

Seattle Area Earthquake Hazards

Seismic Mitigation Workshop
Seattle Fleets and Facilities
March 17th 2015

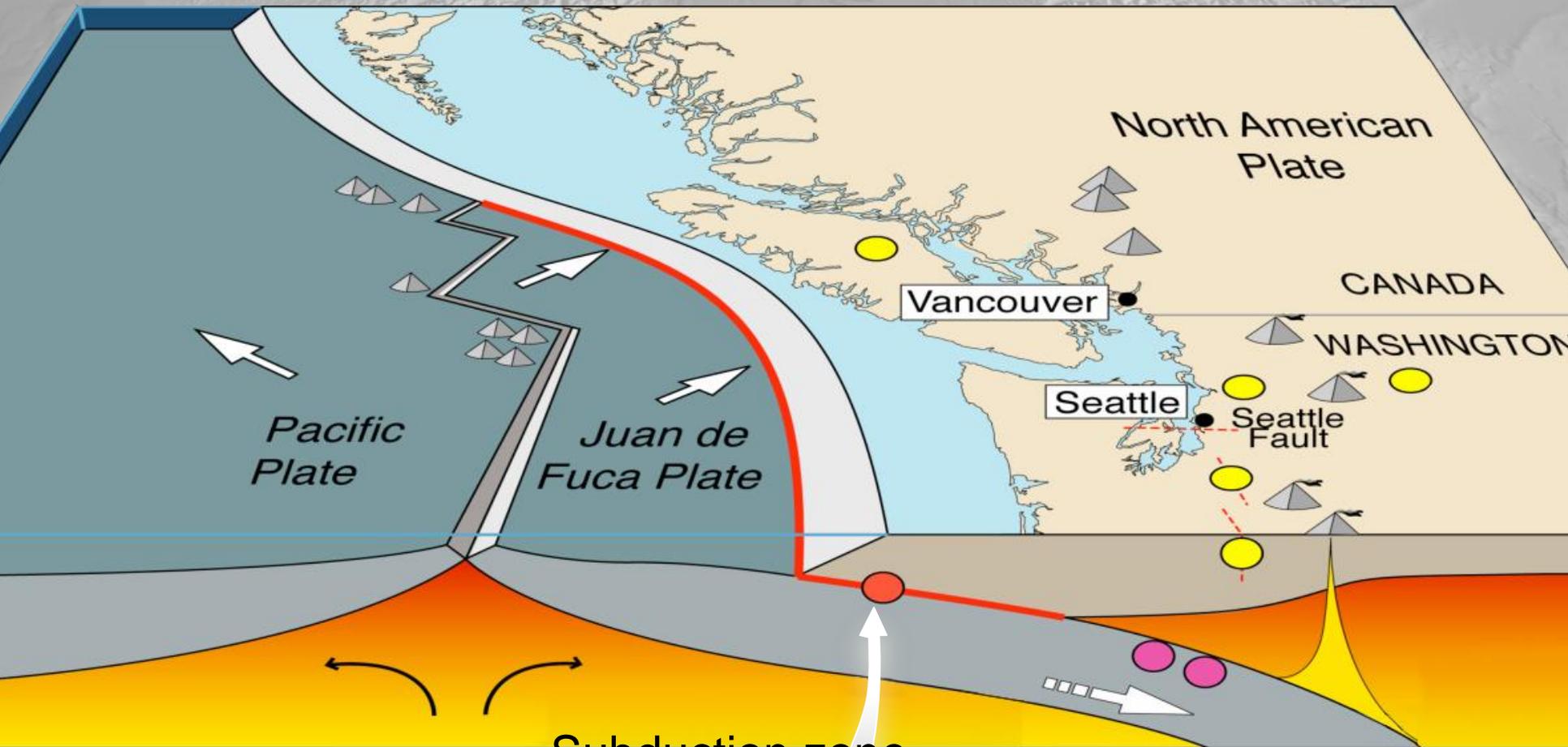
Bill Steele, Director of Information Services
University of Washington
Pacific Northwest Seismic Network
wsteele@uw.edu



Talk Outline:

- Overview of EQ sources and hazards
- The Big One: What we are learning about great Cascadia Earthquakes
- WC Earthquake Early Warning System Development
- Recent developments in the Pacific Northwest

Cascadia: 3 kinds of quakes



Subduction zone earthquakes (1700)

Quake Damage In Millions



Five Dead, Many Hurt In Quake

BY CHARLES DUNSIRE
Western Washington may be declared a disaster area by Gov. Dan Evans, following yesterday's earthquake which left five dead, dozens injured and millions of dollars in property damage in the Pacific Northwest.
The notice written for nearly a full minute at the

Historic Deep Earthquakes

Though bad enough:

Future earthquakes will be larger and stronger

The Olympian

THURSDAY, MARCH 1, 2001 SERVING WASHINGTON'S SOUTH PUGET SOUND www.theolympian.com

Epicerter 11 miles northeast of Olympia More than two dozen buildings damaged Dozens of injuries; no South Sound deaths

6.8 QUAKE

SEVEN DEAD, 59 INJURED EARTHQUAKE LOSS HEAVY



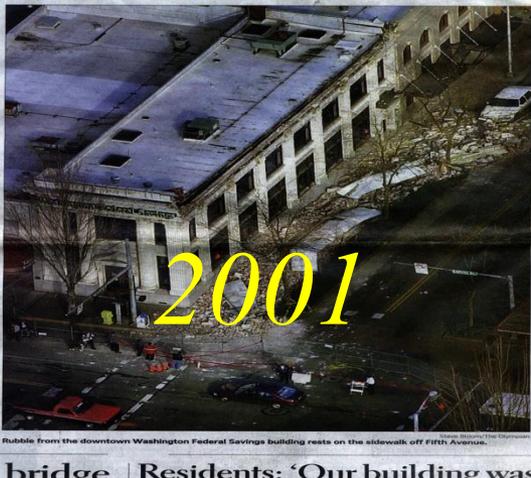
Temblor Lasts Minutes; Olyn Area Is Evacuated

Military Police P Downtown Sea
By Lloyd Stackhouse
Seven persons were killed and were injured seriously in an earth

