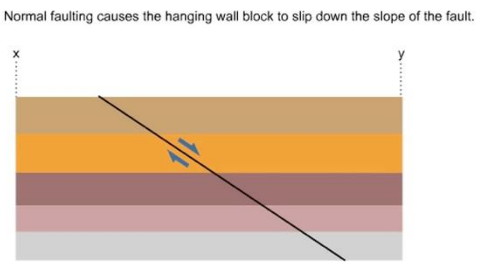
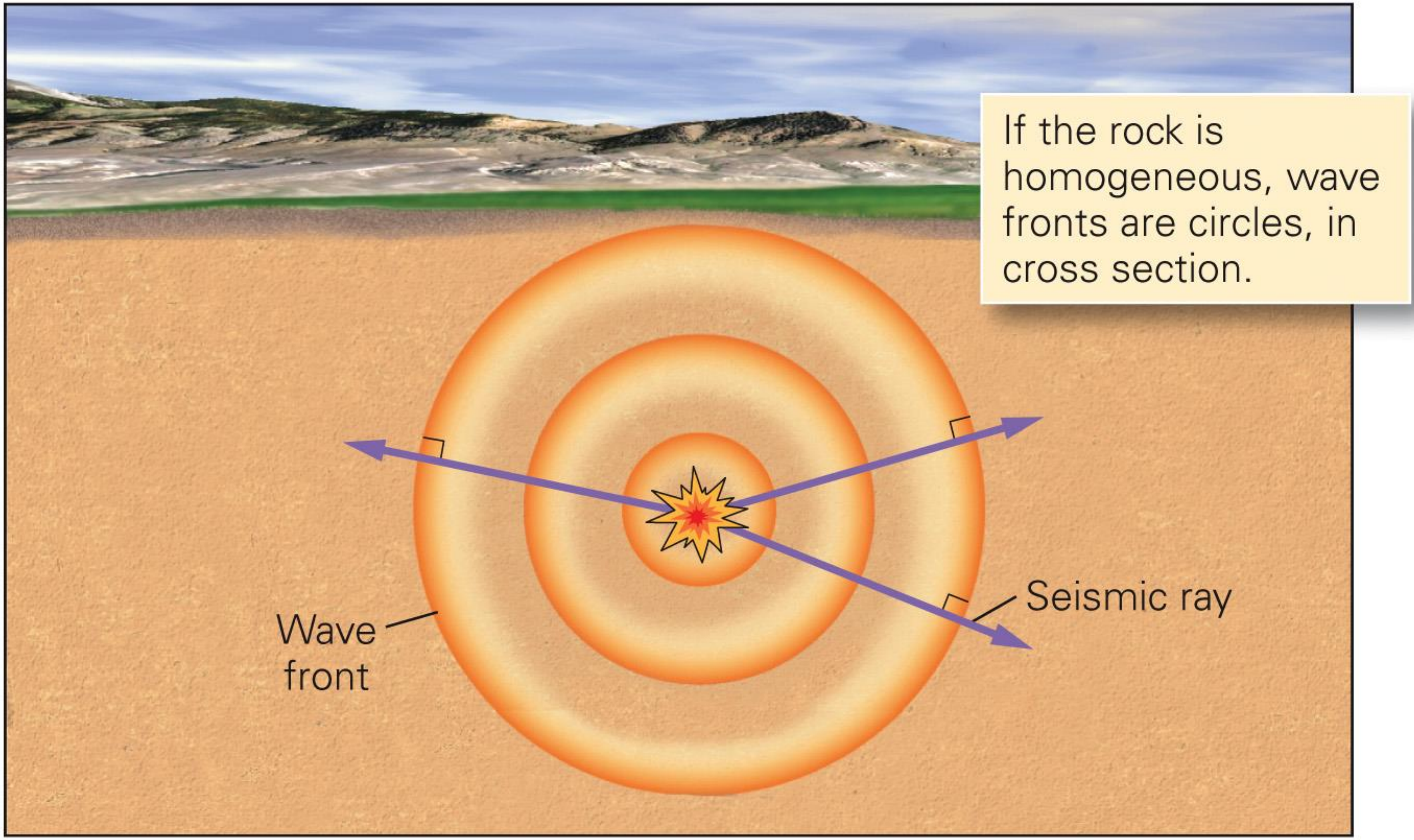
Seismic Activity & Management

- 1. Sound waves
- 2. The first seismic experiment
- 3. Origin of earthquakes
- 4. Seismic sources (ground vibrations)
- 5. Seismic waves - reflection/refraction; types
- 6. Earthquakes – seismic gap; faults; stick-slip
- 7. Monitoring – magnitude/intensity
- 8. Prediction & Dilation
- 9. Management



1. Seismic Waves = Vibration (solid/liquid) – **Sound** (air/gas)

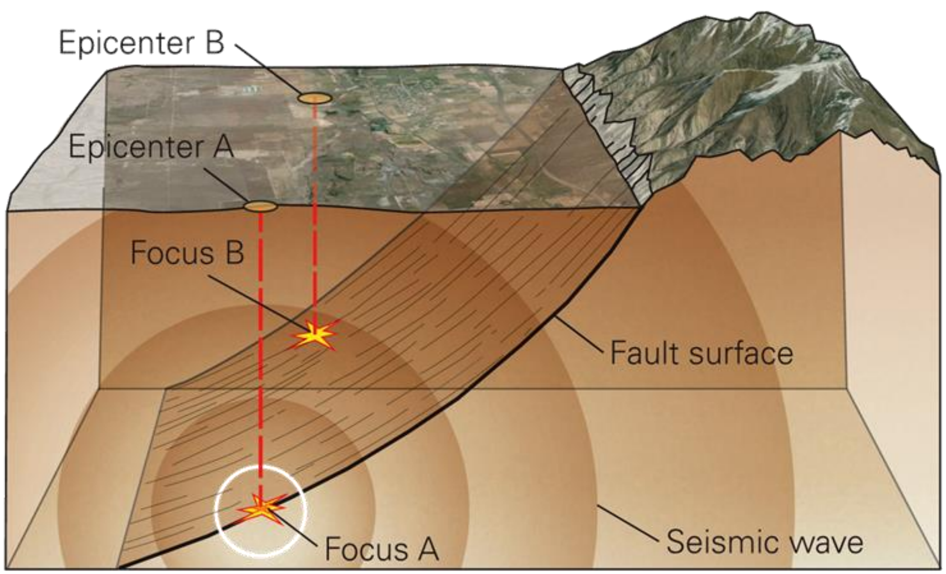


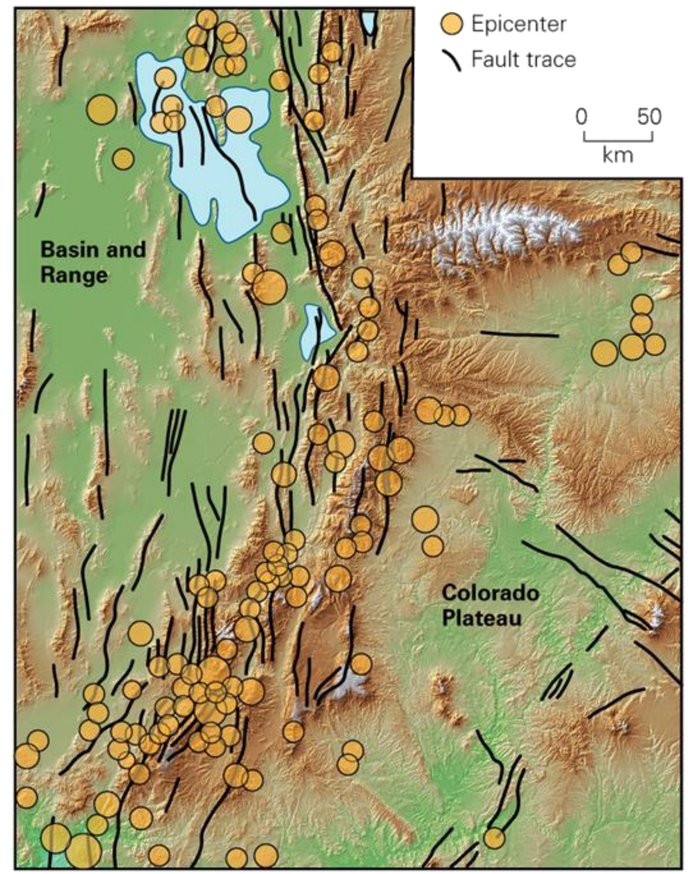
2. The First Seismic Experiment

- Robert Mallet – Killiney Beach, Dublin (1849)
- Gunpowder explosion shock wave travel times

3. Earthquake Origins

- The **hypocenter** (**focus**) is the location where fault slip occurs. Often a fault surface.
- The **epicenter** is the land surface directly above the hypocenter. Maps often portray the location of epicenters.

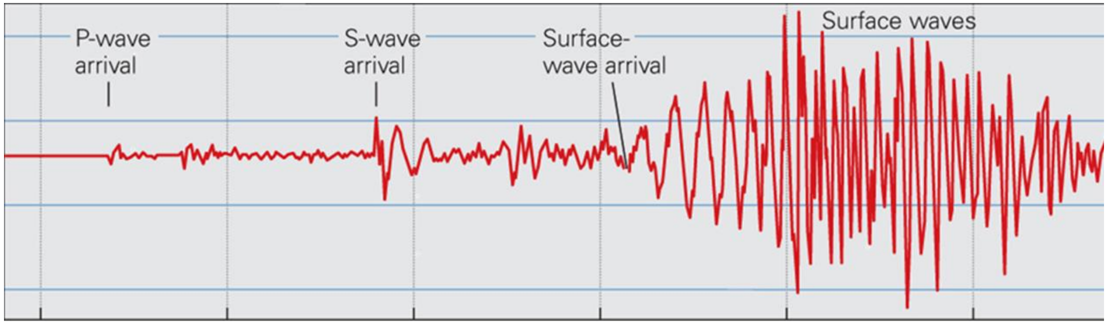




4. Seismic Sources (ground vibration)

- 1. Explosions/vibrations (Mallet; Kursk; exploration)
- 2. Humans, e.g. traffic (Covid Pandemic)
- 3. Landslides
- 4. Volcanoes
- 5. Impacts
- 6. **Tectonics**

(especially faulting)



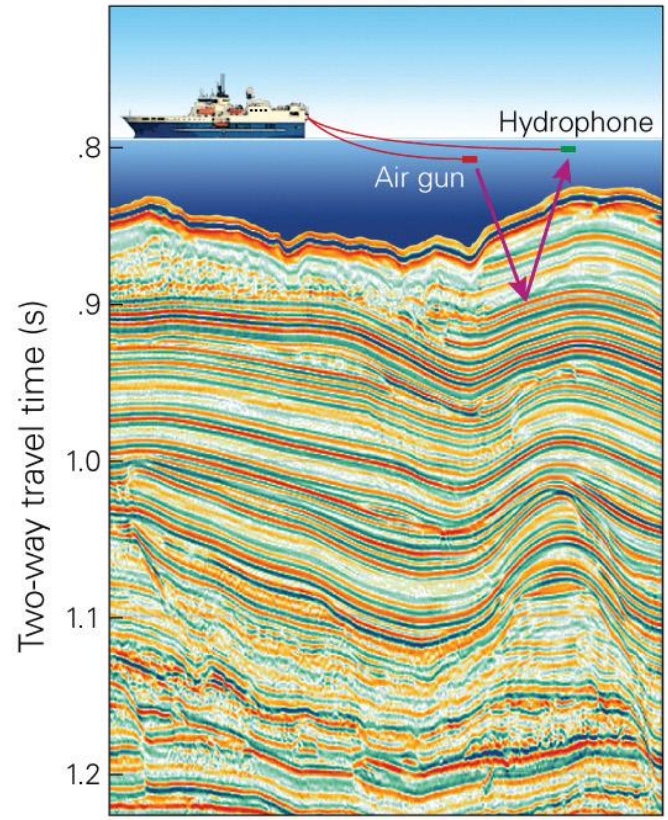
Taylor Swift:

https://www.bgs.ac.uk/news/quake-it-off-taylor-swift-concerts-shake-edinburgh/

Seismic Reflection Profiling (4. Sources)

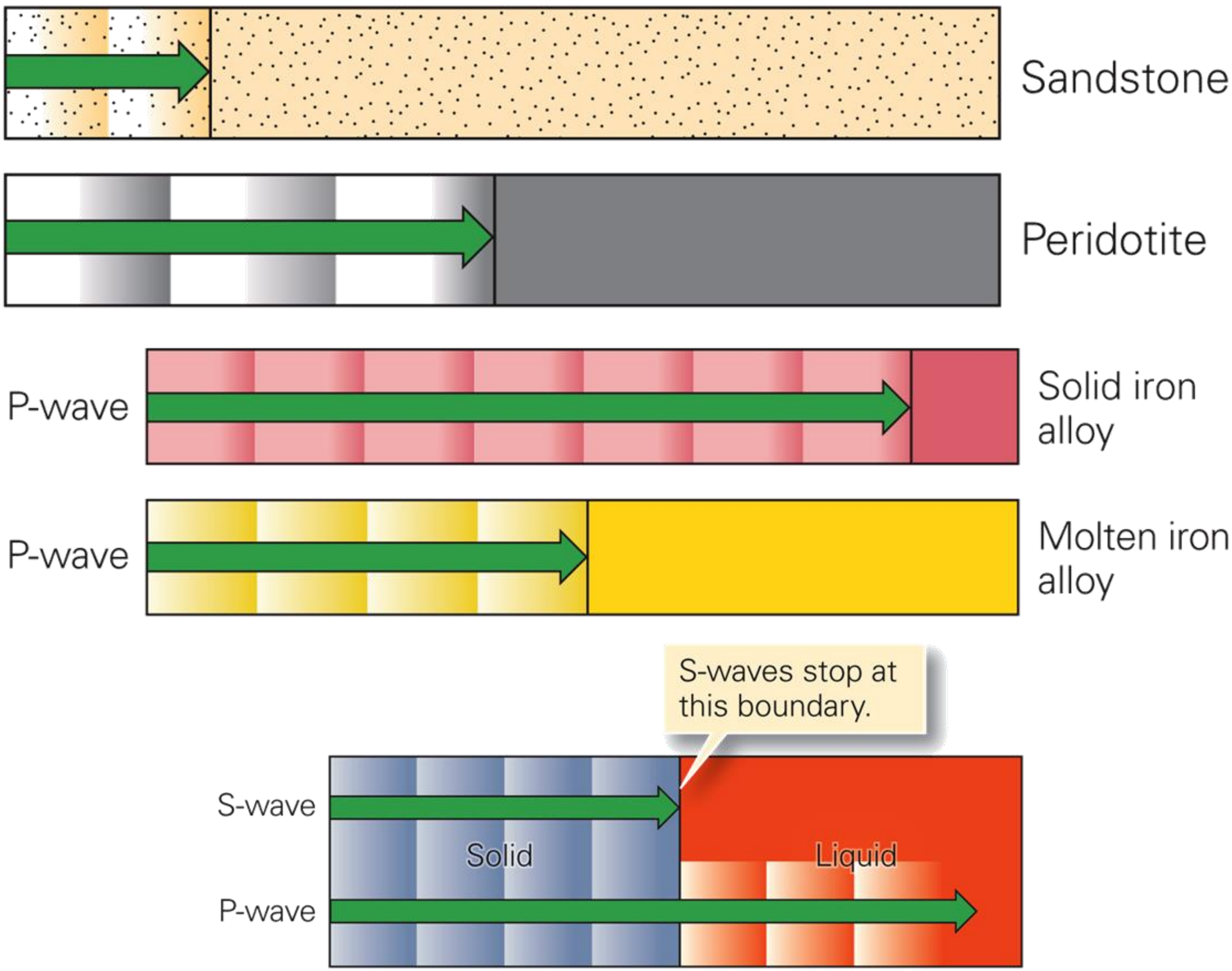
Seismic Reflection Profiling (4. Sources)

Trucks thumping on the ground to generate the signal needed for making a seismic-reflection profile.



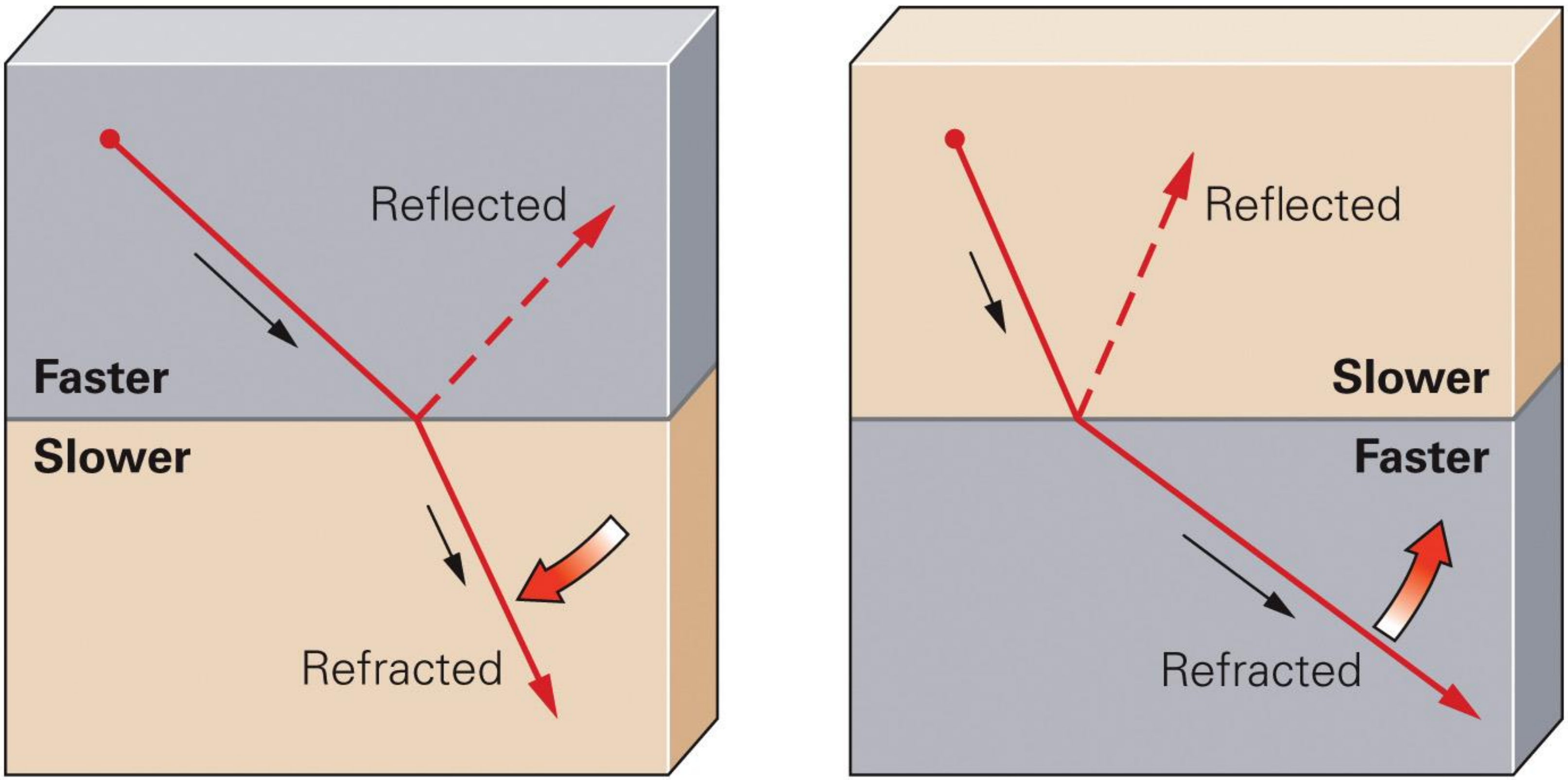
After computer analysis, the data yield a seismic-reflection profile. Color bands represent horizons in the stratigraphic sequence.

