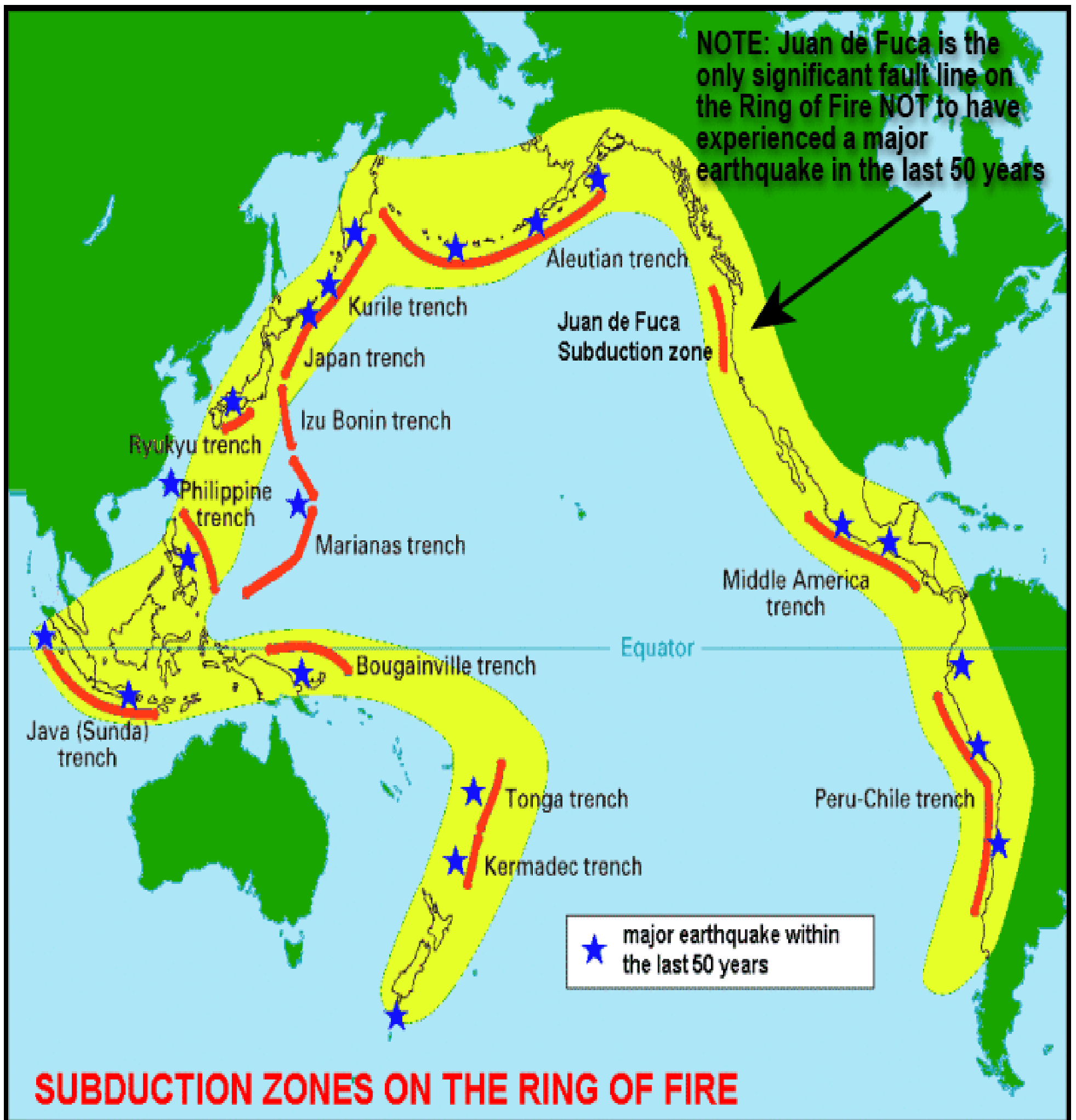


Ring of Fire



Source – Ed Taylor – Sep 2015 Governor's Safety Conference

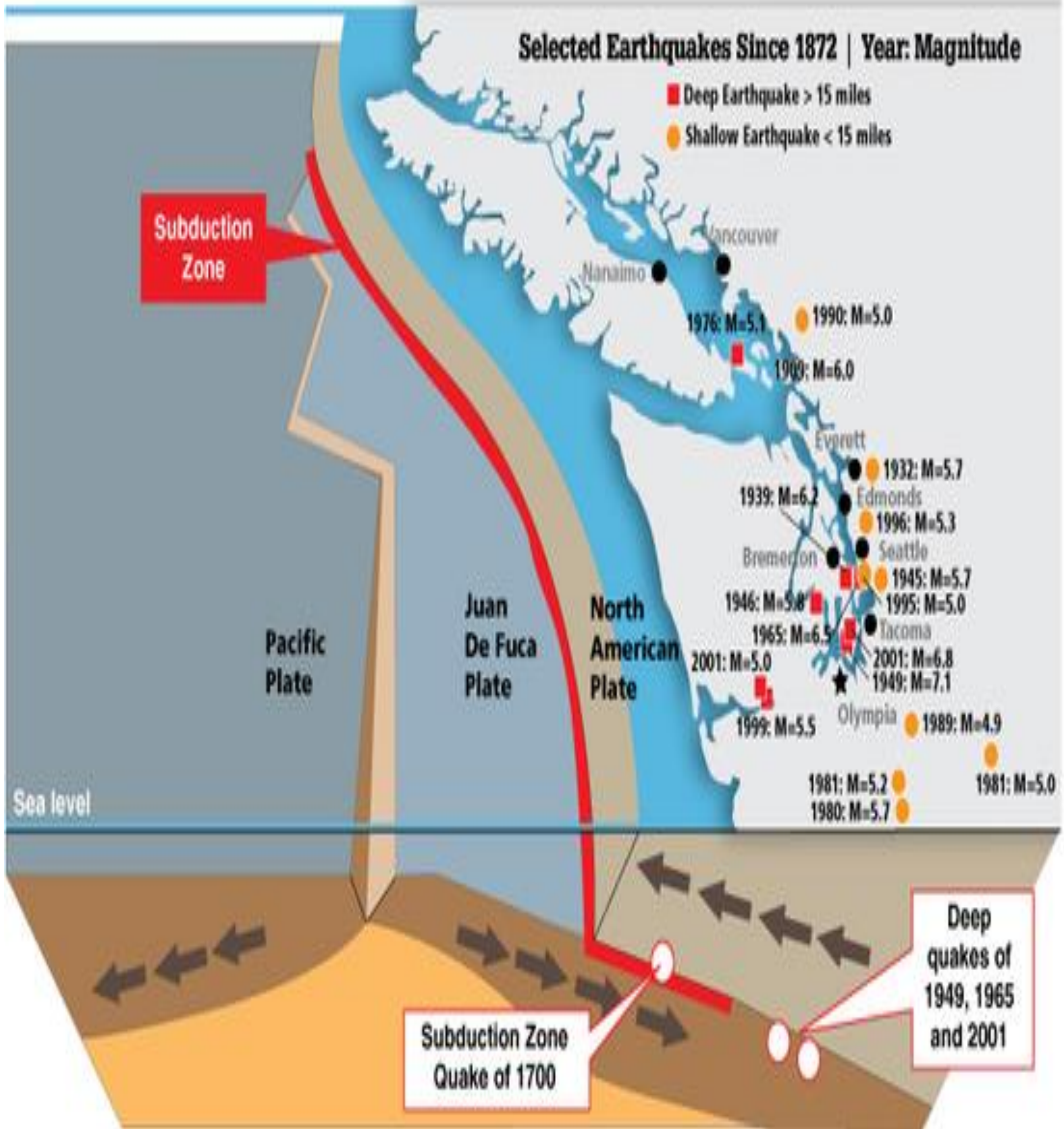
The Ring of Fire accounts for 90% of all earthquakes, and 81% of the world's largest earthquakes

