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Nucleation and size of earthquakes induced by pore-pressure perturbations with large aspect ratios

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Physics-based insights into the conditions controlling nucleation and size of fluid-injection-induced earthquakes is of critical importance. Theoretical estimate of the minimum over-stressed asperity size leading to runaway rupture and theoretical estimate of the final size of self-arrested ruptures are only available for 2D problems and for 3D problems with an asperity aspect ratio close to one. However, reservoirs are often much thinner in the vertical direction than horizontally, which leads to pressurized zones (acting as nucleation asperities) with aspect ratios far from one. Therefore, we have performed a systematic parametric study using numerical dynamic rupture simulations and investigated:
a) how conditions leading to runaway ruptures;
b) how size of the arrested ruptures;
depend on the size and aspect ratio of the asperity and on the background stress.
We found that the transition to runaway ruptures is controlled by either asperity length (numerical results consistent with theoretical 2D estimates) or asperity area (numerical results consistent with 3D estimates for asperities with aspect ratio close to one). The transition be-tween the two regimes is narrow. For the size of arrested ruptures, we found that in addition to length-controlled and area-controlled regimes there is also mixed-regime where neither of the theoretical estimates is applicable. In the context of induced seismicity, our idealized model results provide scenarios that could be either favorable or challenging for traffic light systems (TLSs), and allow to gain insights into the mechanical conditions leading to them.