# LAST-MINUTE WARNINGS MAY MAKE QUAKES LESS DESTRUCTIVE

***BY ERIC NIILER***

Earthquakes are one of nature's most terrifying and destructive forces. Over the past decade, quakes in Haiti, China, India and Nepal have killed 400,000 people, while a 2004 earthquake-driven tsunami killed more than 250,000 people in 14 nations around the Indian Ocean. In November, a quake struck Afghanistan and Pakistan, killing hundreds and destroying thousands of homes.

The United States has been spared the strongest temblors in recent years, but West Coast residents and earthquake scientists continue to worry about "the big one" there.

Now researchers say that with a combination of ground sensors and satellite-based instruments, they are getting closer to giving people a crucial minute or two of warning, though they acknowledge that predicting exactly where and when an earthquake will strike remains an elusive goal.

"When I started in this field 30 years ago, that was the goal," Thomas Heaton, a professor of geology and geophysics at the California Institute of Technology, said about whether it's possible to make such predictions. "But the answer today is pretty clearly, no. The more we looked at the problem, the more we understood that all the earthquakes aren't the same."

A short warning might not help if you are driving along an elevated freeway or if you're on the top floor of a skyscraper. But researchers are working to connect these warnings to automated systems that would slow down trains; turn off gas lines; stop elevators and open their doors before they get stuck between floors; and turn all traffic lights red. The warning systems detect sound waves that occur just before a quake's destructive shock, giving people and machines a little time to hunker down.

Los Angeles and the San Francisco Bay area are moving forward with a system called ShakeAlert because, sitting atop a series of faults, they are most at risk for a quake of around magnitude 8.0. (The last big California quake, in 1989, was magnitude 6.9.) In Seattle, which some scientists believe is overdue for a quake that could be greater than magnitude 9.0, researchers at the University of Washington began testing ShakeAlert this year, receiving data from sensors and then analyzing it and generating alerts that are sent to system testers. In August 2014, California's ShakeAlert system got a real-world test when a 6.0 earthquake rocked the Napa Valley in the middle of the night, injuring more than 100 people. An alert was sent to Bay Area Rapid Transit, which would have slowed trains had they been running at that time.

Some sensors have been deployed along the East Coast by the U.S. Geological Survey and several university partners, but they are being used only to collect data about seismic activity.

Chile's early-warning system helped give people time to prepare for the 8.4-magnitude temblor that struck on Sept. 16 and left eight people dead. A similar quake in 2010 killed more than 500 people; experts credit the warning system, along with infrastructure improvements, with the lower fatality count in the September event.

Mexico, China, Taiwan, Turkey and Israel are also developing earthquake detectors.

In the next five years, U.S. officials hope to be able to send out text messages as much as two minutes before a quake — giving people a chance to duck and cover.

Such alerts, combined with more sophisticated forecasting models and new ways of measuring temblors by using orbiting satellites, are examples of how technology is driving improvements in earthquake science, experts say.

The earth's outer crust is not one solid piece of rock, but is made up of moving plates that bump into, pull away from or slide past each other. Most earthquakes occur where two plates slide past or run into each other.

However, not all earthquakes occur at the edges of plates. Fault lines

→

— cracks in the crust that form as plates move — can be far from the edge, yet earthquakes can readily occur there. When underground rock breaks at a fault line, the energy released causes the ground to shake. Well-known fault lines include the 800-mile-long San Andreas fault in California and the previously unknown fault that caused a 5.8-magnitude quake to rumble through the Washington, D.C., area in 2011, causing cracks in the Washington Monument and the National Cathedral towers.

Earthquakes unleash huge amounts of energy. The 9.0 Tohoku quake in Japan — which released what scientists said were several centuries' worth of tectonic plate pressure — jolted the seafloor 164 feet side to side and upward by 52 feet in 2011, creating a tsunami that killed at least 15,800 people and caused a meltdown at the Fukushima Daiichi nuclear power plant. The 7.8-magnitude Nepal earthquake in April 2015 moved Mount Everest an inch to the southwest.

They are also impossible to predict, according to Yehuda Bock, director of a center at the Scripps Institution of Oceanography in La Jolla, Calif., that supports earthquake research.

"If you go into a lab and stress rocks, and create conditions that are in the real world, you won't know when that rock is going to crack," said Bock, who has been studying earthquakes since the late 1980s. "Eventually you will be able to get more and more information by looking at frictional qualities of the rocks. But to extrapolate to the real world is difficult."

The San Andreas fault, for example, runs 10 to 15 miles below the surface, Bock explained. "There you have different kinds of rocks, there could be water that lubricates the faults; there are very many variables."

All those variables make impossible predictions of weeks, days or even hours. But that doesn't mean that science can't better understand how earthquakes work or how to read quakes' signals.