Subduction zones are shown in red

The Cascadia Subduction Zone (CSZ) fault line is part of the Ring of Fire

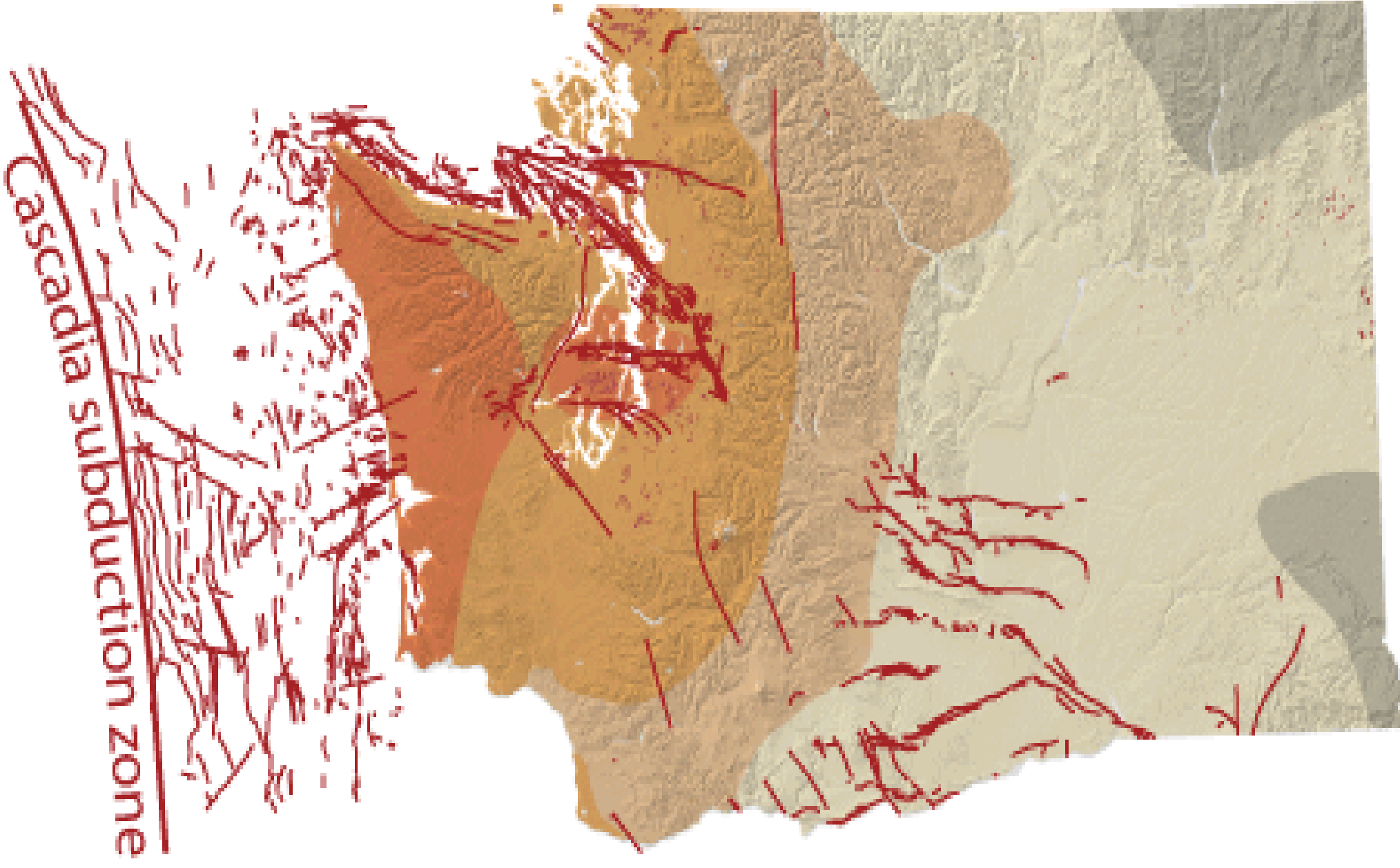
The CSZ is the only significant fault line on the Ring of Fire without a major quake in the last 50 years (see blue stars)

Types of Quakes and Depth in Washington



Subduction Zone Earthquakes Three types of earthquakes are represented in this cutaway view of the ground beneath Western Washington. Subduction earthquakes, which can reach magnitude 9, involve slippage between the North American plate and the Juan de Fuca plate being pushed under it. The last subduction quake in Western Washington occurred in 1700 and created a tsunami that washed up on the beaches of Japan. Deep earthquakes, which are more than 15 miles down, have caused the most damage in recent history. The 6-8 magnitude Nisqually quake in February 2001 was 32 miles deep. Shallow earthquakes, less than 15 miles down, include those along the Seattle fault, which runs across Bainbridge Island and through Central Kitsap. About 1,100 years ago, an earthquake greater than magnitude 7 occurred on the Seattle fault, raising the south end of Bainbridge Island by 21 feet.

Seismic Risk from High to Low



Shaking Hazard

Earthquakes

— Potentially active faults

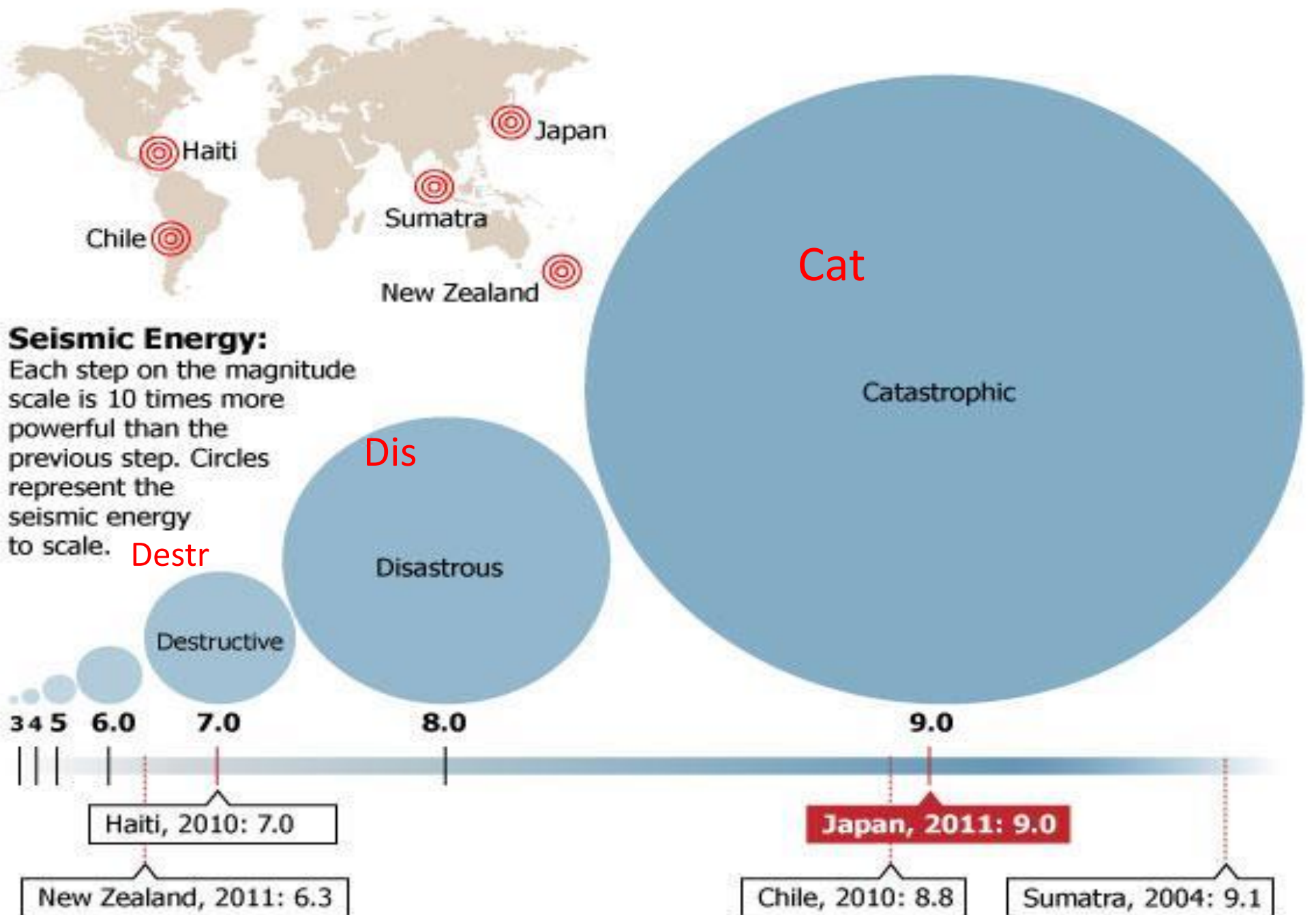


This map shows areas of seismic risk from high (red) to low (grayish-green) and is from a 2007 report on the seismic design categories in Washington.

What does a 9.0 Mean?

