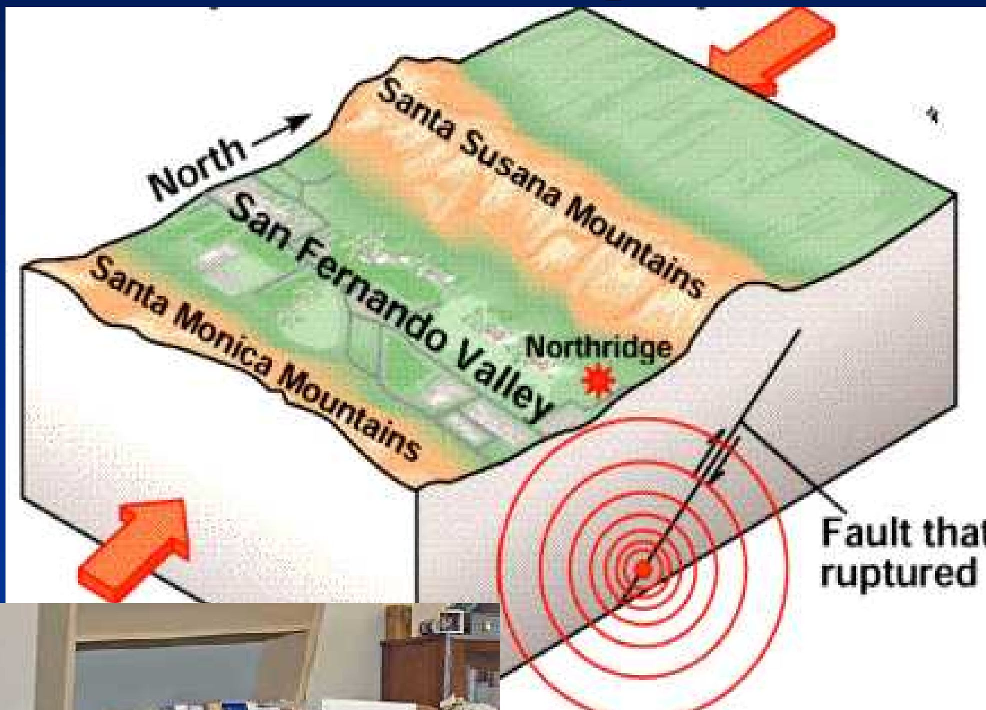
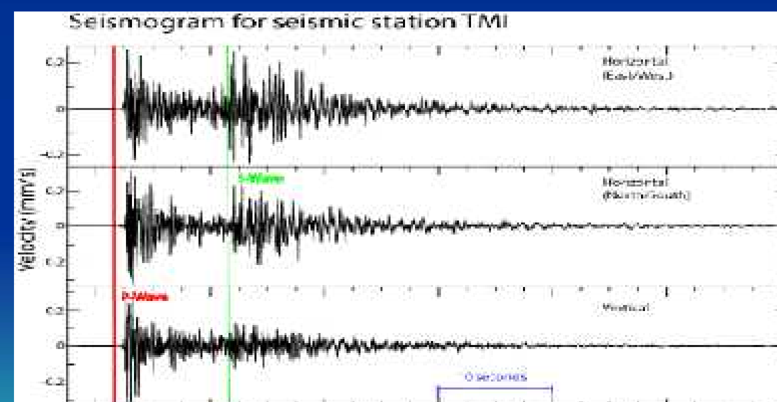
Earthquake!

Principles and Applications





Physical Geology - GEOL 101

Ray Rector - Instructor

EARTHQUAKE TOPICS

What are Earthquakes?

Where and How do Earthquake Form?

How are Earthquakes Measured?

What are the Effects of Earthquakes?

Can we Predict Earthquakes?

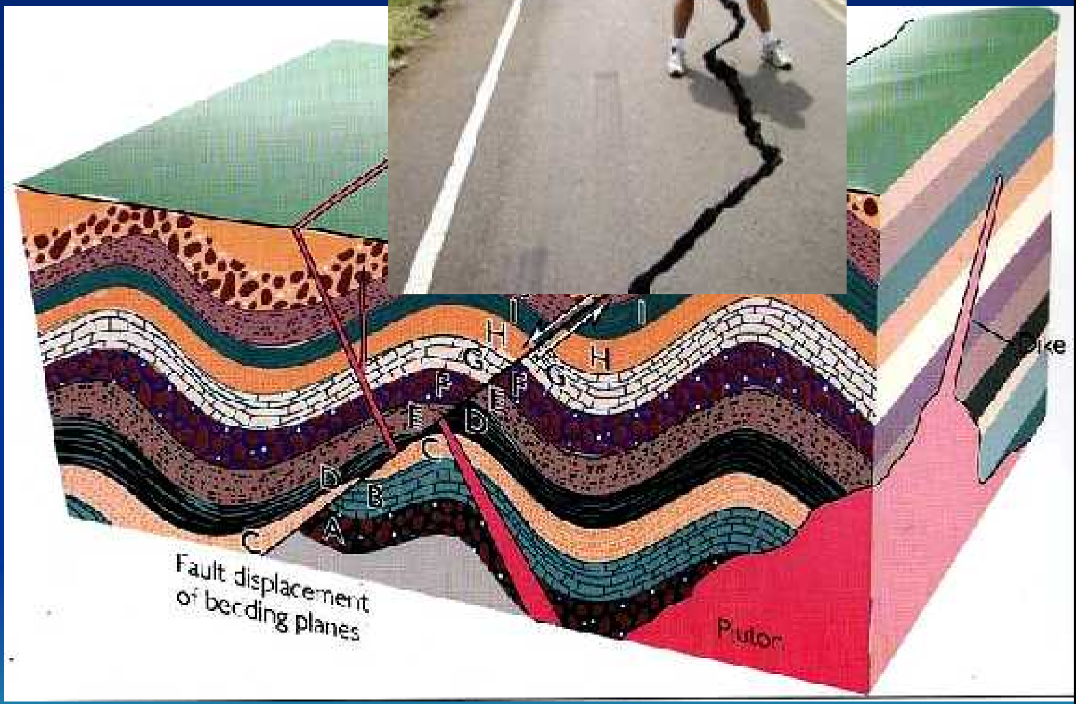
How can we Prepare for an Earthquake?

Earthquakes Occur Along Active Fault Zones

1) Faults are planar surfaces (zones of weakness) in the upper crust where brittle fracture takes place between two offsetting crustal blocks

2) Most active faults occur along tectonic plate boundaries

3) Earthquakes are the instant release of built-up elastic strain energy as result of fault rupture



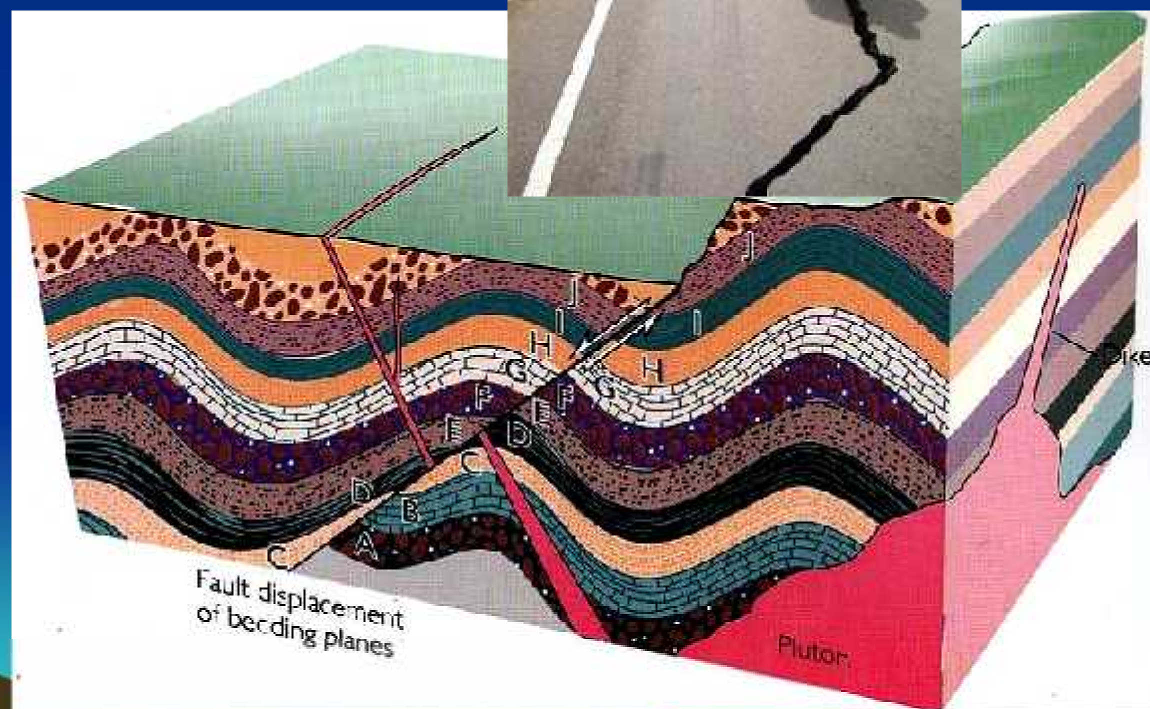
Earthquakes Occur Along Active Fault Zones

1) Most fault activity occurs at or near plate boundaries and regions of volcanism

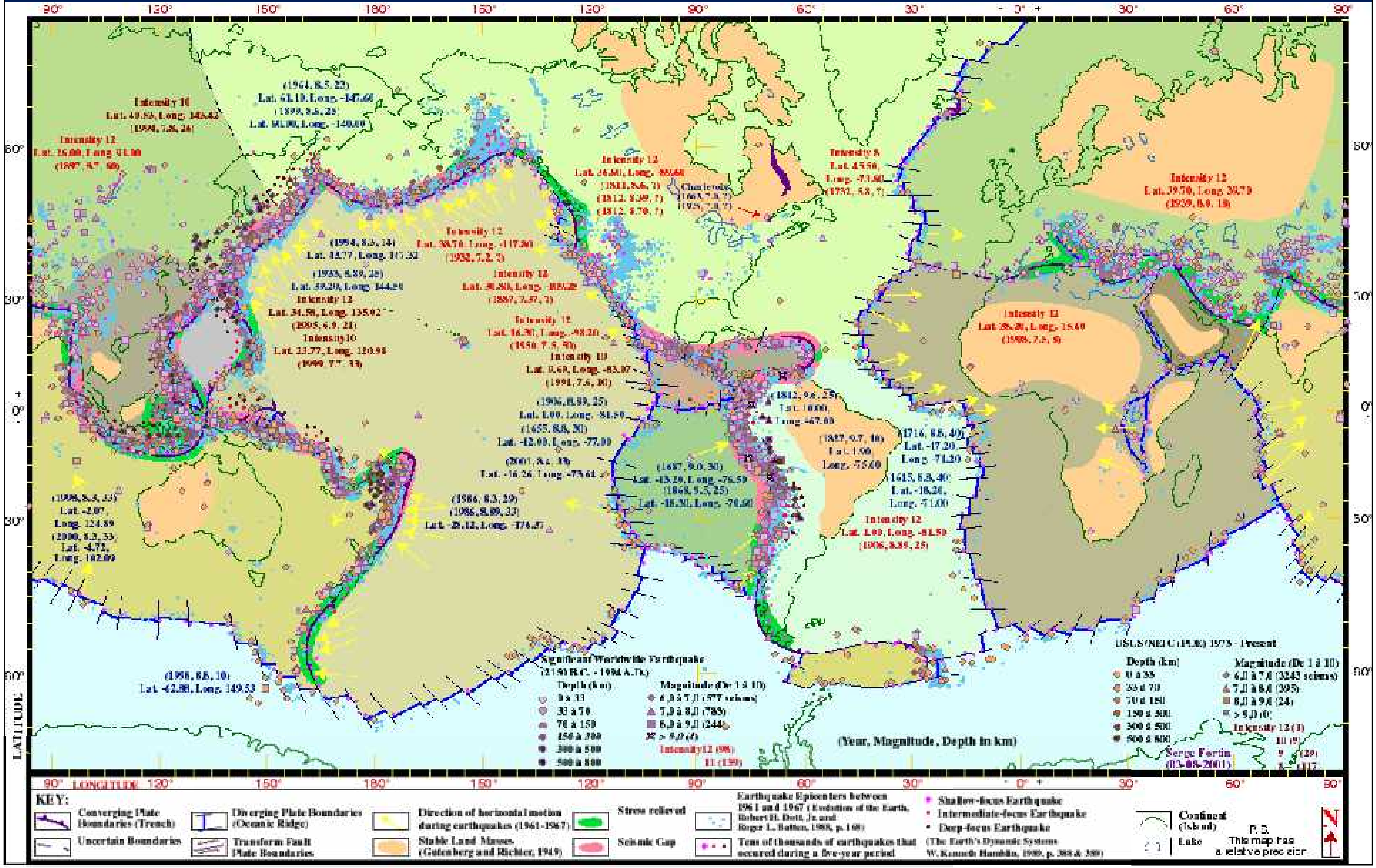
2) Fault activity is associated with tectonic stresses and/or movement of magma

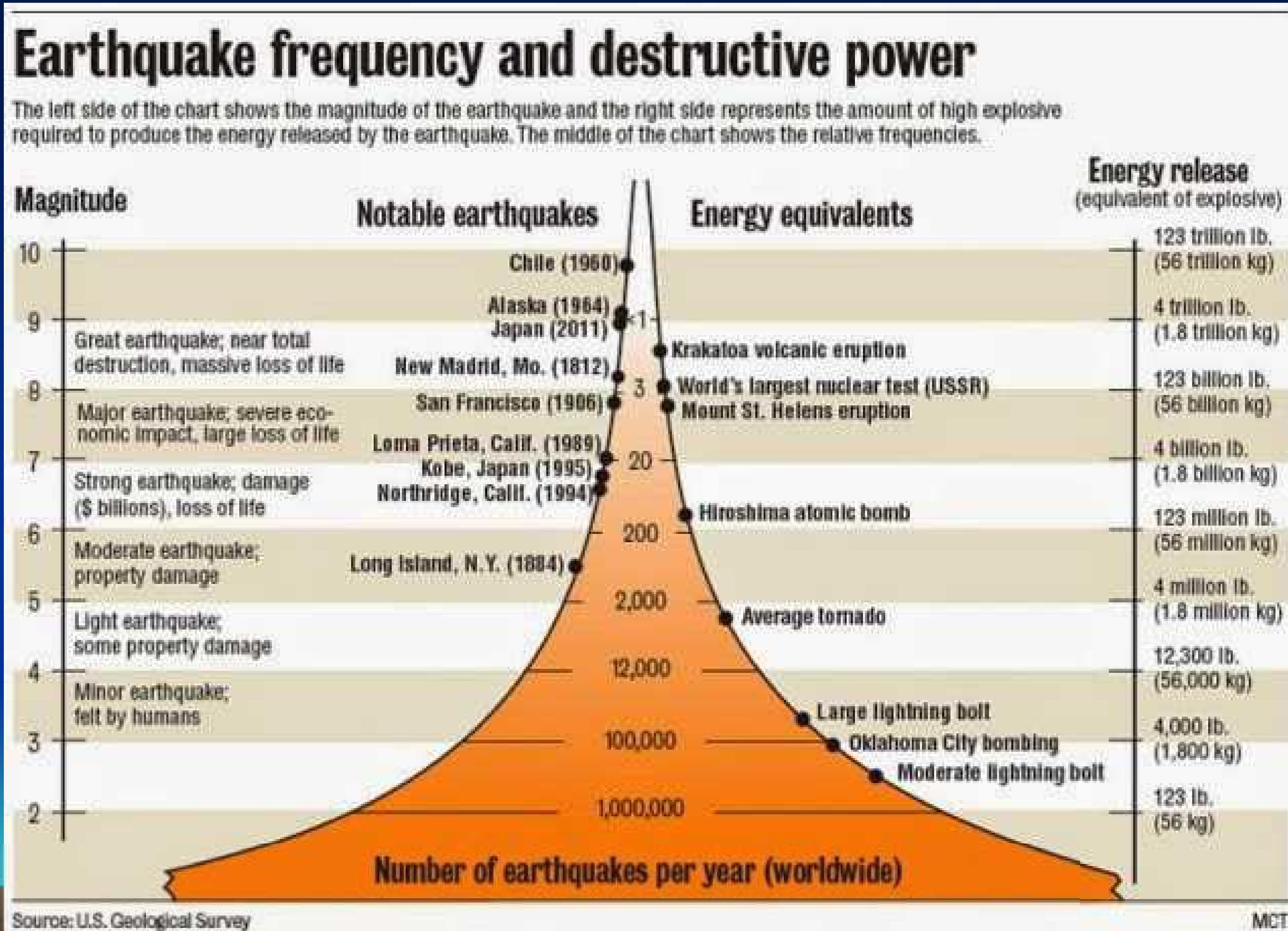
3) Earthquakes are the result of released stress between adjacent blocks of brittle/elastic-behaving crustal rocks

4) Earthquakes can be measured for size, intensity, and location using seismometers.