Bock is a geodesist, someone who studies the shape of the Earth. In 1992, his system, which uses Global Positioning System satellites, was the first to monitor the deformation of the Earth's crust before, during and after an earthquake, a magnitude-7.3 event near Landers, Calif. Two years later, a magnitude-6.7 quake struck in the San Fernando Valley near Los Angeles on a previously unknown fault, causing dozens of deaths and significant damage to infrastructure.

Doug Given-The Washington Post

A team builds a seismic monitoring site in Joshua Tree National Park near the San Andreas fault. Its data will help warn of imminent quakes.

## Detecting Earthquakes – How Much Time?

**By Devorah Klein**

The ability to accurately predict earthquakes, thus allowing people time to evacuate affected areas, still seems to be years away. While researchers continue to work on various methods, no solution is imminent. However, there is some limited ability to detect earthquakes in their early stages, giving a small window within which one can seek safety.

What advantage does that provide? We spoke to Dr. Shoshana Kohen-Kadosh, a science teacher at Shulamith High School in Brooklyn with a doctorate and post-doctoral research in earthquake science, and asked her to explain.

"The ground motion set off by an earthquake goes through various stages," explains Dr. Kohen-Kadosh. "Usually, the first shaking is not the strongest or most damaging. Depending on how far one is from the center of the quake, a certain amount of time passes before one begins to feel the motions and, finally, the more damaging waves. We have the technology to detect the first motion of an earthquake that has already started and broadcast an announcement before nearby communities feel the stronger, subsequent shaking. These early detection systems continue to be further improved."

But these early detection systems give less than one minute's notice — sometimes only a few seconds — before the strong waves of an earthquake are felt. Nonetheless, notifications of those first motions can effect actions that will greatly limit damage from the quake. For example, notifications have been used to alert emergency responders, stop the high-speed bullet trains in Japan, and shut off gas lines in California to prevent fires from breaking out.

What about for the average person at home? Twenty seconds is still enough time to go hide under a table, or move away from a large computer screen that might go flying during a quake. Ideally, this early detection system could be linked to a cell phone alert, thus notifying large numbers of people.

"In the United States, strong construction standards are well enforced," adds Dr. Kohen-Kadosh. "Most buildings do not collapse in earthquakes that are large enough to have caused devastating damage in other countries. Most earthquake injuries in the United States are from flying objects, not buildings collapsing. As scientists often say, 'Earthquakes don't kill people — buildings do.'"

Building codes in the United States call for reinforced walls and strong foundations, among other requirements. Consequently, the greatest danger in an earthquake is being struck by a large object that has been tossed about the room. Therefore, hiding under a table or in some other area where projectiles will not reach is the best action to take.

A case in point: In California in 1999, a group of research scientists were sleeping in tents out in an open field. A strong earthquake measuring over 7.0 on the Richter scale hit the area where they were camped, and yet they all emerged unharmed — there was nothing to fall down on them besides their tents!

Regarding general preparedness for natural disasters, Dr. Kohen-Kadosh explains that preparing for the possibility of earthquakes is not much different from preparing for other natural hazards, like hurricanes or tornadoes. This includes keeping a stock of non-perishable groceries and bottled water, flashlights with working batteries, a basic first aid kit, and making sure your car does not get too low on gasoline should there be a disruption in gas supplies.

In earthquake-prone regions like California, people are advised to secure heavy pieces of furniture to the wall. In local hardware stores, one can buy kits with heavy straps, Velcro or bolts that can be used to attach a dresser or bookshelves to the wall. Kits are also available for attaching large computer monitors or printers to a desk. ■

"Those two earthquakes spurred interest in what we are doing," Bock said. "From that point on, we were able to steadily increase the number of stations."

His system's monitoring stations continuously collect GPS data that is transmitted in real time to the Scripps lab.

Specialized software uses this information to determine the precise position of the station in three dimensions with an accuracy of a fraction of an inch. By observing how the positions shift in seismically active regions, scientists can estimate the slow accumulation of strain in the crust due to tectonic forces. They can use these observations and other data to model the motion of the fault far below the surface. However, it is difficult to extrapolate these motions to the state of stress in the crust.

One way that Bock and others are trying to measure the likelihood of a future earthquake is by looking at the past. If they know that an area has a history of, say, magnitude-6.0 earthquakes every 30 years and there hasn't been one for 60 years, that's a good indication that one is overdue. Based on such information, scientists assign probabilities that a particular geologic fault will erupt within a certain number of years.

Yuri Fialko, a colleague of Bock's at Scripps, has used this type of information to warn that the southern portion of the San Andreas fault is overdue for a large earthquake.

Another indicator is how much the ground has moved on both sides of the fault. "If we can tell this fault should have moved by six inches and hasn't," Bock said, "then enough stress has built up that we are in a danger zone."

"The stress can be released in one large earthquake or several small earthquakes," Bock added. "But we don't know exactly what magnitude it is going to be or when it is going to happen. We're not at a point where we can predict earthquakes; we are at the point where you can issue probabilities of an earthquake happening over the next 50 years over a particular general location. We really can't do much more than that."

