Experimental Seismology: rupture nucleation on periodically heterogeneous fault

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Introduction

Previous experimental studies (Ohnaka and Shen 1999, Latour et al. 2013) on **homogeneous** friction interfaces show that rupture dynamic is composed of 2 different phases:
- Nucleation (localized slip and slow rupture propagation)
- Propagation (fast slip and fast rupture propagation, on larger extent)

Existence of nucleation phase is unclear for earthquakes.

Our **goal** is to try to better **understand** and **characterize** rupture dynamic process on **heterogeneous fault**.

Method

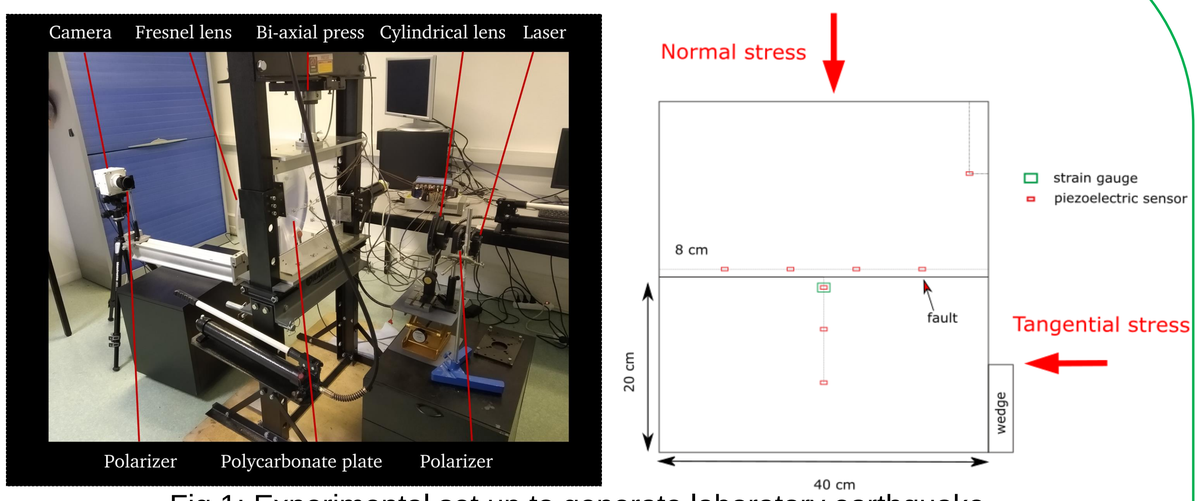

Fig 1: Experimental set up to generate laboratory earthquake

Piezoelectric sensors and **strain gauge** on the plate and **optical set up** allow to **follow** rupture propagation along the **heterogeneous interface** (Fig 2).

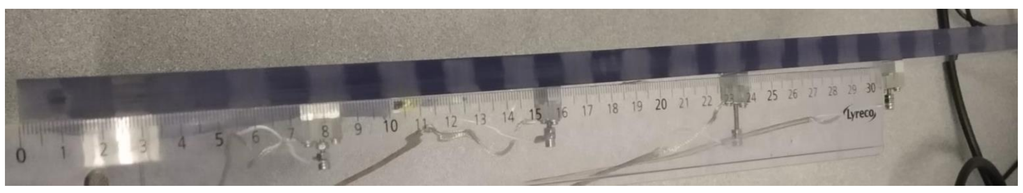

Fig 2: Picture of the heterogeneous fault

We carried out:
- **2** homogeneous experiments with **10** slip events.
- **4** heterogeneous experiments with **10** slip events.

The **ultra fast camera** allows to observe the rupture propagation thanks to the birefringence of polycarbonate and two polarizers. The **position of the rupture front** is highlighted by light intensity changes along the fault, which are plotted in **videograms** for each slip event. (Fig 3).