WHAT YOU NEED TO KNOW NOW

- BRIDGE DAMAGE** — The Fourth Avenue bridge has been closed because of damage to the approach spans. Visible bowing.
- BUILDING DAMAGE** — 19 Capitol Campus and other state buildings have been closed until they can be inspected.
- 13 buildings in Olympia have been evacuated and will remain closed pending inspection of structural damage.
- 14 buildings in Olympia have been ordered to be vacated until a structural engineering report is received.
- Structural engineers are ordered to secure offices or retrieve records.
- ROAD CLOSURES** — Washington Street from Fifth to Logans.
- Fifth Avenue from Capitol Way to Washington Street.
- Lawrence Street to Fifth.
- Maple Street from 12th to 13th.
- 12th Avenue from 12th to 13th.
- 13th Avenue from 12th to 13th.
- 14th Avenue from 12th to 13th.
- 15th Avenue from 12th to 13th.
- 16th Avenue from 12th to 13th.
- 17th Avenue from 12th to 13th.
- 18th Avenue from 12th to 13th.
- 19th Avenue from 12th to 13th.
- 20th Avenue from 12th to 13th.
- 21st Avenue from 12th to 13th.
- 22nd Avenue from 12th to 13th.
- 23rd Avenue from 12th to 13th.
- 24th Avenue from 12th to 13th.
- 25th Avenue from 12th to 13th.
- 26th Avenue from 12th to 13th.
- 27th Avenue from 12th to 13th.
- 28th Avenue from 12th to 13th.
- 29th Avenue from 12th to 13th.
- 30th Avenue from 12th to 13th.
- 31st Avenue from 12th to 13th.
- 32nd Avenue from 12th to 13th.
- 33rd Avenue from 12th to 13th.
- 34th Avenue from 12th to 13th.
- 35th Avenue from 12th to 13th.
- 36th Avenue from 12th to 13th.
- 37th Avenue from 12th to 13th.
- 38th Avenue from 12th to 13th.
- 39th Avenue from 12th to 13th.
- 40th Avenue from 12th to 13th.
- 41st Avenue from 12th to 13th.
- 42nd Avenue from 12th to 13th.
- 43rd Avenue from 12th to 13th.
- 44th Avenue from 12th to 13th.
- 45th Avenue from 12th to 13th.
- 46th Avenue from 12th to 13th.
- 47th Avenue from 12th to 13th.
- 48th Avenue from 12th to 13th.
- 49th Avenue from 12th to 13th.
- 50th Avenue from 12th to 13th.

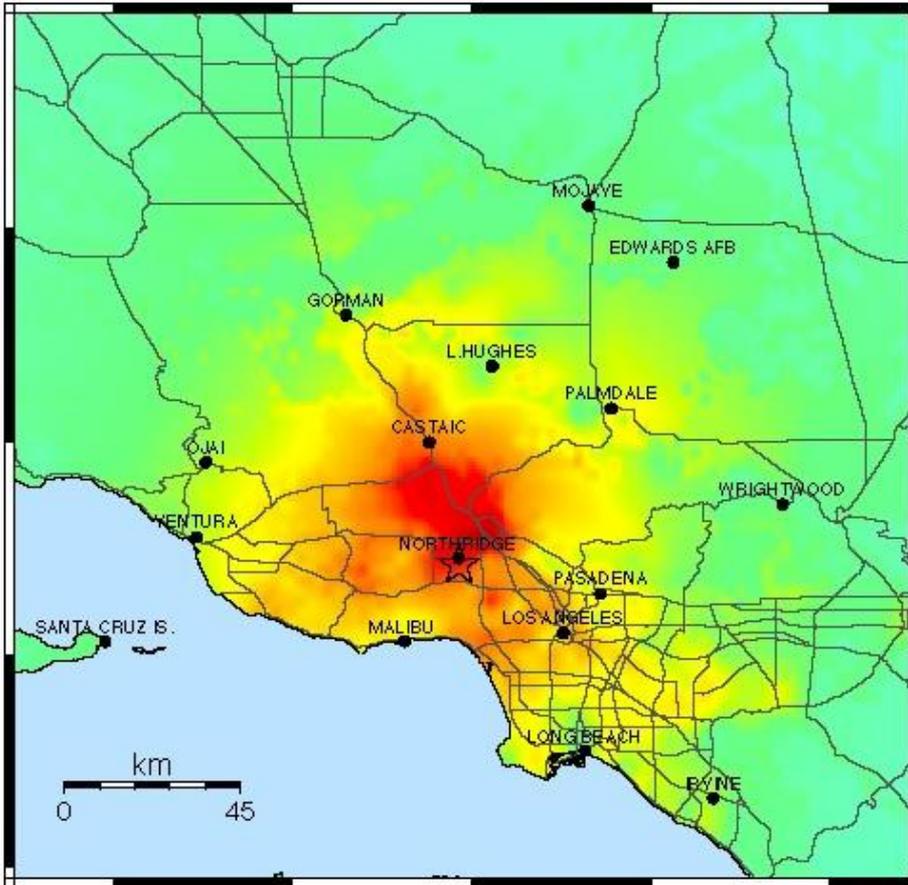
OLYMPIA — South Sound officials will begin to assess the long-term cost from a powerful earthquake that caused thousands of dollars in damage and left intrinsically few seriously injured.



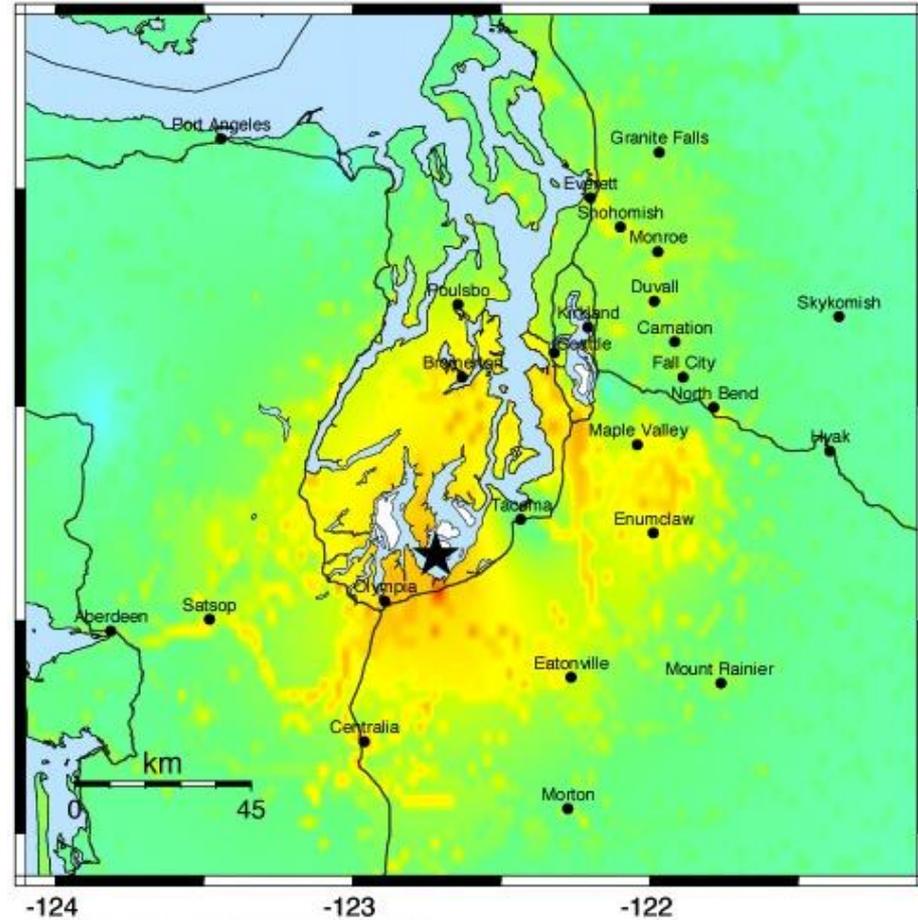
State buildings shut till Monday

BY PATRICK CONDOM, SEBASTIAN SMITH AND LAUREN WALSH
OLYMPIA — The earthquake that struck South Sound on Wednesday morning shook Washington government buildings, causing the stone shell of the state Capitol dome and damaging the steel frame of state office buildings.

