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# Breakdown energy scaling in a self-similar earthquake model

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During an earthquake, the elastic energy released from the Earth's crust is partially radiated as seismic waves and partially dissipated along the tectonic fault. The dissipated energy can be divided into heat, which is produced by friction and other nonlinear mechanisms, and breakdown energy, which is associated with the dynamic weakening process of the fault. This breakdown energy is a key fault property as it directly affects nucleation, propagation and arrest of earthquake ruptures, and, hence, may control the size of an earthquake. However, the breakdown energy is difficult to measure directly on the fault and, therefore, it is routinely inferred from seismological measurements. A common observation is that the inferred breakdown energy, if positive-valued, scales with relative slip along the fault. In other words, larger earthquakes appear to dissipate more energy per unit rupture area through the weakening process, which typically occurs over very short slip distances. This would suggest that the earthquake rupture contains information about the final size of the earthquake starting from a very early stage of the earthquake, which is reasonably disputed in literature. In addition, the inferred breakdown energy is frequently observed to be negative-valued, which would violate thermodynamics. Therefore, we note that our current understanding of the seismologically inferred breakdown energy remains inconsistent. Here, we introduce a self-similar earthquake model that presents a similar scaling of the inferred breakdown energy despite constant and scale-independent fault properties (including the locally dissipated energy). We will show that the observed scaling is the result of a scale-invariant stress drop overshoot that distorts the global energy balance used for determining the breakdown energy. Therefore, our results suggest that the overall rupture mode – whether it is a crack-like or a pulse-like rupture – is a crucial factor for the inferred breakdown energy. Consequently, a pulse-like rupture, which is typically associated to stress drop undershoot, may explain the observed negative breakdown-energy values.