



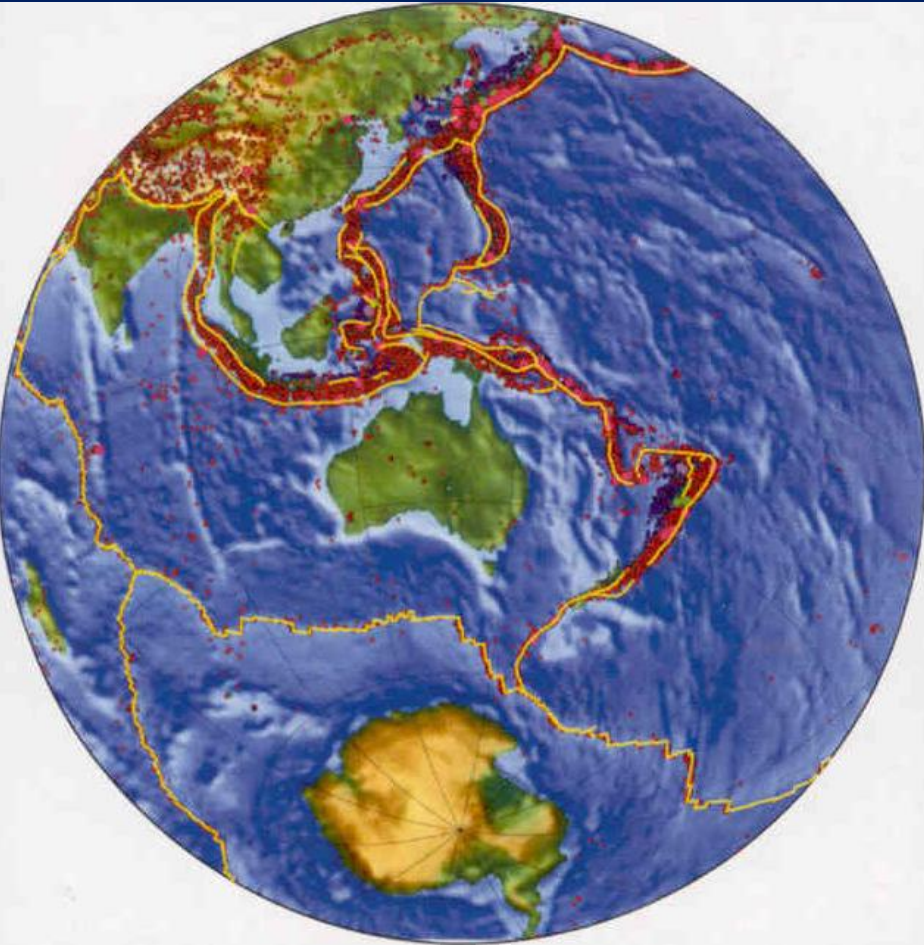
Pacific Northwest Seismicity

Tim Collins, P.E., G.E
Senior Engineer
Portland Water Bureau
May 8, 2013



Introduction – Plate Tectonics

95% of earthquakes occur along the edges of the interacting plates



Source:

http://www.google.com/url?sa=t&source=web&ct=res&cd=1&ved=0CBEQFjAA&url=http%3A%2F%2Fwww.eeri.org%2Ffile%2Fclearin%2Fsumatra_tsunami%2Fpresentation%2FTsunami_FINAL_4-19-05_novideo_website.ppt&ei=ZsWaS_HSJ5OysgPe1sWdAg&usq=AFQjCNFkoW2w14KrfRS4IPGW4I5tCSCpjpg :
from **Earthquakes** by Bruce A. Bolt

Earthquake Magnitudes

- Richter Scale (Charles Richter, 1934), M_L
 - Logarithmic
 - Based on actual seismic record
- Mercalli Scale (Giuseppe Mercalli, 1902)
 - Observation scale based on witness accounts and building damage
 - Not considered scientific
- Moment Magnitude, M_W
 - Based on earthquake geometry, area of rupture \times fault offset



Earthquake Frequency

Magnitude	Earthquake Effects	Estimated Number Each Year
2.5 or less	Usually not felt, but can be recorded by seismograph.	900,000
2.5 to 5.4	Often felt, but only causes minor damage.	30,000
5.5 to 6.0	Slight damage to buildings and other structures.	500
6.1 to 6.9	May cause a lot of damage in very populated areas.	100
7.0 to 7.9	Major earthquake. Serious damage.	20
8.0 or greater	Great earthquake. Can totally destroy communities near the epicenter.	One every 5 to 10 years



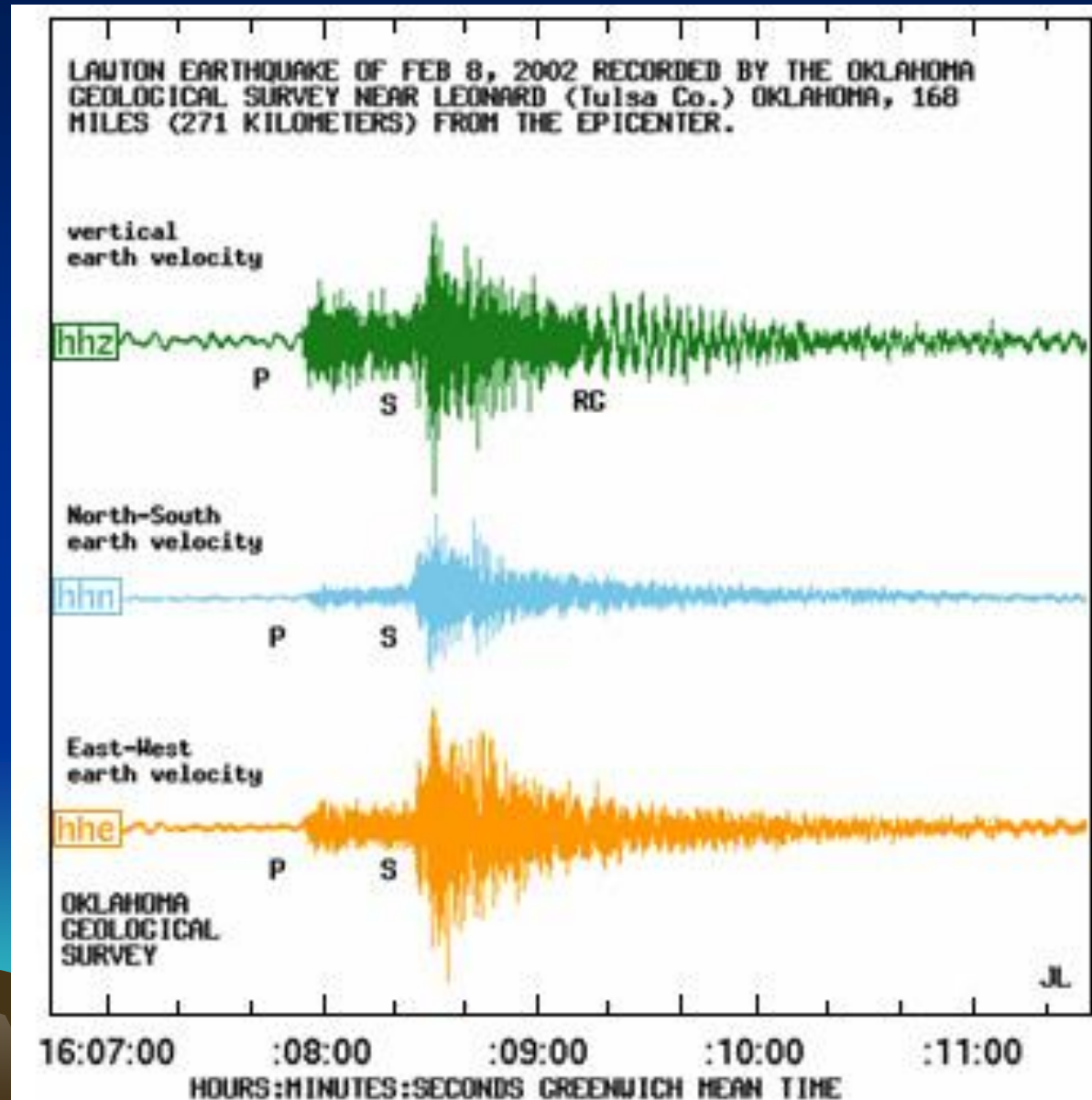
Earthquake Movements

- Primary, P-waves
 - Compressional
 - Think sound waves
- Secondary, S-waves
 - Shear waves
 - Think Jello
- Surface, Raleigh waves
 - Rolling waves
 - Like at the beach

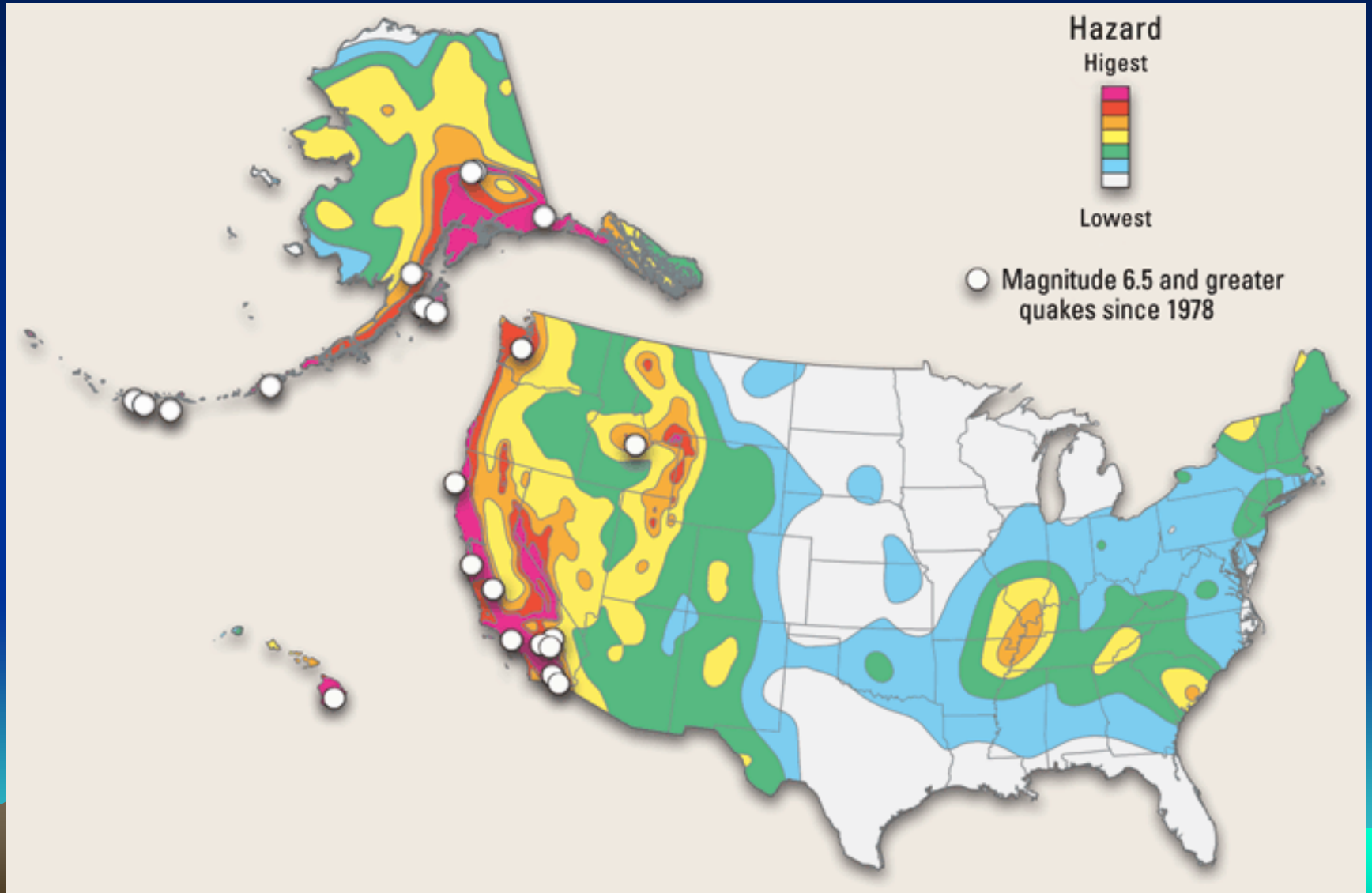


Earthquake Time History

- Showing different wave types



USA Earthquake Hazards



Northwest Seismic Sources

- Crustal, Shallow
 - Kobe, Christchurch, Northridge
- Intracrustal, Benioff
 - Olympia
- Intercrustal, Subduction
 - Sumatra, Chile, Japan



