Faults and Earthquakes

Dr.A.BALUKKARASU

Take-Away Points

1. Earthquakes generate waves that travel through the earth
2. Earthquakes occur when rocks slip along faults
3. Faults are classified by the kinds of movement that occur along them
4. Earthquakes don't kill people, buildings kill people
5. Magnitude and Intensity
6. Seismic waves are used to map the earth's interior
7. Predicting earthquakes is not yet possible

Some Important Earthquakes

1755 - Lisbon, Portugal

- Killed 70,000, Raised Waves in Lakes all over Europe
- First Scientifically Studied Earthquake

1811-1812 - New Madrid, Missouri

- Felt over 2/3 of the U.S.
- Few Casualties

1886 - Charleston, South Carolina

- Felt All over East Coast, Killed Several Hundred.
- First Widely-known U.S. Earthquake

Some Important Earthquakes

1906 - San Francisco

- Killed 500 (later studies, possibly 2,500)
- First Revealed Importance of Faults

1923 – Tokyo - Killed 140,000 in firestorm

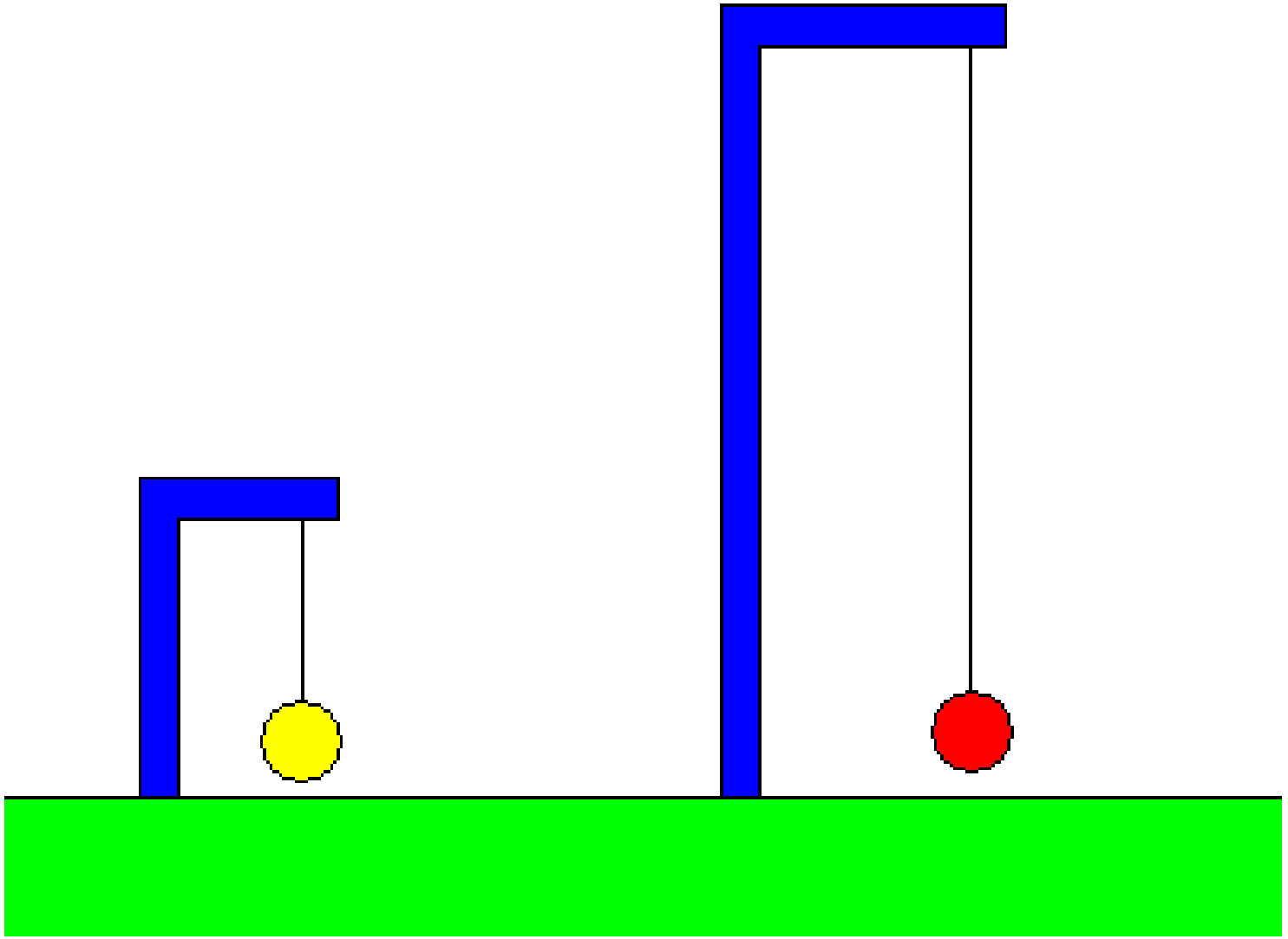
1964 - Alaska

- Killed about 200
- Wrecked Anchorage.
- Tsunamis on West Coast.

1976 - Tangshan, China

- Hit an Urban Area of Ten Million People
- Killed 650,000

How Seismographs Work



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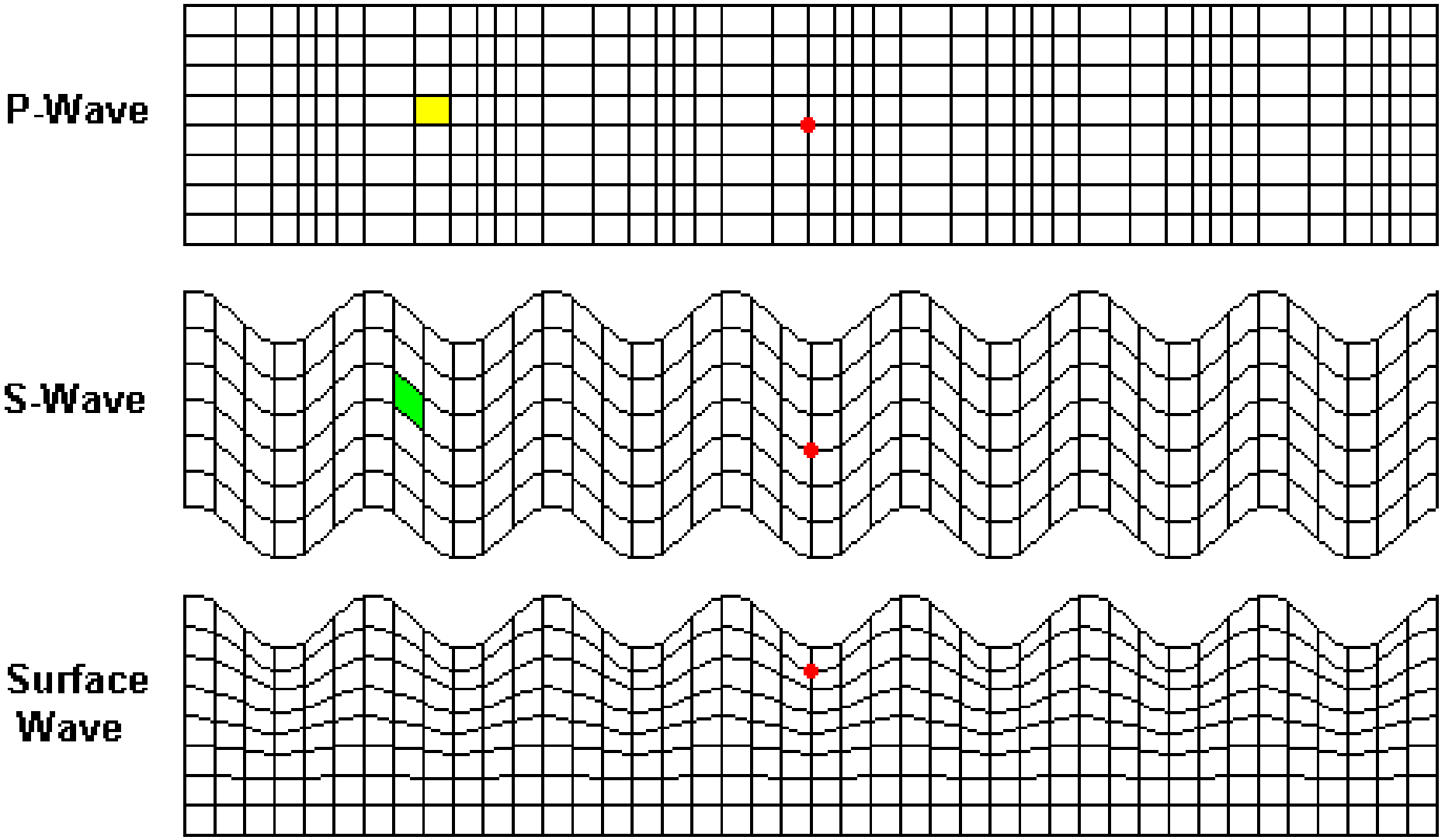
Seismic Waves



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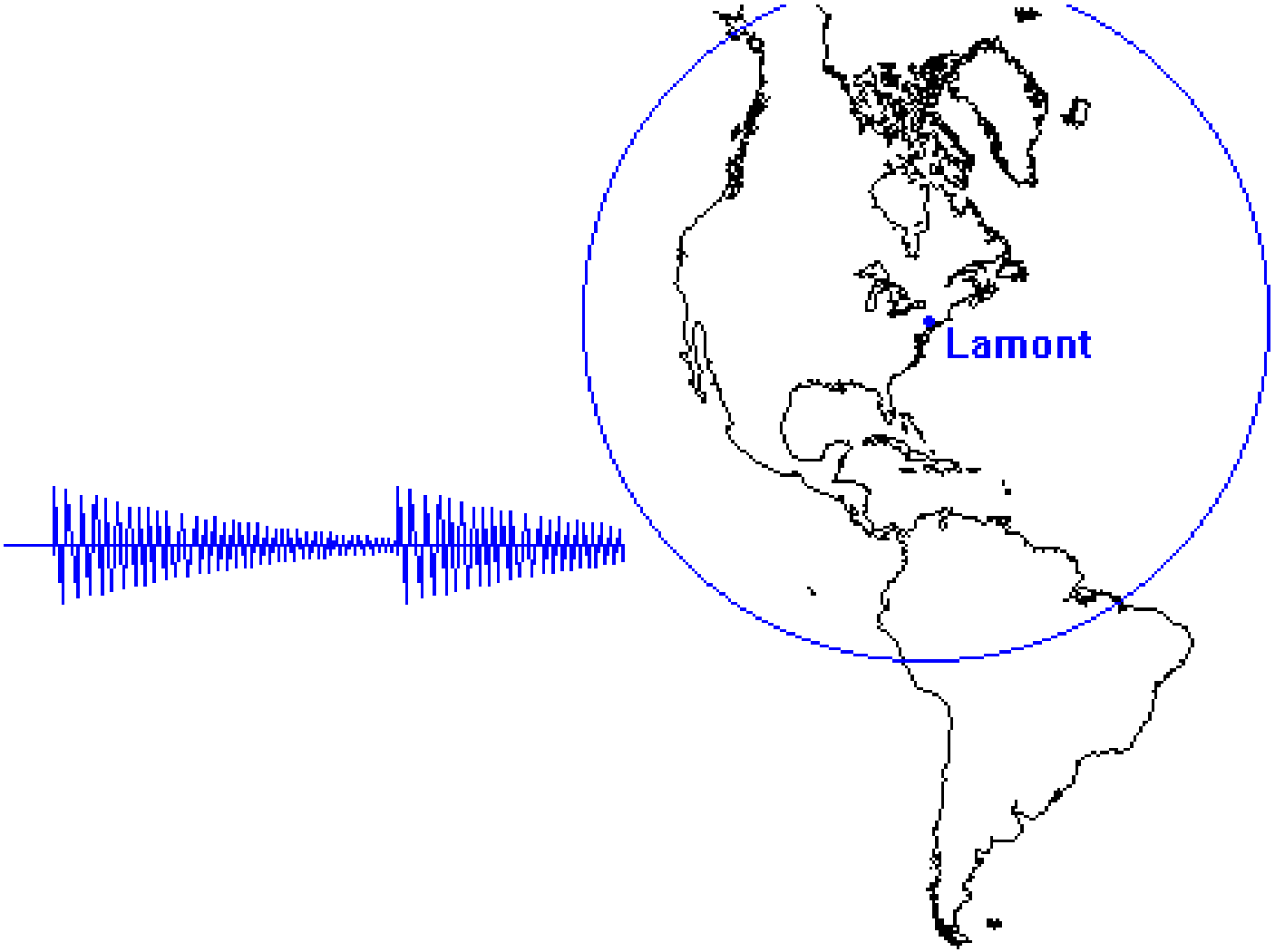
Locating Earthquakes