5. Seismic-Wave Propagation

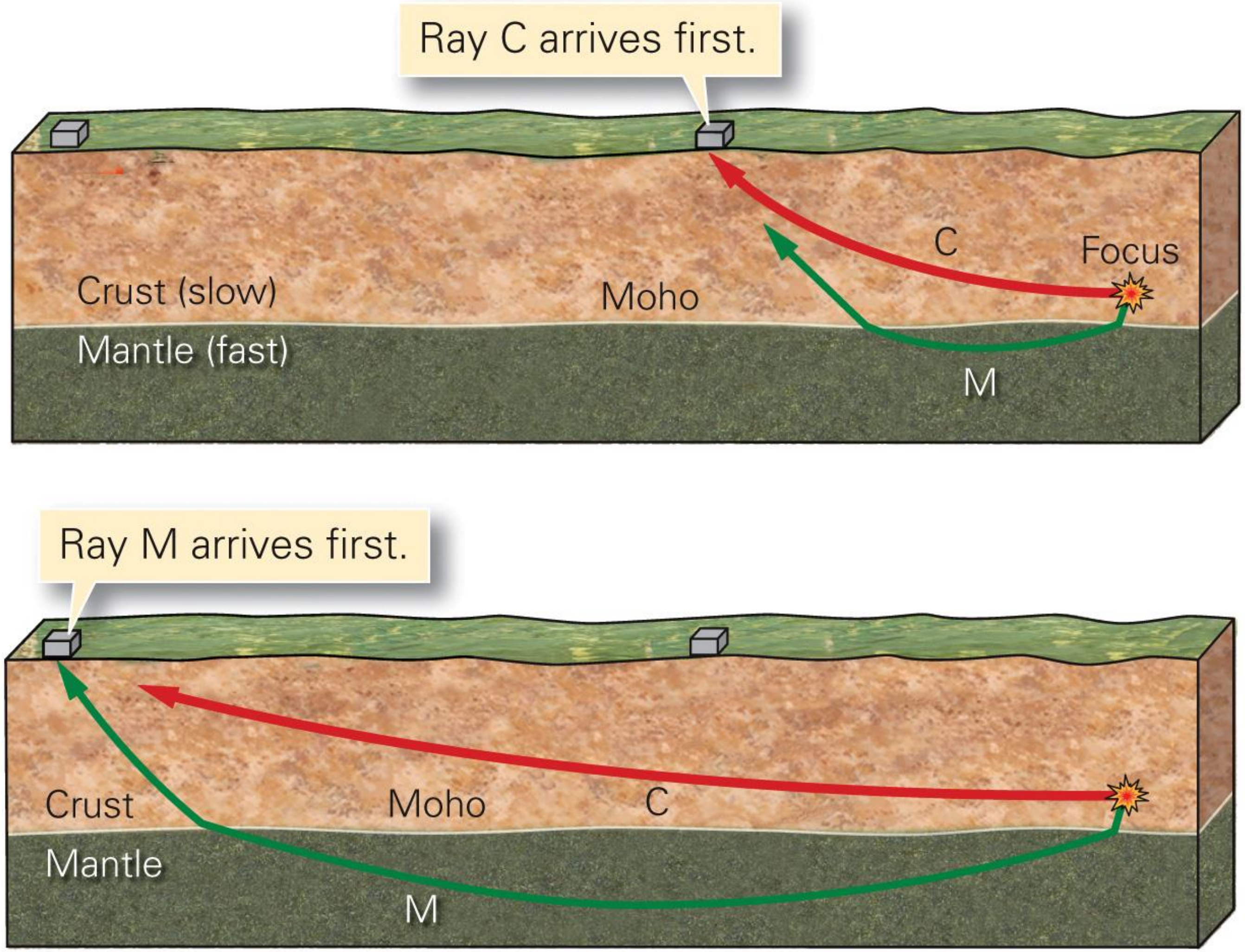


5. Reflection and Refraction

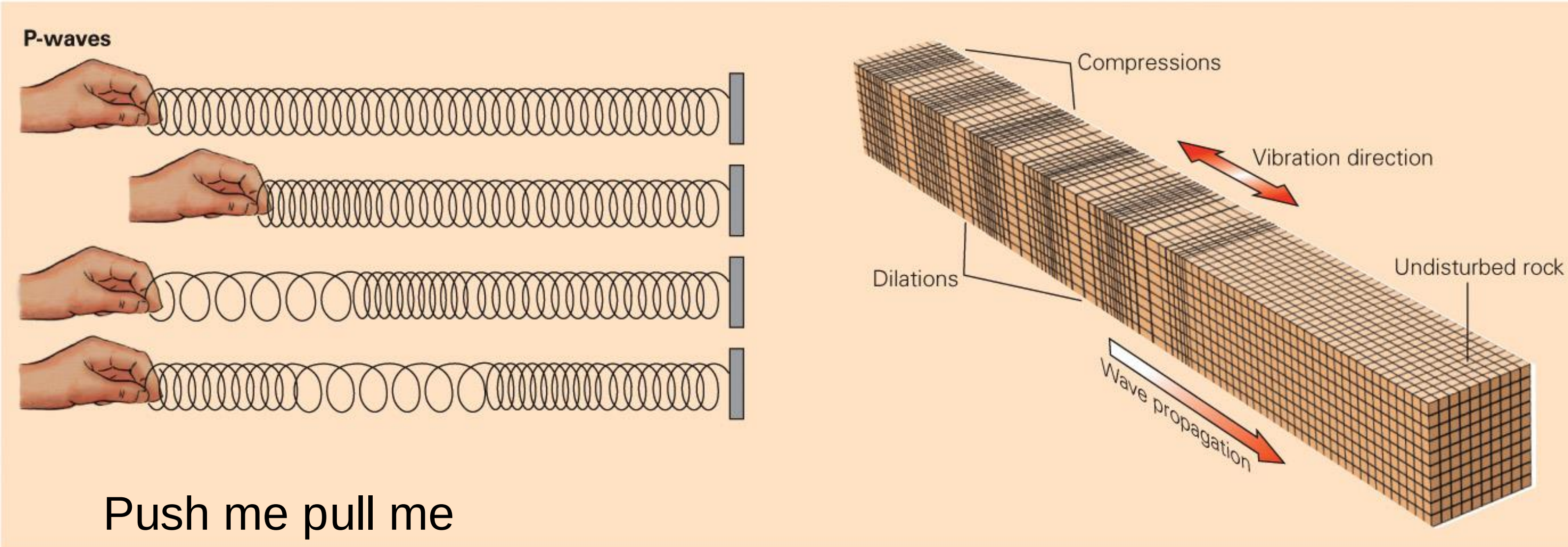
- When a ray hits a boundary between two materials, the ray can undergo:
  - Reflection: bounce off the boundary
  - Refraction: bending as it passes through the boundary



5. Refraction: The Crust-Mantle Boundary (Moho)

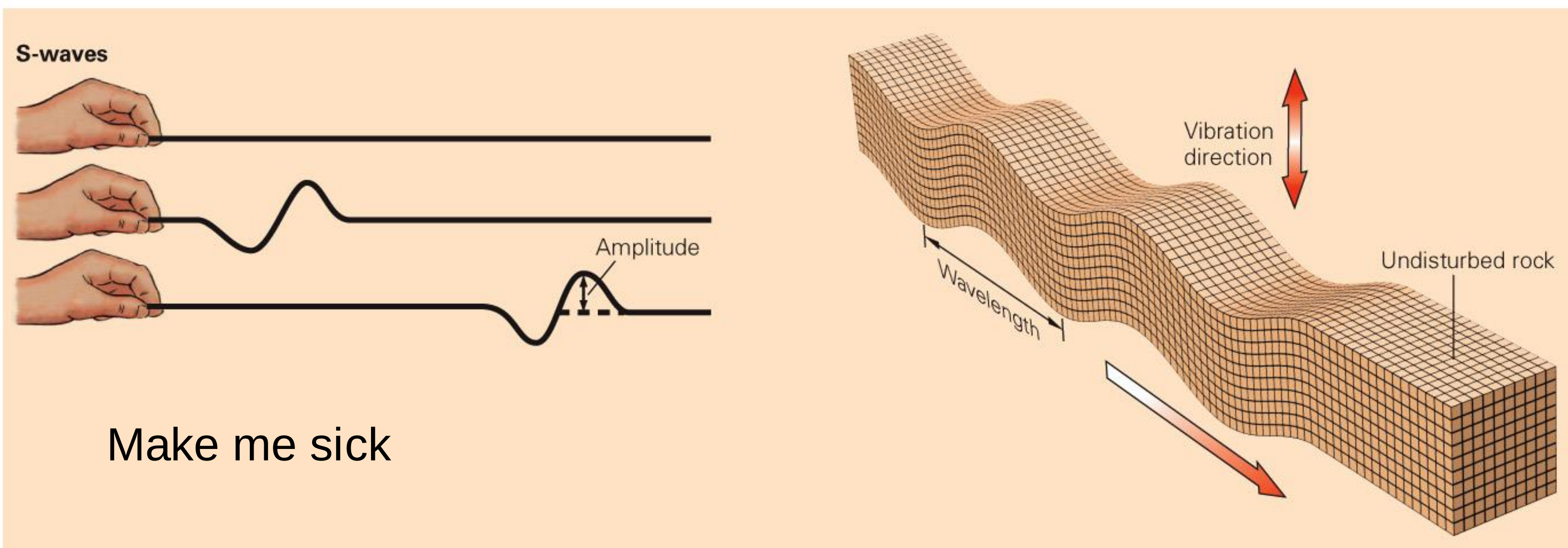


5. Seismic Body Waves: P-waves (liquid & solid)



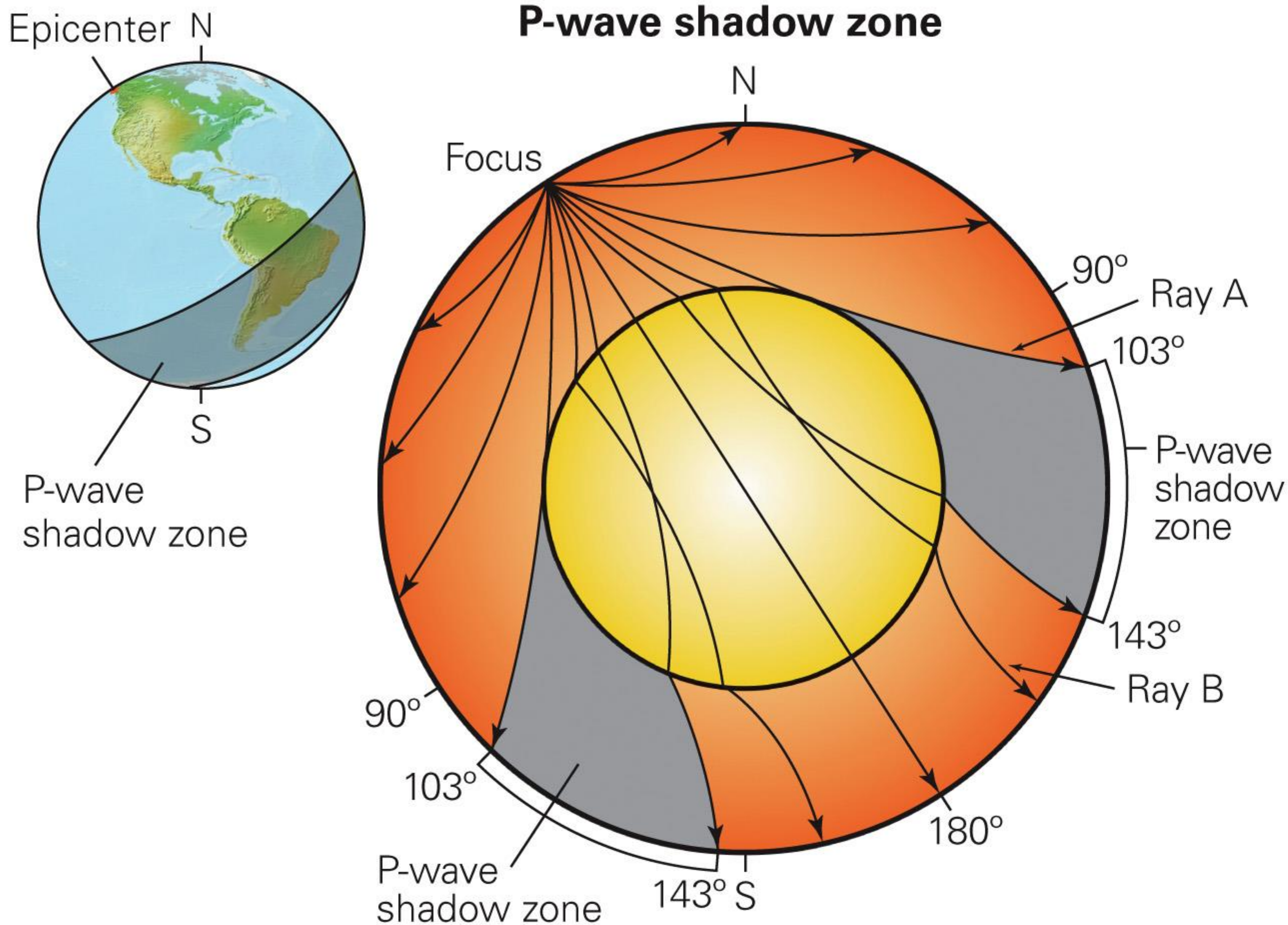
Push me pull me

5. Seismic Body Waves: S-waves (solid)

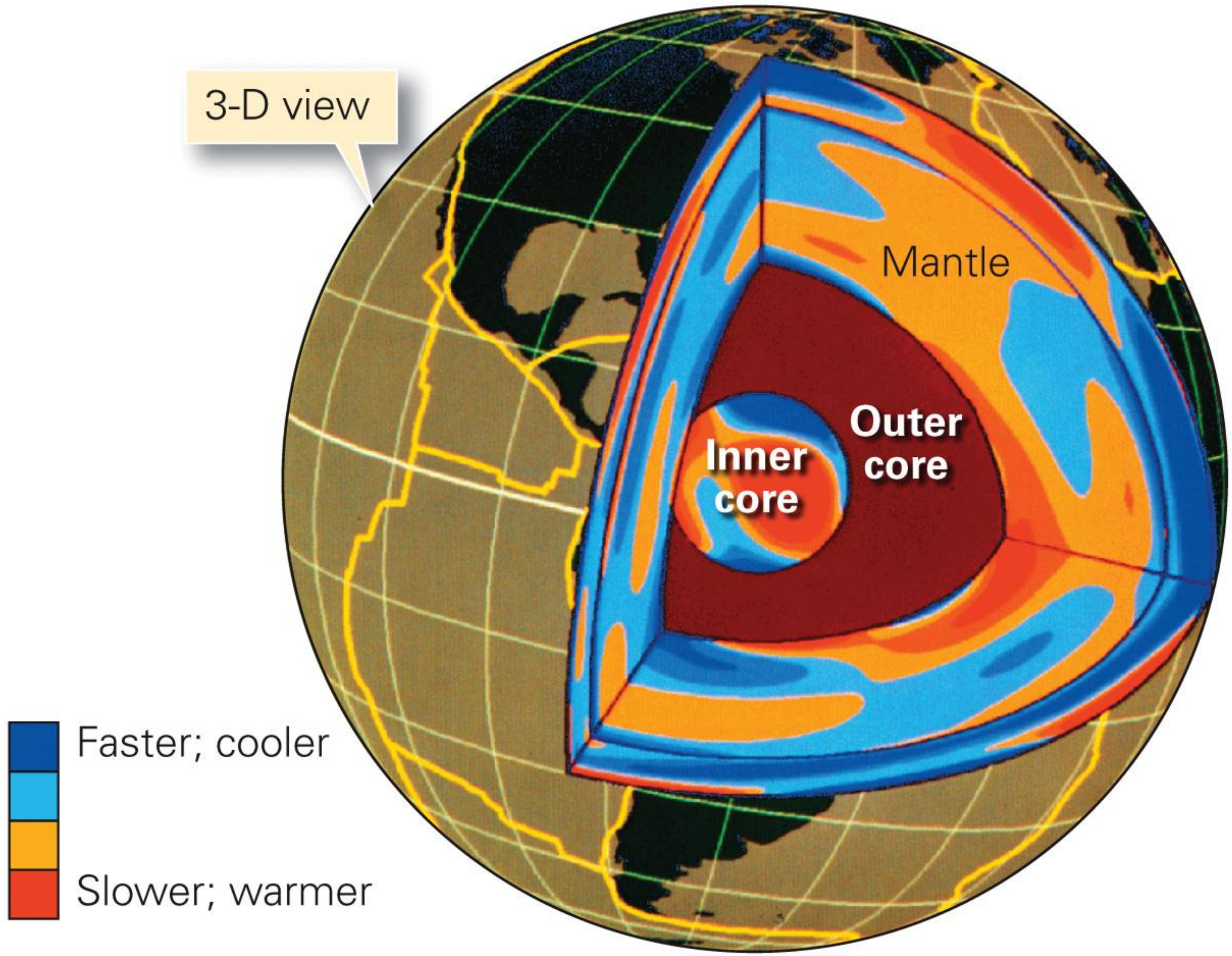


Make me sick

P-Wave Refraction & The Core-Mantle Boundary

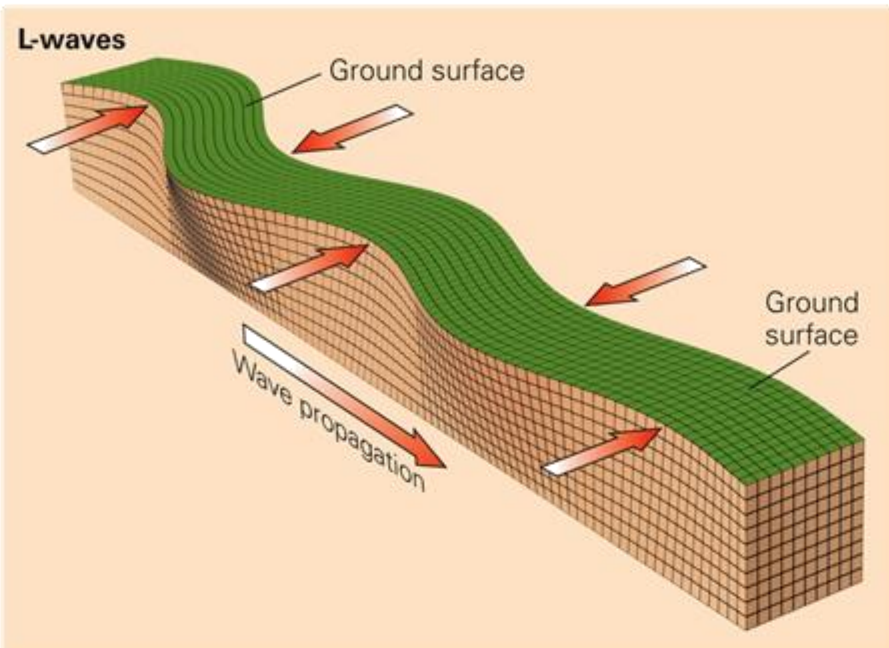


Seismic Velocities - Tomography

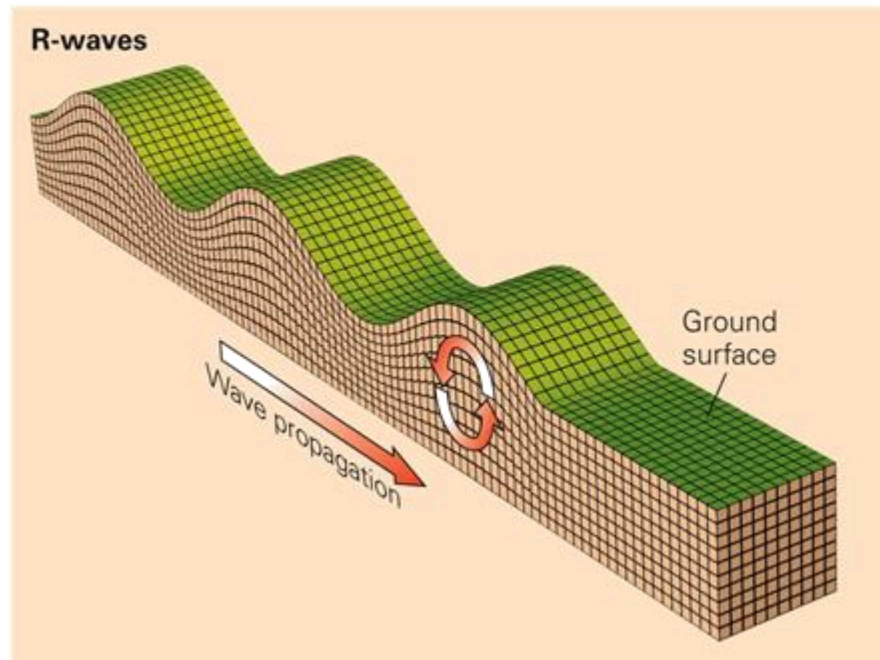


5. Seismic Body Waves: L & R-waves

- Surface waves travel along Earth's exterior. Surface waves are the slowest and most destructive.



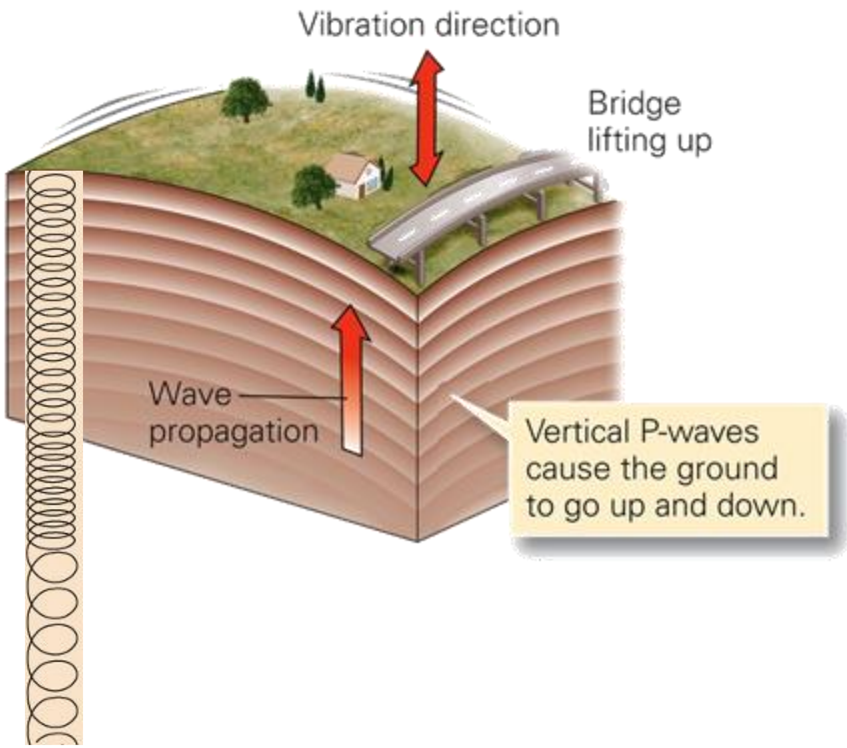
Love waves - lollop

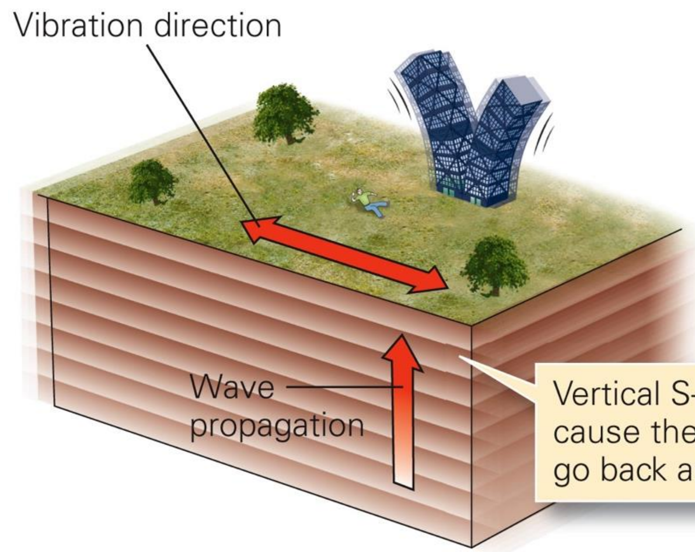


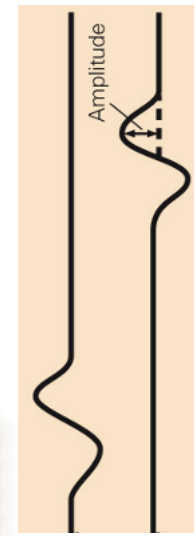
R waves - roll

5. Earthquake Seismic Waves

- Earthquake waves arrive in a distinct sequence with different motions.