Juan de Fuca Plate Details

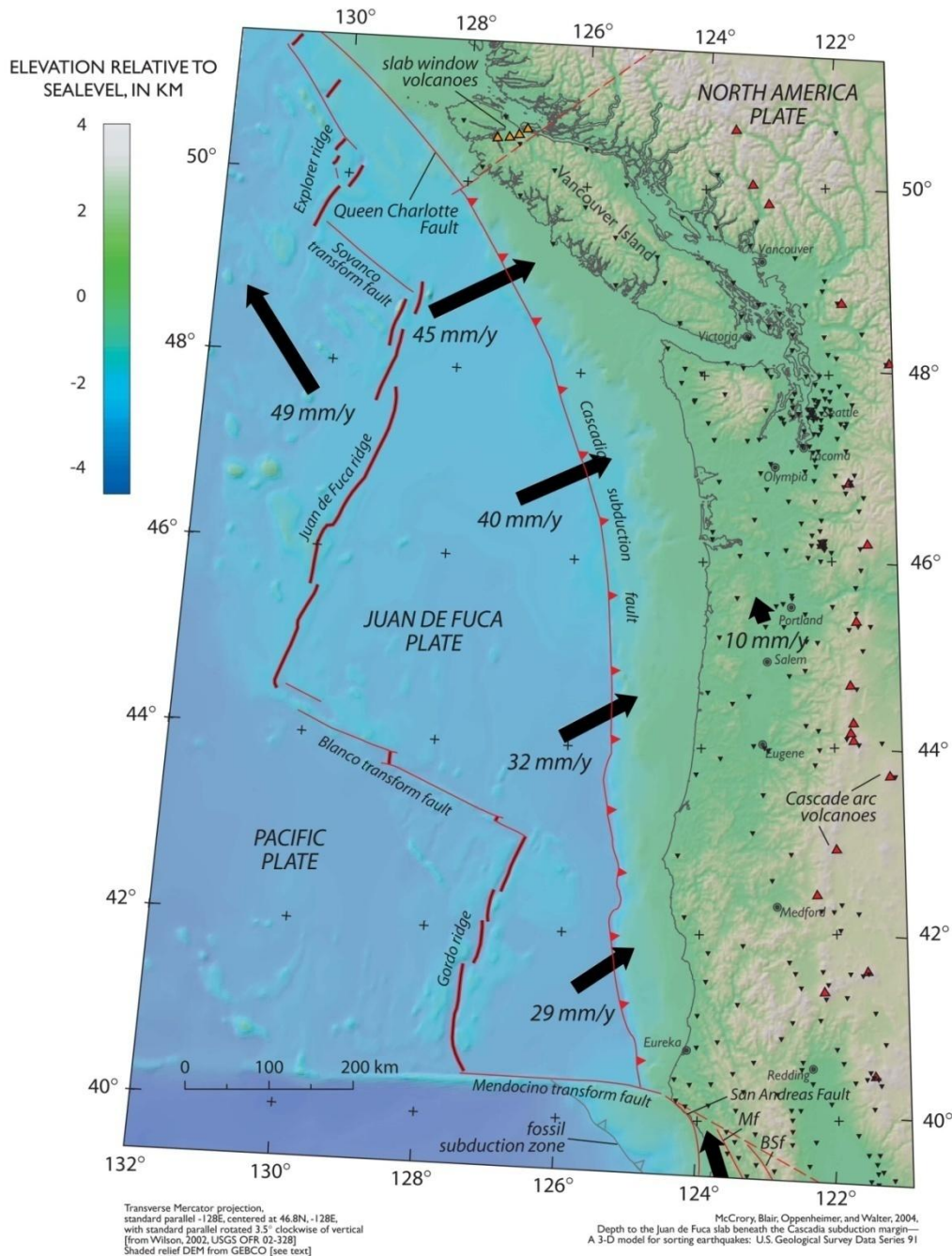


FIGURE I

North American Plate Dynamics

- In PNW, plate is bending around a fixed point near Penticton, British Columbia.

