Geologic Hazards in Earthquake Country

NW Hydro Operators

May 22, 2008

Yumei Wang, PE
Oregon Dept of Geology
& Mineral Industries

www.oregongeology.com (DOGAMI)

Earthquake Setting

- When, where, how big?
- Pacific Northwest's Cascadia Subduction Zone Fault
- Crustal faults

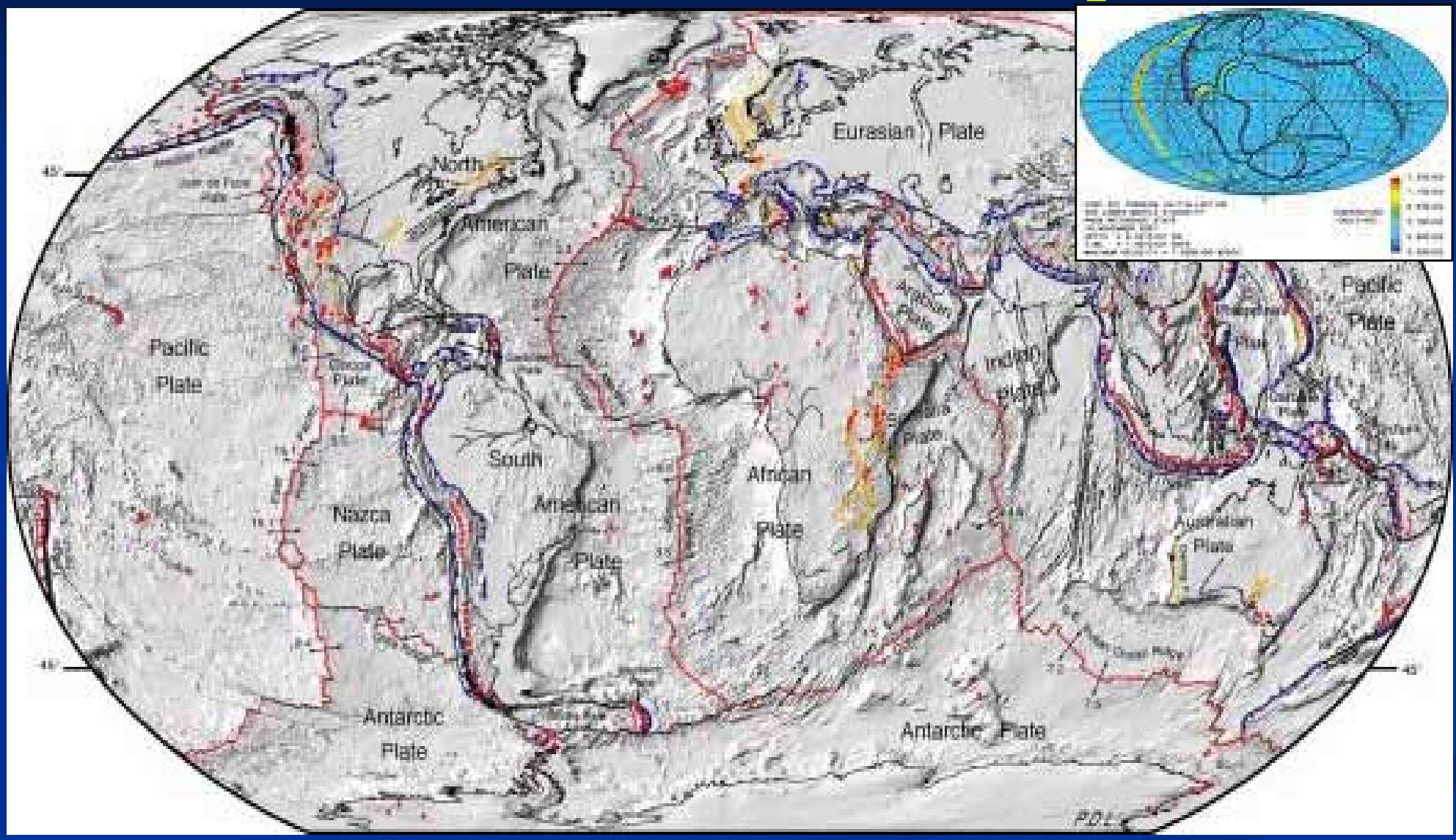
Damaging Earthquakes

Earthquake Hazards

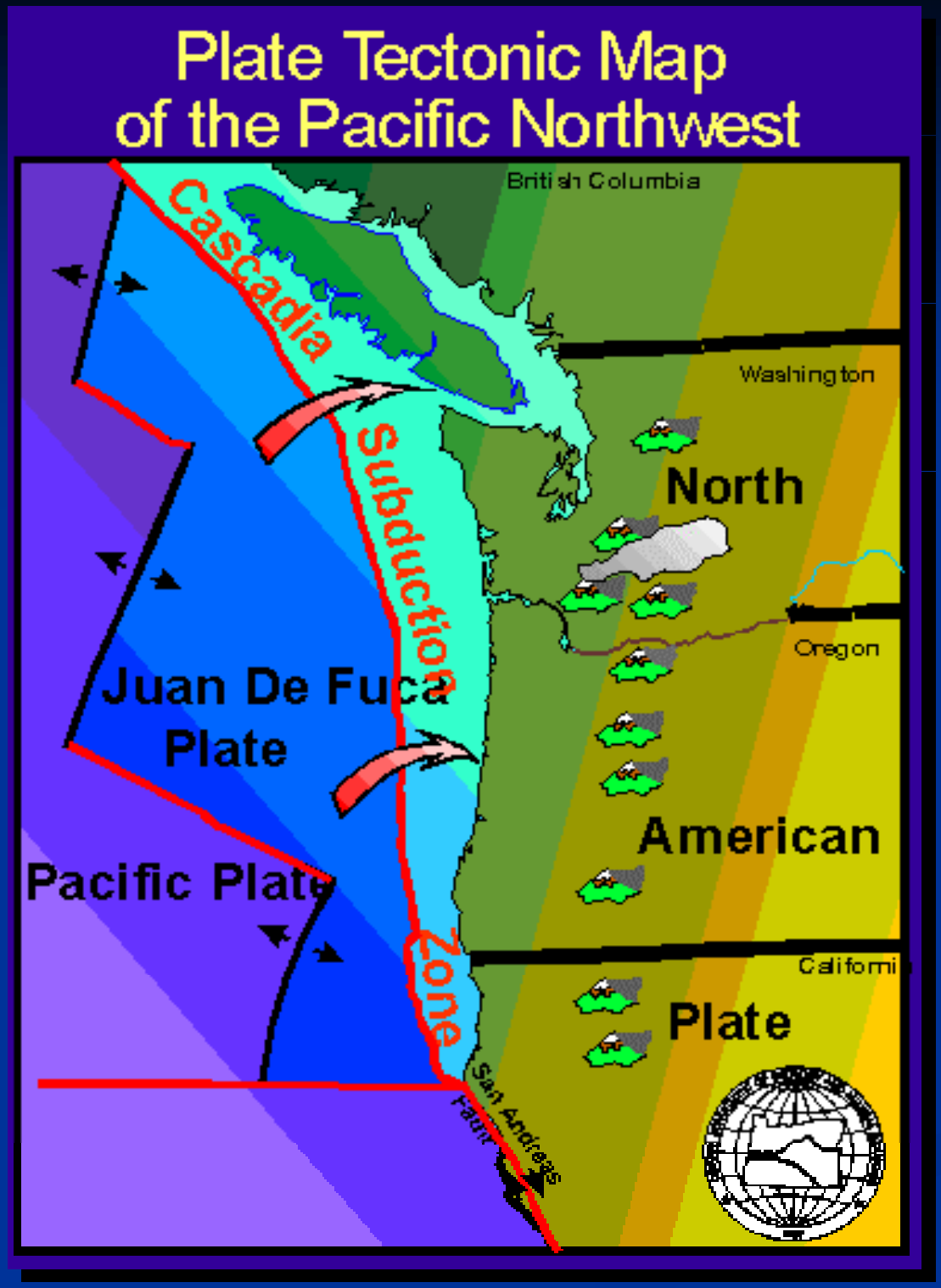
-Rupture, Shaking, Liquefaction, Landslides, Tsunamis

PREPARE for resiliency

Plate Tectonics Map



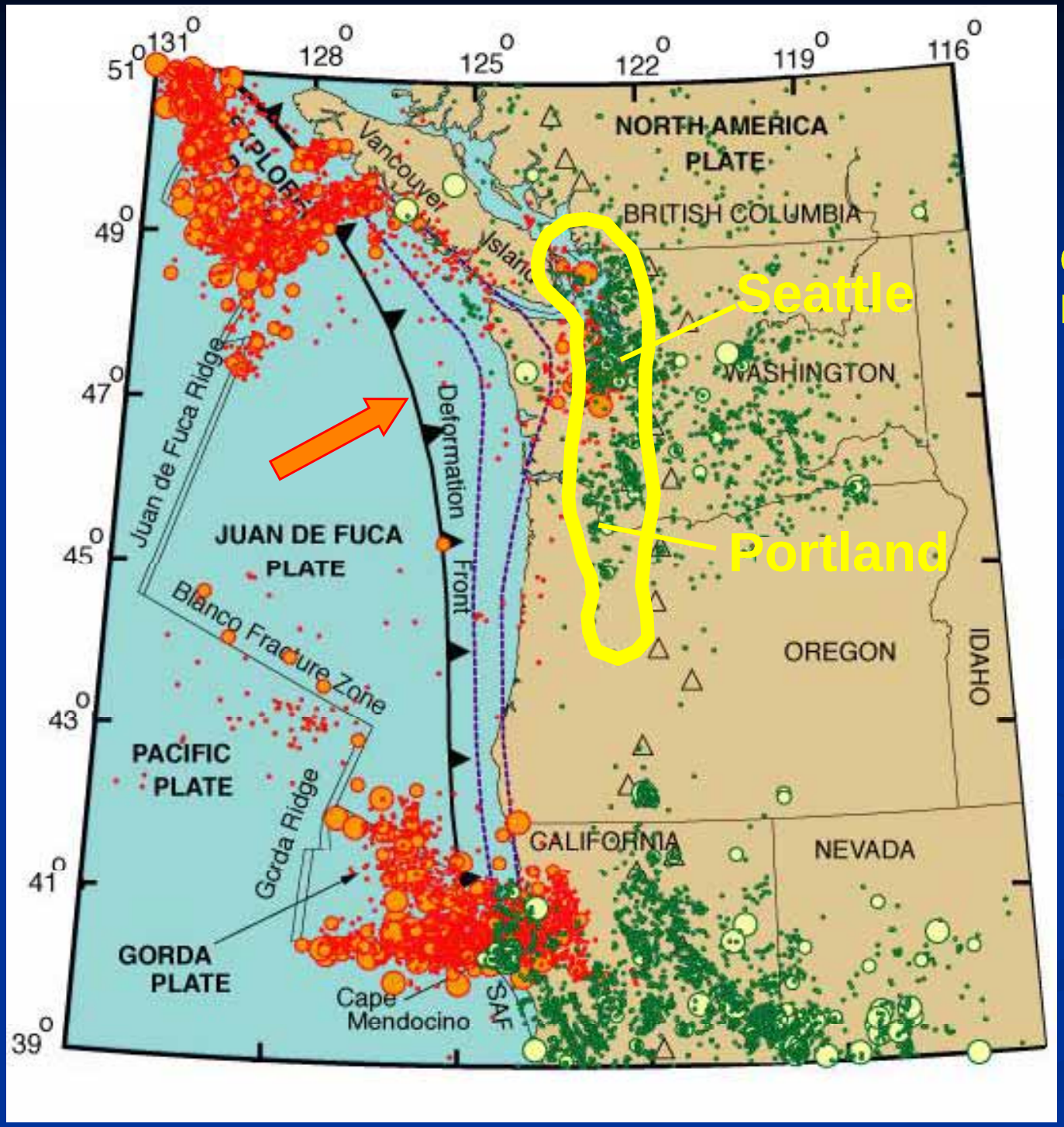
Earthquakes are concentrated at plate boundaries



