

April 23, 2002

# Experts Find Clues to Cause of Deadly Pacific Tsunami

By **KENNETH CHANG**

**A** microphone in the Pacific Ocean near Wake Island recorded a 45-second, low-frequency roar, too low to be heard by human ears. It was the sound of nearly a cubic mile of sediment giving way along an ocean bottom slope 2,200 miles away off Papua New Guinea.

That recently examined recording is the latest evidence that an underwater landslide, not an earthquake, churned up the 30-foot-high tsunami that crashed onto coastal villages of Papua New Guinea on July 17, 1998, killing more than 2,100 people.

Once thought rare, landslide-generated tsunamis have caught the attention of geologists, who now look with concern at other continental shelves that could collapse with equal disaster. Three-dimensional maps of the bottom of Monterey Bay off California, for example, show several sections that have given way — and others that have cracked and may collapse in the future.

What is not known is how often landslides occur and how many tumble fast enough to induce tsunamis.

Small landslides — or ones that slip slowly — do not cause tsunamis. Cataclysmic landslides, like the partial collapse of a midocean volcano, generate giant waves that scour thousands of miles of coastline around an entire ocean basin, but they occur very rarely, once every few hundred thousand years.

But moderate-size underwater landslides like the one off Papua New Guinea may pose an uneasily plausible risk in some places, occurring once every few hundred years.

"It is a reasonably significant hazard," said Dr. Emile A. Okal, a professor of

geological sciences at Northwestern University in Evanston, Ill.

Almost immediately after it happened, scientists realized the Papua New Guinea tsunami was unusual. An offshore earthquake of magnitude 7.0 preceded the waves, but earthquakes that size strike that area every year or two; only the 1998 one was accompanied by a tsunami. The deadly devastation was also confined to a 15-mile stretch of the coast; villages only a few miles east or west escaped almost unscathed.

That led to speculation that the earthquake had shaken loose a landslide that in turn caused the tsunami. Surveys of the ocean bottom found freshly collapsed sediment that slid nearly a mile down a 25-degree slope.

Other scientists argued that a vertical thrust of the sea floor during the earthquake directly caused the tsunami, but that the amphitheater-shaped depression around the epicenter focused the waves onto the small section of the shoreline.

In the latest work, Dr. Okal examined the sound recordings from Wake Island, which captured a low-frequency rumble (measured at seven hertz) that lasted 45 seconds. In the ocean, sound waves can reflect off layers of water of different temperatures, allowing them to travel long distances without fading out. Earthquakes can generate similar low rumbles, but those last only about 10 seconds, Dr. Okal said.

The findings were reported in the April 8 issue of *The Proceedings of the Royal Society of London*.

"For the first time, we are able to identify a landslide from its acoustic signature," said Dr. Costas E. Synolakis, a professor of civil engineering at the University of Southern California and lead author of the paper.

Seismic stations on several Pacific islands also recorded the acoustic rumblings.

Tracing the path the sound waves took, Dr. Synolakis, Dr. Okal and their colleagues concluded that the rumble came from a landslide that occurred 13 minutes after the earthquake. That, the scientists said, agrees with accounts from survivors who said the tsunami followed the first large aftershock, 20 minutes after the earthquake. It also rules out the earthquake as the cause because the waves would not have taken that long to travel the 20 miles from the epicenter to the shore. "We had to find a source which happened 10

to 15 minutes after the main shock," Dr. Okal said.

Eric L. Geist, a research geophysicist at the United States Geological Survey in Menlo Park, Calif., described the paper as a "very intriguing line of research," but not definitive proof of the landslide theory. "It's certainly a plausible story," he said. "We just have no way of verifying it instrumentally right now."

Mr. Geist said the earthquake, or one of its aftershocks, must have also caused a tsunami because instruments in Japan thousands of miles away detected it, a quick-moving wave a few inches high. Landslide-generated tsunamis dissipate quickly and do not travel that far. He added that in the chaos, the witnesses could have mistaken the sequence of events.

The theory that underwater landslides can set off tsunamis dates back more than a century. In recent decades, tsunami researchers shifted their attention to offshore earthquakes, still thought to be the cause of most tsunamis.

But after Papua New Guinea, scientists thought they might have underestimated the dangers of landslides. In 2000, scientists at Pennsylvania State University warned of unstable, waterlogged sediments under the seabed off New Jersey. The weight of rocks above could potentially blow the sediments out the side of the continental slope like a stepped-on water balloon, causing a landslide and a tsunami.

Scientists also see potential collapses in places like the mouth of the St. Lawrence River where sediment from the river piles up. In 1929, a 7.2 earthquake toppled part of the sediment pile, causing a tsunami.

Underwater landslides have also occurred off the coast of California. In Monterey Bay, "you see large numbers of bites taken out of the canyon essentially," said Dr. Steven N. Ward, a research geophysicist at the University of California at Santa Cruz. "Some look very fresh. Some look very old. Some look like they haven't happened yet."

The canyon is cracked in some places, Dr. Ward said, and even a small earthquake near a crack could set off a landslide. Most of the slides in Monterey Bay are small — only about a fortieth the volume of the Papua New Guinea landslide — but because they occur very close to shore, they could still create 15- to 20-foot-high waves that strike a small portion of the coast. "Ten miles up or down the coast, you won't see it," he said. "It's big, but it's fairly local."

To better understand how sliding sediments create tsunamis, Dr. Synolakis and his colleagues conducted experiments earlier this month at Oregon State University. In what looks like a small swimming pool, they slid a wedged-shaped block down the slanted bottom of the pool and measured the size of the waves. They varied the weight of the wedge between 200 and 1,000 pounds by adding lead weights.

The measurements show that, contrary to earlier beliefs, that the largest waves are not caused by the push of the wedge.

"The big thing is sucking water down" behind the sliding wedge, Dr. Synolakis said. "Now we find most of the energy is expended in creating the wave on the back end of the slide," which head in the opposite direction — toward the shore.