Acoustic emissions associated with slow-slip events in quartz gouge friction experiments

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1. INTRODUCTION

Slow slip events have been discovered in subduction interfaces in the past two decades. Previous experiments observed similar quasi-dynamic processes in frictional sliding experiments on fine-grained quartz gouge (Leeman et al., 2015) and suggested loading system stiffness plays a crucial role in the evolution from quasi-dynamic to dynamic slip.

However, these experiments were in the absence of a pore fluid (pressure) which is believed to play a key role in slow slip events and tremor along subduction zone interface (Obara 2002; Rogers and Dragert 2003). Recently, Chen et al. 2017 suggested that water vaporization occurring during rapid seismic slip causes enhanced dynamic weakening. The question can then be raised what the role of pore fluid pressure is during slow slip events and how pore fluid pressure might control the transition from quasi-dynamic to dynamic slip.

We implemented experiments with a ring shear apparatus (*Niemeijer et al., 2008*) and applied different pore fluid pressures (water) to investigate the slip behavior of simulated gouges of fine-grained quartz (Sil-Co-Sil 49, US Silica company). Additionally, to explore potential acoustic emissions from slow slips, a 1 MHz and a 4 kHz piezoelectric acoustic sensor are deployed at the bottom of the vessel that is ~25 cm below the sample (Fig.1).

2. EXPERIMENT SETUP

Quartz powder with grain size < 49 um is used in all experiments to simulate fault gouge. We continuously shear the bottom piston with a velocity of 6 μm/s at room temperature and and effective normal stress of 60 MPa, with pore pressures of 0.1, 10, 100 and 150 MPa.

