TRIGGERING OF VERY SHALLOW EARTHQUAKES BY SURFACE MASS REMOVAL PROCESSES - A CASE STUDY OF THE 2019 MW4.9 LE TEIL, FRANCE EARTHQUAKE

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Faults are typically aseismic at shallow depths due to their velocity-strengthening (VS) frictional behavior. However, very shallow earthquakes do occur, mostly associated with natural or human-caused mass removal processes. The Mw 4.9 Le Teil earthquake in France on November 11, 2019, is a notable example: its hypocenter was located within the area of favorable stress change induced by a cement quarry, and its slip was limited to 1-2 km depth, resulting in extreme ground motions. It is important to understand how very shallow earthquakes are initiated. Here, we evaluate the mechanical viability of the quarry-triggering hypothesis by conducting rock friction tests and numerical simulations.

The Le Teil earthquake nucleated on the La Rouvière Fault, which cuts through layers of limestones, marly-limestones and marls. Our mechanical tests on rock samples from surface outcrops representative of these layers revealed that the limestones can transition from velocity-weakening (VW) to velocity-strengthening at increasing slip rates, while marls remain velocity-strengthening.

Our multi-cycle earthquake simulations confirmed that a 200 kPa stress change due to 200 years of mass removal by quarrying can trigger a shallow rupture. This readily occurs in models with a shallow VW segment driven by creep on a deeper VS segment, but is less trivial in models with a shallow VS fault segment above a VW segment. In the latter case, we found that, under certain conditions, the shallow VS segment can be driven well below steady-state (inter-seismically locked) by the pinning effect of the deeper locked VW segment. In such scenarios, even if the VS fault cannot generate an earthquake spontaneously, it can be triggered by the surface mass removal without breaking the deeper VW segment.