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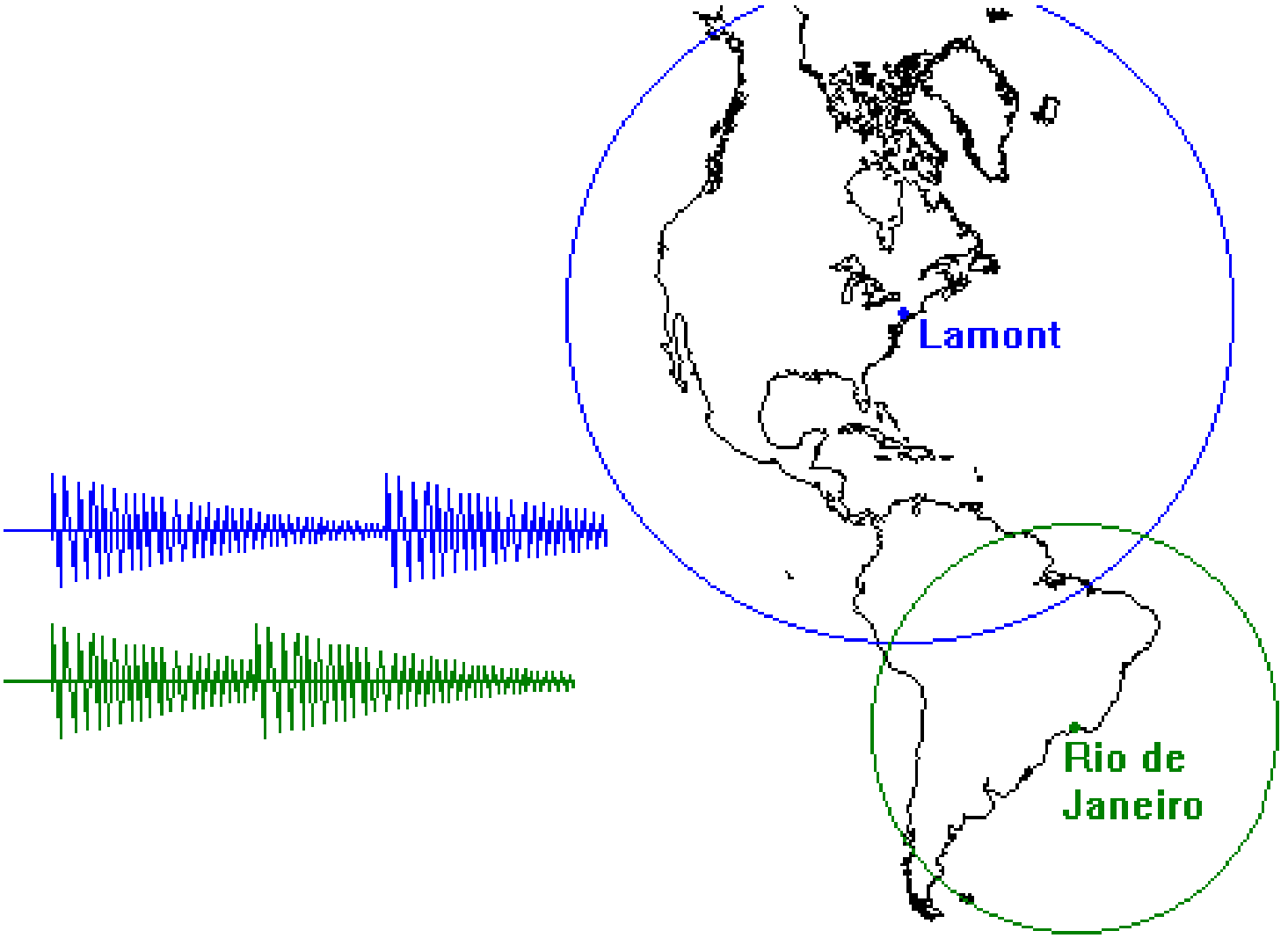

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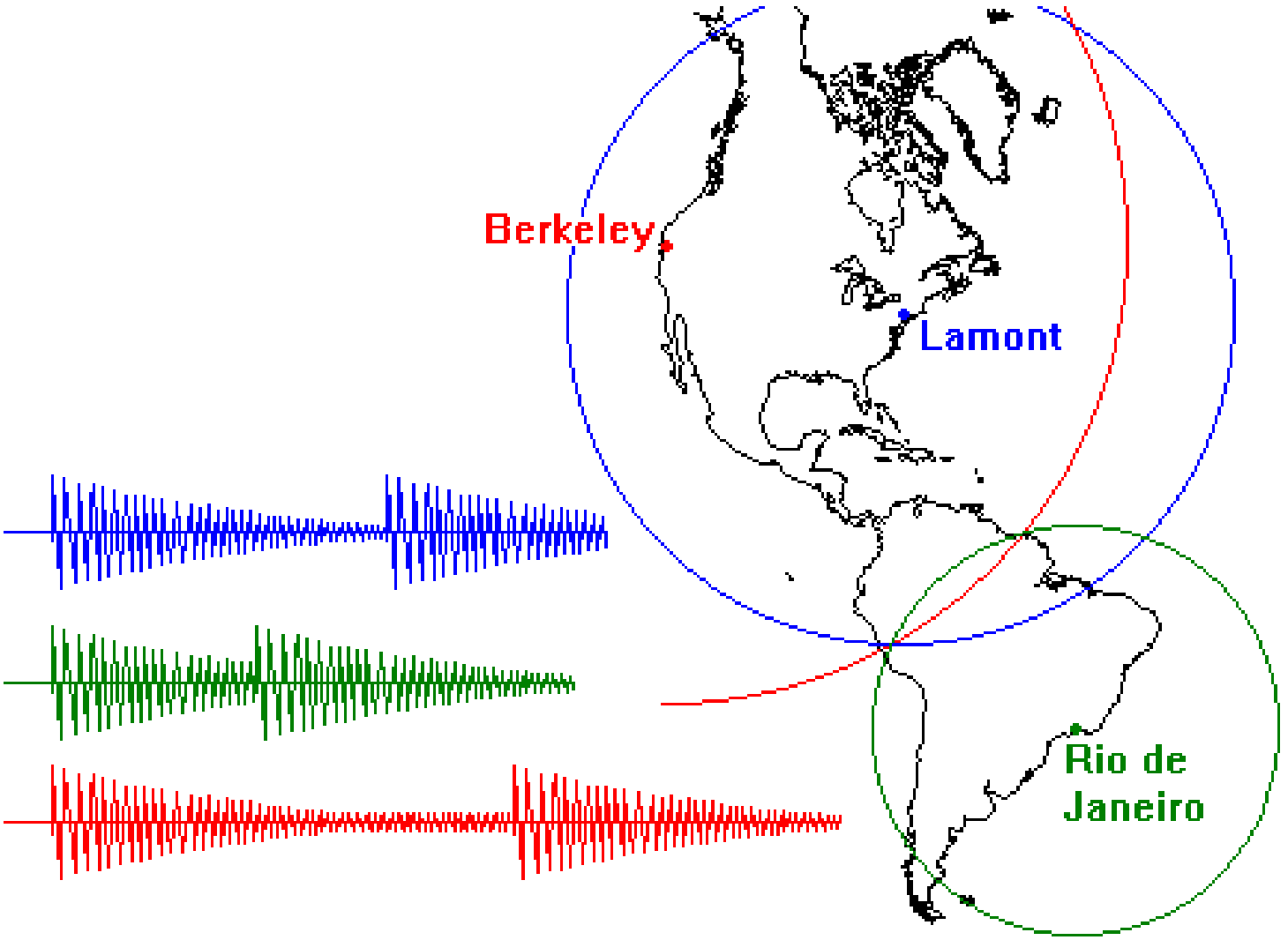
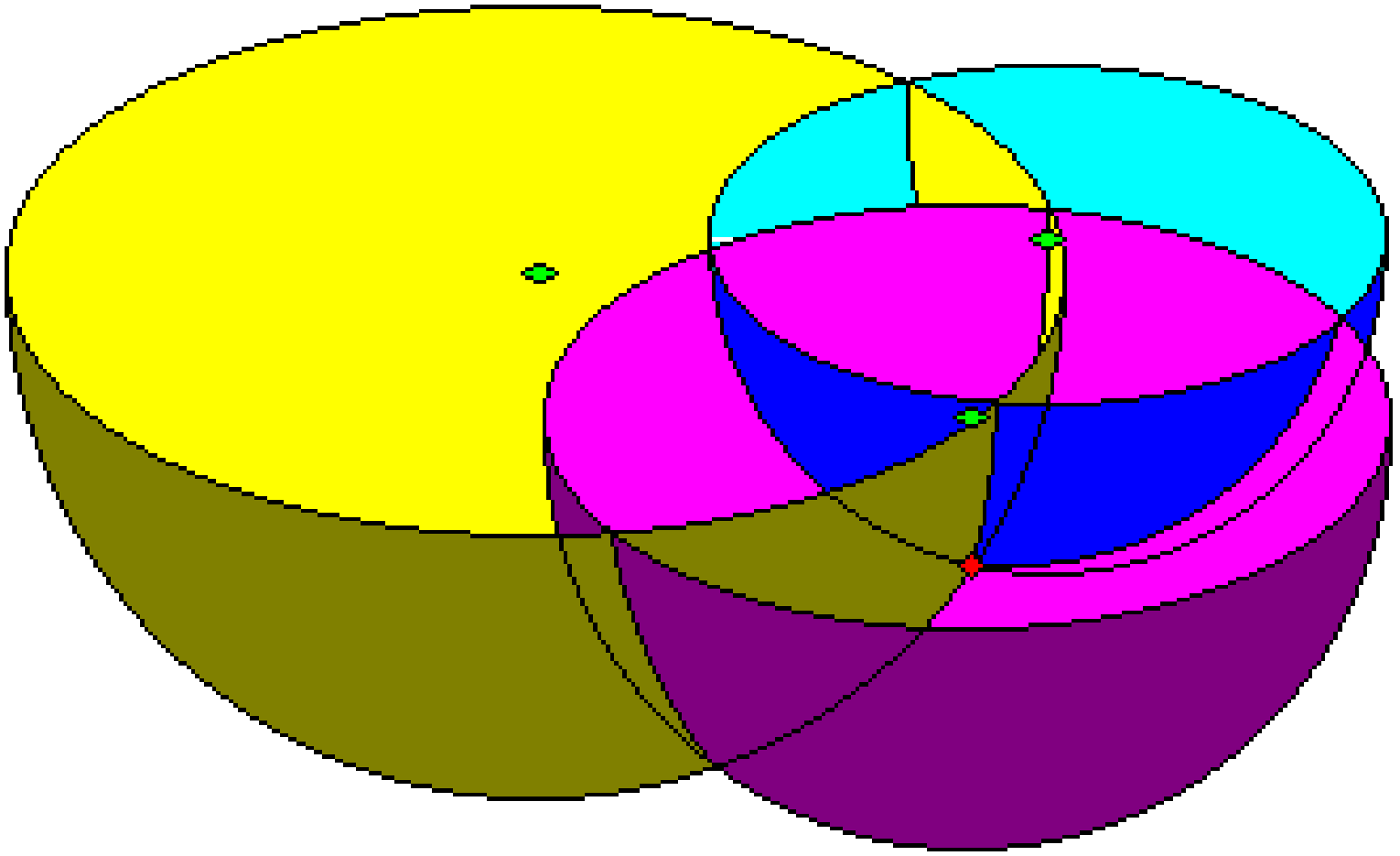
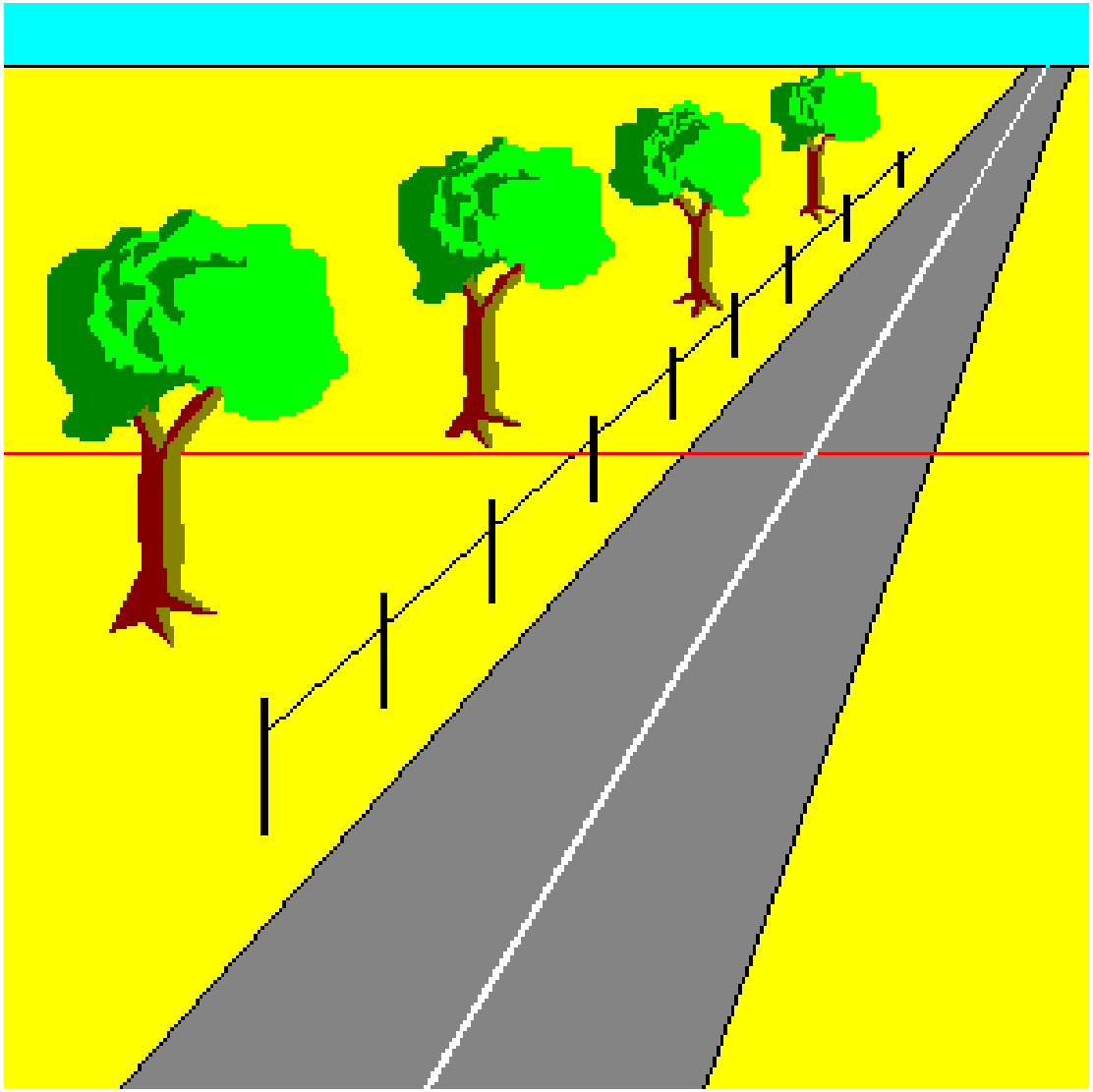


