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Effect of Fluids on Flash Temperature Rise in Sheared Granular Gouge Materials

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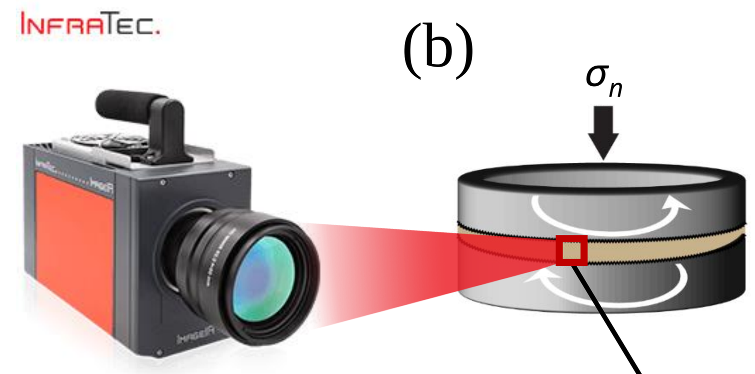
Abstract

During large earthquake slip (i.e., few meters displacement), the generation of frictional heating due to the fast sliding along the fault slip surface can trigger numerous dynamic weakening mechanisms and weaken the faults. However, the physical mechanisms and associated weakening behavior for small magnitude earthquakes (i.e., few centimeters displacement), such as induced seismicities, remain poorly understood. To determine the efficiency of short-term frictional heating at the contact scales and evaluate the effects of pore fluids, we perform friction experiments on quartz gouges at a normal stress of 2.5 to 10 MPa, slip velocity of 5 cm/s under both room-dry and wet conditions using the rotary shear apparatus at Utrecht University equipped with a high-speed infrared camera to capture flash temperature rise occurring at grain contacts. Our preliminary results show that significant weakening only occurs under wet conditions, even though the presence of fluids lowers the flash temperature. This suggests that local flash heating and pore pressurization can weaken a fault even in small earthquakes. More systematical experiments are required to fully quantify the weakening, including measurement of local pore fluid pressures, calibration of the camera for the thermal emissivity of different materials, investigation of peak flash temperature as a function of different grain properties, and experimental conditions.

