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Predictable recovery rates in near-surface materials after earthquake damage

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Earthquakes induce transient mechanical damage in the subsurface, leading to postseismic hazards such as enhanced landsliding, with recovery often taking years to reach steady-state conditions. This behavior has been associated with relaxation, a phenomenon observed across a wide range of materials following strain perturbations. However, systematic controls on recovery duration in the shallow subsurface after seismic shaking remain poorly understood. Here, we investigate the successive impacts of two large earthquakes on subsurface properties by monitoring seismic velocity changes using ambient noise interferometry in the Atacama Desert, Chile. The hyperarid conditions of this region allow us to isolate mechanical effects by minimizing the influence of variable groundwater content. Our analysis reveals that relaxation timescales are governed by the intrinsic properties of the substrate rather than by ground-shaking intensity, suggesting that the subsurface's current mechanical state—not the earthquake's energy—determines recovery dynamics. These findings underscore the predictability of earthquake-induced damage evolution in the shallow Earth and potentially other materials. We reconcile this observation with existing physical frameworks by proposing a model based on the superposition of distinct populations of damaged contacts.

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