A double earthquake threat? Study finds 2 Seattle-area faults ripped about the same time

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With the Cascadia Subduction Zone parked off the coast and shallow faults lurking under most major cities, the Puget Sound area already faces a daunting array of seismic scenarios. A new study adds another: the possibility of a one-two earthquake punch.

Using state-of-the-art tree ring and radiocarbon dating methods, researchers found the most recent major earthquake on the Seattle Fault wasn't a solo act. The Saddle Mountain Fault, which slices across the Olympic Peninsula near Lake Cushman, ruptured at about the same time.

The team also was able to zero in on the date with stunning precision, narrowing it to a six-month window between the fall of 923 A.D. and the spring of the following year—almost exactly 1,100 years ago.

Their results were published Wednesday in the journal *Science Advances*.

The project, which spanned more than five years and included divers with underwater chain saws to sample trees drowned by the quakes, is a scientific tour de force nearly unprecedented in seismology, said Harold Tobin, director of the Pacific Northwest Seismic Network at the University of Washington. To help nail down the date, the team used a new approach that detects traces of ancient solar storms captured in tree rings.

But the findings add a new worst-case possibility to the seismic threats facing a region that's home to 4 million people, said Tobin, who did not

participate in the study. A seismic double whammy would be much more damaging than any single quake, especially to old brick and concrete buildings, and vulnerable bridges and infrastructure. It's a scenario that hasn't been factored into hazard maps, building codes and emergency planning—but it needs to be, Tobin added.

"The chance in any given year is not high, and there's no reason to freak out because of this study," Tobin said. "But it underscores that these are things that we need to be prepared for."

A 2005 analysis estimated a relatively modest magnitude 6.7 quake on the Seattle Fault could kill 1,600 people, destroy nearly 10,000 buildings and cause up to $50 billion in economic losses. If the Seattle and Saddle Mountain faults ruptured simultaneously, the new study estimates, the resulting quake would clock in at magnitude 7.8—nearly 40 times more powerful—and affect a much bigger area.

The exact sequence of the ancient quakes remains unclear, said study co-author Morgan Page, of the U.S. Geological Survey.

Based on statistical analysis of global quake sequences, she calculates a 3-to-1 likelihood the faults ruptured simultaneously. But it's also possible two quakes were separated by hours, days or even months. In that case, the study estimates their magnitudes at 7.3 to 7.5.

Seismologists used to categorize most clustered quakes as aftershocks, and assumed they occurred on the same fault, said John Cassidy, a senior seismologist for Natural Resources Canada who was not involved in the project. But over the past several years, more has been learned about how a slip on one fault can put stress on others. February's devastation in Turkey was caused by a powerful quake that triggered the rupture of an adjacent fault nine hours later.

Shallow quakes near urban areas can be especially nasty because they are so close to the surface. Shaking would be far more intense than from Washington's most recent big earthquake—the magnitude 6.8 Nisqually event in 2001, which originated more than 20 miles underground.

"An earthquake on the Seattle Fault is ... likely to be much, much more catastrophic," Tobin said.

Fortunately, shallow fault quakes are extremely rare in Washington. The seismic mayhem in 923-924 A.D. appears to be the most intense episode since the end of the last ice age 16,000 years ago, the researchers report. Geologists still don't have extensive quake histories for most of the dozen or so faults in the area, but most seem to pop off every thousand to several thousand years, Tobin said. The USGS estimates about a 5% chance of a major Seattle Fault quake in the next 50 years.

But the quake that struck Morocco earlier this month occurred in an area where earthquakes also are rare, and nothing as powerful had ever been recorded, Tobin pointed out.

The new research builds on more than 30 years of geological discoveries. Field work in the early 1990s uncovered multiple clues left by the Seattle Fault quake, which uplifted Alki Point and the southeastern tip of Bainbridge Island as much as 20 feet and spawned a tsunami that swamped the site of the West Point Treatment Plant. It also triggered landslides on Mercer Island that sent old-growth forests sliding into Lake Washington, where some are still standing upright in nearly 300 feet of water.

