# Rattling the Northwest

## Signs of prehistoric superquakes may portend a future shock

By RICHARD MONASTERSKY

Like most parents, geologist Brian Atwater worries about his daughter's safety. But these days, he has an unusual concern: The public school she attends in Seattle has unreinforced masonry walls, a construction notorious for collapsing during earthquakes. The same type of walls crushed hundreds of thousands of people during the 1976 Tangshan quake in China.

A decade ago, Atwater would have paid little notice to schoolroom walls. But over the last several years, he and other scientists have found disturbing signs that the Pacific Northwest has experienced giant quakes in the distant past and that the area may be headed for a catastrophic shock in the near or distant future.

At a meeting of the American Geophysical Union in December, researchers discussed the recently uncovered evidence of quake potential in the Pacific Northwest. While some remain unconvinced that huge earthquakes—with magnitudes of 8 or higher — do indeed strike this region, a growing number consider such shocks a serious possibility.

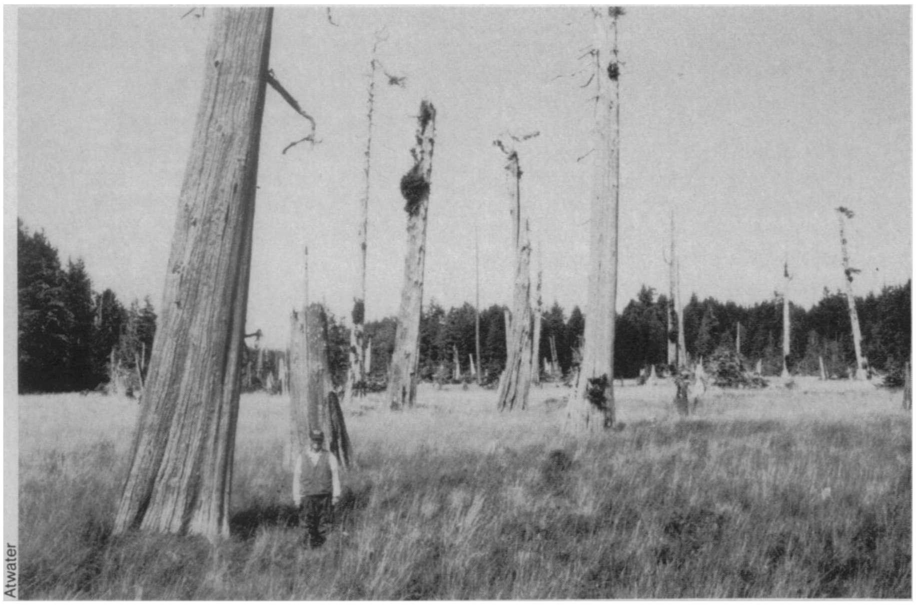
What's worrisome, they say, is that northwestern cities such as Portland, Seattle and Vancouver have not prepared for earthquakes of this magnitude, which could rattle the region's population centers with enough force to make the recent San Francisco-area damage seem mild in comparison.

"I think it's quite true to say that nothing [in these areas] has really been designed with one of these earthquakes in mind," says seismologist Paul Somerville of Woodward-Clyde Consultants in Pasadena, Calif. At the meeting, Somerville and his colleagues presented estimates of the degree of shaking Portland and Seattle would suffer during such a massive earthquake.

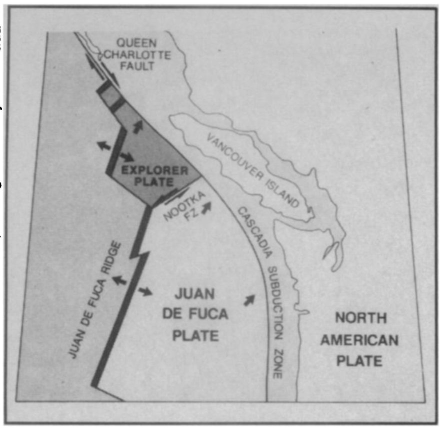
If a Big One does visit the Pacific Northwest, it will originate tens of kilometers below ground, from a tectonic structure called the Cascadia subduction zone that runs offshore from Vancouver Island to Cape Mendocino, Calif. This zone marks the place where a piece of ocean floor, known as the Juan de Fuca plate, is slowly crashing into the edge of the North American plate. As they collide, the more buoyant North American plate runs right over the Juan de Fuca, pushing it down into the Earth's interior.

