

3. Coastal Hazards

1. Plate Tectonics and Landscape Formation:

Building Oregon
Cascadia Subduction Zone
Columbia Plateau Basalt

2. Ongoing Coastal Processes:

Dynamic Duo: Uplift and Erosion
Coastal Headlands

3. Coastal Geological Hazards:

Earthquakes
Tsunamis
Landslides

4. Interpretive Methods:

Presenting Coastal Geology to Coastal Audiences

The Dynamic Landscape of Oregon's Coast: A Tale of Beauty and the Beast

Bob Lillie

Professor of Geology
Certified Interpretive Trainer
Oregon State University

Oregon Coast Region of the Oregon Master Naturalist Program

Unit 9: Geology of the Oregon Coast

Cape Perpetua Scenic Area, Oregon
February 26, 2011

Marine Gardens, Newport, Oregon

Robert J. Lillie



Beauty and the Beast



“The same geological processes that sculpt Oregon’s breathtaking headlands and beaches also threaten our lives with earthquakes, tsunamis, and landslides.”

Robert J. Lillie

Marine Gardens - Otter Crest, Oregon

What is This?

Part of a Detective Story

And the work of The Beast



*1. Carbon Dating says These Trees Died
about 300 Years Ago*

*2. Tree Ring Studies say it was between
1699 and 1700*

*3. How do we know earthquake was on
January 26, 1700?*

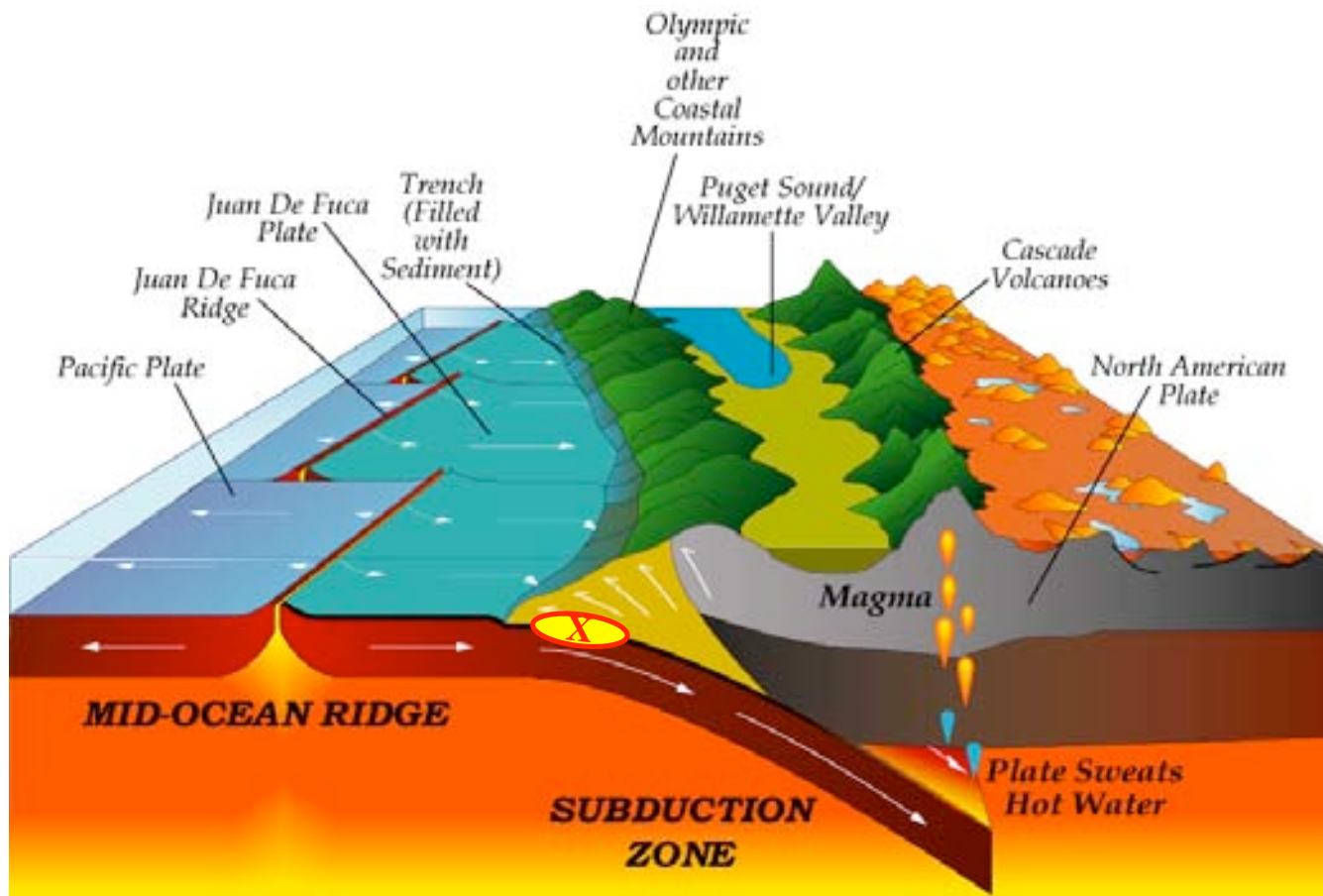
Brian Atwater, U.S.G.S.

Dead forest of western red cedar sticking up through a brackish water tidal marsh at Copalis River on the SW Washington coast. Tree rings show that the trees died after the end of the 1699 growing season and before the beginning of the 1700 growing season. (Text: Yeats, 2004, Living with Earthquakes in the Pacific Northwest. Photo: Brian Atwater, U.S.G.S.)

Cascadia Subduction Zone

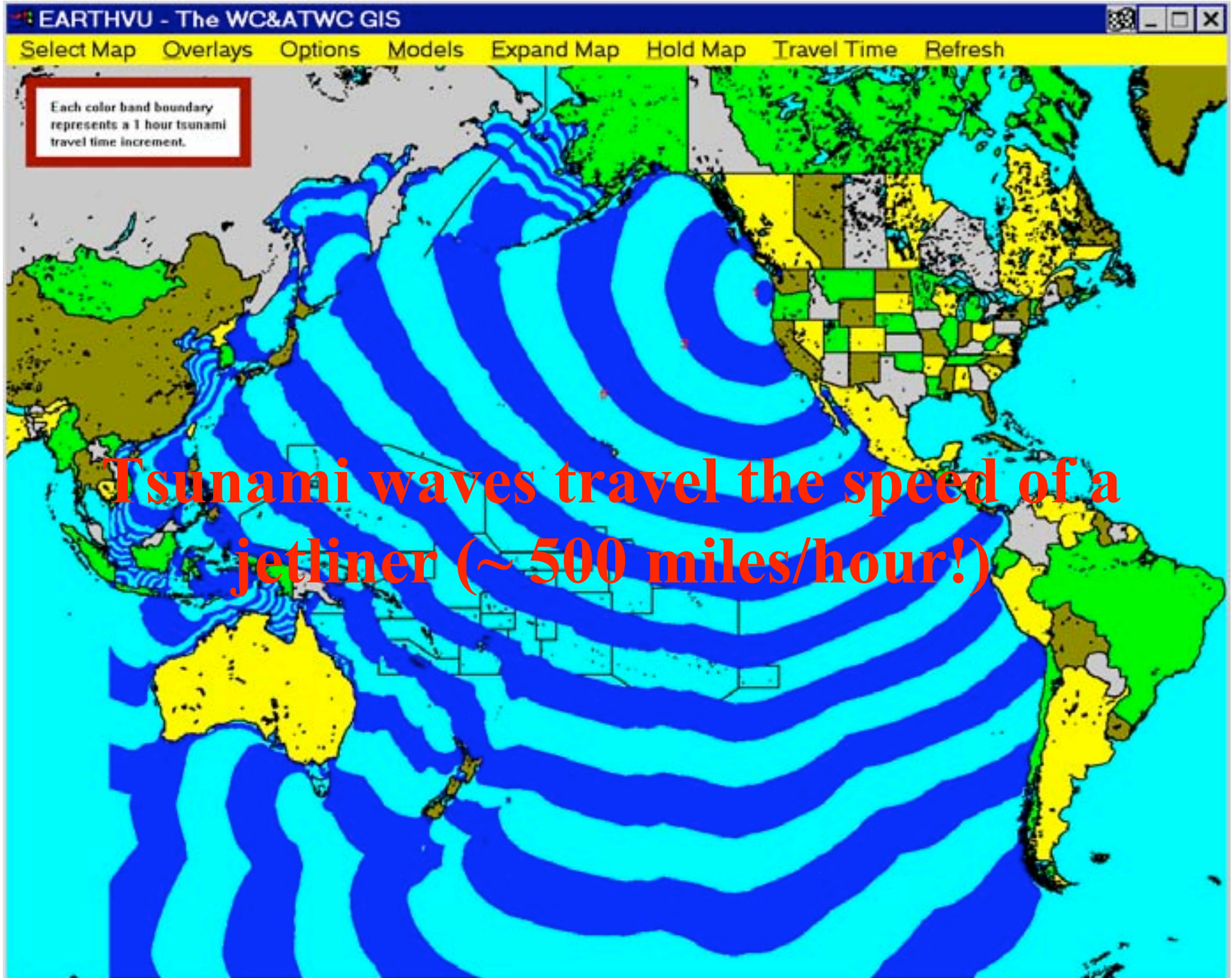
X -- Locked Zone (Mega-Thrust) Earthquakes:

- *Plates lock for 200 to 600 years, then suddenly let go!*
- *Up to Magnitude 9*
- *Last big earthquake was on January 26, 1700.*
- *How do we know?*



One winter's night in the year 1700, a mysterious tsunami flooded fields and washed away houses in Japan. It arrived without the warning that a nearby earthquake usually provides. Samurai, merchants, and villagers recorded the event, but nearly three centuries would pass before discoveries in North America revealed the tsunami's source.

The Orphan Tsunami of 1700 (Atwater and others, 2005)



Japanese Harbor-Master records tell of “Orphan Tsunami” on January 27-28, 1700

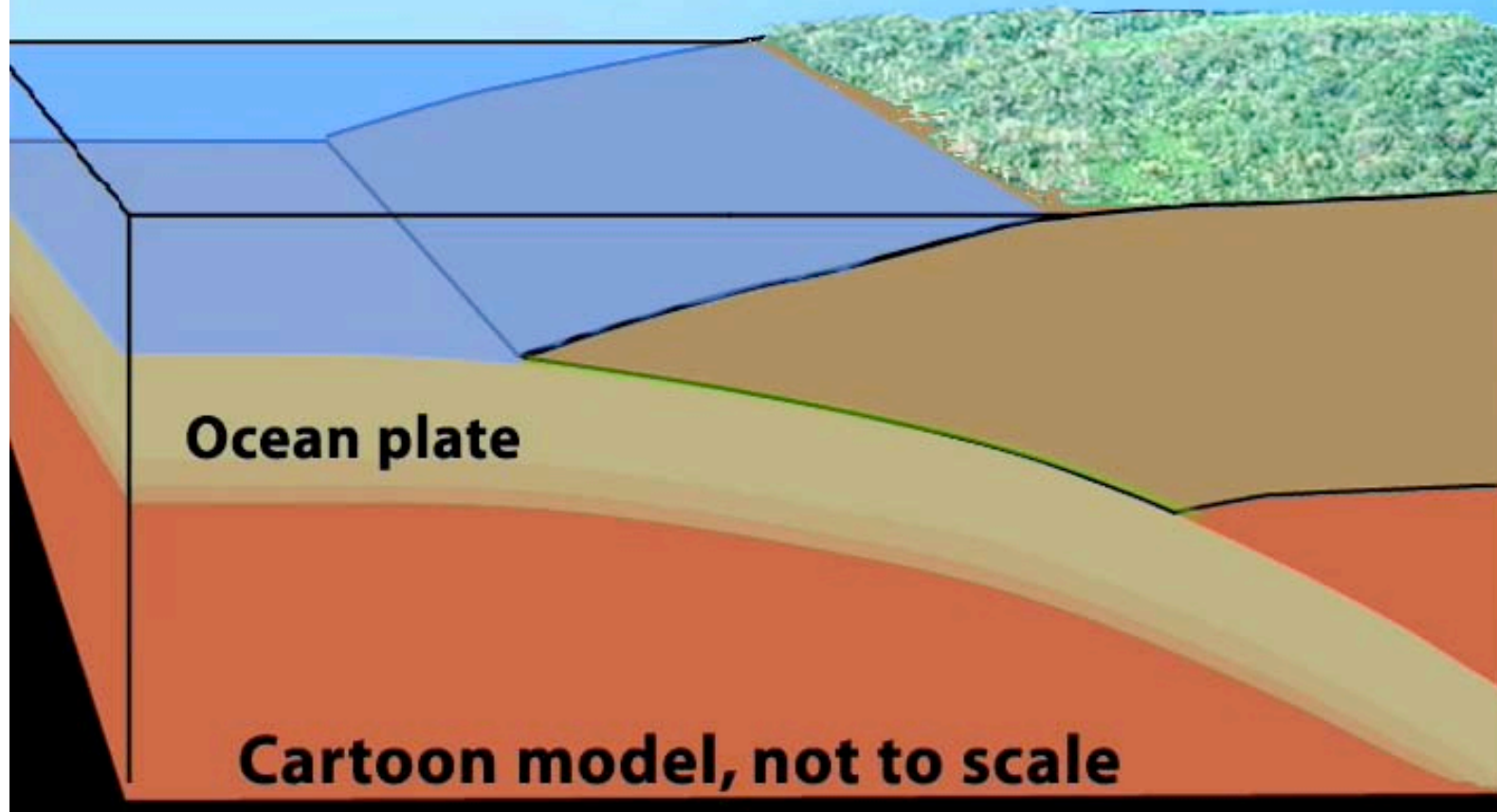
6	<p>早速 katsumai ni oyobi sōjū became famished</p> <p>乃 ni tsuki thereby</p> <p>hitokazu number of people,</p> <p>百五十九 hyaku- gojū-kyū nin 159 people</p> <p>に to,</p>	<p>5</p>	<p>道 dōgu belongings</p> <p>乃 wa as for,</p> <p>無 mōsu ni oyaba zu needless to say</p> <p>何 nani nitemo everything</p> <p>一切 issai at all</p> <p>救 ai-dashi save</p> <p>能 mōsa-nu could not.</p>	<p>4</p>	<p>指 jūsan-ken 13 houses</p> <p>波 nami waves</p> <p>乃 ni by</p> <p>破 uchiyaburaru sōrō were destroyed,</p> <p>乃 yoshi it was reported.</p> <p>水 suika Flood and fire</p> <p>同 ichido- at the same time</p> <p>事 shutai happened.</p> <p>各 sho Various</p>	<p>3</p>	<p>逃 nige mōsu escaped.</p> <p>乃 ato nite Afterwards</p> <p>火 shukka started fire</p> <p>數 jūjū number of houses</p> <p>二十 nijūikken 20 houses</p> <p>燒 shōshitsu burned.</p> <p>乃 hōka ni In addition,</p>	<p>2</p>	<p>之 no of</p> <p>夜 yoru night</p> <p>九 kokonatsu- doku hour of nine,</p> <p>時 tsunami tsunami</p> <p>來 uchiyose came.</p> <p>乃 shōsho ni Here and there,</p> <p>各 manadomo villagers</p> <p>乃 yamayama hills</p> <p>乃 e to</p>	<p>Miyako Miyako</p> <p>o-dairanisho district magistrate's office</p> <p>no uchi within,</p> <p>Kuwagasaki- mura Kuwagasaki village</p> <p>nite in,</p> <p>saru past</p> <p>yōka eighth day</p>
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Tsunami Generation from Subduction Zone Earthquake