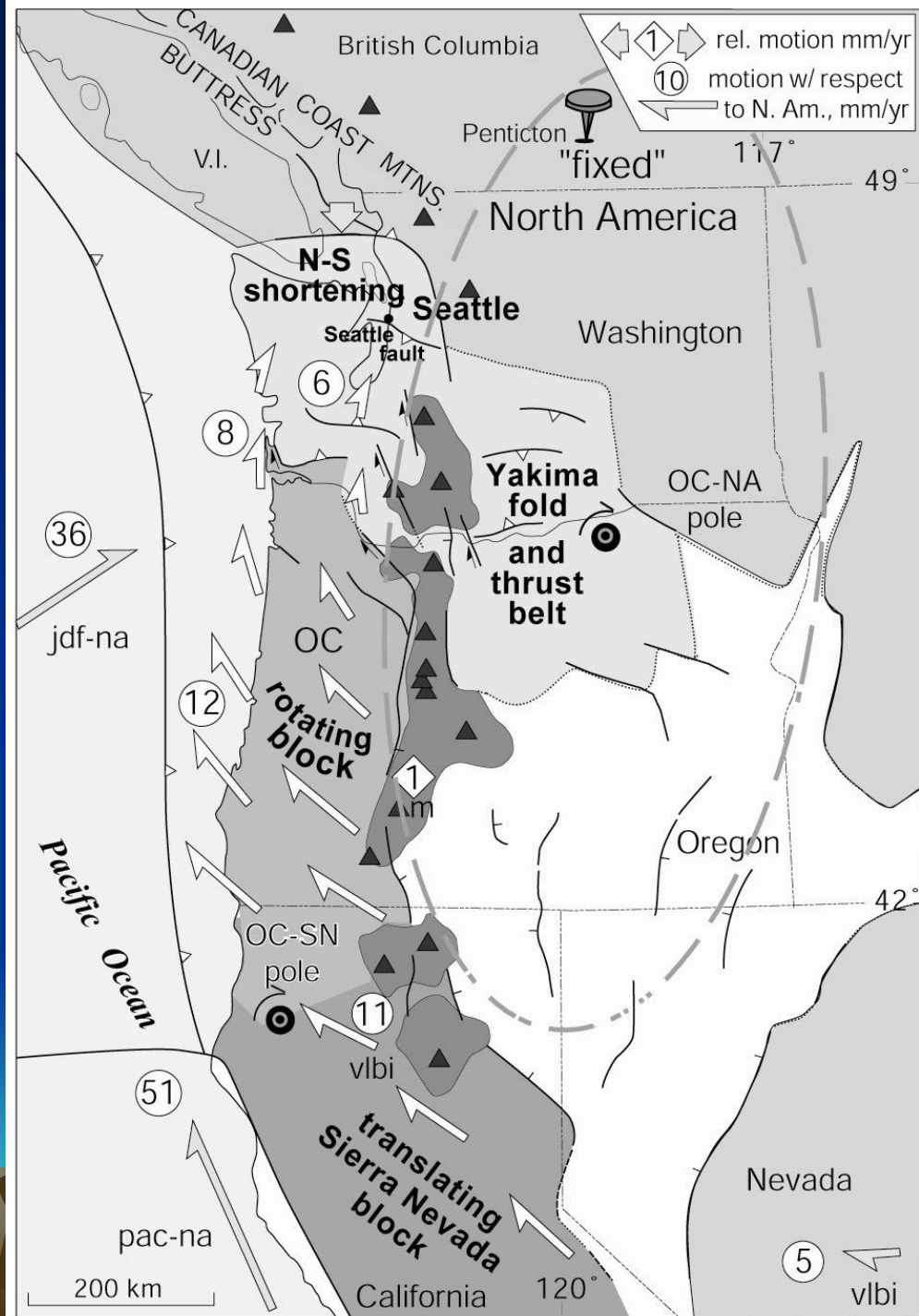
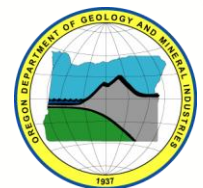
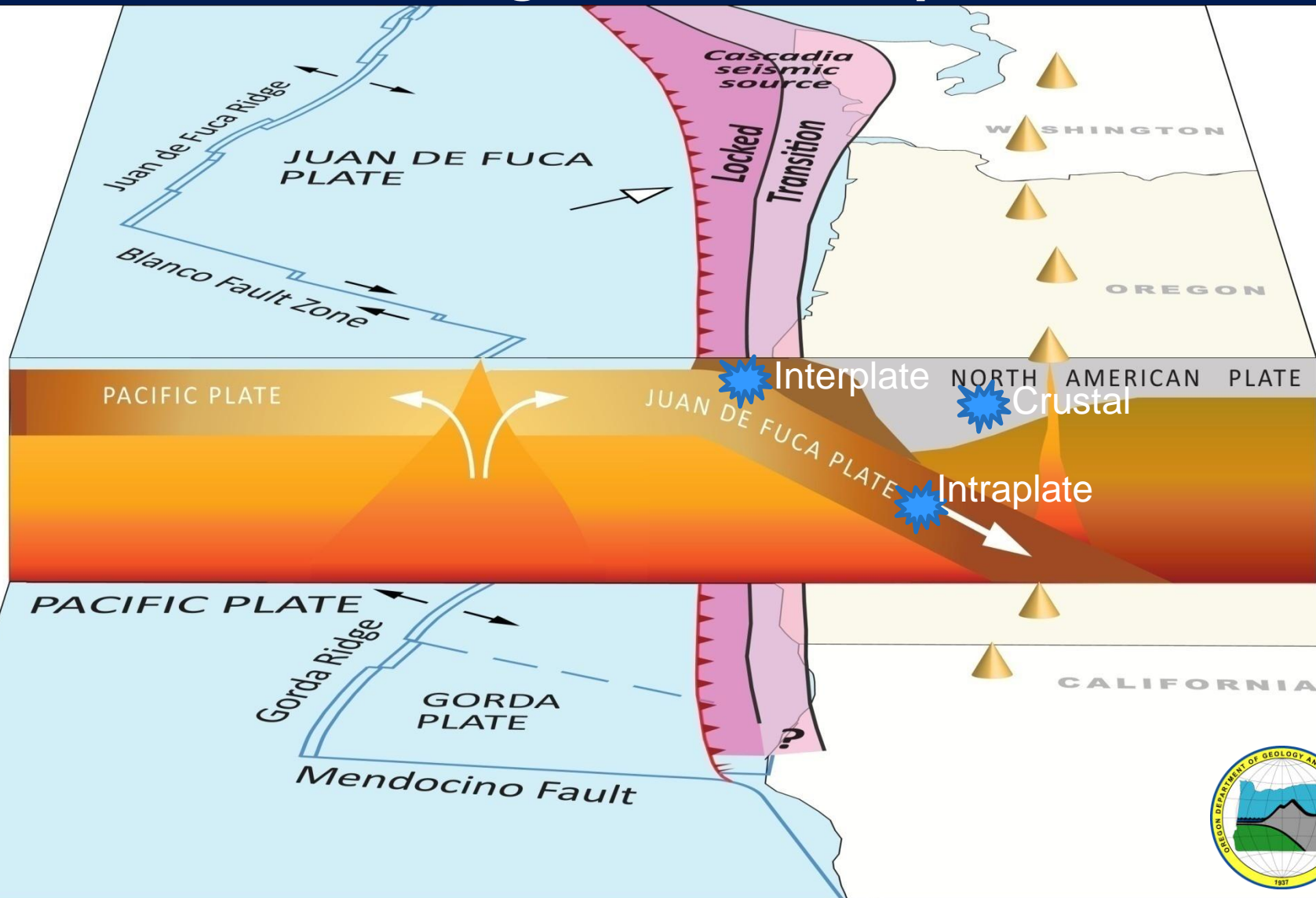
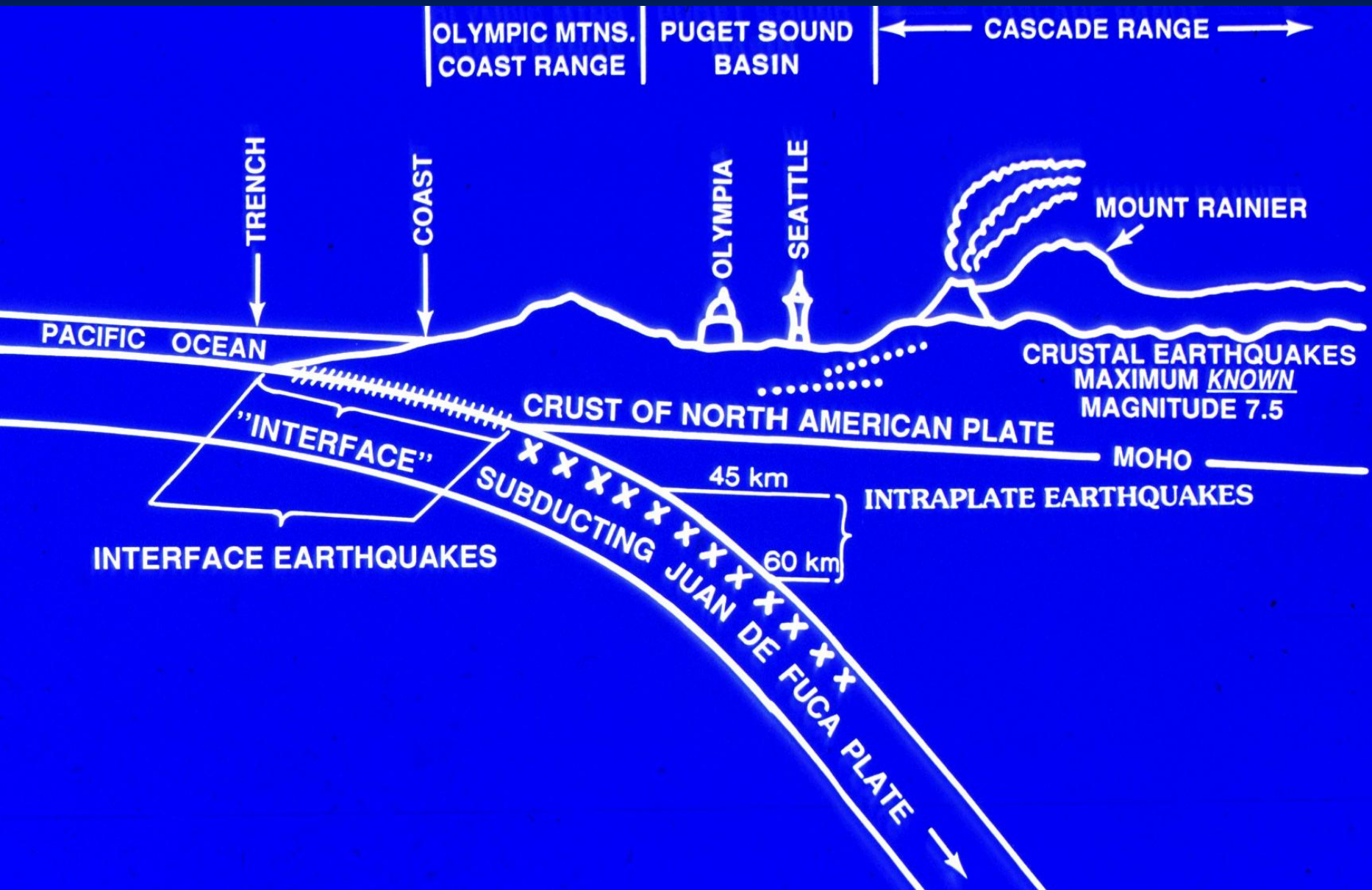