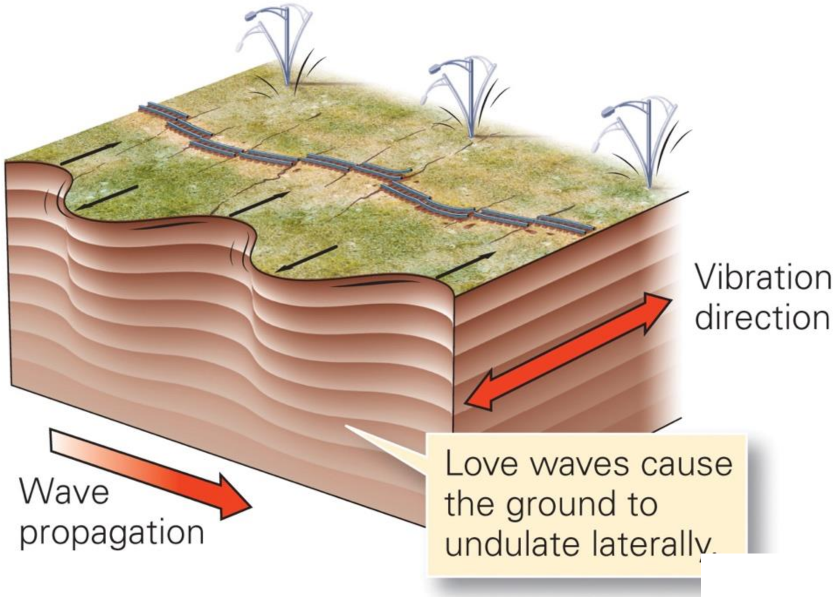




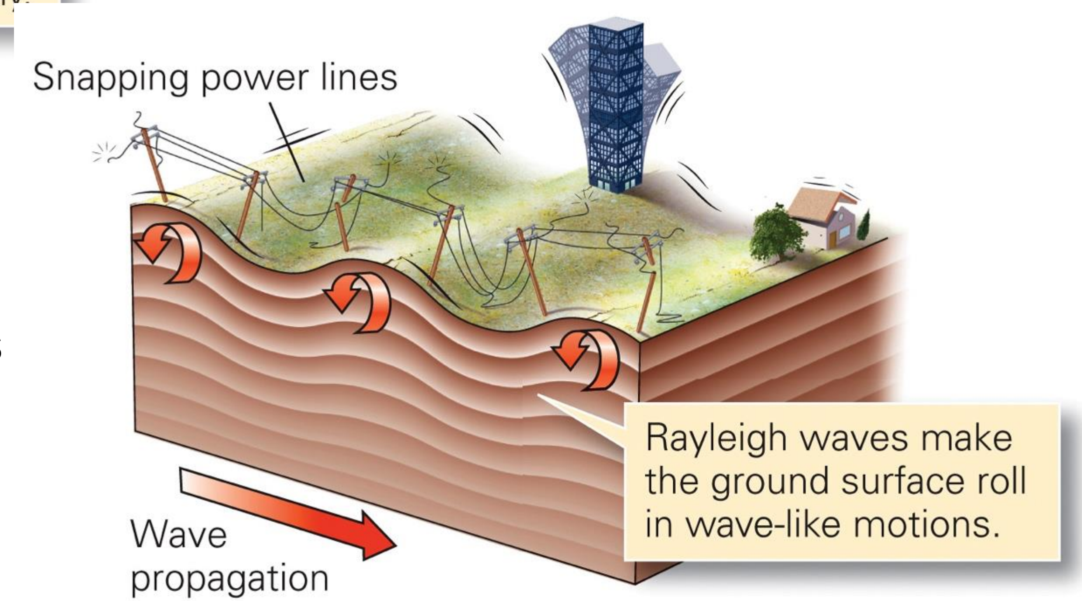
Adapted from Marshak (2019)

5. Earthquake Seismic Waves

L Waves

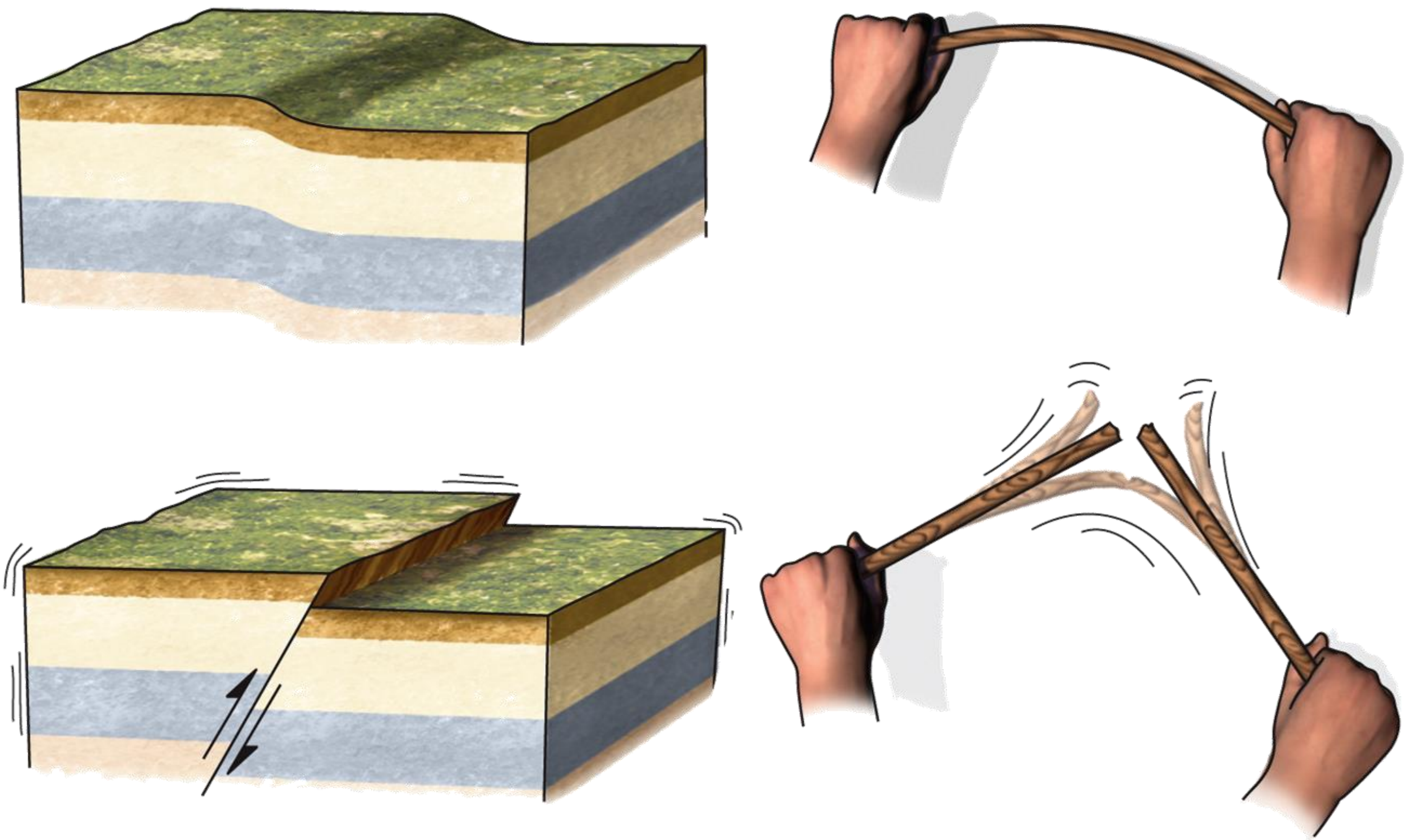


R Waves



6. Earthquakes (all seismic sources) = sudden release of elastic energy. Micro- to fractures: dilation

Time between release: seismic gap



Adapted from: Marshak (2019), Norton/Wiley

6. Earthquakes

6. Earthquakes 2 – Seismic Gap Theory

No.	Mag	Location	Alternative Name	Date (UTC)
1.	9.5	Bio-Bio, Chile Chile	Valdivia Earthquake	1960-05-22
2.	9.2	Southern Alaska Alaska	1964 Great Alaska Earthquake, Prince William Sound Earthquake, Good Friday Earthquake	1964-03-28
3.	9.1	Off the West Coast of Northern Sumatra Sumatra	Sumatra-Andaman Islands Earthquake, 2004 Sumatra Earthquake and Tsunami, Indian Ocean Earthquake	2004-12-26
4.	9.1	Near the East Coast of Honshu, Japan	Tohoku Earthquake Japan	2011-03-11
5.	9.0	Off the East Coast of the Kamchatka Peninsula, Russia	Kamchatka, Russia E Russia	1952-11-04
6.	8.8	Offshore Bio-Bio, Chile Chile	Maule Earthquake	2010-02-27
7.	8.8	Near the Coast of Ecuador	1906 Ecuador-Colombia Earthquake Ecuador	1906-01-31
8.	8.7	Rat Islands, Aleutian Islands, Alaska	Rat Islands Earthquake Alaska	1965-02-04
9.	8.6	Eastern Xizang-India border region	Assam, Tibet Tibet	1950-08-15
10.	8.6	Off the West Coast of Northern Sumatra	Sumatra	2012-04-11

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Papers on Seismology

Seismic Gap Hypothesis: Ten years after

Yan Y. Kagan, David D. Jackson

First published: 10 December 1991 | **https://doi.org/10.1029/91JB02210** |

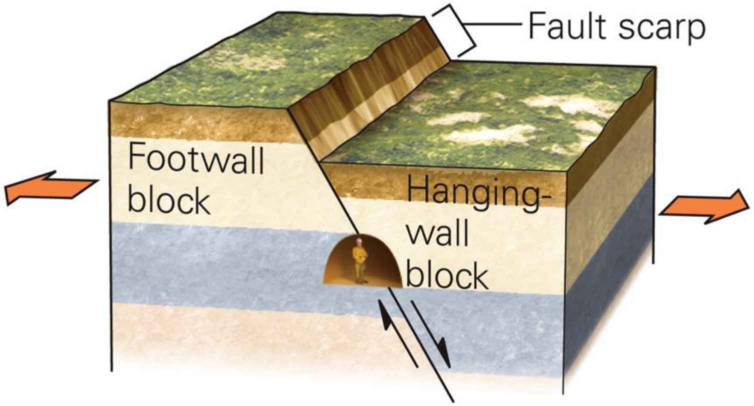
https://doi.org/10.1029/91JB02210

In a known seismic zone, the longer the gap between earthquakes, the greater the magnitude/intensity: Kagan & Jackson (1991) agree with McCann et al. (1979)

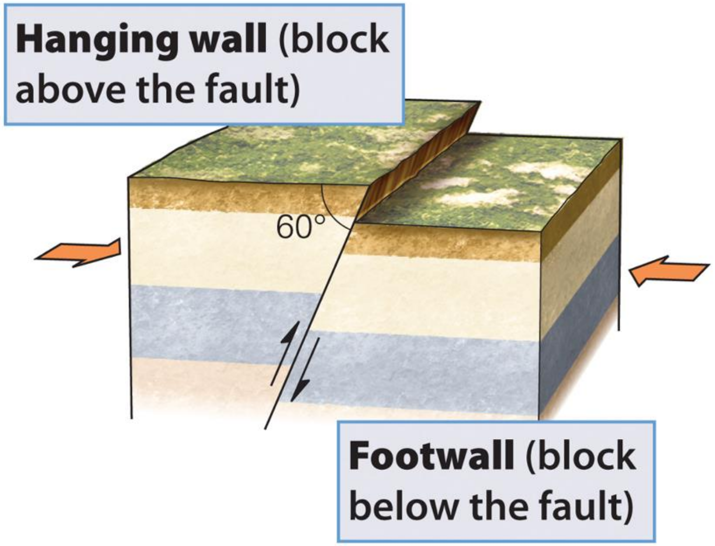
https://www.usgs.gov/programs/earthquake-hazards/science/20-largest-earthquakes-world-1900

6. Faults

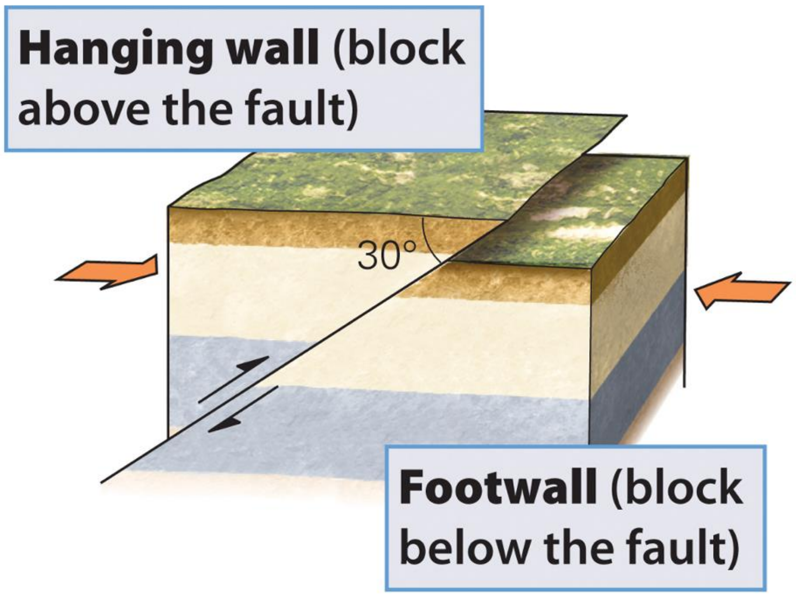
Normal Fault



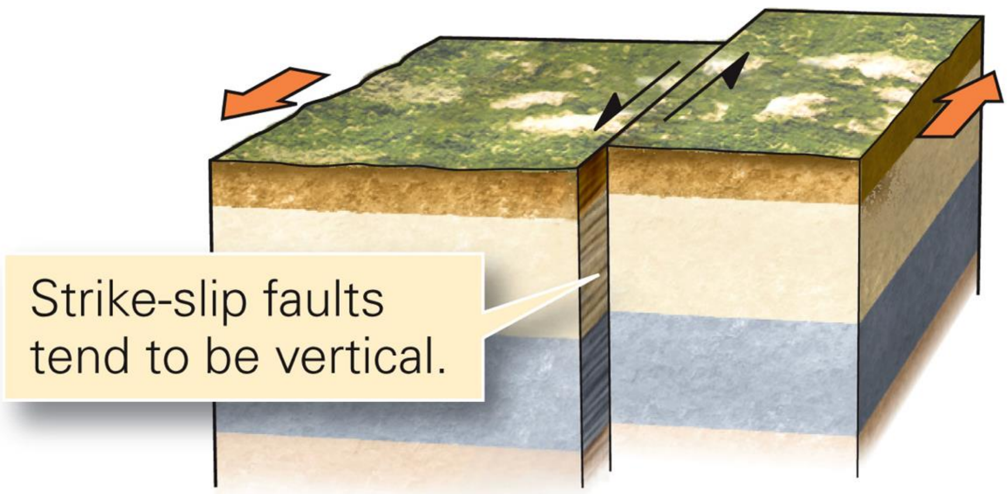
6. Reverse Fault



6. Thrust Fault

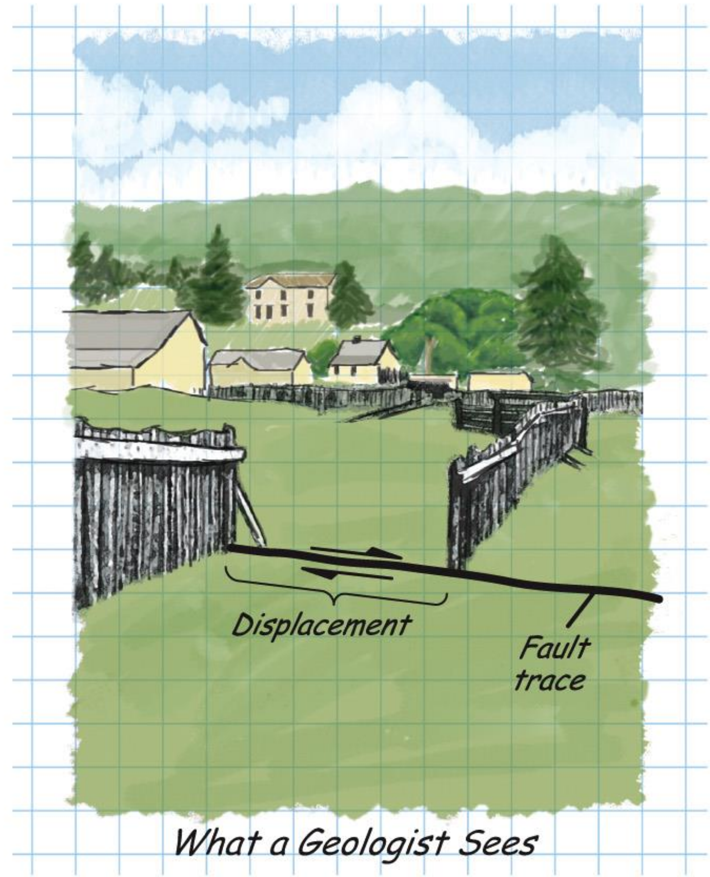


6. Strike-Slip Fault



6. Strike-Slip Fault

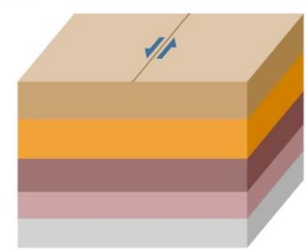
- The **displacement** (or offset) is the amount of movement across a fault.



6. Strike-Slip Fault

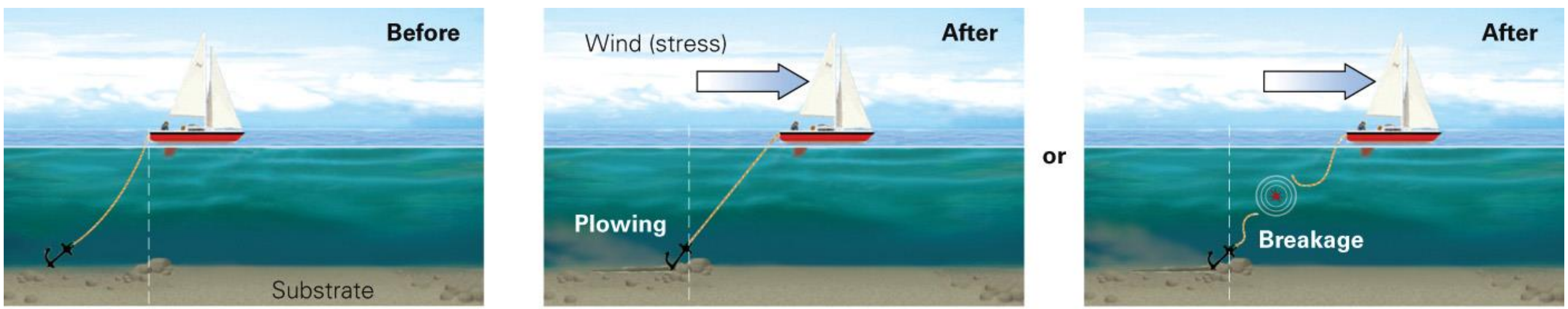
- Faults are found in many places in the crust and include both active and inactive faults.

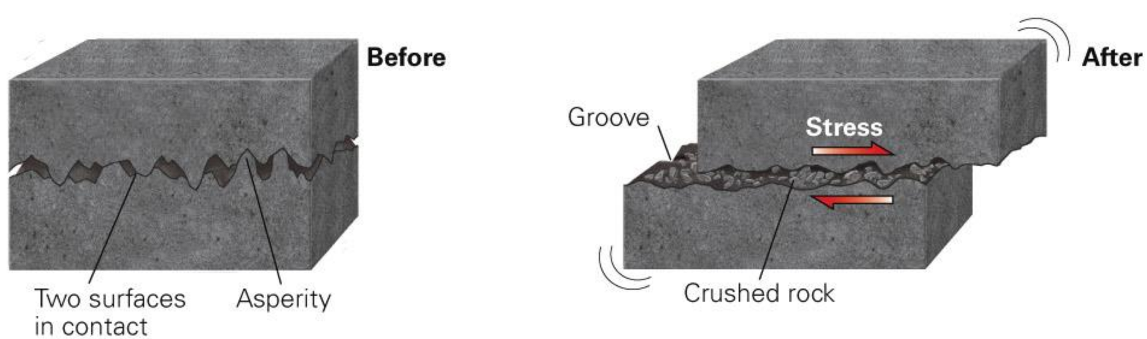
On a strike-slip fault, one crustal block slides laterally past another. There is no motion up and down.