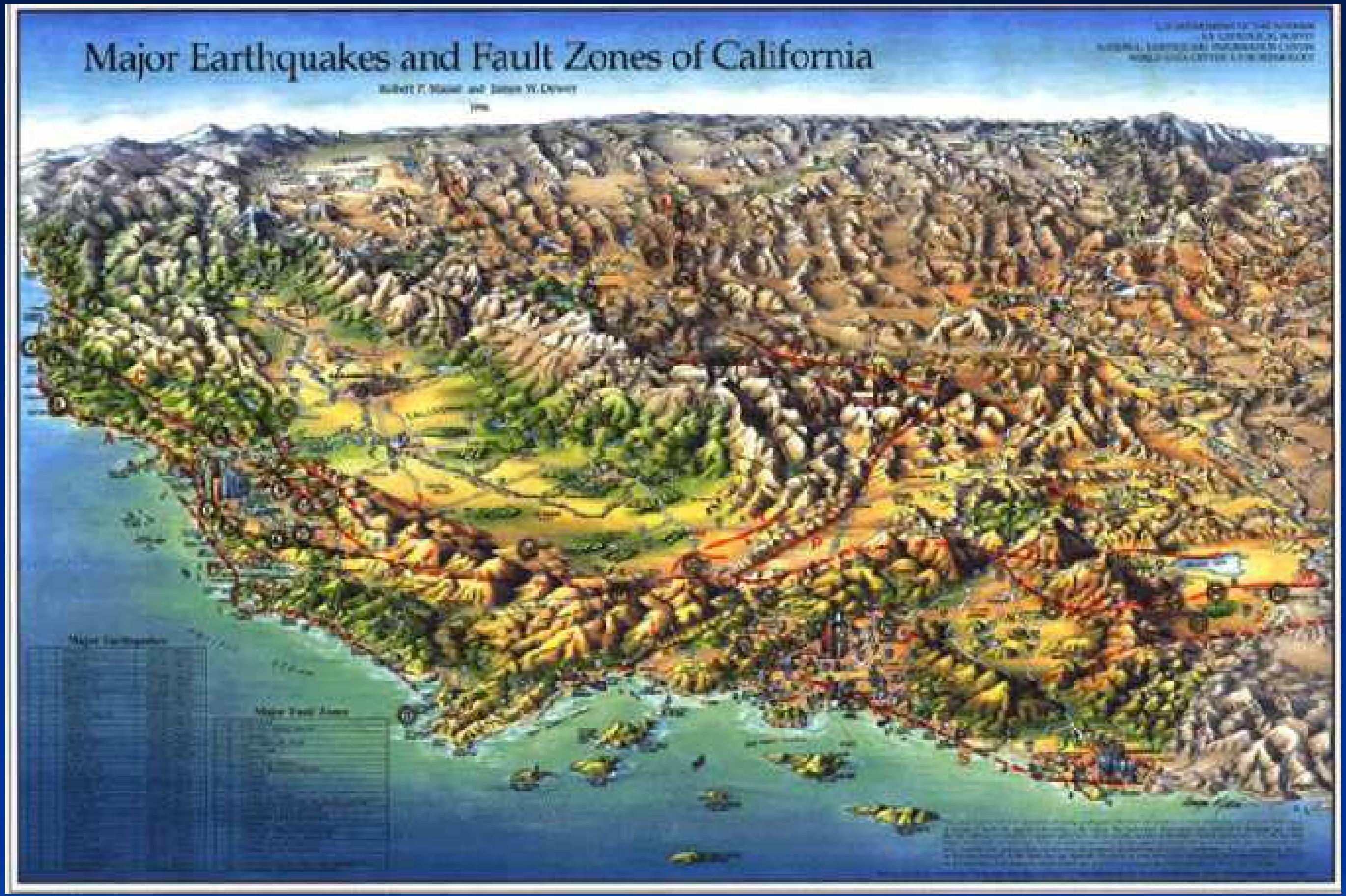
Major Earthquakes and Fault Zones of the World





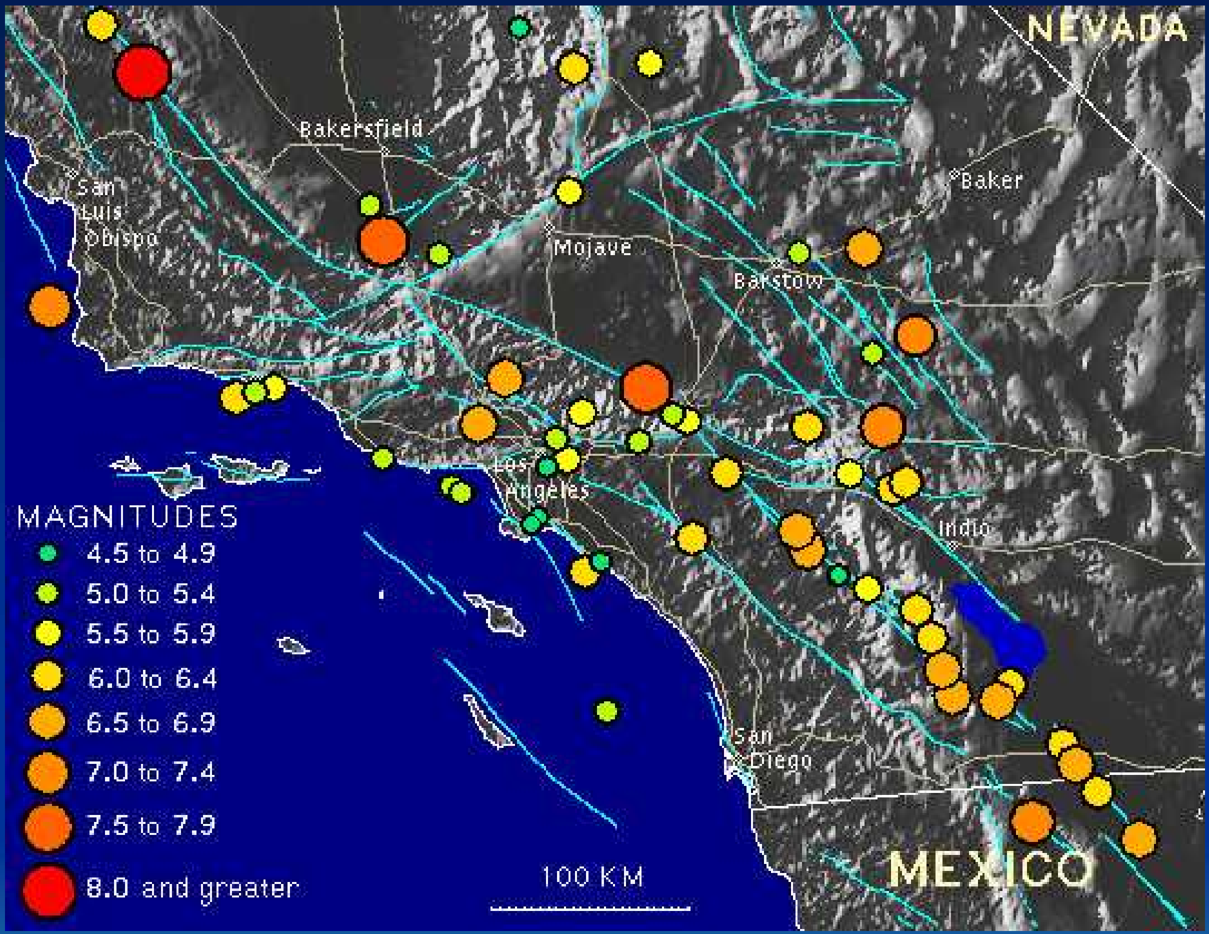
Earthquake frequency and destructive power
The left side of the chart shows the magnitude of the earthquake and the right side represents the amount of high explosive required to produce the energy released by the earthquake. The middle of the chart shows the relative frequencies.
Magnitude
Notable earthquakes
Energy equivalents
Energy release
(equivalent of explosive)
10
9
8
7
6
5
4
3
2
Great earthquake; near total destruction, massive loss of life
Major earthquake; severe economic impact, large loss of life
Strong earthquake; damage ($ billions), loss of life
Moderate earthquake; property damage
Light earthquake; some property damage
Minor earthquake; felt by humans
Chile (1960)
Alaska (1964)
Japan (2011)
New Madrid, Mo. (1812)
San Francisco (1906)
Loma Prieta, Calif. (1989)
Kobe, Japan (1995)
Northridge, Calif. (1994)
Long Island, N.Y. (1884)
<1
3
20
200
2,000
12,000
100,000
1,000,000
Krakatoa volcanic eruption
World's largest nuclear test (USSR)
Mount St. Helens eruption
Hiroshima atomic bomb
Average tornado
Large lightning bolt
Oklahoma City bombing
Moderate lightning bolt
123 trillion lb. (56 trillion kg)
4 trillion lb. (1.8 trillion kg)
123 billion lb. (56 billion kg)
4 billion lb. (1.8 billion kg)
123 million lb. (56 million kg)
4 million lb. (1.8 million kg)
12,300 lb. (56,000 kg)
4,000 lb. (1,800 kg)
123 lb. (56 kg)
Number of earthquakes per year (worldwide)
Source: U.S. Geological Survey
MCT

Major Fault Zones of California



The majority of California's abundance of faults are part of the San Andreas Fault Zone – a transform boundary fault system

Largest Earthquakes of Southern California



The San Andreas Fault is capable of up to 8.0 M earthquakes.
The most active fault in So Cal is the San Jacinto Fault

Most Recent Earthquakes in California

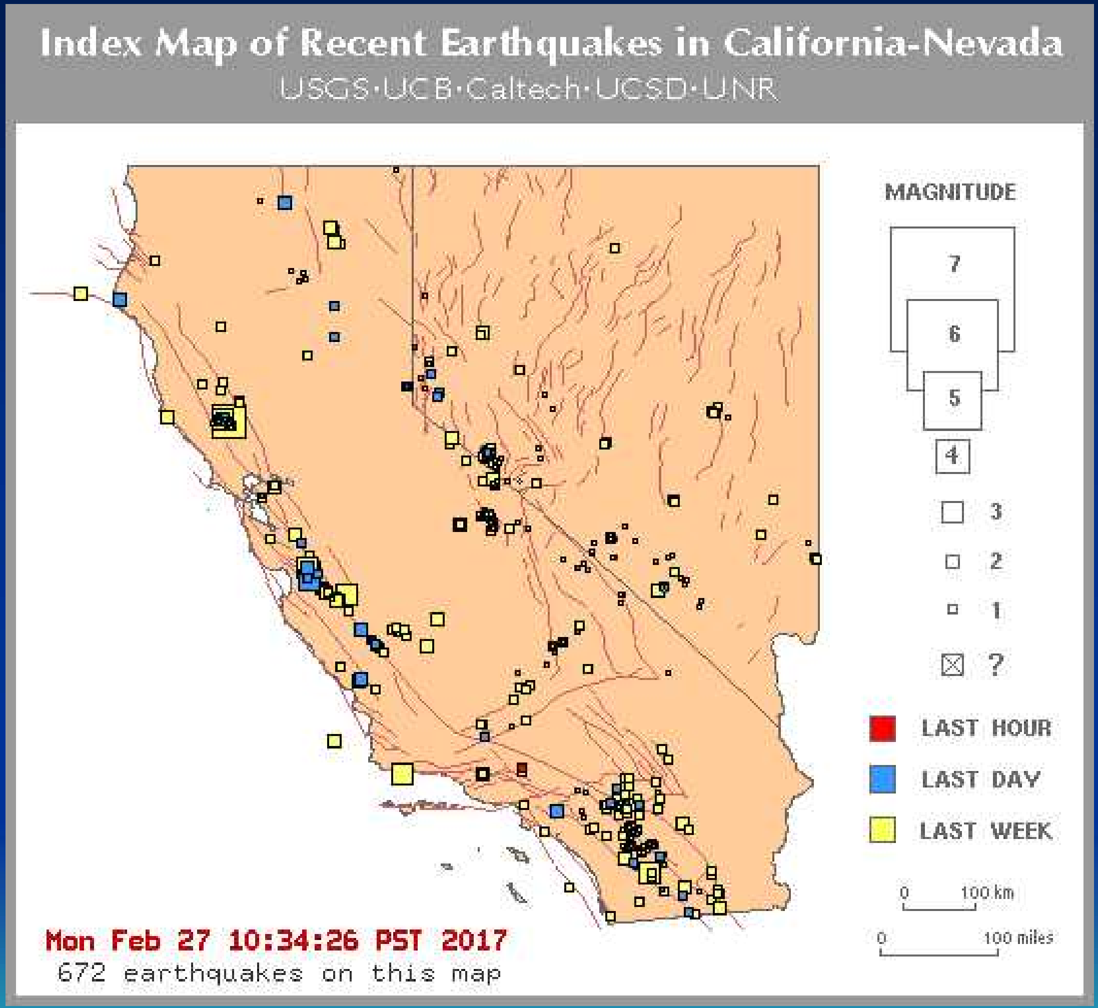
1) Most fault activity is associated with the San Andreas Fault Zone

2) The other zone is the Eastern Sierra region

3) The most active in Southern California are the San Jacinto and Elsinore faults

4) Short range quake prediction does not exist at this time

5) Where will the next "Big One" (> 7.5M) hit?