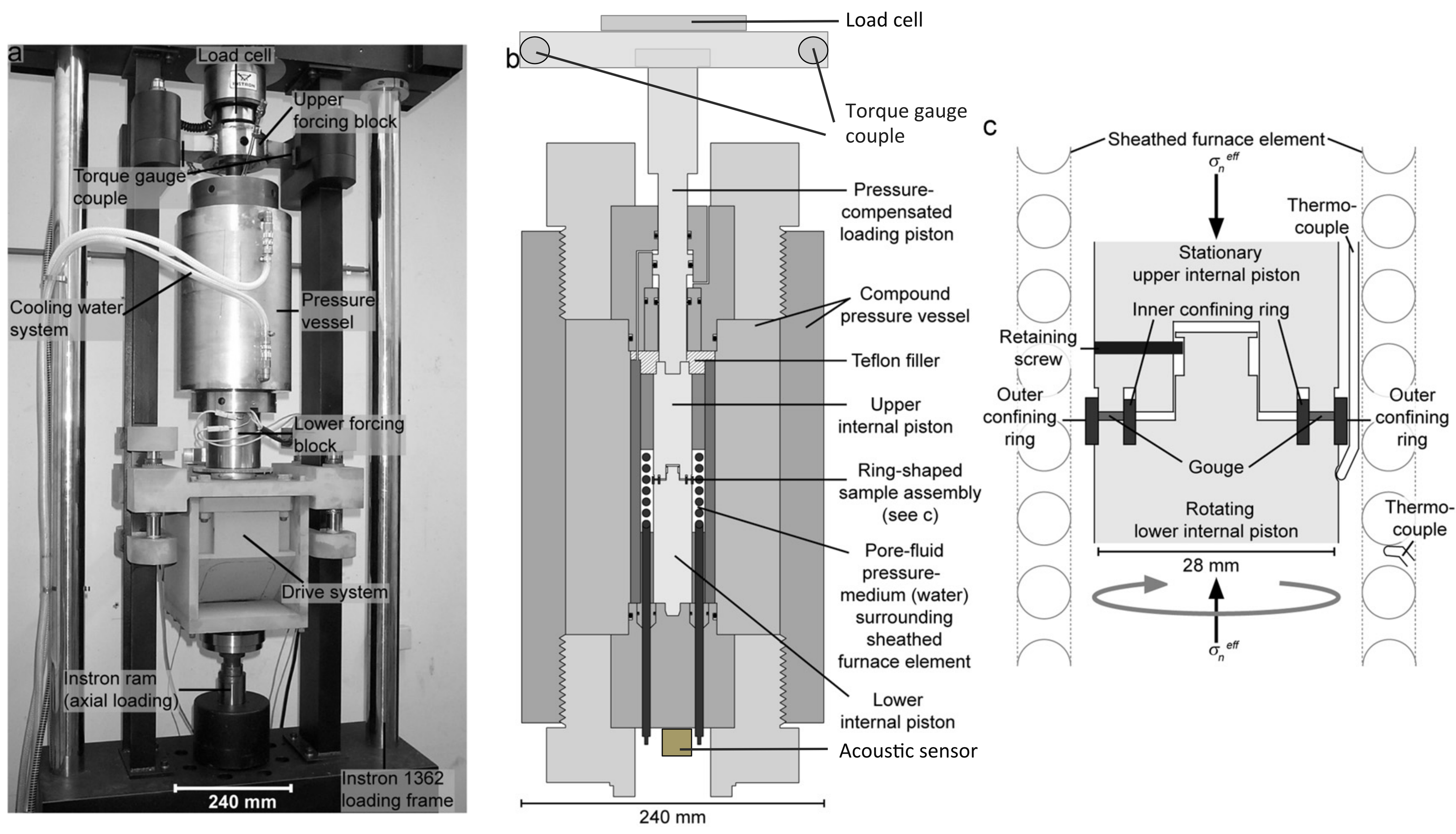

Fig.1. Ring shear apparatus (Niemeijer et al., 2008; Den Hartog et al., 2012)

4. OPEN QUESTIONS

With an original record of shear stress recorded at 5 MHz, its time derivative is calculated to yield the stress drop rate. In a catalogue with ~1000 detected AE events, we obtained stress drops ($\Delta\tau$) varying between 0.3 and 10 MPa. Below a $\Delta\tau$ of 4 MPa, we see an exponential increase of stress drop rate (slip velocity) from ~1 MPa/s to 1 GPa/s. Beyond 4.2 MPa, the stress drop rate increases linearly with stress drop. What is the mechanism behind?

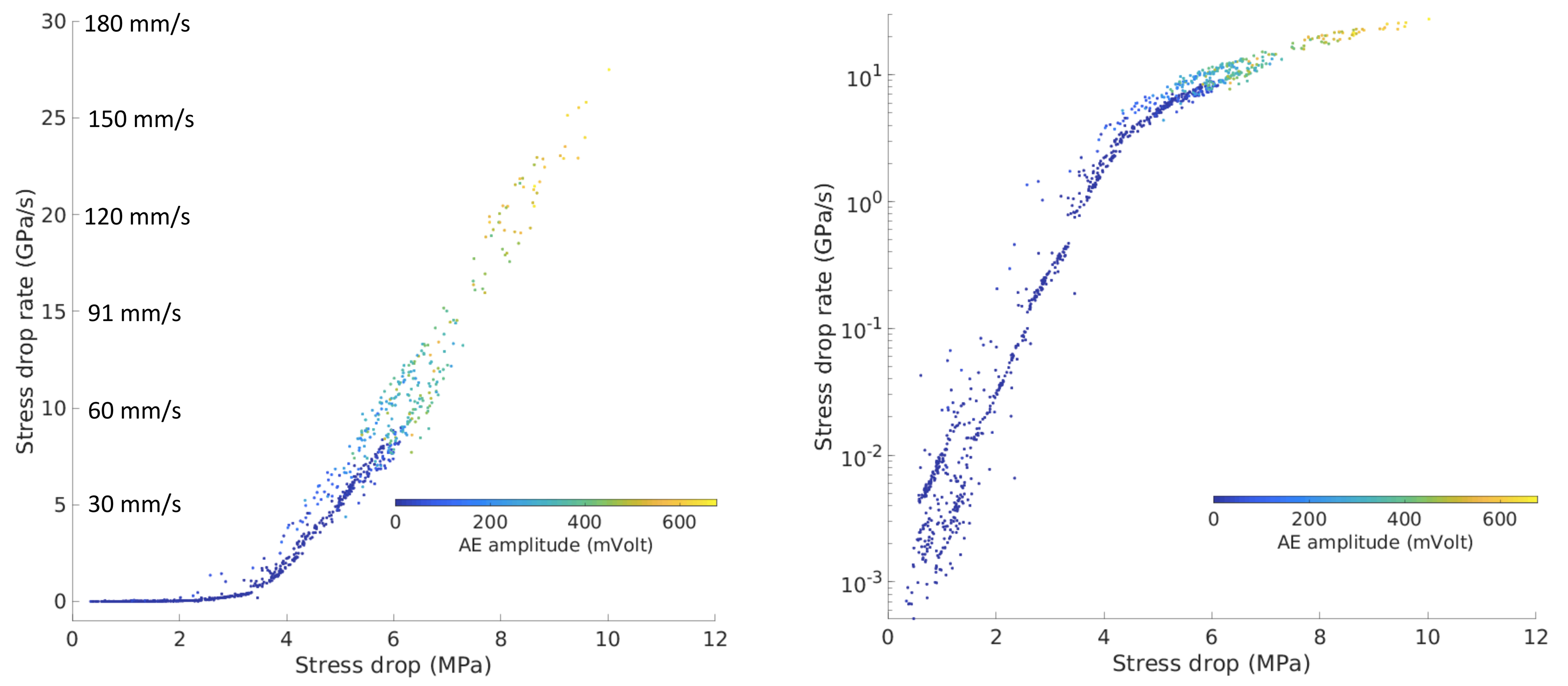

Fig. 3. U771, Stress drop rate varies with stress drop value

Acoustic emission data are recorded with a 5 MHz sampling rate and high passed filtered over 120 kHz to remove the low frequency noise. In Fig. 5, at slip velocity smaller than ~ 1 mm/s, we can clearly identify precursory slow slips which generate stronger AE than regular slow slip events (black).

