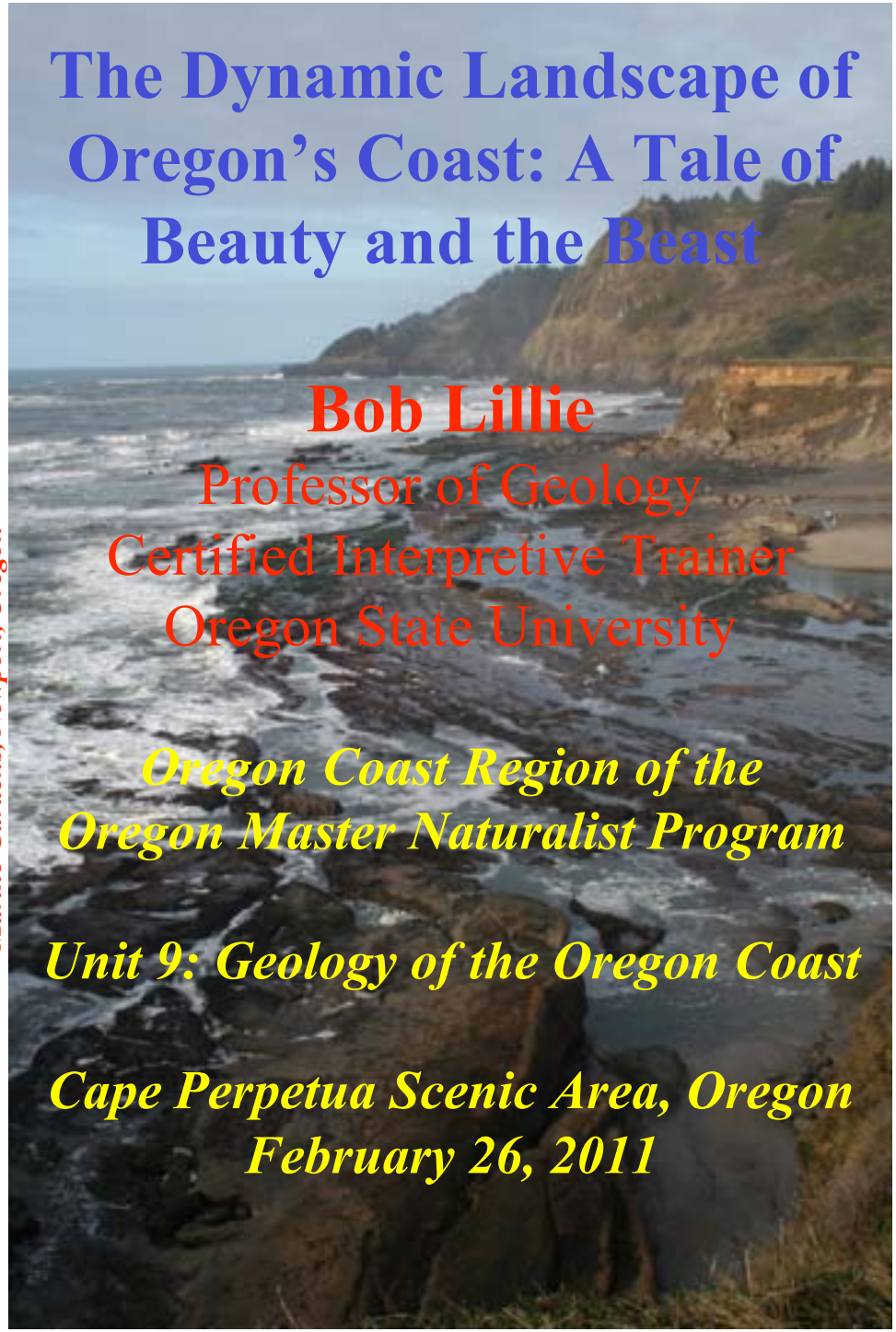
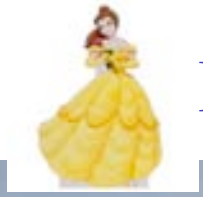
3. Coastal Hazards

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





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."

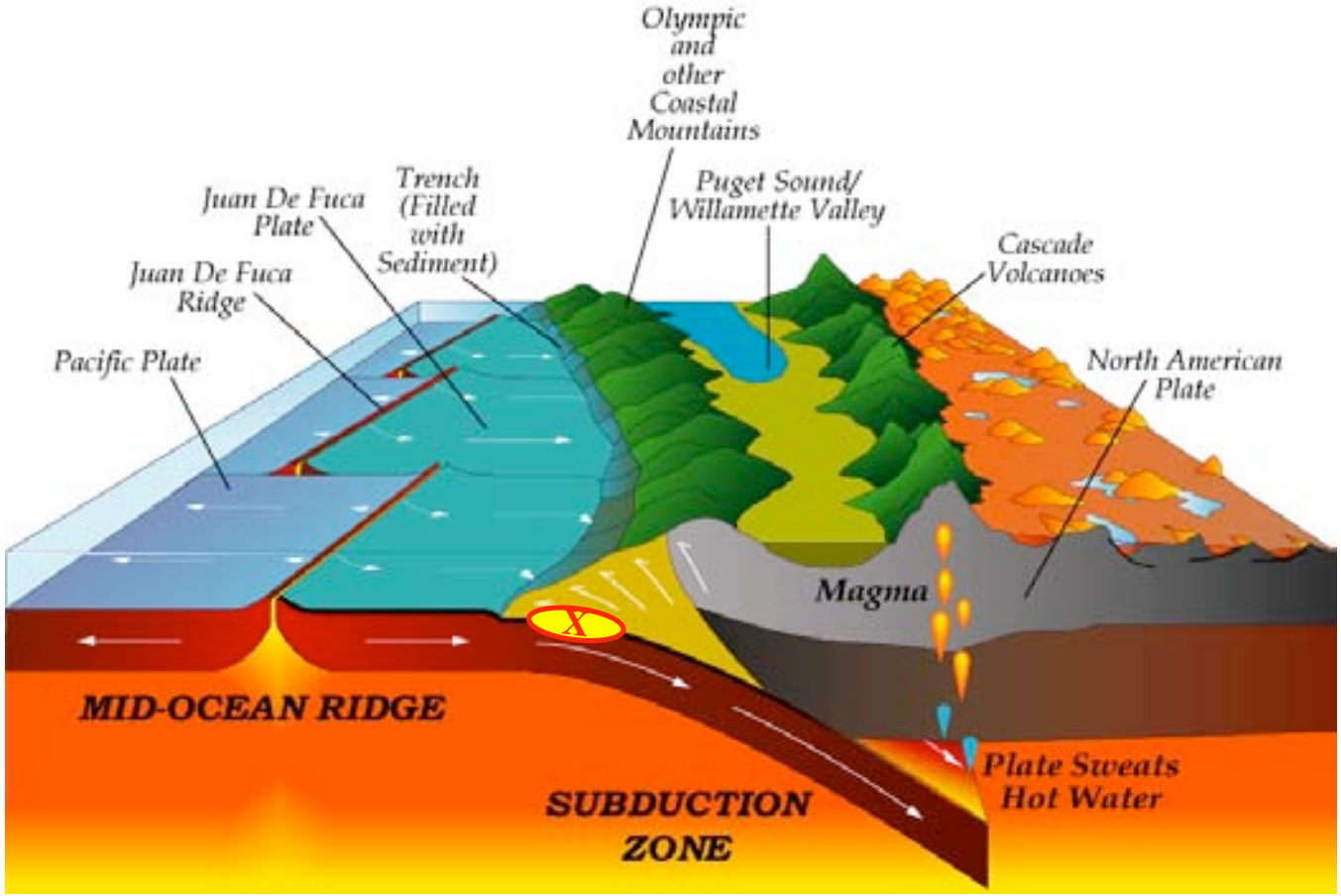
Marine Gardens - Otter Crest, Oregon

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

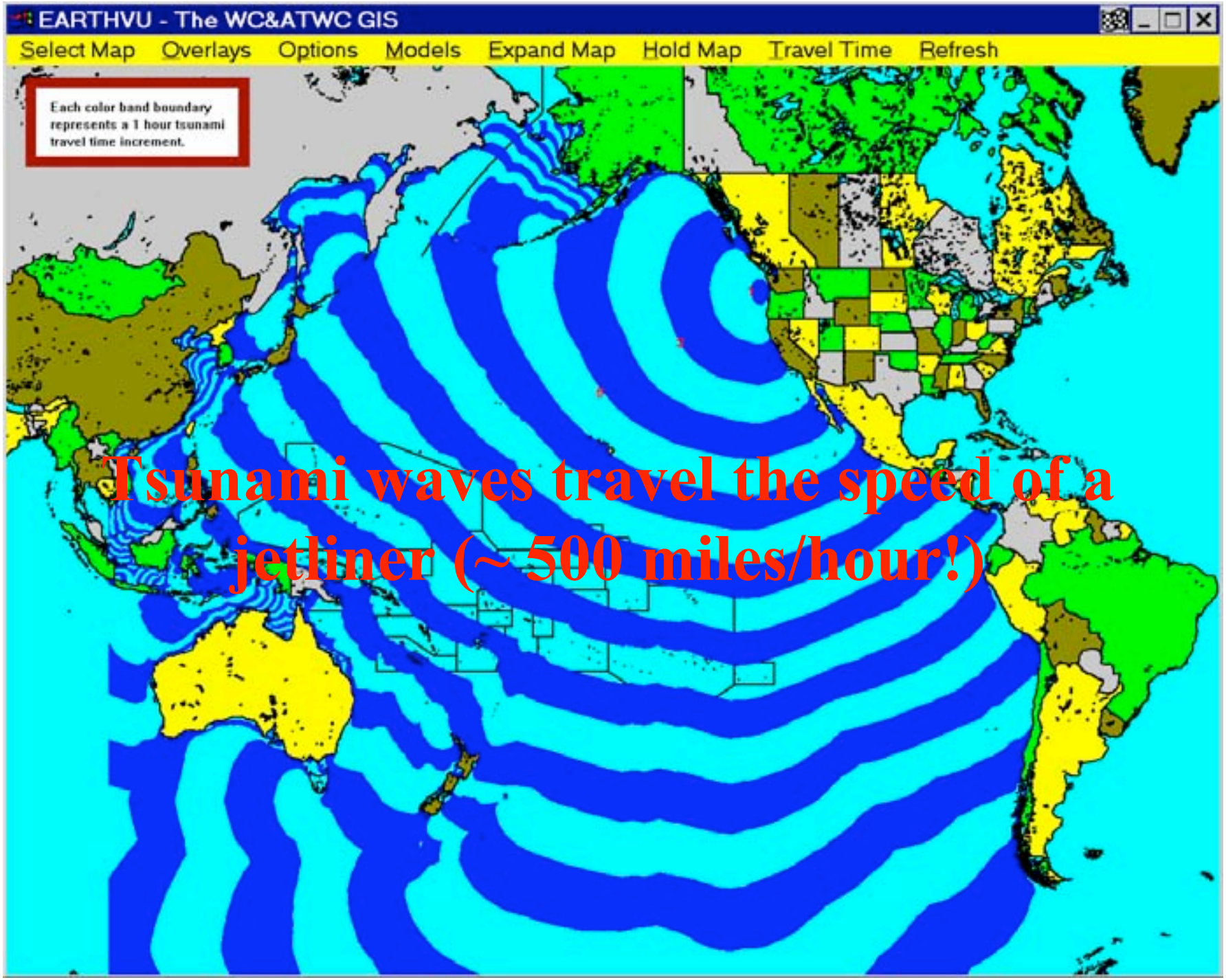
X -- Locked Zone (Mega-Thrust) Earthquakes:

- *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?*

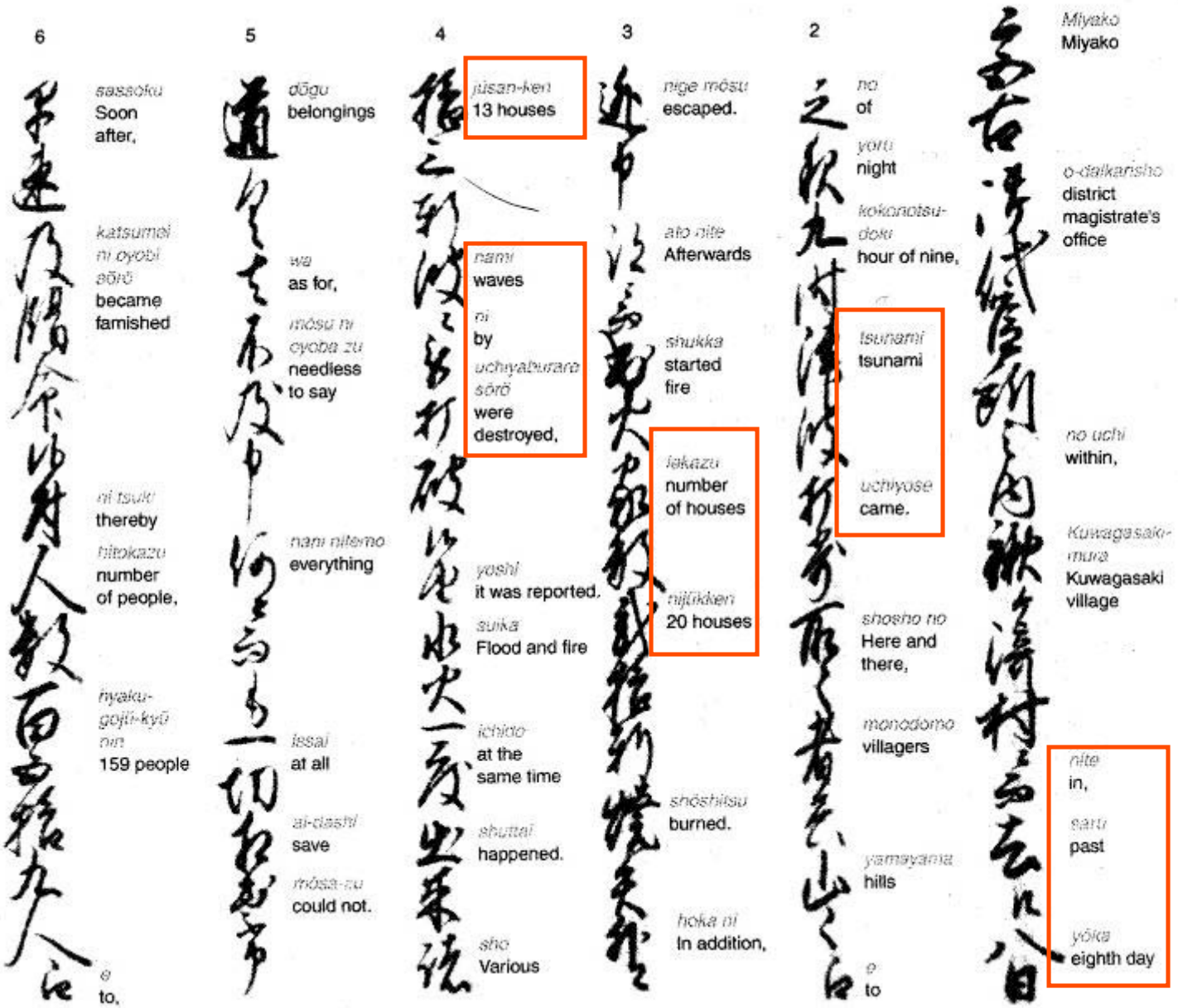


**One winter's night in the year 1700,
a mysterious tsunami flooded fields
and washed away houses in Japan.
It arrived without the warning that
a nearby earthquake usually provides.
Samurai, merchants, and villagers
recorded the event,
but nearly three centuries would pass
before discoveries in North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

