Washington's Seismic Vulnerability: Implications for Transportation Planning and Projects

by

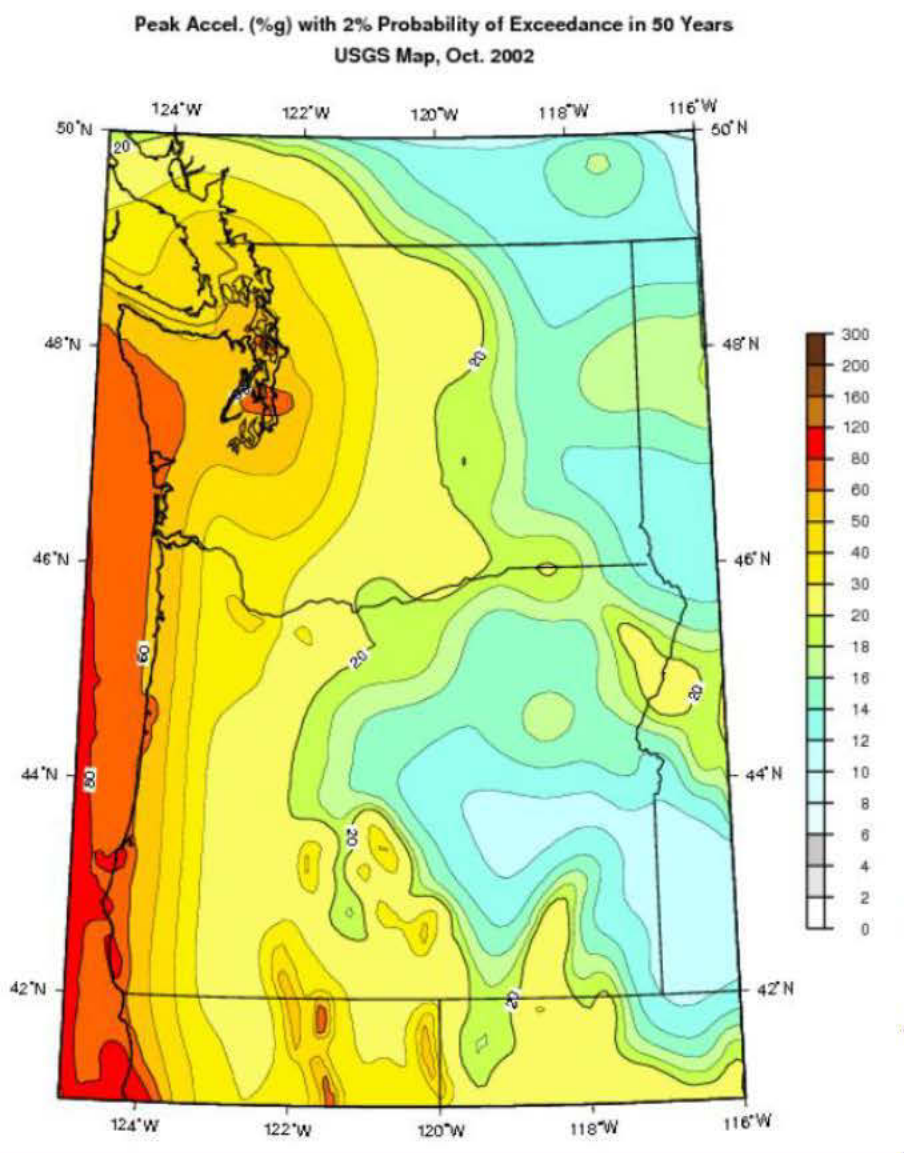
Timothy J. Walsh

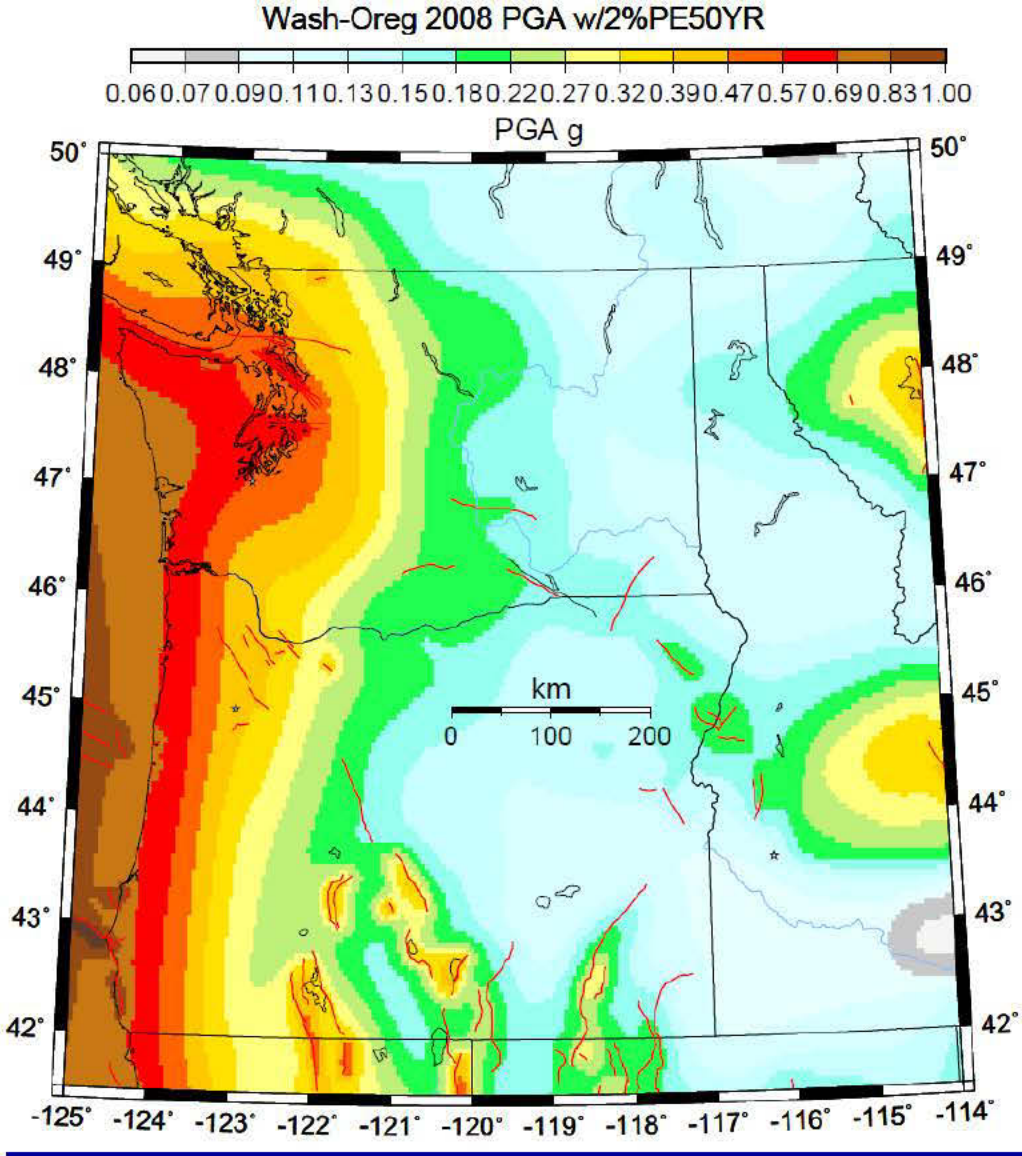
Washington Department of Natural Resources

Division of Geology and Earth Resources

WASHINGTON STATE DEPARTMENT OF
Natural Resources

When I last briefed this commission in March, 2007, the emphasis was on threats to the new 520 floating bridge. Much of that work is still not fully reflected in the building codes, so I will repeat some of it. Most of what I will talk about today is new research (since 2007).





First, a look at the changing seismic building codes. On the left, the seismic hazard map from 2002, 0n the right the map from 2008. The increase in perceived hazard is quite large

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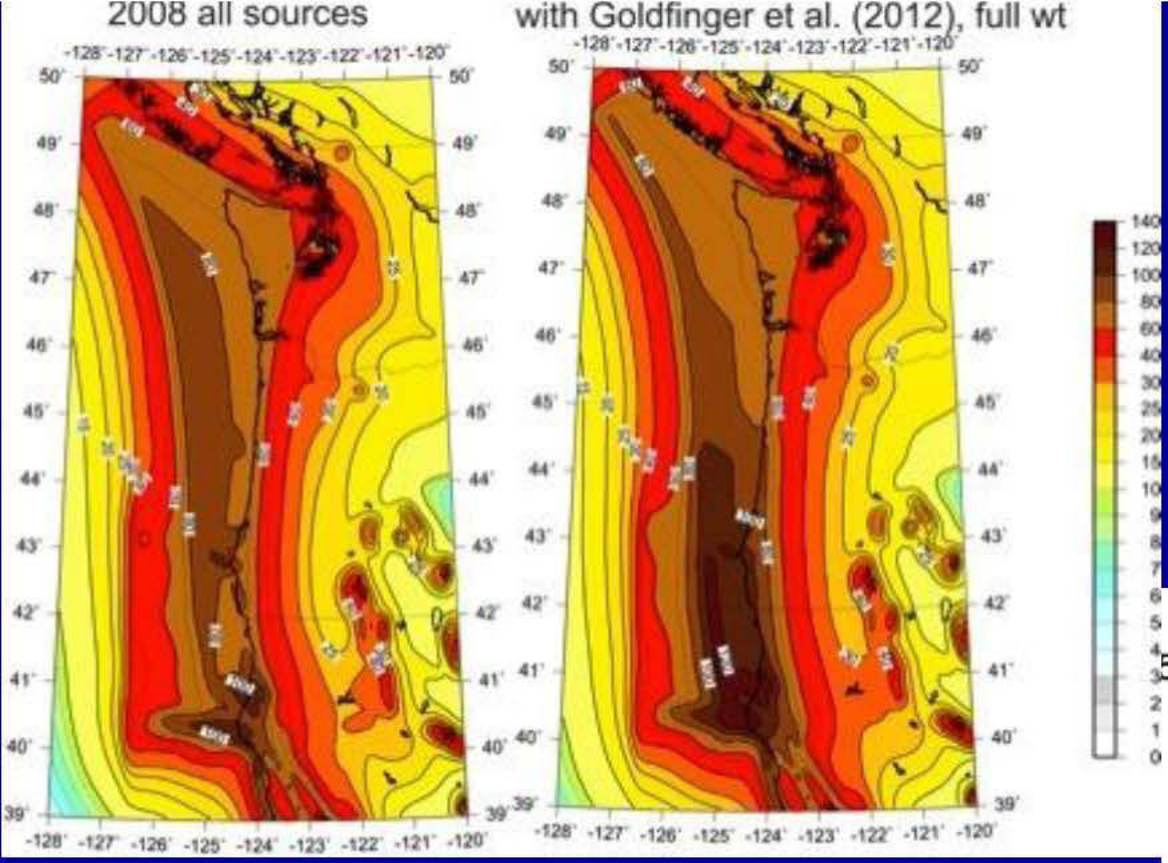
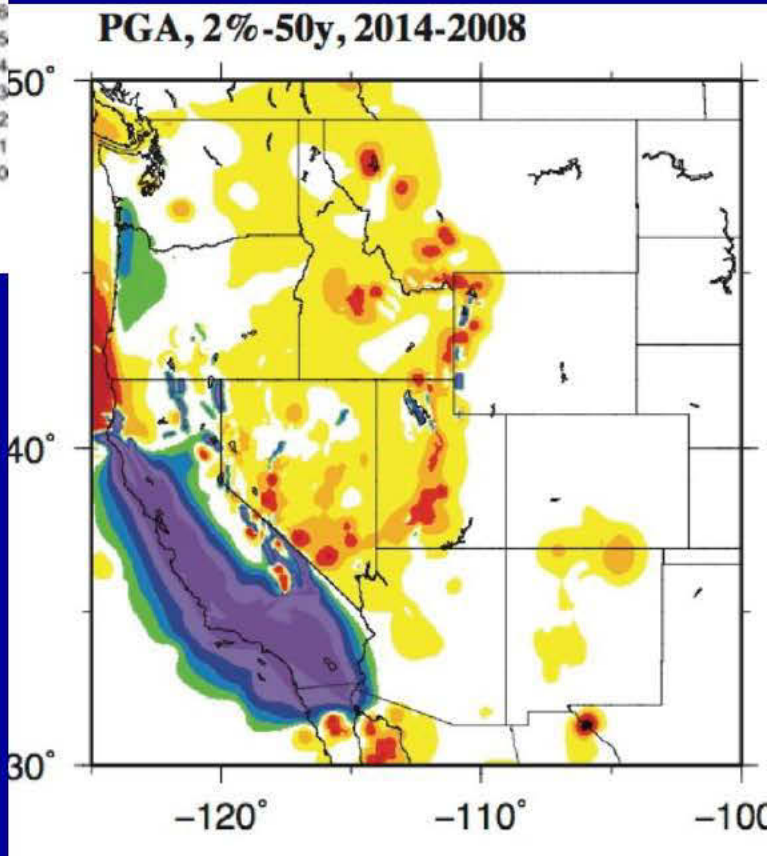


The 2014 seismic hazard map has not yet been published, but will look something like the maps at left.



The map on the right shows the expected change from the 2008 map to the 2014 map. Note that most of the increase is in eastern Washington—more on that following.