Northridge, California (M6.7)



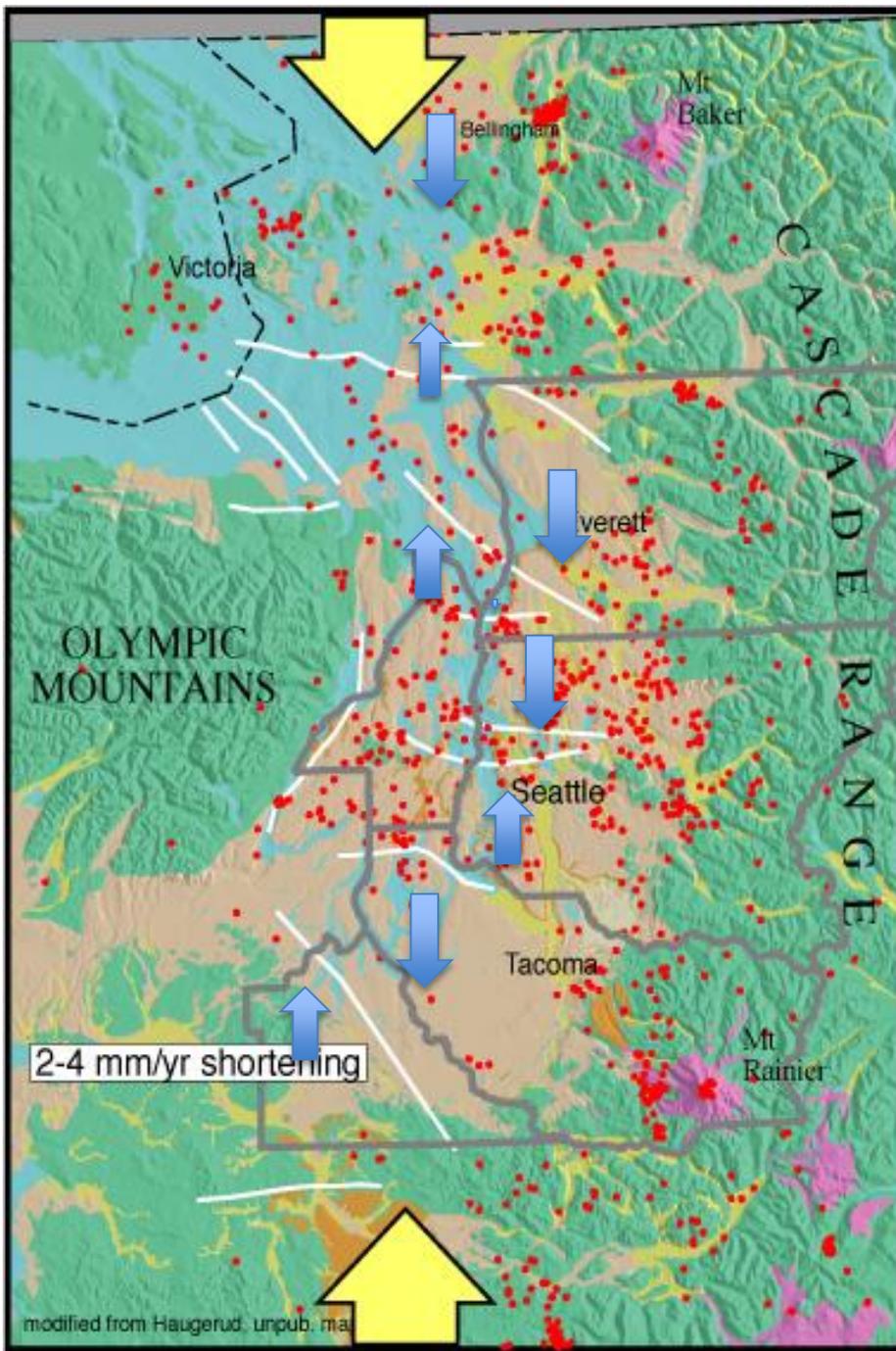
Nisqually, Washington (M6.8)



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL. (cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

The Puget Sound Squeeze Box

Northward compression causes deformation (faulting) and earthquakes in Puget Sound



Explanation

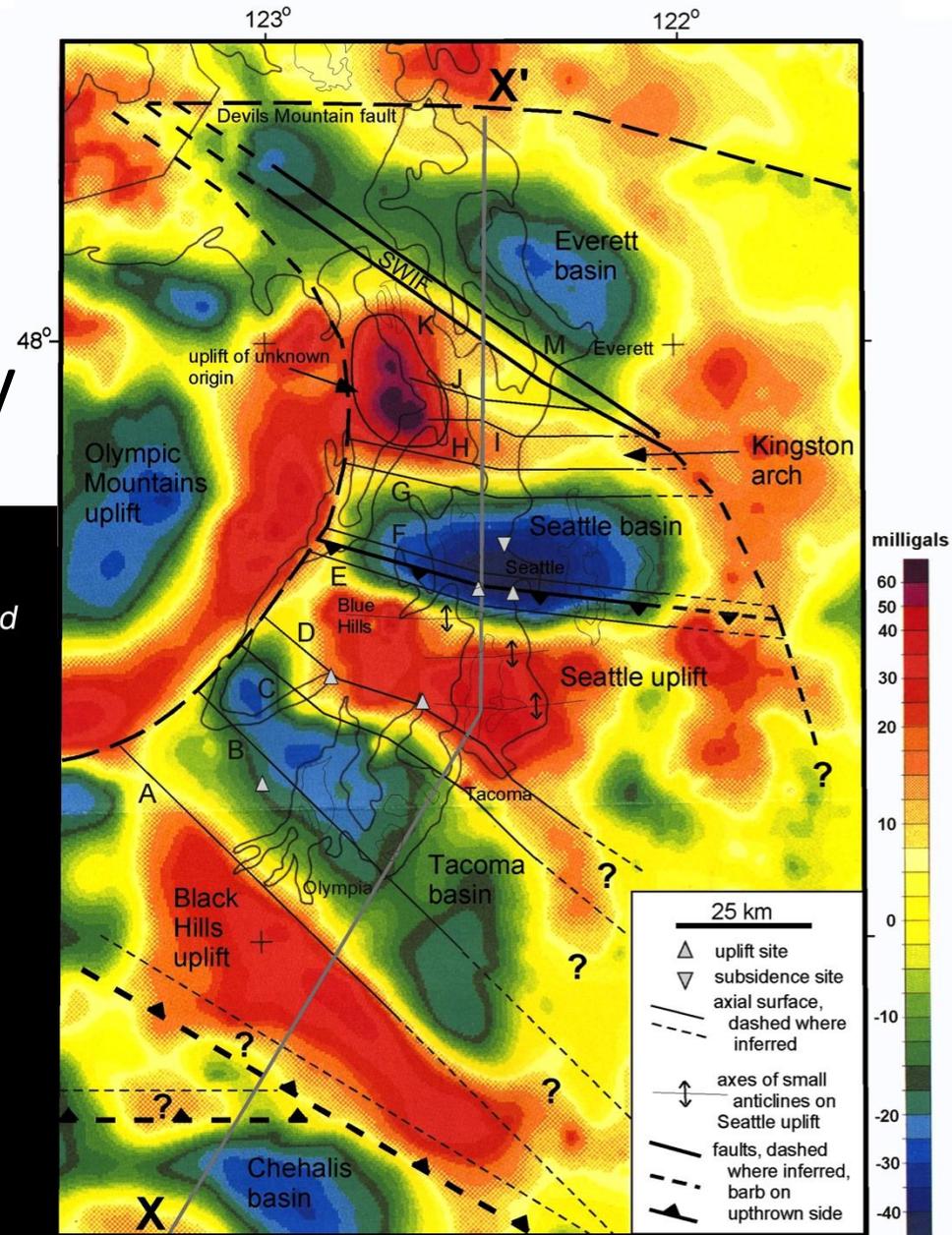
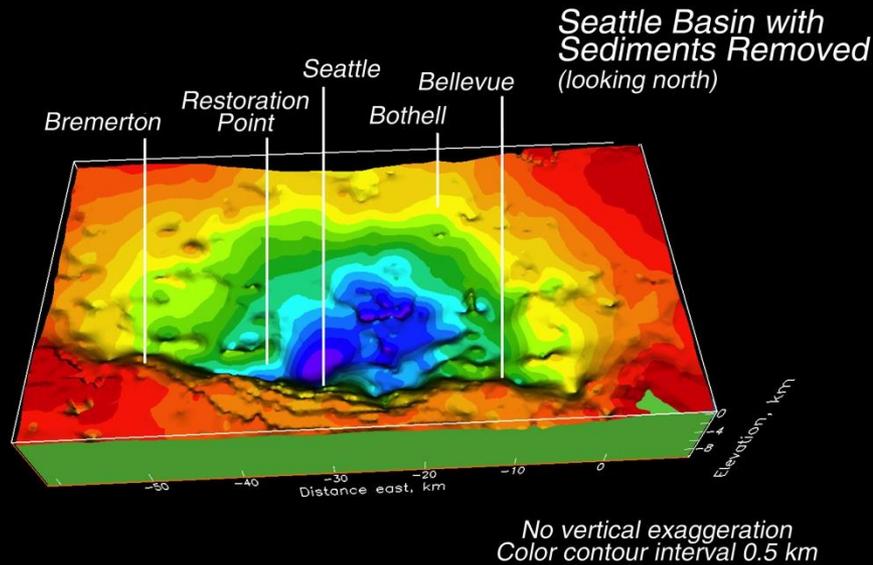
 **Glacial deposits**