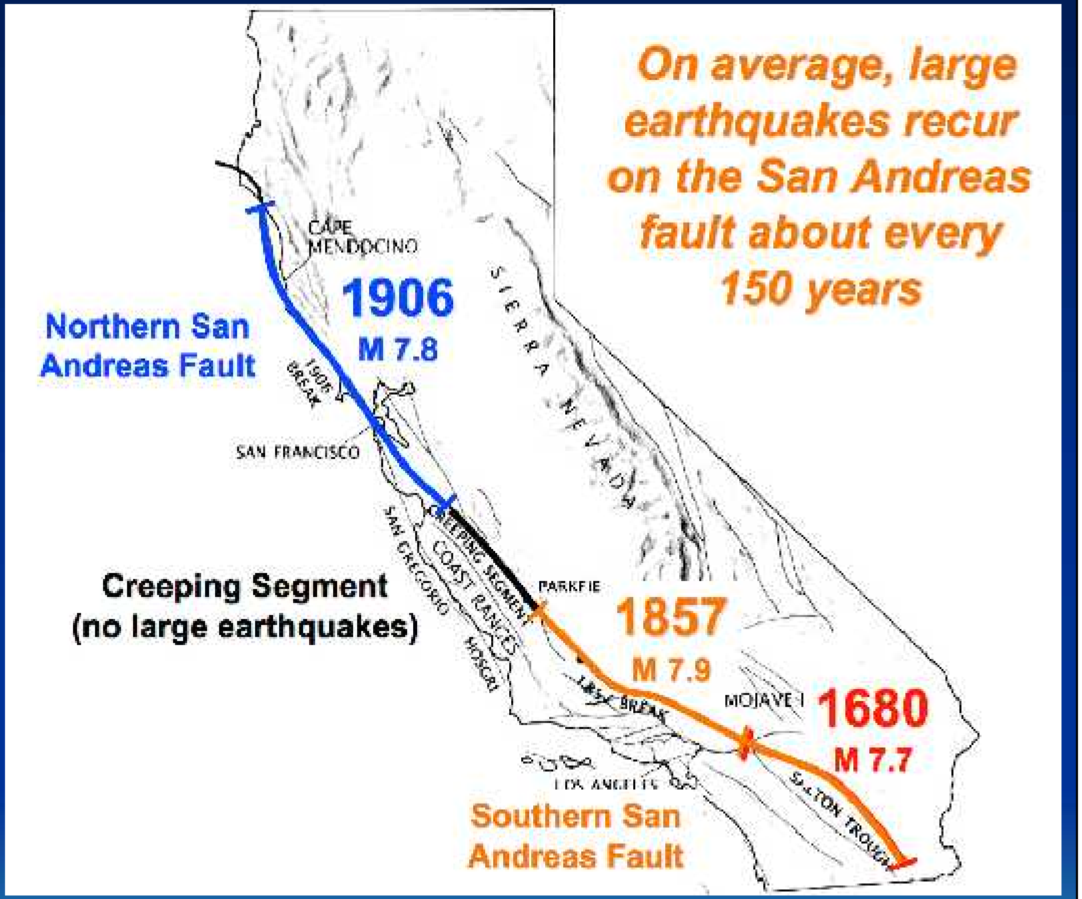
“Big Ones” on the San Andreas

1) Three Big Ones in the last 500 years on the SAF

2) Last Big One was on the Northern California segment in 1906

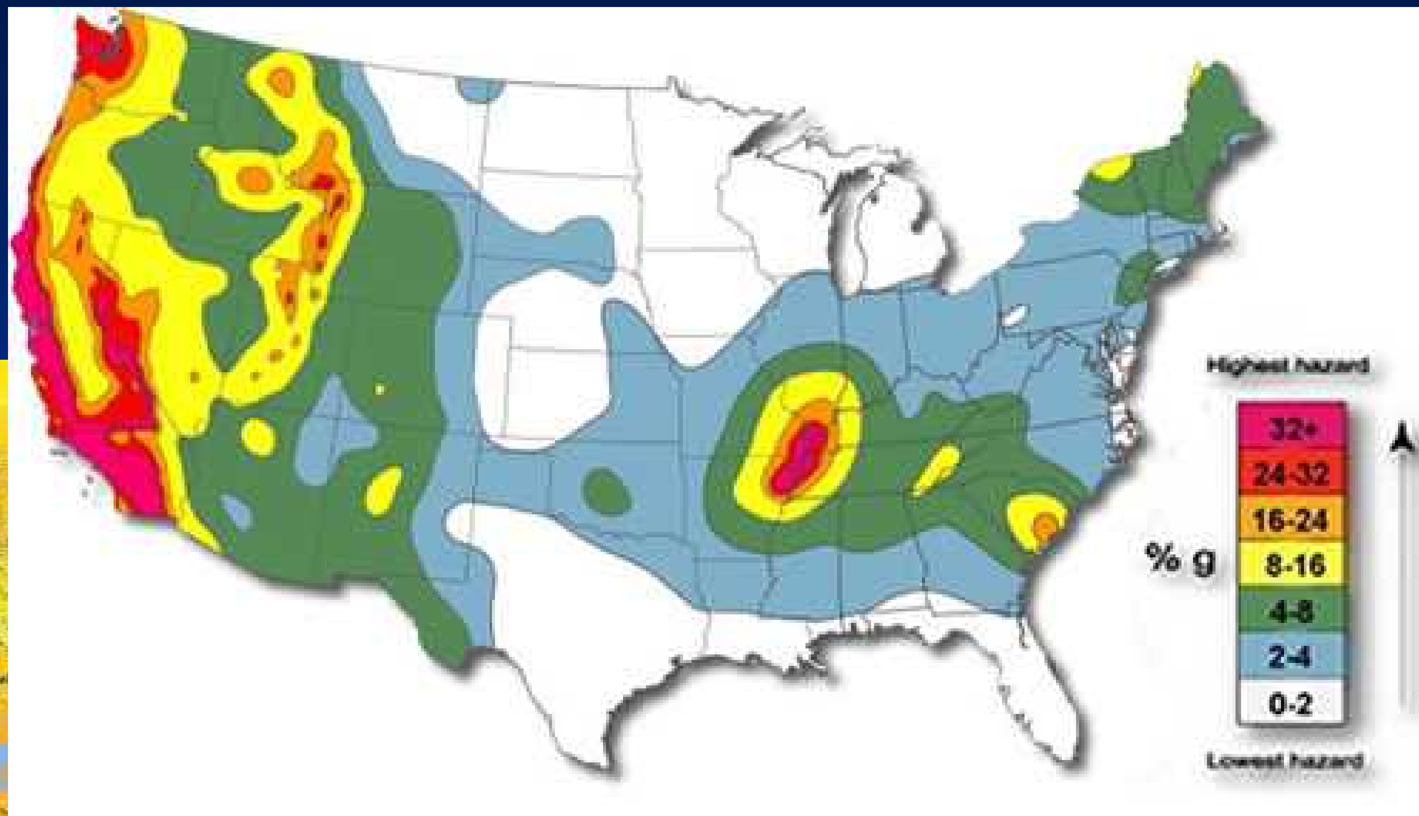
3) Last Big One on the Southern California segment was in 1680

4) A “Big One” occurs about every 400 years on each of the SAF segments



5) Based on this map, where will the next “Big One” on the SAF most likely strike?

Earthquake Probability in USA



1) Geologists cannot predict an earthquake at the present time

2) Geologists can make statistically-based probability estimates for a given faults's chances of rupture

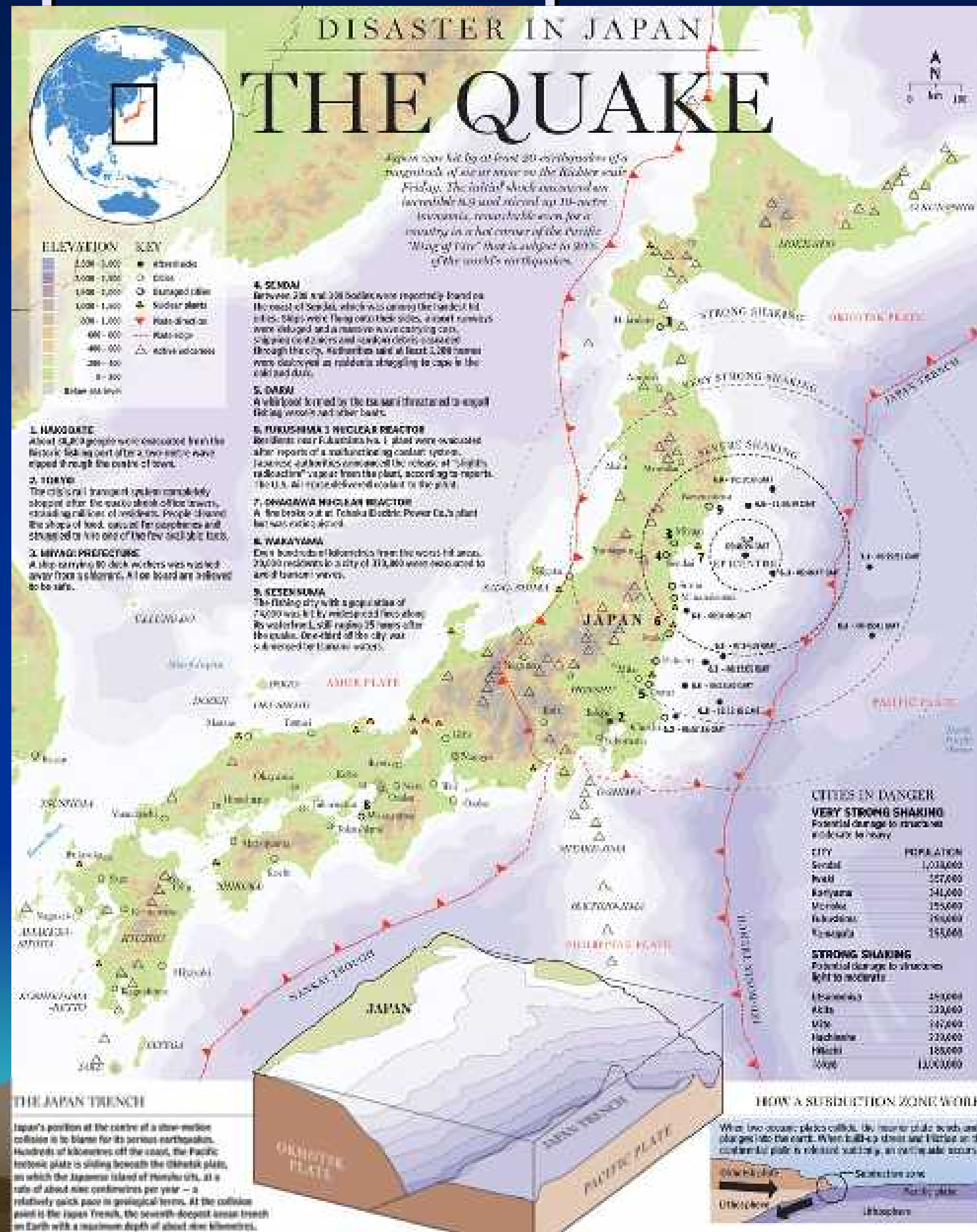
Recent Earthquake in Japan

1) Measured 9.0 on Richter Scale and lasted for over 4 minutes

2) One of the largest earthquakes ever recorded – biggest ever measured in Japan

3) Centered offshore along subduction zone thrust fault

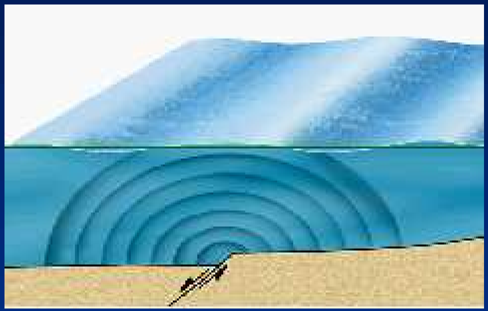
4) Caused super destructive tsunami waves

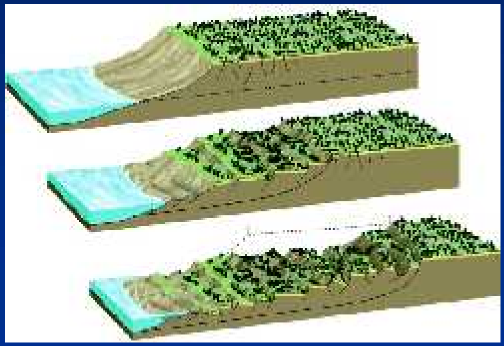


Origin of Tsunami

Tsunami can be generated by several means:

1) Seismic event





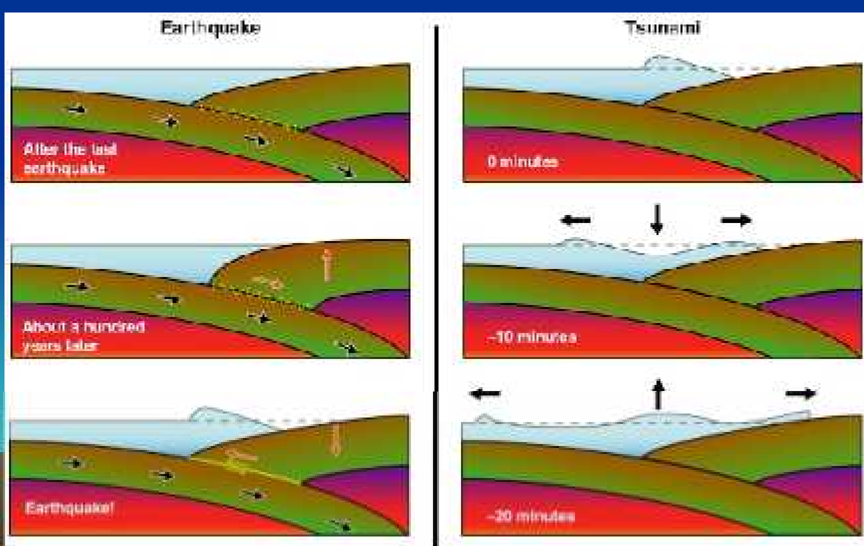
2) Coastal landslide

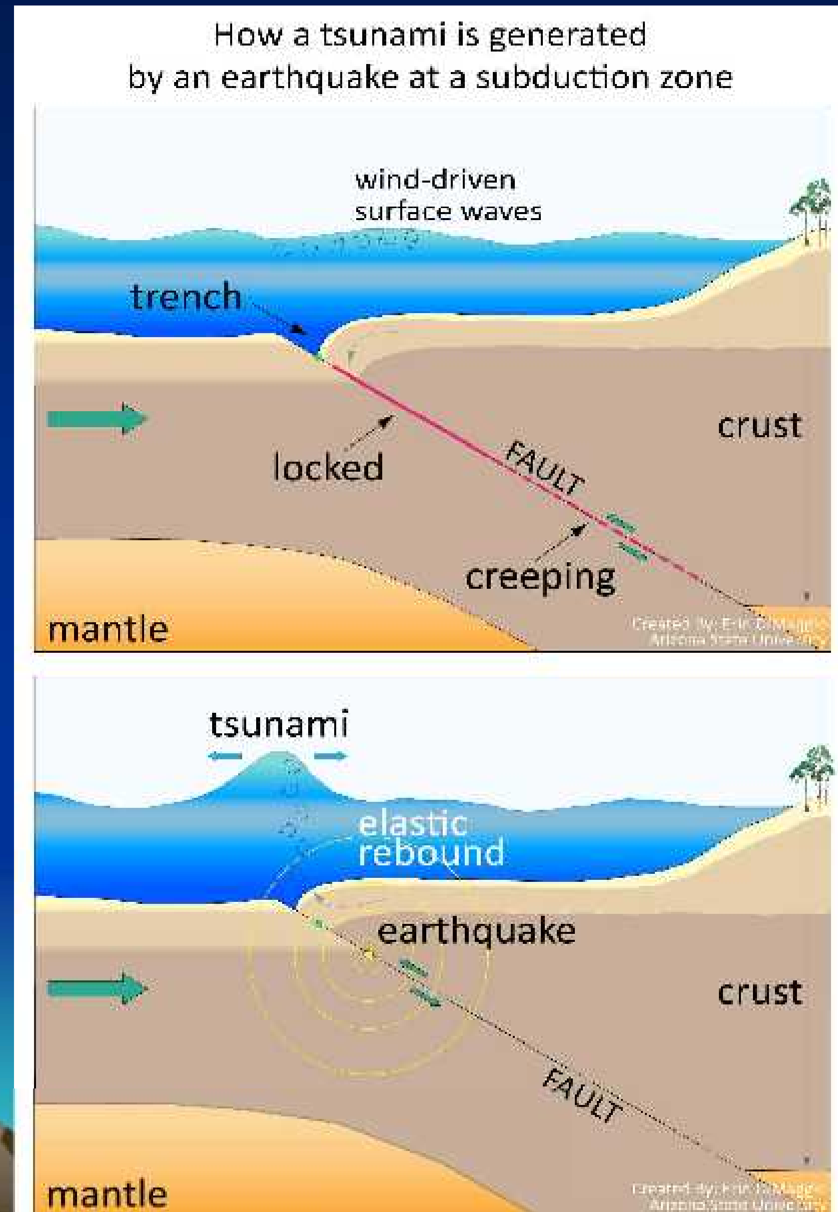
3) Volcanic eruption

4) Bolide ocean impact

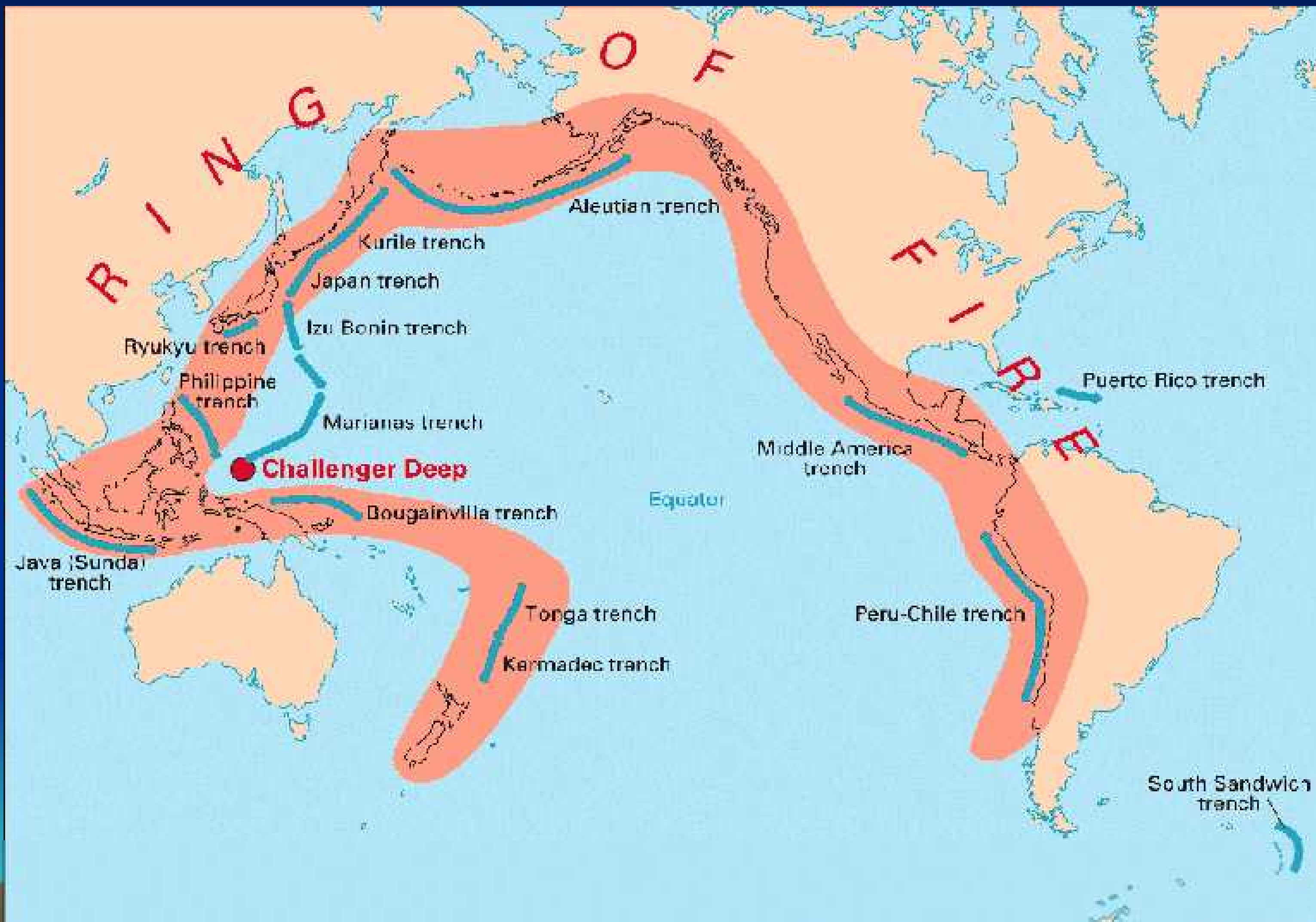
Formation of Seismic Sea Waves

- A seismic sea wave is generated by a rapid vertical displacement of the sea bottom during an earthquake
- Overlying water column is equally displaced, either up or down, depending on direction of the ruptured seafloor
- The influence of gravity on the ocean surface anomaly will cause water column oscillation resulting in a set of outwardly moving concentric tsunami waves

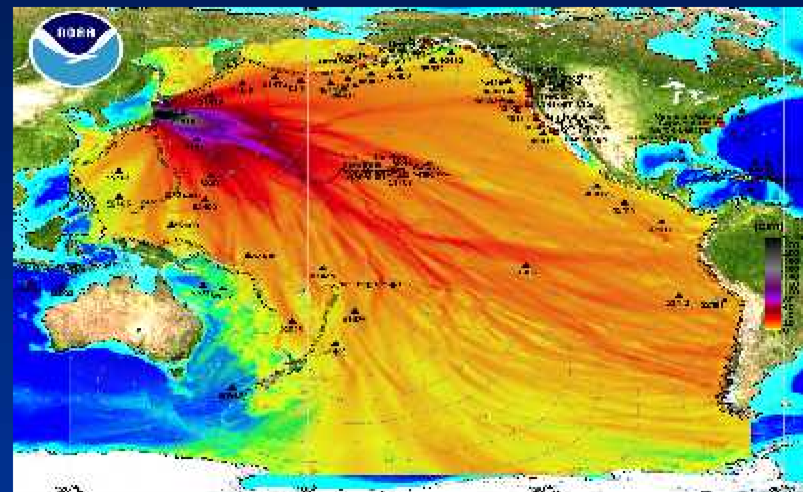




Pacific Rim – Tsunami Factory



Earthquake-Tsunami Combo
The Deadly One-Two Punch



Tsunami = Godzilla Wave?

https://www.youtube.com/watch?v=23VfIsU3kZE

https://www.youtube.com/watch?v=F1ZewAPI7L0

https://www.youtube.com/watch?v=k8IAgUNr6x4

Earthquake Preparation and Mitagation

Fundamentals of an Earthquake

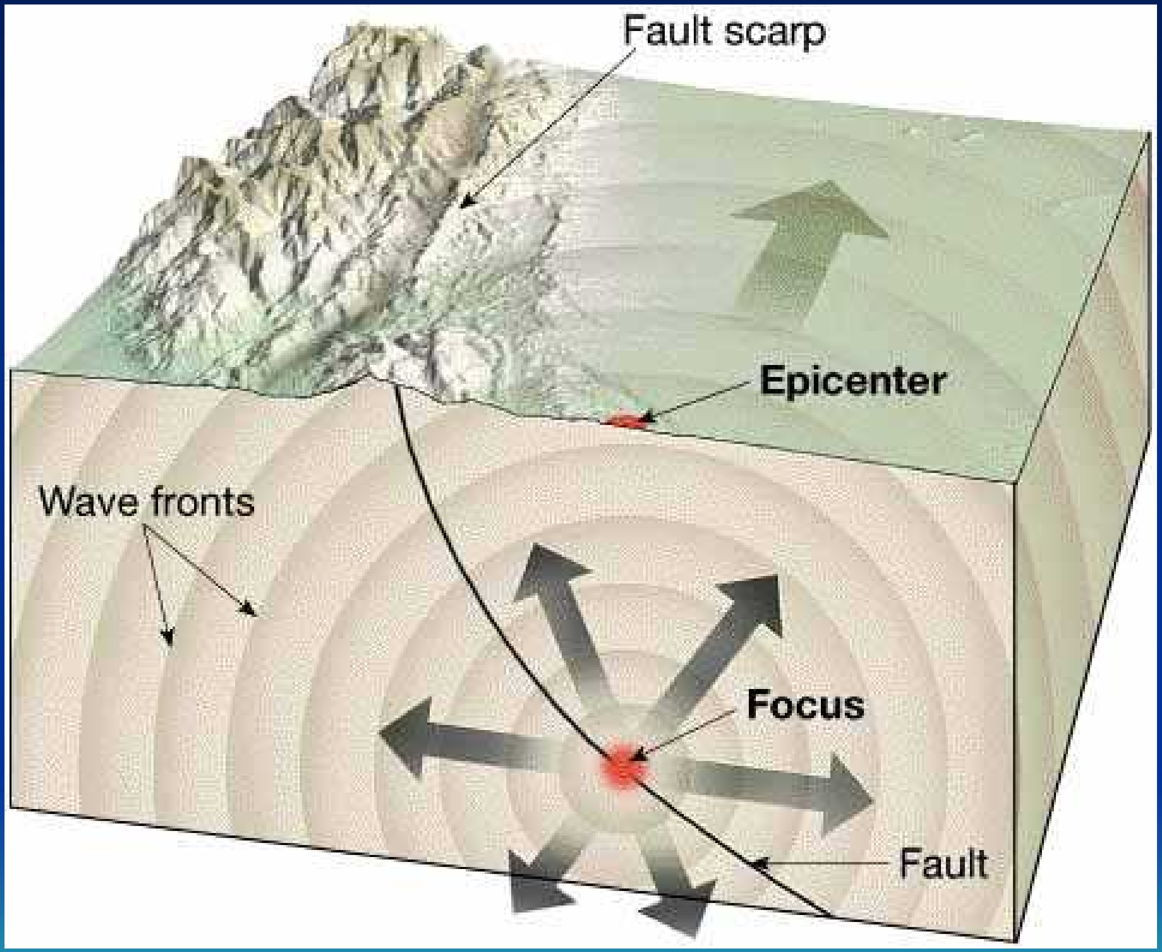
1) Fault rupture

2) Fault scarp

3) Focus

4) Epicenter

5) Seismic Waves



What Causes an Earthquake?

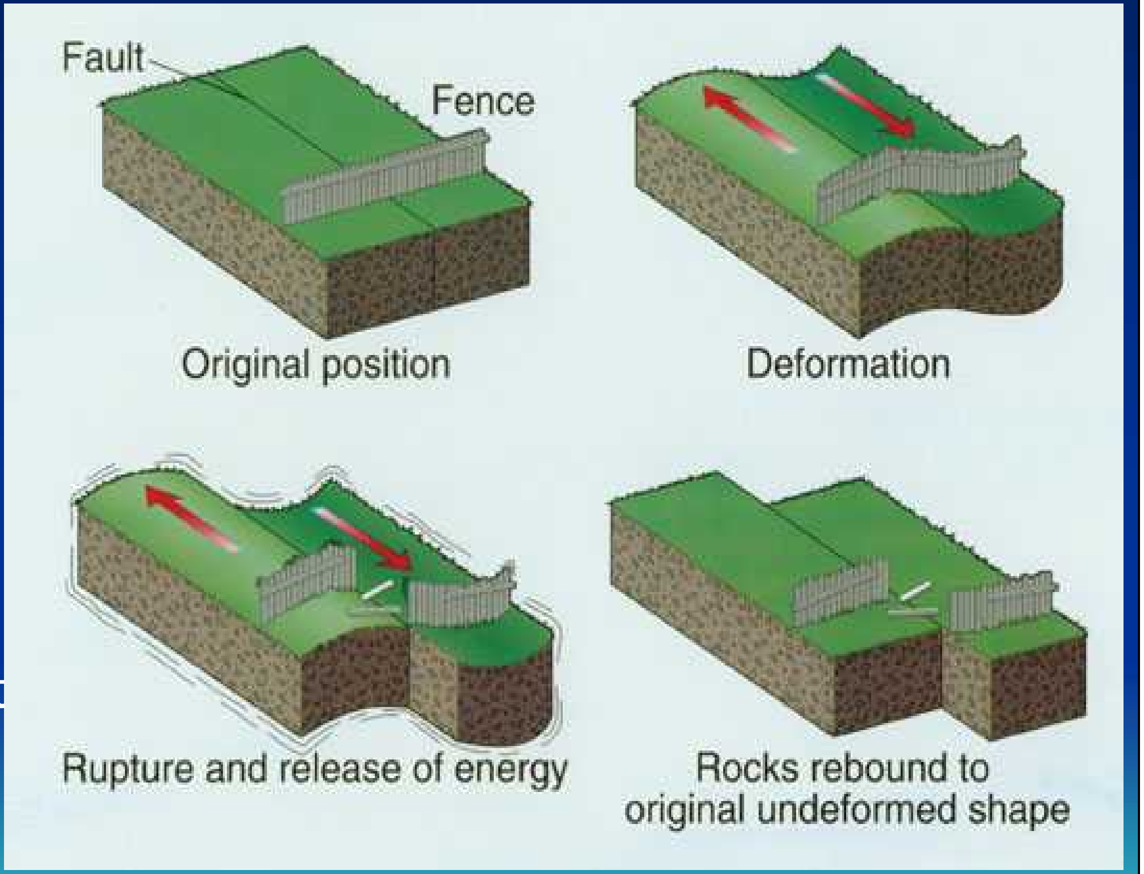
1) Pre-load Period
- No Stress
- No Deformation

2) Bending Period
- Slow Stress Loading
- Elastic Deformation

3) Rupture Period
- Instant Stress Release
- Brittle Deformation/Offset

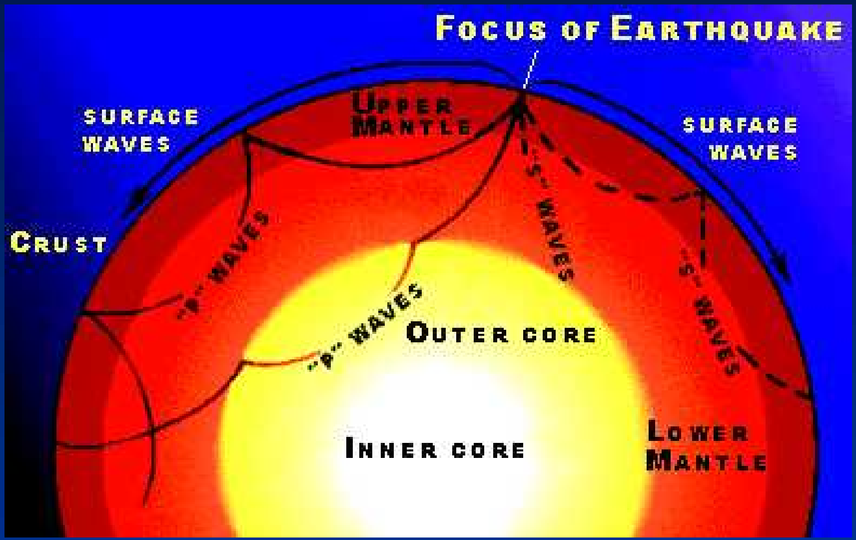
4) Rebound Period
- Removal of Bending
- Stress Relieved