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

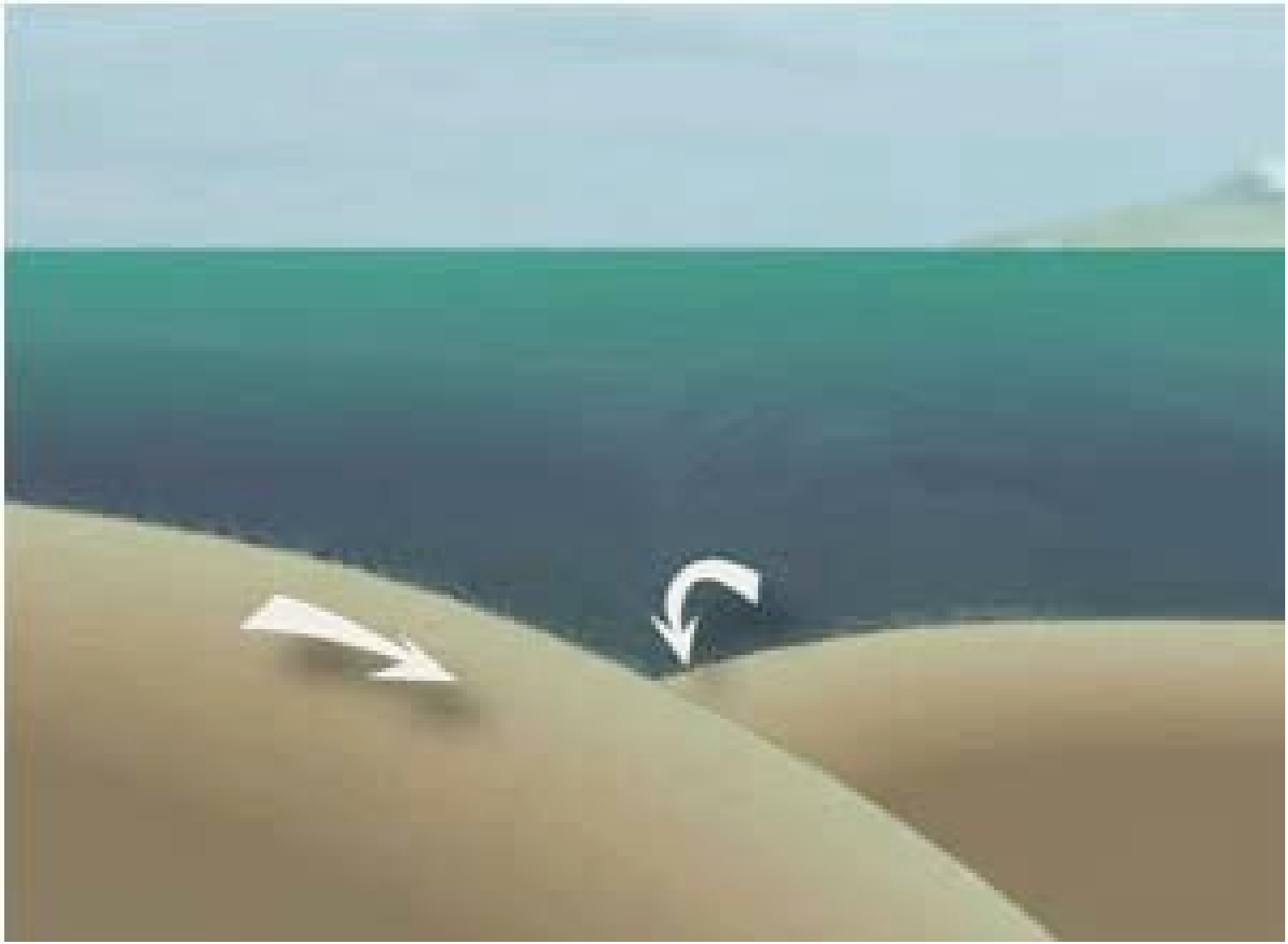

EARTHVU - The WC&ATWC GIS
Select Map
Overlays
Options
Models
Expand Map
Hold Map
Travel Time
Refresh
Each color band boundary represents a 1 hour tsunami travel time increment.
Tsunami waves travel the speed of a jetliner (~ 500 miles/hour!)

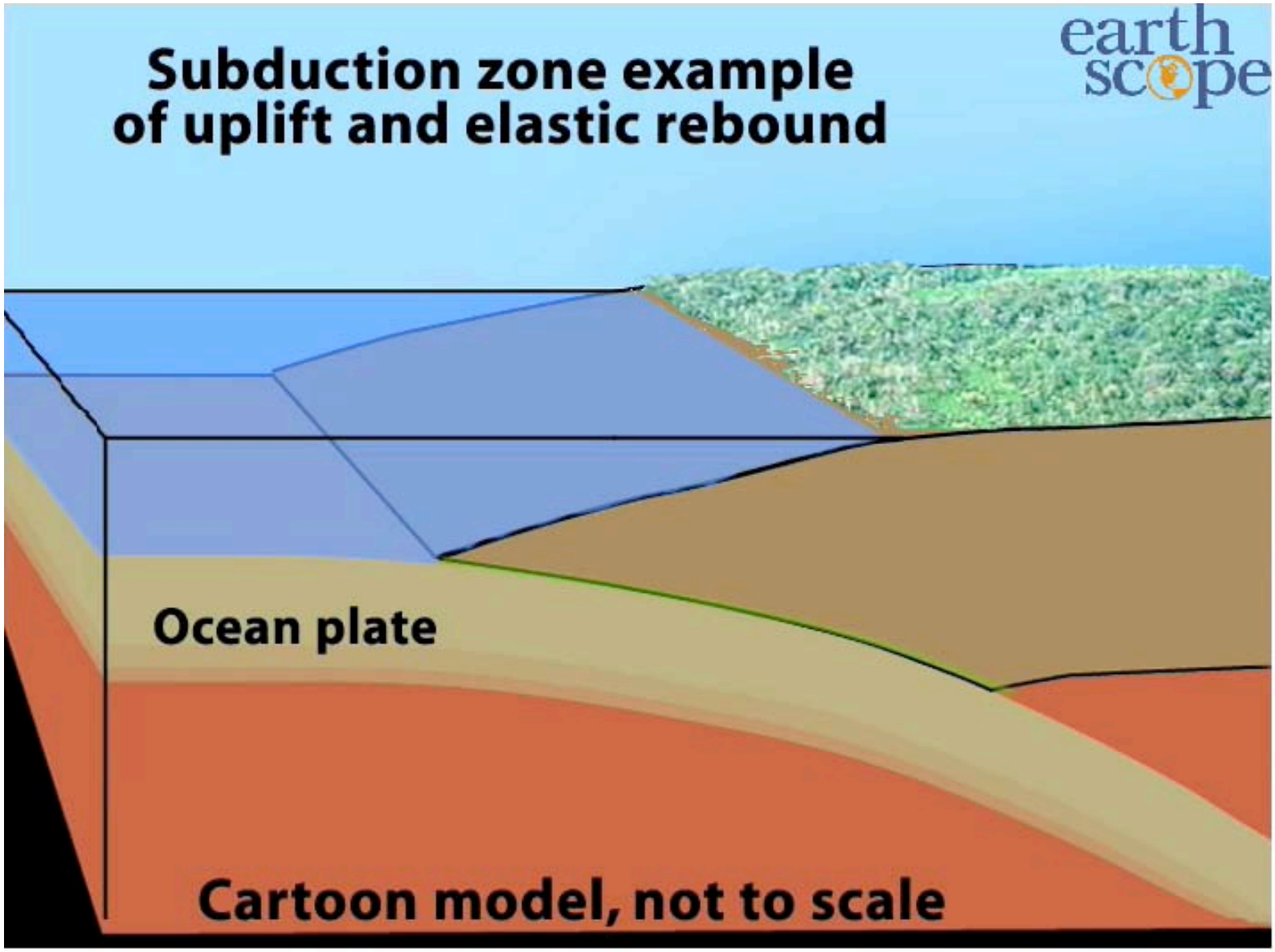
Japanese Harbor-Master records tell of "Orphan Tsunami" on January 27-28, 1700



Tsuji et al., 1998 from B. Atwater

Tsunami Generation from Subduction Zone Earthquake



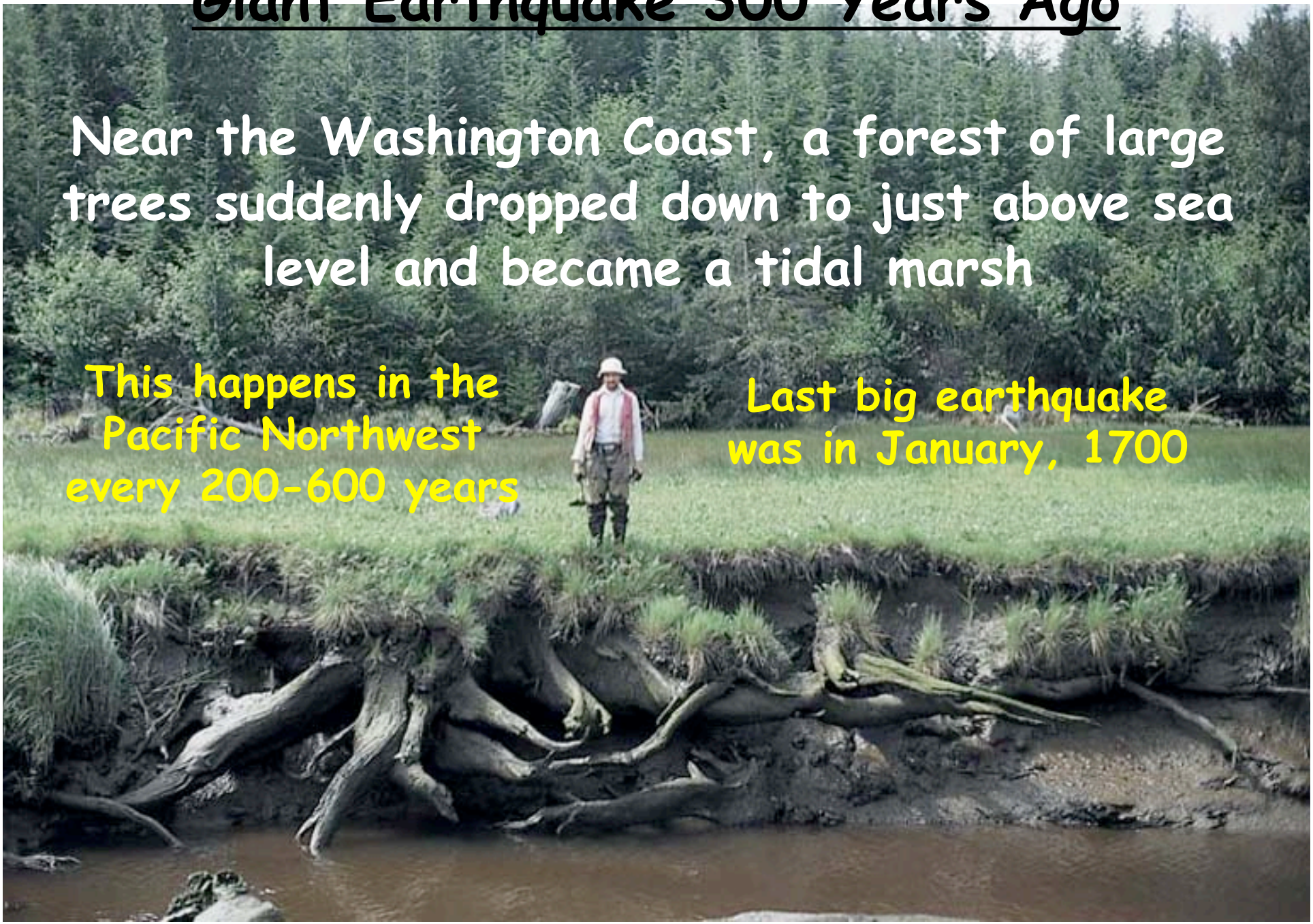


www.iris.edu (Animation by Jenda Johnson)

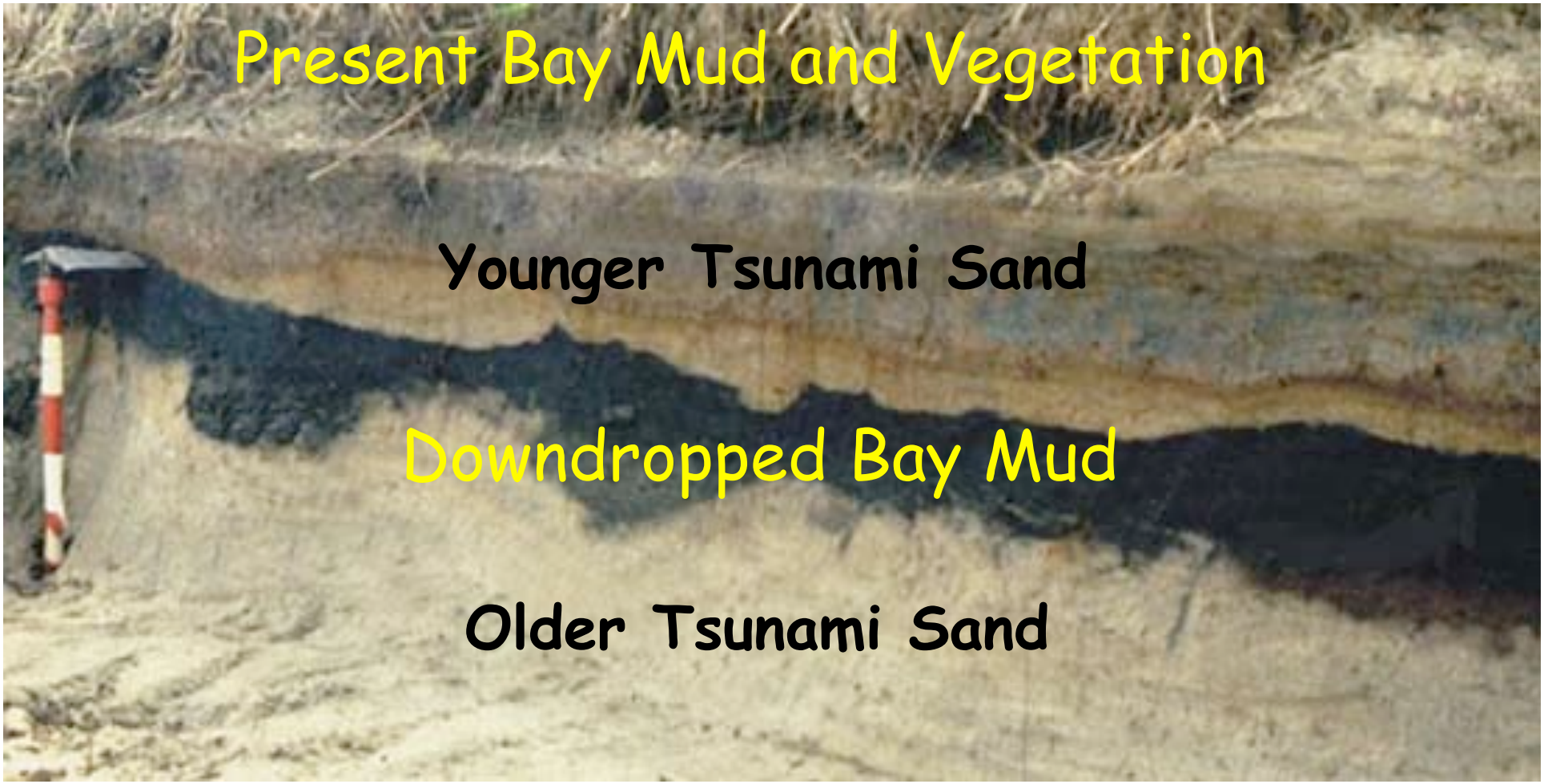
2004 Banda Ache, Indonesia
Damage to Human-Built Infrastructure