Plate Tectonic Map of the Pacific Northwest – the “Cascadia” Region – 3 Earthquake Sources



Sketch of Earthquake Sources

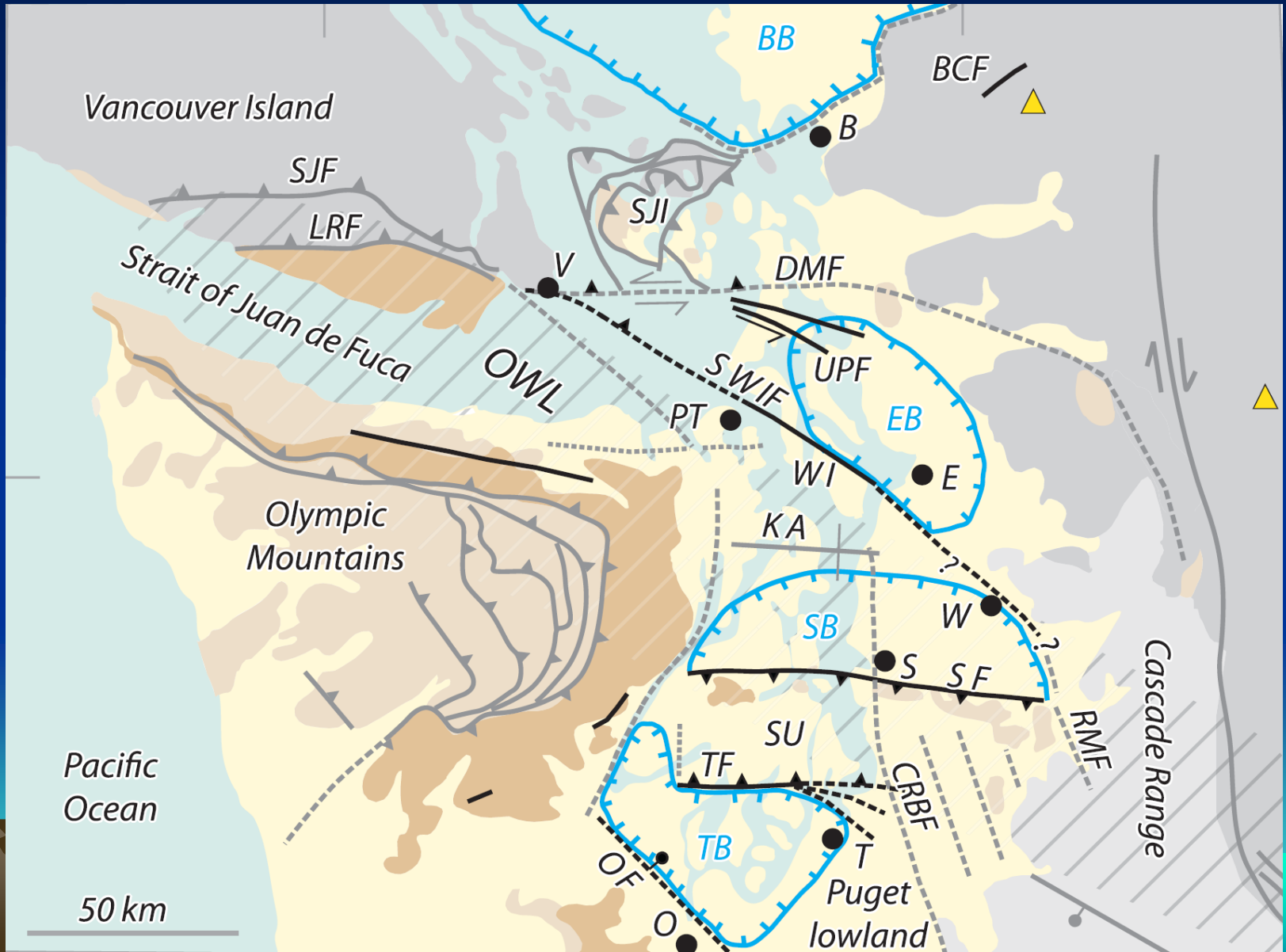


Crustal Earthquakes

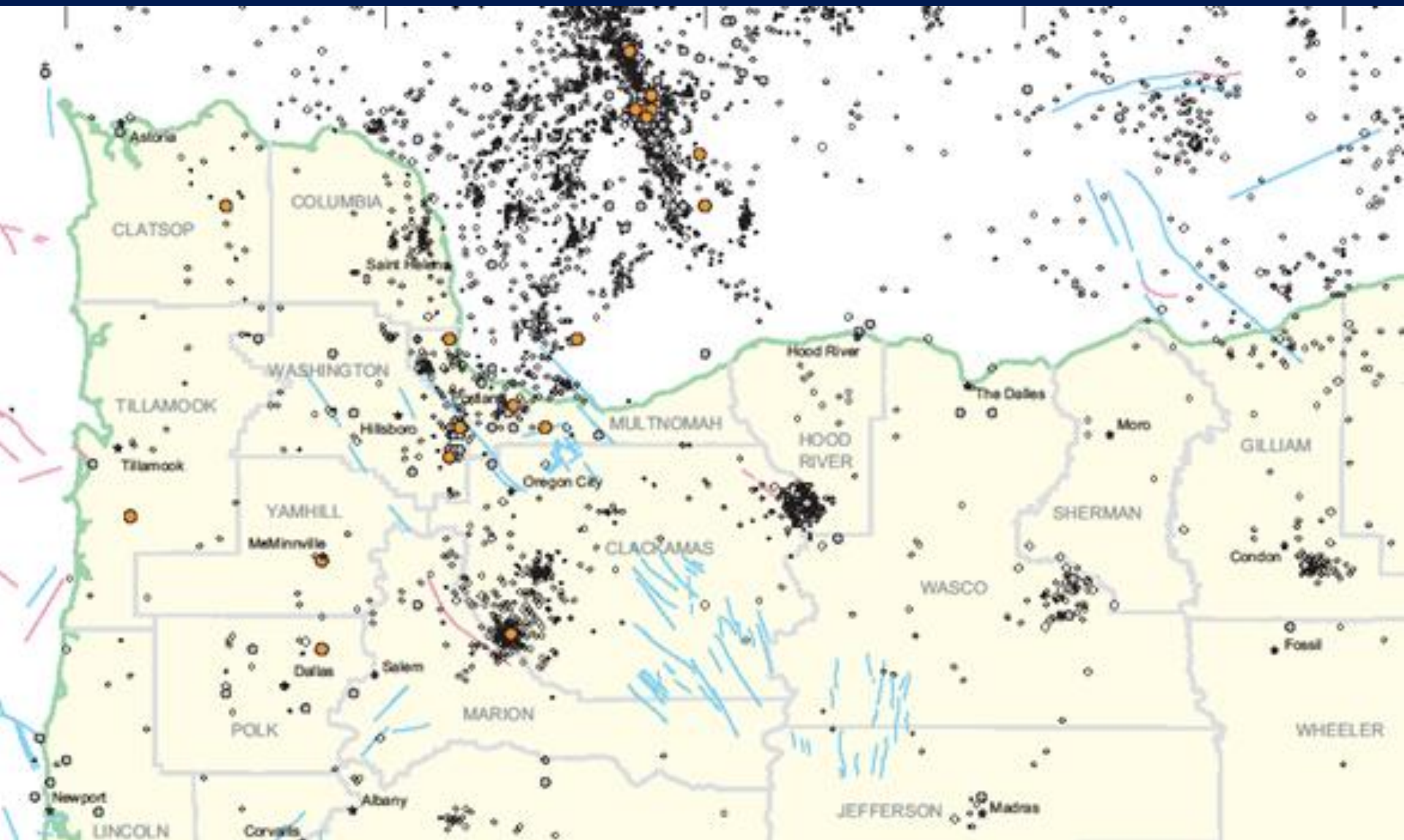
- 0 – 5 km deep
- Short duration (less than a minute)
- County wide zone of impact
- Magnitude, $M_w = 5.0 - 7.0$



Puget Sound Area Faults



Oregon Faults

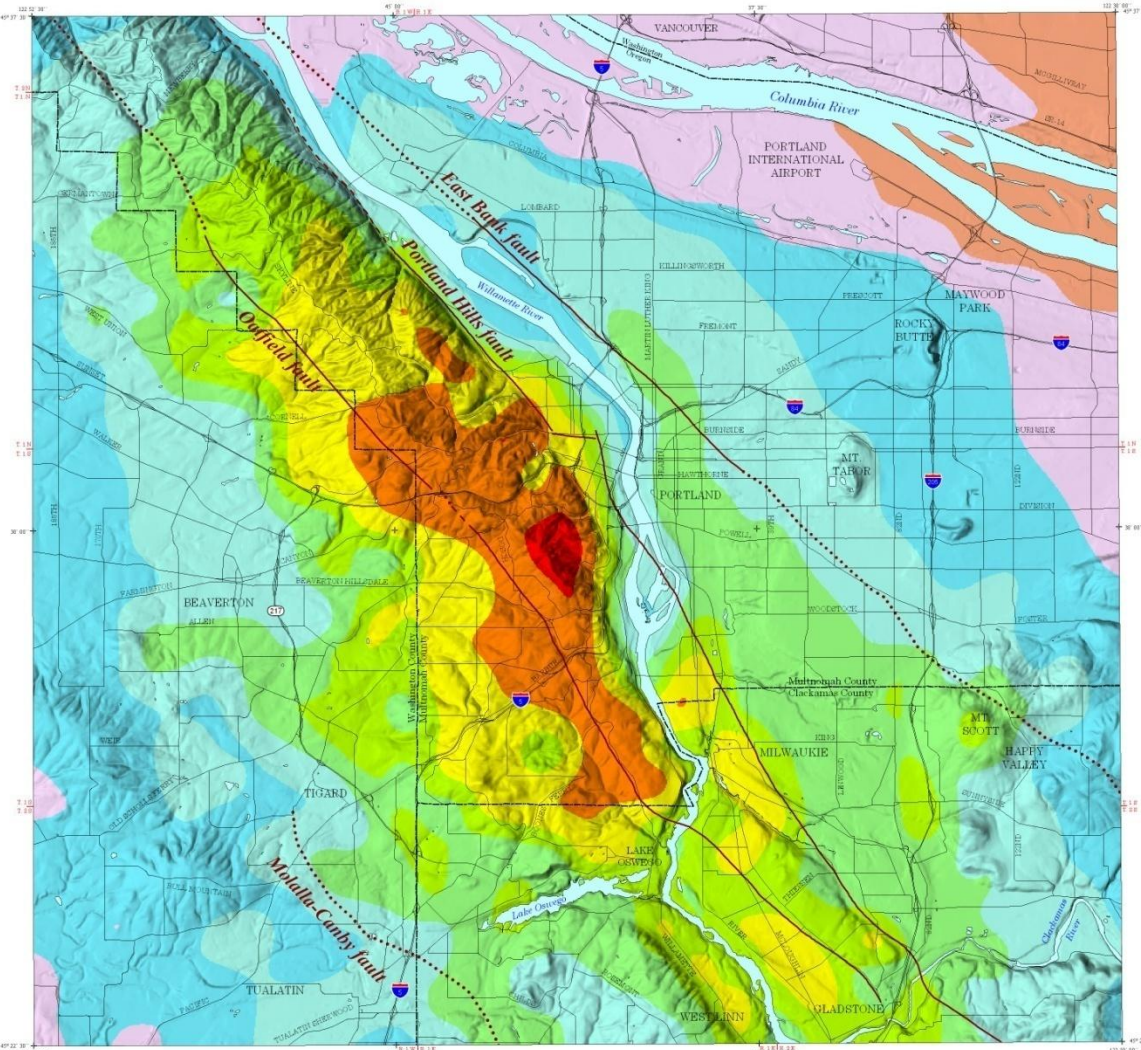


Portland Area Faults

Earthquake Scenario Ground Shaking Map for the Portland, Oregon, Metropolitan Area

Portland Hills Fault M 6.8 Earthquake Peak Horizontal Acceleration (g) at the Ground Surface

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

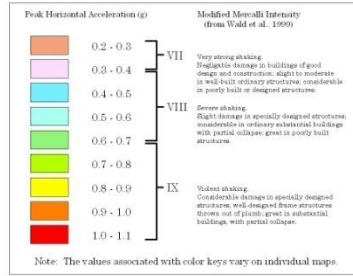


Base map data from REGIONAL LAND INFORMATION SYSTEM.
Mean Data Reference Center. Digital elevation derived from
USGS 7.5 minute quadrangle digital elevation model data.
Universal Transverse Mercator Projection, Zone 10
1987 North American Datum.



IMS - 15
Earthquake Scenario and Probabilistic Ground Shaking Maps
for the Portland, Oregon, Metropolitan Area
by
Ivan Wong, Walter Silva, Jacqueline Bott,
Douglas Wright, Patricia Thomas, Nick Gregor,
Sylvia Li, Matthew Mabey, Anna Sojourner, and Yumei Wang

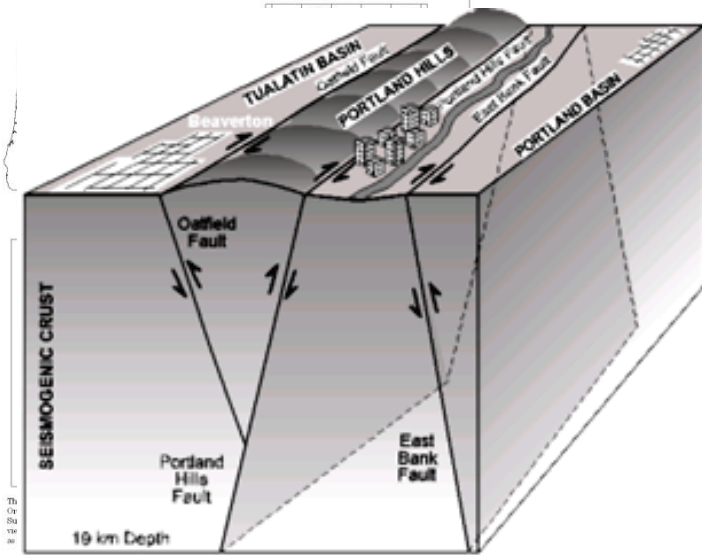
Portland Hills Fault M 6.8 Earthquake Peak Horizontal Acceleration (g) at the Ground Surface



POTENTIALLY SEISMOGENIC FAULTS

- Mapped
 - - - Inferred in this study
 - Interpreted from aeromagnetic data
- Data Sources: Madin, 1990, Bosson et al., 1991, and Blakely et al., 1995

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 aeromagnetic data.



