SEISMOLOGY: Do Early Tremors Give Sneak Preview of Quake's Power?

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SEISMOLOGY

Do Early Tremors Give Sneak Preview of Quake's Power?

Seismologists can give residents of earthquake zones a few seconds' warning of a coming quake—enough time to shut down nuclear reactors and slow high-speed trains—by analyzing the first waves the quake produces. But key information has been missing. "We know in a few seconds where an earthquake occurs, but we cannot predict the magnitude," says Paul Rydelek of the National Research Institute for Earth Science and Disaster Prevention in Tsukuba, Japan. Now, Italian researchers say the same waves can reveal how strong the tremor will be, allowing a more appropriate disaster response. Some experts are skeptical, but Marie-Paule Bouin of the Institute for the Physics of the Globe in Paris finds the data presented by the Italian team "convincing enough" to be looked at seriously.

Hopes flattened. A rescuer passes a school destroyed by a 2002 quake in southern Italy. Early warning systems hope to give several seconds' alarm.

The first earthquake signals to arrive at a seismic station are the primary or p-waves, which are compression waves like sound in air. P-waves travel fast, about 6 kilometers per second, but they do not carry the destructive force of the secondary or s-waves: shear waves that cause the ground to oscillate. S-waves travel at 3.5 kilometers per second and, depending on the distance to the epicenter, can arrive several seconds later.

Early Earthquake Warning (EEW) systems work by spreading seismic detectors over earthquake-prone regions and using fast digital processing to give a few seconds' warning of a coming quake (*Science*, 24 December 2004, p. 2178). By combining the signals received at several stations, an EEW can estimate the position of the epicenter, but judging the magnitude of the quake is trickier. Seismologists can get a rough estimate from the frequency of the early p-waves. But Aldo Zollo and his colleagues at the University of Naples and the National Institute of Geophysics and Volcanology in Rome think the amplitude, or strength, of the p-wave can give a better indication of the tremor's destructive power.

The Italian researchers analyzed records from seismic stations sited less than 50 kilometers from the epicenters of 207 earthquakes that occurred between 1976 and 1999 in the Mediterranean area. The magnitudes of the quakes ranged from 4 to 7.4. The team compared the peak amplitude of the first 2 seconds of the p-waves to the amplitude of the s-wave in their sample and found that both quantities correlate closely enough with the quake's magnitude to be useful in EEW systems.

To use that information to gauge the magnitude of an impending quake, forecasters would need to know the distance to the epicenter. In a real-life situation, that information might not arrive in time, but Zollo thinks future EEWs will be able to supply it. "As the wavefront propagates in the network, you measure the amplitudes and compare the results of each station with the quantities measured at the other stations in the network," he says. In this way, the network will quickly zero in on the location of the epicenter and the magnitude of the event, in time to trigger alarms at sites farther away seconds before the destructive s-waves arrive.

Predicting earthquakes is a notoriously tricky business, and other researchers have expressed some skepticism over Zollo's claims of better warnings. Because Zollo and his team did not study quakes with a magnitude greater than 7.5, their technique may not apply to the most destructive events, says François-Henri Cornet of the Institute for the Physics of the Globe. "The conditions of the propagation of seismic wavefronts change at these magnitudes," he says. Earthquakes also don't always develop in a tidy, symmetrical way. "The seismic wavefronts are often anisotropic, or are projected strongly in one direction, which can introduce errors," admits Zollo.

Errors aside, some researchers don't think it is possible to predict the magnitude of an earthquake, which depends on the total rupture length, by looking at seismic waves produced during its initial moments. "Once an earthquake begins, it will proceed essentially as a series of dominoes being knocked over. Sometimes the domino chain will stop, and at other times it will continue to go for a long distance," says William Ellsworth of the U.S. Geological Survey in Menlo Park, California. Whether the start of the chain holds clues to its ultimate length "is still an open question," he says.

Zollo argues that the initial amplitude peak of the p-wave does carry such clues. "The probability that a fracture grows to a larger size scales with the initial energy available. The stopping mechanisms become less efficient for earthquakes with an initially high energy," he says. Rydelek, however, remains skeptical. "I would like to see the physics that links these first seconds to the rupture propagation over the whole fracture," he says. "You can have twists and turns in the fault, and stress variability, and these really determine how big the earthquake gets, not the initial slip."

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