

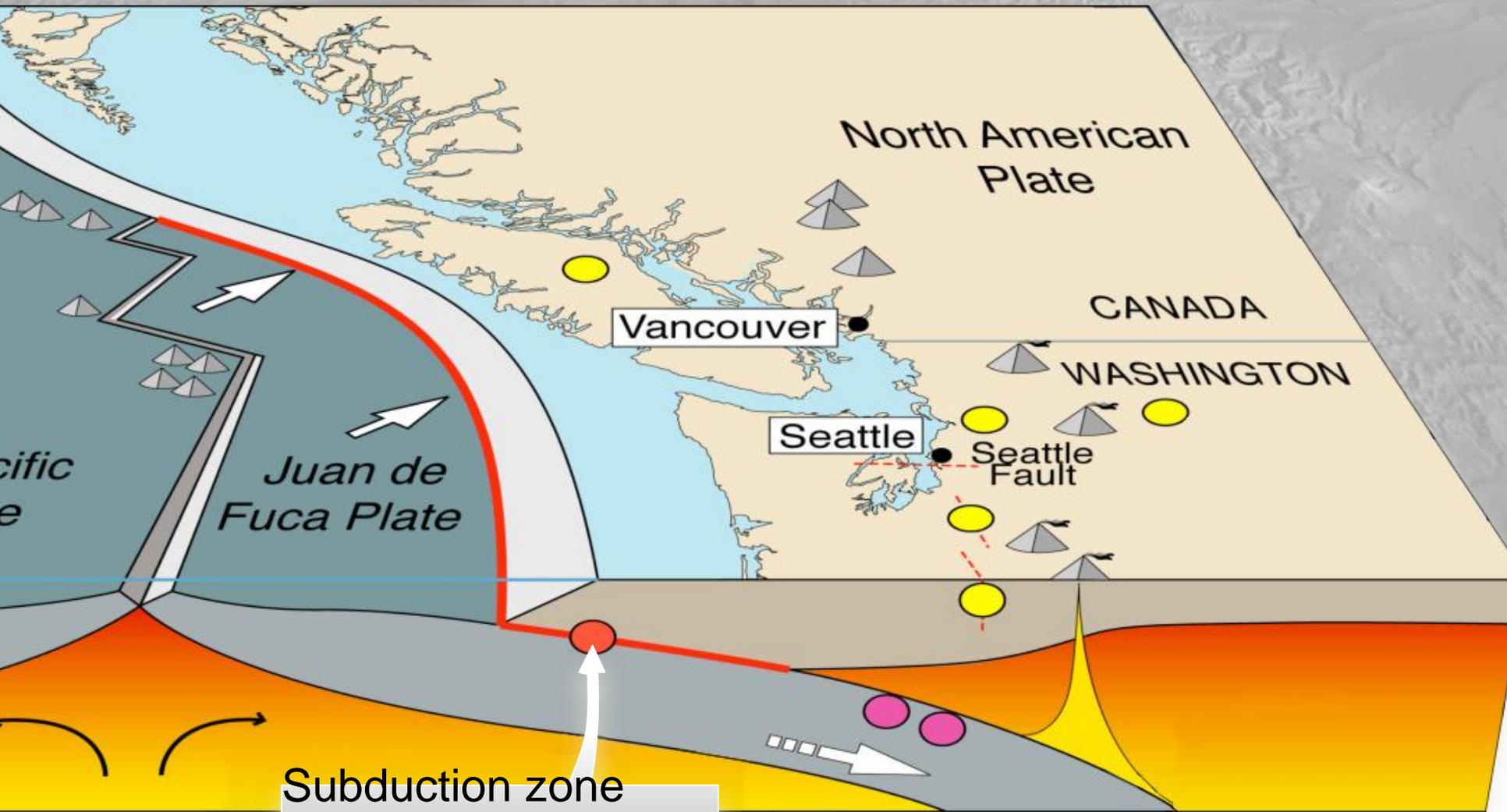
West Coast Earthquake Early Warning: A Moment to Act



Bill Steele, University of Washington
The Pacific Northwest Seismic Network
wsteele@uw.edu



Cascadia: 3 kinds of quakes



Subduction zone earthquakes (1700)

3 Full Pages Quake Pictures Inside

THE WEATHER
Seattle Post-Intelligencer SUNRISE EDITION
 THE QUALITY NEWSPAPER OF THE GREAT NORTHWEST
 102nd Year—No. 241 10c SEATTLE, FRIDAY, APRIL 10, 1965 52 PAGES MA. 7-3000

Quake Damage In Millions



1965

Five Dead, Many Hurt In Quake
 BY CHARLES DUNNIRE

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.

Historic Deep Earthquakes

Though bad enough:

Future earthquakes will be Larger and Stronger

EXTRA **Seattle Post-Intelligencer** SUNRISE EDITION
 SEATTLE, THURSDAY, APRIL 13, 1966 48 PAGES 1c PER COPY

SEVEN DEAD, 59 INJURED, EARTHQUAKE LOSS HEAVY



1949

Temblor Lasts Minutes; Olyn Area Is Evacuated

Military Police Patrol Downtown Seattle
 By David Mackenzie
 Seven persons were killed and 59 were injured seriously in an earth-

The Olympian SERVING WASHINGTON'S SOUTH PUGET SOUND
 GODD MORNING HIGH 51 LOW 316

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

6.8 QUAKE

WHAT YOU NEED TO KNOW NOW ABOUT THE QUAKE
 • The Pacific Northwest has been shaken by a powerful earthquake which was felt throughout the region and caused considerable damage and loss of life.
 • The earthquake occurred at 11:00 a.m. on Thursday, April 13, 1966, and lasted for about 15 seconds.
 • The epicenter of the quake was located 11 miles northeast of Olympia, Washington.
 • The quake was felt throughout the Pacific Northwest, from Seattle to San Francisco.
 • The quake caused damage to buildings, bridges, and roads.
 • Seven people were killed and 59 were injured.
 • The quake caused damage to buildings, bridges, and roads.
 • Seven people were killed and 59 were injured.



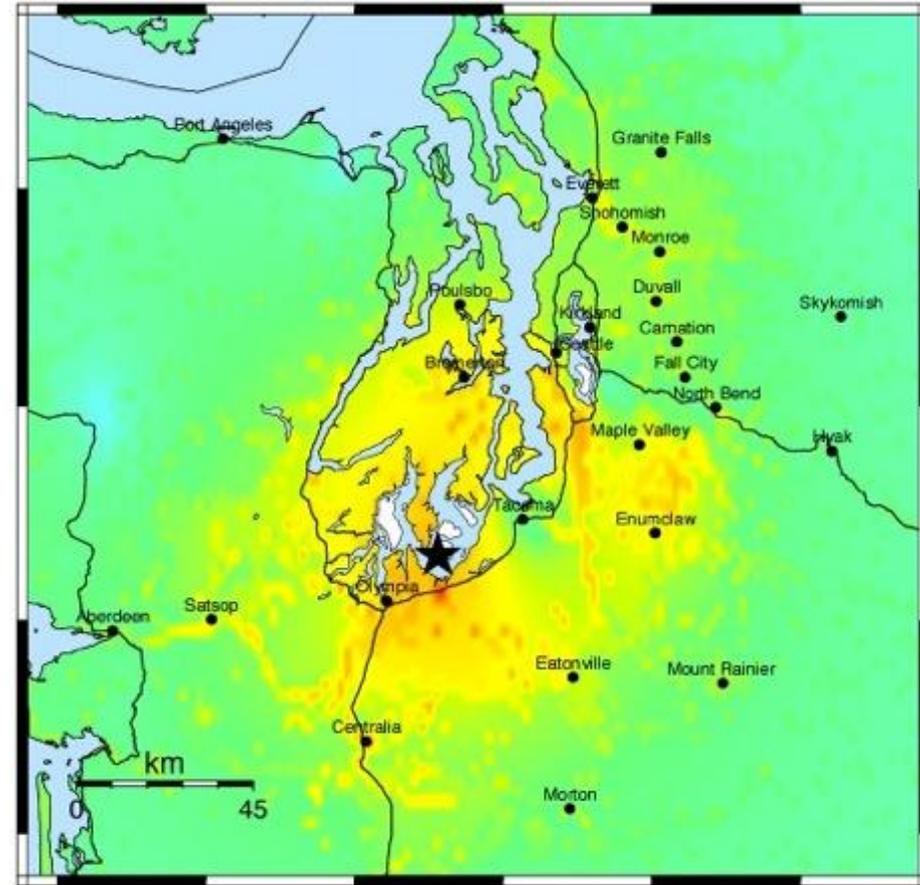
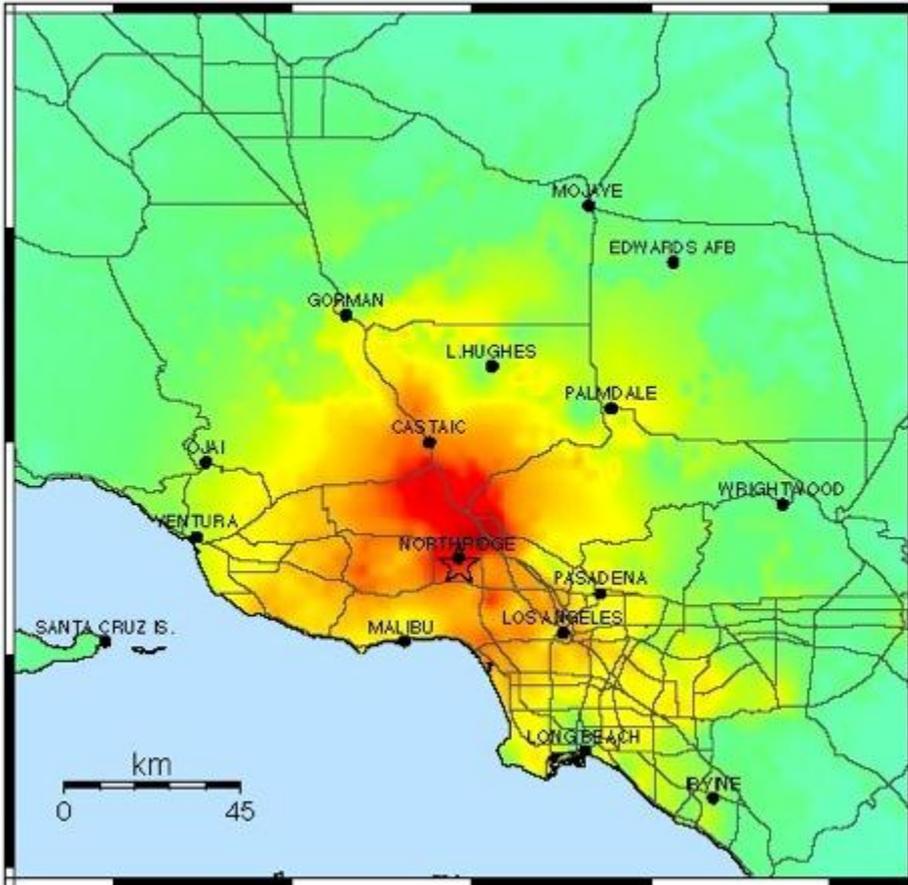
2001

State buildings shut till Monday
 BY FRANK CONNOR
 OLYMPIA — The quake caused the greatest damage to the state buildings here, and the state buildings will be closed until Monday, according to state officials here today.
 The quake, which was felt throughout the Pacific Northwest, caused damage to buildings, bridges, and roads.
 Seven people were killed and 59 were injured.
 The quake caused damage to buildings, bridges, and roads.
 Seven people were killed and 59 were injured.