Magnitudes of Recent Earthquakes

The earthquake off the east coast of Honshu, Japan's largest island, was the fifth-largest ever recorded, according to the U.S. Geological Survey (USGS), and the largest ever recorded in Japan. How it compares in magnitude with other major earthquakes:



SOURCES: USGS, WASHINGTON POST

ROSS TORO, www.OurAmazingPlanet.com

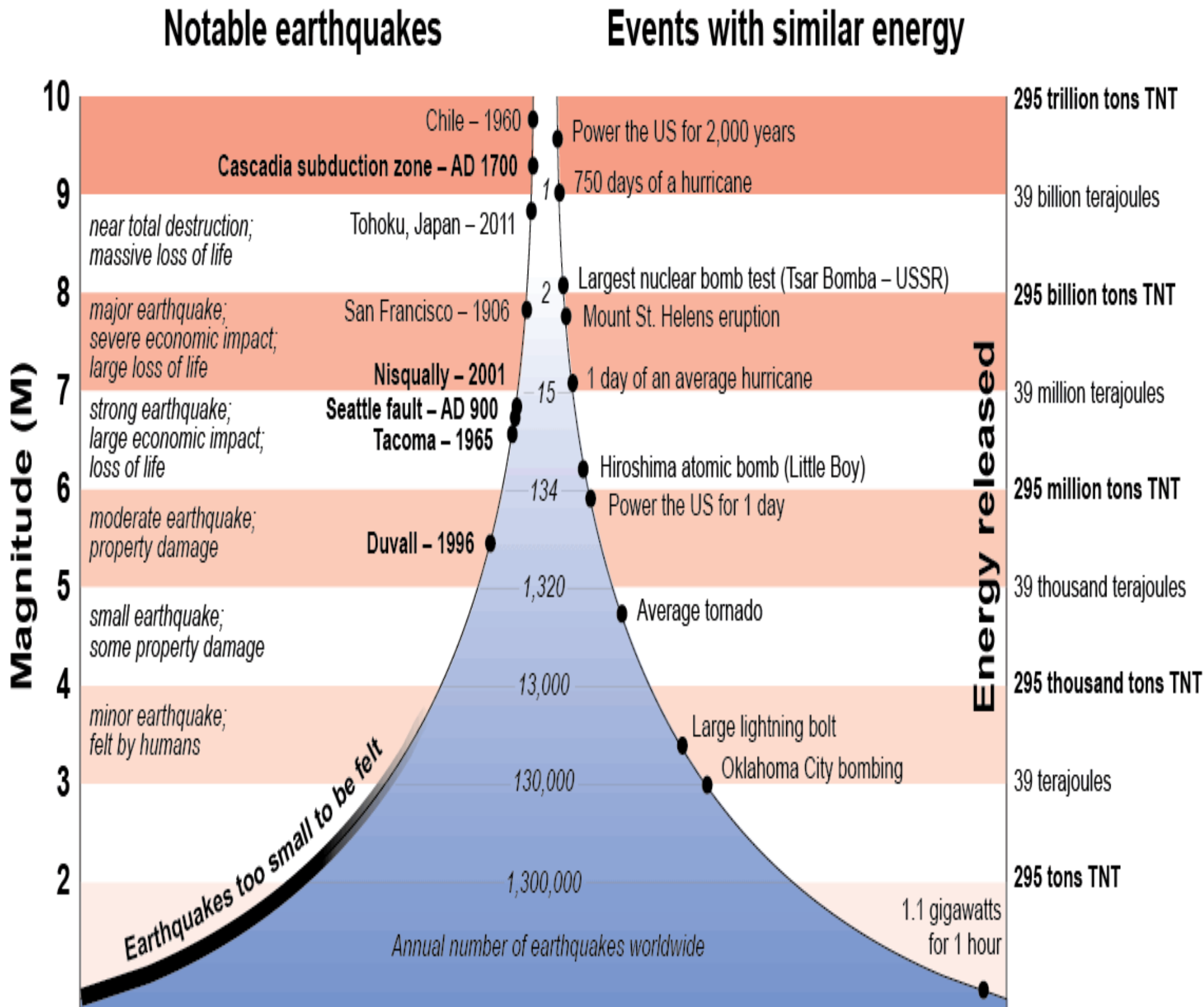
Source – Ed Taylor – Sep 2015 Governor's Safety Conference

9.0 Magnitude Quake will be 100 times more powerful than the earthquake that hit San Francisco in 1989.

9.0 vs. 6.3 Magnitude - New Zealand Quake will be 32,000 times more in energy released

Energy and Frequency

Earthquake energy and frequency



Earthquake data and frequency from USGS at <http://earthquake.usgs.gov/earthquakes/eqarchives/year/eqstats.php>

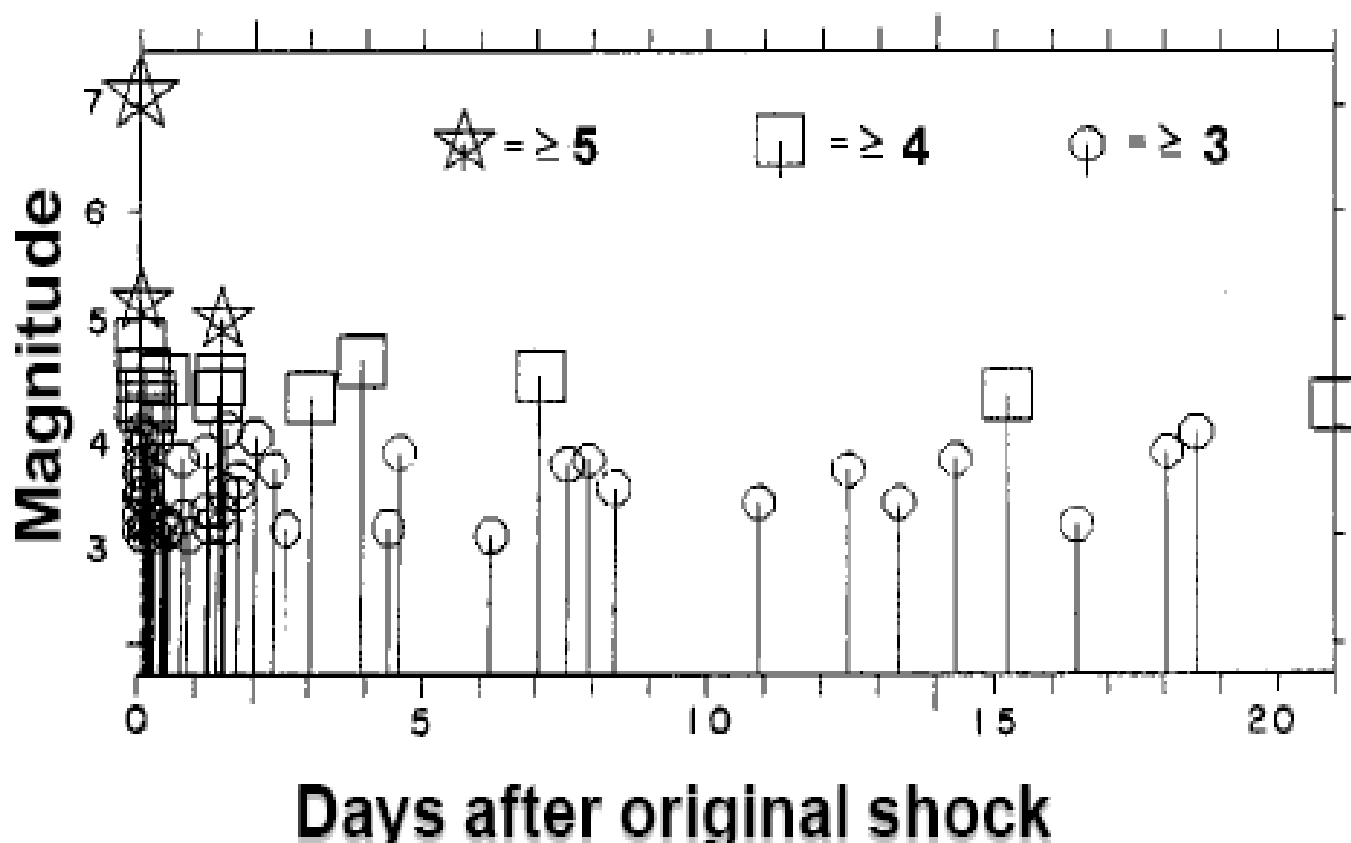
Energy released and events from <http://alabamaquake.com/energy.html> and [http://en.wikipedia.org/wiki/Orders_of_magnitude_\(energy\)](http://en.wikipedia.org/wiki/Orders_of_magnitude_(energy))