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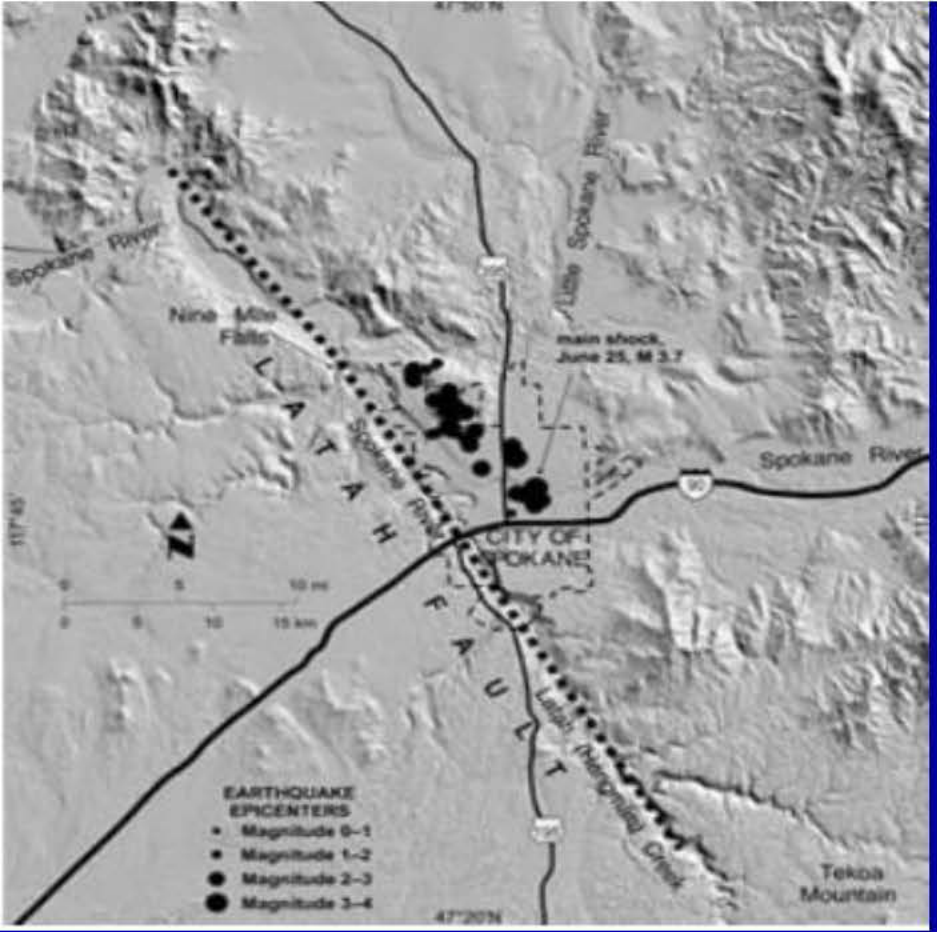
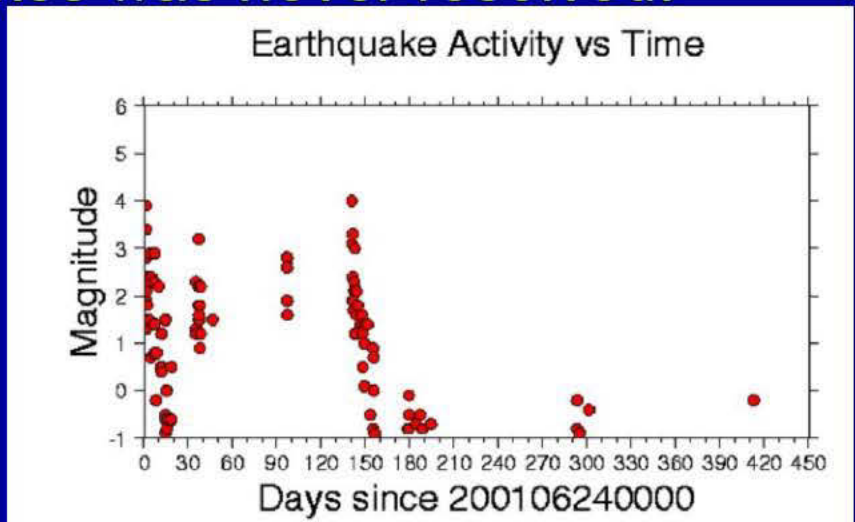


In 2001, there was a sequence of dozens of felt earthquakes in Spokane that were felt (and heard) only north of the Spokane River. When the events began there was only one seismograph within 60 miles, so they were not well recorded. By the time portable seismographs were in place, the sequence was winding down and the source of the quakes was never resolved.

What is shown at the right are only the earthquakes recorded on seismometers but many more were felt or heard by residents.



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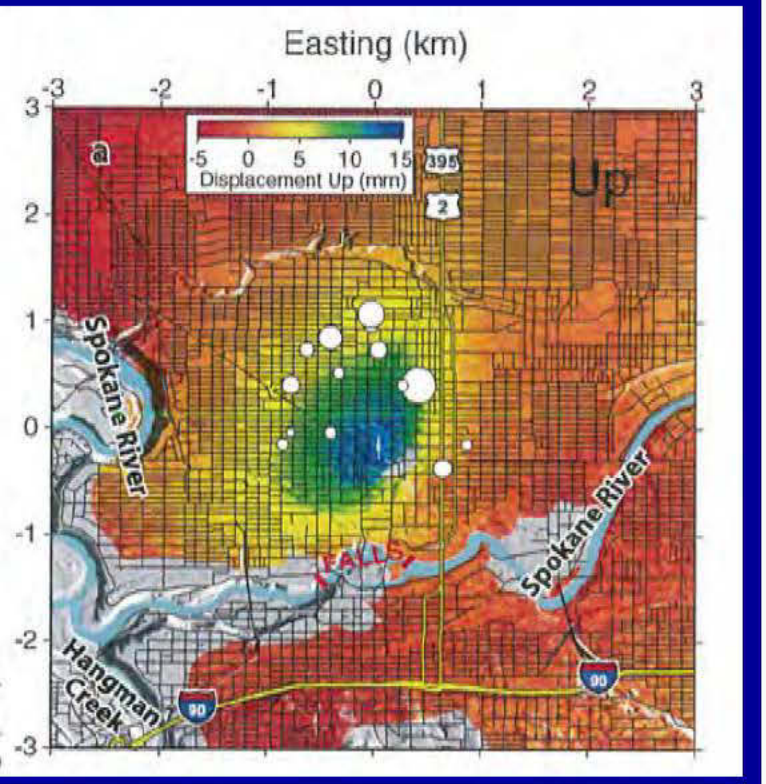
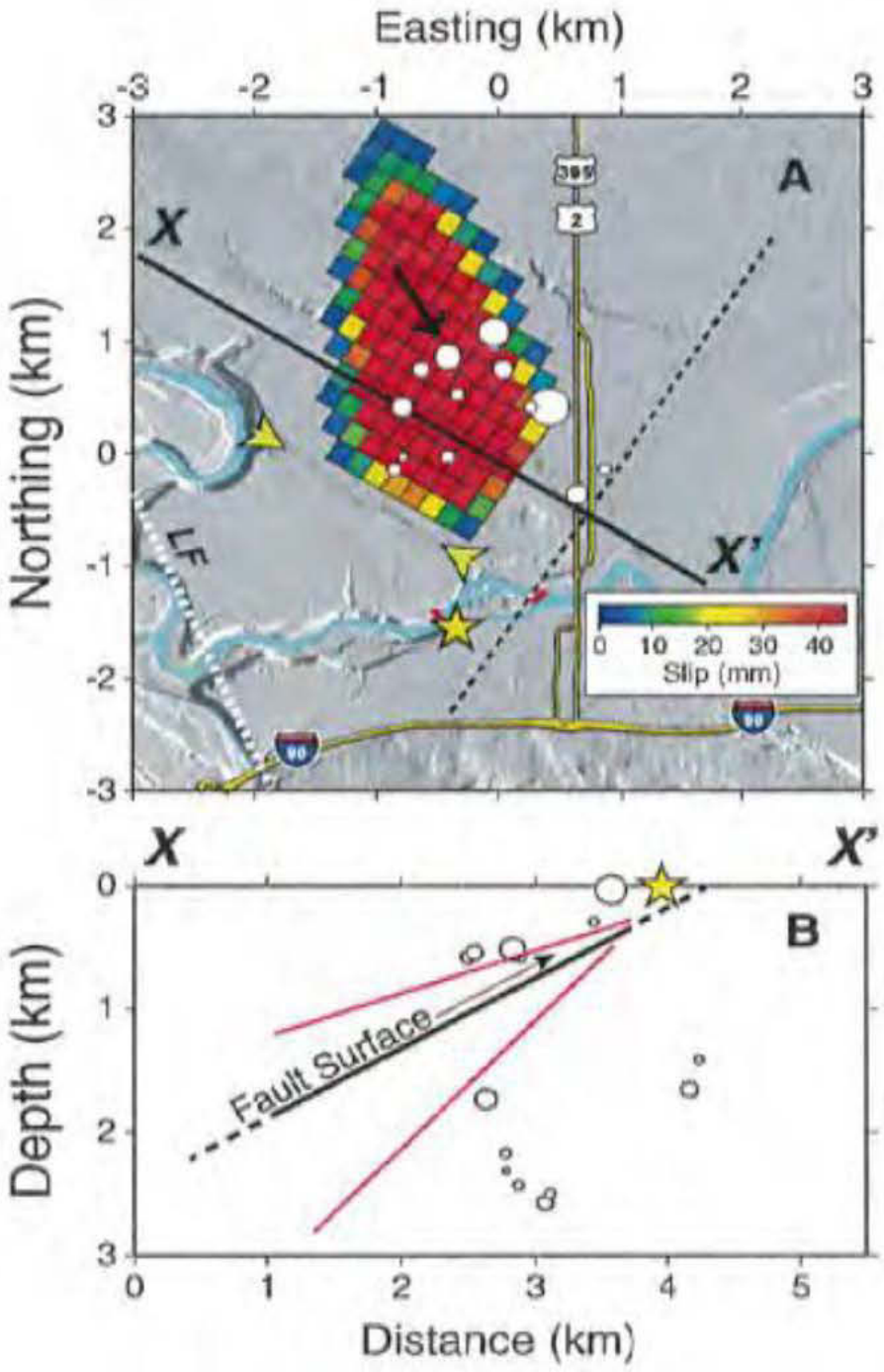
Since then, a new technique called INSAR (Interferometric Synthetic Aperture Radar) allows a very detailed comparison of radar images taken of the same place. This allowed Wicks and others (2013) to approximately locate the source fault.





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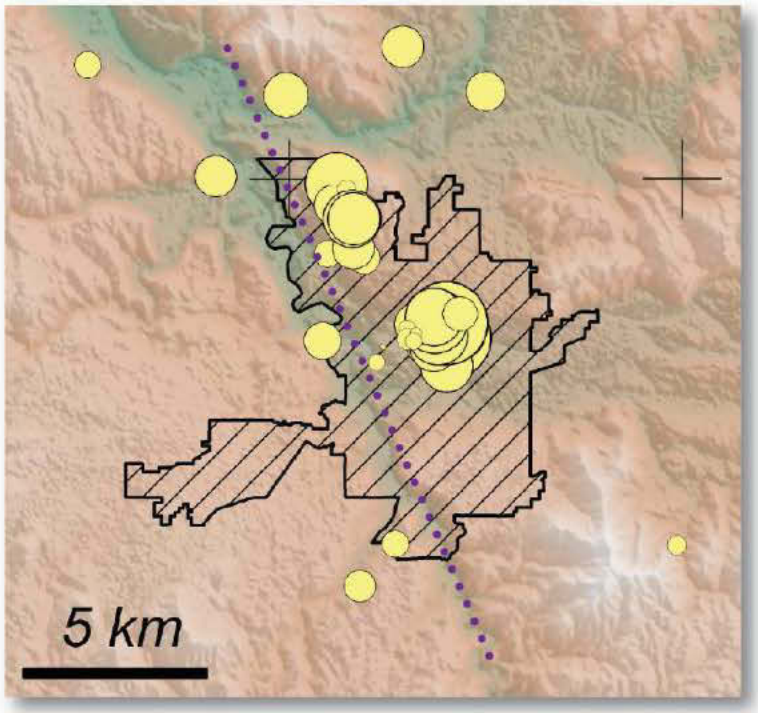

A sequence of 105 small (less than magnitude 4) earthquakes occurred beneath Spokane, Washington in 2001. The yellow circles on this map are location of epicenters in the Spokane area, with symbol size proportional to earthquake magnitude. The Latah Creek fault passes beneath Spokane but is not known to be active.

but there is now a target available for more detailed investigations. A lidar survey in planning will provide significantly more information.

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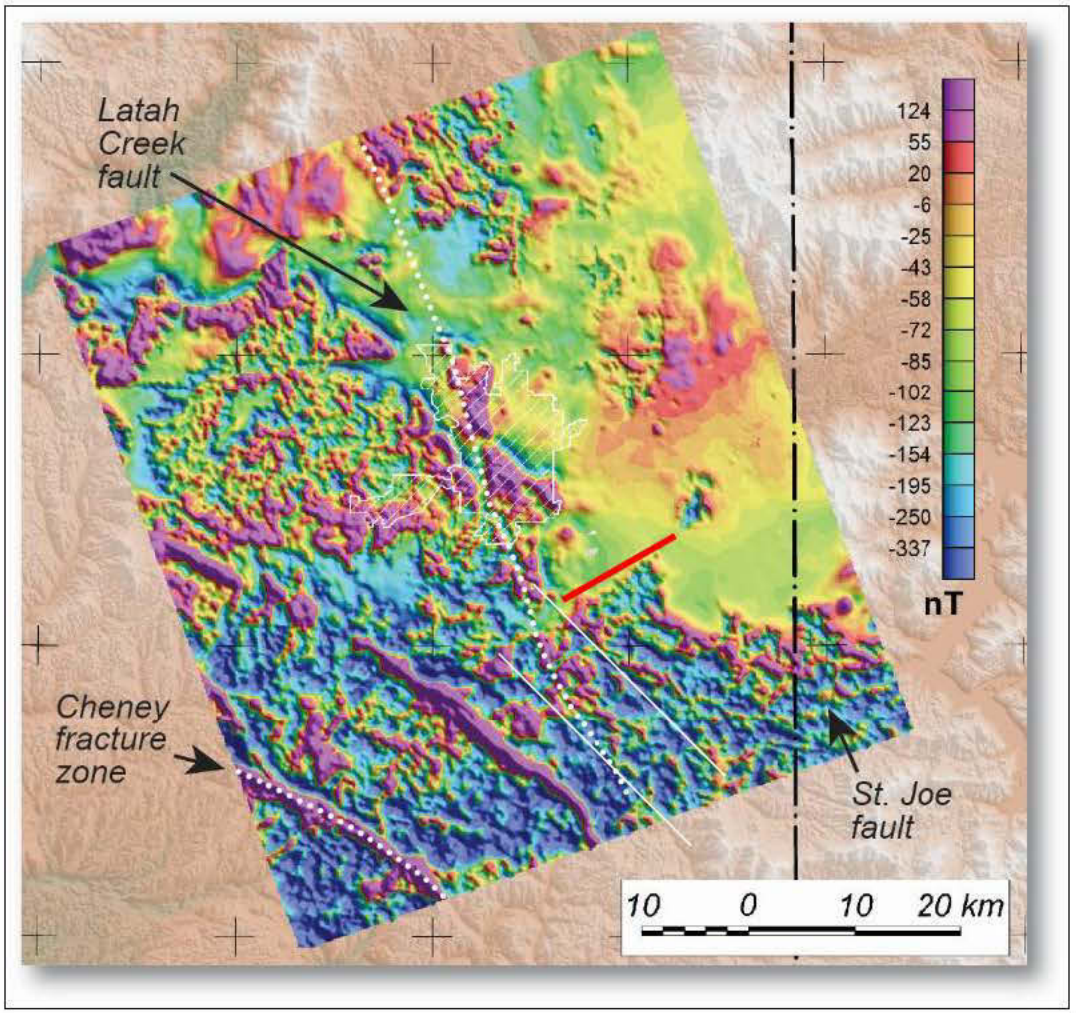
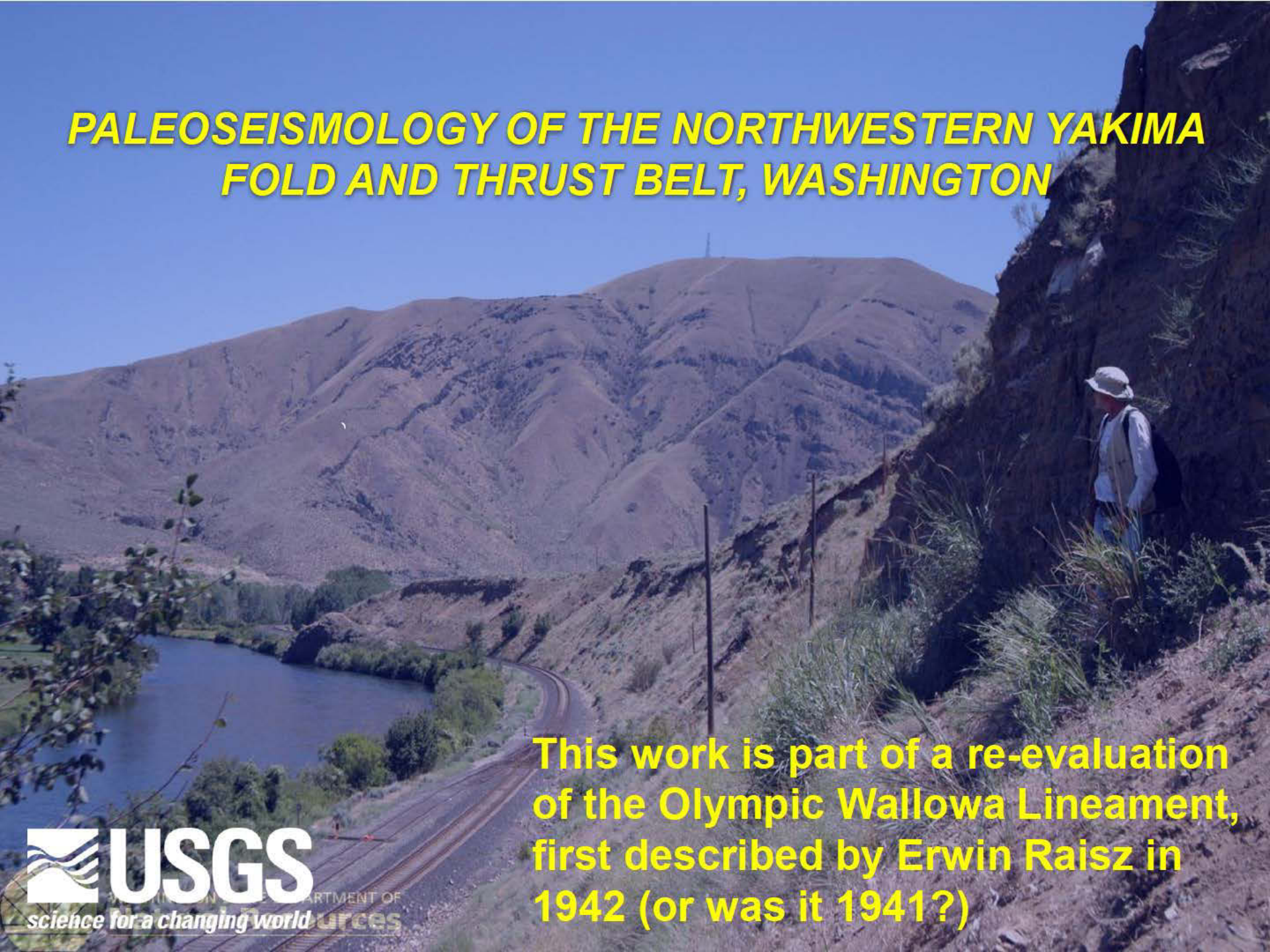
An aeromagnetic survey last year revealed a northeast-trending anomaly that is suspiciously similar to the INSAR anomaly, and is prompting further efforts to study this fetaure. It is premature to predict how large an earthquake thgis might make or how frequently,

