Experimental study of injection-driven fracture instability in granite cores - Comparison between monotonic and cyclic injection

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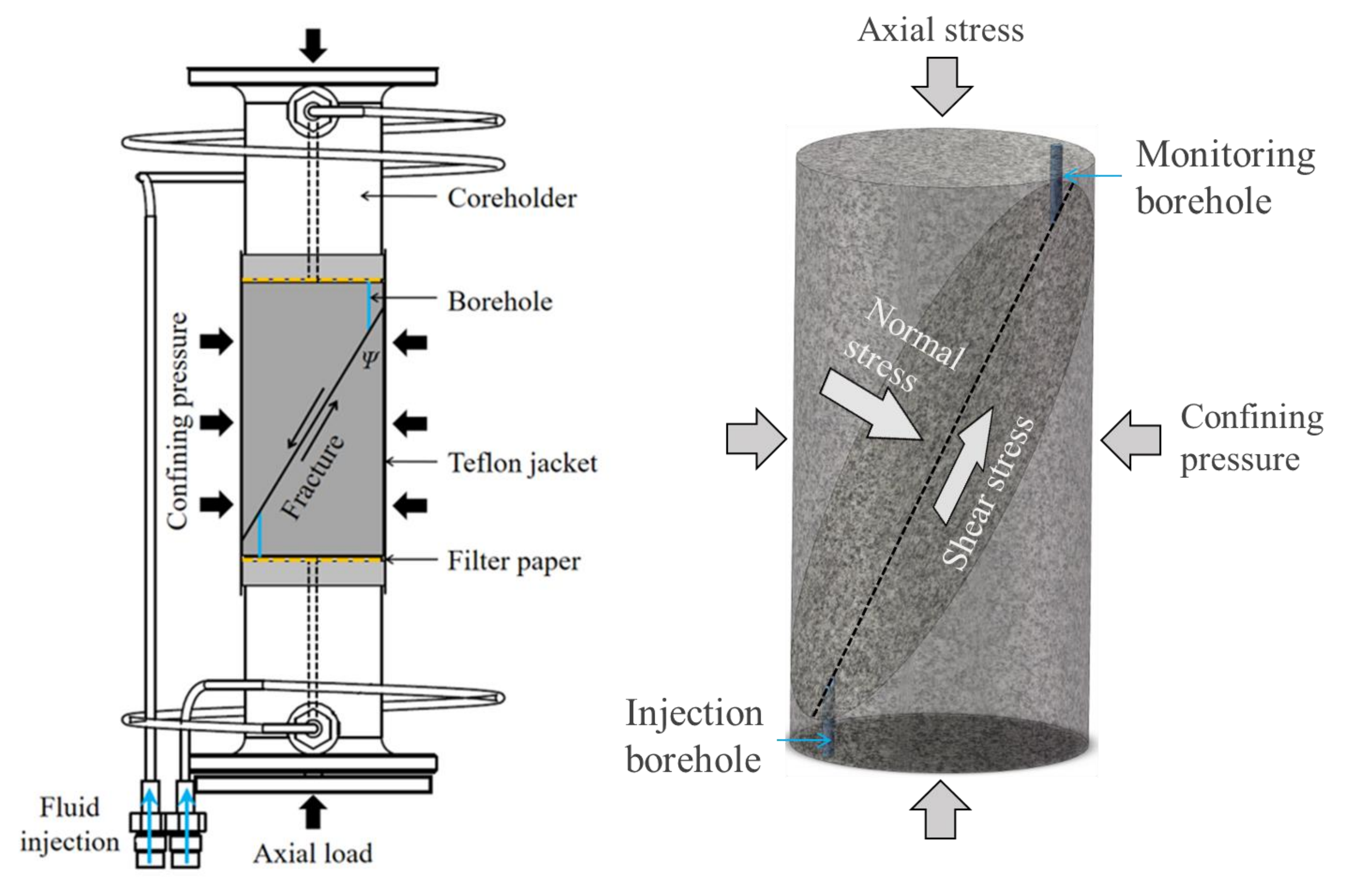
1. Introduction