Earthquake Aftershocks

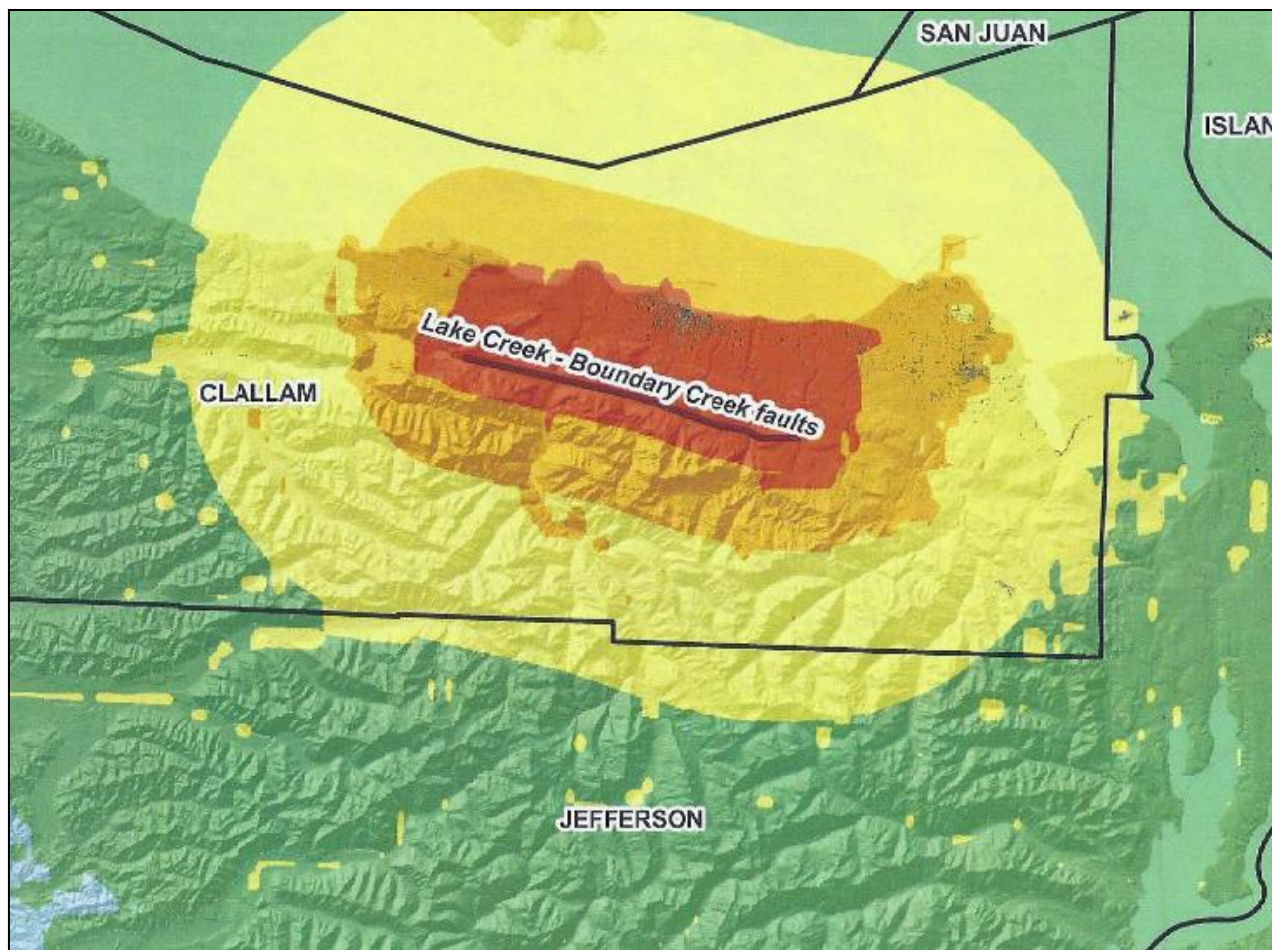
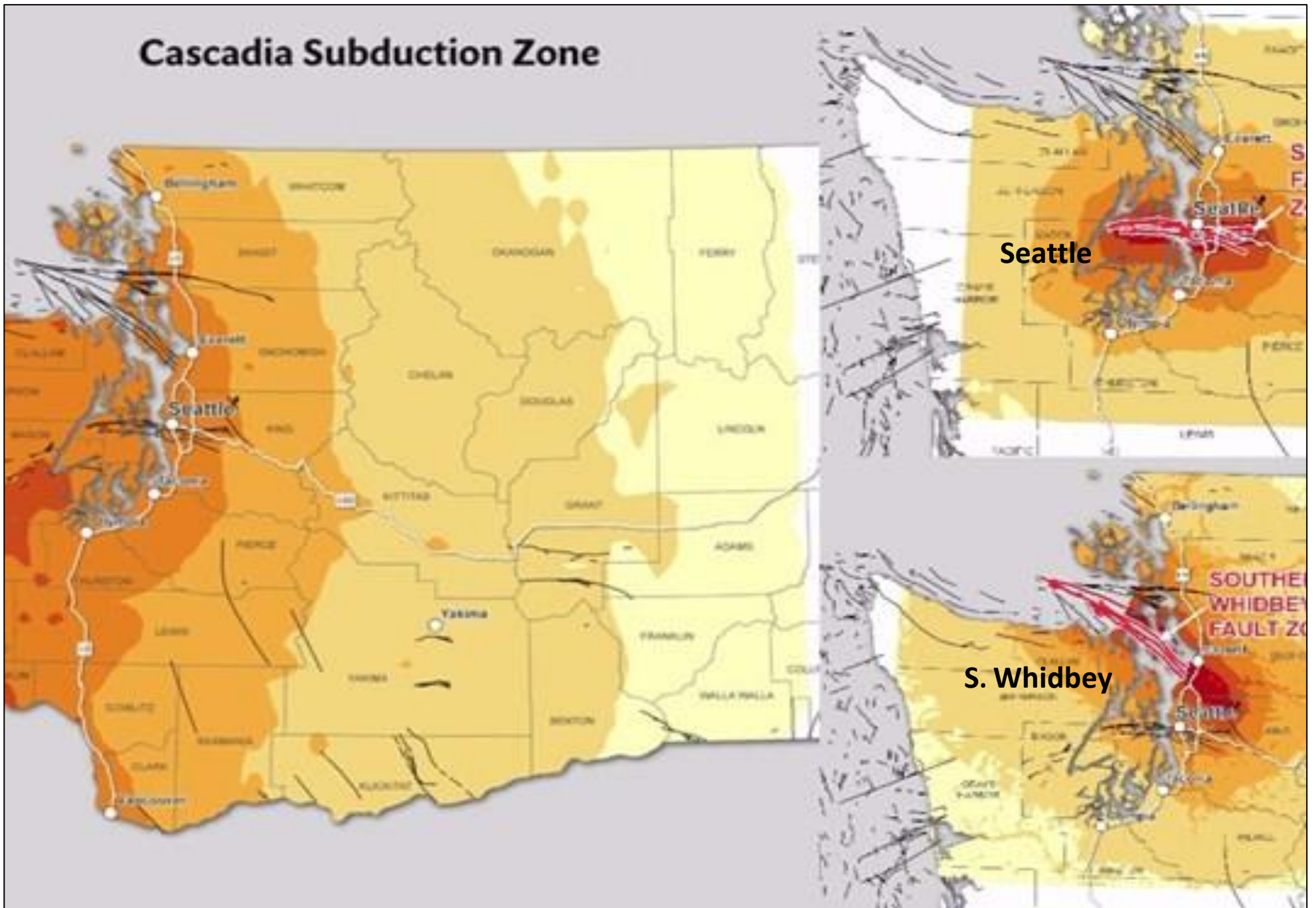
How Many Aftershocks ?

- USGS - Rule of Thumb
 - For every single decrease in magnitude, get 10 fold increase in number
- If original quake is M 7
 - 1 or so aftershock in range of M 6
 - 10 " " " " 5
 - 100 " " " " 4
 - 1000 " " " " 3

1989 Loma Prieta Aftershocks

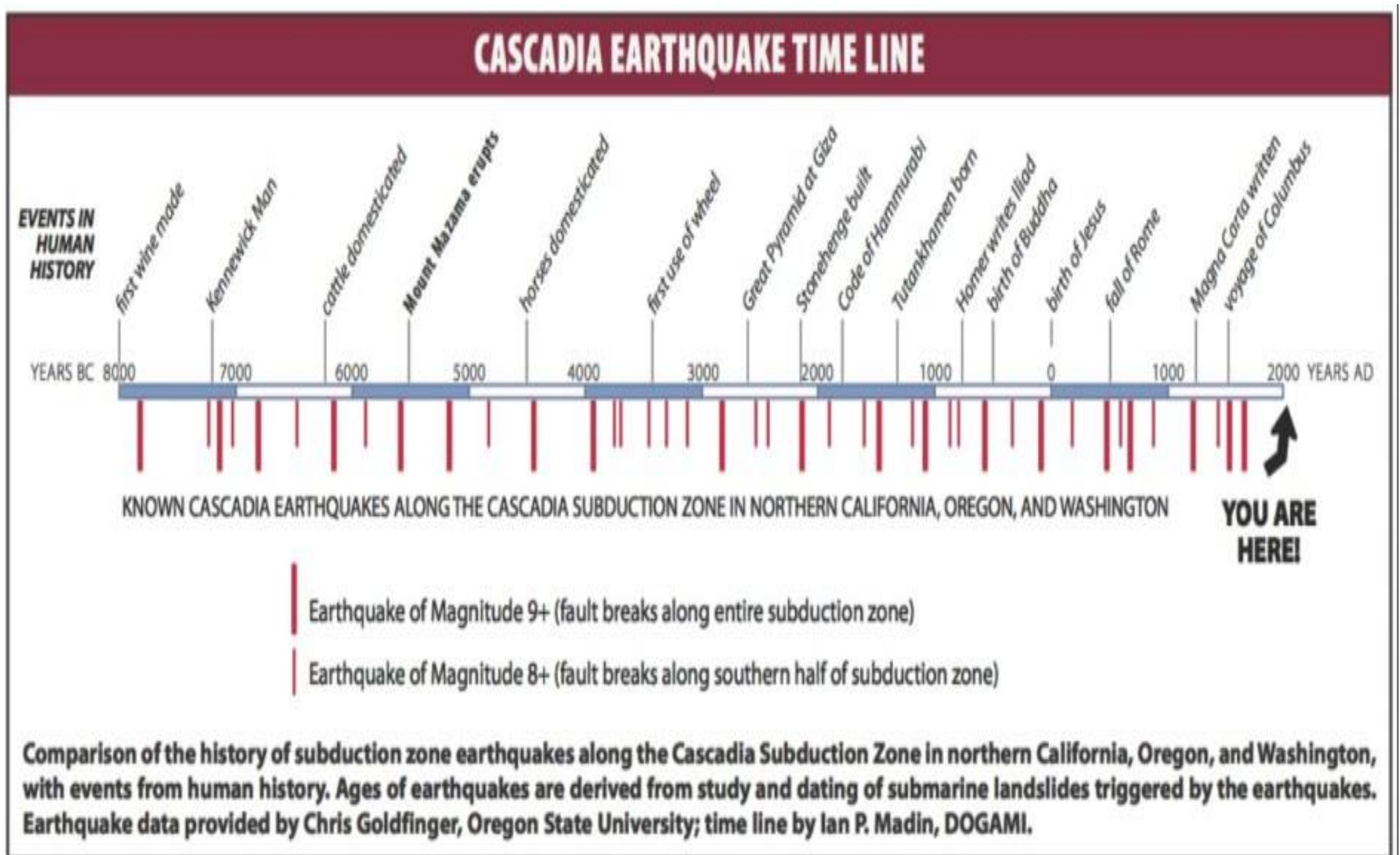


The Big 4 – Cascadia, South Whidbey Island, Seattle Fault, & Lake Creek



Clallam County has a fourth threat –
Lake Creek Boundary aka Lake Crescent

What Are the Odds?