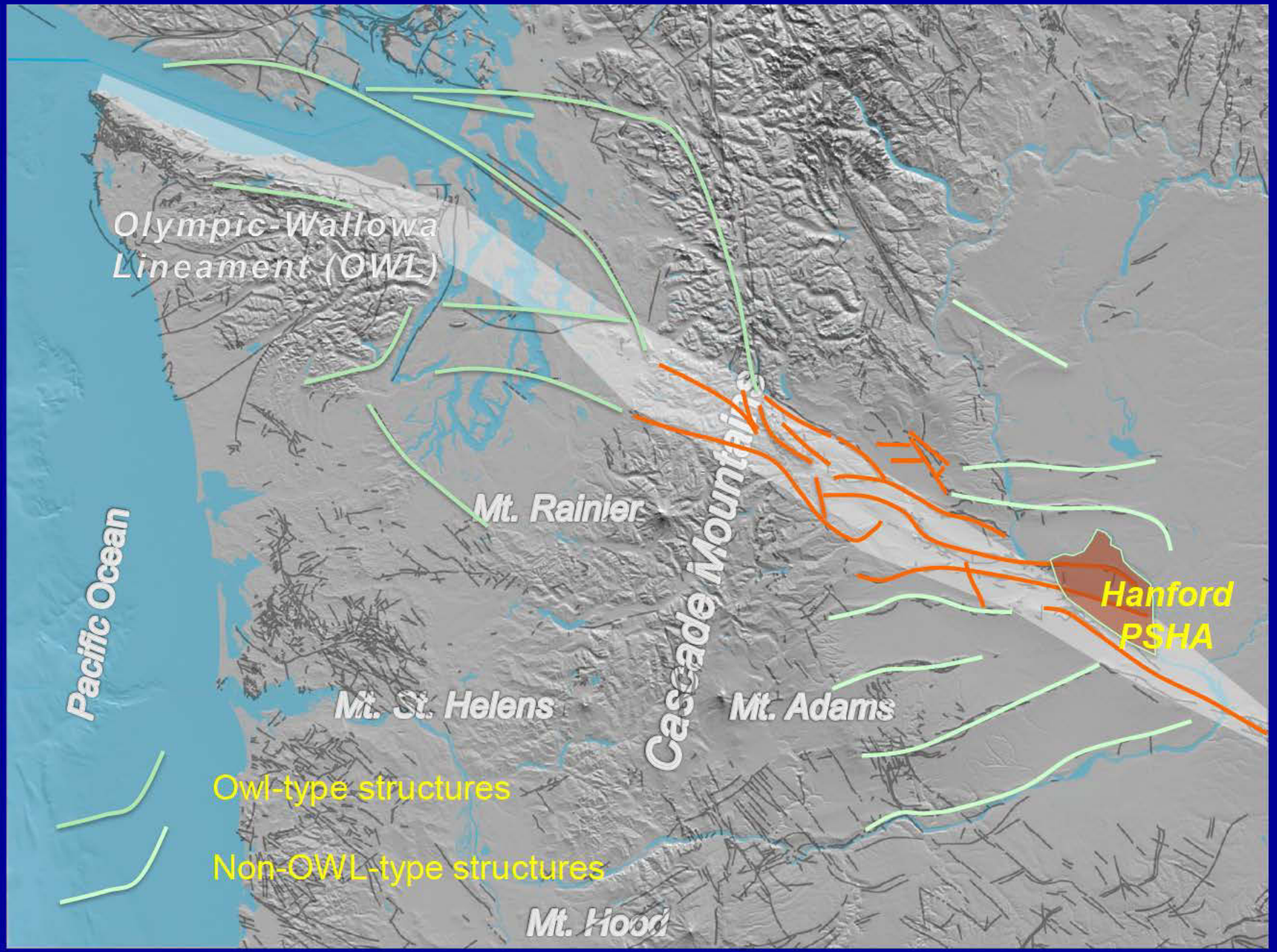


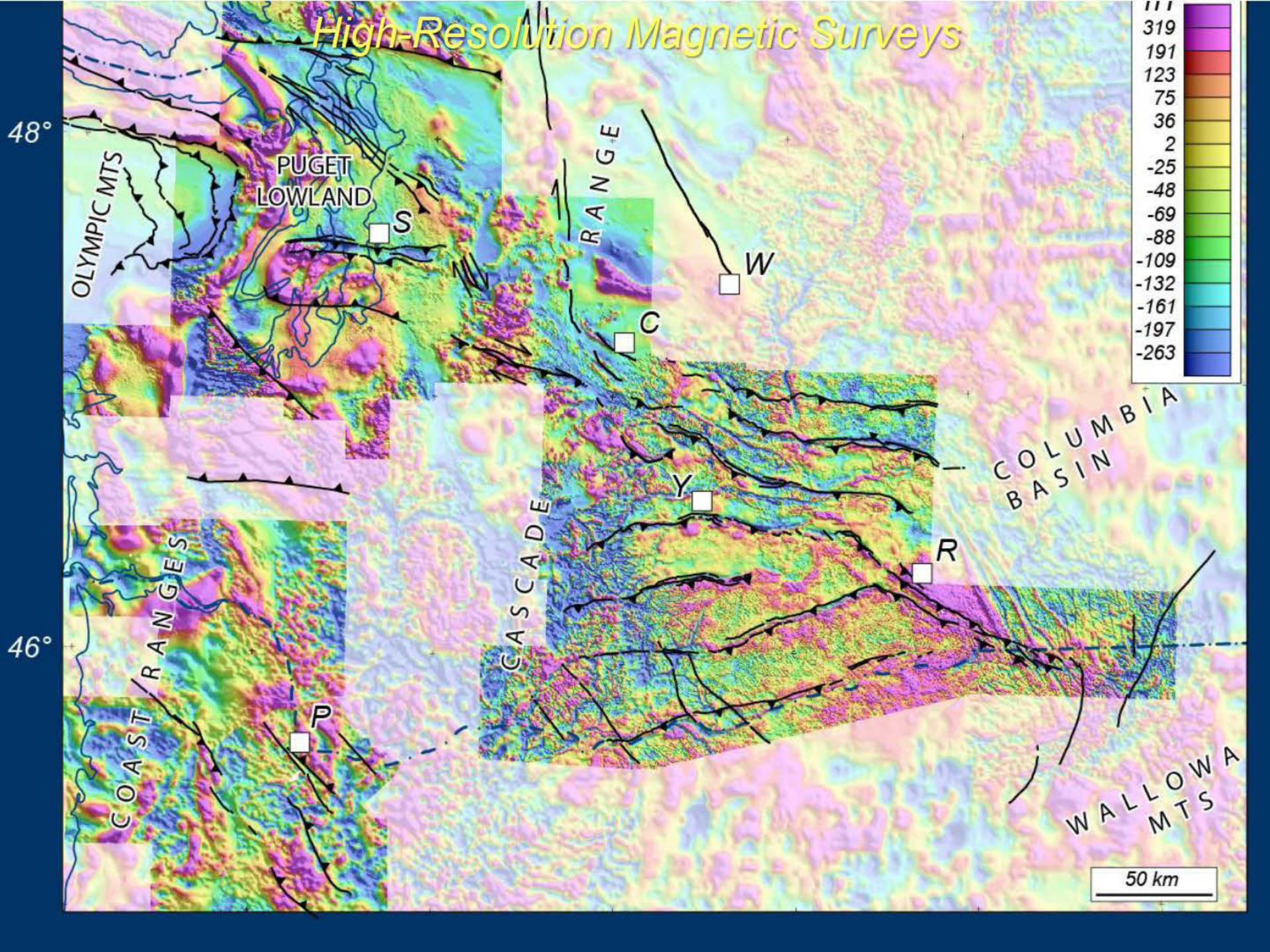


PALEOSEISMOLOGY OF THE NORTHWESTERN YAKIMA FOLD AND THRUST BELT, WASHINGTON

This work is part of a re-evaluation of the Olympic Wallowa Lineament, first described by Erwin Raisz in 1942 (or was it 1941?)

USGS
science for a changing world


Olympic-Wallowa
Lineament (OWL)
Pacific Ocean
Mt. Rainier
Cascade Mountains
Hanford
PSHA
Mt. St. Helens
Mt. Adams
Owl-type structures
Non-OWL-type structures
Mt. Hood