Subduction zones have spawned many powerful earthquakes, including ones in Chile (1960) and Alaska (1964). Such giant jolts occur when the subducting plate fails to slide smoothly beneath the overriding block. The two plates lock together, building up strain for hundreds of years until they suddenly slip past each other, generating a massive shudder.

But not all subduction zones shuffle




*Ghost forest: Although they died centuries ago, these red cedars still stand along the Washington coastline. Their roots sit in soil buried under a layer of tidal mud, which indicates the trees died when the field dropped below the high-tide level. Since that time, the ground has risen above water level again.*



Pacific Geoscience Centre/Geological Survey of Canada

*The Juan de Fuca plate and smaller, connected pieces of ocean floor dive beneath the North American plate along the Cascadia subduction zone, an offshore region running northward from Cape Medocino, Calif., to Vancouver Island, British Columbia.*

along in this lock-slip fashion. At the Mariana trench north of New Guinea, for example, the Pacific plate appears to slide beneath the Philippine plate without causing large earthquakes.

Geologists don't know which type of subduction goes on in the Cascadia region. Sensitive seismometers in the area have not detected any tremors originating from the interface between the Juan de Fuca plate and the North American plate. Researchers seeking to interpret this unusual seismic quiet are thus left with a dilemma: Either the plates have locked together and are preparing to unleash a potential killer quake, or they are safely gliding past each other.

Historical records for the Pacific Northwest can't solve that dilemma. They go back only as far as the early 1800s, covering a time span in which no great earthquake has struck the region. To look at earlier times, several scientists have turned to the geologic record.

Atwater, who works with the U.S. Geological Survey (USGS) in Seattle, started his search by studying creek sediments near bays along the Washington coast, on the assumption that these areas would have preserved the calling cards of any large subduction earthquakes in the region. In other parts of the world, such quakes have caused land along coastal regions to abruptly rise or drop ("subside") by several meters.

In 1987, Atwater reported evidence that sections of the Washington coast had subsided perhaps as many as six times over the last several thousand years (SN: 7/18/87, p.42). Since then, he and his colleagues have traced the quake evidence farther down the coast and have used carbon-14 dating to establish the timing of those events.

At the December meeting, Wendy Grant of the USGS in Seattle reported that signs of repeated subsidence extend several hundred kilometers southward through central Oregon. South of there, the record becomes more complex, but geologists have found indications of either subsidence or uplift as far down the coast as northern California.

Land can rise or subside slowly over hundreds or thousands of years for reasons other than earthquakes. But Atwater points to several factors that link the recently discovered evidence to seismic superjolts. In the sediments, he has found estuarine muds deposited directly on top of soil layers—a pattern suggesting that the lowland areas suddenly dropped below the high-tide level and were quickly covered by mud. If the area had subsided slowly, he says, he would have seen a gradual transition between the soil layer and the overlying mud.

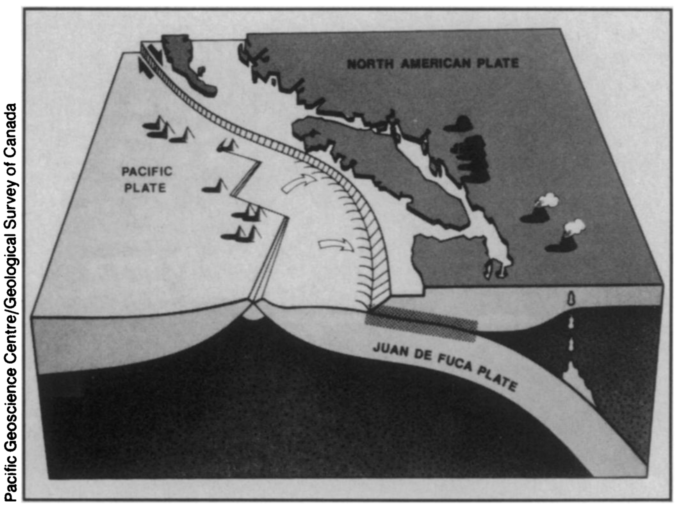
In the same sediments, Atwater has also found signs of the huge waves, called tsunamis, that earthquakes can generate. Some of the subsided sediments show a thin sheet of sand packed between the soil and mud layers. To explain the "sand sandwich," Atwater suggests that a series of enormous, quake-generated waves washed over a subsided section of coastline and deposited the sand, which quickly became submerged in mud.

