PhD proposal (starting in the fall 2024)
EEASY: Experimental EArthquake strike-slip fault SYstems

Pauline Souloumiac[1], Bertrand Maillot[1], Salah Eddine Hebaz[2], Nicolas Wilkie-Chancellier[2] and Yann Klinger[3].

1 : Laboratoire Géosciences et Environnement Cergy (GEC), CY Cergy Paris University.
2 : Laboratoire SATIE, CY Cergy Paris University.
3 : Institut de Physique du Globe de Paris (IPGP).

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Context and pertinence

Large continental strike-slip earthquakes (e.g.: the 2023 Mw 7.8 Turkey earthquake) produce spectacular surface deformations and destructions that are currently increasing because of new urban areas. A better understanding of the dynamics of earthquakes is necessary to improve the assessment of seismic hazard, and reduce the impact of such events. Researchers must increase the quality and quantity of surface measurements, and their modelling. The EEASY project aims to develop innovative seismogenic laboratory scaled physical models of strike-slip tectonics in order to identify the physical parameters controlling surface ruptures and their links to seismic processes at depth. Part of the challenge consists in producing high resolution observations of the dynamic deformation of the surface, a key ingredient to better understand earthquake mechanics and rupture evolution in a continental faulting context.

We can currently produce experimental seismic events over hundreds of seismic cycles, but they need to be characterised in detail, and under various experimental conditions. We also intend to equip the box with suitable sensors for seismological analysis during experiments. The experimental program, constituting the core part of the EEASY project, addresses several fundamental questions, which will be addressed in this PhD thesis:

How does the co-seismic deformation evolve during earthquakes? Is it impacted by the basal fault shape, by a convergent or divergent kinematic component at depth, by the state of stress?

All these questions in turn raise methodological challenges:

- Can we record the stress variations in the granular material? Can we record the seismic radiation with acoustic sensors to produce seismic data that can further be analysed like, and be compared to, natural seismicity data? More generally, can we produce strike-slip co-seismic surface accelerations, velocities and finite displacements in laboratory scale models that verify the similarity conditions?

Methods and expertise

The GEC laboratory has recently acquired a high-speed camera to obtain high-resolution observations in both time and space of the surface displacements during seismic events. In combination with this camera, we will use optical image correlation and stereo-photogrammetry (MicMac software developed for satellite data analysis) to measure the horizontal and vertical surface displacement field.

The ambition is also to record the elastic waves during the experiments and to compare them to real seismograms. Accelerometric sensors will be used with adequate frequency ranges by setting up a micrometric monitoring system in our experimental prototype. This part will benefit from the experimental know-how in rock mechanics at the GEC, by Christian David and with the expertise of SATIE lab with Salah Eddine Hebaz. The core of the project will be carried out by the GEC team which will benefit from the IPGP's long experience in continental seismic deformation as well as from its mastery of recent high-resolution imaging techniques. For the microseismic analysis part, the GEC will also benefit from the expertise of the GFZ in experimental simulations of seismo-tectonic processes. The GEC specialist of seismic modelling and inversion, Christophe Barnes, will supervise the interpretation of the experimental seismic data.

Requirements and expected profile: Master's degree in geology, geophysics or physics. This thesis requires competences in programming language (Python, Matlab, and Linux).

Contact : Pauline Souloumiac (pauline.souloumiac@cyu.fr). The PhD will be mainly carried out at CY Cergy Paris University in the Geosciences and Environment lab (GEC) and SATIE lab in collaboration with IPGP.

Laboratories:

- Laboratoire Géosciences et Environnement Cergy, CY Cergy Paris University (http://www.u-cergy.fr/fr/GEC). This laboratory has research activities in tectonics, geodynamics, rock physics and geomechanics. The approach is essentially based on numerical simulations and physical experimentation, which are at the core of expertize of this group. Various PhD thesis have been carried out on these topics since 2006. The analogue laboratory has been designed to study strike-slip faults since 2018.
- SATIE laboratory, CY Cergy Paris University (https://satie.ens-paris-saclay.fr/fr). The SATIE lab is specialised in the development of instrumental system for multiscale analysis of complex materials, including Non-Destructive Testing and Signal processing for Acoustic / Electromagnetic / Optic imaging. This expertise will be used in the EEASY project to develop the measurement of the dynamic deformation of strike-slip faults (identifying the adequate sensors - amplitude and frequency, their optimal position, and developing the corresponding reconstruction algorithms as well as other detection protocols, …) and by carrying out the signal processing for the detection and localization of the earthquake ruptures.
- The candidate will also benefit from collaboration with the tectonics lab of IPGP (www.ipgp.fr). This lab has as a long experience about continental earthquake deformation. It has been involved in field studies and development of conceptual models of deformation for many years.