Effect of shear strain on wearing fault: laboratory constrains

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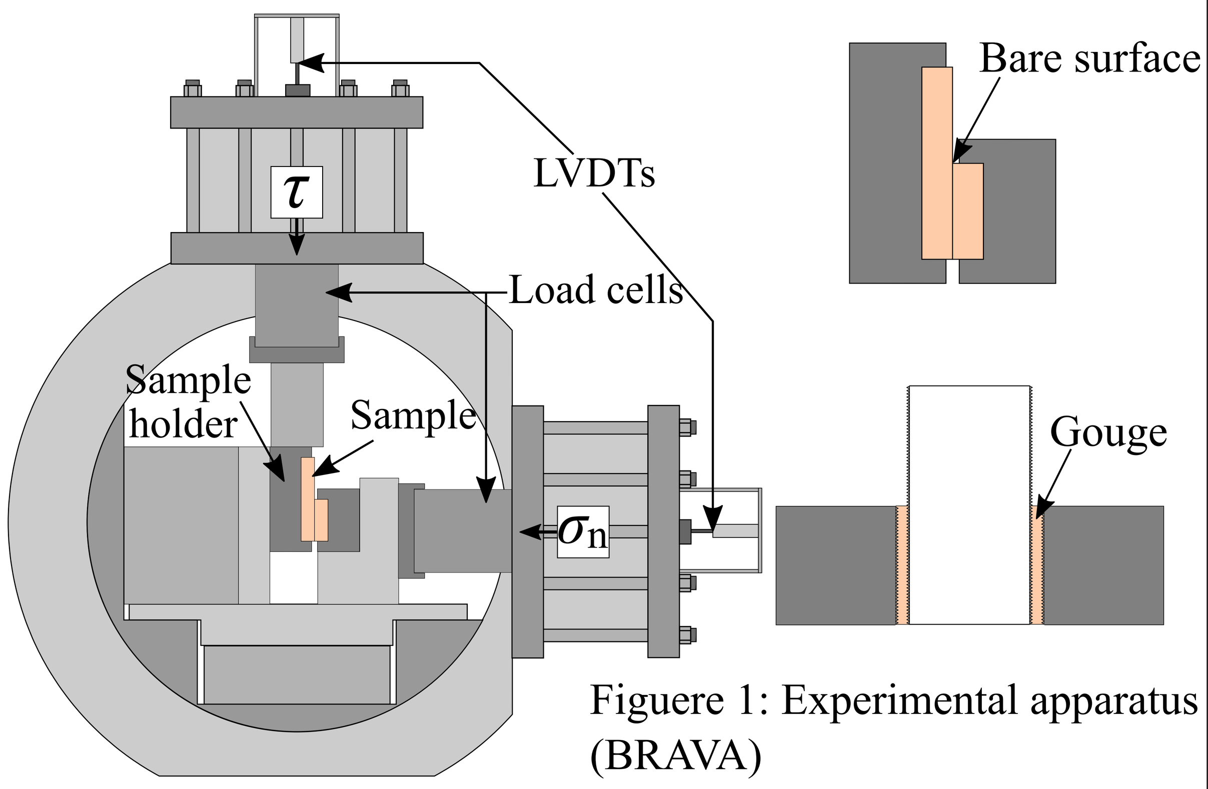
Introduction

Large earthquakes mainly take place on mature faults, having decimetre to kilometres of cumulative slip. These mature faults contain a highly deformed core zone, composed of gouge, where most of the slip occurs. Around this core zone, a damage zone is present and the deformation eases with increasing normal distance to the core. However, most laboratory experiments performed at elevated stresses conditions (≤ 20 MPa) are carried out with a limited amount of slip (> 3 mm). Under these conditions, little wear is produced, which potentially changes the simulated fault mechanics. Here, we aim to fill the gap between the laboratory and field scales by performing experiments at large strain on simulated faults using initially intact rock that have different wearing behaviour. During the experiments, the stability parameters of the fault are measured in order to understand how the development of such structure affects fault mechanics. The results show that, a certain amount of strain is required to nucleate unstable sliding on the tested rocks. We demonstrate that, more that the velocity or normal stress variations, the (local) fault strain and strain localization are the dominant parameters controlling the slip stability.