Other researchers have wondered whether nonseismic processes such as storms could have created the sand deposits, but geologists Mary A. Reinhart and Joanne Bourgeois of the University of Washington in Seattle think not. After studying the buried sediments and then simulating tsunamis with a computer model, they conclude that gigantic waves appear the best explanation for the deposits they examined.

Atwater, Reinhart and Bourgeois traveled to Chile last year to test their theories. Along the coast where the aftermath of the 1960 quake remains visible, they found similar examples of subsided coastline and tsunami deposits, he says.

Some of the most dramatic evidence for prehistoric earthquakes in the Pacific Northwest comes from the ghostly red cedar trees, or "snags," that remain standing in the region though they perished centuries ago.

Tidal mud has buried the lower trunks of the cedar snags, suggesting the trees died when the ground level dropped below the high-tide mark and saltwater flooded their root systems. Using tree rings to try to date the deaths of the cedars, David Yamaguchi of the University of Colorado in Boulder is attempting to determine when and how rapidly the subsidence occurred. So far, his work indicates that a section of the Washington coast, at least 90 km long, dropped suddenly about three centuries ago.



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*A slice through the Earth shows the Juan de Fuca plate subducting under North America. Some scientists think the two plates have stuck together and will not move until accumulating pressure suddenly forces them to slip, generating a catastrophic earthquake. Shaded bar under North American plate highlights the interface between plates.*

By comparing the growth rings in the snags with those in 500-year-old living cedars, Yamaguchi has assigned dates to the outer — and therefore oldest — rings remaining on the snags. At six sites along the coast, he has found drowned trees whose outer rings date to the years 1678 through 1687. These rings cannot reveal the exact year of tree death; that evidence vanished as centuries of wind and rain stripped the snags of their bark and outermost rings. However, because the snags are clustered so closely together, Yamaguchi thinks all the drowned trees died during the same year, sometime between 1684 and 1687. He hopes that future studies on growth rings in spruce roots will help pinpoint the year and even the season of their demise.

The tree-ring evidence for a quake three centuries ago dovetails with less precise carbon-14 dating of the subsided sediments. Most of the coastal areas along the subduction zone appear to have suddenly subsided or uplifted during the late 1600s. However,

## If the Big North One hits

As more scientists become convinced that a giant earthquake could strike the Pacific Northwest, public officials face some tough choices.

Robert McGarrigle, a structural engineer in Portland, Ore., says much of his city could come down during a magnitude 8 shock, which would pack about 30 times more energy than last October's Loma Prieta quake in northern California.

After surveying seismic destruction in Mexico City and in the Bay area, McGarrigle says, "I expect to see significant damage. I expect to see about 10 percent of the structures in our area have major collapses, and another 10 percent have significant structural damage, and a lot of our bridges go down or partially go down."

People in Portland and many other parts of Oregon have never worried about strong earthquakes, he says, mostly because no major shock has struck the area since Europeans first settled there in the early 1800s. On the Uniform Building Code scale of 0 to 4 (which sets constuction standards for new buildings but not for other structures such as bridges and dams), Portland has been assigned a 2. San Francisco and Los Angeles, in contrast, have a code of 4.

Seattle stands in much better shape, largely because of some lessons learned from moderate quakes in 1949 and 1965, says structural engineer James Carpenter, who heads a committee on seismic preparedness for the Seattle-based Structural Engineers Association of Washington. The Uniform Building Code for Seattle is 3, and includes an important ductility provision requiring elements in new buildings to withstand a significant amount of bending.

Yet even these provisions might not suffice during a magnitude 8 quake, which would shake the city for perhaps a minute — an exceedingly long time compared with the 10- to 15-second shudder of smaller quakes. "The long duration is really going to be a killer," says Paul Somerville, a seismologist with Woodward-Clyde Consultants in Pasadena, Calif.