Reduced to simple odds, the chances that an earthquake as large as magnitude 9.0 will occur along the zone within the next 50 years are about one in ten and one in three for magnitude 8.0

How Earthquakes are Measured

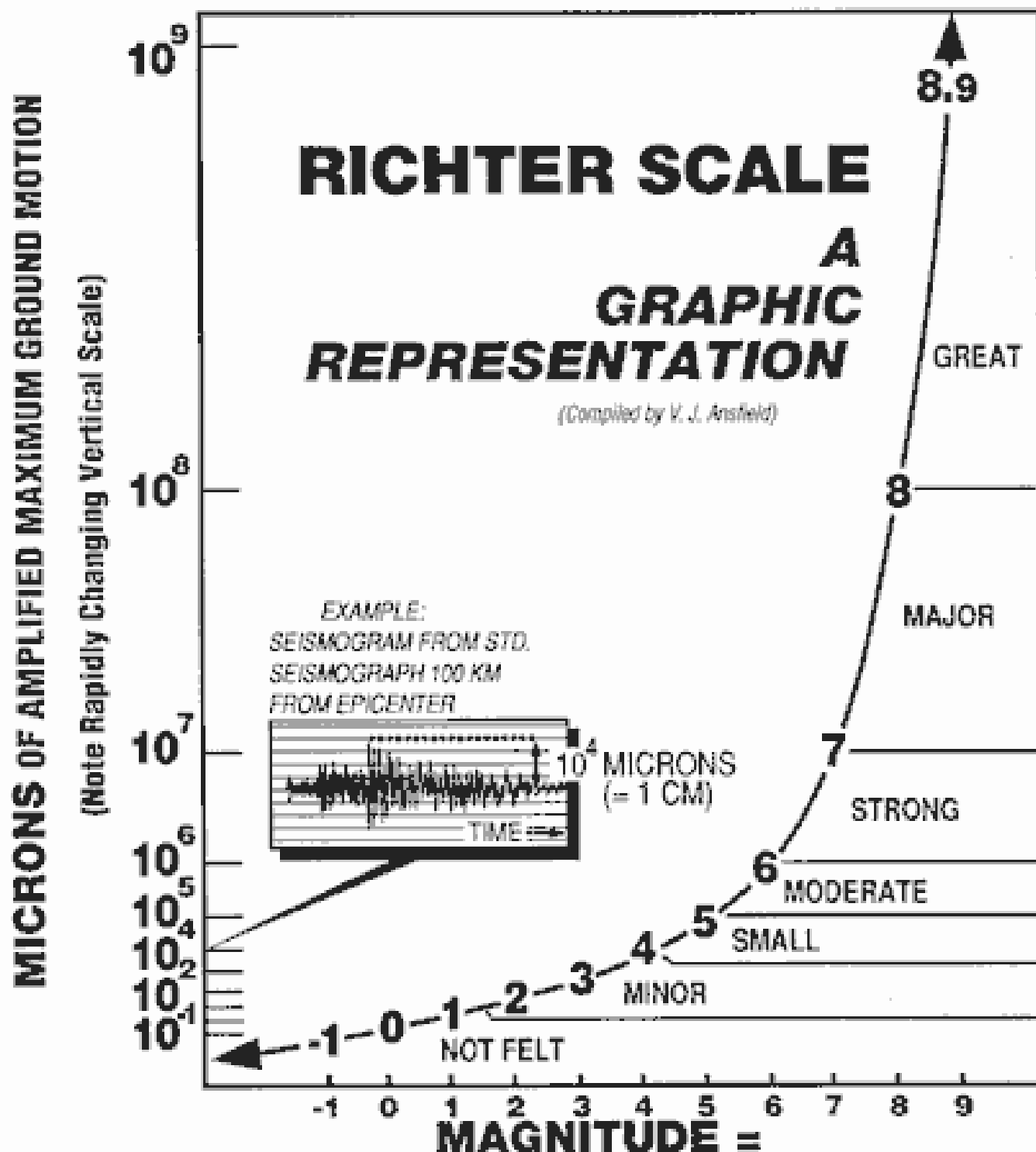
Comparison of the Richter, Mercalli and Moment Magnitude (MM) Earthquake Scales

The Richter Scale	The Modified Mercalli Scale	The Moment Magnitude Scale
<p>The Richter scale is a logarithm scale used to assign an earthquake magnitude based on seismographic measurements.</p> <p>The Richter scale was invented in 1935 to measure quakes between 3.0 and 7.0 in southern California. It was inaccurate over long distances or for quakes above 7.0.</p> <p>The scale was modified a number of times. Progress was limited by computer processing time until 1979.</p>	<p>The Modified Mercalli scale is used to estimate the intensity of an earthquake by comparing the earthquake damage with damage caused by similar known events.</p> <p>The Mercalli scale was developed in 1902. It quantifies the effects of an earthquake on the Earth's surface, humans, objects of nature, and man-made structures on a scale from I (not felt) to XII (total destruction)</p>	<p>The Moment Magnitude scale is used to estimate the energy released by an earthquake. It is based on the a surface-wave or body-wave magnitude of the earthquake, which is equal to the shear modulus of the rock near the fault multiplied by the average amount of slip on the fault and the size of the area that slipped.</p> <p>The Moment Magnitude Scale was introduced in 1979 as computers allowed more accurate measurement of medium to large earthquakes.</p>

“Popular press reports of earthquake magnitude usually fail to distinguish between magnitude scales, and are often reported as “Richter magnitudes” when the reported magnitude is a moment magnitude (or a surface-wave or body-wave magnitude). Because the scales are intended to report the same results within their applicable conditions, the confusion is minor.”

https://en.wikipedia.org/wiki/Moment_magnitude_scale

Richter Scale



Largest Recorded ***
(Offshore Chile, 1960)

Alaska, 1964

New Madrid, MO, 1812

San Francisco, 1906

Great Devastation
and Many
Fatalities Possible *

Loma Prieta, CA, 1989

Damage Begins *
Fatalities Rare

LOGARITHM (BASE 10) OF MAXIMUM AMPLITUDE MEASURED IN MICRONS **

* EFFECTS MAY VARY GREATLY DUE TO CONSTRUCTION PRACTICES, POPULATION DENSITY, SOIL DEPTH, FOCAL DEPTH, ETC.

** MICRON = A MILLIONTH OF A METER

*** EQUIVALENT TO A MOMENT MAGNITUDE OF 9.5

- ◆ **Small:** 4.0 to 4.9
- ◆ **Moderate:** 5.0 to 5.9
- ◆ **Strong:** 6.0 to 6.9
- ◆ **Major:** 7.0 to 7.9
- ◆ **Great:** 8.0 to 8+

A 6.0 releases 32
times more energy
than a 5.0
Loma Prieta was a 6.9,
San Francisco 1906 was a
7.9