2004 Banda Ache, Indonesia
Damage to Human-Built Infrastructure

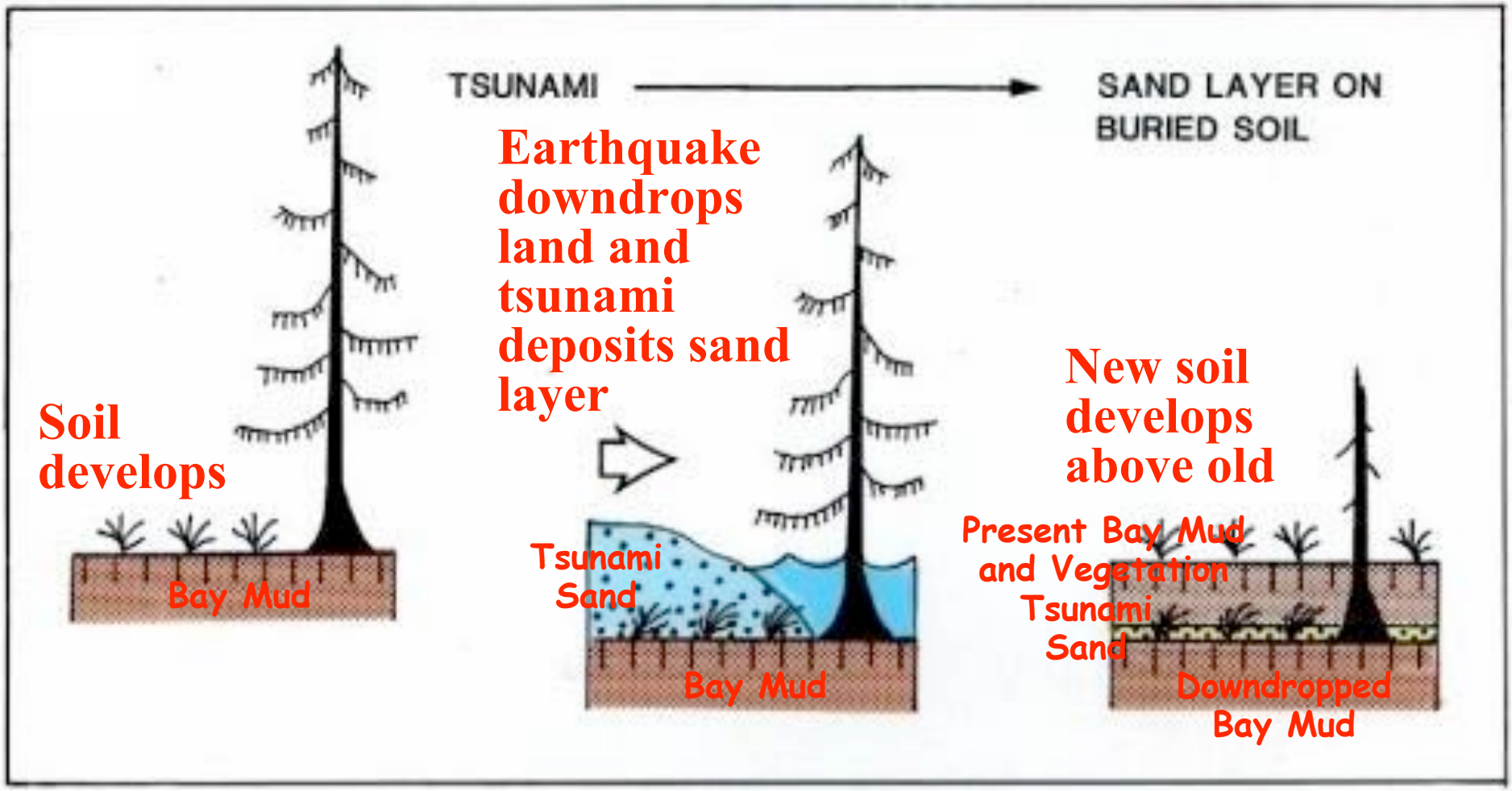
Giant Earthquake 300 Years Ago



Tsunami Sand Deposits Represent Past Earthquakes



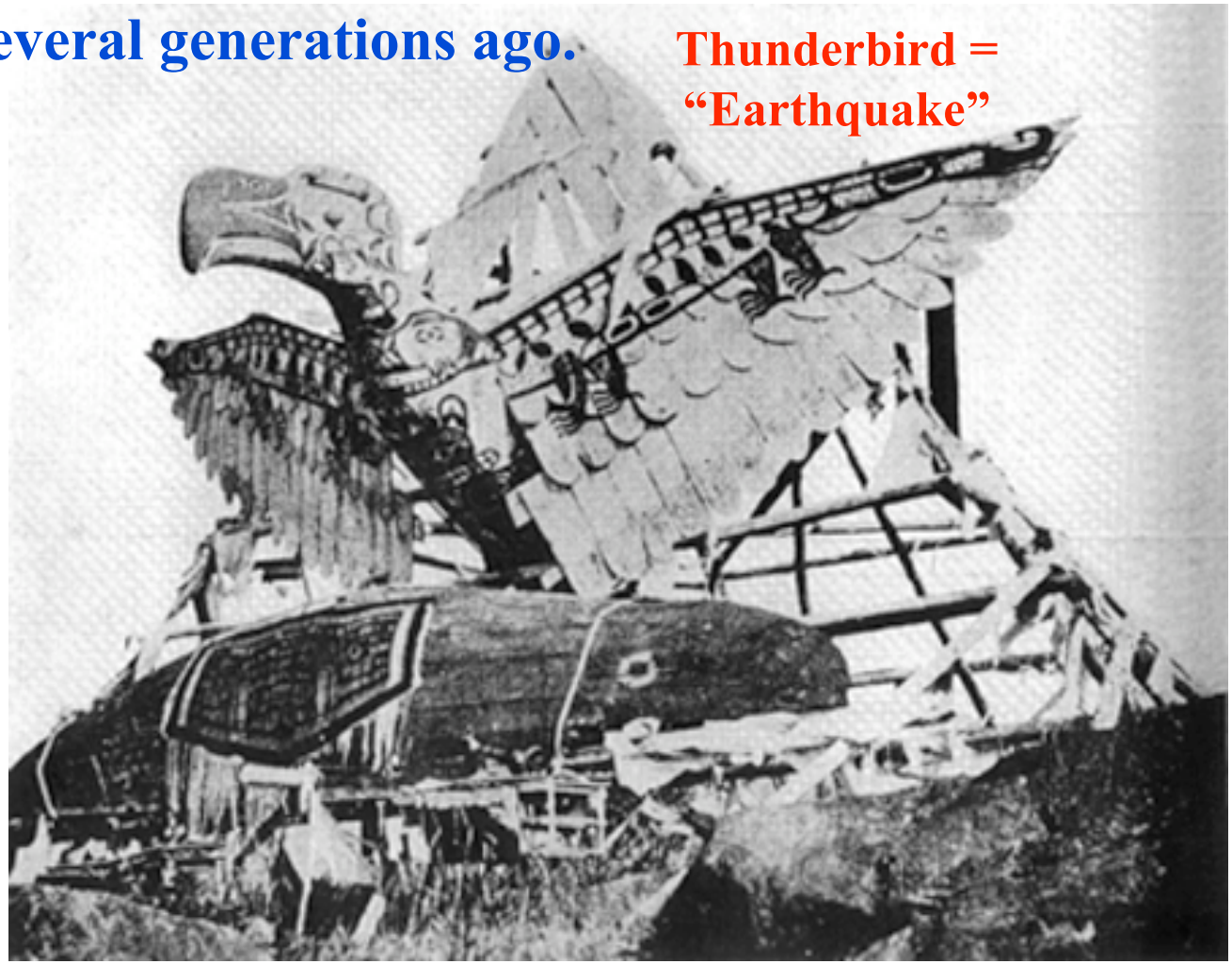
Bay Mud, Tsunami Sands, and Trees Drowned During Earthquake



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

"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).

Thunderbird = "Earthquake"



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).

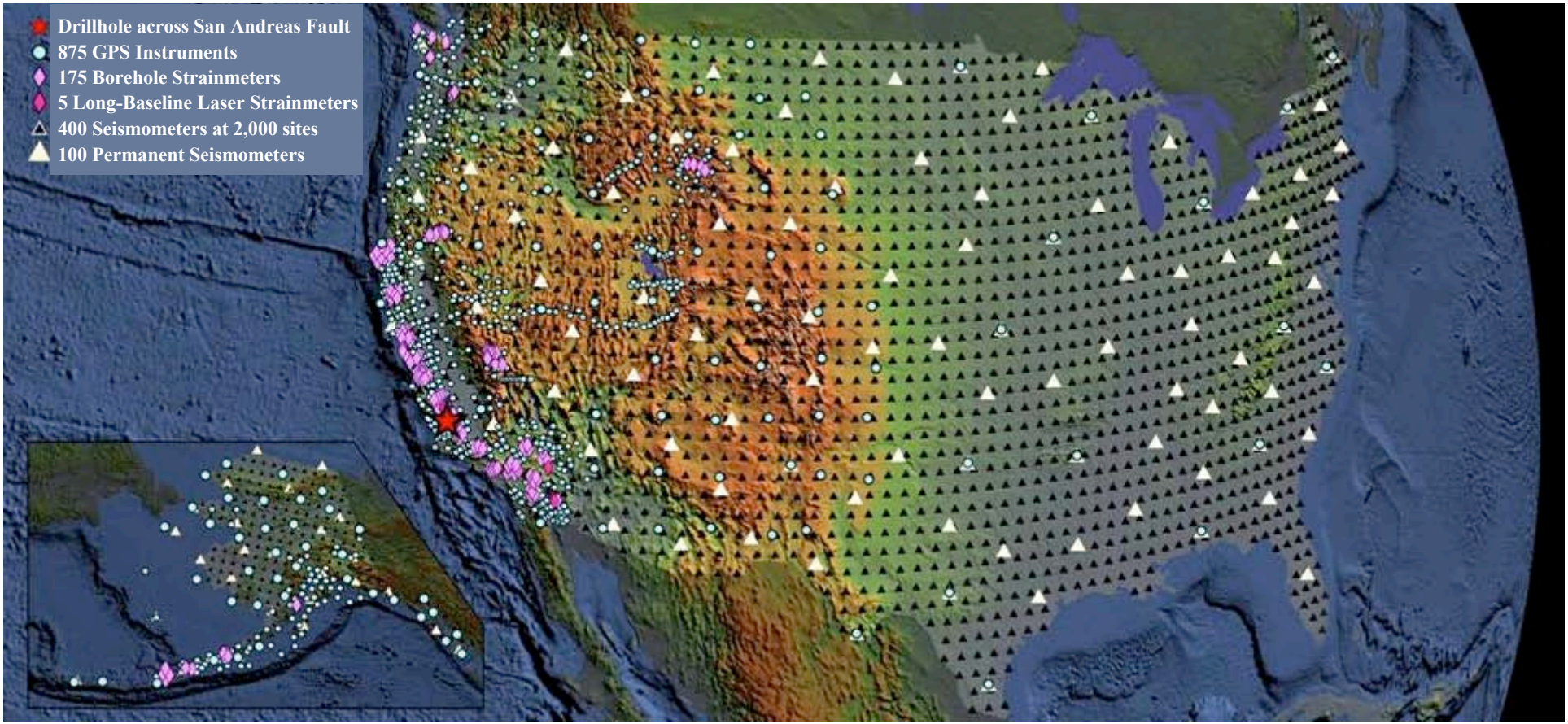
Great Earthquakes in the Pacific Northwest

- 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 ± 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

EarthScope

Seismometers, GSP, and other instruments to …..

