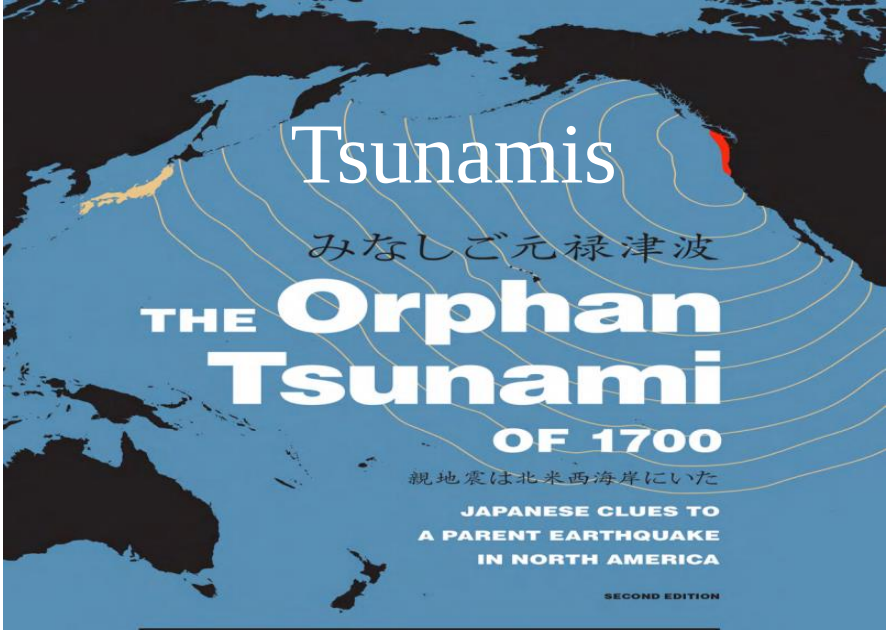

The Cascading Hazards from Cascadia's Earthquakes

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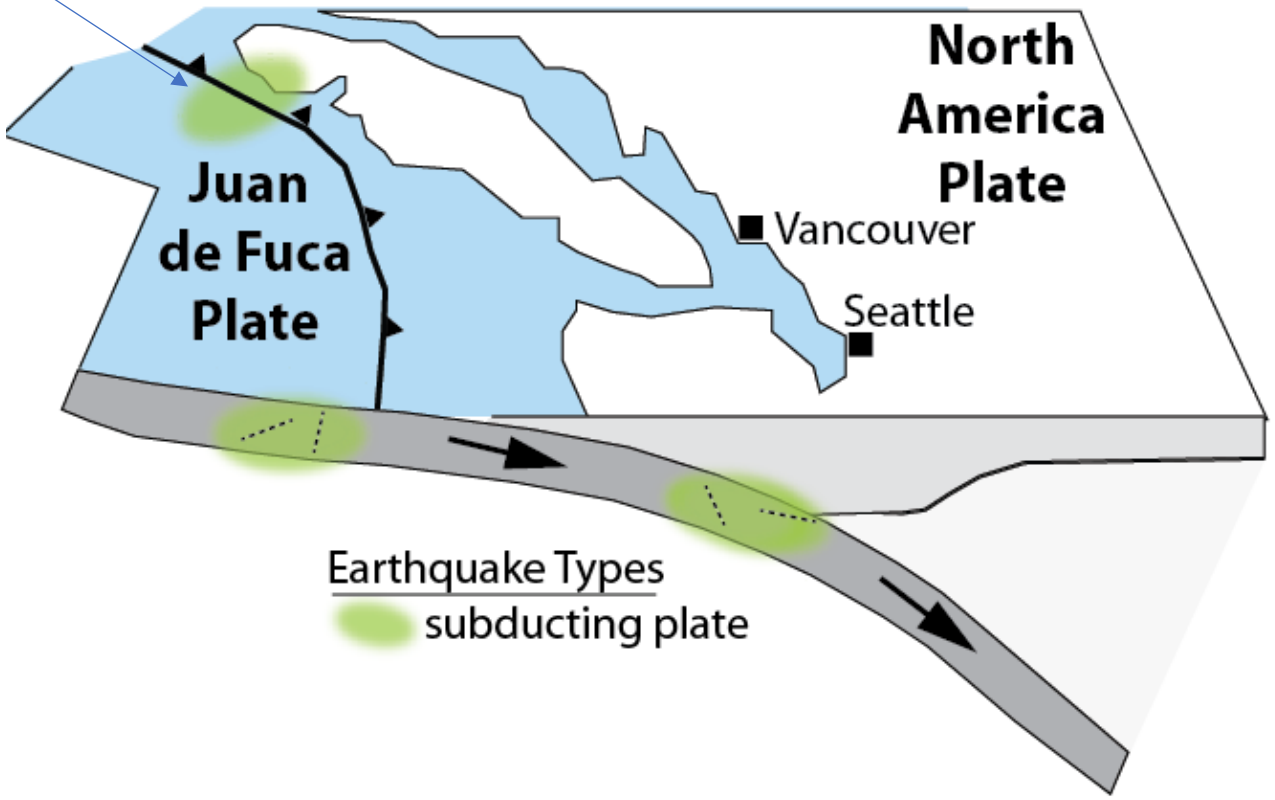
USGS

Earthquakes: Consider other earthquakes! These occur independently, or as aftershocks. In the subducting plate there are

‘outer rise’ earthquakes, where the plate bends as it begins its descent; elsewhere these have been big and devastating, but not thought about in Cascadia!



Earthquakes: Many flavors, each with unique characteristics. In the subducting plate there are

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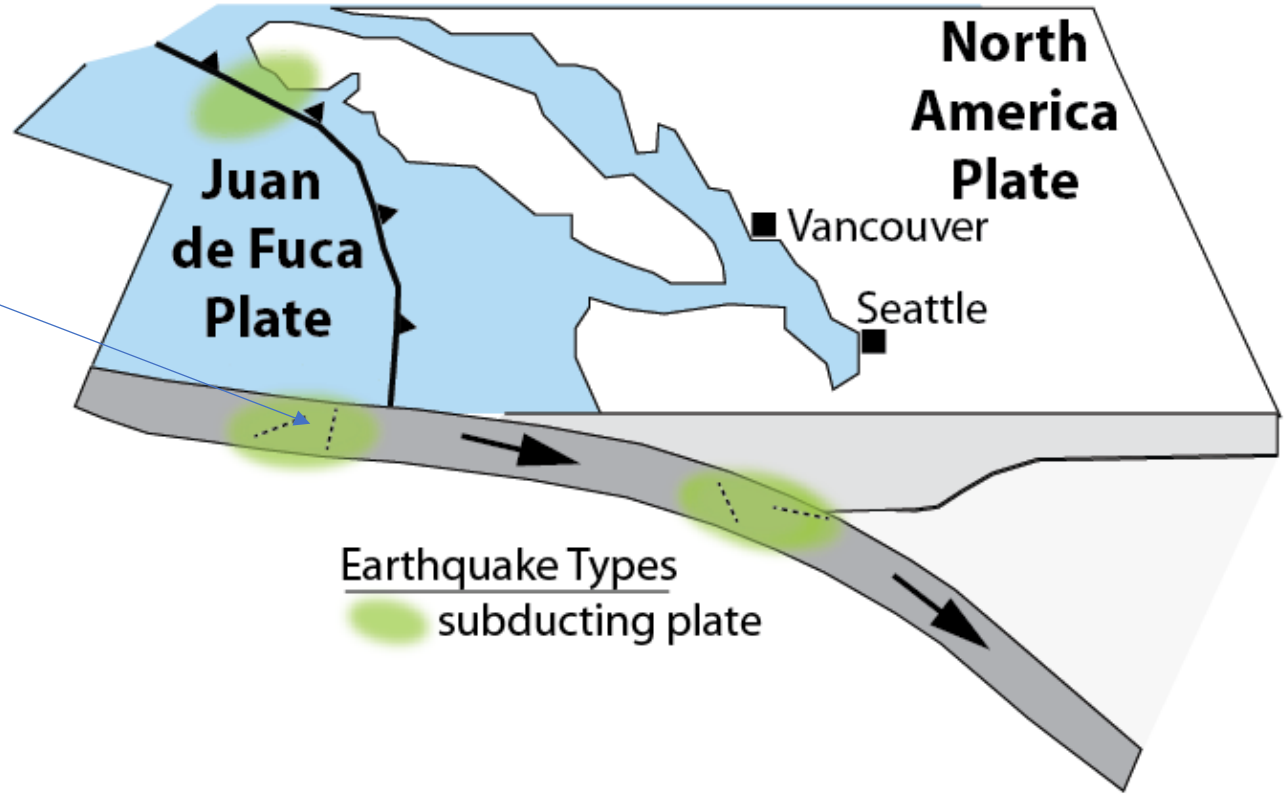
frequent offshore shallow earthquakes, especially southern Cascadia; not hazardous as no one lives nearby!