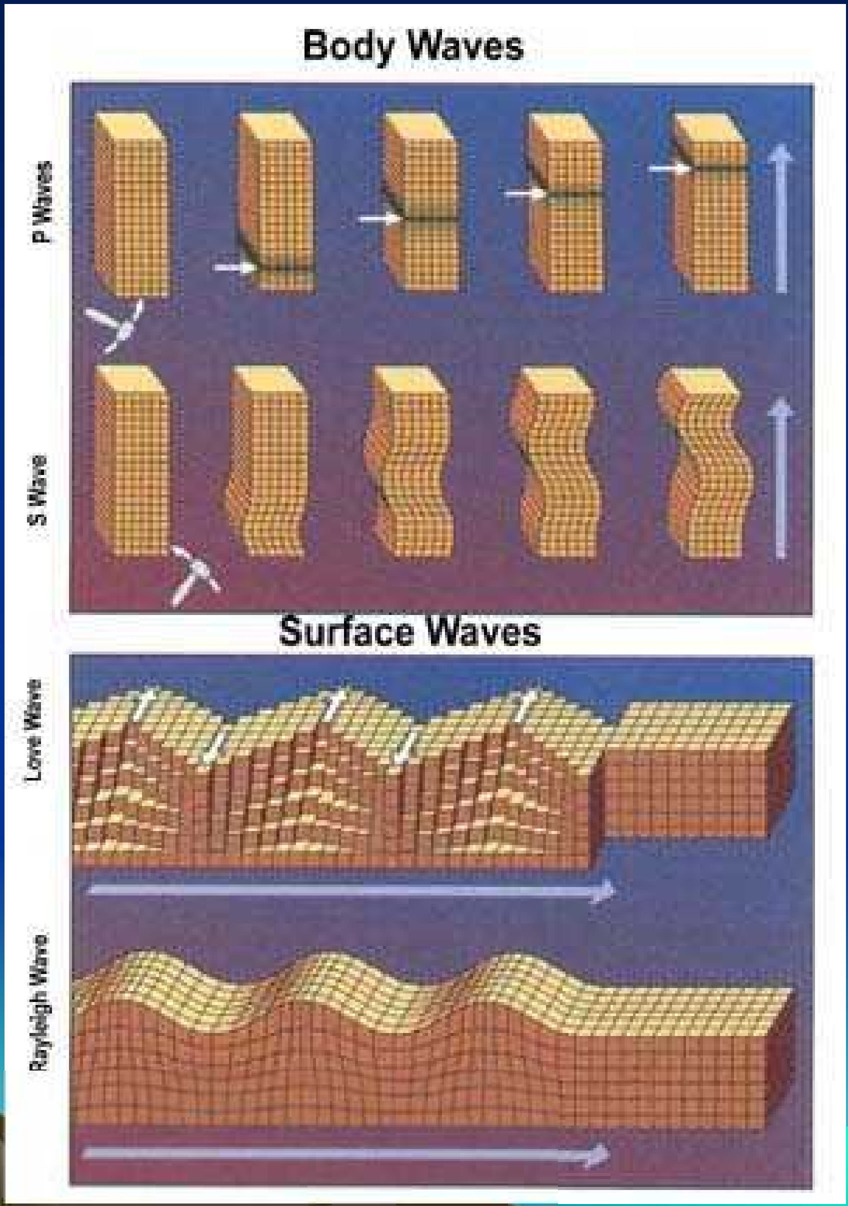
Reid's Elastic Rebound Theory



Four Stages

Types of Seismic Waves





Body Waves

1) P-waves

2) S-waves

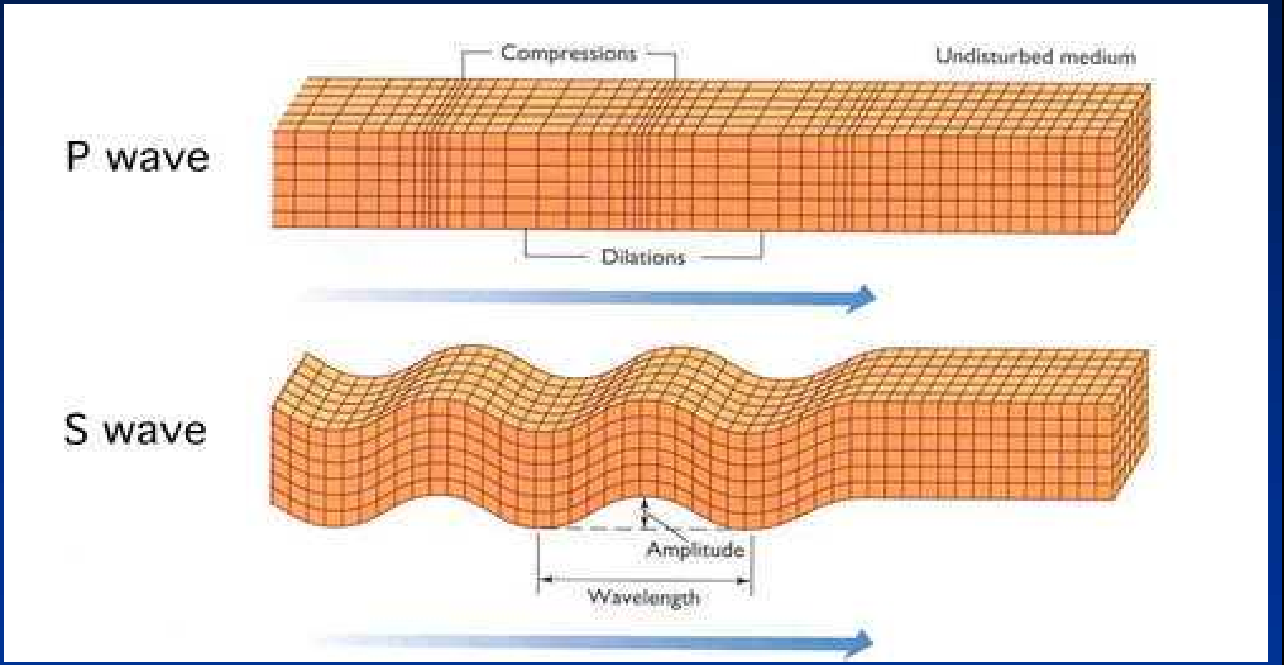
Surface Waves

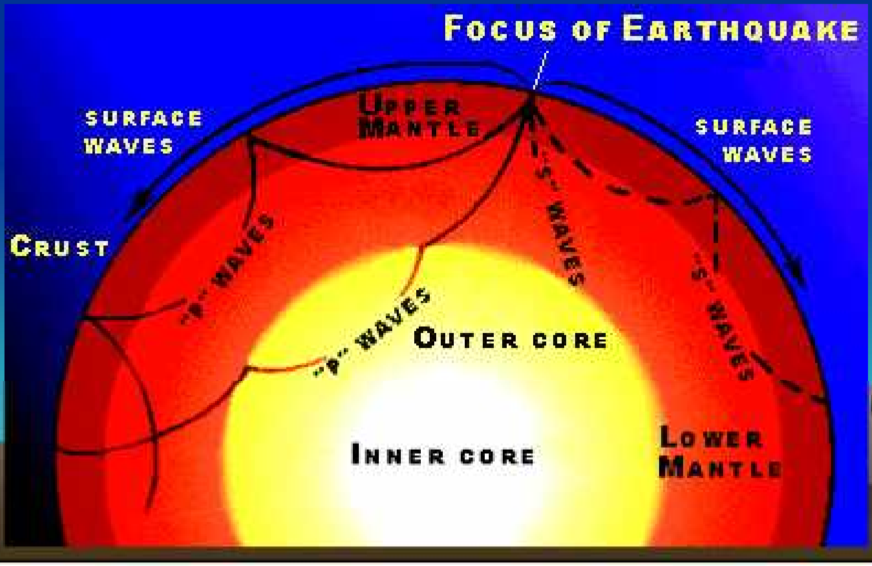
1) Love-waves

2) Raleigh-waves

Two Types of Body Waves

1) **P-waves**
   - Compressional
   - Fast
2) **S-waves**
   - Shear
   - Slow



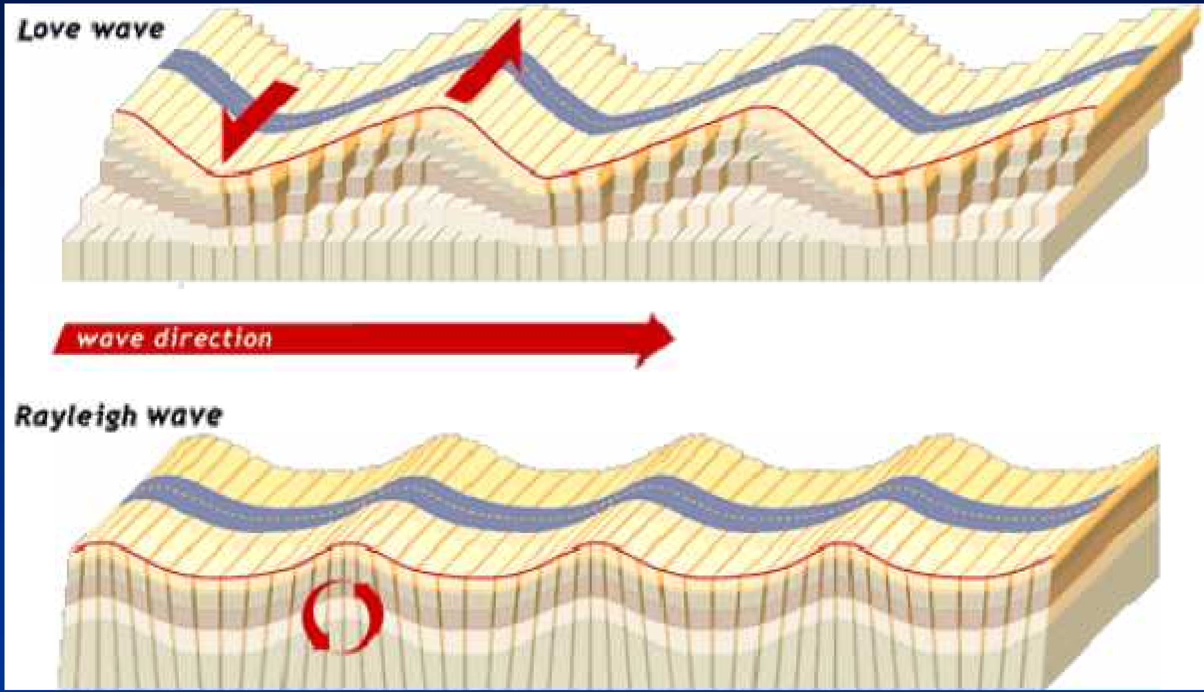


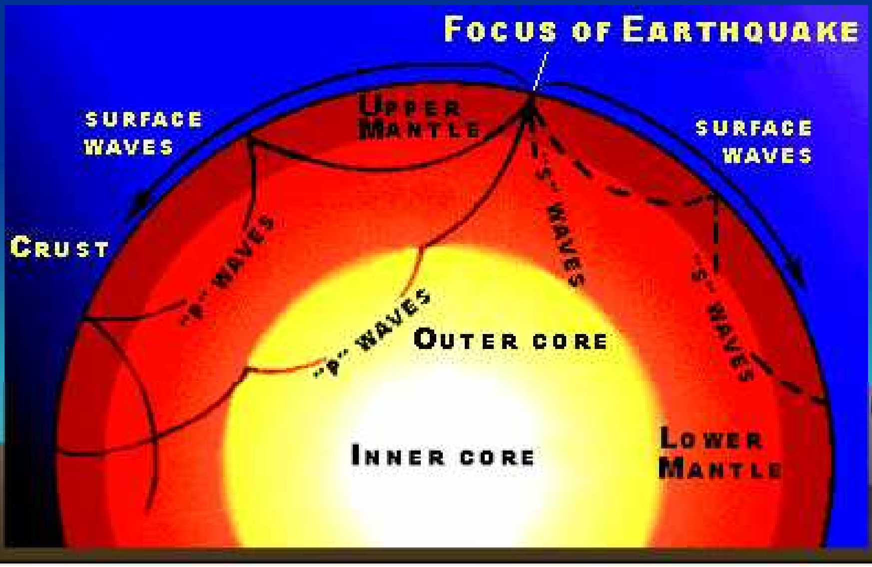
P-waves are twice as fast as S-waves

Two Types of Surface Waves

1) **Love-waves**
   - Side-to-side Shear Motion

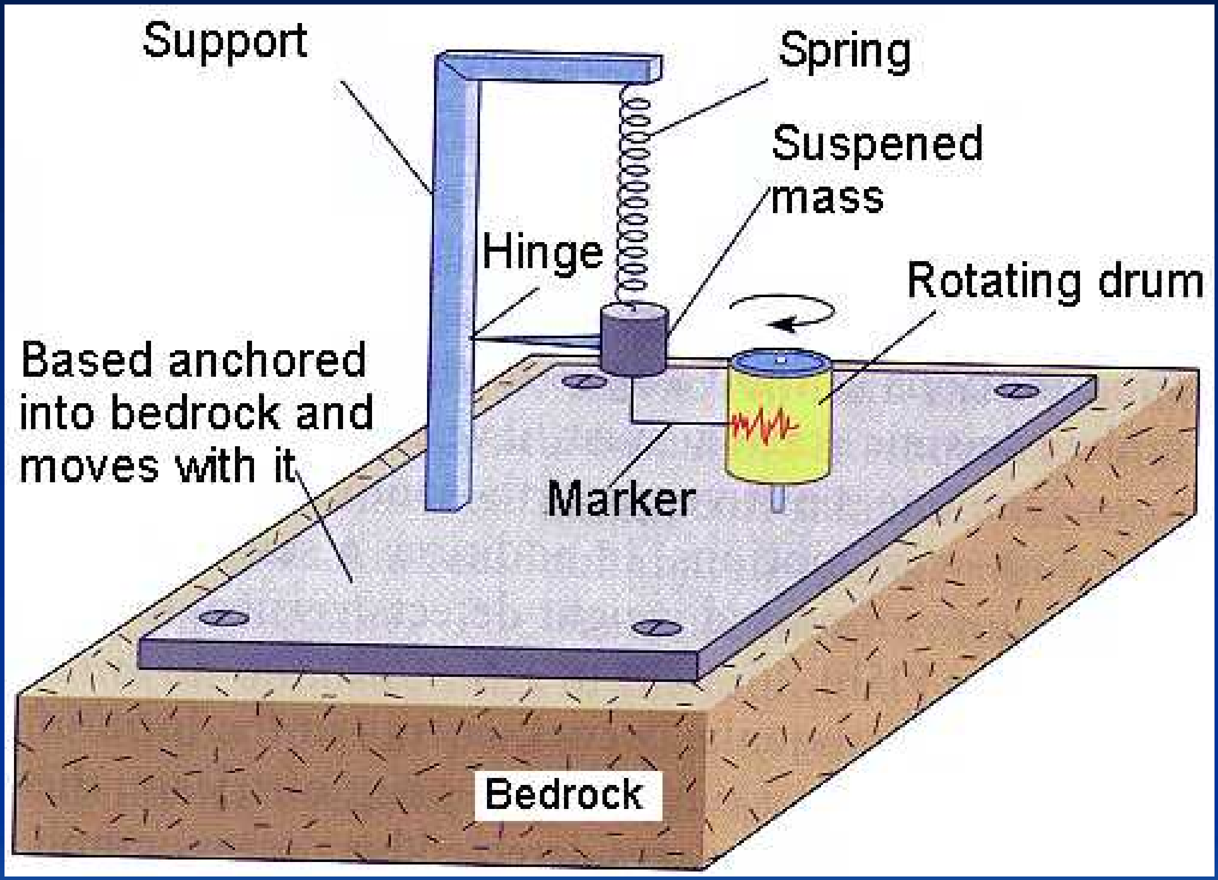
2) **Raleigh-waves**
   - Orbital Rolling Motion