Locating Earthquakes - Depth



Elastic Rebound



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Epicenter and Focus

Focus

- Location within the earth where fault rupture actually occurs

Epicenter

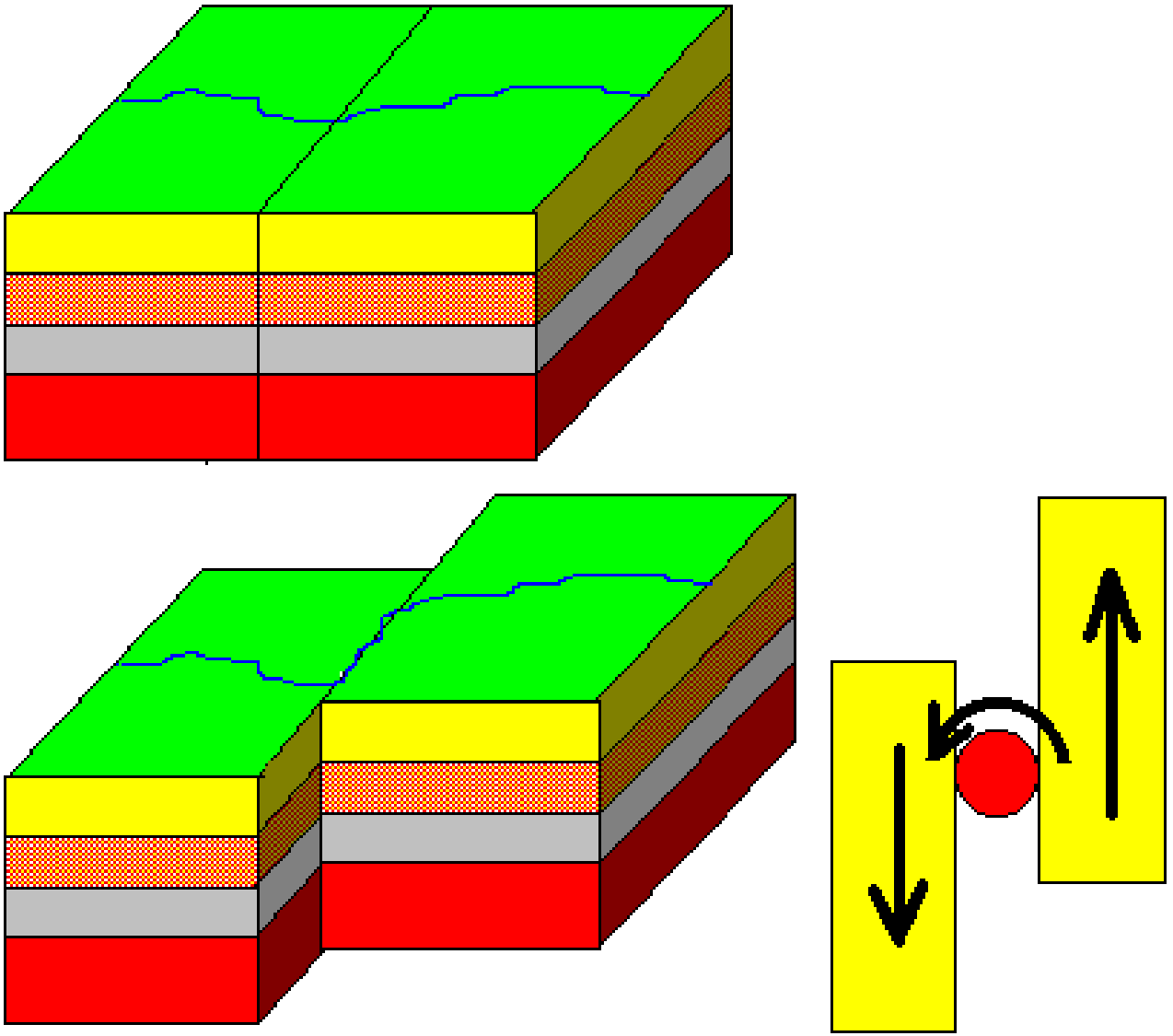
- Location on the surface above the focus

Types of Faults

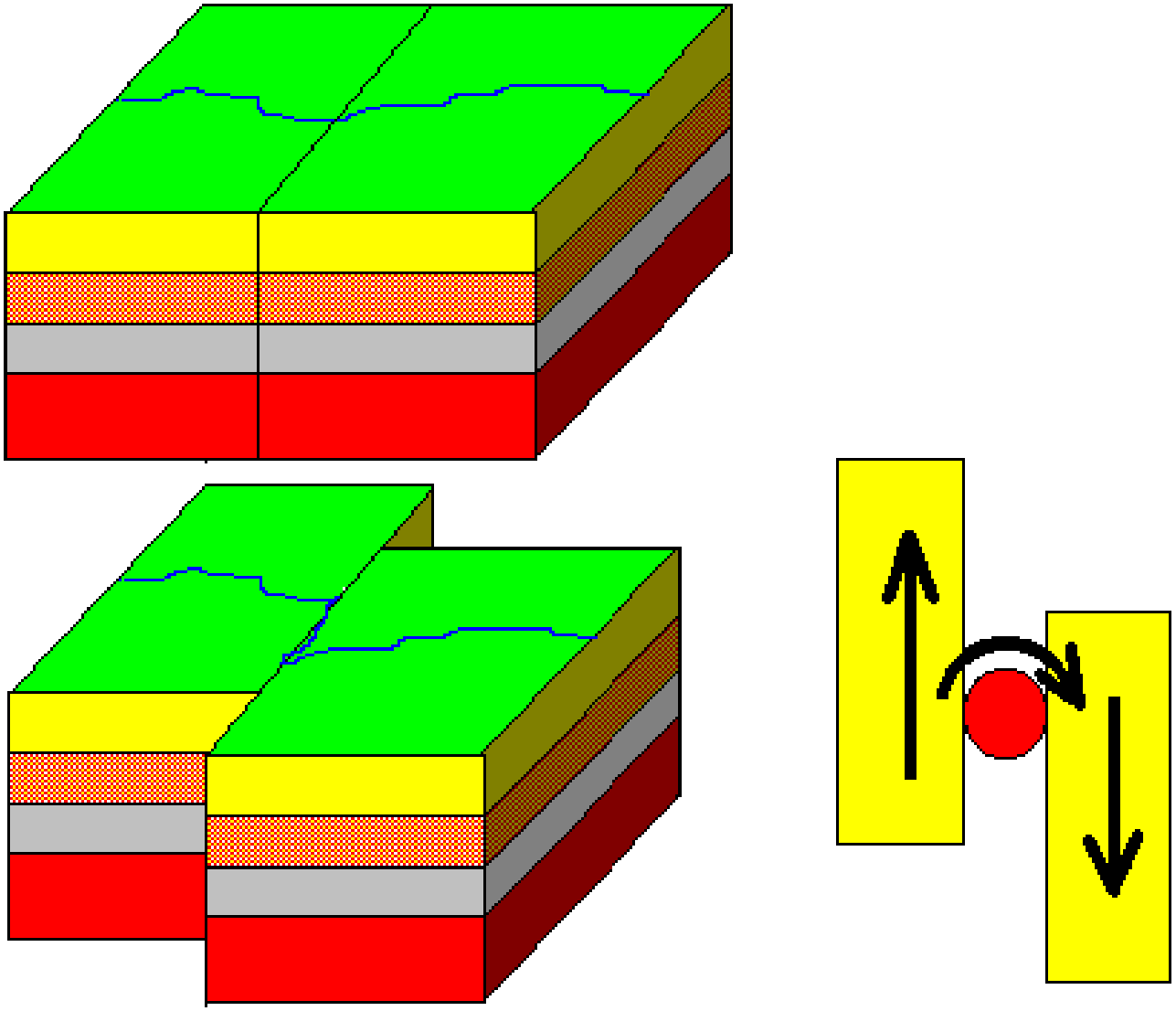
Faults Are Classified According to the Kind of Motion That Occurs on Them

- Joints - No Movement
- Strike-Slip - Horizontal Motion
- Dip-Slip - Vertical Motion

Strike-Slip Fault – Left Lateral



Strike-Slip Fault – Right Lateral



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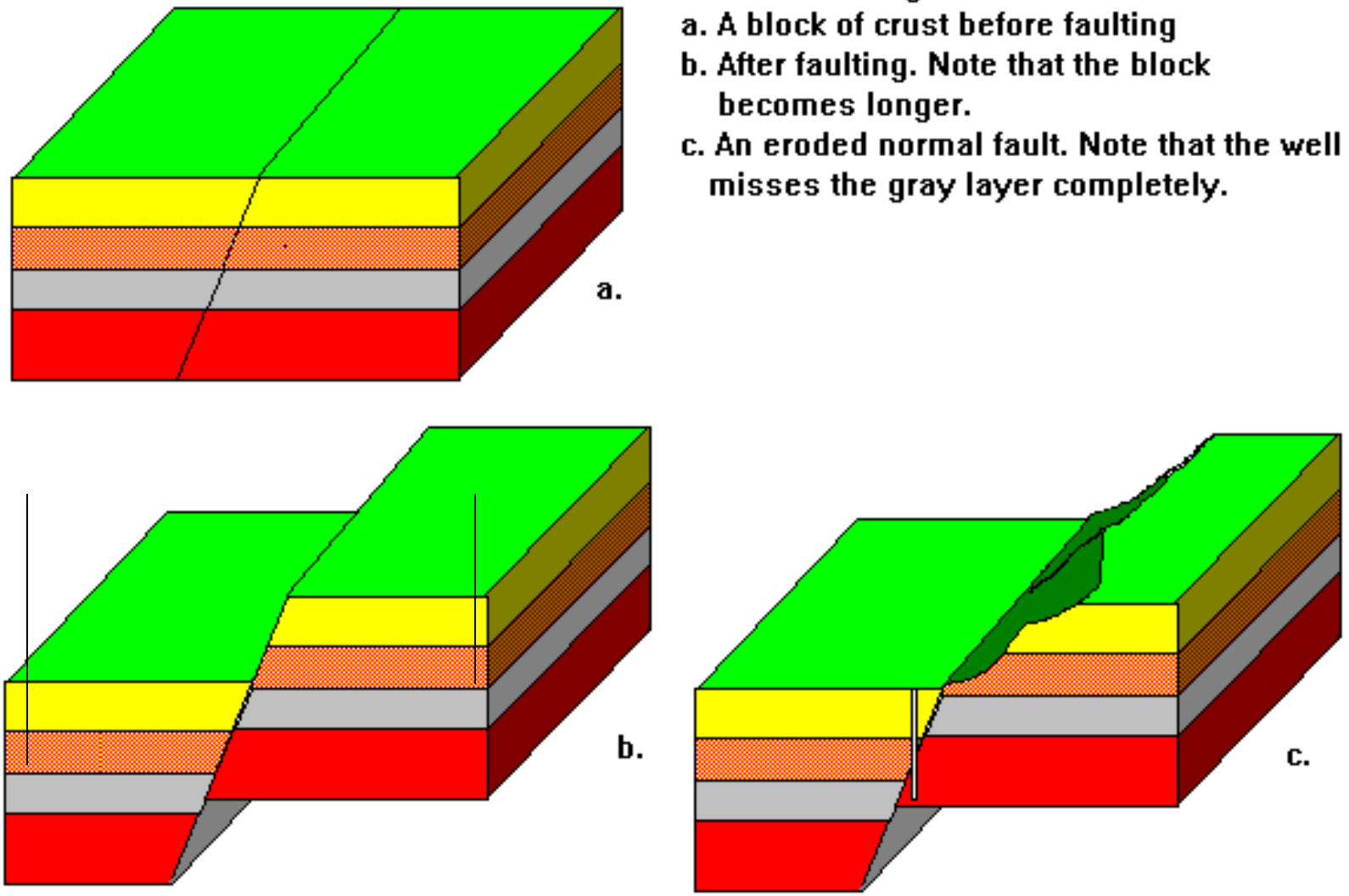
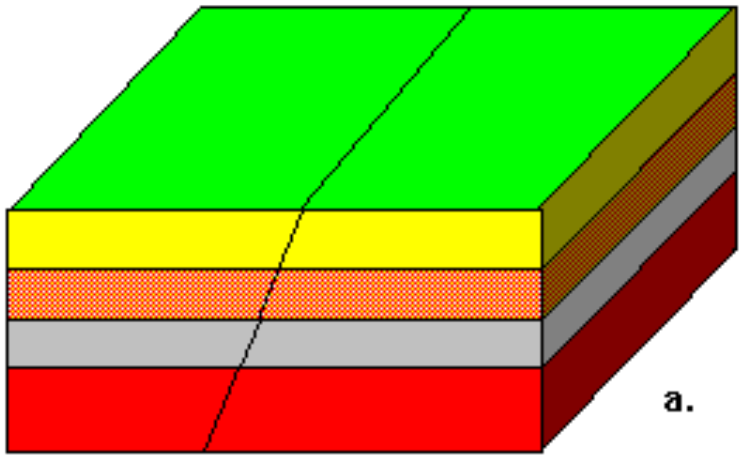
Dip-Slip Fault - Normal