Evidence of > 20 Cascadia earthquakes

Last Cascadia quake on Jan 26, 1700 about Magnitude 9

SEISMICITY

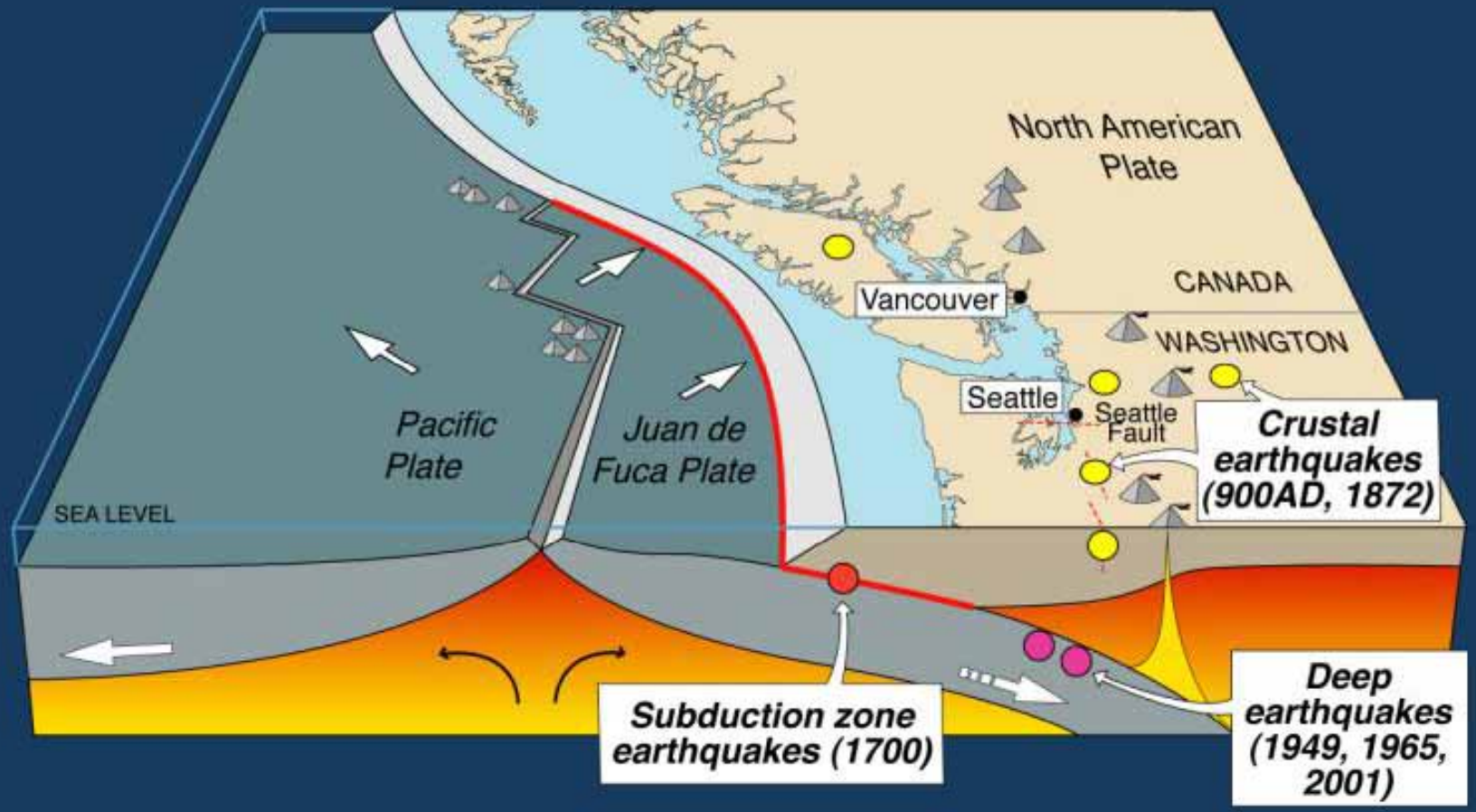


Green = No. Amer. plate
Red = Juan de Fuca plate

Urban Corridor lies in a seismically active fore-arc basin

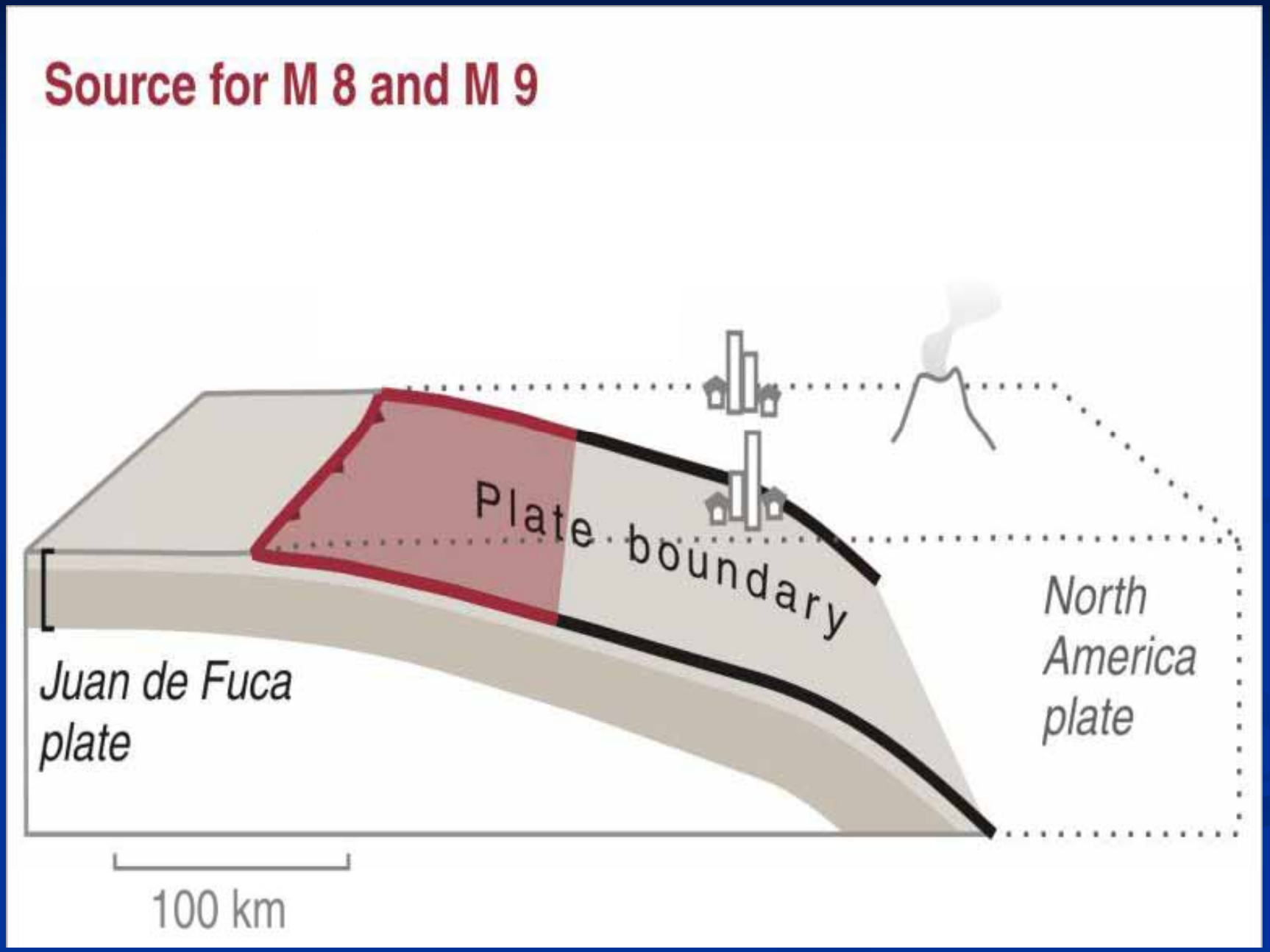
Courtesy: RBlakely

Cascadia earthquake sources



Source	Affected area	Max.Size	Recurrence
Subduction Zone	W. WA, OR, CA	M 9	500-600 yr
Deep JdF plate	W. WA, OR	M 7	30-50 yr
Crustal faults	WA, OR, CA	M 7?	?

Rupture Plane under Coast Range

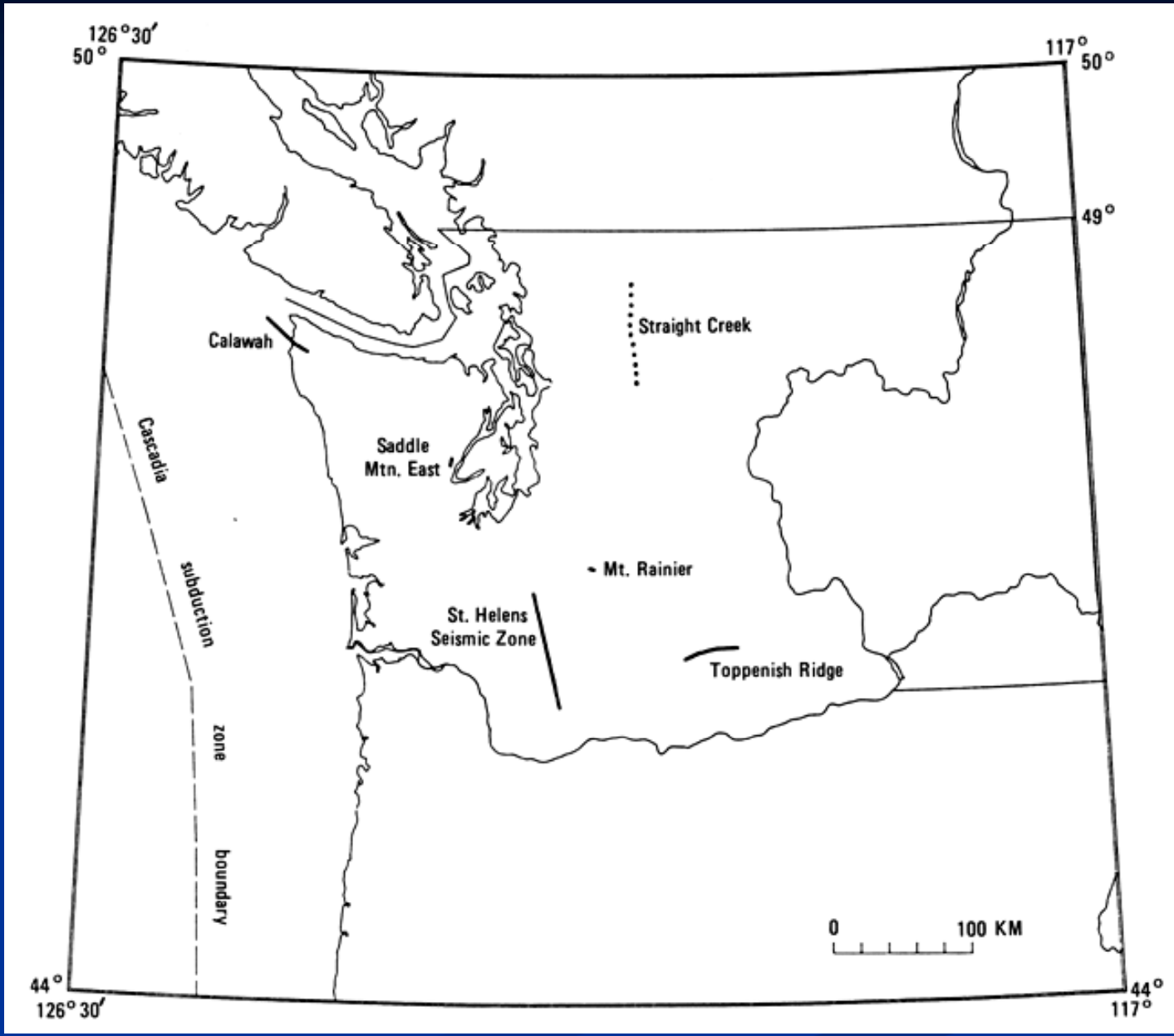


Source: B. Atwater

Not “if,” But…
When, where, how big?

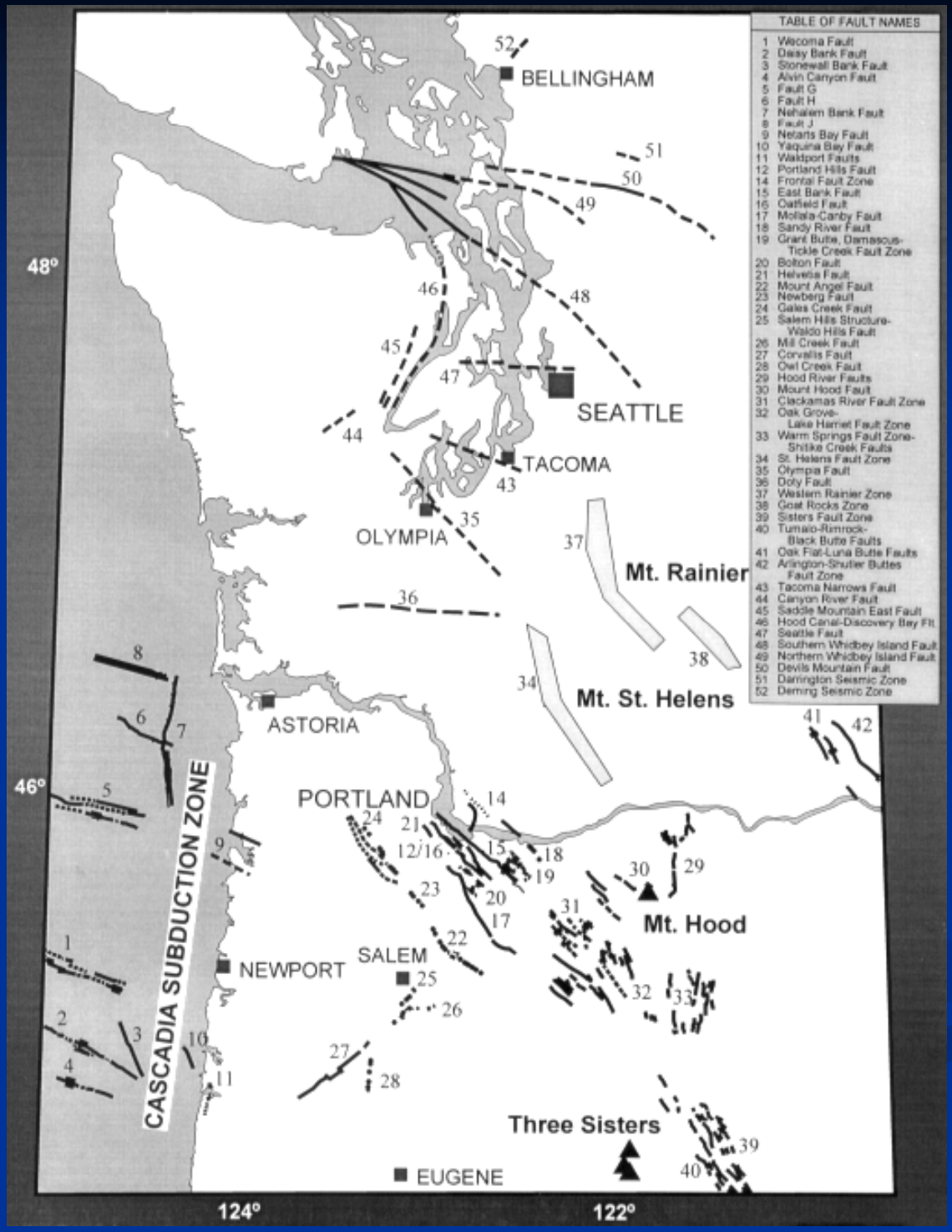
- Can’t predict when (yet…)
- Certain regions are prone to quakes
- Subduction zones produce mega-quakes
- More future megaquakes in Pacific Northwest
- Outcome--Catastrophic disaster or resiliency?