High-Resolution Magnetic Surveys
48°
46°
OLYMPIC MTS
PUGET
LOWLAND
S
CASCADE
RANGE
W
C
Y
R
COLUMBIA
BASIN
COAST
RANGES
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WALLOWA
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111
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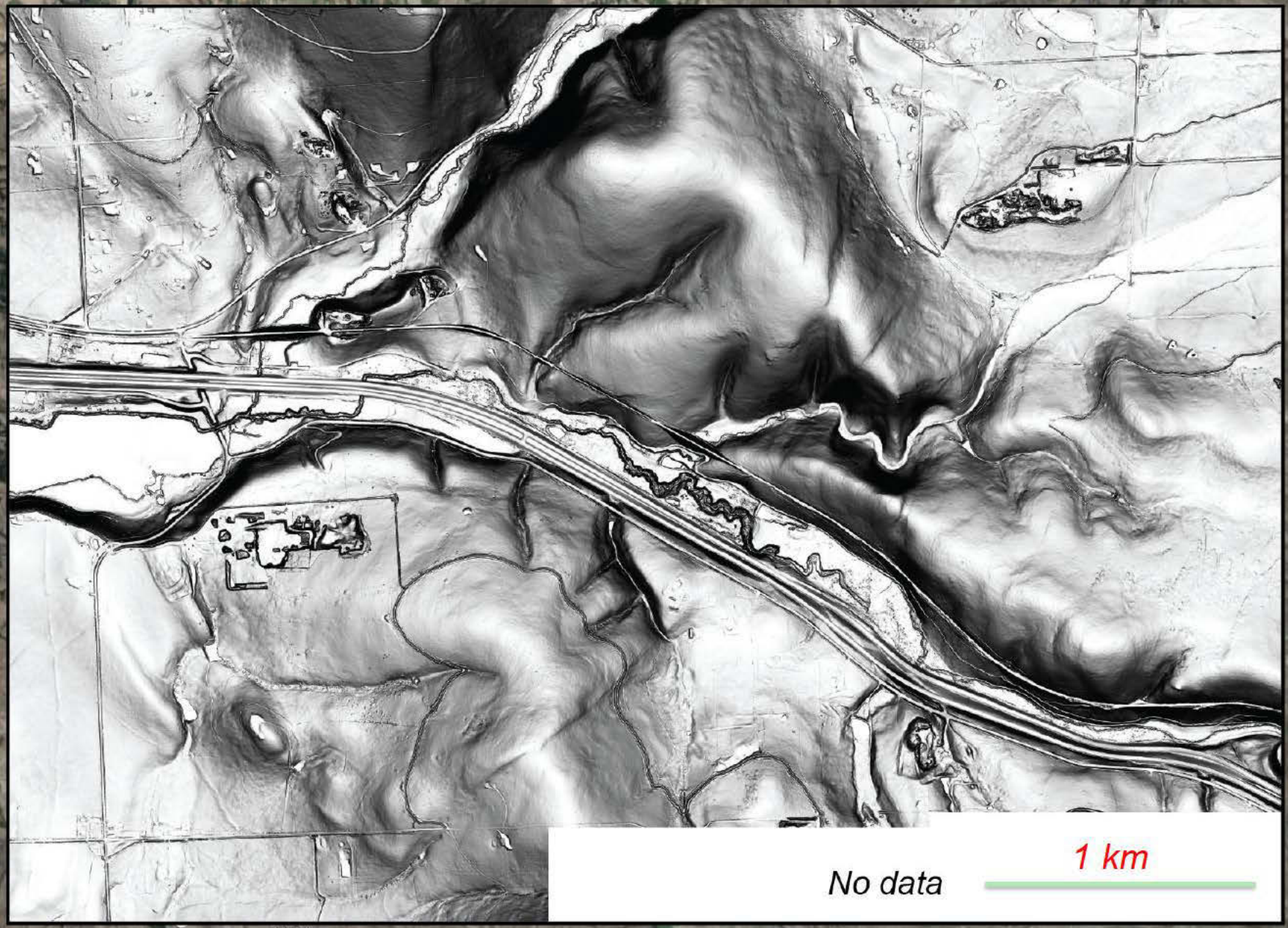
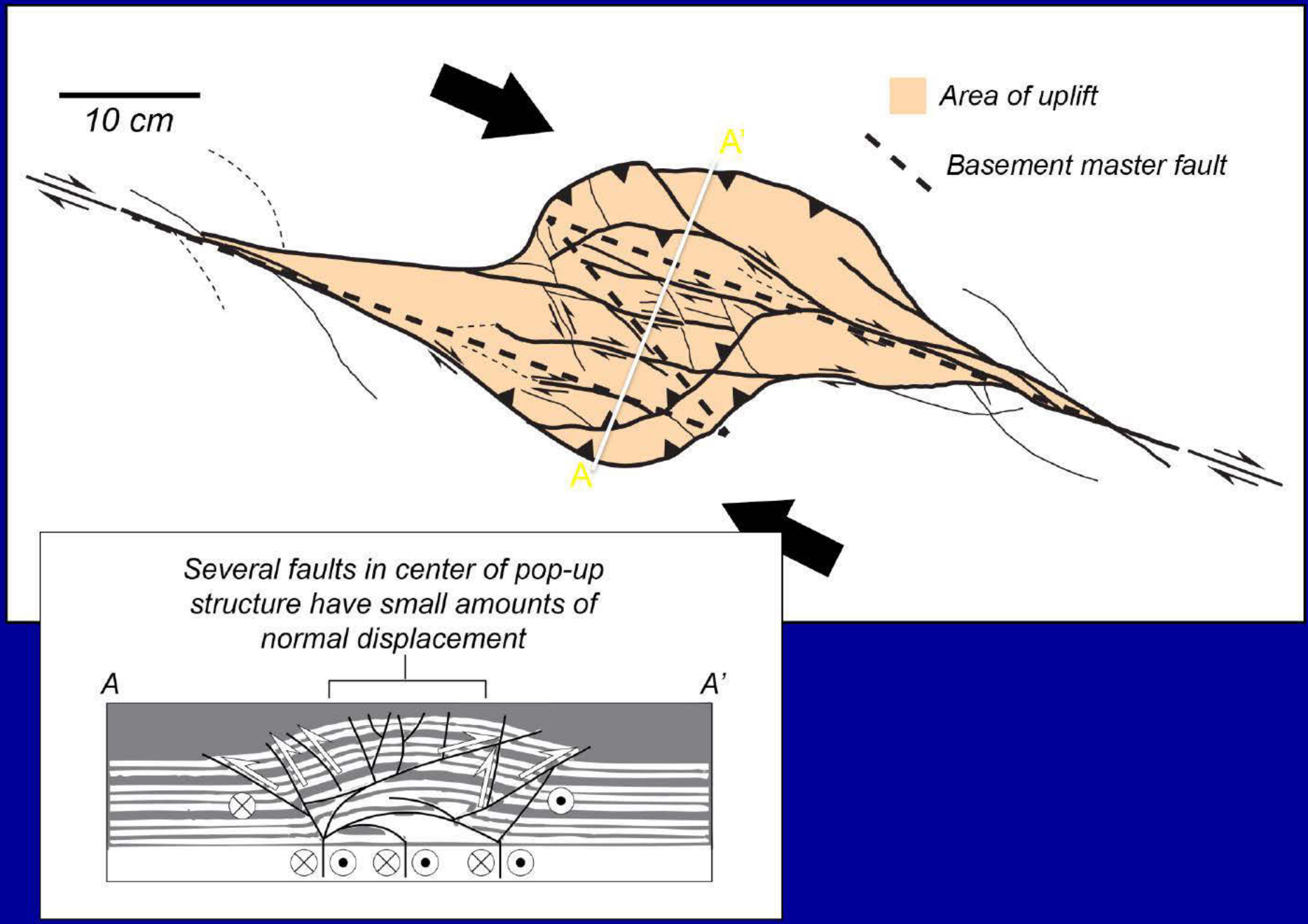
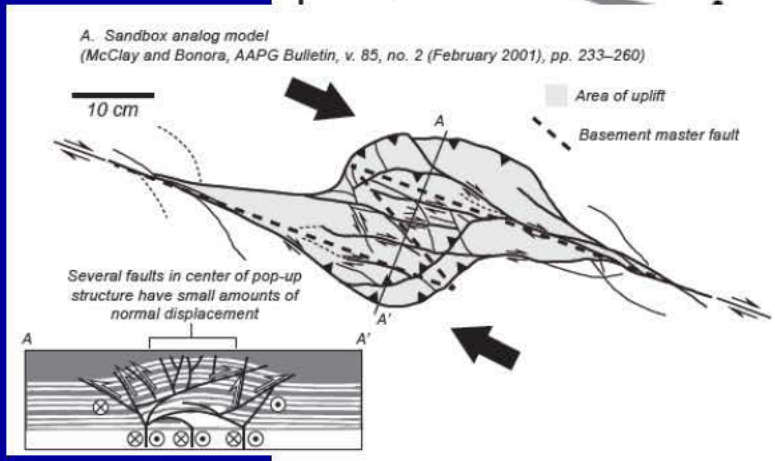
-109
-132
-161
-197
-263

Fault scarp at Boylston Ridge





(McClay and Bonora, AAPG Bulletin, v. 85, no. 2 (February 2001), pp. 233–260)



