



UNESCO/IOC – NOAA ITIC Training Programme in Hawaii (ITP-Hawaii)
TSUNAMI EARLY WARNING SYSTEMS
AND THE PACIFIC TSUNAMI WARNING CENTER (PTWC) ENHANCED PRODUCTS
TSUNAMI EVACUATION PLANNING AND UNESCO IOC TSUNAMI READY PROGRAMME
15-26 September 2025, Honolulu, Hawaii USA

Earthquake Seismology for Tsunami Warning: Nomenclature, Faulting, Magnitude

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Director, PTWC

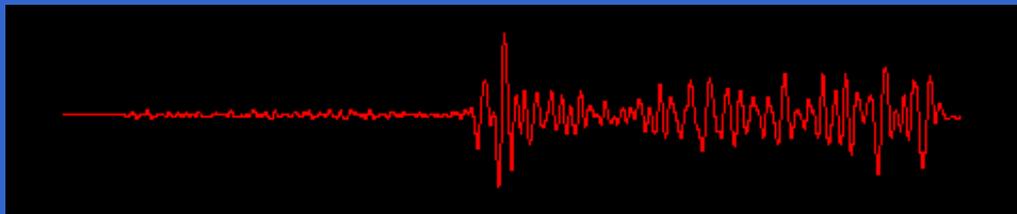


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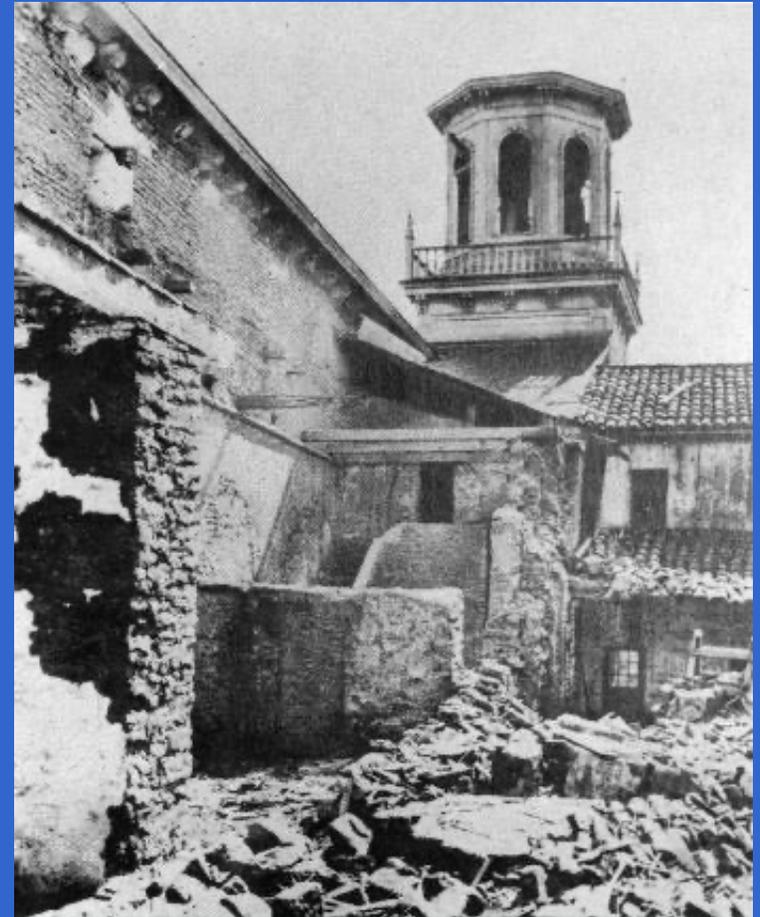
What is an Earthquake?

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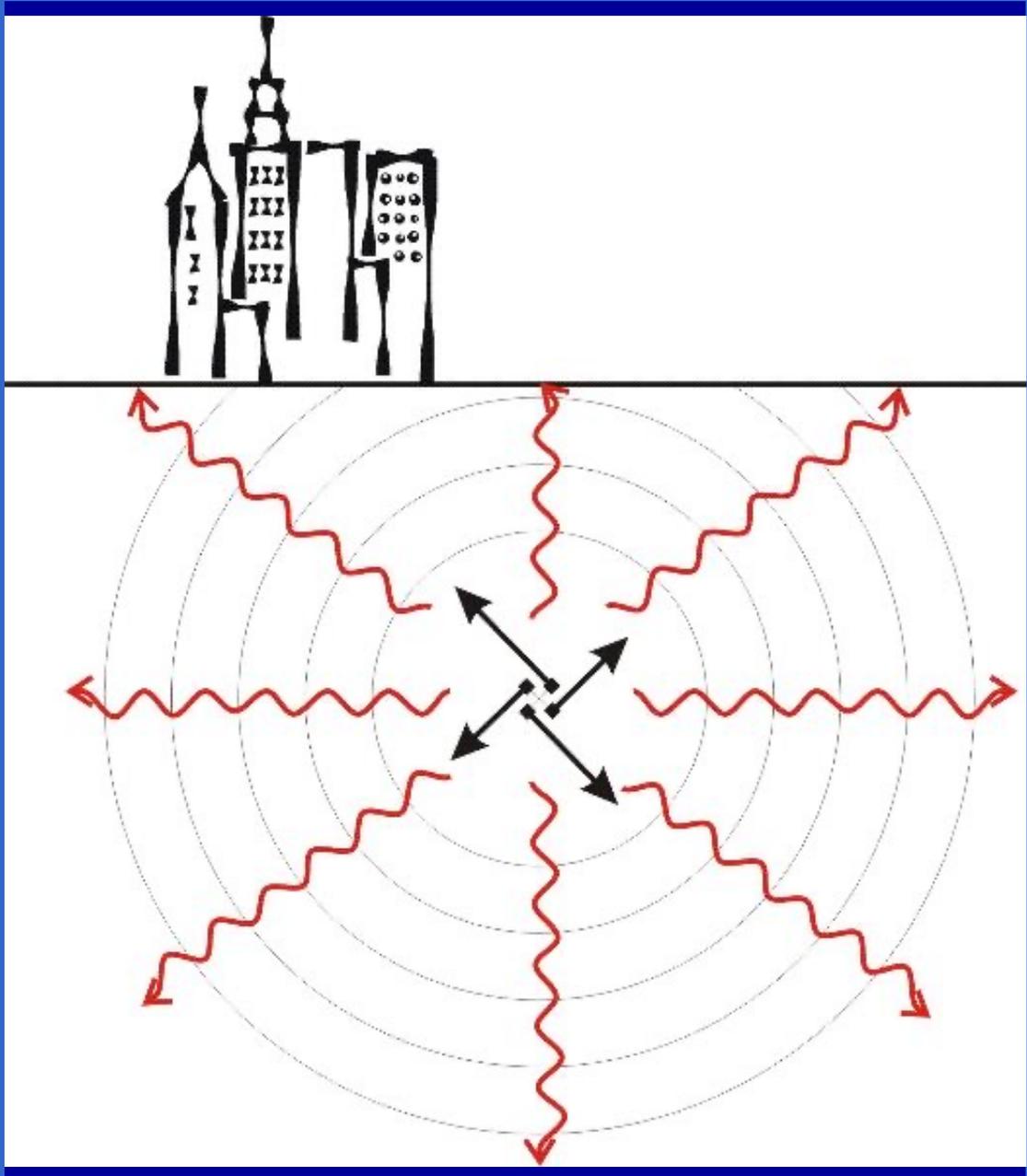
- Movement on a fault within the earth resulting in instrumentally recorded or felt ground vibrations.



