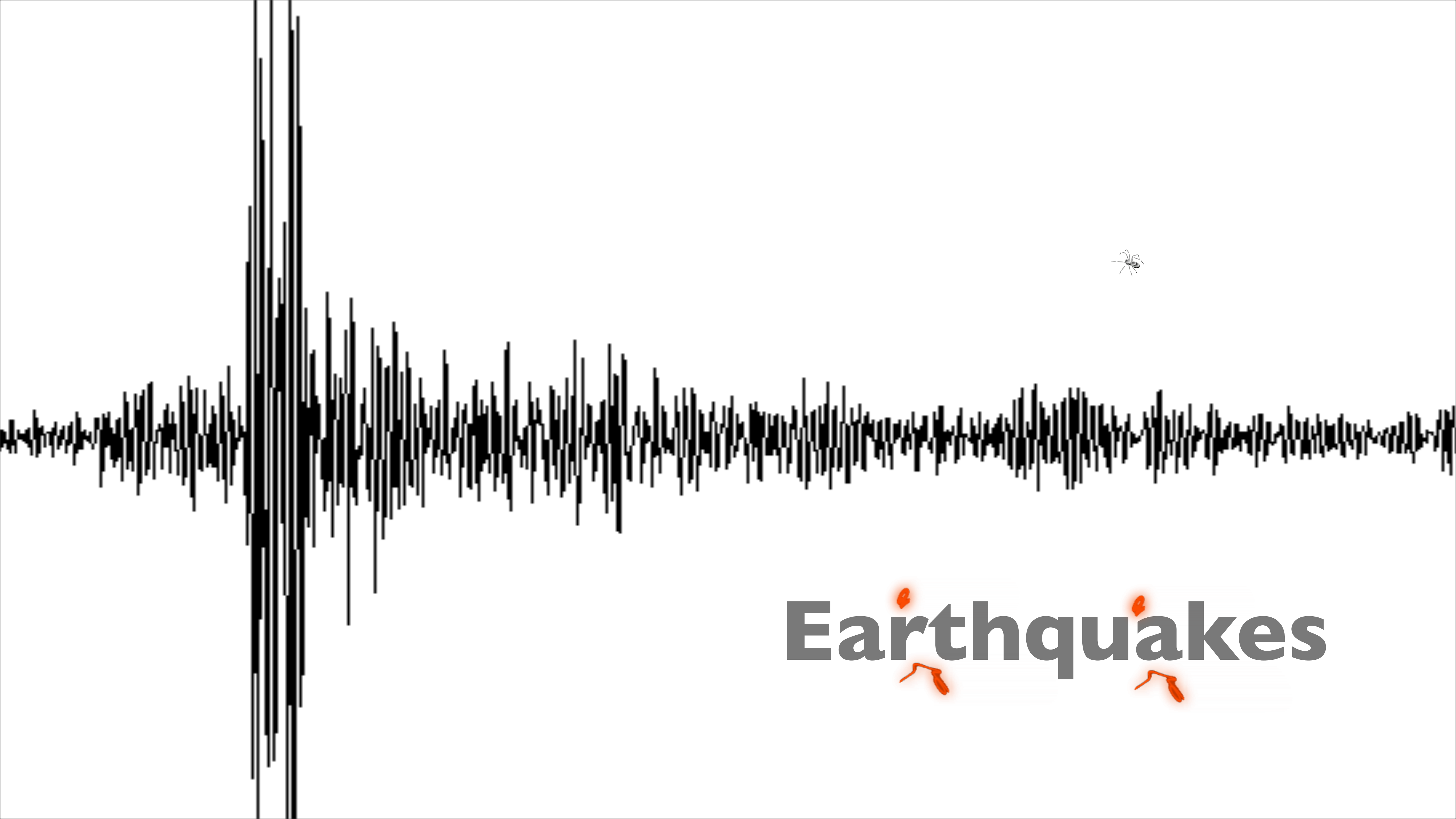
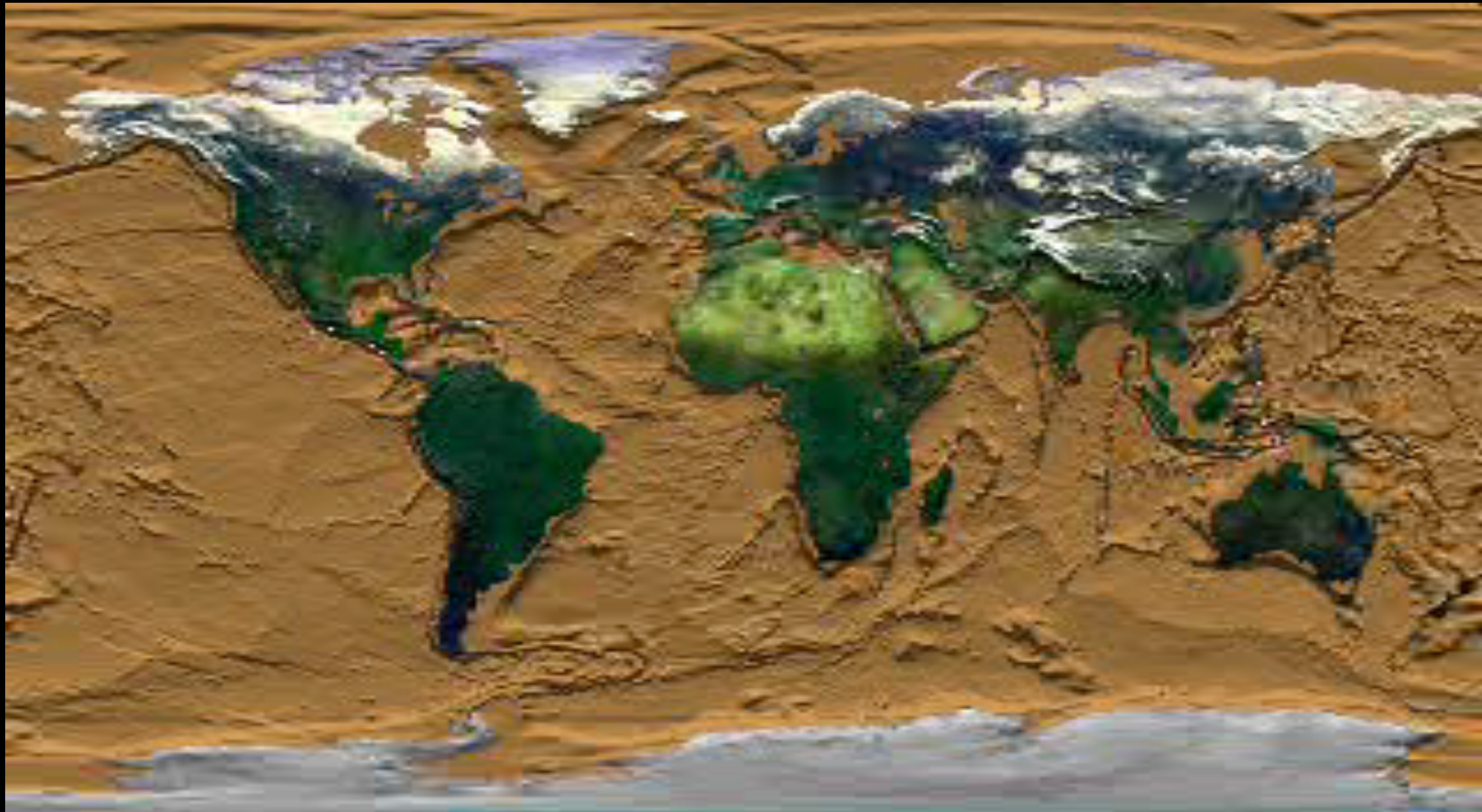




Earthquakes





What is “The Dynamic Crust?”

📌 **Dynamic** means constantly changing

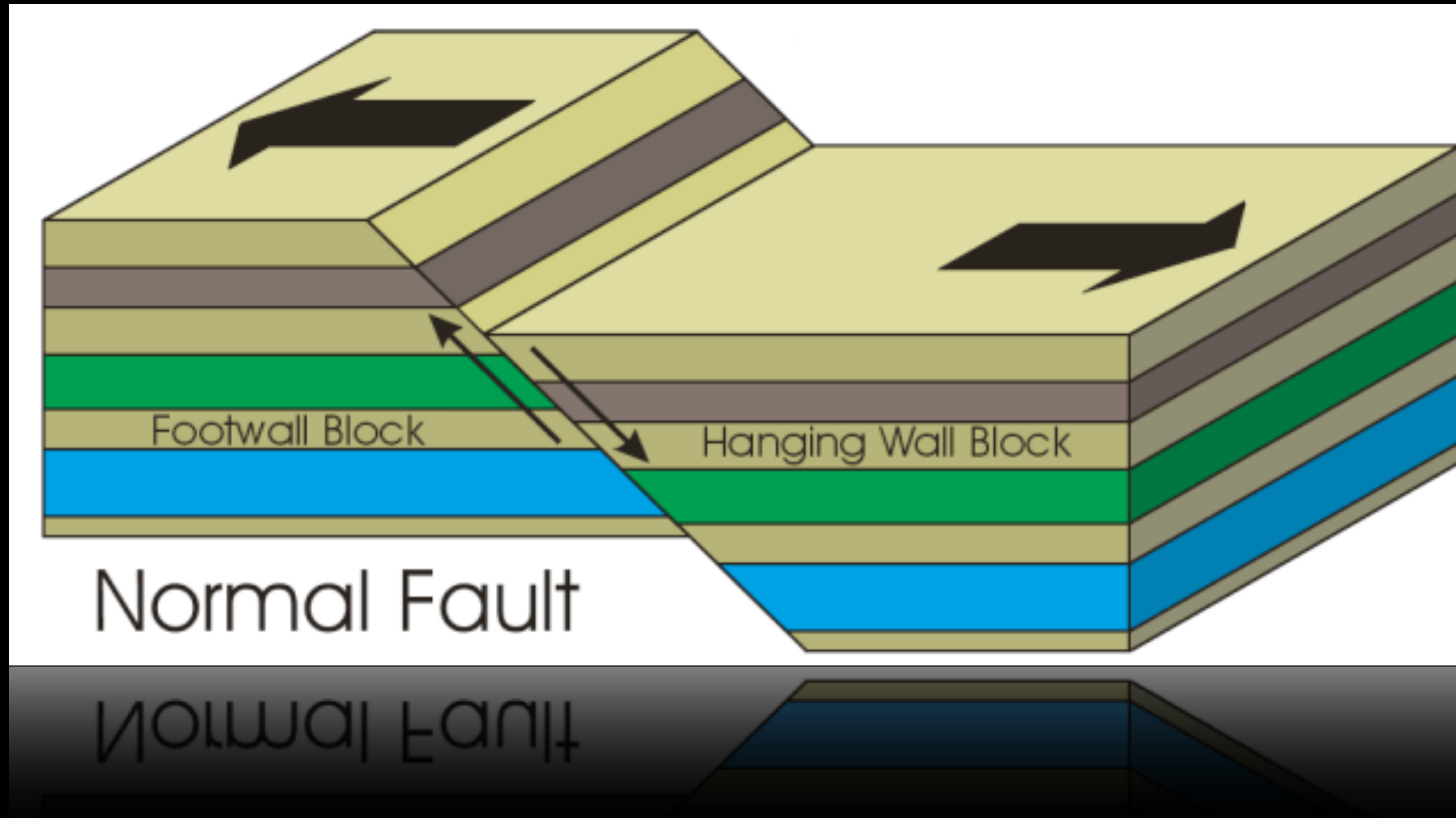
📌 **Crust** is the outer portion of the earth

📌 Dynamic Crust is the term given to how the Earth's Crust is ever changing and evolving through plate tectonics

