# The Cascadia Challenge: High Earthquake Hazard in a Place with Few Earthquakes

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The Cascadia subduction zone, in the Pacific Northwest of the USA and western Canada, is a region of known earthquake hazards from multiple sources, including upper plate crustal earthquakes, lower plate intra-slab events, and potential megathrust subduction tsunamigenic earthquakes of magnitude 8 or 9 class. This region also is home to well over 10 million people, and the 2001 Nisqually M 6.8 event is the costliest earthquake in the USA in the past 25 years. For all of these reasons, the Pacific Northwest is known to have the second highest risk of loss of life and property from seismic activity in the nation, exceeded only by California. At the same time, it has been more than 20 years since the population in Cascadia has experienced an earthquake of magnitude 5 or larger. No great subduction earthquake has occurred in historical times, despite the clearly locked nature of the subduction plate interface extending ~1000 kilometers from northern California to British Columbia, Canada. Similarly, while geologic mapping and paleoseismological investigations have identified numerous crustal faults within the North American plate that are capable of magnitude 7 to 7.8 earthquakes, and there is ample evidence of past events 1000 years ago or more, no such event has taken place since the mid-1800s, when written records begin to be available with the arrival of European settlers.

This situation raises two key questions: first, how can we properly quantify and understand the hazards from earthquakes in the absence of a strong instrumental record? And second, how can we develop an "earthquake culture" of understanding and awareness of seismic risk among the civil authorities, the engineering community, and the general public?

Addressing the first question is a matter of applying our best geological and geophysical tools to build an interdisciplinary model of the seismic hazard. The Cascadia subduction megathrust, or main seismogenic plate interface fault, is seismically very quiet compared to most other subduction zones globally, with extremely few events above mag 4.0 ever recorded. However, we also now know that ~325 years ago, an M8.7 – 9.2 event produced a trans-Pacific tsunami that caused damage in Japan and left a widespread deposit in coastal sediments. Paleoseismic turbidite records and and paleo-tsunami deposits have been used to develop a ~14,000 year record of such events, with an average recurrence of ~450-550 years.

Modern satellite-based GNSS geodesy can now delineate the spatial distribution and degree of fault locking and slip deficit, and seafloor geodesy is now extending that model into the offshore region. Active source seismic reflection & refraction imaging of the fault zone is rapidly improving mapping of the main megathrust geometry, extent, and possible segmentation. Recent work shows that the plate interface between 44˚ and 48˚ N latitude is remarkably flat (low dip angle) and smooth (little topography of the fault itself), coinciding exactly with the known asperity where GNSS geodesy shows near-complete locking of the fault. Numerous splay faults that branch from the megathrust enhance the tsunami hazard via coseismic seafloor displacement, and we have recently mapped and categorized the hazard from many of them. We therefore deem this central region the location of highest hazard of both strong shaking and tsunami source in Cascadia.

Similarly, crustal faults onshore in the forearc such as the Seattle Fault and others, have been shown through careful paleoseismology and dendrochronology to have hosted M7.3 to M7.8 events more than 1000 years ago. A recurrence today would be devastating to the city of Seattle. The recurrence interval and future likelihood of such an earthquake remains poorly understood. By contrast, there have been four intraslab M6.5 to 6.9 events in the past century, all centered beneath the highly populated Puget Sound region where Seattle is located. The risk of damage from these events is well known, yet preparation continues to lag behind other countries such as Japan and Taiwan. Our building inventory still contains many older unreinforced masonry structures as well as non-ductile concrete buildings and bridges. The building code standard in the region remains "life-safety" rather than the preferable "functional-recovery" emphasis on resilience to disasters.

One recent development of note is the introduction of earthquake early warning (EEW) via the ShakeAlert system on the USA west coast, proving both mass alerting via mobile devices and automated actions via embedded systems in civil infrastructure. Public awareness remains a key challenge, which we are trying to address though earthquake drills in schools triggered by EEW alerts. EEW alerts are distributed even for relatively light shaking intensity of III or IV. This may serve an important purpose of keeping earthquake awareness in the public eye. Perhaps alerts for events as small as M4.5 will render the PNW region better prepared for the inevitable future earthquake disaster.

Finally, the frontier for both EEW and assessing hazard is to extend the sensor network to the offshore region. This is growing quickly in Cacadia now, with both seafloor geodetic sites (A-GNSS) and cabled networks of seismometers, but our region still has much to do in that regard.

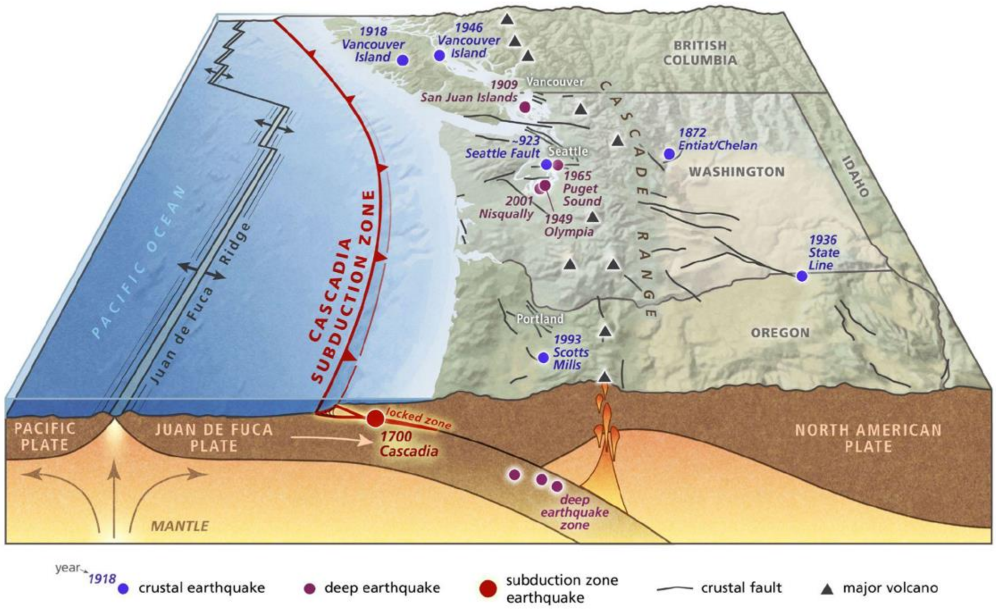


**Figure 1.** Schematic diagram of the Cascadia subduction zone of the western USA and Canada, with selected historic earthquakes identified. Image courtesy Washington Geological Survey.