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Not My Fault: The 2024 mid-year earthquake report

Lori Dengler for the Times-Standard
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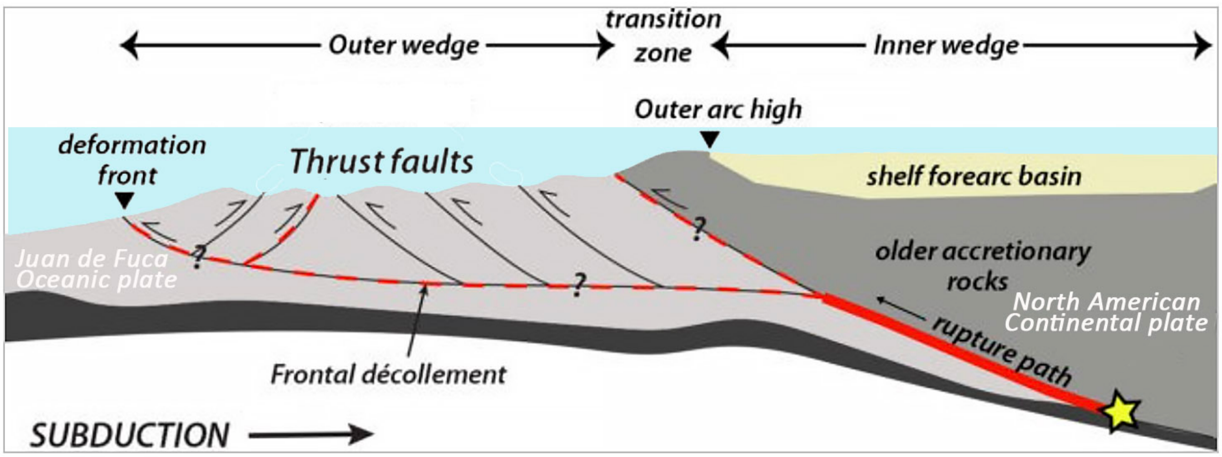
https://www.times-standard.com/2024/06/15/lori-dengler-not-all-parts-of-the-cascadia-region-are-the-same/



Simplified sketch of the Cascadia subduction zone offshore of Washington. A great earthquake is likely to initiate closer to the coast (yellow star). Rupture will move upward and to the west extending offshore along a flat relatively smooth interface (décollement). The offshore area is cut by numerous secondary faults, some of which may also slip in a Cascadia earthquake (modified from the USGS).

An important publication came out on June 7 about the offshore structure of the Pacific Northwest coast. It is one of the most comprehensive examinations of this section of the Cascadia subduction zone and has implications for both ground shaking and tsunami generation when future earthquakes occur.

The study, led by Lamont-Doherty geophysicist Suzanne Carbotte, summarizes the results of a seismic reflection study off the coasts of Oregon, Washington, and Vancouver Island, Canada conducted three years ago. Seismic reflection is a technique where sound waves are artificially generated, and an array of detectors record the small signals that bounce back off underground structures. It's a bit like an echocardiogram on a far larger scale.

The technique has been used on land for over a century. In 1921, several groups tried detonating dynamite in holes beneath the ground and recording the signals on an array of seismographs surrounding the source site. Different rock types have varied seismic velocities and the contrasts between layers cause some of the wave energy to bounce back to the surface.

The records can be stacked to provide a visual image of the substructure with the boundaries between different sedimentary rock layers clearly demarked. Underground folds and faults could be mapped without expensive drilling. It didn't take long for the burgeoning oil and gas industry to adopt the method and it remains the primary exploration tool of the industry today.

Offshore reflection studies are a bit more problematic. We can't easily access the seafloor and explosions in water create a bubble of gasses that diffuse the signal, let alone create environmental havoc. In the 1950s the tuned air-gun source was developed for offshore seismic surveys. The gun releases a series of highly compressed air pulses of different sizes and intervals that can be "tuned" to optimize the reflected signals for the particular area of study.

Carbotte and colleagues used the most recent adaptation of a tuned air-gun study, a 9-mile-long cable with 1200 hundred embedded seismic receivers towed behind the research vessel Marcus G. Langbeth and ran lines parallel to the coast covering the 500 miles from the CA – Oregon border to the middle of Vancouver Island, Canada. The team also ran lines perpendicular to the coast, cutting across the offshore margin to acquire a 3-dimensional picture of the structures.