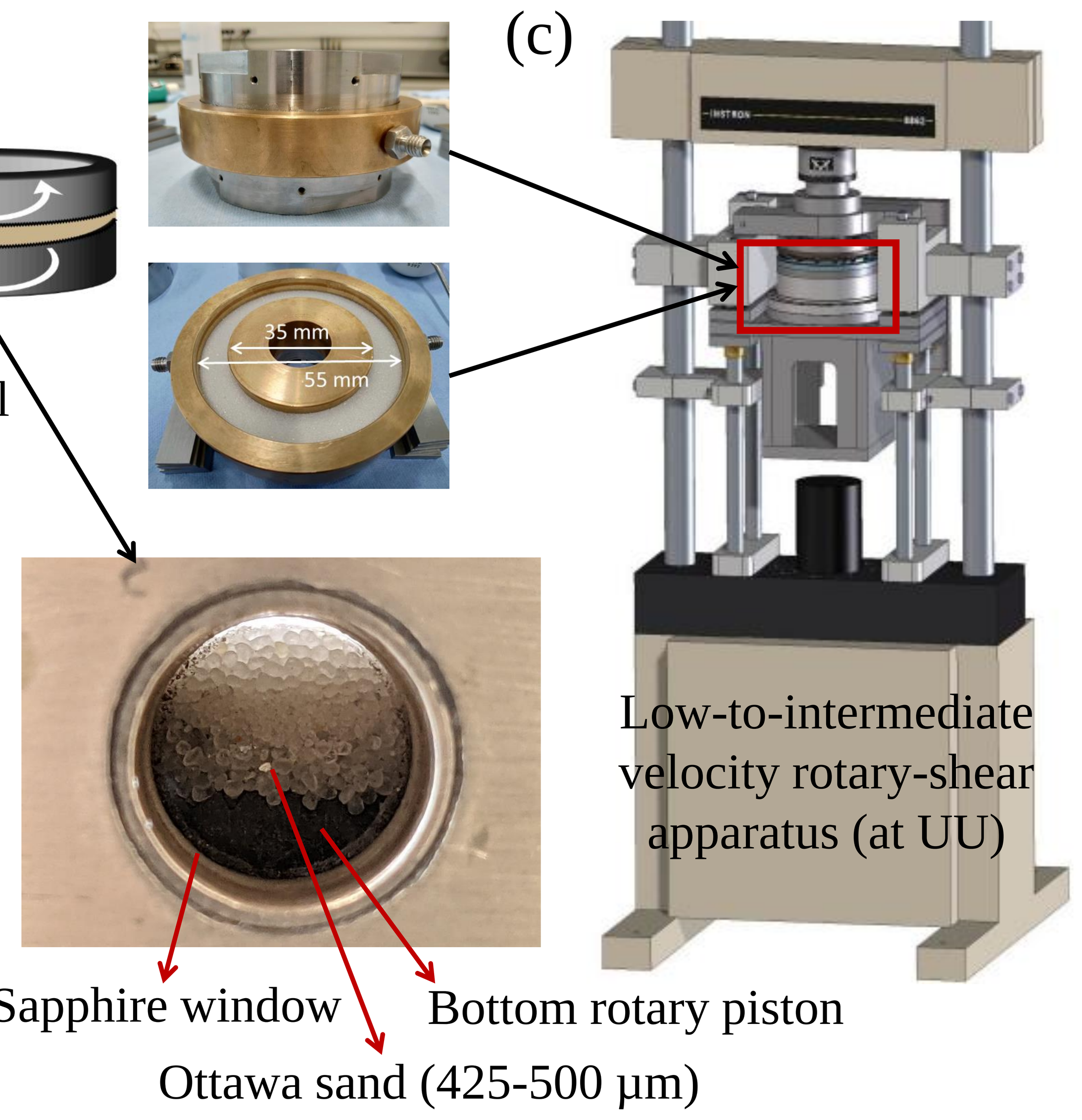
Rotary-Shear Apparatus with Infrared Camera

(a) (b)



- Spatial resolution: 25 μm / pixel
- Field of view (recording rate):
  - 16 mm × 13 mm (300 Hz)
  - 8 mm × 6.5 mm (590 Hz)
  - 4 mm × 3.25 mm (694 Hz)

(c)



(d)

Figure 1. Sample configuration and experiment setup. (a) High-speed infrared camera. (b) Ottawa sand confined by the top and bottom pistons. (c) Low-to-intermediate velocity rotary-shear apparatus (RAP). (d) Real setup.

