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How Earthquakes Can Be Predicted: Researchers Reveal New Means

Researchers at the Hebrew University of Jerusalem who have been examining what happens in a "model earthquake" in their laboratory have discovered that basic assumptions about friction that have been accepted for hundreds of years are just wrong. Their findings provide a new means for replicating, how earth ruptures develop and possibly enabling prediction of coming severe earthquakes.

"The findings have a wide variety of implications for materials science and engineering and could help researchers understand how earthquakes occur and how severely they may develop along a fault line," said Jay Fineberg, the Max Born Professor of Natural Philosophy at the Racah Institute of Physics at the Hebrew University.

The work by Fineberg, his graduate student Oded Ben-David and fellow researcher Gil Cohen, has been published in an article in Science.

For centuries, physicists have thought that the amount of force needed to push an object in order to make it slide across a surface is determined by a number called "the coefficient of friction", which is the ratio between the forces pushing sideways and pushing down (basically, how much the object weighs). First described by Leonardo da Vinci in the 15th century and redefined a few hundred years later, these laws are so widely accepted that consistently appear in introductory physics textbooks.

But, when Ben-David tried to check whether these "laws" work at different points along a block's contact surface, the laws fell apart. In carefully controlled lab experiments, Ben-David found that points along the contact surface could sustain up to five times as much sideways force as the coefficient of friction predicted, and the object still wouldn't budge.

The experiments actually studied two contacting blocks as they just start to slide apart. Although the blocks look like they are smoothly touching, in reality they are only connected by numerous, discrete, tiny contact points, whose total area is hundreds of times less than the blocks' apparent contact area. Performing sensitive measurement of the stresses at contacting points, the researchers noted that the strength at each point along the contact surface could be much larger than the coefficient of friction allows before the contacts ruptured and the block began to slide.

Furthermore, the contacts don't all break at the same time. They, instead rupture one after another in a cadence that sets the rupture speed. These rapidly moving ruptures are close cousins of earthquakes, Fineberg said. The blocks in effect represent two tectonic plates pushing one against each other, and when the force between them is enough to disengage the plates, the resulting contact surface rupture sends shock waves through the blocks, exactly as in an earthquake.

The team found that ruptures come in three distinct modes: slow ruptures that move at speeds well below the speed of sound; ruptures that travel at sound speed; and "supershear" ruptures that surpass sound speeds. Which type of wave one gets is determined by the stresses at the contact points, which provide a measure of how much energy would be released if an actual earthquake were to occur. These different types of earthquakes have all been seen in the earth, but these experiments provide the first clue of how the earth "chooses" how to let go.

"An earthquake is the same system as in the Hebrew University experiments, just scaled up by factors of thousands," Fineberg said. "We can watch how these things unfold in the lab and measure all of the variables that might be actually relevant in a way that you could never observe under the earth."

How an earthquake "chooses" to rupture is not simply an academic question. Each type of rupture mode determines how the earth releases the enormous pressures that are locking tectonic motion and is intimately related to the potential hazards embodied within an earthquake. Whereas sonic earthquakes are destructive, their supersonic cousins are potentially much more dangerous as they release the enormous stored energy within the earth as a shock wave. In contrast, slow ruptures create negligible damage for the same amount of stress release, and while it is still impossible to make detailed measurements of the stresses along a real fault, the Hebrew University results suggest a method by which stresses can be tracked as an earthquake is under way, and how one earthquake can set the stage for the initial conditions for the next one. This new understanding has the potential to provide unprecedented predictive power, estimating both the rupture mode and extent of a future earthquake.