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Effects of Acoustic Waves on Stick—Slip Behavior in Sheared Granular Media With Implications to Dynamic Earthquake Triggering and Slow Slip

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To better understand the physics of dynamic triggering and the influence of dynamic stressing on earthquake recurrence, we are conducting laboratory studies of stick—slip in granular media with and without applied acoustic waves. In our 3-D experiments, glass beads are used to simulate granular fault zone wear material, sheared in a double-direct configuration under constant normal stress, while subject to transient or continuous perturbations by acoustic waves. We find that the horizontal stress applied plays a crucial role in the response of the glass beads to applied waves. Under smaller normal stress (2MPa), and subject to wave amplitudes of >10-6 strain, we observe induced slow (silent) slip and tremor. Under moderate normal stress (4 MPa) and subject to >10-6 strain amplitude we observe both instantaneous and delayed triggering. Waves also cause significant disruption in the recurrence rate. The effects of waves are observed for many major-event cycles after wave excitation ceases, indicating a strain memory of waves in the granular material. Under slightly larger horizontal stress (5MPa), if strain amplitudes exceed 10-6, we observe instantaneous triggering followed by slow dynamics—the shear modulus recovers linearly with the-logarithm-of-time back to equilibrium. Slow dynamics is a classical elastic nonlinear (anelastic) behavior observed in acoustical experiments with rock samples in the lab as well as in Earth. Wave-induced disruption of periodic stick—slip is linked to failure of granular force chains.

In 2-D experiments we are applying photoelastic discs in stick—slip measurements in order to visualize the evolution of the force chain network. Photoelastic measurements provide insight into failure, and in particular small adjustments in the force chains network that presage failure. A phenomenological model similar to Knopoff-Burridge shows the same general behaviors as well. In a companion paper, we show model results emplying a DEM approach (see Griffa et al.). Our results should lead to a new understanding of the importance of seismic energy on earthquake physics and more generally, we anticipate that it will have broad impact on unexpected material failure induced by moderate-amplitude elastic waves, including avalanches, landslide and failure of incipient damage in solids [We gratefully acknowledge the support of the U. S. Department of Energy through the LANL/LDRD Program for this work].