The Saddle Mountain quake broke the ground with a 24-foot-tall scarp that blocked a drainage and created Price Lake, drowning trees as the water rose.

Preserved in oxygen-poor cold water, those submerged trees from Lake Washington, Price Lake and other sites were the key to the new research.

Previous radiocarbon analysis already had dated the Seattle Fault quake to sometime between 900 and 930 A.D. Intriguing hints from several other faults, including Saddle Mountain, Olympia and Tacoma, suggested they also ruptured around then. But conventional methods yielded possible age ranges that spanned centuries at those other sites.

"There was too much uncertainty," said co-author Brian Sherrod, a USGS scientist who has spent most of his career investigating faults across the state.

A chance encounter at a scientific conference between Sherrod and Bryan Black, a leading dendrochronologist from the University of Arizona, set the multiyear odyssey in motion.

"It's a big puzzle. That's why it took so long," said Sherrod. "To me, the story is these new techniques Bryan and his colleagues bring to the picture."

Tree rings can yield much more precise dates than radiocarbon, Black explained. But the samples have to be in good condition, with bark and extensive ring sequences.

One of the most daunting tasks was rounding up dozens of cores and wood slices collected over the years by other researchers. Eventually, Black corralled usable samples from 47 Douglas firs at six sites where trees were drowned by the earthquakes. Some of the samples recorded nearly three centuries of history.

The team had to collect new samples from Price Lake, where stumps of

the quake-killed Douglas firs remain visible. USGS divers struggled in the murky water to slice usable samples with intact bark from the bases of the trees. "It would take up to an hour to cut a single wedge from a tree, because they were working with almost zero visibility," said Black, lead author of the study.

To anchor the tree rings in time, he used a reference sequence from 1,300-year-old firs collected on Vancouver Island in the early 1990s—so the date of the outermost ring is known.

Black sanded each sample multiple times, including with micron-level diamond grit sheets called lapping films. "It's sanded to the point where you can see the individual cells within the wood under a microscope," he said.

As he lined up his samples and compared them with the reference trees, the answer was unmistakable.

The validity of the date was confirmed through radiocarbon analysis of individual tree rings, looking for evidence of cosmic timestamps called Miyake events. Named for the Japanese physicist who discovered them, the events represent spikes of radiation from solar flares or exploding stars centuries or millennia ago. Luckily for dendrochronology, spikes in cosmic radiation generate spikes in atmospheric levels of carbon-14, the isotope whose slow decay is the clock that anchors radiocarbon dating.

Even luckier for Black and his colleagues, a Miyake event occurred in the year 774 A.D. and showed up in their Douglas fir samples, providing an absolute benchmark from which to count.

"Boom," he said. "Everything came together, and we saw that these trees all died with the last completely formed ring being the year 923."

The mystery of exactly when the Seattle Fault ruptured and whether other faults were involved has been around for more than 30 years—and Black said he can now see why. "This has been the most complicated and challenging dating project in my career."

And he and Sherrod aren't done. They're on the hunt for submerged trees linked to the Tacoma and Olympia faults, to find out whether the earthquake outburst 1,100 years ago was even more extensive.

In the meantime, Seattle is once again trying to tackle the hazard posed by old brick buildings, also called unreinforced masonry (URM), which are among the most dangerous places to be in an earthquake. More than 1,000 URM apartment buildings, offices, churches and meeting halls are scattered across the city, and efforts to require retrofits have stalled repeatedly.

The latest development is a new rule that simplifies and standardizes the requirements for retrofits, said URM program manager Amanda Hertzfeld. The next step will be a voluntary retrofit program that could be in place by next spring. The goal is to eventually mandate upgrades, Hertzfeld said, but there's no timeline yet.

More information: Bryan A. Black et al, A multifault earthquake threat for the Seattle metropolitan region revealed by mass tree mortality, *Science Advances* (2023). DOI: 10.1126/sciadv.adh4973