1988 Known Active Faults in Washington & Oregon

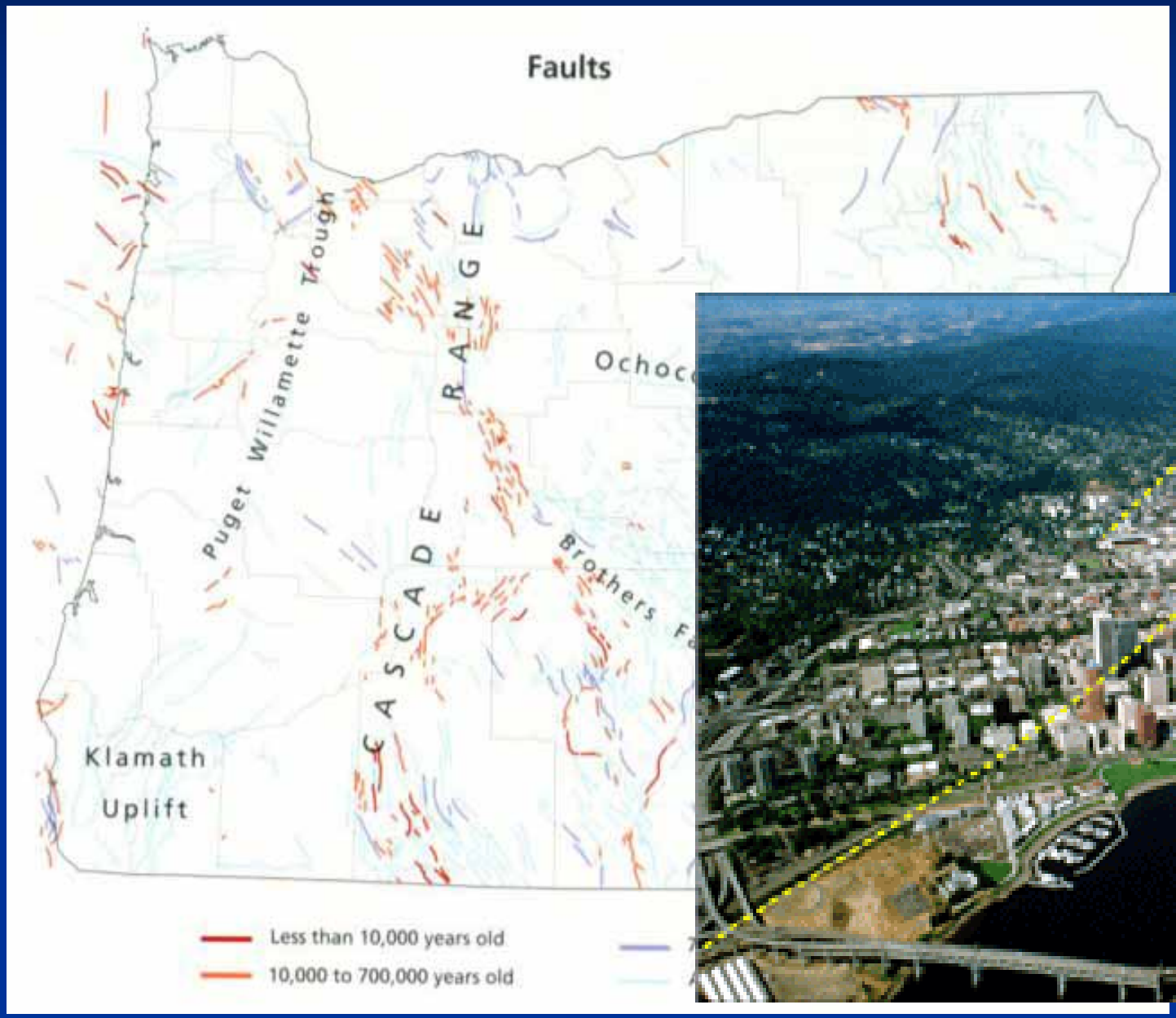


Noson et al., 1988

2004 Active Faults in W. Washington & N. Oregon



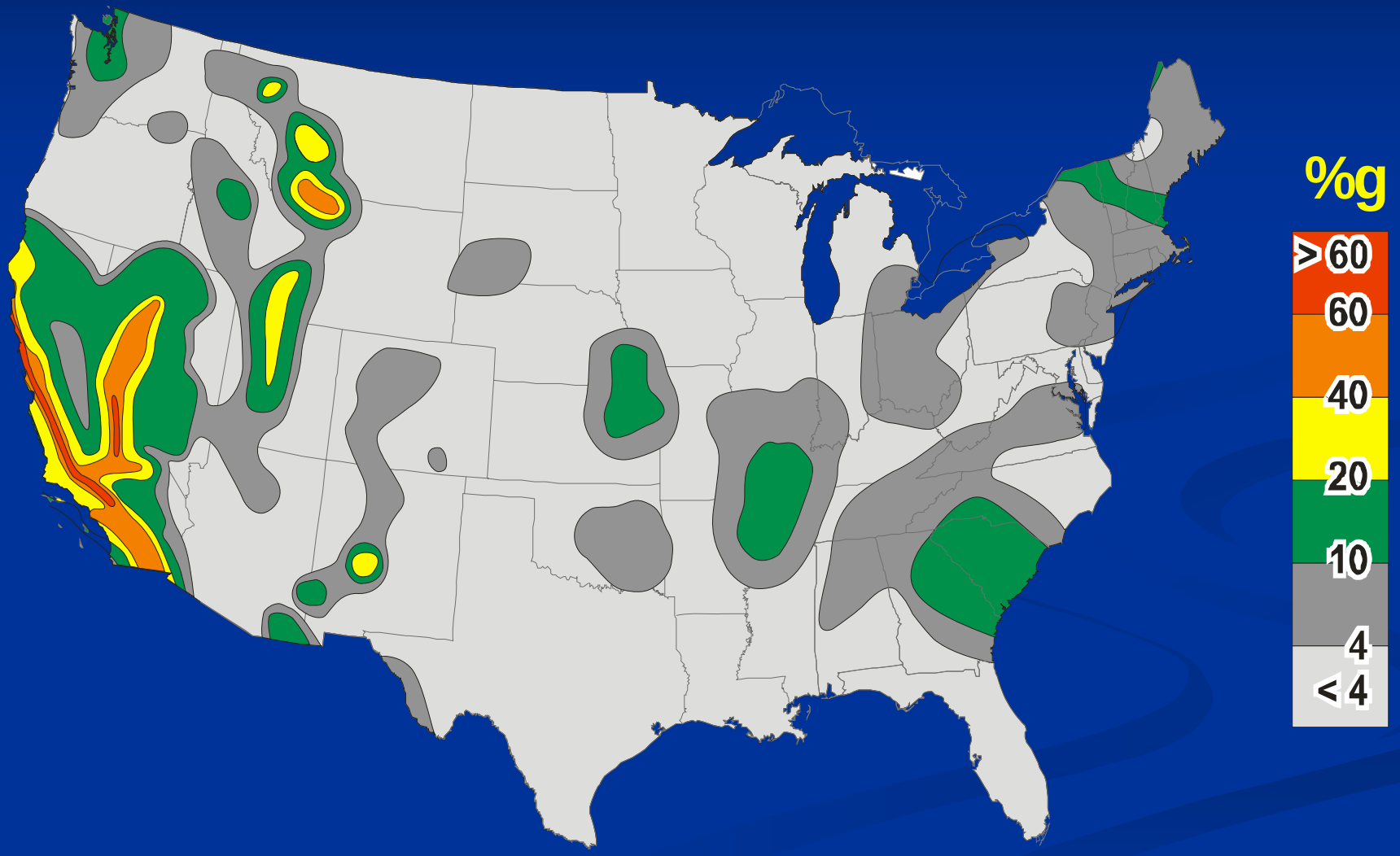
Cascadia & local faults



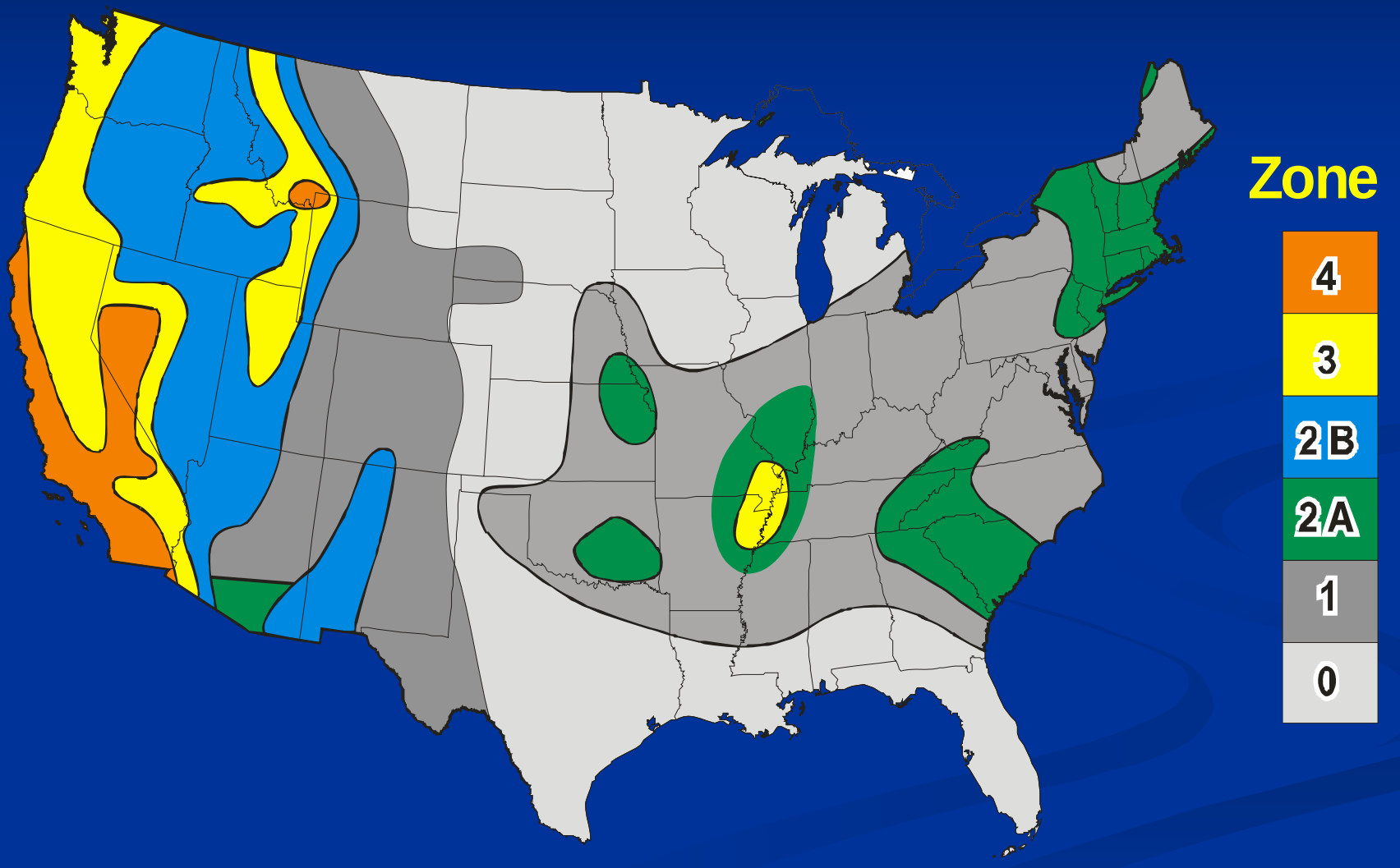
Portland Hills Fault

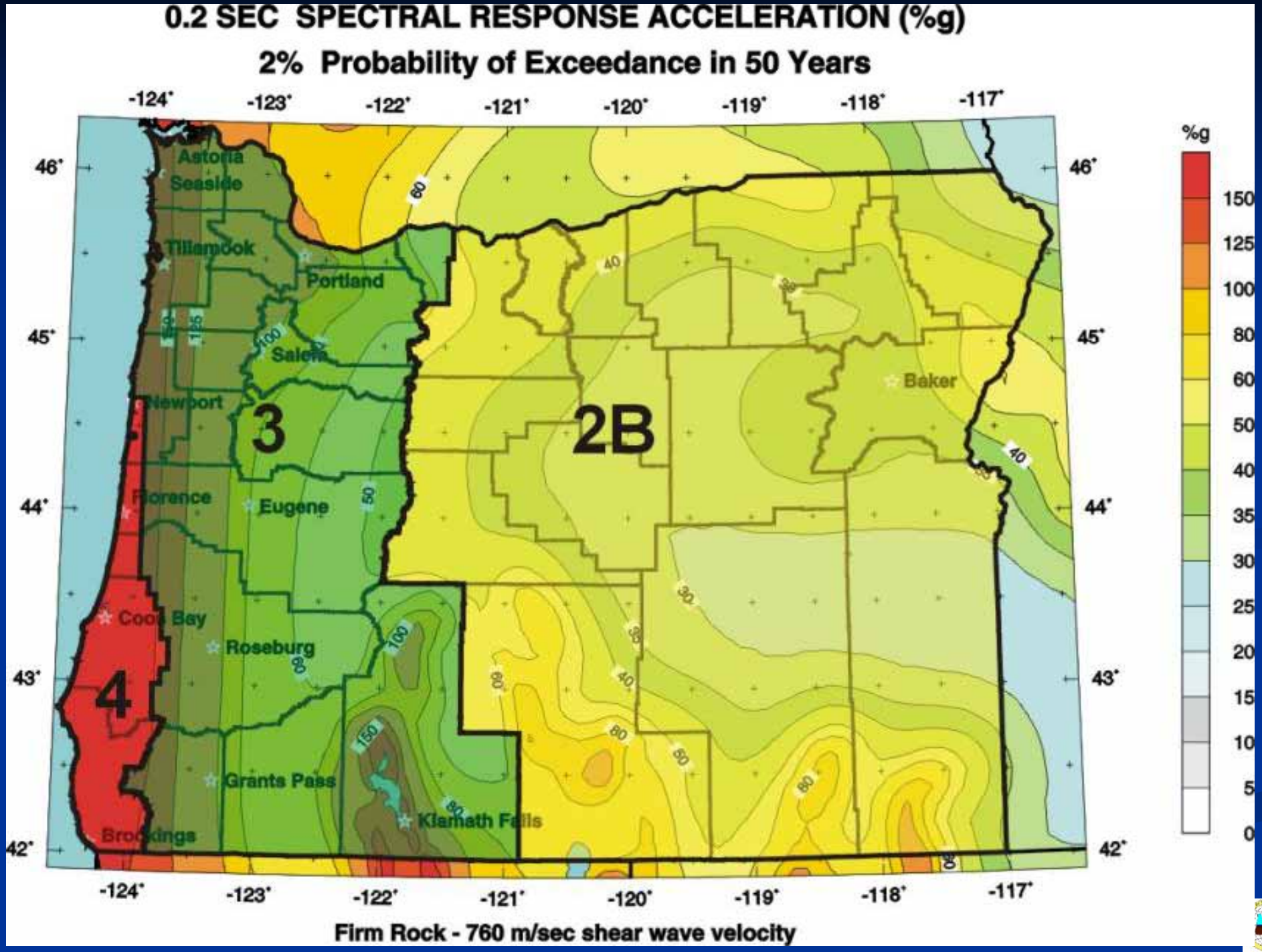
1976 PGA - 10% P.E. in 50 yrs

(Algermissen & Perkins)



1994 UBC Zone Map




0.2 SEC SPECTRAL RESPONSE ACCELERATION (%g)
2% Probability of Exceedance in 50 Years
-124°
-123°
-122°
-121°
-120°
-119°
-118°
-117°
46°
45°
44°
43°
42°
Astoria
Seaside
Tillamook
Portland
Salem
Newport
Florence
Eugene
Coos Bay
Roseburg
Grants Pass
Brookings
Klamath Falls
Baker
3
2B
4
%g
150
125
100
80
60
50
40
35
30
25
20
15
10
5
0
Firm Rock - 760 m/sec shear wave velocity

2008 USGS ground shaking map

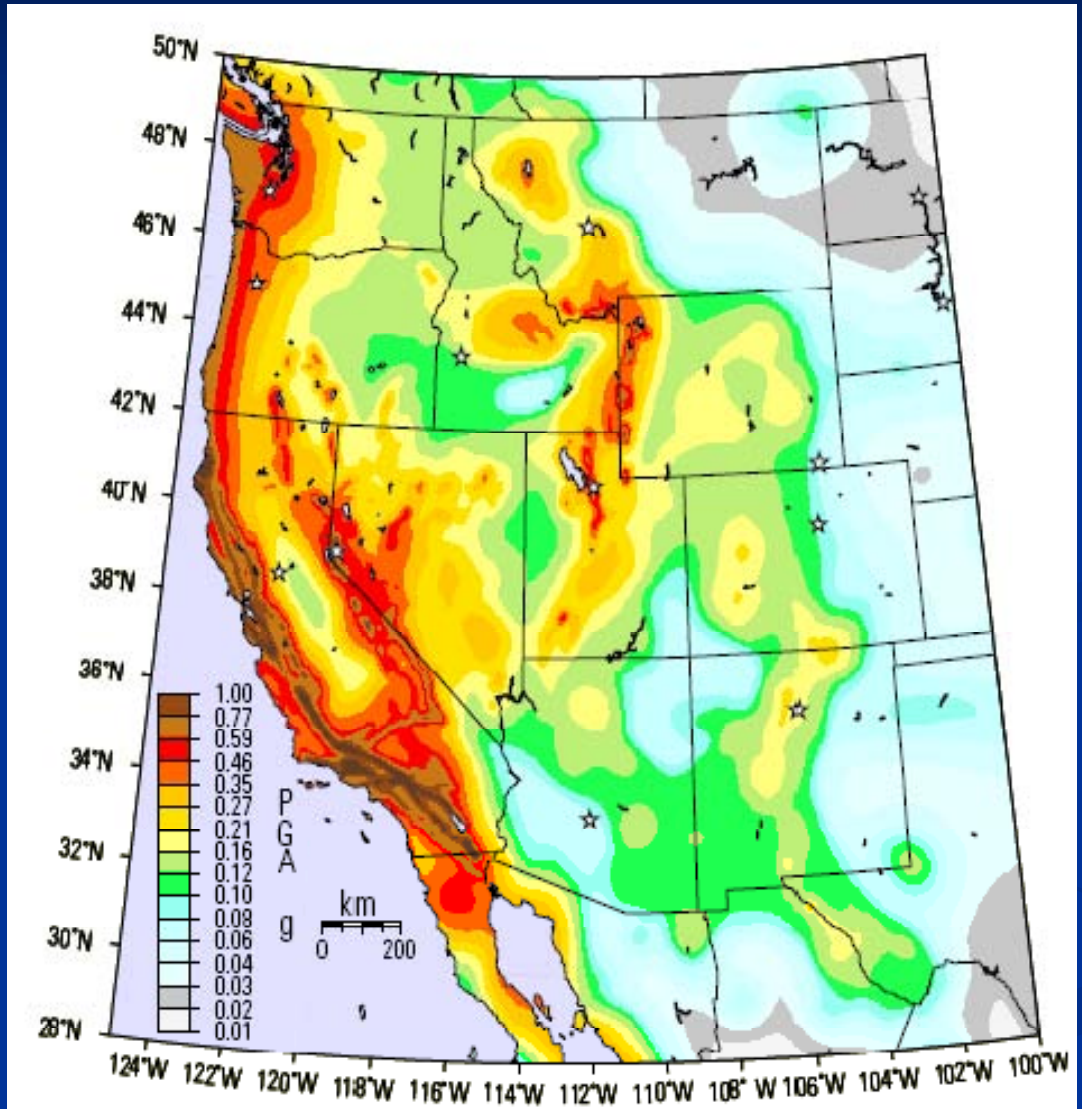


Figure 36. Map of 5-hertz spectral acceleration (SA) for 2-percent probability of exceedance in 50 years in the Western United States in standard gravity (g).

