Scientists Find Way to Estimate Quake Strength

By Usha Lee McFarling, Times Staff Writer

A new analysis suggests weak waves generated in the first few seconds of a large earthquake can be used to predict the magnitude and severity of ground shaking before a fault has finished rupturing, potentially offering crucial seconds of early warning before damage occurs.

"We can rapidly estimate the magnitude and location of an earthquake and create a map of the distribution of ground shaking that we call AlertMap," said Richard M. Allen, a seismologist at the University of California at Berkeley who conducted the study with Erik L. Olson of the University of Wisconsin, Madison. The work is published in Thursday's issue of the journal Nature.

If there were a system in place to transmit the information, notice of impending shaking could be disseminated in about five seconds, Allen estimated. Very large quakes, such as the magnitude 7.9 earthquake that hit Alaska in November of 2002, can last for more than a minute.

Shaking begins almost immediately near an epicenter, but it can take seconds, or tens of seconds, for shaking to occur in areas farther away. An earthquake that began at the far northern edge of the San Andreas Fault, for instance, would not be felt in San Francisco for 80 seconds, Allen said. Damaged areas some 40 miles from the epicenter of the magnitude 6.7 1994 Northridge quake did not feel shaking for 20 seconds, he added.

That may not sound like much, but since earthquakes cannot now be predicted in advance, emergency planners are interested in any warning they can get. Even a few seconds notice could be enough to turn off natural gas to prevent fires, isolate electrical and phone systems to protect them from massive failure, have children dive under their school desks and allow surgeons in the midst of operating to pull scalpels away from vital organs.

"Fifteen seconds, seems huge to me," said Lucy Jones, the scientist-in-charge at the United States Geological Survey office in Pasadena. "We have engineers who say, if you could give me 100 nanoseconds, it would be useful."

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While Jones and many other earthquake and public safety officials are eager for any early warning, they disagree on whether the newly published study will bring their field any closer to a workable system. One problem, said Jones, is that the information yielded in the early seconds of a quake is not precise.

"It tells you it might be a magnitude 3.5 or it might be an 8," she said. "I wouldn't want to be issuing early warnings based on this."

Allen agreed that there was imprecision in his method, which he used to analyze earthquakes around the world in areas where the underlying geology is vastly different. When confined to smaller regions with more consistent geology, it could be more precise, he said.

The method takes advantage of the fact that weak P, or primary waves, start to radiate away from a fault almost immediately and travel at speeds of 3 to 5 miles per second. The S, or secondary waves that jerk and roll the ground and cause most earthquake destruction, travel more slowly.

Allen and Olsen analyzed 71 earthquakes, including 24 that were greater than magnitude 6. They found the frequency signals of P waves were different for small and large earthquakes: large earthquakes emitted P waves of a lower frequency. Using a mathematical model, they were able to estimate the magnitude of the quake in four seconds and sometimes in as few as two seconds. Traditionally, earthquake magnitudes are not estimated until after the earthquake has ended.

The differences in P-wave frequencies suggests that larger earthquakes start off with a large amount of slip on a fault and smaller earthquakes start with a smaller slip, Allen said.

That may sound like an obvious relationship, but scientific doctrine suggests all earthquakes — large and small — start with a small event. In small quakes, the rupture stops relatively soon. In larger quakes, a small slip loads stress onto the patch of fault next to it, and the rupture continues, or cascades, through a longer segment of fault.

In this theory, external factors such as stress buildup on portions of the fault regulate how big an earthquake will eventually become; the first few seconds of the earthquake are not deemed that important.

The new paper is controversial because it is among an emerging body of work suggesting this widely held "cascade model" of how earthquakes propagate is wrong.

"People have been very skeptical," Allen said of his results. "I'm as surprised as anybody."

The cascade model is considered "pessimistic" because if earthquakes all start out the same, there is little hope that early information from earthquakes would be of any use. In contrast, Allen's view offers hope for early warning systems because valuable information may be encoded in the first moments of an earthquake, said Tom Jordan, a seismologist at the University of Southern California and director of the Southern California Earthquake Center.

"When it's a small fraction of what it's going to be, it's already played its cards and said, 'I'm going to be big,'" Jordan said. "That offers hope."

Bill Ellsworth, a geophysicist and former chief scientist at the United States Geological Survey in Menlo Park published a controversial paper in 1995 suggesting that weak, irregular rumblings generated in the very first seconds of an earthquake might provide information about the size of a quake to come.

He said the work being published today is encouraging, but thinks making meaningful predictions for early warning will take a lot more data, and close-up observations of quakes as they occur. That information may start to come from a hole drilled directly into the San Andreas Fault in the earthquake-prone town of Parkfield in central California, where the USGS has an intensive monitoring program, Ellsworth said.

"We have to get inside the earthquake to see what makes it tick," he said.

In southern California, early warning systems would be useful for large quakes generated on the San Andreas Fault some distance from population centers. The information would not be as useful on the many faults that criss-cross the Los Angeles basin near the surface and densely populated areas. "Unfortunately, the reality is the damage is going to be in the epicentral region, where the earthquake begins, and there you don't have any warning," Ellsworth said.

Much simpler early warning systems are already in place in Japan, where the detection of ground shaking slows and stops bullet trains to decrease the risk of derailments. Taiwan, Turkey and Mexico City also have simple early warning systems, based on the detection of distant shaking that are working well, seismologists said.

Simple P-wave detectors are in place in some California fire stations; in some cases, they are rigged to automatically open firehouse doors when shaking occurs so jammed doors do not trap trucks inside.

Allen is currently testing a system he calls ElarmS to create early warning maps. Jones said her USGS office is taking early steps to test if any early information from quakes could provide rapid warning without generating an unacceptable level of false alarms. Both scientists foresee the future possibility of having early warnings go to sirens at schools, personal computers or cell phones.

There are currently no plans for a statewide or regional early warning system, said Eric Lamoureaux, a spokesman for the Governor's Office of Emergency Services. "It's something that's really in its infancy and needs a lot more research from the scientific community," he said.

James Goltz, who is with the earthquake and tsunami program of the Governor's Office of Emergency Services, said emergency managers are interested in an early warning system, but only if it is accurate, reliable and can enhance public safety — a goal he estimates is still several years away. "At this point, it's essentially in research development, not something that's ready for deployment."

Jones of the USGS said any early warning system would require funding to improve the region's existing network of seismic sensors and pay for phone lines required to send out constant streams of monitoring data.

Such an investment would be worthwhile, she said, even before scientists work out the details of how best to use any scant early information from quakes to provide warnings. The existing network of sensors, called the Southern California Seismic Network, provides nearly instant information to help first responders reach earthquake victims and yields data that engineers can use in improving building design. Upgrading the network would improve that capability and prepare the network for use in some future early warning system — one that seismologists agree is long overdue.

"It's frankly appalling to me," Jordan said, "how far behind this country is in developing early warning systems."

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