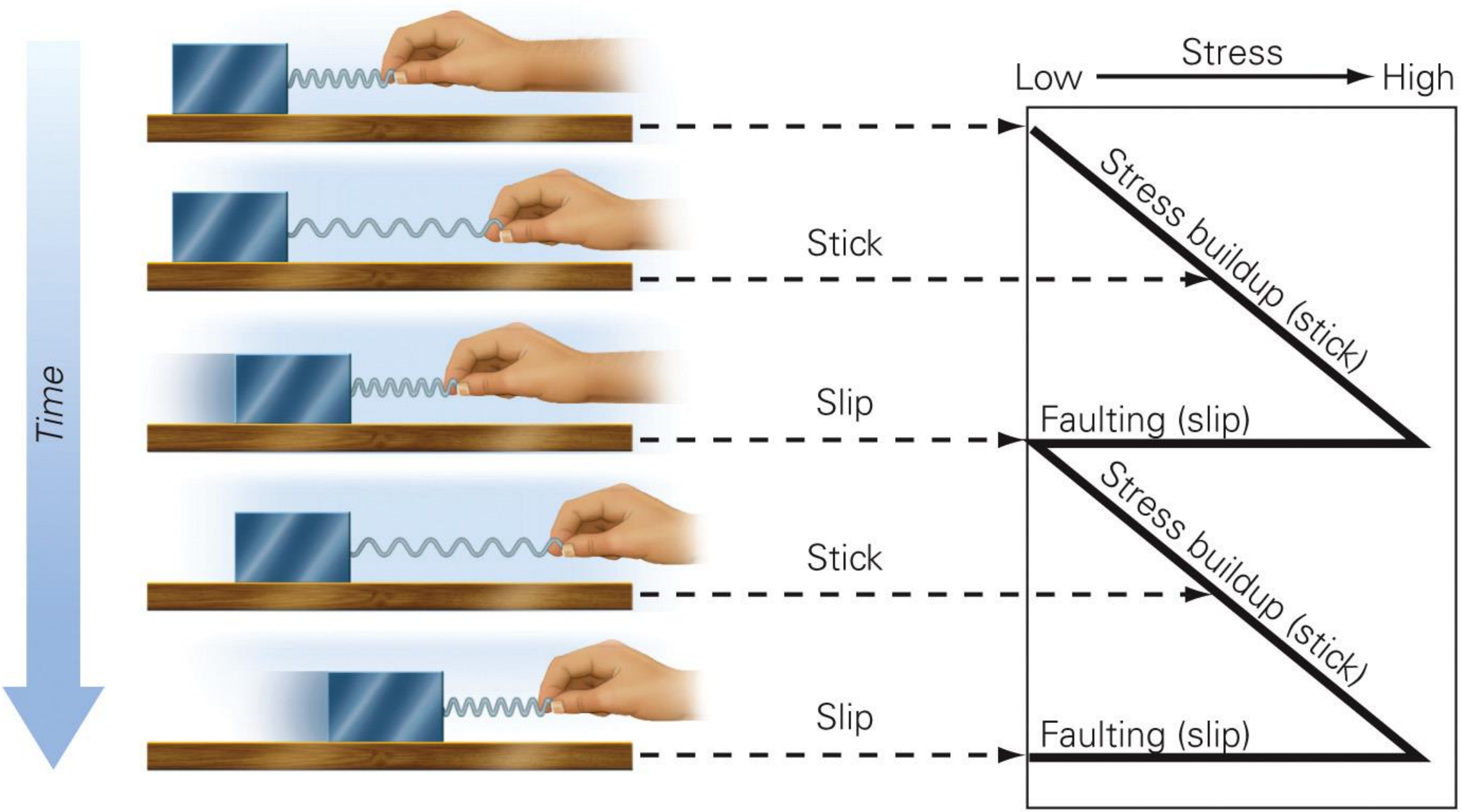
6. Stick-Slip Behavior

- When a fault moves, it is quickly slowed by friction due to asperities (bumps) along the fault. Eventually, strain will build up again through **dilation** and cause another episode of failure and motion.

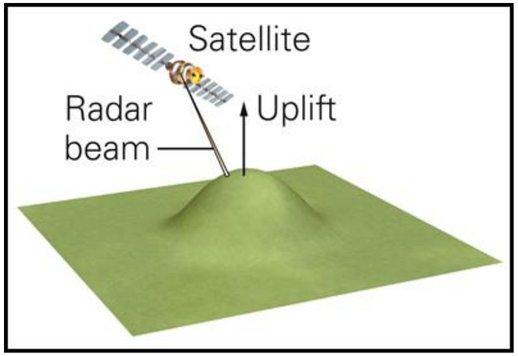


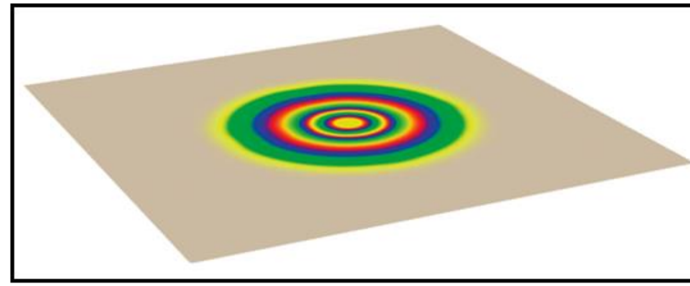


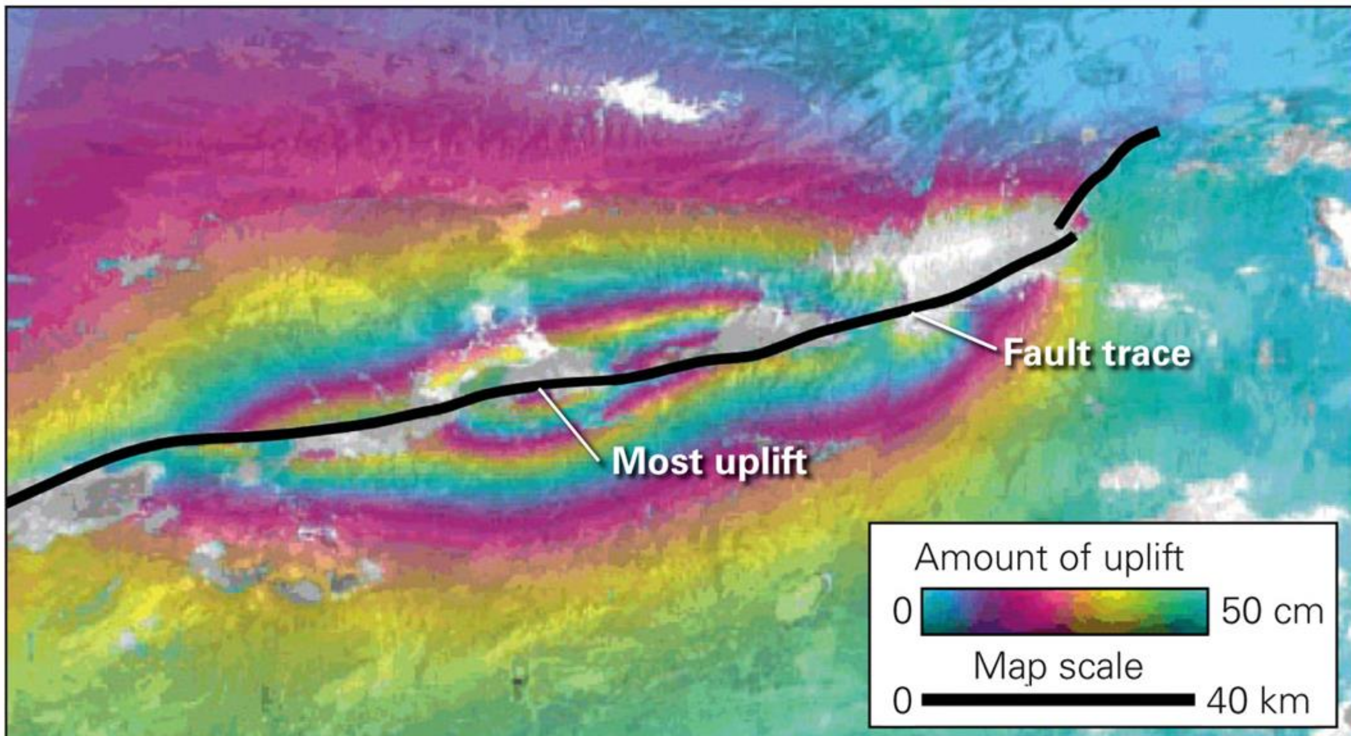
6. Stick-Slip Behaviour



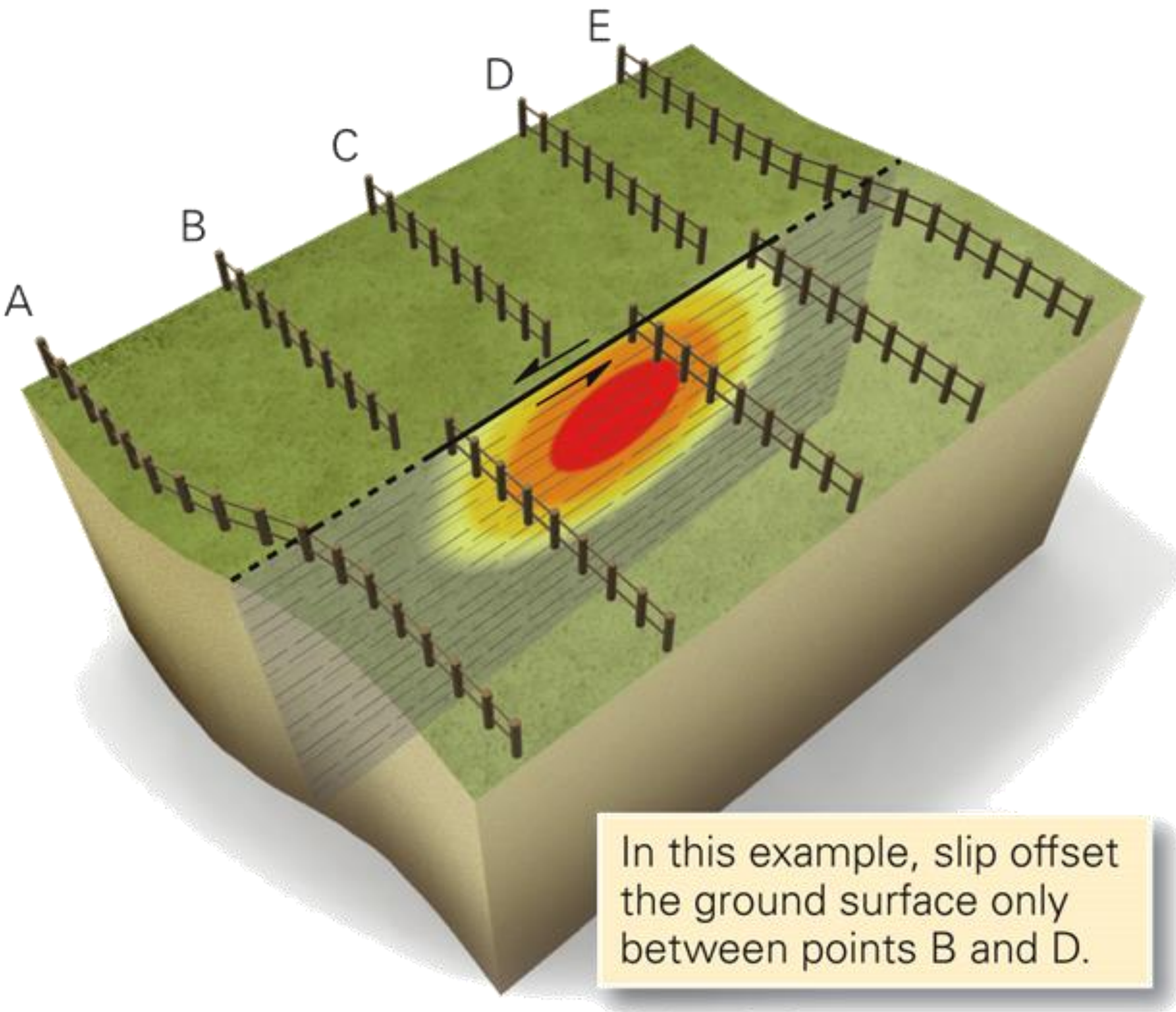
6. Elastic Strain & Dilation





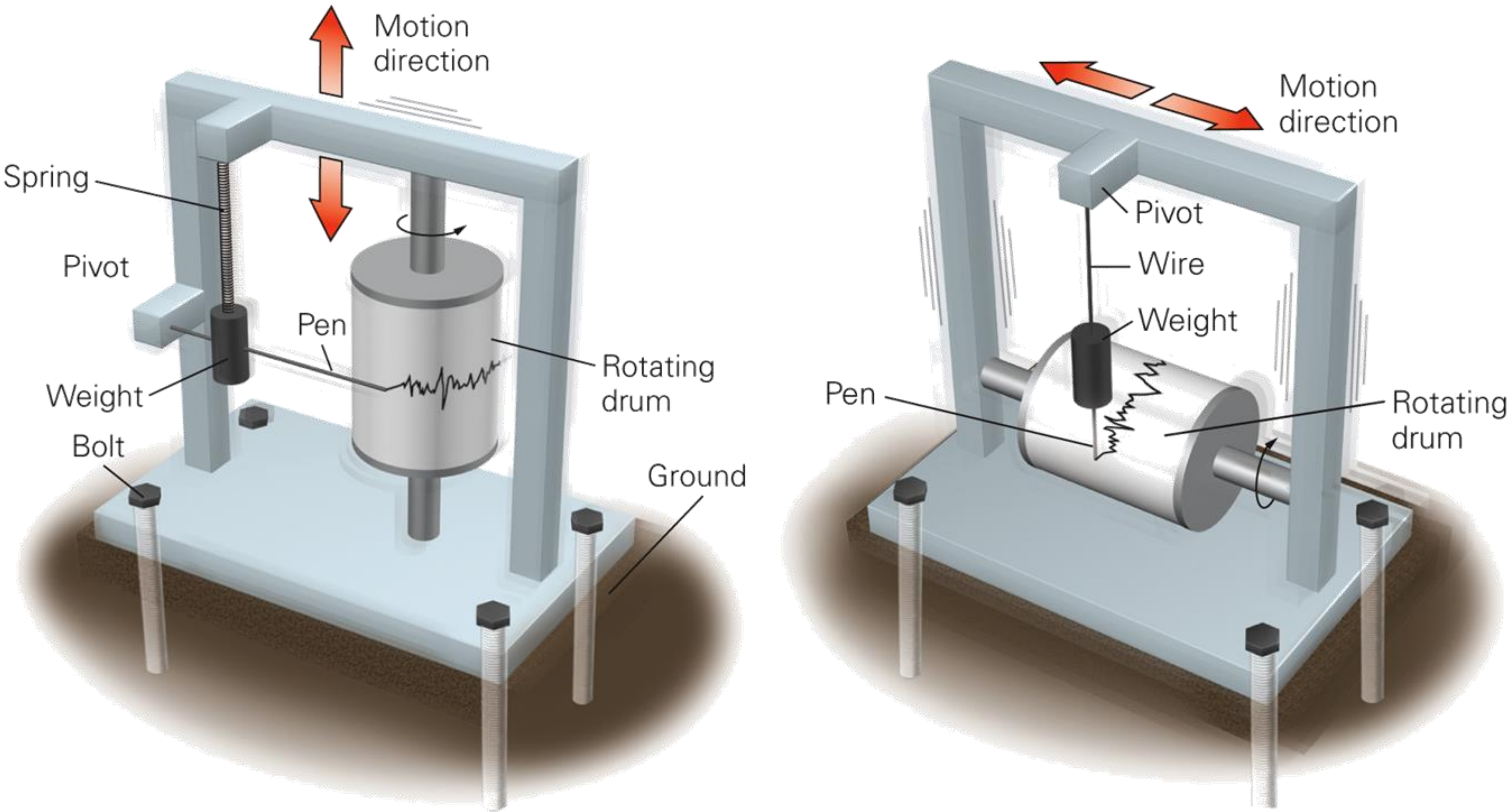


6. Displacement – elasticity

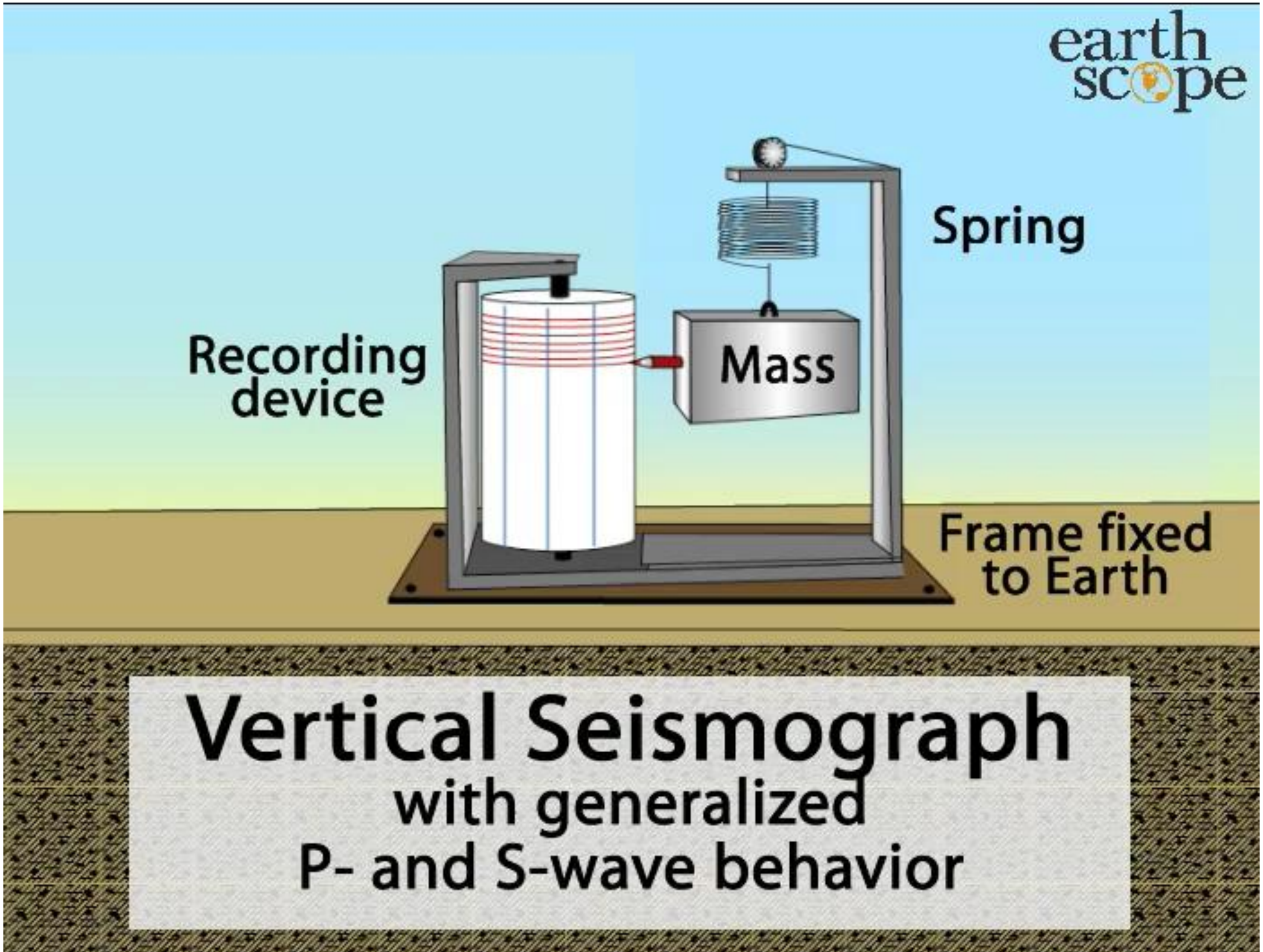


In this example, slip offset the ground surface only between points B and D.

