Section 2- EARTHQUAKES

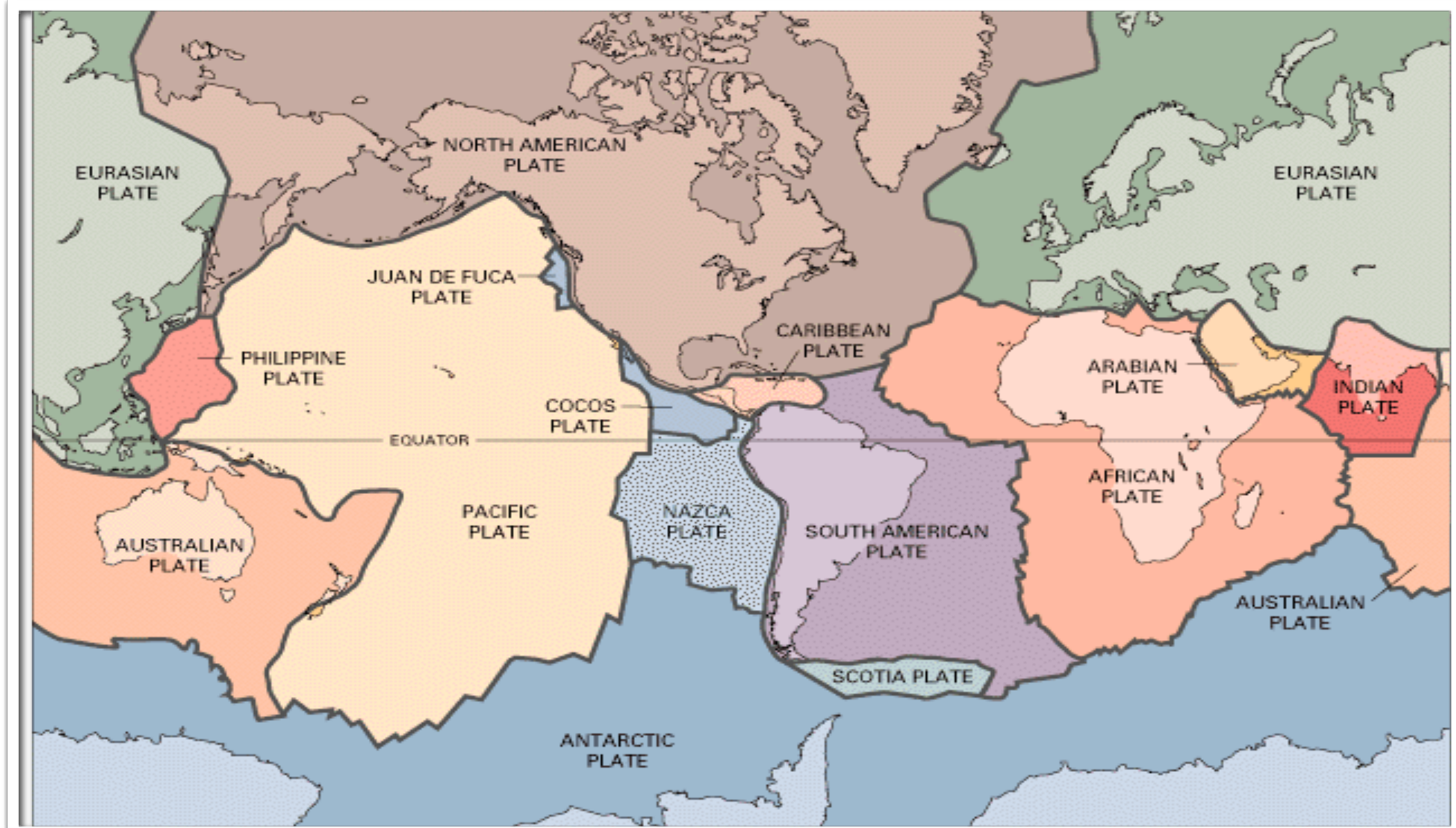
Fig. 18.18

A. What is "The Dynamic Crust?"