Samples and methods

- Samples are all >95% quartz rock:
  - Fontainebleau sandstone (φ = 18.5%)
  - Quartzite (φ = 1.5%)
  - Quartz gouge (grain size < 63 µm)
- Apparatus:



Figuere 1: Experimental apparatus (BRAVA)

- 2 types of experiments:
  - Constant velocity (3, 30, 100 µm/s)
  - Velocity streps (3-30, 3-100, 3- 300 µm/s)

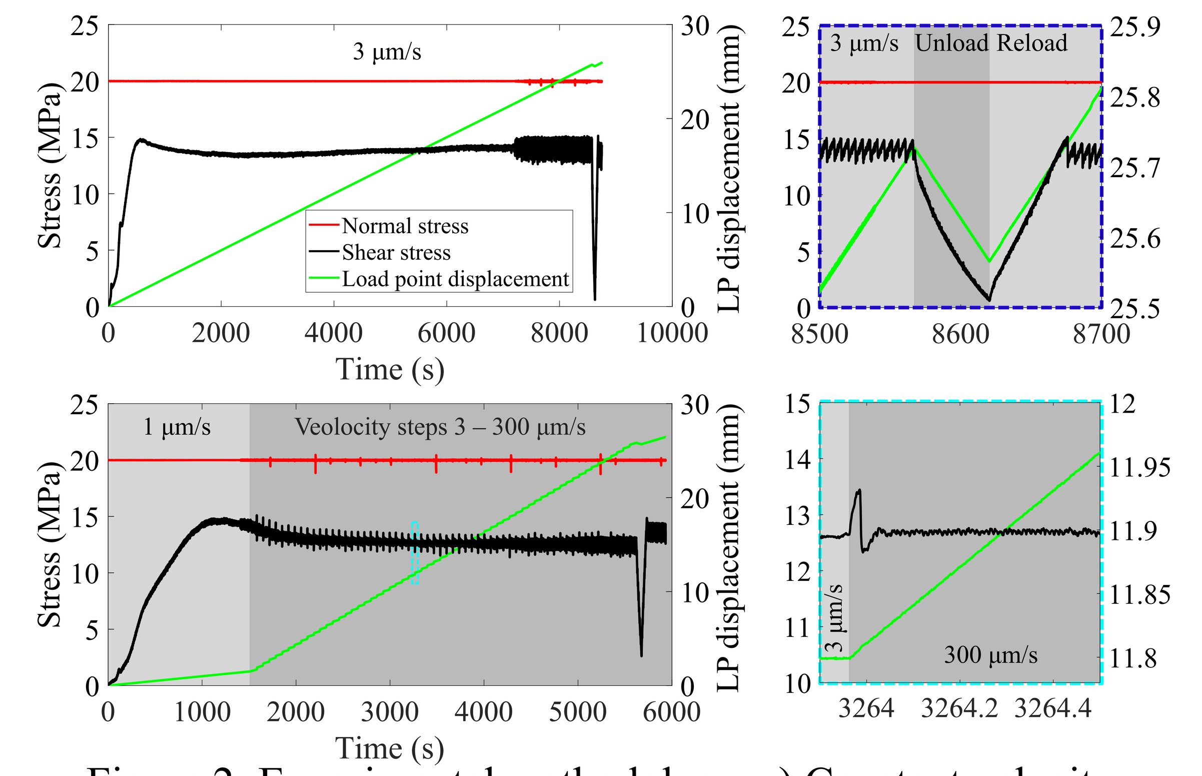


Figure 2: Experimental methodology. a) Constant velocity experiments and b) velocity step experiments.

Results

- Constant velocity experiments:

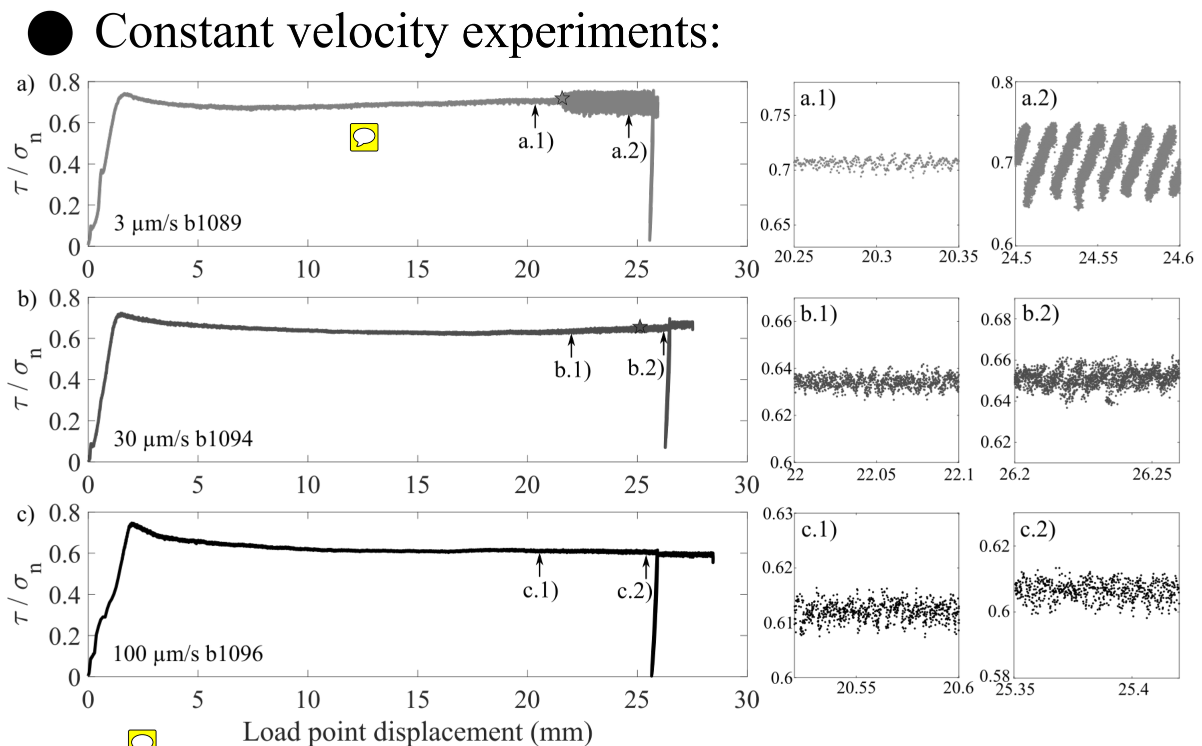


Figure 3: Constant velocity experiments on Fontainebleau sandstone. a) 3 µm/s, b) 30 µm/s and c) 100 µm/s.

- Velocity step experiments:

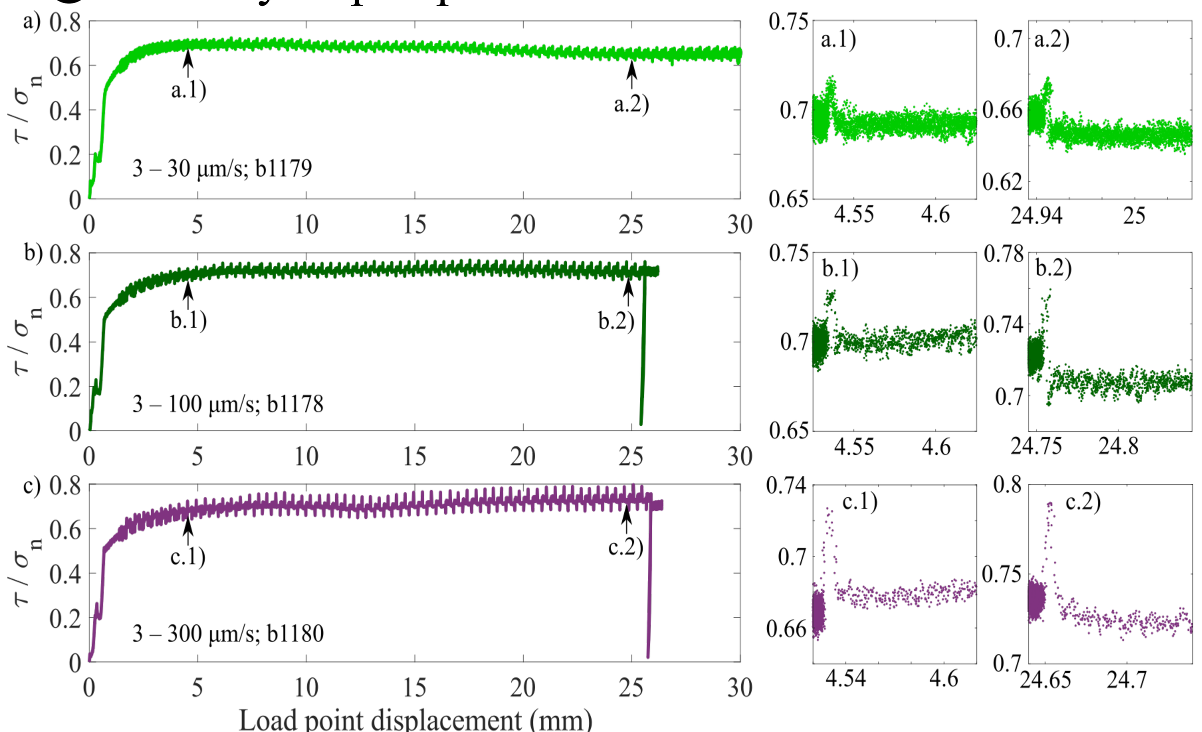


Figure 4: Velocity step experiments performed on quartzite. a) 3 - 30 µm/s, b) 3 - 100 µm/s and c) 3 - 300 µm/s.

