Silent Earthquakes Lurk Beneath Costa Rica

by Michelle Herrick

Tropical destinations like the Nicoya Peninsula in Costa Rica attract not only surfers and beach bums, but also seismologists. A major active fault zone is slipping unnoticeably to an average person beneath the peninsula. To researchers, these slow slips—also known as "silent earthquakes"—became clear thanks to a network of sensitive monitoring stations installed along the peninsula. This discovery, and others like it, may be the key to fully understanding the triggers for major earthquakes. Deciphering the cause of these silent earthquakes may lead to better earthquake and tsunami warning systems in the future.

Susan Schwartz, professor of Earth and planetary sciences at UC Santa Cruz, has monitored earthquake behavior for 25 years. She is the director of the W. M. Keck Seismological Laboratory at UCSC, and she specializes in earthquake and volcano research in Costa Rica. She studies the fault underneath Nicoya Peninsula, a known seismic source that has generated the country's largest earthquakes. This portion of the fault last unleashed its power more than 60 years ago with a magnitude 7.7 earthquake. According to seismologist Marino Protti-Quesada, Schwartz's former graduate student and her current colleague on the project, "The ground motion we are recording indicates that it's due to have another 7.7 magnitude earthquake."

In the early 1990s, Schwartz worked closely with Protti-Quesada, a native of Costa Rica. "I have stayed interested in Costa Rican tectonics ever since," she says. She became intrigued by slow slip movements in 2000. "From the data we collected in 2000, we postulated they might occur but we hadn't really recorded one," comments Schwartz. When a group of scientists in Canada published a paper in 2002 on a slow slip event that occurred on the Cascadia fault zone (near Washington state), Schwartz and her colleagues realized that their observations made in 2000 could have arisen from silent earthquakes.

A silent earthquake has characteristics similar to a "normal" earthquake. Both involve the same fault motion and may be equal in magnitude. The difference is that a slow-slip event happens over weeks to months, while a normal earthquake happens in seconds. Seismologists detect these events with an extensive network of monitoring devices that utilize the Global Positioning System (GPS). Data transmitted by the GPS satellites reveals movement along the faults over a period of time, allowing scientists to distinguish each specific motion.

Schwartz and her Costa Rican colleagues recorded their first silent earthquake in fall 2003. "We only had three GPS instruments that were recording continuously," Schwartz says. "Before that we would make a measurement and come back the next year and make another measurement so we could see what the velocity of the ground was doing."

Since then, Schwartz has come a long way in Costa Rica. She and her colleagues have installed a total of 13 continuous GPS monitoring stations, the densest network in Central America.

In 2007, the team recorded a clear slow-slip event with most of these stations. The motion detected was equivalent to magnitude 6.0, which would have been a disastrous earthquake. However, it occurred over a period of a month, not seconds. "The event that year was very nicely recorded," says Schwartz.

Installing the GPS monitoring stations is challenging. The team must dig 15-foot-deep holes on the beaches, and they've gotten stranded during flash floods in recent years. But it's all part of Schwartz's job. She flies back to the country each year and drives the hazardous Pan American highway to the northern part of Costa Rica, where her monitoring stations are located.

"If you look at the map on the wall," Schwartz says, pointing to a blue oversized map in her office, "the Nicoya Peninsula, where these slow slips are occurring, is surrounded by the Middle America Trench."

The Middle America Trench borders one of Earth's small tectonic plates, called the Cocos Plate. It spans the seafloor beneath Central America and caused the last three major earthquakes in Costa Rica in 1853, 1900, and 1950. The fault is a major subduction zone, where two plates continuously collide and slowly push one plate beneath the other. Earthquakes occur in this zone, directly beneath the Nicoya Peninsula—a silent trigger set for a devastating rupture.

The important cities in Costa Rica lie above the active fault zones, which makes the country susceptible to harmful earthquakes. "In January 2009, a magnitude 6.1 earthquake killed 13 people in central Costa Rica," states Protti. "We don't need big earthquakes to kill people. A moderate earthquake can produce lots of casualties."

While the silent earthquakes recorded in Costa Rica were significant, Schwartz says instruments have recorded slow movements of greater magnitudes and longer durations elsewhere. The largest occurred in 2001 in Mexico, with a magnitude of 7.5 lasting six to seven months. In comparison, the longest slow-slip event yet measured occurred in the Tokai region of Japan, lasting more than four years.

Costa Rica is unique from other seismically active sites under scrutiny for slow-slip events. Instead of having to install instruments on the ocean floor (like in the Cascadia fault zone off Washington and Canada), Schwartz and her team use a network of land-based instruments. This is possible because the geography of Costa Rica allows for monitoring the seismic activity on the land surface, making Schwartz's research less complicated. "It's much harder to put instruments on the ocean floor," she comments.

Detecting a slow-slip phenomenon literally requires measuring creeping motions of inches along the ground. The team uses very precise orbits from the satellites in the GPS navigating system. Because planet Earth moves in many different ways, the satellites track the positions of GPS receivers relative to fixed points deep in the ground.

The GPS monitoring devices contain an antenna, which receives signals from satellites. A computer program continuously "corrects" the data produced from the signals to trace the positions as time passes. From the corrected data, Schwartz and her colleagues can interpret whether the ground motions are slow or normal. "They can tell you which areas on the plate boundary are locked, and presumably will have a lot of slip in an upcoming earthquake," says Schwartz.

Another advantage for doing research in Costa Rica is that normal earthquakes occur along with slow earthquakes on the same plate boundary. That's uncommon on other seismically active faults. This is important to Schwartz and her Costa Rican colleagues, because they can compare the two different types of earthquakes.

"Our focus has been on how do these very slow earthquakes occur, and how do they change the occurrence interval when large earthquakes occur," Schwartz says. "We just want to understand how the plate moves."

Challenges arise when working in developing countries like Costa Rica. "We actually had a really BIG problem one day when we were digging up holes to place the instruments into," Schwartz recalls. "We came back to put the instrument in the hole only to find a cow, obviously dead, in one of the 15-foot holes. We had to find a crane to get the cow out and pay the landowner for the cow." But Schwartz does not dwell on these problems. She says the results are more gratifying when you install everything yourself.

With the discovery of silent earthquakes around the world, scientists would like to learn their ultimate impacts. Do slow-slip events load the locked portion of the active fault with dangerous new stress? Or, do they relieve stress because these events occur on parts of the fault that are not locked? If these silent earthquakes happen frequently and increase strain along the fault, they may set off a catastrophic earthquake. "The more we understand the phenomenon, the closer we are to addressing that question," Schwartz says.

She believes that ongoing research ultimately will have earthquake planning implications. Her team predicts that with enough data on the physical changes in the fault over time, seismologists will be able to anticipate how much damage will arise from a future earthquake and where that will occur. These details are crucial for building earthquake and tsunami warning systems for cities that lie above or near active faults. "We are just far from understanding the physics of the fundamental properties, and it's too early to say," comments Schwartz. "The next five years will be an explosion in our understanding."

The life of a seismologist is as active as the seismic faults they study. Getting stranded because of a severe tropical storm, watching your car float down the street during a flash flood, communicating only through cell phones, and playing charades with the guy at the hardware store because you don't speak the language are all part of the colorful life of a seismologist performing research in a tropical setting like Costa Rica.

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