- Hydraulic fracturing of intact granite samples
  - Compared to continuous injection, cyclic injection can help to reduce breakdown pressure, induced seismicity and to create more complex fractures
- Injection induced shear slip on an existing fracture or fault generates retainable permeability enhancement, and on the other hand could cause larger seismic events in field
- Preliminary experimental study on cyclic injection to an artificial fractured sample with rough surface fracture

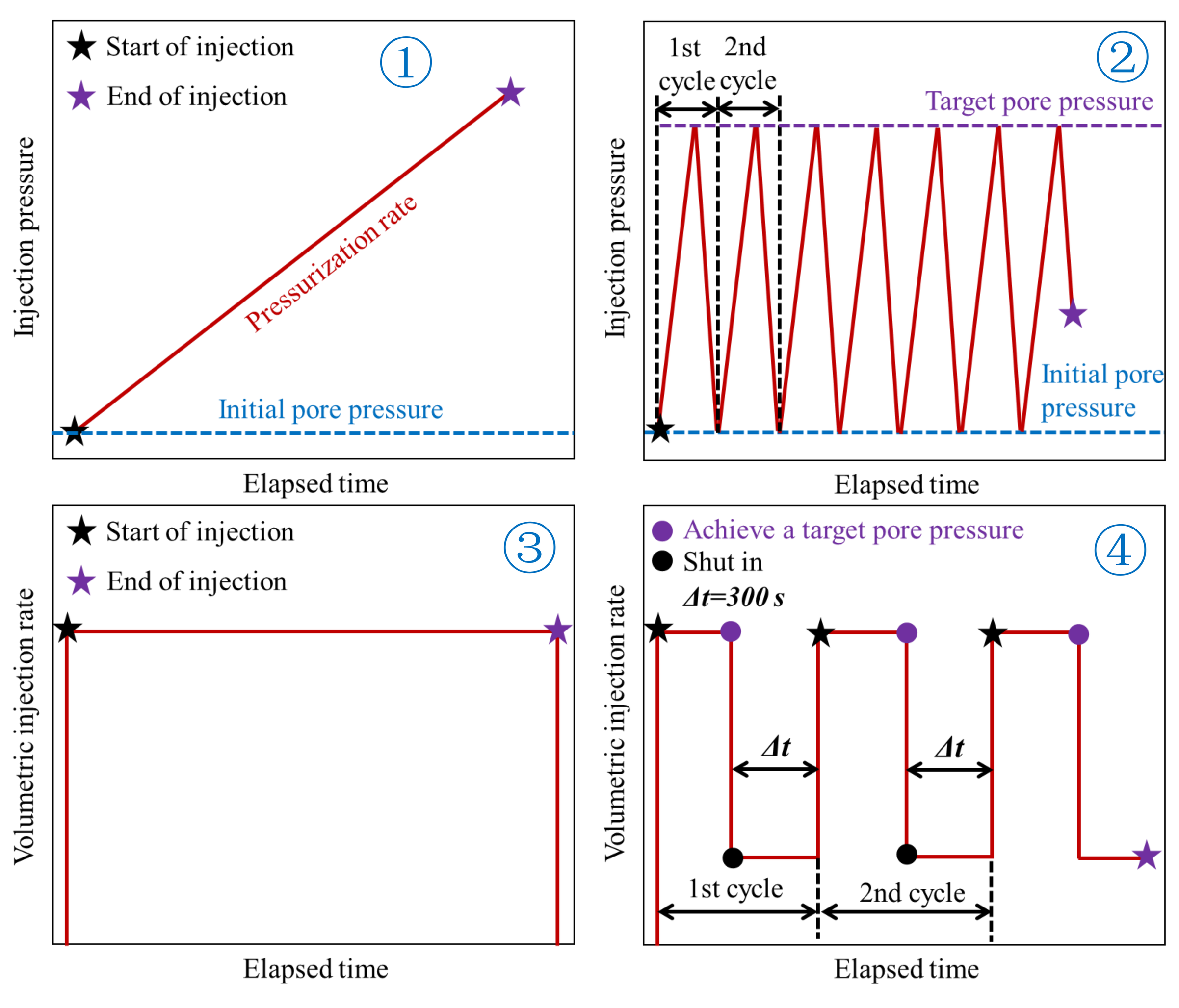
2. Experimental setup

Sketch of the triaxial shear-flow experiment



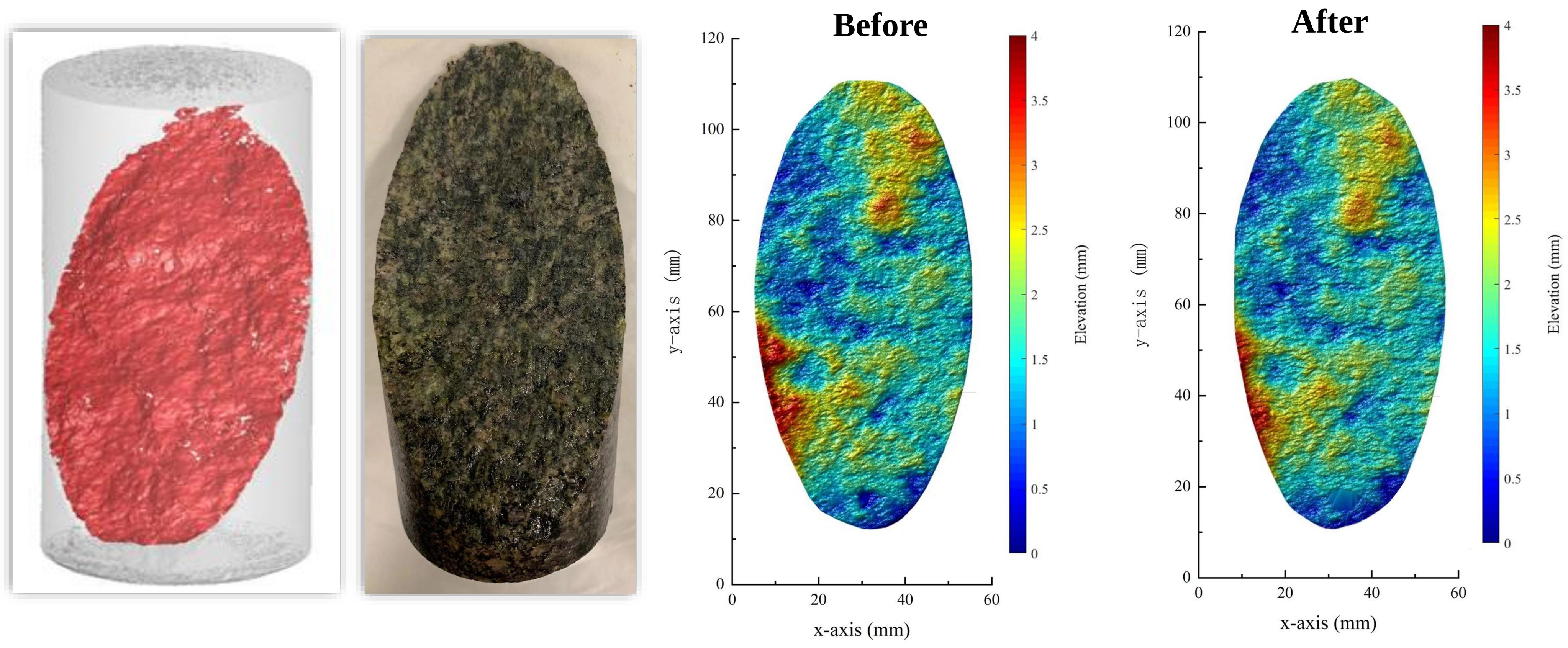
Four steps of continuous and cyclic injections on the same ONE sample