Subduction zone example of uplift and elastic rebound

earth
scope



www.iris.edu (Animation by Jenda Johnson)

2004 Banda Aceh, Indonesia
Damage to Human-Built Infrastructure



2004 Banda Aceh, Indonesia
Damage to Human-Built Infrastructure

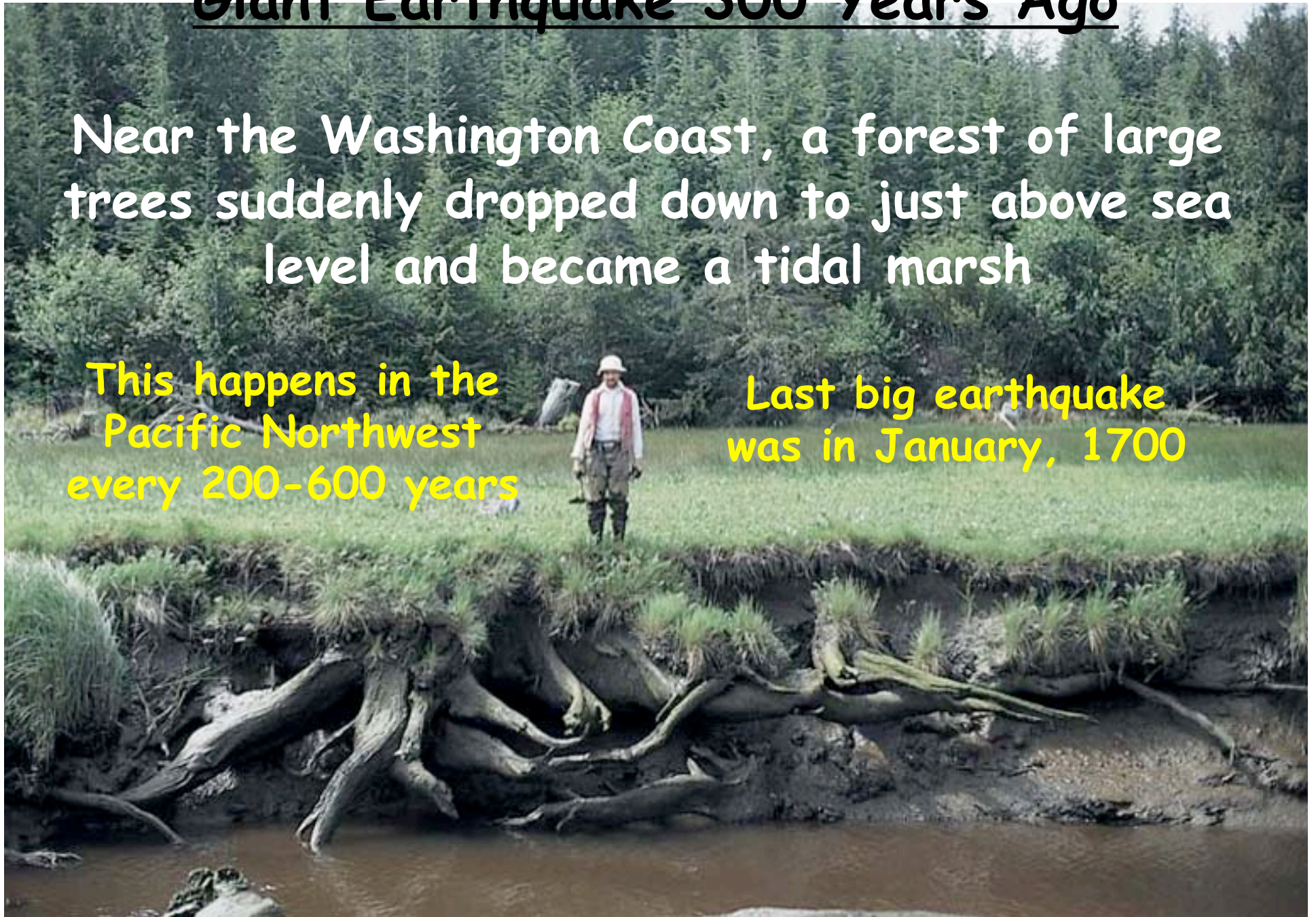


Giant Earthquake 300 Years Ago

Near the Washington Coast, a forest of large trees suddenly dropped down to just above sea level and became a tidal marsh

This happens in the Pacific Northwest every 200-600 years

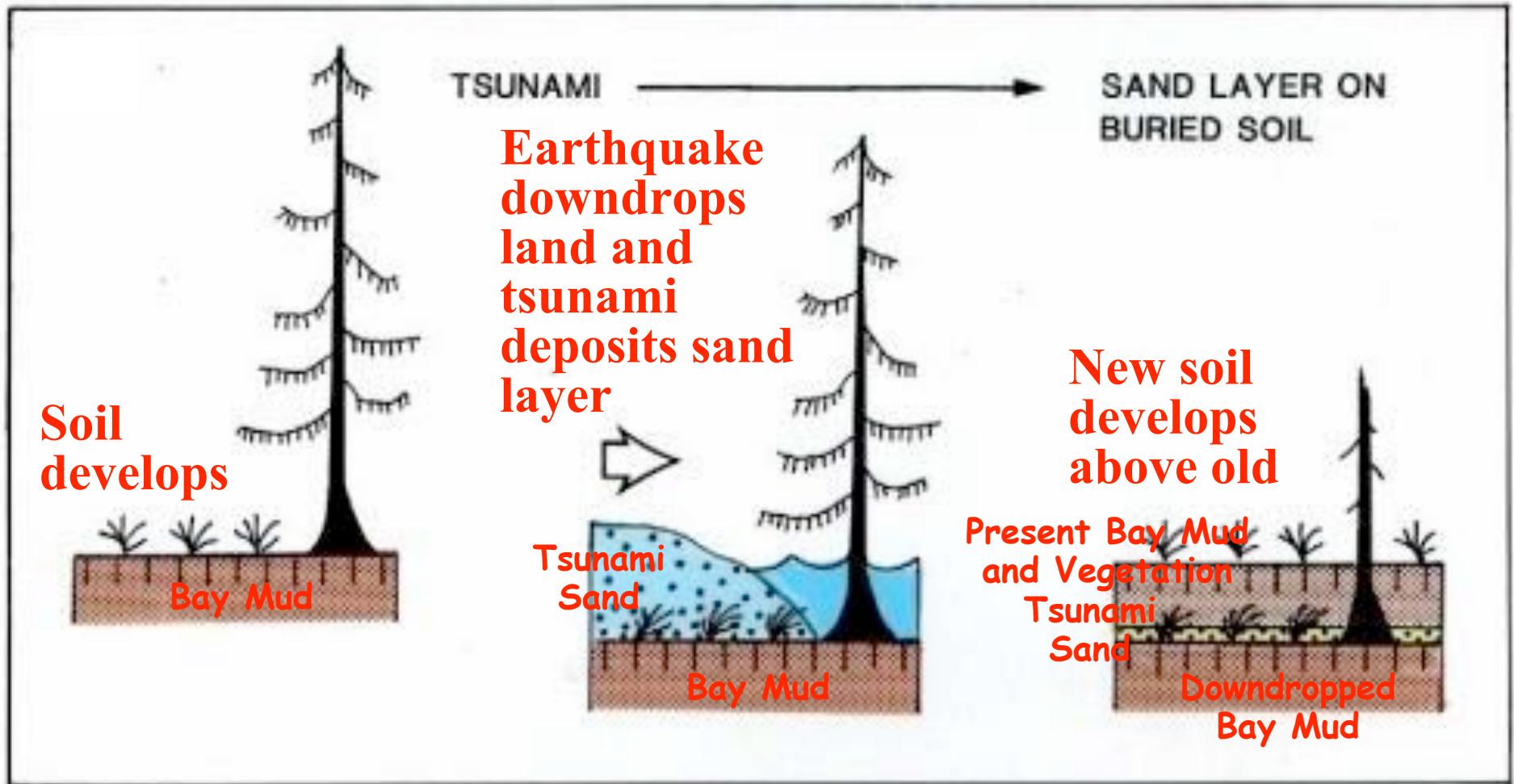
Last big earthquake was in January, 1700



Tsunami Sand Deposits Represent Past Earthquakes



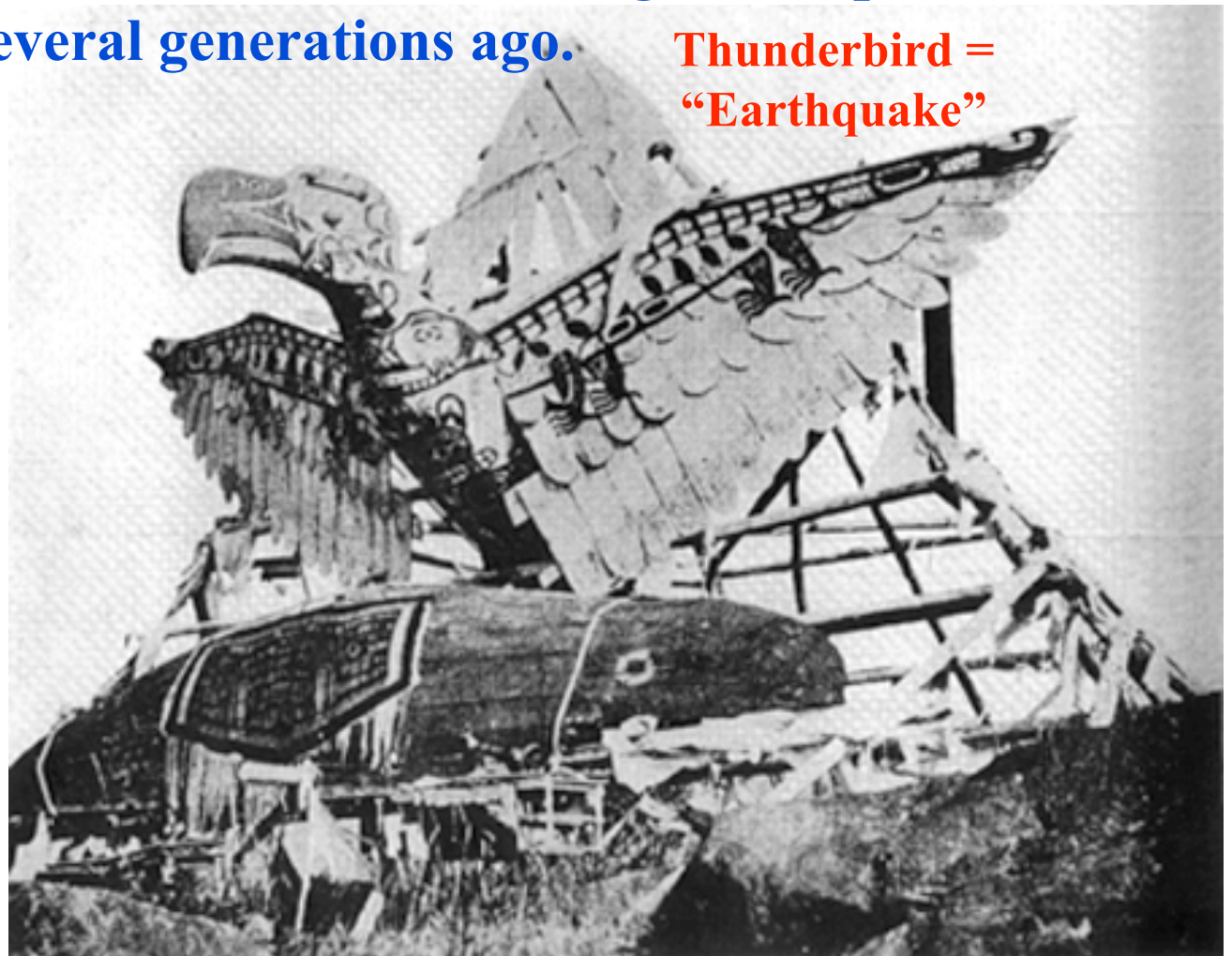
Bay Mud, Tsunami Sands, and Trees Drowned During Earthquake



Native American oral stories hint at large earthquakes and tsunamis several generations ago.