Surface waves are very destructive to building, dams, and bridges

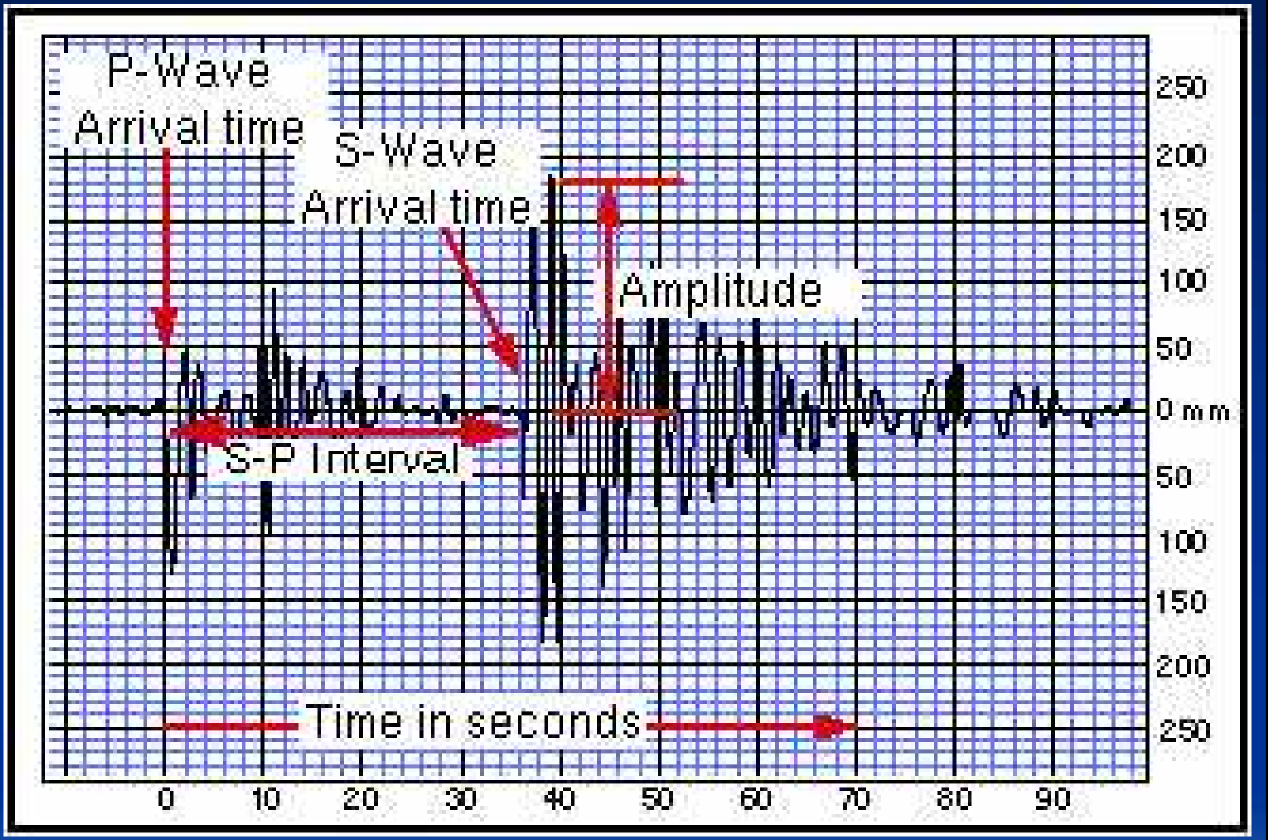
Recording Seismic Activity



A Simple Seismometer

Fundamentals of a Seismogram

1) P-wave Arrival time
2) S-wave Arrival time
3) S-P Interval
4) Amplitude



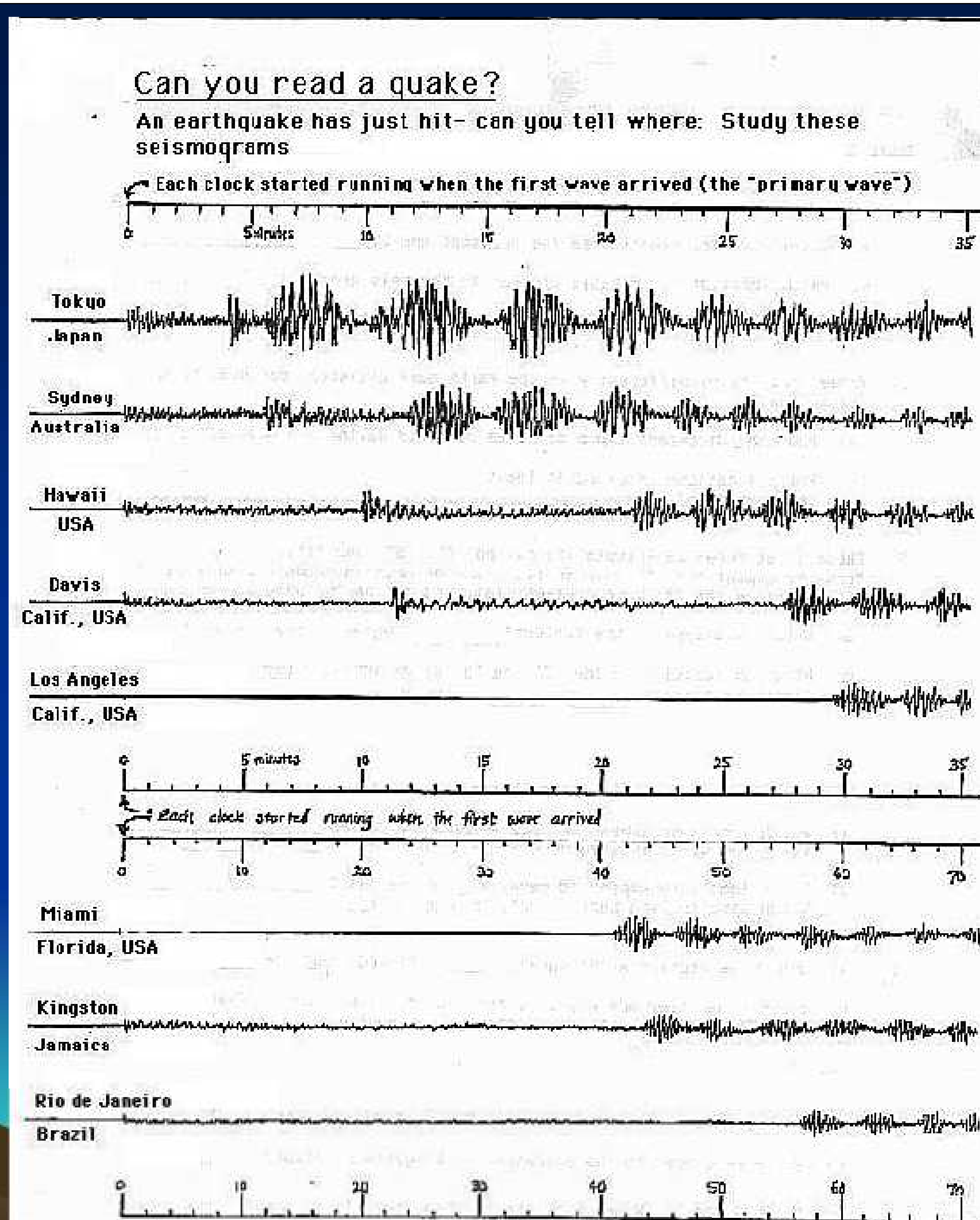
Reading a Seismogram

1) P-wave Arrival time

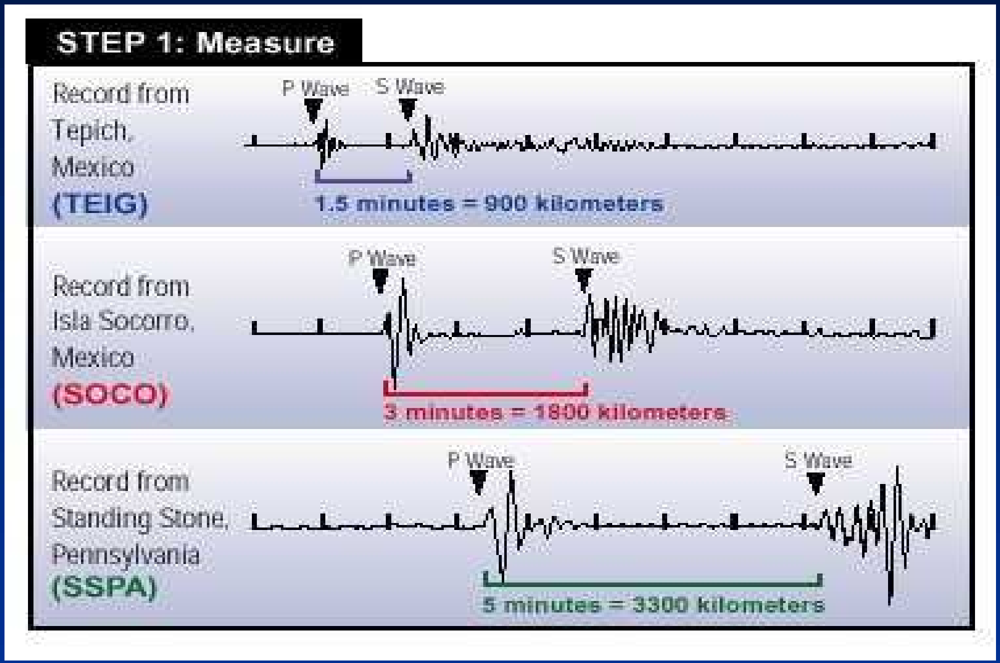
2) S-wave Arrival time

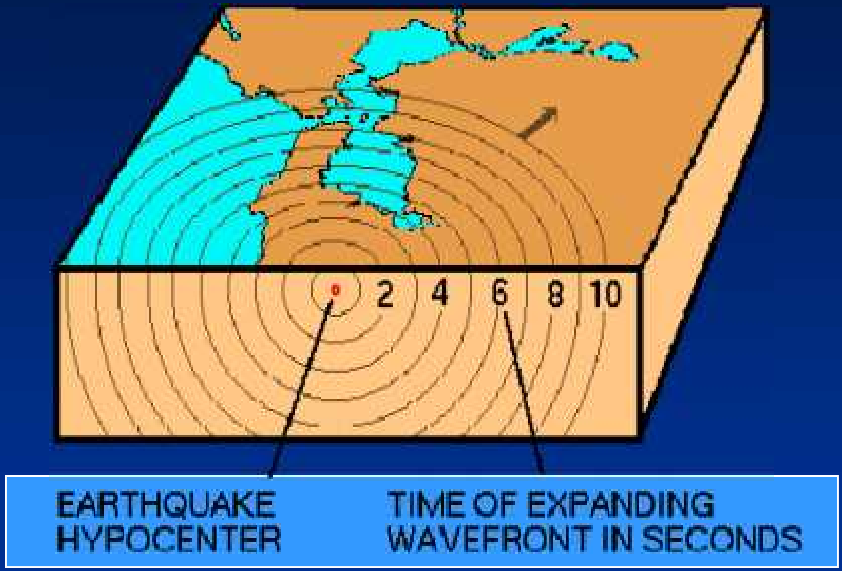
3) S-P Interval

4) Amplitude

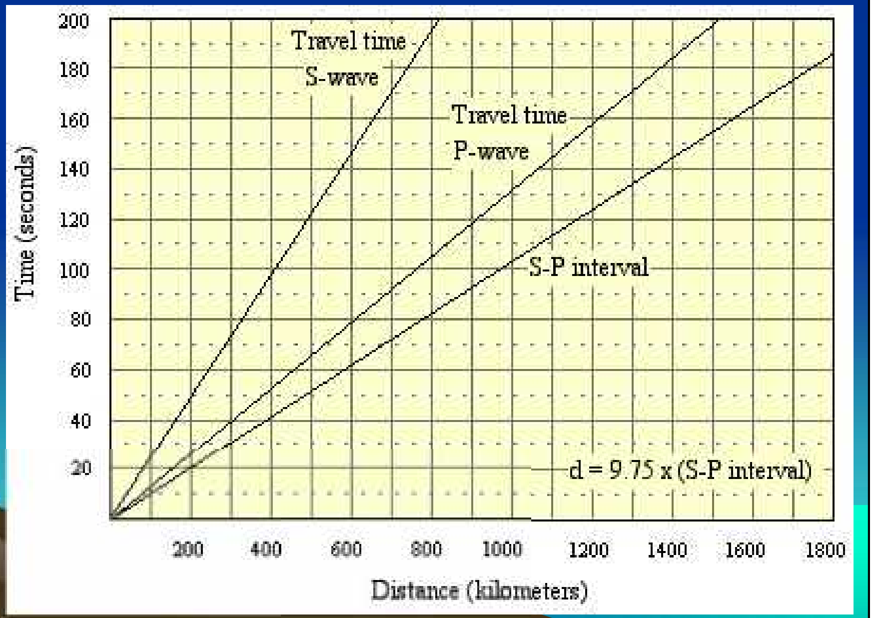


Determining Distance to Epicenter





1) Measure S-P Interval for each station



2) Convert S-P Interval time into ground distance from epicenter using conversion chart