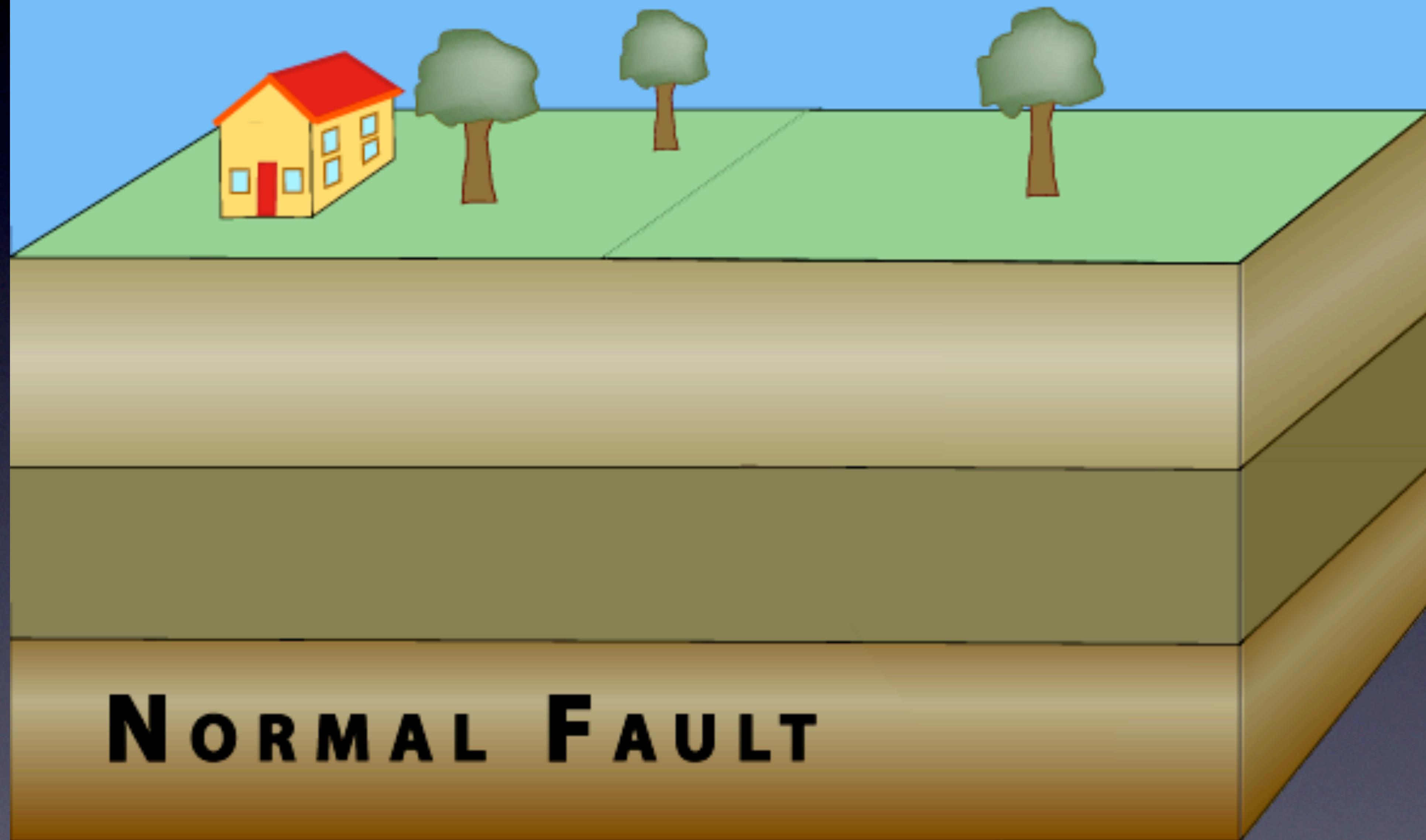
Plate Boundaries and Plate Tectonics



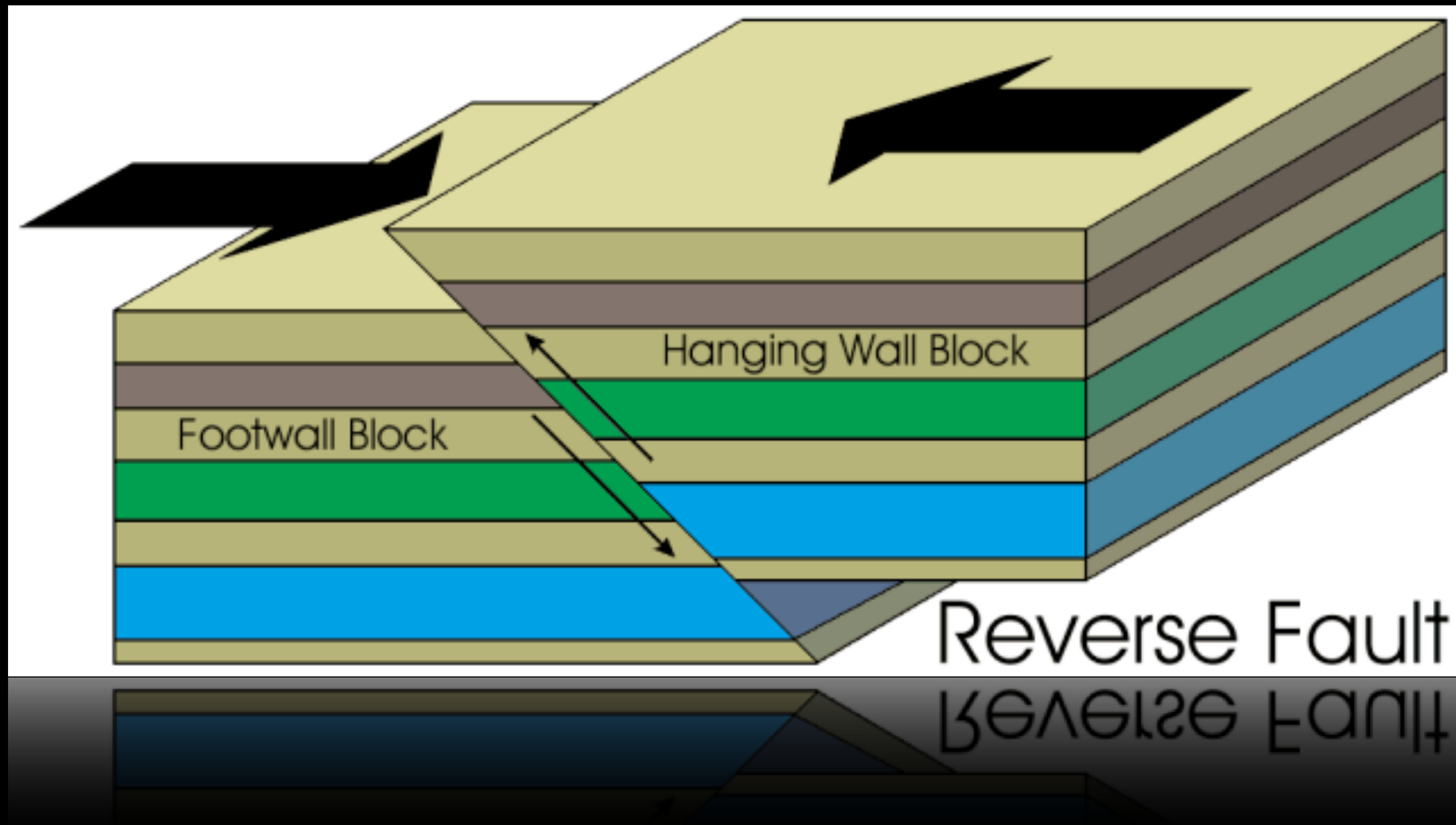
Normal Fault



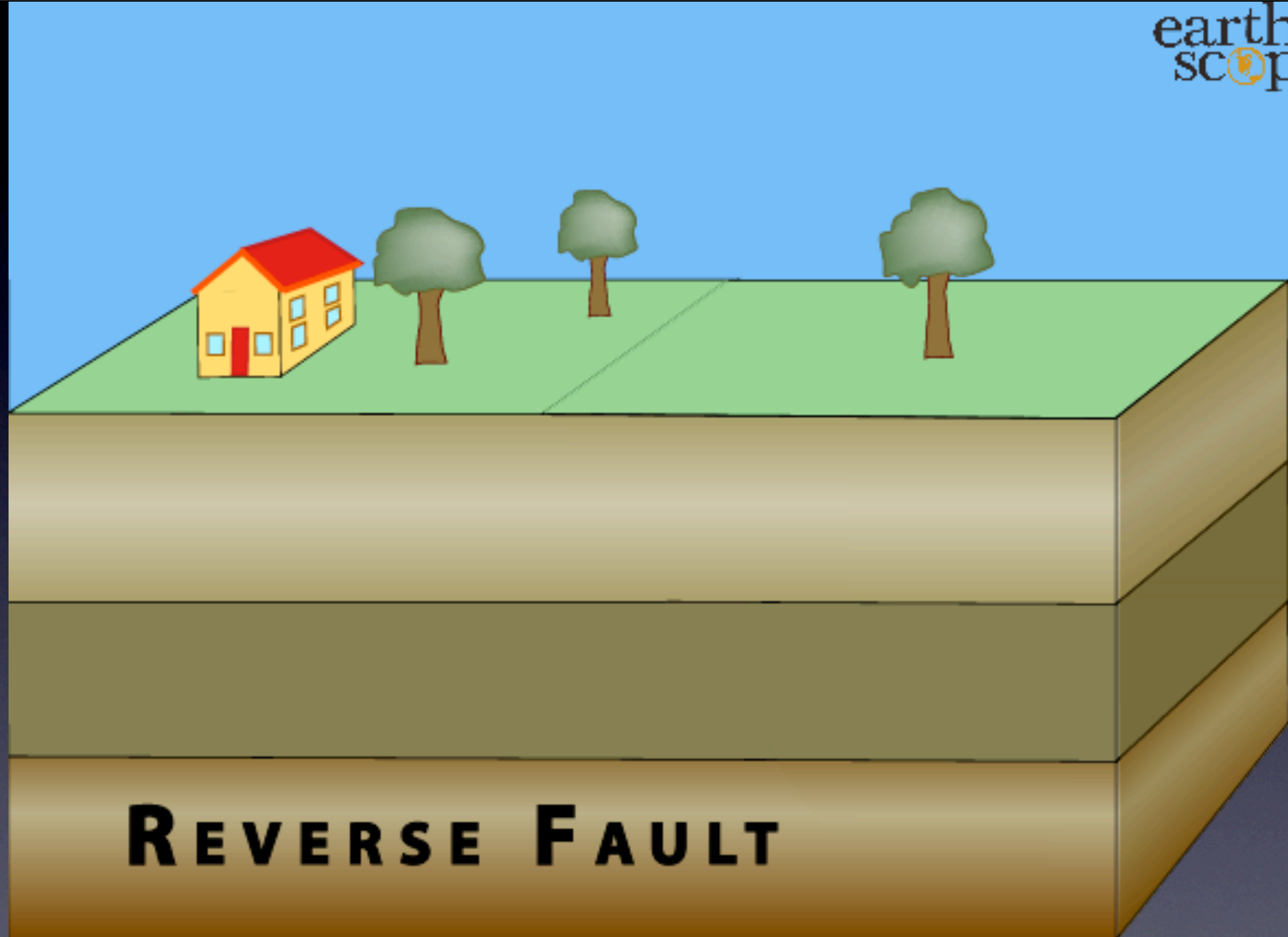
- Footwall slides upward in relation to the hanging wall sliding down.
- The angle produced at the surface is greater than 90 degrees (Obtuse Angle)
- Rock layers do not match up
- This is called Tension Stress



REVERSE FAULT



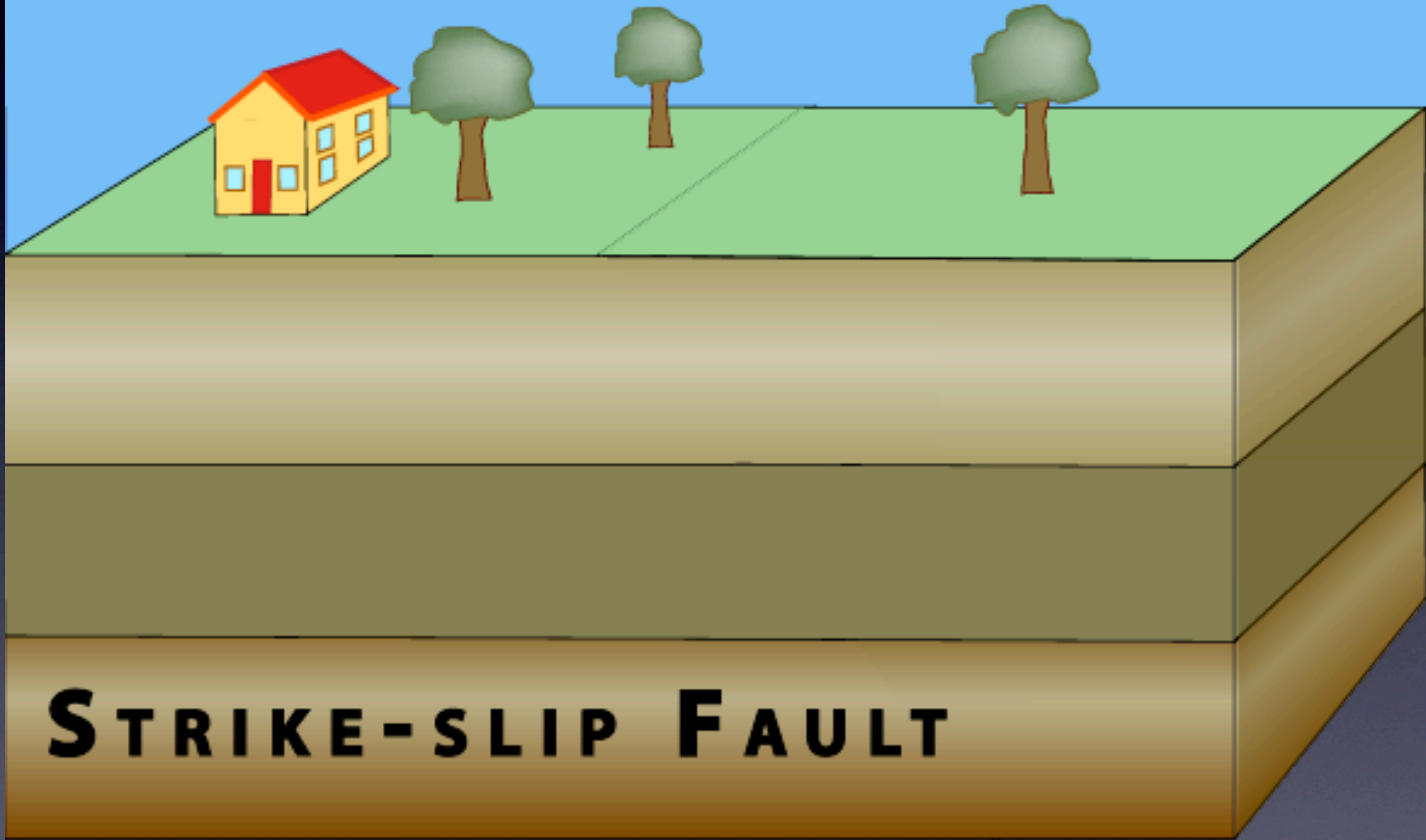
- Hanging wall slides upward in reference to the foot wall
- Produces an angle at the surface less than 90 degrees (Acute Angle)
- Rock layers do not match up
- This is produced by Compressional Stress