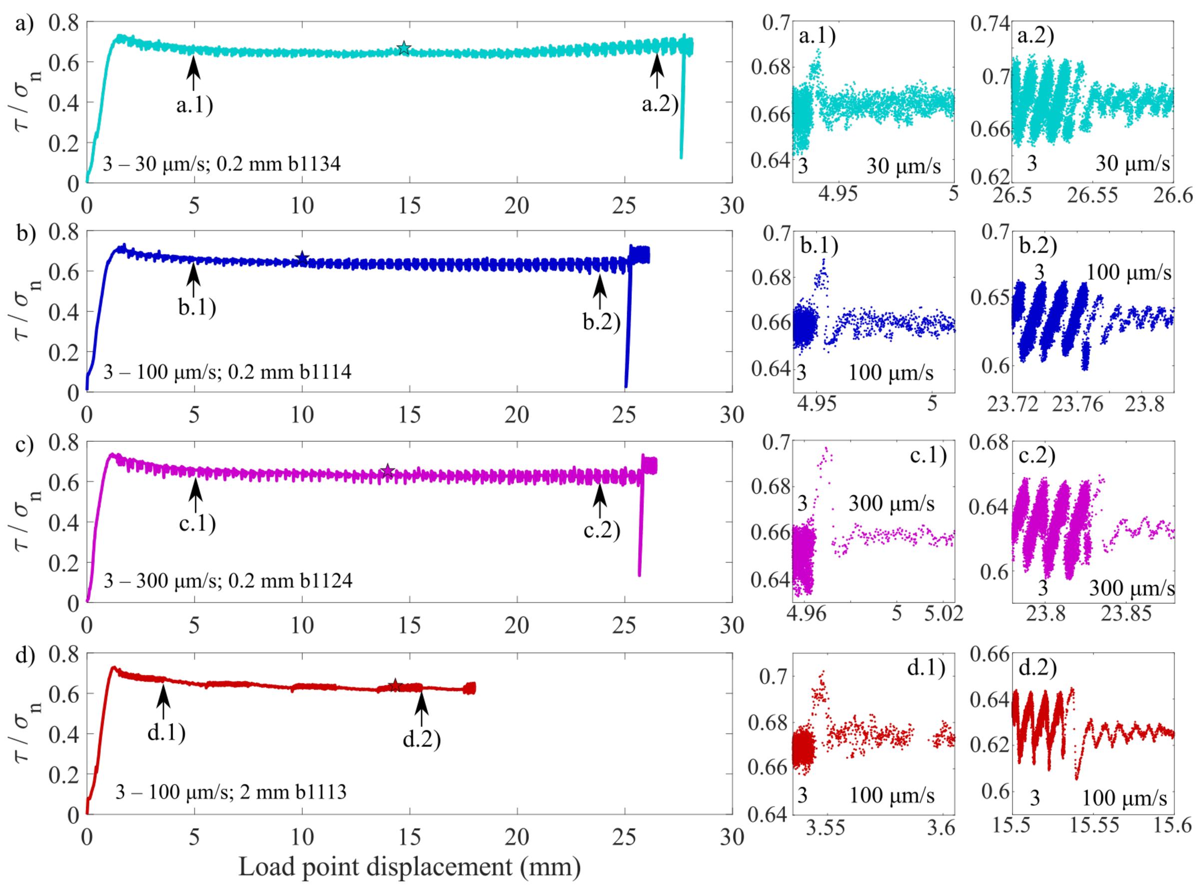


Figure 5: Velocity step experiments performed on Fontainebleau sandstone. a) 3 - 30 µm/s, b) 3 - 100 µm/s and c) 3 - 300 µm/s.

