Origin of the temporal evolution of elastic properties during laboratory seismic cycle.

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Introduction

Co-seismic changes in elastic velocities reveal changes in fault zone properties (Brenguier et al 2008).

→ often attributed to co-seismic damage during earthquake.

But faults are surrounded by a zone of damage.

What is then causing these velocity drops?
- Co-seismic damage on fault surfaces due to rupture propagation?
- Elastic properties of surrounding medium?

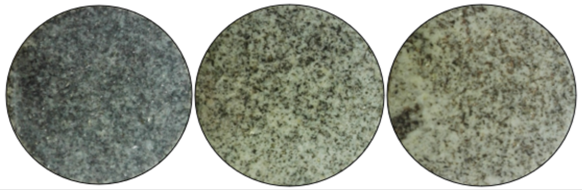
↓

Stick-slip experiments on Lapeyratte granite under triaxial configuration

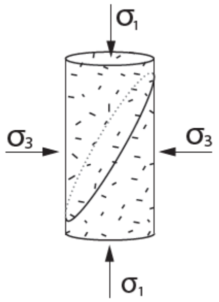
Materials

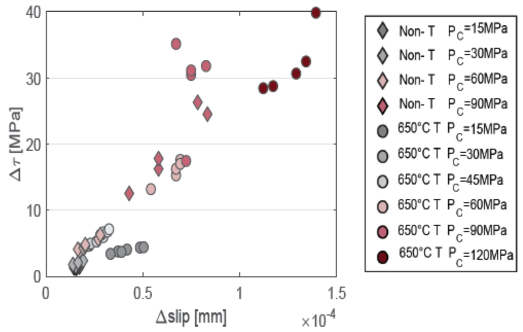
Damage zone elastic properties were simulated with thermal treatment (i.e. inducing intense microcracking), producing different degrees of damage in the samples' bulk.

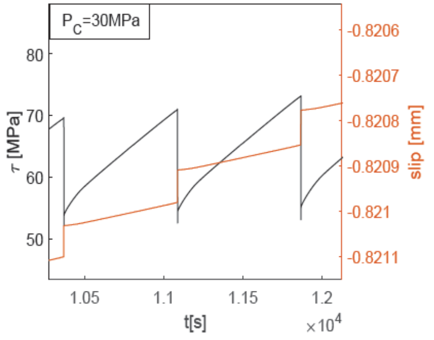
Not thermally treated	Thermally treated at 650 °	Thermally treated at 950 °
Porosity: 0.4%	Porosity: 3.1%	Porosity: 6.6%
Density: 2.63 g/cm³	Density: 2.58 g/cm³	Density: 2.47 g/cm³

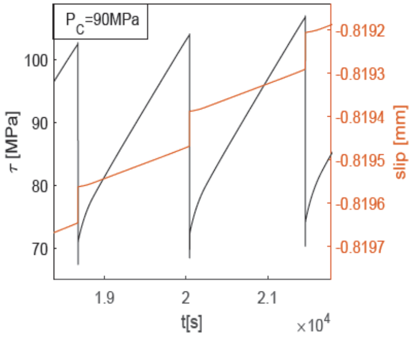


Mechanical results



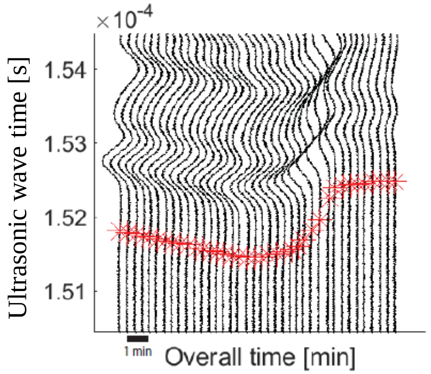


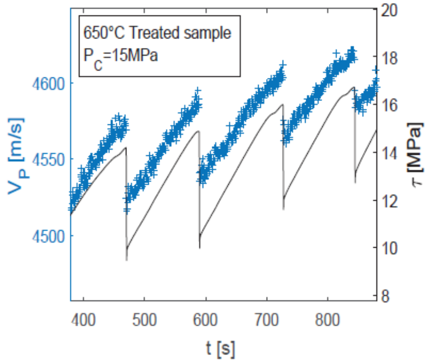




Stick-slip events were induced at different confining pressures (P_C).
A linear mutual dependence was observed between shear stress drop and associated slip.
The scaling relationship does not change with initial damage.

