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A mechanism of aftershock generation based on progressive material softening

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Observations of aftershocks after major seismic events show that the rate of aftershock generation reduces according to the generalised Omori's law. This law reproduces itself at a variety of scales starting from the scales of the earthquakes to the laboratory scale. Furthermore, the Omori's law holds for different types of fracture event from shear fracture propagation over the faults to failure in compression to failure in tension. In particular our tests show that the Omori's law describes the aftershocks in crystalline rocks in a laboratory model of hydraulic fracture and after bending failure of beams.

We propose a new universal mechanism of aftershock generation that reproduces the Omori's law. We firstly note that it is not the residual stress, as conventionally assumed, but the residual strain that is created by the preceding fracture process. The aftershocks are created by the residual stress that is related to the residual strain through elastic moduli. The accumulation of the aftershock-related microcracks reduces the elastic moduli and thus reduces the residual stress. This overall reduction of the residual stress with the number of aftershocks is the reason for the rate reduction in aftershock generation. Naturally this process might be accompanied by the reduction in wave velocities, albeit, as we show, the reduction is rather low.

The effect the accumulated microcracks have on the moduli considerably depends on the microcrack distribution over both positions and orientations. We found that (a) if the microcracks have isotropic distribution over orientations the classical Omori's law is reproduced; (b) if the microcracks are shear and parallel to each other but randomly situated in space the generalised Omori's law is reproduced with the exponent $p<1$; (c) if the microcracks are represented by sliding zones distributed over a fault, the generalised Omori's law is reproduced with the exponent $p>1$. The main feature of the latter case is the existence of a critical value of the number of sliding zones: when it is reached a large-scale sliding zone is formed.