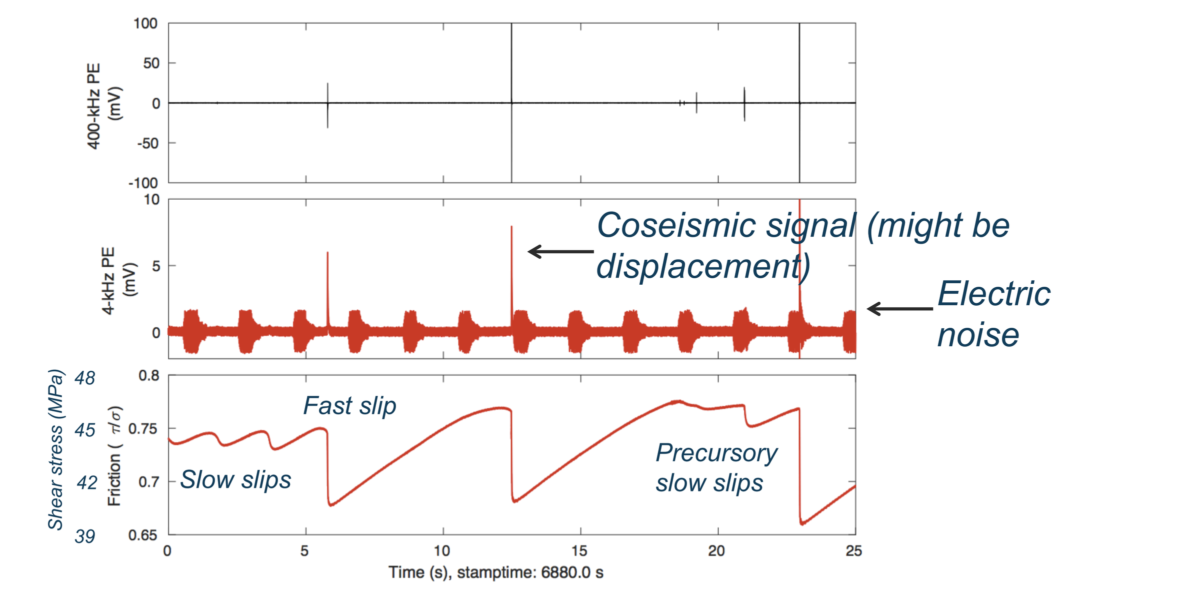

Fig. 4. U771, examples of slow slip and precursory slow slip in a 25 second window.

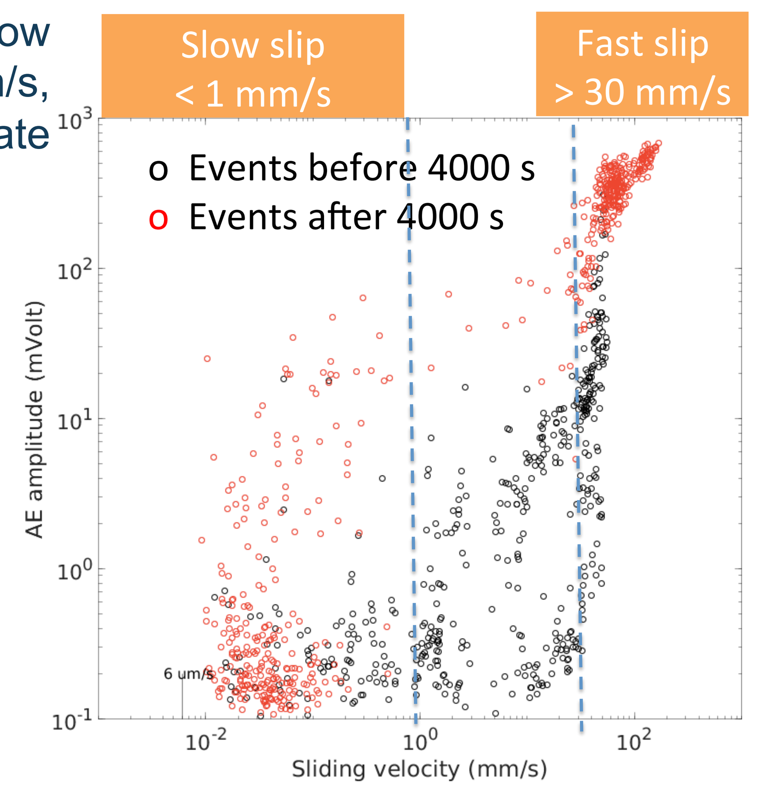

Fig. 5. U771, Maximal amplitude of Acoustic emissions vs. slip velocity.