- Dynamic means constantly changing

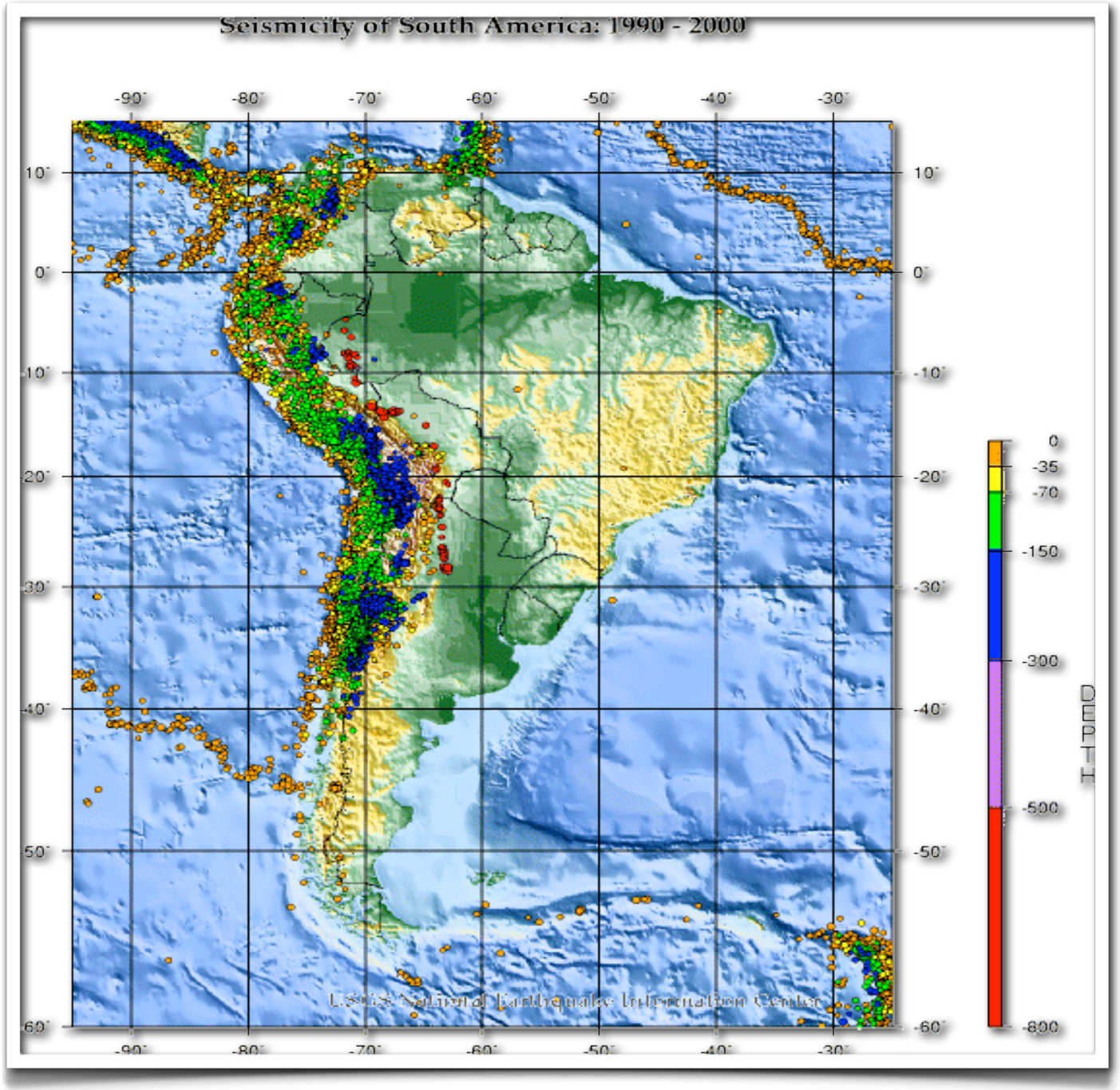
- Crust is the outer portion of the earth

