Silent earthquakes may foreshadow destructive temblors

July 5 2006

A team of American geoscientists is urging colleagues around the world to search for evidence of tiny earthquakes in seismically active areas, such as the Pacific Northwest, that are periodically rocked by powerful temblors of magnitude 8 and higher.

The scientists' call for action, published in the July 6 edition of the journal *Nature*, is based on their surprising discovery in Hawaii that slow-moving "silent earthquakes"--so-called because they produce no seismic waves--can, in fact, trigger swarms of tiny conventional temblors.

"In the last six years, there's been an explosion in research in what people are calling slow, silent or aseismic earthquakes," said Paul Segall, professor of geophysics at Stanford University and lead author of the Nature study. "In our paper, we describe four aseismic events that occurred on the Big Island of Hawaii. What made them interesting to us is when we realized that all four were associated with swarms of small seismic earthquakes of M2 and M3."

These swarms of micro-earthquakes are a clear sign that the silent temblor is adding stress to the fault zone, say the authors, and some day might provide an early warning that a harmless silent event is likely to trigger a destructive mega-earthquake of M8 or larger.

Global hazards

Unlike seismic earthquakes, which release sudden shock waves, silent temblors are too slow to cause ground shaking and thus are not considered hazardous. However, some researchers have speculated that silent quakes may be precursors of M8 and M9 mega-temblors that regularly occur in subduction zones--seismically active regions where one tectonic plate is constantly diving ("subducting") beneath another. Some of the biggest earthquakes ever recorded have occurred in subduction zones, including the devastating M9.2 Sumatra temblor in 2004, which generated huge tsunamis that killed more than 200,000 people.

"Silent earthquakes have recently been discovered in subduction zones in the Pacific Northwest, Japan, Mexico and elsewhere," Segall says. "It is likely that as these silent slow-slip events occur, the probability of a bigger seismic quake goes up."

The Pacific Northwest subduction zone along the coast of Washington State and British Columbia was struck by a M9 earthquake in 1700, and another is expected within 300 years. Given that thousands of lives are at risk in greater Seattle and Vancouver, scientists are eager to come up with a more precise time frame for the next big one. In 2001, Canadian geophysicists offered a glimmer of hope with the discovery that silent quakes in the Pacific Northwest occur every 14 months or so, like clockwork. The remarkable predictability of these aseismic events has raised the possibility that silent temblors may be useful in seismic hazard forecasting, not only in the Pacific Northwest but in other subduction zones around the world.

But first, Segall cautions, seismologists need to find a dependable method of pinpointing the source of silent temblors, and tiny earthquakes may hold the key.

"One of my goals is to convince my colleagues to go back to the subduction zones and look very carefully where these silent events are occurring, and see if we can find any micro-earthquake activity during that period," he said. "Then if we detect an increase in the rate of those very small earthquakes, that would give us a way of quantifying how much the hazard has gone up, because each of those small events has some probability of growing into a very large event."

Volcanic quakes

In the Nature study, Segall and Stanford graduate students Emily Desmarais and David Shelly, along with U.S. Geological Survey scientists Asta Miklius and Peter Cervelli, focused on four silent earthquakes that struck Kilauea volcano on Hawaii's Big Island between 1998 and 2005. The four events were detected by a dense network of Global Positioning System (GPS) stations installed along the active southern flank of the volcano. "All four silent quakes seem very similar," Segall says. "They displaced the ground in the same place, the same GPS stations moved in the same direction and more or less the same amount."

Of particular interest was a slow moving silent quake of M5.7 that struck on Jan. 26, 2005 and continued for about 48 hours. "In the Pacific Northwest, slow-slip events typically last about two weeks," Segall observed. "In Japan, they seem to come in two flavors--short, on the order of a couple of days, and long events that last from months to years."

What made the Kilauea event stand out was the fact that it was accompanied by a swarm of about 60 conventional micro-earthquakes of M2 and M3, or roughly 30 micro-earthquakes per day. That's about six times higher than the number of small quakes that typically occur on that section of the volcano.

