Spatiotemporal patterns in laboratory faults:
uncovering the mechanisms of earthquake nucleation.

(Proposer: Prof. Giacomo Pozzi, co-supervision prof. Telemaco Tesei)

Rationale

Earthquakes are among the most powerful phenomena on our planet, capable of suddenly reshaping the Earth's surface and affecting countless lives every year. They emerge from a complex, dynamic system of mechanisms operating at small scales and inaccessible depths within the Earth (Fig. 1). As such, it is impossible to observe the onset of an earthquake in its early stages in nature. To overcome this issue, laboratory rock deformation experiments represent the best way to reproduce conditions similar to natural ones and to simulate small-scale earthquake cycles. The objective of this PhD project is to advance beyond traditional experiments by utilizing a novel design to directly observe the mechanisms driving earthquake nucleation.

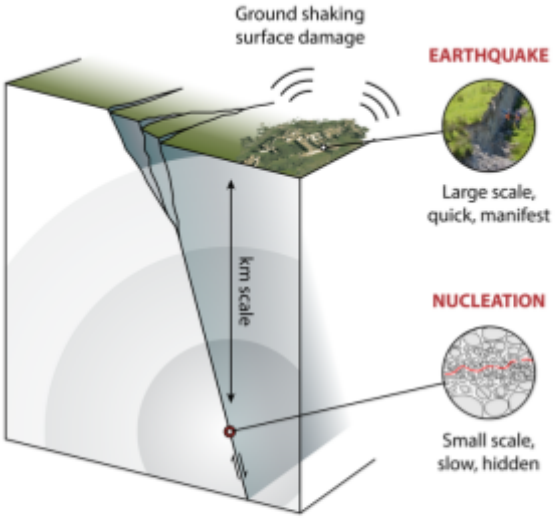

Figure 1 – The origin of earthquakes is in small-scale deformation mechanisms that reside undetected at depth in the crust.

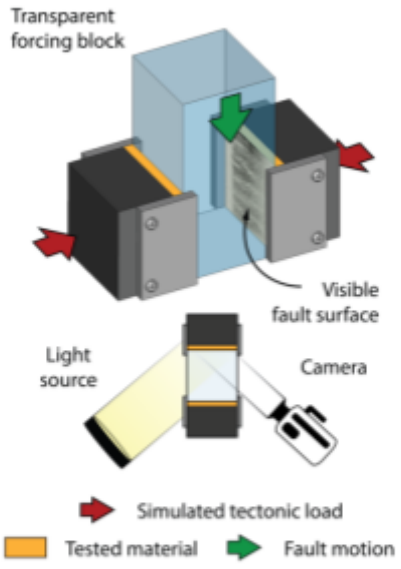

Figure 2 – Experimental configuration.

Research Activities

The candidate will design and operate rock deformation experiments on the biaxial apparatus STARDUST, a new prototype hosted in Padova, to reproduce small-scale earthquake cycles. The sample holder will consist of transparent glass blocks (Fig. 2) that allow for the continuous monitoring of the deforming material throughout the experiment. Mechanical data will be integrated with footage captured by high-speed cameras (optical and thermal) to identify the early stages of fault rupture and assess the mechanisms at play. The candidate will apply machine learning (ML) techniques to the analysis of mechanical and video data to find spatiotemporal patterns characteristic of laboratory seismicity. They will also apply nonlinear system dynamics analysis combined with Extreme Value Theory to retrieve the minimum number of independent variables required to fully represent the dynamics of the system.

Quantitative analysis will be complemented by the qualitative study of deformed samples, which will be recovered and prepared for microstructural investigation carried out using a scanning electron microscope. The aim of the study is to couple a rigorous physical framework of earthquake nucleation with the phenomenology of fault rock deformation. During their studies,

the candidate will familiarise themselves with the concepts of fault structures, fault friction, rock deformation, and earthquake physics.

Collaborations and Impact

The PhD candidate will work in the newly extended rock mechanics laboratory in Padova and operate the novel deformation apparatus STARDUST. They will work in a dynamic environment alongside experts in earthquake physics and rock mechanics (Prof. T. Tesei, Padova), machine learning applied to geohazards (Prof. F. Catani, Padova), and nonlinear dynamical systems (Prof. A. Gualandi, Cambridge). They will also collaborate with the HPHT laboratory of the Istituto Nazionale di Geofisica e Vulcanologia (Rome).

This project has the potential to shed new light on how the complexity of natural rocks affects rupture dynamics, moving towards the formulation of a new, more reliable physical framework for the description of earthquake nucleation. Furthermore, the production of novel video documentation detailing the early stages of earthquakes will provide strong dissemination material for a broader audience.

Funding

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