The Global Importance of Continental Seismic Sequences

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Large continental earthquakes necessarily involve cascading rupture of multiple faults or segments (e.g. El Mayor-Cucapah 2010). But these same critically-stressed systems sometimes rupture in drawn-out sequences of smaller earthquakes over days or years (e.g. Central Italy 2016), instead of in a single large event. Due to the similarity in the initial conditions of both scenarios, seismic sequences may be considered as 'failed' multi-segment earthquakes, whereby cascading rupture is prematurely halted before all available slip deficit is released.

These two modes of strain-release have vastly different implications for seismic hazard. Recent work on the 2016 Central Italy earthquake sequence, which is the first seismic sequence to be studied with modern high-quality geodetic and seismological datasets, showed that complexity in fault structure appeared to exercise a dual control on both the timing and sizes of events throughout this sequence. However, it is unclear if this structural control is common for all continental seismic sequences, how important seismic sequences are for the global seismic moment budget, and how this contribution to moment budget may vary between different tectonic regions.

Here we select shallow crustal continental earthquakes from the Global Centroid Moment Tensor catalog, and identify seismic sequences as agglomerates of clustered pairs of earthquakes where the summed moment ($M_0$) of all aftershocks is greater than 50% of the $M_0$ of the first event in the sequence. We analyse the relative number of seismic sequences compared to other earthquakes for normal, reverse, and strike-slip faulting regions, and also calculate the relative $M_0$ release of seismic sequences and other earthquakes in these three regimes.

We find that although seismic sequences are equally common by number in all continental tectonic regimes, seismic sequences account for a much higher proportion of $M_0$ release for normal faults (~20%) than for reverse faults (~10%), with strike-slip faults intermediate between these two end-members. We also find that the proportion of $M_0$ release in seismic sequences is higher for events that occur in regions characterised by a diversity of different earthquake types (e.g. both reverse and strike-slip faulting) than for events that occur in regions characterised by a single earthquake type (e.g. strike-slip faulting only). Together these findings imply that complexity of fault network is an important factor in controlling the occurrence of large-$M_0$ seismic sequences, and that ‘failed’ multi-segment earthquakes and therefore large-$M_0$ seismic sequences are more likely to occur in regions with complex fault networks.