**Thunderbird =
“Earthquake”**

“Throughout Cascadia, earth shaking and/or tsunami-like effects are frequently described in stories about the acts and personalities of supernatural beings, often in the guise of animals. Many stories from western Vancouver Island and northern Washington tell of a struggle between **Thunderbird and Whale**, and throughout Cascadia stories about these figures frequently include explicit mention or visual imagery suggesting **shaking and/or tsunami-like effects**. (From Ludwin, R. S. and others, “Dating the 1700 Cascadia Earthquake: Great Coastal Earthquakes in Native Stories,” *Seismological Research Letters*, 2005, V. 76, Num. 2, p. 140-148).



Nootka Sound Memorial, erected 1902–1903 to honor a Chief Maquinna, who died in 1902. Thunderbird and Whale are shown as similar in size to the most prominent peak in the area, Conuma Peak (represented by the conical form in the background, originally covered by canvas [Drucker, 1955]). Photograph by C.H. French, Royal British Columbia Museum PN11478-A. (From Ludwin, R. S. and others, “Dating the 1700 Cascadia Earthquake: Great Coastal Earthquakes in Native Stories,” *Seismological Research Letters*, 2005, V. 76, Num. 2, p. 140-148).

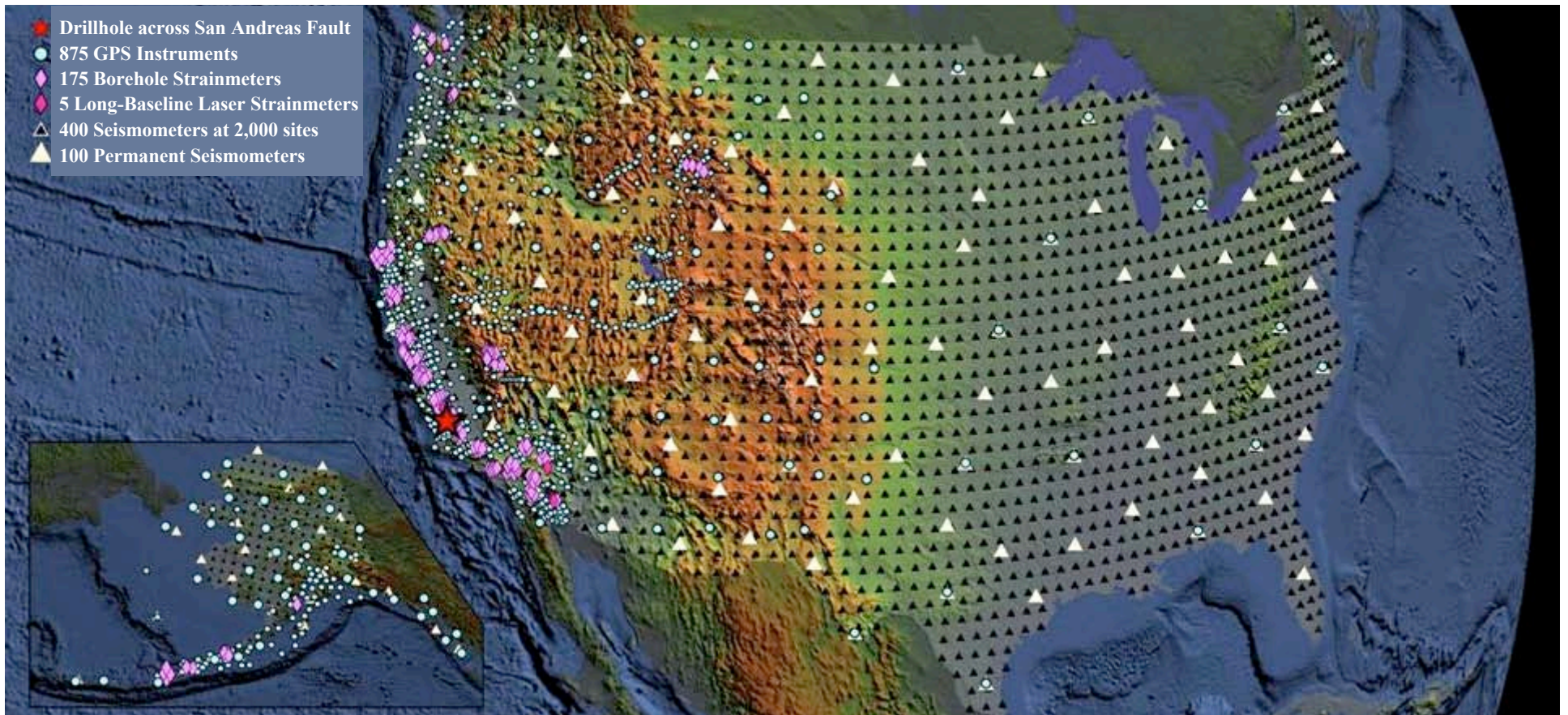
Great Earthquakes in the Pacific Northwest

- Large (magnitude 8 - 9) earthquakes occur about every 200 to 600 years
- Last big earthquake was 300 years ago:
 - Buried tsunami sand
 - Dead forests
 - Carbon dated 300 years \pm 10 years
 - Tree rings say the trees died between fall of 1699 and spring of 1700
 - Large tsunami of unknown origin hit Japan the next day
 - Earthquake ~ 9 PM, January 26th, 1700 (Pacific Time)
 - Native Americans have stories of a large earthquake and tsunami several generations ago, that hit at night in winter
- Cascadia Subduction Zone "locked and "loaded:
 - GPS stations show coastal areas moving northeastward
 - "Stuck" to Juan de Fuca Plate
 - May suddenly release as devastating earthquake



Seismometers, GSP, and other instruments to

- Explore the structure and evolution of North American continent
- Study processes that cause earthquakes and volcanic eruptions

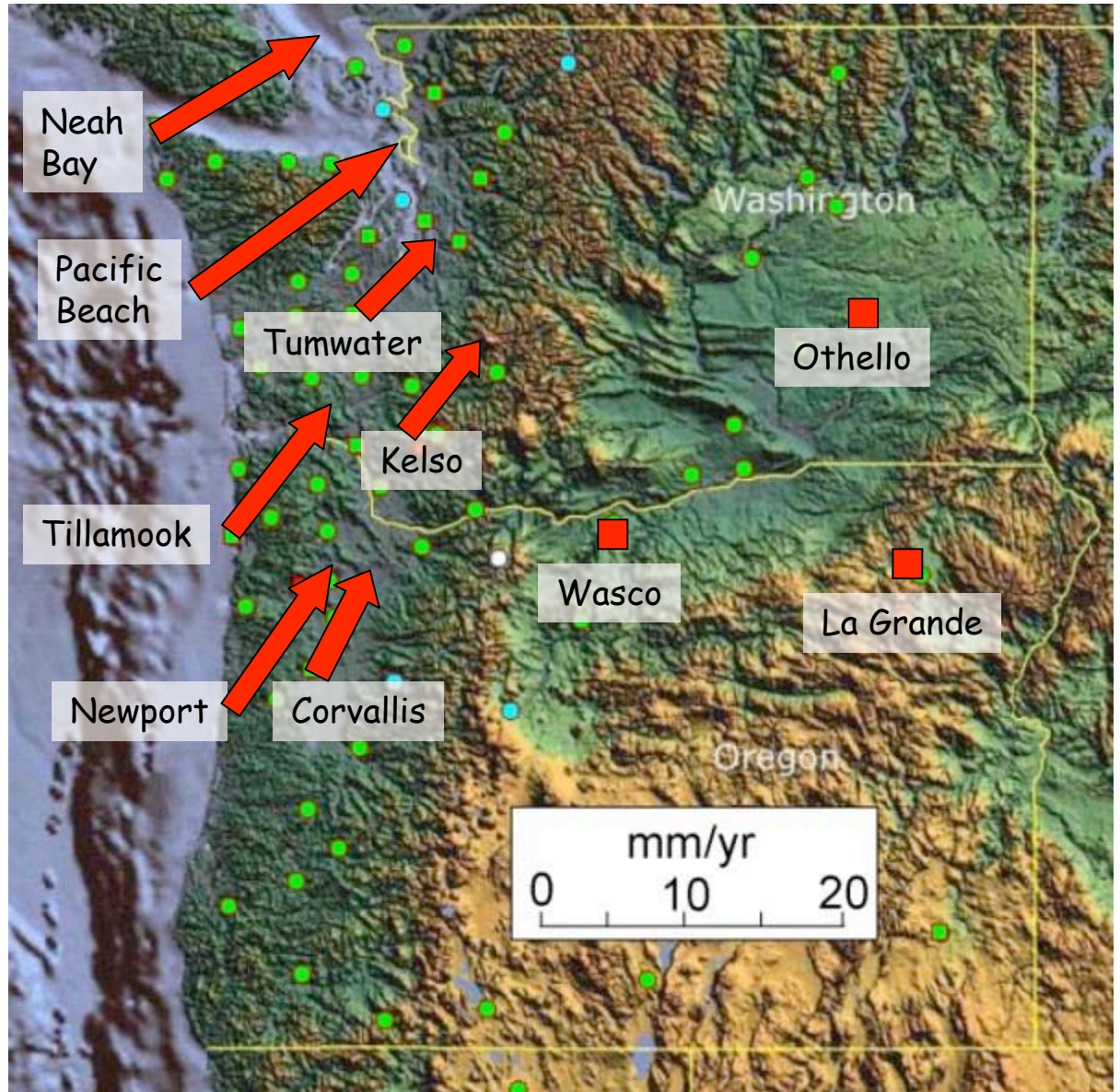


Cascadia Subduction Zone -- Locked and Loaded

- Western Oregon and Washington are being pushed toward the northwest.
- The region is “stuck” to the Juan de Fuca Plate