7. Monitoring: seismographs

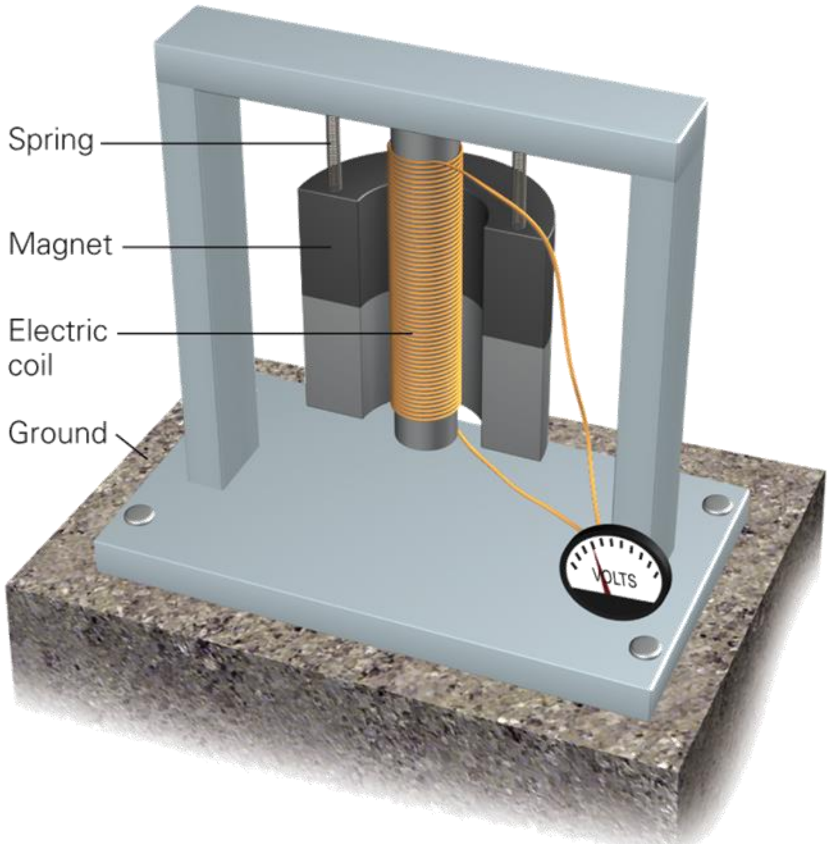


Seismic Waves = Vibration (solid/liquid) – **Soun**d (air/gas)



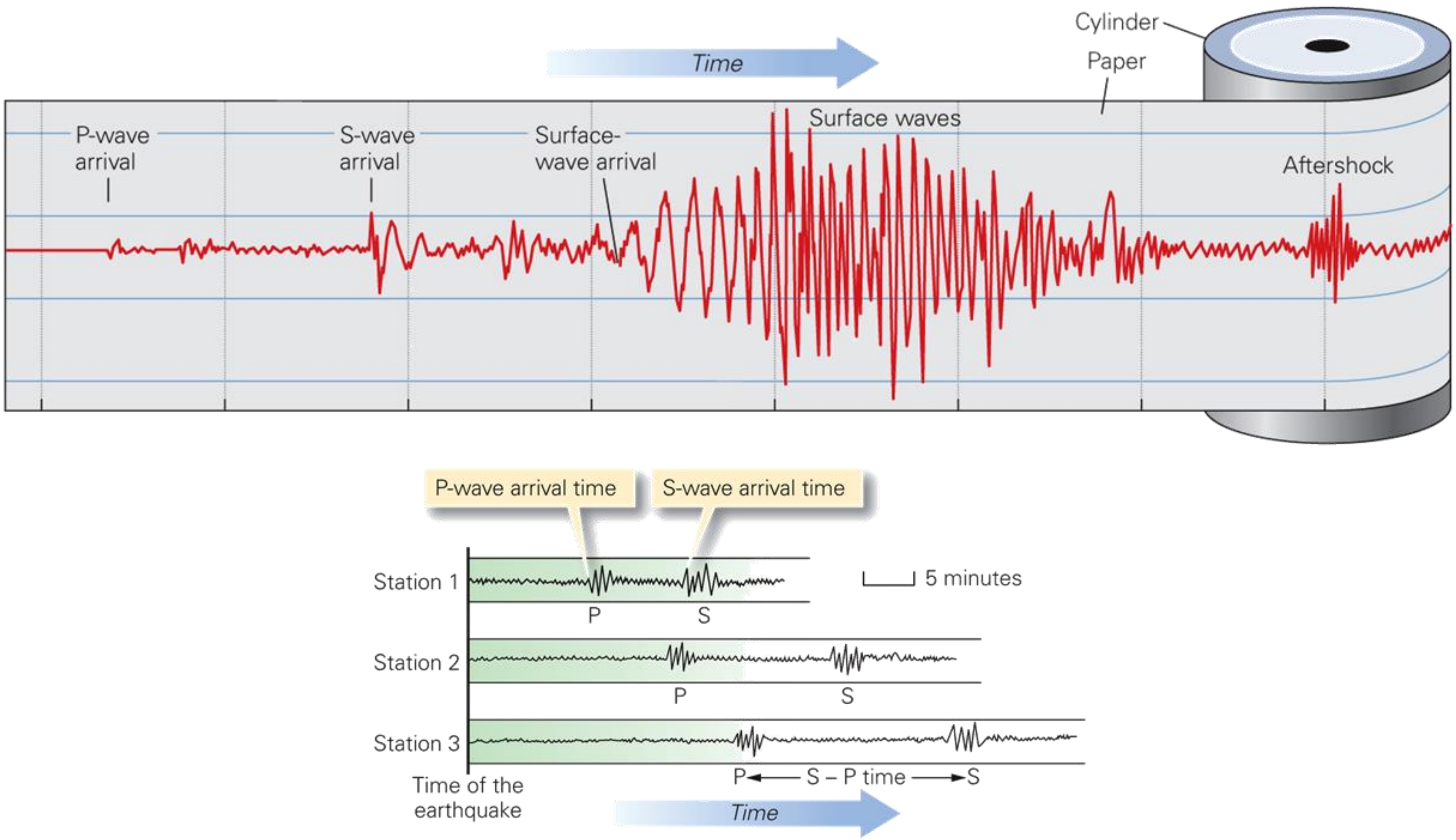
www.iris.edu

7. Seismographs



7. Seismogram

- Seismogram is the data record by a seismograph. It depicts earthquake wave behavior, particularly the arrival times of the different waves, which are used to determine the distance to the epicenter.

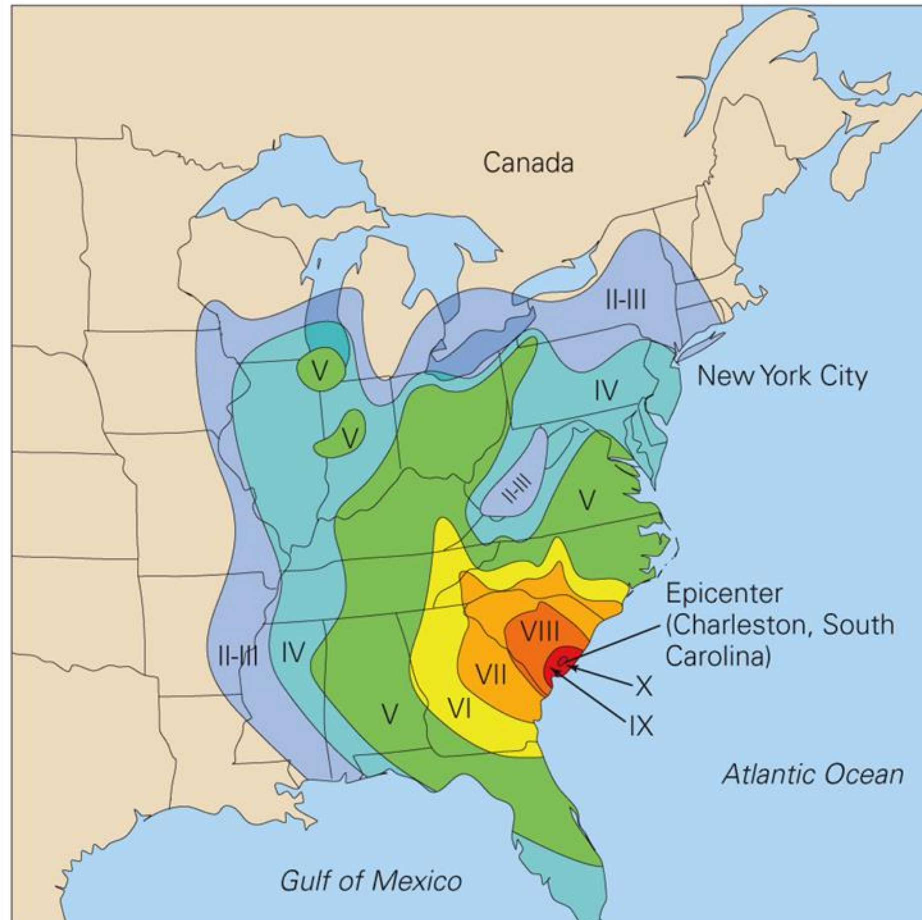


7. Magnitude and Intensity

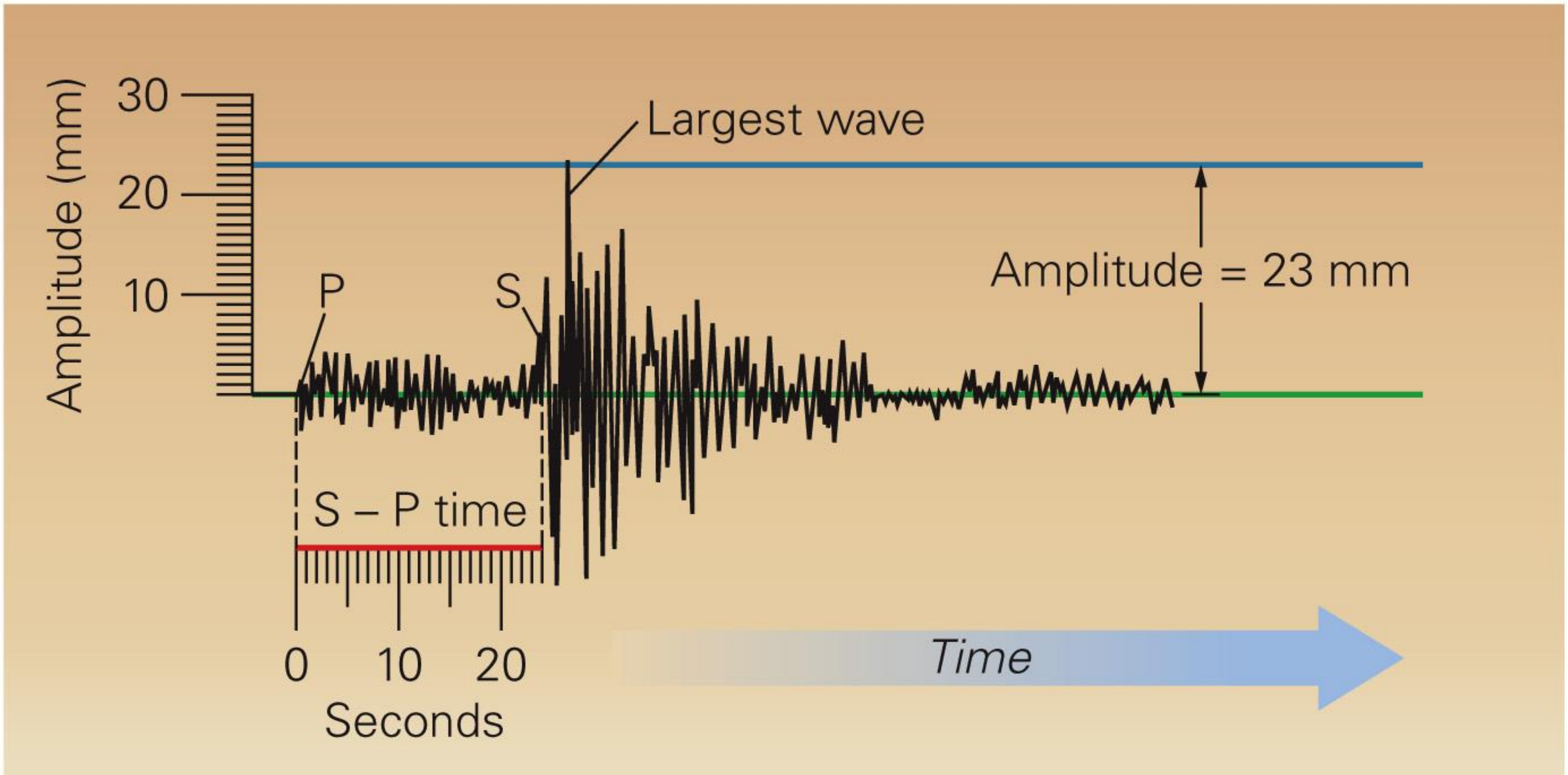
TABLE 10.3 Adjectives for Describing Earthquakes

Adjective	Magnitude	Approximate maximum intensity at epicenter*	Effects
Great	>8.0	X to XII	Major to total destruction
Major	7.0 to 7.9	IX to X	Great damage
Strong	6.0 to 6.9	VII to VIII	Moderate to serious damage
Moderate	5.0 to 5.9	VI to VII	Slight to moderate damage
Light	4.0 to 4.9	IV to V	Felt by most; slight damage
Minor	<3.9	III or smaller	Felt by some; hardly any damage

*For upper-crustal earthquakes in continents.

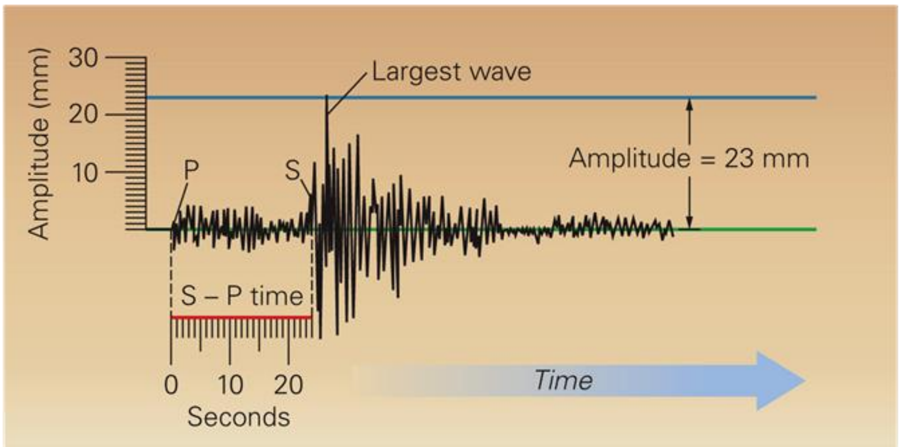


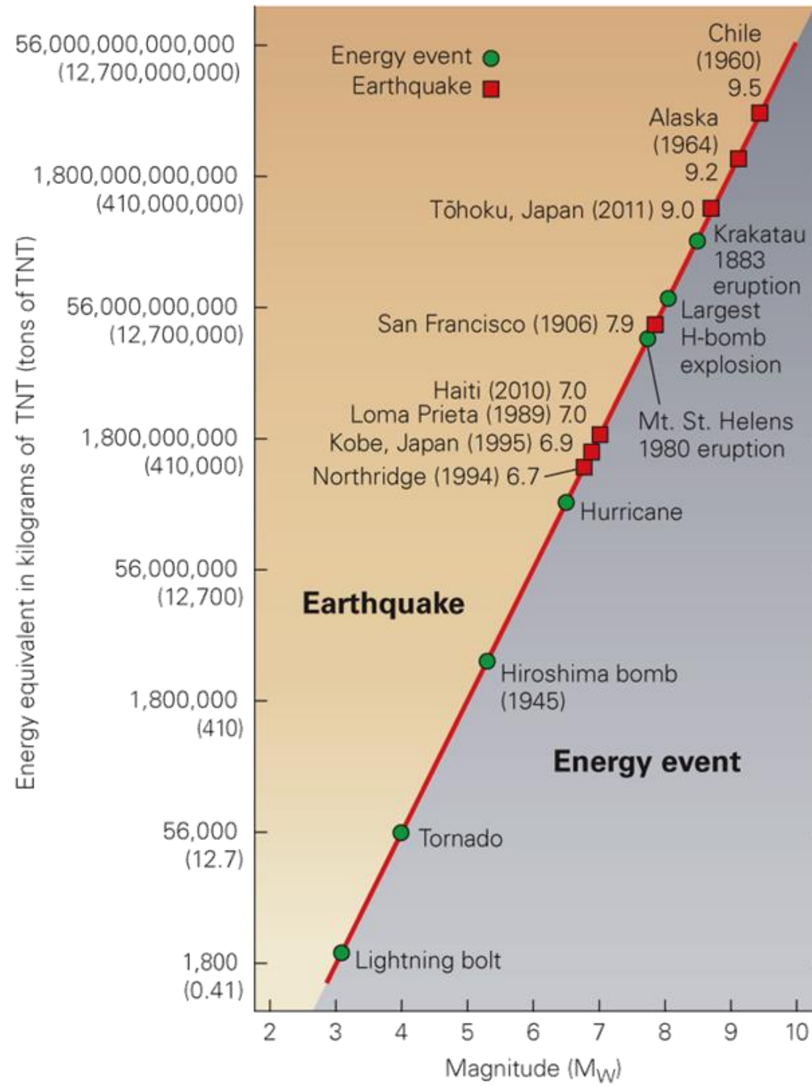
7. Magnitude



Amplitude (mm)
30
20
10
Largest wave
Amplitude = 23 mm
P
S
S – P time
0
10
20
Seconds
Time

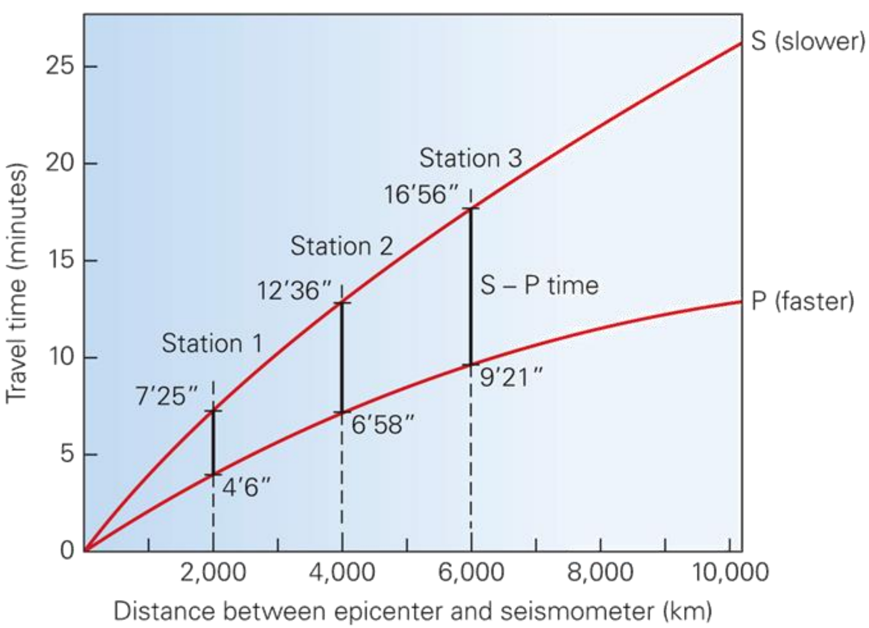
7. Magnitude measurement of size based on the maximum amplitude of seismograph waves.

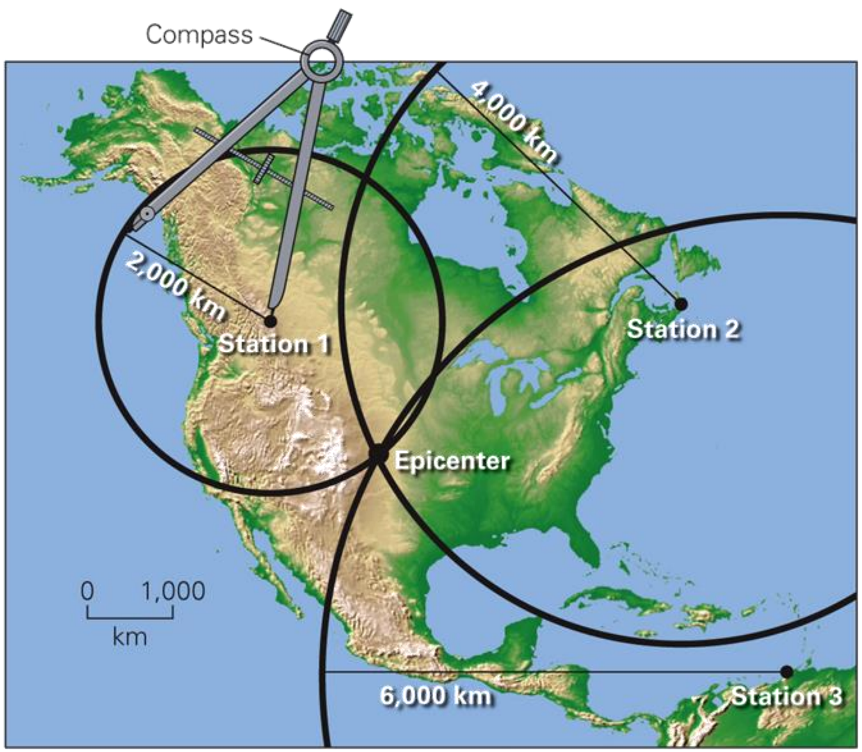




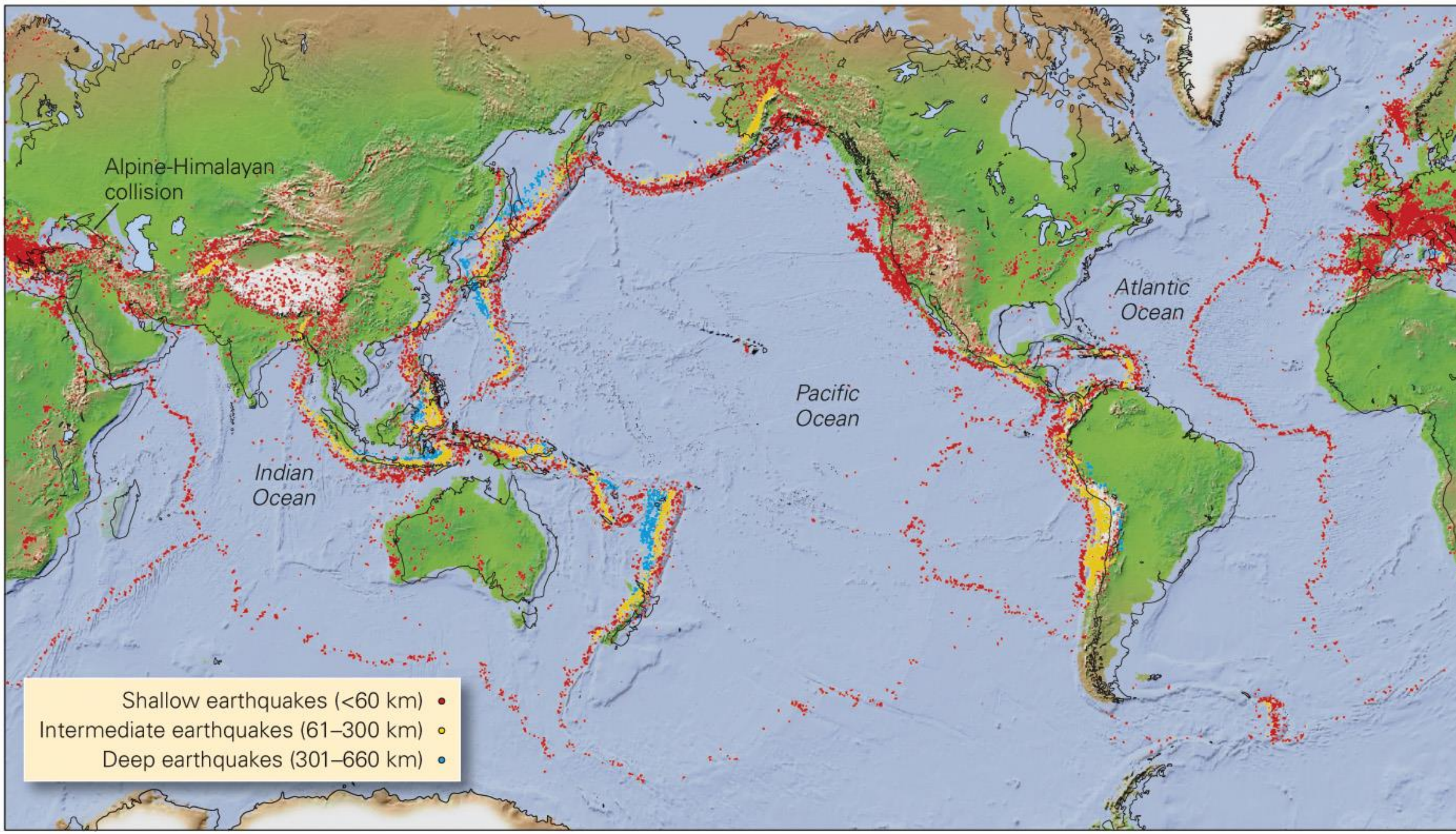
8. Prediction: Locating the Epicenter

- P-wave and S-wave arrival times can be graphed. A travel-time curve plots the increasing delay in arrivals. The time gap yields distance to the epicenter.

