotectonic scale.

The TRIGS consortium

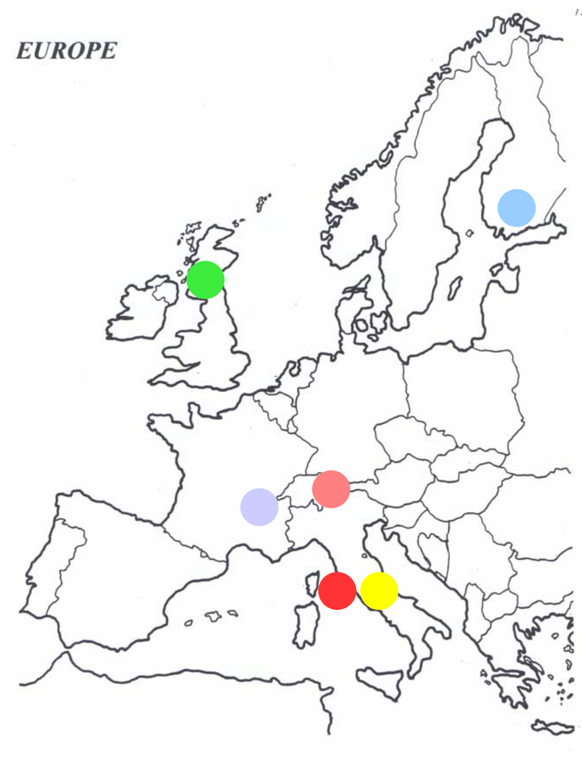

Fig 1. The TRIGS consortium: CNR (Roma), INGV (Roma), UEDIN (Edinburg), HUT (Helsinki), UJF (Grenoble), WSL/SLF (Davos)

CNR: CNR, the National Research Council, is the Italian coordinator for all public institutions devoted to science and research. The CNR team represents a collaboration between researchers based at ISC (Istituto dei sistemi complessi) and reasearchers from CNR-INFM (Istituto Nazionale per la Fisica della Materia). The CNR team, lead by Stefano Zapperi brings to the consortium its experience in the modeling of interacting complex systems, non-equilibrium dynamics, self-organized criticality, avalanche phenomena and disordered materials.

INGV: The Istituto Nazionale di Geofisica e Vulcanologia is a large research institute working in geosciences and environmental monitoring. The INGV team, lead by Patrizia Tosi, has expertise to evaluate the natural risks associated with geophysical systems and possess experimental facilities and infrastructures for the study of physical properties of rocks and magmas.

UEDIN: Center for Materials Science and Engineering (CMSE), The University of Edinburgh, Edinburgh, Scotland. The UEDIN team, lead by Michael Zaiser, brings key expertise in the integration of complex systems modeling, laboratory experiments and macroscale data analysis into a comprehensive picture of geohazard genesis and evolution.

HUT: Helsinki University of Technology is the largest of its kind in Finland. It will participate with the Laboratory of Physics and at a National Center of Excellence, COMP, for research into computational nanoscience. The HUT team, lead by Mikko Alava, has a wide expertine in the application of complex systems ideas to materials science, in particular to the physics of paper in collaboration with KCL, the Finnish pulp and paper industry research institute.
UJF: The Université Joseph Fourier is a major international centre of excellence in teaching and research and is associated with CNRS. The Laboratoire de Geophysique Interne et Technophysique (LGIT) is part of the Grenoble Observatory. The UJF team , lead by Agnès Helmstetter, carries out fundamental research on wave propagation in heterogeneous media and rupture analysis of geological objects including volcanoes, landslides and earthquakes.
WSL/SLF: The Swiss Federal Institute for Snow and Avalanche Research (SLF) belongs to the Swiss Federal Research Institute on Forest, Snow and Landscape (WSL). The WSL/SLF team, lead by Jürg Schweizer, has broad experience with the complex snow slope instability problem, laboratory experiments, multi-scale field studies and numerical simulations.

The TRIGS research project

The TRIGS project is the first of its kind to study triggering, combining the three separate aspects: the physics of complex systems, materials science, and geophysics applications. One of its strengths is the presence of several parallel geophysical applications of the methodology, in particular in view of statistical data analysis, where existing methods can be made beneficial for materials problems. Complexity theory has traditionally concentrated on describing qualitative features of various phenomena with simple, rather universal models, and on identifying the corresponding universal 'signatures' in experimental data series. Our intention is to shift the focus from the paradigmatic to the pragmatic by inserting laboratory testing on materials in between abstract modeling and data analysis. Instead of performing a global analysis of natural hazards in terms of their universal signatures, we will use the basic framework of complexity theory and the associated models but study specific responses to well defined "triggers", and work out experimental strategies that allow for a quantitative assessment of system specific, hence necessarily non-universal parameters. This will lead to more realistic models and more quantitative forecasting strategies. The TRIGS project represents an European initiative for analyzing complex behaviour in materials failure from the atomic and nanoscale up to the geotectonic scale in terms of complex systems theory. While application of tools and ideas from complexity to geosystems has some tradition, such an approach has only very recently been adopted in materials science. In both disciplines, the use of complexity tools has mostly focused on the general signatures of universality, and we perceive a growing need to shift the attention from the abstract general thinking typical of complexity to a more quantitative, experimentally based analysis. This process should take advantage of the progress made in the different fields towards detailed modeling of materials and geosystems, yet at the

same time be guided by the characteristic ‘system perspective’ of complex systems theory to avoid the danger – only too apparent in many multiscale modeling efforts – of neglecting system scale complexity because of an unwarranted attention to detail.

The TRIGS project will classify and quantify the effect of external perturbations which trigger instabilities in materials and geosystems, devising a series of experiments in which the effect of different external perturbation on the system stability is tested systematically for friction, fracture and slope failure. The TRIGS project will integrate numerical modeling with laboratory tests to address the various triggering mechanisms. To this end we will review the literature on complex system modeling of the triggering of mechanical instability and check their applicability to experiments. In particular, we will consider failure nucleation models, cellular automata, rate and state models and theory of metastability. To understand size effects in failure, we will investigate how materials strength depends on the relevant characteristic size in fracture, plasticity and friction. The expected outcome should be a microscopic understanding of the origin of size effects in different contexts and the identification of a theoretical framework to describe them. This issue is related to the possibility to obtain reliable physically based laws from the laboratory scale and transfer the information to larger scales. A positive outcome could help us to develop and improve microstructure-sensitive probes of local strength in complex materials and relate local (microscopic) and macroscopic strength Finally, the TRIGS project will try to understand to understand how to extract statistical datafrom field recordings and analyze them in conjunction with data from laboratory tests. The aim is to transfer the knowledge gained on triggering and size effects through models and laboratory tests to the geophysical objects, such as landslides, snow avalanches and earthquakes.

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