REVERSE FAULT

San Andreas Fault

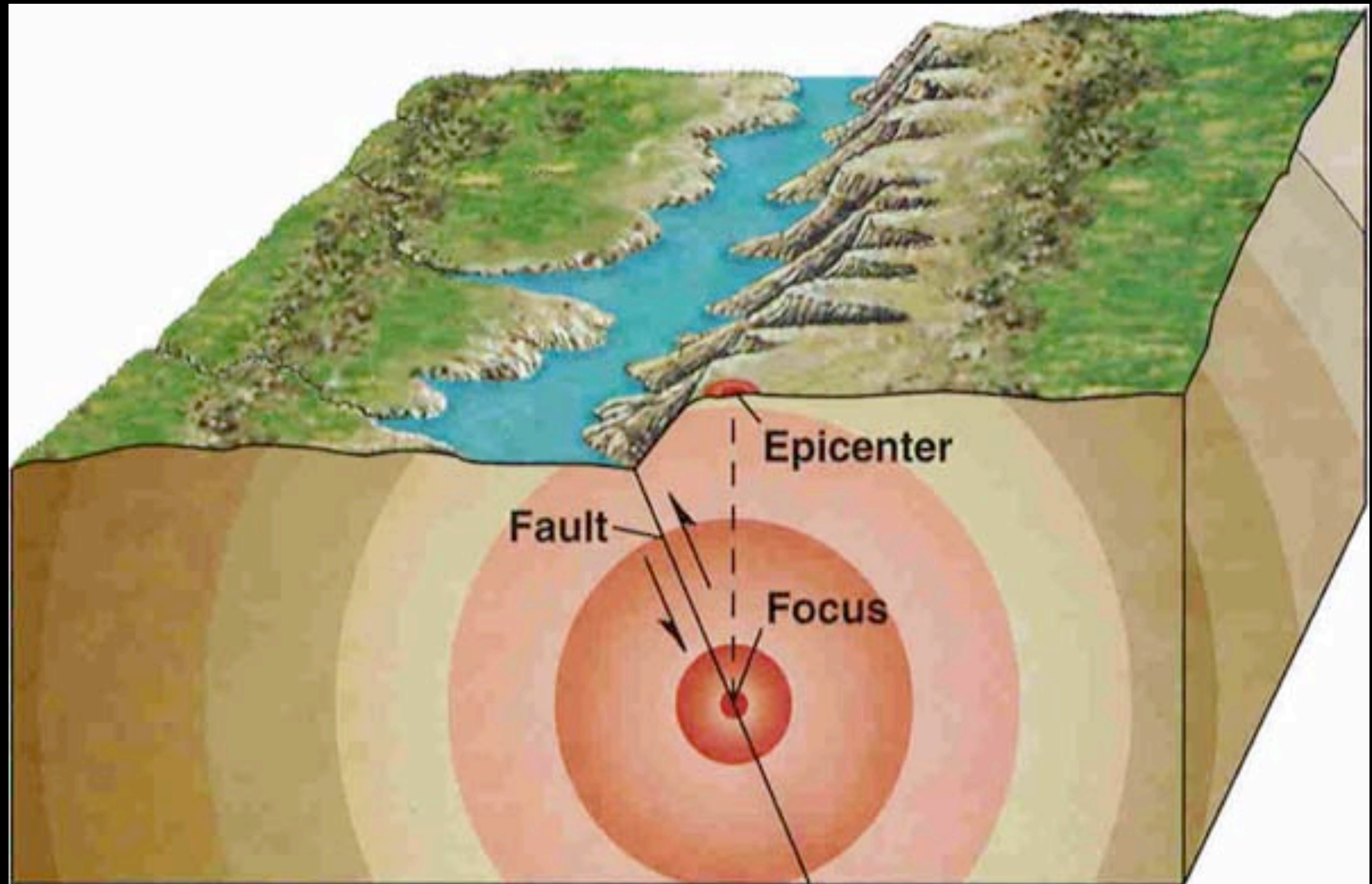


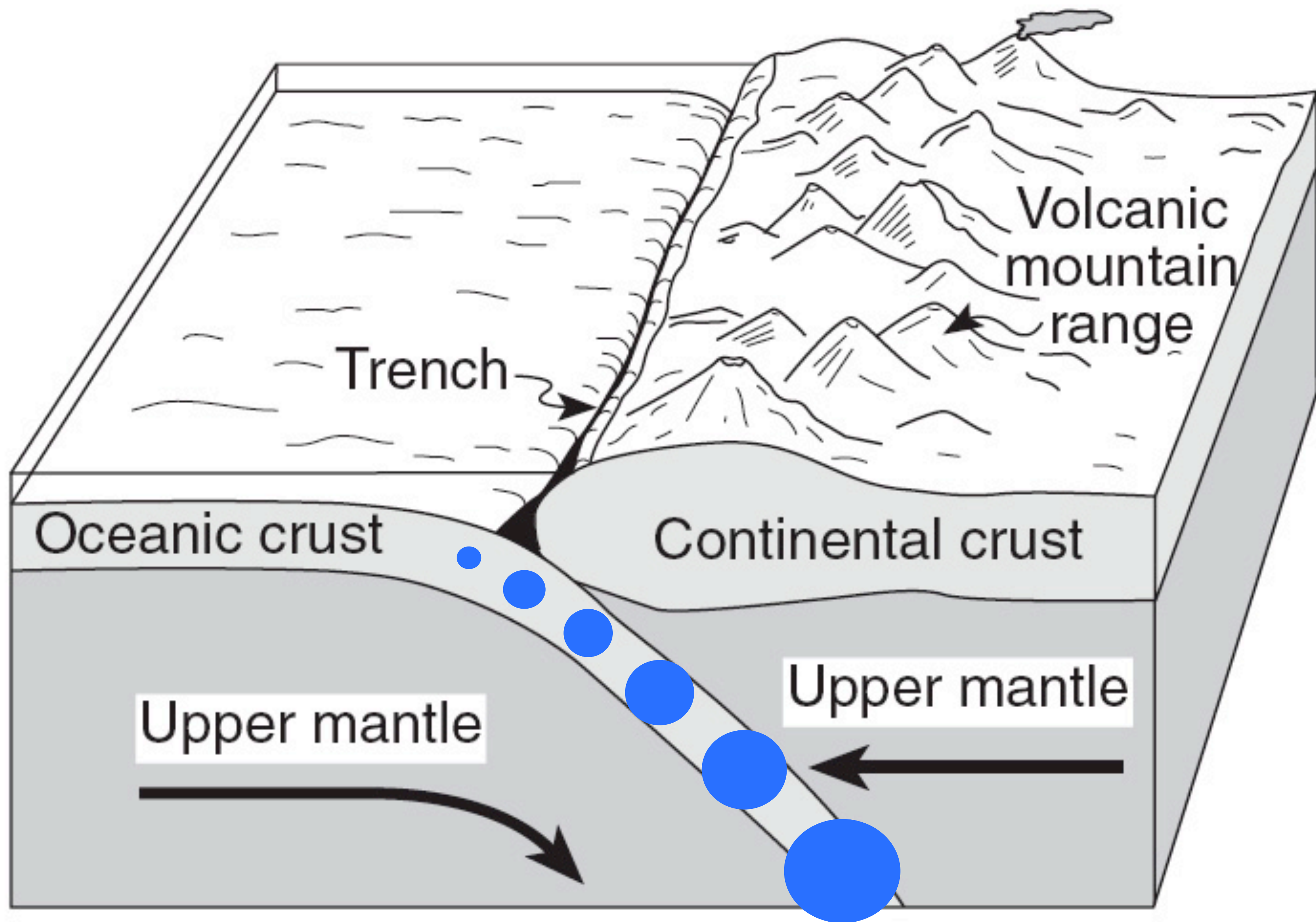


STRIKE-SLIP FAULT

Parts of an Earthquake

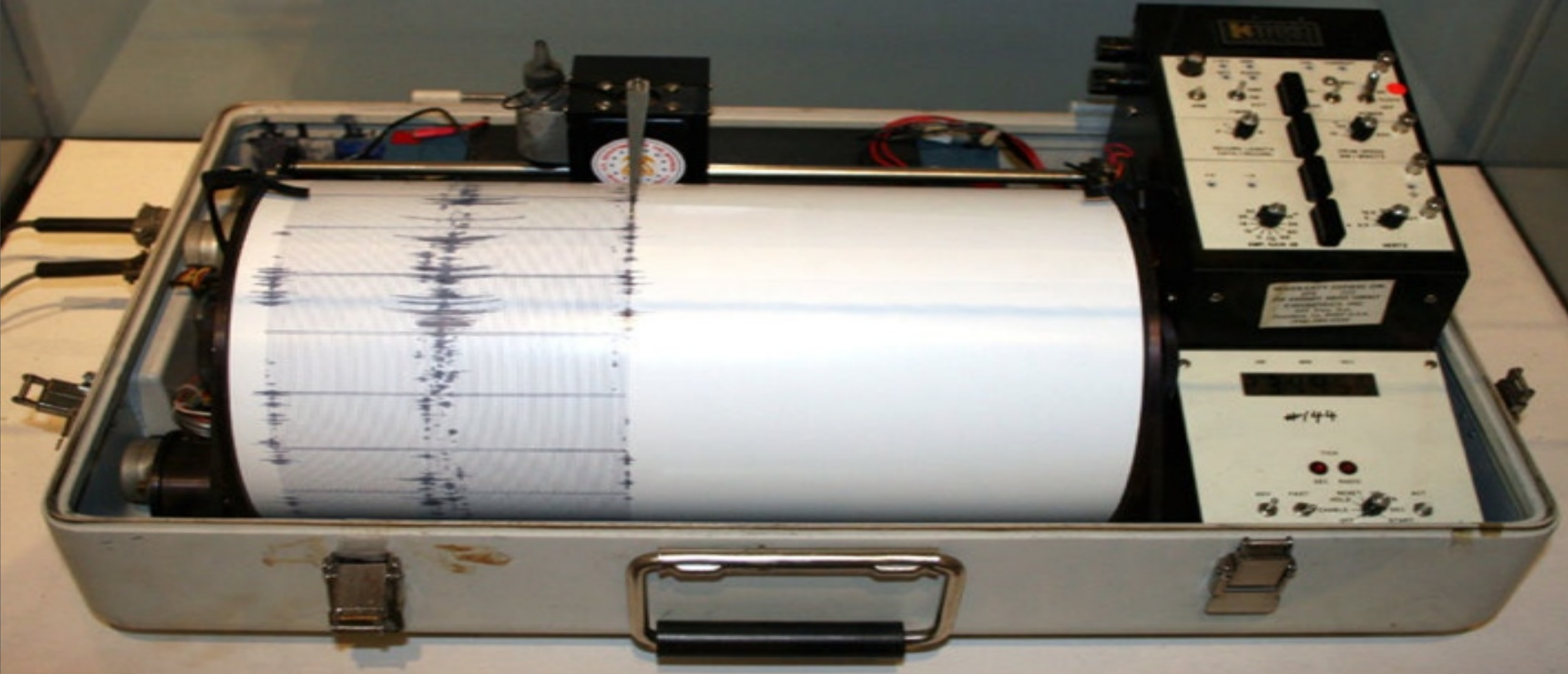
- 📌 **Focus** is where the Earthquake actually occurs inside the Earth
- 📌 Deeper the Focus, the stronger the earthquake. Think about a subduction zone!!!!!! (**Focal Depth**)
- 📌 **Epicenter** is the location at the surface of crust just above the Focus.
- 📌 **Seismic Waves** are the different waves (vibrations) that are sent throughout the planet from the earthquake
- 📌 P- Waves
- 📌 S-Waves



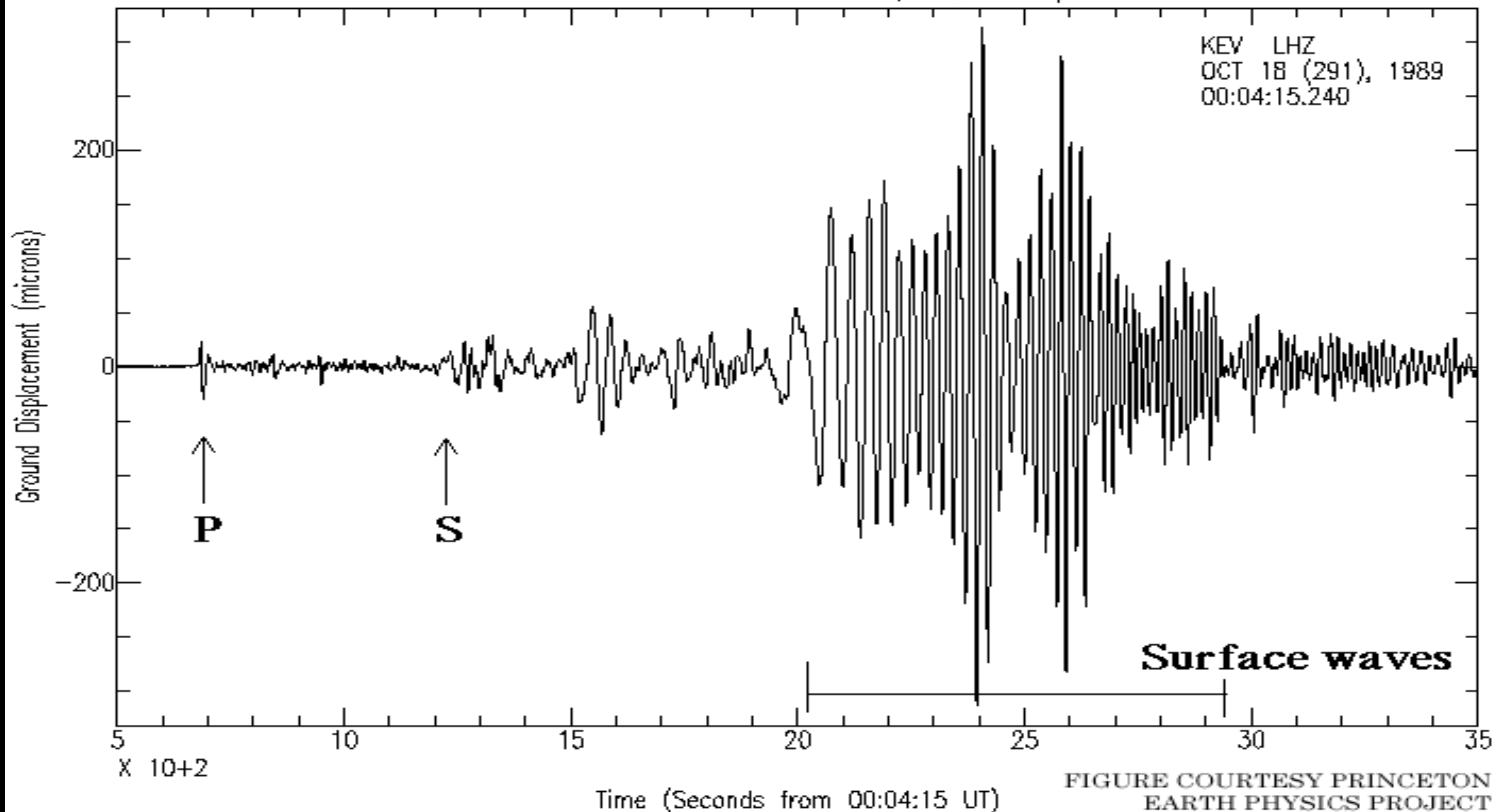


“SEIS”=Earthquake

- 📌 **Seismologist**-Someone who studies earthquakes
- 📌 **Seismograph**-Machine that picks up vibrations on the ground
- 📌 **Seismogram**-Printout of the vibrations
- 📌 Vibrations are measured by how big the “zig-zag” pattern is (Amplitude of Waves)
 - 📌 Bigger they are...stronger the earthquake...closer
 - 📌 Smaller they are...weaker the earthquake...farther