"In the *Nature* paper, we looked very carefully at when the GPS stations started moving, because we wanted to know, did the earthquakes begin first and then the slow slip, or did the slow slip start and the earthquakes follow?" Segall asked. "In other words, which was causing which?"

An analysis of the GPS data revealed that the silent quake moved first, triggering the swarm of micro-earthquakes within 24 hours. "So the fault is moving, and it's causing these tiny co-shocks and aftershocks to occur," Segall explained. "That's never been seen before in Hawaii, the Pacific Northwest, Japan, Mexico, Peru, Alaska--anyplace where these slow events are kicking up."

Once the research team knew the correct sequence of events, they were able to apply the basic principals of geophysics to determine where the silent quake began. "We're very confident that the slow slip occurred at a depth of about 5 miles [8 kilometers], whereas using the GPS data alone it was very ambiguous," Segall said. "The bottom line is that these small earthquakes actually allow us to pin down where the slow slip is occurring. That's neat. That helps us understand how Kilauea volcano is working."

The Hawaiian Islands are located in the middle of the Pacific tectonic plate above a hotspot that's continually spewing magma from the Earth's mantle. But Segall and his colleagues hope that a similar pattern--a silent slip followed by micro-earthquakes--can be found in subduction zones as well.

"First of all, we have to establish whether we can even see these micro-events in places like Washington State or Japan," he said. "On Kilauea, small earthquakes are an everyday occurrence. But in the Pacific Northwest, you might only have one micro-earthquake per year, and even if you increase that to 10 events per year, you still might not see the pattern."

If seismologists discover that silent temblors do, in fact, trigger micro-earthquakes in subduction zones, they will be able to use those tiny temblors to determine the depth of the silent event and whether it's adding stress to the fault system, he added: "We assume that slow-slip events in subduction zones occur at least 25 miles [40 kilometers] below the surface at the interface of the tectonic plates, but we can't prove that, because the data we have now are insufficient to accurately locate them."
Runaway quakes

Finding swarms of small earthquakes is only part of the story, say the authors. The next task will be to determine if the magnitude of the triggered quakes increases over time. According to Segall, conventional seismic earthquakes follow a statistical pattern: For every step down in magnitude, there is a ten-fold increase in the number of smaller earthquakes. For example, for every M6 there will be 10 M5s, 100 M4s and so on. Likewise, if there is one M6 per year, it will correlate with one M7 per decade and one M8 every 100 years.

"We don't know if that pattern is true for silent slow slip events, but that's something we should look for," he explained. "One of the models for earthquake nucleation is that a big earthquake is just a little earthquake that runs away. If you start nucleating, like we did in Hawaii, an extra 25 or 30 events per day, one of those does have the potential to grow into a bigger event. So one of those small ones, instead of stopping at a M2, could keep going."

Seismologists estimate that mega-thrust events of M8 or larger occur in the Pacific Northwest roughly every 500 years, in Sumatra about every 300 to 500 years and in Japan every 200 years or so.

"As we move through those cycles, the overall stress level on the fault is gong to rise and rise," Segall said. "These little events like we see in Hawaii are places where the stress is locally a little bit higher, and that's why get those M1s and M2s. But the overall stress level in the fault is going up year after year, until eventually we get a mega-thrust event--a big one. It's possible that each time a slow event occurs, and as we get later and later in the cycle, or closer and closer to the really big one, these slow events should start to get bigger, because the area that's getting closer to failure will have grown larger. And as we get closer to the big event, what starts out as a M1 today could start growing into M2s, M3s, M4s and so on. If we could see such a pattern, then each slow event will become like a gauge that tells us something about the distribution of stress in the area where the big earthquake eventually is going to nucleate.

"In other words, we could use these micro-earthquakes as a way of studying the stress on the plate interface in subduction zones. It's potentially very exciting, and I'm hoping that our paper will prompt seismologists around the world to look very carefully at their data sets to see if there is any evidence for very tiny events."

Source: Stanford University

Citation: Silent earthquakes may foreshadow destructive temblors (2006, July 5) retrieved 24 April 2024 from
https://phys.org/news/2006-07-silent-earthquakes-foreshadow-destructive-temblors.html