Seismogram of the 1906 earthquake recorded in Germany



San Francisco 1906 (USGS)



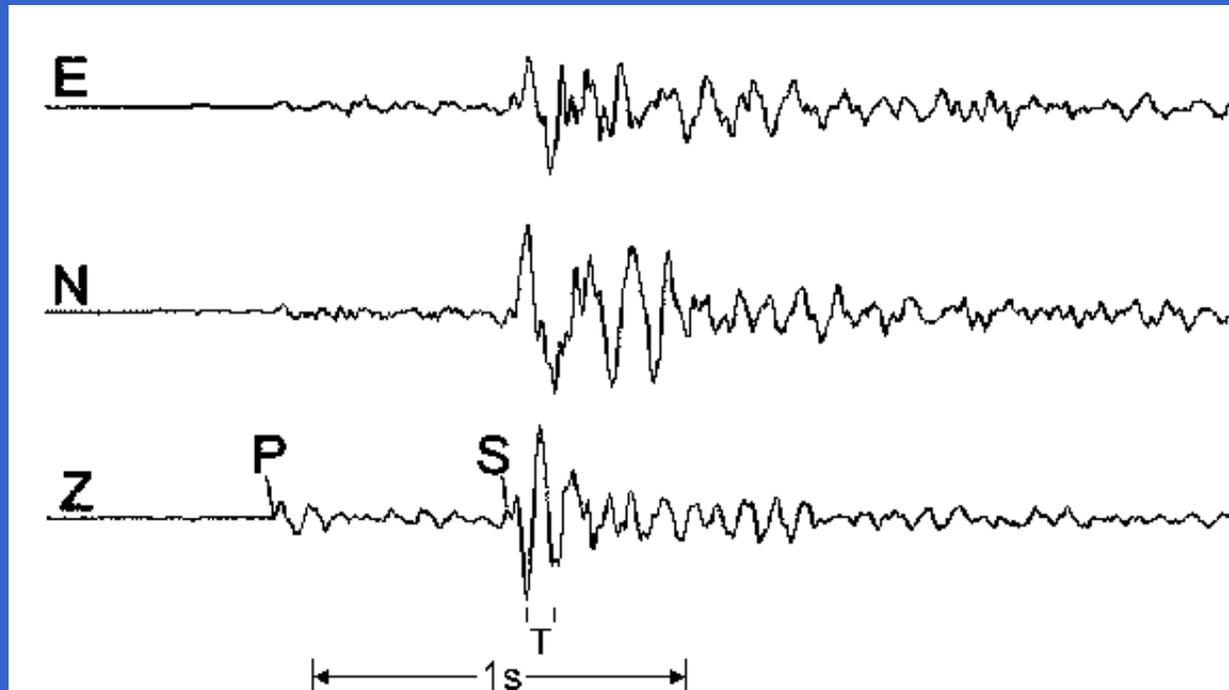
Broadband seismometer

Faulting



Seismic waves

Types of Seismic Wave



Three-components of a seismometer record proportional to ground velocity of the P and S waves from a local aftershock of the Killari-Latur EQ, India (1993), at a hypocentral distance of 5.3 km

Earthquake Nomenclature

Described by Time (t) and Location (x,y,z)

Hypocenter (Focus):

Origin Time,
Latitude, Longitude, Depth
Location in Earth where
energy in the rock being
strained is released

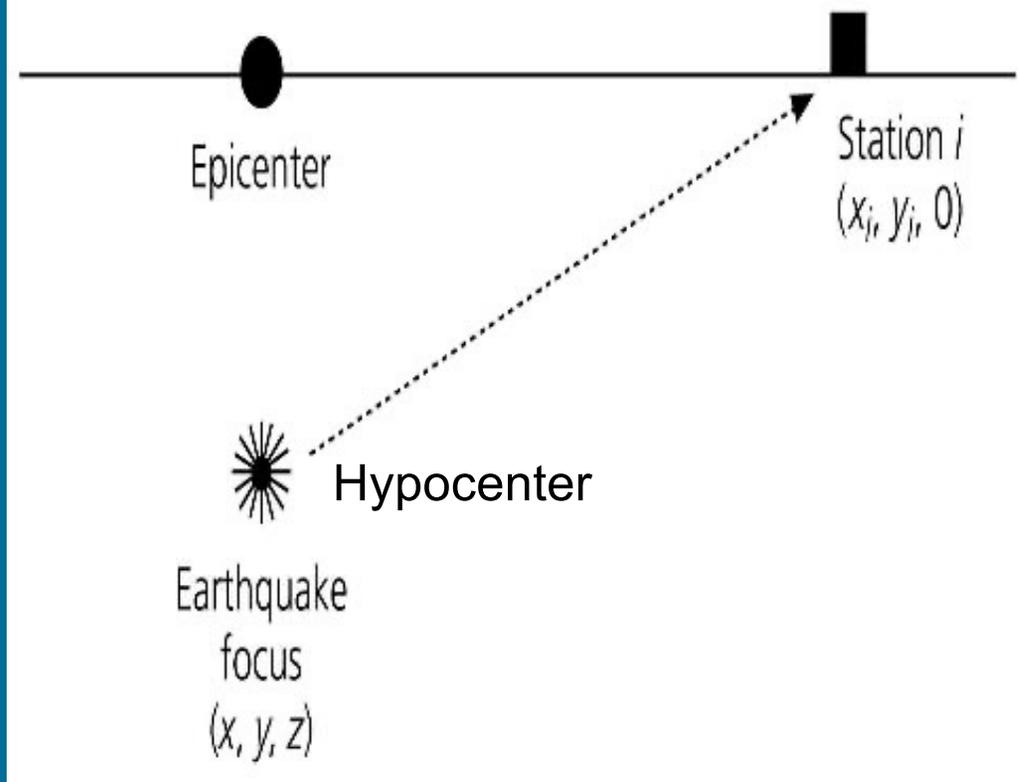
Epicenter:

Latitude, Longitude
Point on Earth's surface
directly above Hypocenter

Origin Time:

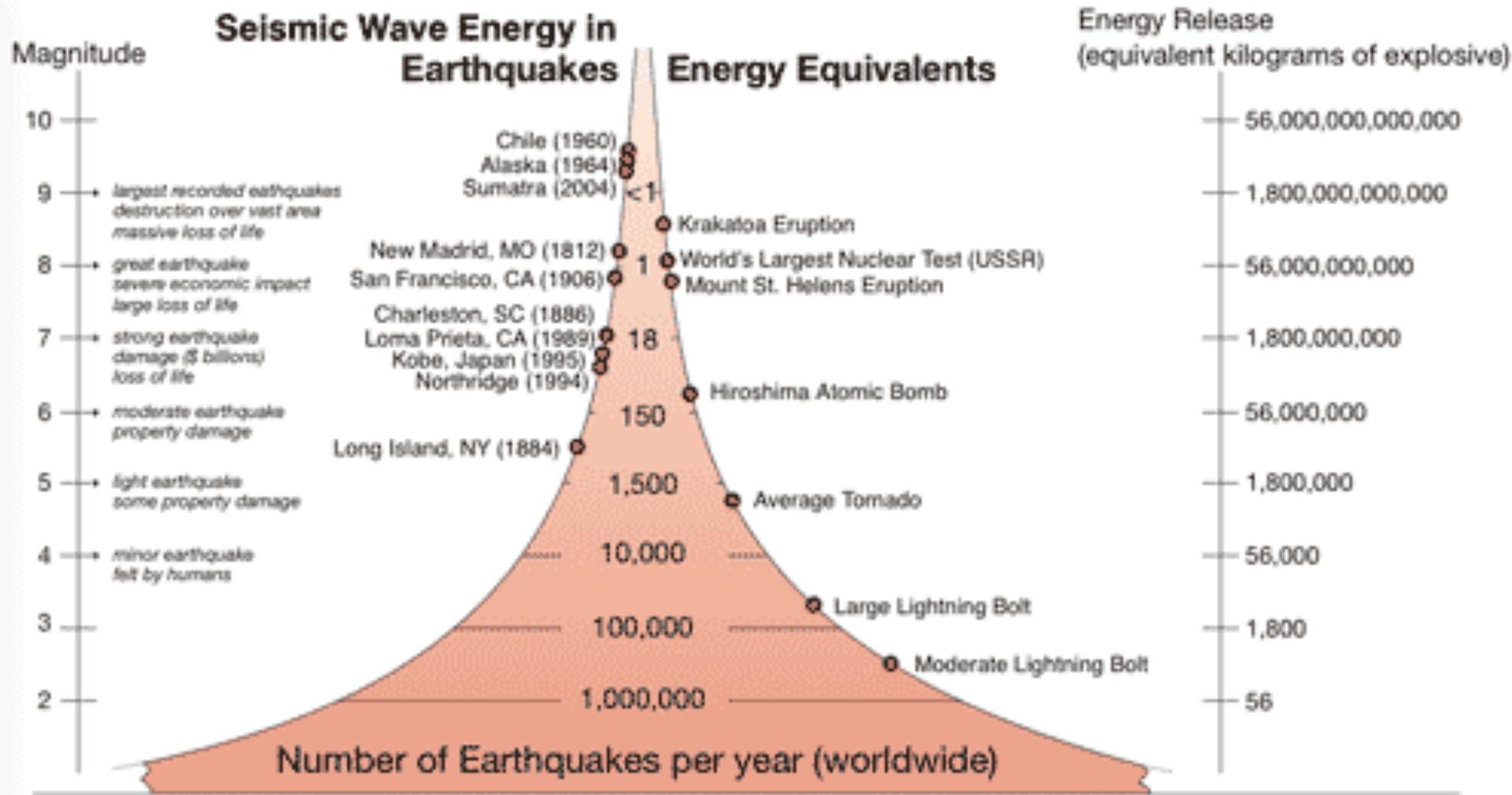
Mo/Da/Yr hr:mn:sc
When the rupture first started

Figure 7.2-1: Geometry for earthquake location in a homogeneous halfspace.



Comparing an earthquake to the breaking of a chopstick

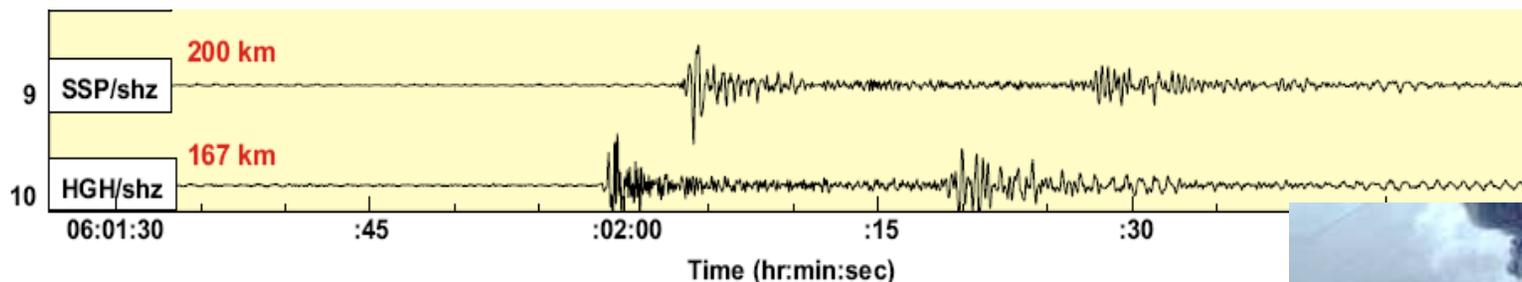
- Failure - breaks at weakest point
- Build-up of stress (strain energy)
- Difficult to predict time and place
- Sometimes hear precursors
- Sound of breaking same as seismic waves



Earthquake faulting

TYPES OF EARTHQUAKES

- 1) Tectonic Earthquake – MOST COMMON (FAULTS)
- 2) Volcanic Earthquake – magma movement, eruptions
- 3) Collapse Earthquake – cave collapse, rock fall
- 4) Explosion Earthquake – man-made



BGS recordings of an explosion at an oil storage depot near London Dec 16, 2005.
Equivalent to M2.4 earthquake