Loma Prieta recorded at KEV (Kevo, Finland)



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

Guiseppe
Mercalli



Richter Magnitude/ TNT Equivalent

1.0	6 ounces	
1.5	2 pounds	
2.0	13 pounds	
2.5	63 pounds	
3.0	397 pounds	
3.5	1,000 pounds	
4.0	6 tons	Small atomic bomb
4.5	32 tons	Average tornado
5.0	199 tons	
5.5	500 tons	
6.0	6,270 tons	
6.5	31,550 tons	
7.0	199,000 tons	San Francisco (7.1) 1989
7.5	1,000,000 tons	Los Angeles (7.4) 1992
8.0	6,270,000 tons	San Francisco (8.3) 1906
8.5	31,550,000 tons	Anchorage, Alaska 1964
9.0	199,999,000 tons	

8.0	199,999,000 tons	
8.2	31,550,000 tons	Anchorage, Alaska 1964

Magnitude
=
Strength



Charles Richter

Earthquake Magnitudes and Expected World Incidence

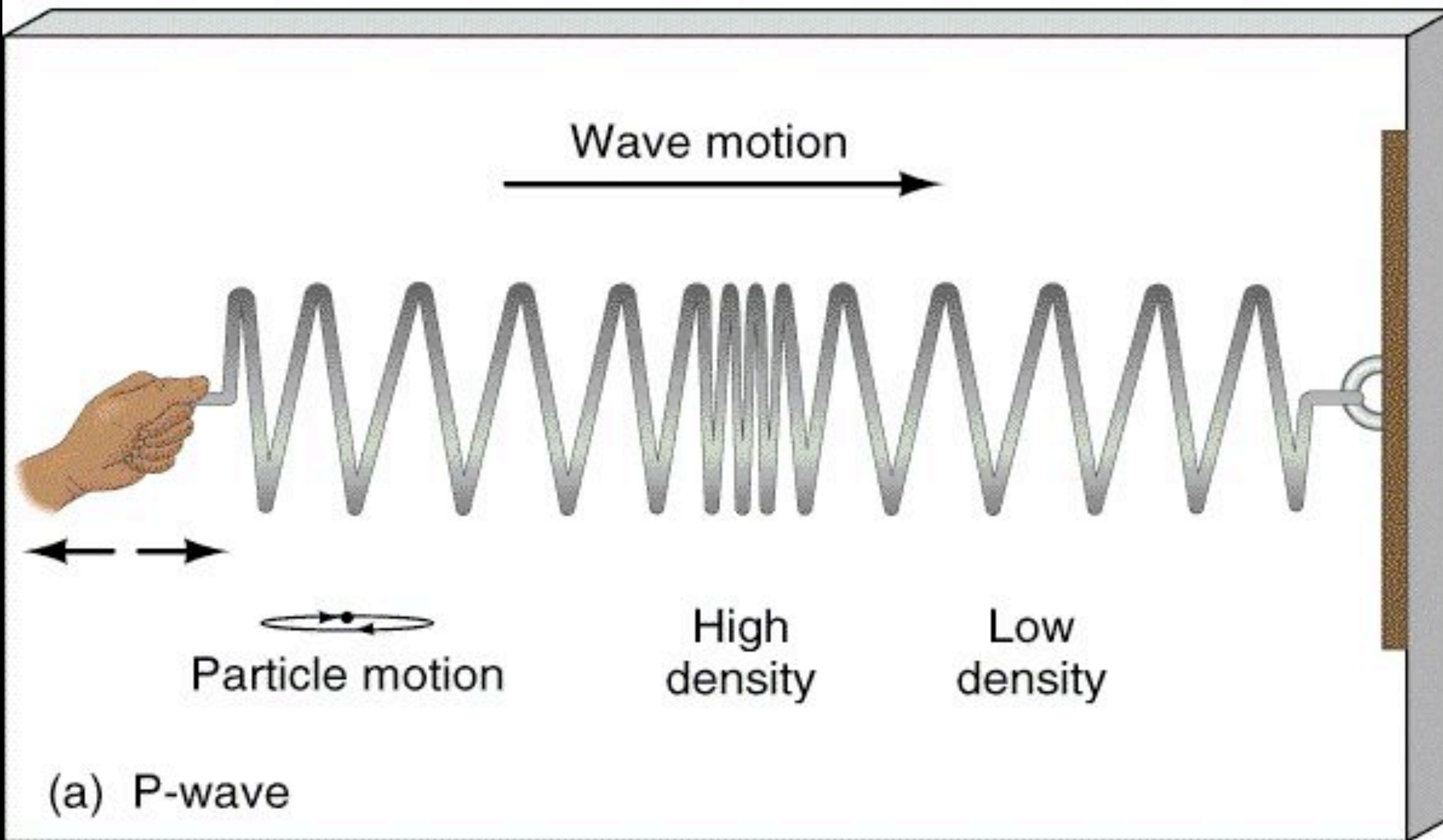
Moment Magnitudes	Effects Near Epicenter	Estimated Number per Year
< 2.0	Generally not felt, but can be recorded	> 600,000
2.0–2.9	Potentially perceptible	> 300,000
3.0–3.9	Rarely felt	> 100,000
4.0–4.9	Can be strongly felt	13,500
5.0–5.9	Can be damaging shocks	1,400
6.0–6.9	Destructive in populous regions	110
7.0–7.9	Major earthquakes; inflict serious damage	12
8.0 and above	Great earthquakes; destroy communities near epicenter	0–1

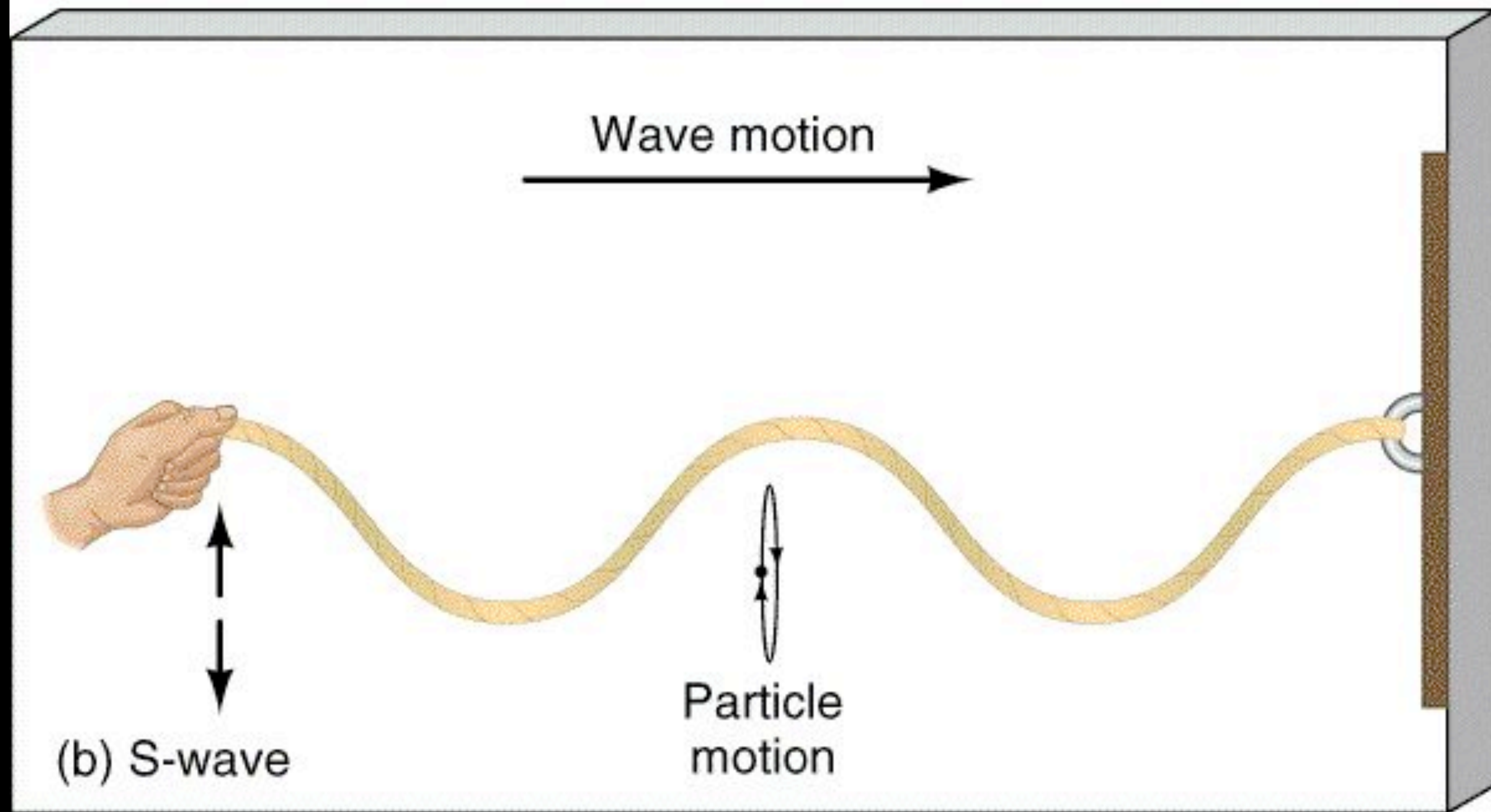
8.0 and above

near epicenter

Great earthquakes; destroy communities

0–1





J. Easy way to remember the waves

- 📌 **P**-Waves/Compression

- 📌 **P**Primary Waves

- 📌 **P**hirst to seismic station

- 📌 **P**haster than S wave

- 📌 **P**ush-**P**ull

- 📌 **P**ass through solids, liquids and gases

- 📌 **P**orsche

- 📌 **S**-Waves

- 📌 **S**econdary Waves

- 📌 **S**econd to seismic station

- 📌 **S**lower than P wave

- 📌 **S**hear

- 📌 **S**olids Only!!