4th Ave. bridge Residents: 'Our building was dancing'

Northridge, California (M6.7)

Nisqually, Washington (M6.8)



-124

-123

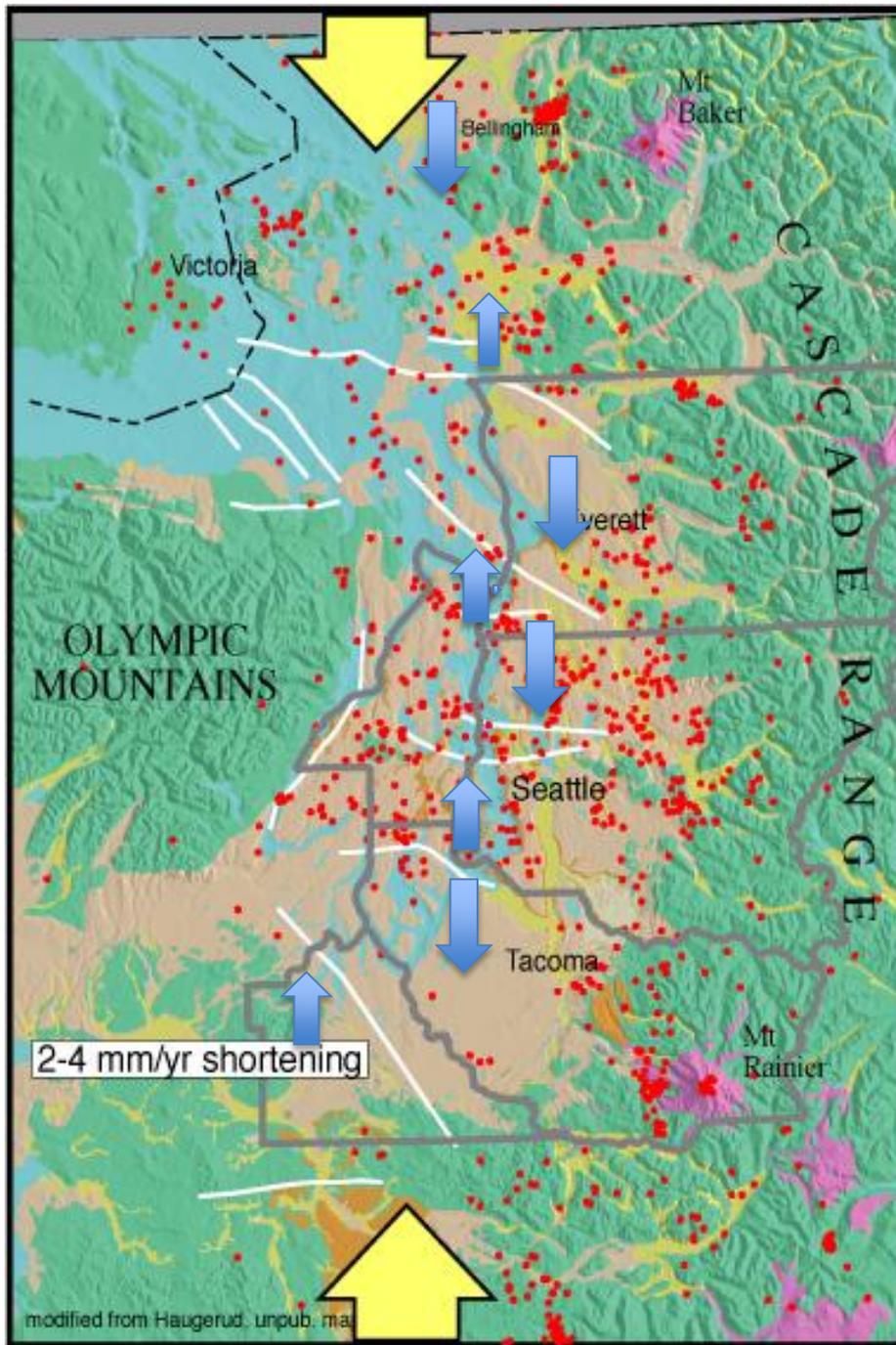
-122

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

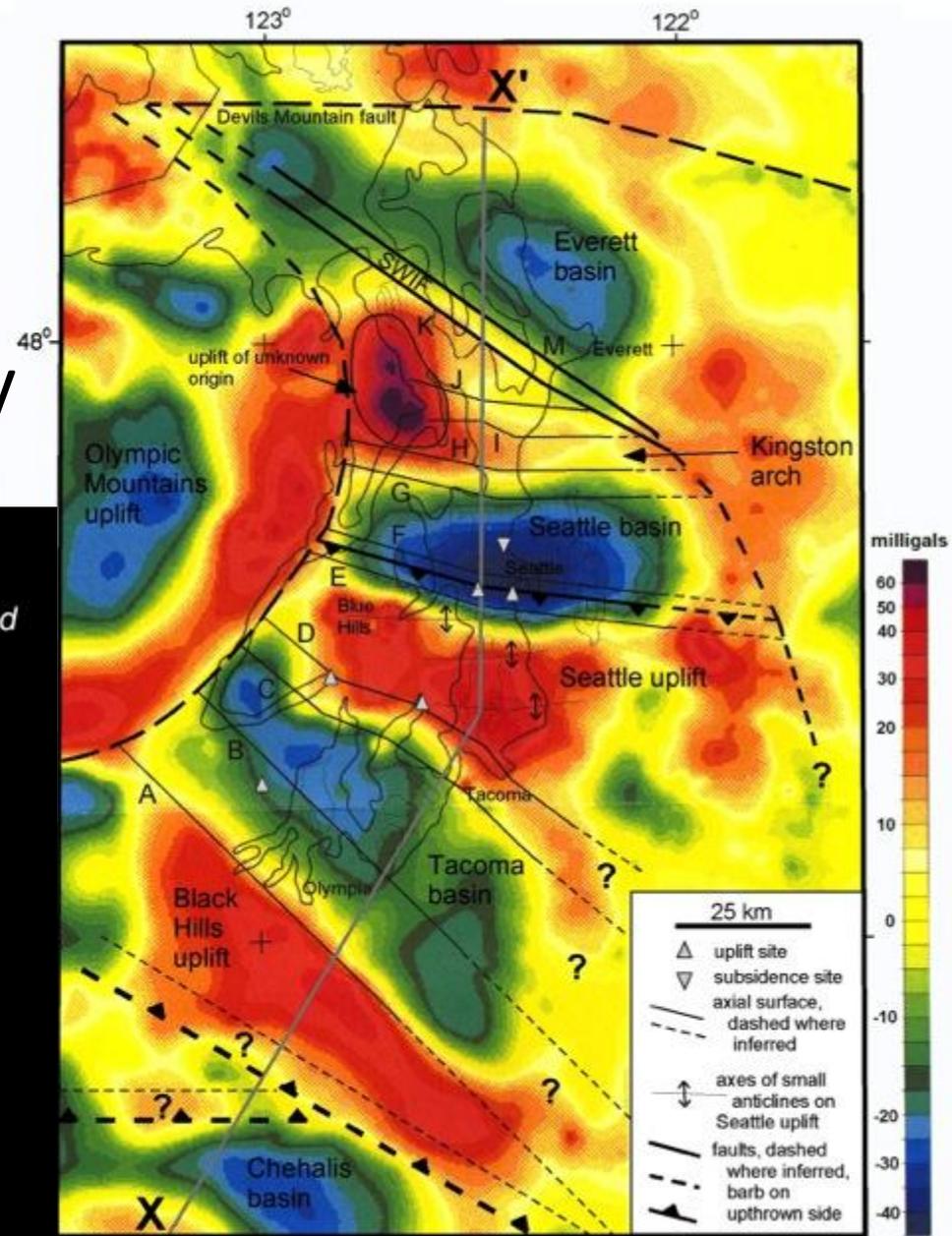
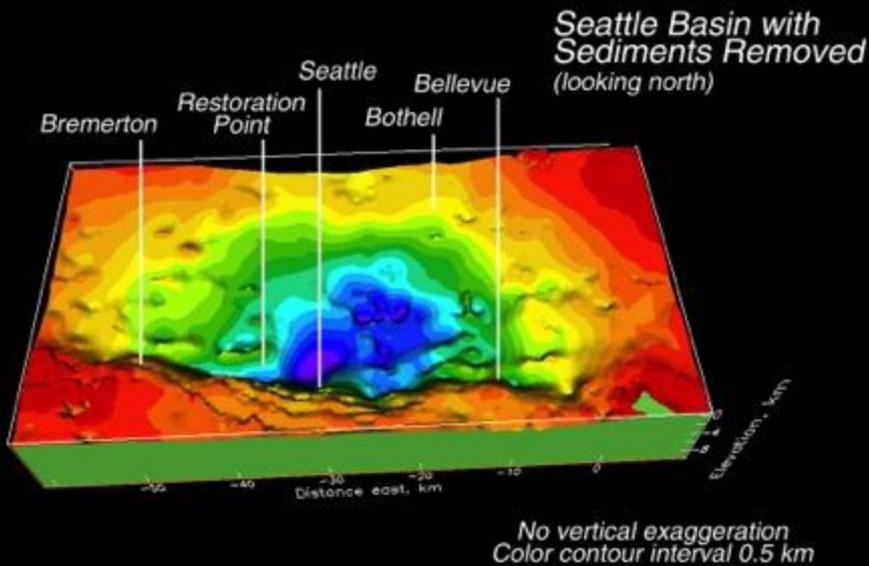