Types of Earthquake Faulting - Tectonic

- Normal fault
- Thrust or reverse fault
- Lateral slip or strike-slip fault

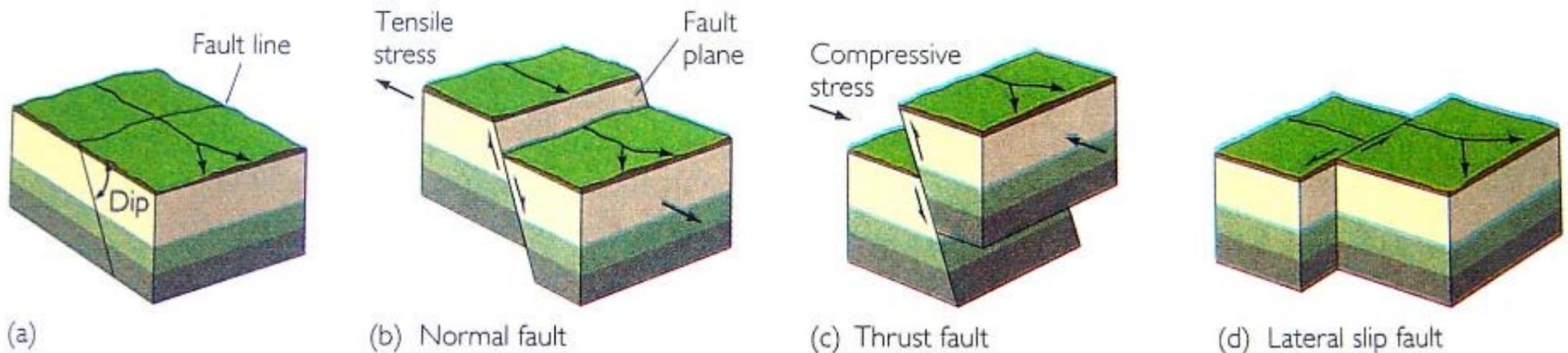
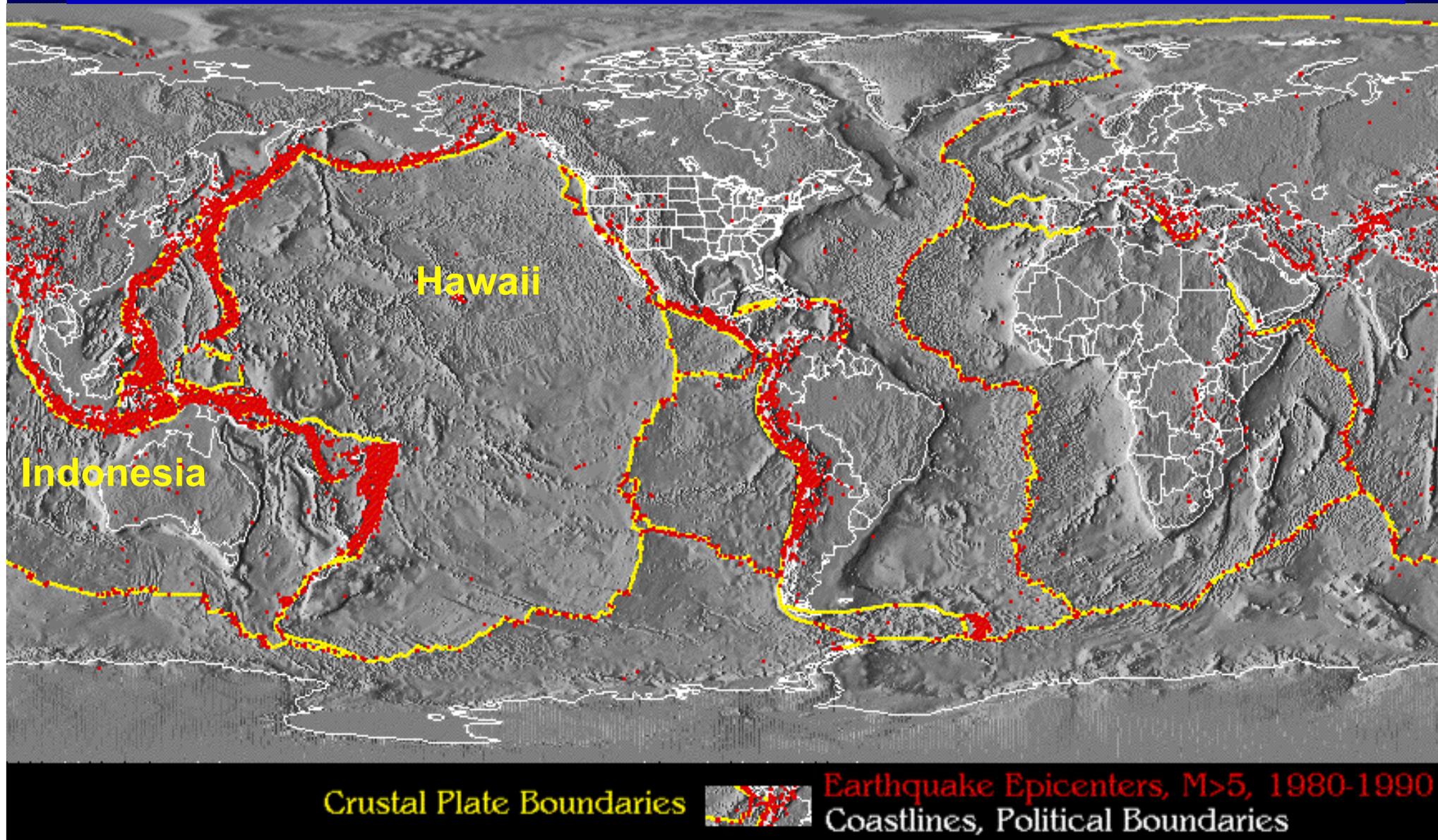
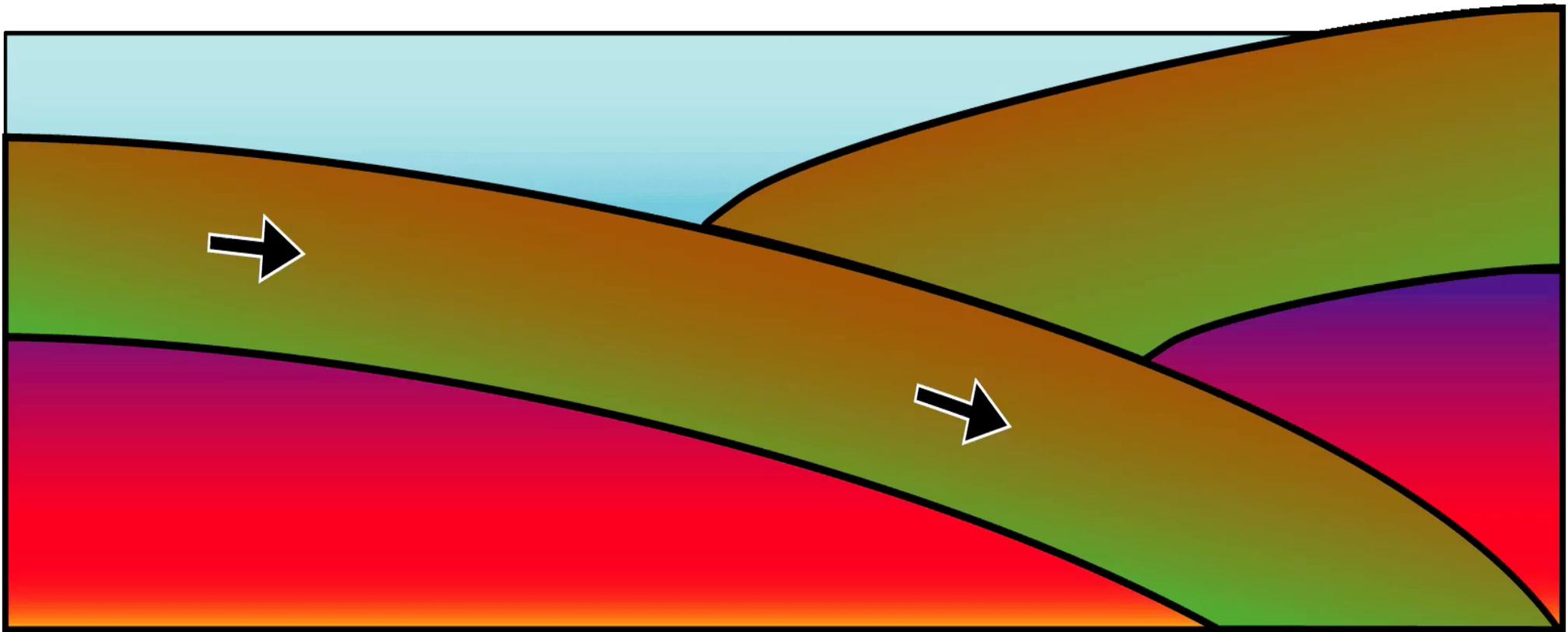


FIGURE 18.12 The three main types of fault movements that initiate earthquakes, and the stresses that cause them: (a) situation before movement takes place; (b) normal fault due to tensile stress; (c) thrust (or reverse) fault due to compressive stress; (d) lateral slip (or strike-slip) fault due to shearing stress.

