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No aftershocks, fluid-driven aftershocks, and Omori's Law

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Aftershock sequences follow three empirical laws; Gutenberg Richter, Omori, and Bath. Unless they don't. This raises the question as to why most earthquakes follow empirical laws, while other earthquakes generate few, if any, aftershocks. For example, a magnitude 7.1 earthquake in Mexico in 2017 and a magnitude 8 earthquake in Peru in 2019 generated no aftershocks, while a magnitude 7.1 earthquake in 2019 in California and a magnitude 6.4 earthquake in 2020 in Puerto Rico generated thousands of aftershocks. In this work, I show from numerical modelling and comparisons with data that the differing behaviours rests with the presence of high-pressure fluids at depth. Using a simple model of non-linear diffusion, I compare model results with well-located aftershocks from four Southern California earthquakes and show strong spatial correlation between measured hypocenters and calculated fluid pressure emanating from a high-pressure source. I also show that Omori's Law arises from permeability dynamics. That is, permeability: 1) is effective-stress dependent, 2) undergoes a co-seismic step-like increase, and 3) exponentially heals through either precipitation processes or tectonic re-compaction. I find excellent temporal correlation (Omori's Law) between the number of measured and modelled earthquakes from the strike-slip earthquakes of Joshua Tree and Landers (1992), the strike-slip Hector Mine earthquake (1999), and the thrust Northridge earthquake (1994). Finally, I demonstrate that the fit to the Omori-Utsu Law depends only on the rate of permeability recovery, and argue that all rich aftershock sequences are fluid-driven, while fluid-absent geodynamic settings produce few, if any, aftershocks.