Aeromagnetic lineament

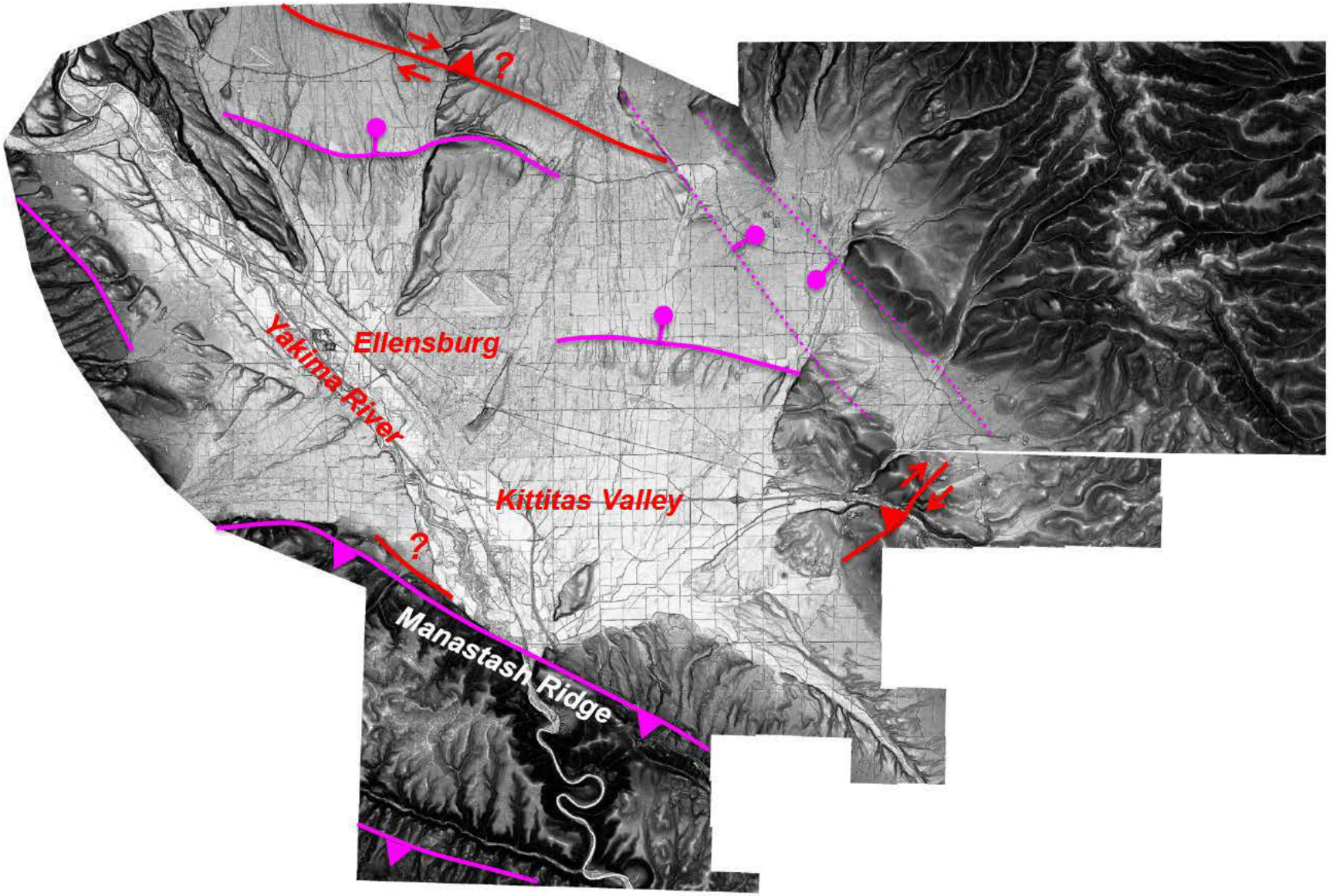
Area of uplift

Mapped fault

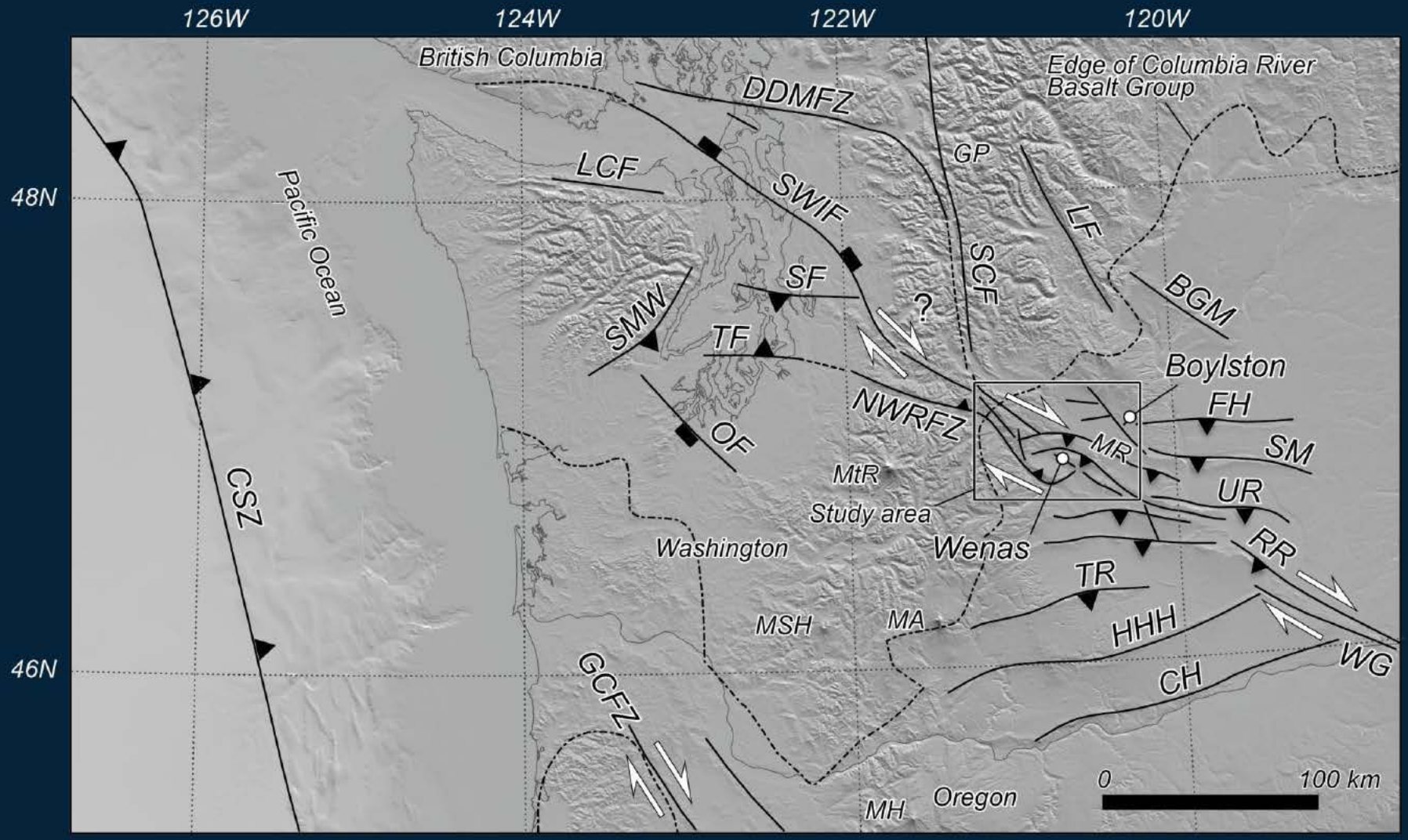
Anticline axis

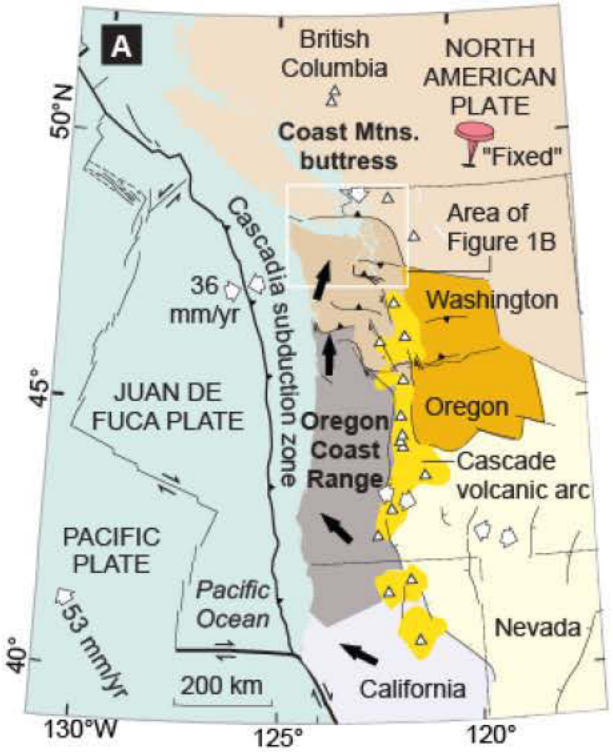
Syncline axis

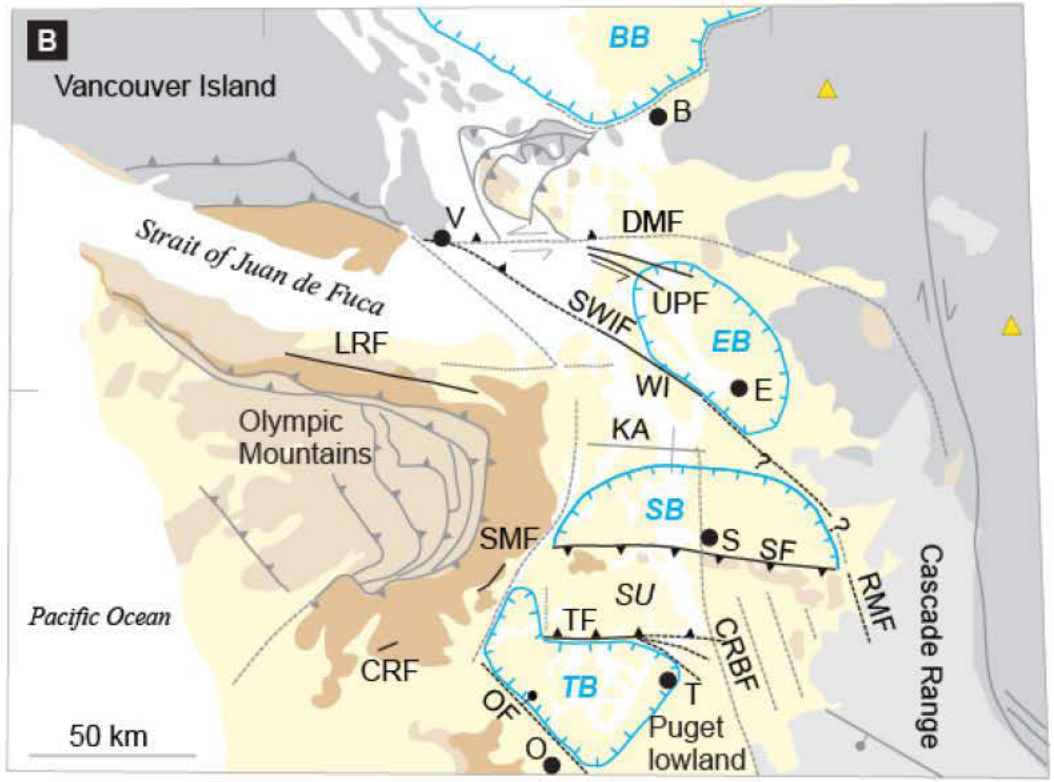
Scarp (bar and ball on downthrown side for normal fault scarps; teeth on hanging wall for reverse faults)


?
Yakima River
Ellensburg
Kittitas Valley
?
Manastash Ridge

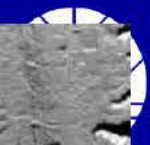
Regional Interpretation of Trans-arc Fault System







Southern Whidbey Island fault (SWIF) hazard



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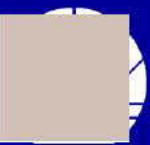

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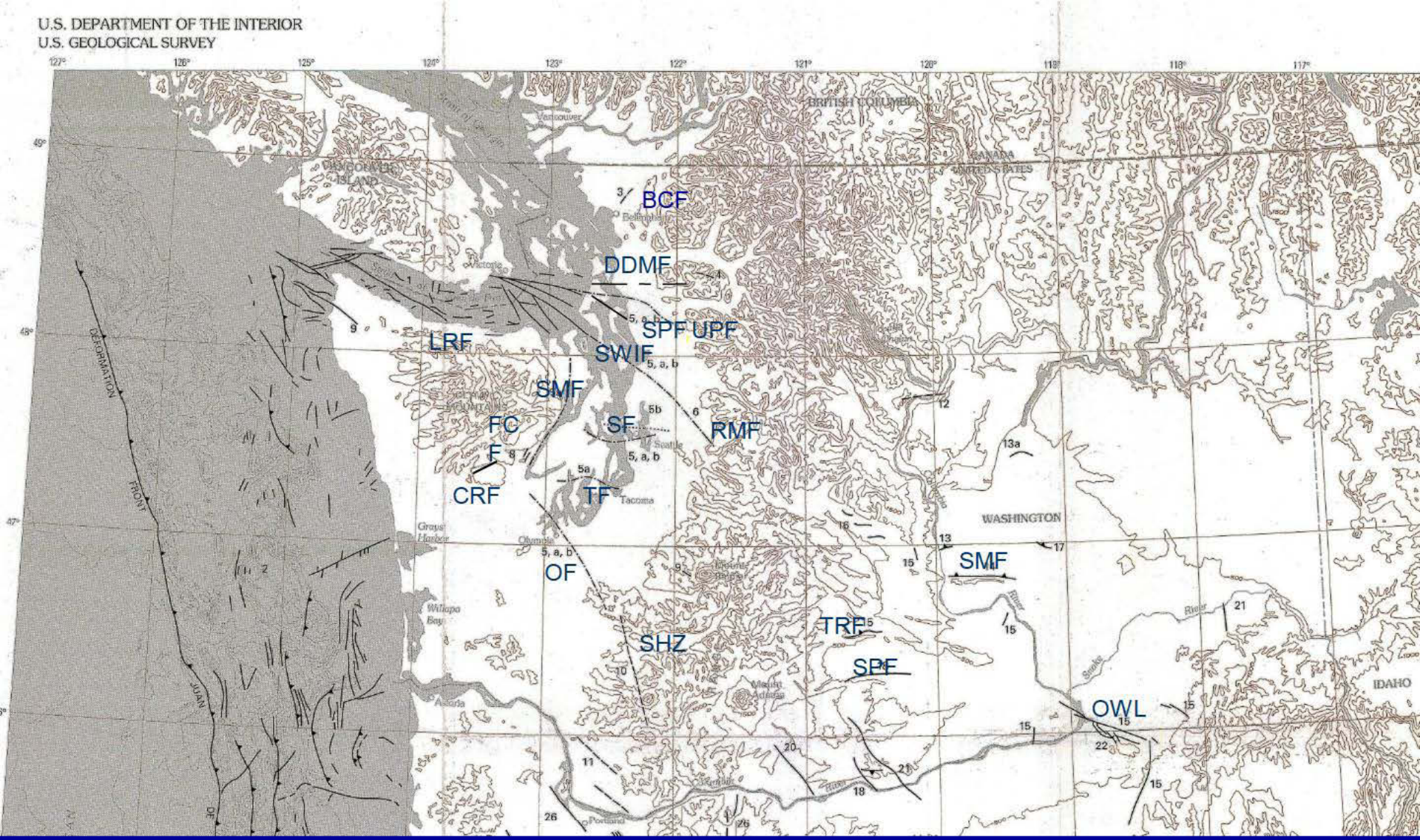

LRF, Little River fault; SMF, Saddle Mountain East and West faults; FCF, Frigid Creek fault; CRF, Canyon River fault; OF, Olympia fault; SHZ, St. Helens Zone; TF, Tacoma fault; SF, Seattle fau SWIF, Southern Whidbey Island fault; SPF, Strawberry Point fault; UPF, Utsalady Point fault; DDMF, Darrington-Devil's Mtn. Fault; RMF, Rattlesnake Ridge fault; TRF, Toppenish Ridge fault; SPF, Satus Pass fault; SMF, Saddle Mountain fault; OWL, Olympic-Wallowa Lineament.

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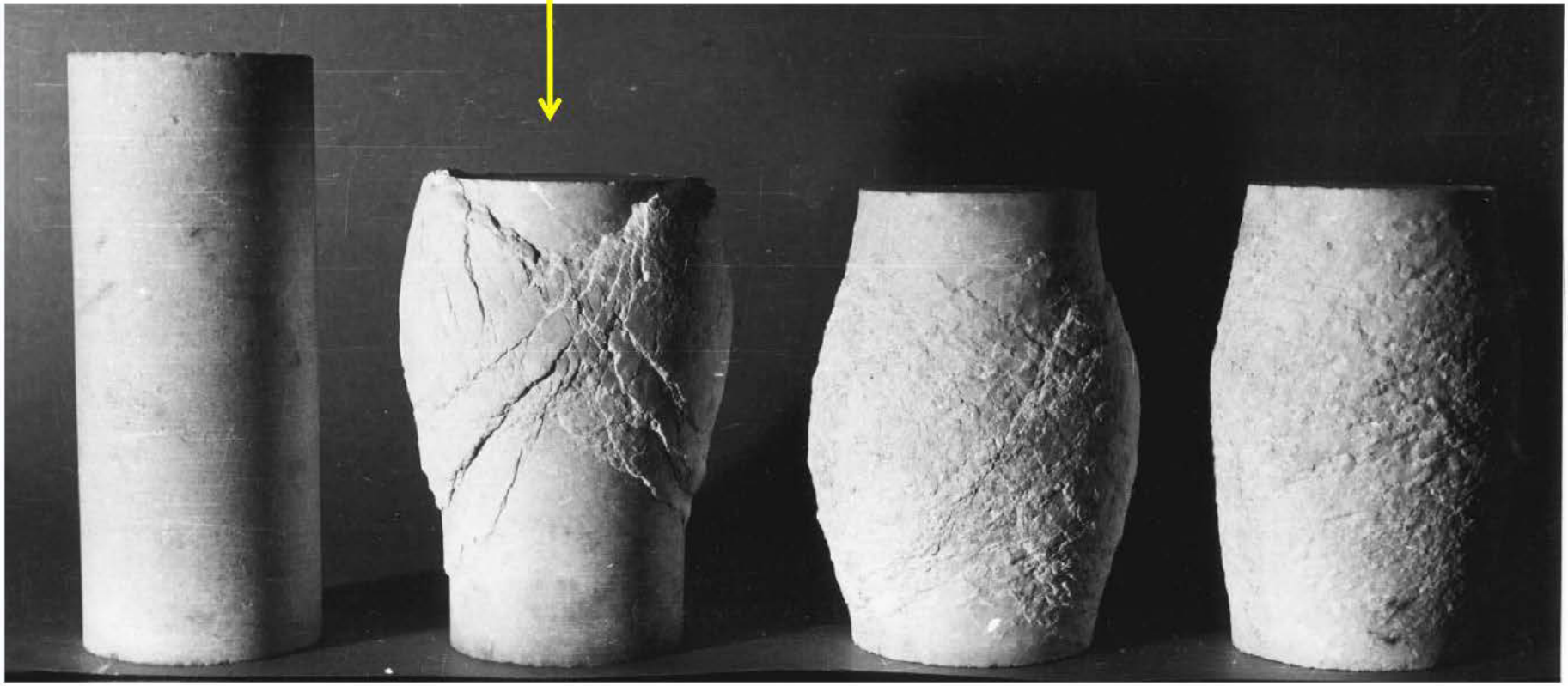
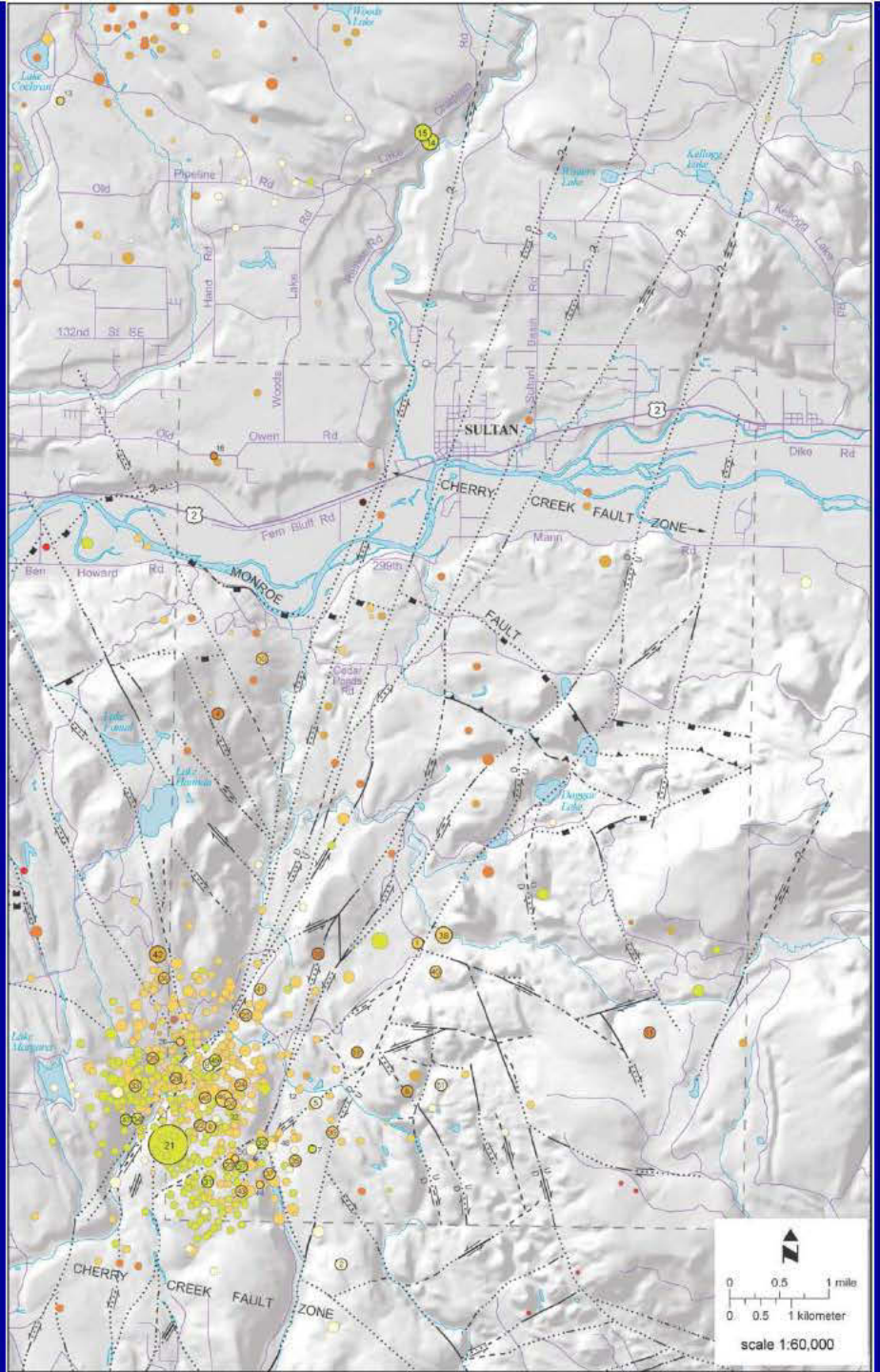
Squeeze these from top to bottom (north to south) and this pattern emerges



This map shows the 1995 M5.4 Duvall earthquake. We think we have found the fault responsible for it, which Dragovich and others named the Cherry Creek fault, which is conjugate to the southern Whidbey Island fault