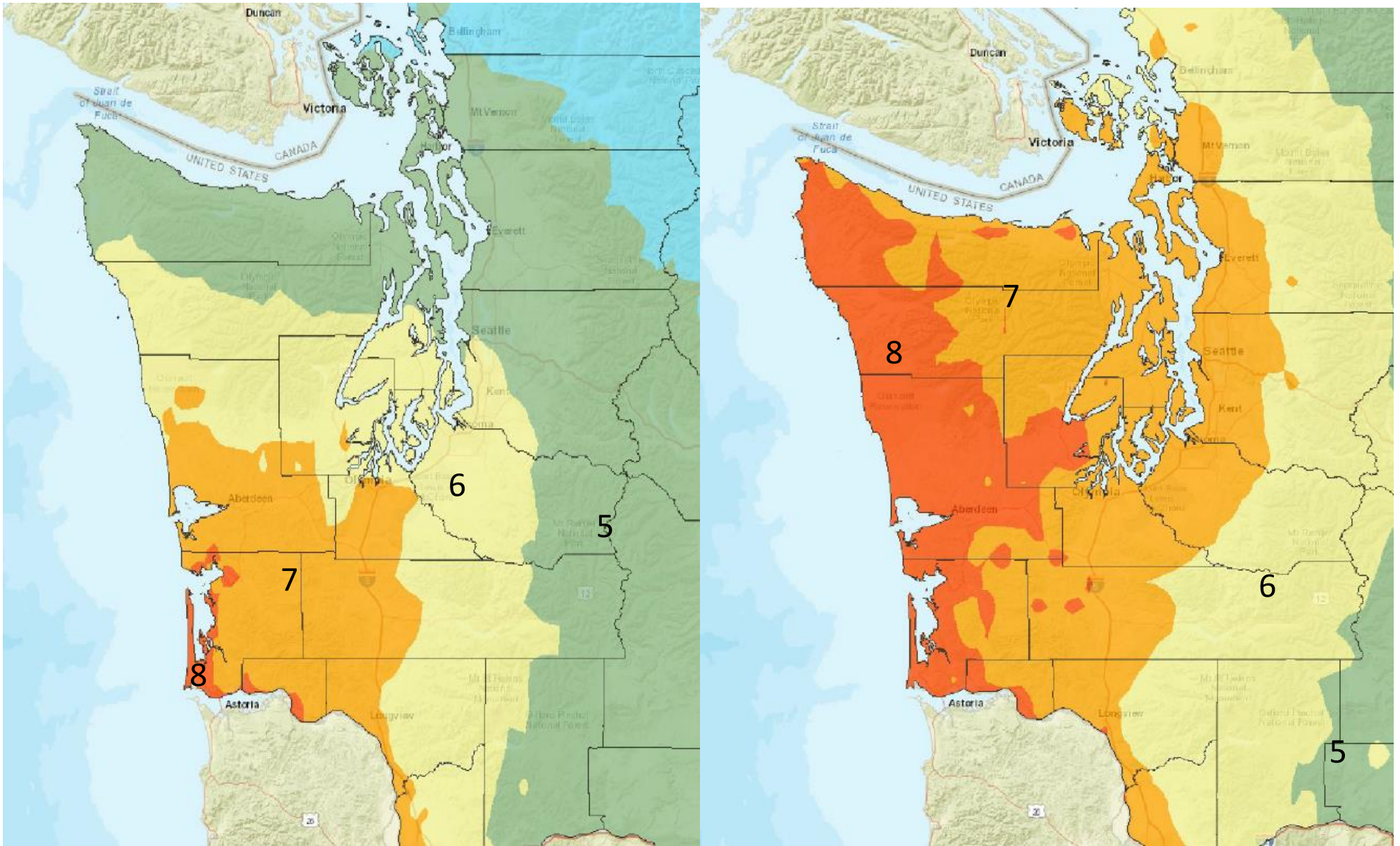
Comparision of Richter and Mercalli

Richter Scale Measure Power of Quake while Mercalli measures Intensity

Category	Effects	Richter Scale (approximate)
I. Instrumental	Not felt	1-2
II. Just perceptible	Felt by only a few people, especially on upper floors of tall buildings	3
III. Slight	Felt by people lying down, seated on a hard surface, or in the upper stories of tall buildings	3.5
IV. Perceptible	Felt indoors by many, by few outside; dishes and windows rattle	4
V. Rather strong	Generally felt by everyone; sleeping people may be awakened	4.5
VI. Strong	Trees sway, chandeliers swing, bells ring, some damage from falling objects	5
VII. Very strong	General alarm, walls and plaster crack	5.5
VIII. Destructive	Felt in moving vehicles, chimneys collapse; poorly constructed buildings seriously damaged	6
IX. Ruinous	Some houses collapse; pipes break	6.5
X. Disastrous	Obvious ground cracks; railroad tracks bent; some landslides on steep hillsides	7
XI. Very disastrous	Few buildings survive; bridges damaged or destroyed; all services interrupted (electrical, water, sewage, railroad; severe landslides	7.5
XII. Catastrophic	Total destruction; objects thrown into the air, river courses and topography altered	8

The Moment Magnitude Scale

Moment Magnitude Scale Numbers for Cascadia



“8.0” Richter Scale Cascadia Event Partial Rip of Fault at Newport Oregon

“9.0” Richter Scale Cascadia Event Full Rip of Fault

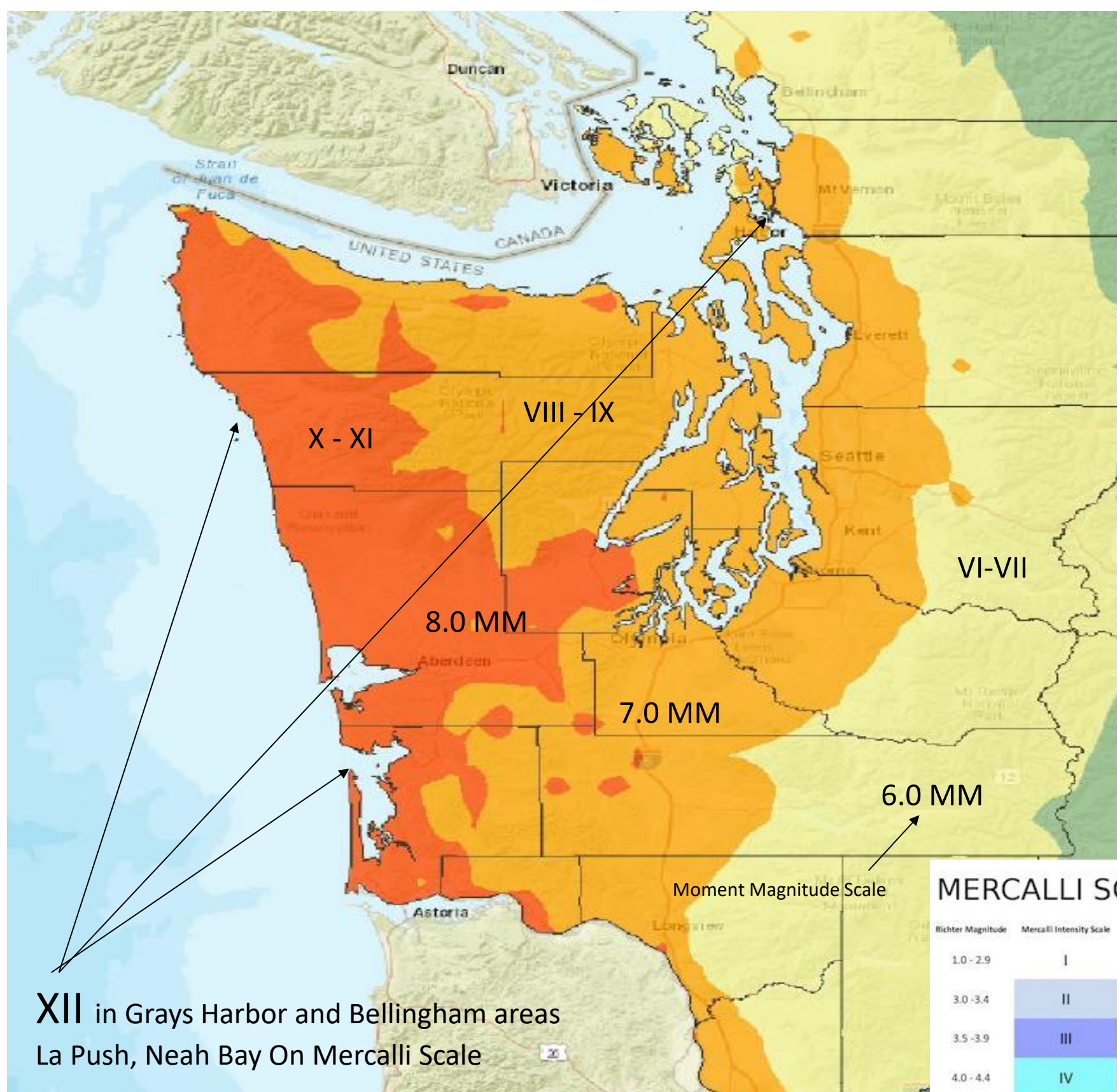
The Moment Magnitude Scale was introduced in 1979 and has since become more commonly used than the Richter Scale.