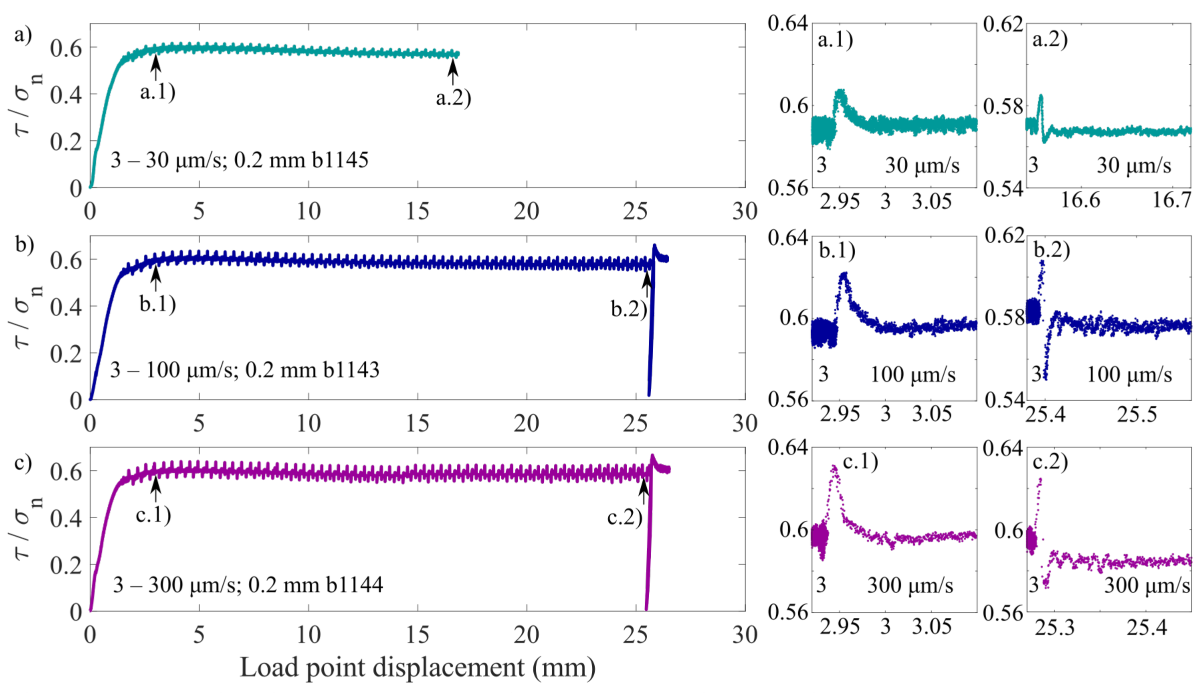


Figure 6: Velocity step experiments performed on quartz gouge. a) 3 - 30 µm/s, b) 3 - 100 µm/s and c) 3 - 300 µm/s.

- Post-mortem samples

Figure 7: Post-mortem photograph of Fontainebleau sandstone (left) and quartzite (right).