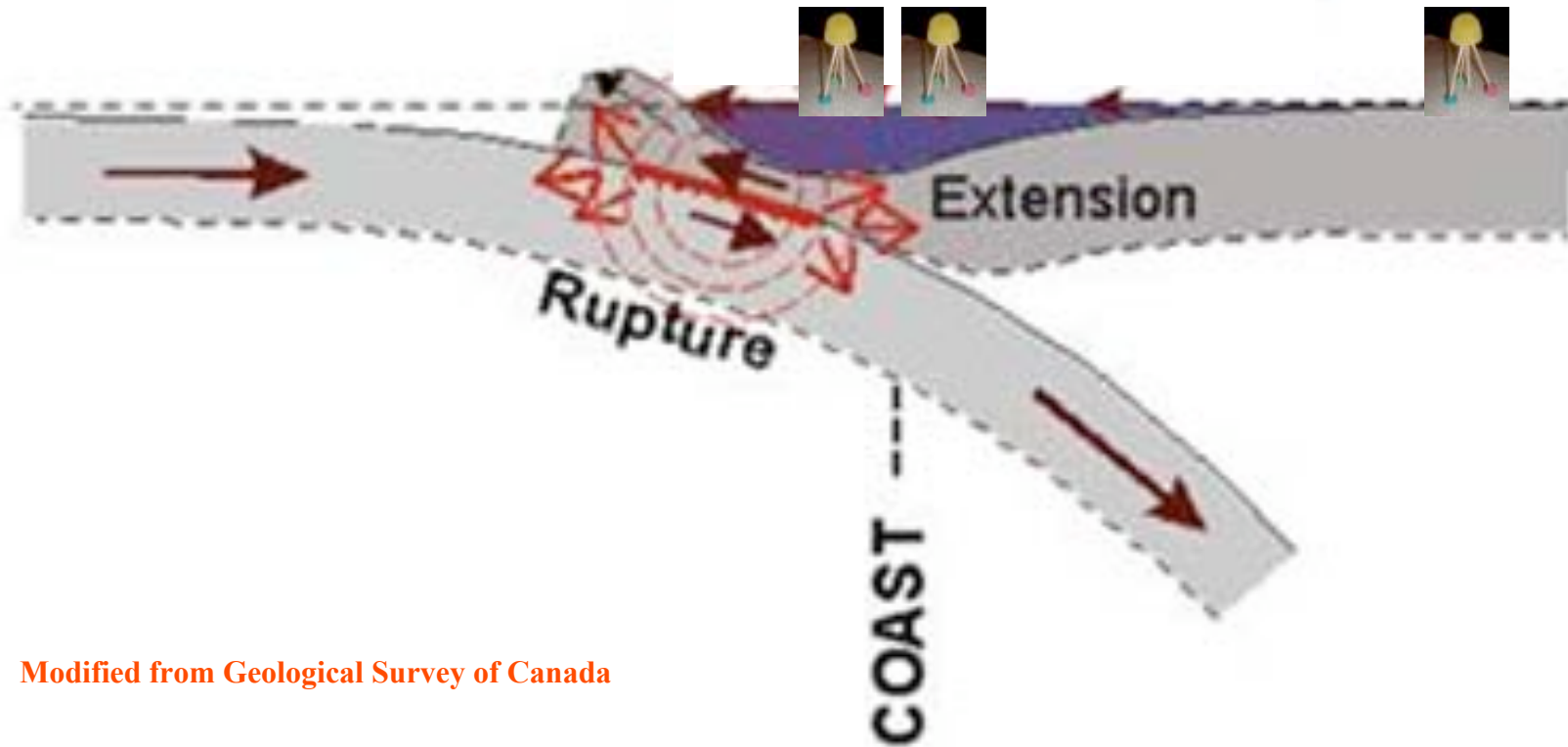


(Modified from Bob Butler, University of Portland)



GPS Stations Monitor Ground Motion

GPS Stations



Modified from Geological Survey of Canada

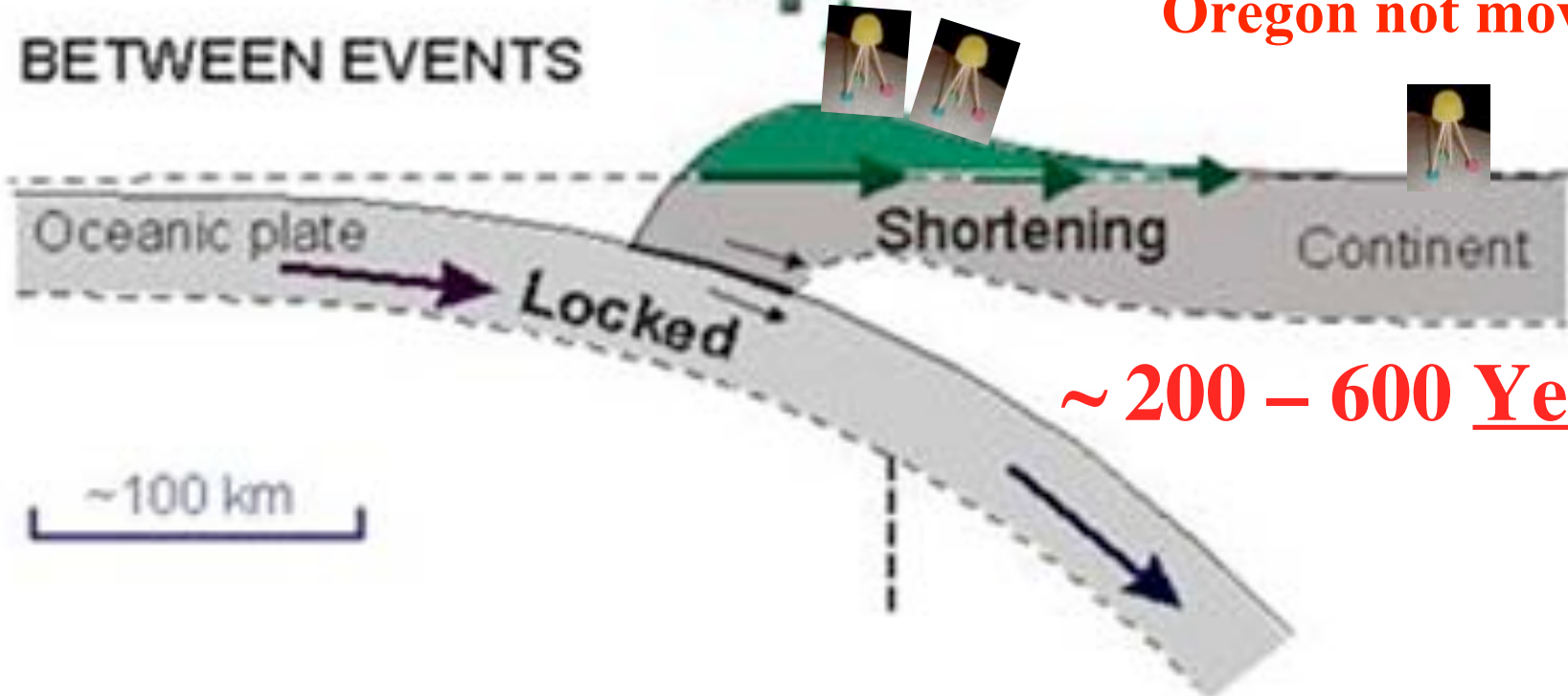
“Locked” Subduction Zone

Stations in western Oregon moving upward and NNE

Stations in eastern Oregon not moving

BETWEEN EVENTS

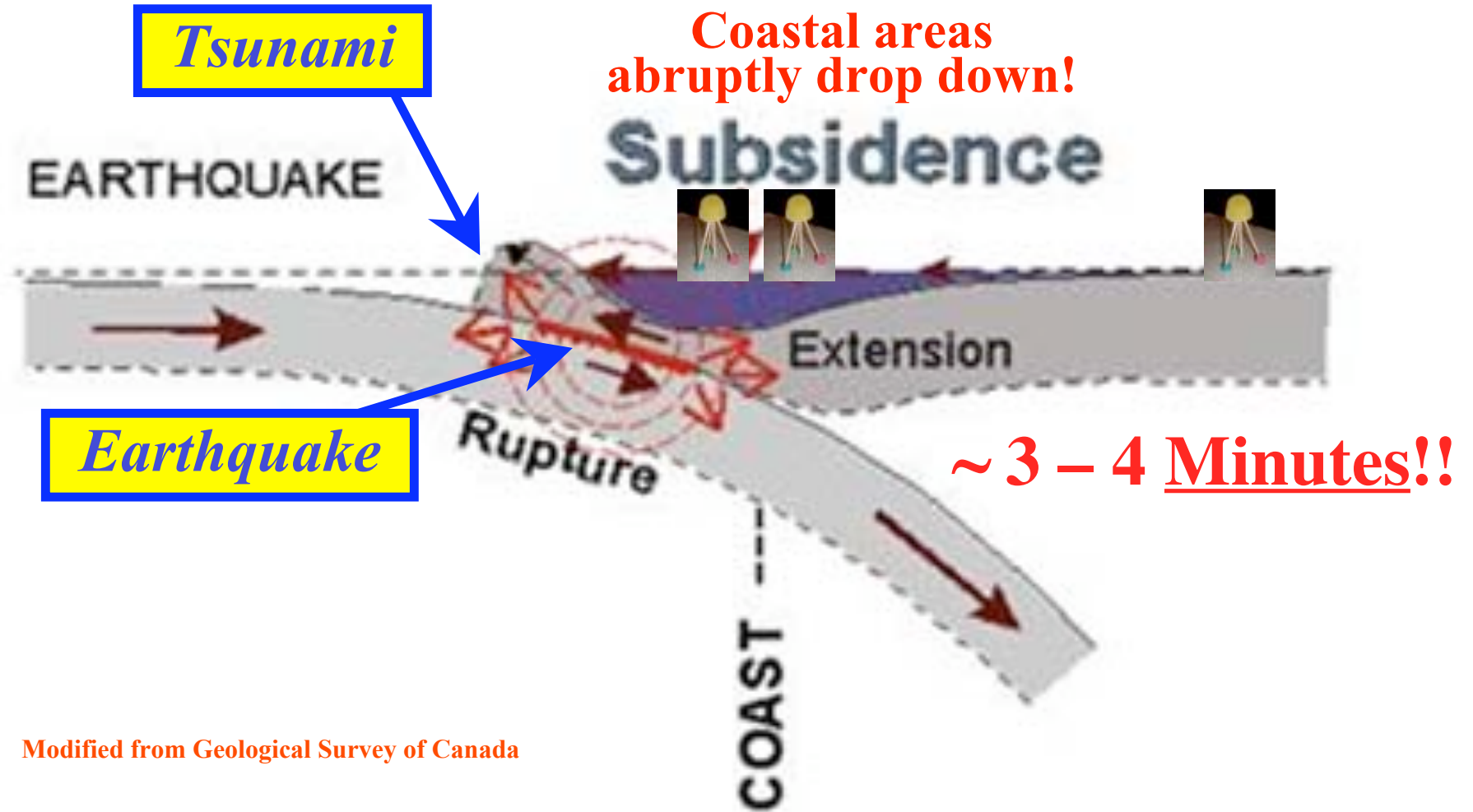
Uplift



~ 200 – 600 Years

Modified from Geological Survey of Canada

Suddenly Unlocks!!



Modified from Geological Survey of Canada

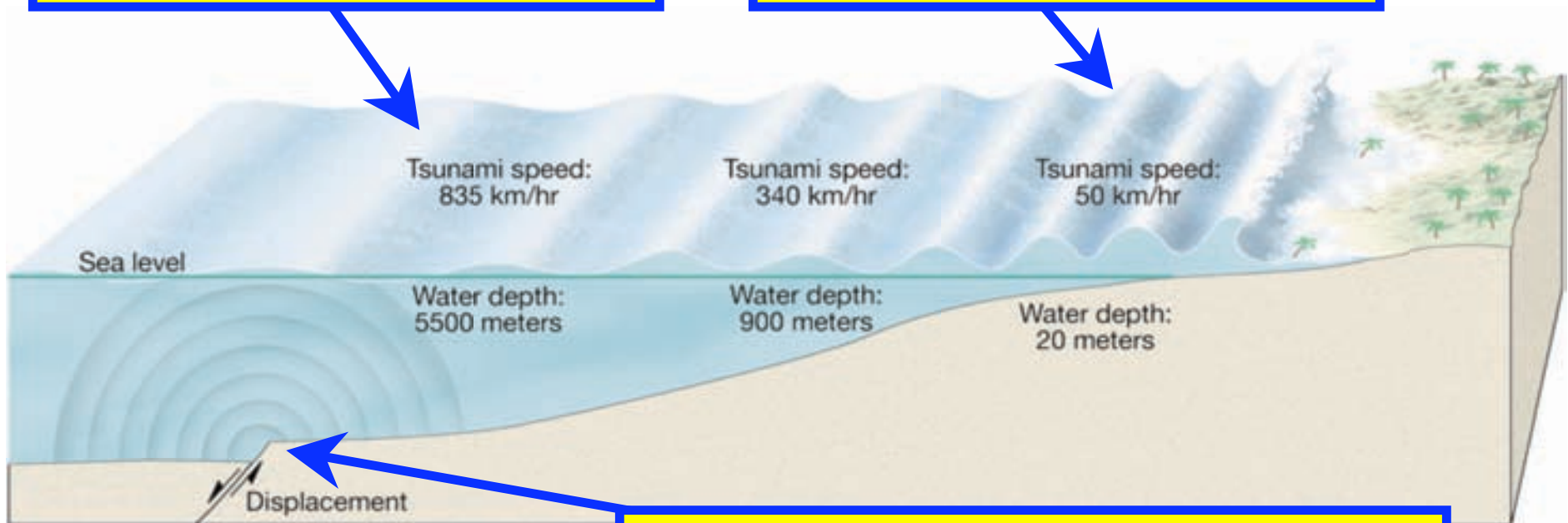
Tsunami Caused by Displacement of Ocean Floor

Waves in Deep Ocean:

- Small Amplitude
- Travel Speed of Jetliner

Approaching Land:

- Waves Slow Down
- Amplitude Increases

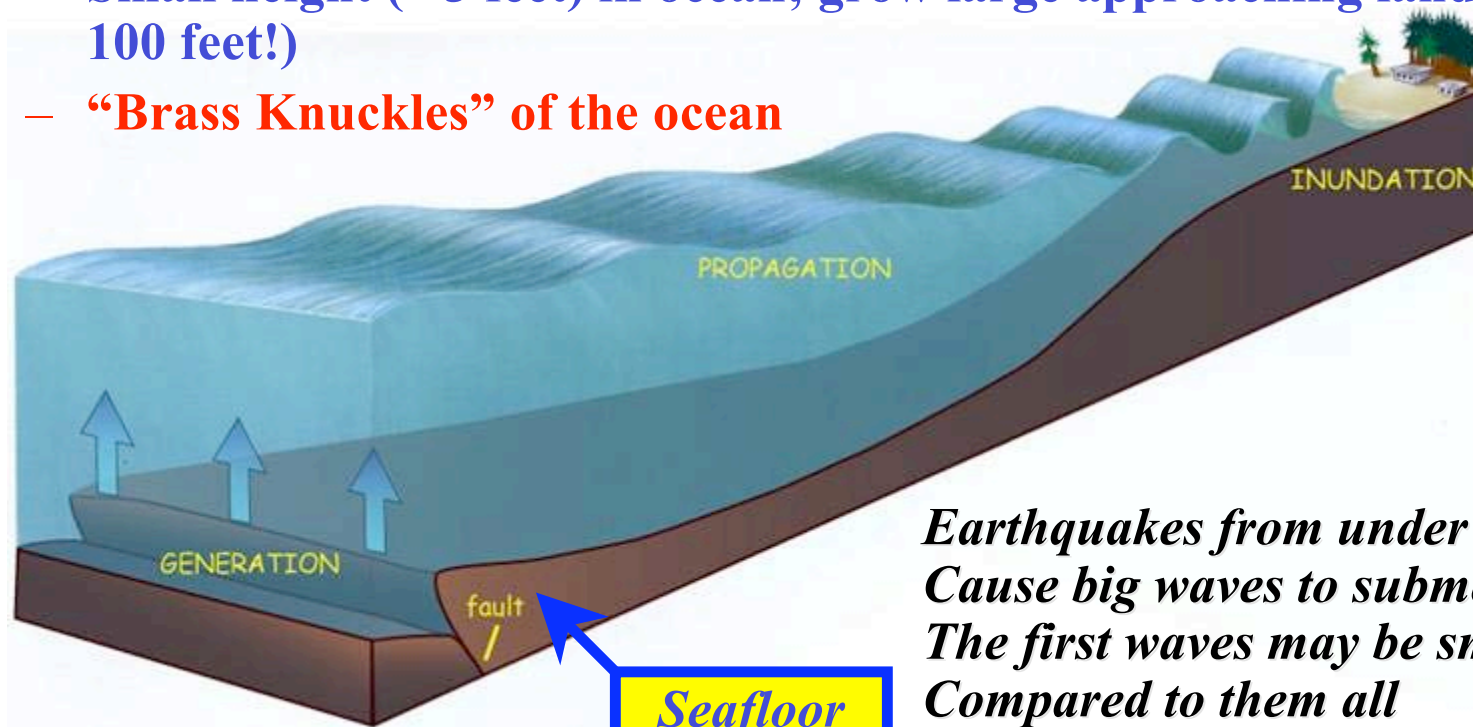


Seafloor Shifts Up or Down:

- Commonly due to Earthquake

Tsunami – A series of broad waves that grow in shallow water

- Means “Harbor Wave” (not tidal wave)
- **Movement of sea floor displaces a huge mass of water:**
 - Commonly from an Earthquake
- Spreads out as a series of waves
 - Travel the speed of a jetliner (~ 500 miles/hour!)
 - Small height (~ 3 feet) in ocean; grow large approaching land (up to 100 feet!)
 - “Brass Knuckles” of the ocean



*Earthquakes from under the seas
Cause big waves to submerge the trees
The first waves may be small
Compared to them all
These waves we call – tsunamis! ☺
(Limerick by Jen Natoli)*

Tsunami - "Brass Knuckles of the Ocean"



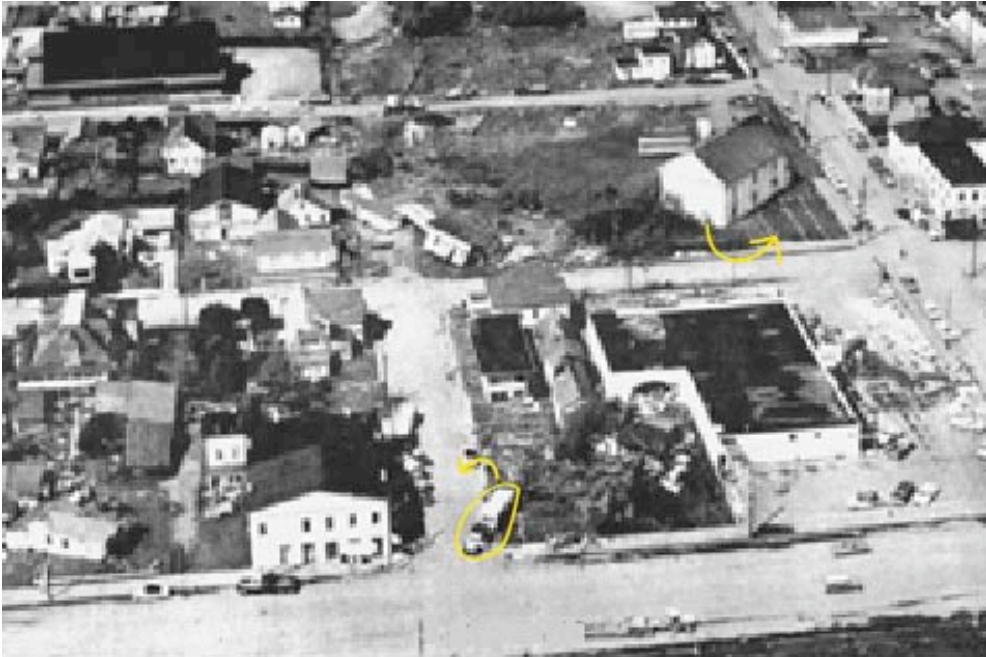
1957
Oahu
Tsunami



- Tsunamis are a series of waves
- Initial wave is mostly water ("bare fist")
- Later waves contain rock, metal, wood, etc. ("brass knuckles")

Tsunami - "Brass Knuckles of the Ocean"

Crescent City California, 1964



A



B

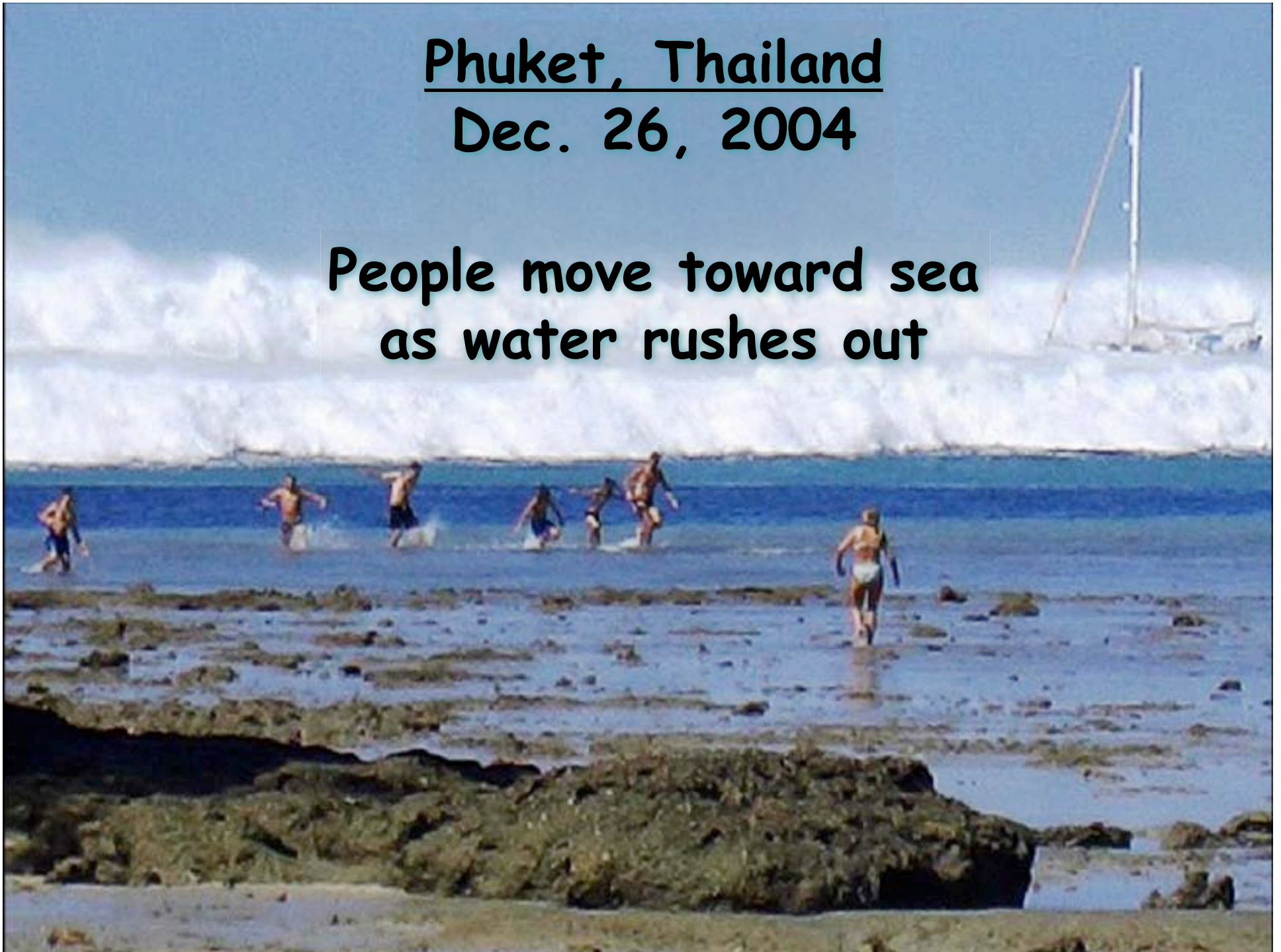
"Brass knuckles" of the ocean. The photograph of F and G Streets in downtown Crescent City (A) was taken two days after the 1964 tsunami surged onto the North Coast. Note the house in the upper left corner, shoved at an angle from its foundation. The semi-truck at the bottom center was shoved from the street onto the adjacent lawn. A close view of the streets of downtown Crescent City (B) also shows a car thrown onto another and a house ripped off its foundation (arrow). (Modified from Dengler and Moley, 1999)

Tsunami Run-up and Inundation



Phuket, Thailand
Dec. 26, 2004

People move toward sea
as water rushes out



Indonesian Earthquake and Tsunami - December 26, 2004

What reaches India first (peak or trough)?

What about Thailand?

Series of
Waves

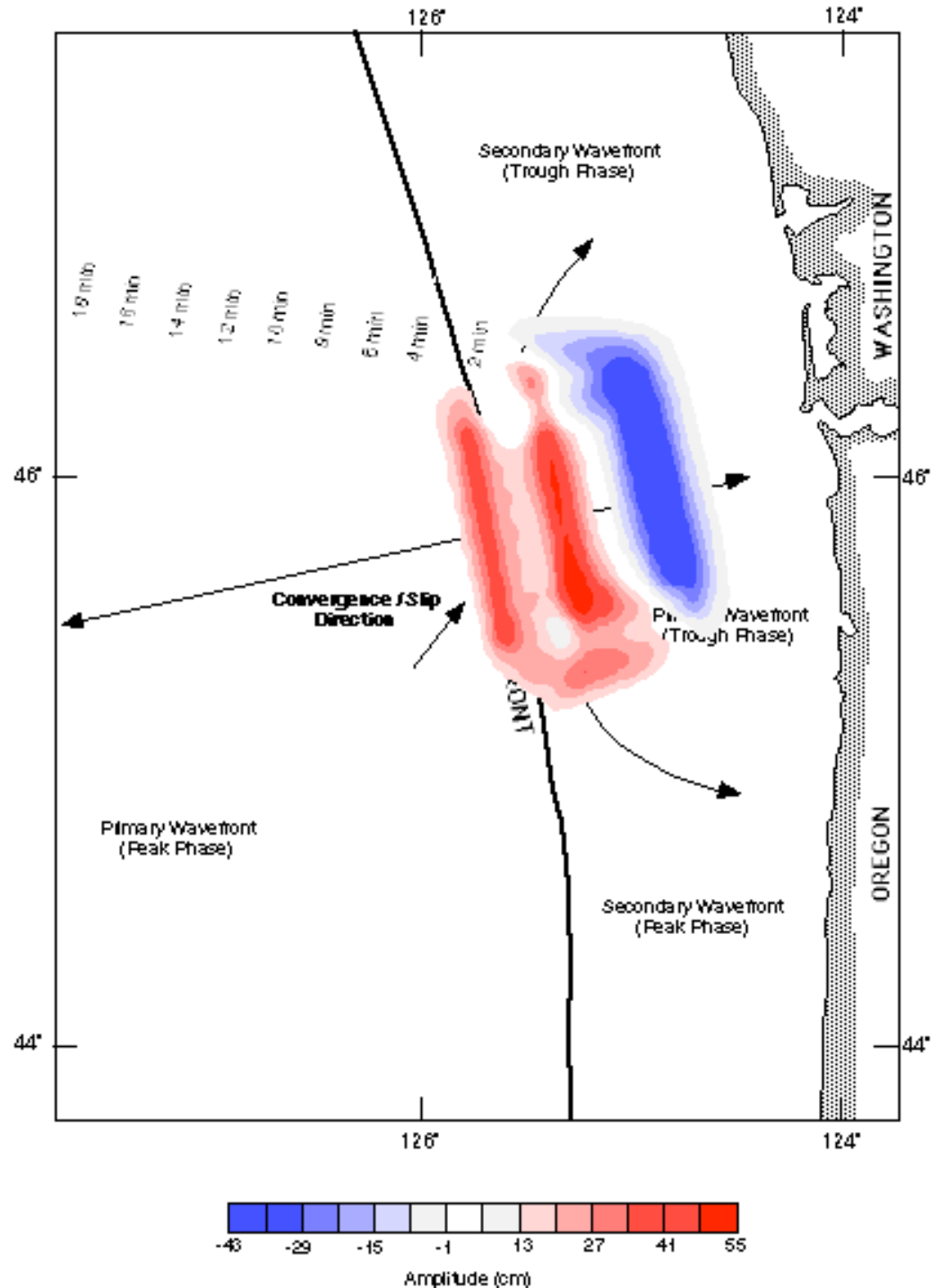
Red = Peak

Blue = Trough



Tsunami Variables

- Distance from Source
 - Wave amplitudes generally lessen with distance traveled
- Initial Arrival of Tsunami
 - Peak first (water rises)
 - Trough first (water recedes)
- Directivity
 - Waves may hit coastline head-on or obliquely
- Duration
 - Big waves for up to 12 hours
- Coastal Morphology
 - Run-up (maximum elevations reached by water)
 - Inundation (maximum distance water reaches inland)