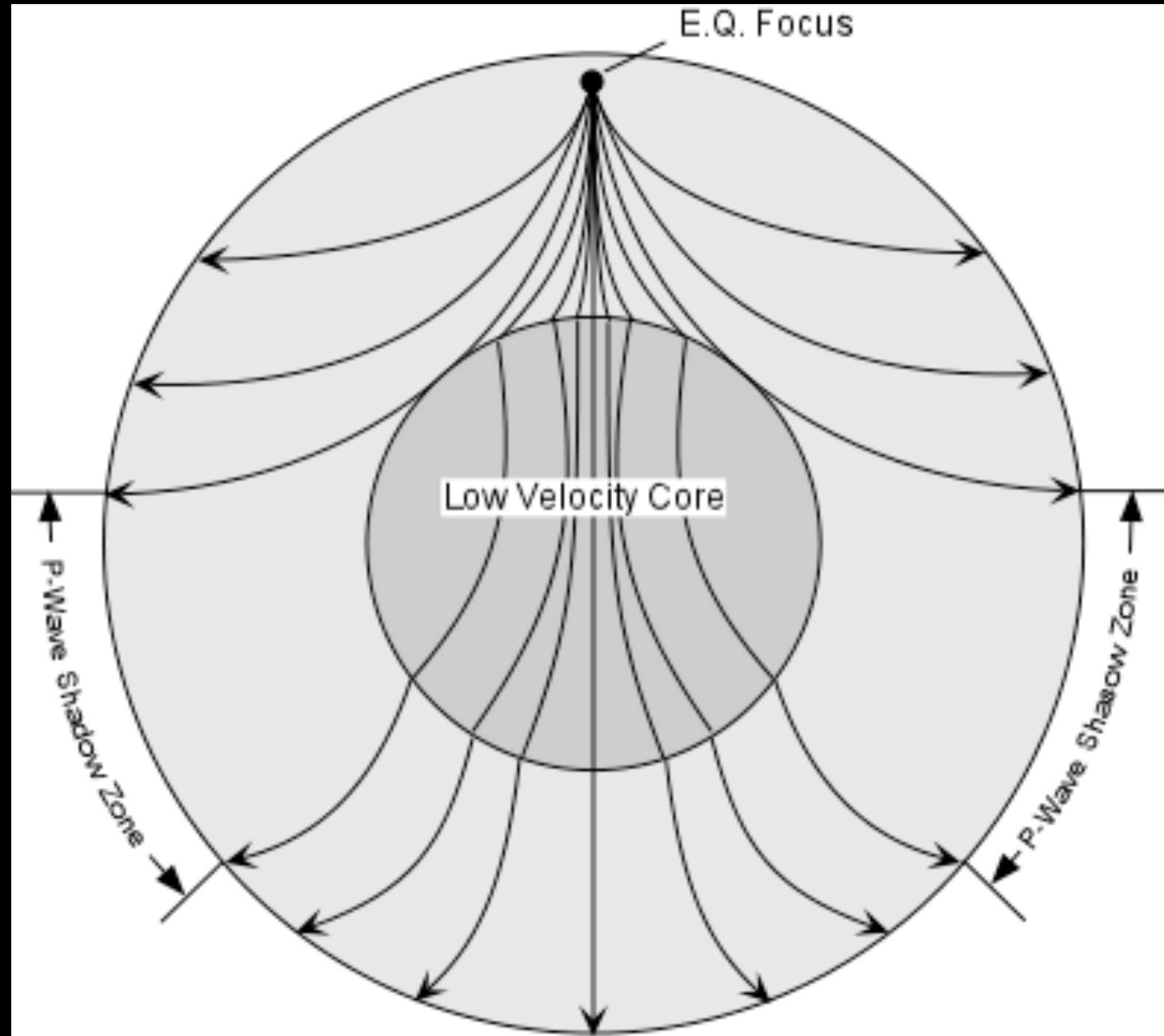
- 📌 Travels in an “**S**”-like pattern

- 📌 **S**aturn

Porsche vs. Saturn

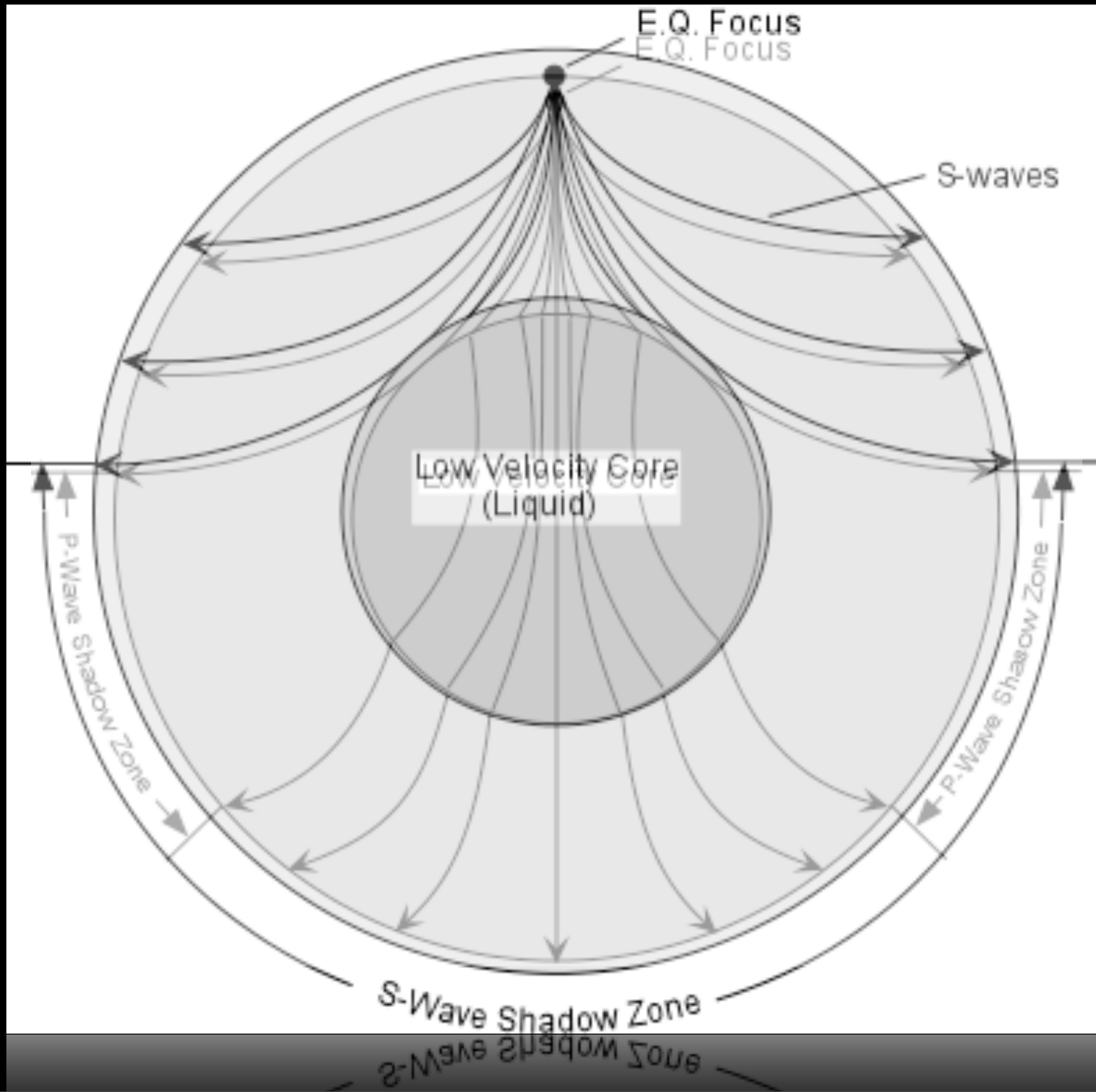


P -Wave Shadow Zone



- ➊ Caused by density differences between mantle and outer core
- ➋ P-Waves bend (Refract)
- ➌ Area Between 103-142 degrees away from epicenter do not receive P-Waves
- ➍ Area not receiving P-Waves is in the Shadow Zone

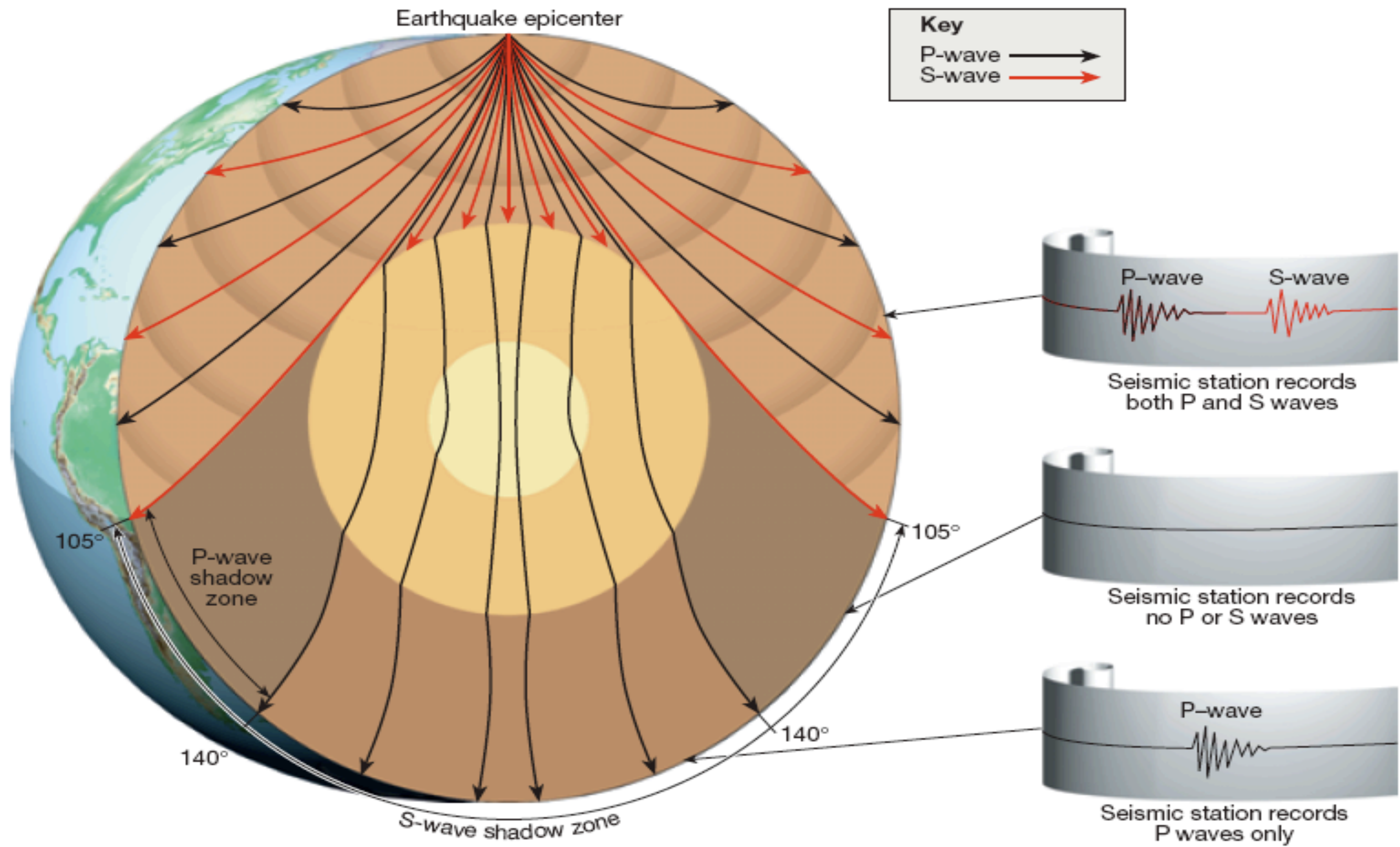
P. S-Wave Shadow Zone



📌 Caused by S-Waves not being able to pass through the liquid outer core

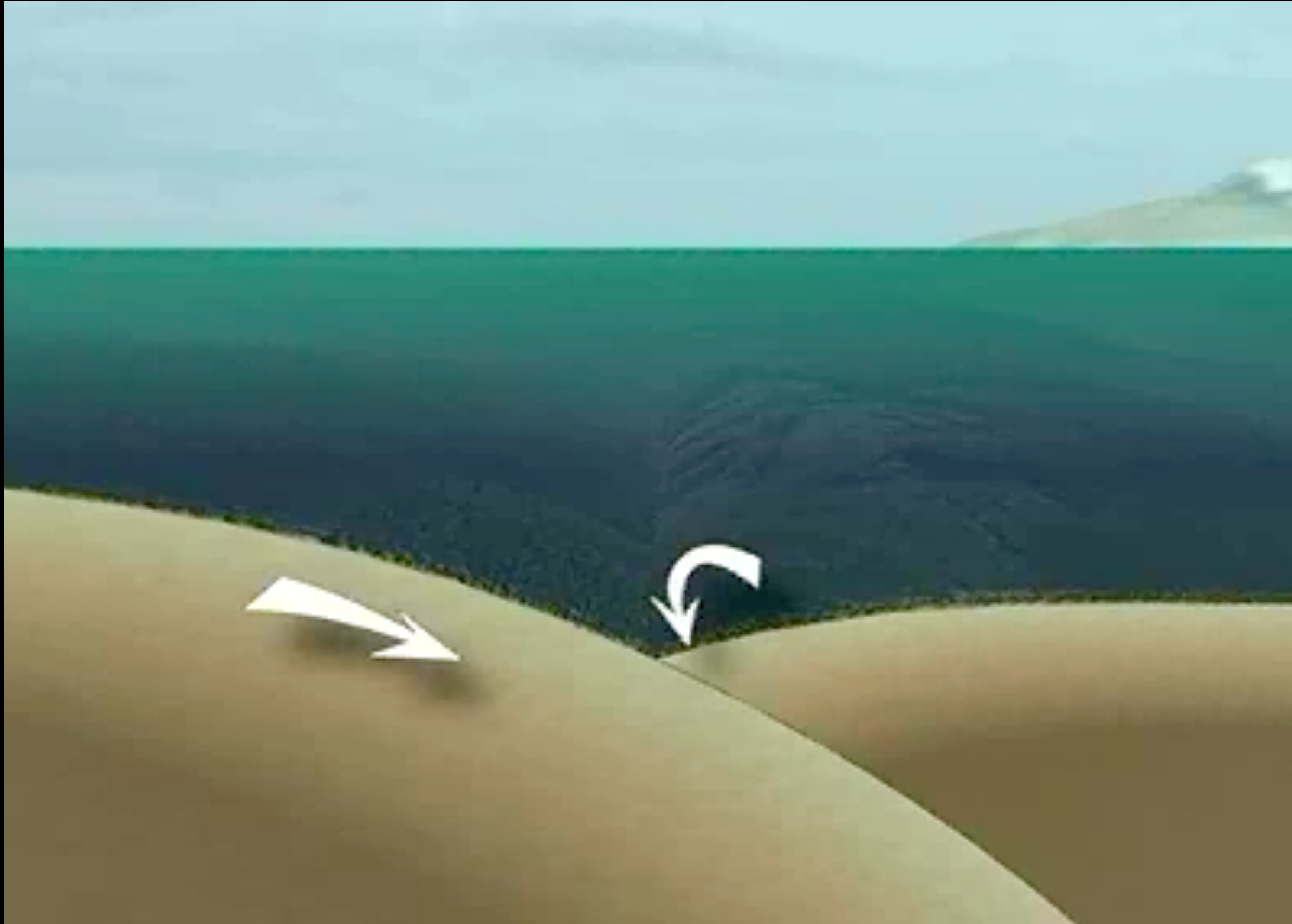
S-Waves get absorbed by the liquid outer core