 **Earthquakes**

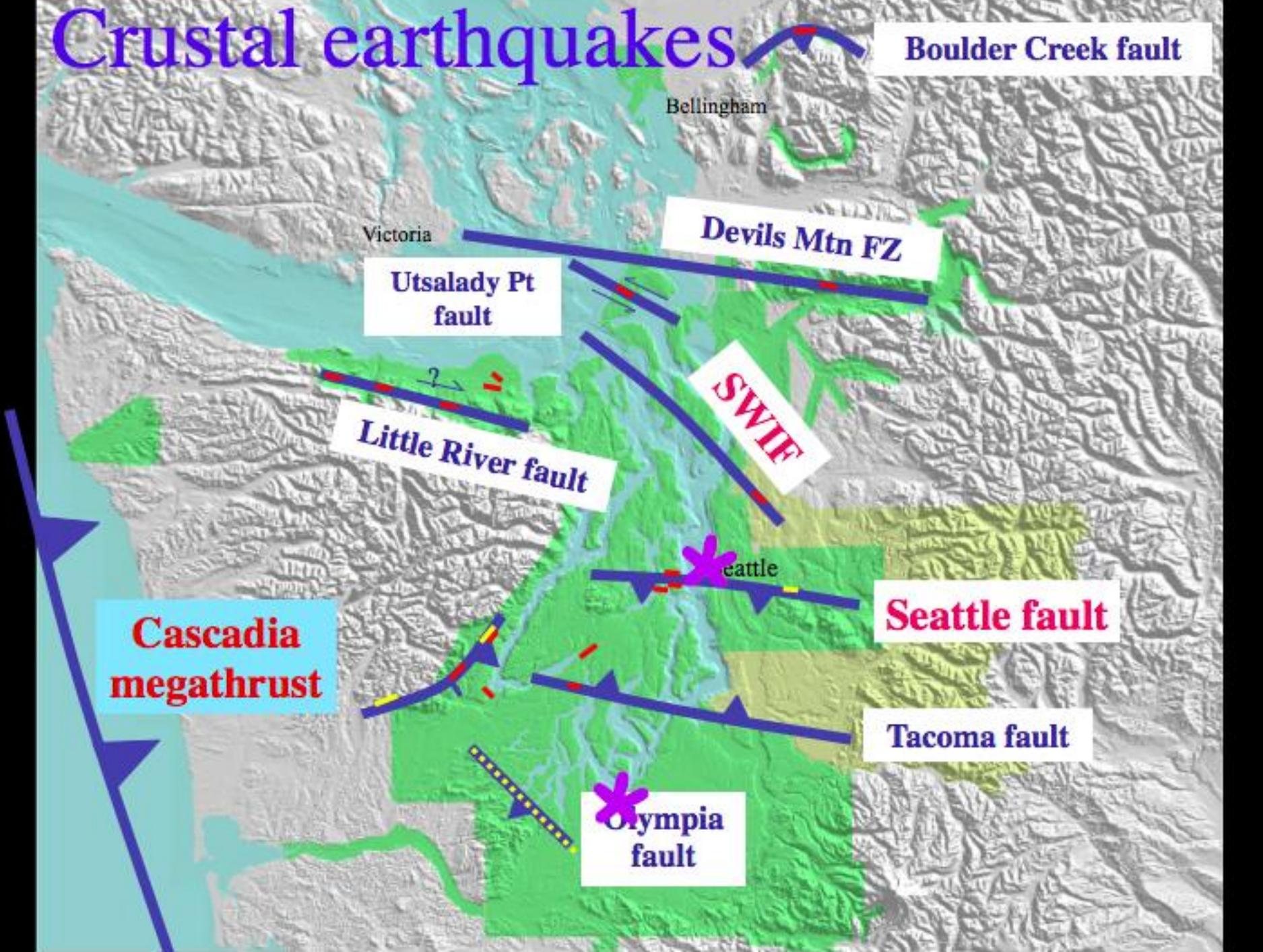
 **Crustal Faults**

Gravity measurements Reveal deep structure

Basins Trap Seismic Energy



Crustal earthquakes

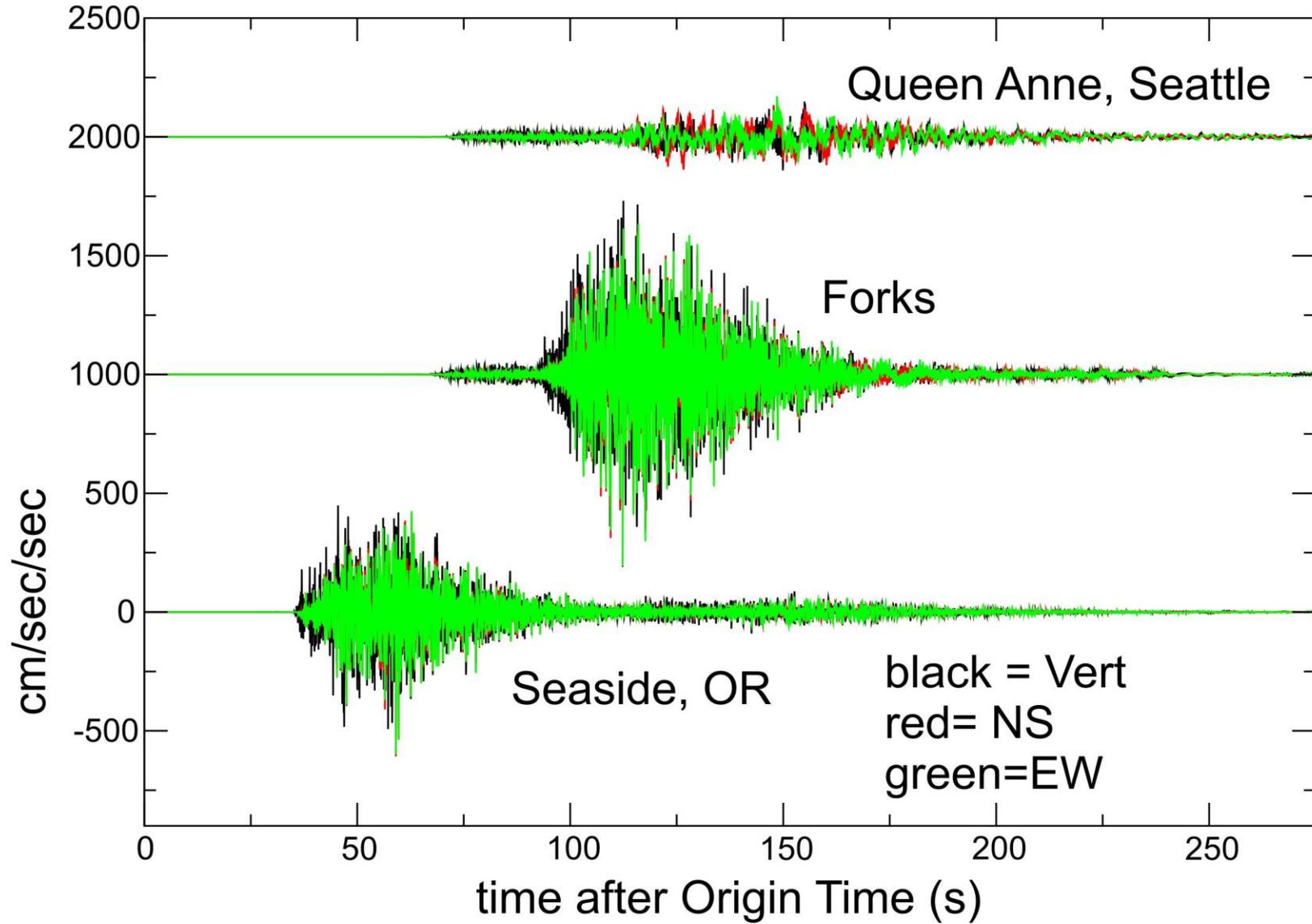