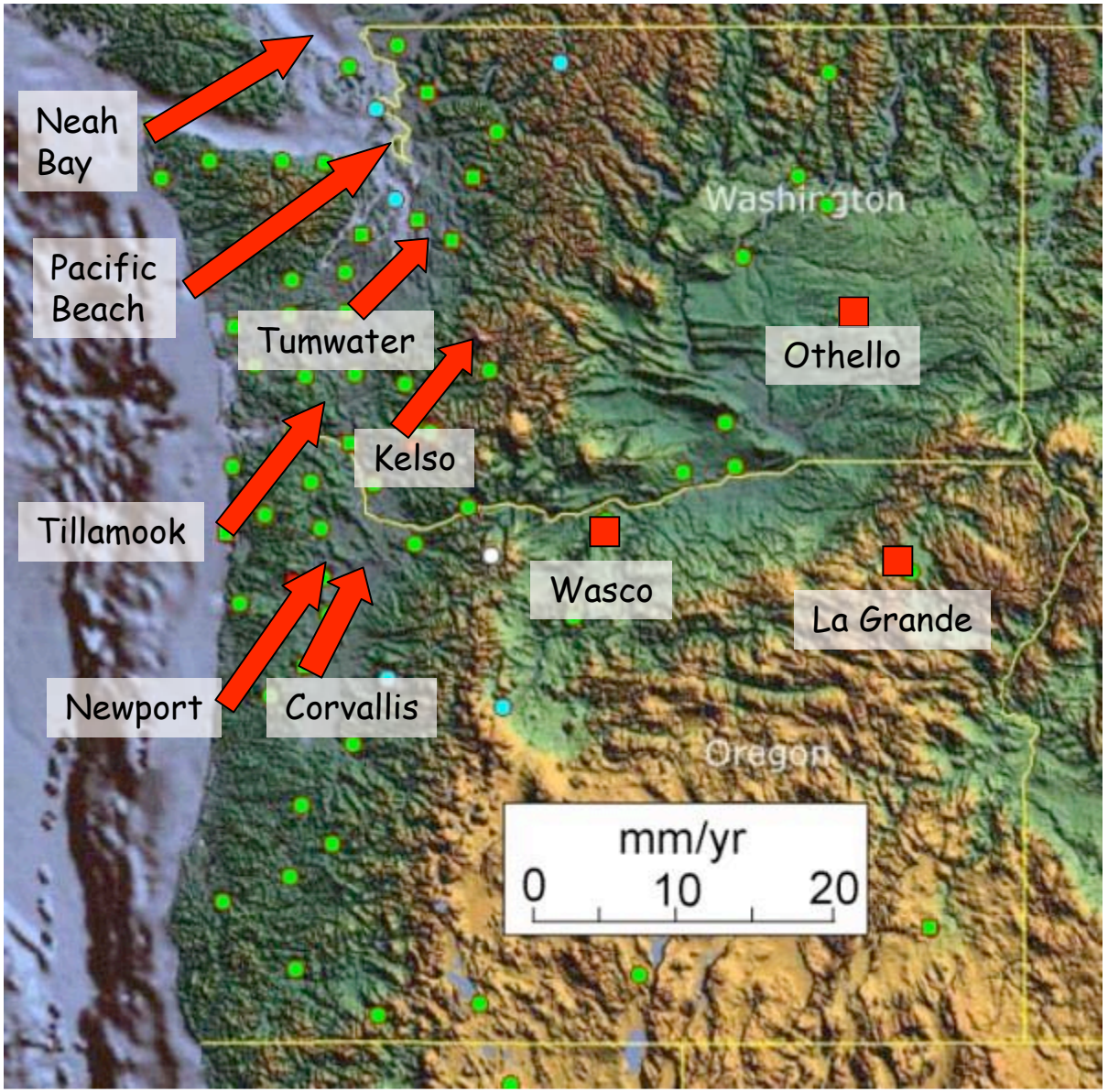
- Explore the structure and evolution of North American continent
- Study processes that cause earthquakes and volcanic eruptions



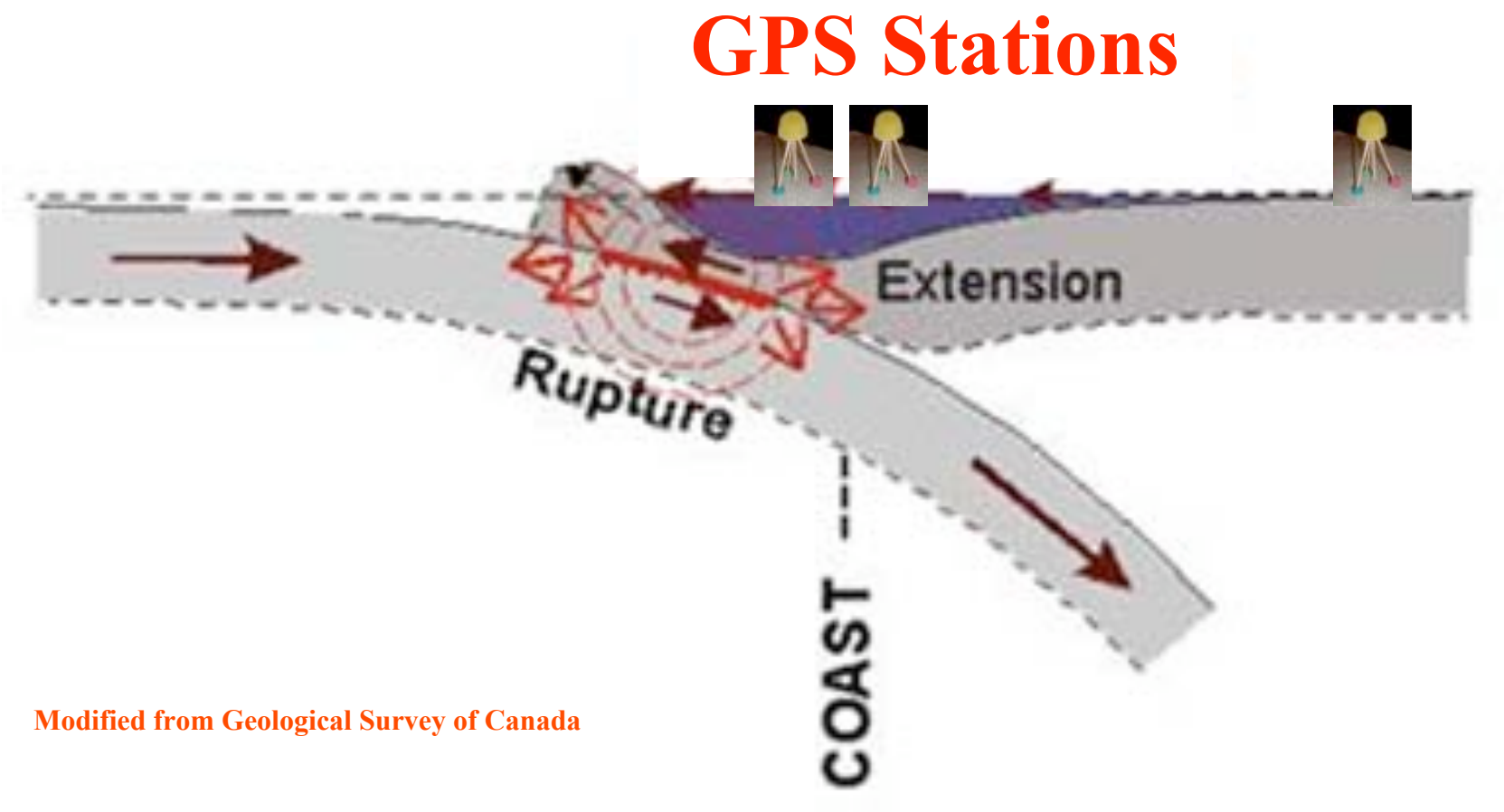
Cascadia Subduction Zone -- Locked and Loaded

- **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)



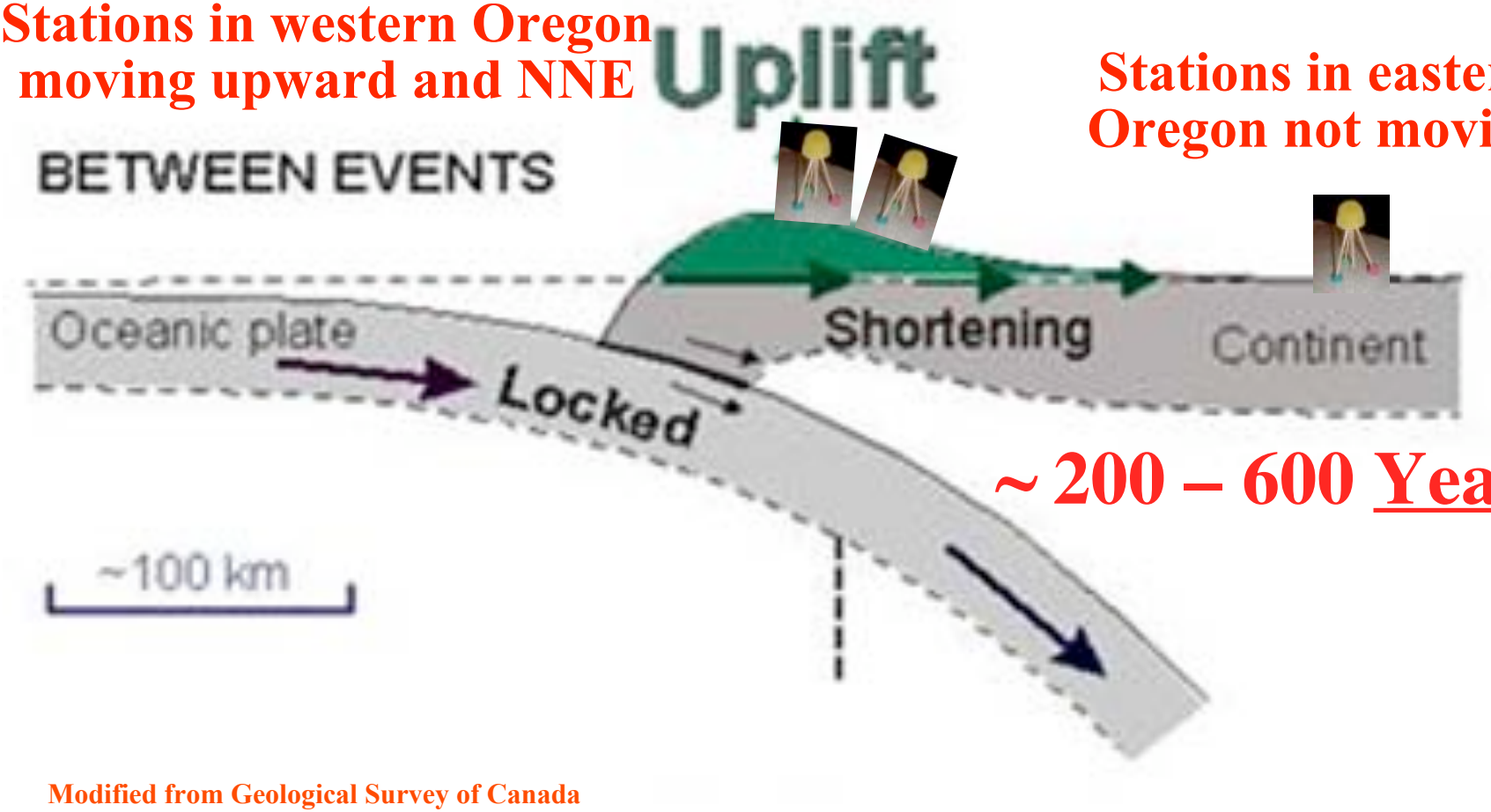
GPS Stations Monitor Ground Motion



Modified from Geological Survey of Canada

"Locked" Subduction Zone

Stations in western Oregon moving upward and NNE

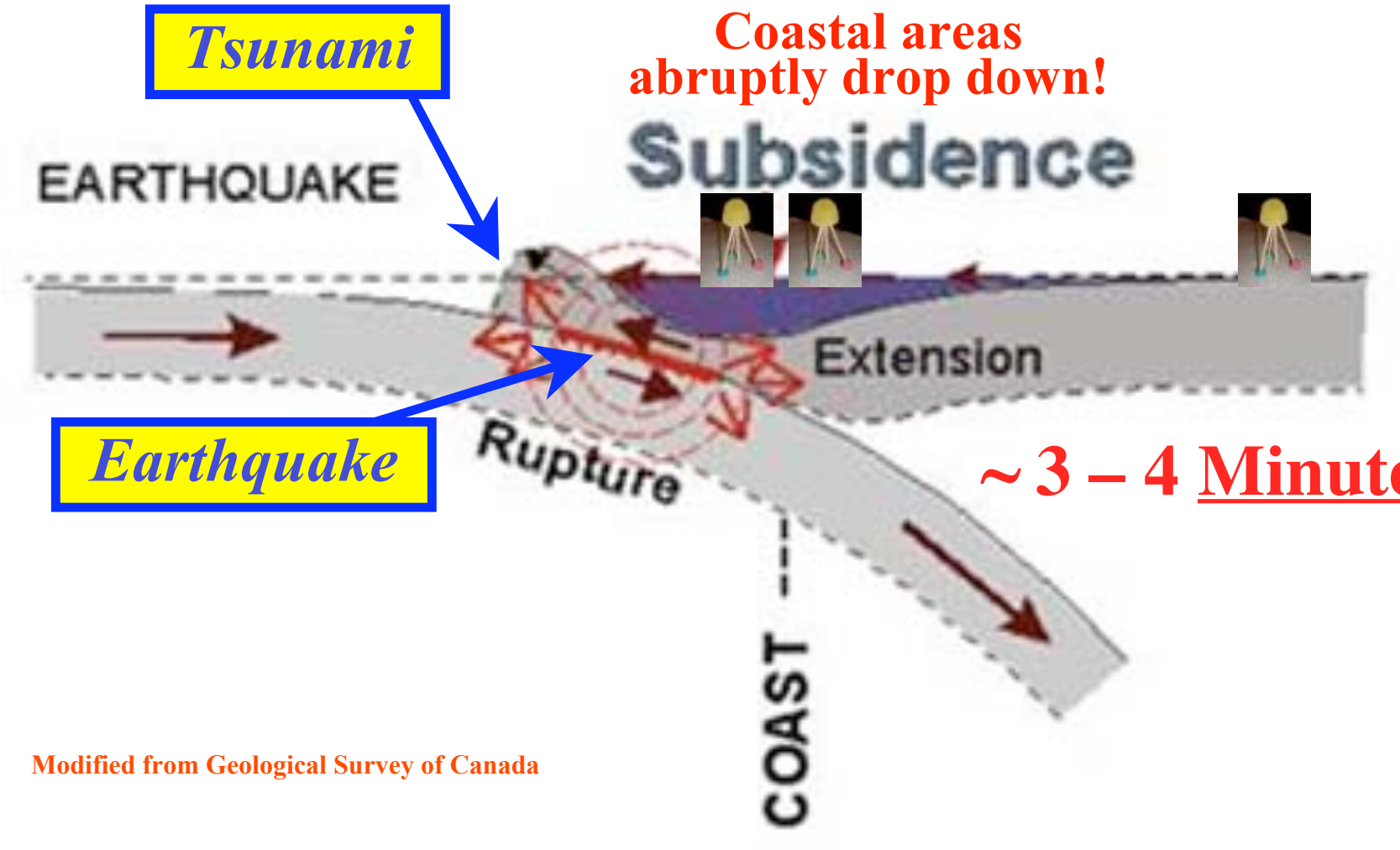


Stations in eastern Oregon not moving

~ 200 – 600 Years

Modified from Geological Survey of Canada

Suddenly Unlocks!!