Temperature and Mechanical Results

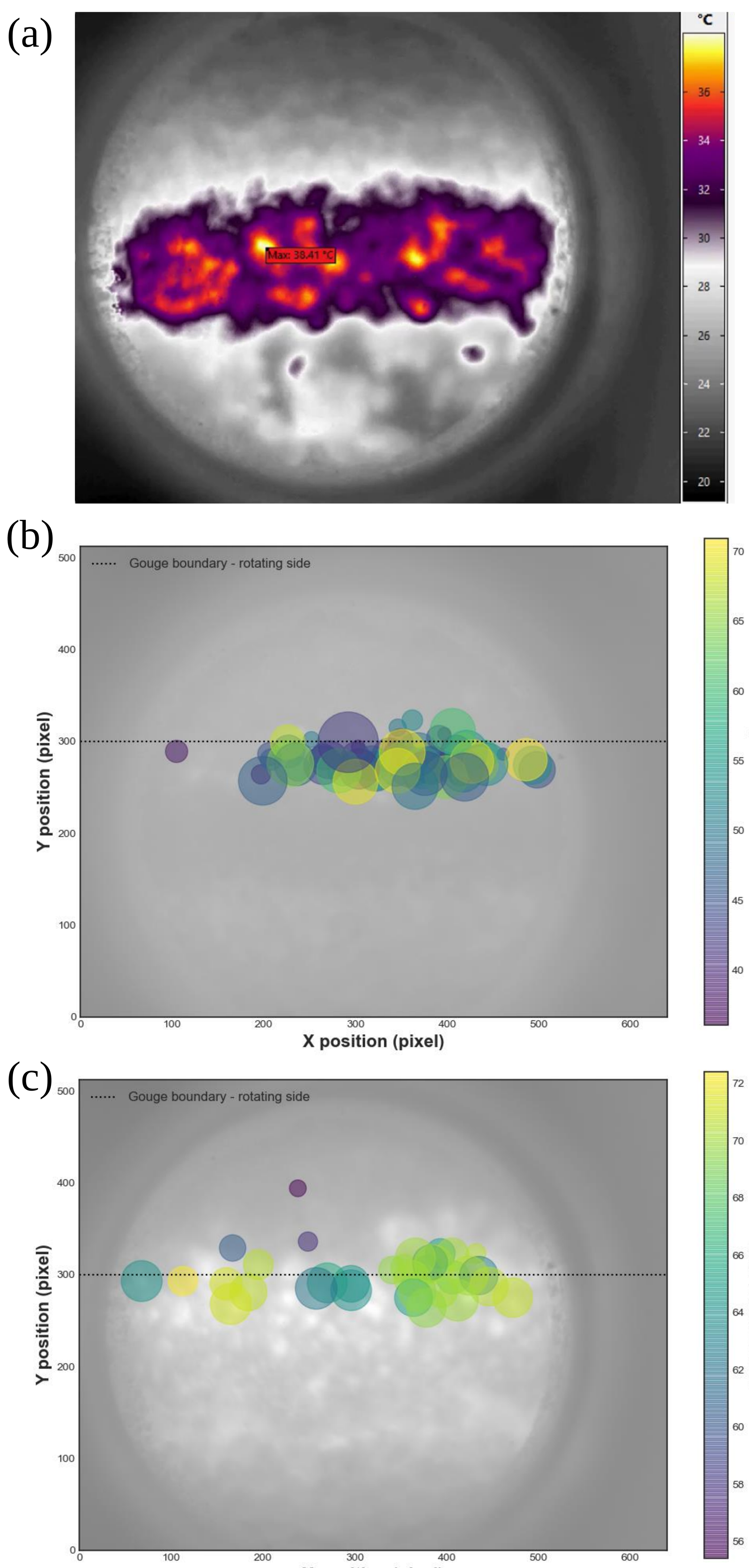


Figure 2. Temperature profile of the gouge layer in the transparent window in the first slip of the experiment r208. (a) Distribution of temperature within 3.3 ms of exposure time. (b) Position of flashes with ΔT > 10 °C (C) Position of flashes with ΔT > 20 °C. Larger dots occur later.