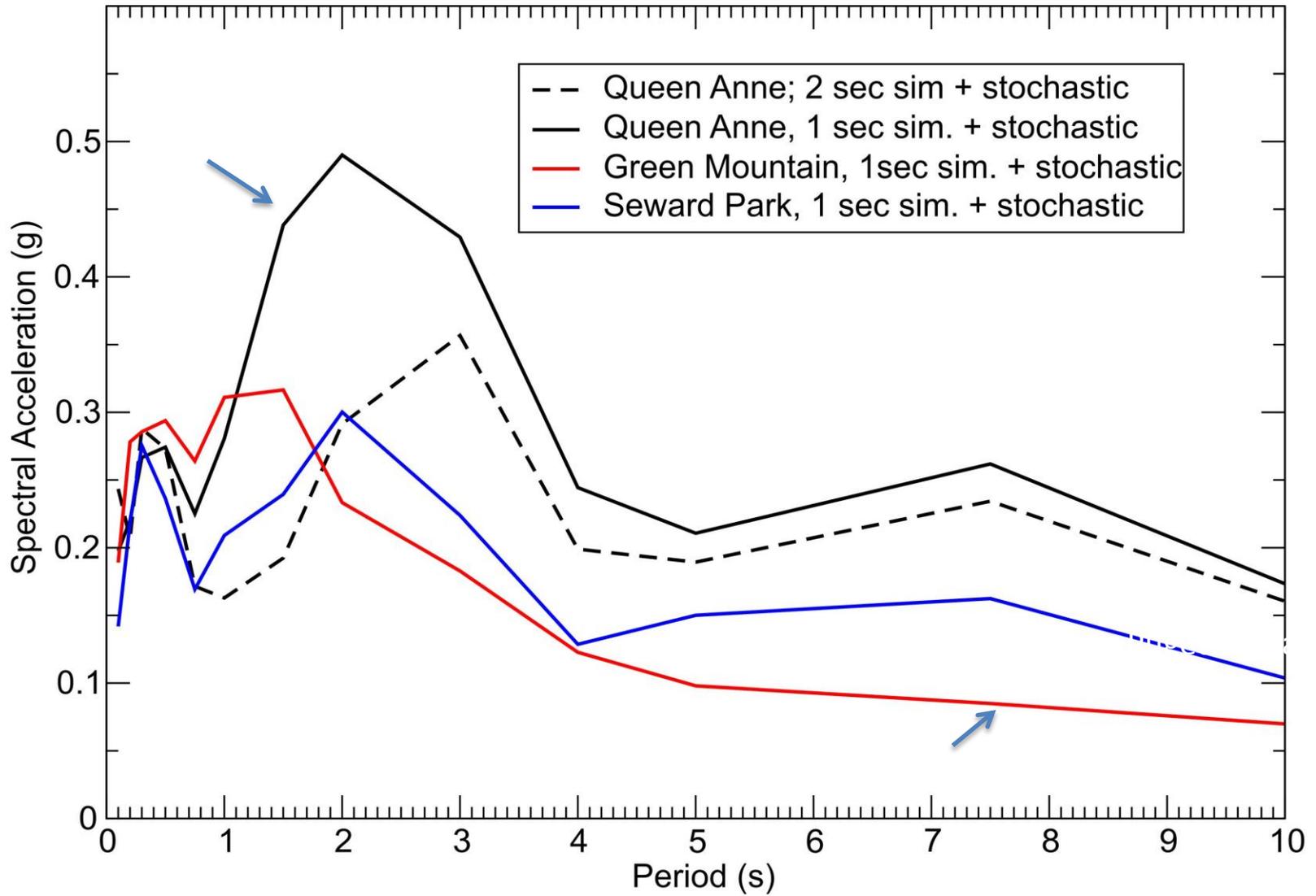


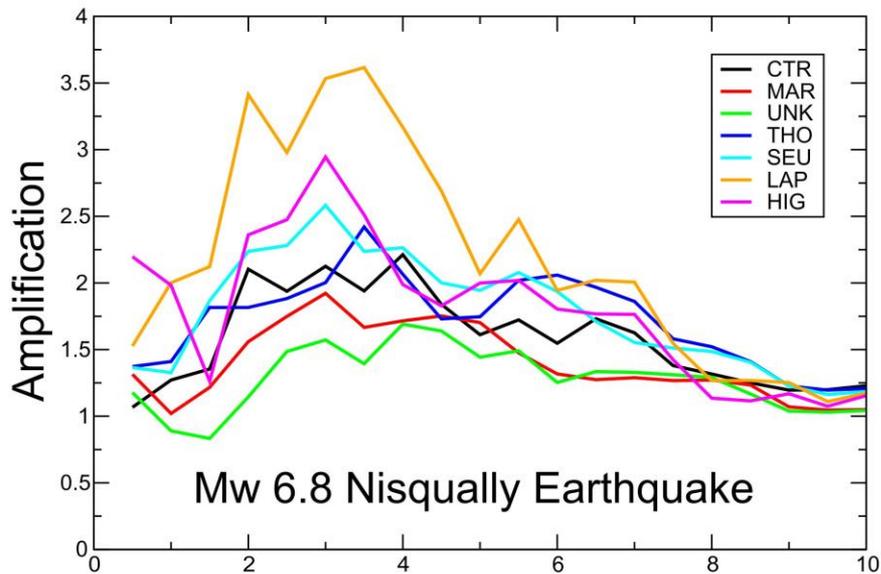
The Unexpected Hit: Twice



Synthetic acceleration records for M9.0 Cascadia Earthquake assumes $V_{s30} = 500$ m/s

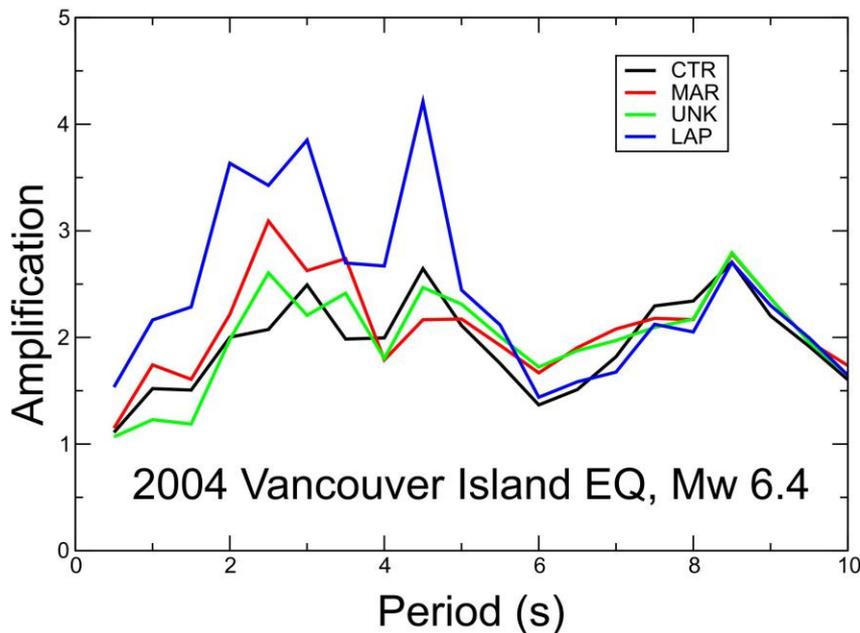