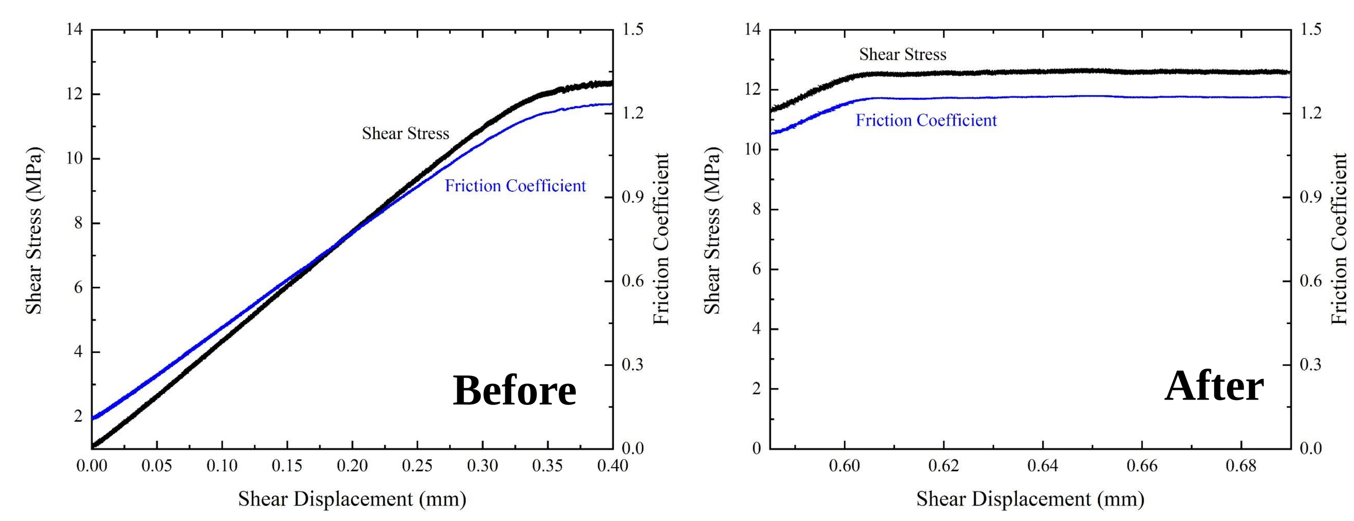
- Step ① & ② Pressurization rate control 0.01 MPa/s
- Step ③ & ④ Injection rate control 0.2 mL/min



Normal stress 11 MPa, Initial pore pressure 1 MPa
Shear stress level: 90% shear strength
Maximum pore pressure: 95% of monotonic failure