Time Record of Crustal Earthquake

M = 6.9 Loma Prieta

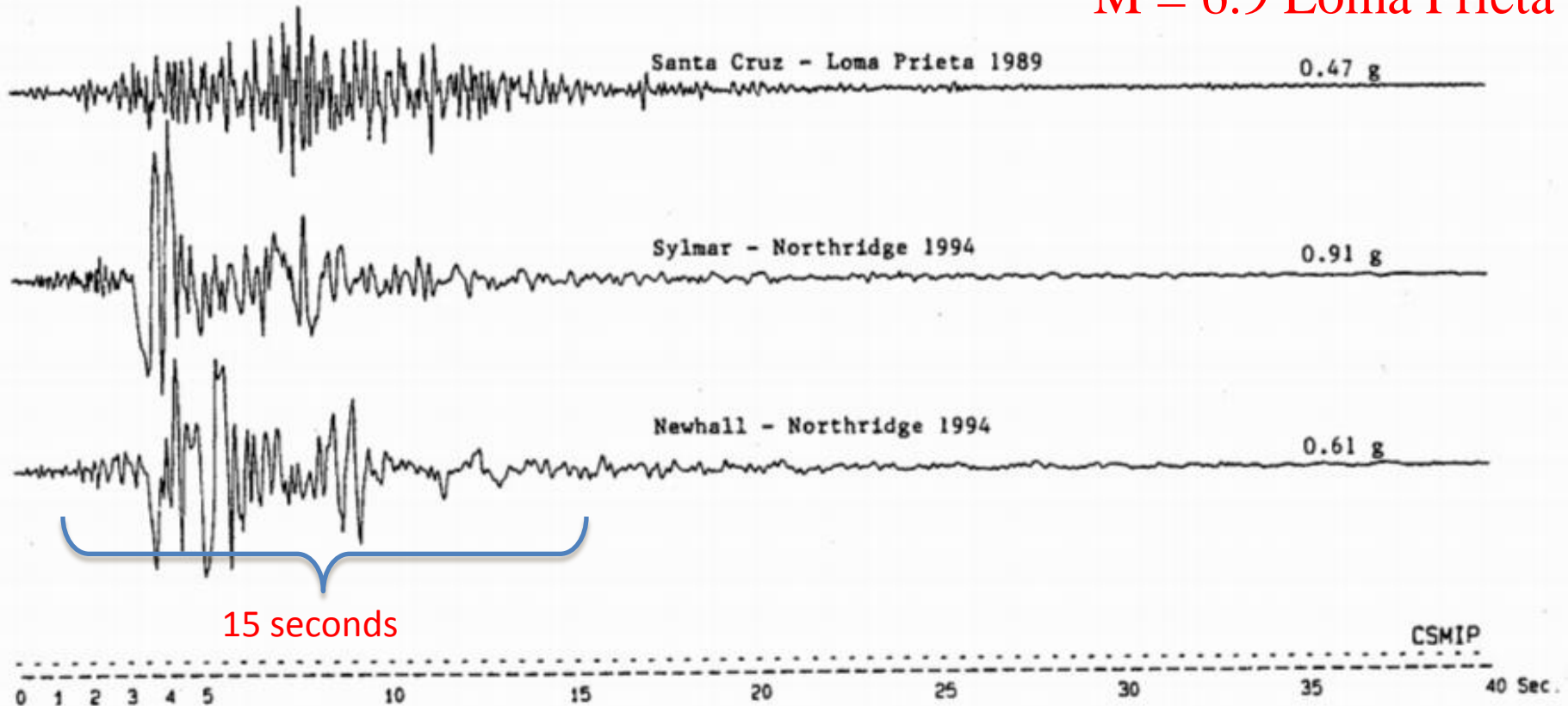


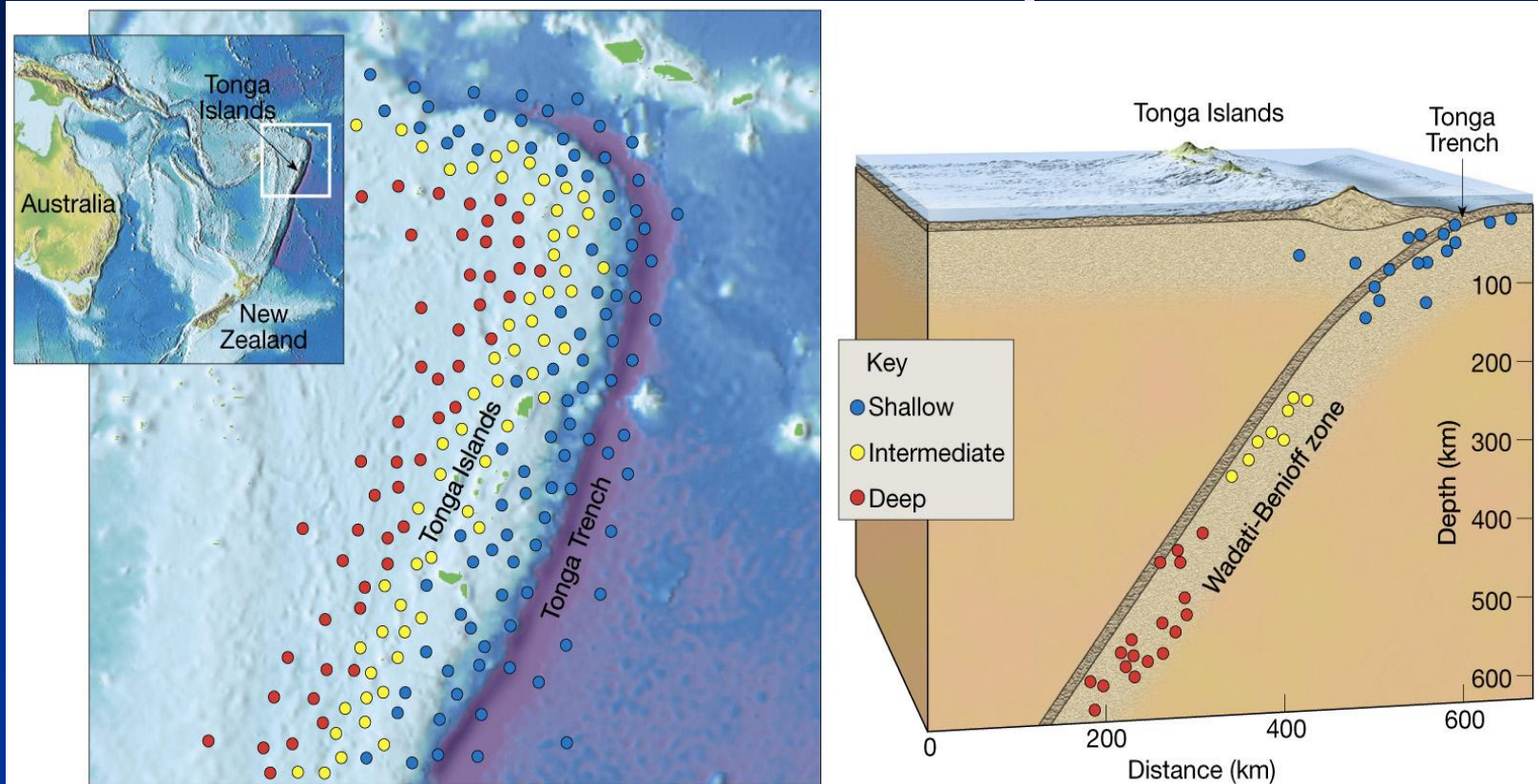
Figure 5. Duration of strong ground shaking. Accelerograms are from Joshua Tree for the 7.3 M Landers earthquake, Santa Cruz for the 7.1 M Loma Prieta earthquake, and Sylmar and Newhall for the 6.7 M Northridge earthquake. Stations are located at similar distances (10 - 20 km) from the fault.

Intraslab/Benioff Zone Earthquakes

- 45 – 60 km deep
- Moderate duration (few minutes)
- State wide impact
- Magnitude $M_w = 6.0-7.5$



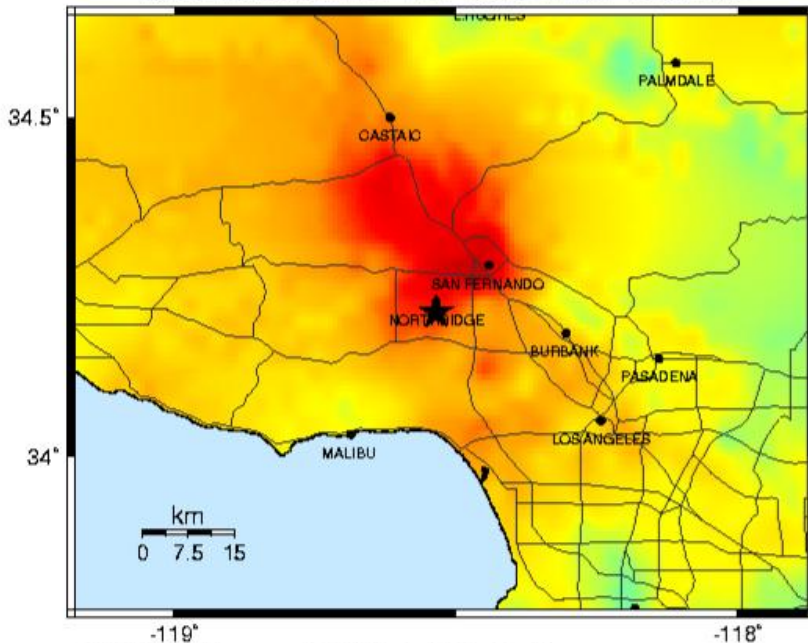
Intraslab Earthquakes



Most of the damaging earthquakes in Washington have been of a type called Wadati-Benioff, or just Benioff Zone earthquakes. Most recently, we have had magnitude ~6.5—7 earthquakes in 1949, 1965, and 2001.

Zone of Impact between Crustal and Intraslab Earthquakes

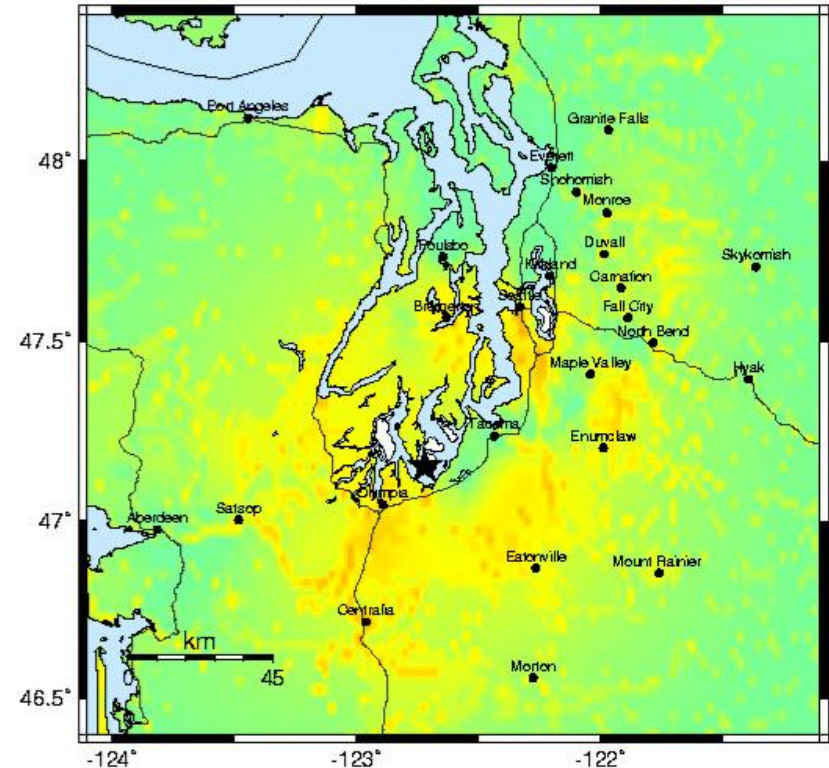
TriNet Rapid Instrumental Intensity Map for Northridge Earthquake
 Mon Jan 17 04:30:55 AM PST M 6.7 N34.21 W118.54 ID:Northridge



PROCESSED: Tue Jul 25 02:36:57 PM PDT, Produced by ShakeMap V2

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.(%)	<.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+

PNSN Rapid Instrumental Intensity Map Epicenter: 17.6 km NE of Olympia, WA
 Wed Feb 28, 2001 10:54:00 AM PST M 6.8 N47.15 W122.72 ID:0102281854