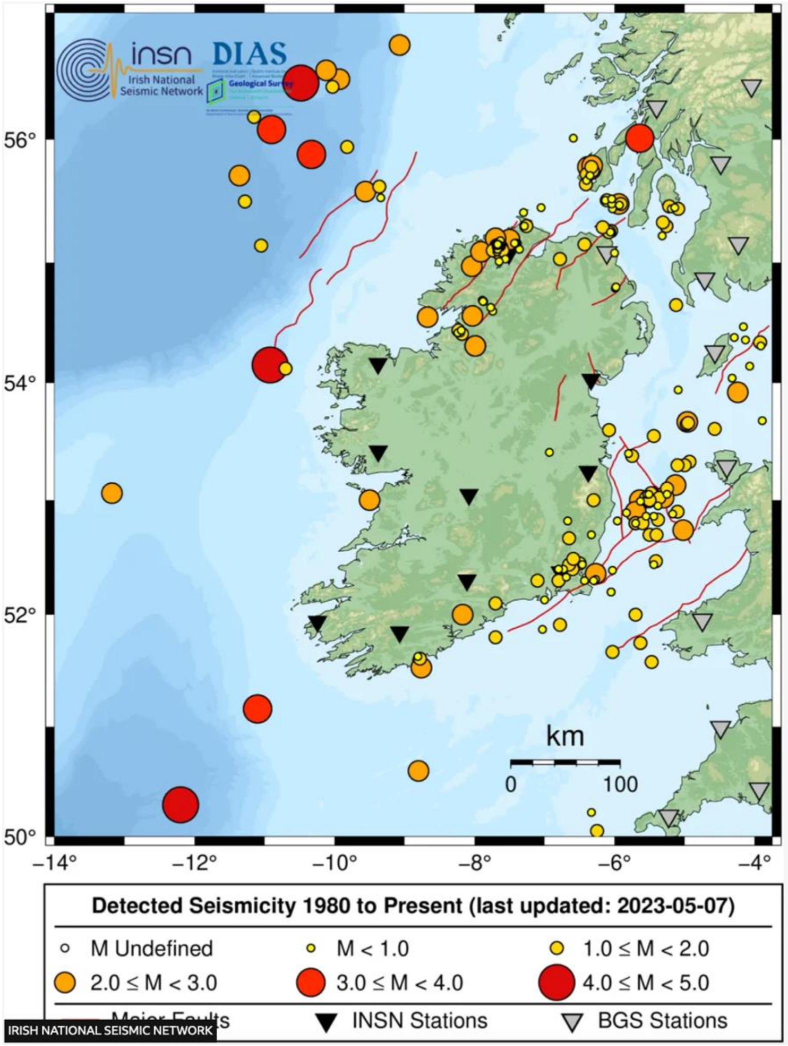




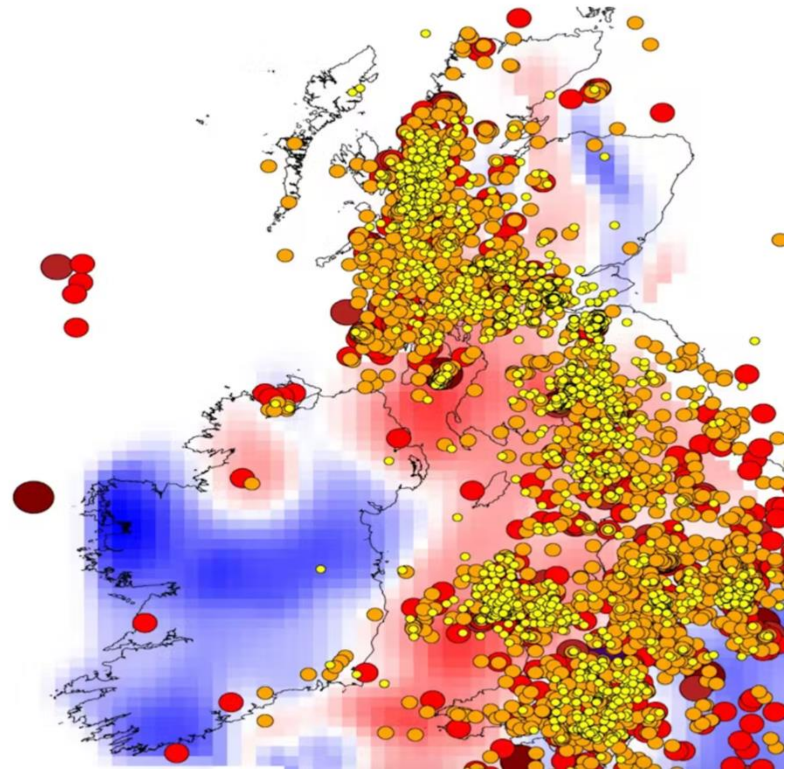
8. Prediction. Earthquakes at Plate Boundaries



8. Intraplate Settings: Away From Tectonic Plate Boundaries



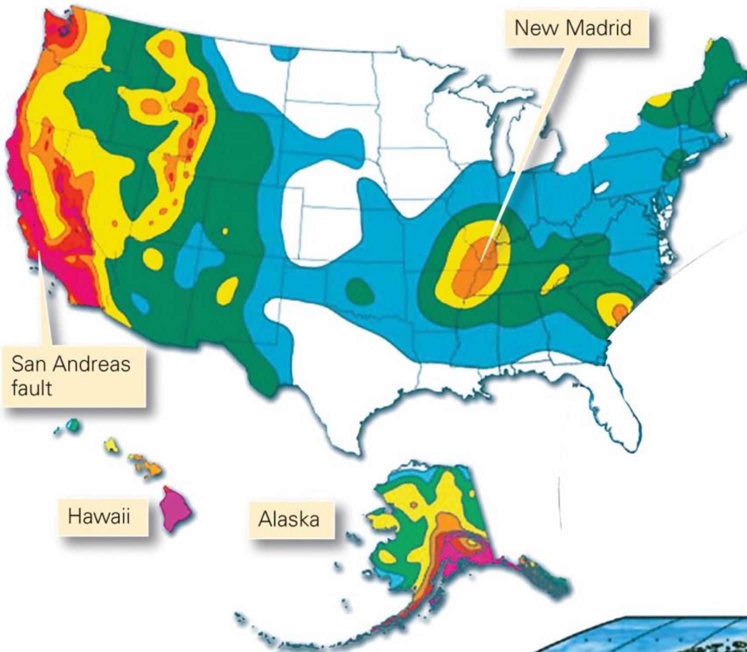
https://www.geplus.co.uk/news/ireland-gets-first-underground-seismic-station-09-08-2022/

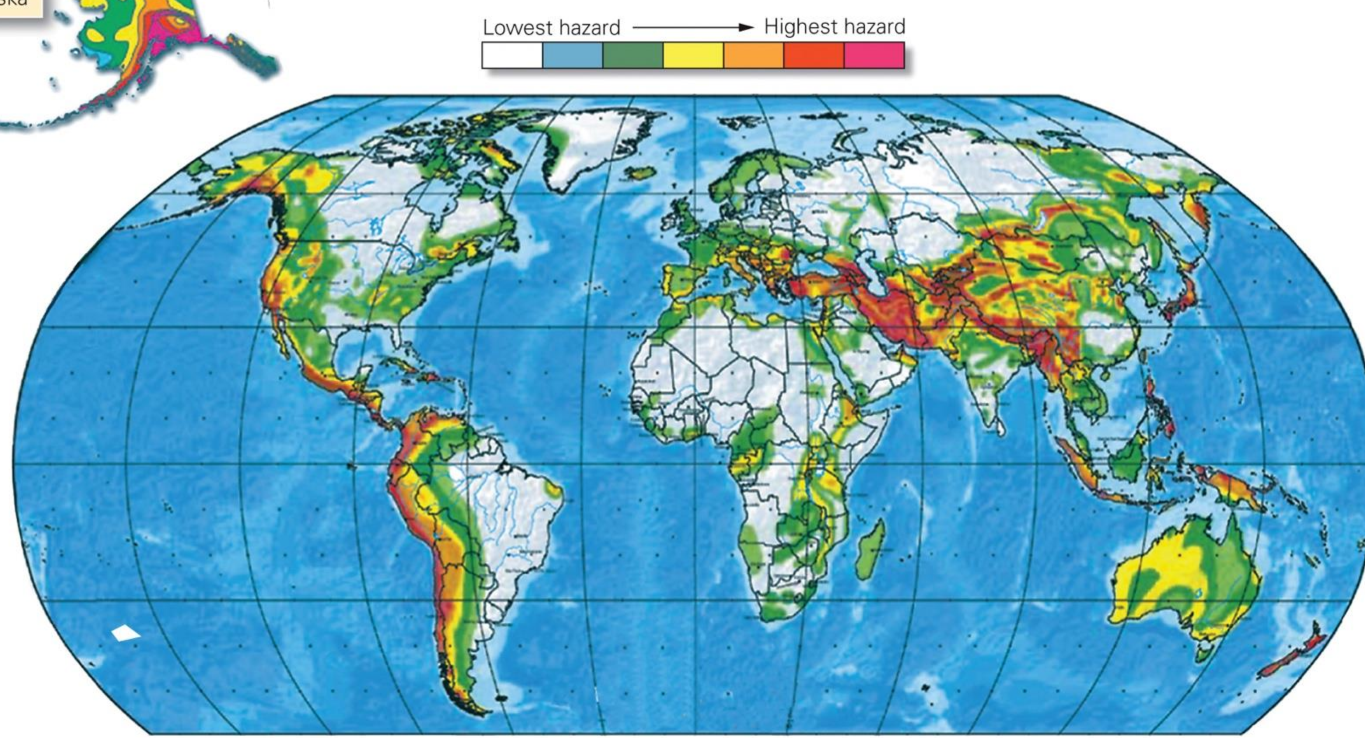


thicker, cooler crust

https://theconversation.com/why-earthquakes-happen-all-the-time-in-britain-but-not-in-ireland-207695

8. Can We Predict Earthquakes?





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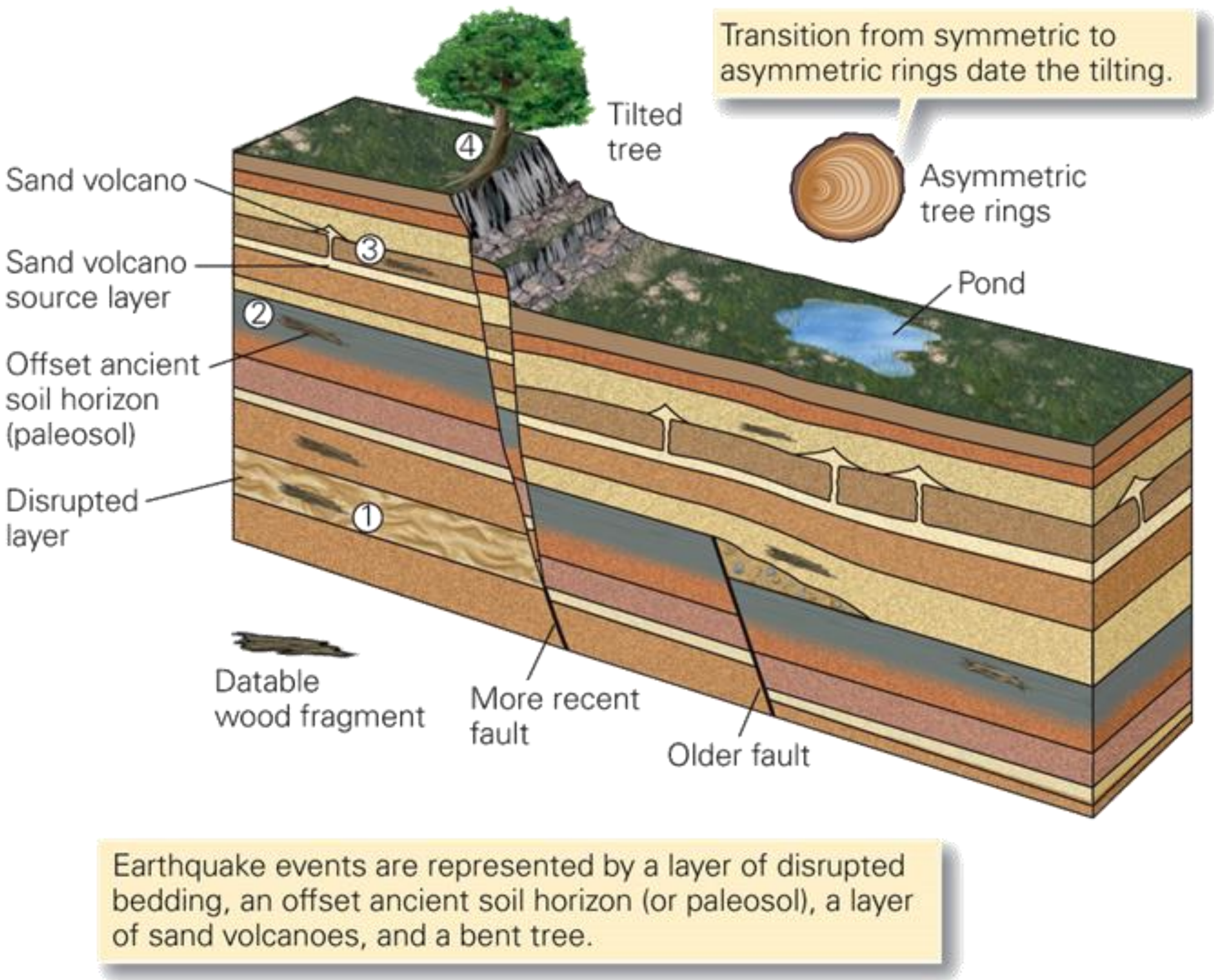
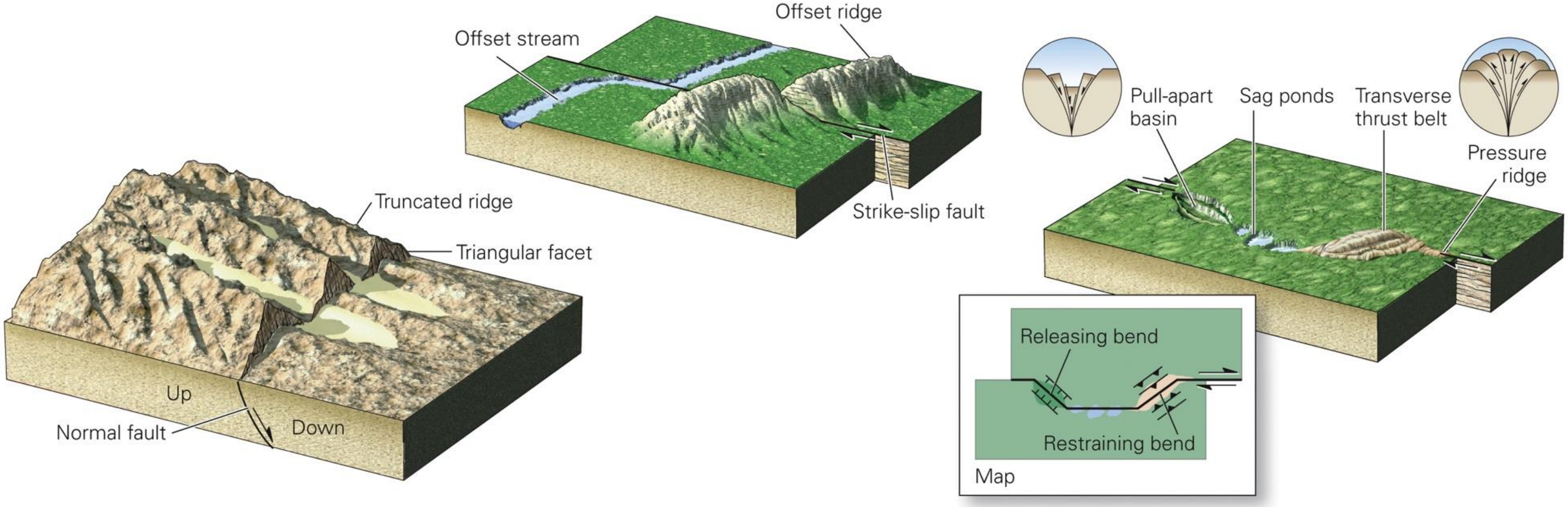
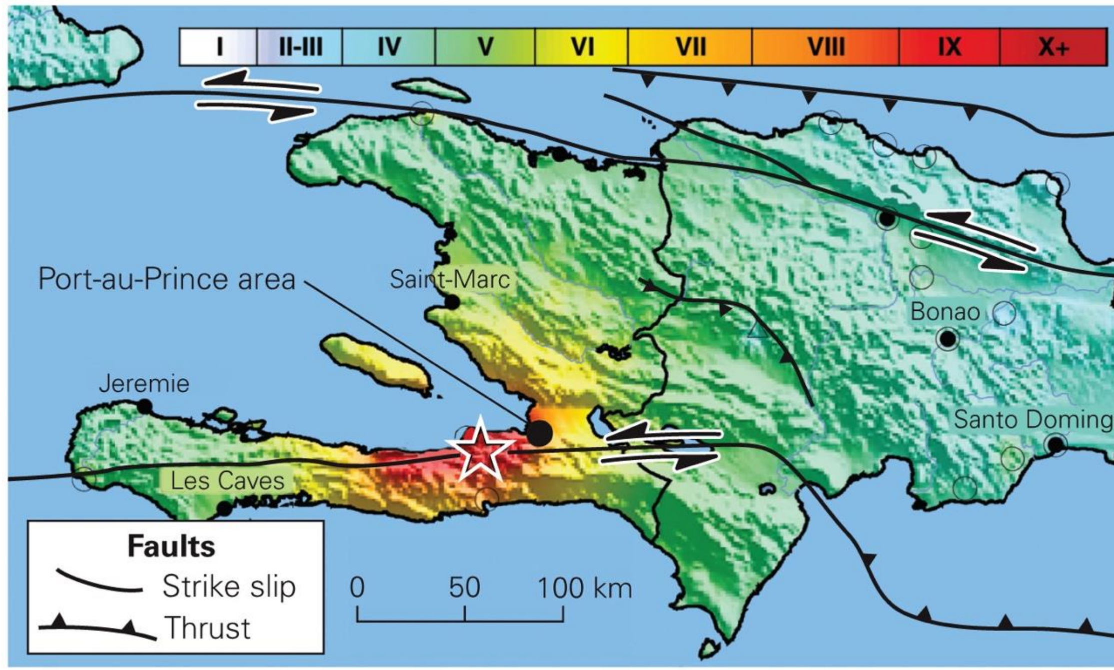


8. Identifying Recent Faults



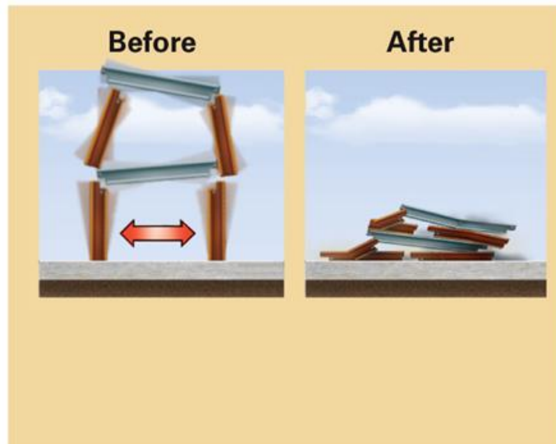
8. Short-Term Predictions

- Earthquakes have precursors:
  - Clustered foreshocks
  - Crustal strain - **dilation**
  - Level changes in wells
  - Gases (Rn, He) in wells
  - Unusual animal behavior

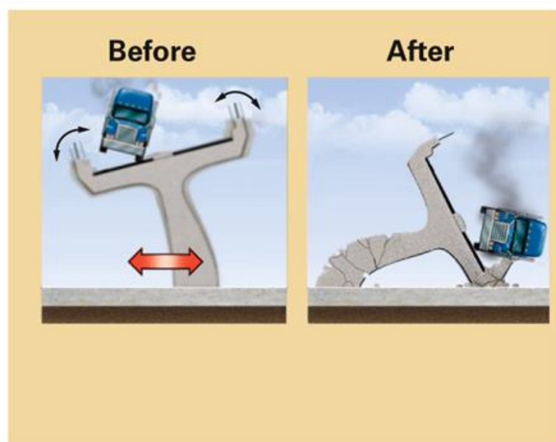


9. Earthquake Damage

- Building floors “pancake.”