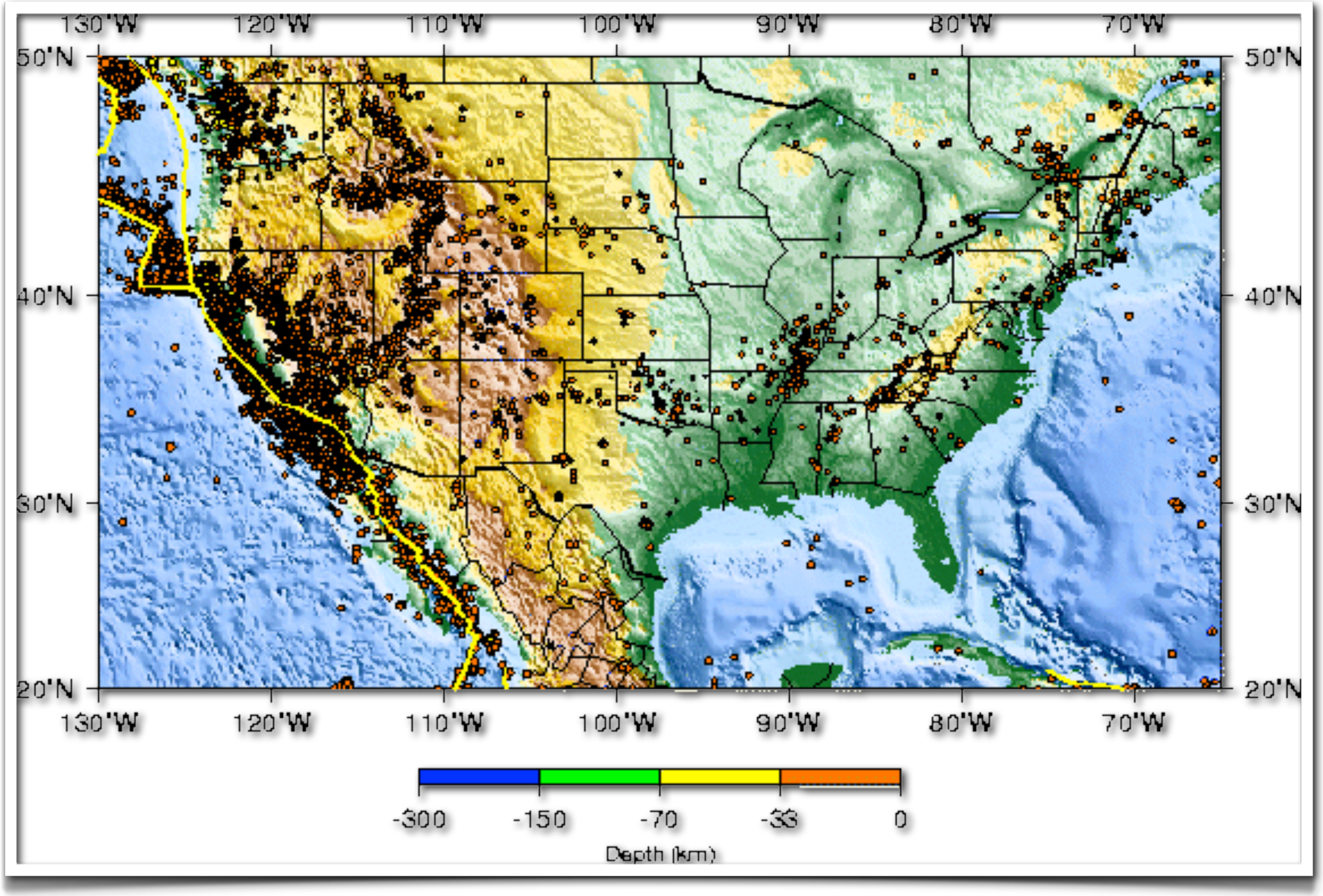
- Dynamic Crust is the term given to how the Earth's Crust is ever changing and evolving through plate tectonics