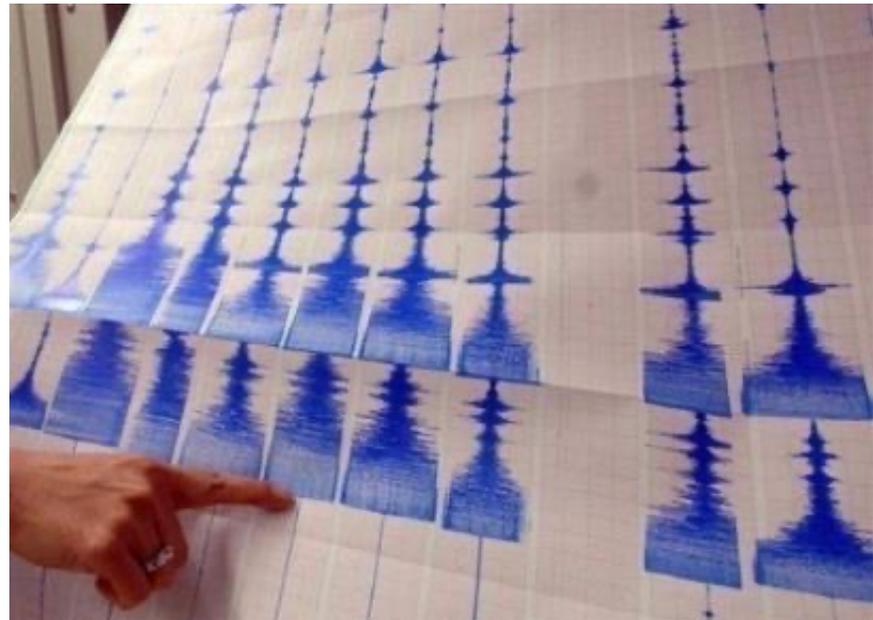
Earthquakes delineate Crustal Plate boundaries



**Most Tsunamis are caused by
Shallow, Large Earthquakes beneath
the Seafloor at Subduction Zones**



Earthquake Magnitude



M7, PNG earthquake

Measuring Earthquake size

- **Historical measures (Macroscopic) – pre-1900**
 - Fatalities
 - Maximum shaking
 - Area of intense shaking
- **Do not correlate well from one quake to next**
 - Because the damage and devastation produced by an earthquake will depend on
 - its location, the distance from the epicenter
 - the building designs,
 - surface material (rock or dirt) the buildings rest on
 - depth
 - proximity to populated regions, as well as its "true" size.

Measuring Earthquake size (macroscopic)

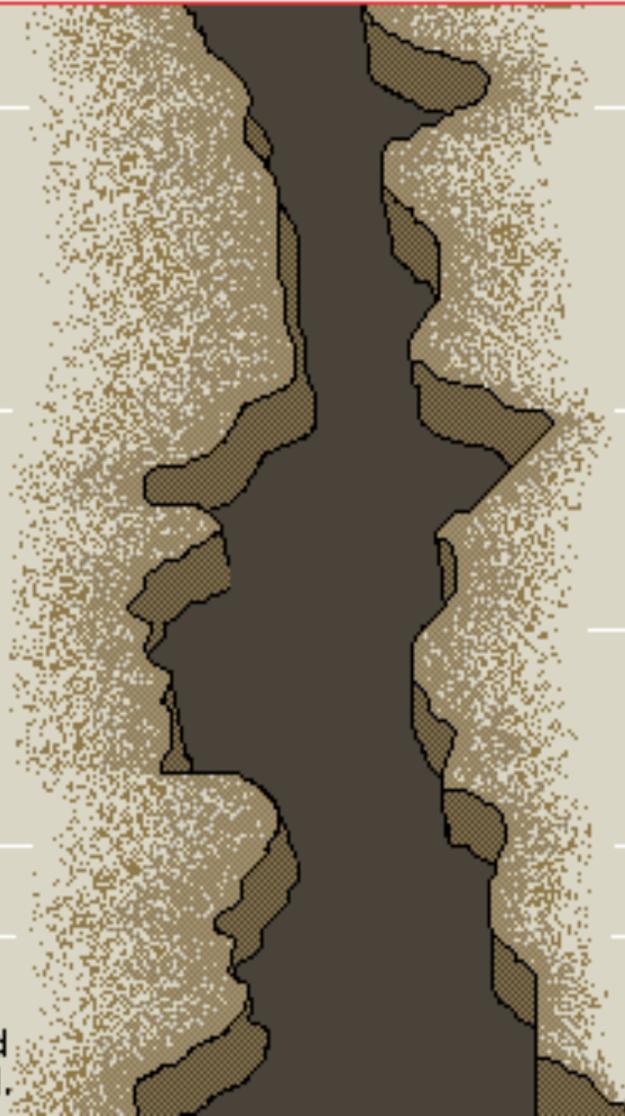
Modified Mercalli Intensity

Modified Mercalli Scale

- I.** Felt by almost no one.
- II.** Felt by very few people.
- III.** Tremor noticed by many, but they often do not realize it is an earthquake.
- IV.** Felt indoors by many. Feels like a truck has struck the building.
- V.** Felt by nearly everyone; many people awakened. Swaying trees and poles may be observed.
- VI.** Felt by all; many people run outdoors. Furniture moved, slight damage occurs.
- VII.** Everyone runs outdoors. Poorly built structures considerably damaged; slight damage elsewhere.
- VIII.** Specially designed structures damaged slightly, others collapse.
- IX.** All buildings considerably damaged, many shift off foundations. Noticeable cracks in ground.
- X.** Many structures destroyed. Ground is badly cracked.
- XI.** Almost all structures fall. Bridges wrecked. Very wide cracks in ground.
- XII.** Total destruction. Waves seen on ground surfaces, objects are tumbled and tossed.

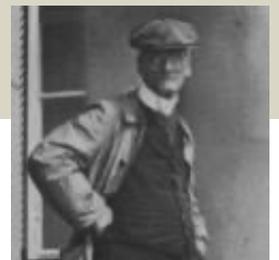
Richter Scale

- 2.5** Generally not felt, but recorded on seismometers.
- 3.5** Felt by many people.
- 4.5** Some local damage may occur.
- 6.0** A destructive earthquake.
- 7.0** A major earthquake.
- 8.0 and up** Great earthquakes.



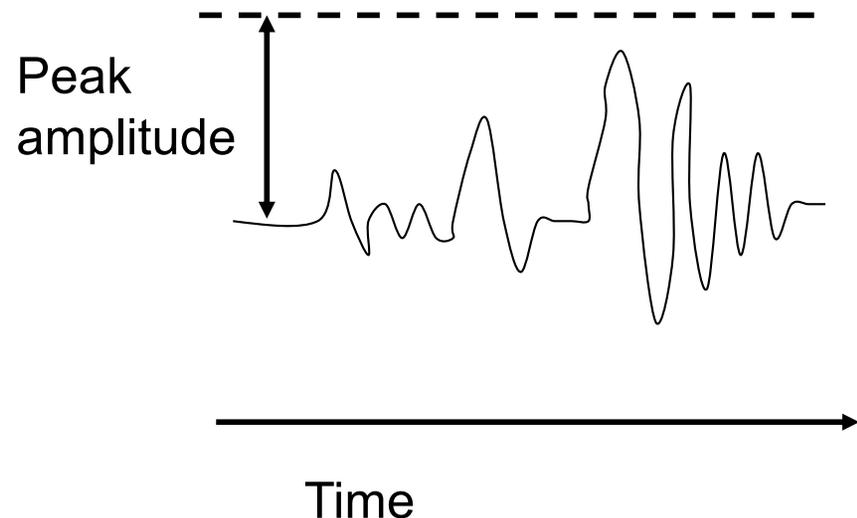
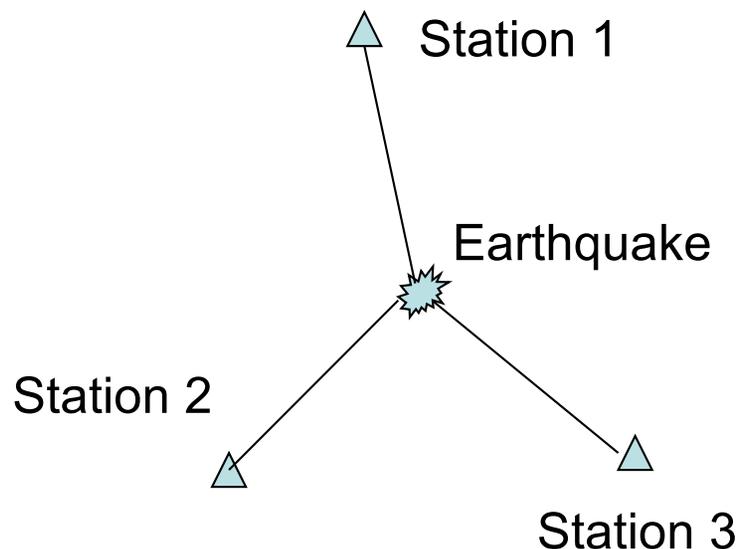
http://encarta.msn.com/media_461531420/earthquake_scales_modified_mercalli_and_richter.html

