

A new scaling law from tremor to silent earthquakes

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Recently, a series of unusual earthquake phenomena have been discovered in many subduction zones in the world. These are deep episodic tremor, low-frequency earthquakes (LFEs), very low-frequency earthquakes (VLFs), slow slip events (SSEs), and silent earthquakes. Each of these has been demonstrated to be shear slip, similar to regular earthquakes, but with longer characteristic durations and radiating much less seismic energy. These events follow a simple scaling relationship that unifies these phenomena and clearly differentiates their behavior from that of regular earthquakes. The seismic moment of ordinary earthquakes scales as the cube of the characteristic duration. In contrast, the seismic moment of these unusual earthquakes is proportional to the characteristic duration itself. This proportionality suggests that these events have constant moment-rate. Indeed, the displacement spectra of LFEs and VLFs exhibit f^{-1} high-frequency decay, which is consistent with constant moment-rate. The scaling law for regular earthquakes limits the smallest size of these unusual earthquakes, which is also confirmed by recent observations.

This scaling relationship shows that they are essentially the same phenomena with different characteristic lengths and durations. While large slow slip migrates 100 km at a velocity about 0.1 m/s, some of tremor activity propagates within 10-20 km at about 10 m/s. The rupture velocity of smaller events might be much faster. One possible mechanism for such scale dependent rupture propagation is diffusional propagation of stress drop with almost constant slip. A small constant stress drop also explains the behavior, although background physical mechanism is unclear. There are diverse class of unusual seismic events that is explained by this scaling law. Investigating the background mechanism of this scaling law should lead to a better understanding of the plate subduction process and large earthquake generation.