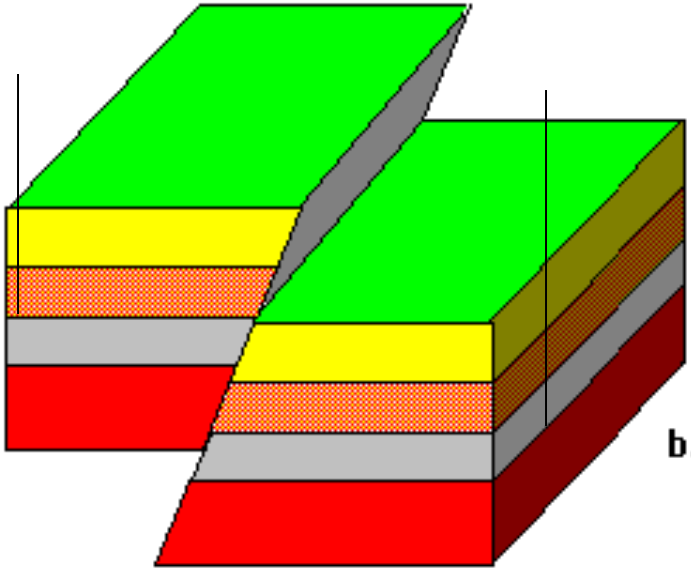


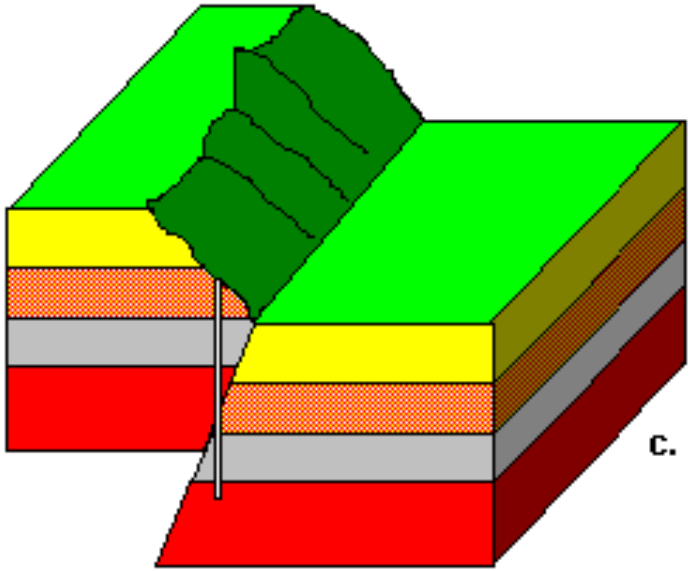
Normal Faulting
a. A block of crust before faulting
b. After faulting. Note that the block becomes longer.
c. An eroded normal fault. Note that the well misses the gray layer completely.

Dip-Slip Fault - Reverse



Reverse or Thrust Faulting
a. A block of crust before faulting.
b. After faulting. Note that the block becomes shorter.
c. An eroded reverse fault. Note that the well passes through several layers twice.

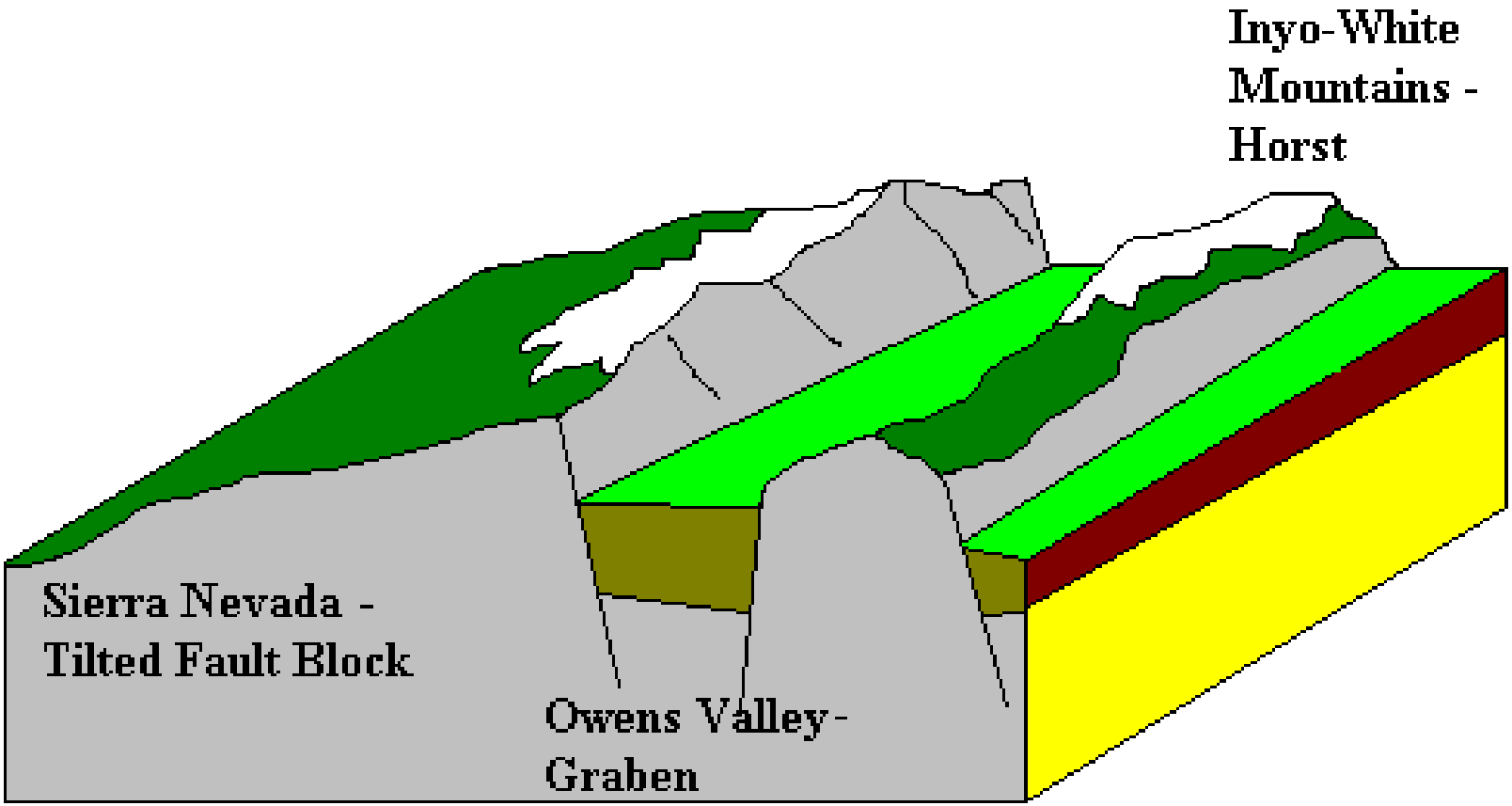




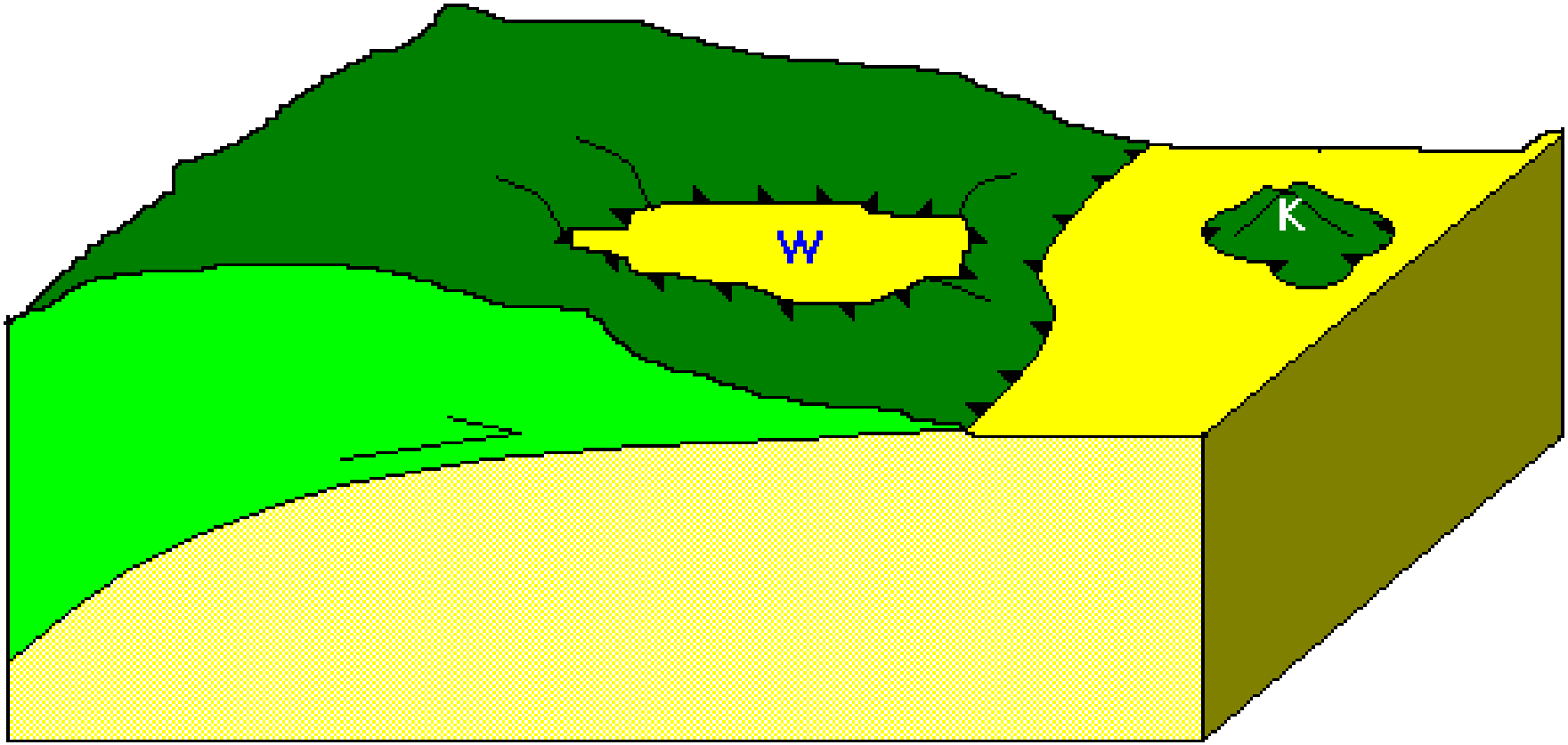
Dip-Slip Faults

- Normal Faults: Extension
- Reverse Faults: Compression
  - Reverse Faults are often called Thrust Faults

Normal Fault Structures



Reverse Fault Structures



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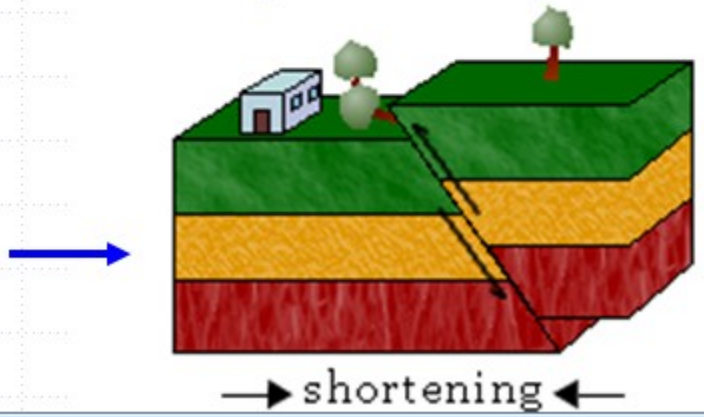
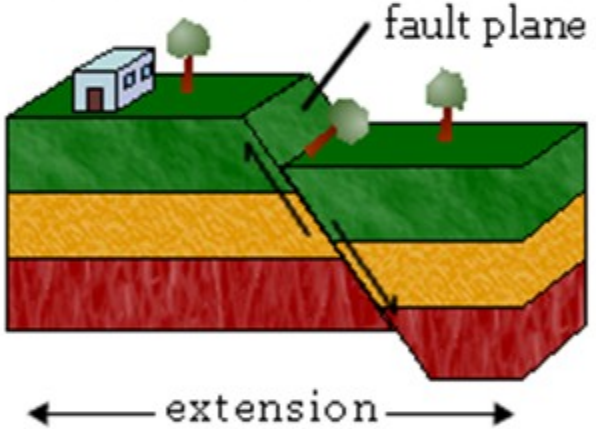
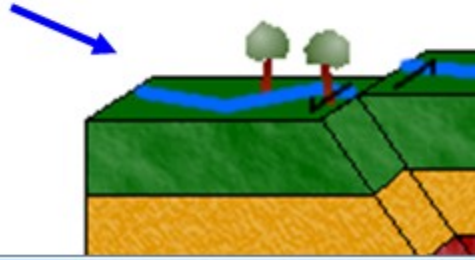
Types of faults

Thrust (Reverse) fault







Sources [Compatibility Mode] - Microsoft PowerPoint

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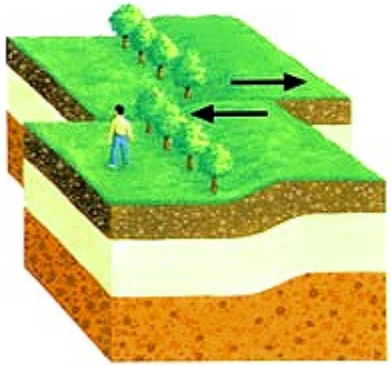
Text Direction Align Text Convert to SmartArt — Paragraph

Strike-Slip Faults



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Right-lateral

Faults and Earthquakes [Compa...