Explanation

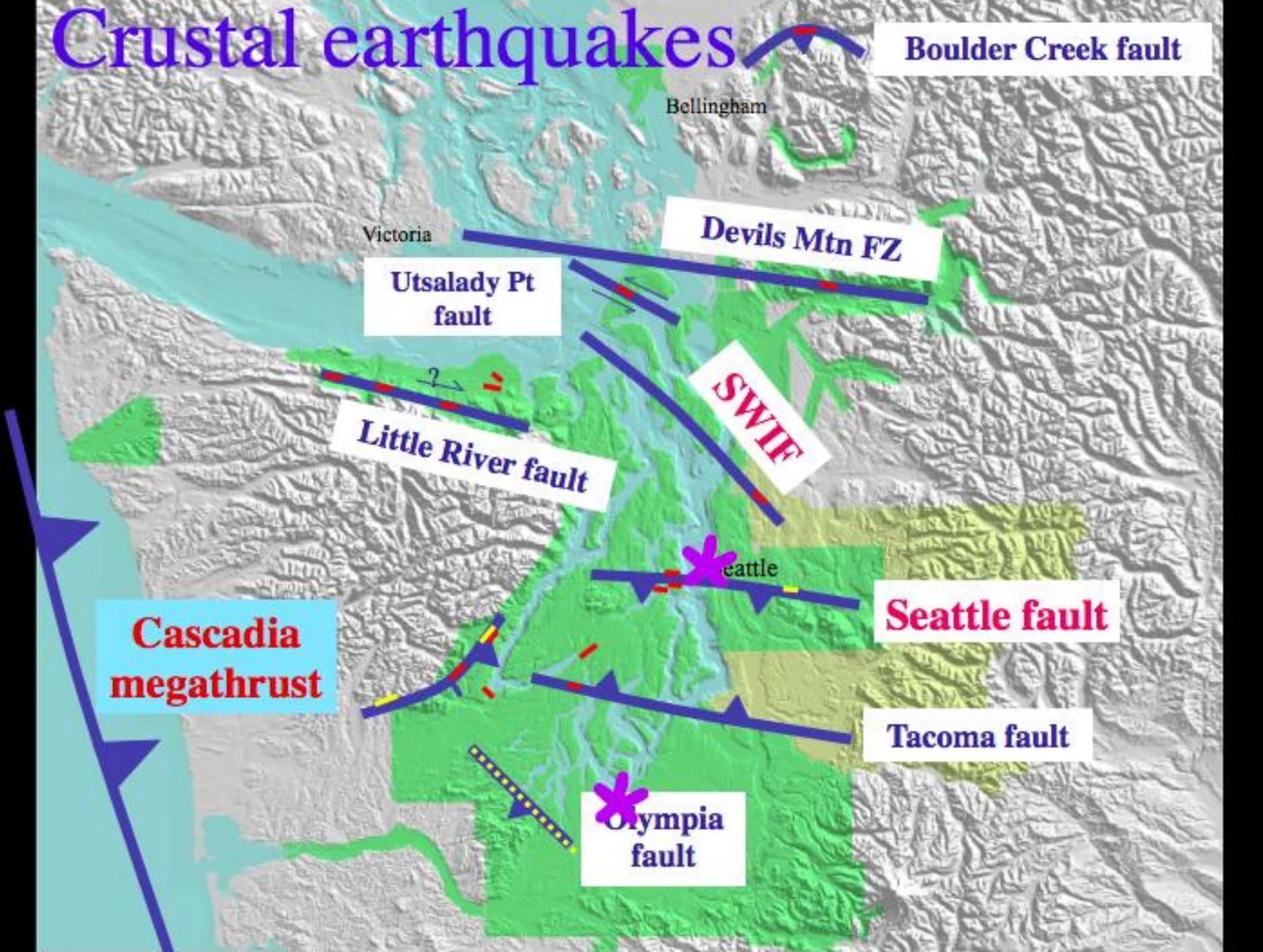
-  **Glacial deposits**
-  **Earthquakes**
-  **Crustal Faults**

Gravity measurements Reveal deep structure

Basins Trap Seismic Energy



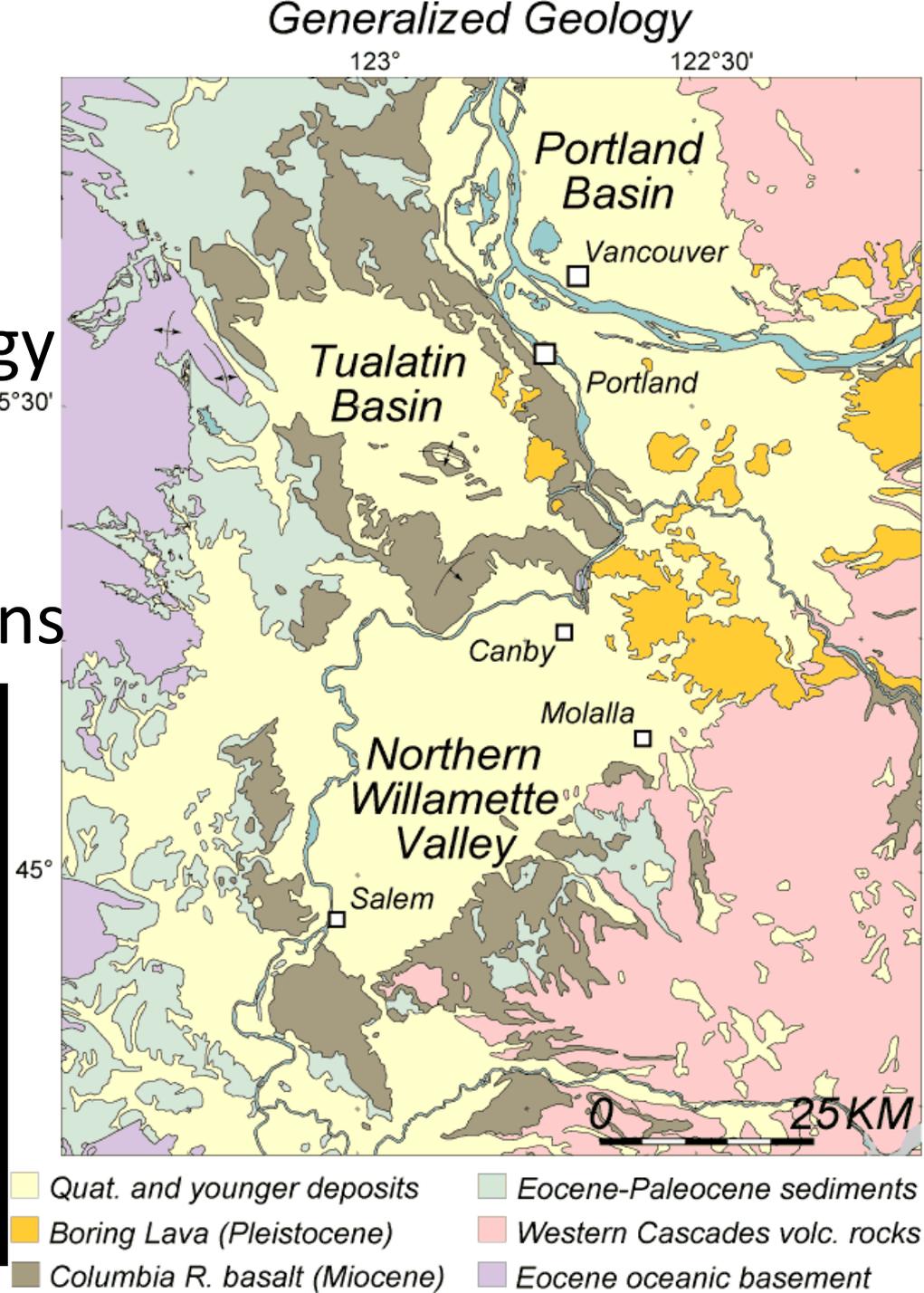
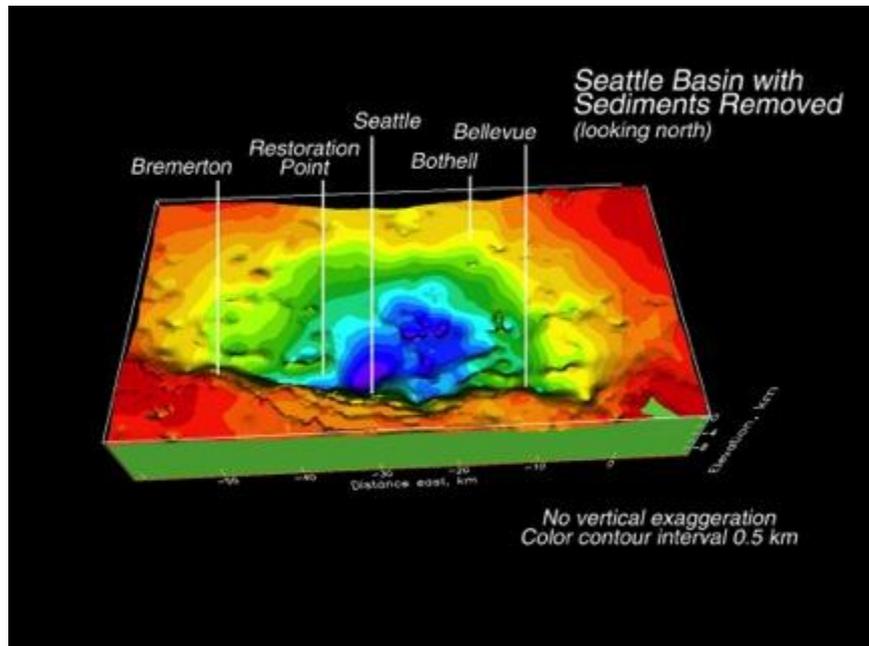
Crustal earthquakes



Gravity measurements
Reveal deep structure

Basins Trap Seismic Energy
45°30'