Tsunami Variables: Effects of Coastal Morphology

Directivity:

- Waves hit coastline head-on or obliquely

Run-up:

- Maximum elevations reached by water

Inundation:

- Maximum distance water reaches inland



Tsunami Arrival Time and Inundation Estimate

Long Beach, Washington



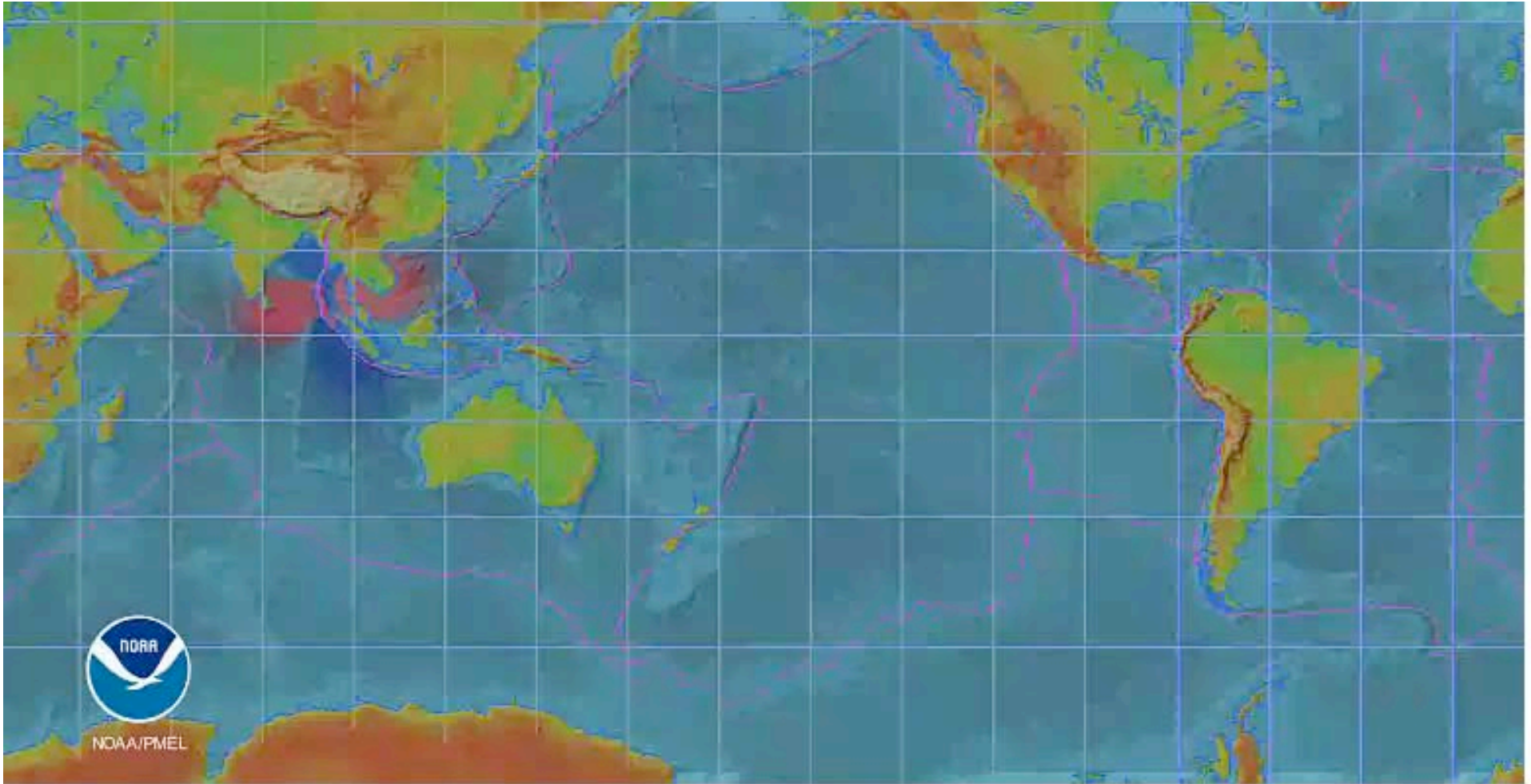
Tsunami Inundation Simulation -- Seaside, Oregon



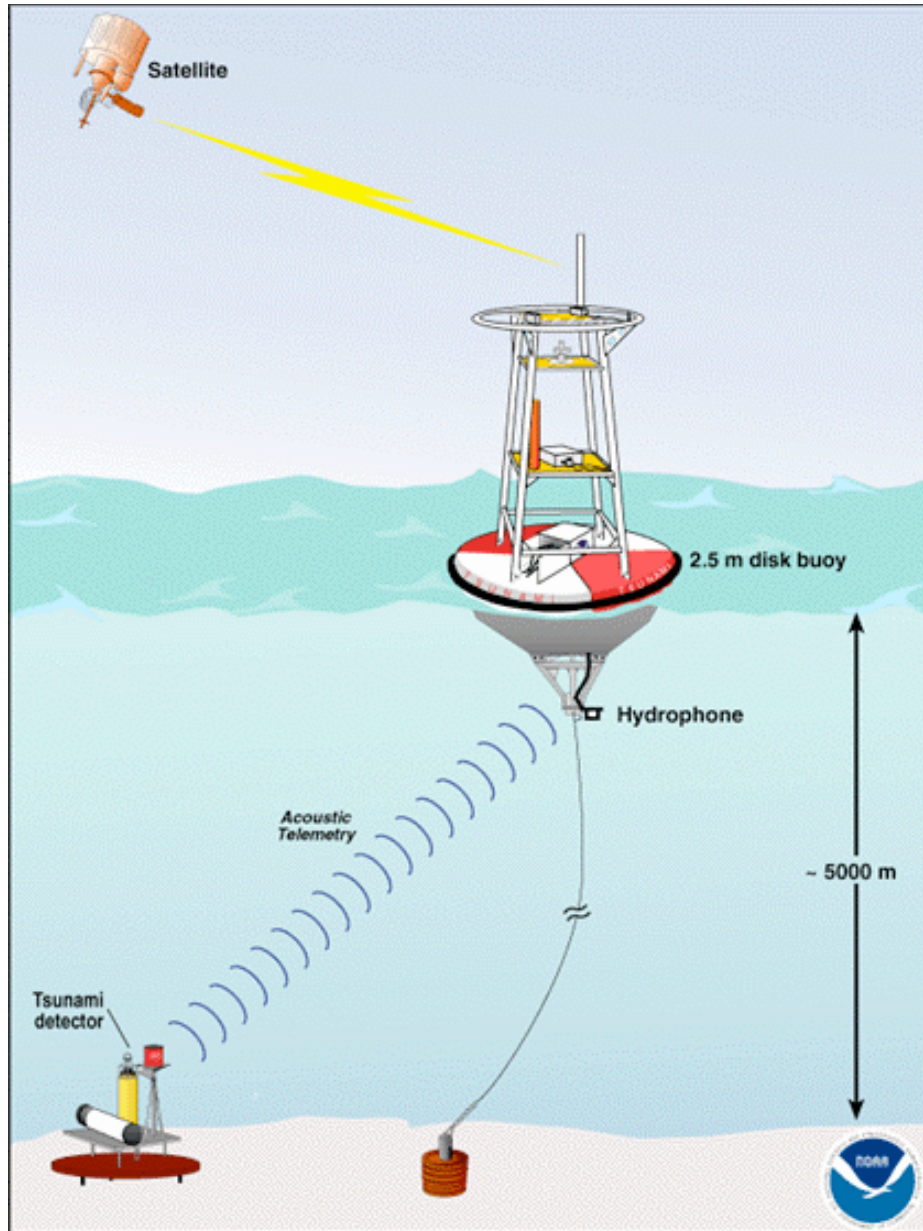
Hinsdale Wave Tank, Oregon State University