Area 103 degrees in all directions from epicenter do not receive S-Waves

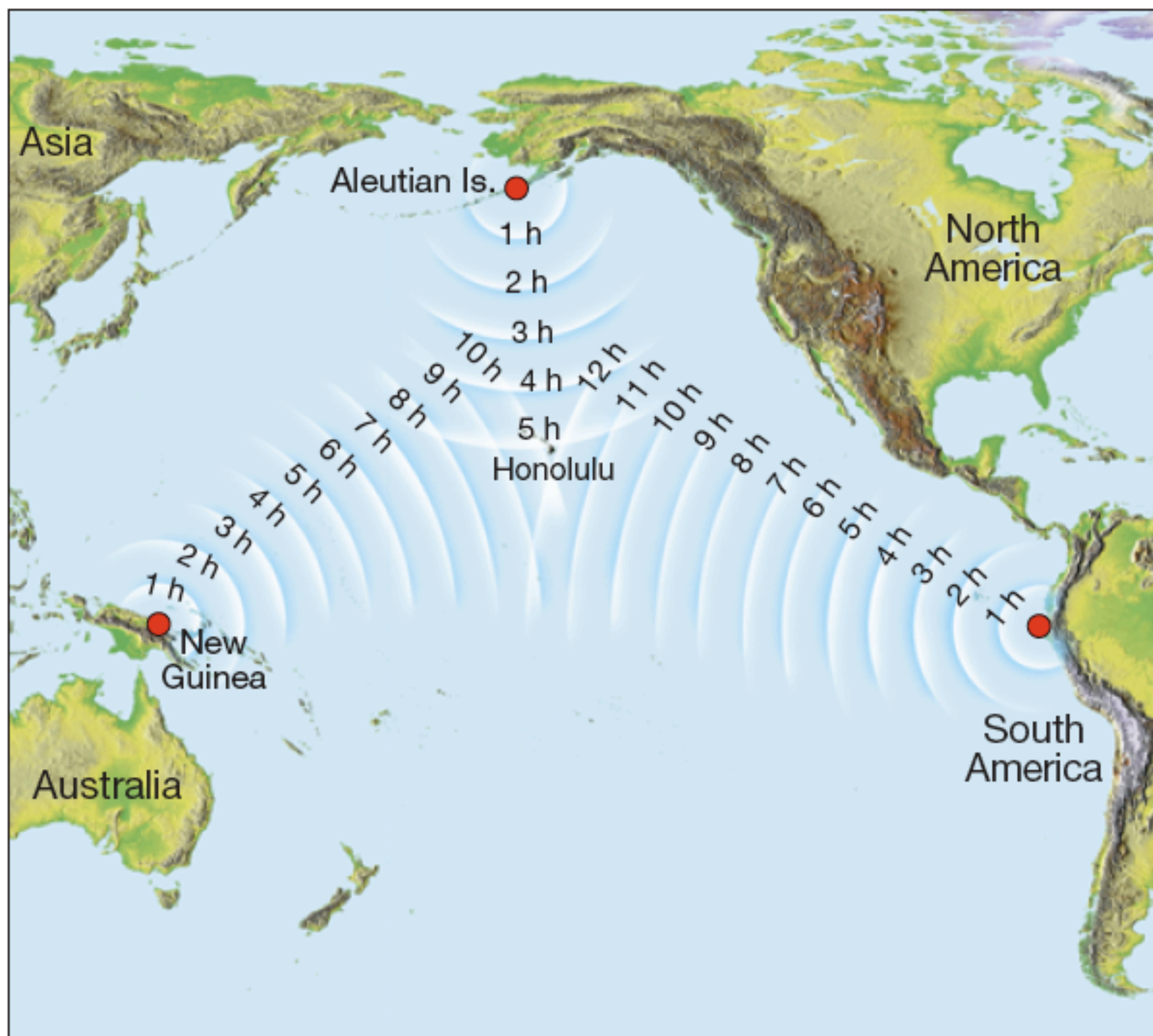


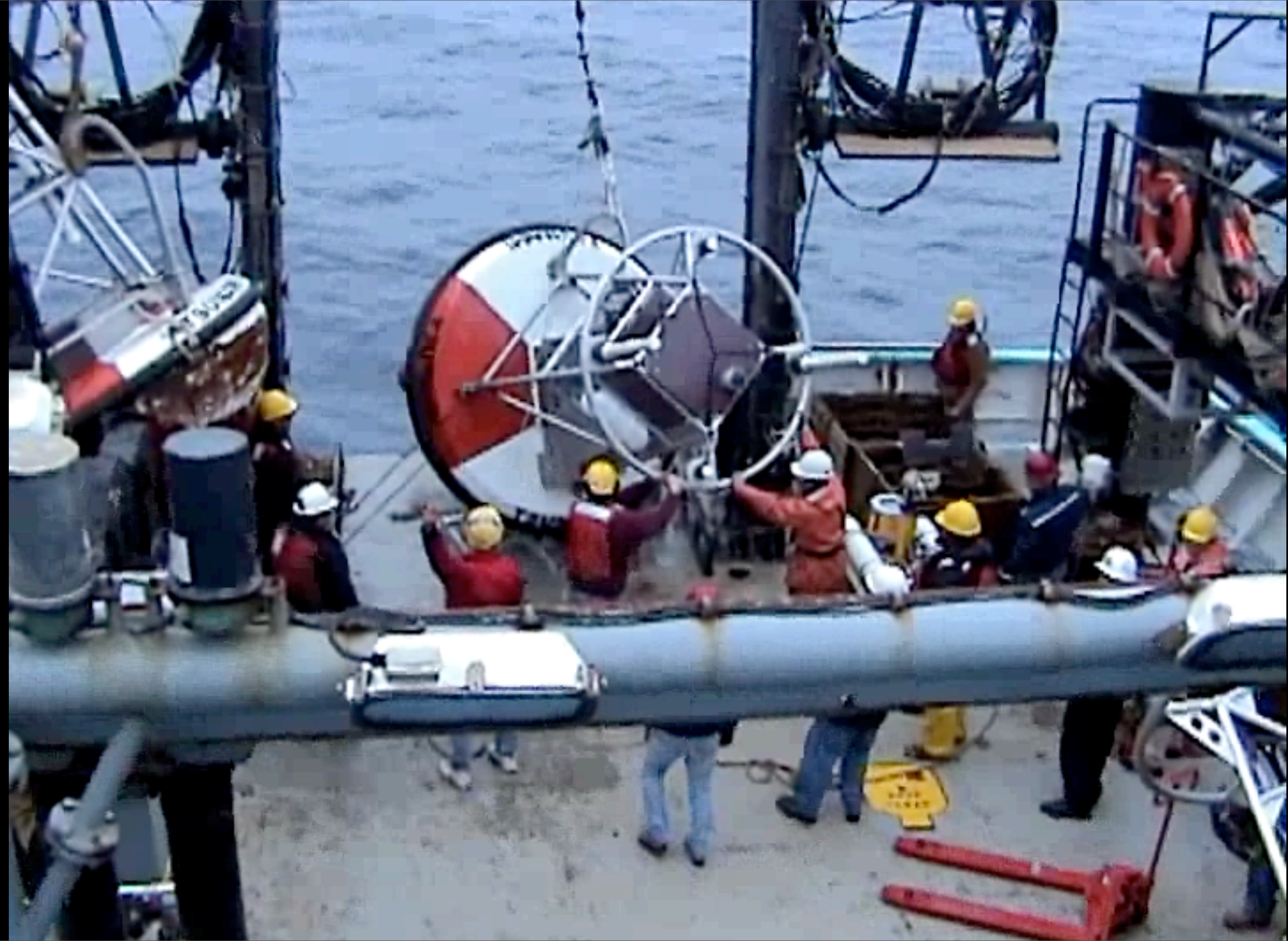


Underwater earthquakes may cause a tsunami.









K. How to determine epicenter location

- 📌 1 **Seismic Station** only tells you epicenter distance, not location
- 📌 2 **Seismic Stations** take an infinite number of possible locations and narrows it down to 2 possible points for epicenter location
- 📌 3 **Seismic Stations** will let you know exactly where the epicenter is located.
- 📌 Look to see where all 3 circles intersect (**TRIANGULATION**)
- 📌 The closer a seismic station is to the epicenter, the smaller the circle
- 📌 The farther a seismic station is to the epicenter, the larger the circle

We have also determined that the epicenter is 1500 miles from seismograph station B

The epicenter may be located anywhere along a circle around the station with a radius of 1000 miles

We have determined that the epicenter of the earthquake is 1000 miles from seismograph station A

Three Seismograph Stations

1000 miles

ATLANTIC OCEAN

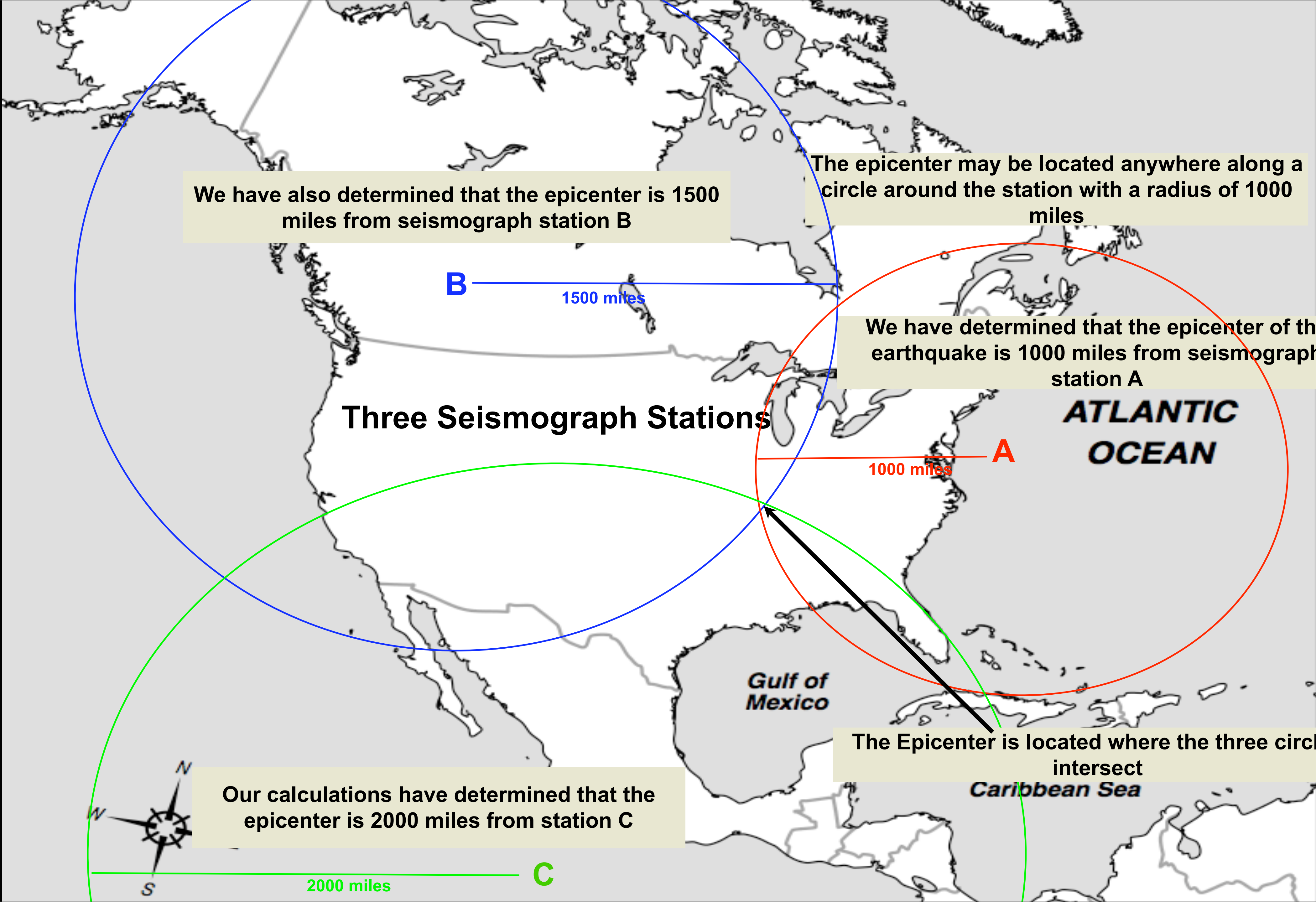
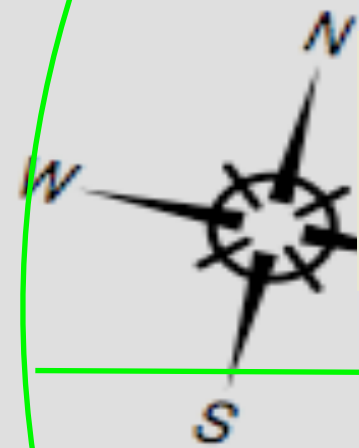
Gulf of Mexico