Earthquakes Damage & Losses

1994 Northridge, CA (M6.7) 60 killed & >$40 billion losses

1995 Kobe, Japan (M6.9) >5,500 killed & $200 billion losses

1999 Chi-chi, Taiwan (M7.6) 24,000 killed & $15 billion losses

2001 Gujarat, India, 20,023 killed

2003 Bam, Iran, 26,200 killed

2005 Pakistan/India, >80,000 killed

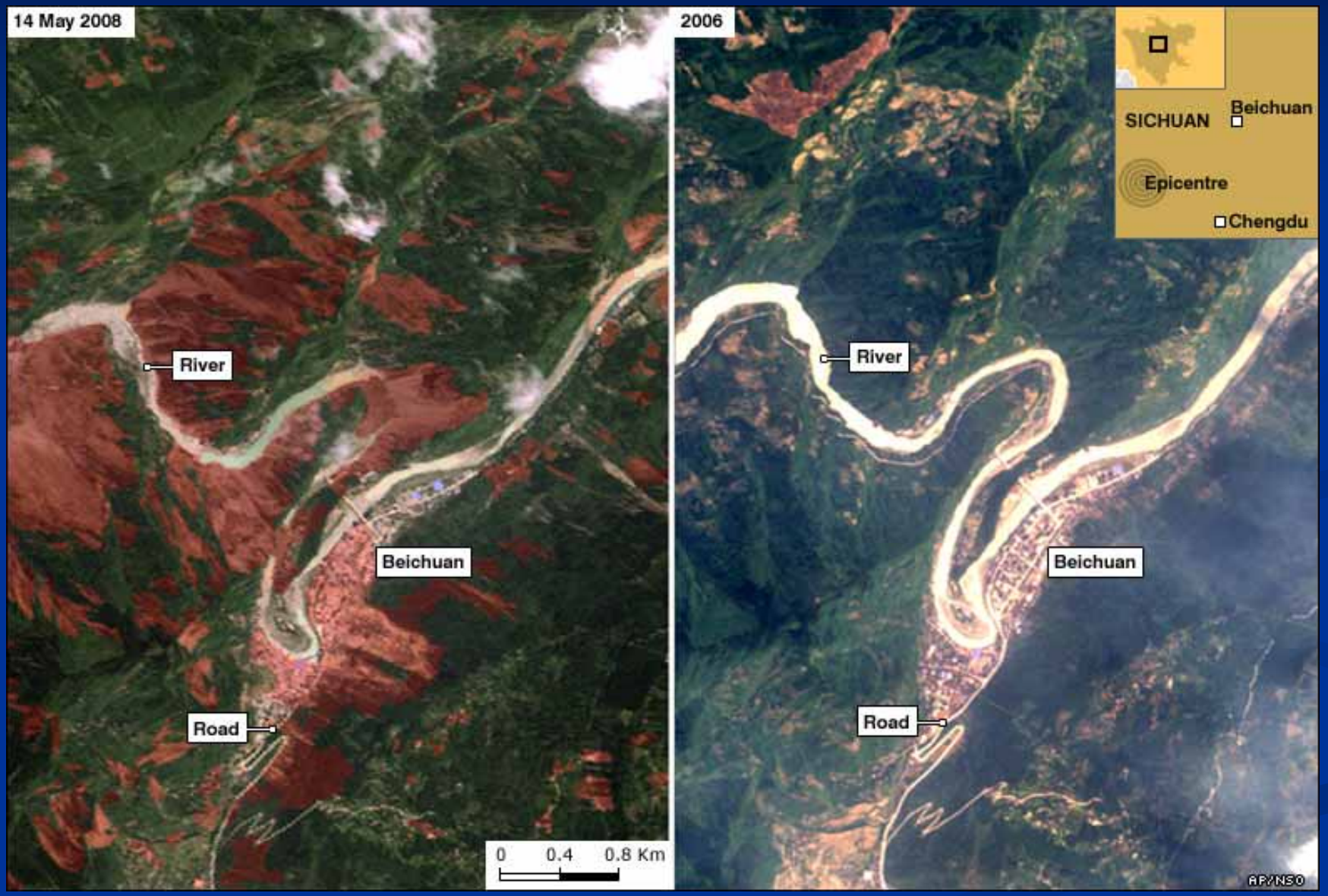
2008 China (M7.9), >70,000 & counting

May 12, 2008 China Quake

- Sichuan 7,000 dams, 70% built 1950s - 60s
- 5/13 5pm inspections: safety problems at:
  - 391 reservoirs (2 big, 28 medium, 361 small)
  - 4 provinces
- Damage: foundations & dam structures, & bearing capacity loss
- 21 earthquake-triggered landslide dams ("barrier lakes")

http://www.probeinternational.org

Pre- & Post quake satellite image



http://news.bbc.co.uk/2/hi/asia-pacific/7404614.stm

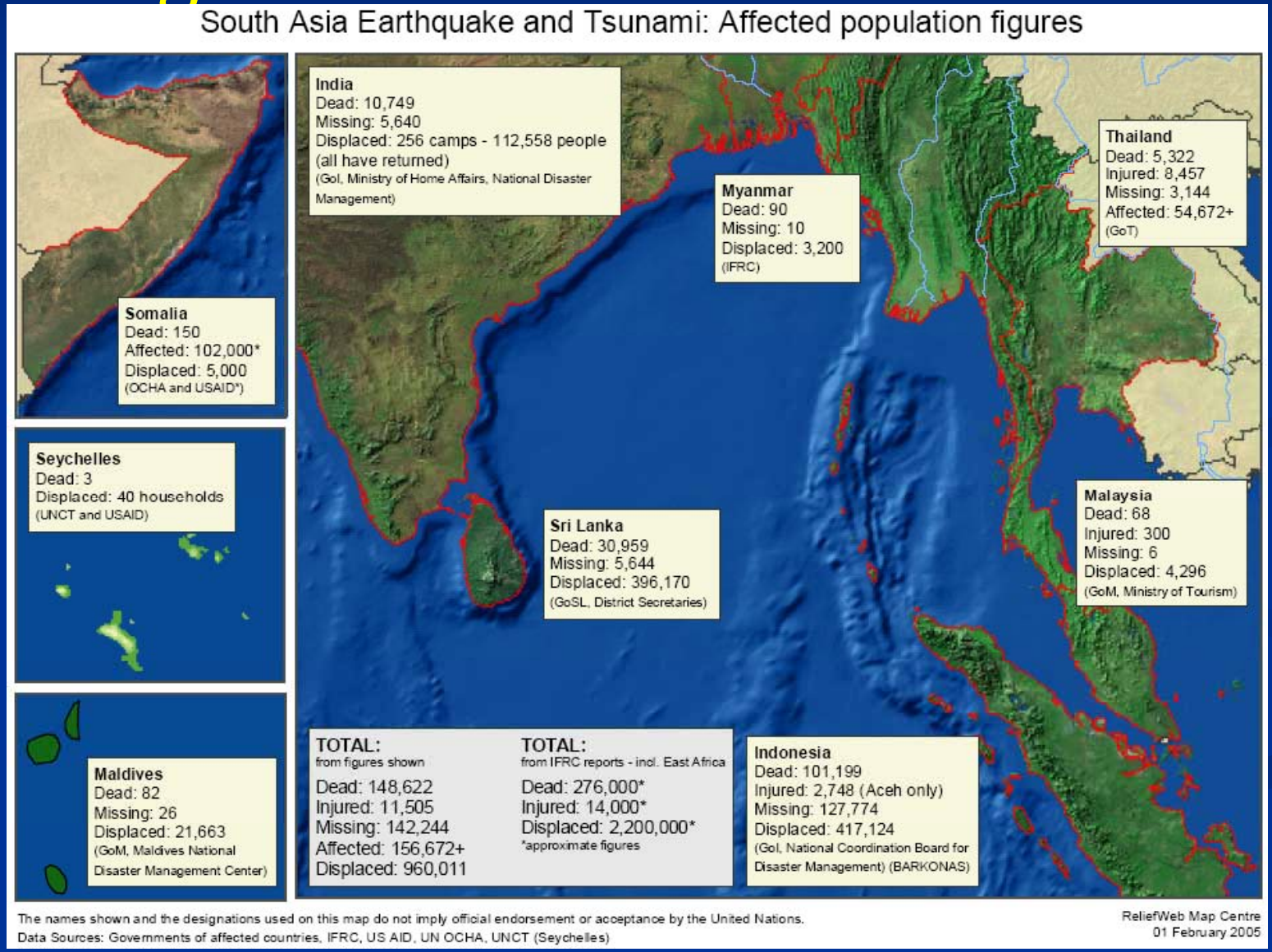
If the dam system had failed, Dujiangyan "would be swamped"

China Ministry of Water Resources. Photo: Guang Niu/Getty Images

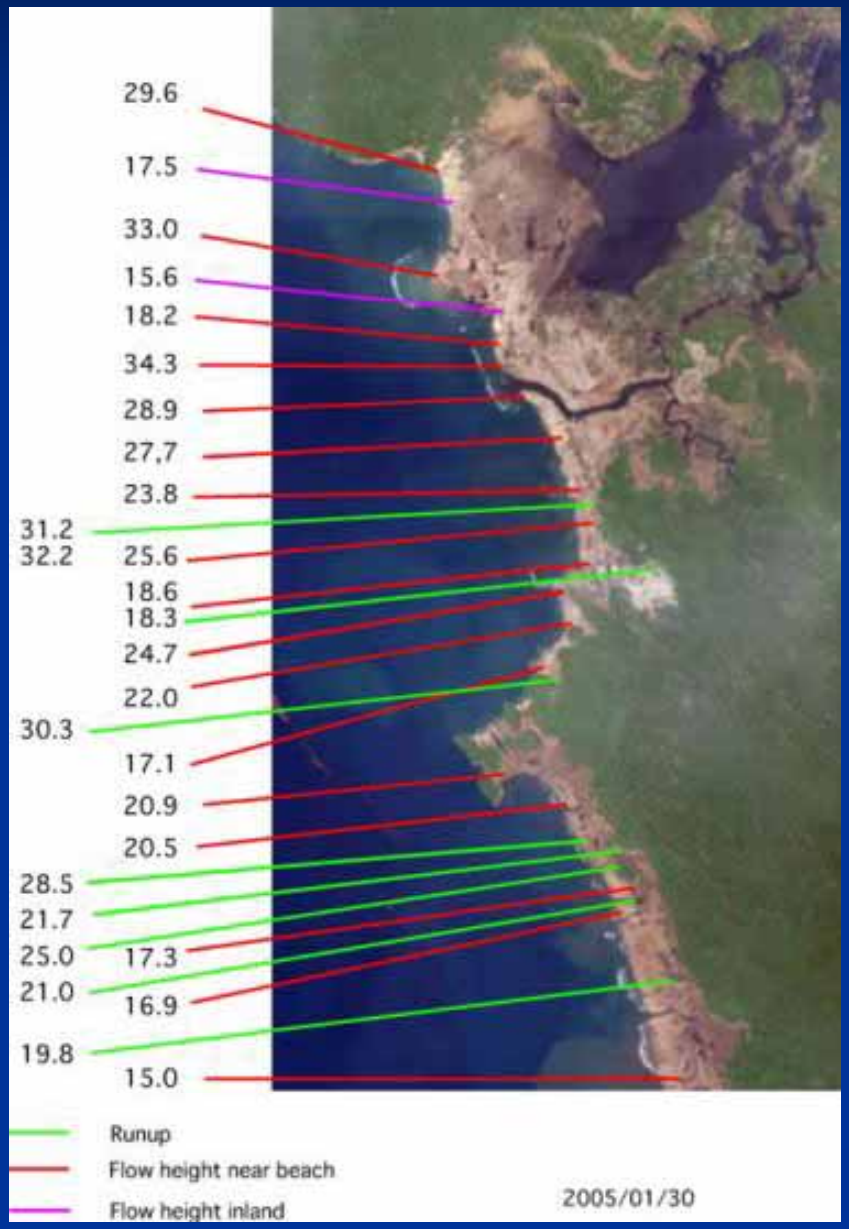
Subduction Zone Earthquakes: biggest & tsunamis

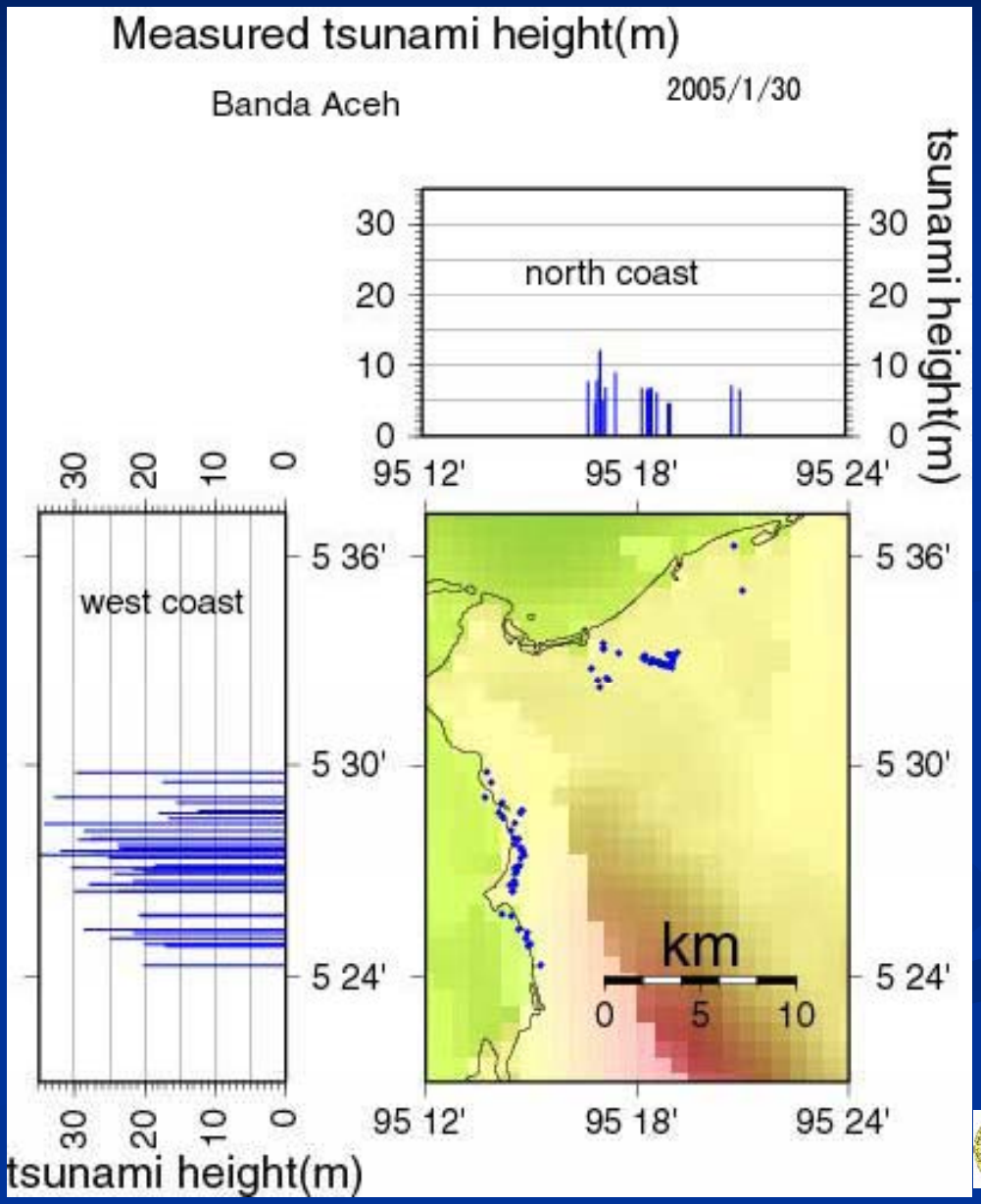
1939 Chile	M 7.8	28,000 killed
1960 Chile	M 9.5	>2,000 killed
1964 Alaska	M 9.2	15 killed
1970 Peru	M 7.8	>70,000 killed
1985 Mexico	M 7.9	9,500 killed
2004 Sumatra	M 9.1	230,000 killed

What Happened in Sumatra?
Magnitude 9.1 Subduction Earthquake
Shaking Felt Across the Indian Ocean



Tsunami Run Up Heights in Sumatra (100 ft)