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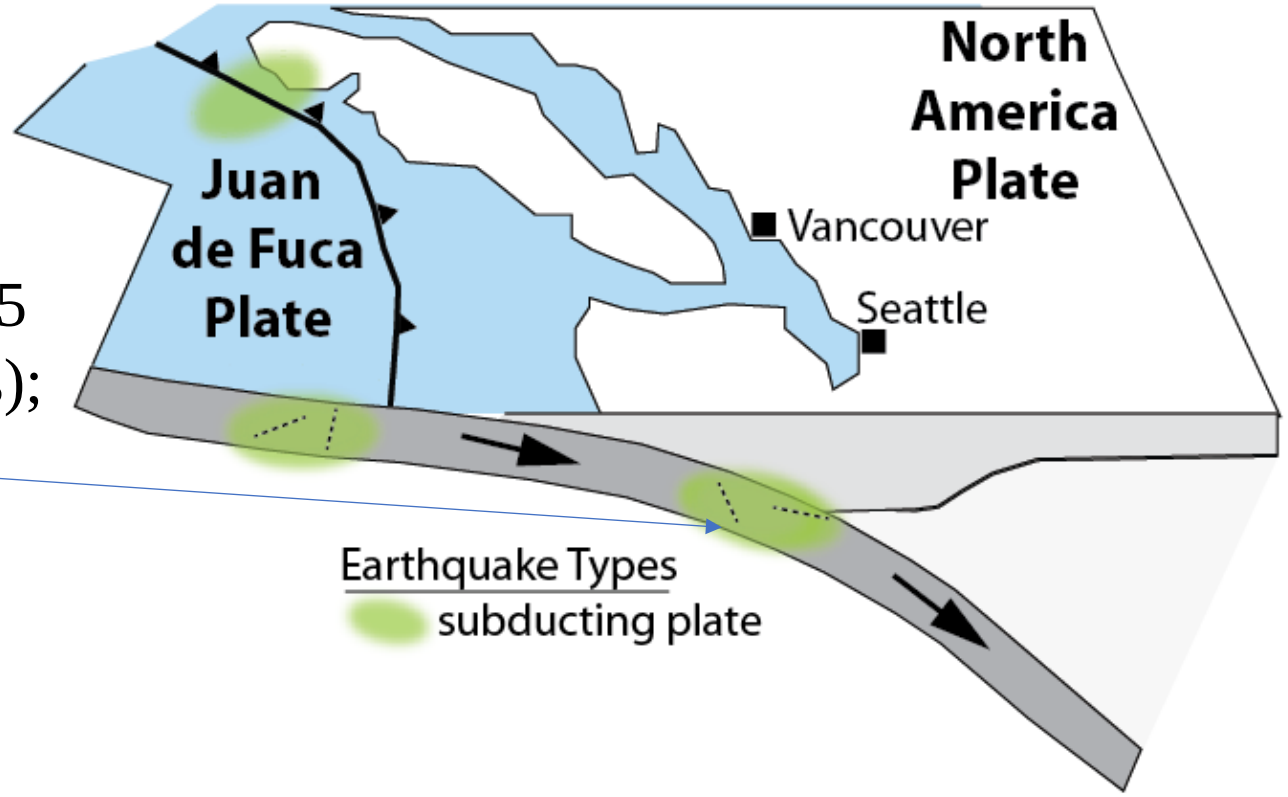
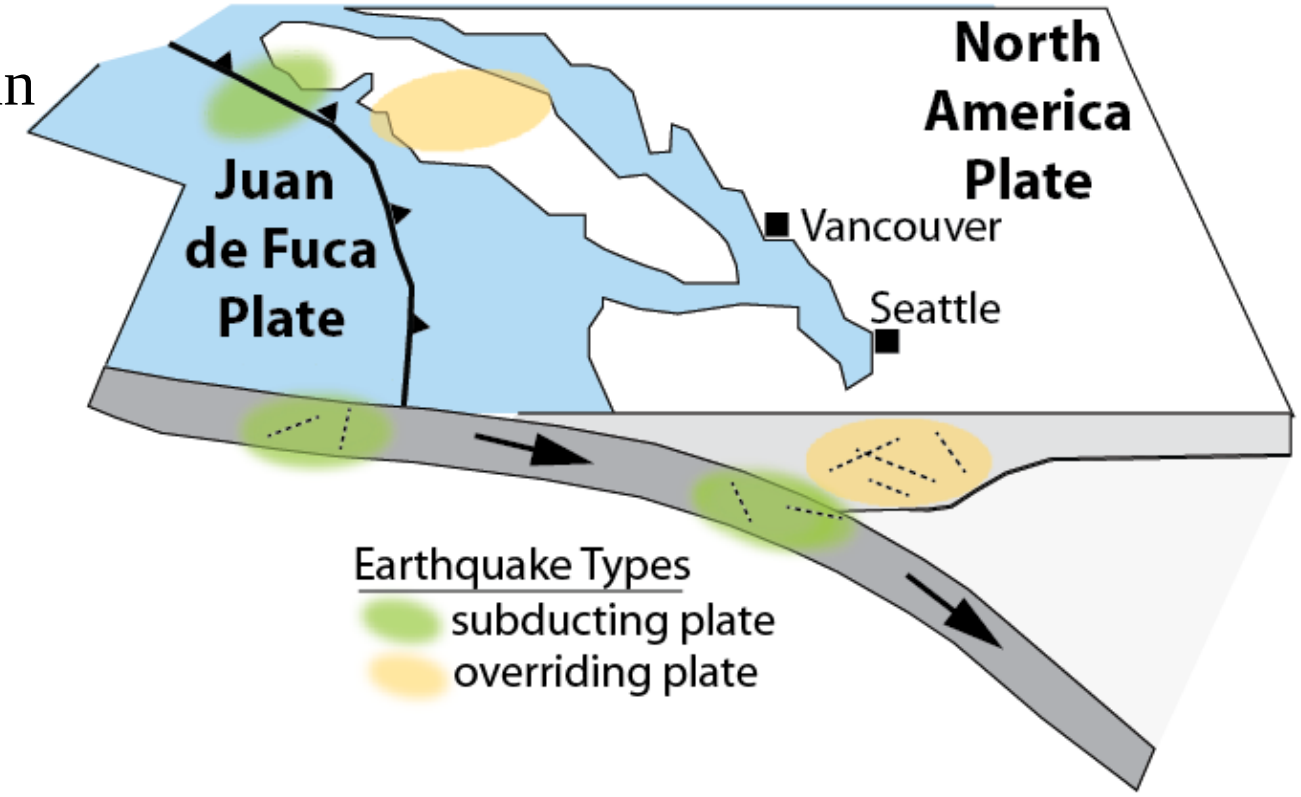
deep earthquakes, are most common (M≥6.5 near Seattle probability is ~84% in 50 years); location beneath populations makes them hazardous (but few aftershocks).



Earthquakes: In the overriding plate there are

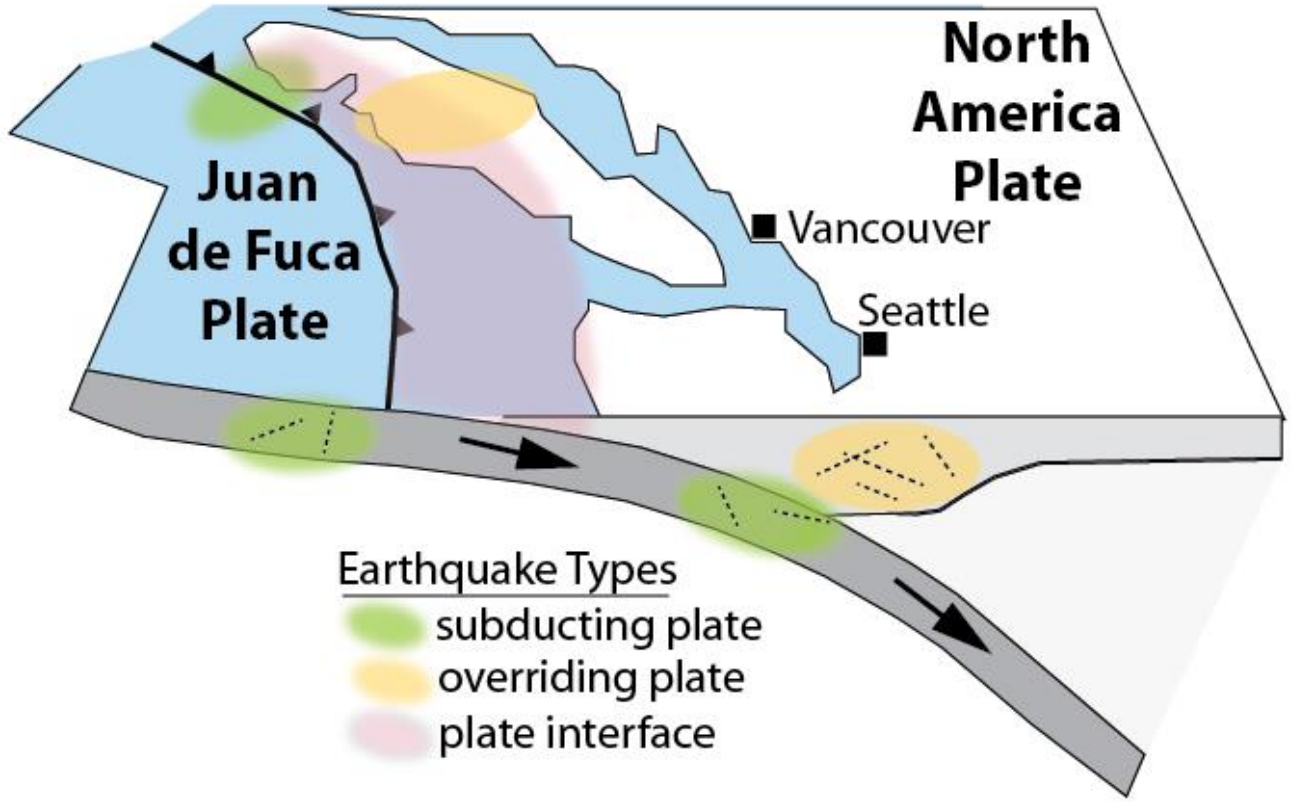
shallow earthquakes, which can shake hard locally because they're so close. Each fault breaks at intervals of thousands of years or more, but there are lots of faults.

~15% probability of a M≥6.5 near Seattle in 50 years.



Earthquakes: Along the plate interface

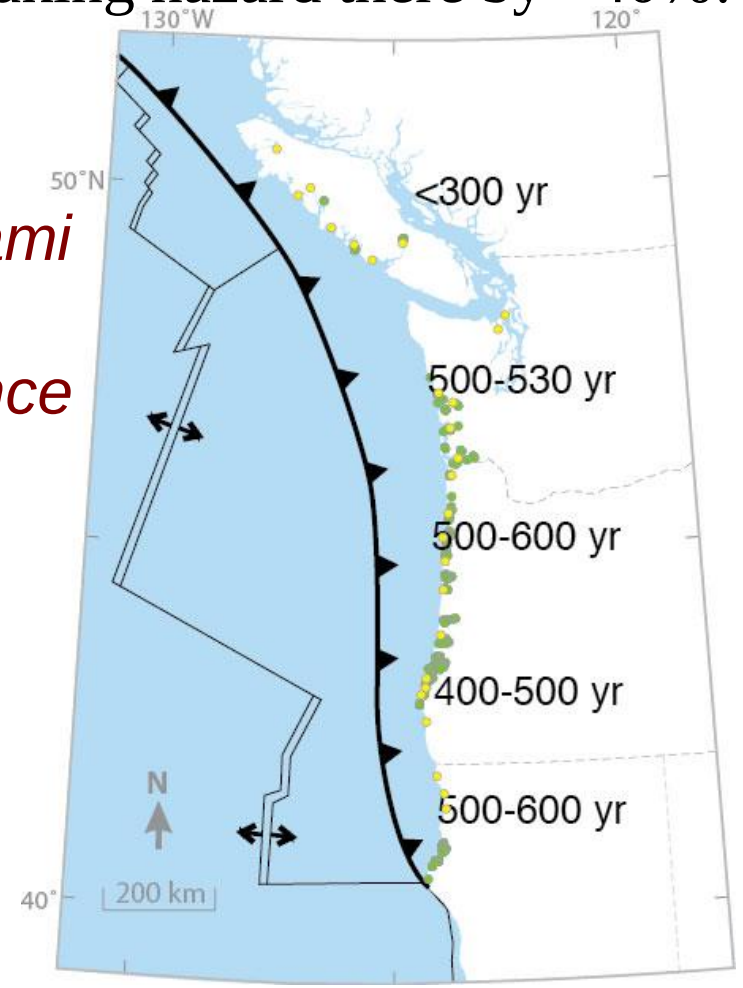
‘megathrust’ (M~9) earthquakes recur every ~500 years on average, and otherwise the fault is enigmatically silent.