Longer period resonance
match CSZ ground motions

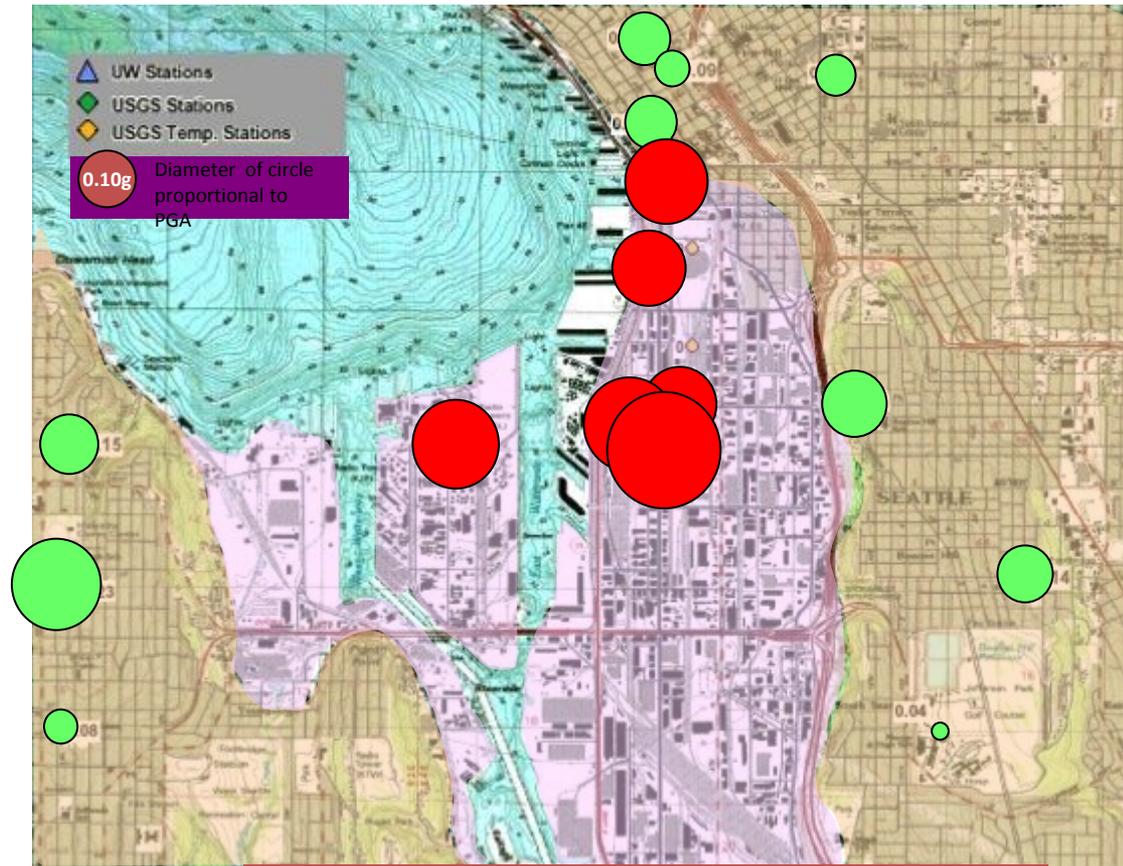


Soil Amplification during the Nisqually Earthquake

Dependant 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

Nisqually Earthquake

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

Near Port of Seattle



Olympia



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



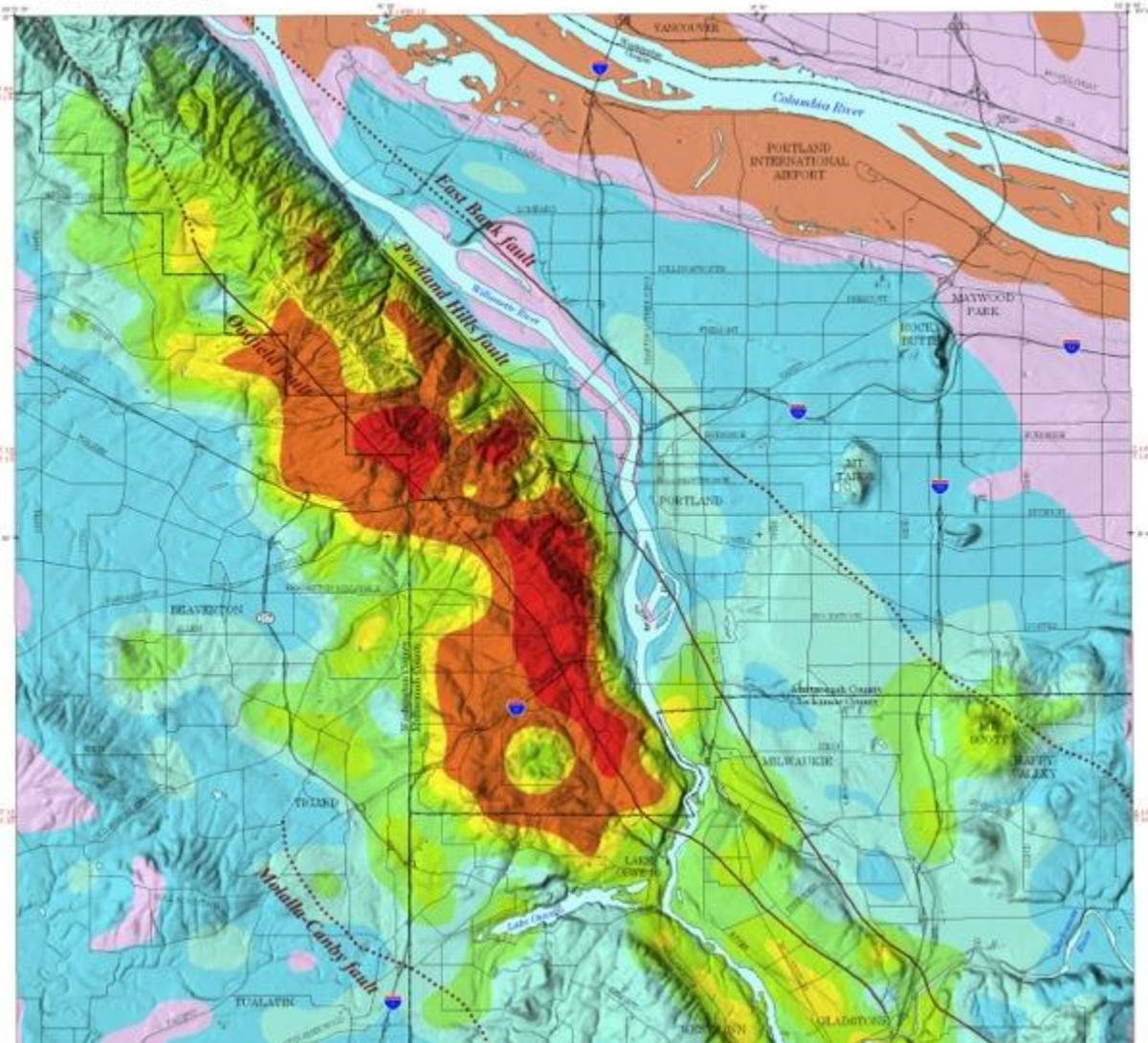
Looking NW from
Beacon Hill, Seattle



Courtesy of Prof. Steve Kramer, Univ.
of Washington

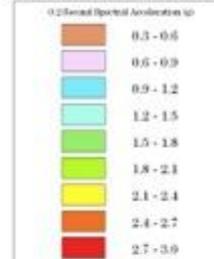
Portland Area Crustal Faults

DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
JOHN D. BRANTLEY, STATE GEOLOGIST



DAUGHTER WRIGHT, FARRIS THOMAS, TUCK GREENE,
Sylvia Li, Matthew Mahay, Anna Sajornam, and Yumei Wang

Portland Hills Fault M 6.8 Earthquake
0.2 Second Spectral Acceleration (g) at the Ground Surface



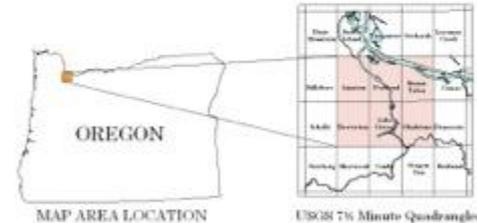
Note: The values associated with color keys vary on individual maps.

POTENTIALLY SEISMOGENIC FAULTS

- Mapped
- - - - Inferred in this study
- Inferred from seismogenic data

Data Sources: Madin, 1990; Brown et al., 1991, and Blahy et al., 1992

Note: The locations of faults as depicted on these maps may have errors of up to 500 meters or more, particularly if they are concealed or based on seismogenic data.



MAP AREA LOCATION

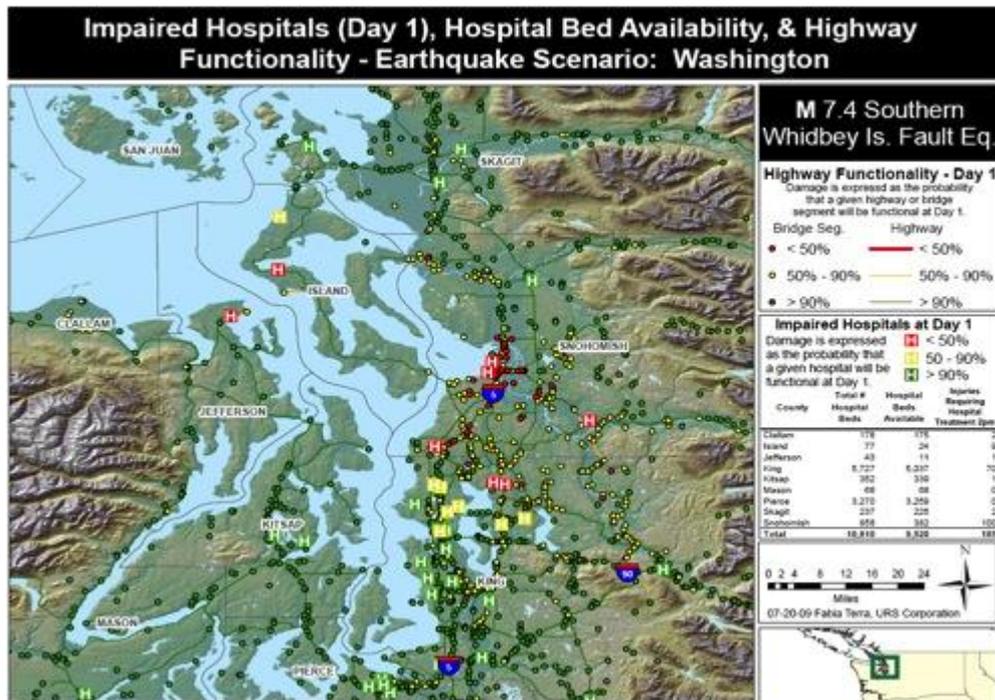
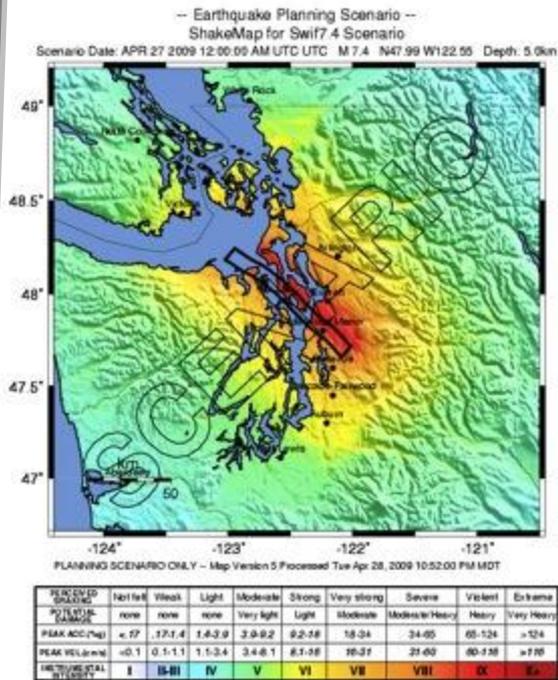
USGS 7.5 Minute Quadrangles

Limitations

There are large uncertainties associated with ground motion prediction in the Pacific Northwest due to a limited amount of region specific information and data on the characteristics of stress in sources and ground motions. In the past, the of the characteristic surface wave acceleration, the acceleration in the geometry and structural extent of the rupture are particularly large. Additional uncertainty arises from the characterization of the subsurface geology beneath Portland and the structures of the associated in-situ stress fields in ground motions. Thus, this map should not be used for site-specific design or in place of site specific hazard evaluations.

This project was a cooperative effort between USGS (Oregon) and the Oregon State Department of Geology and Mineral Industries. The project is supported by the U.S. Geological Survey under the National Earthquake Hazard Reduction Program Award 24149G00000000000000. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

Earthquake Scenario Catalog



Projected Uses:

- Mitigation Planning
- Response Planning
- Exercises & Training
- Earthquake Response

Suite of Materials Including:

- USGS ShakeMap
- HAZUS (Loss Estimation) Report
 - Statewide & 7 most impacted counties
- Community Vulnerability Report
- Variety of Quick Reference Maps

Near-Realtime PNSN Information

- Recent earthquakes

PNSN
Pacific Northwest Seismic Network

REQ2
RECENT EARTHQUAKES IN THE NORTHWEST
Beta Version

PNSN Pages REQ2 Other EQs Products

File updated: Sat Mar 20, 2010 10:02:01 PDT

Map Satellite Terrain

Control Panel

Magnitudes:

- All EQ's
- > 4.0
- 3.0 - 3.9
- 2.0 - 2.9
- 1.0 - 1.9
- < 1.0

Webcoders:

- Short-Period
- Broadband
- Volcanoes
- SMO North
- SMO Seattle
- SMO South

Plot EQ's by:

- Time
- Depth

Event Webcoders: None Selected

Reset Map

List of 16 EQ(s) on Map

Mag	Date	Time(UTC)	Depth
1.2	2010/03/18	23:50:09	18 Km
1.1	2010/03/18	20:42:33	00 Km
1.4	2010/03/18	08:29:13	06 Km
1.8	2010/03/17	19:42:10	50 Km
1.1	2010/03/17	12:31:13	44 Km
1.9	2010/03/17	01:37:09	22 Km
1.6	2010/03/15	14:00:39	20 Km
1.3	2010/03/14	03:43:21	10 Km
1.3	2010/03/13	15:02:30	26 Km
1.2	2010/03/13	08:52:20	02 Km
1.5	2010/03/12	00:42:20	18 Km
1.0	2010/03/10	06:51:59	71 Km
1.7	2010/03/08	23:48:44	12 Km
1.3	2010/03/08	09:15:55	12 Km
1.1	2010/03/07	05:20:50	05 Km
1.0	2010/03/06	22:33:59	06 Km

Legend

Magnitude: 1, 2, 3, 4, 5, 6, 7

Time:

- Last 2 Hours
- Last 2 Days
- Last 2 Weeks

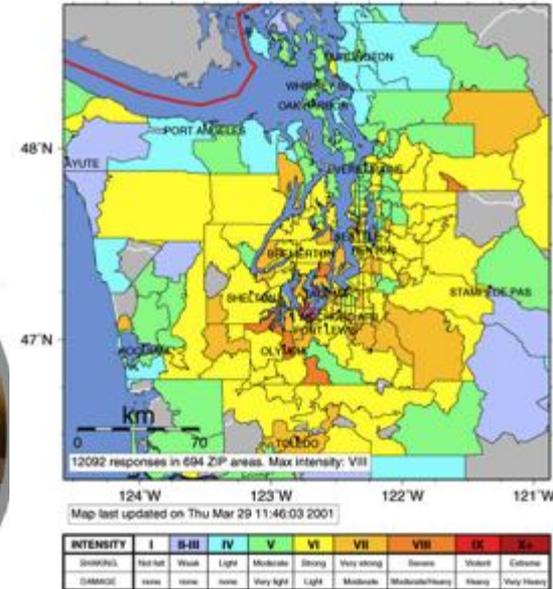
Not in PNSN Network

Webcorder



- Did you feel it?

