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Acoustic Precursors to Laboratory Induced Fault Slip and Failure

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With human activities in the subsurface increasing, so does the risk of induced seismicity. For mitigation of the seismic hazard and limiting the risk, monitoring and forecasting are essential. A laboratory study was performed to find precursors to fault failure. In this study, Red Pfaelzer sandstones samples were used, which are analog to the Groningen gas reservoir sandstones. A saw-cut fault was cut at 35 degrees, and the samples were saturated. Fault slip was induced by loading the sample at a constant strain rate, and simultaneously active acoustic transmission measurements were performed. Every 3 seconds 512 S-waves were sent, recorded, stacked to reduce the signal-to-noise ratio, and analyzed. The direct seismic wave velocity, coda wave velocity, and transmissivity were monitored before and during the reactivation of the faulted samples. Different loading patterns and confining pressures were investigated in combination with active acoustic monitoring. Velocity and amplitude variations were observed before the induced fault slip and can be used as precursory signals. Two methods to determine changing velocities were used. Direct S-wave velocities are compared to velocity change obtained by coda wave interferometry. Both analyses gave similar precursory signals, showing a clear change in slope, from increase to decreasing velocities and amplitudes prior to fault reactivation. Fault reactivation is preceded by fault creep and the destroying of some of the asperities on the fault plane, causing the seismic wave amplitude and velocity to decrease. Combining all precursors, the onset of fault slip can be determined and therefore upcoming slip can be forecasted in a laboratory setting. Our results show precursory changes in seismic properties under different loading situations and show a clear variation to the onset of fault reactivation. These results show the potential of continuous acoustic monitoring for detection and forecasting seismicity and help the mitigation of earthquakes.