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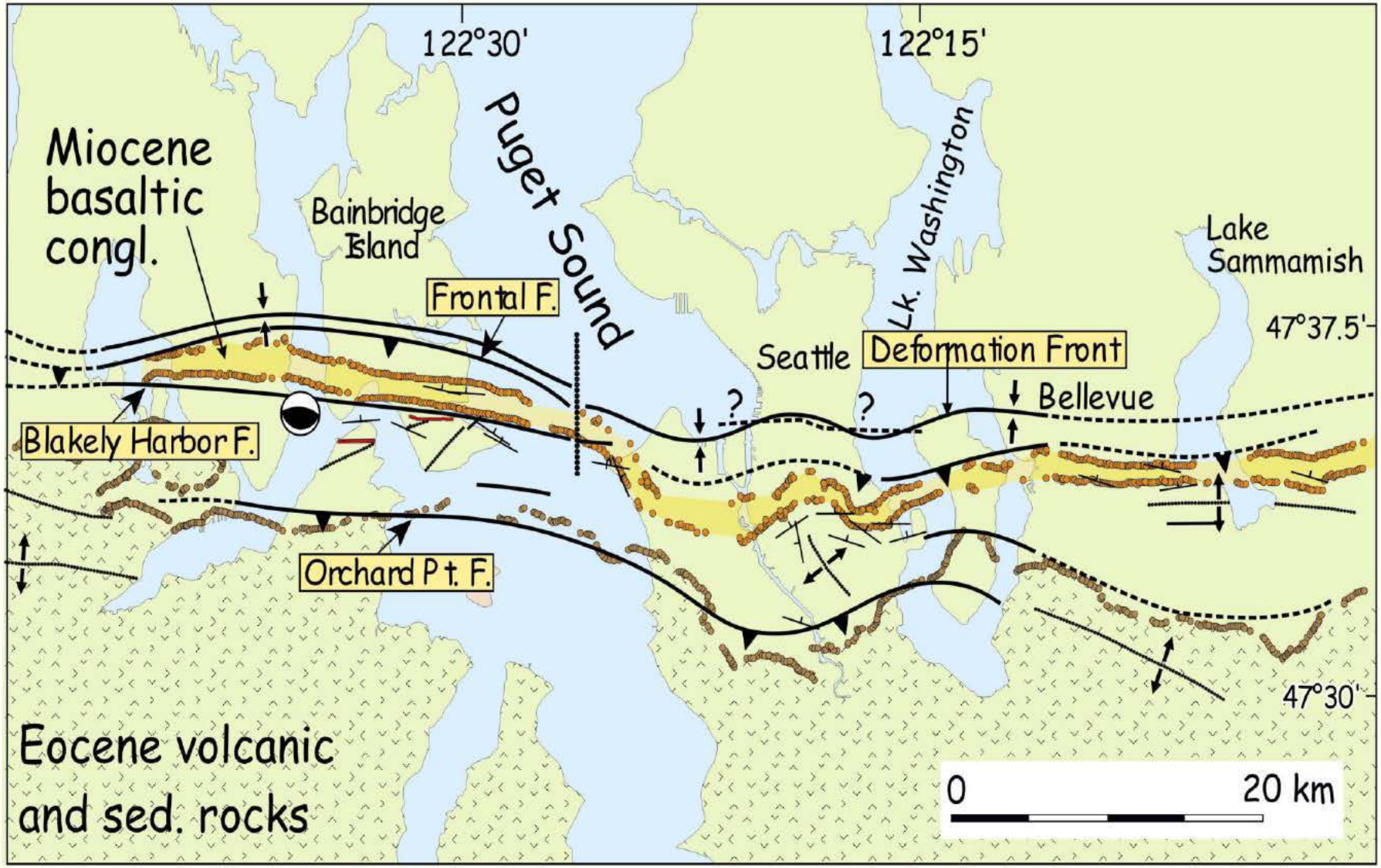
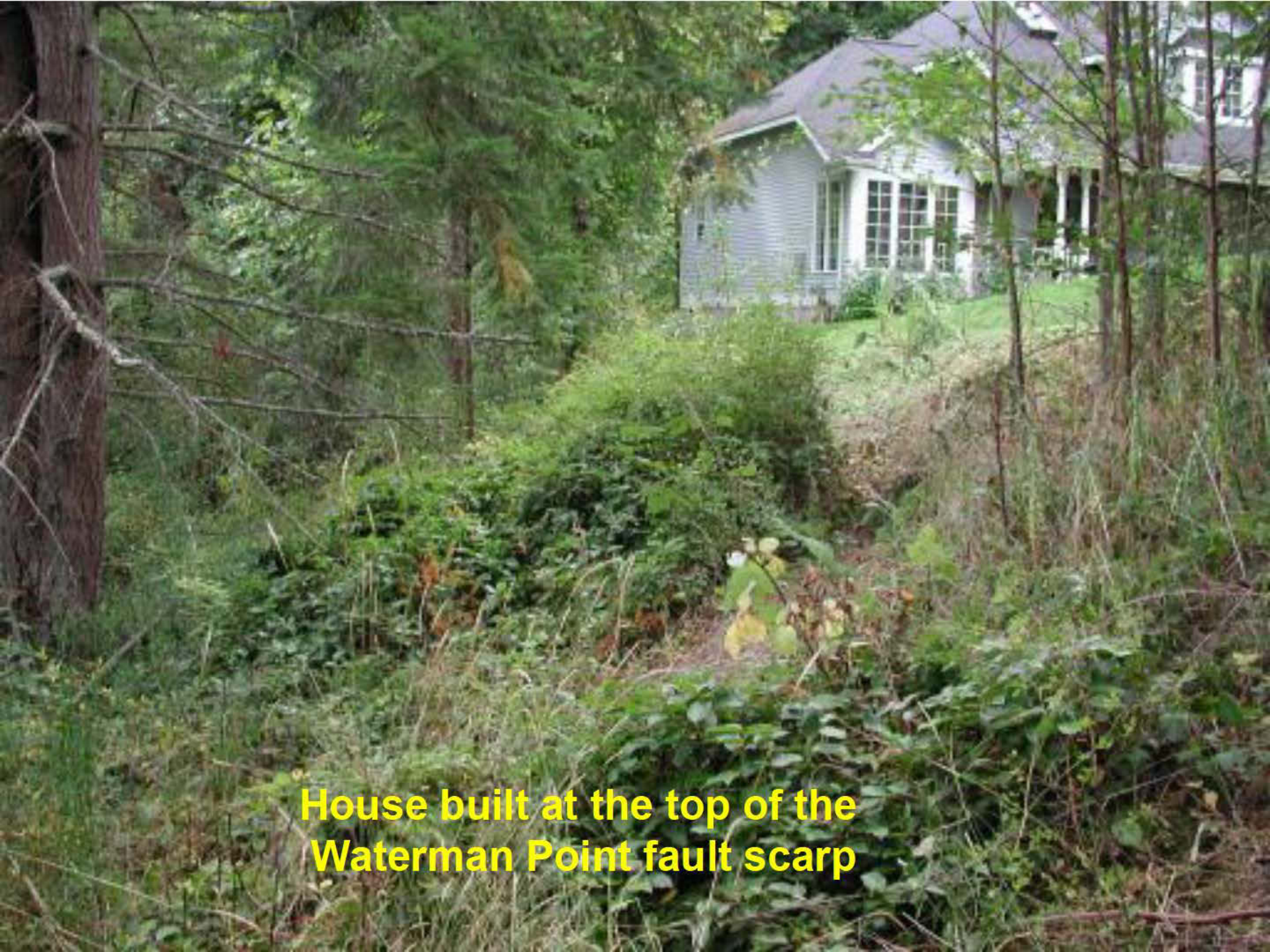


Interpreted Aeromagnetic Map of the Seattle Fault Zone

Epicenter, M 4.9
Bainbridge Island earthquake


House built at the top of the
Waterman Point fault scarp

Washington also has a locally generated tsunami hazard from faults in Puget Sound. We have modeled inundation in Seattle and Tacoma from simulations on the Seattle and Tacoma faults

Tsunami sand sheet at Cultus Bay on Whidbey Island

Using estimated land level changes at Restoration Point, Alki Point, West Point , and Winslow Marsh, we constructed a Seattle fault model to use in the tsunami simulation

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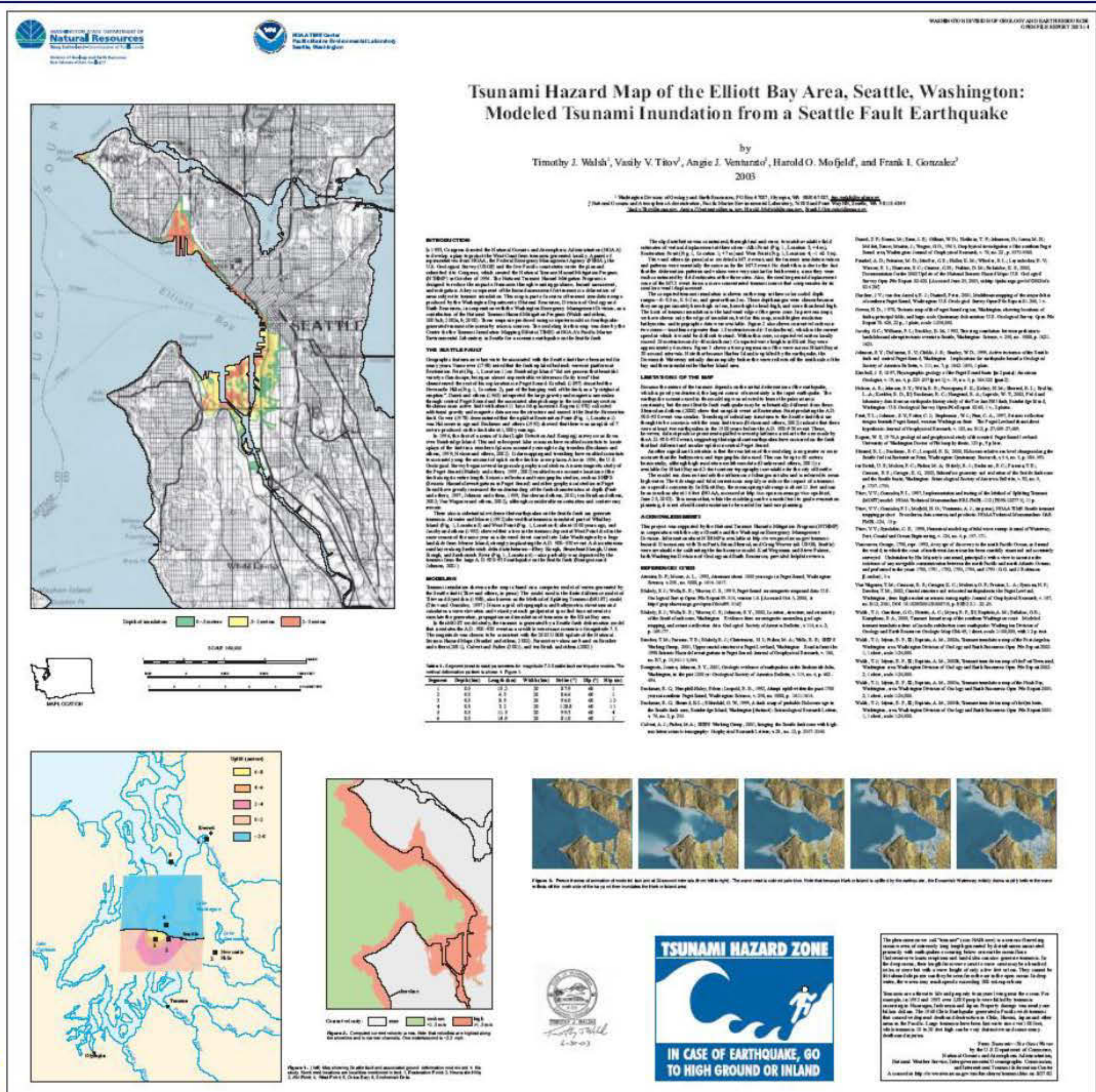
Natural Resources
Tsunami Hazard Map of the Elliott Bay Area, Seattle, Washington:
Modeled Tsunami Inundation from a Seattle Fault Earthquake
by
Timothy J. Walsh, Vasily V. Titov, Angie J. Venturato, Harold O. Mofjeld, and Frank I. Gonzalez
2003
SEATTLE
TSUNAMI HAZARD ZONE
IN CASE OF EARTHQUAKE, GO TO HIGH GROUND OR INLAND

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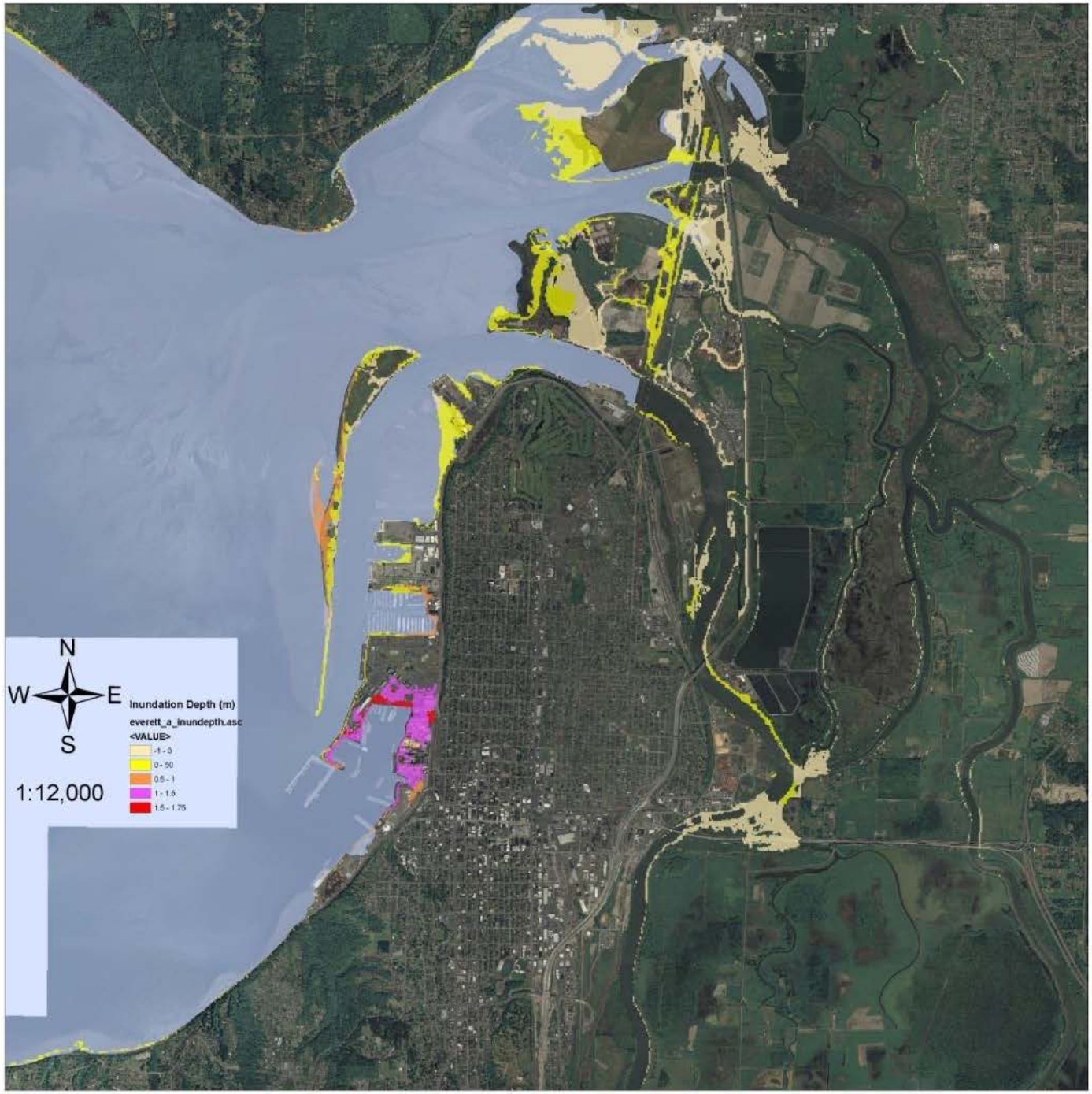
Seattle animation

This draft inundation map for Everett models a M7.3 Seattle fault earthquake , the same event modeled for Seattle and Tacoma. Also modeled are a M6.7 Seattle fault earthquake and a M7.0 earthquake on the southern Whidbey Island fault.