3. Experimental result analysis

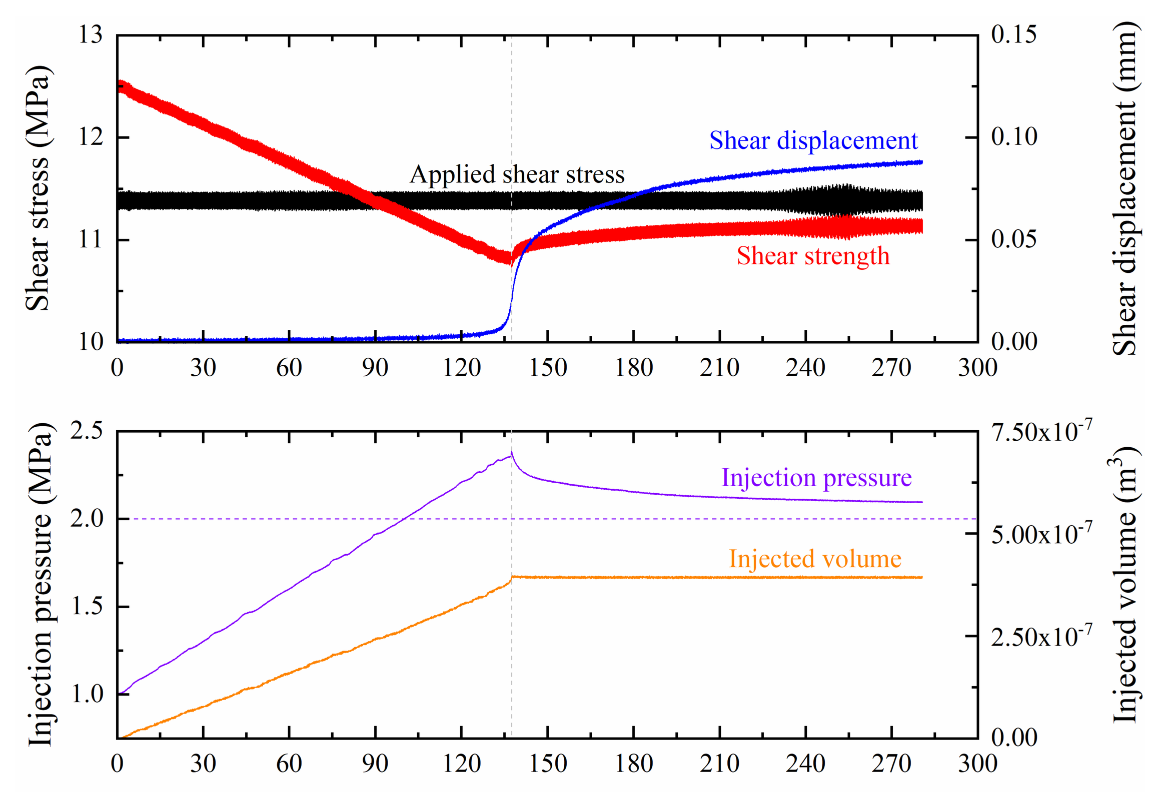




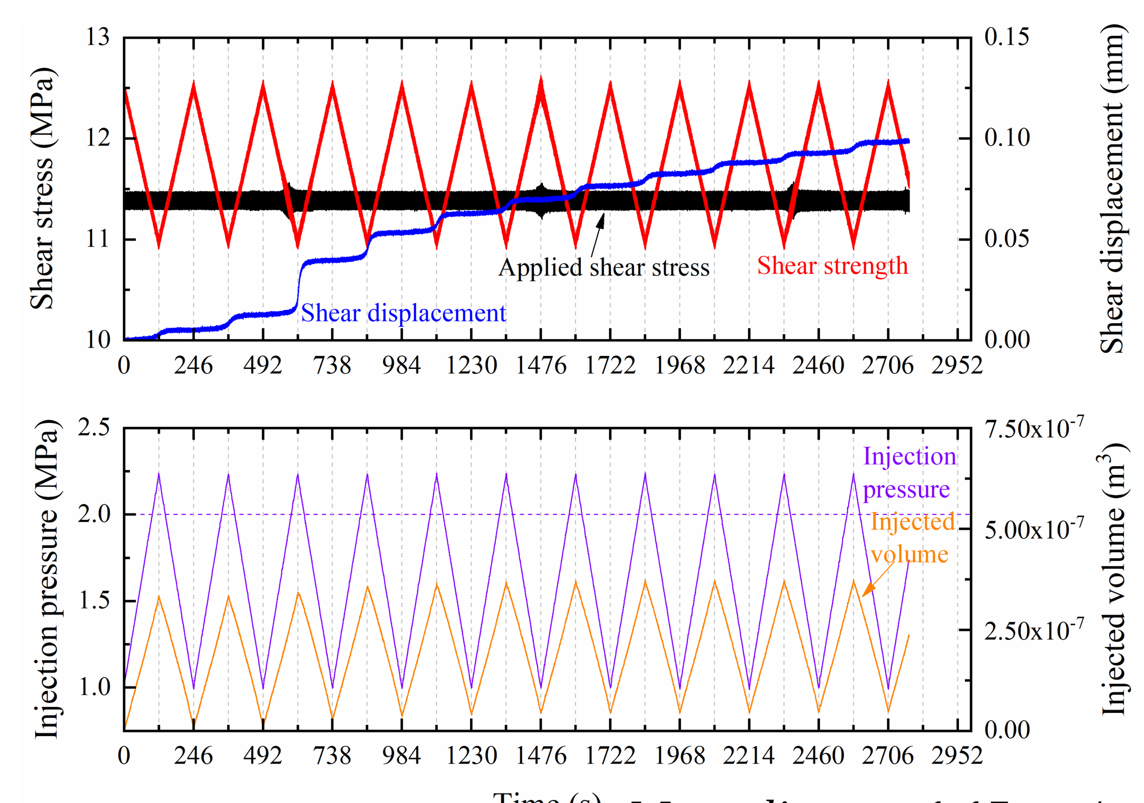
Before and after the experiments

- ***Root mean square asperity height:* 1.79 *mm* → 1.71 *mm***