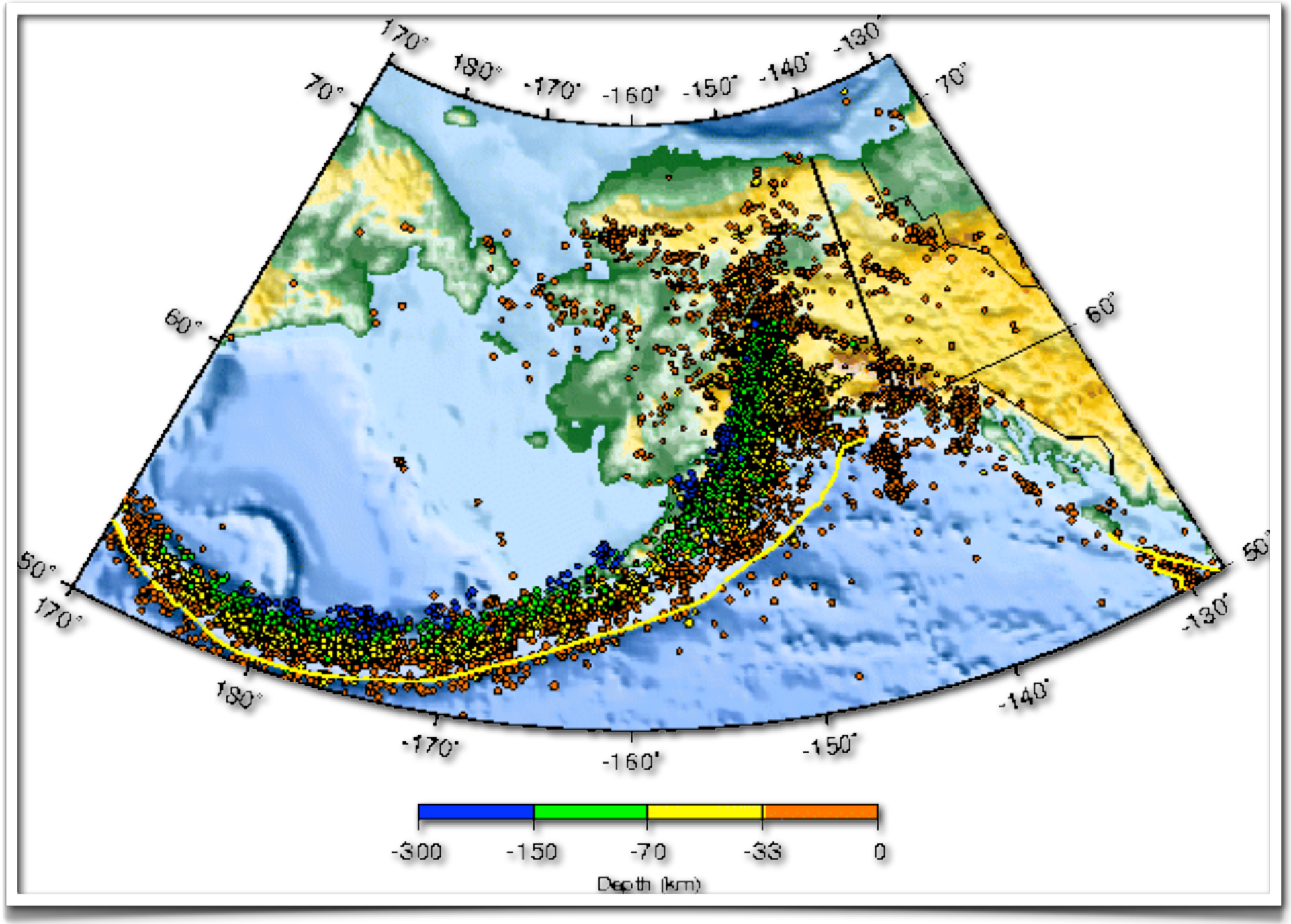

EURASIAN PLATE
NORTH AMERICAN PLATE
EURASIAN PLATE
JUAN DE FUCA PLATE
CARIBBEAN PLATE
PHILIPPINE PLATE
ARABIAN PLATE
INDIAN PLATE
COCOS PLATE
EQUATOR
AFRICAN PLATE
PACIFIC PLATE
NAZCA PLATE
SOUTH AMERICAN PLATE
AUSTRALIAN PLATE
AUSTRALIAN PLATE
SCOTIA PLATE
ANTARCTIC PLATE