Giuseppe Mercalli
(1850-1914)



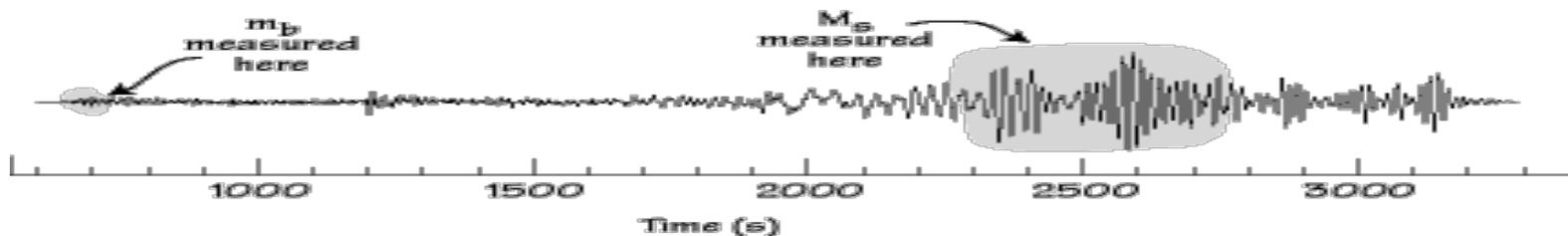
Instrumental Magnitude – since 1935

- Originally derived as size based on seismograms, e.g., maximum or "peak" ground motion measured
- Measure of amount of energy released by earthquake
- **Base-10 logarithmic scale** $M = \log(A/T) + F(h, \Delta) + C$
- 1st magnitude scale by Charles Richter (1935) to measure California earthquakes.
- Now, many scales for various observational conditions.



Magnitude Scales – wave type, period

			Period Range
M_L	Local magnitude (California)	regional S & surface waves	0.1-1 sec
M_j	JMA (Japan Meteorol. Agency)	regional S & surface waves	5-10 sec
m_b	Body wave magnitude	teleseismic P waves	1-5 sec
M_s	Surface wave magnitude	teleseismic surface waves	20 sec
M_w	Moment magnitude	teleseismic surface waves	> 200 sec
M_{wp}	P-wave moment magnitude	teleseismic P waves	10-60 sec
M_m	Mantle magnitude	teleseismic surface waves	> 200 sec



Ref: USGS Seismology and Tsunami Warnings, 2006 (Earthquake Source)

EARTHQUAKE ENERGY

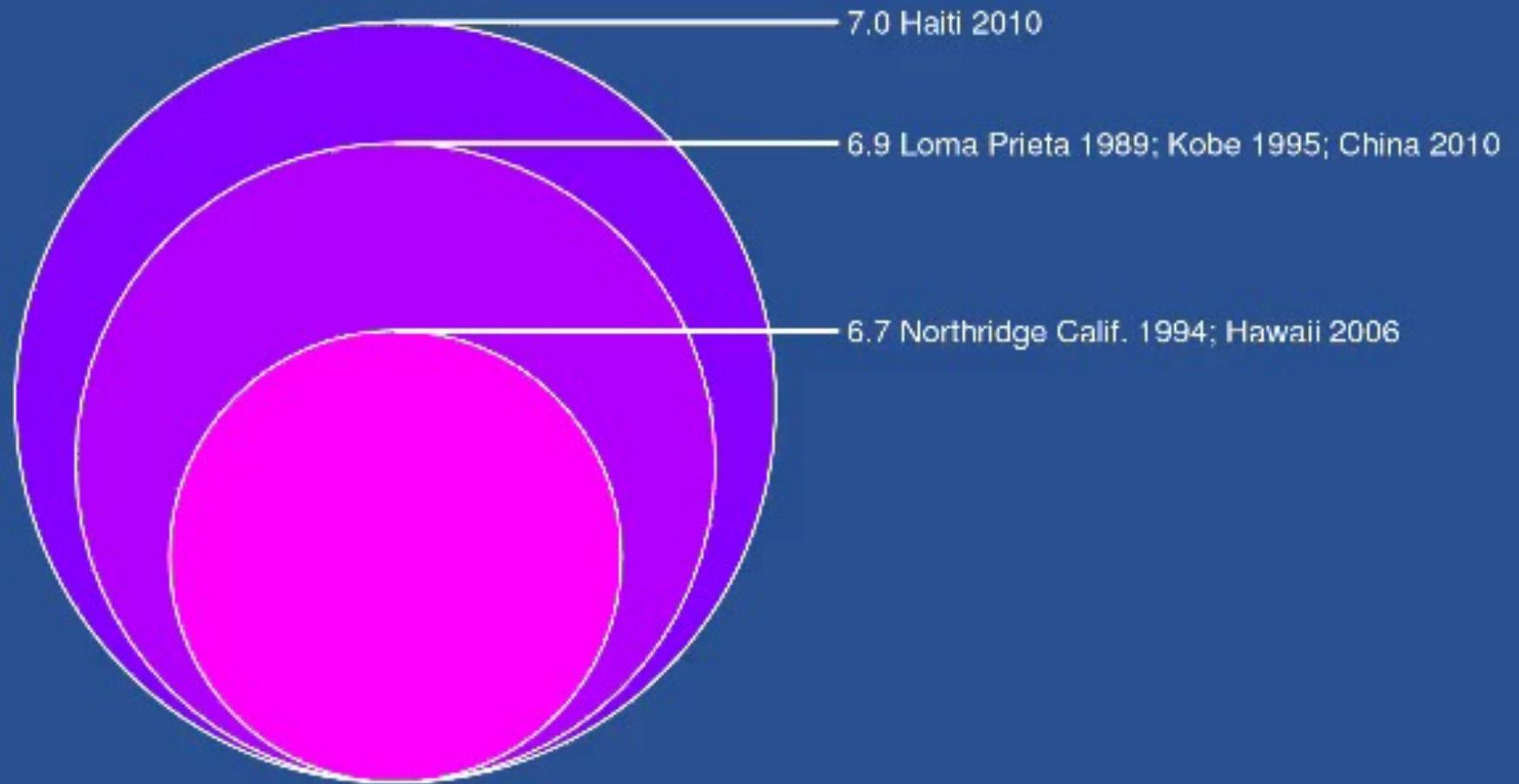
Use Mw to find real energy release

- Incr of 1 in magnitude:
 $10^{1.5} = 31.6$ times incr energy
- Incr of 2 in magnitude:
 $10^3 = 1000$ times incr in energy