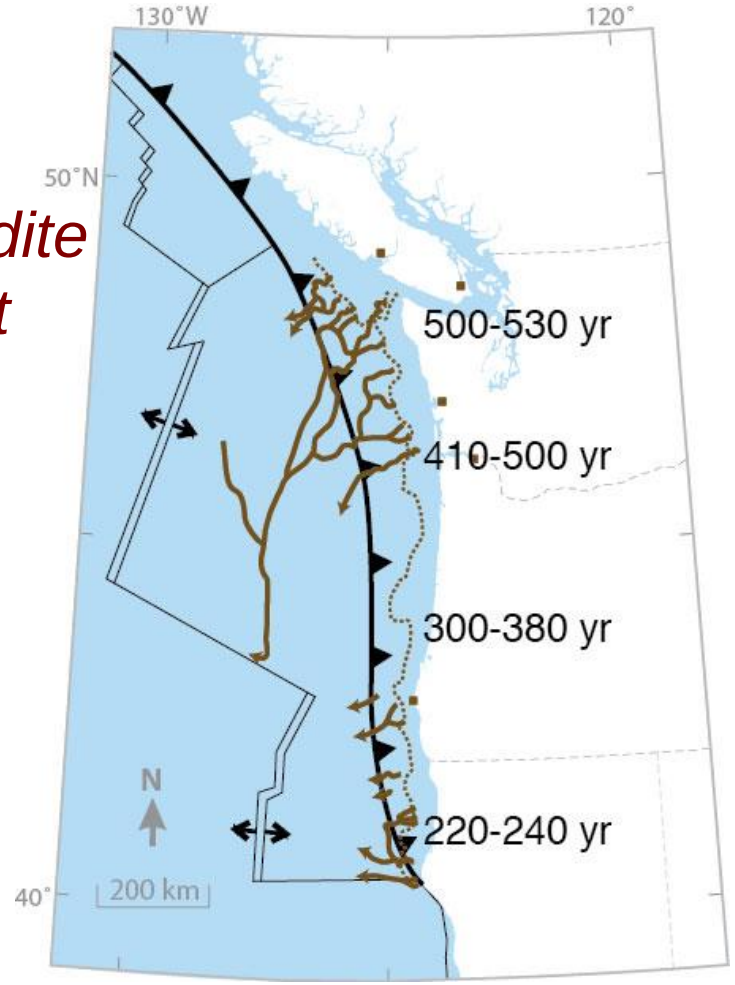
Earthquakes: Along the plate interface – how often?

Mud and sand deposits offshore have been interpreted as resulting from megathrust earthquake shaking, and to be more frequent going southward. The onshore geologic record does not require this north-south difference. More frequent megathrust earthquakes in the south increases the shaking hazard there by ~40%!

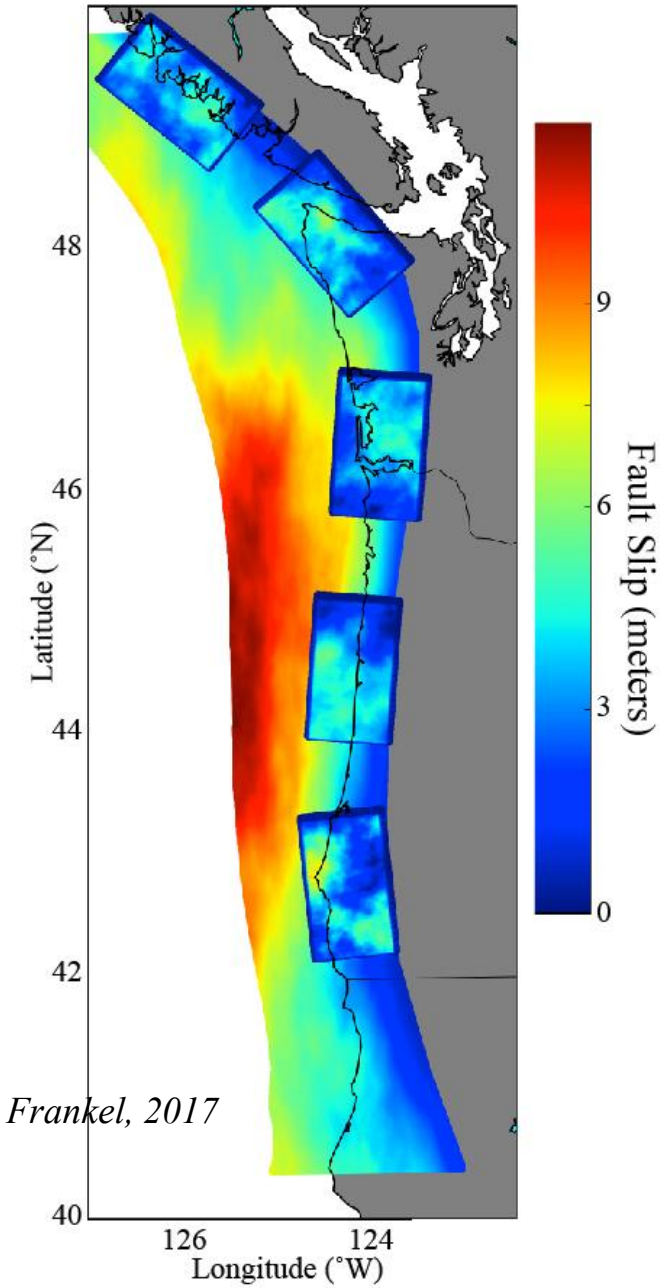
onshore tsunami & coastal uplift/subsidence record



offshore turbidite & sediment record



Earthquakes: The radiated seismic waves (shaking) vary a lot.

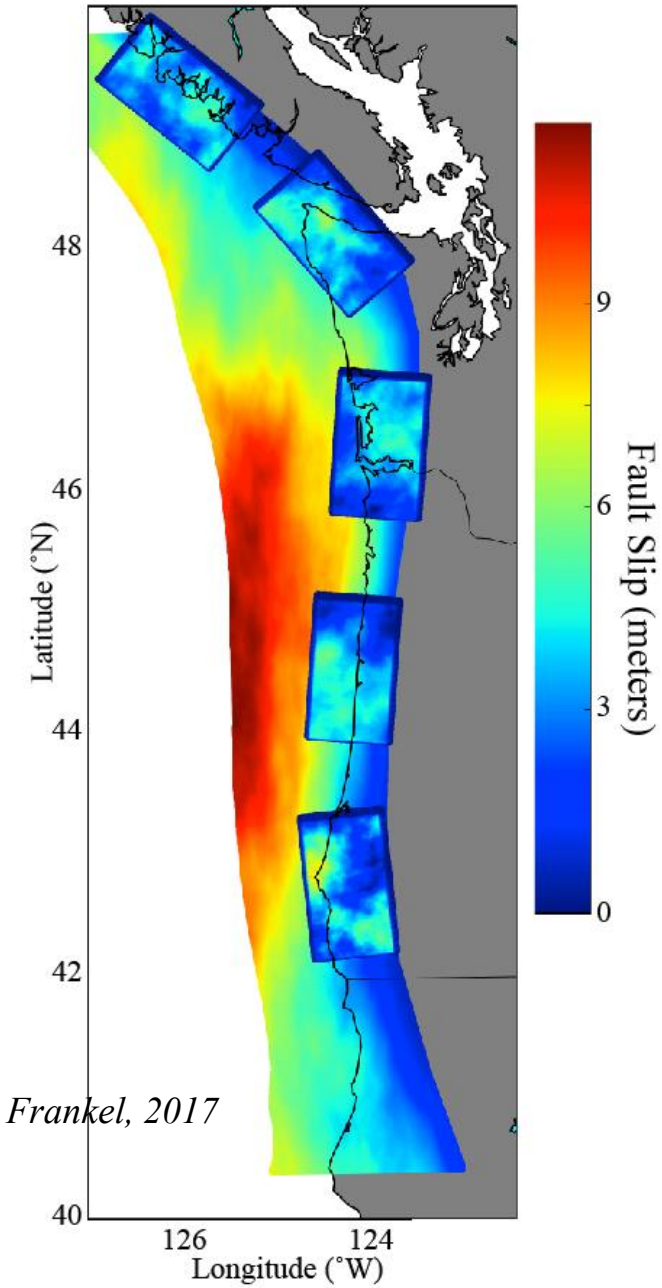


From Wirth & Frankel, 2017

Recent megathrust earthquakes elsewhere result from large, slow slippage along nearly the entire fault + smaller, faster slip on patches.

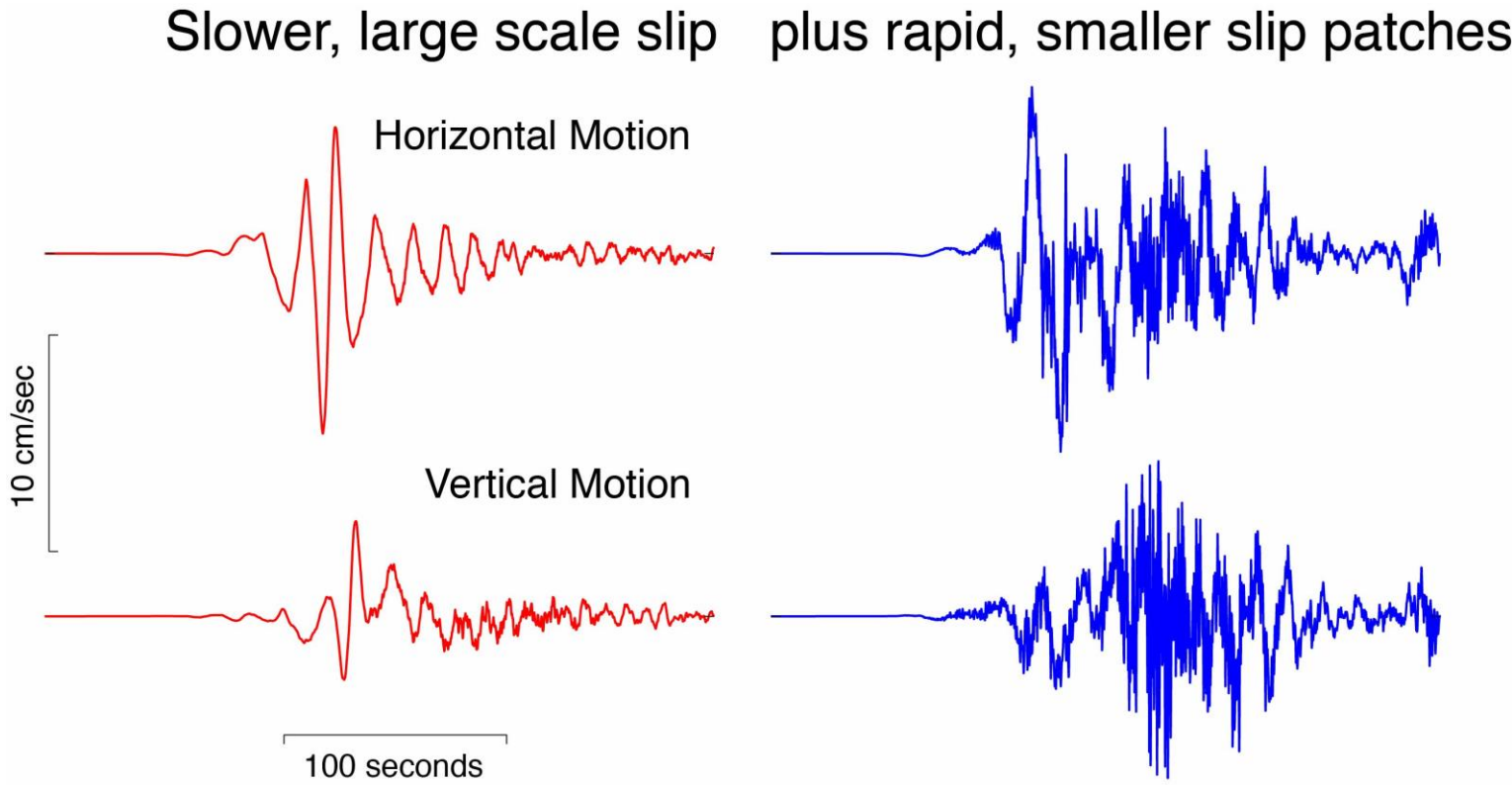
The amount and rate of slippage affect the radiated waves and other processes; the shallow slip may generate a large tsunami, but waves radiated oscillate too slowly to damage most buildings.

