Washington's volcanoes are experiencing seismic tremors from an unlikely source—glaciers

October 23 2023, by Jenna Travers

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Most people think of seismic activity as the result of movement along faults or of violent volcanic eruptions. But seismic events can have other

causes, including floods and even large crowds of excited fans—such as those at Taylor Swift's recent Seattle shows, whose enthusiastic reception caused seismic activity equivalent to a 2.3 magnitude earthquake—and glaciers.

Decades ago, scientists who research seismic activity in the Washington Cascades recorded a number of small seismic events and eventually determined that they were caused by glacier movement. These events, called "glacier quakes," allow for important insight into seismic activity, patterns of glacier movement and even climate events.

For Washington state residents, seismic activity is nothing new. Washington is part of the Pacific Ring of Fire, an arc along the edge of the Pacific Ocean where tectonic plate interactions frequently lead to more earthquakes and volcanic eruptions.

In 1980, Mount St. Helens erupted in southern Washington, killing 57 people and causing the most disastrous volcanic eruption in US history. Washington also falls within the Cascadia Subduction Zone, where a fault line between the Juan de Fuca Plate and North American Plate threatens a 9.0 magnitude or more earthquake in the coming century.

In the Washington Cascades, glaciers are another frequent culprit of quakes. According to Seth Moran, a research seismologist at the USGS Cascades Volcano Observatory, when seismologists first set up seismometers on Mount Rainier decades ago, they were nervous when they saw small quakes reminiscent of the ones that preceded the eruption of Mount St. Helens. "However, we were eventually able to improve tracking and clearly determine that these quakes were coming from glaciers, not volcanic activity," Moran told GlacierHub.

Using seismometers, researchers identified similar glacier quakes on Mount St. Helens and Mount Baker in the following years, and these

have continued to the present day, primarily occurring in the summer months, "because glaciers are moving more in warmer months, so we're seeing more of the internal crackling then," said Moran.

Washington glaciers are not alone in triggering these glacier quakes. The Alaska Earthquake Center detects between 1,500 and 2,000 glacial quakes per year—some comparable to magnitude 3 earthquakes. Most of these occur in Southcentral Alaska, and these quakes follow the same seasonal pattern as the Washington glacier quakes.

Similarly, many national parks and hiking sites have had growing numbers of visitors following a nationwide spike in outdoor recreation and the end of COVID travel restrictions over the past few years. More visitors means more people in areas where they might be able to feel some of these quakes, leading to recent media coverage of the glacier quakes.

But how exactly do glaciers cause these earthquakes?

Jackie Caplan-Auerbach, a professor of geology at Western Washington University, located just west of Mount Baker, told GlacierHub that "anything that shakes the ground can be recorded by seismometers." For instance, glacier lake outburst floods, which occur when water builds up behind a glacier dam until the pressure becomes so intense that it bursts through, also create seismic vibrations due to the large volume of water suddenly rushing downstream.

In the case of glacier quakes in the Cascades, likely causes include crevasse formation—which occurs when the lower part of a glacier moves more quickly than the upper part, spreading the ice until a gash forms—and stick-slip behavior at the glacier ice-rock interface. Caplan-Auerbach elaborated, "As the ice flows, it gets stuck on underlying material and eventually slips forward once the stresses build up to a

certain point. That slip is what we record as a tiny quake." In Alaska, calving of tidewater glaciers can also cause glacier quakes.

While these glacier quakes have all been detected on volcanoes, that doesn't mean the phenomenon occurs only on glaciated volcanic mountains. "We're likely seeing these events at these volcanoes because they have large glaciers and/or they are heavily instrumented with lots of nearby seismometers," said Caplan-Auerbach.

The combination of these two factors has led groups that track quakes, such as the Pacific Northwest Seismic Network, to show high numbers of quakes around Mount St. Helens and Mount Rainier—where there are several seismometers that can pick up even small quakes—and much fewer around Mount Baker, where there is only one seismometer, at Glacier Peak.

As demonstrated by the Alaskan glaciers, many of which were not on volcanoes, these glacier quakes can be measured in most places where there is a large glacier and a seismometer to track movement.

Moran notes that the activity on Mount Rainier was especially interesting to researchers at first. After they determined that the small, repetitious quakes were not a sign of impending eruption like at Mount St. Helens, they were able to establish, in the late 2000s, that the glacier quakes were connected to storm systems in the area. Moran explained that these storms "were putting [rain]water into the glacier and allowing it to slip more readily for a short time," which increased the frequency of the quakes.

Another interesting glacier quake that researchers are still puzzling over is a repeating quake coming from the Easton Glacier on Mount Baker. Not only has this quake occurred every day in the same spot for the past 15 to 20 years during quake season, it is also much stronger than other

glacier quakes in the area, measuring around magnitude 2 on the Richter Scale.

"The waveform [of this quake] is identical from event to event, which is unusual for an environment like a glacier where you'd be expecting a lot of change," Moran said. "This [identical waveform] means the quake is happening in the exact same place and nothing has changed—the ice is the same thickness and the rock is the same composition." This quake is likely the result of a stick-slip behavior of the glacier, but researchers are still eager to learn more about it.

Some of these glacier quakes are too small for people in the area to feel, but others, like the repeating Easton Glacier terminus quake, has been recorded on seismometers out to 100 kilometers away, said Moran. Mauri Pelto, a professor of environmental science at Nichols College and science director of the North Cascades Glacier Climate Project, told GlacierHub that his team of researchers and artists felt the small glacier quakes almost every day during their annual field season in the North Cascades.

Pelto has studied the Easton Glacier for the past 40 years and seen significant terminus retreat, meaning that the identical waveform glacier quakes must be occurring somewhere on the ice-rock interface other than at the terminus.

While these glacier quakes are of interest to researchers, they pose little to no threat to tourists and surrounding communities. John Mutter, a professor of earth and environmental sciences at Columbia University, told GlacierHub that few researchers focus on this topic for that precise reason. "One important motivation for studying earthquakes is that they cause damage and deaths. Glacier quakes do not," Mutter said.

Although there was initial concern when these quakes were first spotted

on seismometers decades ago, seismologists have clearly defined the difference in volcanic activity and glacier activity and these relatively small quakes are too small to trigger volcanic events.

As technologies and access to these areas improve, the data we have will follow suit, allowing seismologists and climatologists to have a better understanding of glacier movement and the overlap of climate patterns and ice flow.

Provided by State of the Planet

Citation: Washington's volcanoes are experiencing seismic tremors from an unlikely source—glaciers (2023, October 23) retrieved 9 May 2024 from https://phys.org/news/2023-10-washington-volcanoes-experiencing-seismic-tremors.html