Indian Ocean Tsunami

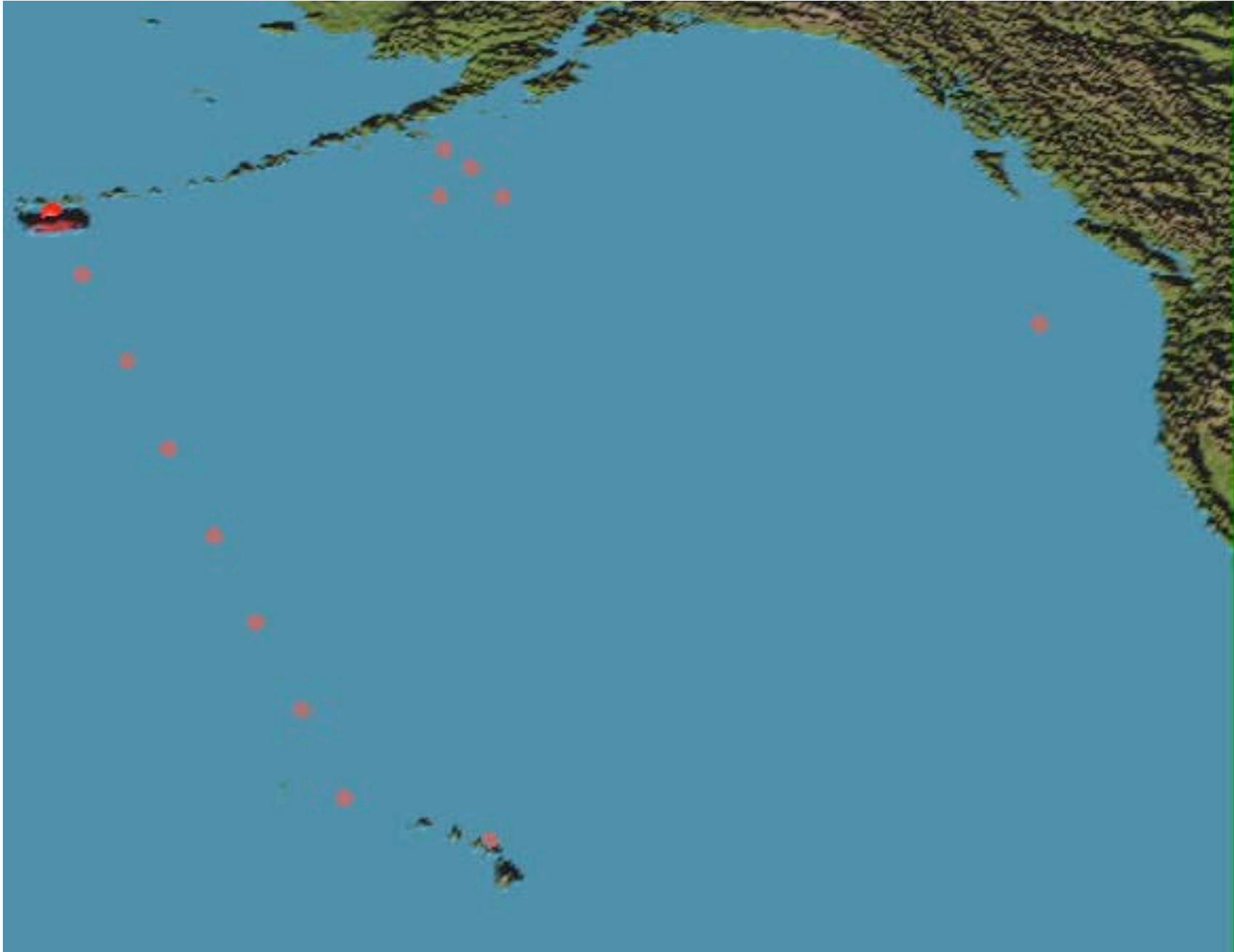
December 26, 2004



Tsunami Detection

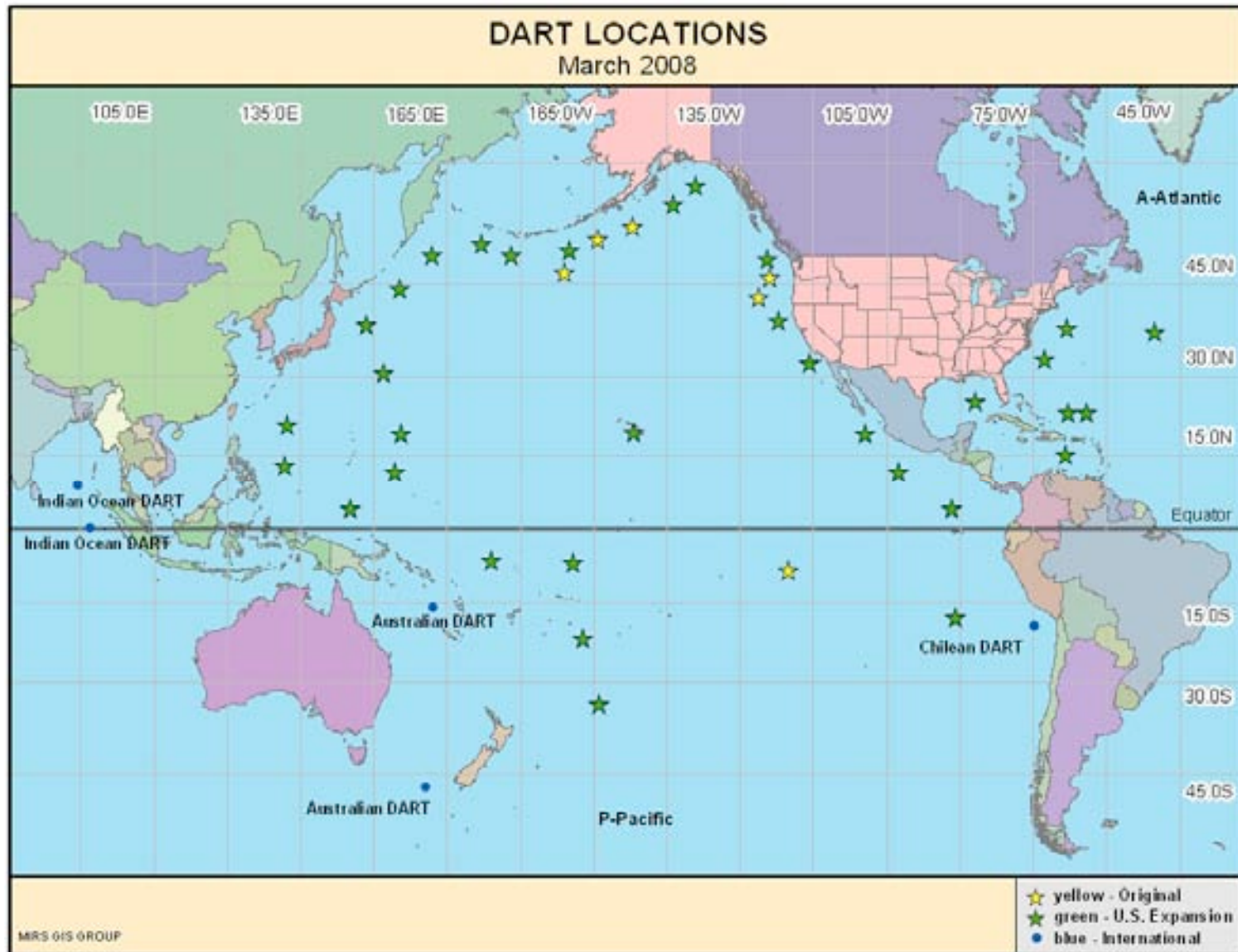


Andranov Earthquake, 1996

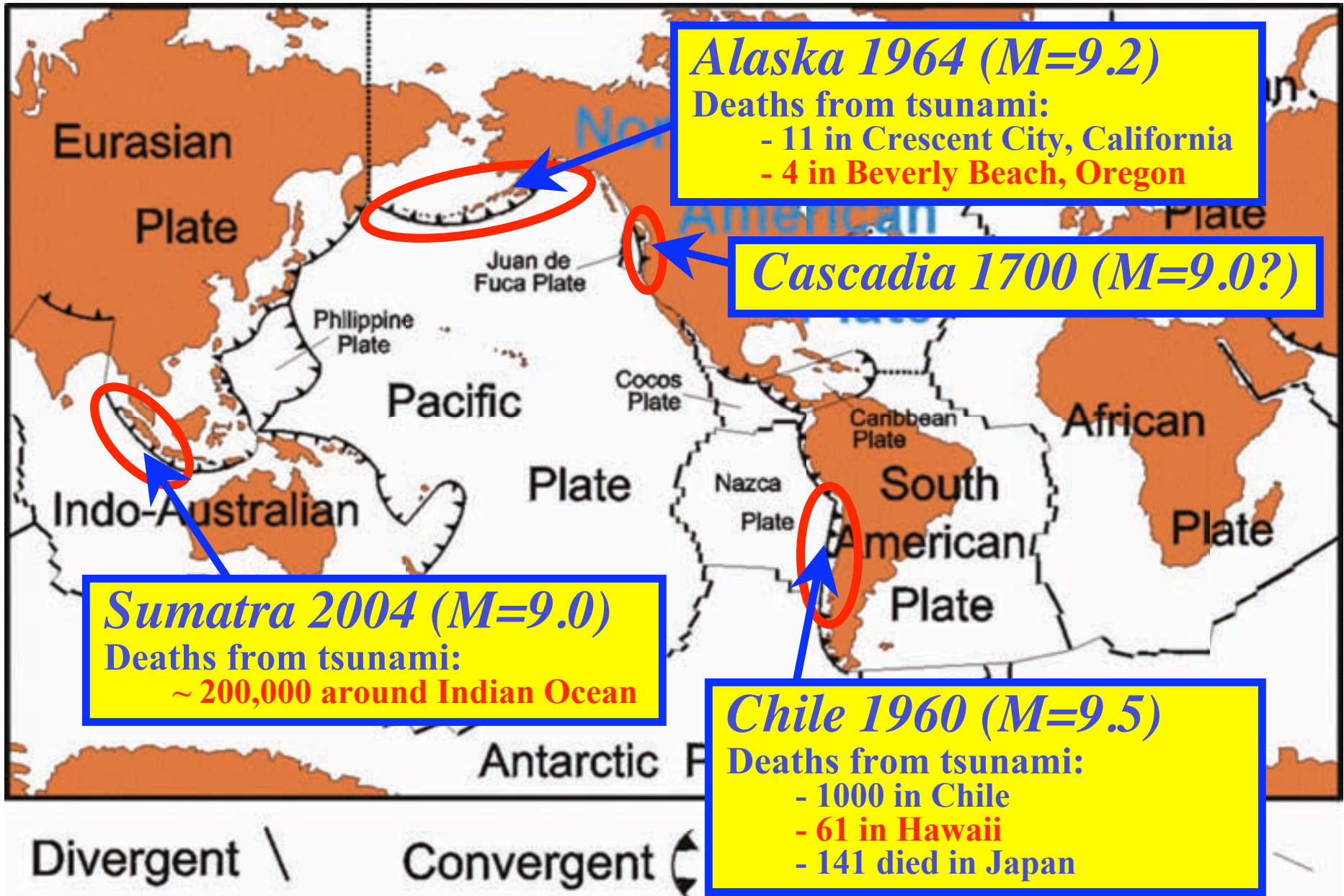


Pacific Tsunami Warning System

Deep-ocean Assessment and Reporting of Tsunamis (DART)

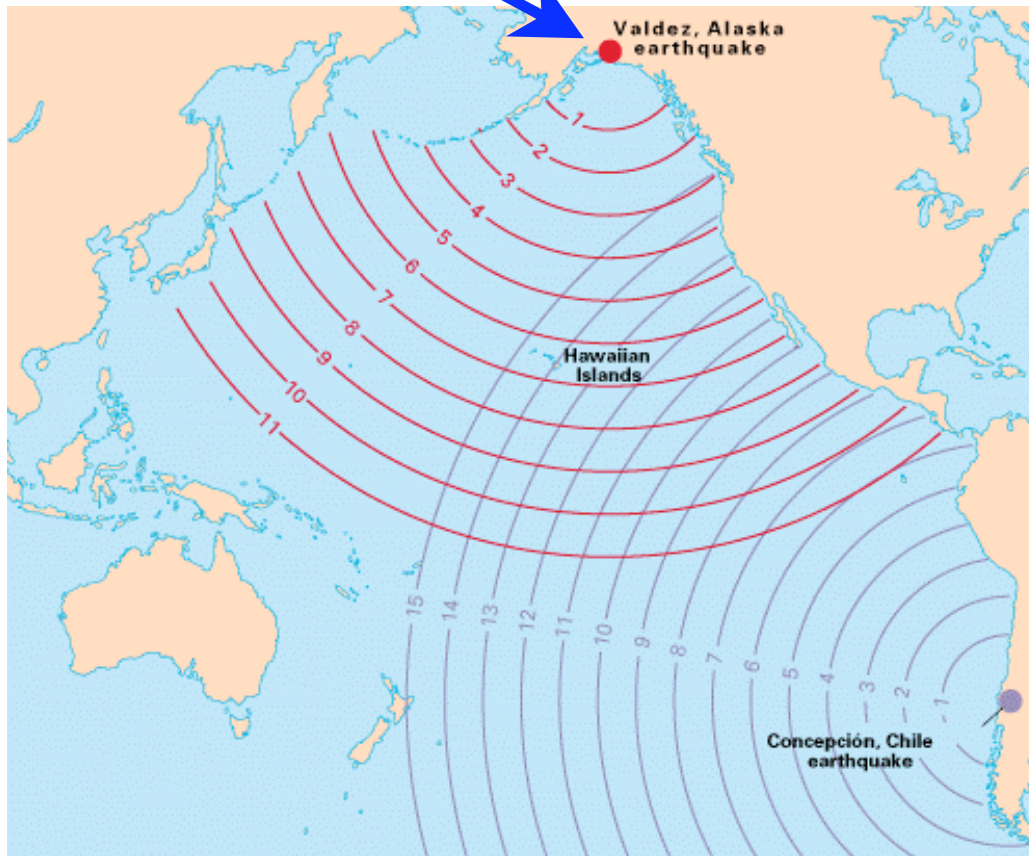


Subduction Zone Earthquakes can generate devastating Tsunamis



1964 Alaska Earthquake

Tsunami waves travel the speed of a Jetliner
(~ 500 miles/hour!)



- 11 people killed in Crescent City, California
- 4 people killed at Beverly Beach, Oregon – just north of Newport!
- ~ 4 hours warning time.

- How much warning time for a tsunami caused by a Cascadia Subduction Zone earthquake?

*Whale Watching Center
Depoe Bay, Oregon*



**4 People killed by
1964 Great Alaska Earthquake Tsunami**

Robert J. Lillie

Beverly Beach State Park, Oregon



Robert J. Little

Whale Watching Center, Depoe Bay, Oregon

*Whale Watching Center,
Depoe Bay, Oregon*

Robert J. Lillie





Robert J. Little

Whale Watching Center, Depoe Bay, Oregon

*Whale Watching Center,
Depoe Bay, Oregon*

Morris Grover



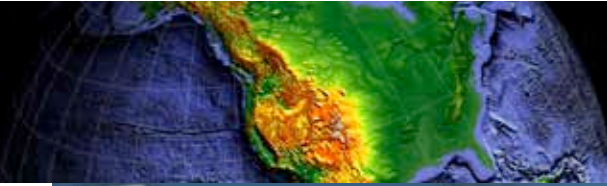
Robert J. Lillie

*Whale Watching Center,
Depoe Bay, Oregon*

Kay Wyatt



Robert J. Lillie



IRIS Active Earth Display

ACTIVE EARTH



Touch a scene to explore how it can be linked to data

www.iris.edu/aed2/index.phtml?code=cascadia

Cascadia Module



EARTHQUAKES



Earthquakes can shake up cities without warning, reminding us that we are living on an active Earth.



VOLCANOES



The majestic Cascades volcanoes formed by one tectonic plate sinking under another.

ANGER BENEATH THE PACIFIC NORTHWEST



TSUNAMIS



Tsunami waves from undersea earthquakes have drowned the coast of the Pacific Northwest in the past.



PLATE TECTONICS



The Coast Ranges would not exist if two tectonic plates were not smashing together beneath them.

