Scientist gains fresh insight into the origins of earthquakes

October 13 2020

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Sometimes barely noticeable, and at other times devasting, earthquakes are a major geological phenomenon which provide a stark reminder that our planet is constantly evolving. Scientists have made significant progress in understanding these events over the past 50 years thanks to sensors set up around the world. And while we know that earthquakes are caused by shifts in tectonic plates, a lot remains to be learned about how and why they occur.

Passelègue, a scientist at ENAC's Laboratory of Experimental Rock Mechanics (LEMR), has been studying the dynamics of faults—or the areas between tectonic plates, where most earthquakes occur—for the past ten years. He recently made a breakthrough in understanding the rupture mechanisms that eventually lead to seismic shifts along fault lines. His findings were published in the prestigious *Nature Communications* on 12 October 2020.

"We know that rupture speeds can vary from a few millimeters per second to a few kilometers per second once nucleation occurs [the process by which a slip expands exponentially]. But we don't know why some ruptures propagate very slowly and others move quickly," says Passelègue. "However, that's important to know because the faster the propagation, the quicker the energy that accumulates along the fault is released."

An earthquake will generally release the same amount of energy whether it moves slowly or quickly. The difference is that if it moves slowly, its seismic waves can be absorbed by the surrounding earth. These types of slow earthquakes are just as frequent as regular ones; it's just that we can't feel them. In extremely fast earthquakes—which occur much less often—the energy is released in just a few seconds through potentially devasting high-frequency waves. That's what sometimes occurs in Italy, for example. The country is located in a friction zone between two tectonic plates. While most of its earthquakes aren't (or are barely) noticeable, some of them can be deadly—like the one on 2 August 2016 that left 298 people dead.

In his study, Passelègue developed an experimental fault with the same temperature and pressure conditions as an actual fault running 8 km deep. He installed sensors along the fault to identify the factors causing slow vs. fast rupture propagation. "There are lots of hypotheses out there—most scientists think it's related to the kind of rock. They believe that limestone and clay tend to result in slow propagation, whereas harder rocks like granite are conducive to fast propagation," he says. Passelègue's model uses a complex rock similar to granite. He was able to replicate various types of slip on his test device, and found that "the difference isn't necessarily due to the properties of the surrounding rock. A single fault can demonstrate all kinds of seismic mechanisms."

Passelègue's experiments showed that the amount of energy released during a slip, and the length of time over which it's released, depend on the initial strain exerted along the fault; that is, the force applied on the fault line, generally from shifting tectonic plates. By applying forces of different magnitudes to his model, he found that higher strains triggered faster ruptures and lower strains triggered slower ruptures. "We believe that what we observed in the lab would apply under real-world conditions too," he says.

Using the results of his model, Passelègue developed equations that factor in the initial strain on a fault and not just the amount of energy accumulated immediately before a slip, which was the approach used in other equations until now. "François is one of the first scientists to measure rupture speeds in rocks under the same temperature and pressure conditions that you find out in nature. He developed a way to model the mechanisms physically—something that had never been done before. And he showed that all earthquakes follow the same laws of physics," says Marie Violay, head of LEMR.

Passelègue warns that his model cannot be used to determine when or where an earthquake will occur. Since faults run too deep, scientists still aren't able to continually measure the strain on rock right along a fault. "We can identify how much strain there needs to be to cause a rupture, but since we don't know how much a fault is 'loaded up' with energy deep underground, we can't predict the rupture speed."

One implication of Passelègue's research is that earthquakes may not be as random as we thought. "Most people think that faults that have been stable for a long time will never cause a serious earthquake. But we found that any kind of fault can trigger many different types of seismic events. That means a seemingly benign fault could suddenly rupture, resulting in a fast and dangerous wave propagation."

Provided by Ecole Polytechnique Federale de Lausanne