Earthquakes: The radiated seismic waves (shaking) vary a lot.

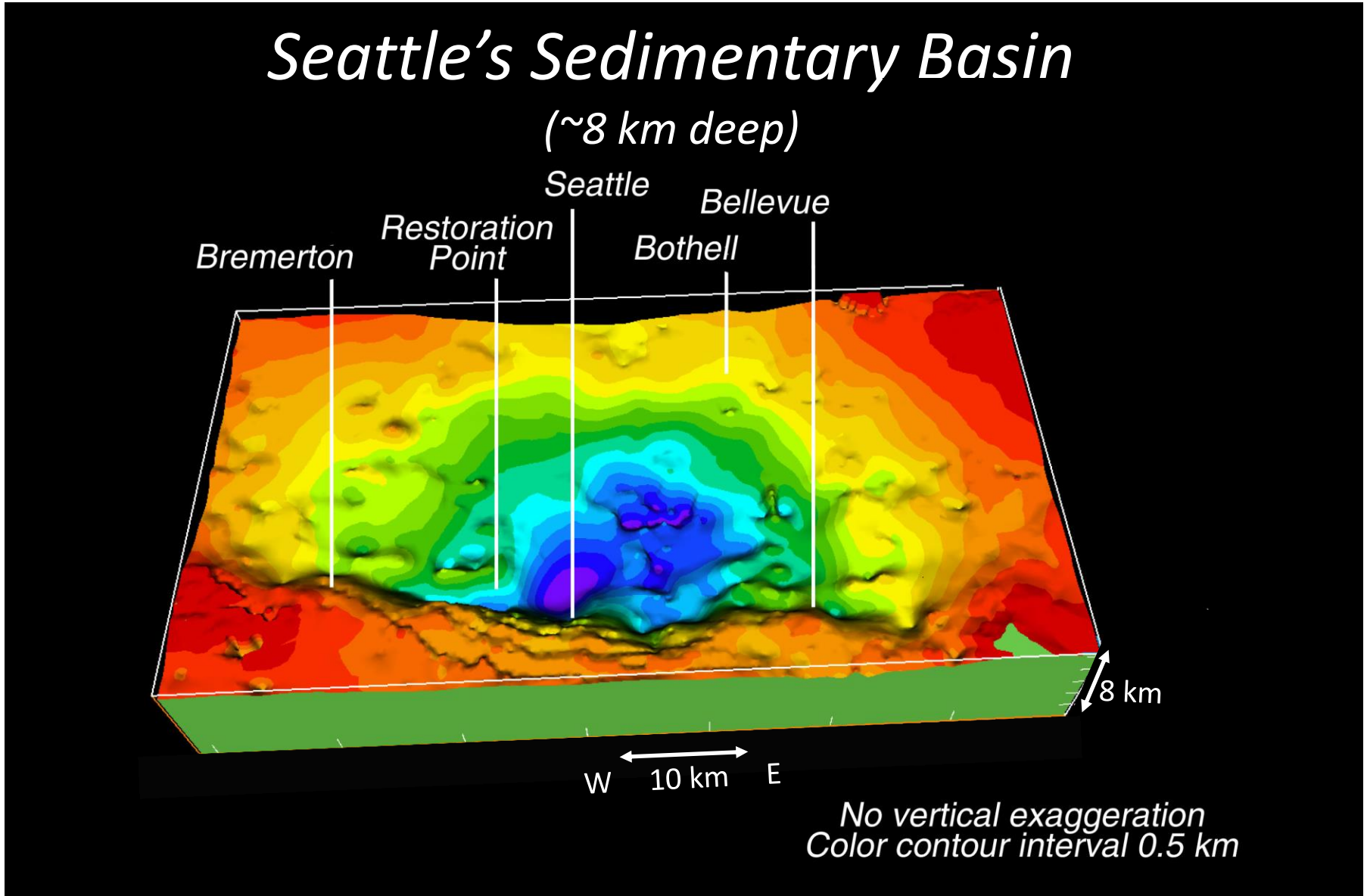


From Wirth & Frankel, 2017

The added M8+ 'patches' radiate waves with higher frequency oscillations, that can damage buildings.



Earthquakes: Seismic waves are changed by the rocks and sediments they travel through.



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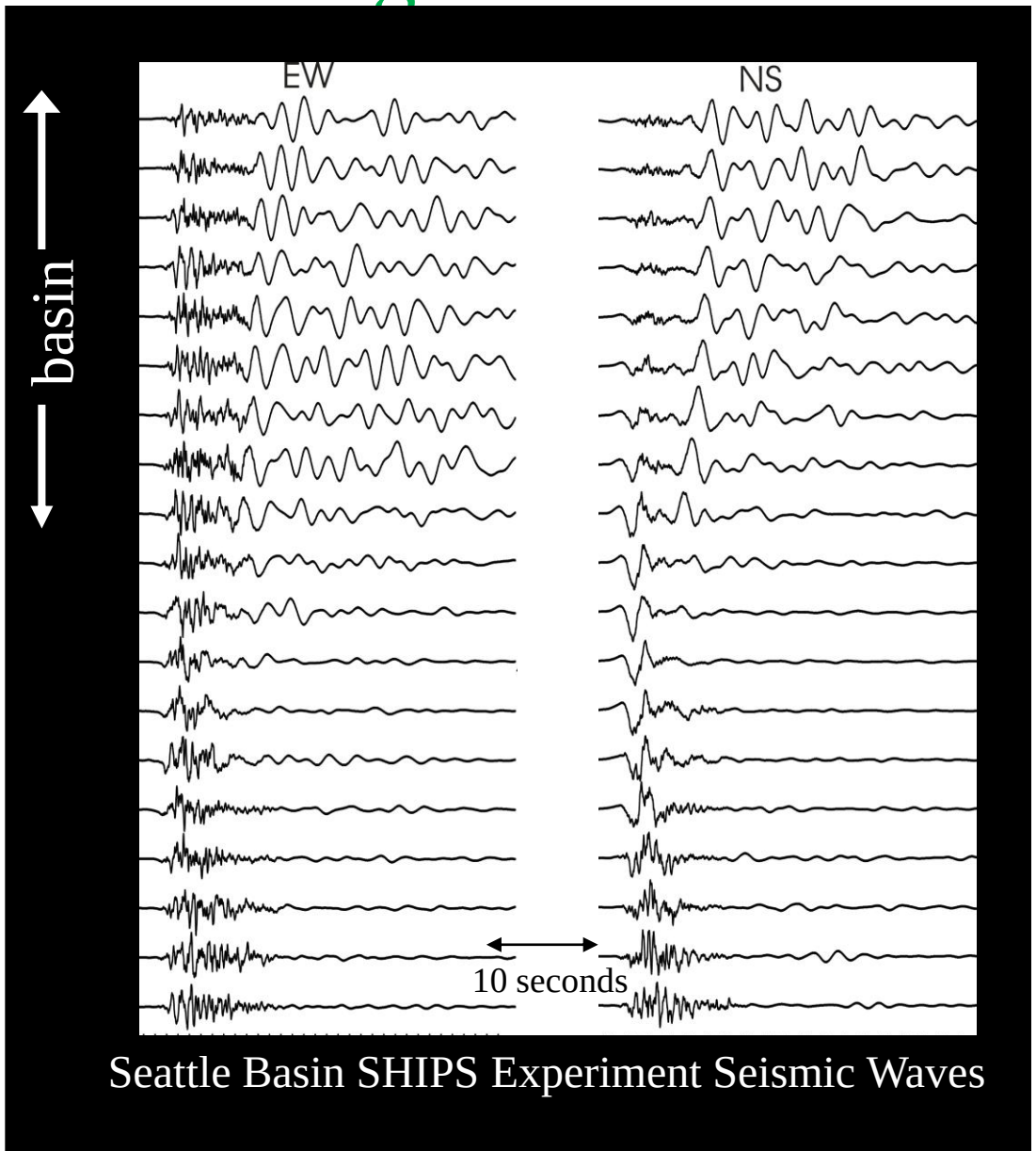
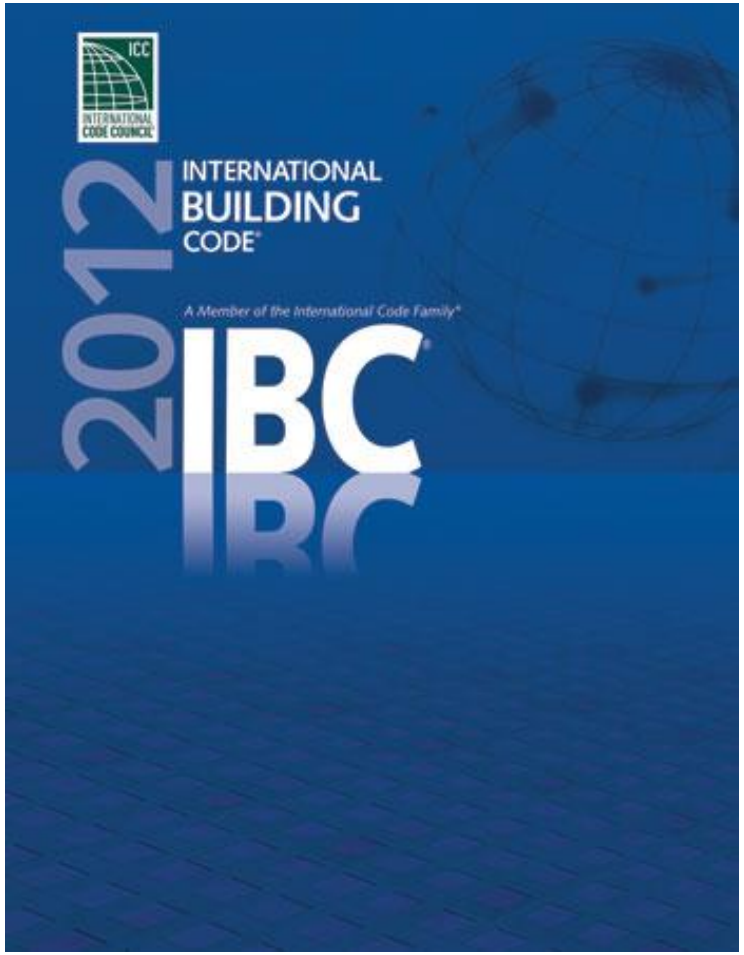
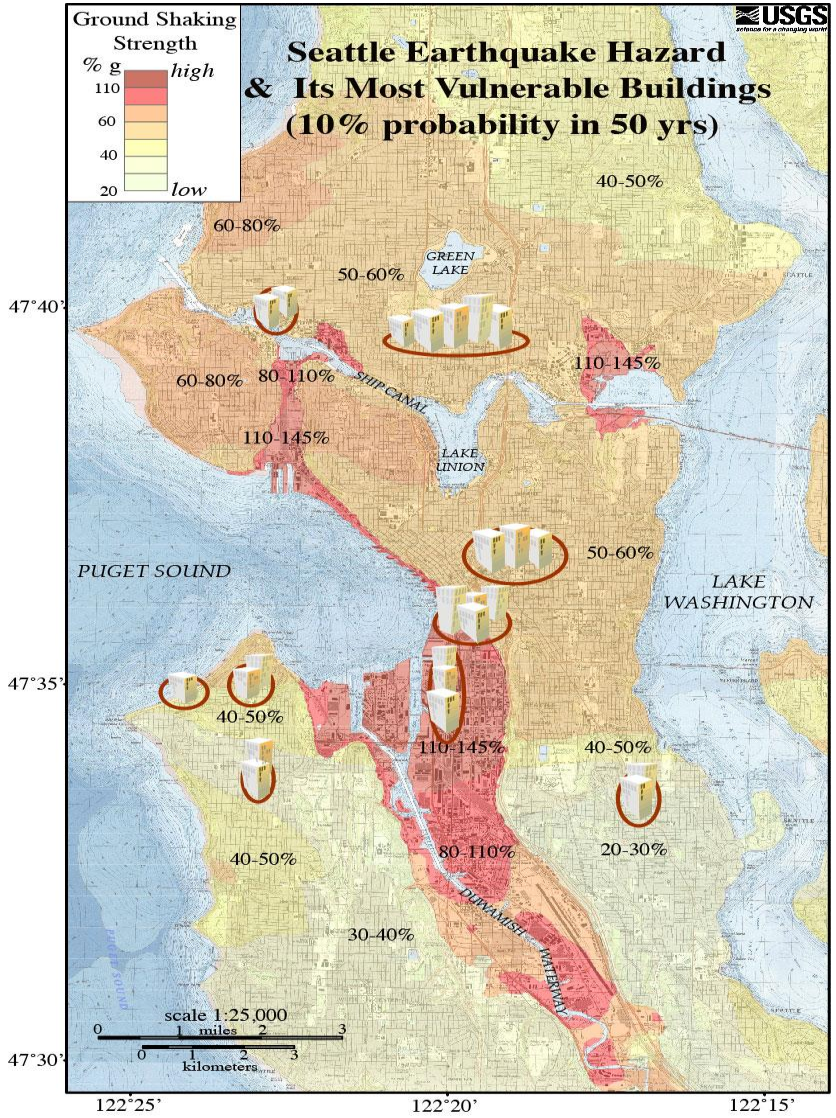