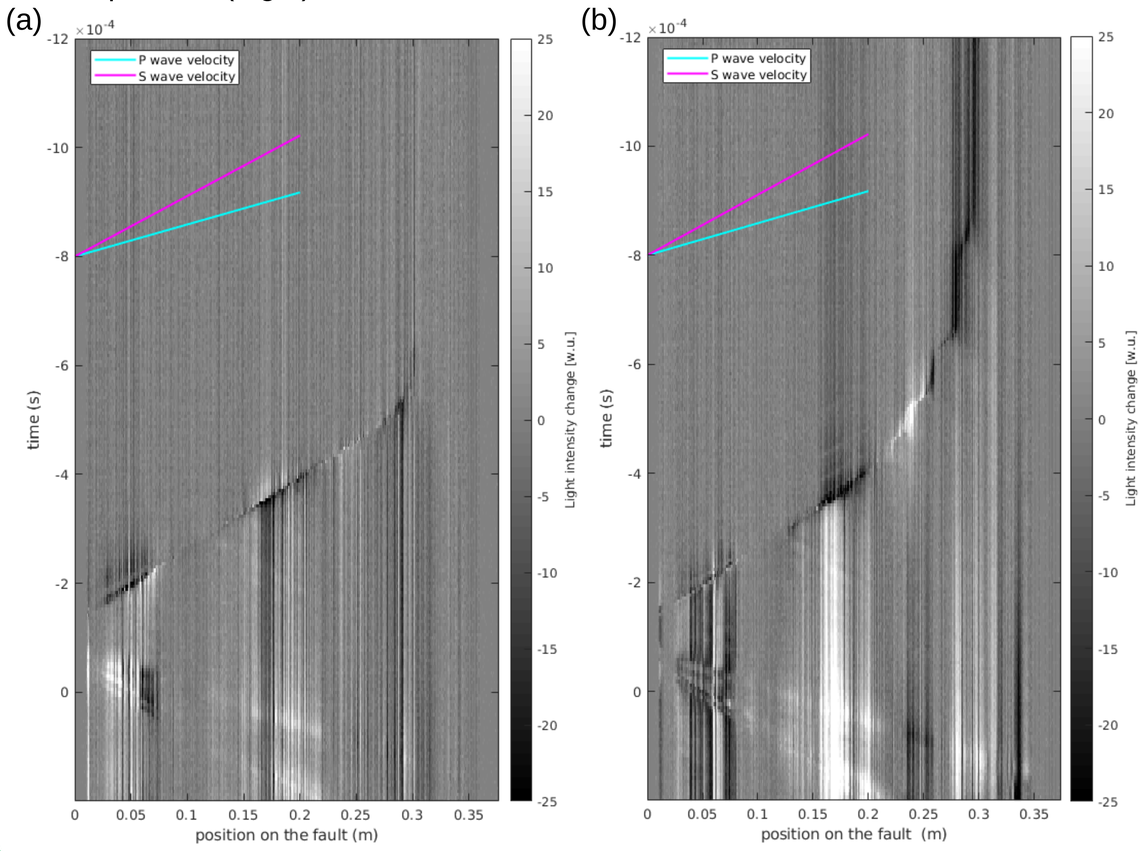

Fig 3: Videogram of (a) an homogeneous event (b) an heterogeneous

Results

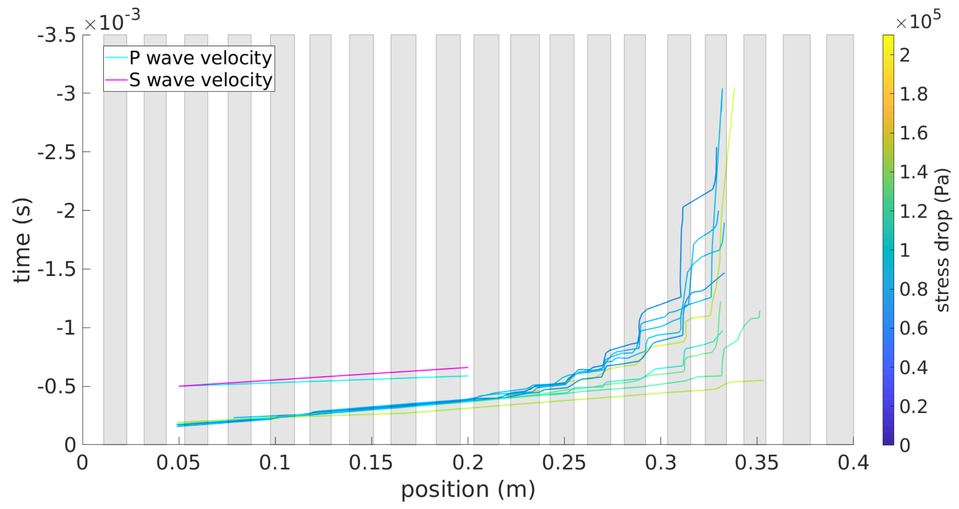

Fig 4: Evolution of the rupture peak for 10 heterogeneous events of the same experiment

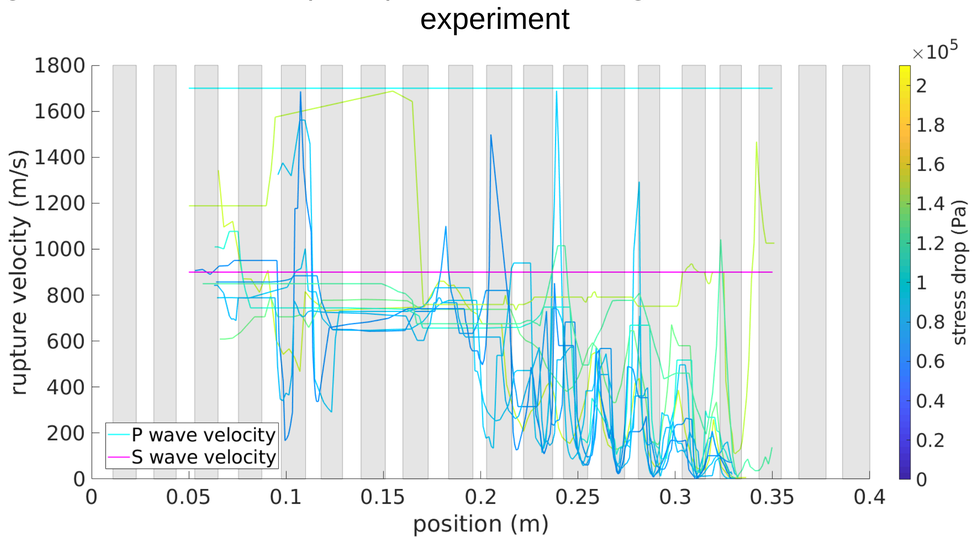

Fig 5: Evolution of the rupture velocity for 10 heterogeneous events of the same experiment

We observe a **variability** in the **duration** and **length** of nucleation phase (Fig 4). However, for all the nucleation phases, there are **velocity variations** always at the **same position** correlated with **heterogeneities positions**.
Moreover, the Fig 5 shows a **global process of acceleration** during the nucleation phase, **perturbed** by velocity variations.
For each heterogeneity, the **maximum rupture velocity** increase with the value of the **stress drop.**

Discussion

Our results are the **first experimental observations** of nucleation process with heterogeneous interface. The **heterogeneities have an effect on the rupture dynamic process**, with velocity variations that perturbed the global process of acceleration. These observations resemble to **numerical simulations** (Fig 6, Yabe and Ide 2018) as well as some aspect of natural observations (Fig7, Kato et al. 2016).
However, a **high variability** between experiments and events is also seen. It can be explained by an **heterogeneous stress field** difficult to control and that has effects on rupture velocity (Ben-David et al. 2010, Rubinstein et al. 2011).

Fig 6: Detailed slip behaviors of the heterogeneous fault obtained with numerical simulation modified from Yabe and Ide (2018)

Fig 7: Space-time diagram of all detected events (blue circles) before the 2014 Iquique, Chile Mw 8.2 earthquake, from 1 January 2008 modified from Kato et al. (2016)

References

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