Tree rings reveal a new kind of earthquake threat to the Pacific Northwest

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Price Lake, in the eastern Olympic Mountains, formed when the Saddle Mountain fault impounded a stream and flooded the forest. Lead author Bryan Black and his team of divers collected the samples using an underwater hydraulic chainsaw. Credit: Bryan Black

In February, a 7.8-magnitude earthquake shook the Turkey-Syria border, followed by one nearly as large nine hours later. Shallow faults less than 18 miles beneath the surface buckled and ruptured, causing violent

focused quakes that leveled thousands of buildings and killed tens of thousands.

Similar shallow faults ruptured about 1,000 years ago in the Puget Lowlands in western Washington, according to new University of Arizona-led research. Tree rings helped pinpoint that the seismic event occurred in late A.D. 923 or early 924. Their findings mean that a repeat event has the potential to again shake the region that is now home to over 4 million people, including Seattle, Tacoma and Olympia. The results were published in the journal *Science Advances*.

The ancient quake was either the result of all the shallow faults in the region rupturing together to produce an estimated 7.8-magnitude earthquake or—like in Turkey and Syria—twin quakes that occurred back-to-back with estimated magnitudes of 7.5 and 7.3, researchers found. Shallow faults typically result in more violent and focused shaking than earthquakes generated from other geological configurations.

While earthquakes are not new to the Pacific Northwest, the study identified that events on these shallow faults are linked to each other in some way, either by connections underground or by one fault transferring stress to the other. Regional hazard models, used to develop engineering design and policies, don't currently reflect this possibility—but should, said paper first author Bryan Black, an associate professor of dendrochronology in the UArizona Laboratory for Tree-Ring Research.

Homing in on the millennial cluster

Scientists have been uncovering shallow faults in the region since the 1960s, when the Seattle Fault was first discovered, followed by the Saddle Mountain Fault, which runs along the eastern foothills of the

Olympic Mountains, and the Tacoma and Olympia faults.

"These are four shallow faults that had shown evidence of having ruptured roughly 1,000 years ago in a cluster of earthquakes called the millennial cluster," Black said. For example, "a 25-foot cliff was thrusted into the air from west Seattle out to Puget Sound. It also triggered a local tsunami and landslides that stripped mountainsides of whole forests and discarded them into nearby lakes Washington and Sammamish."

Until now, scientists weren't clear on exactly when and how these faults last gave out.

"These quakes could have ruptured at the same time, hours apart or centuries apart," Black said."We weren't sure."

So, he turned to the trees.

Diving deep

With each passing year, trees add a ring around their trunks. The ring width is determined by the climate they experience. Favorable conditions mean wider rings and unfavorable conditions mean thinner. As climate varies from year to year, it creates time-specific patterns like a bar code in the growth of trees within a region.

Dendrochronologists can match these time-specific growth patterns in dead trees with patterns from living trees. If there is overlap with living trees, the exact dates over which the dead trees lived—and died—can be established. This was the approach used to determine when the earthquake-killed trees died in the Puget Sound region.

In 2021, Black trekked into the mountains of the Pacific Northwest to

participate in harvesting stumps from trees that had died when the Saddle Mountain Fault impounded a stream that flooded a forest. The lake and the stumps of these drowned trees remain today.

The team strapped two canoes together and slapped a large piece of plywood atop them both to create a makeshift barge that would hold a generator to power underwater chainsaws. With these in hand, divers leaped into the water to cut samples of trees killed when the lake formed from the millennial cluster.

Black and his team also had sections sourced from nearby trees killed around the same time during a rock avalanche that impounded a stream that flooded a nearby streambed. They also acquired sections from trees collected more than 30 years ago that had drowned in landslides into Lake Washington and Lake Sammamish during a large earthquake on the Seattle Fault.

When he compared the growth patterns, Black observed that the trees died the exact same year across both the Saddle Mountain and Seattle faults. He also saw that the trees died during their dormant season, which narrows the time of death—and the earthquake by extension—to the late fall through early spring.

To determine an exact calendar year of death, the team built a 1,300-year chronology from living but extremely old trees, which, when matched with the earthquake-killed trees, showed that the dormant season of death was late 923 to early 924.

"Our team was also lucky that there was a massive solar storm between the years 774 and 775, which caused a sudden global spike in radiocarbon," said associate professor of dendrochronology and co-author Charlotte Pearson. Radiocarbon fluctuations, like climate, can be used to date tree rings. "We measured radiocarbon in the rings of

earthquake-killed trees to show that this spike occurred right where we thought it should."

This independently confirmed their earthquake date.

"Combined, the evidence showed us that these trees from across the region died together, and this was in fact a linked event," Black said. "We've taken uncertainties around these two faults that used to span decades or centuries and narrowed it down to within one season. It's a much different scenario if we have earthquakes on these two faults separated by 100 years versus 100 hours. Demonstrating that these faults can rupture synchronously or in very rapid succession has really changed what we understand about the hazard in the region."

Yet, current hazard models don't currently recognize that linked faulting is possible, he said.

"If Saddle Mountain and Seattle faults went together it would be on par with the 1906 earthquake in San Francisco," Black said. "Or, like the quakes in Turkey, they can also go at rapid succession. If that were the case, the infrastructure and landforms already weakened by one quake are then going to get the knockout punch with a second quake. It will still be quite destructive: thrusting up water mains, severing roads, triggering landslides and local tsunamis."

Luckily, he said, the bigger and more severe the quake, the less frequent it is. So, while quakes of this size would be devastating to the region, they are relatively uncommon.

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

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