MM Intensity

- IV Light
- V Moderate
- VI Strong
- VII Very Strong
- VIII Severe

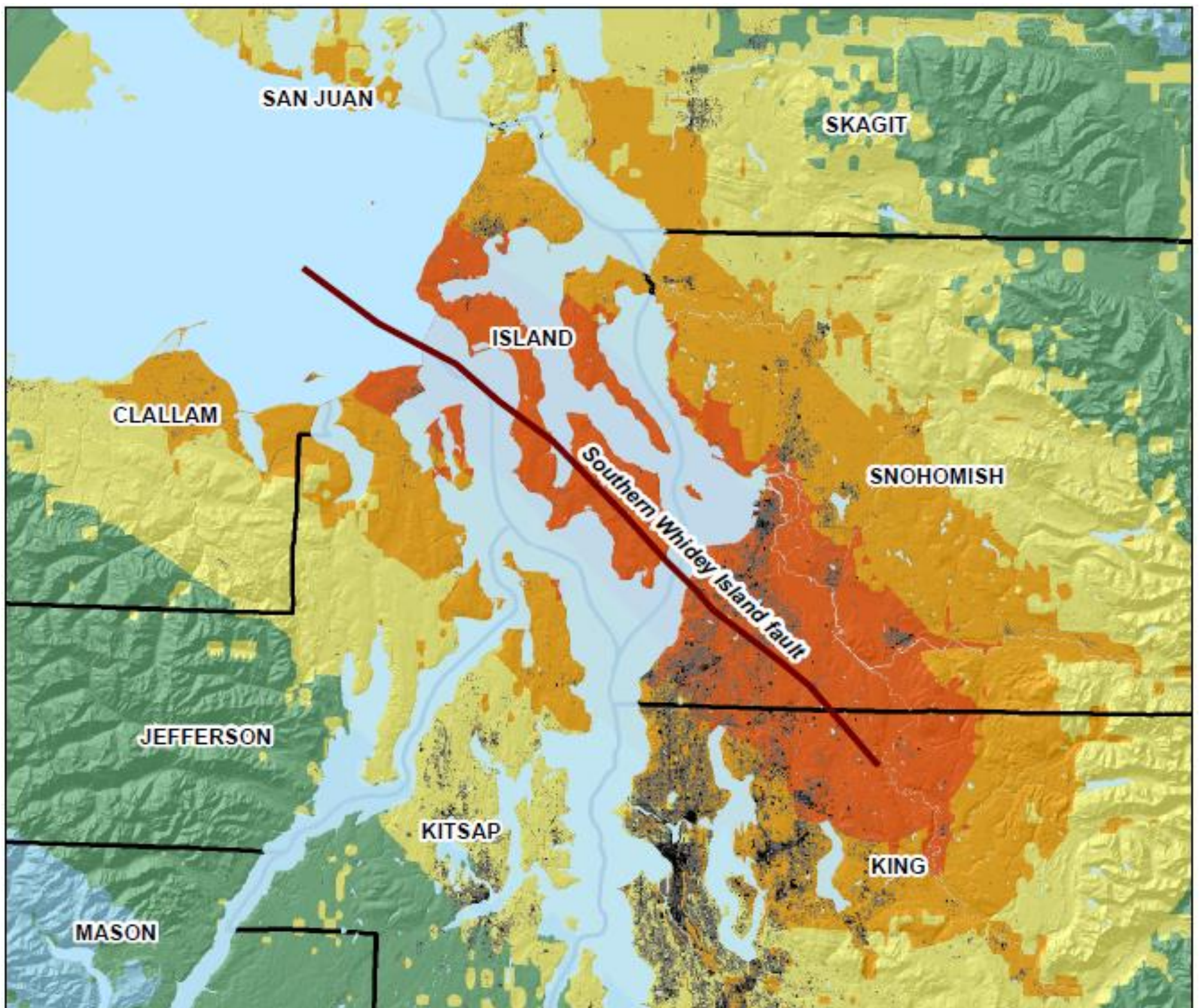
Combining The Three scales: Richter, Mercalli, and Moment Magnitude. Intensity of Shaking for a Richter 9.0 Cascadia

The intensity of the shaking will decrease with distance from the fault. Even so, Seattle is expected to experience a 7.0 magnitude (Richter) or higher earthquake



Whidbey Island Fault

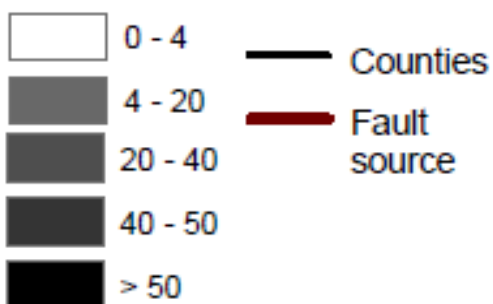
Population Density and Ground Shaking Intensities -
Earthquake Scenario: Washington



Sources: 2009 HAZUS runs by URS Corporation, MMI Map USGS 2009
Projection: NAD83 Harn State Plane Washington 4602 (feet)

Population Density

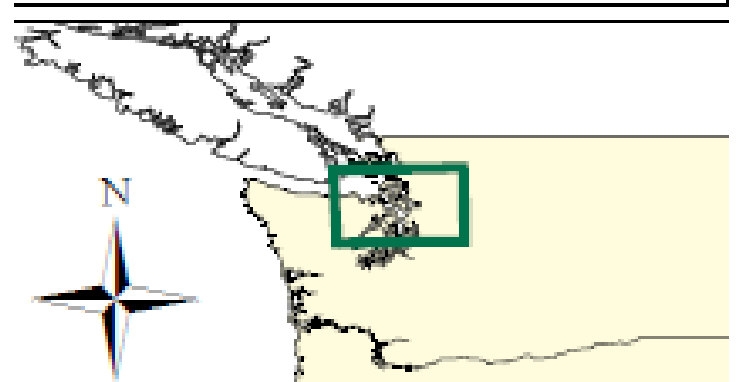
People



MM Intensity

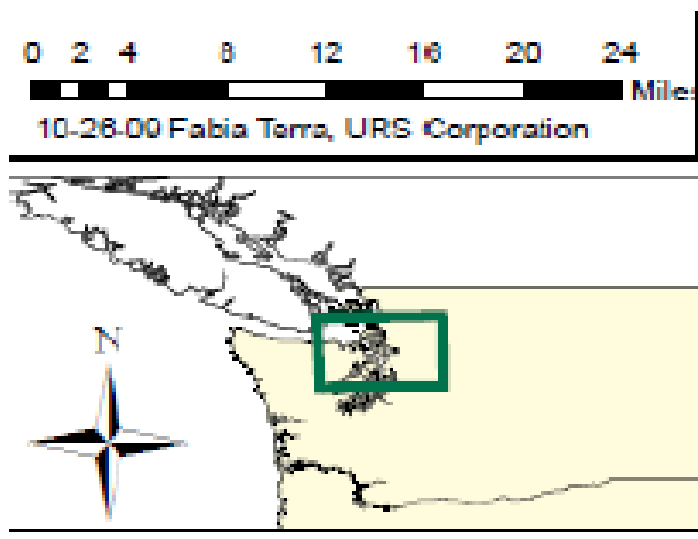
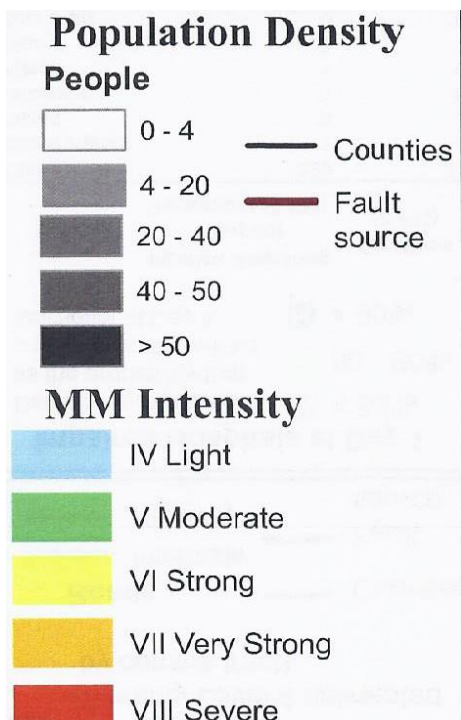
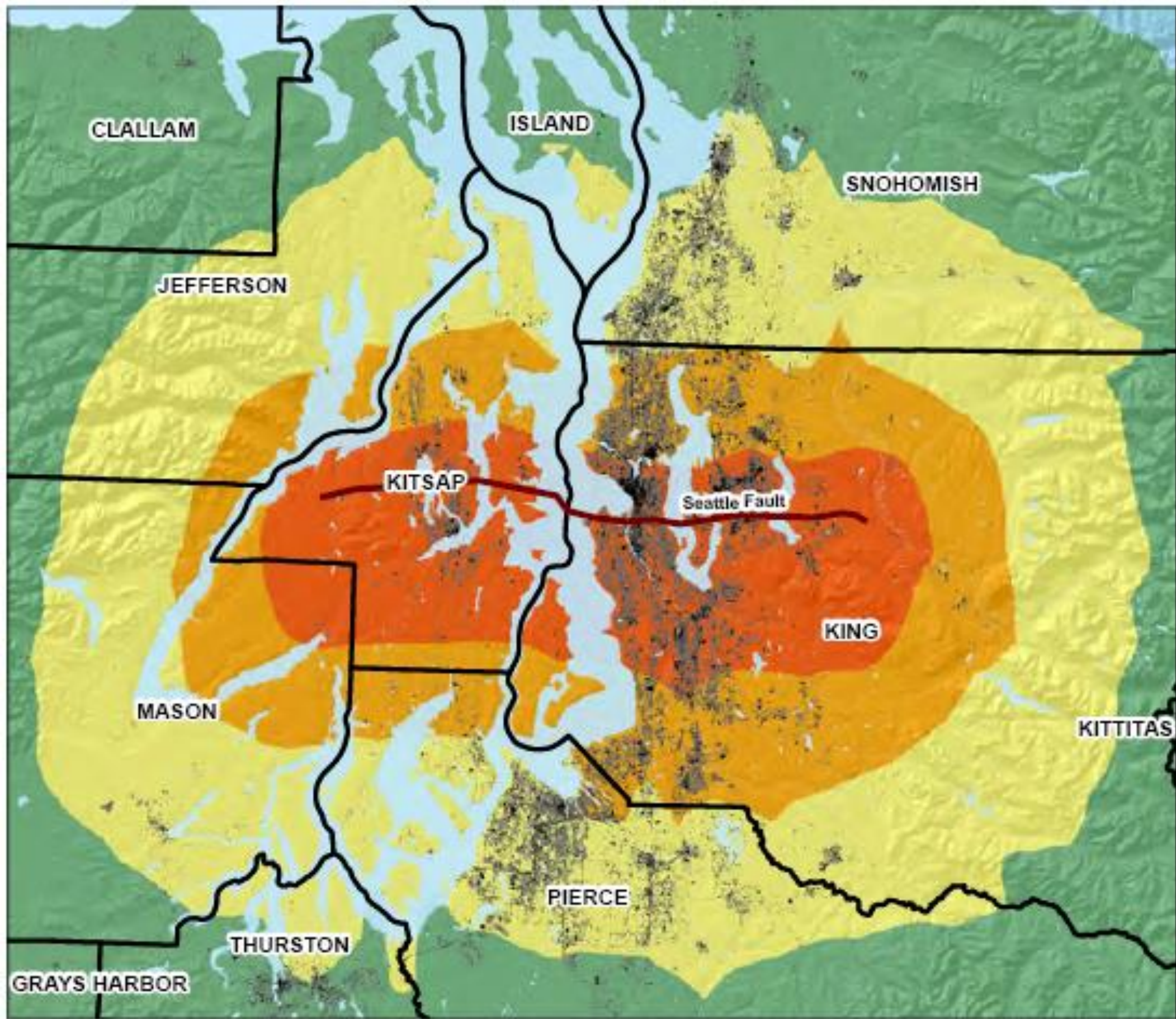