B. Where do Earthquakes Occur?

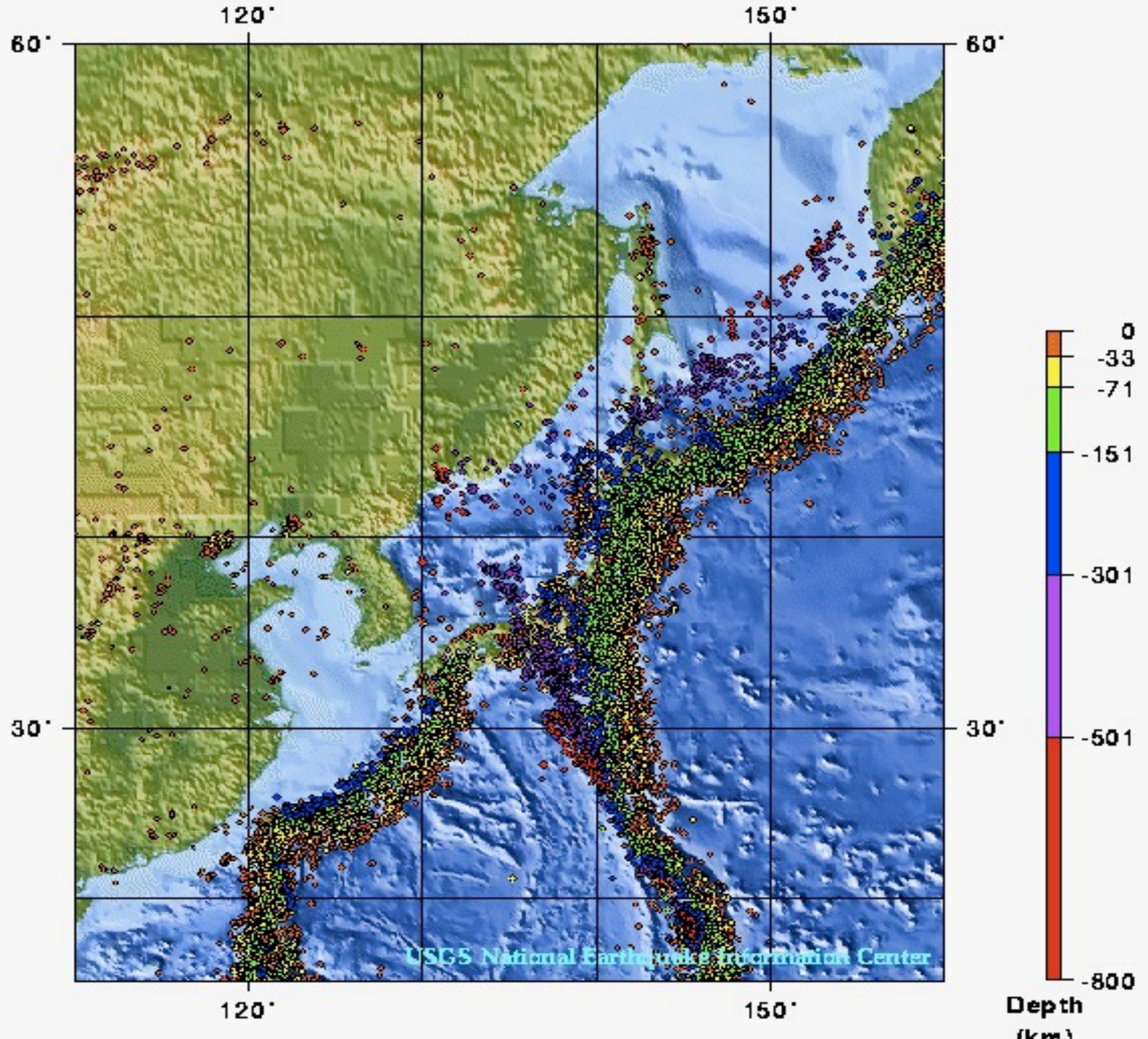
- They occur along plate boundaries
  - trenches
  - subduction
  - volcanoes
  - mountains
- Anywhere there is convergence, divergence or transform plate boundaries.
- Convergent boundaries most violent earthquakes
- Deeper the earthquake is, the stronger it is!!!


Seismicity of South America: 1990 - 2000
-90°
-80°
-70°
-60°
-50°
-40°
-30°
10°
0°
-10°
-20°
-30°
-40°
-50°
-60°
0
-35
-70
-150
-300
-500
-800
DEPTH
USGS National Earthquake Information Center