Sources [Compatibility Mode]

Slide 15

Major Hazards of Earthquakes

- Building Collapse
- Landslides
- Fire
- Tsunamis (Not Tidal Waves!)

Safest & Most Dangerous Buildings

- Small, Wood-frame House - Safest
- Steel-Frame
- Reinforced Concrete
- Unreinforced Masonry
- Adobe - Most Dangerous

Tsunamis

Probably Caused by Submarine Landslides

Travel about 400 M.p.h.

Pass Unnoticed at Sea, Cause Damage on Shore

Warning Network Around Pacific Can Forecast Arrival

Whether or Not Damage Occurs Depends on:

- Direction of Travel
- Harbor Shape
- Bottom
- Tide & Weather

Magnitude and Intensity

Intensity

- How Strong Earthquake Feels to Observer

Magnitude

- Related to Energy Release
- Determined from Seismic Records
- Rough correlation between the two for shallow earthquakes

Intensity

How Strong Earthquake Feels to Observer

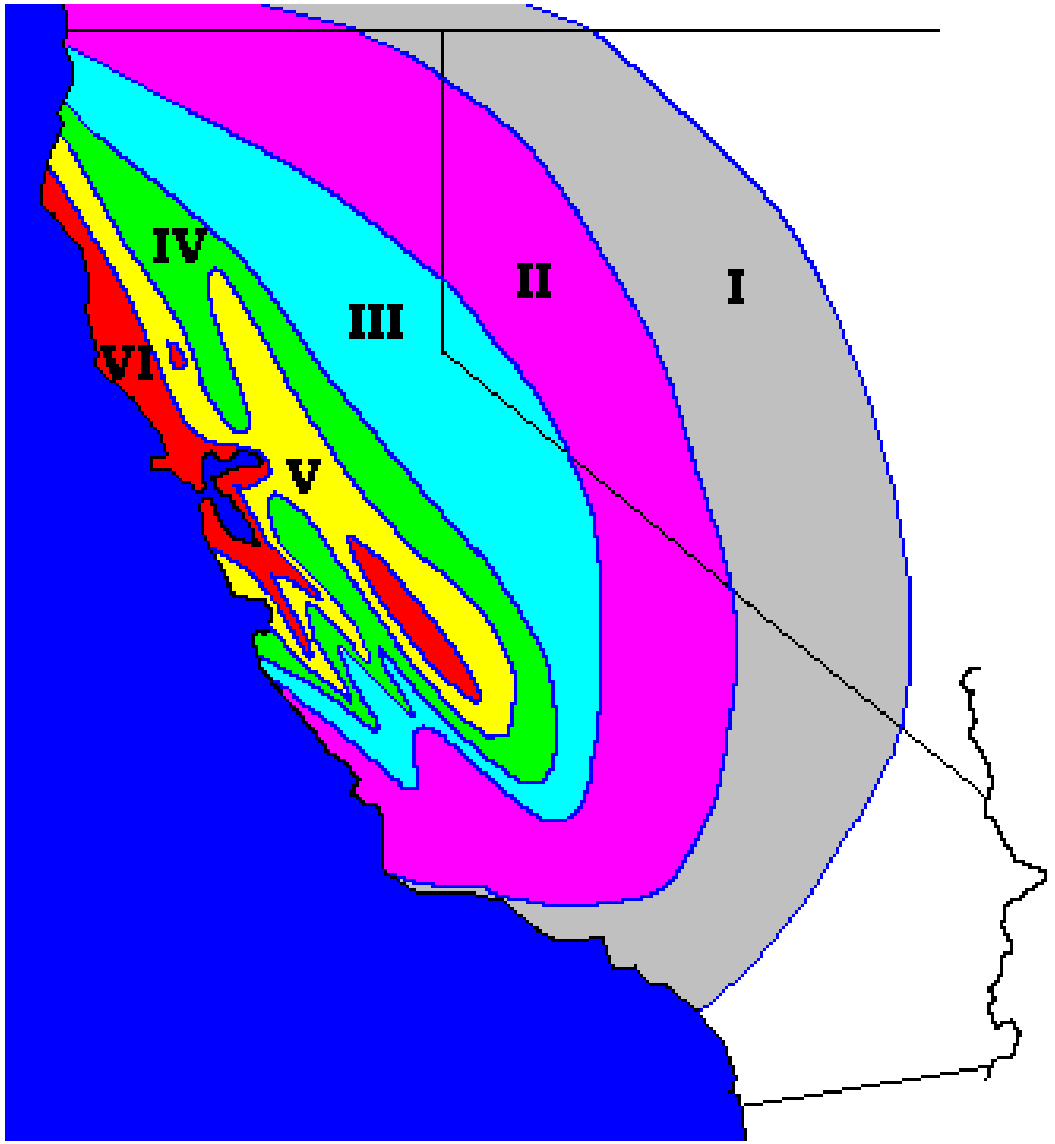
Depends On:

- Distance to Quake
- Geology
- Type of Building
- Observer!

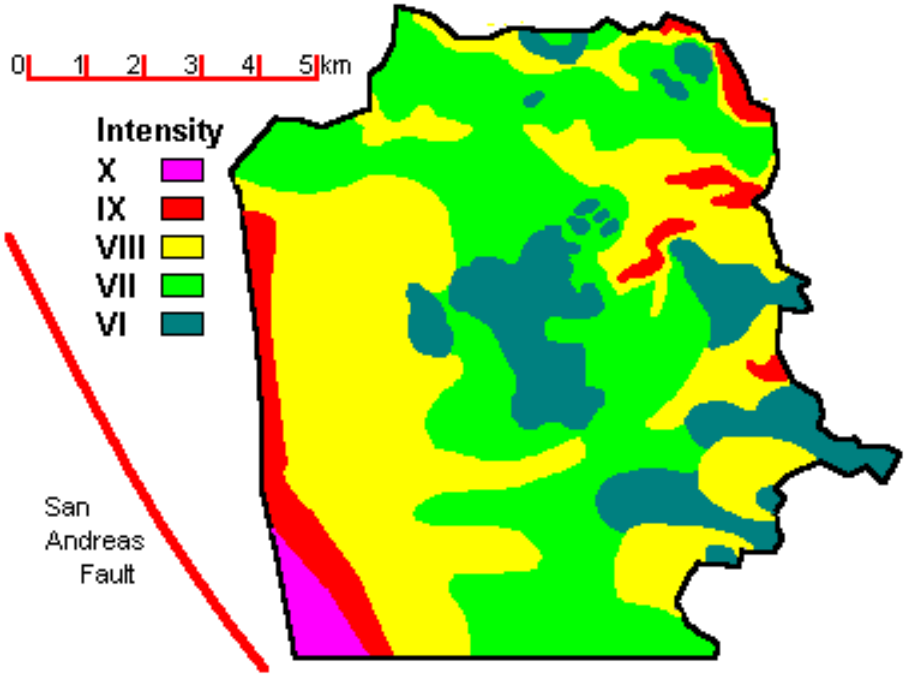
Varies from Place to Place

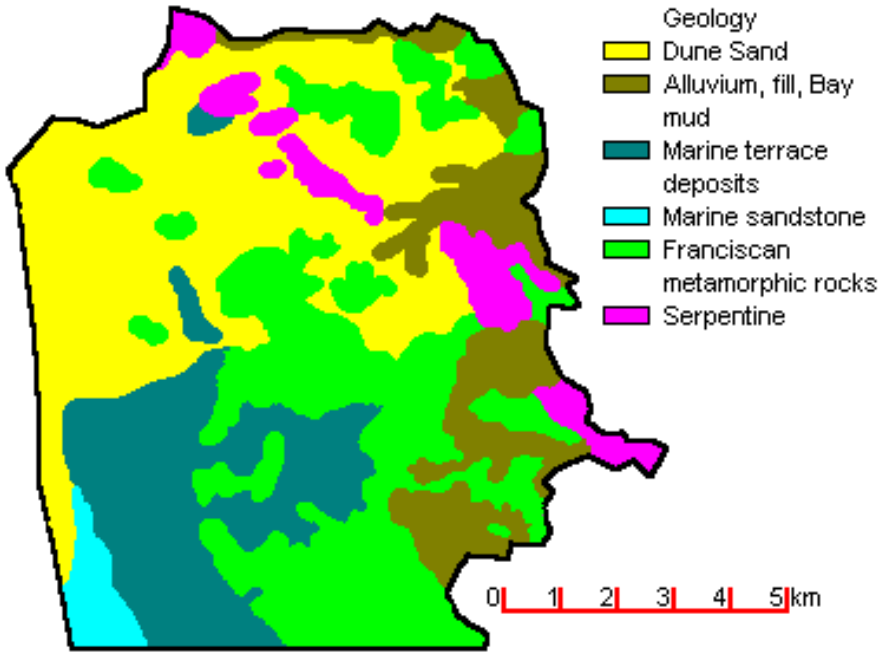
- Mercalli Scale- 1 to 12

Isoseismals from the 1906 San Francisco Earthquake



Intensity and Geology in San Francisco, 1906





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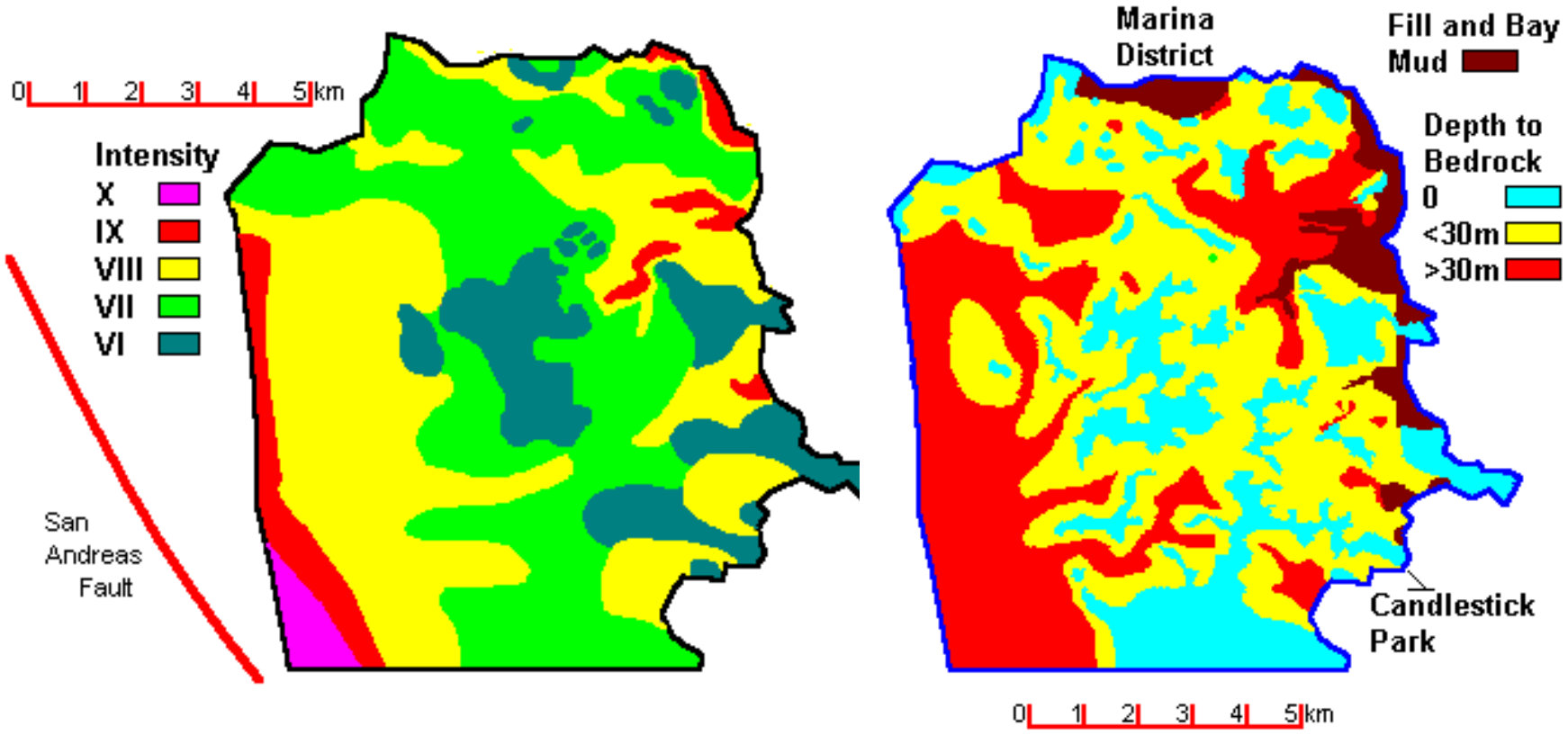
Intensity and Bedrock Depth in San Francisco, 1906