- Rate-and-state inversion

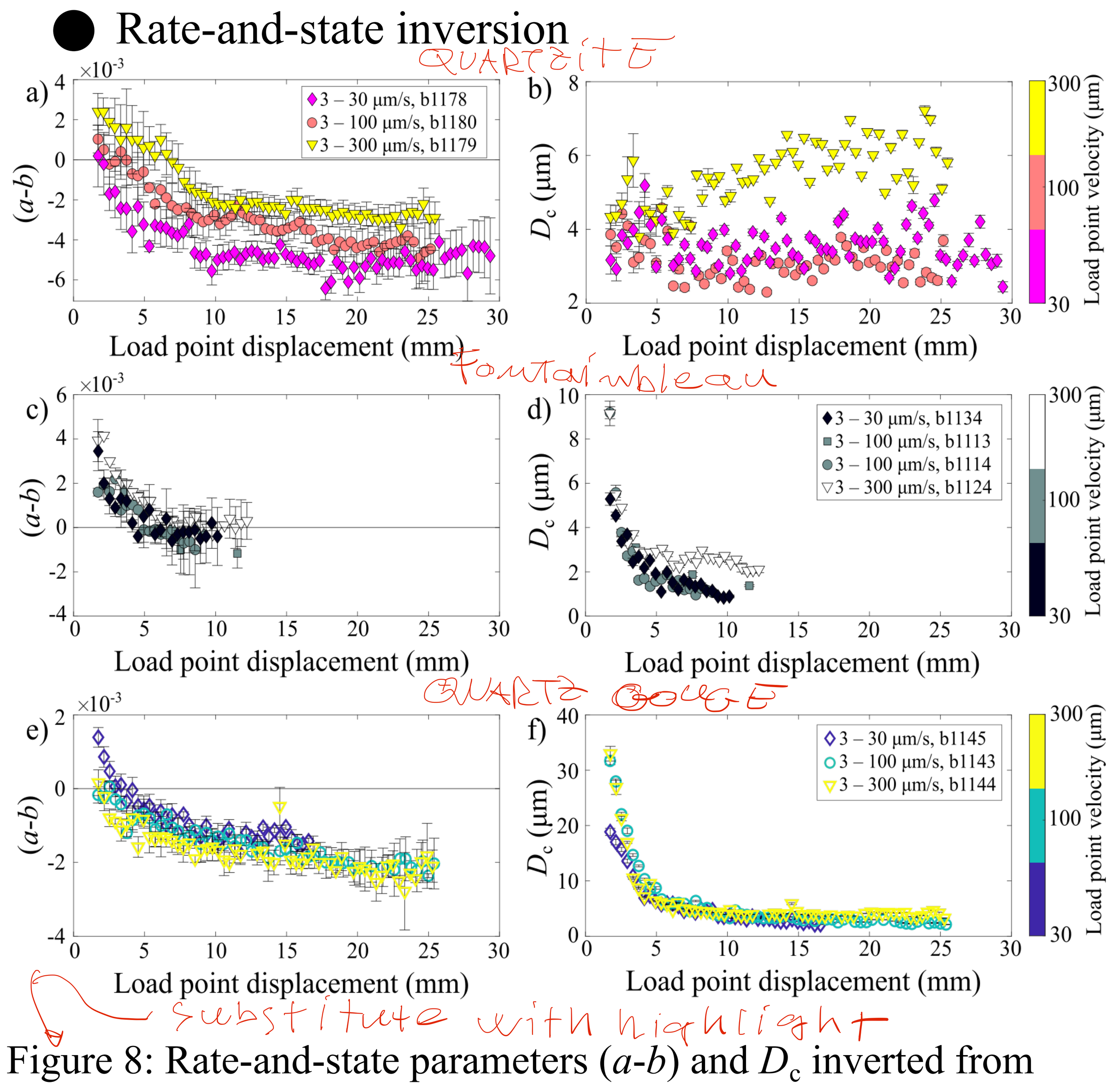


Figure 8: Rate-and-state parameters (a-b) and D_c inverted from velocity step experiments as a function of load point displacement. a and b) quartzite, c and d) Fontainbleau sandstone, and e and f) quartz gouge.

