Monitoring stress-induced changes of laboratory fault by ultrasonic coda wavesMonitoring stress-induced changes of laboratory fault by ultrasonic coda waves

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It is increasing important to understand evolution in fault zone and find clear precursors to the earthquake. Nevertheless, the evolving behavior of crustal faults remains changeling due to its inaccessible and weakness.

Duo to their highly sensitivity, the seismic coda waves have been long used at kilometer scale to investigate stress changes by tracking seismic relative velocity changes during earthquake. However, detecting such changes and imaging their spatial distribution with satisfied resolution are still an ongoing project, for which laboratory developments may be useful.

This work aims to explore the applicability of coda waves to monitor spatiotemporal changes of laboratory fault.

Laboratory-scale experiments are performed by meter-scale biaxial loading apparatus in which coda waves at ultrasonic frequencies (100 kHz to 400 kHz) are transmitted and received by 16 broadband piezoelectric transducers using the state-of-the-art ultrasound research platform (Verasonics Vantage 64 Low Frequency Edition) across a 1.5-meter long granite simulated fault.

Before stick-slip events occurred by increasing shear stress at loading rate of 1 um/s , the normal stress was kept 500KPa constant for 60 minutes. The ultrasonic coda waves were recorded throughout the entire process of stress accumulation along the fault.

Coda wave interferometry (CWI) and Coda wave decorrelation (CWD) are performed to detect relative velocity changes and microstructural changes along the fault by measuring phase shifts and loss of coherence of received coda waves respectively.

We observe a ~0.4e-3 velocity increase and ~0.5% coherence loss within logarithm of stationary contact time during 1-hour normal stress holding time. A significant 1.4e-3 increase in relative velocity changes and 8% coherence loss during shear stress increasing test followed by 0.5e4 decease in relative velocity changes and 2% decrease in coherence loss respectively caused by ~200kPa stress drop of the emerging stick-slip event. We also observe that the such changes are localized at upper center of the fault by comparing the changes extracted at different transducers along the fault.

The results suggest that ultrasonic coda waves are a promising means to monitor weak but localized stress-induced changes of laboratory fault by detecting and characterization velocity and micro-structural changes. Considering such advantages, further works to temporal critical observations, such as nucleation process of laboratory earthquake, are conceivable from a practical and instrumental point of view.

Keywords: laboratory earthquake , stick slip , coda waves, stress-induced changes