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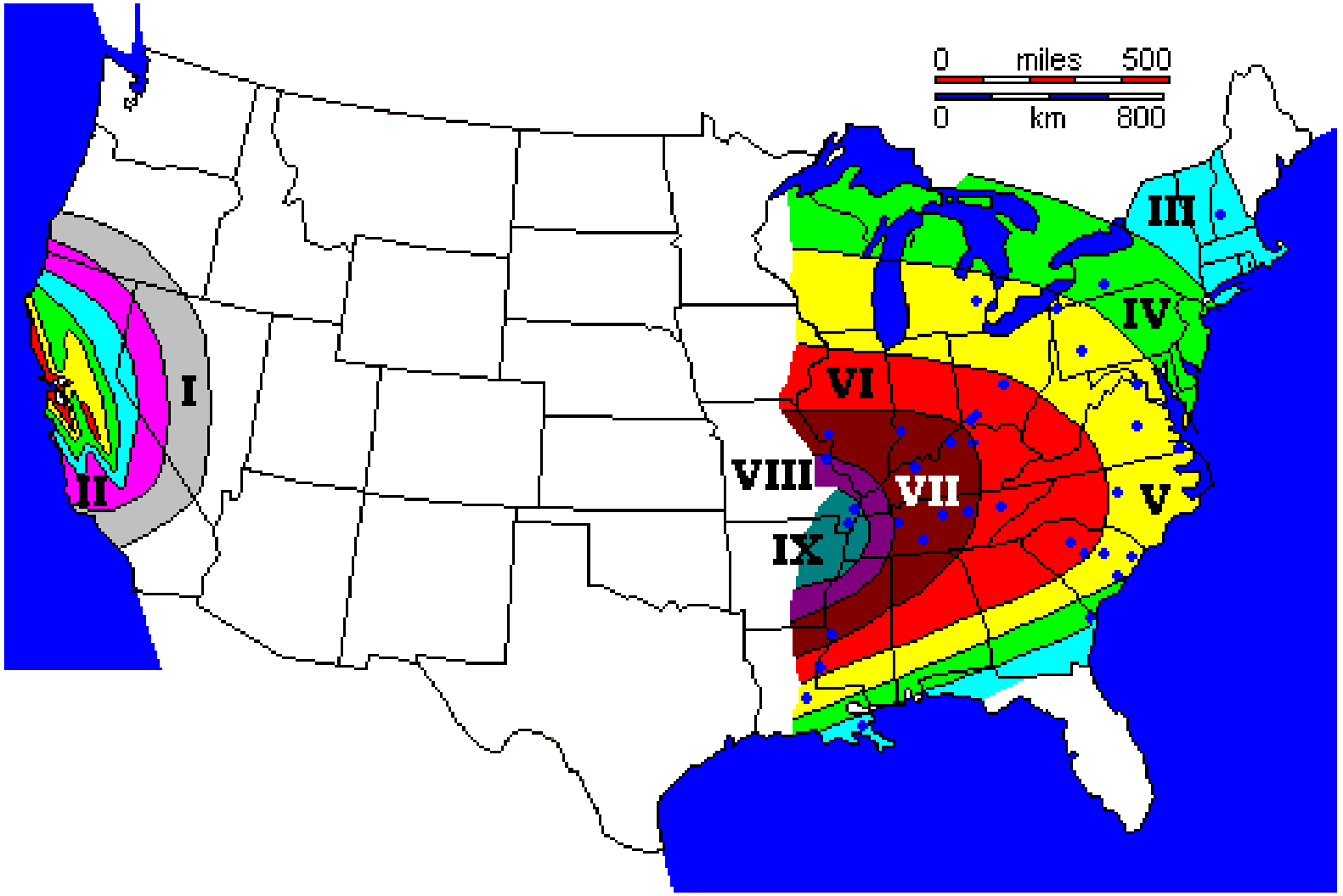
San Francisco and New Madrid Compared



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Magnitude - Determined from Seismic Records

Richter Scale:

- Related to Energy Release
- Exponential
- No Upper or Lower Bounds
- Largest Quakes about Mag. 8.7

- Magnitude-Energy Relation
  - 4 - 1
  - 5 - 30
  - 6 - 900:
  - 1 Megaton = about 7
  - 7 - 27,000
  - 8 - 810,000

Seismic - Moment Magnitude

A Seismograph Measures Ground Motion at One Instant But --

- A Really Great Earthquake Lasts Minutes
- Releases Energy over Hundreds of Kilometers
- Need to Sum Energy of Entire Record
- Modifies Richter Scale, doesn't replace it
- Adds about 1 Mag. To 8+ Quakes

Magnitude and Energy

Magnitude	Energy	Explosive Power	Example
9	U.S. Energy Use for a month		Alaska 1964 Indonesia 2004
8	U.S. Energy Use for a day		San Francisco, 1906
7		One Megaton	World Series Earthquake, 1989
6	U.S. Energy Use for a minute	Large Thunderstorm	
5		One Kiloton	
4			
3		One ton of explosives	World Trade Center Collapse

Magnitude and Energy

Magnitude	Energy	Explosive Power	Example
3		One ton of Explosives	World Trade Center Collapse
2			
1	Topple 50-meter tree	One kilogram of explosives	Head-on colision at 60 mph
0	Drop a car 10 meters	Half stick of dynamite	Very bad day skydiving
-1	Impact of bullet	One gram of explosives	
-2	Hammer blow		
-3	Dribbling a basketball		

Seismology and Earth's Interior

Successive Approximation in Action

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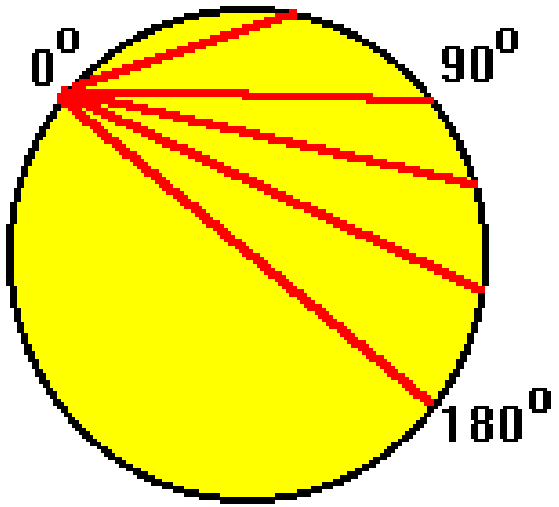
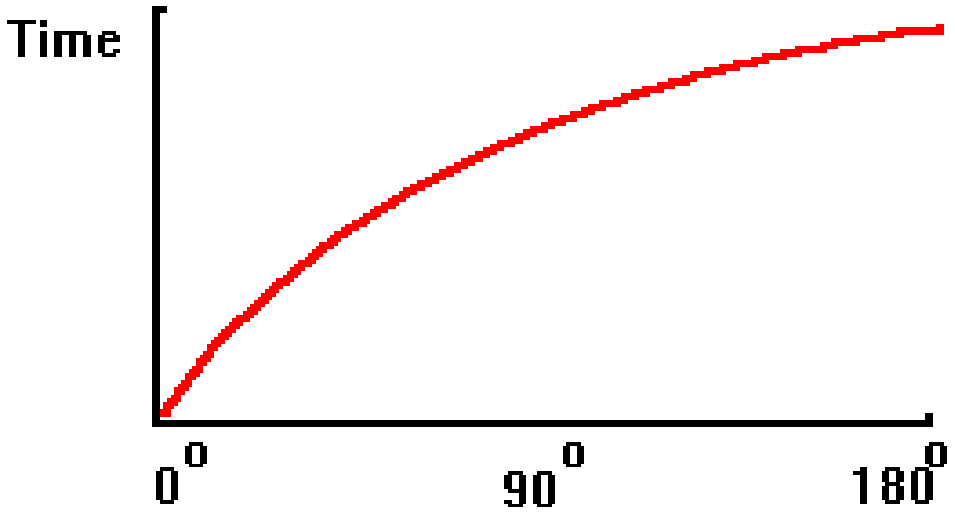
1. Assume the Earth is uniform.

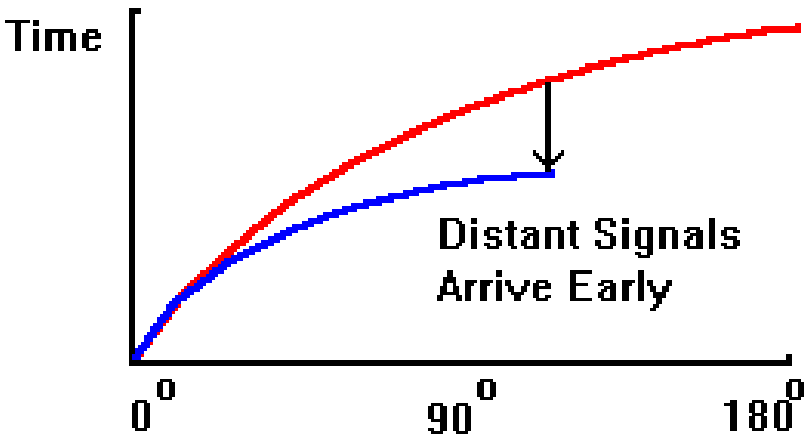
- We know it isn't, but it's a useful place to start. It's a simple matter to predict when a seismic signal will travel any given distance.

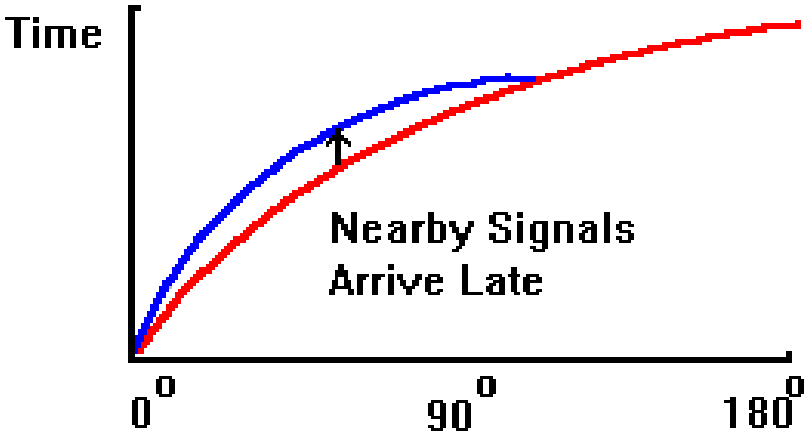




2. Actual seismic signals don't match the predictions

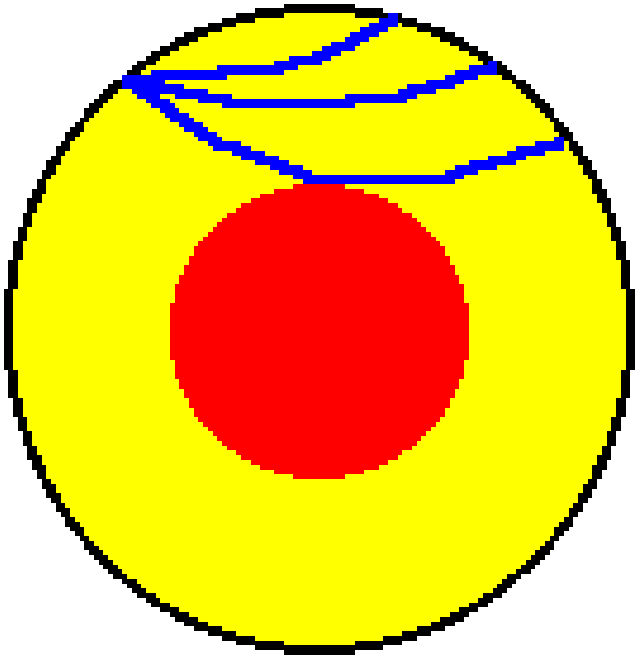
- If we match the arrival times of nearby signals, distant signals arrive too soon
- If we match the arrival times of distant signals, nearby signals arrive too late.
- Signals are interrupted beyond about 109 degrees



