ÉCOLE DOCTORALE
SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT ET PHYSIQUE DE L'UNIVERS, PARIS

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Subject title: Seismic triggering of rockfalls at Piton de la Fournaise volcano

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IPGP- Seismology Team – UMR7154

Financing: Doctoral contract with or without teaching assignment

Presentation of the subject:

Unstable slopes in mountainous, costal or volcanic area are subject to different forcings acting at different time scales, leading the slopes to fall down and generate landslides or rockfalls. Our recent work on rockfalls in the crater Dolomieu of Piton de la Fournaise, La Réunion showed that the small seismicity related to magma ascent in the fragmented edifice may cumulate and trigger rockfalls even if the magnitude of these volcano-tectonic events is much smaller than standard triggering thresholds reported in the literature [1,2] (Fig. 1). We also showed that the response of the slope to seismicity and rainfall is strongly related to its stability state, i.e. its closeness to the failure, as observed with lab-experiments on granular slopes [3] (Fig. 2).

In this PhD, we want to further investigate these effects by digging into the spatio-temporal evolution of rockfalls and quantifying the correlation between the rockfalls themselves as well as between rockfalls, rainfall and seismicity on more than 15 years of data collected by the Piton de la Fournaise Volcano Observatory (OVPF). This will be done in parallel to lab-scale experiments performed with Institut Langevin in the line of our previous work on ultrasound triggering of granular avalanches [3].

Fig. 1. Dolomieu crater, Piton de la Fournaise volcano, where lots of rockfalls occur every day. Their triggering and volume is related to the small repetitive seismicity generated by magma ascent in the damaged crater walls [2].

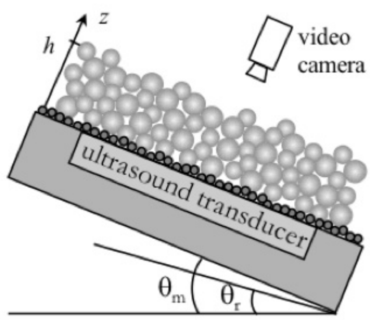

Fig. 2. Granular layers made of glass beads (diameter ~100 µm) are submitted to ultrasonic waves at the laboratory scale to mimic rockfall triggering. Avalanche triggering by ultrasound vibrations is monitored by a fast camera [3].

At the laboratory scale, an inclined granular bed begins to flow beyond a maximum angle, i.e., the avalanche angle (θ_m), and stabilizes again at a lower angle, i.e., the angle of repose (θ_r). At an angle less than the avalanche angle, the granular bed may also flow if subjected to an external disturbance (Fig. 2). This is how, for example, certain landslides or rockfalls originate from vibrations linked to local seismic activity, or even to distant earthquakes. If the phenomenon is known, it is still imperfectly understood [1,2].

We have shed a new light on this issue by a series of laboratory experiments using ultrasound [3]. In these experiments, the granular bed consists of glass bead layers (diameter: d ~ 0.1-1 mm) with controlled thickness and deposited on an ultrasonic transducer with different surface roughness. The granular layer is inclined at an angle less than the avalanche angle (see Fig. 1), and then the ultrasonic source is excited by a sinusoidal signal to produce nanometer-amplitude vibration. Two regimes of triggered flows were observed. When the inclination is slightly less than the avalanche angle, the ultrasonic vibration triggers a stationary granular flow whose speed is independent of the ultrasonic amplitude. At a lower inclination angle, the flow caused by ultrasound is creep-like. The flow speed depends on the amplitude of the ultrasound and stops when the ultrasound is turned off. In both cases, the vibration amplitude is too small to induce any macroscopic rearrangement of grains, instead, the ultrasound lubricates/fluidizes the grain contacts and reduce the interparticle coefficient of friction.

In this PhD work, we will investigate the spatial correlation of the granular flows (creep and continuous) triggered by small ultrasonic strain ($< 10^{-5}$), both in dry and underwater granular packings. We particularly monitor the size growth of the sliding clusters (patches) and the delay time prior to the avalanche, as a function of interplay between the inclined angle, the ultrasound amplitude, frequency and duration. We also study the interlocking effect due to the particles shape (sands) and the wetting [4], and compare the experiments with numerical simulations [5].

This work will provide a better understanding of the triggering of landslides and earthquakes by seismicity [6].

Collaborations and field campaign: This work will be done in collaboration with Institut Langevin, Pascal Bernard from IPGP and Virginie Durand from Geoazur, Nice. It will be connected to the Doctoral Network EnvSeis (https://www.envseis.eu/) funded by Europe and involving 10 European laboratories working on environmental seismology with about 20 PhD students, regular European schools and workshops.

Profile sought

We are looking for a student with a Master's degree, engineering school or equivalent with a solid background in fluid mechanics, physics and/or acoustics and geophysics. Candidates should be motivated by a multidisciplinary work at the interface between several teams and disciplines.

[1] V. Durand et al, “On the Link Between External Forcings and Slope Instabilities in the Piton de la Fournaise Summit Crater, Reunion Island”, J. Geophys. Res. 123, 2422 (2019)

[2] V. Durand et al., “The competing roles of seismicity and rainfall in slope destabilization: rockfalls triggered on a metastable volcanic edifice, Science Advances, in review.

[3] J. Léopoldès, X. Jia, A. Tourin, and A. Mangeney, “Triggering granular avalanches with ultrasound”, Phys. Rev. E 102, 042901(2020)

[4] P. Derand, “Controls on the ultrasonic triggering of granular avalanches” (Master Geosciences, ENS Paris, Feb. 2022)

[5] H. Martin, Ph.D thesis, “Coupling between granular flow models and wave propagation models” (Ph. D thesis, Université de Paris Cité, Dec., 2019)

[6] C. Scholz, The Mechanics of Earthquakes and Faulting (3rd edition, Cambridge University Press, 2019); P. Johnson and X. Jia, “Nonlinear dynamics, granular media and dynamic earthquake triggering,” Nature 437, 871 (2005)