Seattle Basin SHIPS Experiment Seismic Waves

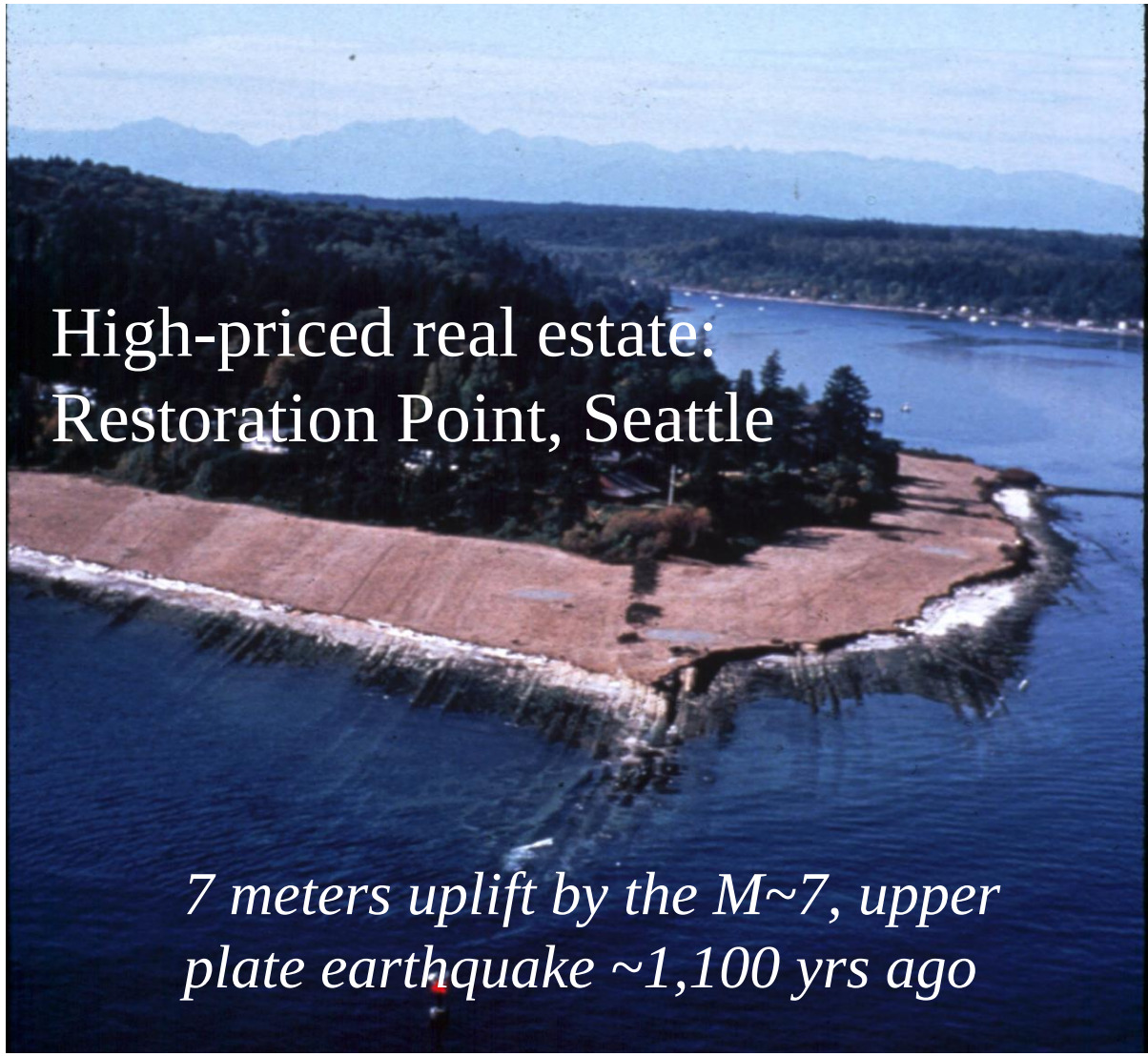
Sediment-filled basins may amplify shaking.

Earthquakes: Science underpins seismic building codes, engineering designs, and public policy.





Earthquake-induced widespread, permanent land-level changes: these alter environments.



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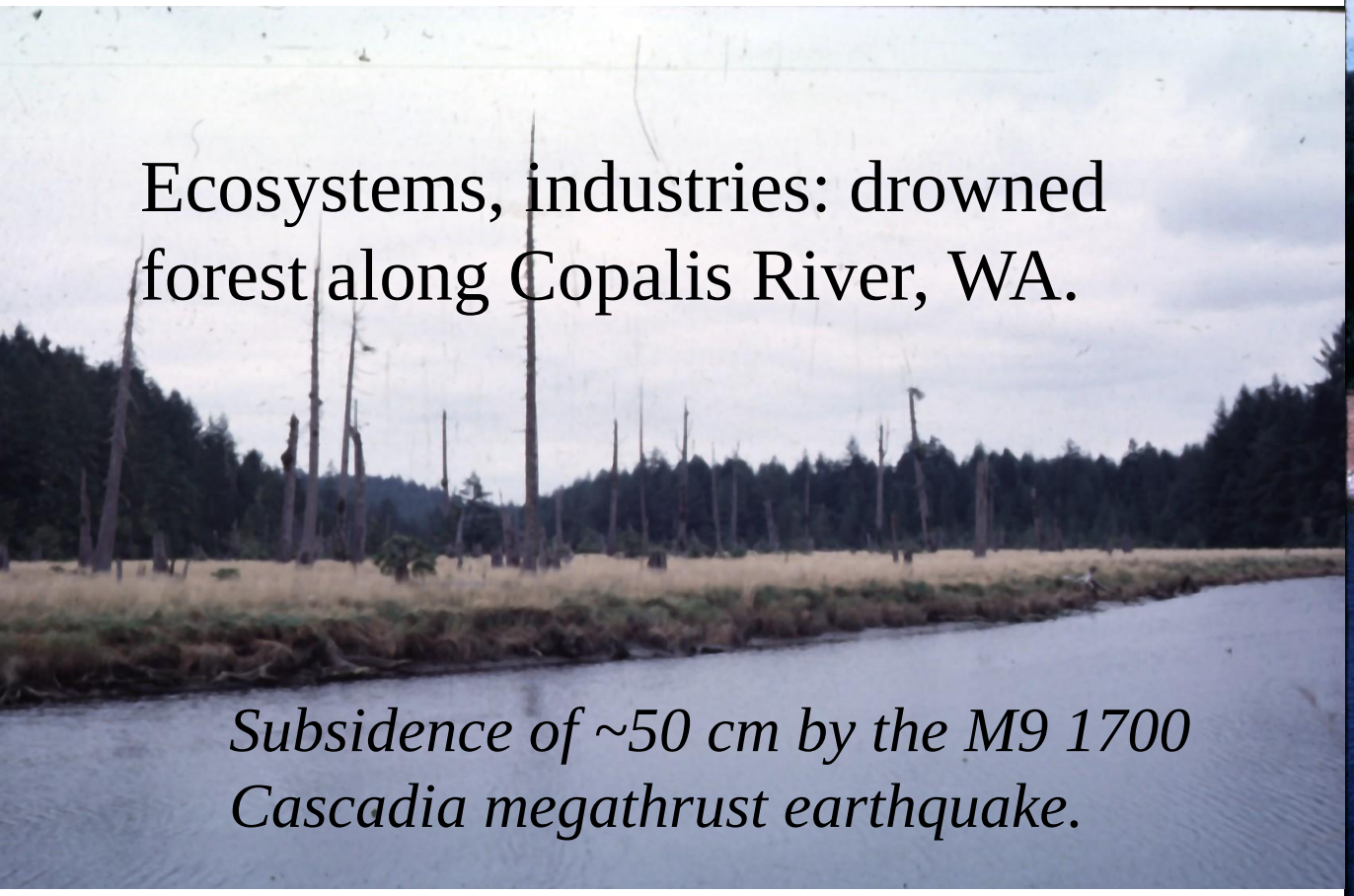
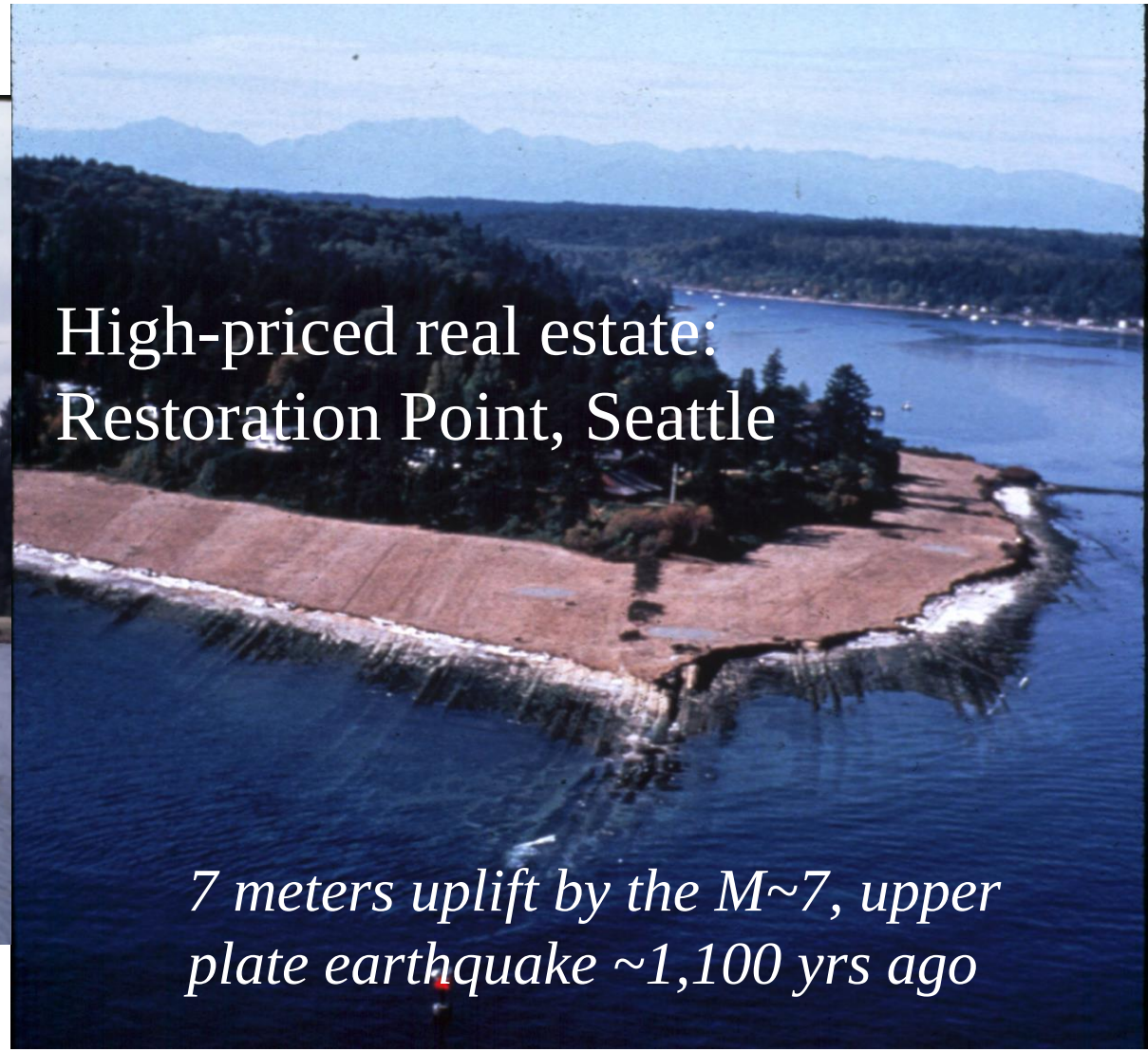