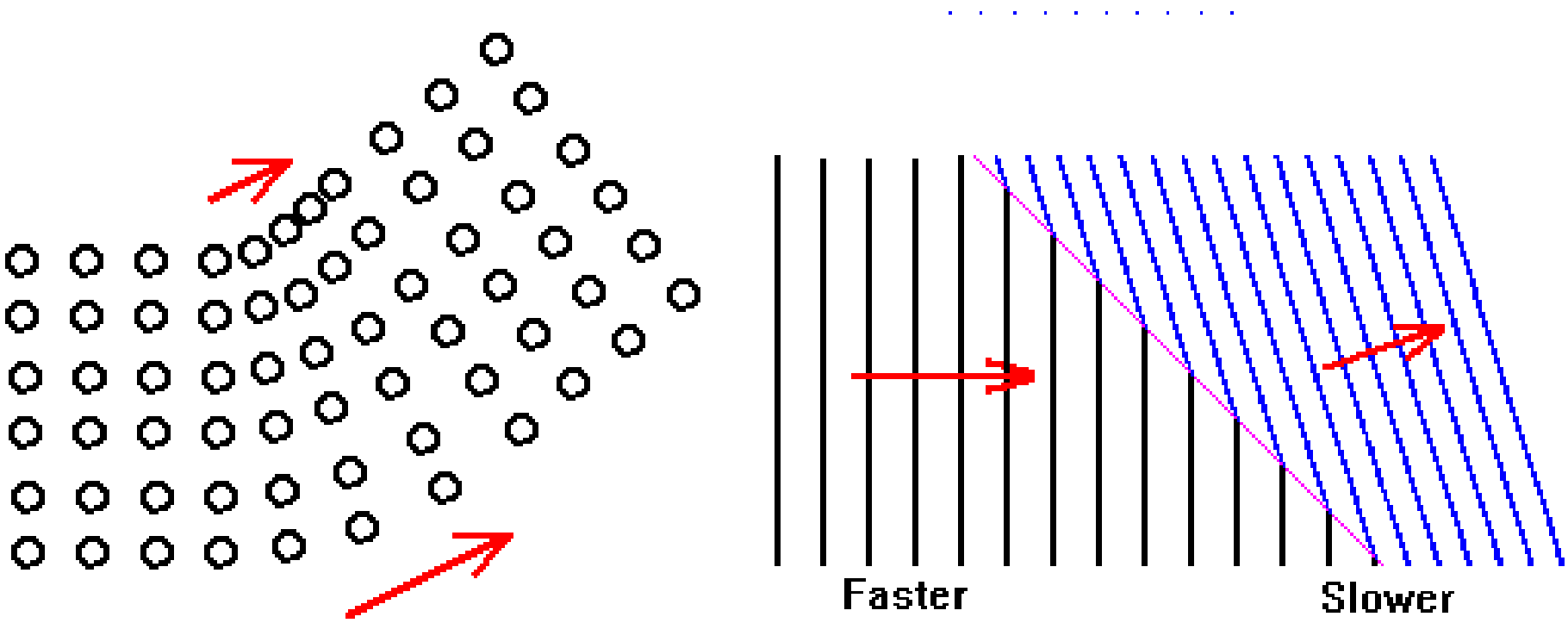


3. We conclude:

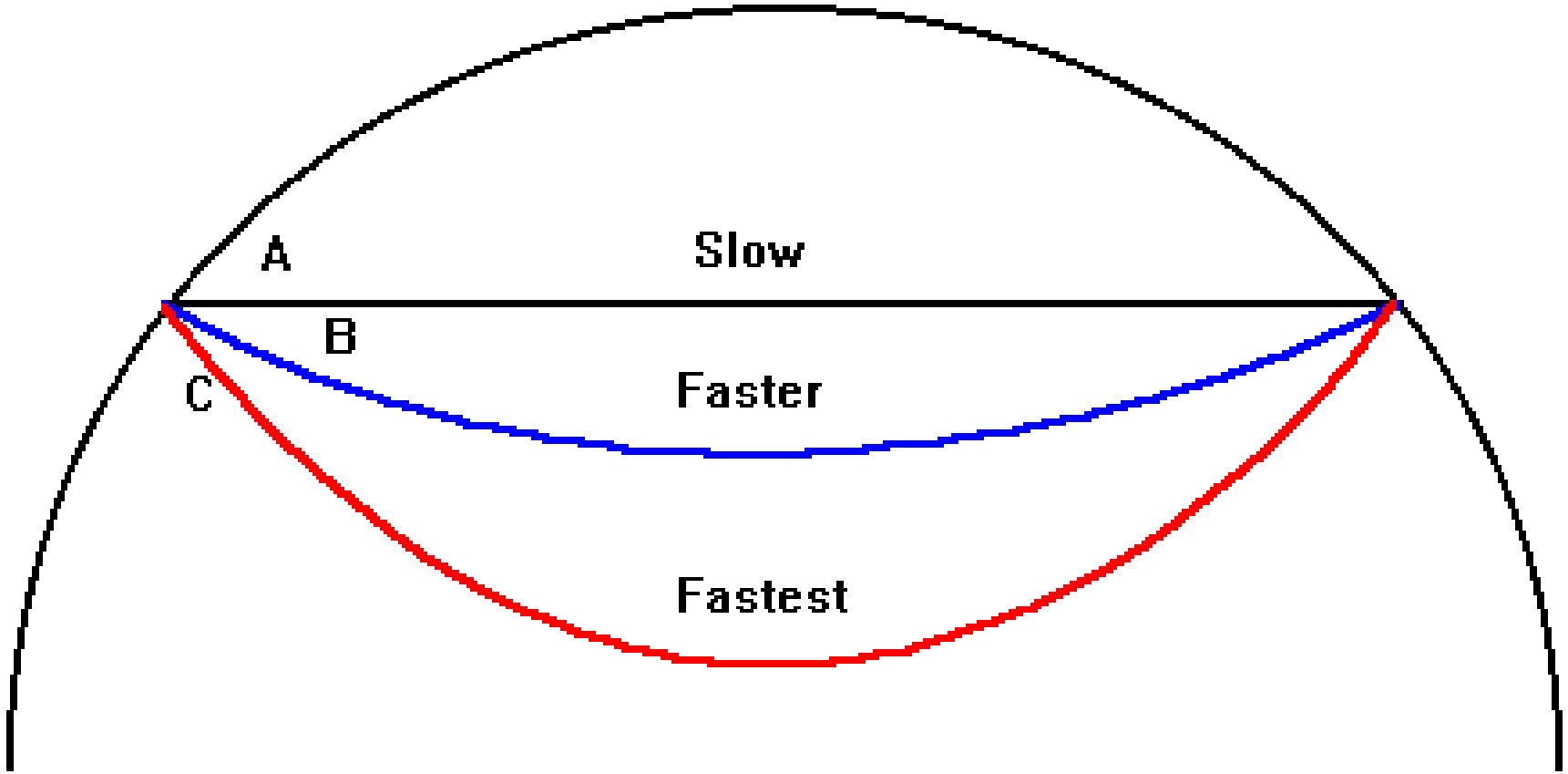
1. Distant signals travel through deeper parts of the Earth, therefore ..
2. Seismic waves travel faster through deeper parts of the Earth, therefore ….
3. They travel curving paths (refract)
4. Also, there is an obstacle in the center (the core).



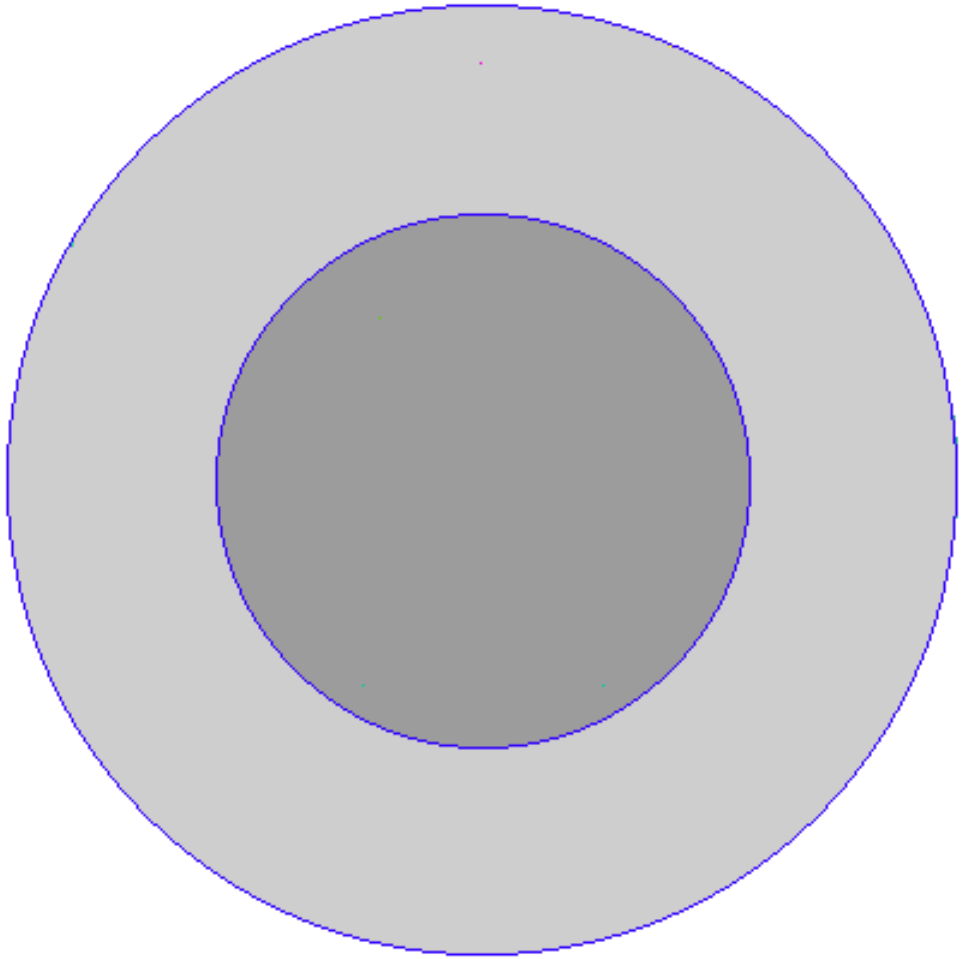
Why Refraction Occurs



Waves Travel The Fastest Path



Seismic Waves in the Earth



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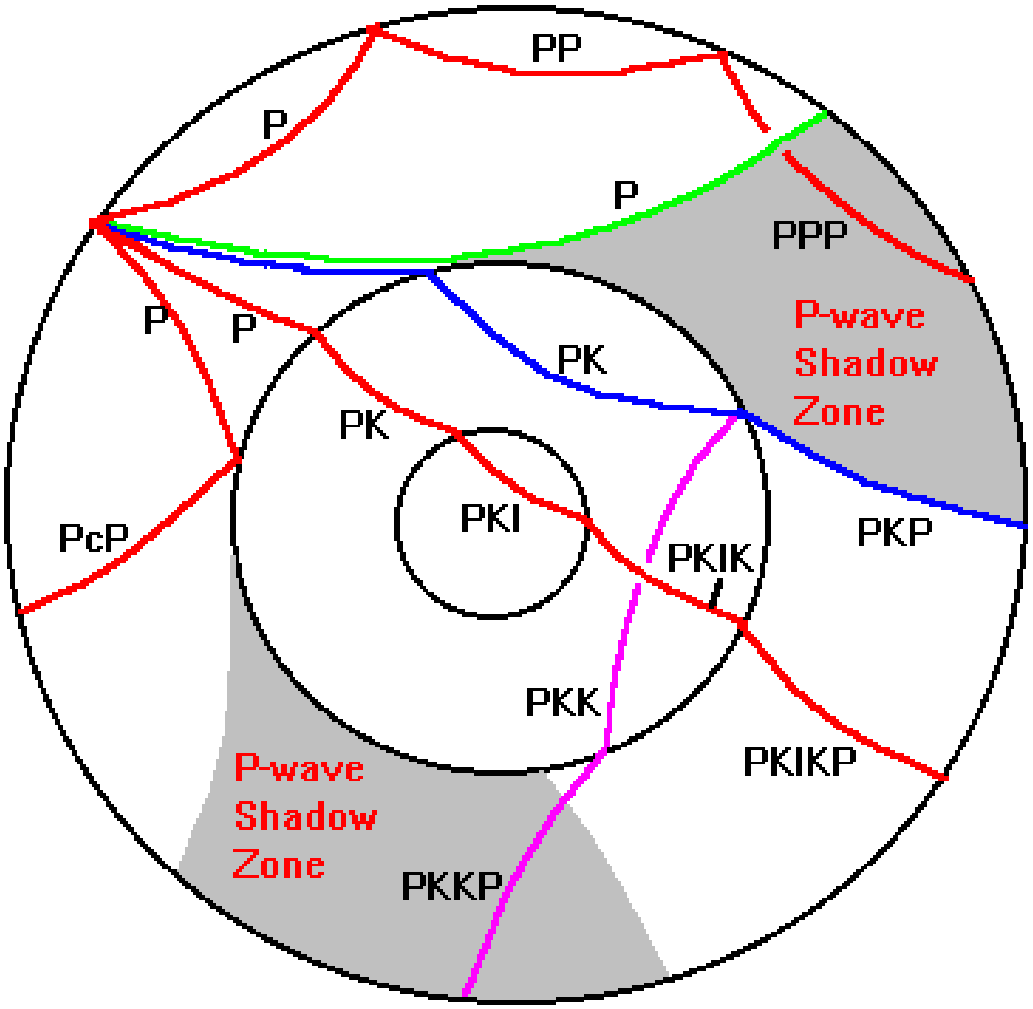
Inner Structure of the Earth



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The overall structure of the Earth