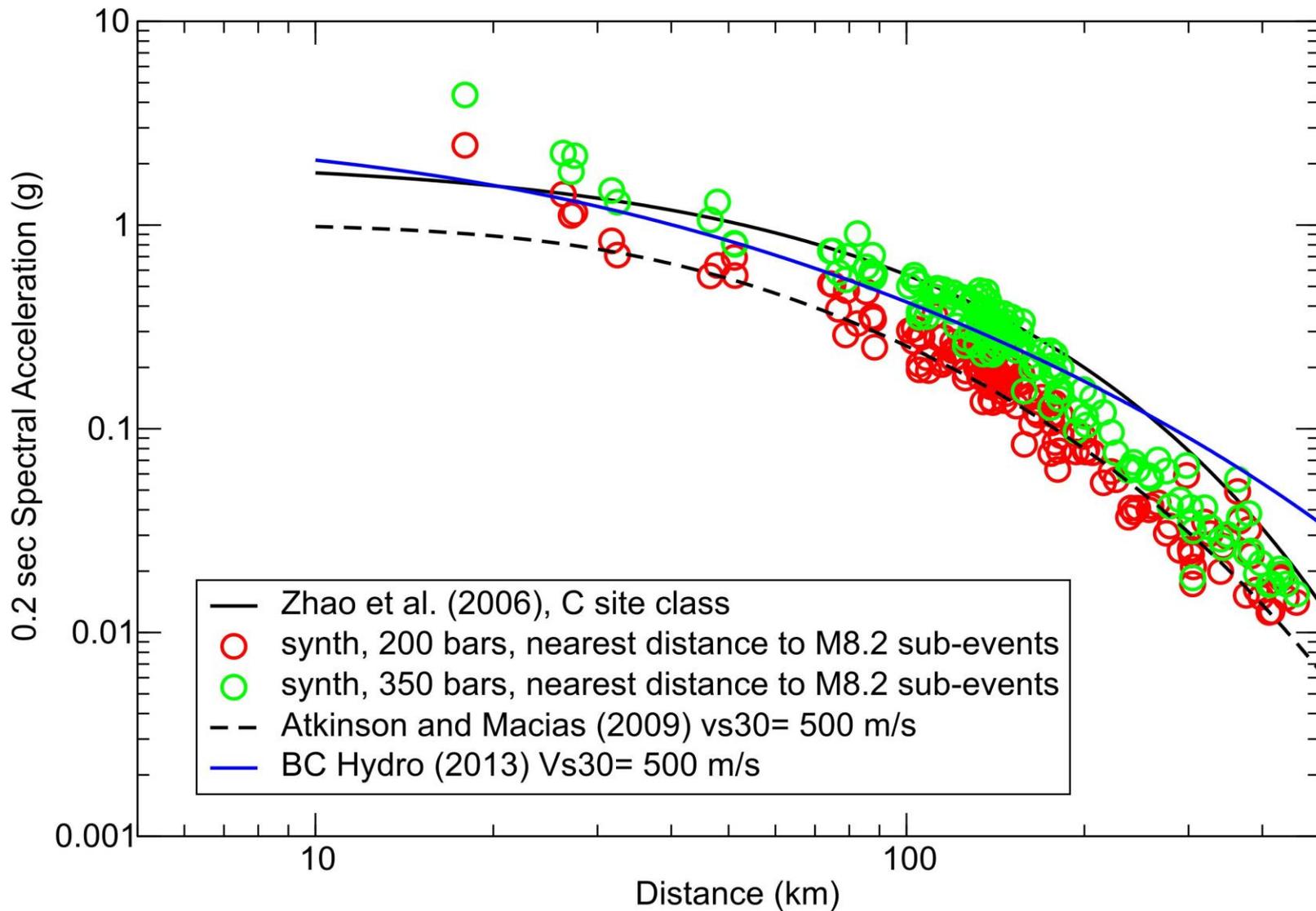
Observed amplification of spectral response values for stiff soil sites in the Seattle basin

Referenced to site with thin soil over firm-rock outside of basin



These sites have similar Vs30 Values.