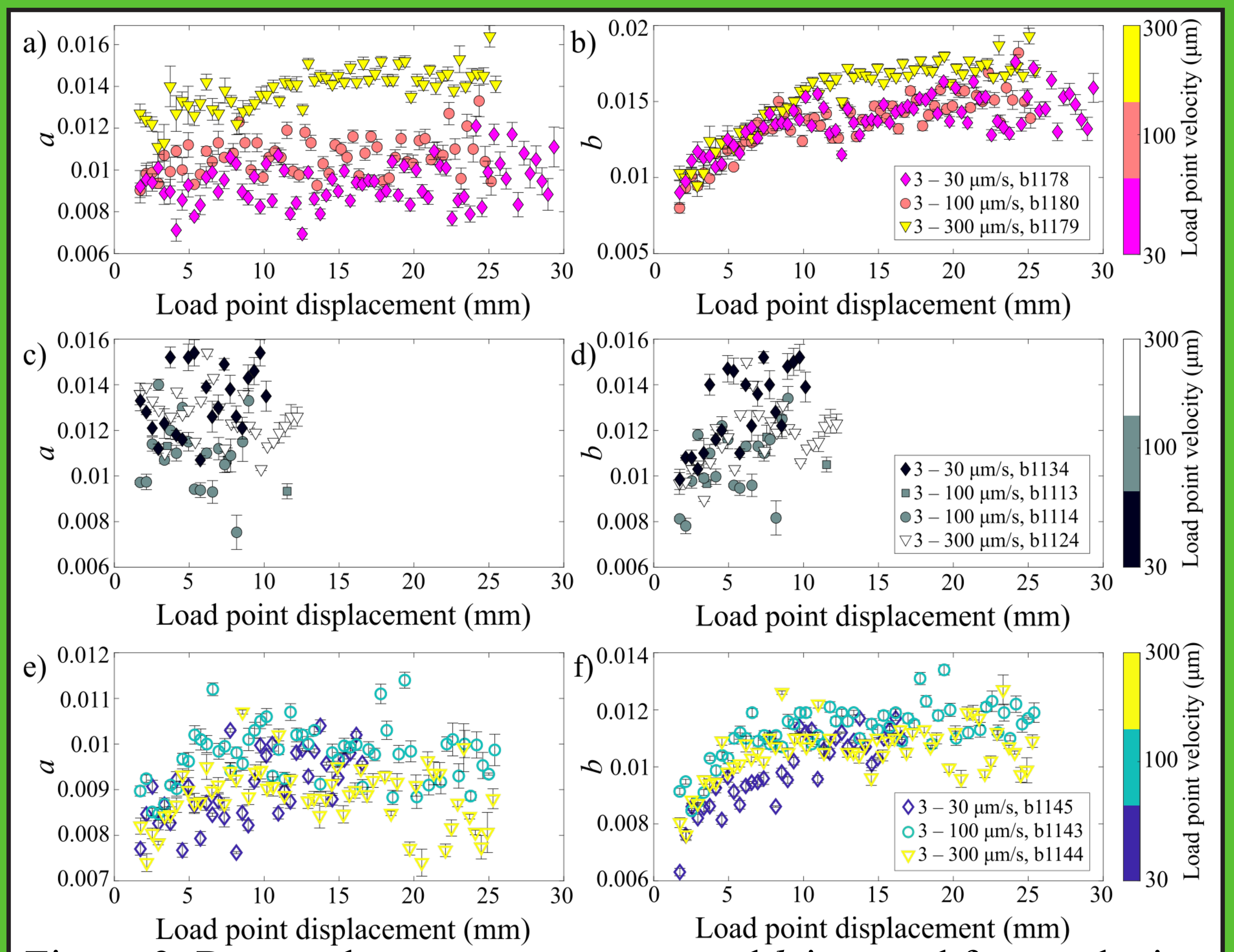


Figure 9: Rate-and-state parameters *a* and *b* inverted from velocity step experiments as a function of load point displacement. a and b) quartzite, c and d) Fontainbleau sandstone, and e and f) quartz gouge.

