Dual control of fault intersections on stop-start rupture in the 2016 Central Italy seismic sequence

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Abstract

Large continental earthquakes necessarily involve failure of multiple faults or segments. But these same critically-stressed systems sometimes fail in drawn-out sequences of smaller earthquakes over days or years instead. These two modes of failure have vastly different implications for seismic hazard and it is not known why fault systems sometimes fail in one mode or the other, or what controls the termination and re-initiation of slip in protracted seismic sequences.

Our understanding of these issues has been severely limited by a paucity of high-resolution observations of modern seismic sequences, buta series of three Mw> 6 earthquakes from August to November 2016 in Central Italy represents a uniquely well-observed example. Here we exploit a wealth of geodetic, seismological and field data to define the causative fault geometry at depth and then solve for the spatio-temporal evolution of slip on these faults throughout the sequence. We find that the earthquakes ruptured several major SW-dipping normal faults, along with several subsidiary oblique and antithetic faults that intersect these main structures.

Our results suggest that these intersecting fault structures controlled the extent and termination of rupture in all three events in the sequence, as they closely bound the extent of major slip for each earthquake. In addition, aftershocks following the first Mw 6.2 earthquake appear to migrate northwards along these same fault intersections, with a temporal evolution consistent with a diffusive process. This migrating front of seismicity reached the hypocentre of the next major earthquake, a Mw 6.1 event, at the time of its nucleation, suggesting a causal relationship. The rate of migration is consistent with fluid diffusion, which has previously been observed following other earthquakes in central Italy, and we therefore suggest

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that fluids channelled along high-permeability fault intersections determined the timing of rupture re-initiation. This may also explain why the sequence 'jumped' over the fault region of the third and largest Mw 6.6 earthquake, which ultimately ruptured the region between the first two events.

Fault intersections therefore appear to have exercised a dual control on the stop-start rupture throughout this earthquake sequence, first preventing rupture in a single large earthquake, and second determining the temporal evolution of failure over the following two months. This strong structural control in seismic sequences may be common, and we suggest that future efforts should focus on investigating its prevalence.