Magnitude versus ground motion and energy

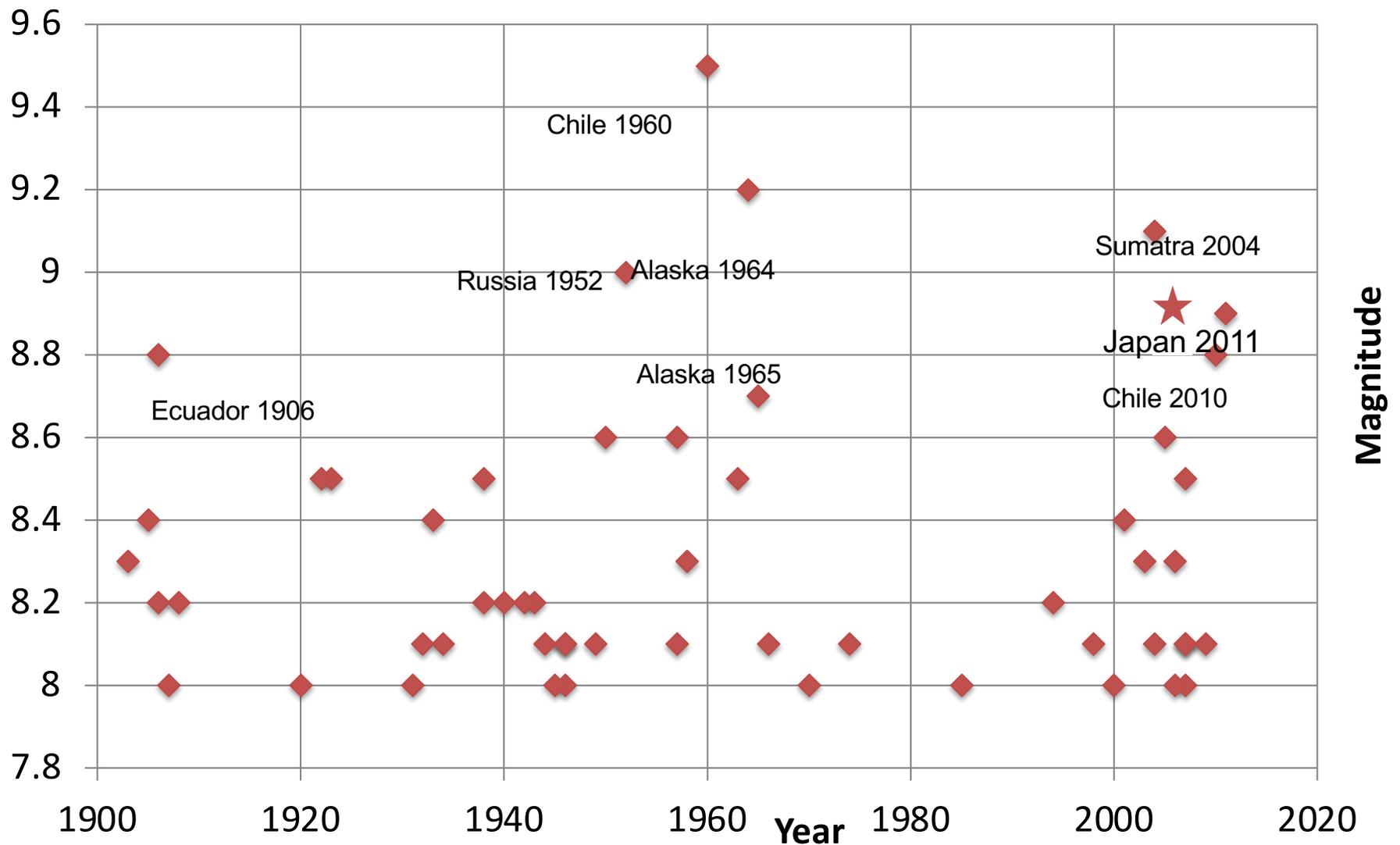
Magnitude	Ground Motion	Energy
1.0	10.0 times	about 32 times
0.5	3.2 times	about 5.5 times
0.3	2.0 times	about 3 times
0.1	1.3 times	about 1.4 times

Comparison of Recent and Historic Earthquakes by Energy Release



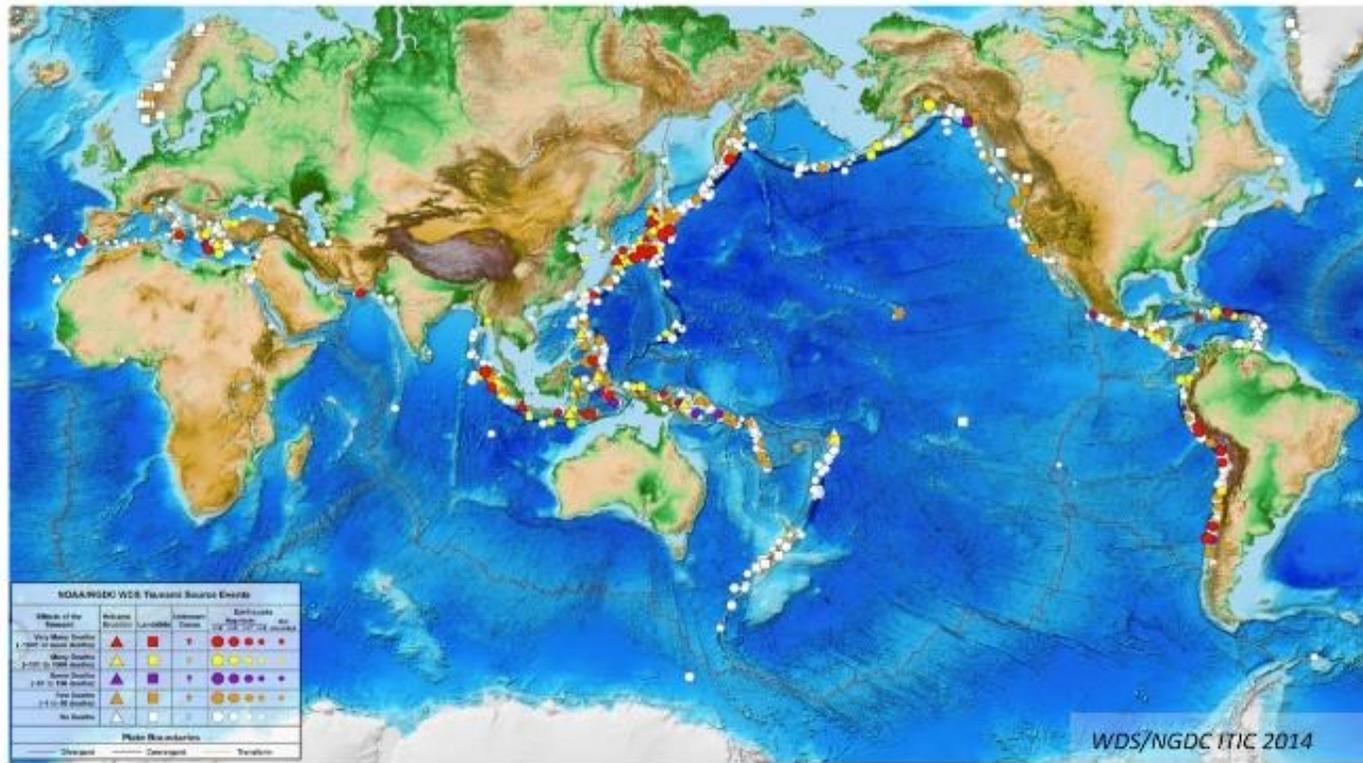
Earthquake and Tsunami Statistics

Great ($M > 8$) Earthquakes since 1900 (avg 2.1/yr)