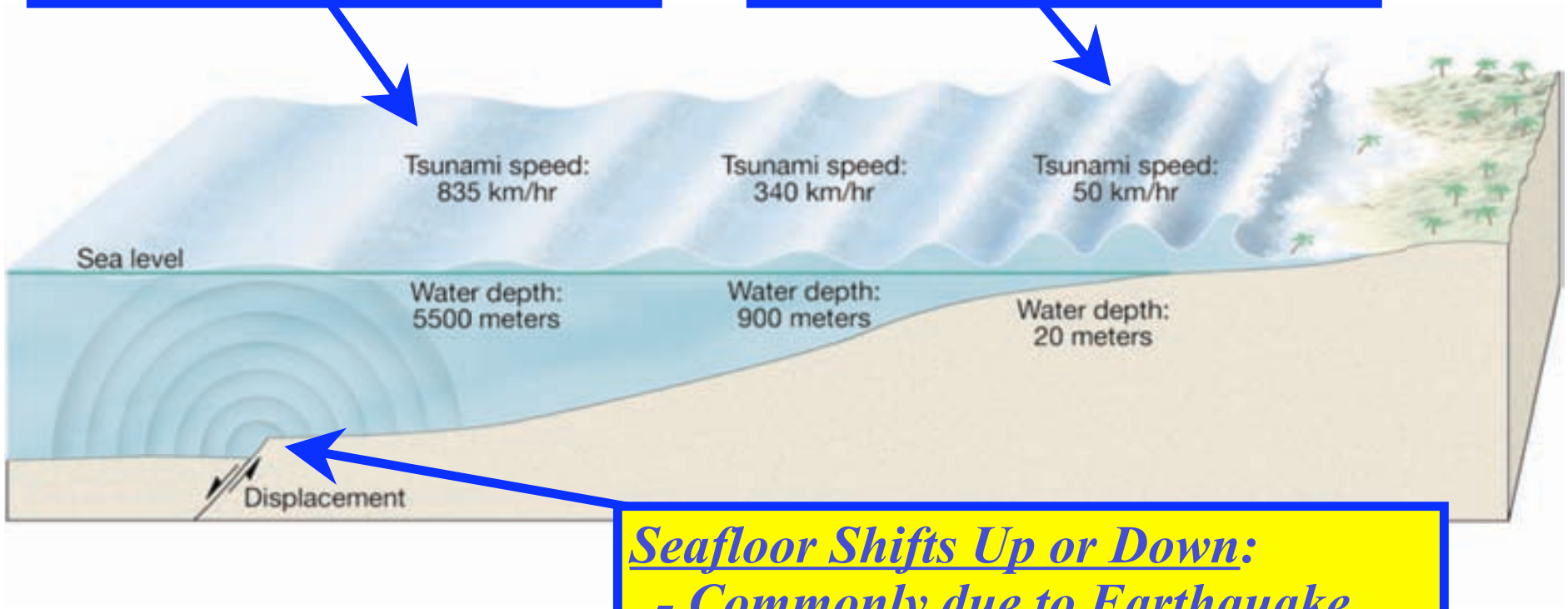
~ 3 – 4 Minutes!!

Modified from Geological Survey of Canada

Tsunami Caused by Displacement of Ocean Floor

Waves in Deep Ocean:
- *Small Amplitude*
- *Travel Speed of Jetliner*

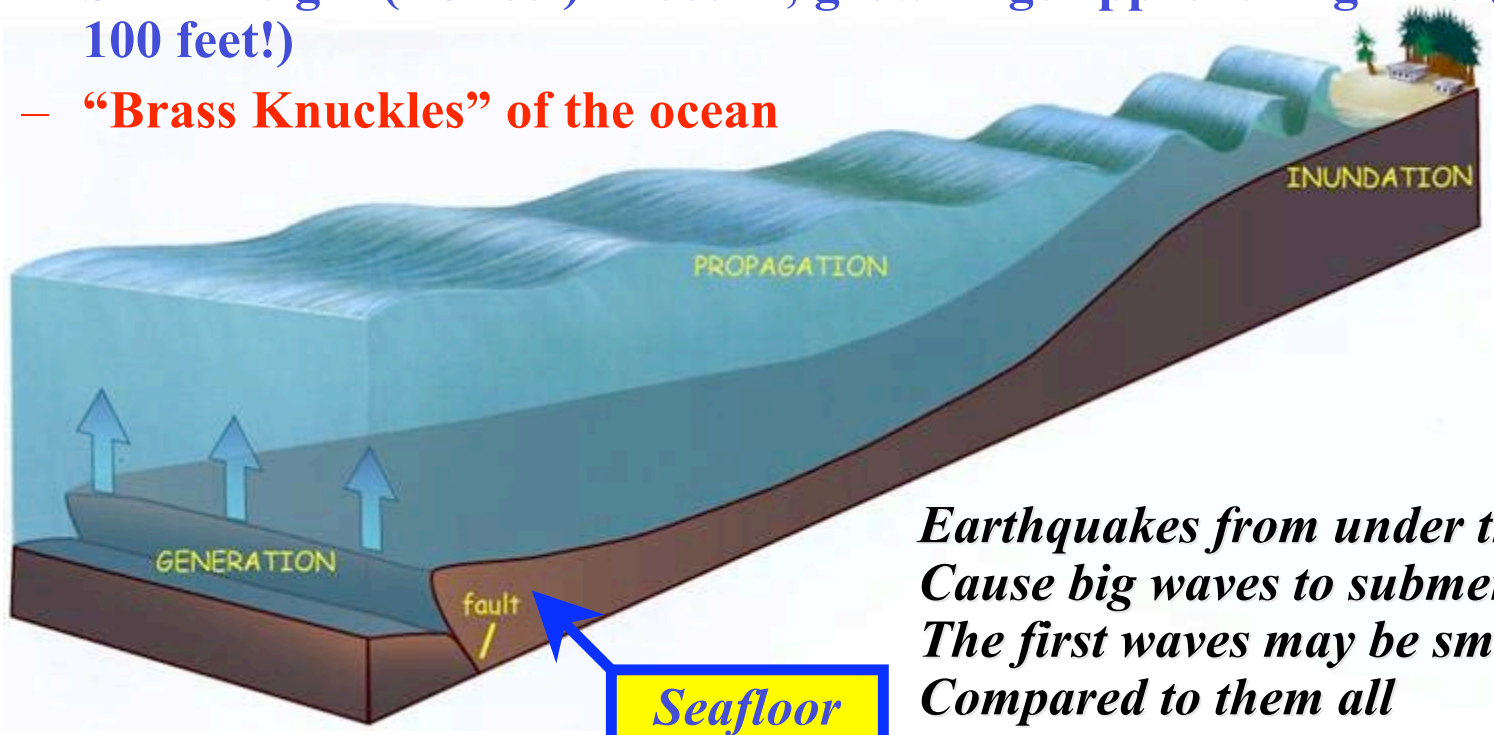
Approaching Land:
- *Waves Slow Down*
- *Amplitude Increases*



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)

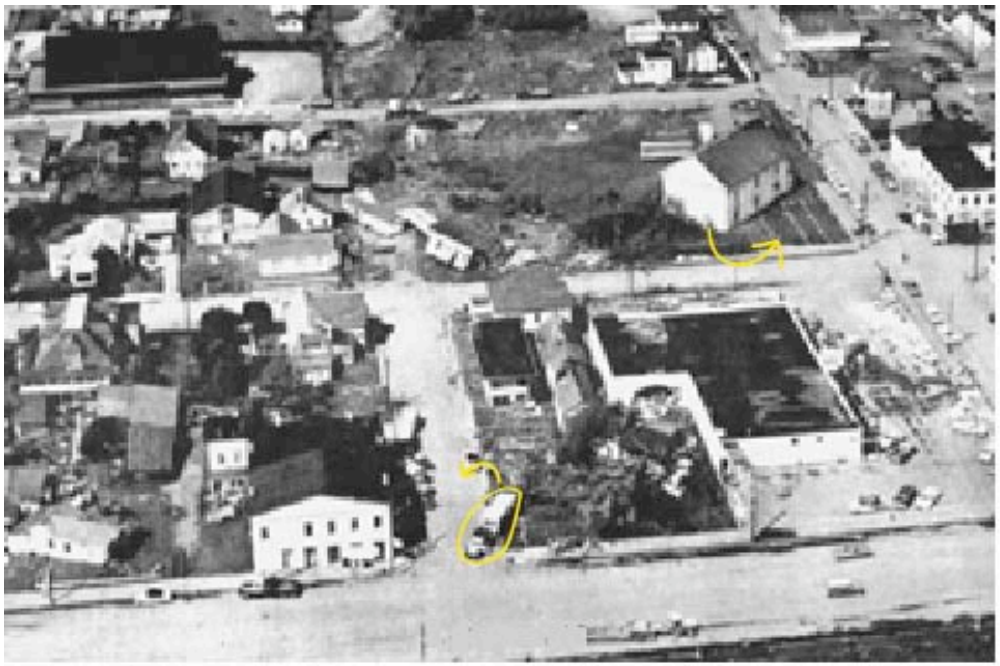
Tsunami – "Brass Knuckles of the Ocean"

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

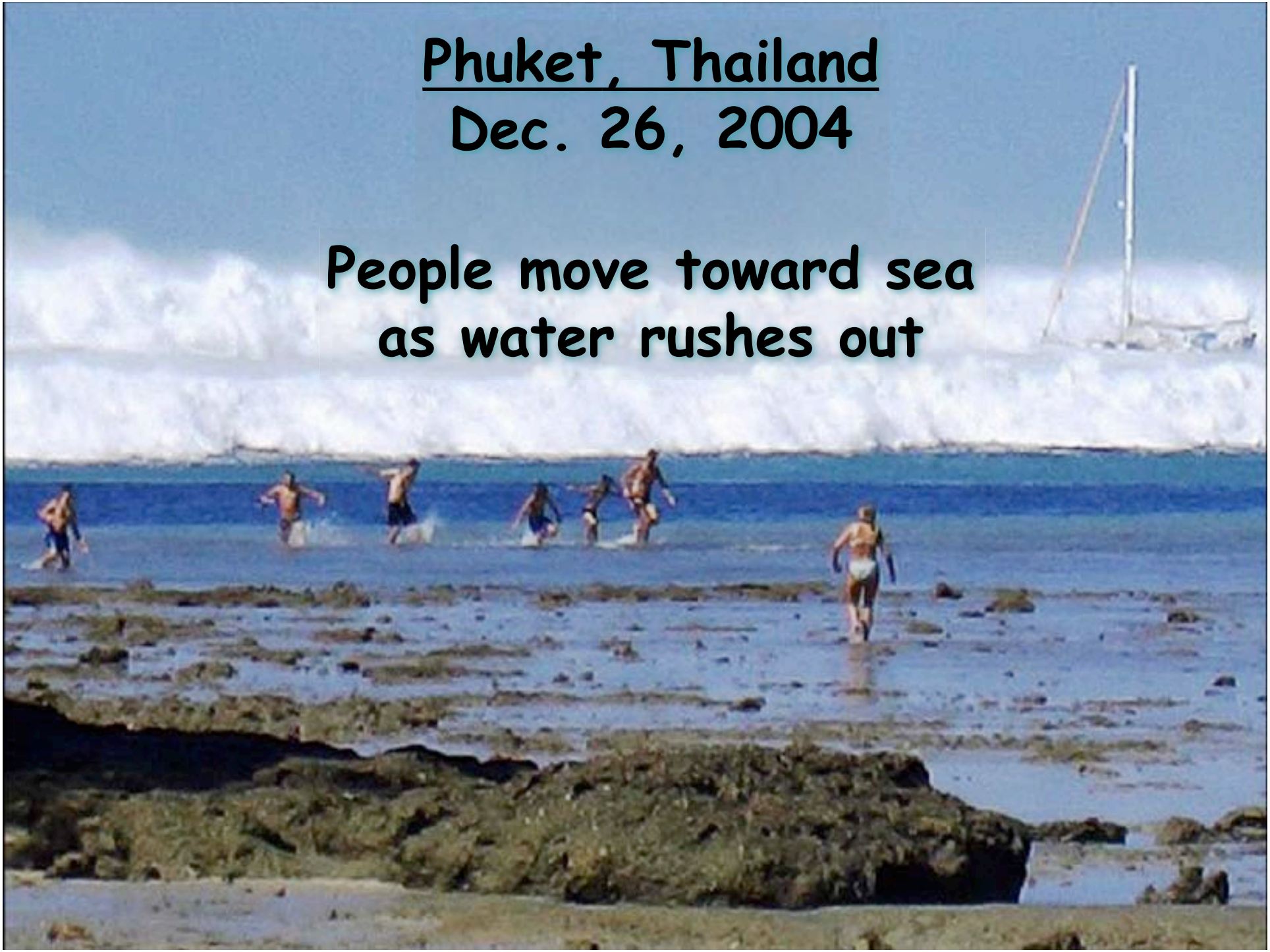


A

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

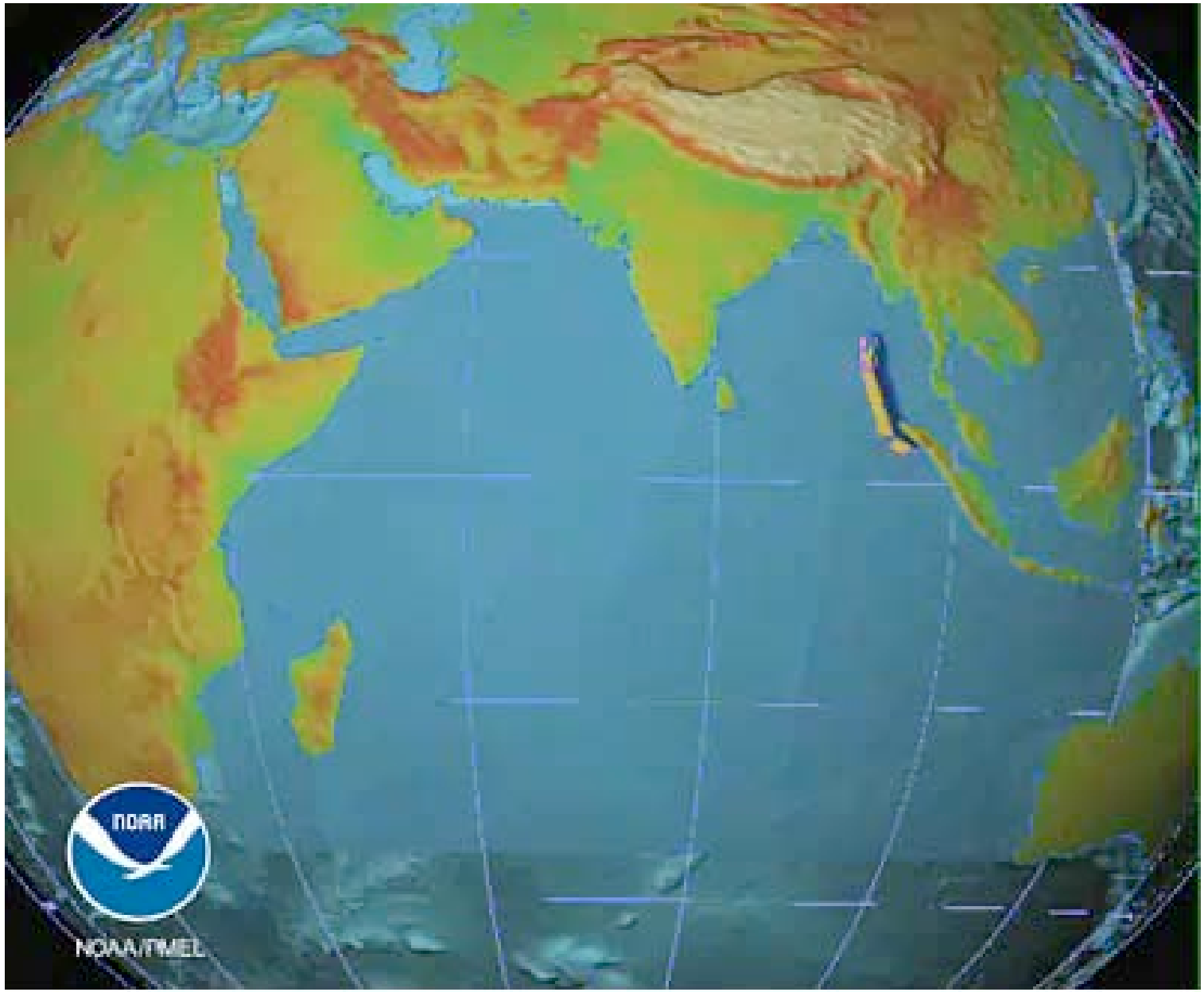
Indonesian Earthquake and Tsunami - December 26, 2004

What reaches India first (peak or trough)?