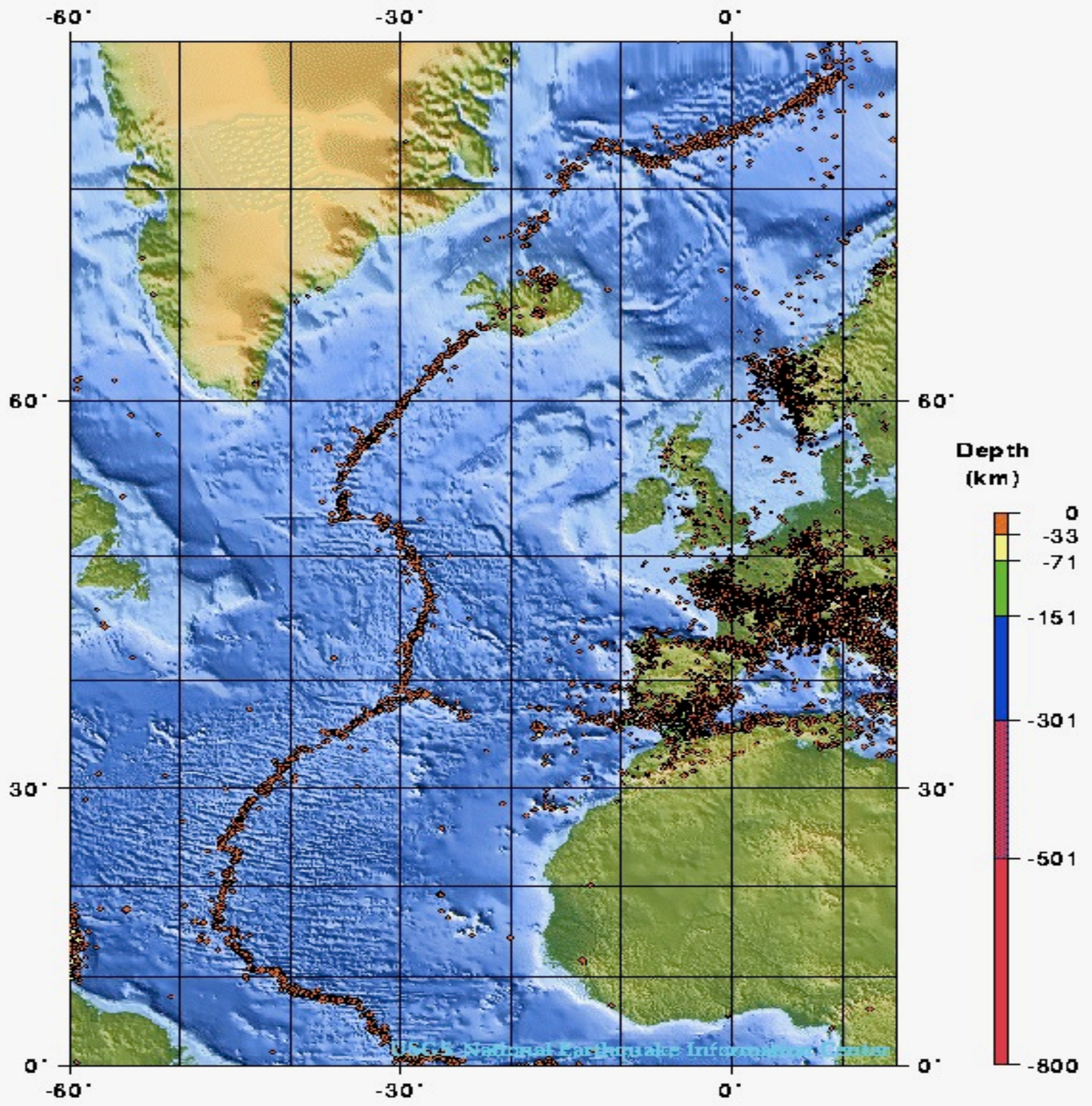

130°W
120°W
110°W
100°W
90°W
80°W
70°W
50°N
40°N
30°N
20°N
-300
-150
-70
-33
0
Depth (km)


170°
180°
-170°
-160°