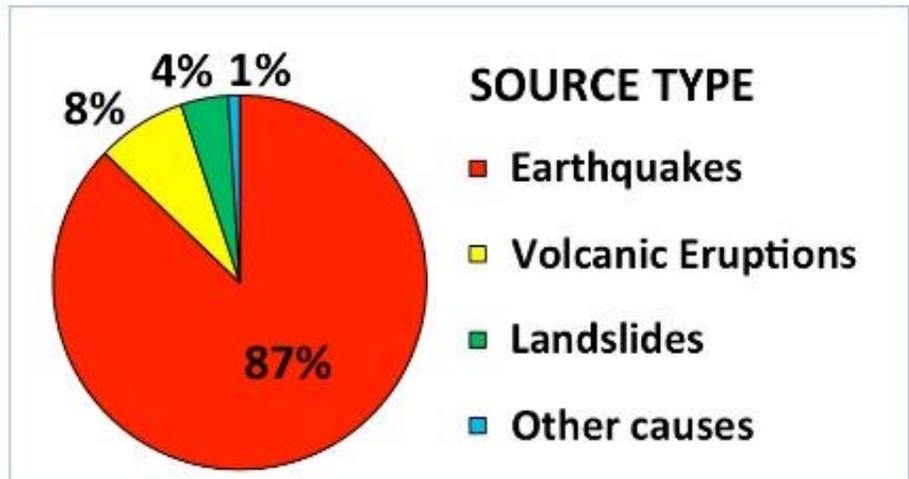
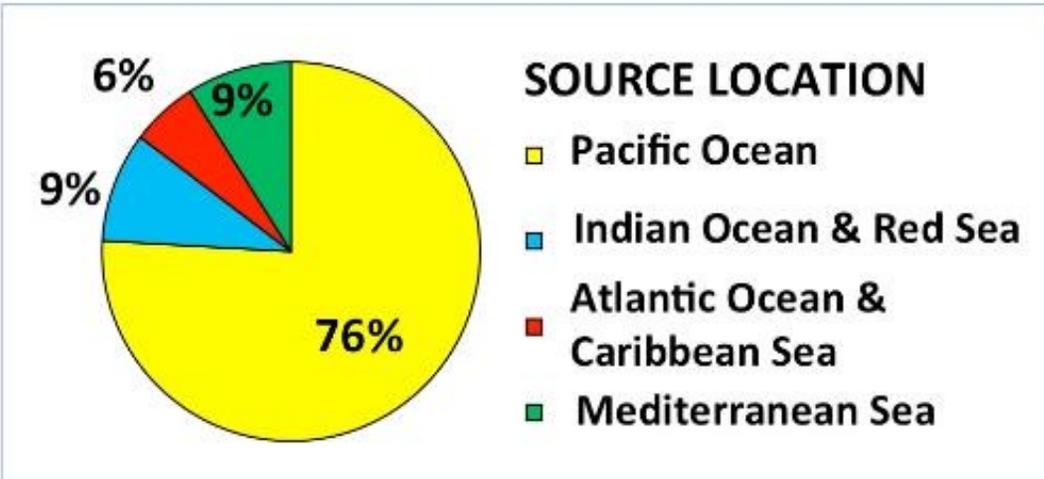
TSUNAMI SOURCES 1610 B.C. to A.D. 2016

FROM EARTHQUAKES, VOLCANIC ERUPTIONS, LANDSLIDES, AND OTHER CAUSES



➤ **1,235**
Confirmed
Tsunamis

➤ **249**
Deadly
Tsunamis

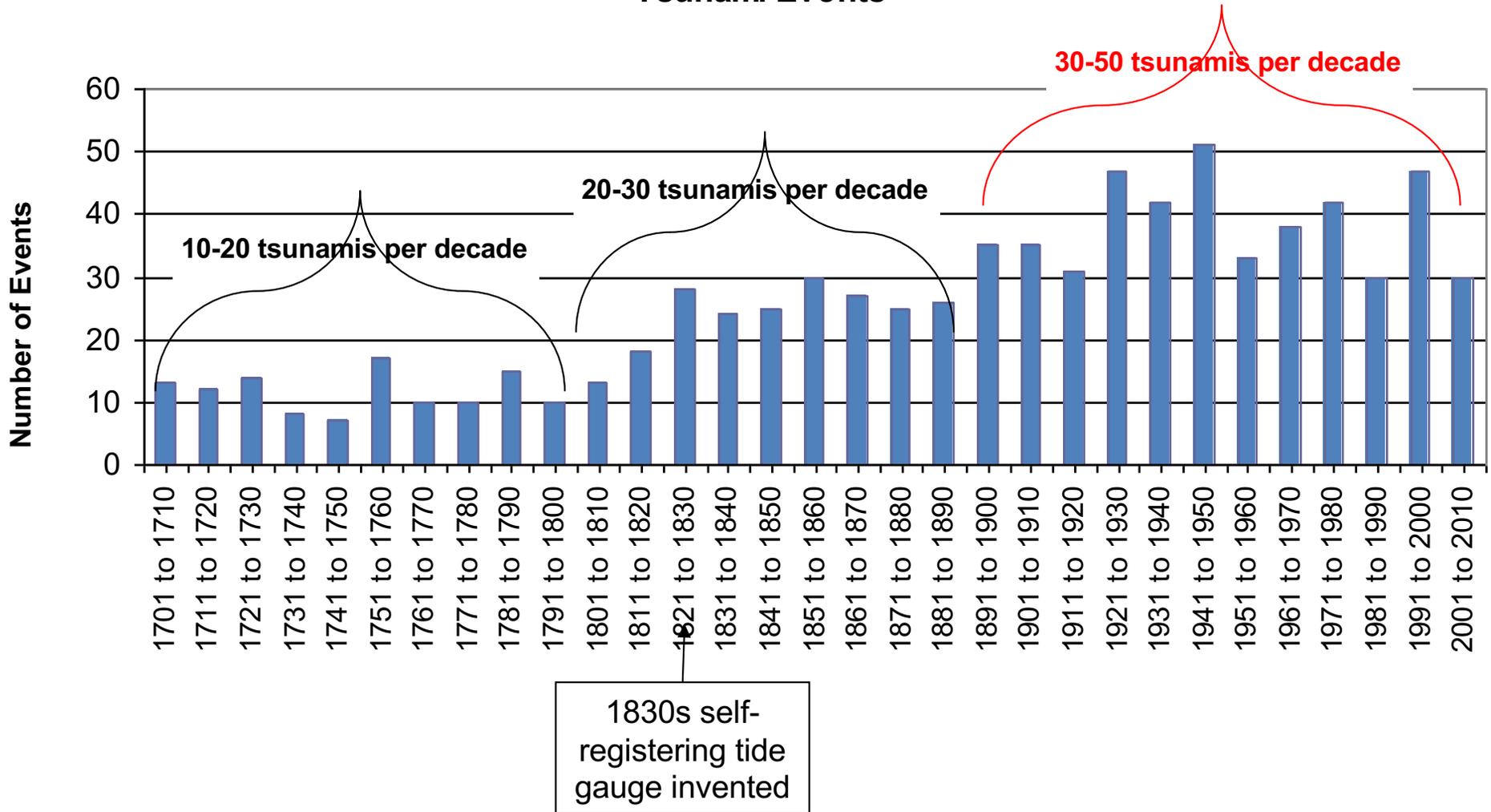




Are Tsunamis Increasing?



Tsunami Events



Total # tsunamis not increasing (due to improved reporting)



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Thank You

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