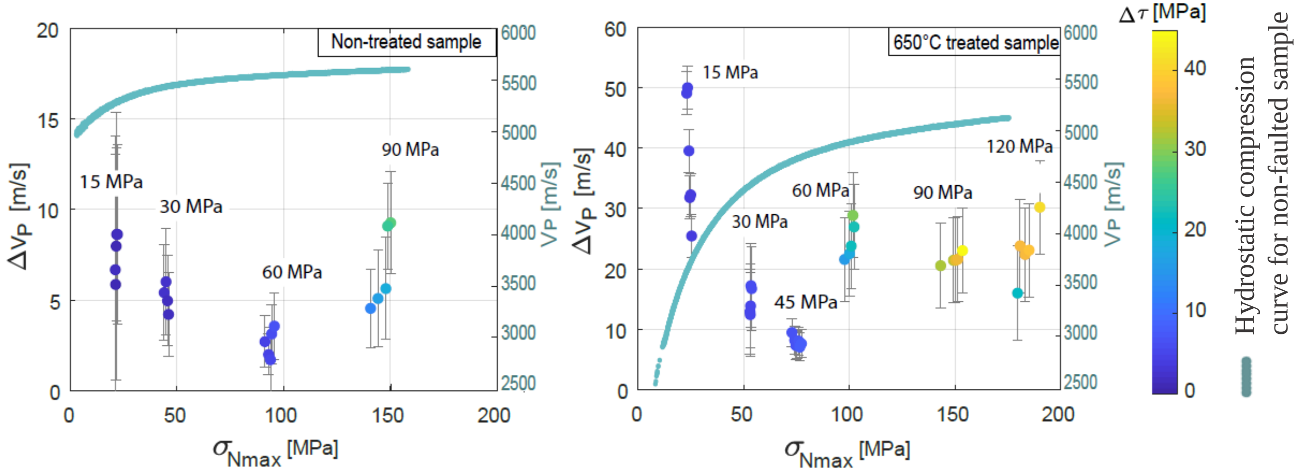
P-wave acquisition and Vp evolution during stick-slip event





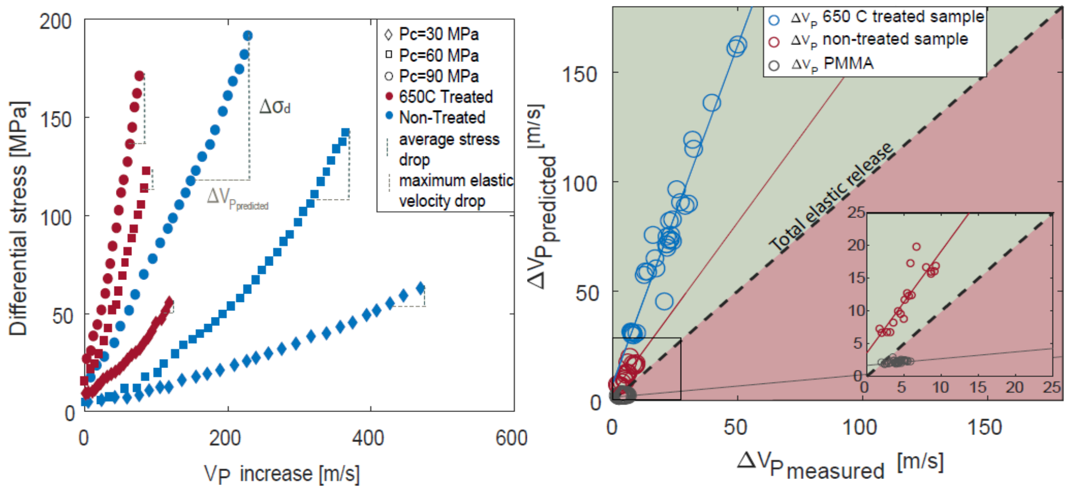
Elastic waves travelling across the sample were continuously recorded during the experiments. P-wave arrival was automatically detected and P-wave velocity estimated (V_P).
An increase in V_P was observed during hydrostatic increase of P_C and during differential loading.
Drops in V_P (ΔV_P) occurred during stress drops.

Evolution of co-seismic velocity drops with stress conditions



ΔV_P observed in the non-treated sample are visibly smaller than the ones observed in the treated sample (i.e. higher initial damage degree) .
ΔV_P evolution with stress conditions (σ_N or $\Delta\tau$) is non linear

Elastic Vp drops prediction



Elastic ΔV_P were predicted by comparing differential stress increase with the total V_P increase during elastic loading right before instability occured.
A linear dependence between $\Delta V_{P\ predicted}$ (i.e. drops due to the opening of the cracks present in the bulk of the sample, caused by the only stress release) and $\Delta V_{P\ measured}$ was observed.
$\Delta V_{P\ predicted}$ are than $\Delta V_{P\ measured}$, suggesting that part of the kinetic energy is lost in dissipative processes during seismic slip.

Conclusions

Our results suggest that co-seismic velocity drops observed during stick-slip events are mostly caused by bulk's microcracks opening occurring during the stress release phase.

Implications for natural observations: co-seismic velocity drops observed in nature might be explained by opening of the cracks present in the damage zone due to stress release, rather than the creation of new ones during rupture propagation.