News Releases

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Researchers demonstrate existence of earthquake supershear phenomenon

PASADENA, Calif.--As if folks living in earthquake country didn't already have enough to worry about, scientists have now identified another rupture phenomenon that can occur during certain types of large earthquakes. The only question now is whether the phenomenon is good, bad, or neutral in terms of human impact.

Reporting in the March 19 issue of the journal Science, California Institute of Technology geophysics graduate student Kaiwen Xia, aeronautics and mechanical engineering professor Ares Rosakis, and geophysics professor Hiroo Kanamori have demonstrated for the first time that a very fast, spontaneously generated rupture known as "supershear" can take place on large strike-slip faults like the San Andreas. They base their claims on a laboratory experiment designed to simulate a fault rupture.

While calculations dating back to the 1970s have predicted that such supershear rupture phenomena may occur in earthquakes, seismologists only recently began assuming that supershear was real. The Caltech experiment is the first time that spontaneous supershear rupture has been conclusively identified in a controlled laboratory environment, demonstrating that super-shear fault rupture is a very real possibility rather than a mere theoretical construct.

In the lab, the researchers forced two plates of a special polymer material together under pressure and then initiated an "earthquake" by inserting a tiny wire into the interface, which is turned into an expanding plasma by the sudden discharge of an electrical pulse. By means of high-speed photography and laser light, the researchers photographed the rupture and the stress waves as they propagated through the material.

The data shows that, under the right conditions, the rupture propagates much faster than the shear speed in the plates, producing a shock-wave pattern, something like the Mach cone of a jet fighter breaking the sound barrier.

The split-second photography also shows that such ruptures may travel at about twice the rate that a rupture normally propagates along an earthquake fault. However, the ruptures do not reach supershear speeds until they have propagated a certain distance from the point where they originated. Based on the experiments, a theoretical model was developed by the researchers to predict the length of travel before the transition to supershear.

In the case of a strike-slip fault like the San Andreas, the lab results indicate that the rupture needs to rip along for about 100 kilometers and the magnitude must be about 7.5 or so before the rupture becomes supershear. Large earthquakes along the San Andreas tend to be at least this large if not larger, typically involving rupture lengths of about 300 to 400 kilometers.

"Judging from the experimental result, it would not be surprising if supershear rupture propagation occurs for large earthquakes on the San Andreas fault," said Kanamori.

Similar high-speed ruptures propagating along bimaterial interfaces in engineering composite materials have been experimentally observed in the past (by Rosakis and his group, reporting in an August 1999 issue of Science). These ruptures took place under impact loading; only in the current experiment have they been initiated in an earthquake-like set-up.

According to Rosakis, an expert in crack propagation, the new results show promise in using engineering techniques to better understand the physics of earthquakes and its human impact.

According to Kanamori, the human impact of the finding is still debatable. The most damaging effect of a strike-slip earthquake is believed to be caused by a pulse-like motion normal to the fault caused by the combined effect of the rupture and shear wave. The supershear rupture suppresses this pulse, which is good, but the persistent shock-wave (Mach wave) emitted by the supershear rupture enhances the fault-parallel component of motion (the ground motion that runs in the same direction that the plates slip) and could amplify the destructive power of ground motion, which is bad.

The outstanding question about supershear at this point is which of these two effects dominates. "This is still being debated," says Kanamori. "We're not committed to one view or the other." Only further laboratory-level experimentation can answer this question conclusively.

Several seismologists believe that supershear was exhibited in some large earthquakes, including those that occurred in Tibet in 2001 and in Alaska in 2002. Both earthquakes were located in a remote region and had little, if any, human impact, but analysis of the evidence shows that the fault rupture propagated much faster than would normally be expected, thus implying supershear.

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