In 1988, the U.S. Geological Survey said that Parkfield, California, was overdue for a magnitude-5.5 earthquake and expected one within the next five years. The agency wired the town with lots of sensors. But the quake didn't happen until 2004, and despite the sensors it occurred without warning. Since then, USGS officials have shied away from making similar predictions.

"In academic circles, there is a fairly widespread feeling that [prediction] is not something that respectable people do," said John Rundle, a distinguished professor of physics and geology at the University of California at Davis. "It stems from the fact that there have been many failures."

While the five-year prediction about Parkfield didn't come true, the USGS is taking the lead in the ShakeAlert warning system, which is relying on a combination of traditional seismic sensors and the type of GPS receivers that Bock and others have been using.

In 2013, the California legislature passed a bill requiring the establishment of such an alert system, but it didn't approve any money. The federal government has approved only a small portion of the funds needed to build and operate the system. According to Doug Given, the USGS earthquake early-warning coordinator, about 600 of the planned 1,600 sensors have been installed, mostly paid for by cooperating companies and utilities.

For Given and others, the real challenge is not so much the science but the software engineering needed to get the alert out. The trick is picking up the initial signal of the quake, called the p-wave, or primary wave, and getting out that information before the s-wave, or shock wave, hits a particular spot, a time lag that can be as little as 10 seconds or as long as several minutes, depending on the spot's distance from the quake's epicenter.

"How do you get the notification out to millions of people in as little time as possible?" Given said from his office in Pasadena, Calif. "Most people assume that you can just send them a text message. No system can send 12 million text messages at one time." (The population of the Los Angeles area is more than 18 million.)

Until such issues are worked out, earthquake alerts are currently going out only to first responders, utilities and companies that have earthquake-sensitive operations, Given said. The ShakeAlert system was used during an August 2014 earthquake that struck the Napa Valley, just northeast of San Francisco. The Bay Area Rapid Transit system received the alert; however, because the temblor hit at 3:20 a.m. trains weren't running.

Sending mass alerts to "the general public is the very last step," Given said. "It will require a significant amount of training and education. With the first Amber Alerts, many people were annoyed, and very upset. There's a lot of social science and psychology to have alerts go right with the public." *(The Washington Post)* ■

# A STUDY IN MAGNETIC FIELDS

**BY RHONA LEWIS**

While researchers at the California Institute of Technology are using a combination of ground sensors and satellite-based instruments to try to predict where and when an earthquake will strike, Ezra Mizrahi of Geomap is researching how the Earth's magnetic field can be used to predict the same thing. The challenge, Mizrahi points out, is that many other factors — such as solar wind, which is a stream of charged particles flowing outwards from the sun — also affect the Earth's magnetic field.

It all begins with brief fluctuations, or pulses, in the Earth's magnetic field that have been detected before many earthquakes. Instruments called magnetometers near the earthquake's epicenter can pick up these pulses, which become more frequent as the day of the earthquake approaches.

Mizrahi's research, however, doesn't focus on the pulses themselves. In a phenomenon called coupling, these pulses are reflected in changes in the ionosphere of the Earth, and even further away, in the visible photosphere of the sun. "Before the tsunami in 2004, I was able to spot the formation of a sunspot on the sun's photosphere," says Ezra. Knowing that a sunspot is an area of a strong magnetic field, which can, under some conditions, reflect the pulses of the earth's magnetic field, Mizrahi knew that there would be a large earthquake, but he couldn't pinpoint when or where. Three months after the original tsunami, a second earthquake struck the same region. As he expected, Mizrahi noticed a similar sunspot that had formed on the same area of the sun's photosphere. "The number of sunspots waxes and wanes with an approximate 11-year cycle," he says. "Since global earthquakes don't follow any cycle, any prediction becomes more complicated. Therefore, I've moved on to a second area of research."

This second area concerns the dynamic waves that are released after an earthquake. "The energy that is released when an earthquake happens doesn't affect only that earthquake," Mizrahi says. "It affects also the earthquake that comes after it." These phenomena are known as remotely triggered shocks. Think of a row of dominoes or cards lined up. Touch one and you affect the rest of the row. "I am now in the process of checking a learning algorithm (step-by-step data processing) that I have deduced against the historical data that we have of past earthquakes. Once I am able to accurately match my algorithm to past earthquakes, I'll have more information on how to predict the location of future earthquakes."

Mizrahi's breakthrough will come when he is able to combine both areas of his research. The first, on changes in the magnetic field of the sun, will give us information on the time of the next earthquake. The second, on the dynamic pressure of earthquakes, will give us information on its location.

So how close are we to being able to predict the next earthquake? "In about five to 10 years, when we will be able to unify the majority of variables that cause an earthquake, we will be able to predict one," answers Mizrahi. And should Israel prepare for a possible earthquake? "According to statistics, we're due for an earthquake that could reach 6.0 on the Richter scale," he says. "But keep calm, because statistics are unpredictable and we don't see any other signs to worry about." ■