-150°
-140°
-130°
70°
60°
50°
-300
-150
-70
-33
0
Depth (km)

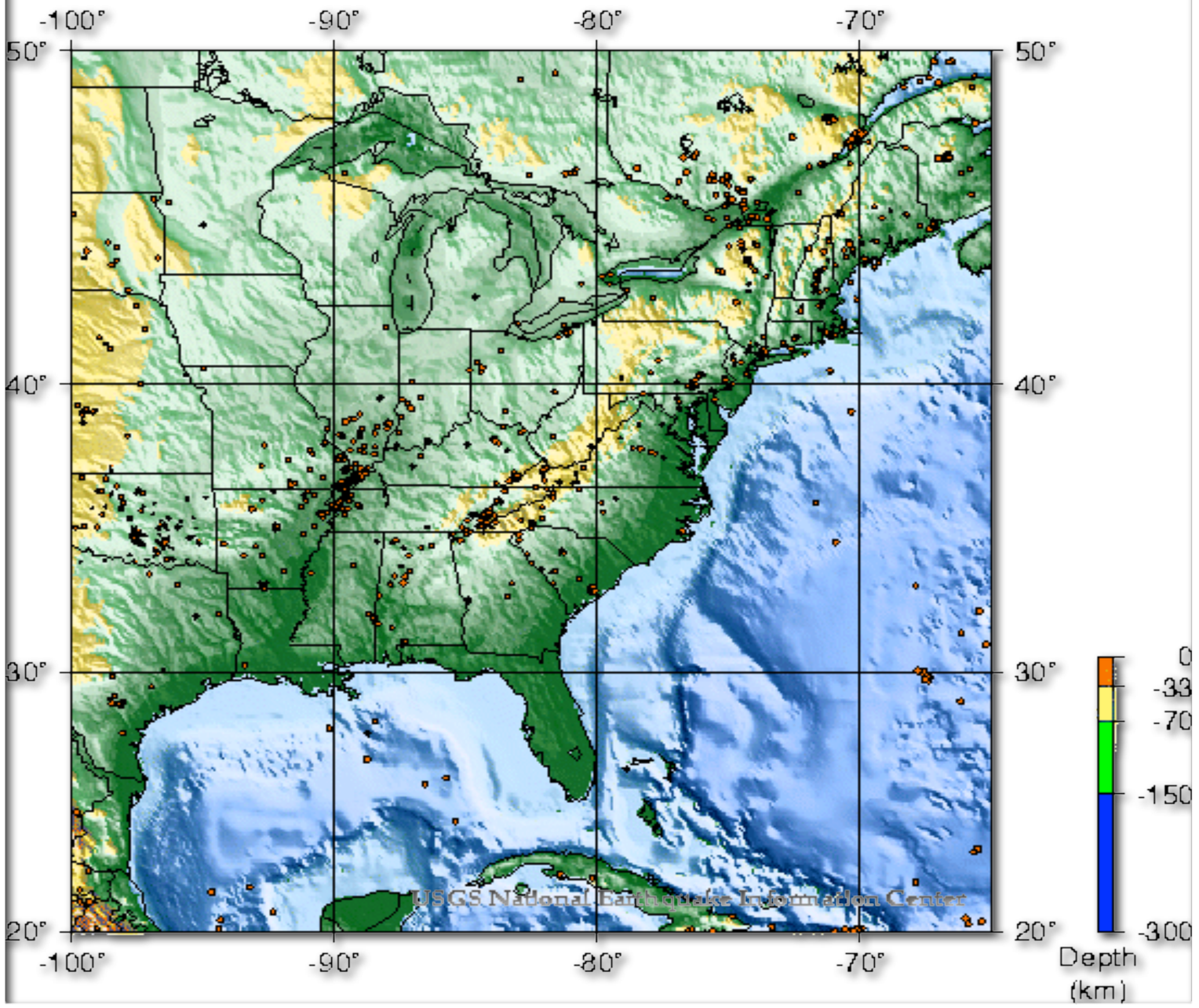
Seismicity of Japan and Kuril Islands: 1975 - 1995