- ***Frictional coefficient:* 1.25 → 1.26**

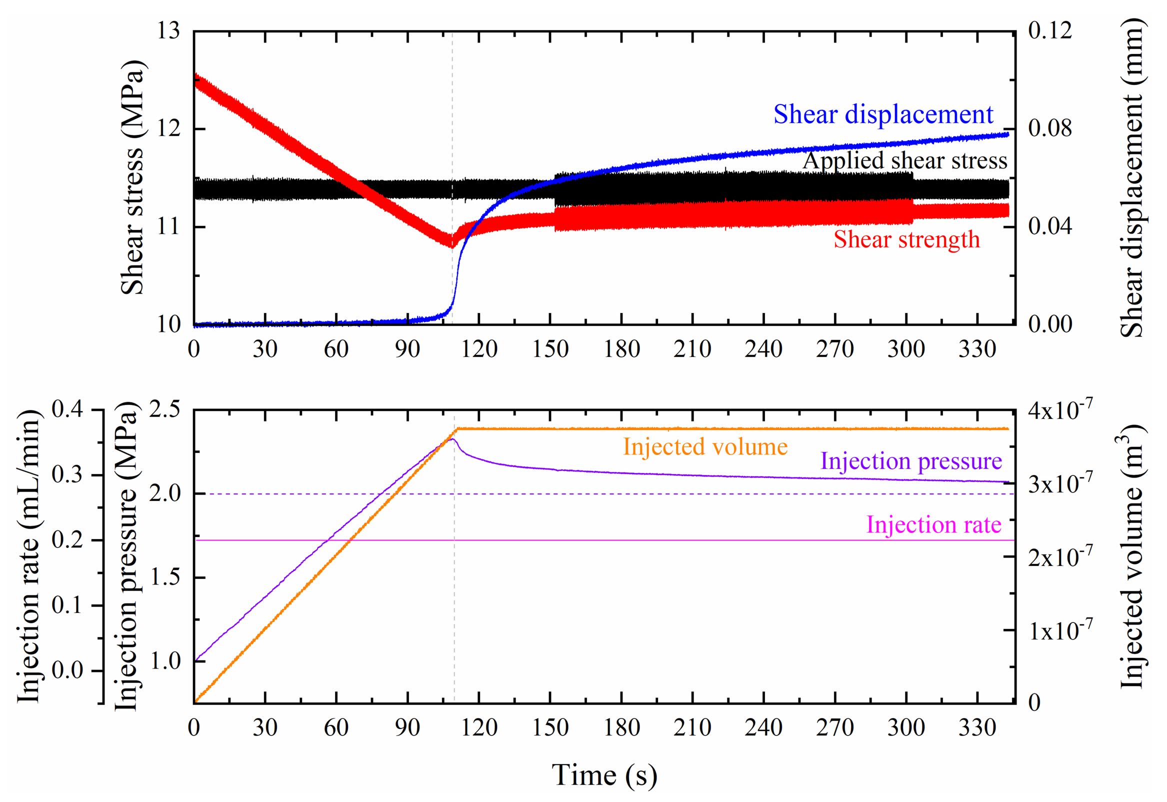
Evolutions of injected volume, shear displacement and injection pressure