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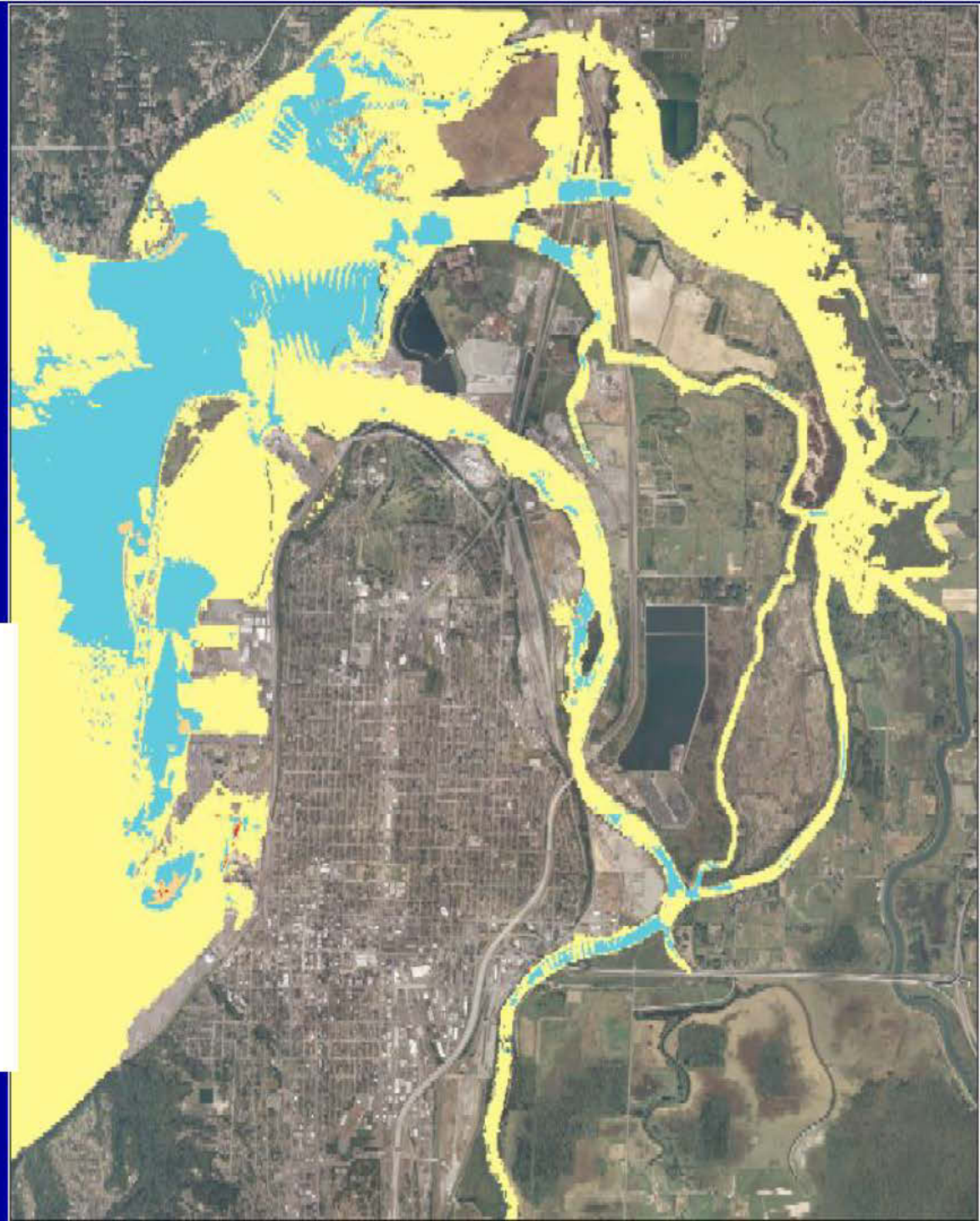
This map shows the currents generated by this tsunami, which reaches 14 knots around the Port of Everett



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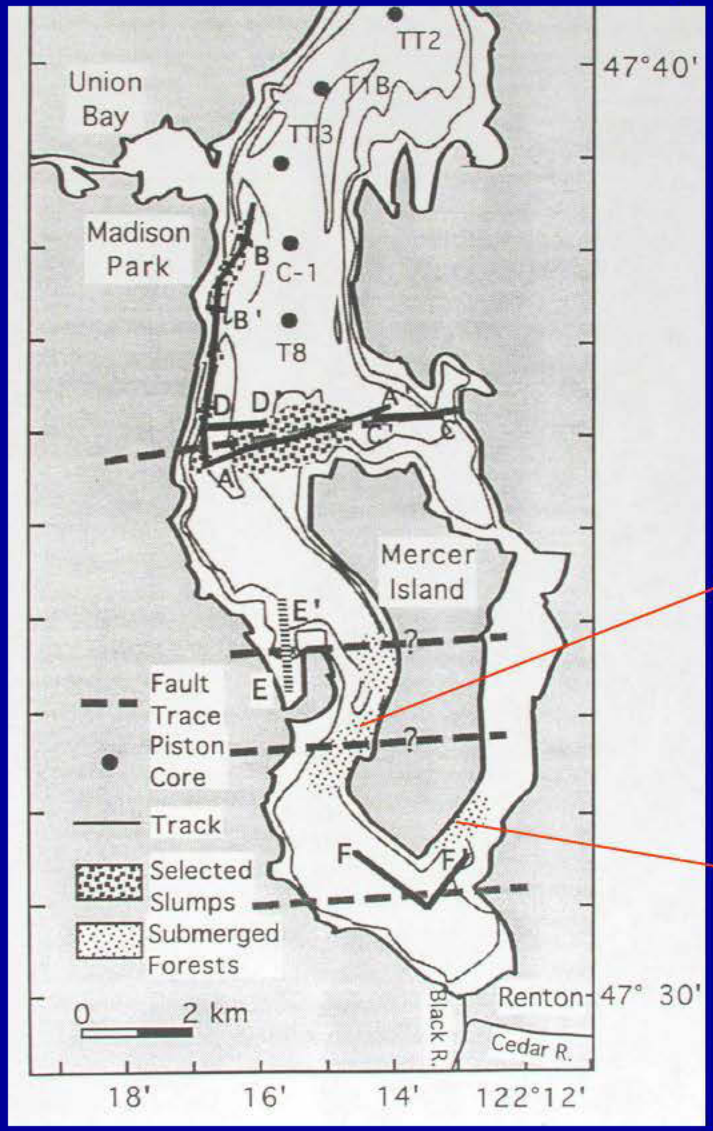
Everett animation

Seattle Fault Earthquake-Induced Landslides



From: Karlin, 1996

Shaded-relief lidar image of Mercer Island highlighting possible inactive (?) landslide Areas (note: areas not field checked)

Large landslide off SE side of Mercer Island with associated ± 1,000 year old submarine landslide

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Old growth forest in Lake Washington

- **Earthquake-induced landslides in Lake Washington drowned old Growth Forests about 1,000 years ago**

Eastside Journal: 8/16/94

AUG 16 1994

Allen's P.C.S. Est. 1888

Underwater logging?

IV-45

Kirkland man charged with illegal harvest

By Christopher Jarvis
Journal American Staff Writer

Investigators looking into the rupture of a sewer line off Mercer Island in the spring of 1992 smelled more than sewage seeping into the lake.

They smelled a scam that late last week resulted in 22 charges being filed against a 50-year-old Kirkland man now accused of illegally harvesting ancient logs from the bottom of the lake. Some of the logs were more than 1,100 years old.

John J. Tortorelli is accused of theft, trafficking in stolen property, criminal profiteering and making false statements, according to papers filed by Senior King County Deputy Prosecutor Lynn Prunhuber.

The case came to light when investigators with the state Department of Ecology and the federal Environmental Protection Agency interviewed Tortorelli and his crew because their tug, barge and crane had been working in Lake Washington near the site of the rupture.

Though Tortorelli said he had all the proper permits to harvest submerged logs from the lake, a subsequent investigation by six state and federal agencies determined otherwise.

Involved in the probe were the King County prosecutor's office, the state Attorney General, the state Department of Natural Resources, the state Department of Fisheries, the ecology department and the EPA.

What they uncovered was an apparent harvesting scheme in which tons of logs from ancient submarine forests and other logs — some of which sank to the lake bottom while being towed — were illegally taken between the spring of 1991 and June 1992.

They were then sold to sawmills for processing.

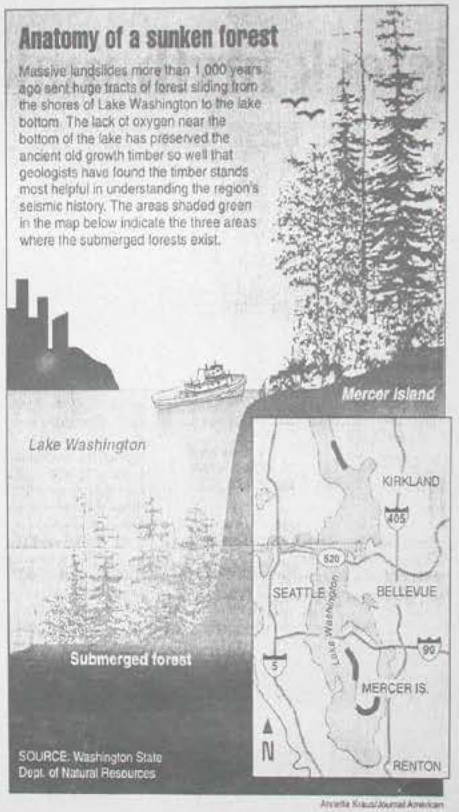
By state law, the state owns all the natural resources at the bottom of Lake Washington.

The ancient forests slid into the lake about 1,000 years ago in massive landslides probably caused by an earthquake. Because of the lack of oxygen, the ancient timber is well preserved and offers significant clues to deciphering the area's ancient history.

See Forest on A-4

Anatomy of a sunken forest

Massive landslides more than 1,000 years ago sent huge tracts of forest sliding from the shores of Lake Washington to the lake bottom. The lack of oxygen near the bottom of the lake has preserved the ancient old growth timber so well that geologists have found the timber stands most helpful in understanding the region's seismic history. The areas shaded green in the map below indicate the three areas where the submerged forests exist.



SOURCE: Washington State Dept. of Natural Resources

Arvielle Kraus/Journal American

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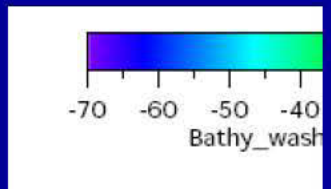
Lake Washington tsunami hazards from a fault offset. We hope to model landslide induced tsunamis soon



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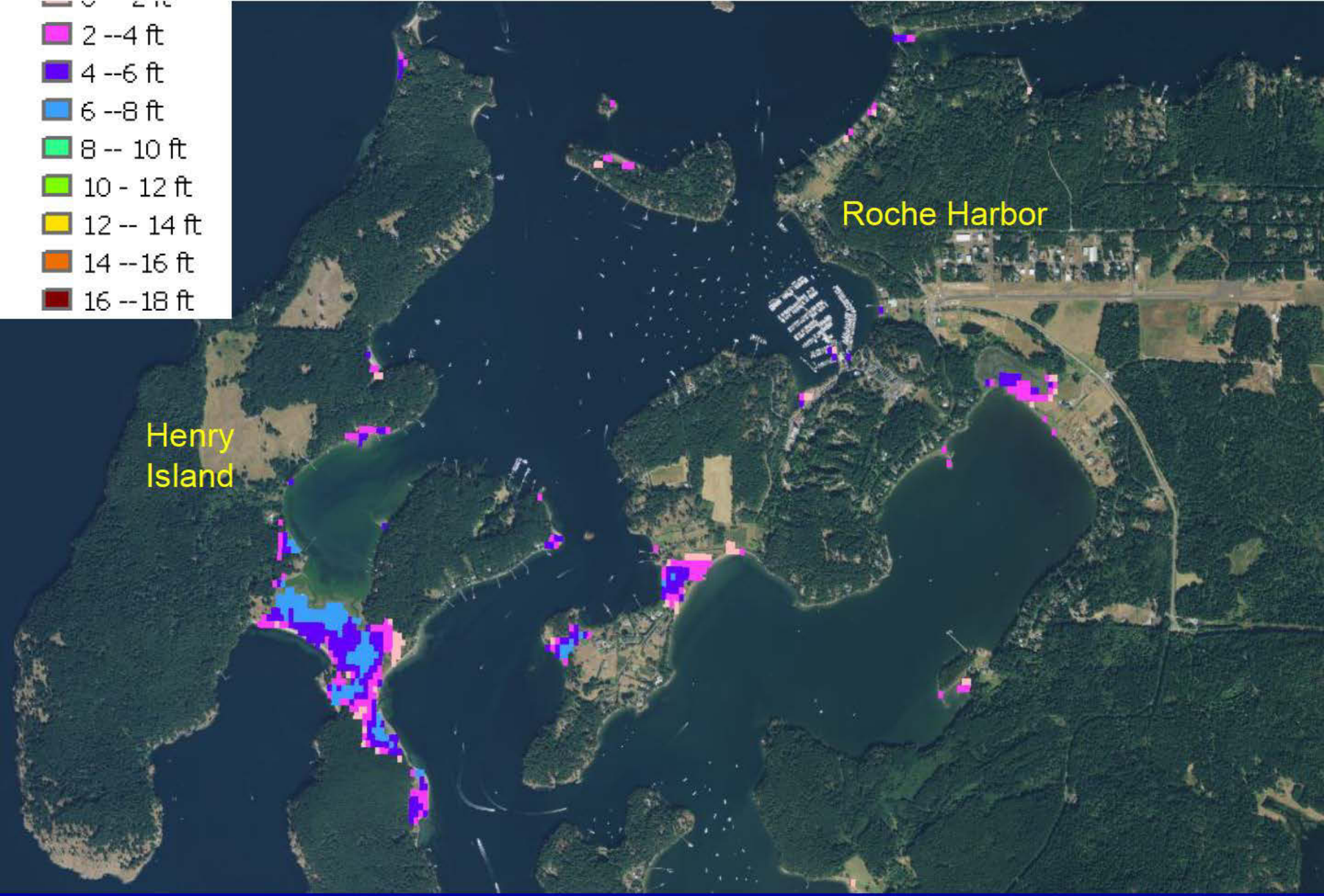
2 --4 ft
4 --6 ft
6 --8 ft
8 -- 10 ft
10 - 12 ft
12 -- 14 ft
14 --16 ft
16 --18 ft
Roche Harbor
Henry
Island