Source: USGS

“Distant” Tsunami in Thailand

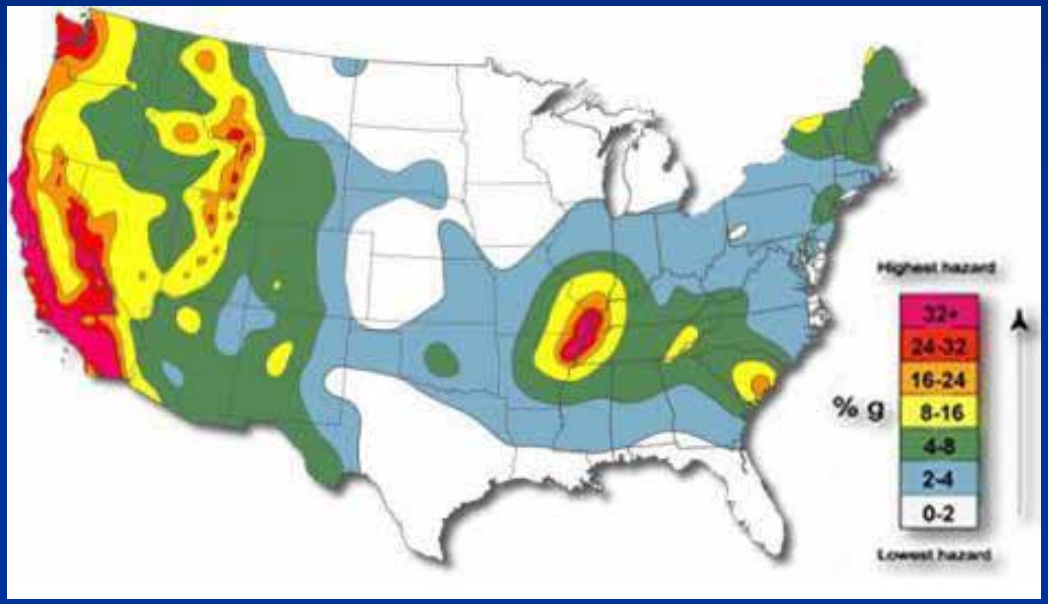
(Photographer: unknown)

Krabi (kodak)

Thailand's "Distant" Tsunami

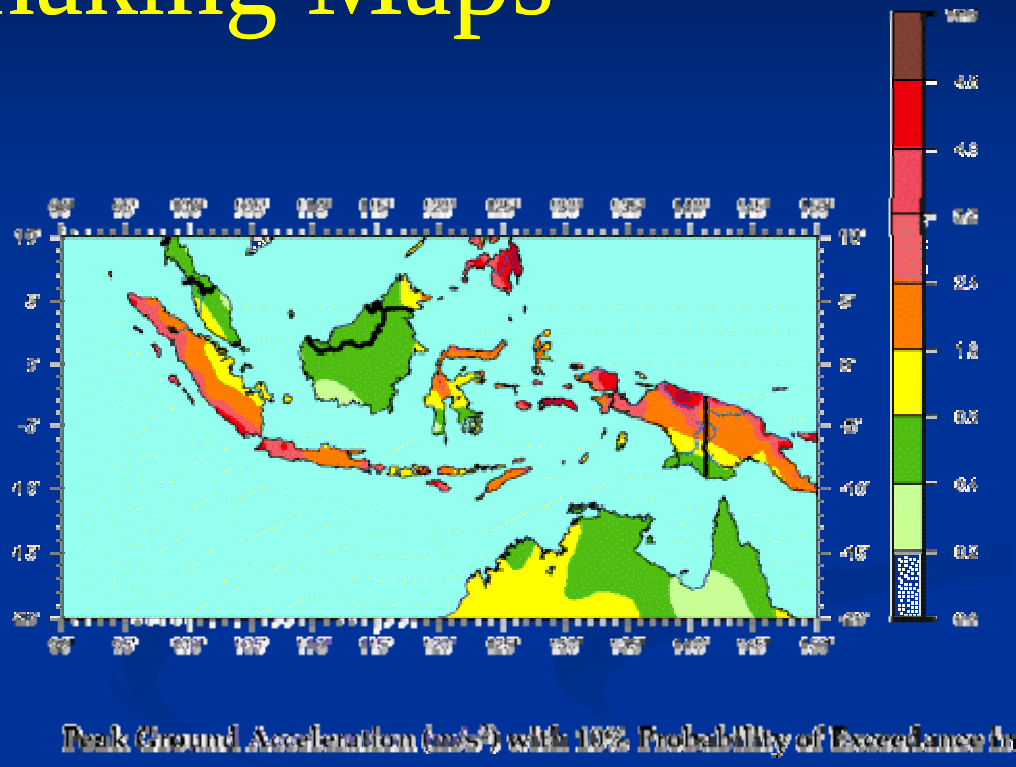
Khao Lak: Blue Village Pakarang before & after

United States & Indonesia Ground Shaking Maps



PGA 10 % probability of being exceeded in 50 yrs (on rock)

(USGS, http://eqhazmaps.usgs.gov)

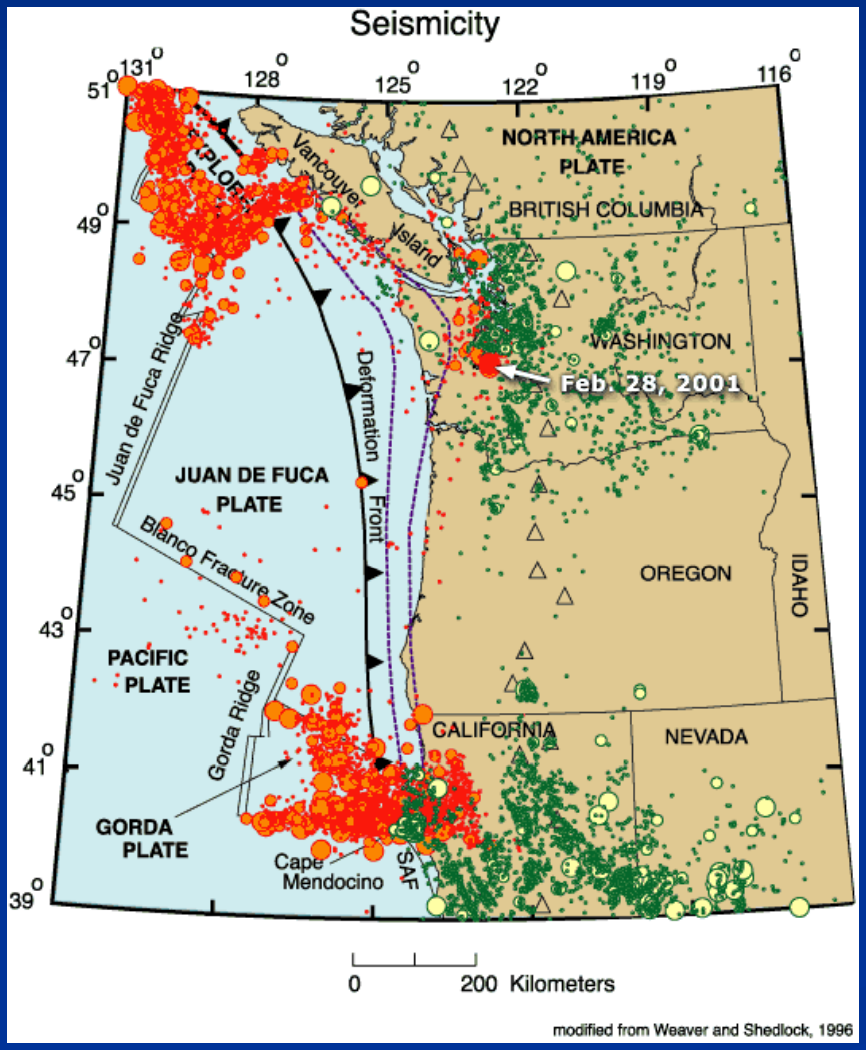


PGA 10 % probability of being exceeded in 50 yrs (on rock)

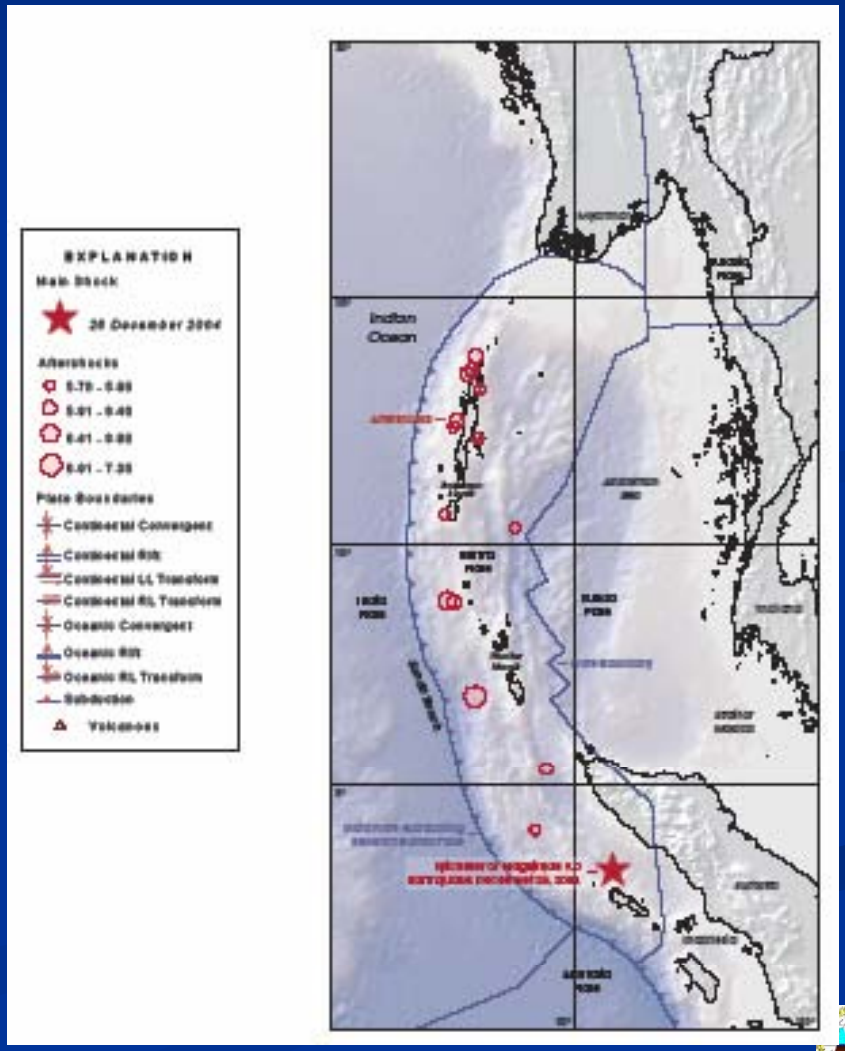
(USGS, http://neic.usgs.gov/neis/world/indonesia/gshap.html)

Comparing Plate Settings

Cascadia Subduction Zone
Pacific Northwest, US



Sumatra Earthquake:
Sunda Trench



(USGS, http://earthquake.usgs.gov/eqinthenews/2004/usslav/)

Comparing Damage Statistics

Sumatra Earthquake

- Magnitude 9.1
- Shaking for 10 minutes
- Generated Tsunami
- Long term recovery
- 230,000 fatalities
- Cost unknown
- Tsunami Hit 12 countries
- Strong shaking >125 mi

Cascadia "Model" Quake

- Magnitude 8.5-9
- Minutes of Shaking
- Generates Tsunami
- Long term recovery
- Est. >5k fatalities (Oregon)
- Est. building losses >$32 billion (in Oregon)
- Strong shaking in valley

Geologic Hazards

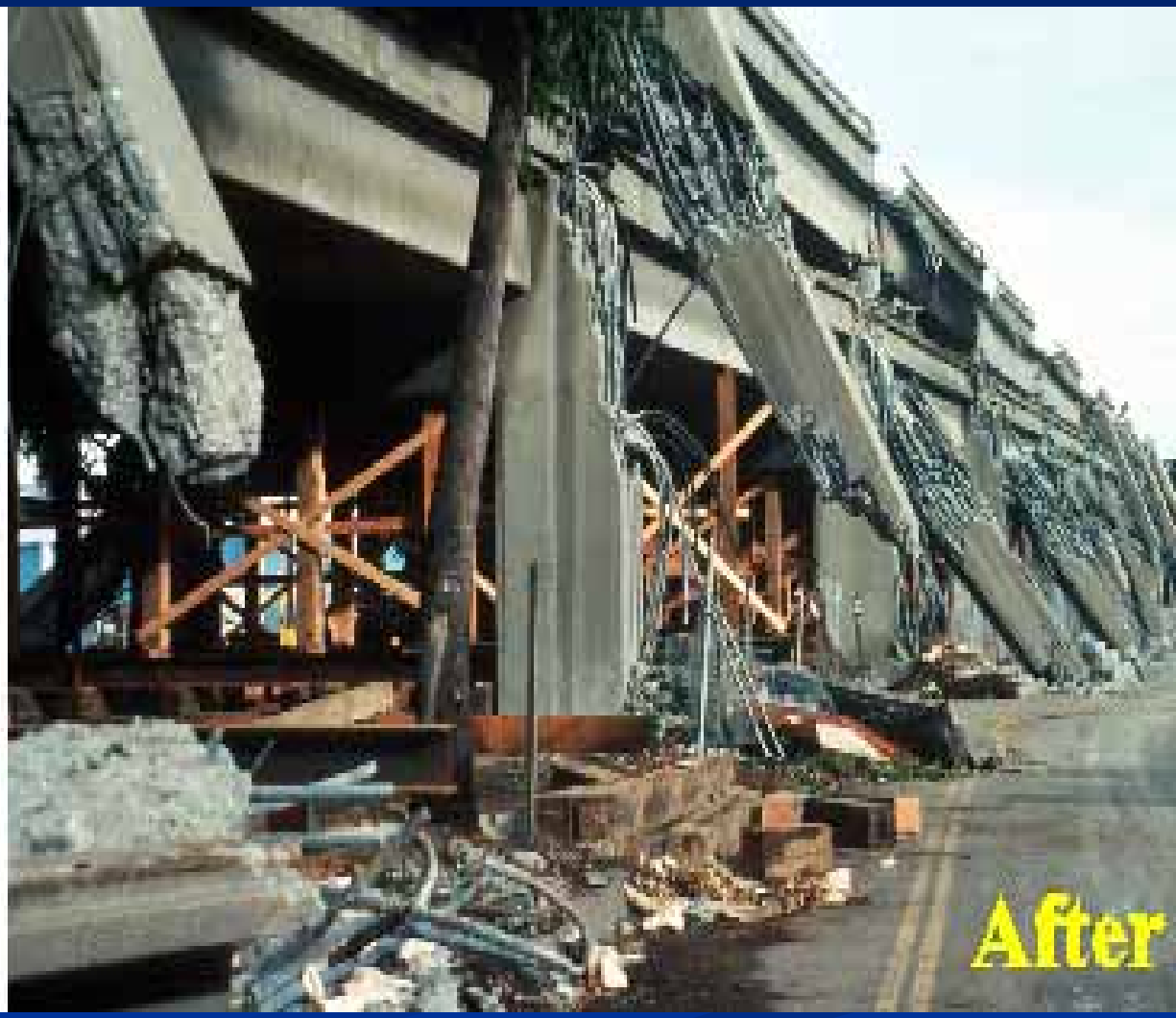
- Fault Rupture
- Ground shaking
- Ground response (Soil amplification)
- Liquefaction & lateral spreading
- Landslides
- Tsunamis

Fault Rupture

Fault rupture damage to dam

New water fall and collapsed bridge section caused by about 7 m of fault rupture

Shaking Amplification (soft soils)