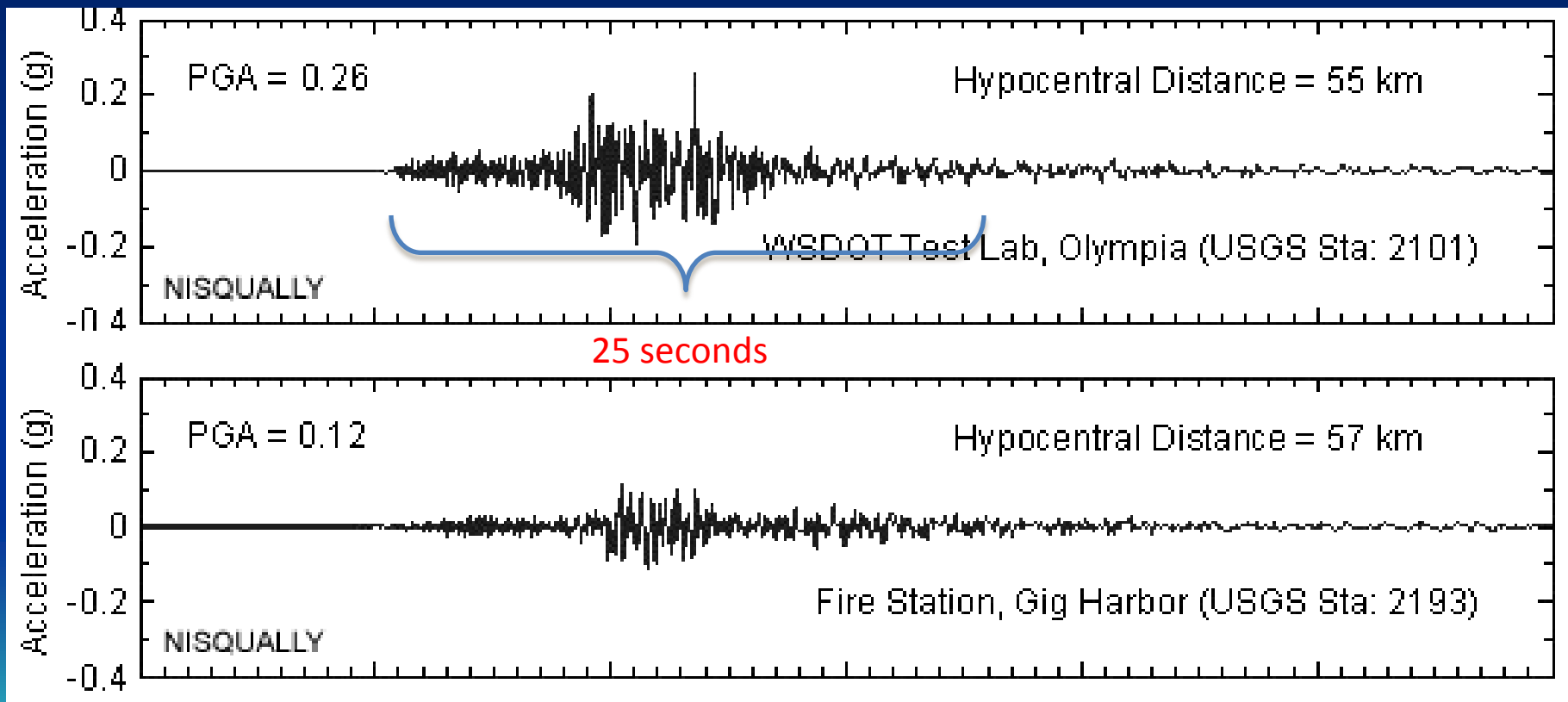


PROCESSED: Thu Apr 19, 2001 03:38:38 AM PDT,

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.(%)	<.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+

Time History of Intraplate Earthquake

M=6.8 Nisqually

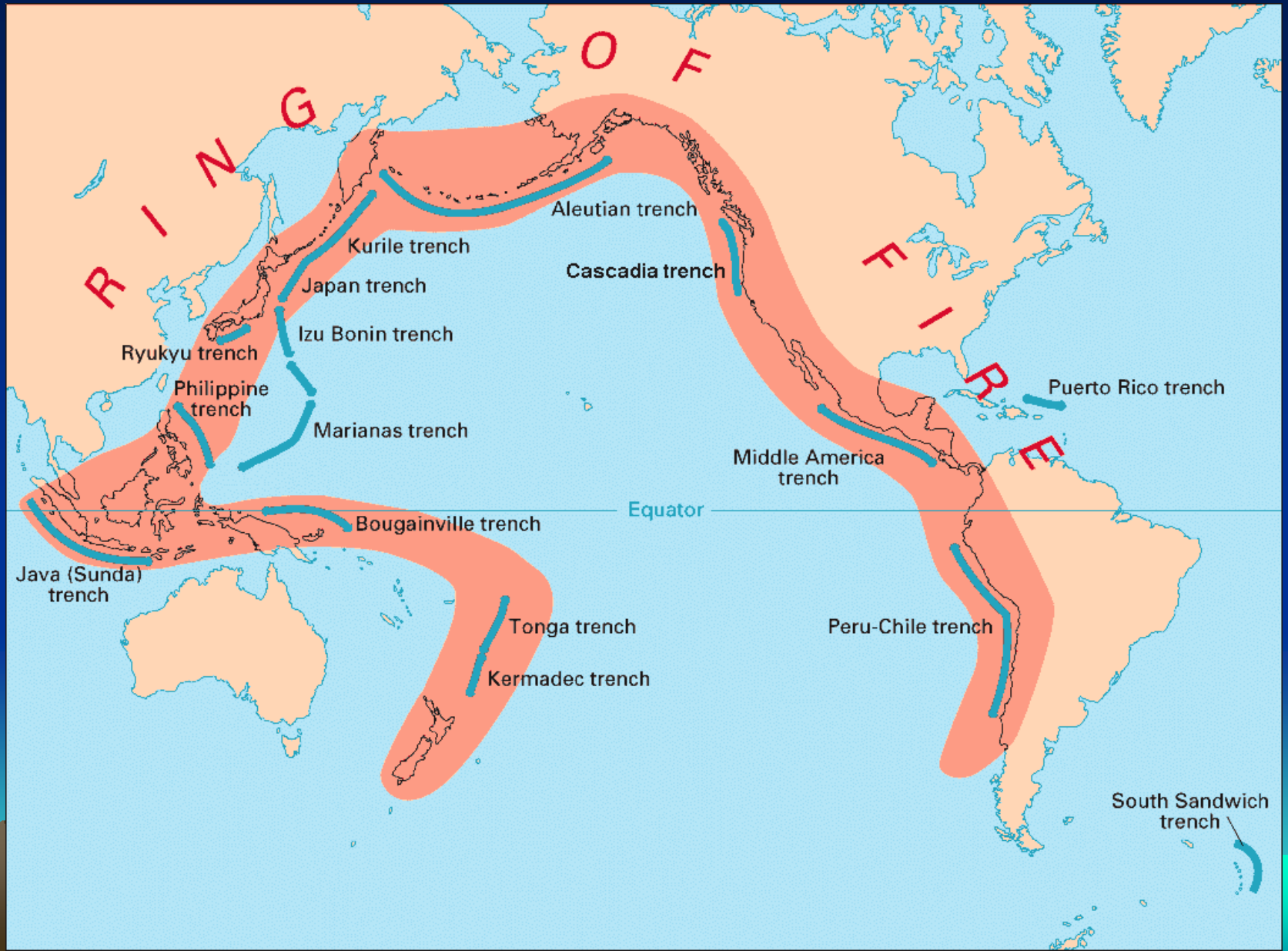


Subduction Zone Earthquakes

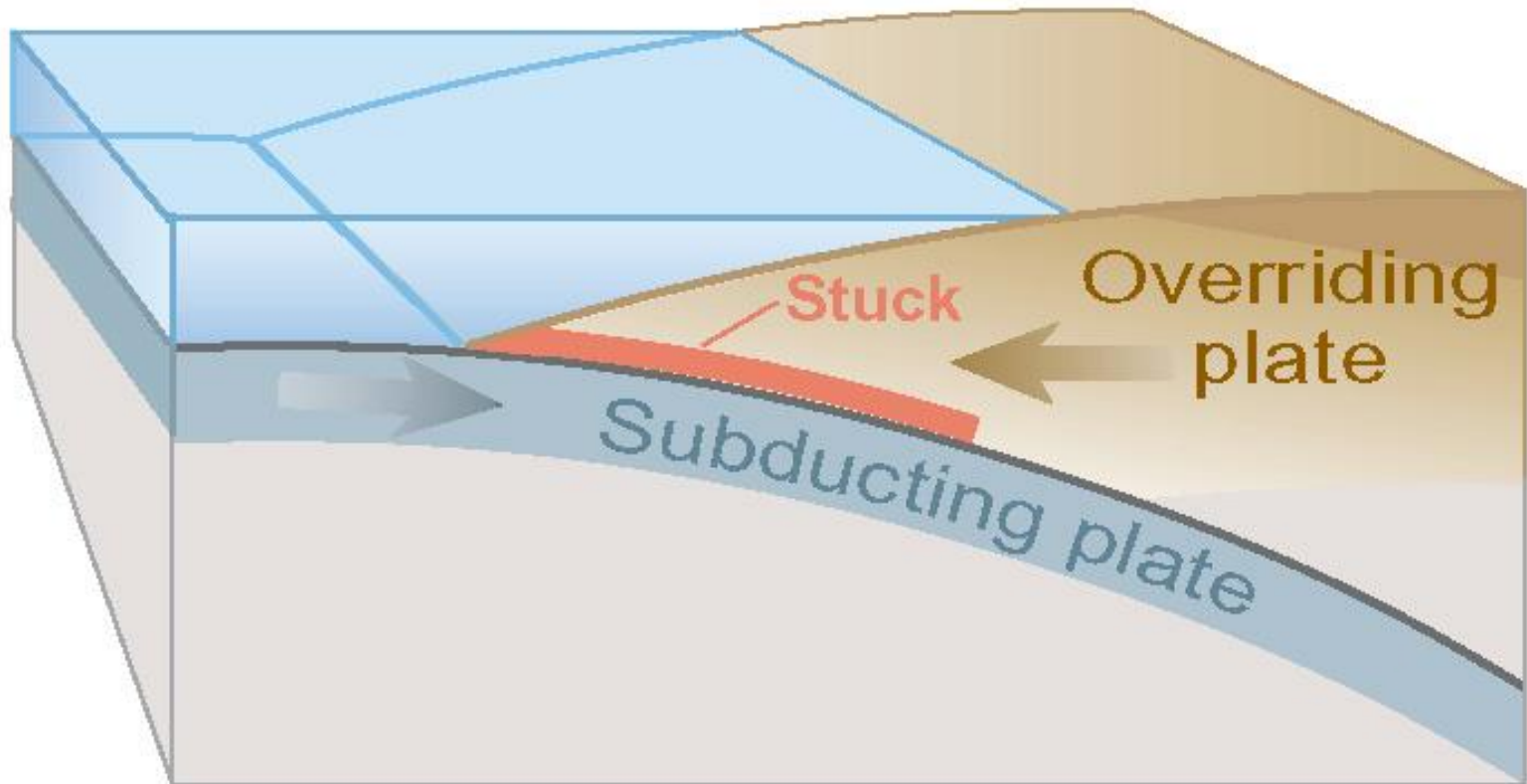
- 10 -30 km deep
- Long duration (many minutes)
- Region wide impact
- Long rupture zone
- Maximum magnitude $M_w = 9.2$