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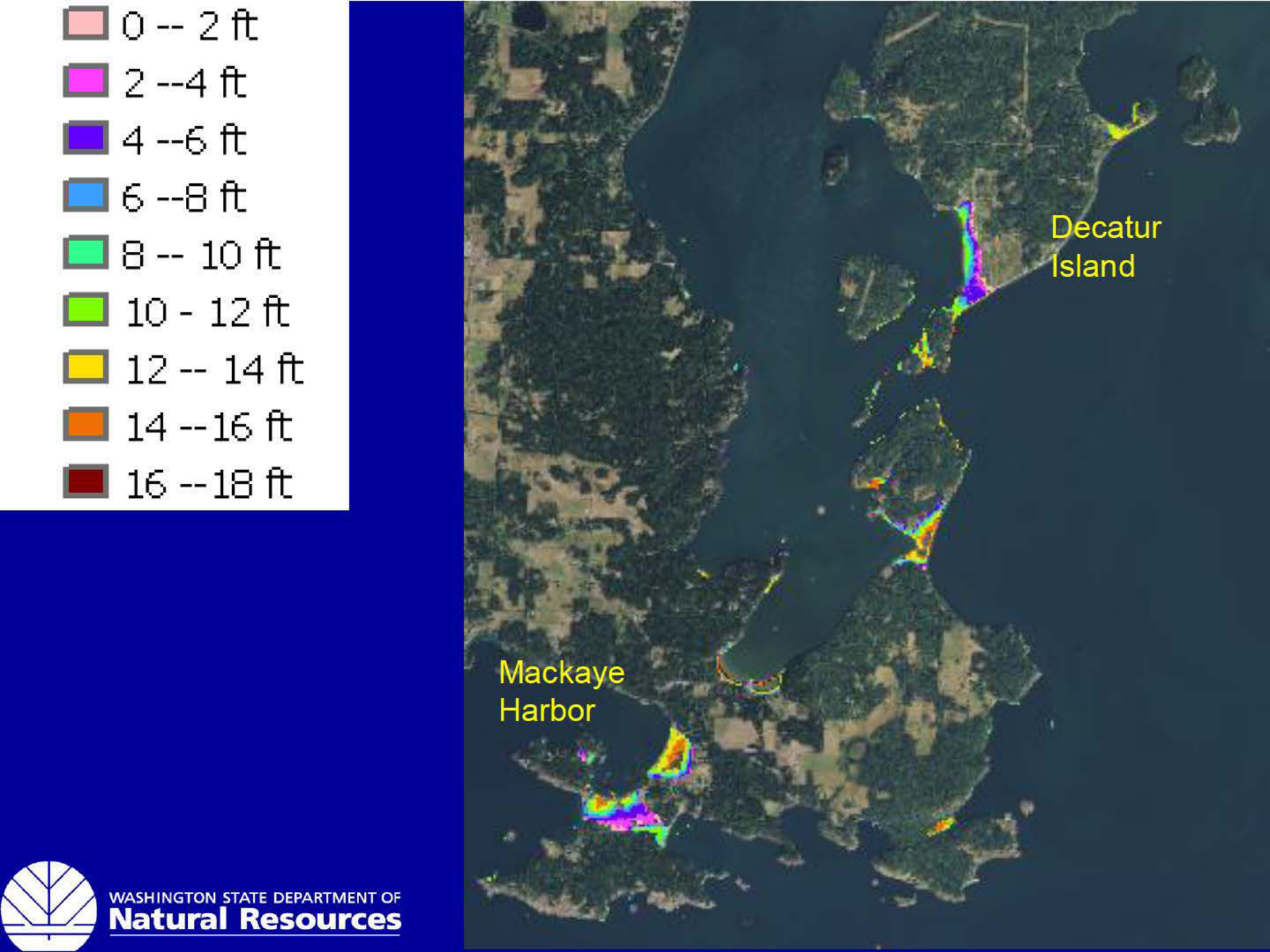
0 -- 2 ft
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Decatur Island
Mackaye Harbor
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0 -- 2 ft
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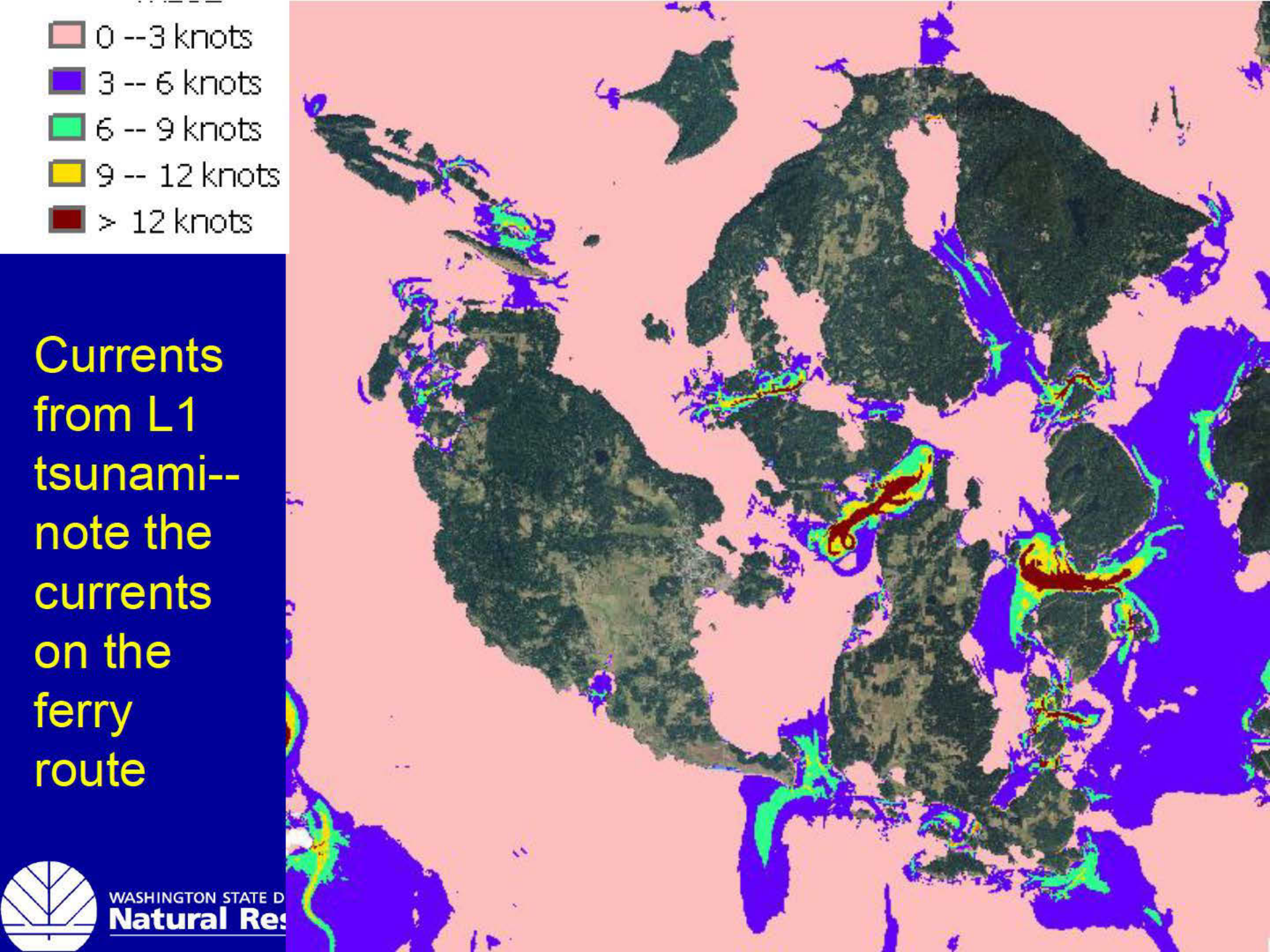
Waldron Island
Eastsound



Currents from L1 tsunami-- note the currents on the ferry route

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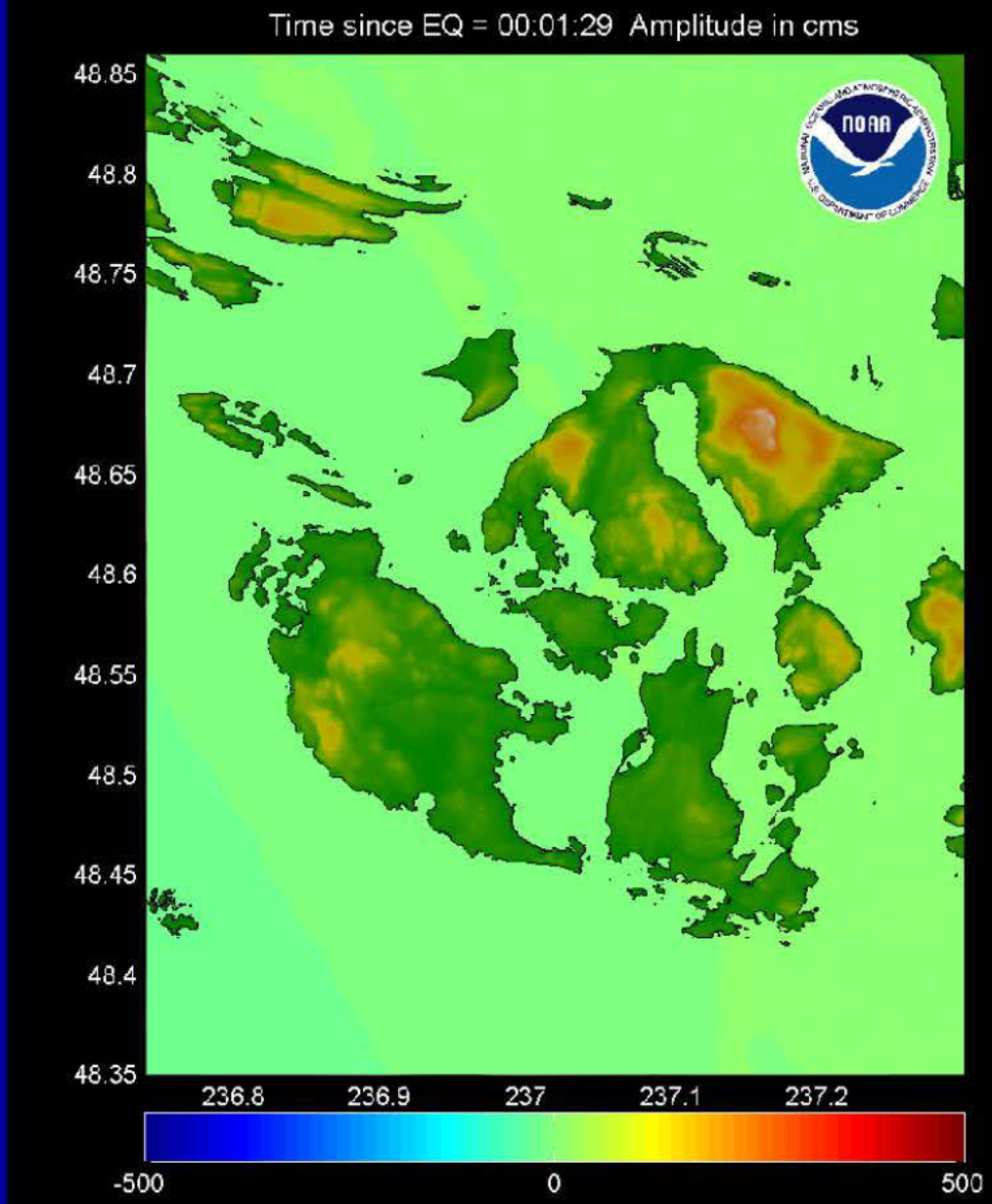

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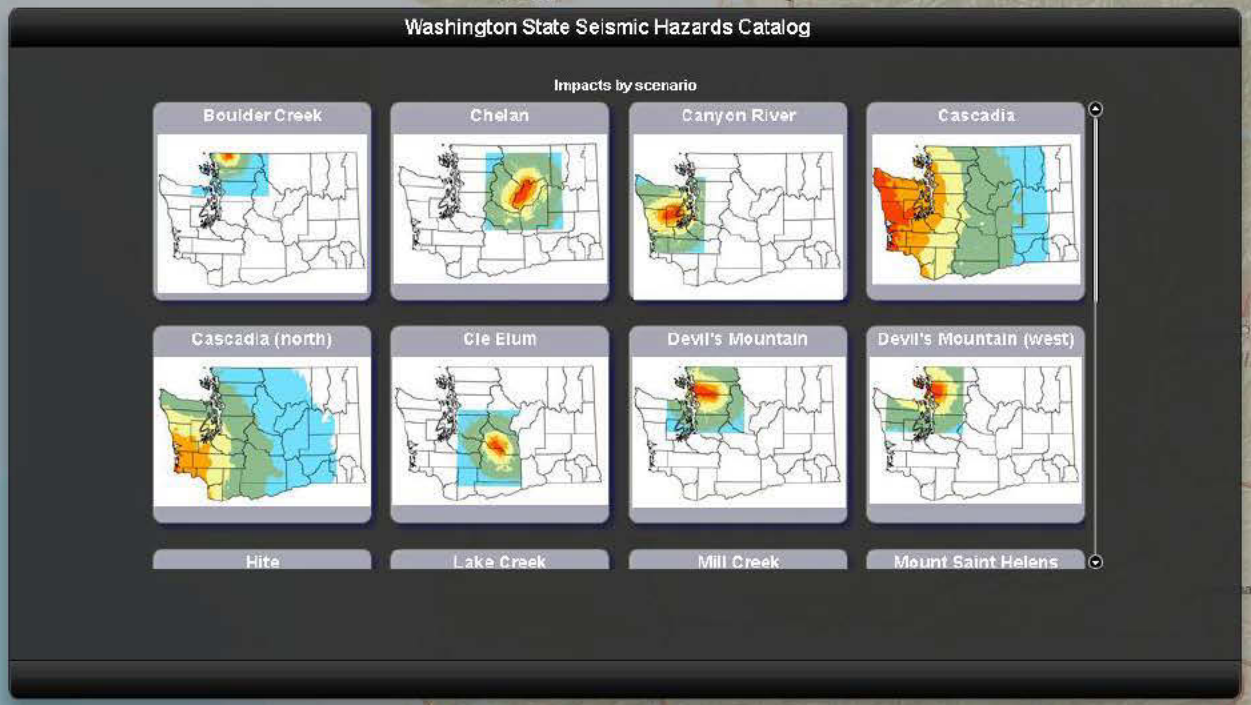
https://fortress.wa.gov/dnr/seismicscenarios/



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For more Information

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