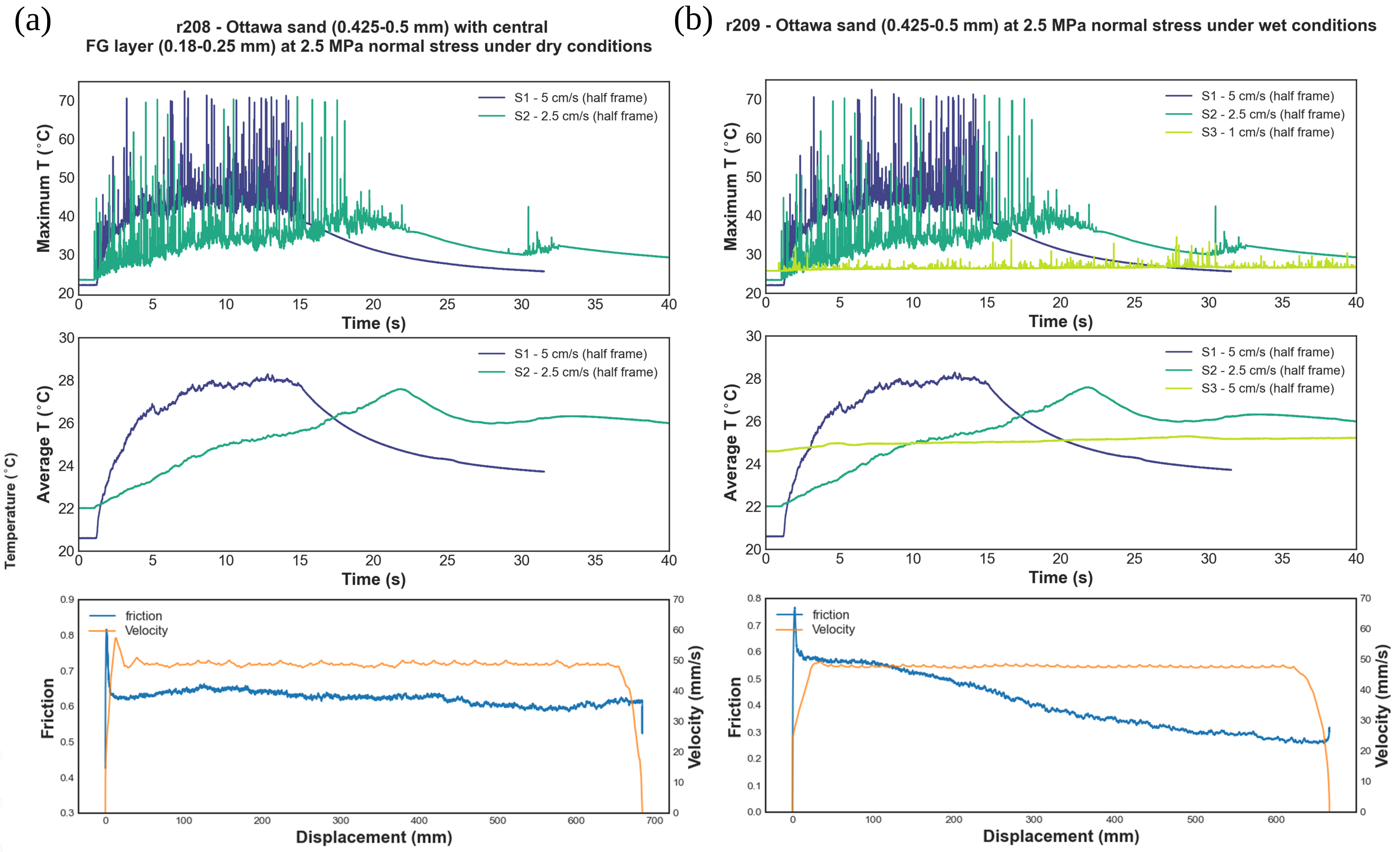


Figure 3. Evolution of maximum temperature, average temperature, and friction as a function of time and displacement for the (a) experiment r208 under dry conditions, and (b) experiment r209 under wet conditions.

Summary

1. Flash temperature can occur and be monitored in the actual gouge zones.
2. The presence of water can inhibit flash temperature rise.
3. Significant weakening only occurs for the wet quartz gouges, suggesting that local flash heating and pore pressurization can weaken a fault even in small earthquakes.

Future Work

1. Local pore fluid pressure measurement at rotary side.
2. Calibration of camera (thermal emissivity) for different materials (quartz and feldspar).
3. Normal high-speed camera to calculate the sliding velocity at grain-to-grain contacts.
4. Systematically investigate peak flash temperature as a function of sliding velocity, (initial) grain size, grain shape (round vs. angular), grain roughness, and effect of different fluids.