TSUNAMI INFORMATION

Tsunami Warning Response

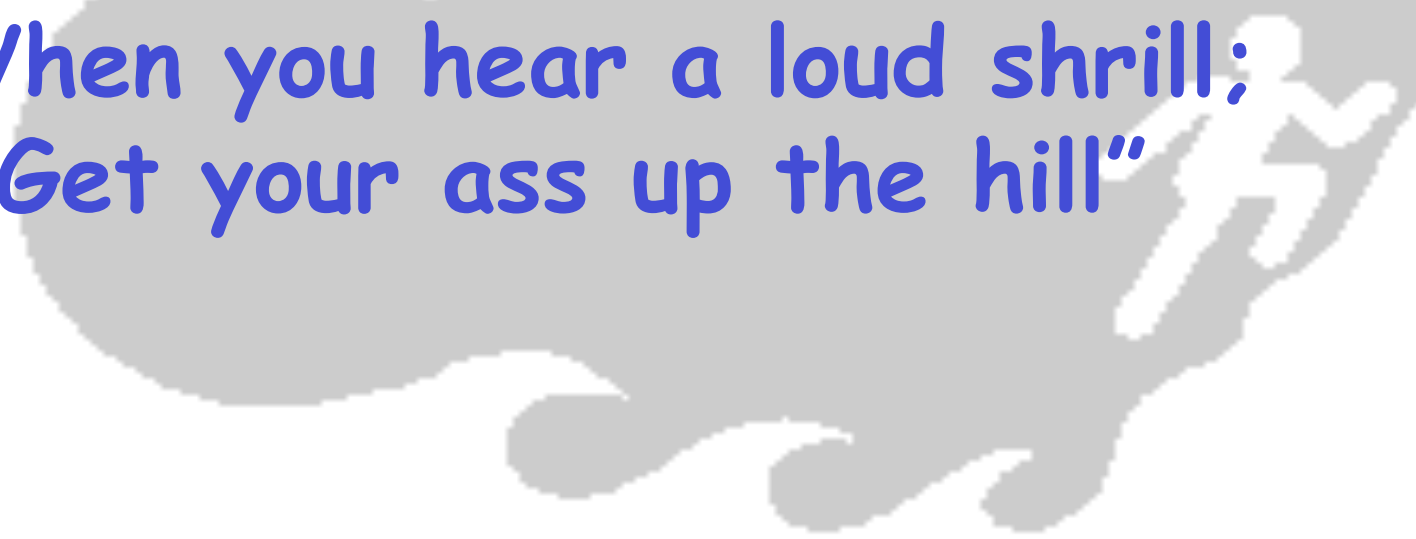
Get to high ground!

- Nearby earthquakes only give a few minutes notice
- Distant earthquakes allow several hours notice

IN CASE OF EARTHQUAKE, GO TO HIGH GROUND OR INLAND

TSUNAMI INFORMATION

*“When you hear a loud shrill;
Get your ass up the hill”*



IN CASE OF EARTHQUAKE, GO
TO HIGH GROUND OR INLAND

Magnitude 8.8 OFFSHORE MAULE, CHILE

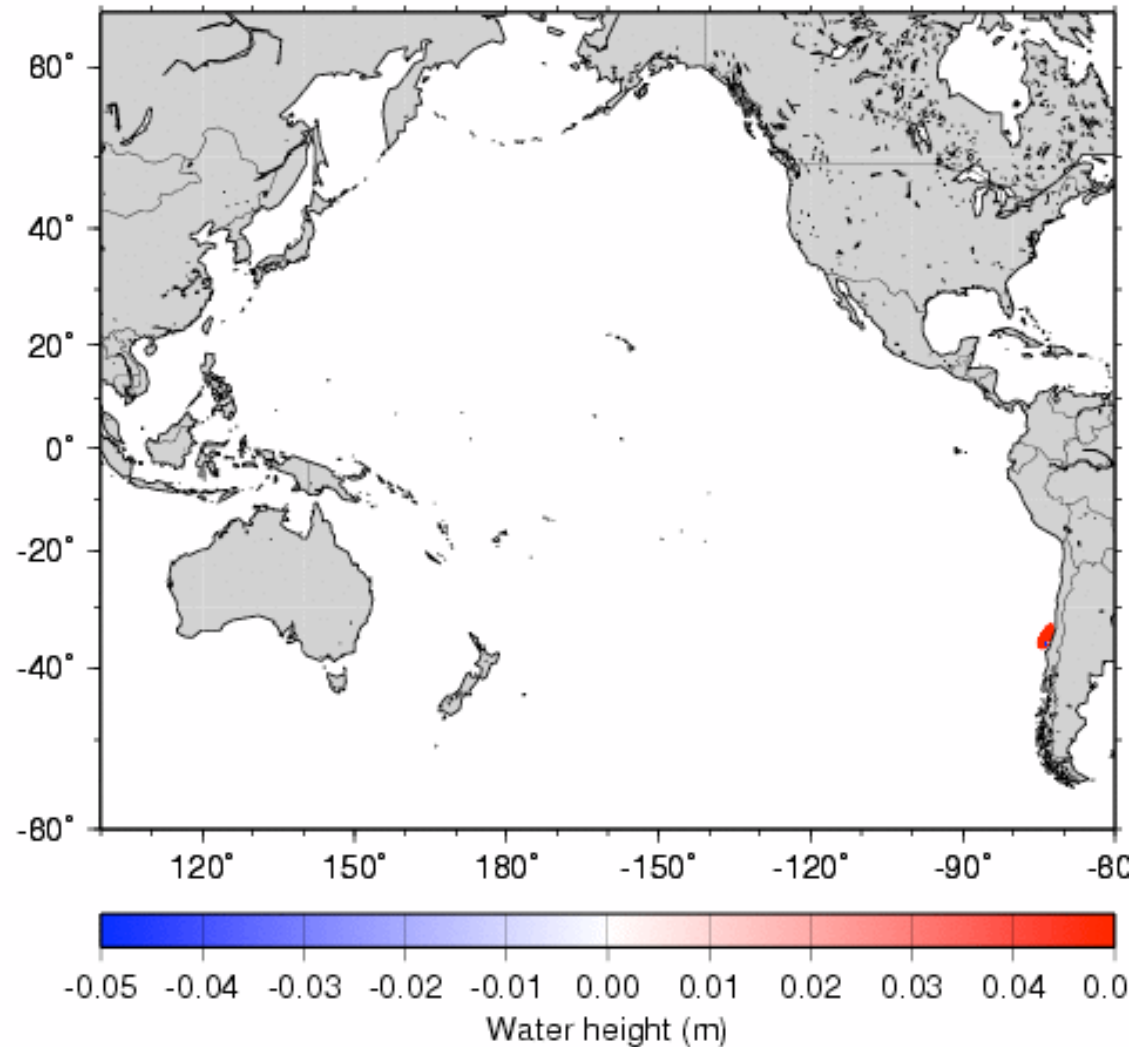
Saturday, February 27, 2010 at 06:34:17 UTC

0 hour 10 min

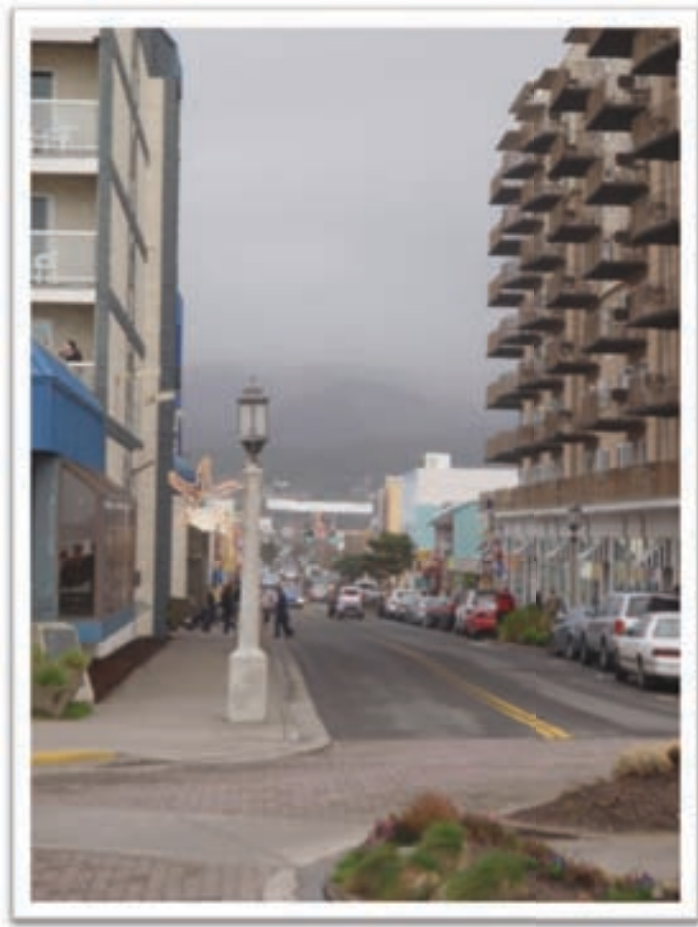


Tsunami Model for Chilean Earthquake

(Earthquake Research Institute, Tokyo)



Earthquake Research Institute, Tokyo



Seaside is the most vulnerable community to tsunamis due to its flat terrain and multiple waterways and wetlands between where people are and where they need to get to.

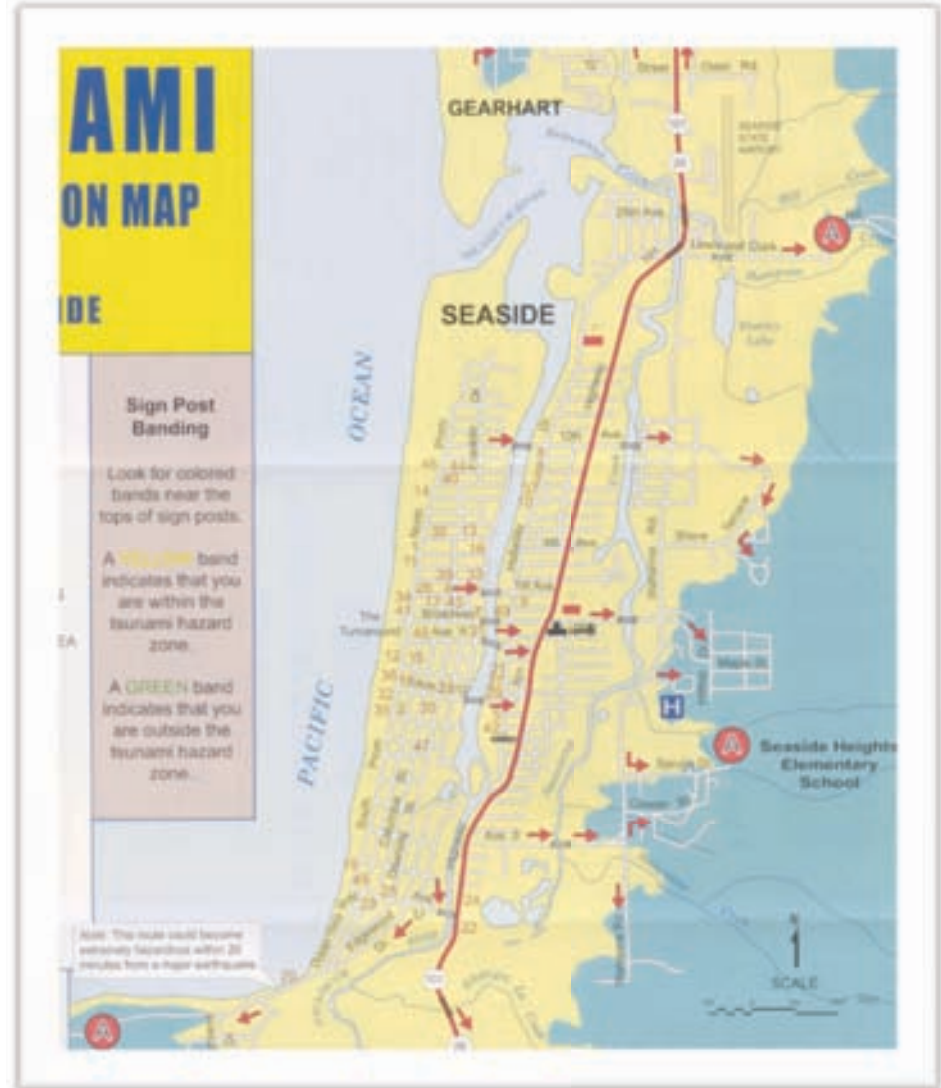
It is also a major destination for visitors who are largely clueless about the danger. **These are visitors coming to the beach to watch the tsunami on Feb. 27, 2010. Are you in this picture?**



From: Pat Corcoran, OSU Extension

Seaside, Oregon: Tsunami Preparation

(From Pat Corcoran, OSU Extension)



Are we Prepared?

- Research in the past 25 years has revealed that Cascadia has “Gi-normous” earthquakes and accompanying tsunamis.
- Occur every 200 to 600 years.
- Last one was in 1700



From Pat Corcoran
OSU Extension

11 Largest Earthquakes Ever Recorded

(Most are at Subduction Zones)