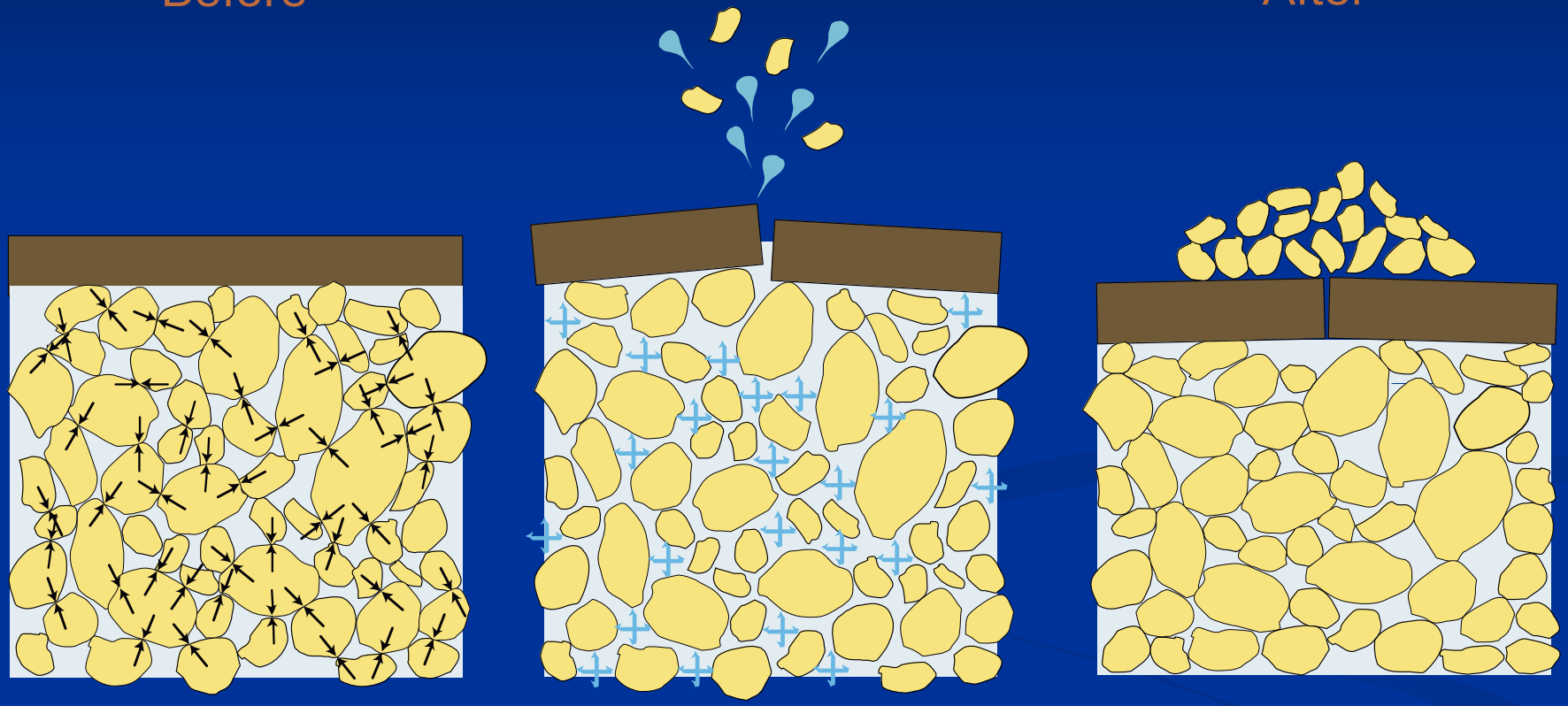


Soil Liquefaction

Before

During Shaking

After



Sand supports loads through grain-to-grain contacts

Fluid pressure rises
Grains float apart
Sand loses strength & can flow downhill
Water, sand ejected

Sand is compacted
Sand volcanoes on surface

Courtesy: ERoeloffs

Sand boils, Nisqually Wildlife Refuge.

Photo: Nisqually Earthquake Clearinghouse

Courtesy: ERoeloffs

Liquefaction at Waste water plant

Water Main broke at river crossing

Lateral Spreads at Sand mine by Incinerator

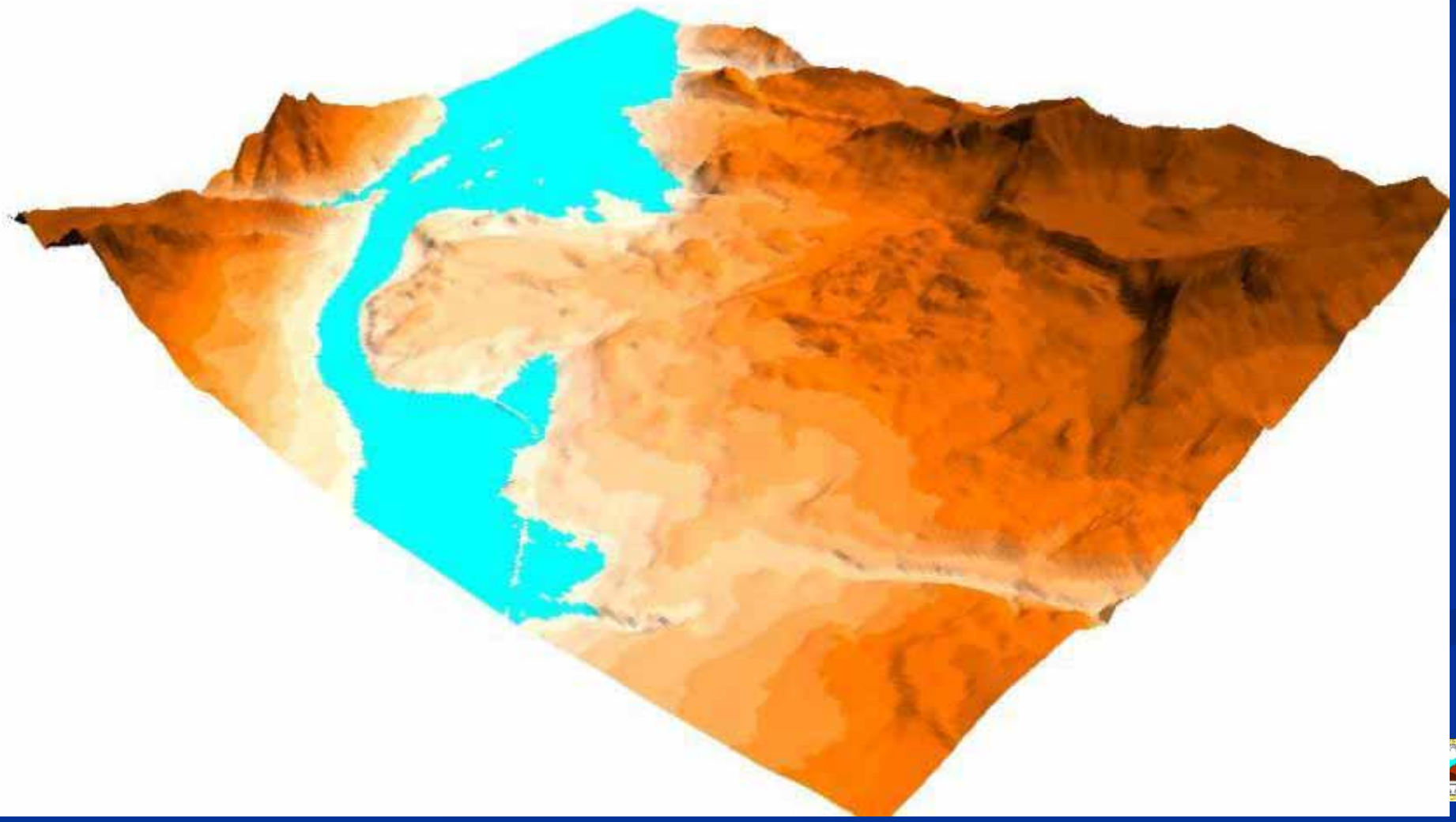
Photo credit: A.Tang

Lateral spreading at Port

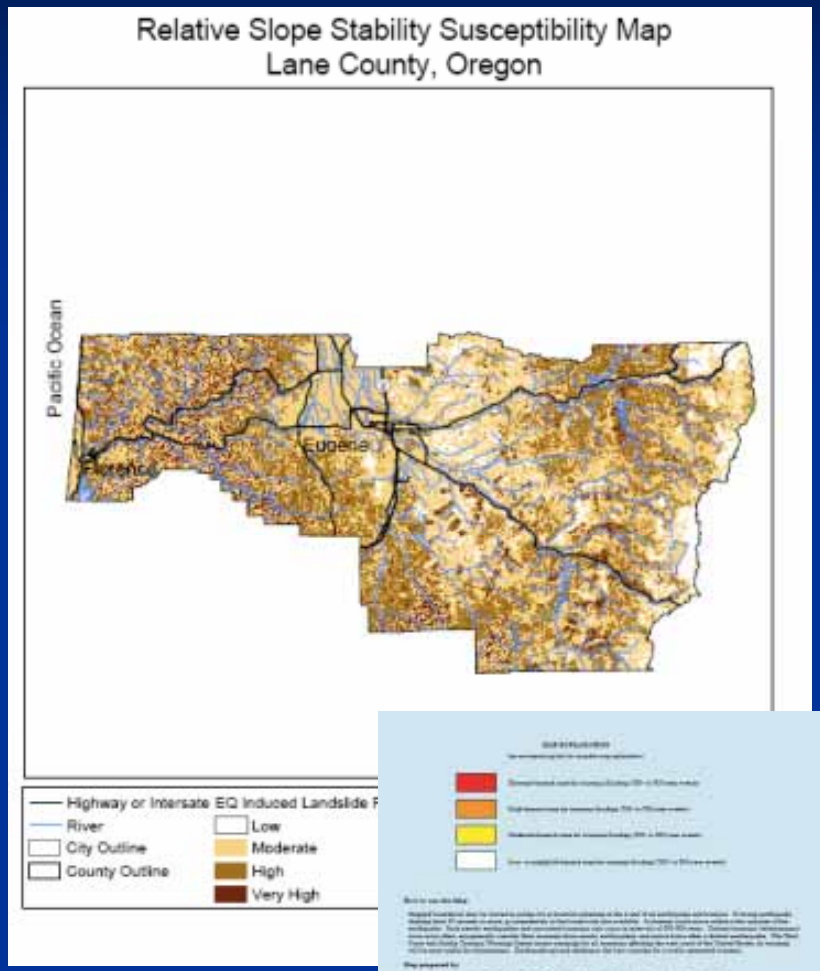
Coastal Highway landslides

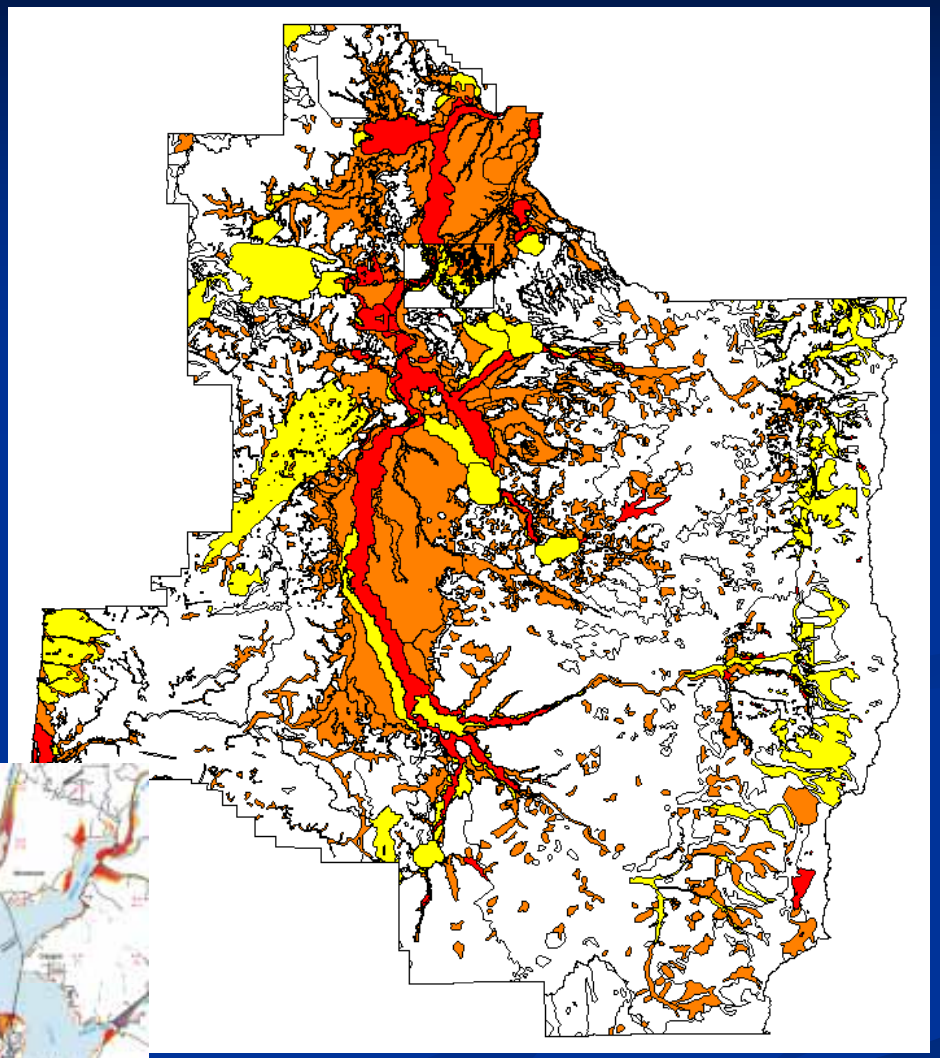
Bonneville Hydroelectric Facility on earthquake triggered landslide?

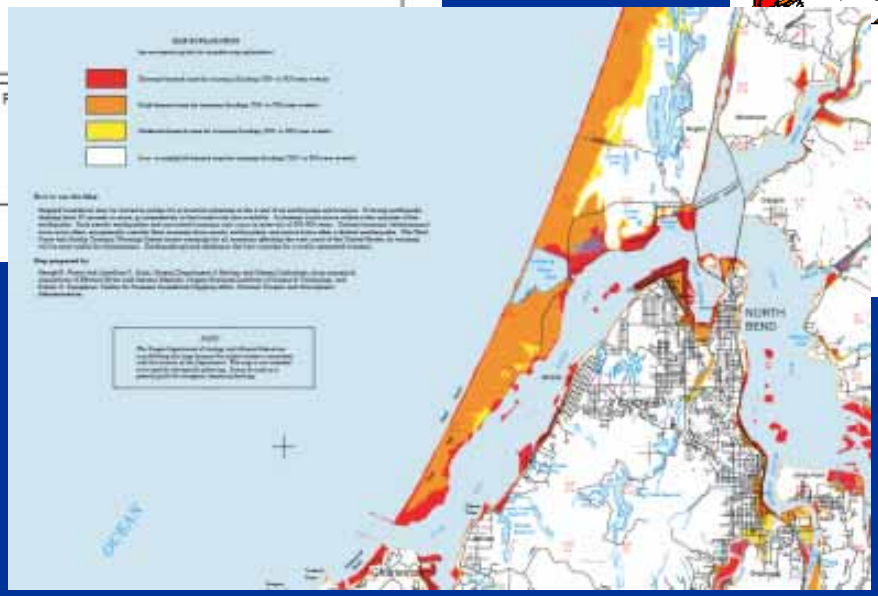
LANDSLIDE TRIGGERED BY EARTHQUAKE?