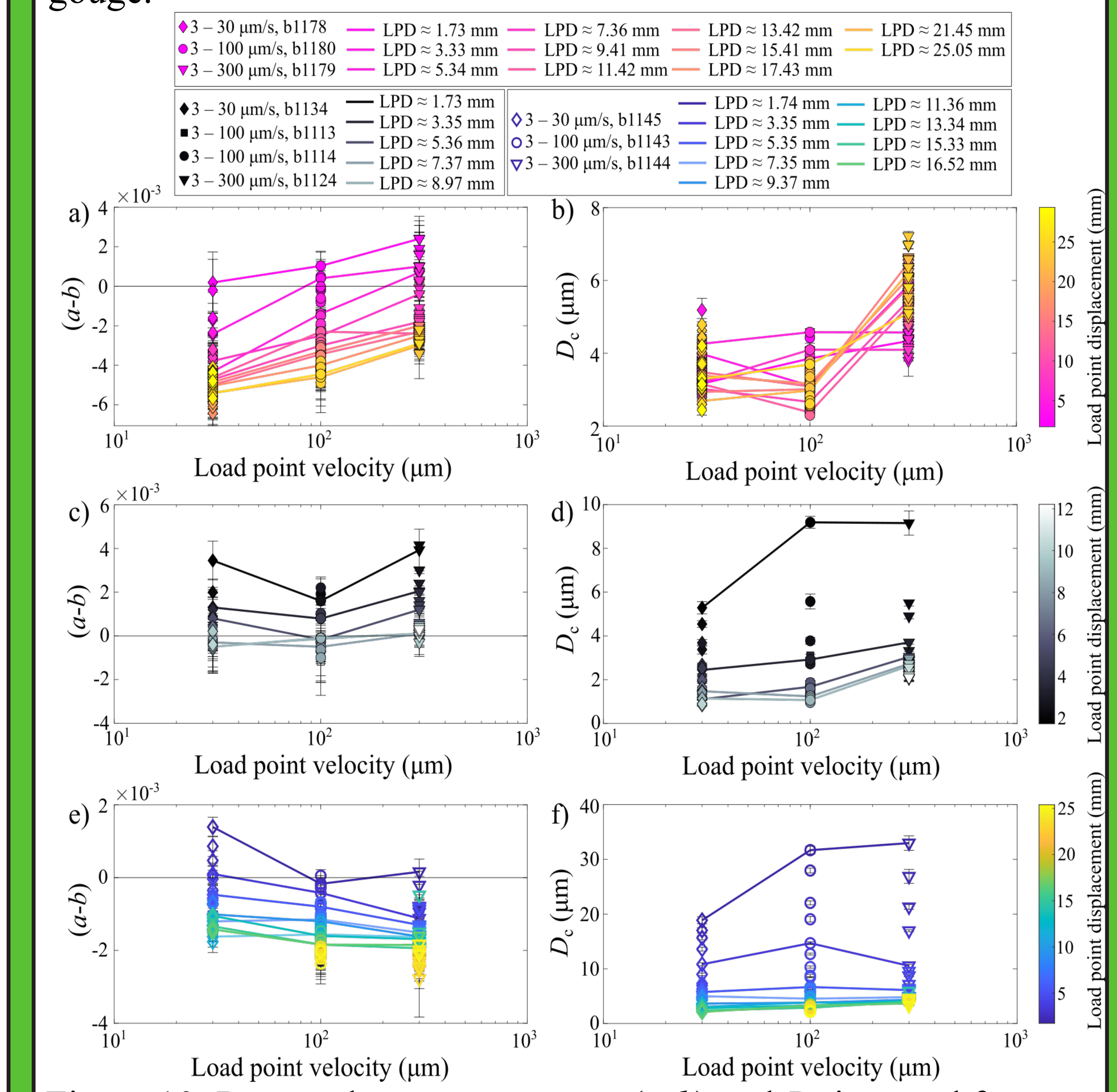


Figure 10: Rate-and-state parameters (a-b) and D_c inverted from velocity step experiments as a function of load point velocity. a and b) quartzite, c and d) Fontainbleau sandstone, and e and f) quartz gouge.

Discussion

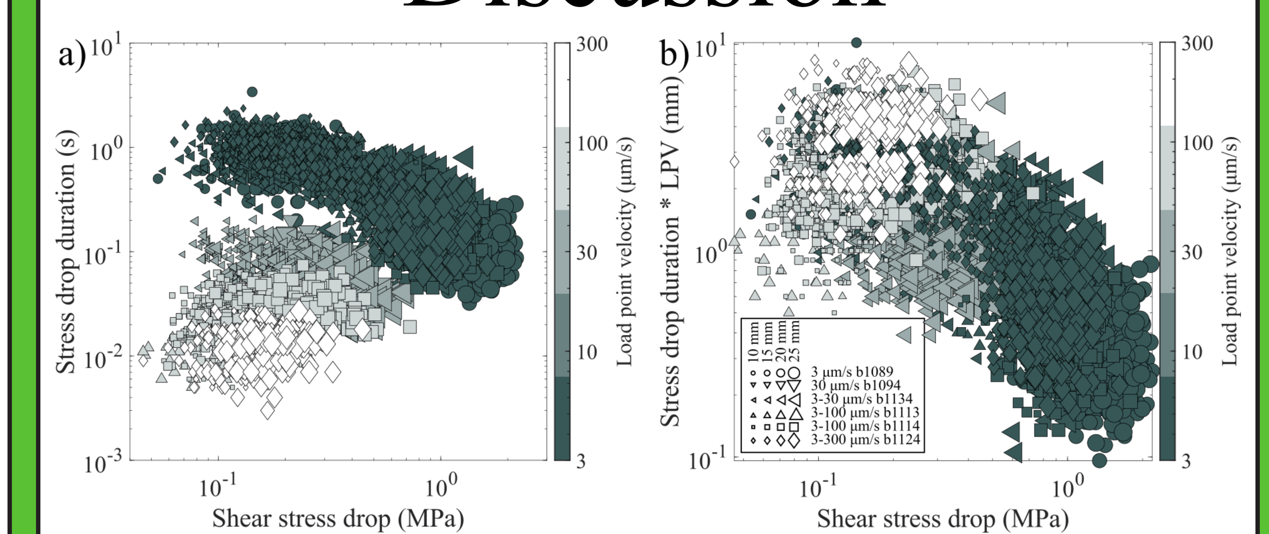


Figure 11: a) Stress drop duration and b) stress drop duration times load point velocity as a function of the shear stress drop for all the experiments performed on Fontainebleau bare surface.

Conclusions

10 biaxial experiments, performed on two initially intact rocks (with drastically different wearing rates) and simulated gouge demonstrated that:

1) Instabilities (i.e., stress drops) are favoured at high shear strain.

2) Bare surfaces with high wearing rates and simulated gouge show a fast decrease of (a-b) and D_c within the first 5 mm of shear displacement, followed by a slower (but continuous) decrease between 5 and 25 mm of shear displacement.

3) Bare surfaces with low wearing rates show a fast decrease of (a-b) within the first 10 mm of displacement, followed by a slower (but continuous) decrease between 10 and 25 mm of shear displacement. Here, D_c is not affected by the shear strain.

4) More than the load point velocity, the (local) fault strain and strain localization are the dominant parameters controlling the fault slip stability.