Ecosystems, industries: drowned forest along Copalis River, WA.

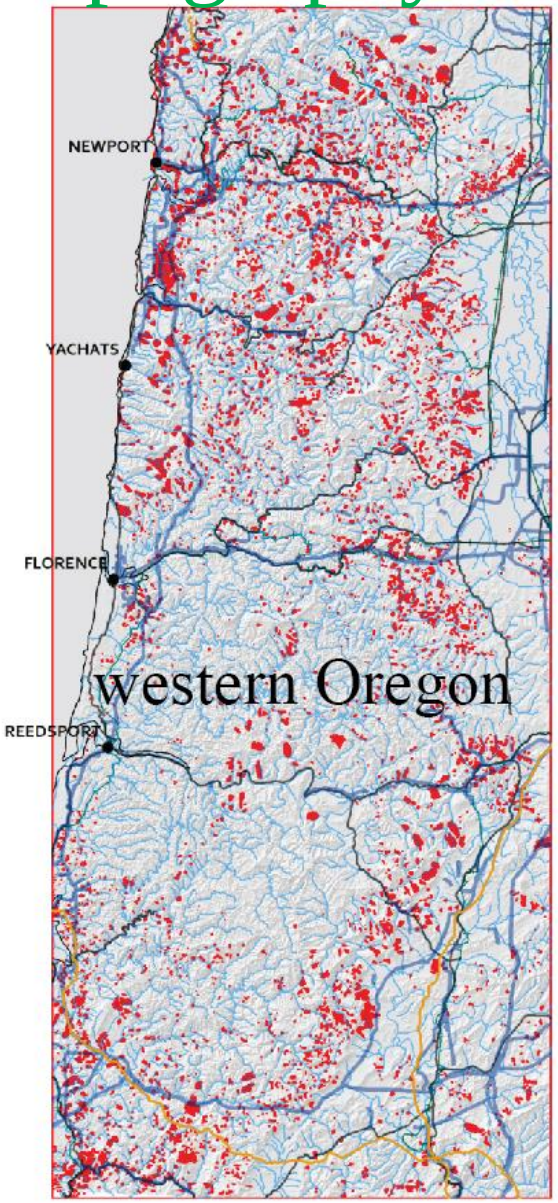
Subsidence of ~50 cm by the M9 1700 Cascadia megathrust earthquake.

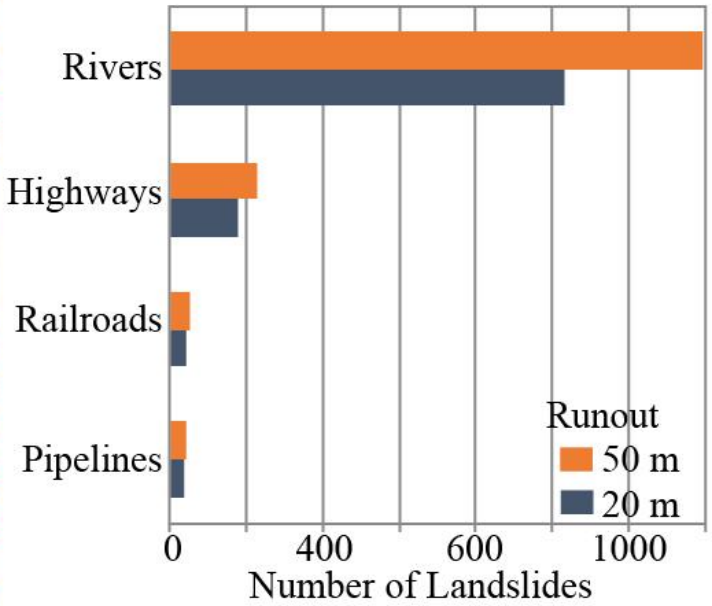


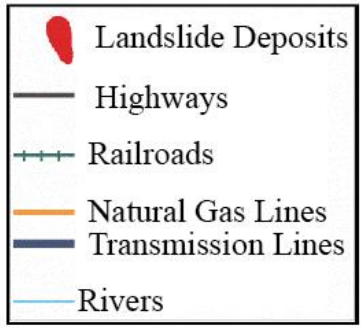
High-priced real estate: Restoration Point, Seattle

7 meters uplift by the M~7, upper plate earthquake ~1,100 yrs ago

Earthquake-triggered Landslides: Subduction creates steep topography & climatic conditions ideal for landslides.

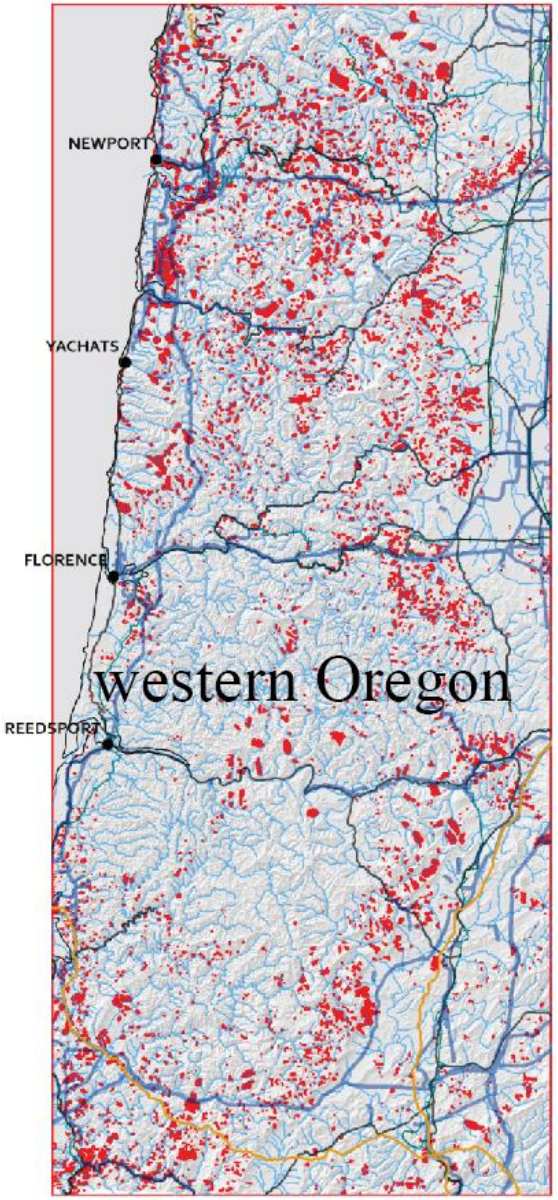


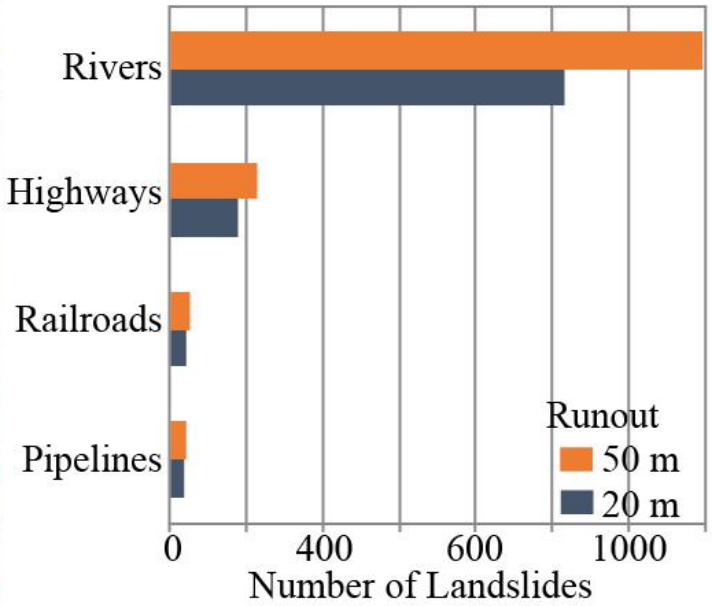


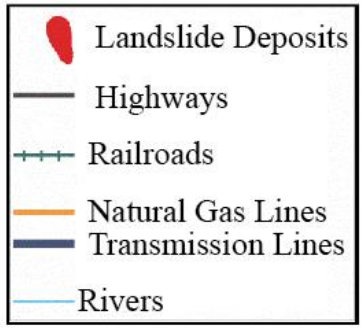


Cerovski-Darriau, USGS

Earthquake-triggered Landslides: Most landslides occur when rainfall saturates vulnerable slopes.







