SEISMOLOGY

Faraway Tsunami Hints at a Really Big Northwest Quake

Is the Pacific Northwest in for a really massive quake? The area lies near a long offshore fault that's capable of generating quakes, but in written memory it has been spared a big one. Since the mid-1980s, however, researchers digging in coastal marshes all the way from northern California to Vancouver Island have found signs of seemingly instantaneous land subsidence some 300 years ago, followed by a tsunami—a quake-generated sloshing of the sea—that blanketed the marshes in a layer of sand. But did these clues record a series of magnitude 8 earthquakes that struck different parts of the coast in quick succession, creating a decade or two of terror? Or are they the signature of a single magnitude 9-plus earthquake, a disaster 30 times more powerful?

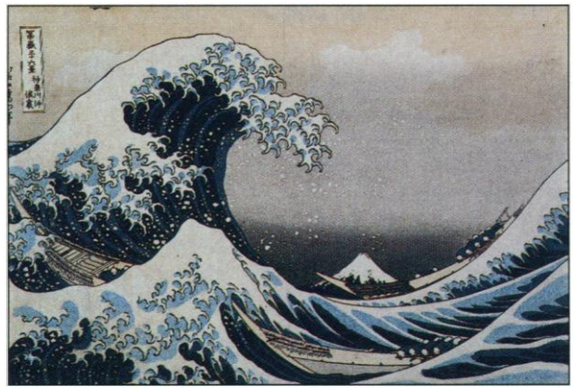
There were no instruments around to gauge earthquake size, and the subsidence and sand layers haven't been dated precisely enough to distinguish between a swift series of shocks and a single event. But the Pacific Ocean itself seems to have ensured a record of the event—and it looks like it was a big one. In a computer model, tsunami specialist Kenji Satake of the University of Michigan has found that a magnitude 9 quake off the Northwest coast would have roiled the Pacific enough to send a 2-meter-high tsunami surging onto Japan. And that's just what the historical record shows: On the night of 27 January 1700, smack in the middle of the two- or three-decade window paleoseismologists have proposed for the most recent quake or quakes, a tsunami of just the right size struck Japan.

"The coincidence is remarkable," says tsunami specialist Eddie N. Bernard of the Pacific Marine Environmental Laboratory in Seattle. "It hasn't been proven, but I think we can say that it probably was a large tsunami," indicating a very large earthquake rather than a series of smaller ones. Seismologist Thomas Heaton of the U.S. Geological Survey (USGS) in Pasadena, California, agrees that the coincidence alone is not enough to prove anything, "but the pieces are falling into place." It's looking more and more likely, says Heaton, that the 1000-kilometer-long Cascadia subduction zone paralleling the Northwest coast—where an oceanic plate dives beneath the North American plate—can rupture all at once, generating earthquakes that rank with the largest ever recorded.

Satake didn't start off trying to trace tsunamis across the Pacific. He just wondered how big a Cascadia quake was needed to wash up the deposits of sand found on the subsided marshes. So he fed quakes of varying size into his computer model and found that a magnitude 9 quake would produce a 10-meter-high wave on the Pacific Northwest coast, about the right size.

That work, first reported at last September's Workshop on Paleoseismology in Marshall, California, wasn't enough to sway his colleagues toward the magnitude 9 scenario. But, impressed by reports at the workshop of the sand deposits' narrow age range, Satake and his former dissertation adviser, Kunihiko Shimazaki of the University of Tokyo, decided to pursue the question. They thought they might be able to distinguish between a decade of terror and a megaquake by looking farther afield than Cascadia.

Almost as an afterthought to his original tsunami modeling, Satake had run the model out until the tsunami spread to Japan. A magnitude 8 quake off North America would have produced an inconsequential 30-centimeter wave at Japan, he had found. But the tsunami from a magnitude 9 would have been 2 meters high. Because a tsunami, unlike an ordinary breaker, takes many minutes to rise and fall, a 2-meter tsunami would have caused widespread damage and earned itself a place in Japanese records. So Shimazaki went back to Japan and searched for reports of a tsunami around 1700. He found one.



ART RESOURCE

High water. A giant Cascadia quake may have triggered a tsunami like one thought to have inspired Hokusai's "The Wave."

"We are sure that Japanese records show there was a seismic tsunami on 27 January 1700" between midnight and early morning that measured 2 to 3 meters in height, says Shimazaki. It was clearly not a surge driven by a storm, as it was reported at three coastal sites spanning 1000 kilometers. And it wasn't generated by a smaller, nearby earthquake; none was felt. There is nothing like it in Japanese documents for 50 years before or after 1700, Shimazaki says.

Shimazaki and Satake acknowledge that the link between this "orphan tsunami" and a magnitude 9 Cascadia quake is far from certain. For one thing, about 10% of all tsunamis are produced by earthquakes that generate disproportionately large tsunamis, perhaps because the quakes trigger huge underwater landslides. And even if the event was a megaquake, it might have taken place somewhere other than Cascadia; the Pacific is ringed with earthquake-prone subduction zones. Shimazaki and Satake eliminate South America as a source, because Spanish records there don't mention a large earthquake, but that leaves lots of territory lacking historical records: Alaska, the Aleutian Islands, and the Kuril Islands north of Japan.

But there's one more clue linking the tsunami to Cascadia: the stories of earthquakes and tsunamis told by Northwest Indians. Paleoseismologist Gary Carver of Humboldt State University in Arcata, California, and his wife, Deborah Carver, have compiled a dozen such stories, most recorded by ethnographers early in this century. The Carvers found that half the stories mention or imply that a quake and flooding struck in the late evening or at night; none mentions a daylight occurrence. Tsunamis cross the open ocean at the speed of a jetliner; to have arrived in Japan soon after midnight, it must have been launched from the Northwest Coast around 9:00 p.m. local time, just when Indian oral tradition has the earthquake.

Researchers familiar with all the new evidence (it has yet to be published) think it makes a good case for an ancient megaquake—and against arguments that the Cascadia subduction zone should rupture only in segments, generating earthquakes no larger than magnitude 8 (*Science*, 23 September 1994, p. 1802). "After what Kenji has done," says Heaton, "you'd guess that it does have 9s." Sometimes the Cascadia fault might break piecemeal in a sequence of magnitude 8s, shaking coastal areas for about a minute each time and generating modest tsunamis; at other times, says Heaton, 1000 kilometers or more of fault may go at once, subjecting the land to 3 to 5 minutes of shaking and sending a 10-meter tsunami inland.

Even so, Heaton says that if you had a choice between a decade of terror and a megaquake, you might choose the really big one. Unlike the next magnitude 8, another megaquake wouldn't be due for centuries.

–Richard A. Kerr