- Bridges and roadways topple.

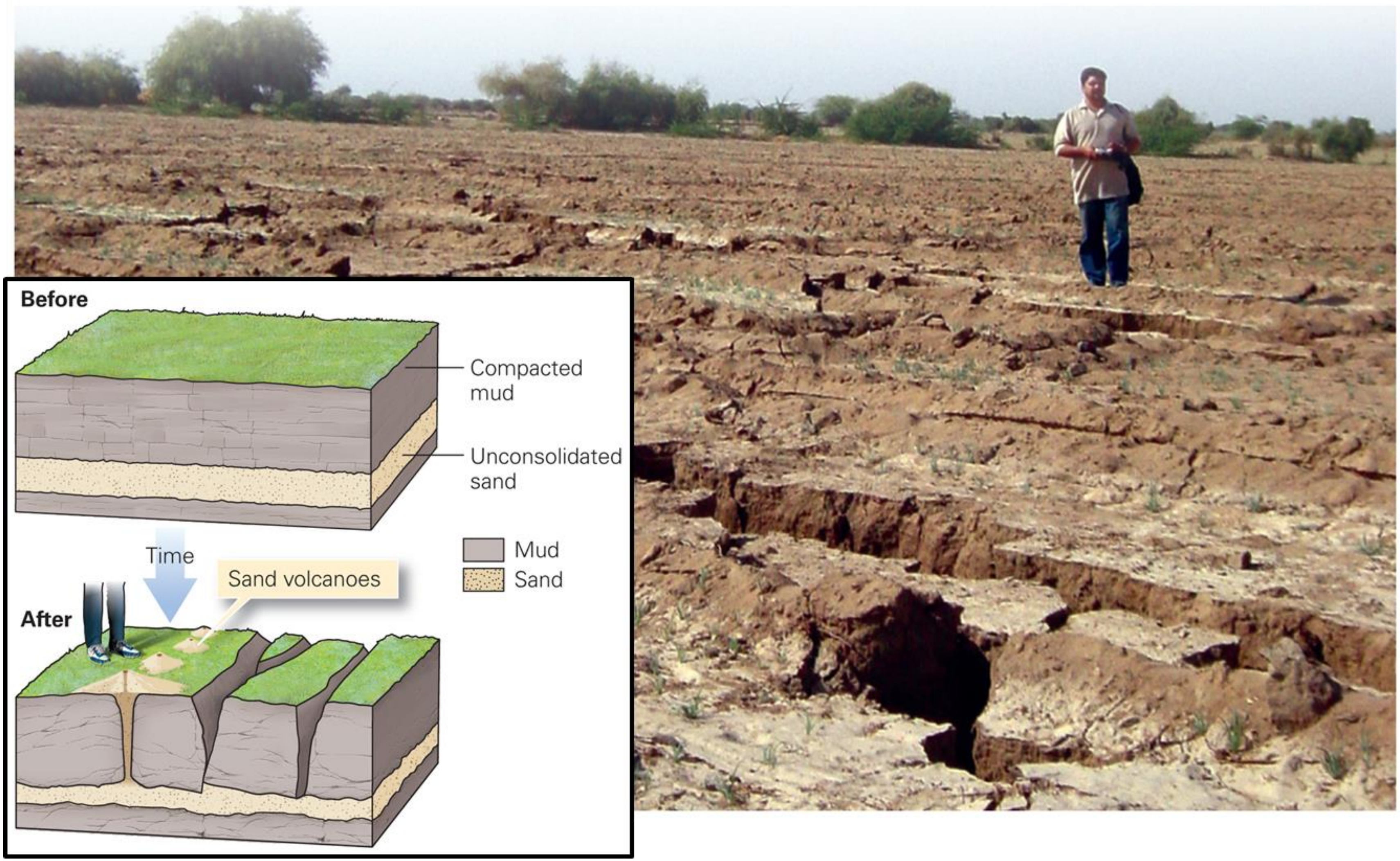


AP Photo; Pacific Press Service/Alamy

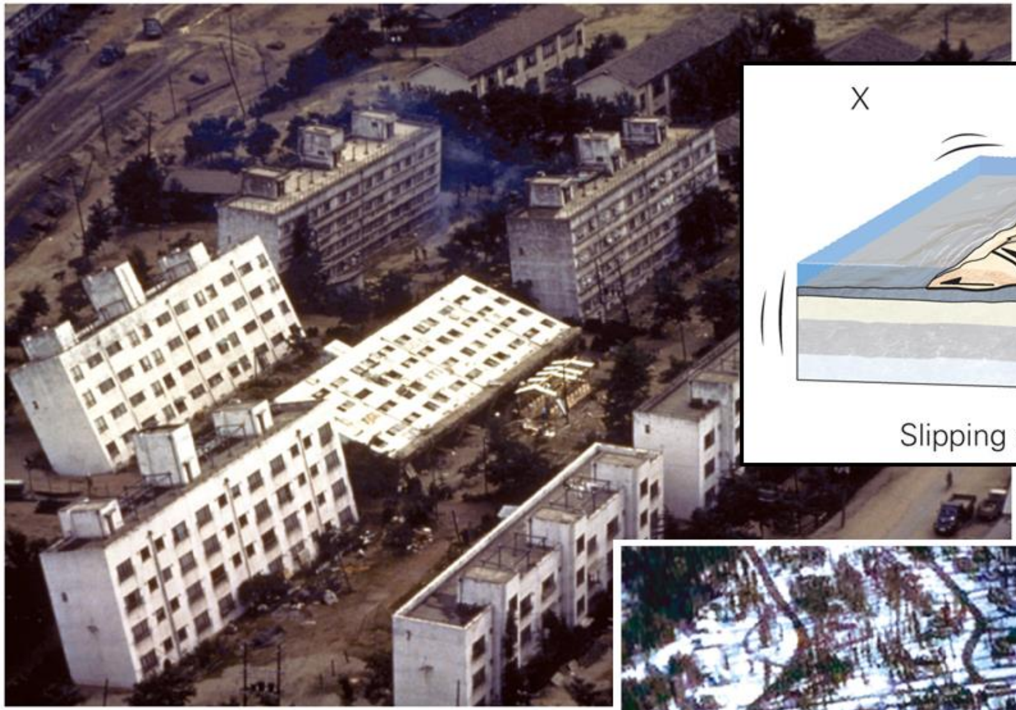
9. Earthquake Hazards: Landslides and Avalanches

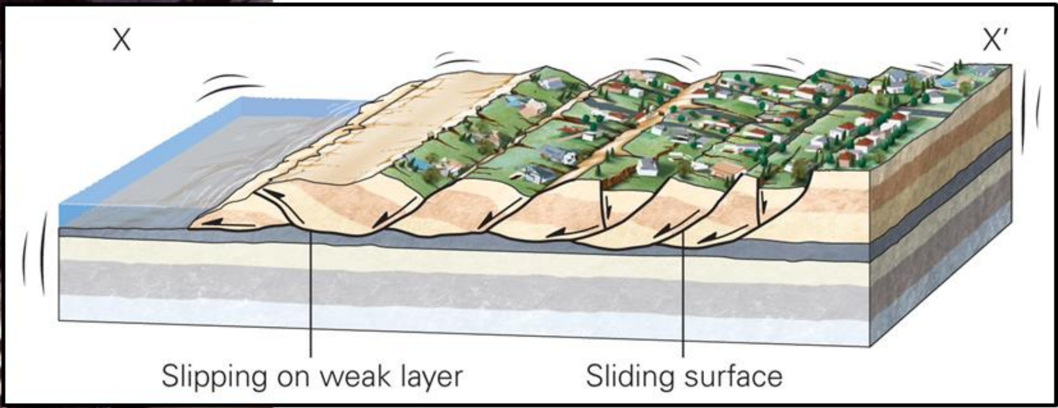
AP Photo; Pacific Press Service/Alamy

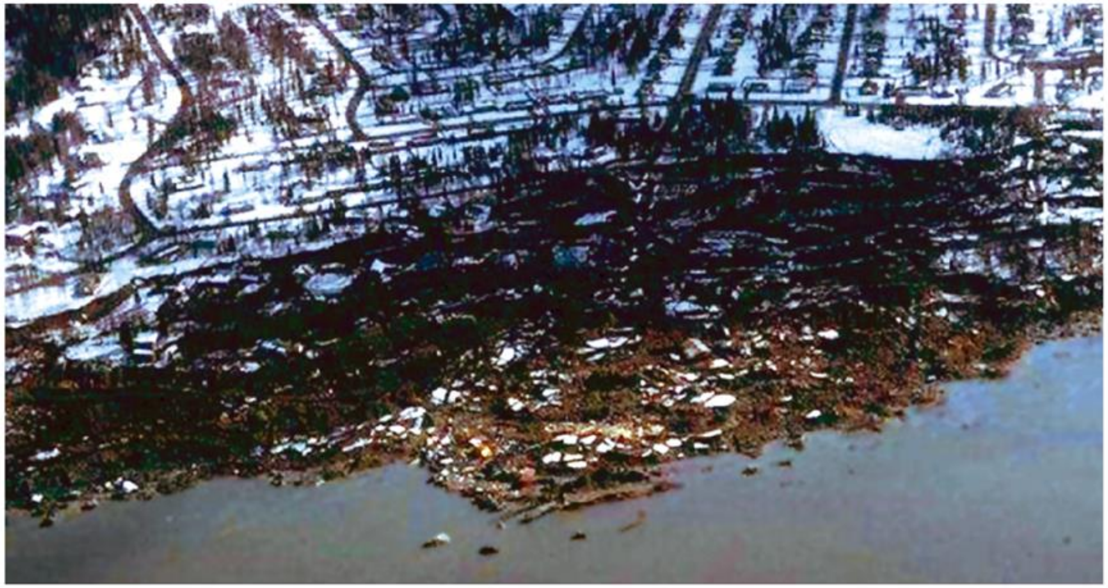
9. Earthquake Hazards: Liquefaction



9. Earthquake Hazards: Liquefaction



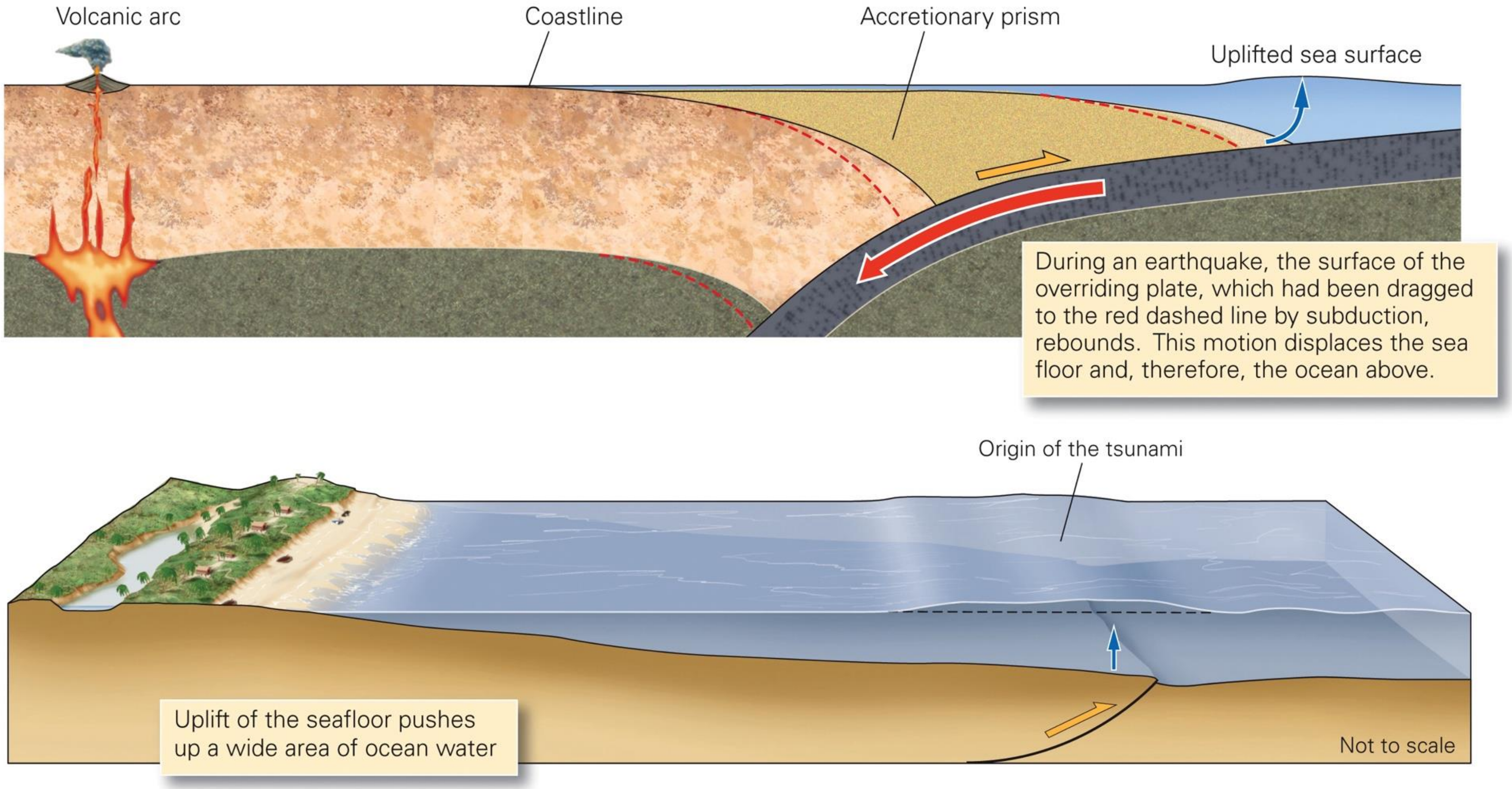




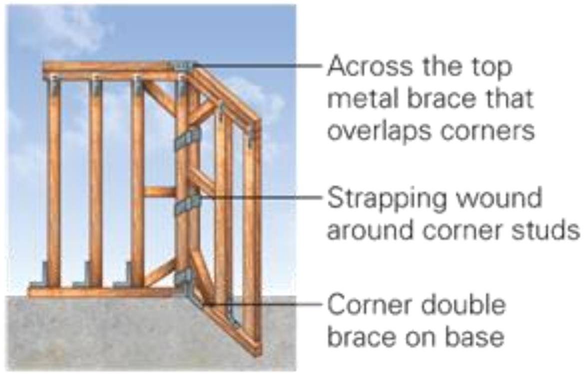
9. Earthquake Hazards: Fire

9. Earthquake Hazards: Tsunamis

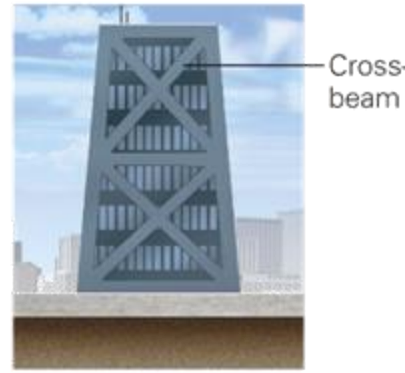
- Destructive tsunamis occur frequently, about one per year.



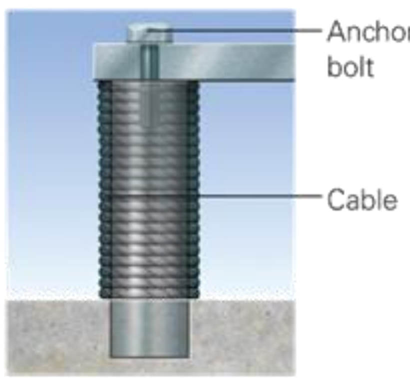
9. Management (Preparedness)



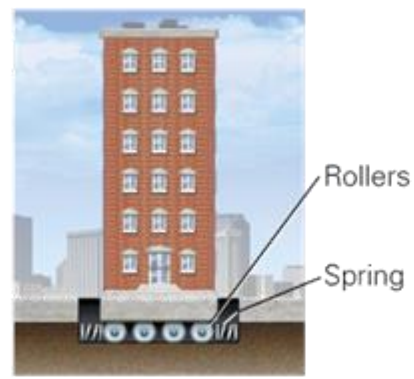
Adding corner struts, braces, and connectors can substantially strengthen a wood-frame house.



Buildings are less likely to collapse if they are wider at the base and if crossbeams are added for strength.



Wrapping a bridge's support columns in cable and bolting the span to the columns will prevent the bridge from collapsing so easily.

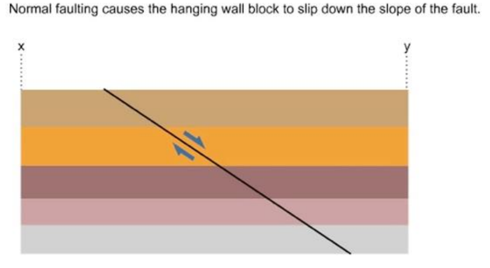


Placing buildings on rollers or shock absorbers lessens the severity of the vibrations.

9. Management (Preparedness)

Seismic Activity & Management

- 1. Sound waves
- 2. The first seismic experiment
- 3. Origin of earthquakes
- 4. Seismic sources (ground vibrations)
- 5. Seismic waves - reflection/refraction; types
- 6. Earthquakes – seismic gap; faults; stick-slip
- 7. Monitoring – magnitude/intensity
- 8. Prediction & Dilation
- 9. Management



Useful Web Resources

- Incorporated Research Institutions for Seismology (IRIS)

  http://www.iris.edu/hq/

- Surviving a Tsunami—Lessons from Chile, Hawaii, and Japan

  http://pubs.usgs.gov/circ/c1187/

- Story of the Svaerd Family Who Survived the Tsunami

  http://news.bbc.co.uk/2/hi/europe/4141733.stm

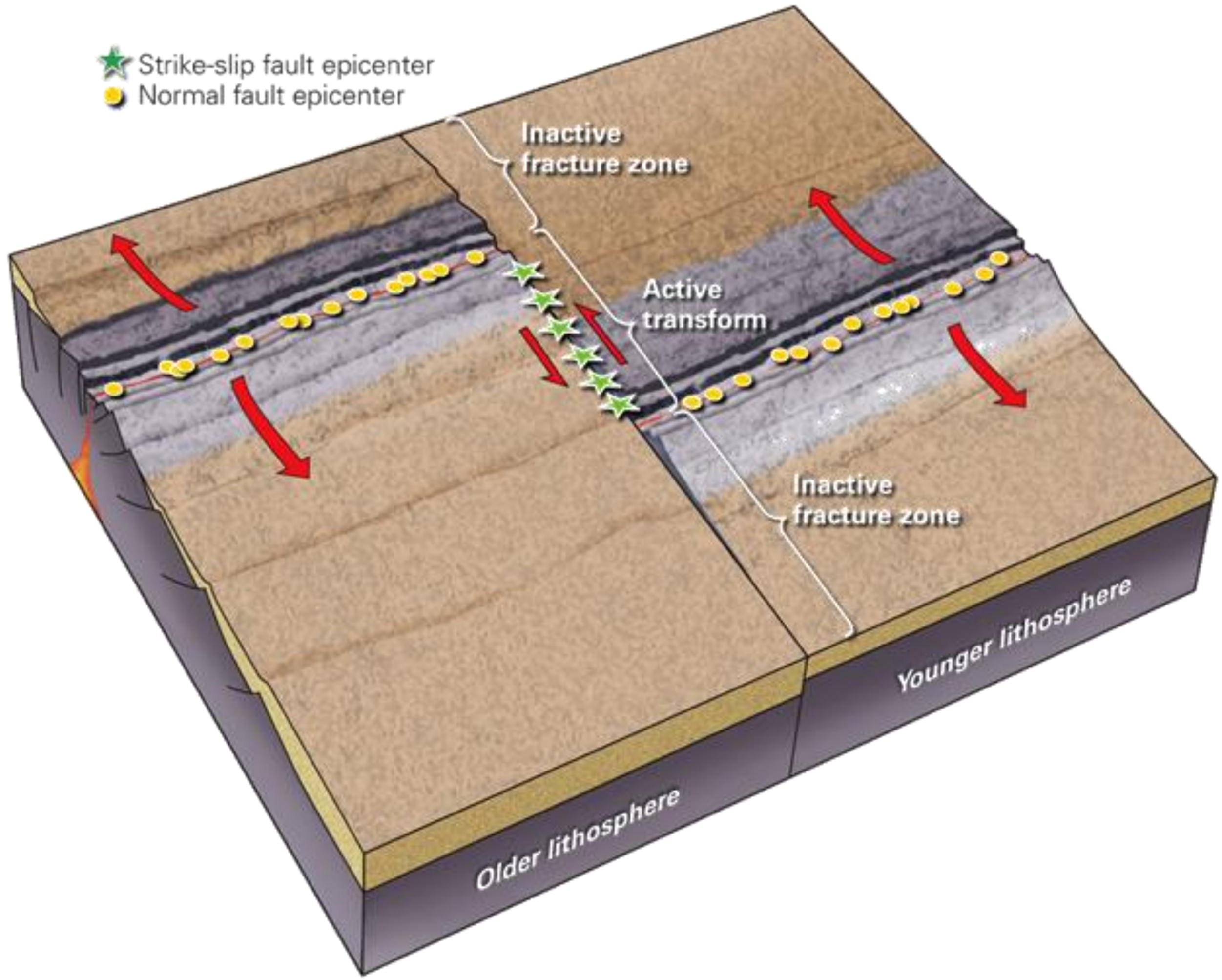
  http://www.smh.com.au/news/Asia-Tsunami/Survivors-against-all-odds/2005/01/02/1104601241841.html?oneclick=true