Community Internet Intensity Map (10 miles NNE of Lacey, Washington)
ID:2281854 10:54:33 PST FEB 28 2001 Mag=6.8 Latitude=N47.15 Longitude=W122.73



http://earthquake.usgs.gov/eqcenter/ens/?page=help

USGS Earthquake Hazards Program

Earthquake Notification Service

science for a changing world

Home Earthquake Center Regional Information About Earthquakes Research & Monitoring Other Resources

You are here: Home > Earthquake Center

Latest Earthquakes

USA Earthquake Notification Service Documentation

World

- The earthquake notification service



ShakeCast 2 *beta*

[Home](#) [Earthquakes](#) [Search](#) [FAQ](#) [Profile](#) [Administration Panel](#) [Log out \[scadmin \]](#)

[Latest Earthquake](#) [Earthquake Archive](#) [Scenarios](#)

Table View

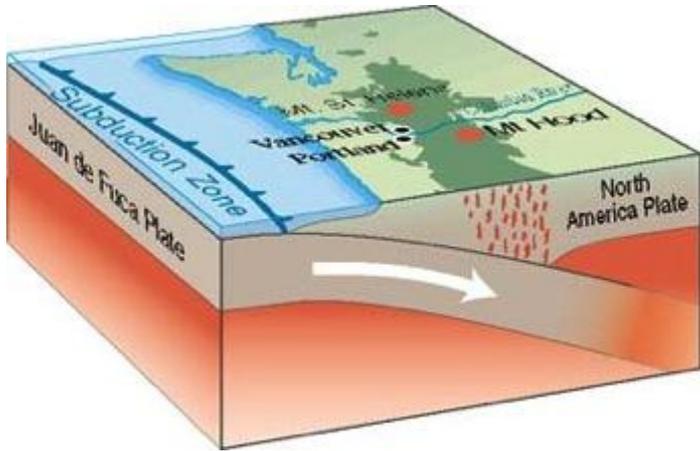
Google Maps for ShakeMap SAF_south7.8_se

Facility Type: [All](#) **BRIDGE**

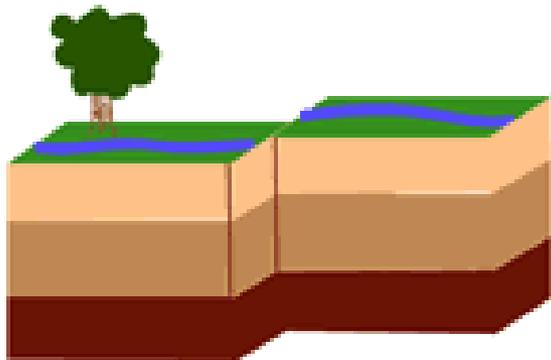


- Mission Creek BRIDGE
- Garnet Creek BRIDGE
- Garnet Creek BRIDGE
- Ramon Wash BRIDGE
- Salvia Wash BRIDGE
- Indian Ave Oc BRIDGE
- Palm Drive Oc BRIDGE
- Eden Wash BRIDGE
- Whitewater River BRIDGE
- Whitewater River BRIDGE
- Whitewater Oc BRIDGE
- 562 E 10 Connector Oc BRIDGE

Two kinds of faults along Western U.S.

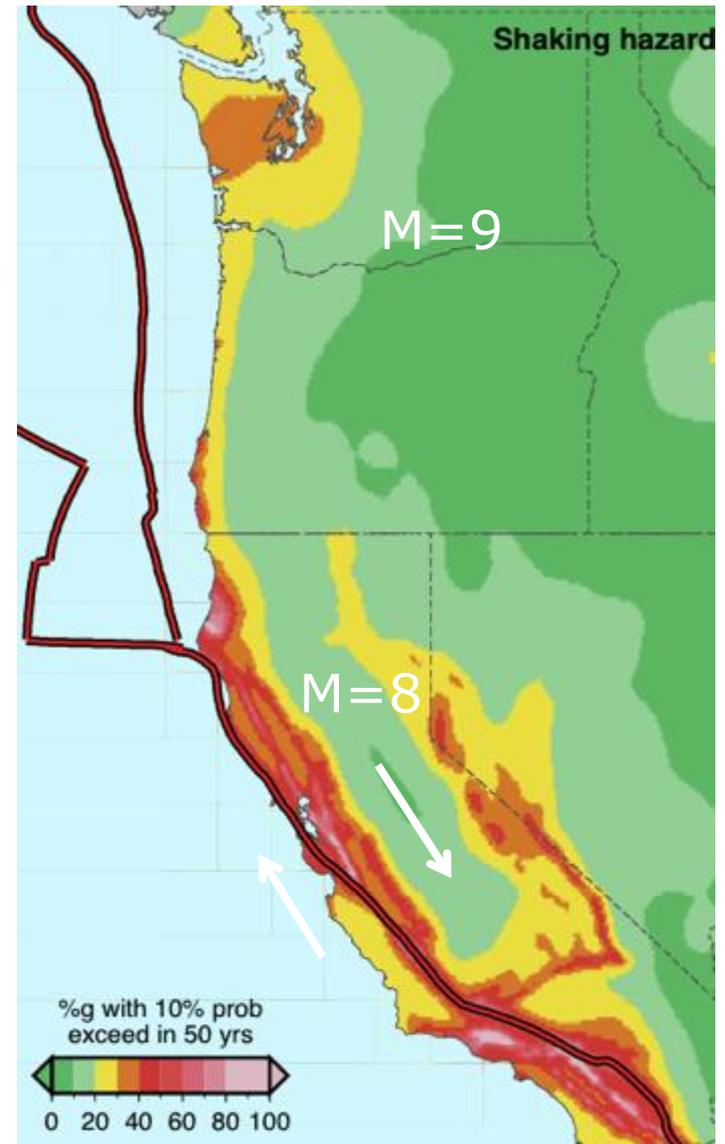


Cascadia:
Subduction

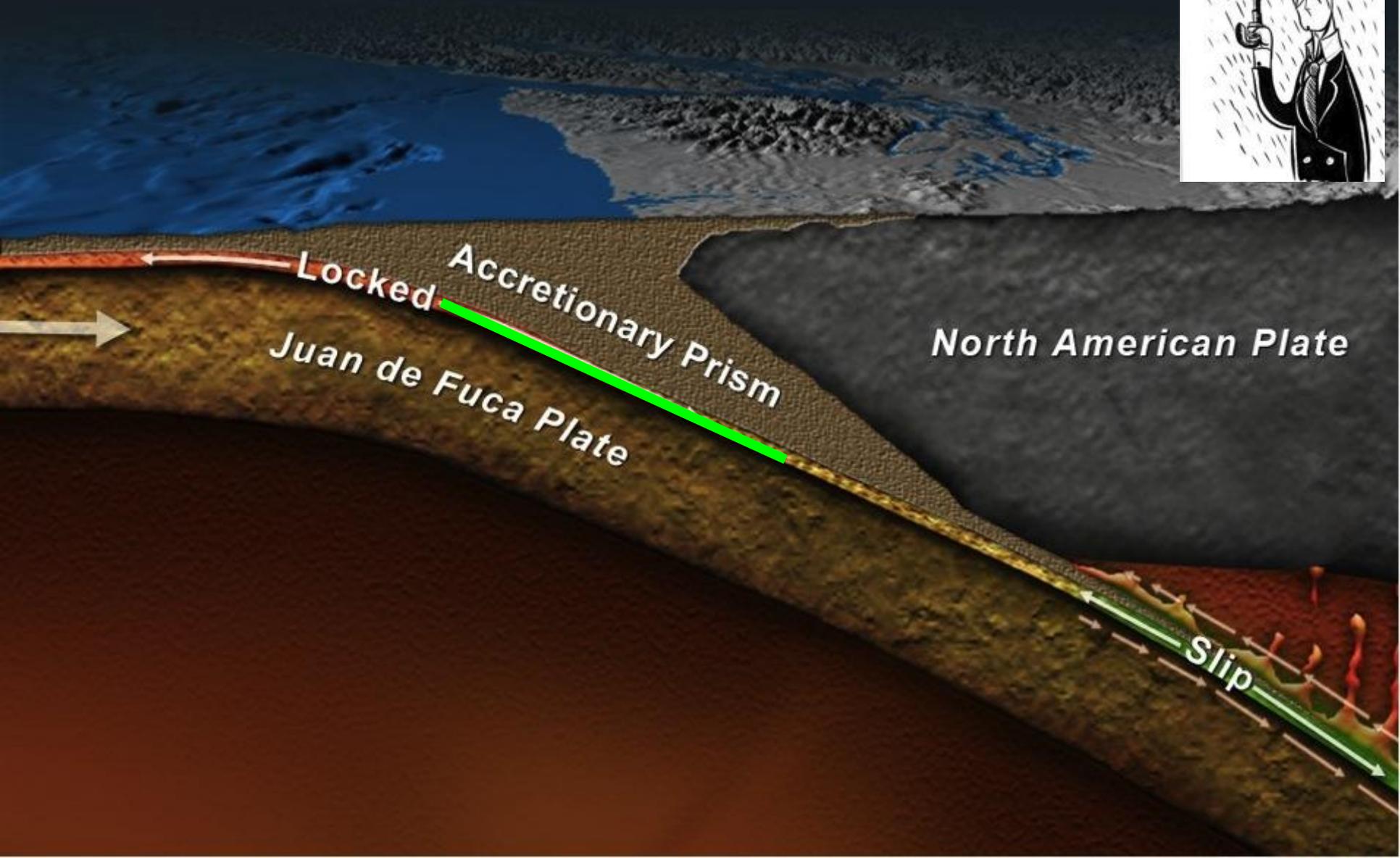


Strike-slip

San Andreas:
Strike-Slip



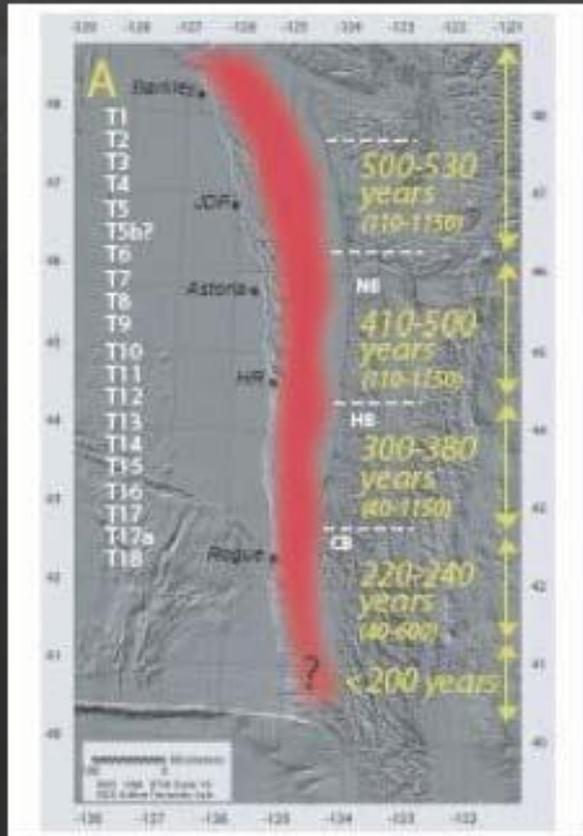
Subduction plate boundary



How often does Cascadia break?

