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Strain-dependent partial slip on rock fractures under seismic-frequency torsion

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Authors
Saltiel, Seth
Bonner, Brian P
Ajo-Franklin, Jonathan B

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Strain-dependent partial slip on rock fractures under seismic-frequency torsion

Seth Saltiel

Brian P. Bonner

Jonathan B. Ajo-Franklin
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Abstract

Measurements of nonlinear modulus and attenuation of fractures provide the opportunity to probe their mechanical state. We have adapted a low-frequency torsional apparatus to explore the seismic signature of fractures under low normal stress, simulating low effective stress environments such as shallow or high pore pressure reservoirs. We report strain-dependent modulus and attenuation for fractured samples of Duperow dolomite (a carbon sequestration target reservoir in Montana), Blue Canyon Dome rhyolite (a geothermal analog reservoir in New Mexico), and Montello granite (a deep basement disposal analog from Wisconsin). We use a simple single effective asperity partial slip model to fit our measured stress-strain curves and solve for the friction coefficient, contact radius, and full slip condition. These observations have the potential to develop into new field techniques for measuring differences in frictional properties during reservoir engineering manipulations and estimate the stress conditions where reservoir fractures and faults begin to fully slip.

Plain Language Summary

We present experimental results showing that there is a frictional signature from the initiation of slip on rock fractures due to seismic waves. Large waves displace regions of the fracture surface very small distances, while the centers of contacts remain stuck. These small displacements shrink contacts and cause the surface to soften, which can be seen in the speed and size of the transmitted waves. By sending different size waves across the fracture and measuring the wave

properties, we can infer information about the friction on the rock interface and how it varies along the fault, over time, and with changes in fault conditions such as water injection. This information is valuable for understanding the mechanical state of faults, how they change with natural and human actions, and subsequent earthquakes that occur in the studied area. Although our measurements are made on pinky finger-size samples in the laboratory, they suggest that these processes apply to seismic waves in field-scale faults and fractures capable of producing earthquakes and/or fluid pathways.