Why focus a study on this offshore region? The Cascadia subduction zone extends from Cape Mendocino in southern Humboldt County to Vancouver Island Canada. Subduction zones are places where nature recycles tectonic plates, and one plate is "pulled" by gravity beneath another. There are just under 30 mapped subduction zones on the planet, and they account for over 90% of the seismic energy released annually. They are also the only places where the largest quakes can occur – earthquakes in the upper magnitude 8 to mid 9 range.

The Cascadia subduction zone is problematic in several ways. It is adjacent to and partly beneath the most populated areas of the Pacific Northwest. It is estimated that roughly 15 million people could be directly affected by Cascadia ground shaking and communities in throughout the Pacific, including Hawaii, Alaska, and Japan could be hit by a Cascadia tsunami. Damage to coastal port and harbor facilities may ripple throughout the U.S. and Canada and economic impacts could have global repercussions.

Cascadia is also an enigmatic subduction zone. It is currently seismically quiet and virtually no earthquakes of any size have been detected along the fault interface in historic times. Paleoseismologists, scientists who study prehistoric earthquakes, have found multiple lines of evidence that place the last Cascadia quake in January 1700. That evidence also points to a complete rupture – from Humboldt County to Vancouver Island putting the magnitude at about 9.0. The recurrence of these great quakes is not regular and can be as close as 200 years or as long as 800.

The 2021 expedition was not the first offshore seismic reflection in the Cascadia offshore region, but it is the most comprehensive in the central and northern parts of Cascadia and revealed differences in structures only hinted at from previous work. These differences are important for likely extent of rupture, ground motions, and tsunami potential.

We've known for years that not all parts of Cascadia are equal. Just a quick glance at a map shows the margin is much closer to the coast in Northern California and further offshore in Washington. The coastal topography and geology differ too, with rugged mountains in California and Washington's Olympic Peninsula and more subdued terrain in the central part of the Cascadia region. Patterns of low-level seismicity called episodic tremor and slip show at least four distinct regions going from north to south.

The Carbotte-led study shows these differences are prevalent in the offshore structure as well. The reflection profiles delineate the offshore zones of slip in Cascadia earthquakes (the décollement, from the French meaning to detach). In the central part of Cascadia from the California border to northern Oregon this slip zone is rough, cut by faults and subducted seamounts. To the north off the Washington and southern British Columbia coasts, the décollement is very smooth and nearly horizontal.

Why does the shape and geometry matter? The length and width of an earthquake rupture and the amount of slip are controlled by rough patches. Once rupture initiates, flat smooth areas can move more easily. One implication of the study is that slip could extend into inland areas of Puget Sound and Vancouver Island producing stronger ground shaking than previously estimated. The amount of slip controls tsunami generation as well.

This variability supports the idea of partial ruptures, that instead of one single rupture of the whole interface, we might get four or five segment ruptures. My colleague Gary Carver used to call this the decades of terror model – a sequence of upper M7s to mid 8s over a decade or two.

This study says nothing about the southern section of Cascadia in Humboldt and Del Norte Counties. The research proposal was for the entire Cascadia subduction zone, including the 115 miles off the Humboldt and Del Norte County coasts. But California regulations prevented the group from acquiring the permits in a timely manner to examine what we call the Gorda region of Cascadia.

After hearing media reports last week about the new study, several people told me we were off the hook when it came to Cascadia hazards. Omission does not mean no hazard and the authors make it clear that studying the offshore California coast is a high priority to gaining a full understanding of Cascadia threats.

For a deeper dive into the details of the study, read the complete article at https://www.science.org/doi/10.1126/sciadv.adl3198.

Lori Dengler is an emeritus professor of geology at Humboldt State University, an expert in tsunami and earthquake hazards. The opinions expressed are hers and not the Times--Standard's. All Not My Fault columns are archived online at https://kamome.humboldt.edu/taxonomy/term/5 and may be reused for educational purposes. Leave a message at (707) 826-6019 or email Kamome@humboldt.edu for questions and comments about this column or to request copies of the preparedness magazine "Living on Shaky Ground."