Hazard Maps: examples







Liquefaction hazards in Mid Willamette Valley

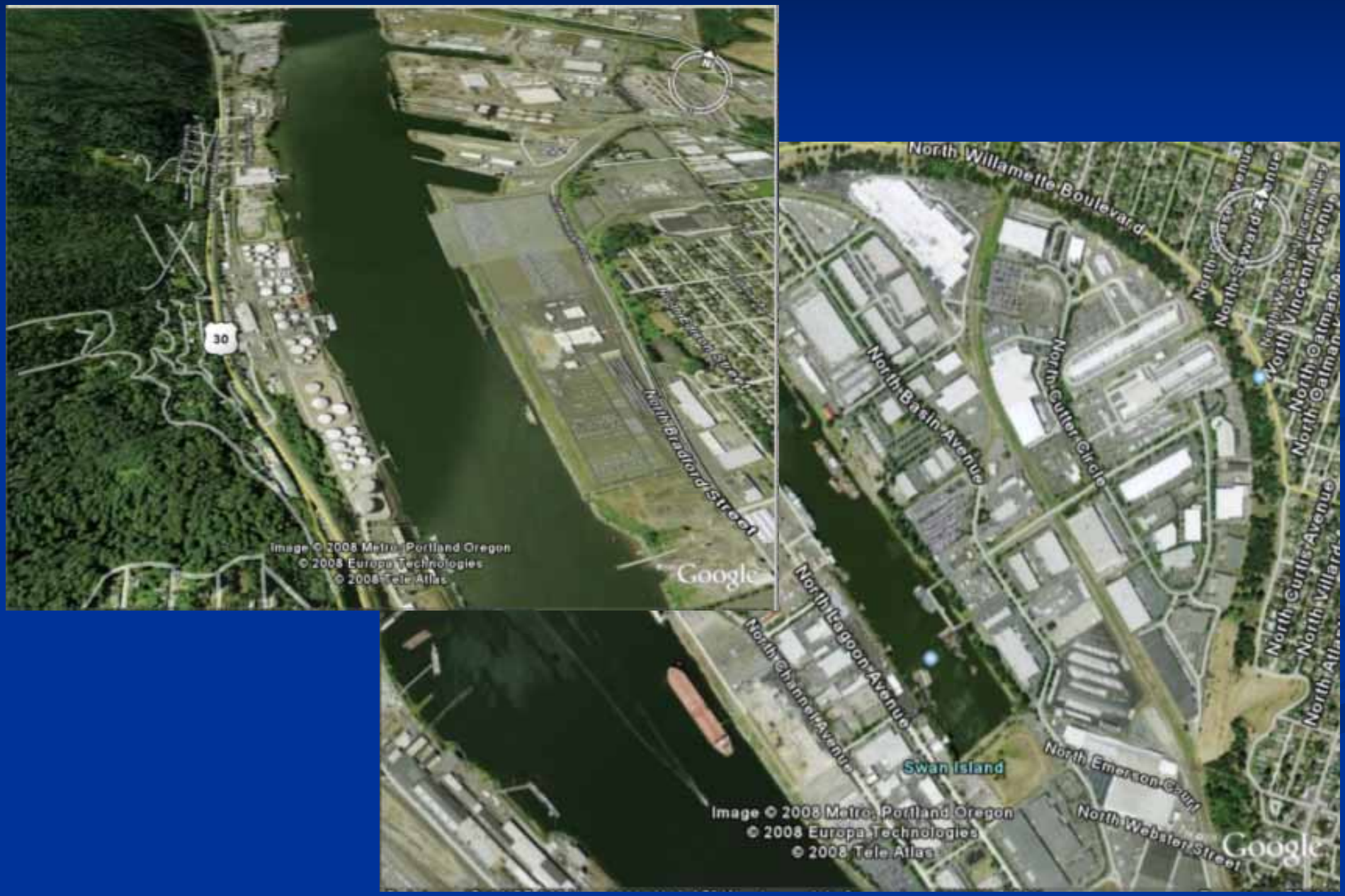
Exposure


port of portland
Projects, Plans and Studies
Troutdale Airport
Mulino Airport
Hillsboro Airport
Reynolds Industrial Site
Portland International Airport (PDX)
Terminal 2
Terminal 4
West Hayden Island
Rivergate Industrial District
Terminal 6
Terminal 5
E
N
S
W

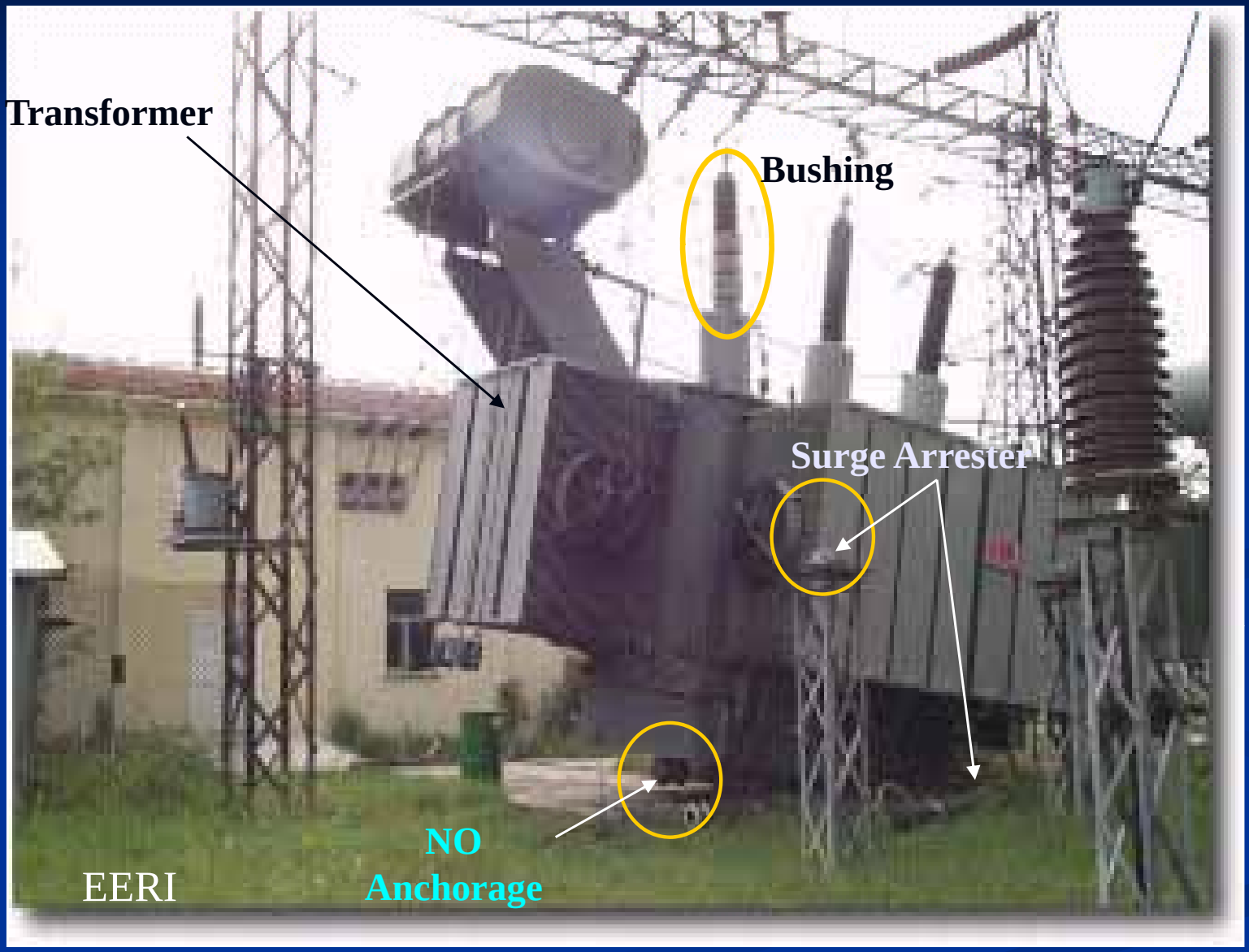

Airport Access
Portland International Center
Updates

Lower Willamette River

Willamette River, Portland



1999 Turkey M_w 7.4



Slide: Leon Kempner, BPA, 11/05

http://mdn.mainichi-msn.co.jp/photospecials/graph/070716earthquake/

1999 Taiwan M_w 7.3

Live Tank Circuit Breakers

Lightning Arresters

Ceramic Insulators

Gas Insulated Line Relays

Gas Circuit Switches

Rigid Bus Failures

Slide: Leon Kempner, BPA, 11/05

BATTERIES

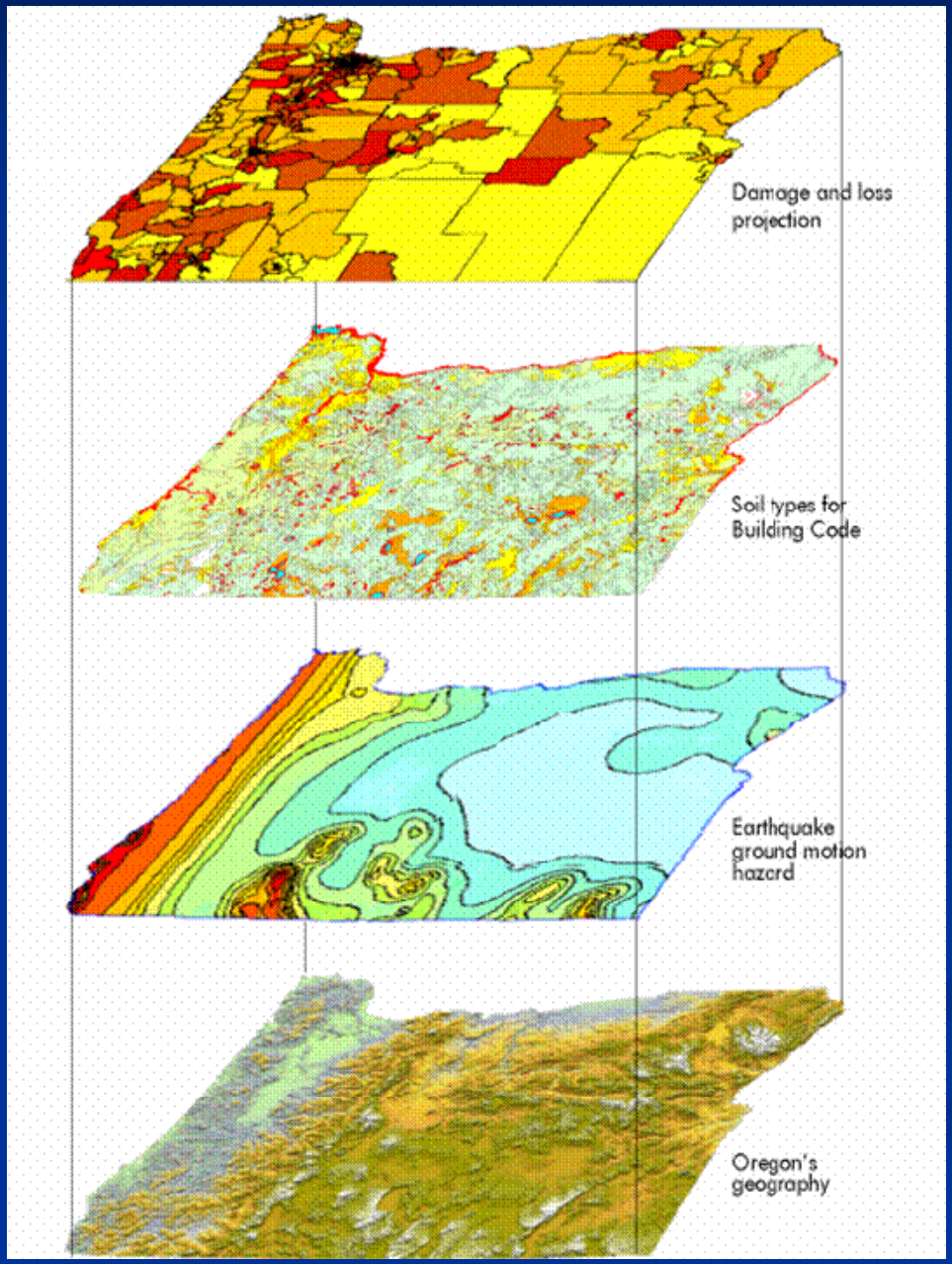
Matsuda

Back up batteries at cell control houses?