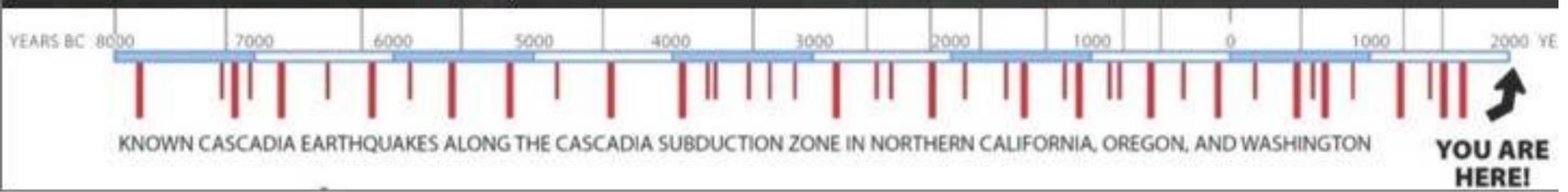
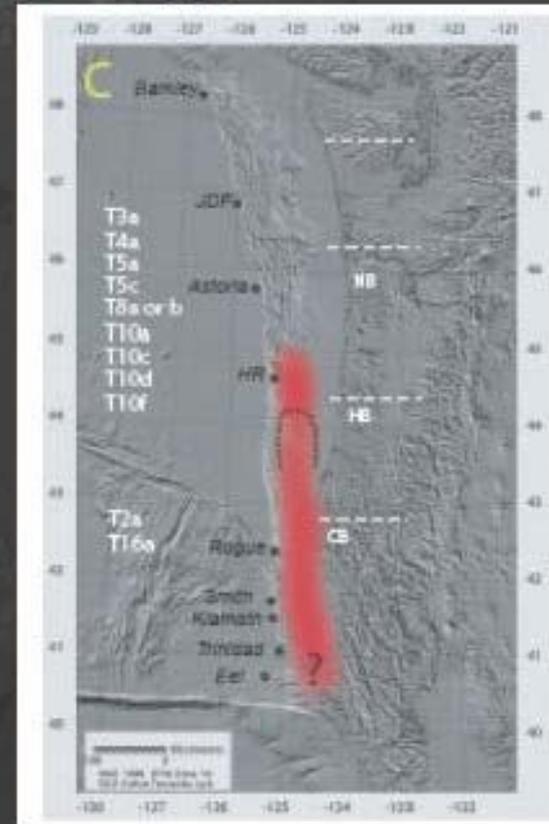
- 500-year recurrence for **M9** ruptures
- that breaks whole CSZ
- 1000-year recurrence for **M8.0-8.7**
- that only ruptures southern CSZ
- so for southern portion of Cascadia subduction zone: 340-year recurrence time for M8.0 or larger earthquakes
- How many **M6s** and **M7s**? Not clear.

Last 10,000 years of big earthquakes from offshore geology



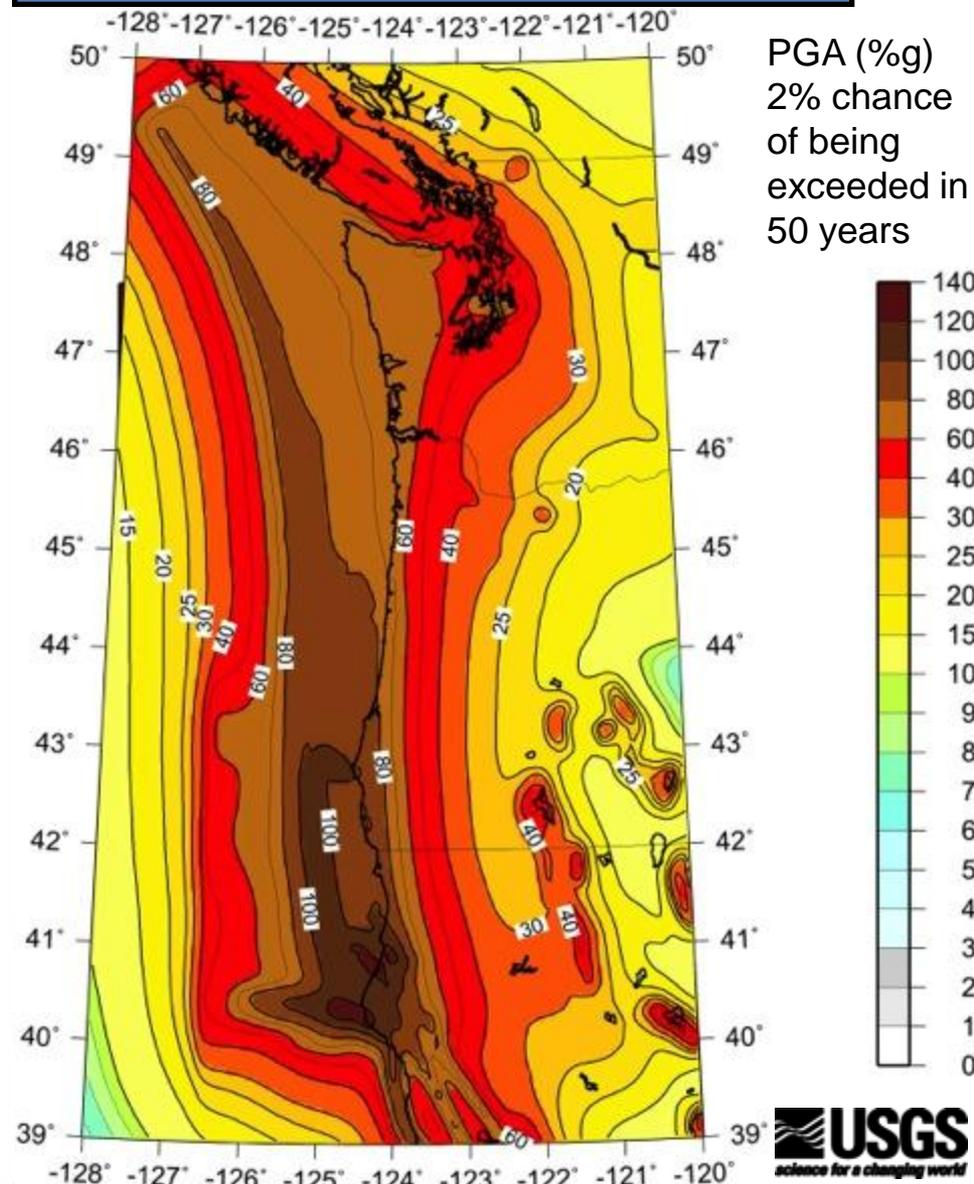
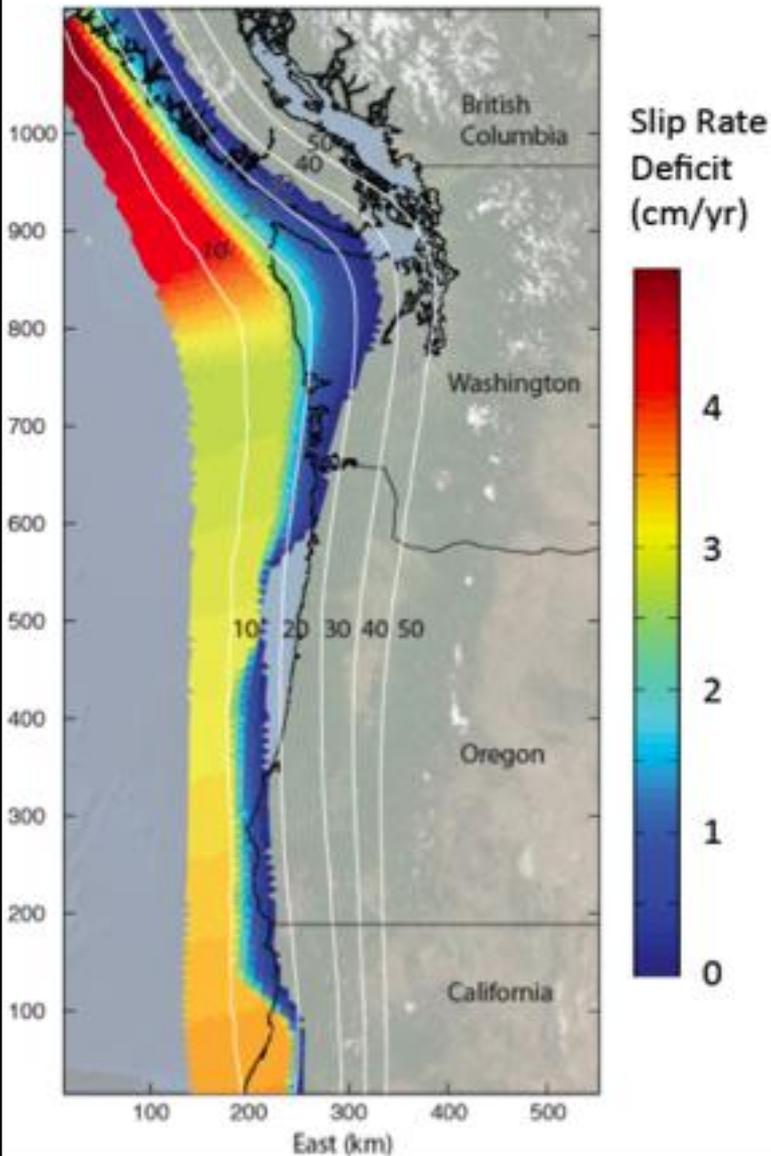
20 ~M9 events,

20 ~M8 to M8.5 events



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

Big earthquakes and their hazard



Approximate 50-year probabilities

- Today's target:
- Cascadia M9: 14%
- Southern Cascadia M8-8.5: >25-40%
- Requires denser, better instrumentation
 - Shallow Seattle Fault M \leq 6.5: 5%
 - Shallow M \leq 6.5 in entire Puget Sound area: 15%
 - Deep M \leq 6.5: 84% (from 1949, 1965, 2001)