3. SLOW-SLIP AND PRECURSORY SLOW-SLIP EVENTS

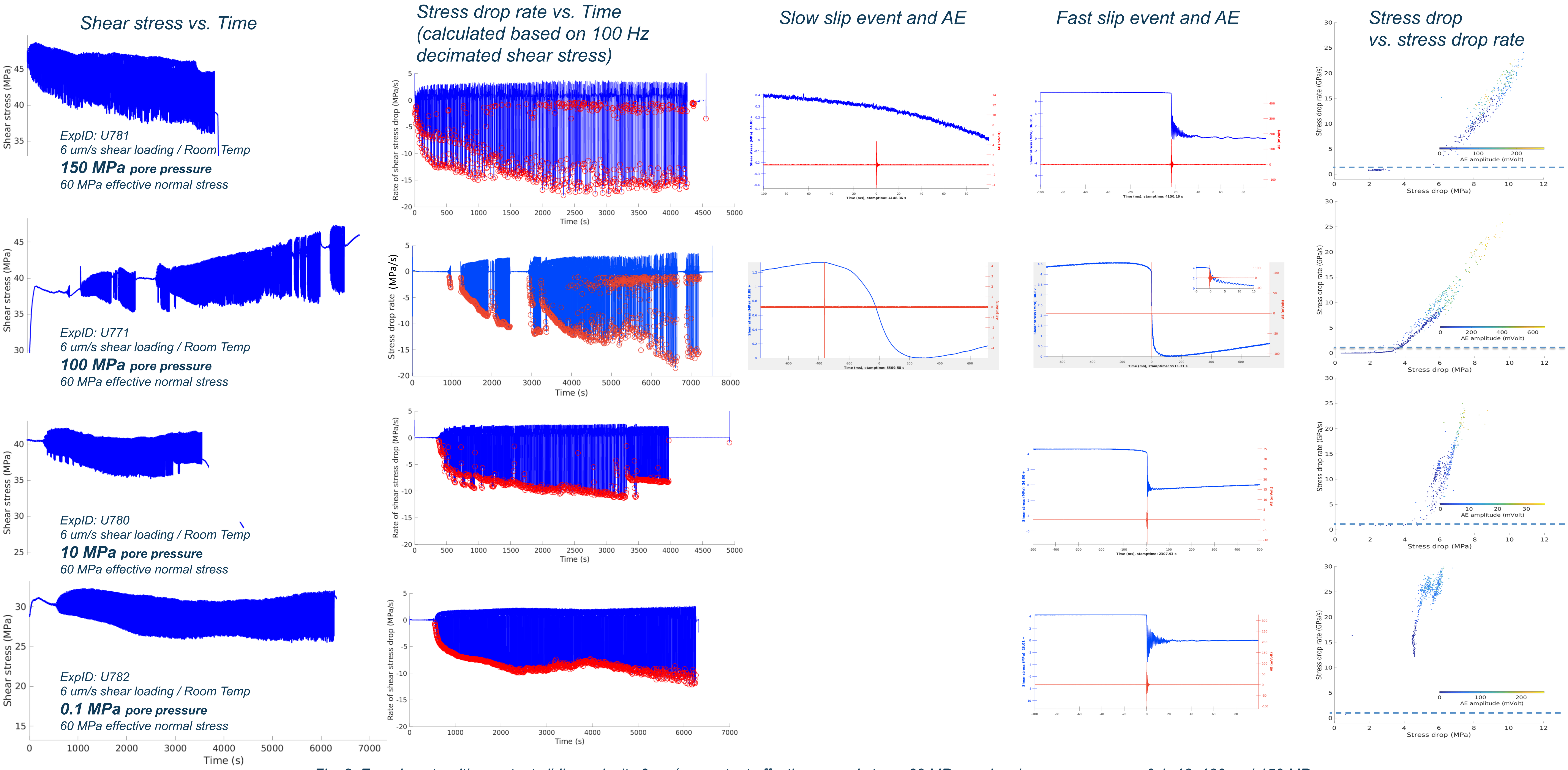

Fig. 2. Experiments with constant sliding velocity 6 um/s, constant effective normal stress 60 MPa, and various pore pressure 0.1, 10, 100 and 150 MPa.
Slow-slip events are well developed in high pore pressure experiments (u771 & u781).
Low pore pressure experiments show larger stress drop rate (slip velocity) (column 5).

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