Caribbean Sea

The Epicenter is located where the three circles intersect

Our calculations have determined that the epicenter is 2000 miles from station C

2000 miles



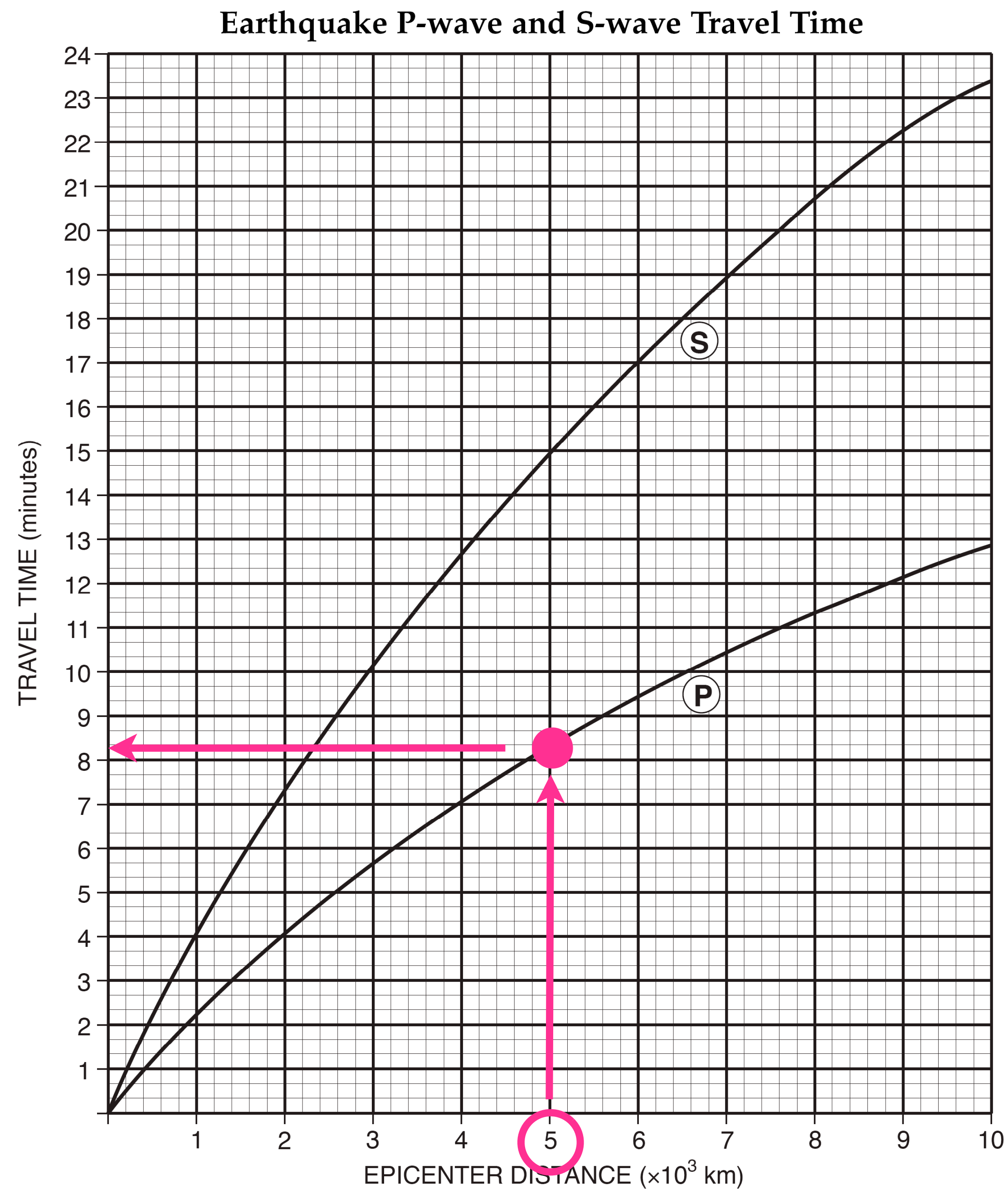


Things to think about.....

- 📌 **Travel Time**- Amount of time it takes for a P wave or S wave to travel a specific distance (Use Chart Directly!!)
- 📌 **Arrival Time**- The time a P wave or S wave arrives at a seismic station (Subtract P wave and S wave time and use paper method)
- 📌 **Lag Time**-Difference between P-Wave and S-Wave Arrival Times
- 📌 **Origin Time**-When the earthquake started
- 📌 Bigger the difference between arrival times, the farther away the epicenter is
- 📌 The smaller the difference between arrival times, the closer the epicenter is

Things we need to be able to determine...

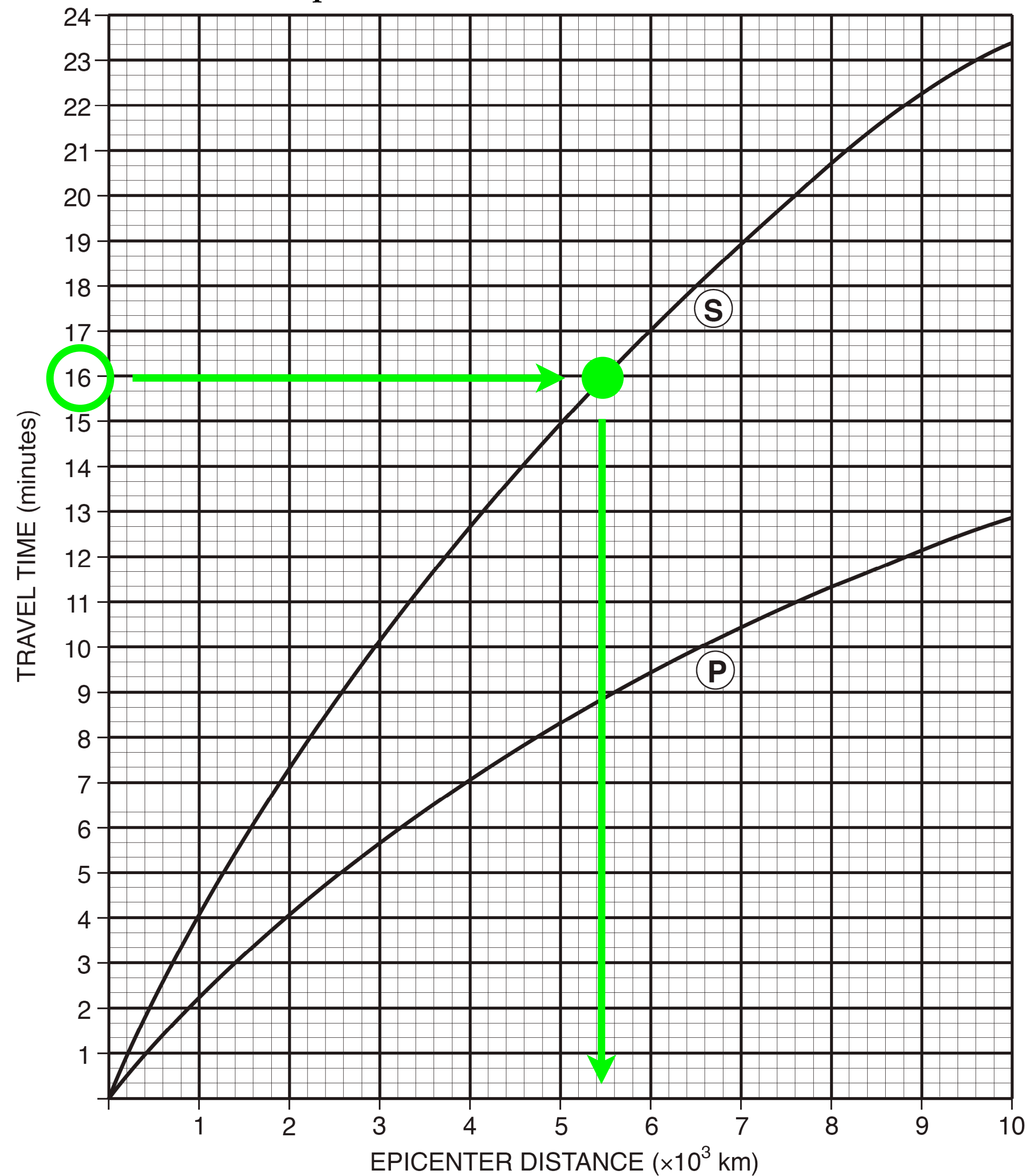
- ✓ P-wave travel time (P_{tt})
- ✓ P-wave arrival time (P_{arr})
- ✓ S-wave travel time (S_{tt})
- ✓ S-wave arrival time (S_{arr})
- ✓ Lag time ($P_{arr} - S_{arr}$)
- ✓ Epicenter distance (E_{dis})
- ✓ Epicenter location



How long does it take a
p-wave to travel 5,000
km?

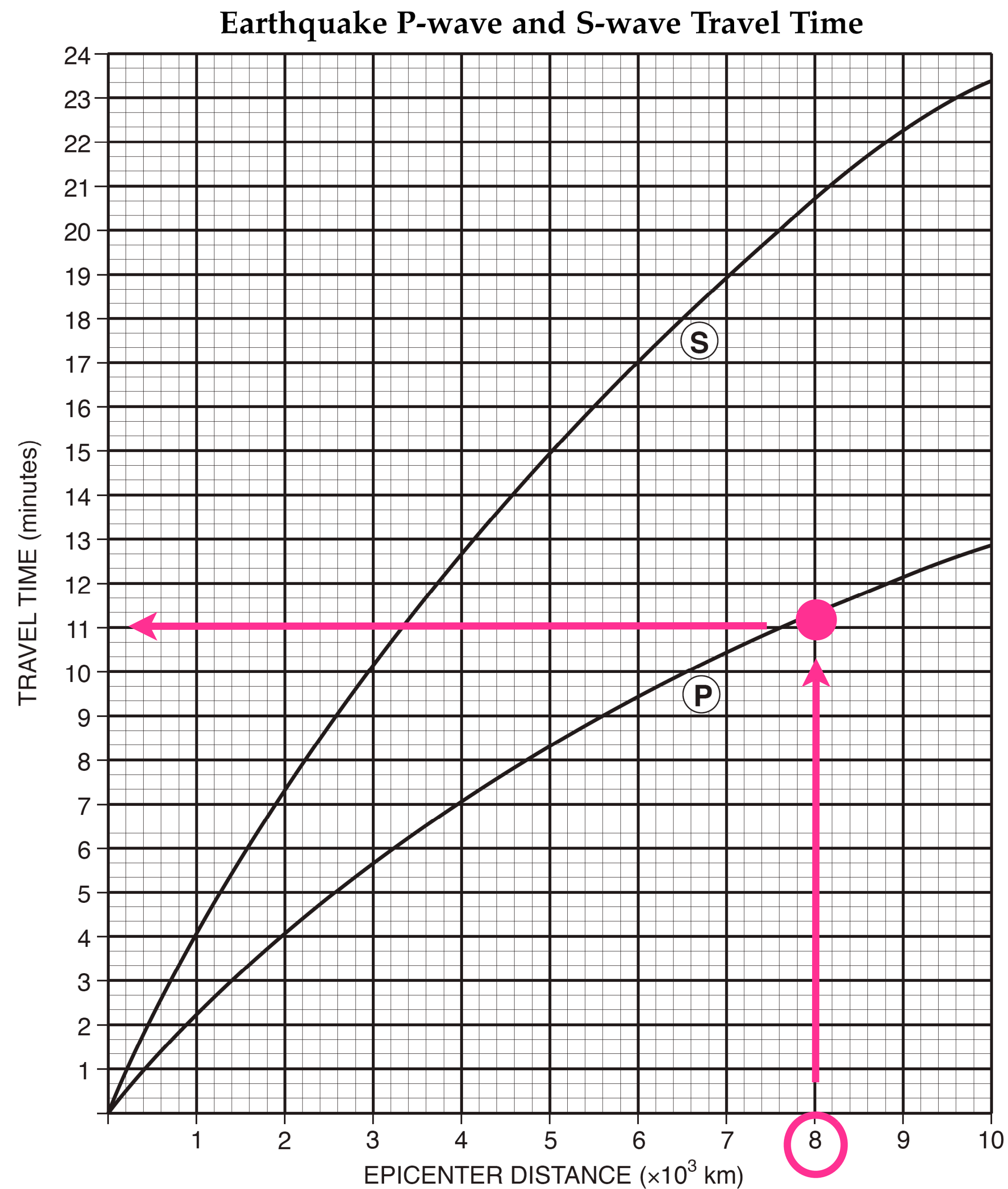
**8 minutes
20 seconds**

Earthquake P-wave and S-wave Travel Time



How far does an S-wave travel in 16 minutes?

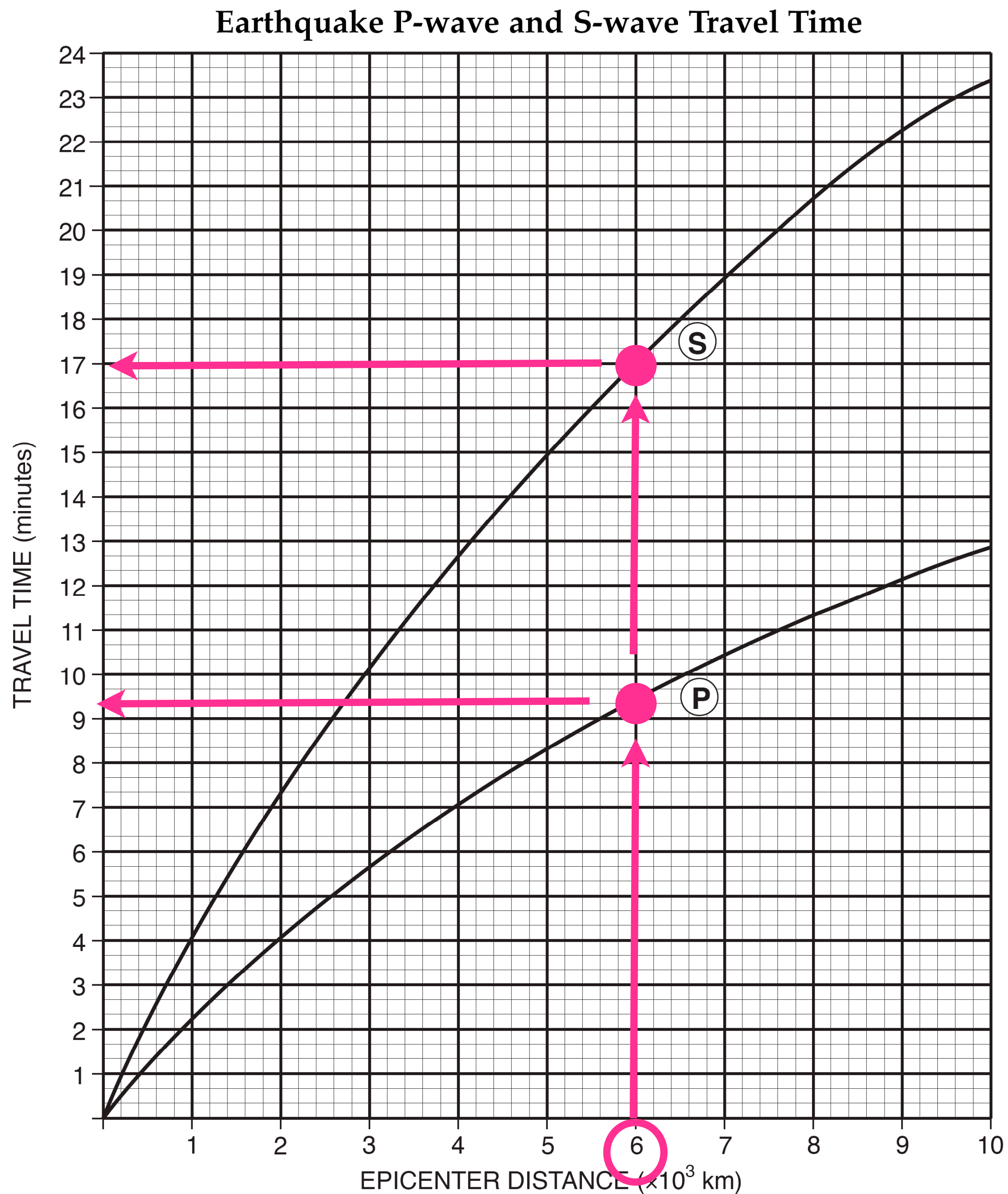
5,400 km



If an Earthquakes P-Wave travels 8000km and arrives at a seismic station at 11:40am, What is the origin time of the Earthquake?