Taiwan

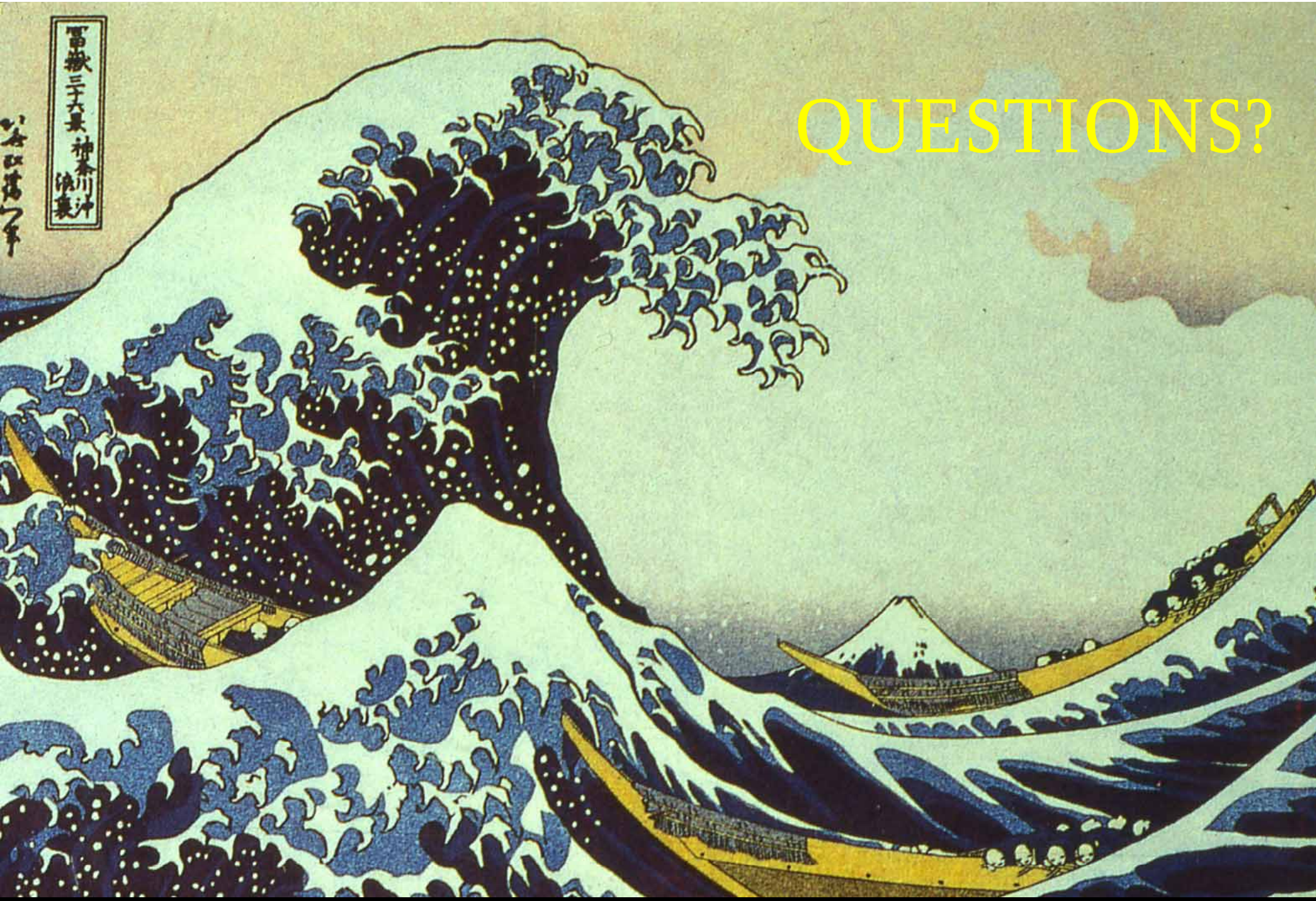
Slide: Leon Kempner, BPA, 11/05

Earthquake Risk Assessment

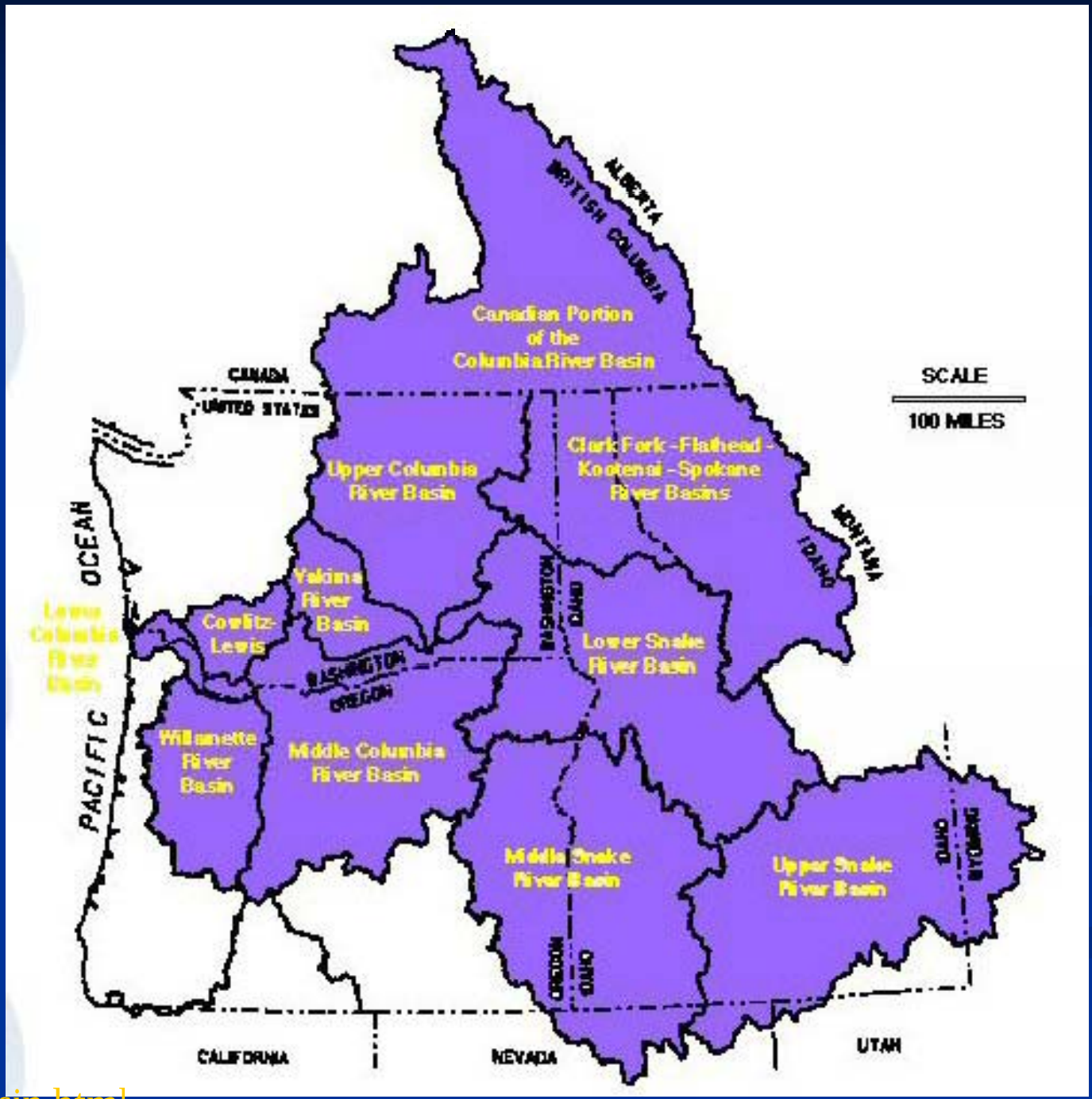


PREPARE

- System Seismic vulnerability assessment
- Interdependencies- e.g., water system- drinking, fight fires, cooling telcom, waste water, etc
- Long term, institutionalized mitigation program


QUESTIONS?

Columbia River Basin



www.fwee.org/basin.html

Ex. Considerations

- Falling hazards, rockfalls, etc

Bridal Veil I-84 off-ramp

I-84 E. of Hood River

Seismic risks considerations

- Evaluate hazards impacting transportation system- components, vulnerability, reliability, redundancy
- Risk Assessments: direct losses, indirect losses & functionality
- Asset management, emergency routes, priority routes (e.g., to hospitals), restoration plans
- Co-located lifelines (e.g., on bridges)
- Interdependencies (e.g., electricity for signage, movable bridges)
- Prioritized Mitigation
- Post disaster response

Some Recommendations

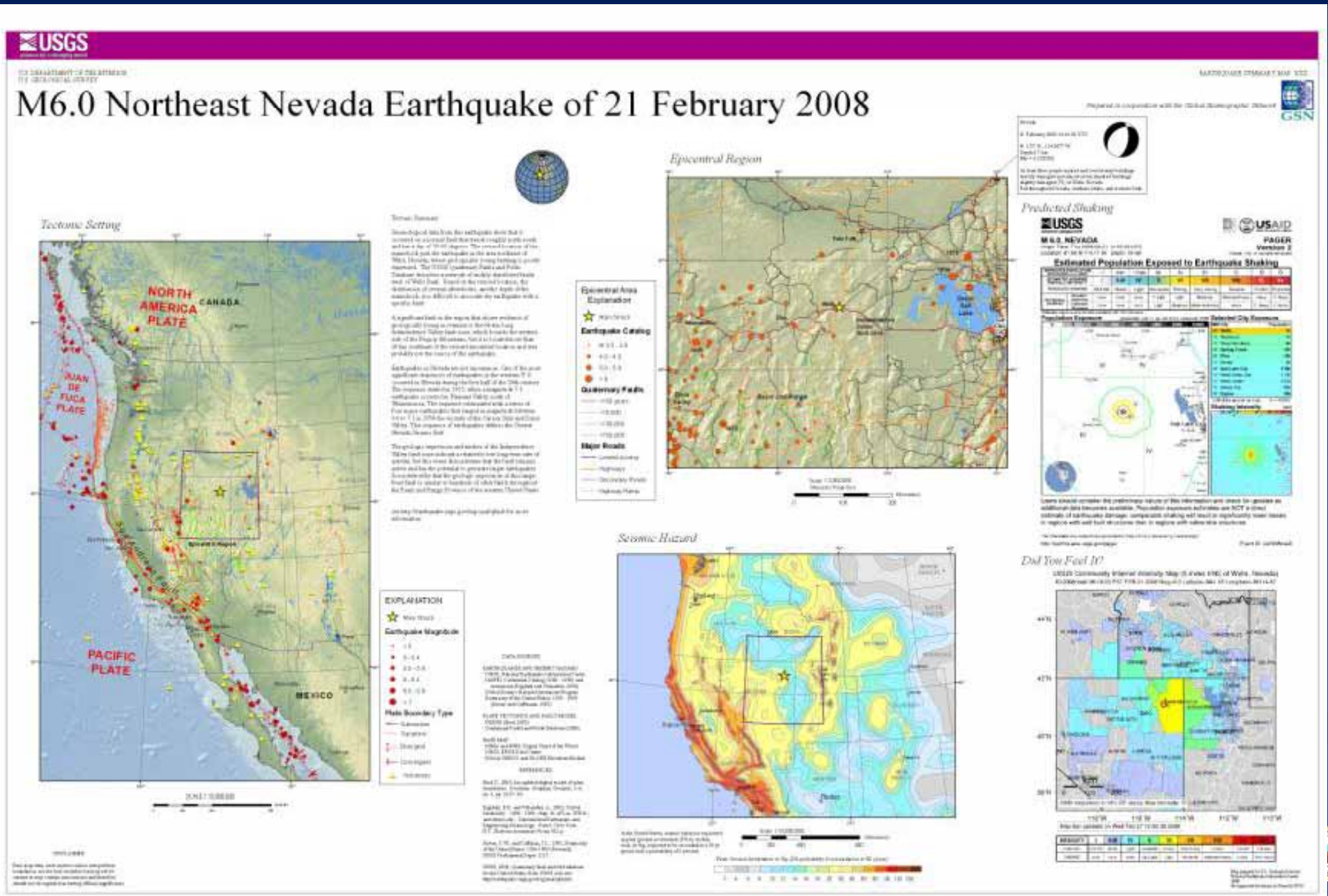
- Strengthen schools & emergency facilities
- Strengthen existing vulnerable communities
- Mitigate critical lifelines, incl. transportation
- Build smarter to avoid disasters
- Build tsunami evacuation buildings

Ex. Considerations

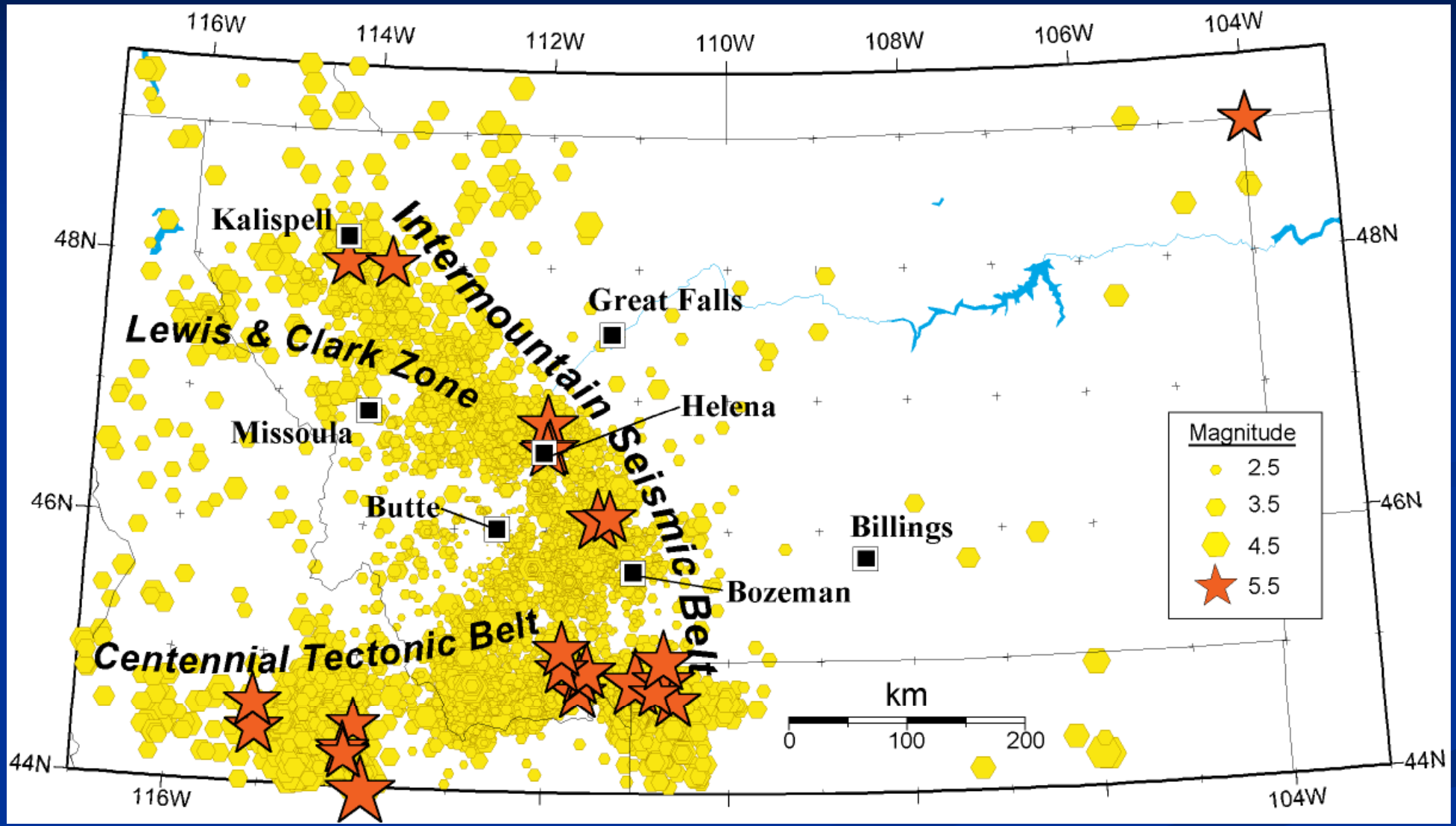
- Bridges (incl. movable bridges- poor performers)

Source: ODOT, Highway 35, 2006

USGS Poster of recent quake

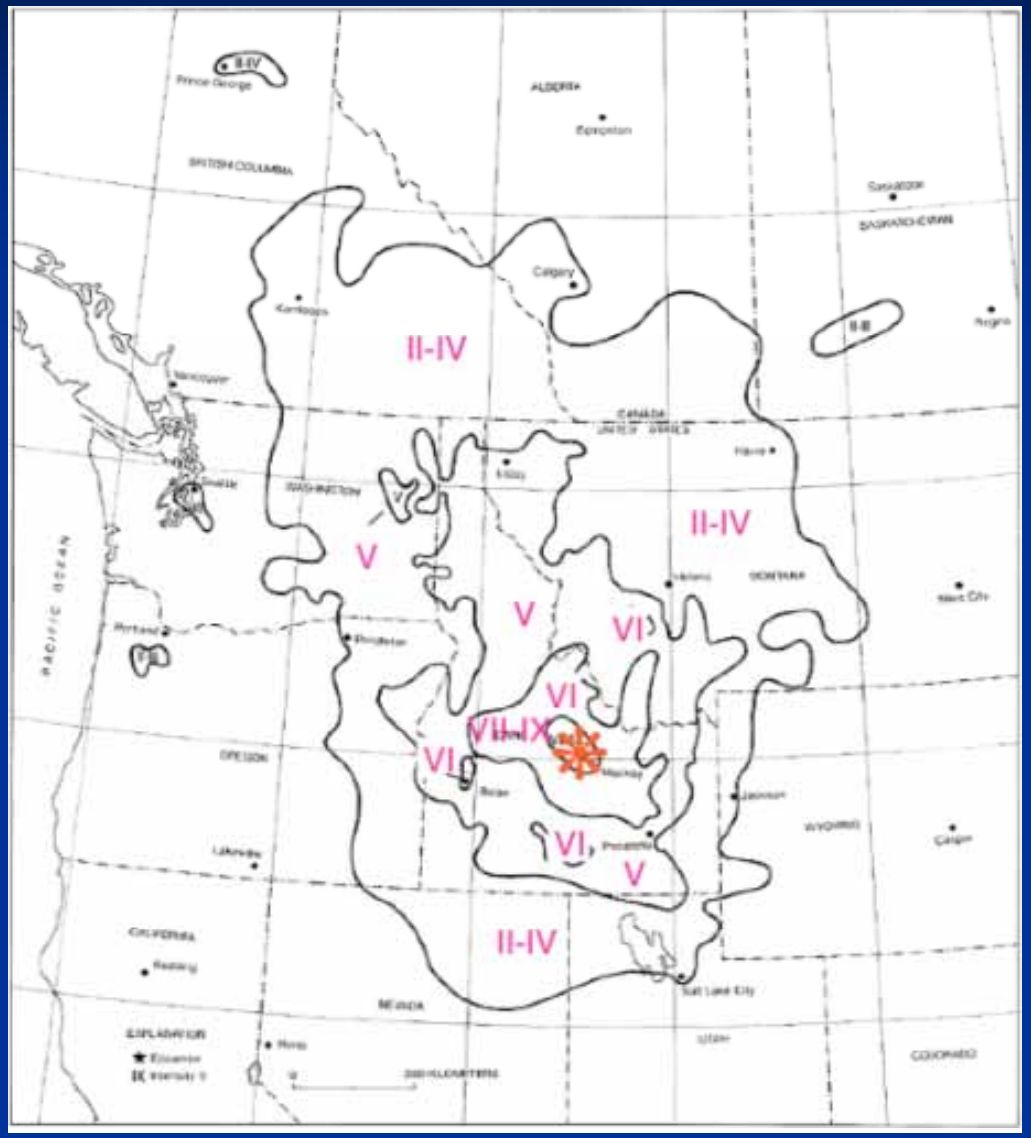


Seismic Belts Around Idaho



Courtesy: ERoeloffs

Earthquake Intensity: Perceived Shaking and Damage



Mercalli Intensity	Examples of Effects
I-III	Not felt or felt weakly
IV	Very light damage
V	Cracked Plaster
VI	Fallen Plaster, heavy furniture moved
VII	Chimneys broken
VIII	Great damage to poorly built structures. Changes in well water.
IX	Buildings shift off foundations. Underground pipes broken.
X+	Most masonry structures destroyed. Bridges and underground pipelines destroyed.

1983 Borah Peak Earthquake

- Magnitude 7.3
- Idaho's largest historic earthquake (so far)

Courtesy: ERoeloffs

Movable bridges

- XXX