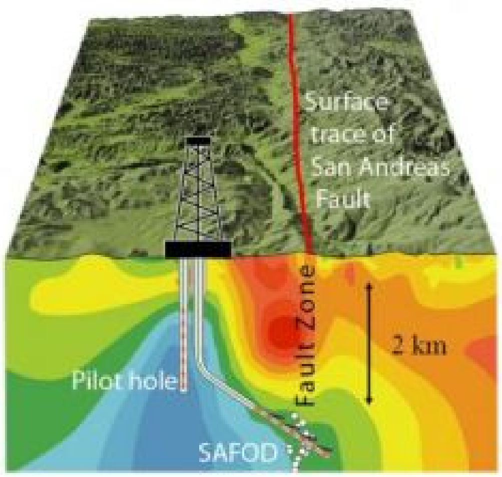
Early earthquake warning: New tools show promise

July 9 2008



Seismic waves were generated in the pilot hole of the San Andreas Fault Observatory at Depth, near Parkfield, Calif., and detected in the main hole, at depths of approximately one kilometer. An inverse correlation was found between changes in wave travel time and barometric pressure, causing increased stress in the rock. Credit: NSF

Using remarkably sensitive new instruments, seismologists have detected minute geological changes that preceded small earthquakes along California's famed San Andreas Fault by as much as 10 hours.

If follow-up tests show that the preseismic signal is pervasive, researchers say the method could form the basis of a robust early warning system for impending quakes.

The research appears this week in the journal *Nature*.

"We're working with colleagues in China and Japan on follow-up studies to determine whether this physical response can be measured in other seismically active regions," said Rice University seismologist Fenglin Niu, the study's lead author. "Provided the effect is pervasive, we still need to learn more about the timing of the signals if we are to reliably use them to warn of impending quakes."

Today's state-of-the-art earthquake warning systems give only a few seconds' warning before a quake strikes. These systems detect P-waves, the fastest moving seismic waves released during a quake. Like a flash of lightning that arrives before a clap of thunder, the fast-moving P-waves precede slower moving but more destructive waves.

Findings from the new study indicate that the stresses measured by the new instruments precede the temblor itself, so a warning system using the new technology would be fundamentally different from current warning systems.

"Detecting stress changes before an earthquake has been the Holy Grail in earthquake seismology for years and has motivated our research," said study co-author Paul Silver of the Carnegie Institution of Science's Department of Terrestrial Magnetism. "Researchers have been trying to precisely and continuously measure these velocity changes for decades, but it has been possible only recently, with improved technology, to obtain the necessary precision and reliability."

In experiments near Parkfield, Calif., in late 2005 and early 2006, Niu, Silver and colleagues from Lawrence Berkeley National Laboratory (LBNL) gathered two months of measurements at the San Andreas Fault

Observatory at Depth, or SAFOD, a deep well seismologists use to make direct measurements of the fault.

The team installed a high-precision seismic source made by a stack of donut-shaped piezoelectric ceramic cylinders that expand when voltage is applied -- a sophisticated device akin to a stereo speaker -- about one kilometer beneath the surface. At the same depth in an adjacent well, the scientists set up an accelerometer to measure the rhythmic signals from the source device.

When rocks are compressed, the stress forces air out of tiny cracks in the rock. This causes seismic waves to travel slightly faster through the rock. Niu said the variations are so slight they can be measured only with very precise instruments. For example, though the Parkfield instruments were more than a half mile below ground, the setup was sensitive enough to measure fluctuations in air pressure at the Earth's surface.

"Scientists tried as early as the 1970s to measure changes in wave speed that are associated with the stress changes that precede seismic activity," Niu said. "For a variety of reasons, their measurements were inconclusive. Using the precision instruments built by our collaborators at Lawrence Berkeley National Laboratory, along with new signal enhancement techniques, we were able to reach the fine level of precision required."

In analyzing the seismic data, Niu and colleagues found that a distinct change occurred in the rock before each of the minor earthquakes near Parkfield during the test period. A measurable change preceded a magnitude 3 quake on Christmas Eve 2005 by 10 hours. This was the largest local event during the observation period. A smaller but closer magnitude 1 temblor five days later was preceded by a signal about two hours before the quake.

Source: Carnegie Institution