What about Thailand?

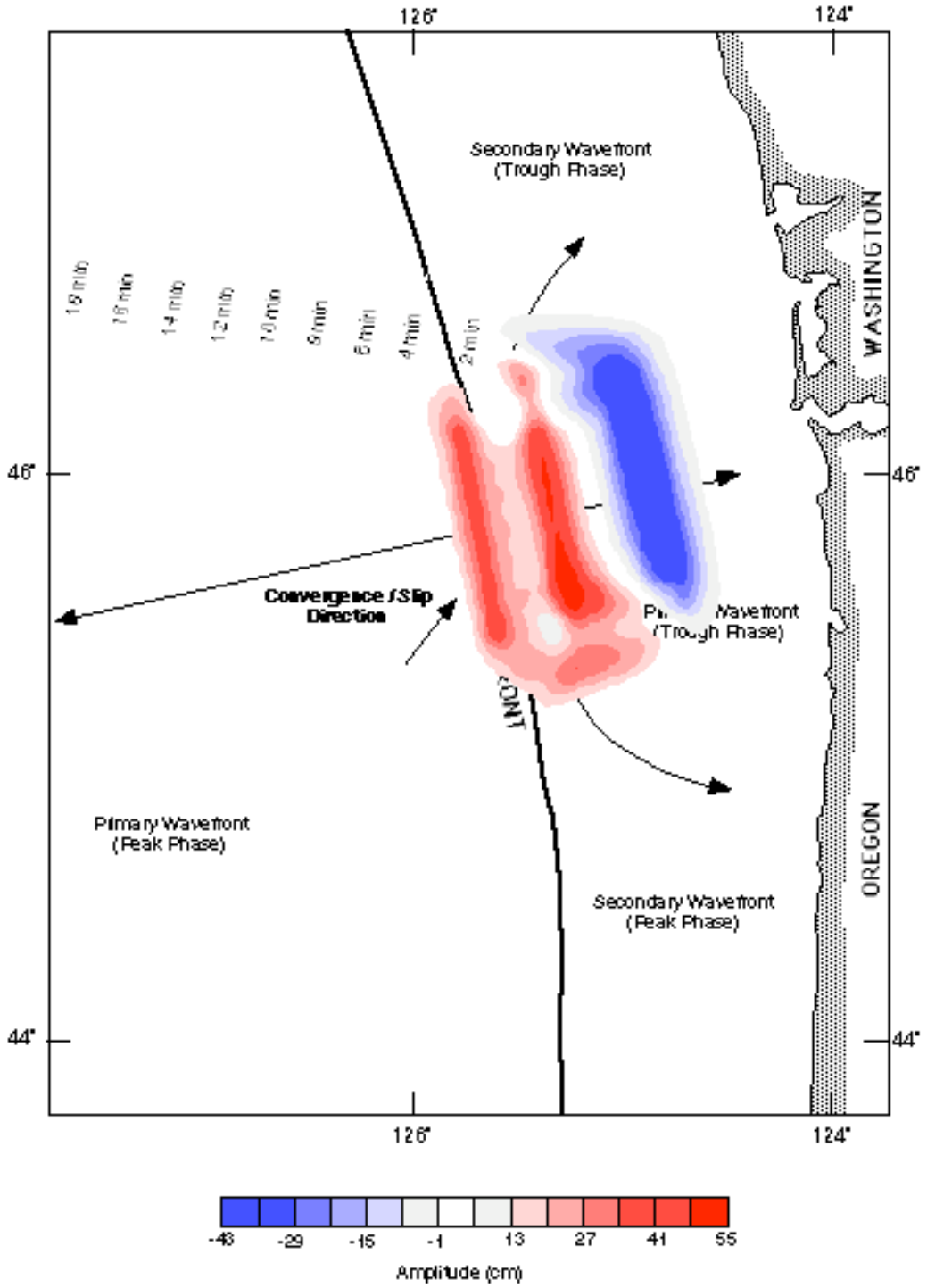
Series of Waves

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**

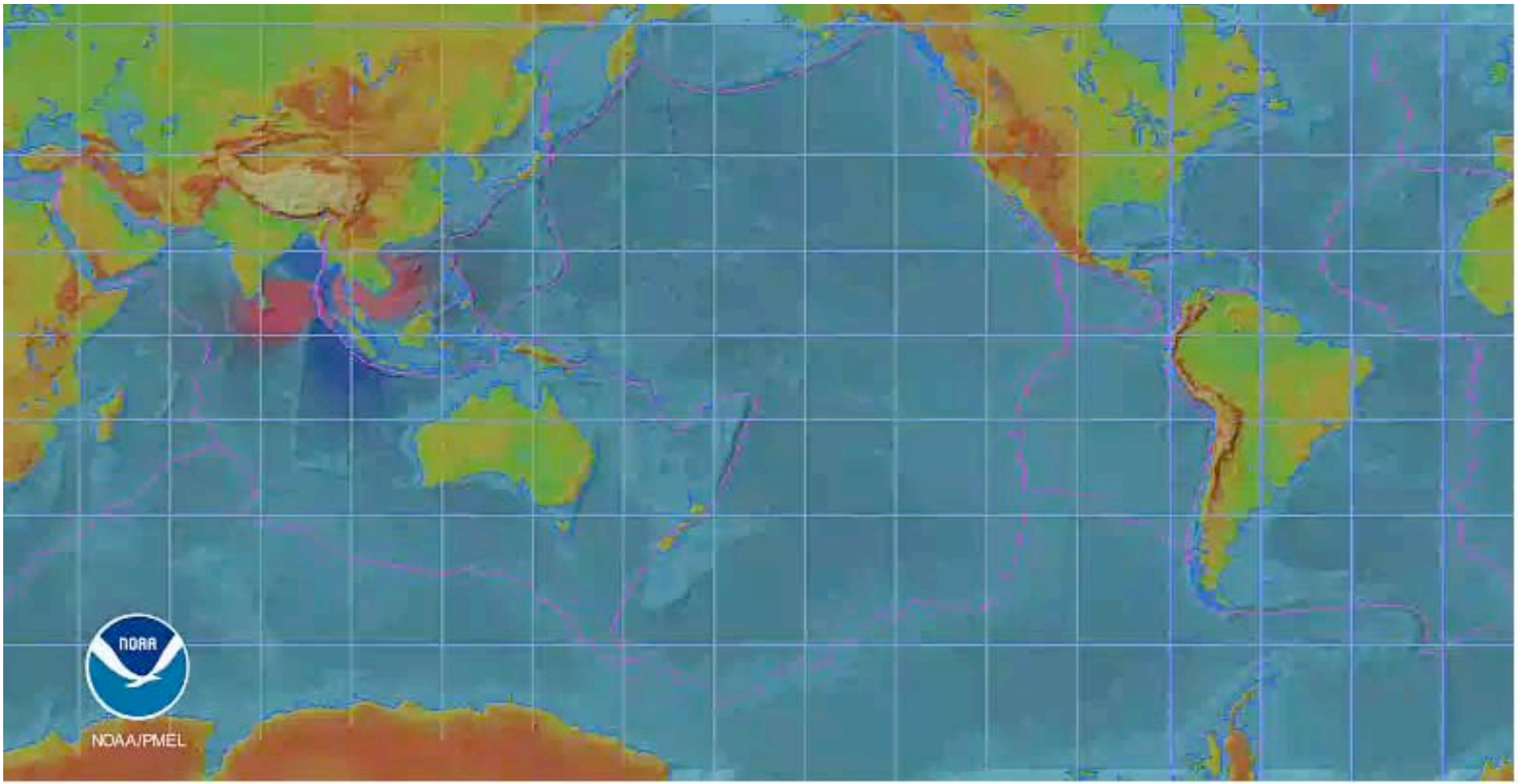
Tsunami Arrival Time and Inundation Estimate

Long Beach, Washington

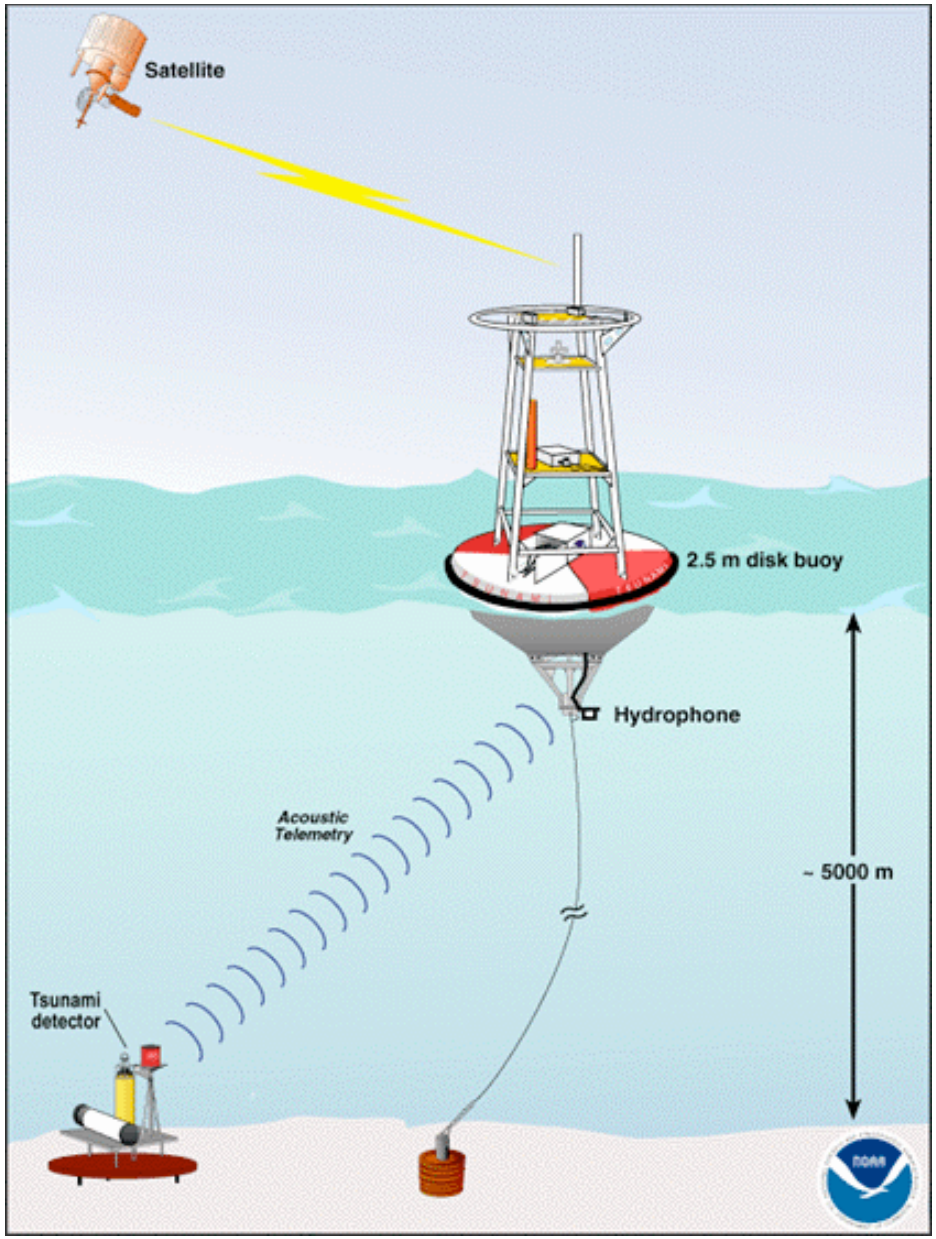
Tsunami Inundation Simulation -- Seaside, Oregon