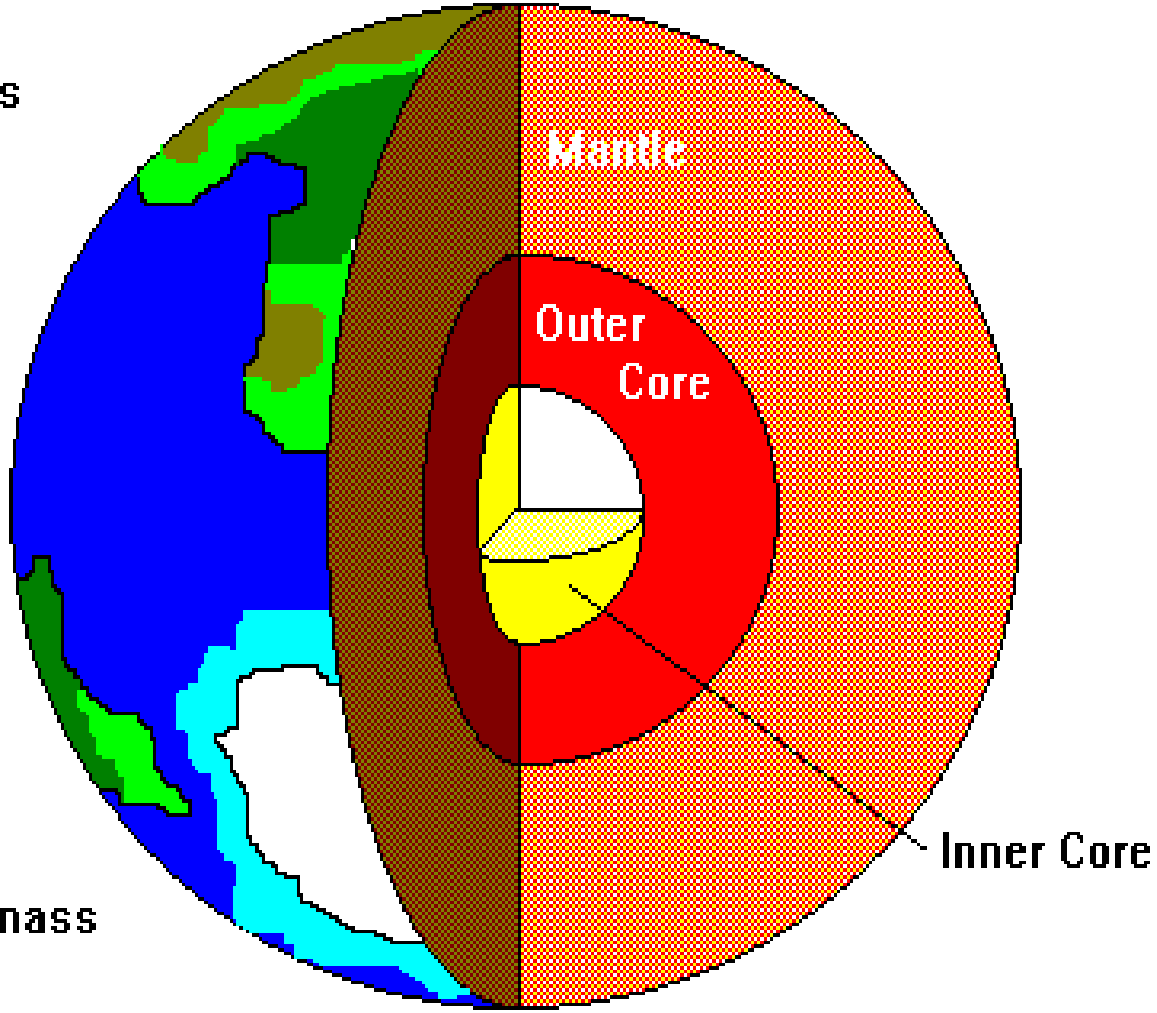
Atmosphere: 1/1,000,000 of Earth's mass

Oceans: 2/10,000 of Earth's mass

Crust: 1/250 of Earth's mass

Mantle: 2/3 of Earth's mass, 5/6 of volume

Core: 1/3 of Earth's mass 1/6 of volume



Strategies of Earthquake Prediction

Lengthen Historical Data Base

- Historical Records
- Paleoseismology

Short-term Prediction

- Precursors

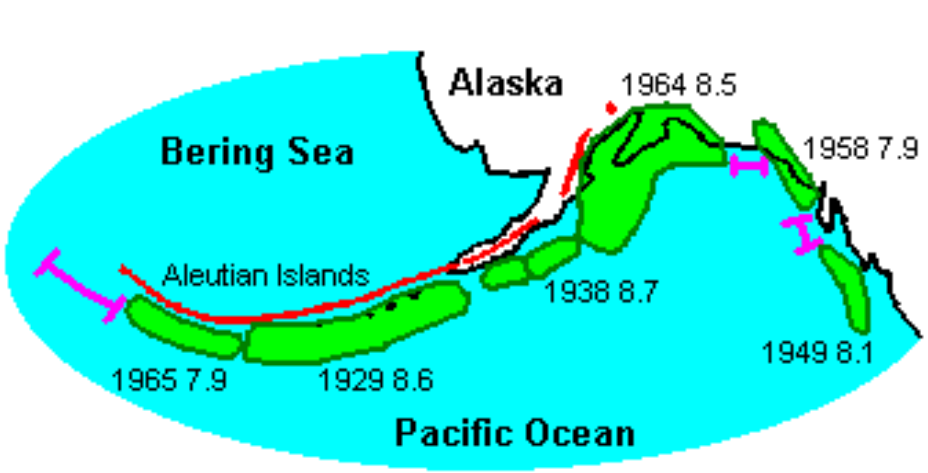
Long-term Prediction

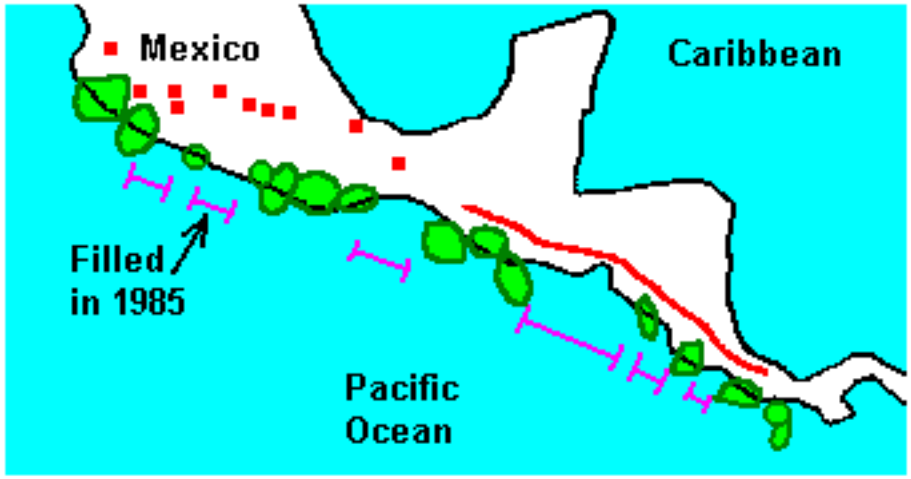
- Seismic Gaps
- Risk Levels

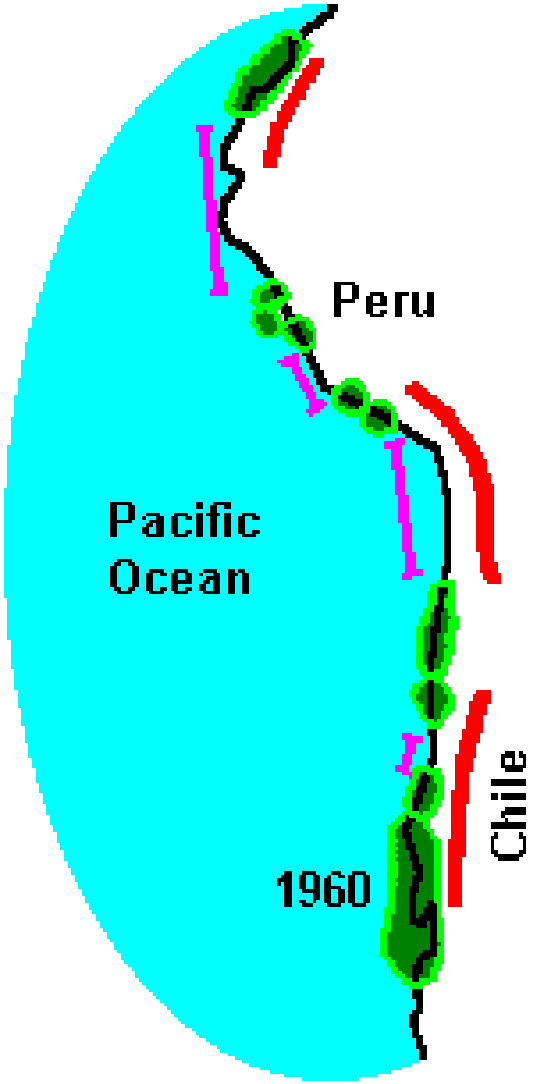
Modeling

- Dilatancy - Diffusion
- Stick - Slip
- Asperities (kinks)
- Crack Propagation

Seismic Gaps







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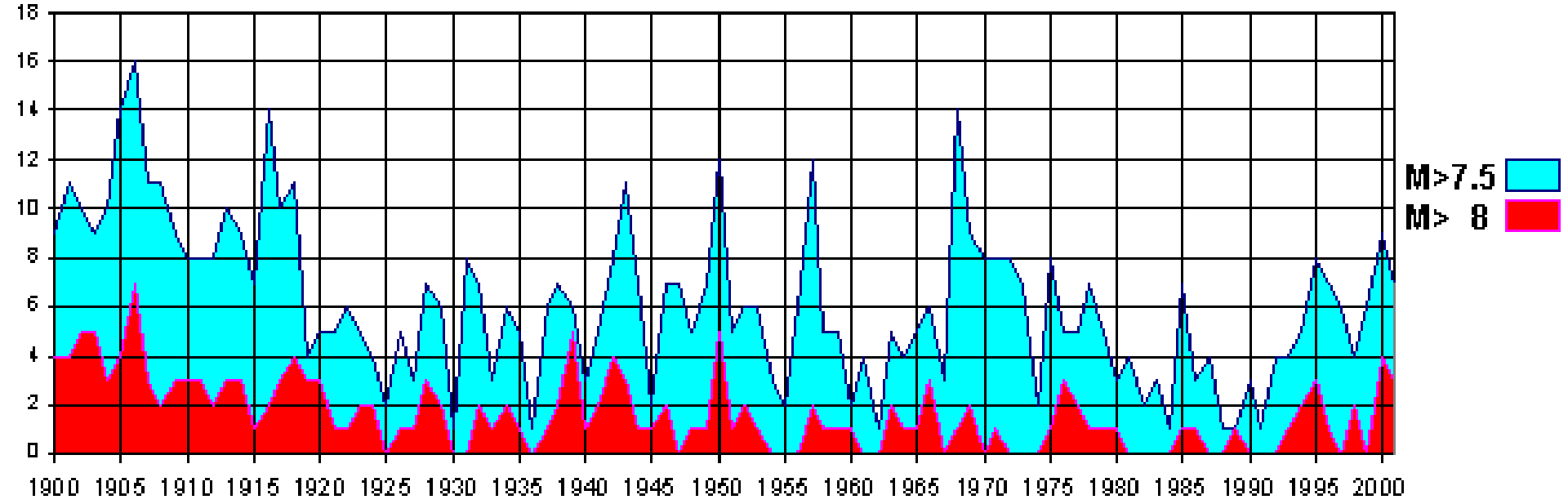
Are Earthquakes Getting More Frequent?



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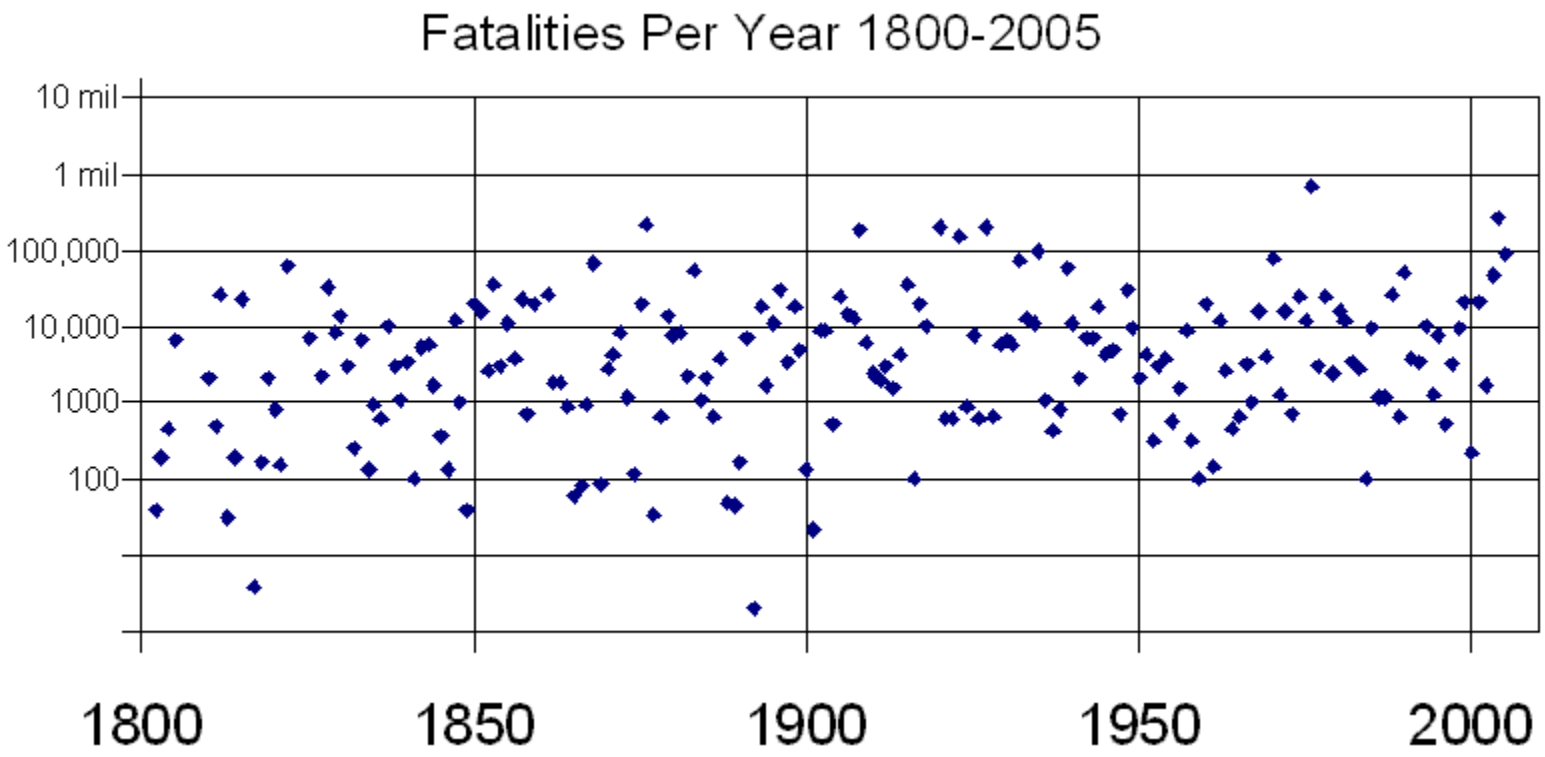
Earthquake Fatalities Since 1800



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