Note there is likely more Amplification when referenced to sites outside of Puget Lowland



Nisqually Earthquake

- Liquefaction observed in Seattle, Olympia, other areas
- Liquefaction not observed in Puyallup, Kent valley

Near Port of Seattle



Olympia



**Liquefiable soils
may be deposited
by nature, or by
man.**



Looking NW from
Beacon Hill, Seattle



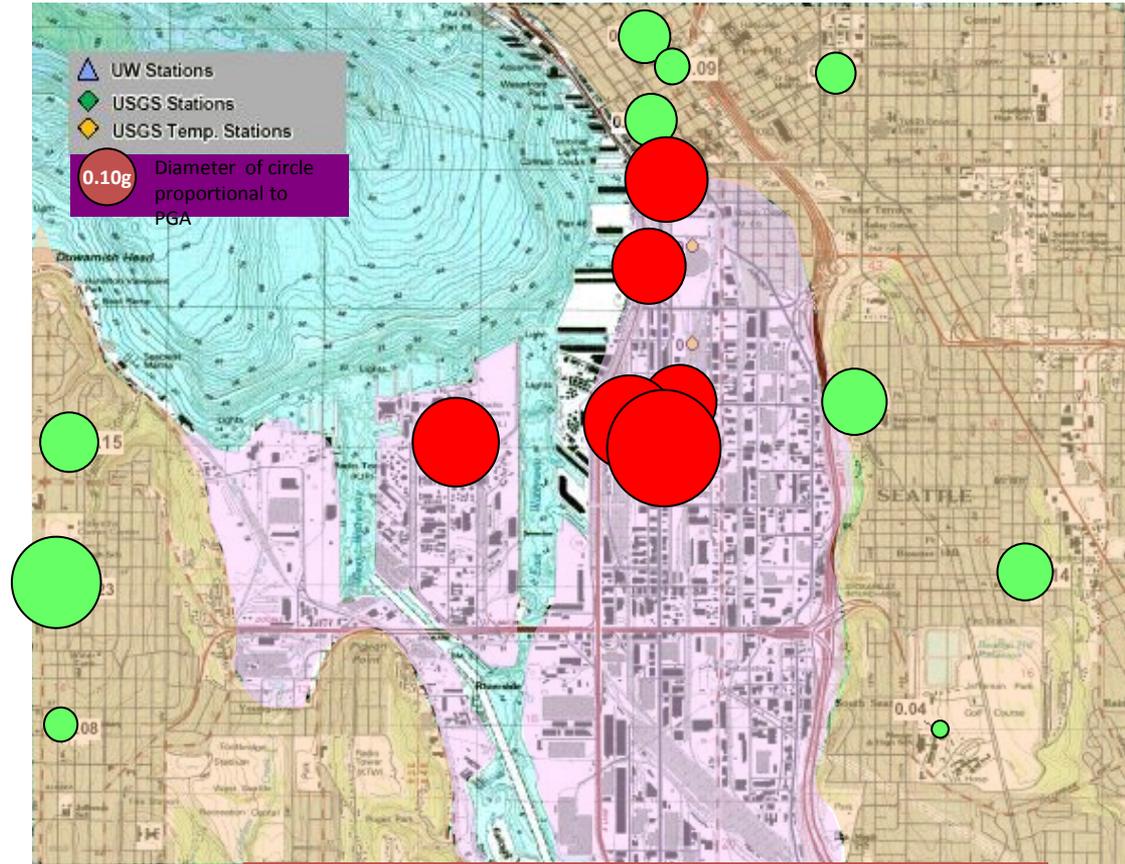
Courtesy of Prof. Steve Kramer, Univ.
of Washington

Soil Amplification during the Nisqually Earthquake

Dependent on:

- Soil type
- Soil stiffness
- Soil thickness
- Soil geometry

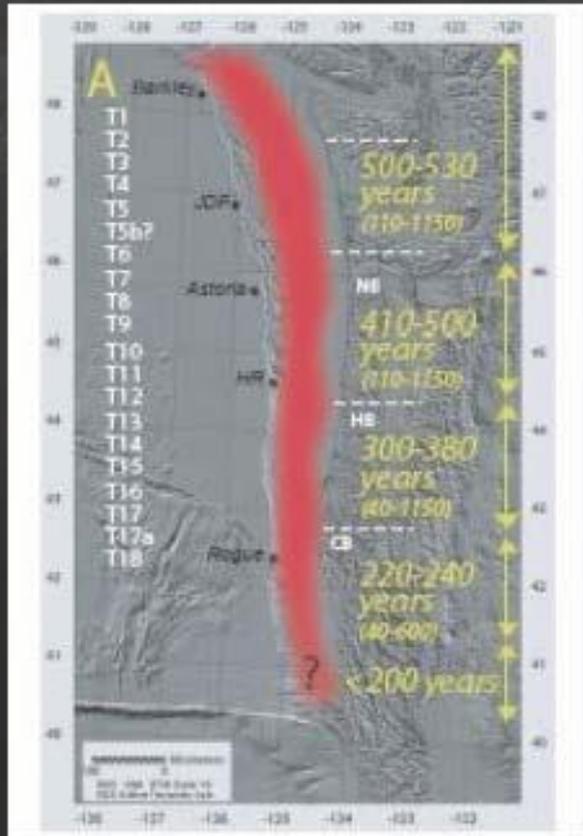
Happy 10th
Anniversary!
2/28/2011



Motions in filled areas (pink) stronger than in hilly areas (beige)

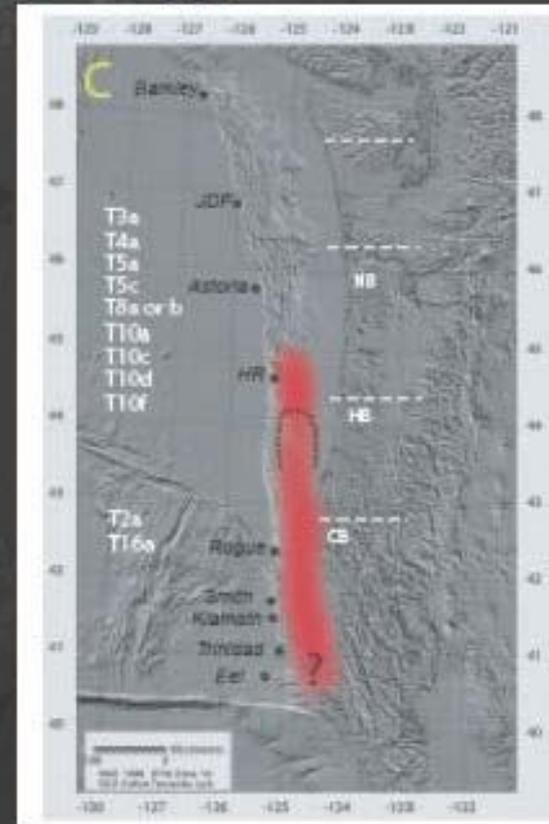
Shear wave velocities
High in hilly areas
Low in Sodo, Duwamish areas