Hinsdale Wave Tank, Oregon State University

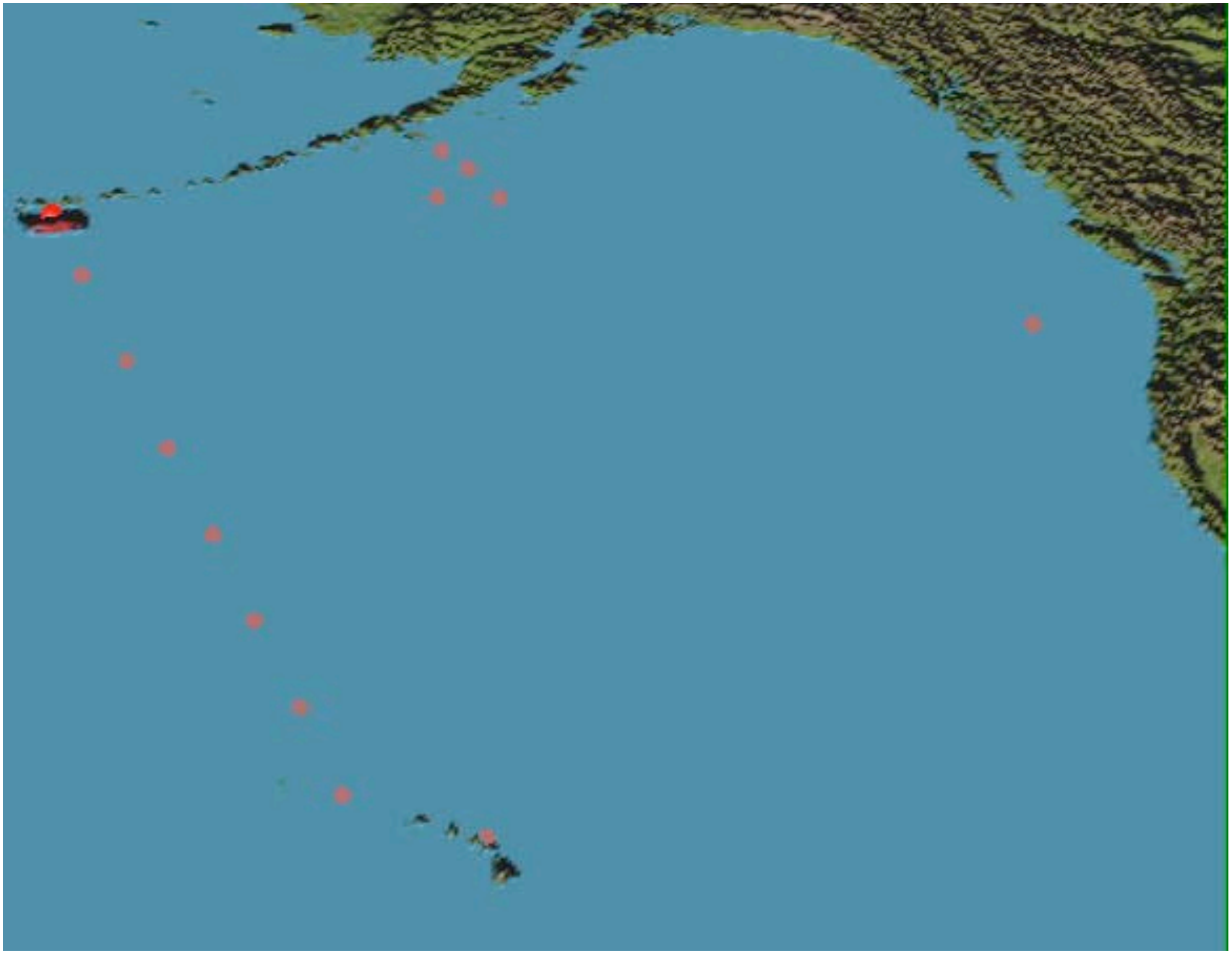
Indian Ocean Tsunami
December 26, 2004



Tsunami Detection

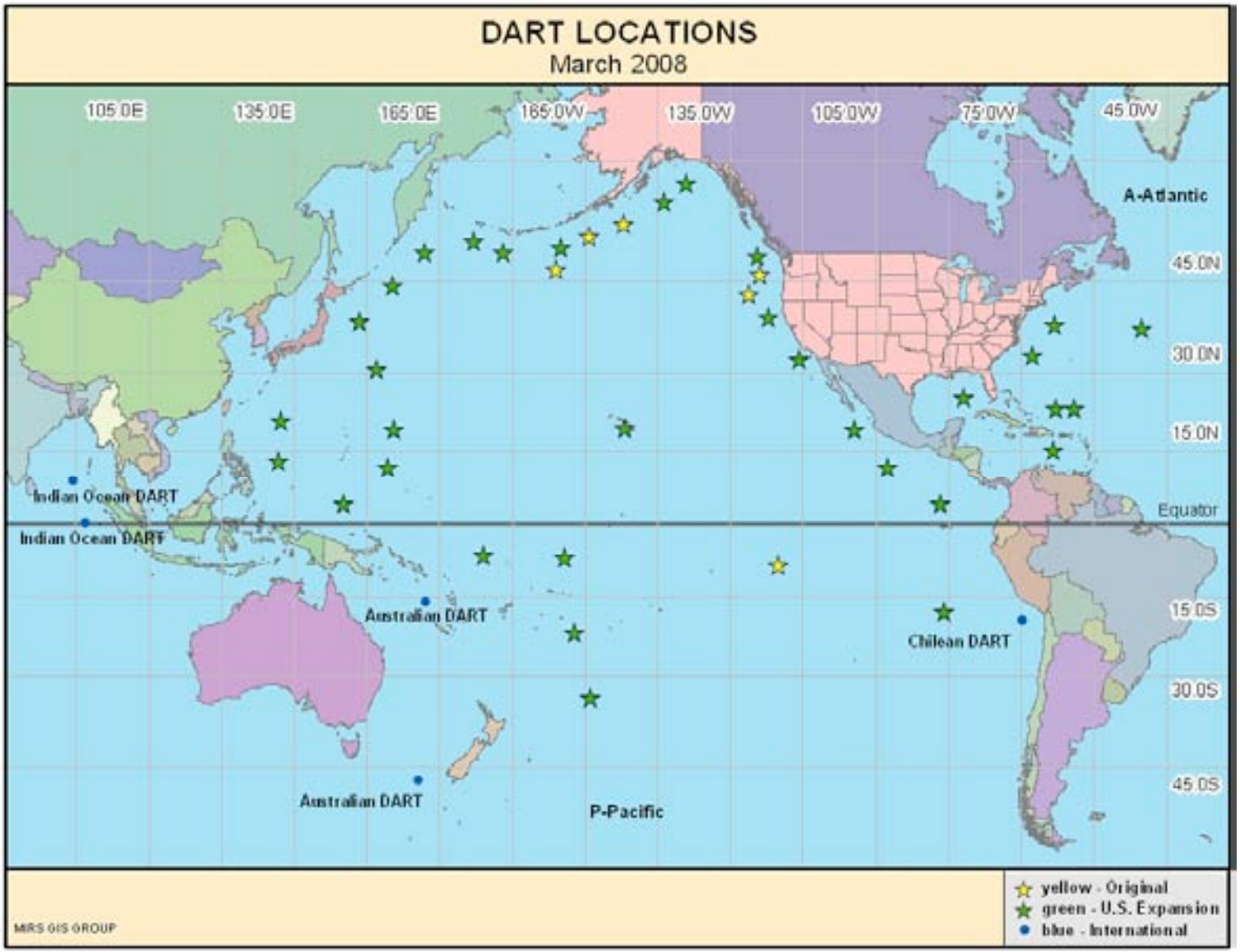


Andranov Earthquake, 1996

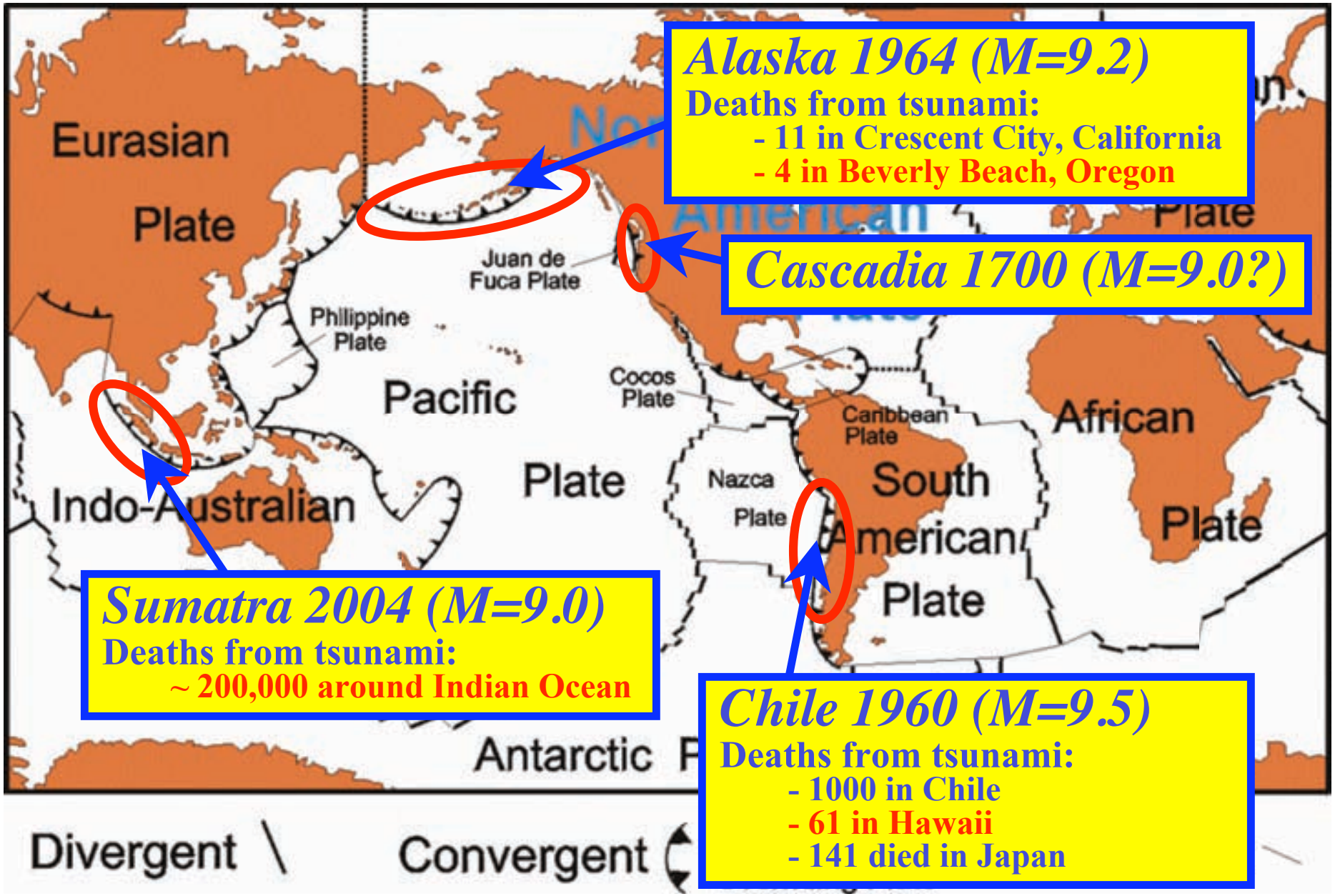


Pacific Tsunami Warning System

Deep-ocean Assessment and Reporting of Tsunamis (DART)

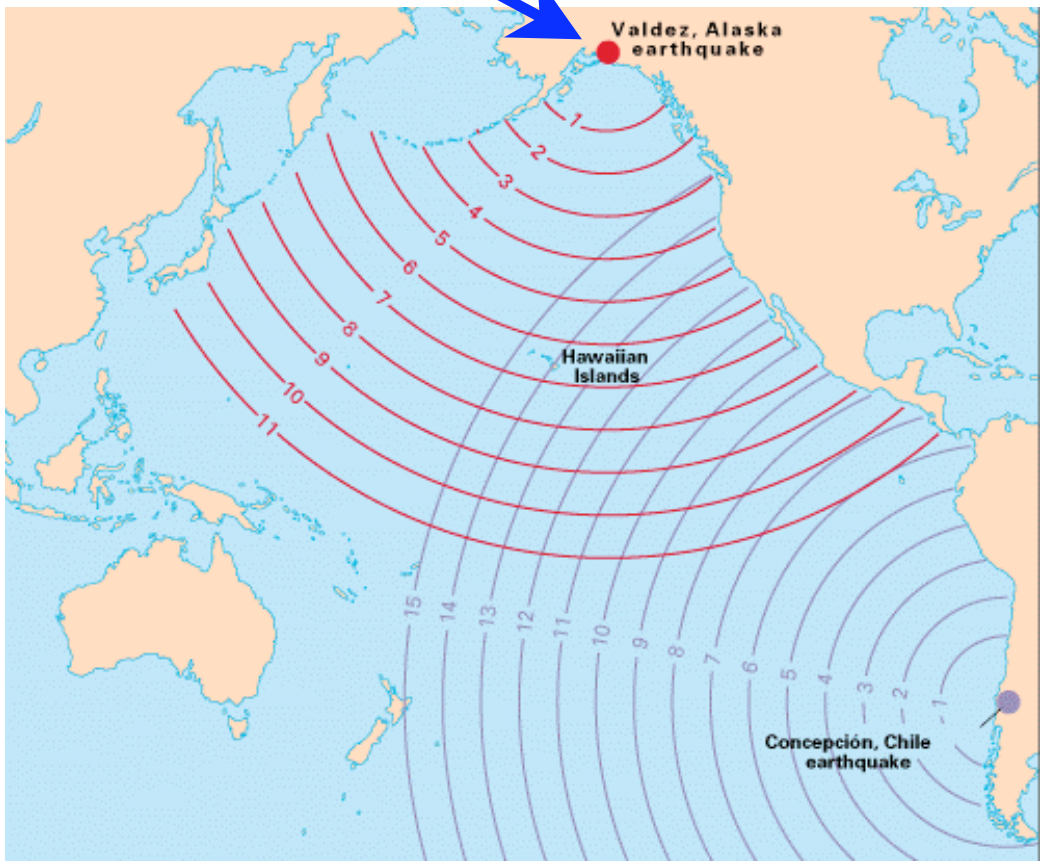


Subduction Zone Earthquakes can generate devastating Tsunamis



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?

Beverly Beach State Park, Oregon

Whale Watching Center, Depoe Bay, Oregon

Whale Watching Center,
Depoe Bay, Oregon

Robert J. Lillie

Whale Watching Center, Depoe Bay, Oregon

Whale Watching Center, Depoe Bay, Oregon

Morris Grover

Robert J. Lillie

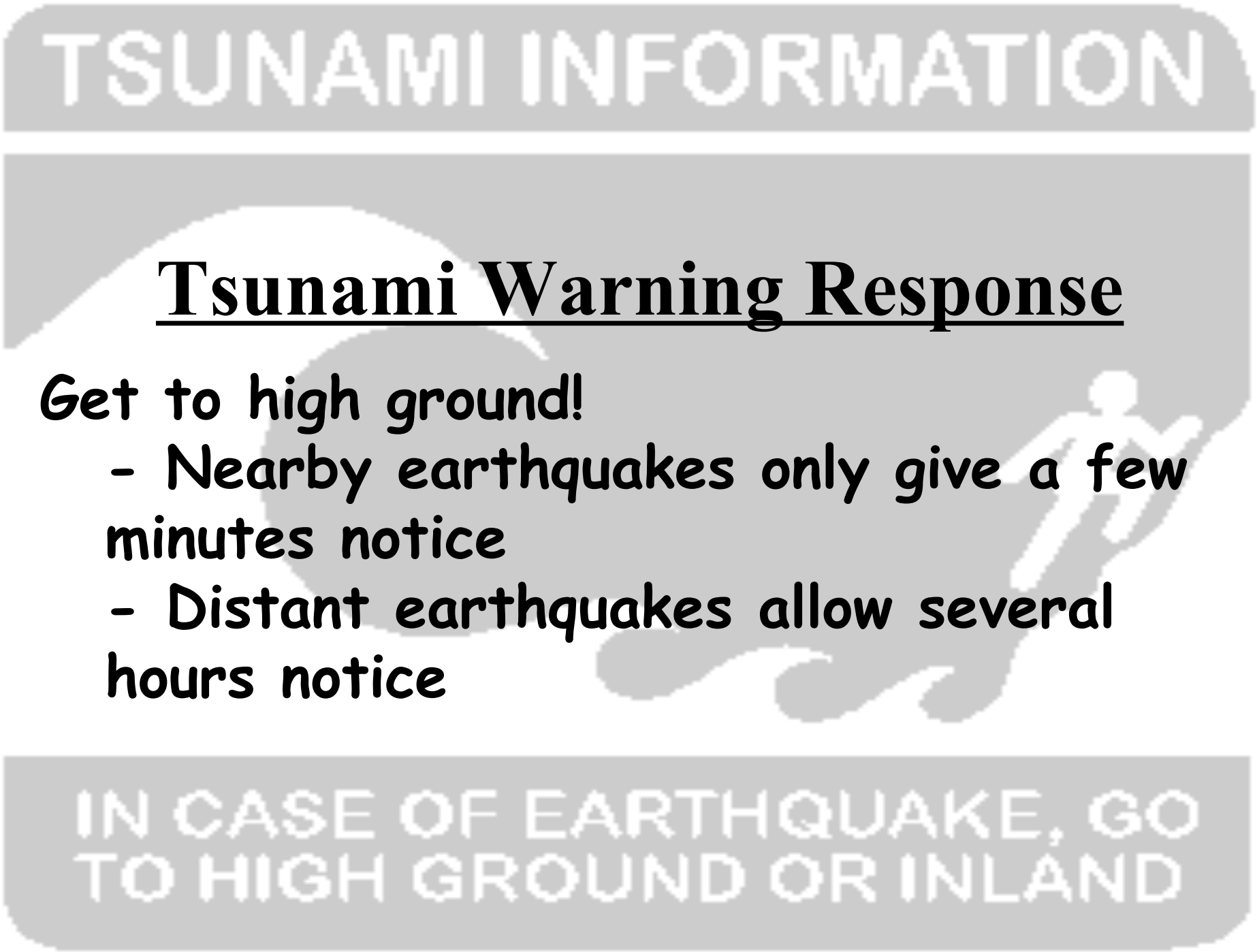
Whale Watching Center, Depoe Bay, Oregon