10-26-09 Fabia Terra, URS Corporation



Seattle Fault

Population Density and Ground Shaking Intensities -
Earthquake Scenario: Washington



Washington vs. California Risk

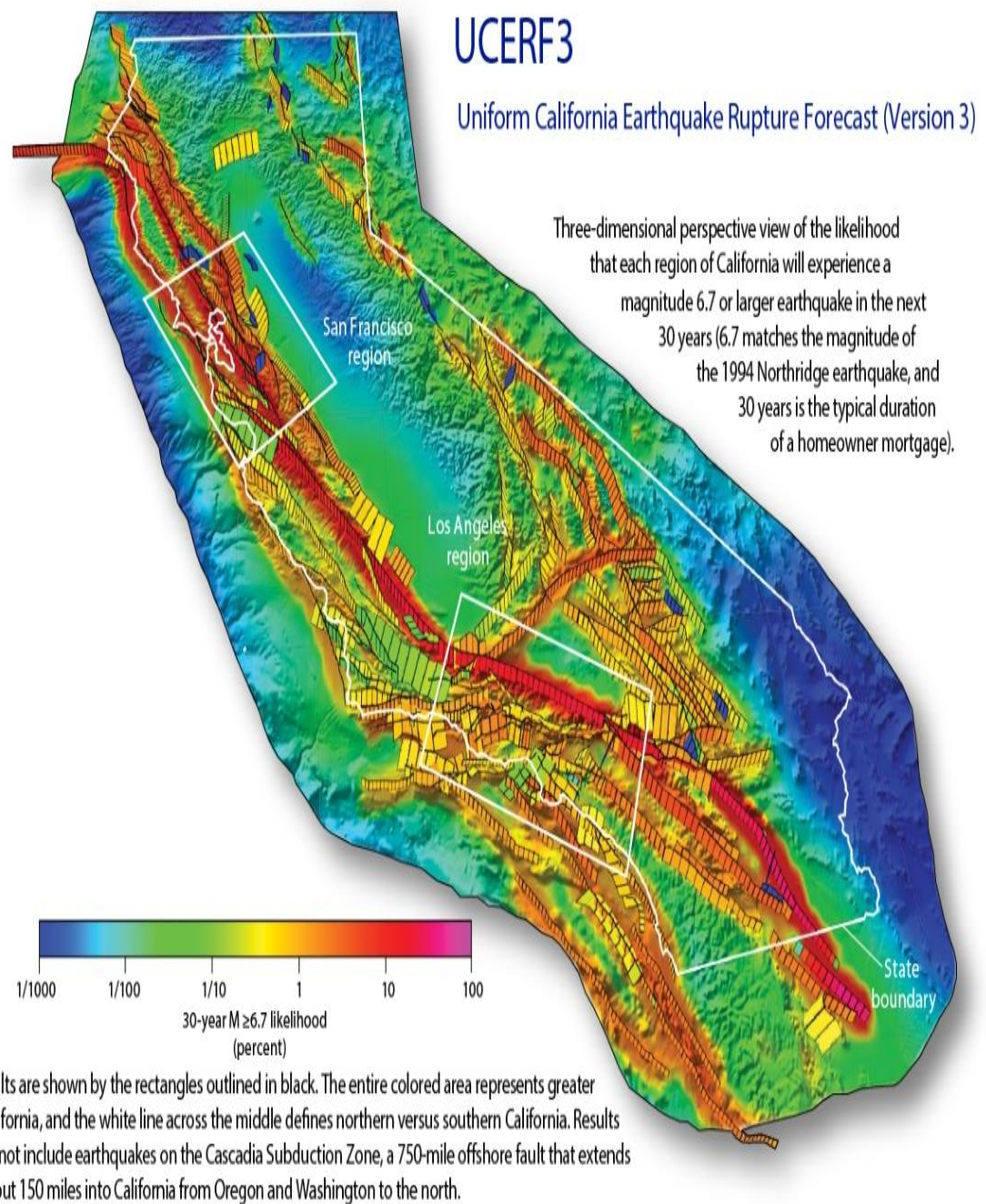
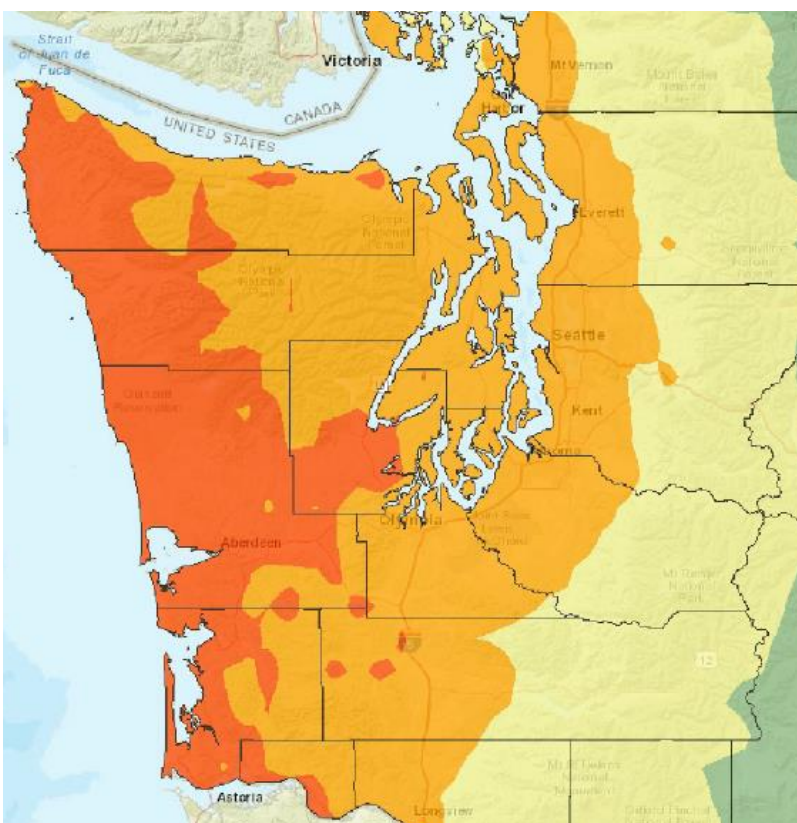
Washington Risk in 50 Years

Cascadia 8.0	33-43%
Cascadia 9.0	10-20%
Seattle or Tacoma	10-15%
S. Whidbey 7.5	10%
Lake Creek 7.2	10%
Total Risk	73-88%

California Risk in 30 Years

California's Risk	30% Average
Populated Areas	22%
Normalized to 50	40-50%

The likelihood of a California quake of greater than 6.7 in the next 30 years is 30% on average.



Washington quakes are less frequent but more severe than California quakes.

Three quakes are large enough to effect the major population center of the state.

Damage from these quakes will cut off mutual aid from the rest of the state for days or weeks.

California quakes are more frequent but less severe than Washington quakes.

No quake is large enough to effect all population centers of the state at once.

California will also have the advantage of mutual aid as the quakes do not effect all parts of the state.