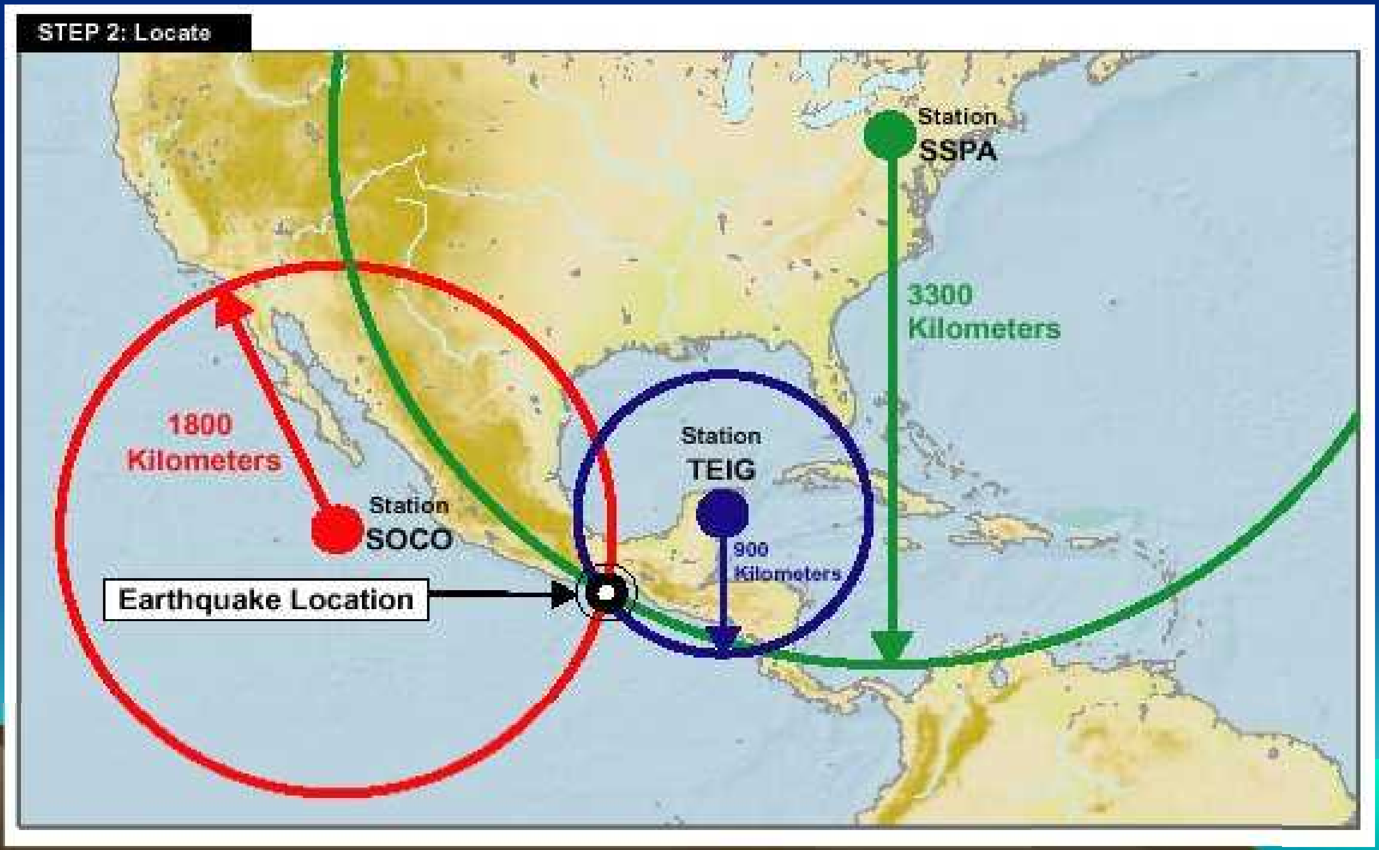
Determining Earthquake Epicenter

1) Need at least three seismograph stations

2) Find distance from station to epicenter for each station

3) Plot distance circles for each station

4) Epicenter located where all three circles intersect



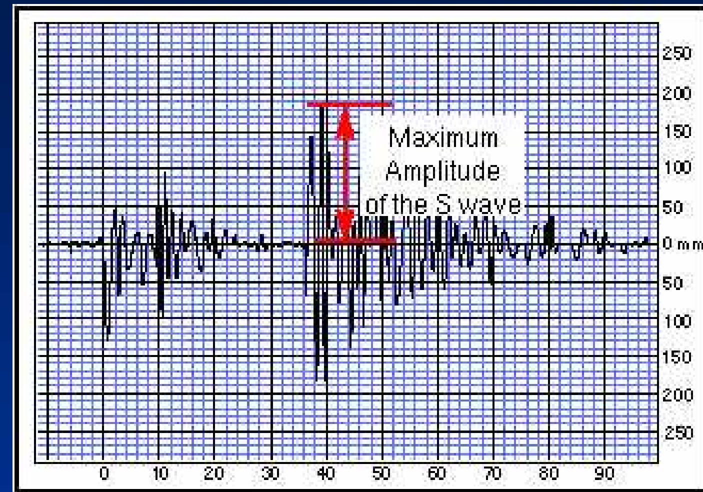
Determining Earthquake Magnitude

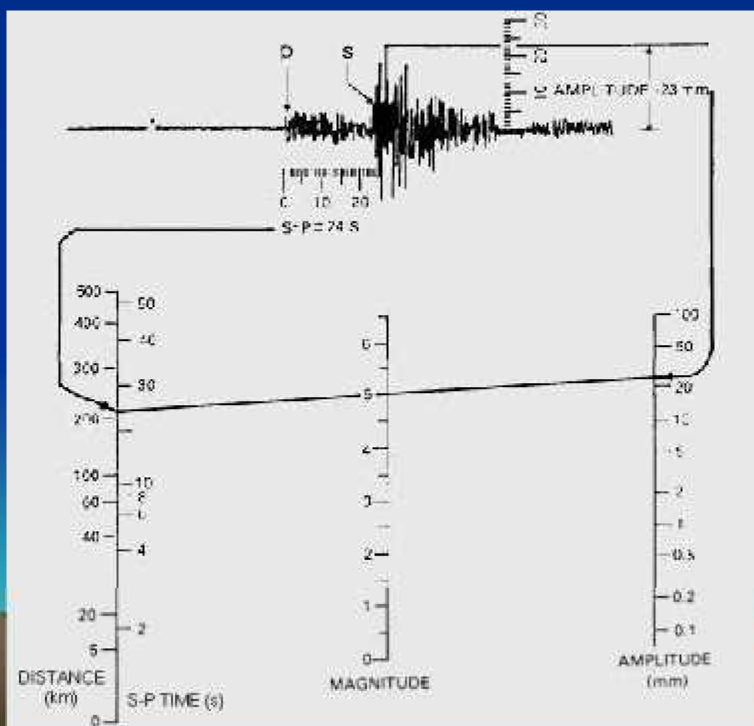
1) Measure amplitude of largest S-wave

2) Plot line from distance to amplitude

3) Magnitude is read from center scale

4) Only need 1 station for determination





Earthquake Epicenter and Magnitude Internet Exercise

Virtual Earthquake Internet Exercises

Virtual EQ Certificate

Measuring Ground Shaking

Modified Mercalli Intensity Scale

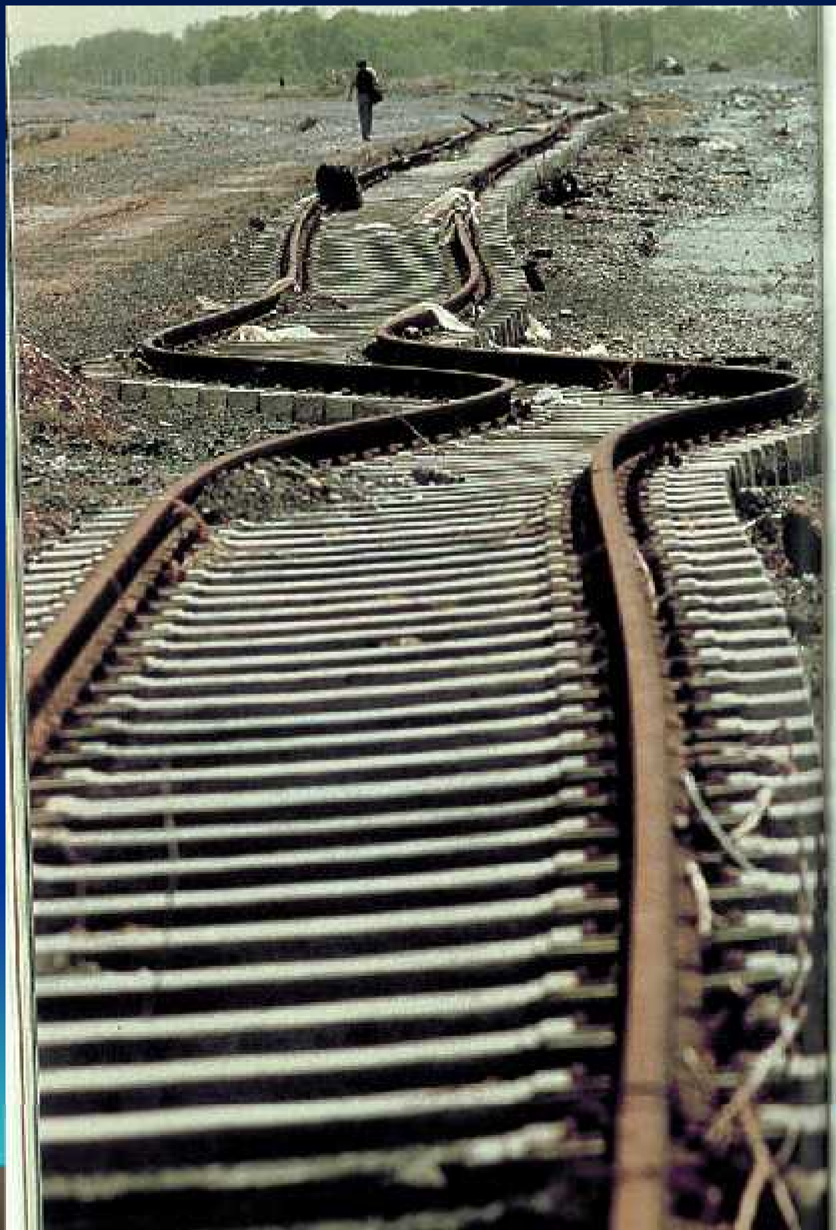
I	Not felt
II	Felt only by persons at rest
III–IV	Felt by persons indoors only
V–VI	Felt by all; some damage to plaster, chimneys
VII	People run outdoors, damage to poorly built structures
VIII	Well-built structures slightly damaged; poorly built structures suffer major damage
IX	Buildings shifted off foundations
X	Some well-built structures destroyed
XI	Few masonry structures remain standing; bridges destroyed
XII	Damage total; waves seen on ground; objects thrown into air

Ground Shaking and Building Motion

Japan Earthquake - Building Shaking

Alaska Earhquake - Modeled Building Motion

Surface Displacement Along Active Faults



Earthquake Ground Shaking:

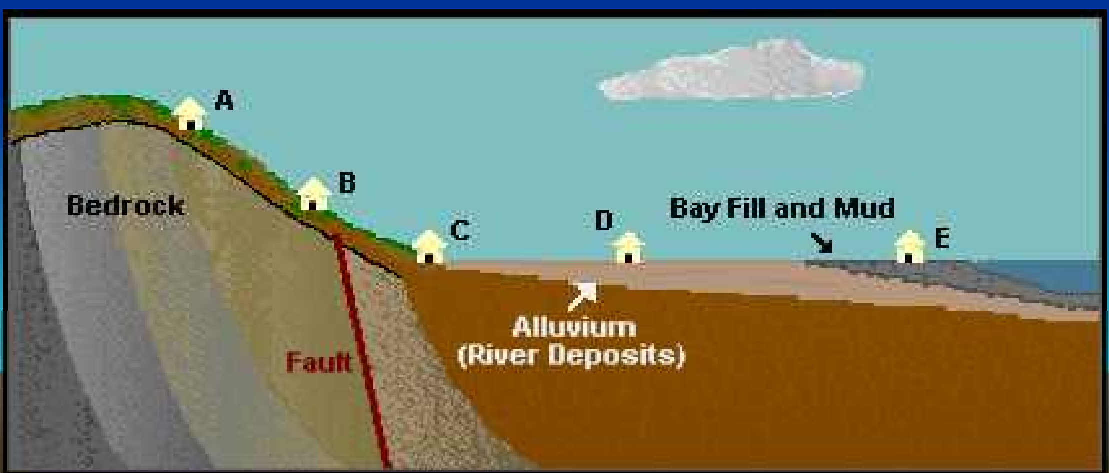
Variations in Substrate

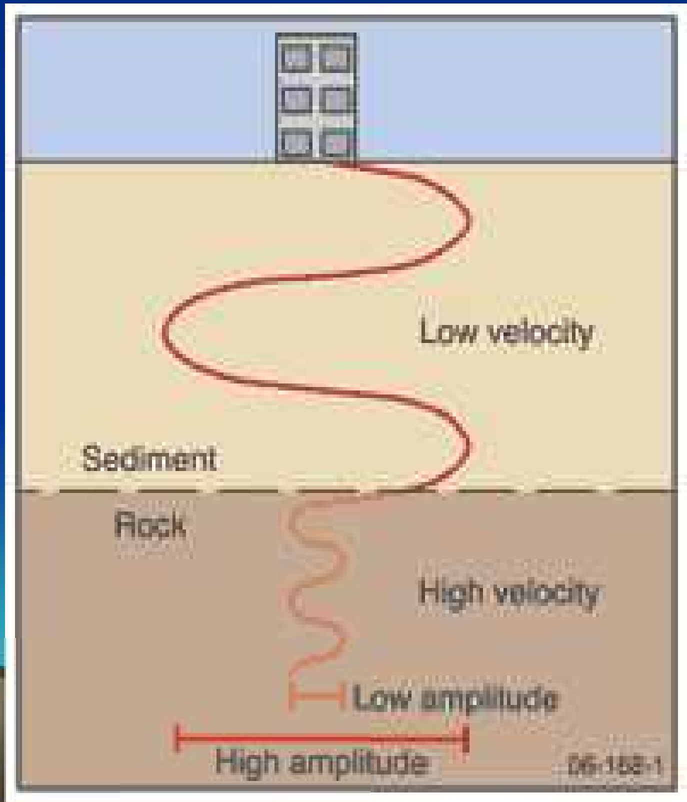
1) Different types of ground materials behave differently to seismic waves

2) The softer the material, the greater the shaking

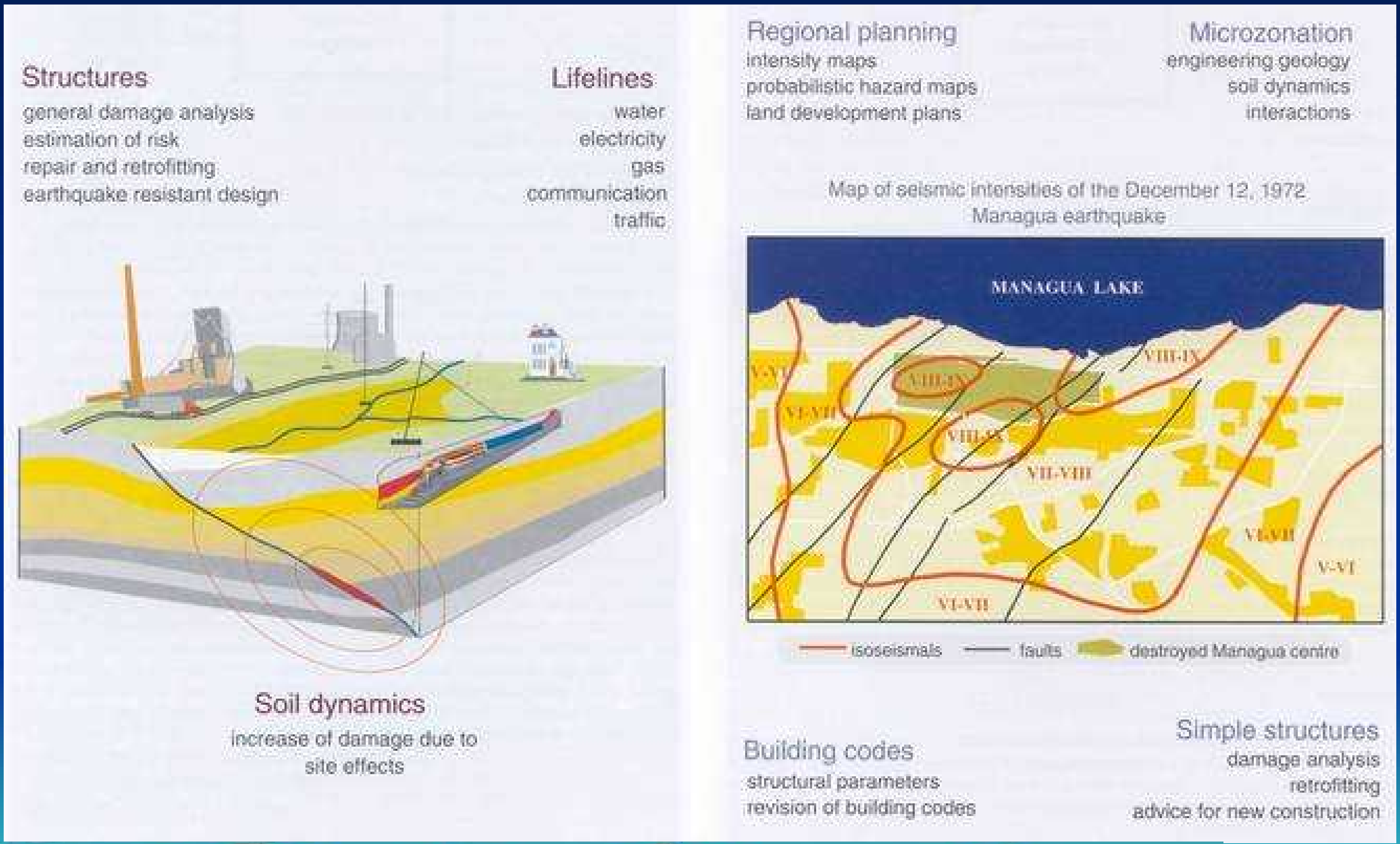
3) Solid rock is favorable over sediment

4) Dry sediment favorable over saturated



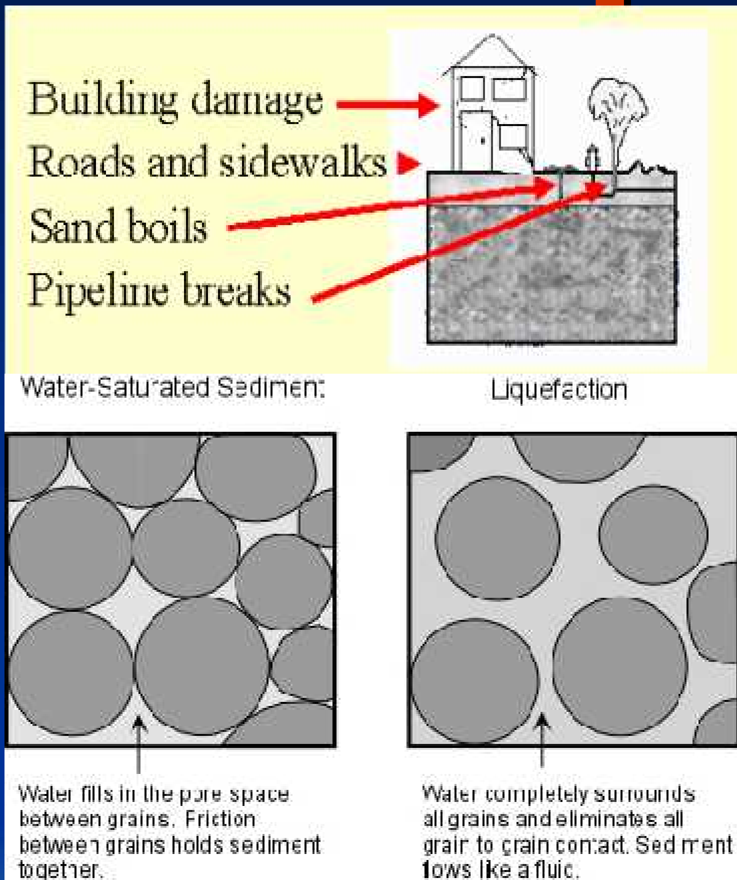


Substrate Type Versus Ground Shaking



Liquifaction!

Liquifaction!