West Coast Earthquake Early Warning System Development

- Early work by Berkeley and Cal Tech
- USGS ANSS coordination
- Moore Foundation research support
- UW focuses on the Cascadia Subduction Zone
- Development of partnerships to implement loss reduction strategies
- Explore use of I/UCRC structure to enhance system development.
- Obtain support for Federal development and management of operational system. (~5-7 year horizon)

West Coast Earthquake Early Warning System, prototype for the Nation

Earthquake early warning Around the world

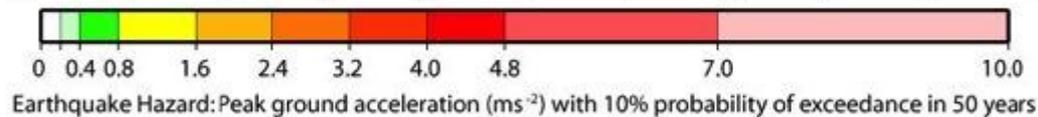
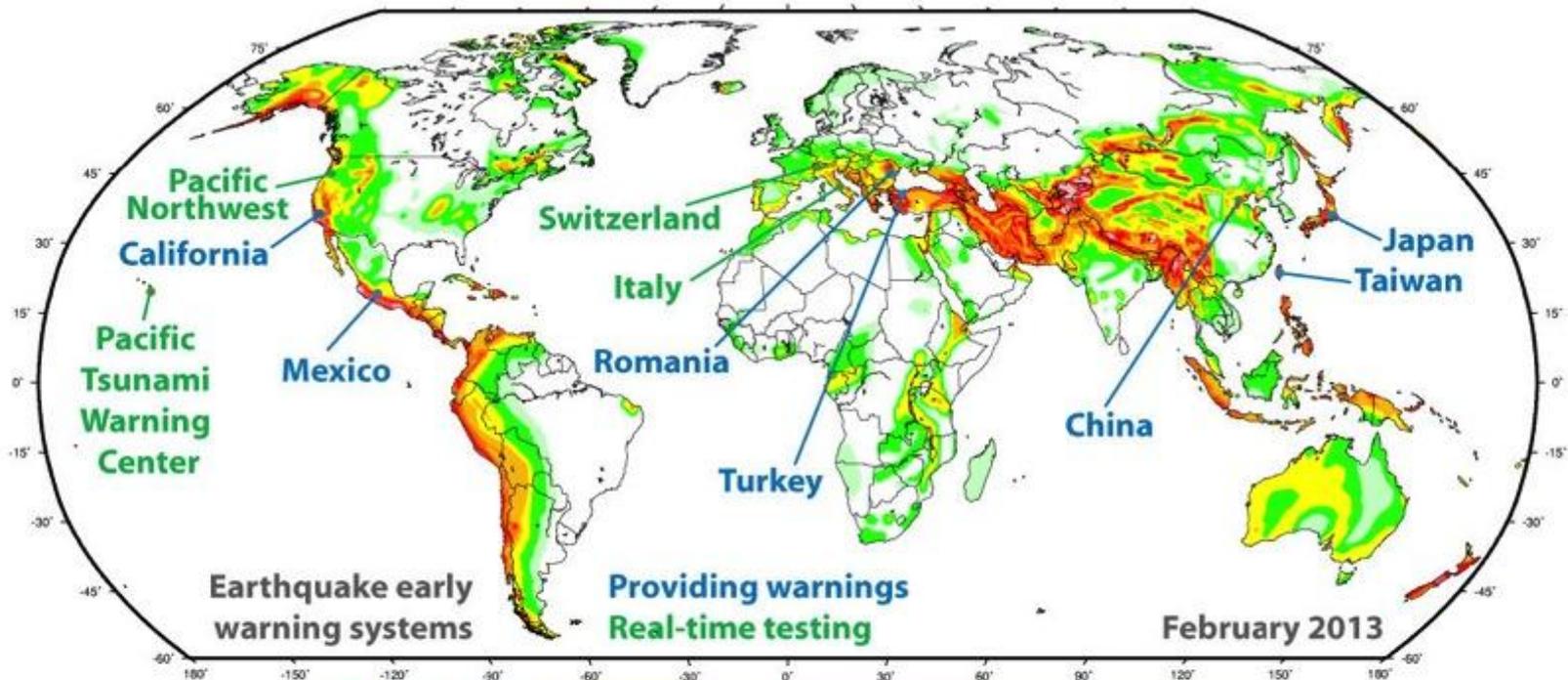
Mexico: Since 1991,
subway, schools

Turkey: rail, power grid,
expanding system, OBS

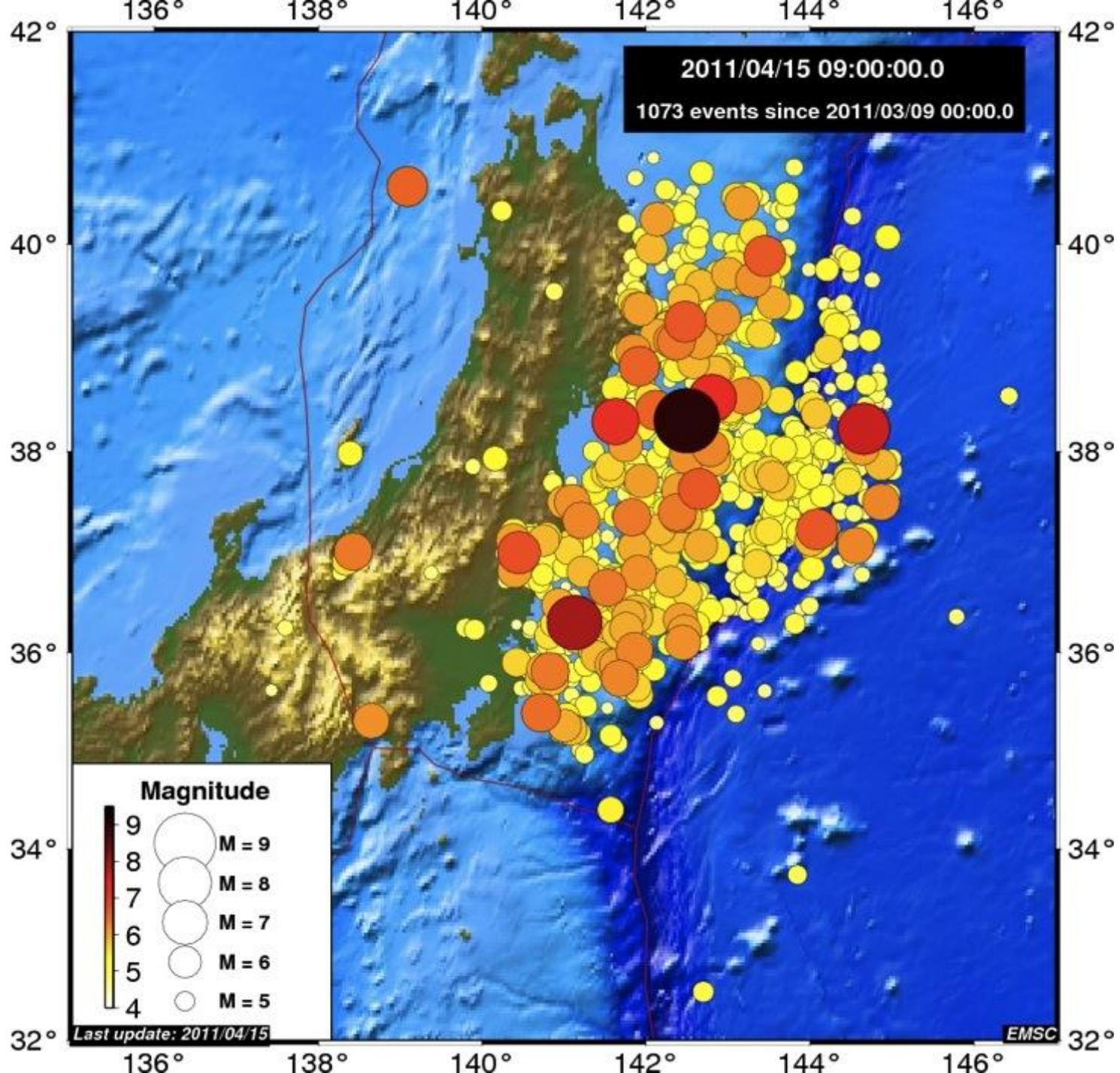
Taiwan: Railroad,
hospital, new networks

Romania:
Nuclear research facility

China: multiple regional
systems, Twitter release



“Early Warning” documentary by Mahesh Punyamurthula





Japan

Communicating the warning

TV and radio announcements

- 124 of 127 TV stations (98%)
- 41 AM, 35 FM radio (75%)

J-Alert messages

- 226 municipalities receive the warnings
- 102 announce them with public address systems

Cell phones

- 3 companies (Docomo, AU, Softbank)
- 52 million can receive them (47%)

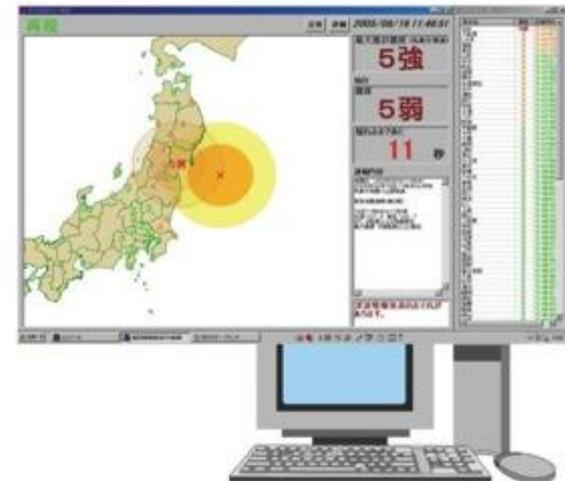
Dedicated providers serve

- power plants
- factories
- schools
- hospitals
- shopping malls



earthquake location and hazard

estimated shaking in your area



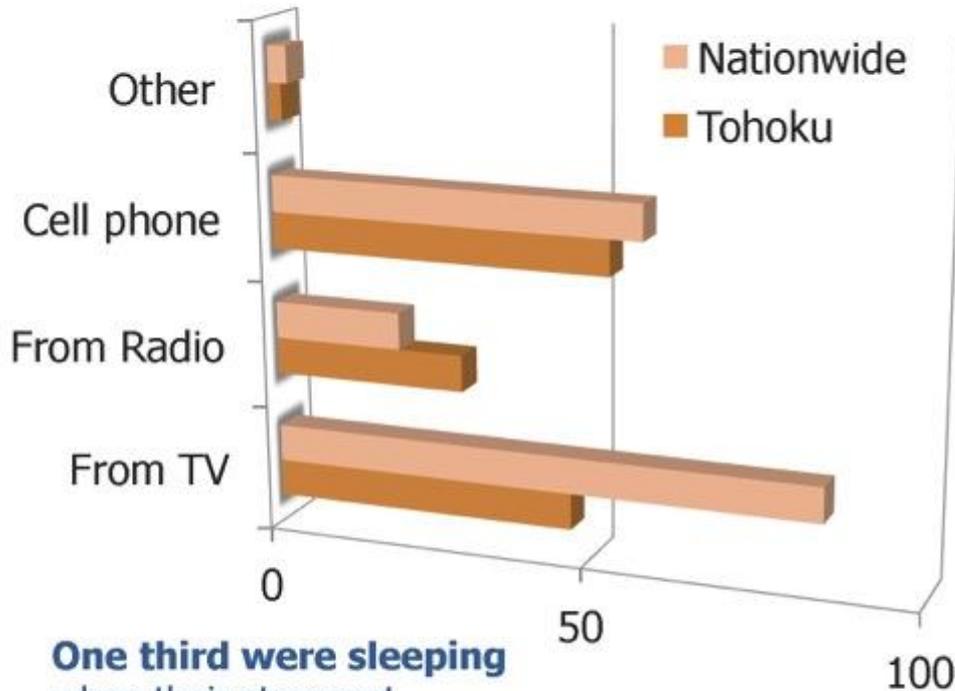
A photograph of three young children in a crowd, looking concerned. The child in the center is wearing a light blue vest with red and white polka dots over a red long-sleeved shirt. The child on the left is wearing a dark jacket with a white collar. The child on the right is wearing a dark jacket. The background is blurred, showing other people in a public setting.