Subduction Zone Earthquakes

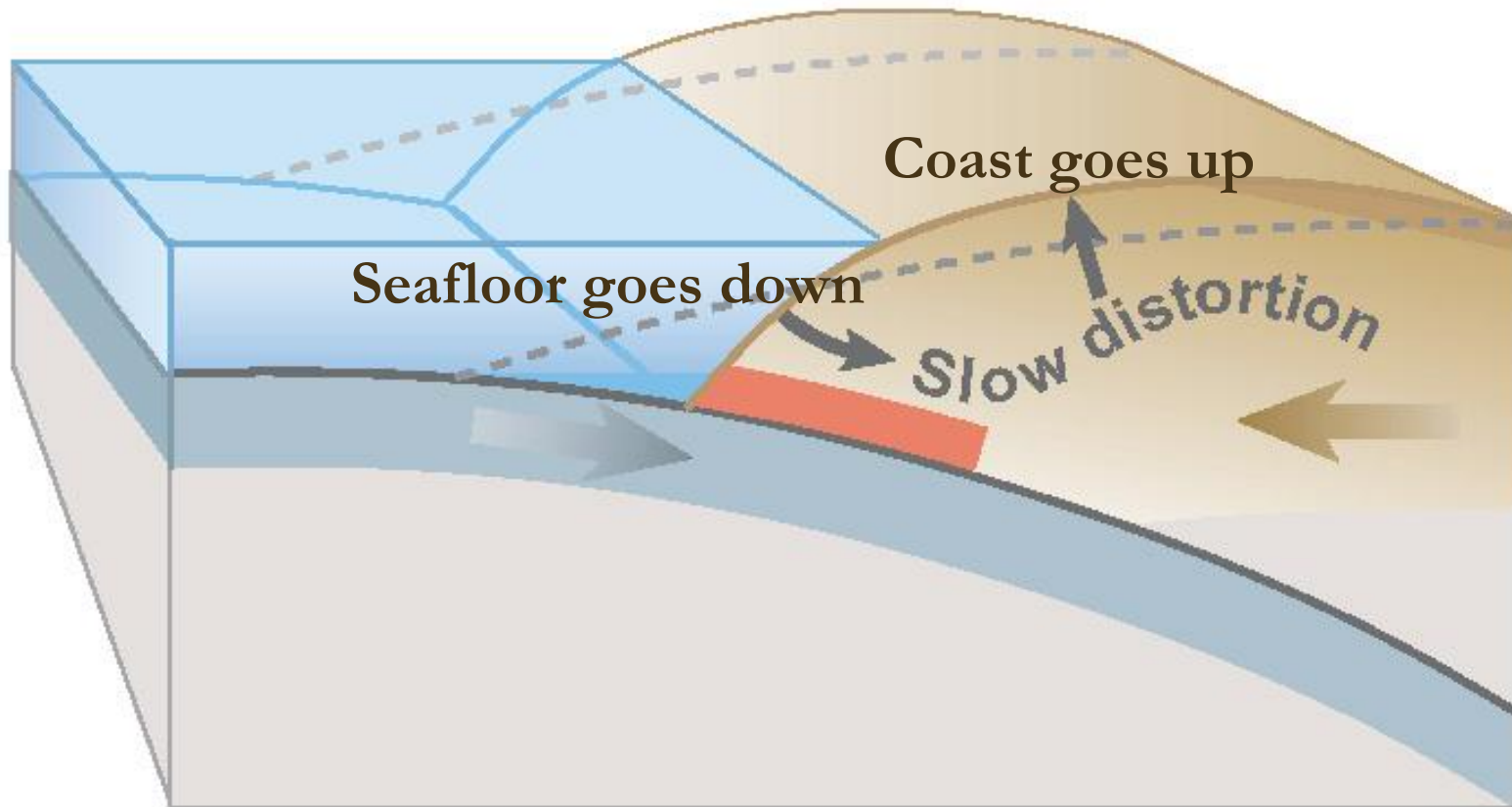


Vertical Slice through Subduction Zone



Source: <http://pubs.usgs.gov/circ/c1187/>

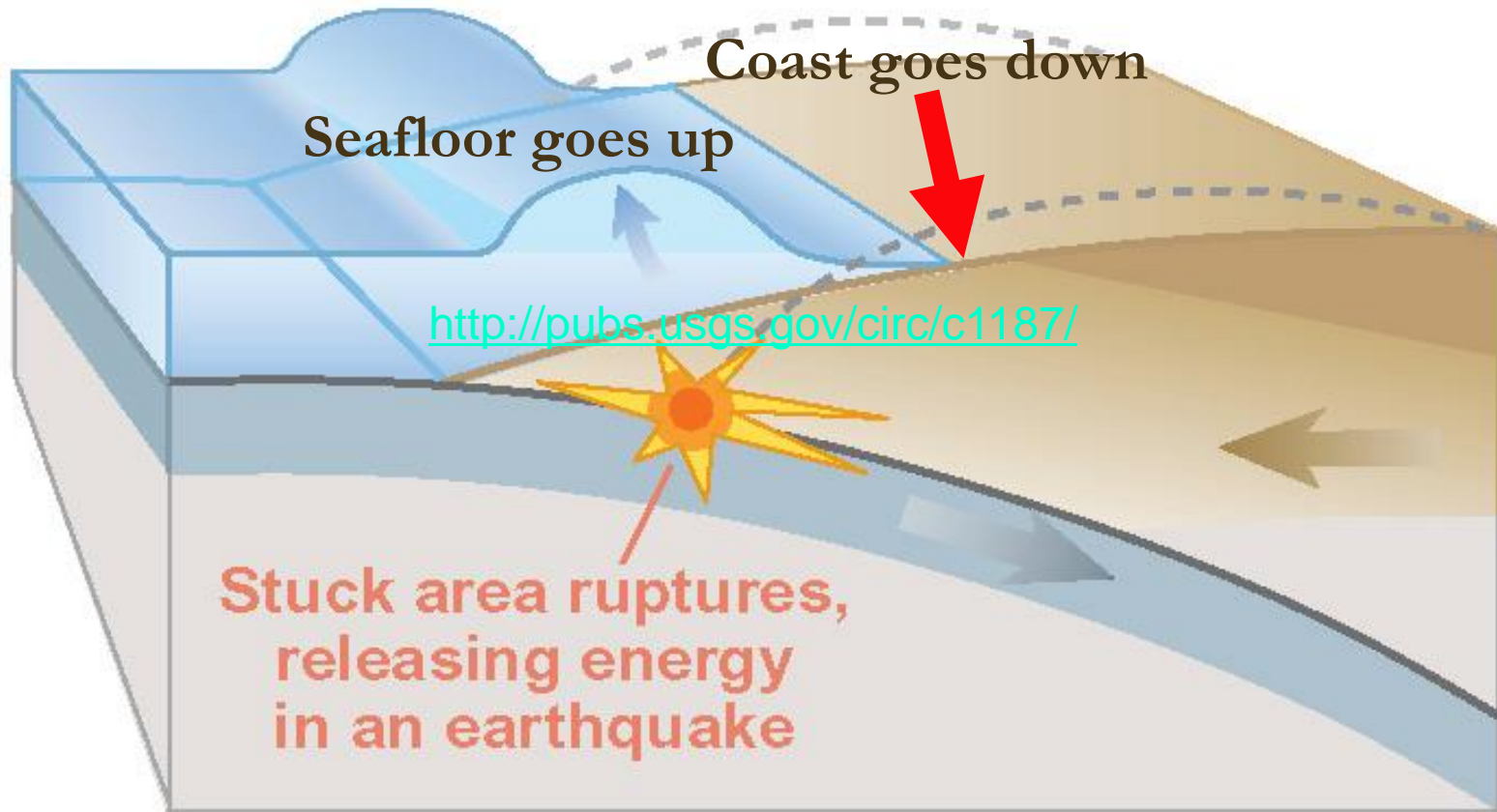
Between Earthquakes



Source: <http://pubs.usgs.gov/circ/c1187/>

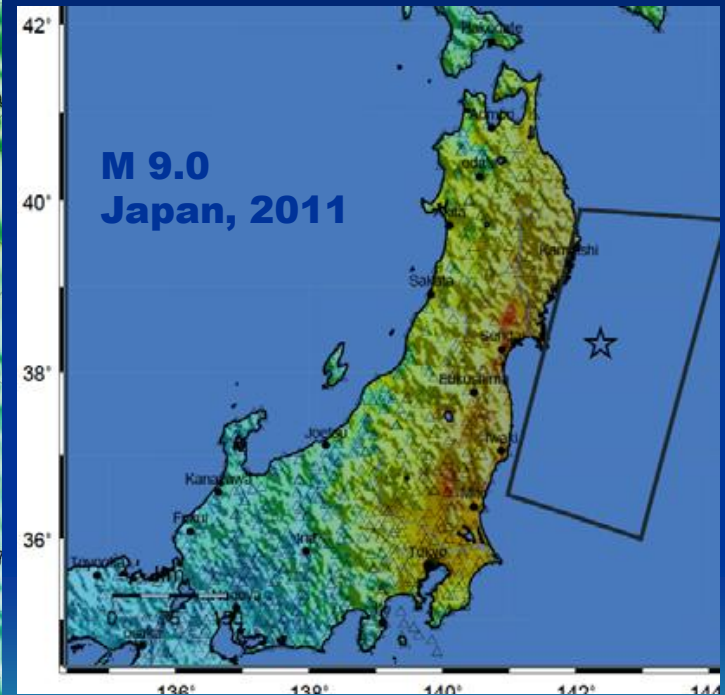
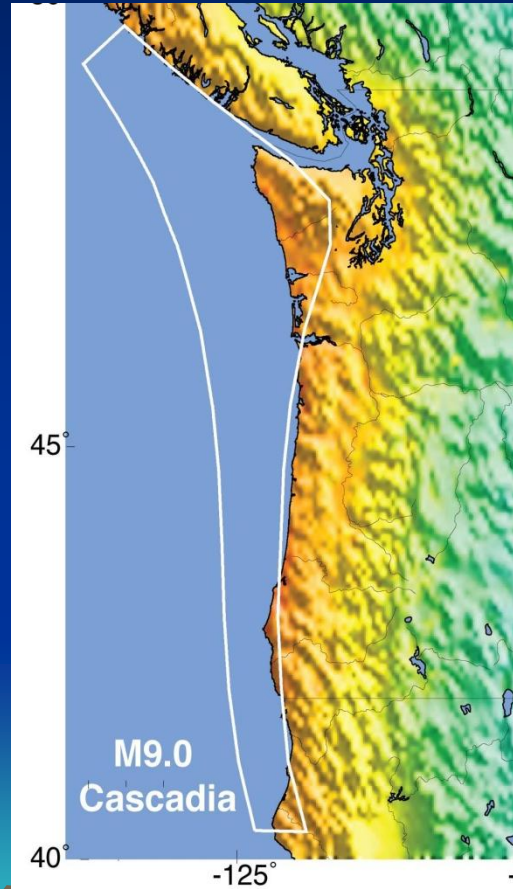
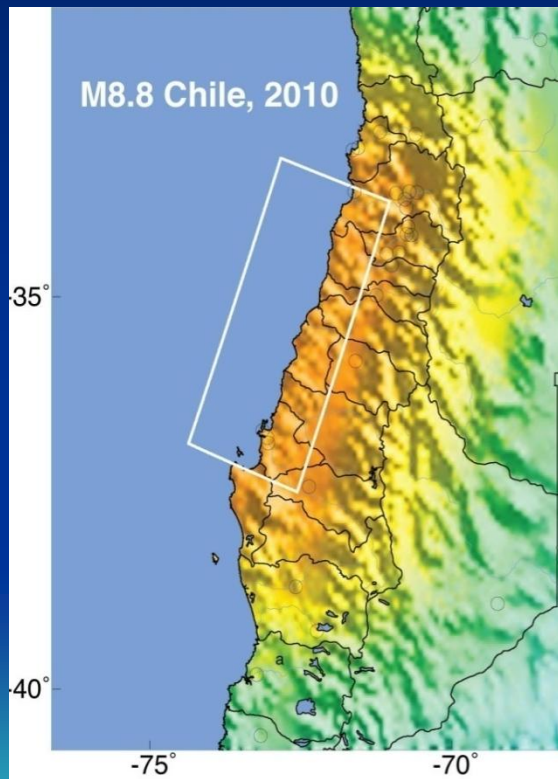
During an Earthquake