Video 1

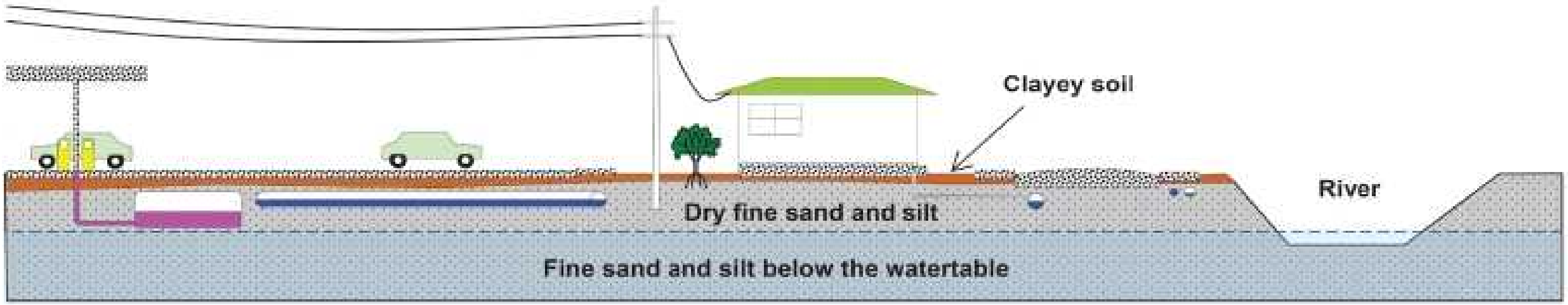
Video 2

Liquifaction

Liquefaction and its Effects

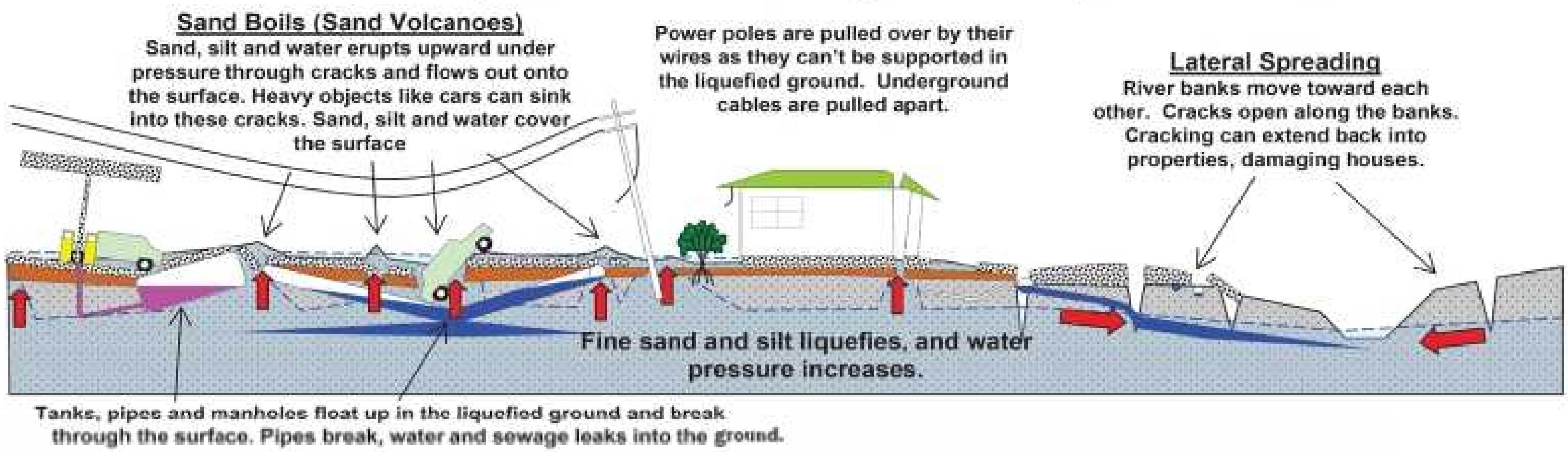
Before the Earthquake

Areas of flat, low lying land with groundwater only a few metres below the surface, can support buildings and roads, buried pipes, cables and tanks under normal conditions.



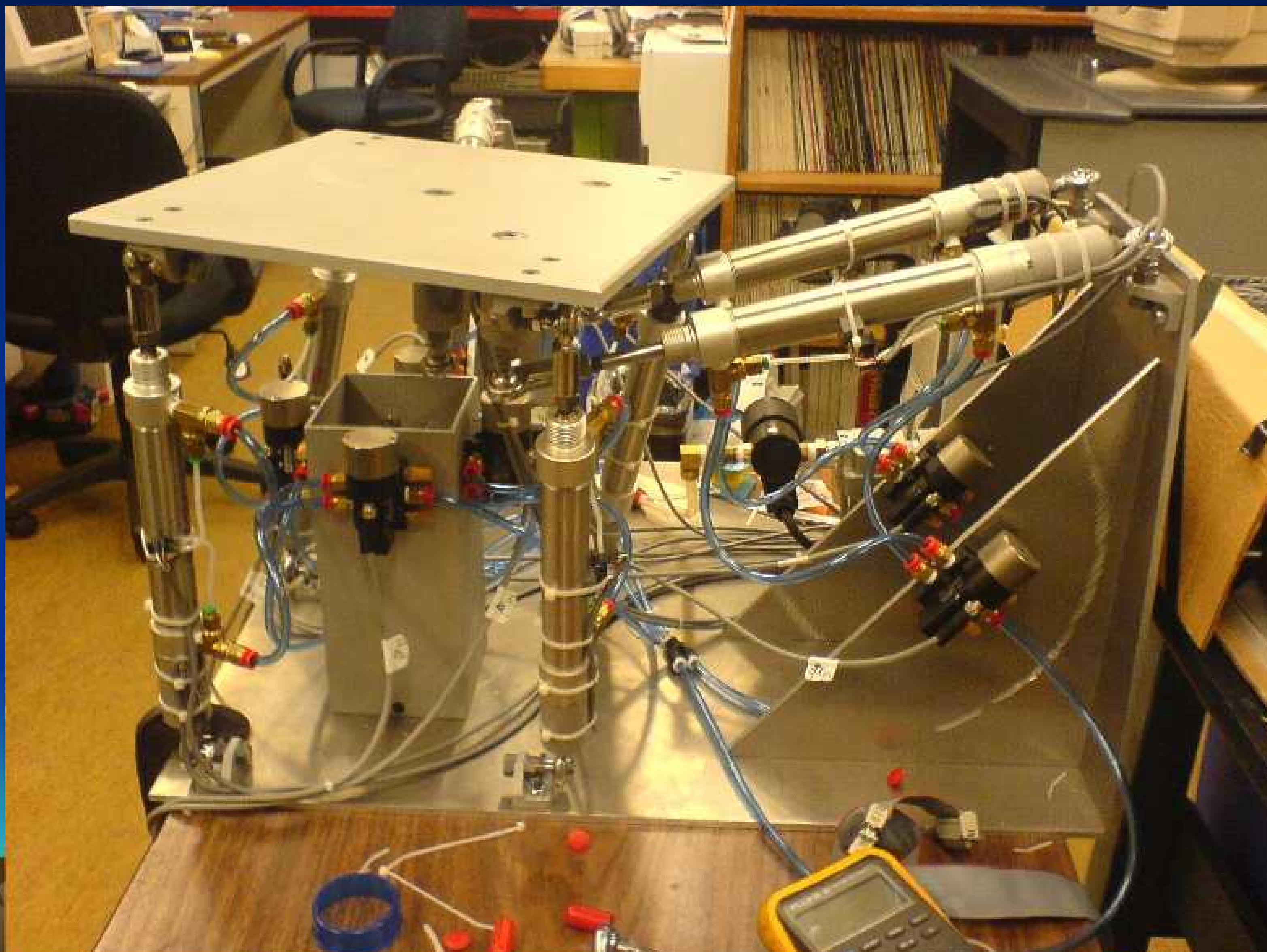
During and after the Earthquake

During the earthquake fine sand, silt and water moves up under pressure through cracks and other weak areas to erupt onto the ground surface. Near rivers the pressure is relieved to the side as the ground moves sideways into the river channels.



Simple Earthquake Modeling

Advanced Earthquake Modeling



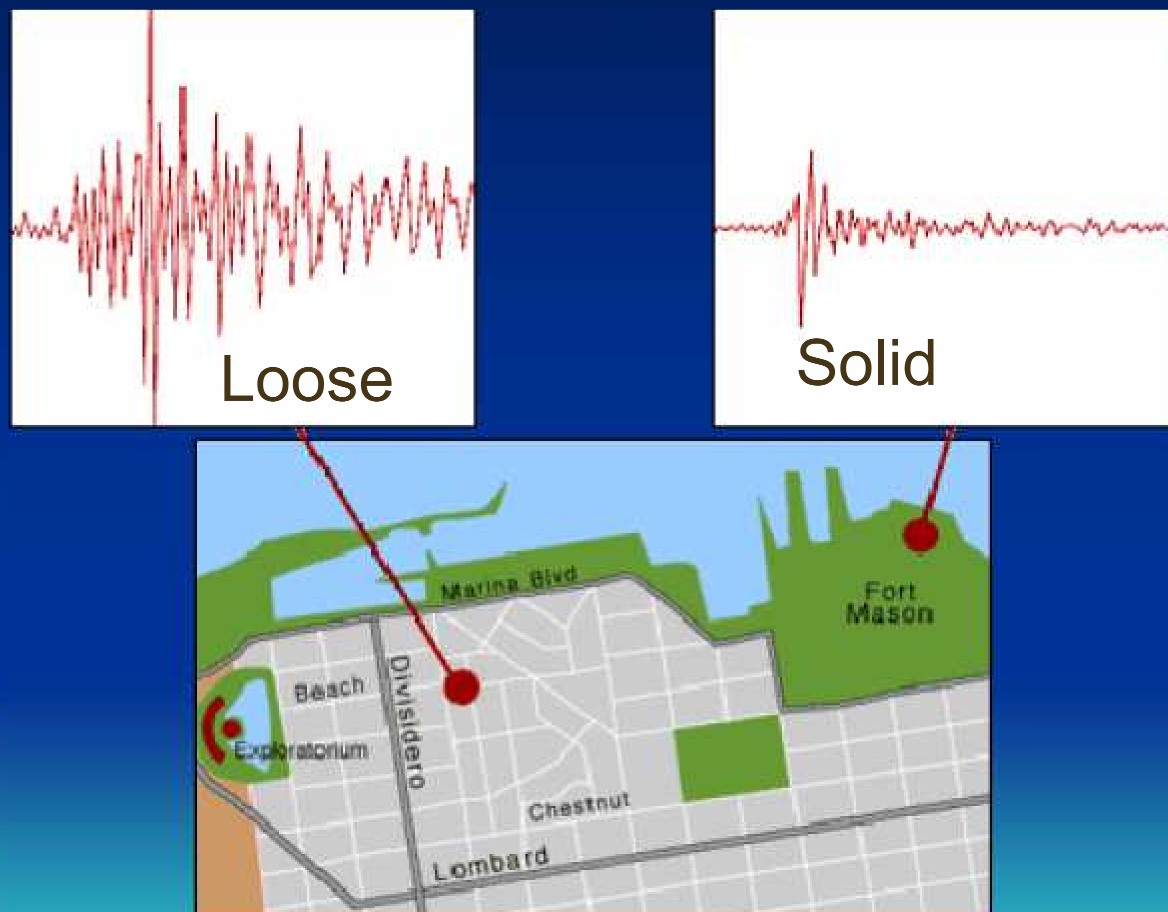
Bay Area Earthquake Analysis

Comparing Substrate Type with Observed Ground Motion

1) Solid Rock

2) Dry Loose Sediment

3) Water-saturated Loose Sediment



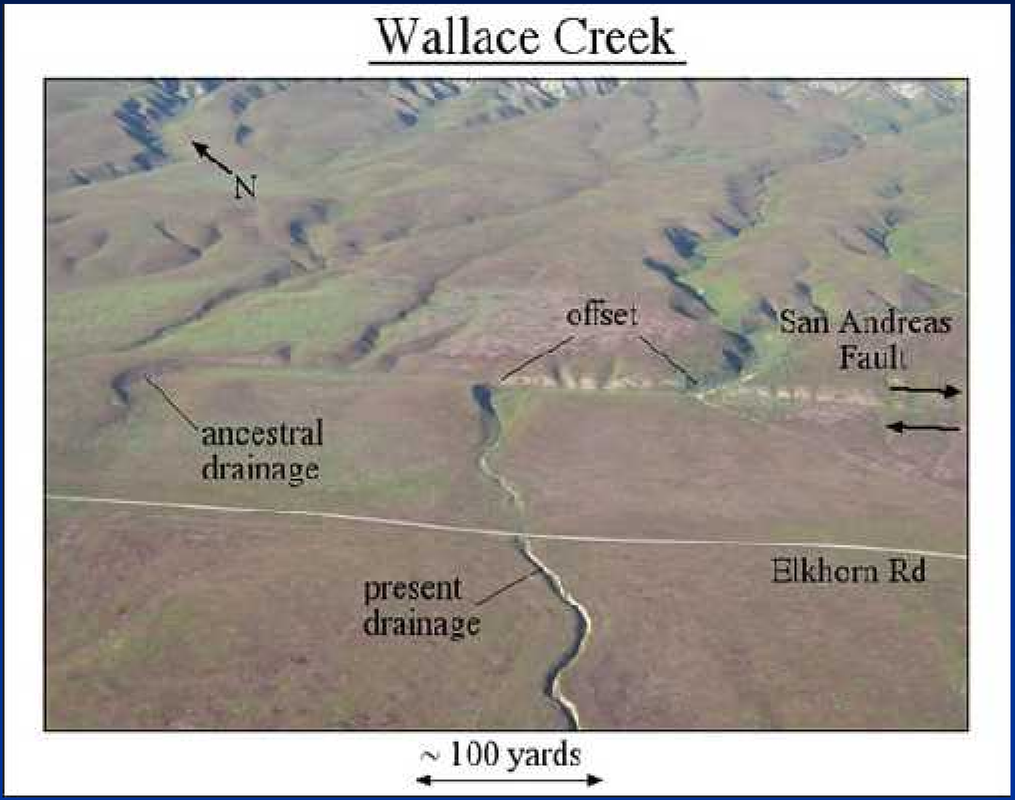
Using Aerial Photos to Interpret Fault Movement

1) Recognizing the offset of linear surface features

- ✓ Drainage channels
- ✓ Ridgelines
- ✓ Geologic formations

2) Relative direction of offset feature shows the relative movement direction

3) Amount of offset along disturbed feature shows the amount of fault movement



Surface Displacement Along San Andreas Fault

4) Age of offset feature gives averaged rate of displacement

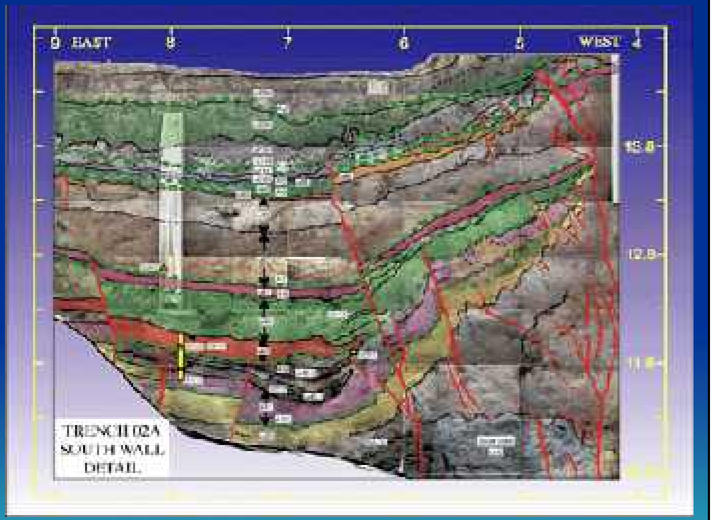
Using Trenching to Interpret Faulting History

1) Trench perpendicular to active fault zone along a stream channel

2) Trace and record all rupture surfaces and offset bedding and rock units

3) Date ruptured stream deposits using carbon 14 method on charcoal grains

4) Correlate offset events to ruptured layers using cross-cutting principle and C-14 dates.



Fault Trenching Studies

Head's-Up for Next Week's Lab

Structural Geology and Geologic Maps

Next Week's Lab Activities

1) Analyze structural block diagrams
2) Construct structural diagrams
3) Take compass bearing

Preparation

Recommended Pre-Lab Web Activities (Click on Link)

1) Construction of topographic and bathymetric profiles
2) Plotting map locations and taking bearings
3) World ocean bottom features and Tectonic plate boundaries