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## Earthquake Behaviors in Earthquake Cycle Simulations With Fault Damage Zones

Faults are usually surrounded by damage zones associated with localized deformation. Here we use fully dynamic earthquake cycle simulations to quantify the behaviors of earthquakes in fault damage zones. We show that fault damage zones can make a significant contribution to the spatial and temporal seismicity distribution. Fault stress heterogeneities generated by fault zone waves persist over multiple earthquake cycles that, in turn, produce small earthquakes that are absent in homogeneous simulations with the same friction conditions. Shallow fault zones can produce a bimodal depth distribution of earthquakes with clustering of seismicity at both shallower and deeper depths. Fault zone healing during the interseismic period also promotes the penetration of aseismic slip into the locked region and reduces the sizes of fault asperities that host earthquakes. Hence, small and moderate subsurface earthquakes with irregular recurrence intervals are commonly observed in immature fault zone simulations with interseismic healing. To link our simulation results to geological observations, we will use simulated fault slip at different depths to infer the timing and recurrence intervals of earthquakes and discuss how such measurements can affect our understanding of earthquake behaviors. We will also show that the maturity and material properties of fault damage zones have strong influence on whether long-term earthquake characteristics are represented by single events.

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