Laboratory experiments reproduce statistical behavior of earthquakes

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Mechanical failure of materials is a complex phenomenon underlying many accidents and natural disasters ranging from the fracture of small devices to earthquakes. Despite the vast separation of spatial, temporal, energy, and strain-rate scales, and the differences in geometry, it has been proposed that laboratory experiments on brittle fracture in heterogeneous materials can be a model for earthquake occurrence.

A study led by researchers from the University of Barcelona, and published on the journal Physical Review Letters, has carried out experiments with a material loaded under compression that reproduces the four main statistical laws of seismicity: the Gutenberg-Ritcher law, the Omori's law, the distribution of waiting times between consecutive events and the productivity law.

The researcher Eduard Vives, from the Faculty of Physics of the UB, led the research in which collaborated several researchers from the Faculty —located at the BKC—, Xavier Illa, Antoni Planes and Jordi Baró (the main author), as well as Álvaro Corral, from the Centre for Mathematical Research (CERCA – Government of Catalonia), and researchers from the University of Cambridge, the University of Viena and the Institute for Scientific and Technological Research of San Luis Potosi (Mexico).

The material, analyzed by means of a device developed by the Materials Technological Unit of the Scientific and Technological Centers of the UB, is a porous glass (40 % porosity), designed for industrial applications, and named Vycor. The sample, about 5mm, was introduced between two plates and subjected to uniaxial compression that increases linearly until the sample fragments into pieces. Acoustic sensors were place on the compression plates. They will function as seismographs which measure ultrasonic acoustic waves and detect sample's fractures.

"The experiment carried out simulates the emergence of a new fault", explains the UB researcher Eduard Vives. "By this means —he continues—, we observed time distribution, which at the laboratory corresponds to some hours and in earthquakes to thousands of years". On the contrary, seismology study the space statistical changes considering the data obtained from high seismic activity areas, as California, and low activity ones. According to the researcher, "this symmetry in space and time reveals that it is probable that earthquakes behavior corresponds to any kind of self-organized criticality —as some theories state—, and if it could be proved, it would be a great advance to apply existent theories.

Several works have previously tried to establish comparisons between earthquakes and laboratory fracture of materials, mainly using rocks, but results were not completely reliable, as they do not reproduce all the properties of earthquakes. "This material allows to carried out experiments that control several parameters, such as or magnitude or speed", concludes Vives.

Four laws of statistical seismology

The results of the experiments performed with this material fulfill the four fundamental laws of statistical seismology. On the one hand, the energy detected by acoustic emissions varies as the Gutenberg-Ritcher law affirms; this law states that the number of earthquakes as a function of their radiated energy decreases as a power law.

To get a general idea of the different scales, it is important to remember that a big earthquake (magnitude 8) equals 1,000 Hiroshima bombs, whereas the maximum energy measured in the laboratory equals the fission energy of one uranium atom. This different magnitude corresponds, approximately, to a factor of 1027.

Another experiment made with this material studied the number of aftershocks produced after a big fracture and it has been observed that it decays with time, so the tendency to follow Omori's law is clear. "Laboratory maximum rate of aftershocks with time corresponds to some hours, whereas in earthquakes it last more than one hundred years", remarks the UB researcher.

The third law of statistical seismology is the one related to waiting times, which relates the time between two consecutive earthquakes. In this case, laboratory results obtained were compared to the ones got from the earthquakes happened in Southern California, and "although different scales, similarity is higher", affirms Vives. Finally, the productivity law was also proved, which relates the rate of aftershocks triggered by a mainshock to its magnitude: larger-magnitude earthquakes produce on average more aftershocks.

More information: Baró, J. et al. Statistical similarity between the compression of a porous material and earthquakes, *Physical Review Letters*, 22nd February 2013. DOI: 10.1103/PhysRevLett.110.088702

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