Kay Wyatt

Robert J. Lillie

IRIS Active Earth Display

Cascadia Module

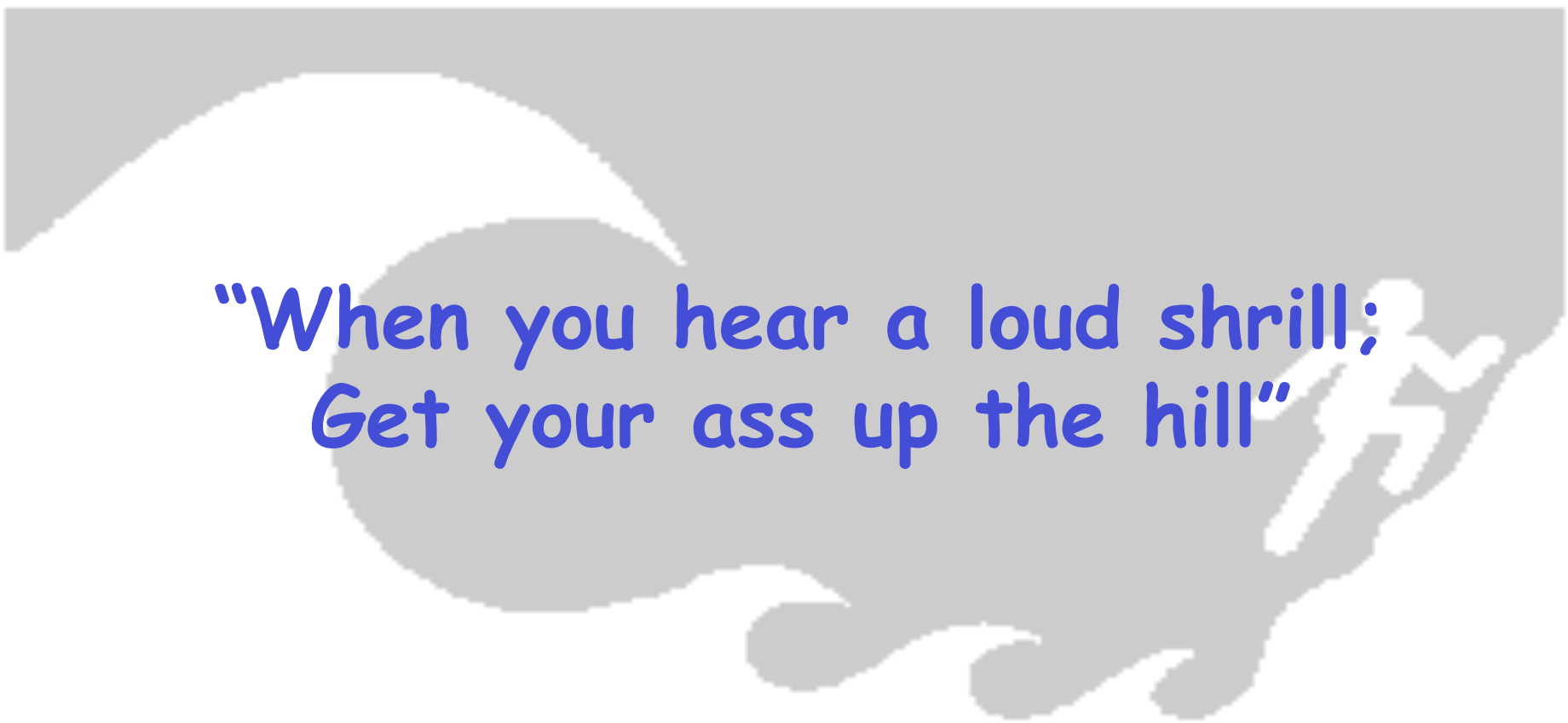


Tsunami Warning Response

Get to high ground!

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

TSUNAMI INFORMATION



"When you hear a loud shrill;
Get your ass up the hill"

IN CASE OF EARTHQUAKE, GO
TO HIGH GROUND OR INLAND

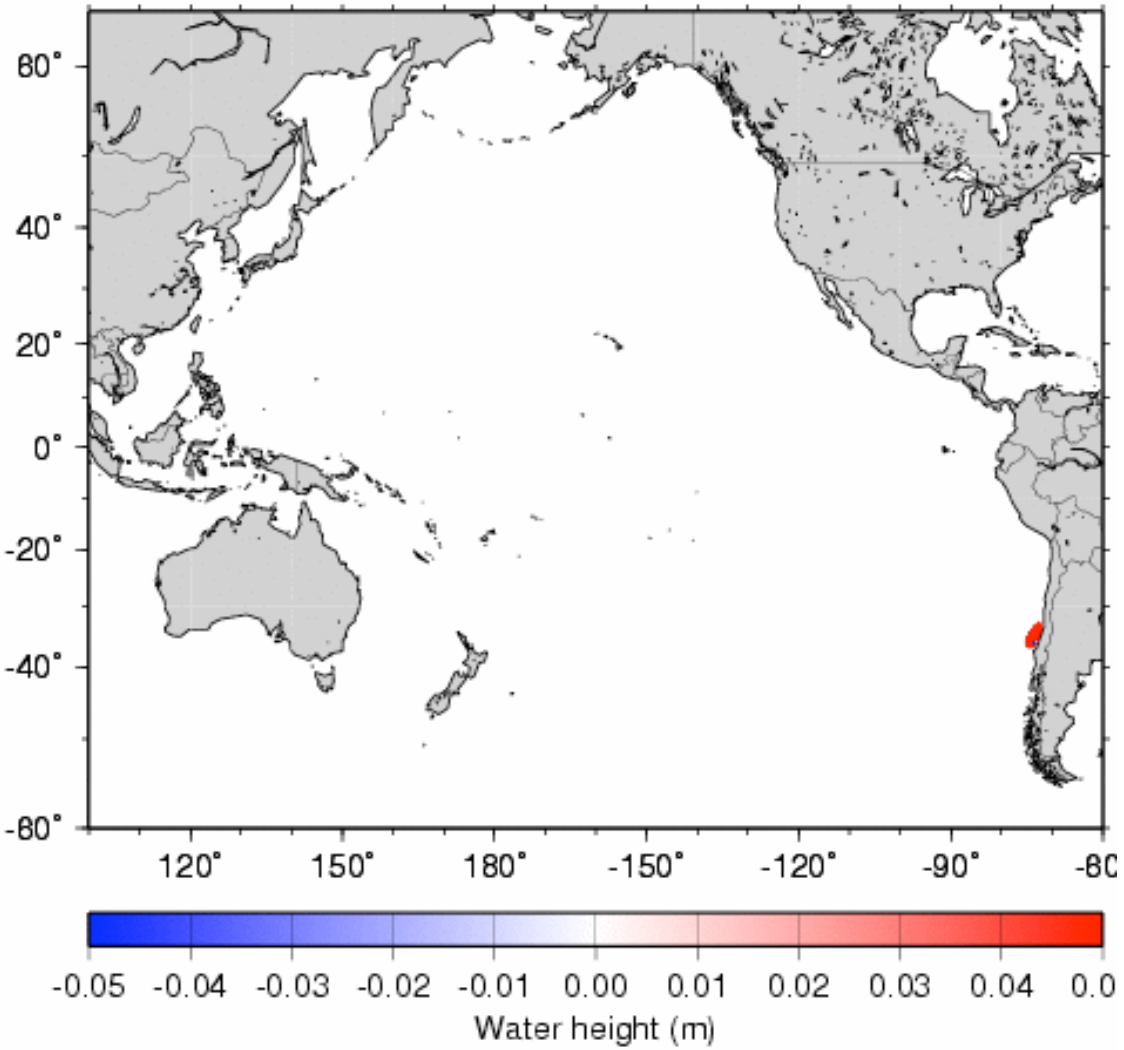
Magnitude 8.8 OFFSHORE MAULE, CHILE

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

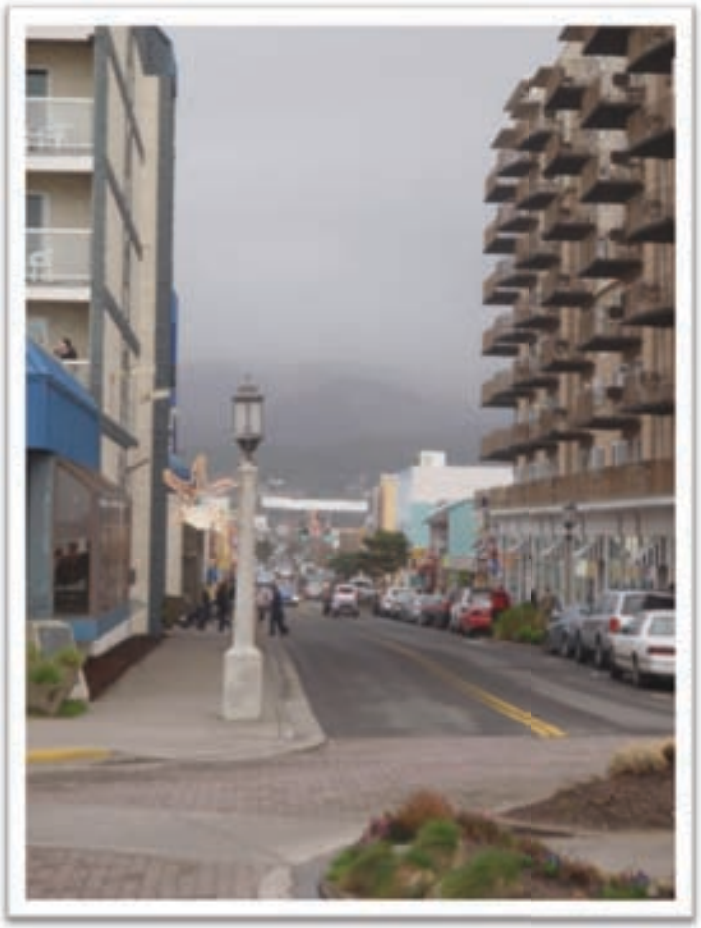
0 hour 10 min

Tsunami Model for Chilean Earthquake

(Earthquake Research Institute, Tokyo)



Earthquake Research Institute, Tokyo



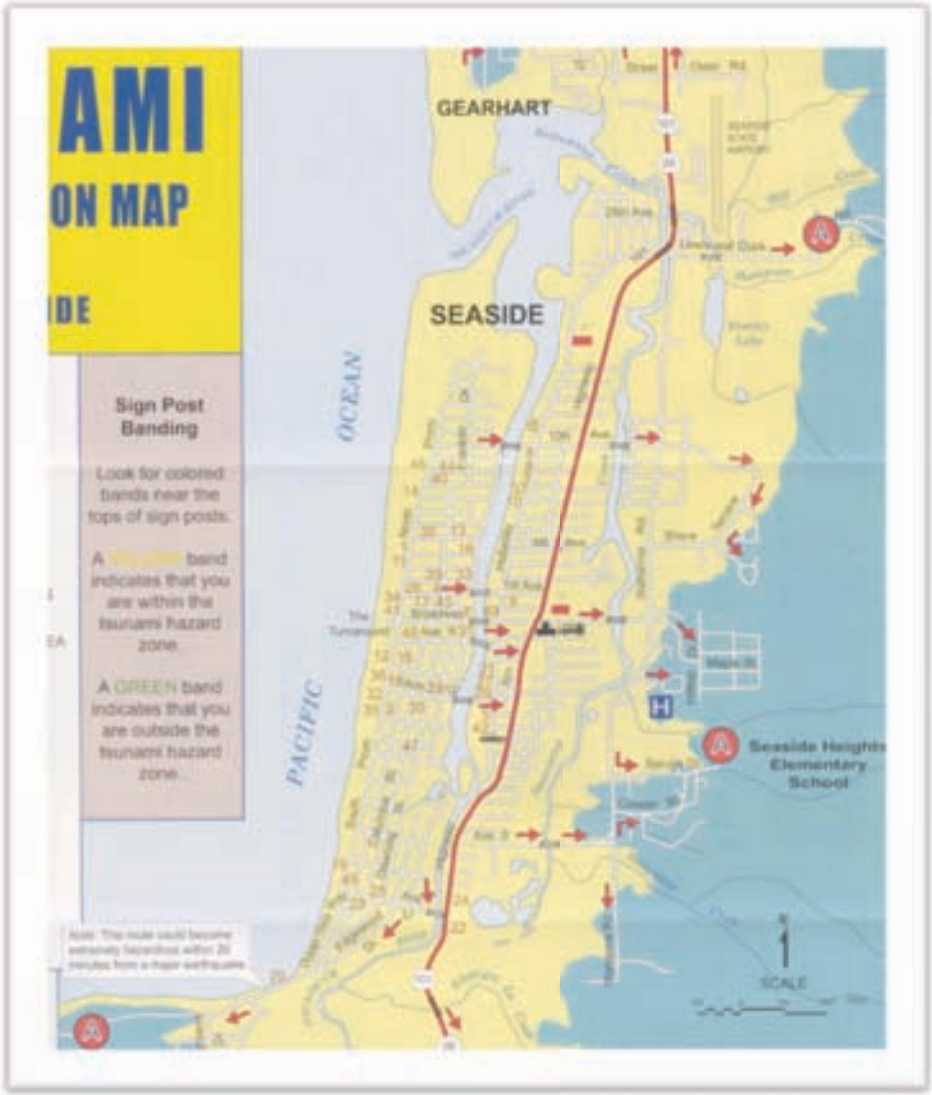
Seaside is the most vulnerable community to tsunamis due to its flat terrain and multiple waterways and wetlands between where people are and where they need to get to.

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)