While all this sounds dire, the possibility remains that a subduction zone quake might not strike for several hundred years. The current scientific uncertainty regarding the superquake's timing forces officials to ponder some difficult questions. Should cities and towns spend precious funds on a risk that may lie decades away? Should regulations force landlords to strengthen older buildings — a move that would ultimately raise rents in areas that have witnessed a dramatic increase in homeless populations over the last decade?

Neil Hawkins, a structural engineer at the University of Washington, thinks the risks are great enough to warrant action, especially since seismologists say the magnitude 6 and 7 quakes that shook Seattle in midcentury could recur about every 100 years and may strike elsewhere in the Northwest. Hawkins contends that most northwestern population centers — including Seattle — have failed to prepare for even moderate shocks such as these.

"These ones are much more frequent than the subduction quakes, and we know they are going to occur," he says. "No one is going to argue about that. Yet I don't believe the level of awareness has reached the stage where people accept the fact we should be almost as well prepared as California."

*— R. Monastersky*

Atwater and his colleagues cannot tell whether they are looking at the results of one huge, magnitude 9 quake or a series of jolts similar to the pair of magnitude 8 shocks that hit Japan in 1944 and 1946.

More distressing to area residents, the carbon-14 work suggests the Cascadia quakes do not hit with a predictable frequency. On average, the subsidence events recurred about 600 years apart, but that figure is misleading, Atwater says. The shortest span between subsidence events lasted only a few centuries; the longest lasted more than 1,000 years. "The only thing fairly certain is that they don't recur like clockwork," he says.

This makes it difficult to speculate on when a future superquake might hit. It may lurk several centuries in the future — or "it could happen tomorrow, it could happen in five minutes," says geophysicist Paul Vincent of the University of Oregon in Eugene. "That's the scary thing about this. We don't know how much time we have to prepare."

As Atwater and his co-workers collect signs of prehistoric quakes, Vincent and several other researchers are finding evidence that the Cascadia subduction zone is storing up energy for a future quake. By analyzing data collected by surveying crews over the last 60 years, they have determined that the coastline bordering the subduction zone has warped significantly over that period. This suggests the subduction zone is locked and building up strain as it bends the edge of the North American plate. At some point the plate will snap back, Vincent says.

While the recent reports have convinced many researchers that the Cascadia subduction zone will someday unleash a huge quake, some find the evidence lacking.

"I tend to be a little bit skeptical of the evidence as it stands right now," says University of Washington seismologist Robert Crosson. Though he thinks prehistoric earthquakes probably did cause the submergence features found along the coast, Crosson says he wonders if they were moderate offshore quakes instead of huge subduction shocks. Even so, he thinks there is a high probability that the Northwest does indeed suffer subduction quakes.

Seismologist Lynn Sykes of Columbia University's Lamont-Doherty Geological Observatory in Palisades, N.Y., takes a dimmer view, saying he's dubious about the potential for a Cascadia subduction earthquake.

Sykes bases his position on theories of how rocks fracture. The recipe for a subduction quake calls for strong rocks lining the interface between the overriding and subducting plates. As these rocks lock together, they must resist the motion of the plates and store up elastic strain for several centuries. In the case of the Cascadia subduction zone, however, most portions of the interface are far too weak to build up enough strain for a huge earthquake, Sykes maintains.

Seismologist Tom Heaton disagrees. "I think the materials underneath the continental margin are perfectly strong enough to make a large quake," he says. He adds, however, that "until someone sees one of these earthquakes, the debate will never be settled." Heaton, of the California Institute of Technology in Pasadena, was one of the first to raise concerns about quake potential in the Cascadia subduction zone (SN: 4/27/85, p.270).

But public officials cannot wait for seismic devastation to settle the debate, and will have to make practical decisions based on the kinds of information scientists are currently gathering.

For Seattle school administrators, the threat of unreinforced masonry walls might seem small compared with other concerns, such as the growing drug problem and the epidemic of teen pregnancies gripping most urban areas. Yet when Atwater thinks about his daughter's school, the seismic signs appear clear enough to prompt action. "The evidence in hand right now favors the hypothesis that great earthquakes can happen here," he says. "The cautious approach as far as seismic hazard is concerned is to view these earthquakes as a real possibility." □