Earthquake Warning

Earthquake Early Warning
Saved Lives

JMA Survey of the Public

How have you received warnings?



One third were sleeping

when their strongest earthquake occurred

Of those sleeping

62% in the Tohoku region, and **75% nationwide** were

woken by cell phone warning

Most useful cell phone app

1. Email 58%
2. **Earthquake alerts 25%**
3. TV 23%
4. Twitter, Blog 17%
5. Transportation info 11%

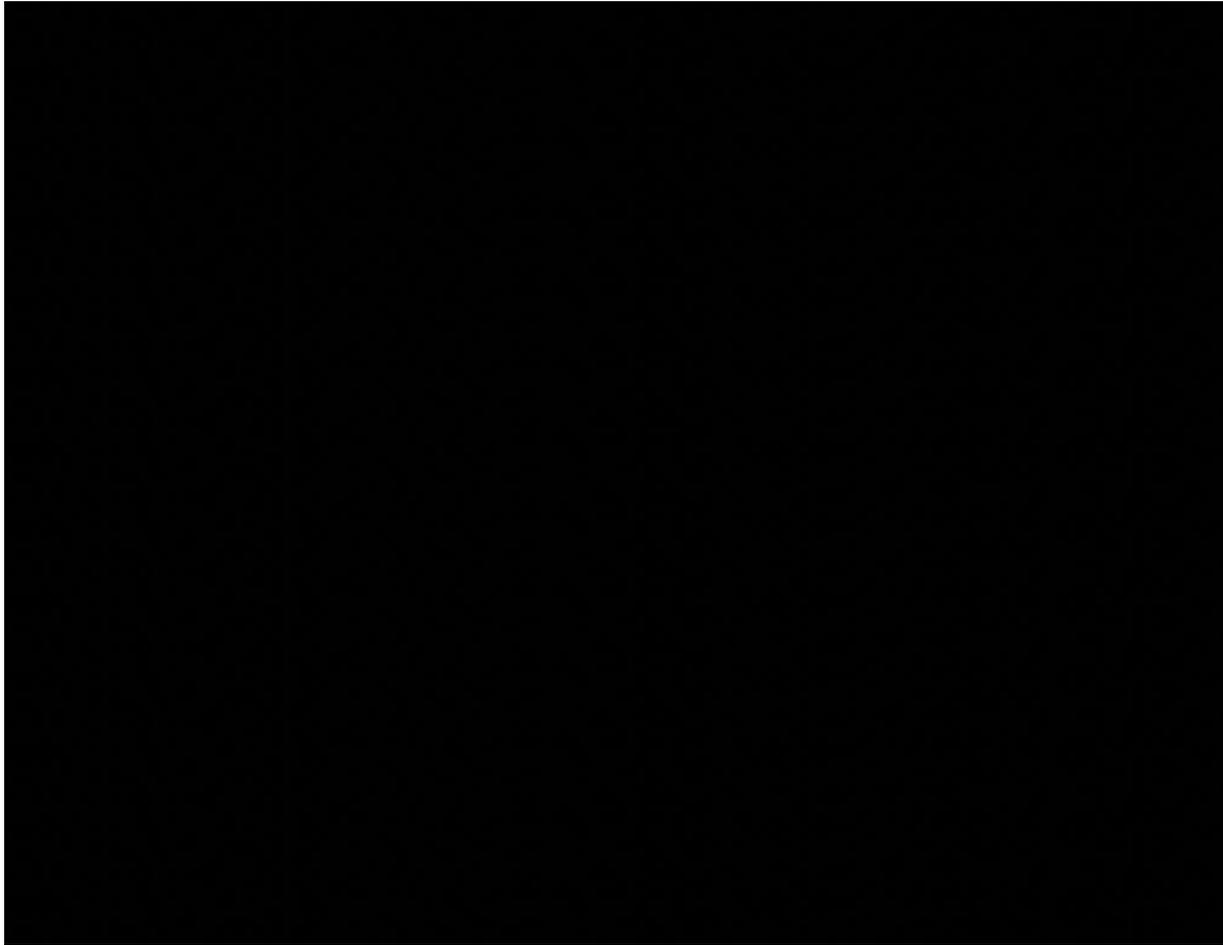
Asahi Shinbun Newspaper – June 2011



Data provided by Hoshiba

<http://www.jma.go.jp/jma/press/1203/22c/manzokudo201203.html>

Earthquake Early Warning: Loma Prieta



California leads in implementation, UW will deploy within a year.



“At Caltech this morning, announcing my introduction of a bill to create an earthquake Early Warning System in California. An early warning system could help save lives by providing a warning up to 60 seconds in advance before the shaking starts.” California Senator Alex Padilla

Cascadian Capabilities

- **Megathrust Earthquakes**
 - 1/2 minute to 4 minutes warning to urban centers (depending on quake starting point and location).
 - Can forecast chance of M7+ growing to M9.
 - Enhanced tsunami forecasts possible (w/ NOAA).
- **Other Earthquakes (crustal, deep)**
 - Seconds to up to a minute of warning.
 - “Blind Zones” currently limit usefulness of proximate warnings.
 - Requires denser instrumentation.

Developing EEW Partnerships

February workshop reveals strong public and private sector interest.

Diverse group of organizations targeted for follow-up meetings.

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 ie, provide feedback and attend quarterly affiliates meetings.
- Help with cost benefit analysis
- Help us communicate usefulness to government



Invited to join PNSN Affiliates

Microsoft

Port of Seattle

Boeing, (signed agreement)

Sound Transit

British Petroleum/ Olympic Pipeline

Puget Sound Energy

Intel

Bonneville Power Administration

City of Seattle

Providence Medical Foundations

Washington State Emergency Management



Next Steps:

- Establish PNSN Research Affiliates: Identify a small, diverse group companies and agencies to participate In system development and testing and to provide feedback
- Hold Workshop with California and PNW affiliates and the National Science Foundation to explore the establishment of a I/UCRC (Industry/ University Cooperative Research Center.
- Quarterly Affiliates meetings this year as demonstration warning system is rolled out.
- Partner agreement, on use of this “experimental system”

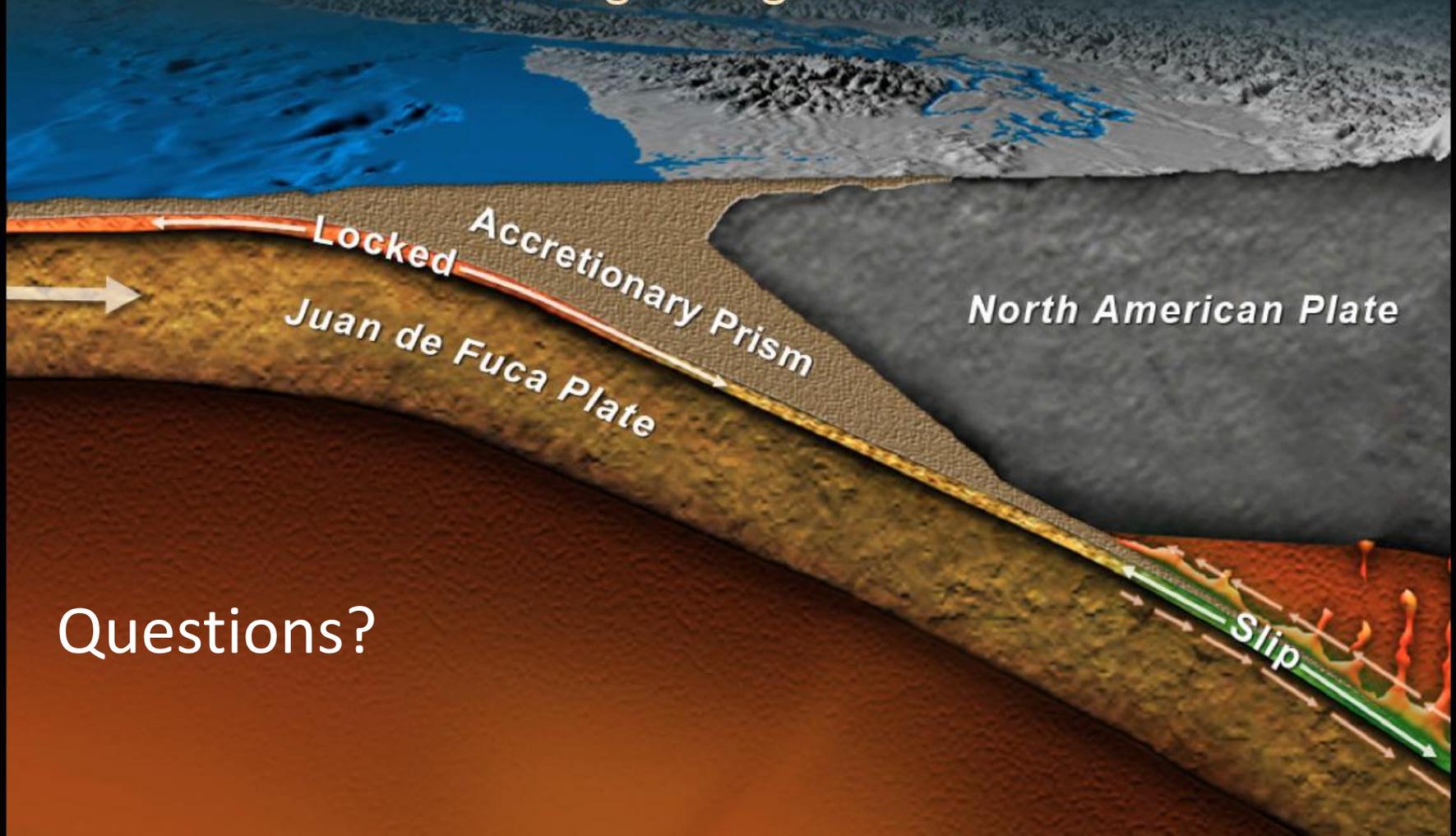


PNW System Roll out:

- Fall 2013 PNSN ShakeAlert messaging for $> M 3$ eqs
- Spring 2014, CSZ earthquake alerts integrating real-time GPS Data



Locked section of Cascadia subduction zone starts breaking allows warning of strong shaking at large distances



Questions?