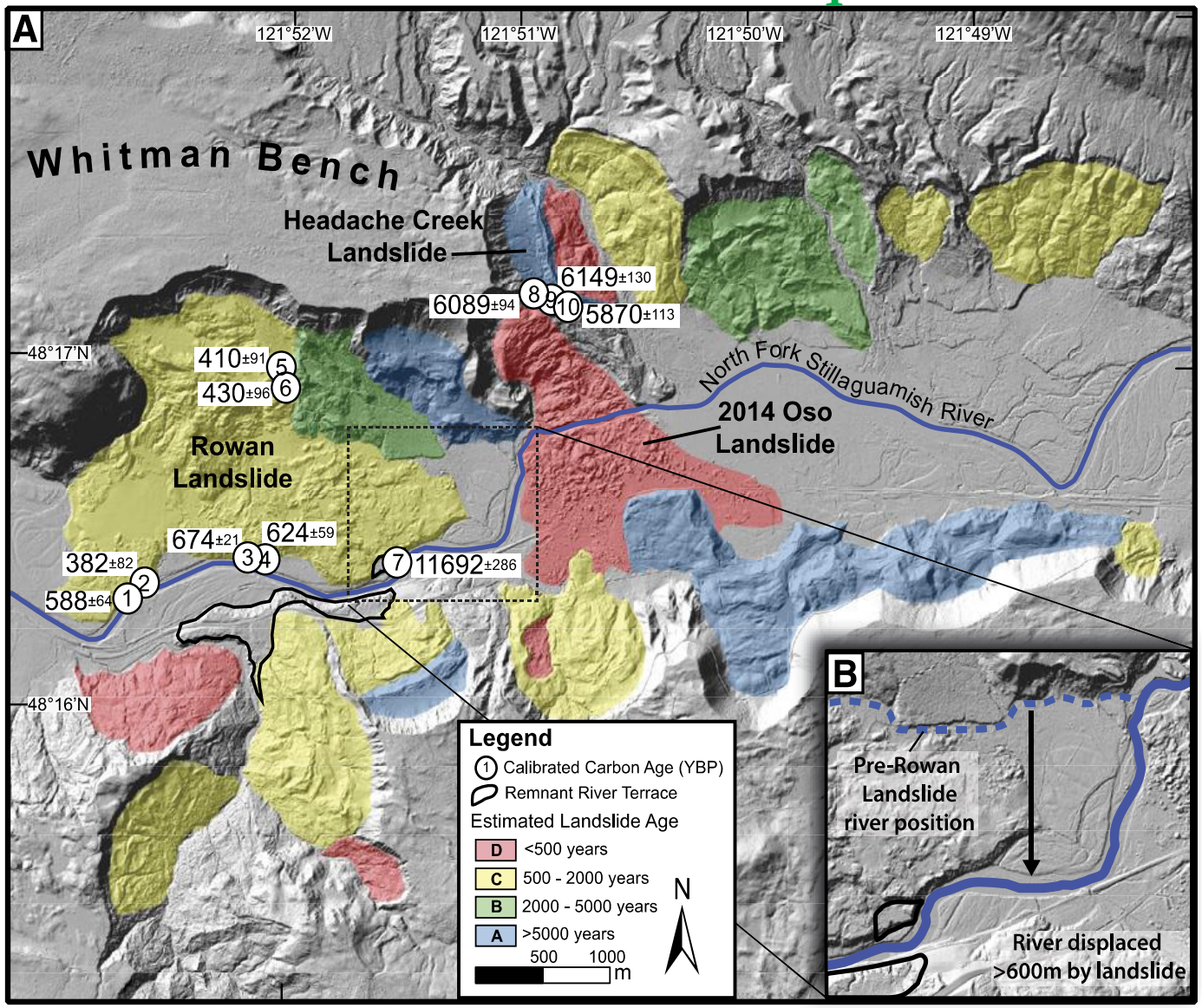
Cerovski-Darriau, USGS

Washington's 2014 Oso landslide (43 lives, >$150,000,00 lost) failed after weeks of rain.

Earthquake-triggered Landslides: To date, no landslide has been confidently linked to the 1700 M9 Cascadia earthquake.

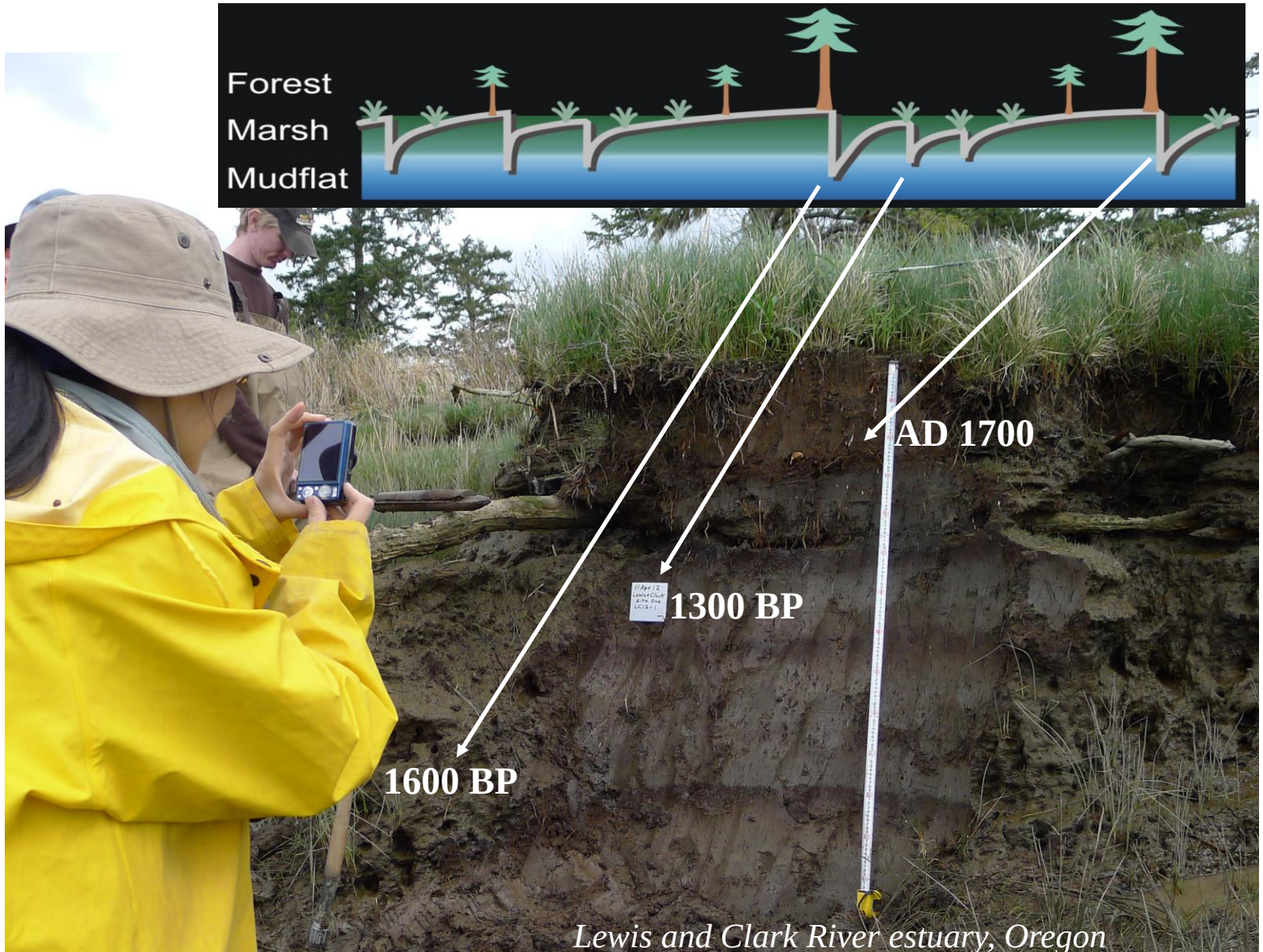
We assume the next major Cascadia earthquake will cause widespread landslides, but no evidence of this exists from previous Cascadia megathrust earthquakes!

Dating past individual and episodes of widespread landsliding is challenging, but new approaches using characteristics of the topography to date landslides may hold promise.



LaHusen et al. (2015), Geology

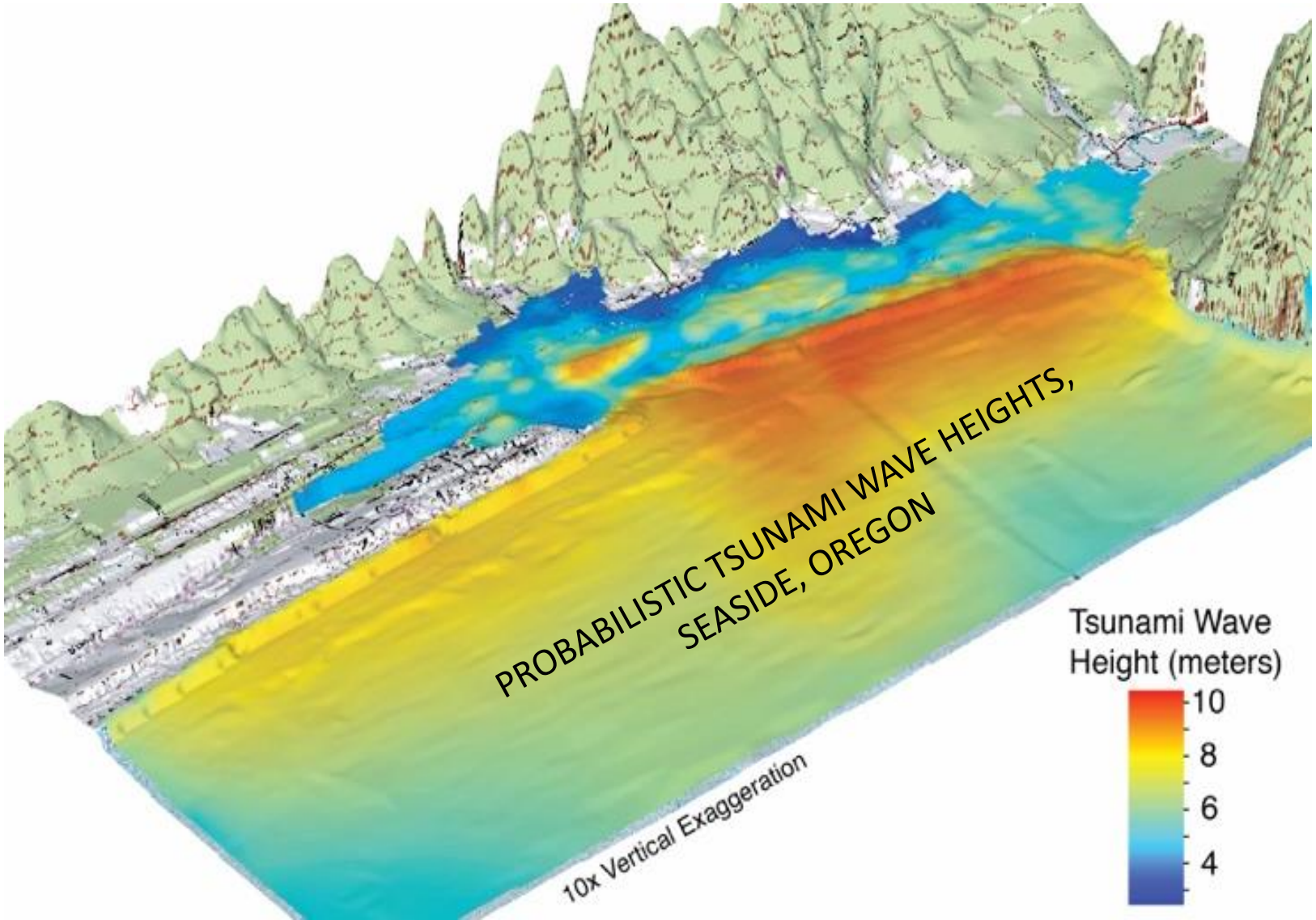
Earthquake-triggered Tsunamis: Deposits help constrain the recurrence of Cascadia megathrust earthquakes.