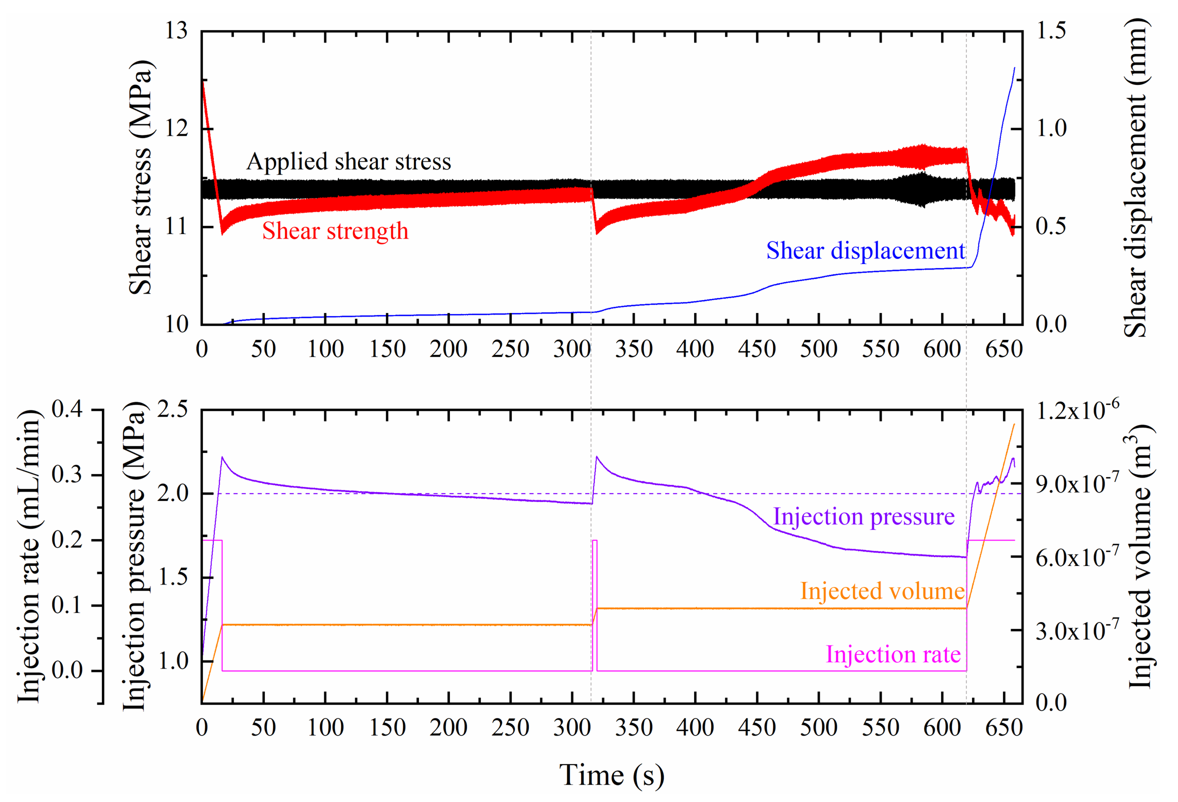
Max. slip rate ***5.59*** *μm/s*



Max. slip rate ***1.15*** *μm/s*



Max. slip rate ***6.18*** *μm/s*



*Slip rate (1st cycle) 0.07 → **1.88** → 0.11 μm/s*
*(2nd cycle) 1.96 → 0.41 → **2.52** → 0.28 μm/s*
*(3rd cycle) 0.28 → **32.15** μm/s*

4. Summary & Next plan

Under the specified test conditions applied in this study:

- For the quasi-static shear slip, the maximum slip rate can be reduced by cyclic injection, compared to continuous injection
- Slip rate could increase during a shut-in stage, accompanying (or can be predicted by) larger/faster fluid pressure drop. This indicates that fracture permeability is enhanced by the shear slip
- Continue injection after the unstable shut-in stage has the potential to induce rapid fracture slip with larger slip rate

Next plan

- Use CT data and 3D carving to prepare fractures with similar surface roughness
- Apply modified injection schemes

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