Earthquake starts tsunami

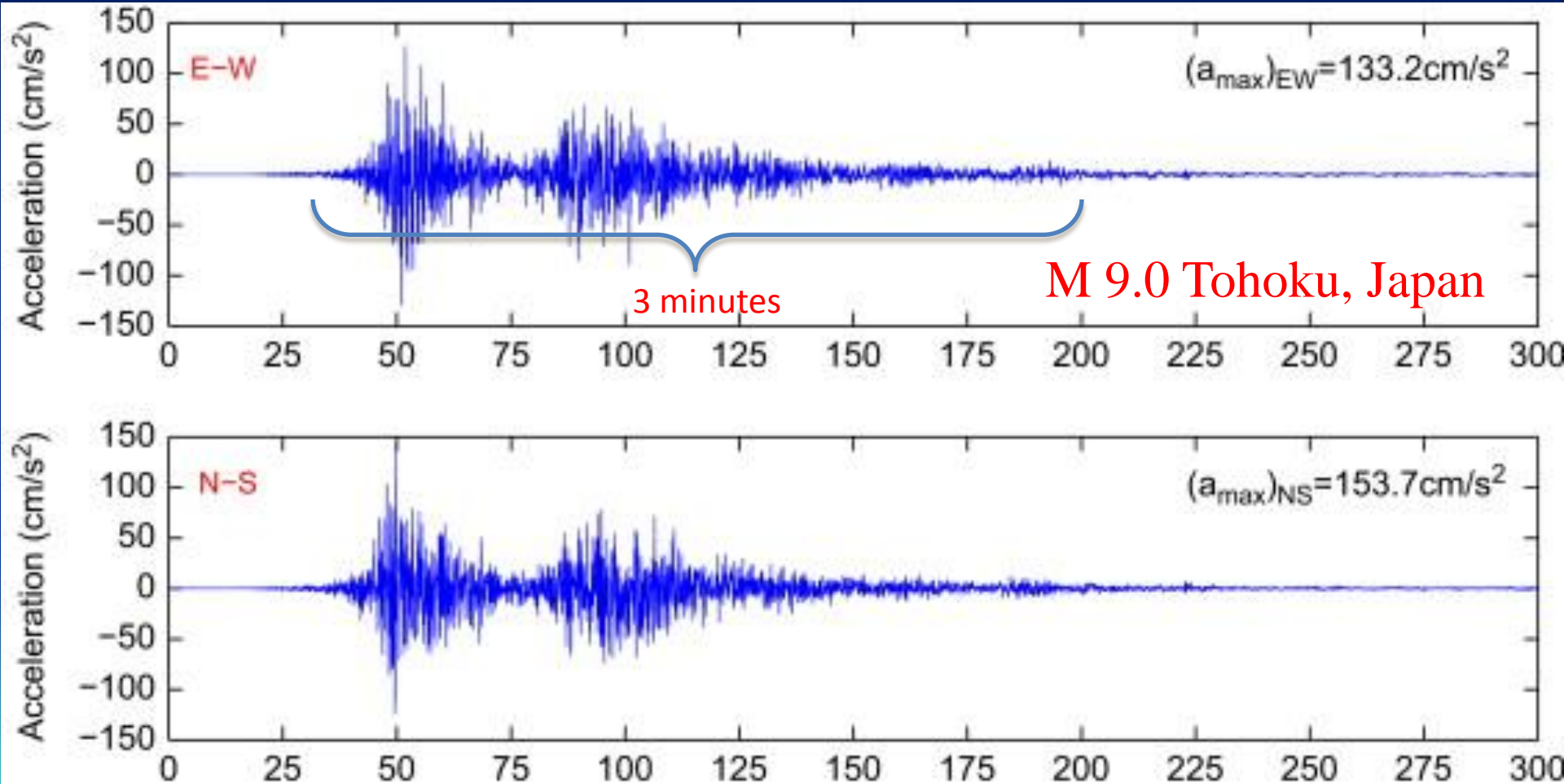


Source: <http://pubs.usgs.gov/circ/c1187/>

Comparison to Cascadia SZ and PacNW

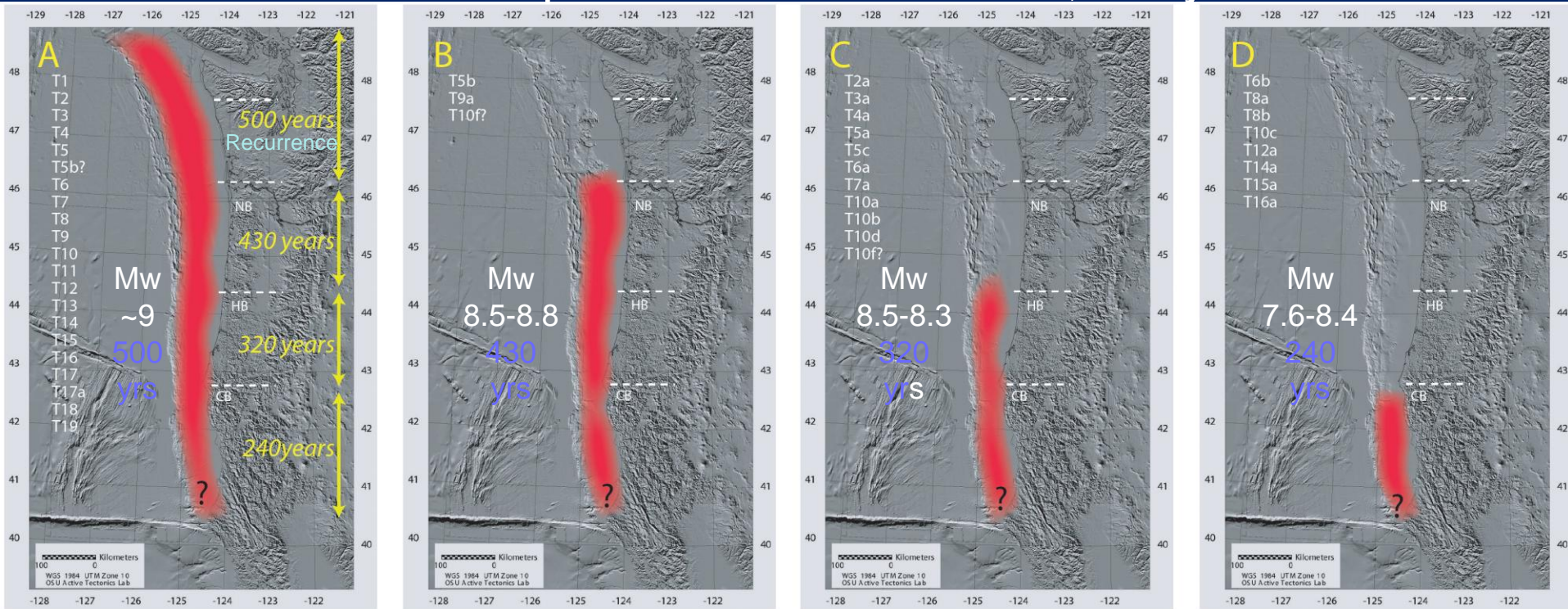


Time History of Subduction Zone Earthquakes



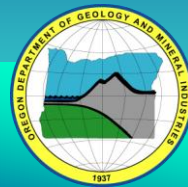
Cascadia Subduction Zone Earthquakes

Turbidites show how much of the subduction zone ruptured in ~42 earthquakes over the last 10,000 years.



- 20 earthquakes ruptured all of the subduction zone.
- 2 to 3 earthquakes ruptured three quarters of subduction zone.
- 19 earthquakes ruptured the southern half or quarter of the subduction zone.

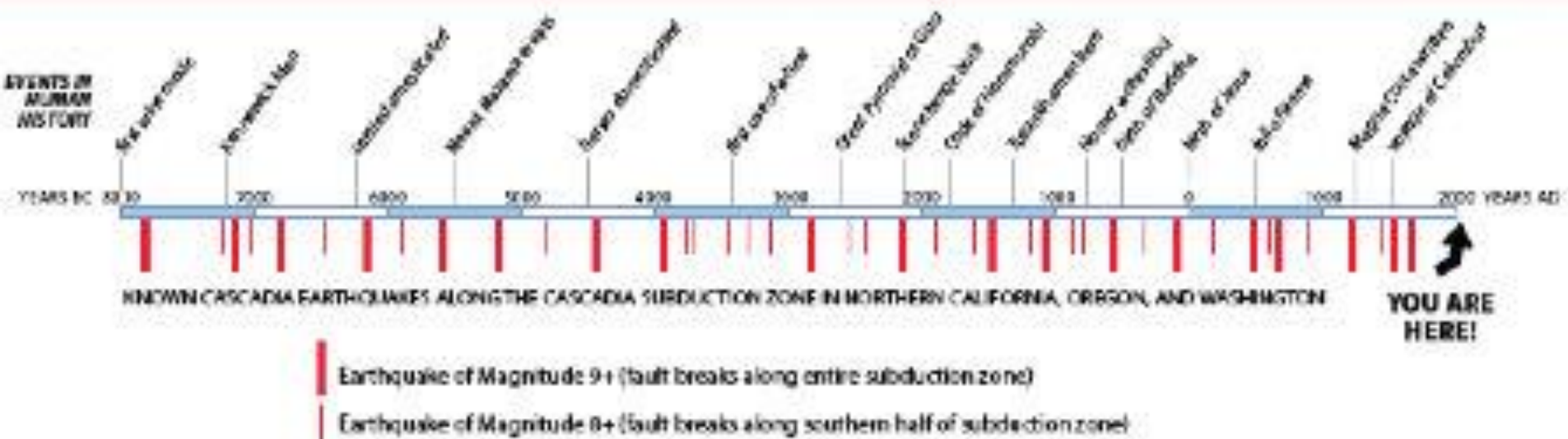
(Modified from Goldfinger et al. (in press) by adding magnitude estimates and some labels)



Frequency of Cascadia Zone Earthquakes

Chris Goldfinger – Oregon State

CASCADIA EARTHQUAKE TIME LINE



KNOWN CASCADIA EARTHQUAKES ALONG THE CASCADIA SUBDUCTION ZONE IN NORTHERN CALIFORNIA, OREGON, AND WASHINGTON

YOU ARE HERE!

Comparison of the history of subduction zone earthquakes along the Cascadia subduction zone in northern California, Oregon, and Washington, with events from human history. Ages of earthquakes are derived from study and dating of submarine landslides triggered by the earthquakes. Earthquake data provided by Chris Goldfinger, Oregon State University; time line by Ian P. Martin, DOGAMI.

Earthquake Induced Phenomenon

- Strong Shaking
- Liquefaction
- Landslides
- Tsunami
- Fault Ruptures



A scenic landscape photograph of a snow-capped mountain peak reflected in a calm lake, surrounded by evergreen trees. The mountain is the central focus, with its peak and slopes covered in snow. The lake in the foreground is still, creating a clear reflection of the mountain and the surrounding forest. The trees are dark green and appear to be evergreens. The sky is a pale, hazy blue, suggesting a clear day. The overall mood is peaceful and serene.

Thanks to:

Yumei Wang, DOGAMI

Timothy Walsh, Washington DNR

Allison Pynch, Shannon and Wilson

Questions