6. Earthquakes 1

TABLE 10.1 Some Notable Earthquakes

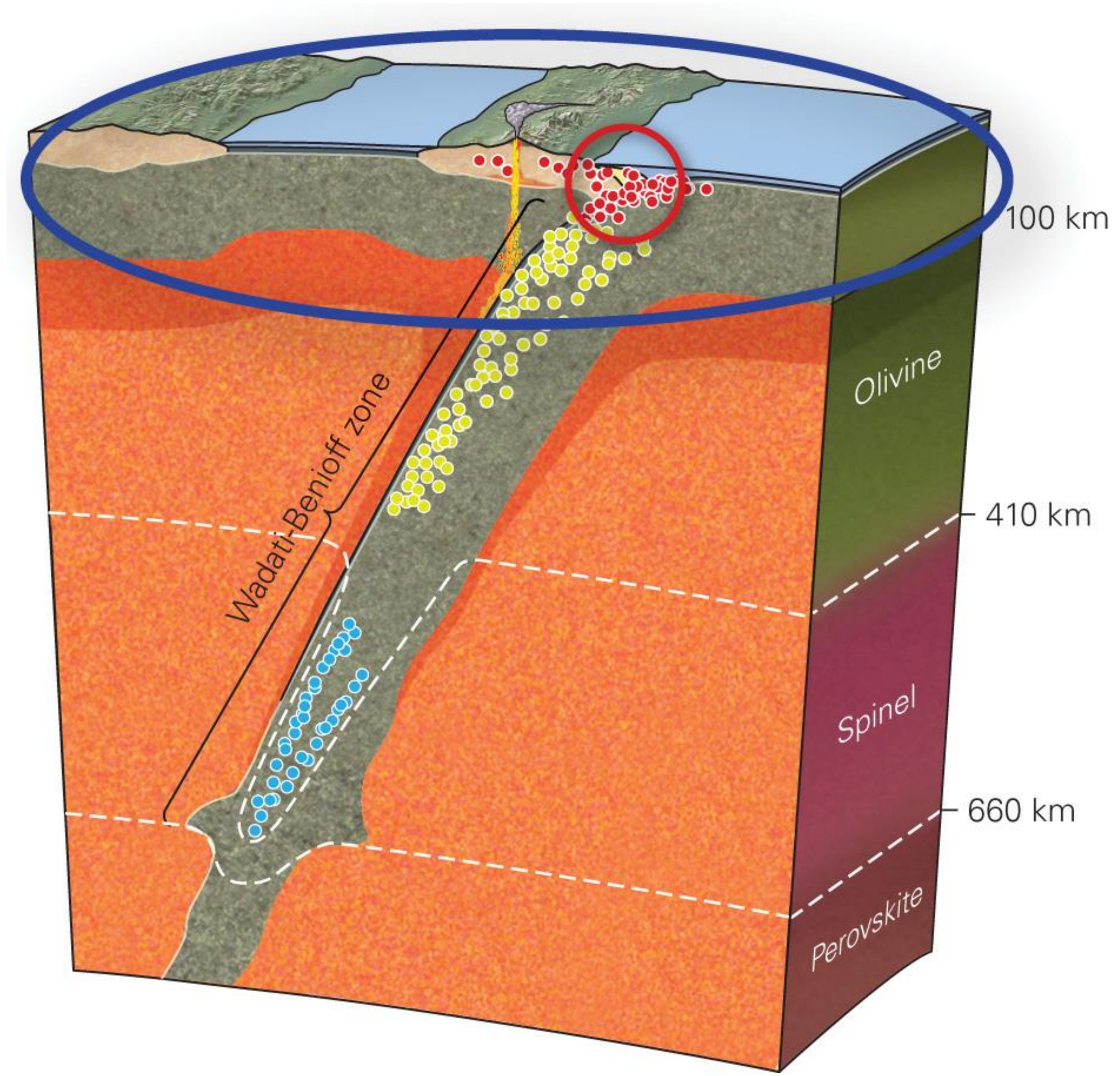
Year	Location	Deaths
2017	Mexico City, Mexico	369
2011	Tōhoku, Japan (tsunami)	20,000
2011	Christchurch, New Zealand	180
2010	Haiti	230,000
2010	Concepción, Chile	1,000
2008	Sichuan, China	70,000
2005	Pakistan	80,000
2004	Sumatra (tsunami)	230,000
2003	Bam, Iran	41,000
2001	Bhuj, India	20,000
1999	Calaraca/Armenia, Colombia	2,000
1999	Izmit, Turkey	17,000
1995	Kobe, Japan	5,500
1994	Northridge, California	51
1990	Western Iran	50,000
1989	Loma Prieta, California	65
1988	Spitak, Armenia	24,000
1985	Mexico City	9,500
1983	Turkey	1,300
1978	Iran	15,000
1976	T'ang-shan, China	255,000
1976	Caldiran, Turkey	8,000
1976	Guatemala	23,000
1972	Nicaragua	12,000
1971	San Fernando, California	65
1970	Peru	66,000
1968	Iran	12,000
1964	Anchorage, Alaska	131
1963	Skopje, Yugoslavia	1,000
1962	Iran	12,000
1960	Agadir, Morocco	12,000
1960	Southern Chile	6,000
1948	Turkmenistan, USSR	110,000
1939	Erzincan, Turkey	40,000
1939	Chillán, Chile	30,000
1935	Quetta, Pakistan	60,000
1932	Gansu, China	70,000
1927	Tsinghai, China	200,000
1923	Tokyo, Japan	143,000
1920	Gansu, China	180,000
1915	Avezzano, Italy	30,000
1908	Messina, Italy	160,000
1906	San Francisco	500
1896	Japan	22,000
1886	Charleston, South Carolina	60
1866	Peru and Ecuador	25,000
1811–12	New Madrid, Missouri (3 events)	Few
1783	Calabria, Italy	50,000
1755	Lisbon, Portugal	70,000
1556	Shen-shu, China	830,000

8. Divergent-Plate Boundary: Mid-Ocean Ridges

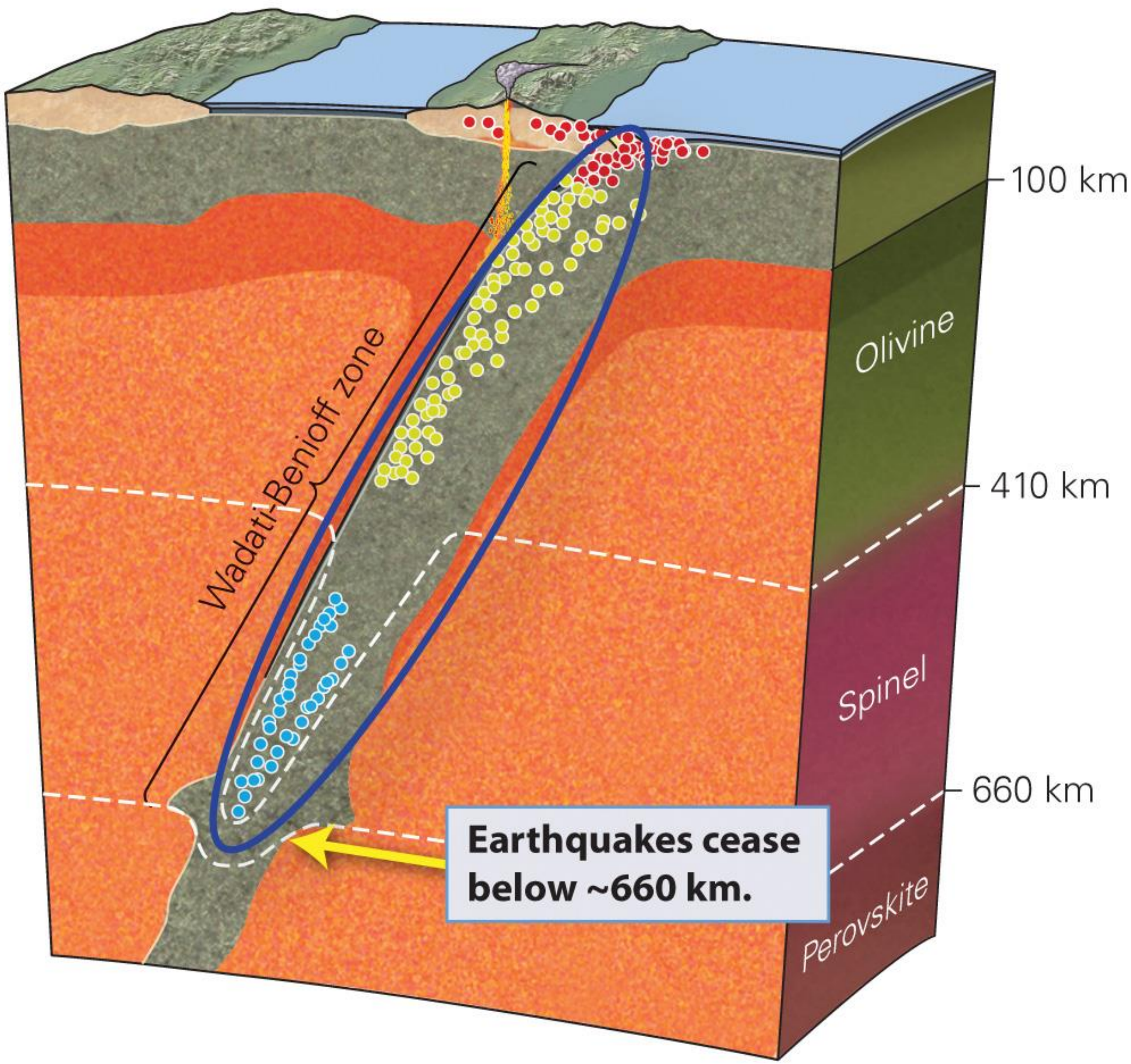


8. Convergent-Plate Boundaries

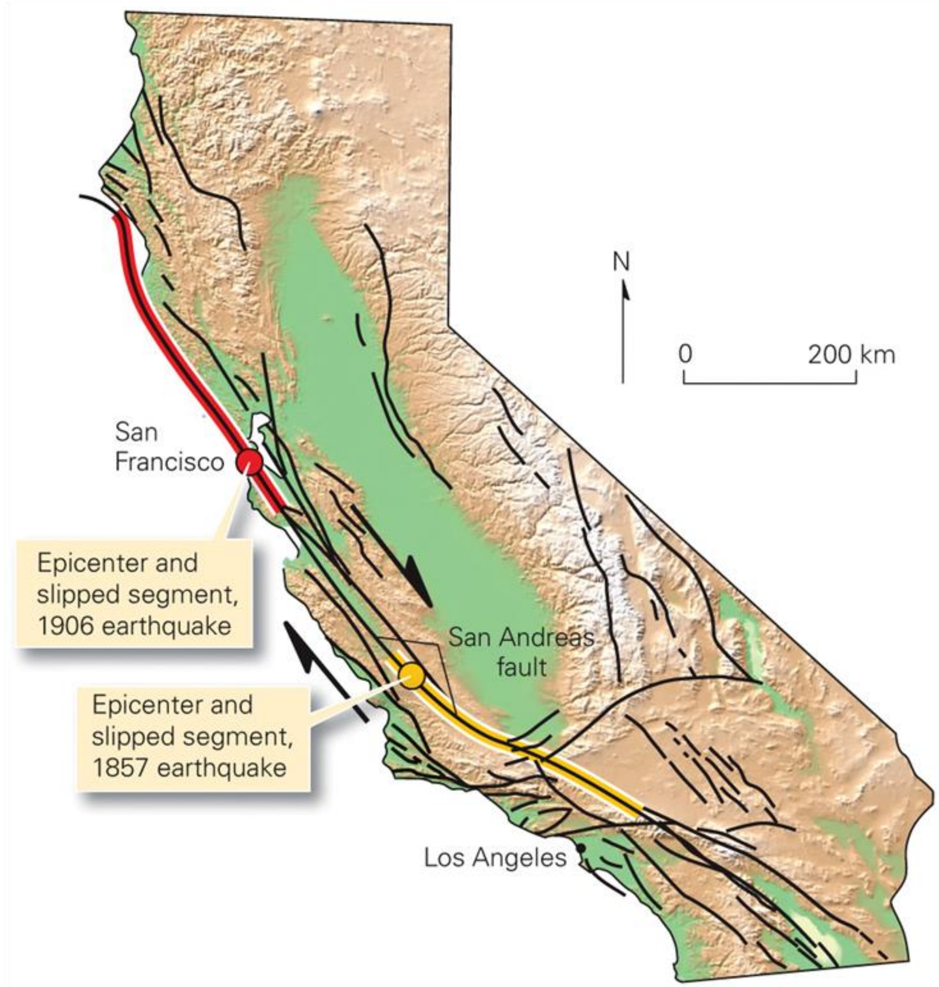
- Convergent-plate boundaries have shallow, intermediate, and deep earthquakes.



8. Convergent-Plate Boundaries

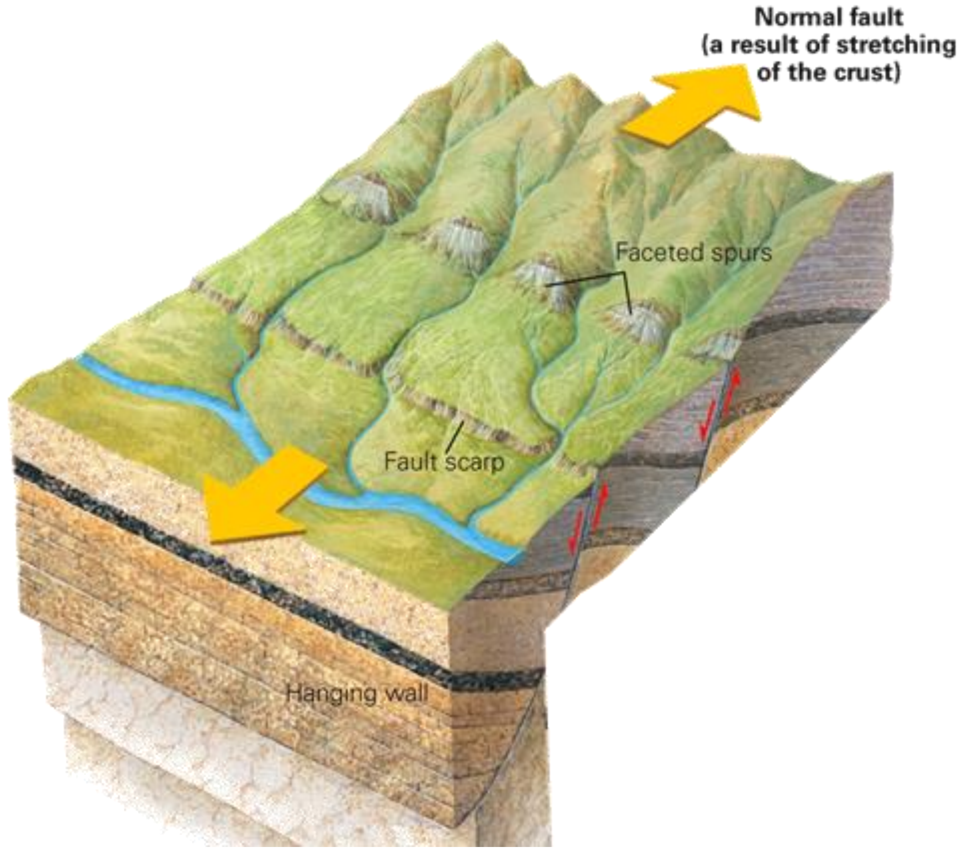


8. Continental Transform-Plate Boundaries

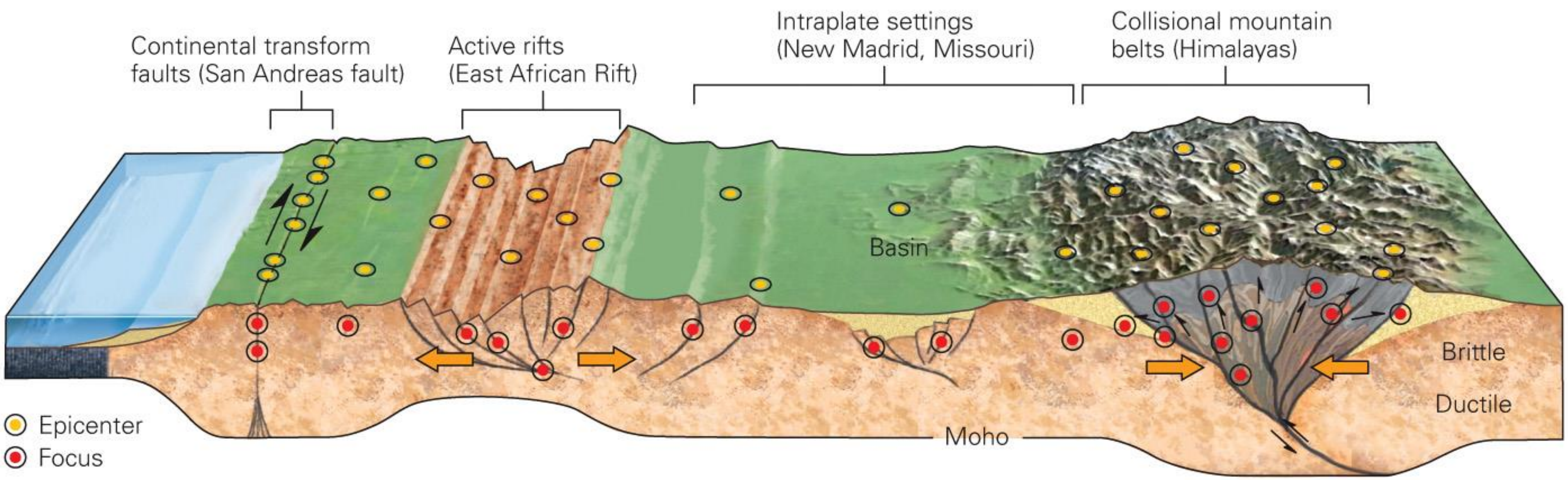


8. Continental Rifts

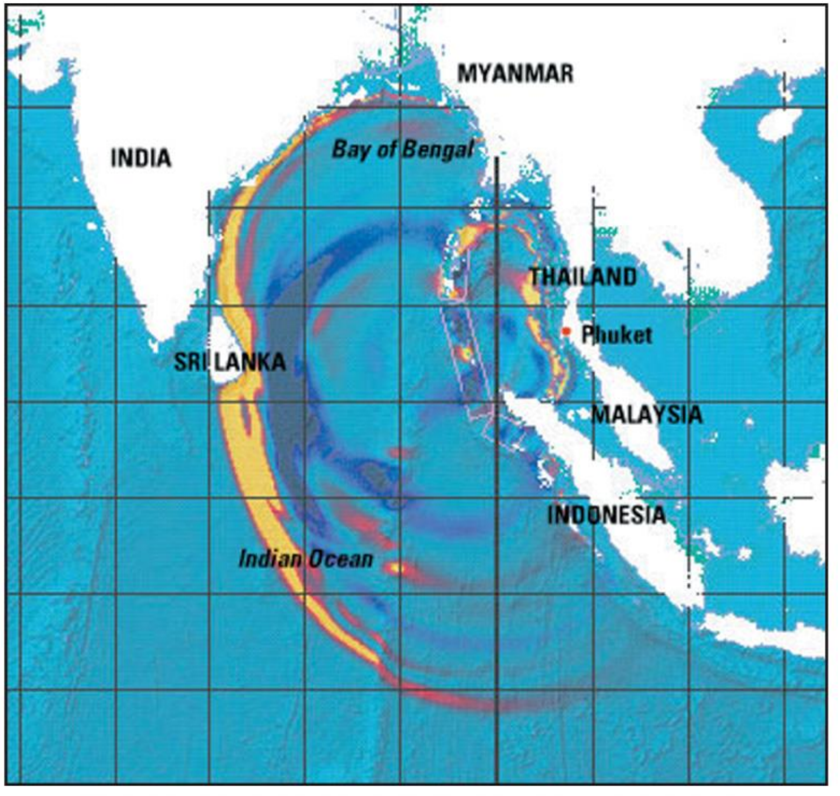
- Examples: Basin and Range Province (Nevada, Utah, and Arizona); Rio Grande Rift (New Mexico); East African Rift



8. Orogenic Crustal Compression: Tectonic Collisional Mountain Building



9. Earthquake Hazards: The Indian Ocean Tsunami



In this computer model, colors represent wave height—yellow is highest. There were several waves.

9. Earthquake Hazards: Tsunamis

9. Earthquake Hazards: Tsunamis Prediction

- Tsunami detection is expanding. Tsunami detectors are placed on the deep sea floor. Sense pressure increases from changes in sea thickness. Prediction/detection can save thousands of lives.