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Controls on the long term earthquake behavior of an intraplate fault revealed by U-Th and stable isotope analyses of syntectonic calcite veins

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U-Th dates on calcite precipitated in coseismic extension fractures in the Loma Blanca normal fault zone, Rio Grande rift, NM, USA, constrain earthquake recurrence intervals from 150-565 ka. This is the longest direct record of seismicity documented for a fault in any tectonic environment. Combined U-Th and stable isotope analyses of these calcite veins define 13 distinct earthquake events. These data show that for more than 400 ka the Loma Blanca fault produced earthquakes with a mean recurrence interval of 40 $\pm$ 7 ka. The coefficient of variation for these events is 0.40, indicating strongly periodic seismicity consistent with a time-dependent model of earthquake recurrence. Stochastic statistical analyses further validate the inference that earthquake behavior on the Loma Blanca was time-dependent. The time-dependent nature of these earthquakes suggests that the seismic cycle was fundamentally controlled by a stress renewal process. However, this periodic cycle was punctuated by an episode of clustered seismicity at $\sim$430 ka. Recurrence intervals within the earthquake cluster were as low as 5-11 ka. Breccia veins formed during this episode exhibit carbon isotope signatures consistent with having formed through pronounced degassing of a CO_2 charged brine during post-failure, fault-localized fluid migration.

The $\sim$40 ka periodicity of the long-term earthquake record of the Loma Blanca fault is similar in magnitude to recurrence intervals documented through paleoseismic studies of other normal faults in the Rio Grande rift and Basin and Range Province. We propose that it represents a background rate of failure in intraplate extension. The short-term, clustered seismicity that occurred on the fault records an interruption of the stress renewal process, likely by elevated fluid pressure in deeper structural levels of the fault, consistent with fault-valve behavior. The relationship between recurrence interval and inferred fluid degassing suggests that pore fluid pressure along the fault may have been driven by variations in CO_2 content, thereby fundamentally affecting earthquake frequency. Thus, the Loma Blanca fault provides a record of "naturally induced" seismicity, with lessons for better understanding anthropogenic induced seismicity.