11 Minute Travel Time

Origin Time-11:29am

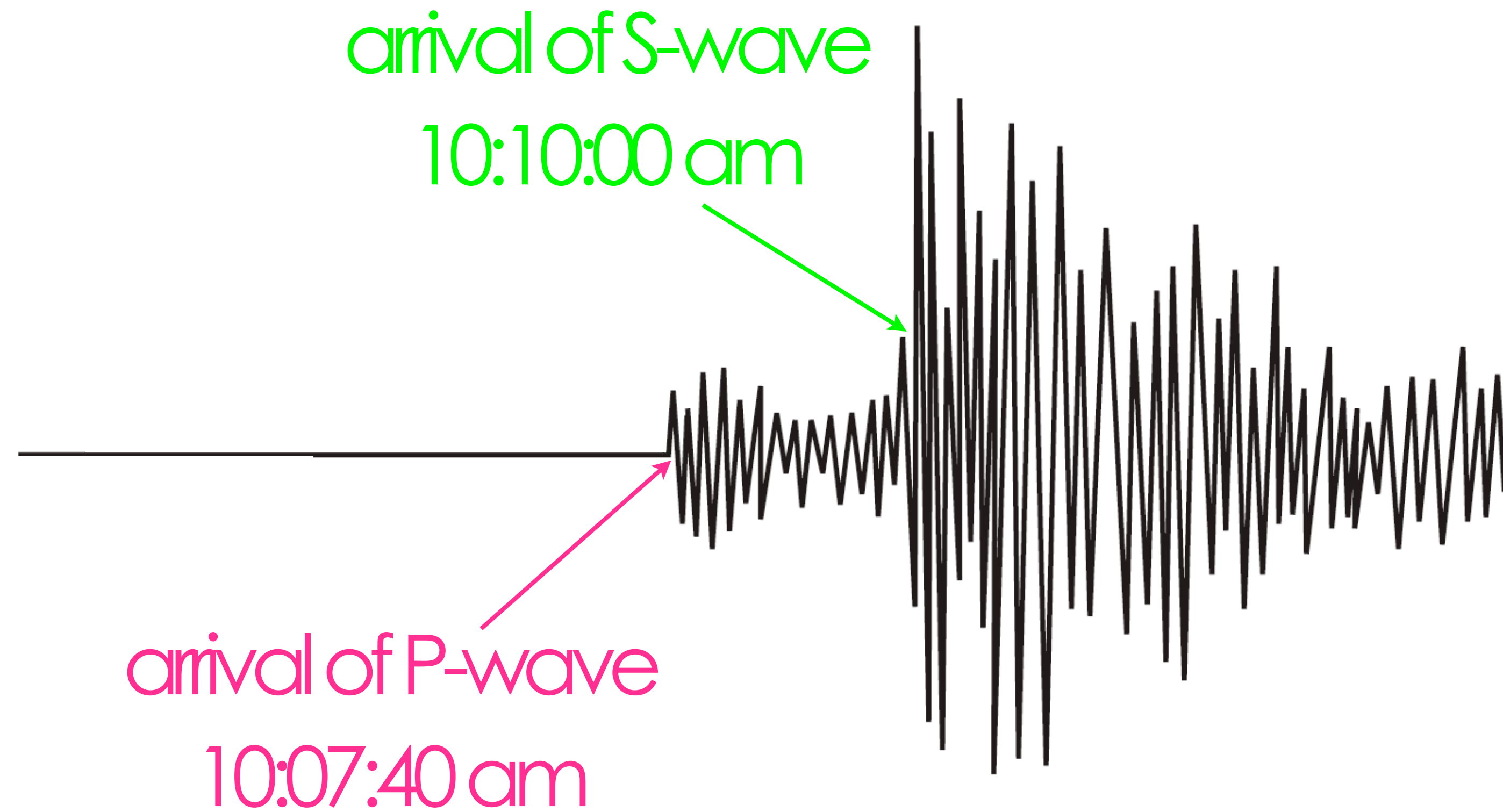


If an Earthquakes P-Wave arrives at 12:00pm and travels 6000km, what time will the S-Wave arrive?

P-Wave Travel Time:
00:09:20

S-Wave Travel Time:
00:17:00

Difference: 00:07:40
Time of Arrival: 12:07:40



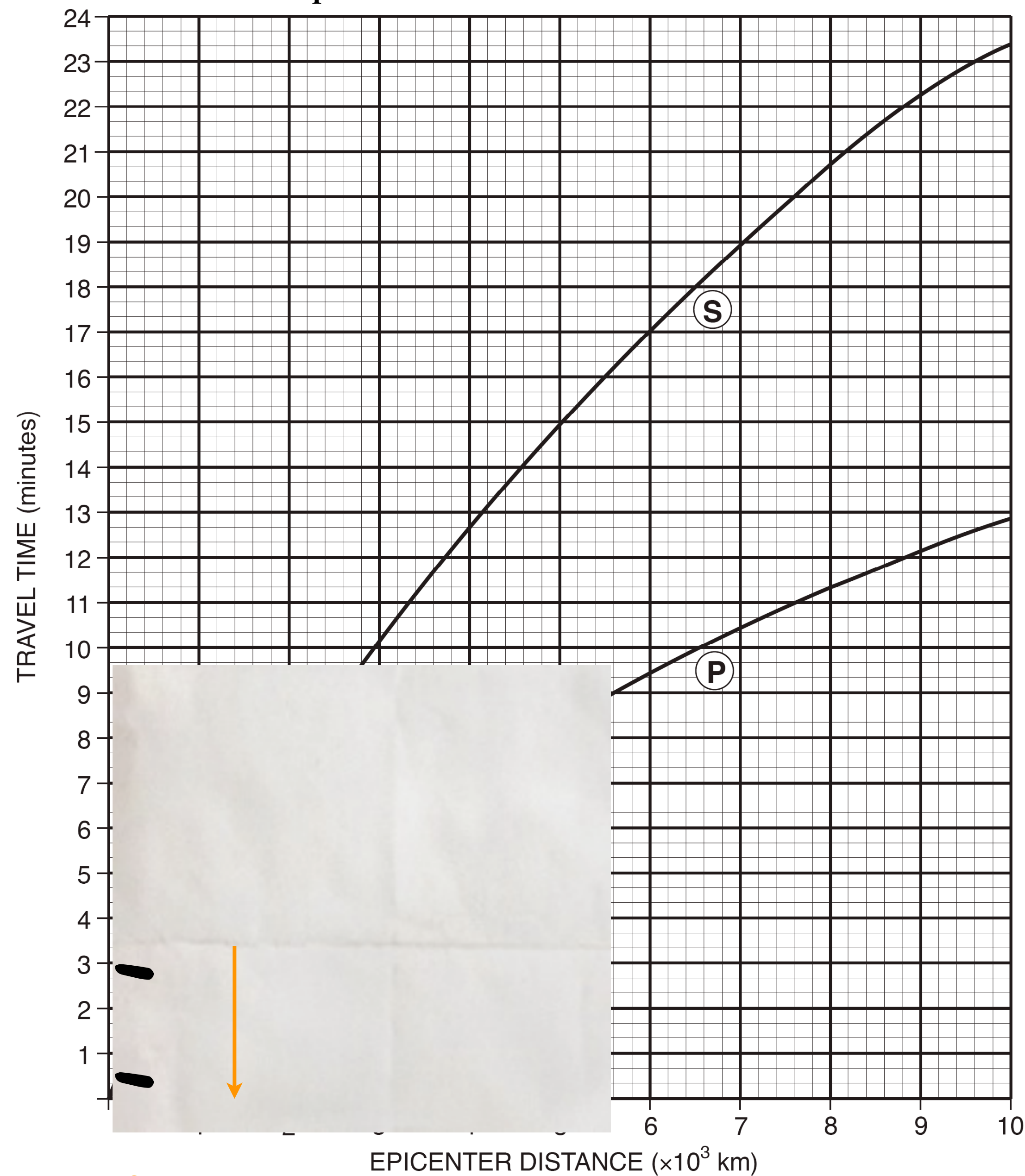
✓ $P_{arr} = 10:07:40$

✓ $S_{arr} = 10:10:00$

✓ Lag time = 00:02:20

✓ Epicenter distance?

Earthquake P-wave and S-wave Travel Time

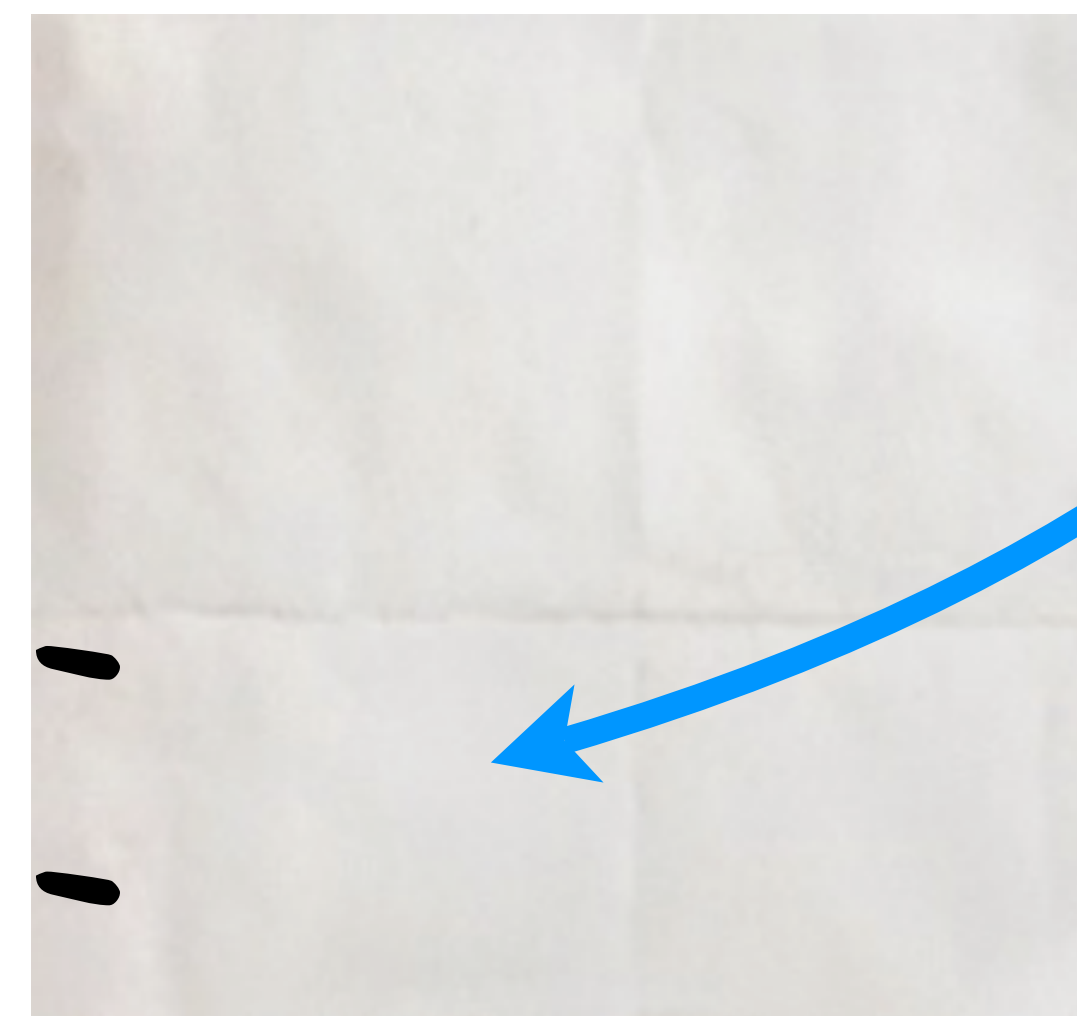


✓ $S_{arr} = 10:10:00$

✓ $P_{arr} = 10:07:40$

✓ Lag time = 00:02:20

✓ Epicenter distance?



Epicenter distance = 1,400 km