Last 10,000 years of big earthquakes from offshore geology

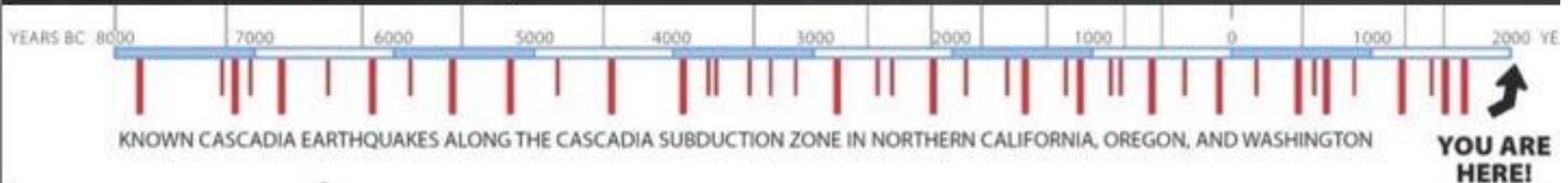


20 ~M9 events,

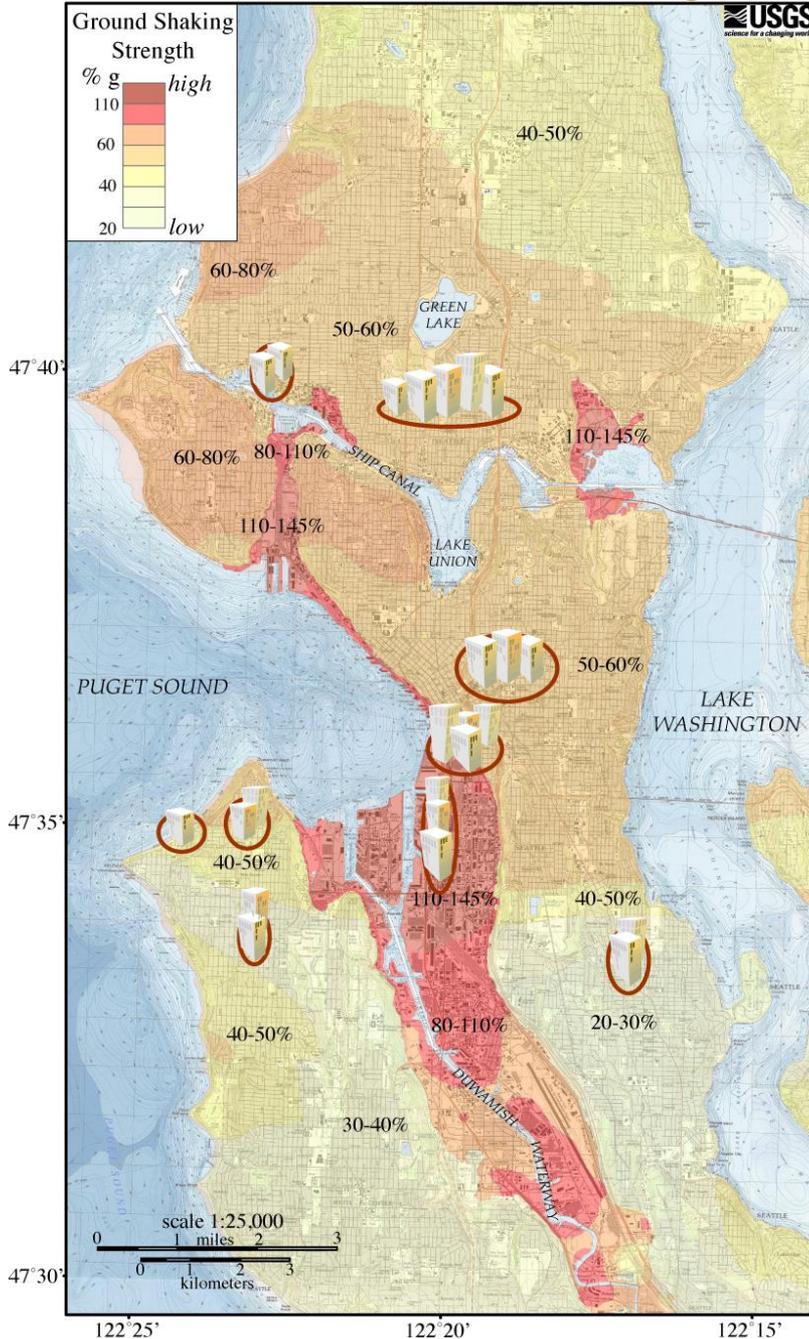
20 ~M8 to M8.5 events



(Goldfinger et al., 2008, Bull. Seis. Soc. Amer)



Seattle Earthquake Hazard (10% probability in 50 yrs) & Its Most Vulnerable Buildings



Hazard maps help inform the prioritization of mitigation efforts.

City understands Building inventories fragility, occupancy & function.

Overlay modified shaking hazard, ground failure potential (liquefaction and landslide), and other hazards.

Developing EEW Partnerships

February 2014 workshop revealed strong public and private sector interest.

Diverse group of organizations targeted for follow-up meetings. Seattle is the only city participating in the first round of EEW development.

Prime objective is to learn how EEW can be utilized to reduce loss of life and the cost of disaster response and recovery.

EEW experimental feed to stakeholders who:

- Agree to terms
- Participate in product development i.e., provide feedback and attend quarterly affiliates meetings.
- Help with cost benefit analysis
- Help us communicate usefulness to the federal and State governments.



Invited to join PNSN Affiliates

University of Washington

Microsoft

Port of Seattle

Boeing, (signed agreement)

Sound Transit

British Petroleum/ Olympic Pipeline

Puget Sound Energy

Intel

Bonneville Power Administration

City of Seattle (EOC, Public Utilities, City Light, etc.)

Providence Medical Foundations



Federal Support for EEW:

Gordon and Betty Moore Foundation funding to develop prototype system expiring.

USGS provided some early seed money ~1 million overall.

Implementation plan calls for 16 million annually for West Coast System build out and maintenance. (5-6 Million for PNW)

2014 Congress appropriated 5 million (of the 16) with bi-partisan support to continue WCEEW development.

USGS will allocate federal dollars
2/3 California, 1/3 Oregon and Washington?

January 2015 President Obama adds an additional 5 million for EEW in his 2016 budget request.



EEW and Hazard Mitigation in Structures

Bring elevators to next floor
and open door.

Spin down HVAC system.

Warn occupants to take cover
Or move to safer area.

Open Firehouse doors

What other automated actions?