Lewis and Clark River estuary, Oregon

Earthquake-triggered Tsunamis: Science underpins high-resolution forecasts for a few coastal communities.

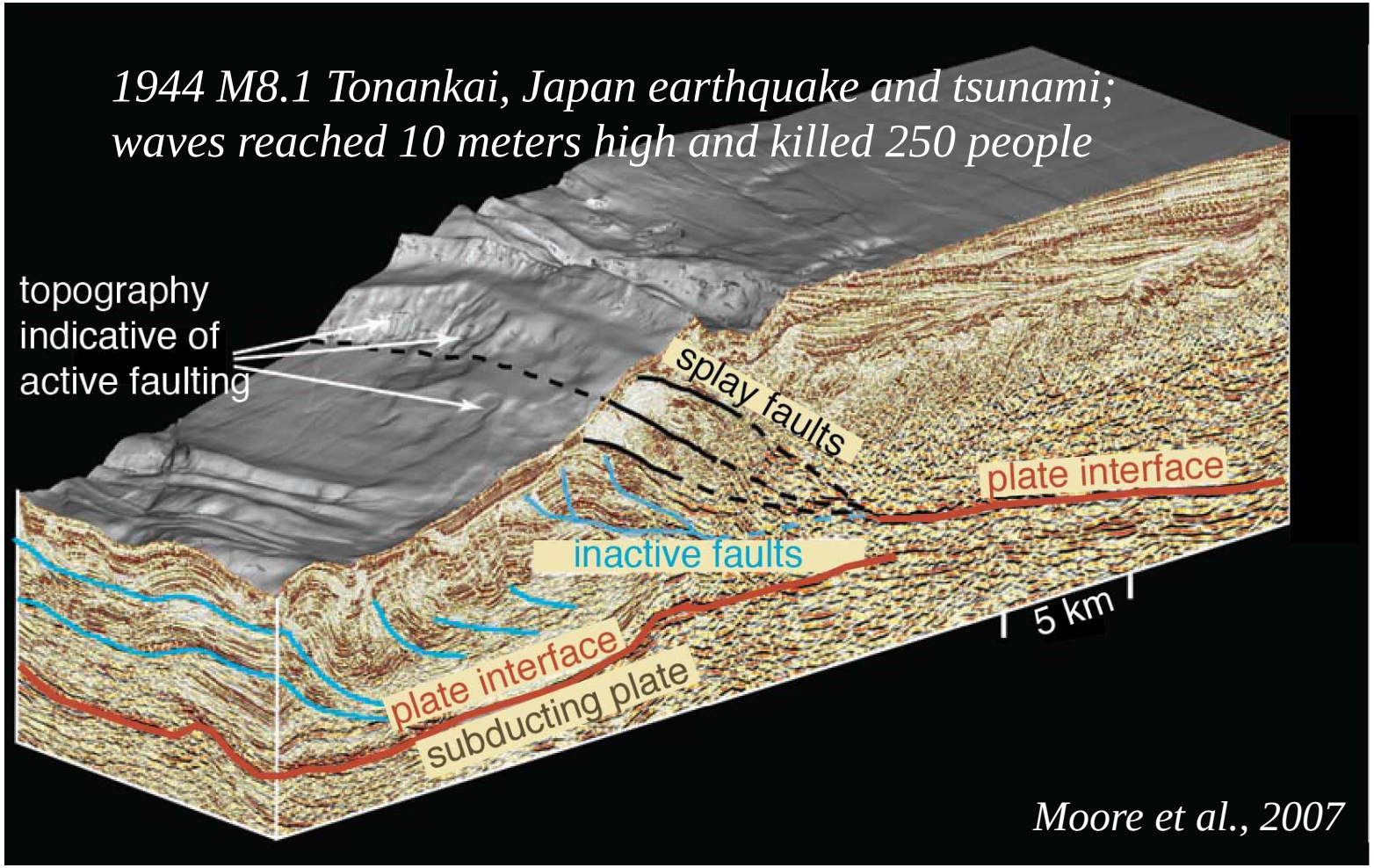
State-of-the-art forecasts account for a range of possible megathrust earthquakes and details of the seafloor topography that can focus or defocus waves. However, they are missing some key cascading processes.



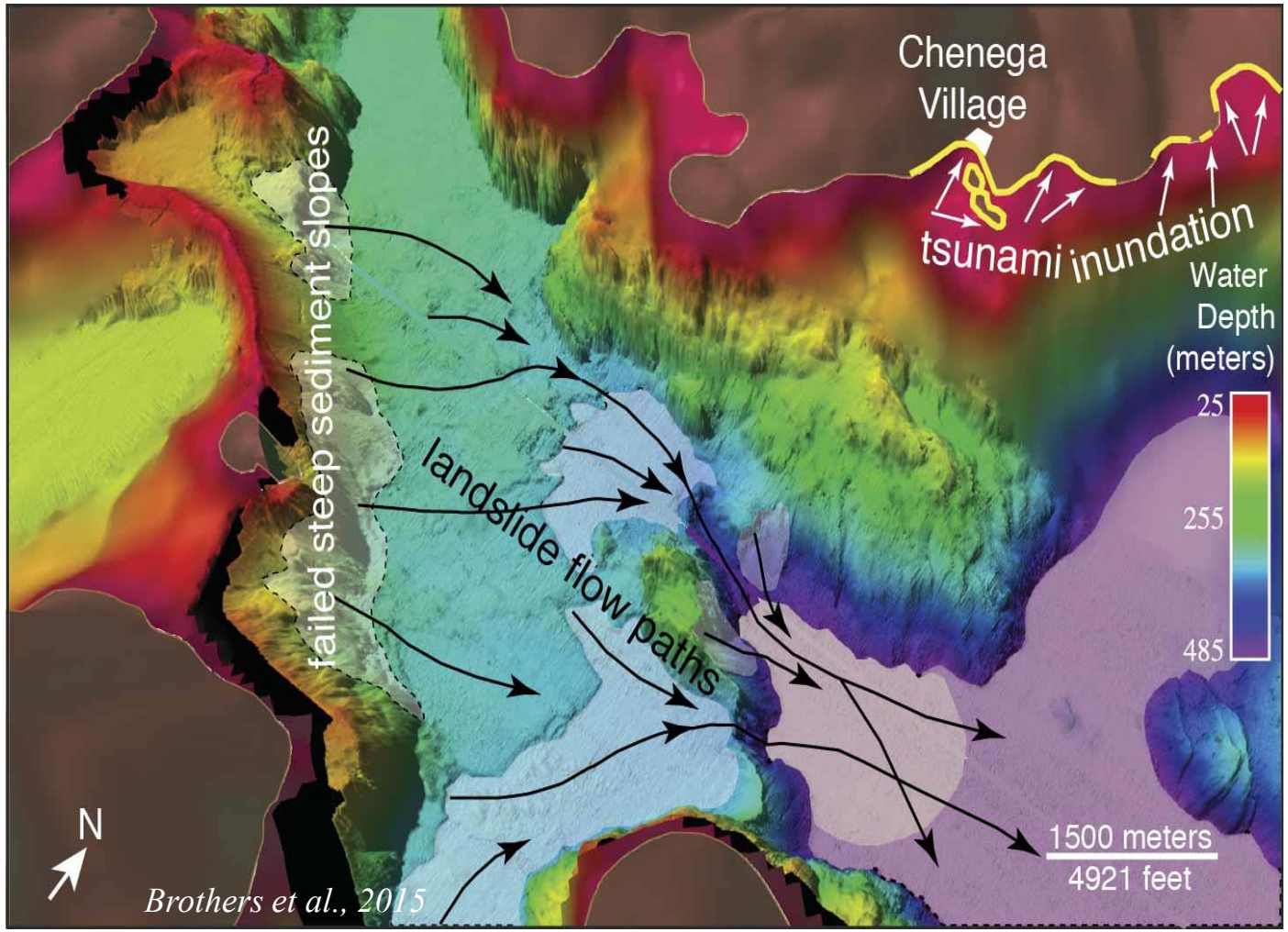
Earthquake-triggered Tsunamis: Secondary, shallow offshore faults affect tsunami generation.

Subsurface images of megathrust earthquakes elsewhere show sliding transfers from the plate interface to steeper, secondary, ‘splay’ faults, locally amplifying the resulting tsunami.

Splay faults exist in Cascadia, but the likelihood of them slipping is unknown.



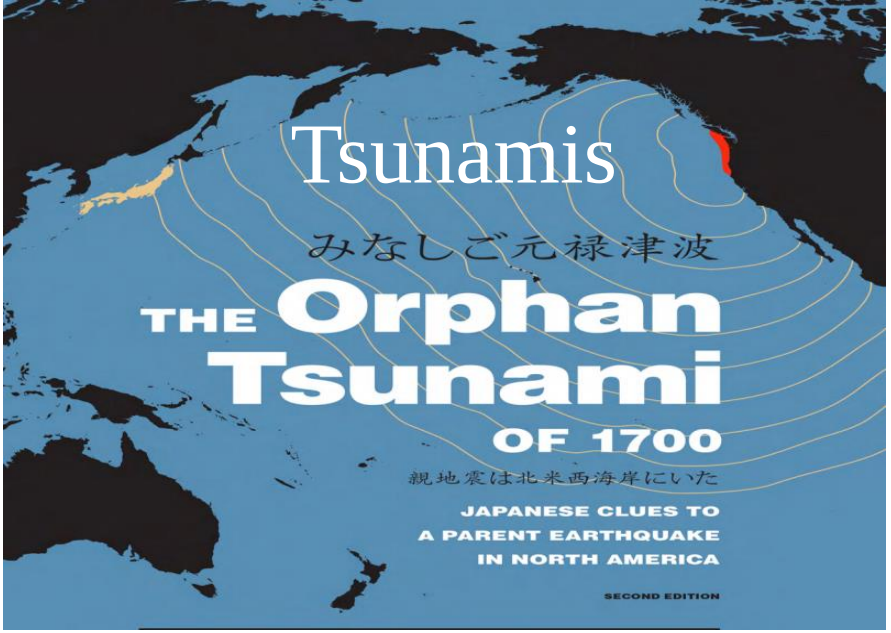
Earthquake-triggered Landslides/Tsunamis: Offshore shaking-triggered landslides can initiate tsunamis & break communications cables.



The tsunami triggered by the 1964 M9.2 Alaska megathrust earthquake was extraordinarily large and devastating at Chenega Village (23 fatalities). High-resolution seafloor topography revealed that the shaking caused a coastal landslide, which generated tsunami waves that were larger than those from the M9.2 earthquake.

Earthquake-triggered Volcanic Eruptions: Volcanic unrest is sometimes linked to megathrust earthquakes. Local earthquakes can initiate a cascade of events that results in an eruption.

In early 1980 a bulge began to build on Mount St. Helens's summit as magma and pressures built inside. On May 18th a M5.1 earthquake occurred, along with collapse of the bulge and a tremendous avalanche. This uncapping cascaded quickly into the most spectacular eruption historically in the lower 48.



Thank you!
Questions?

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