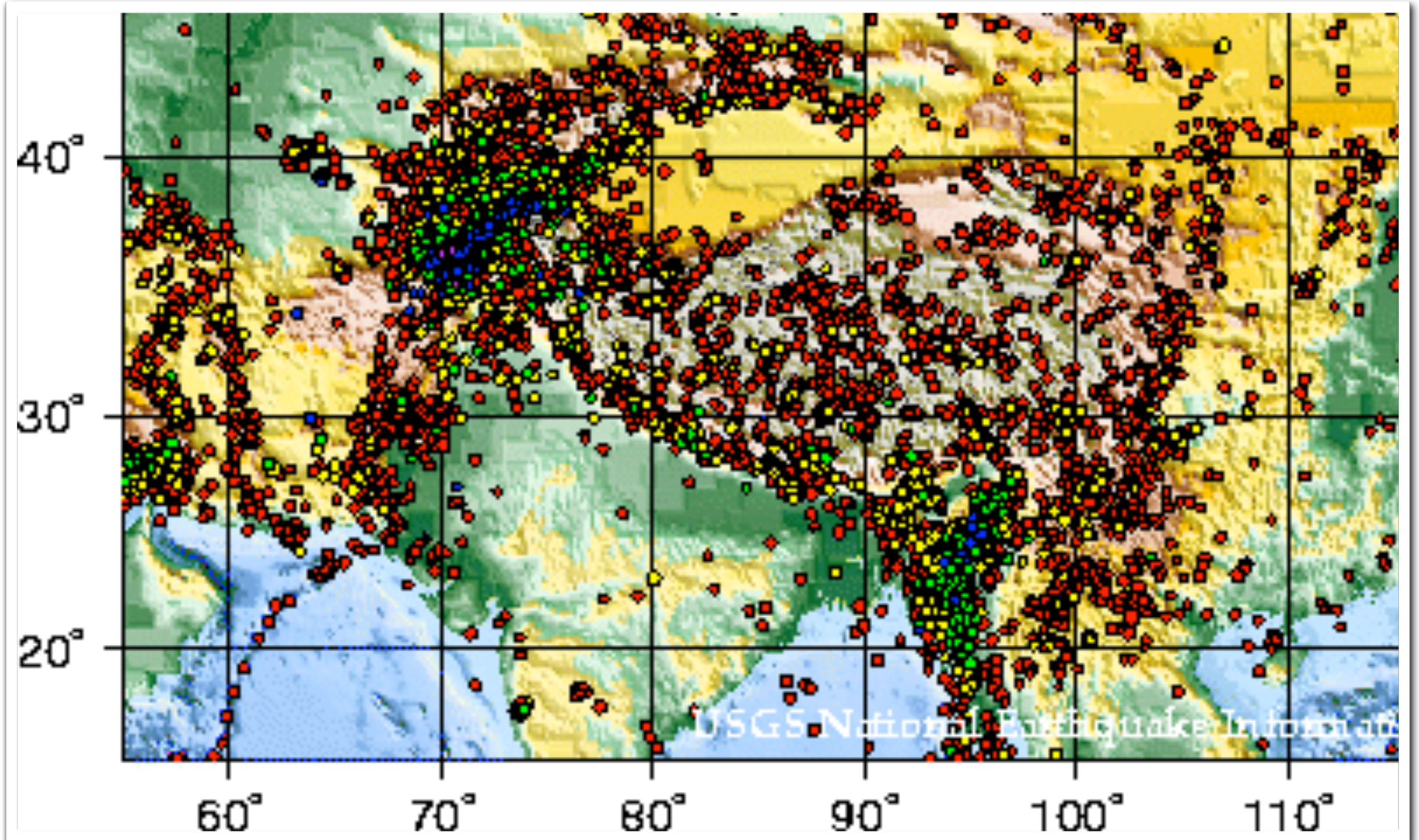


Seismicity of the North Atlantic Ocean: 1975 - 1995



Seismicity of the Eastern United States: 1977 - 1997

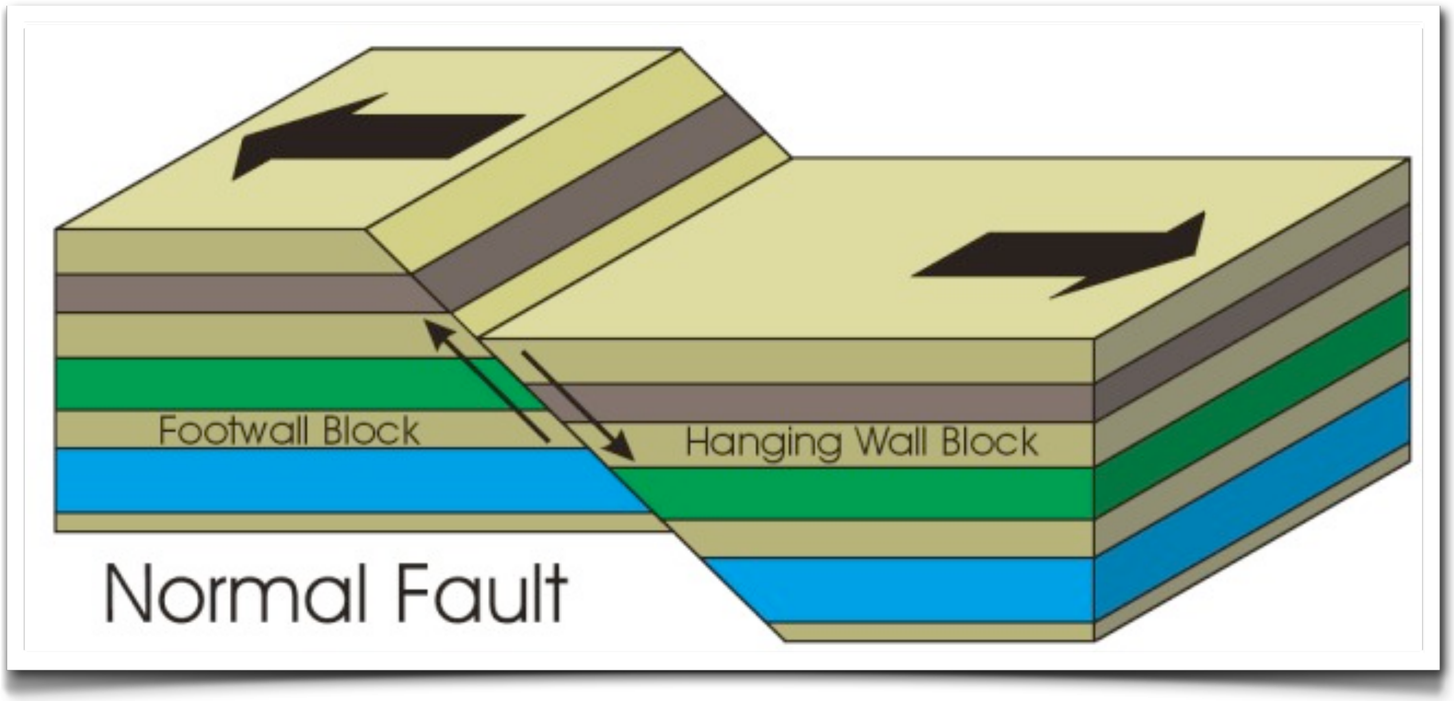



40°
30°
20°
60°
70°
80°
90°
100°
110°
USGS National Earthquake Information

C. What causes Earthquakes?

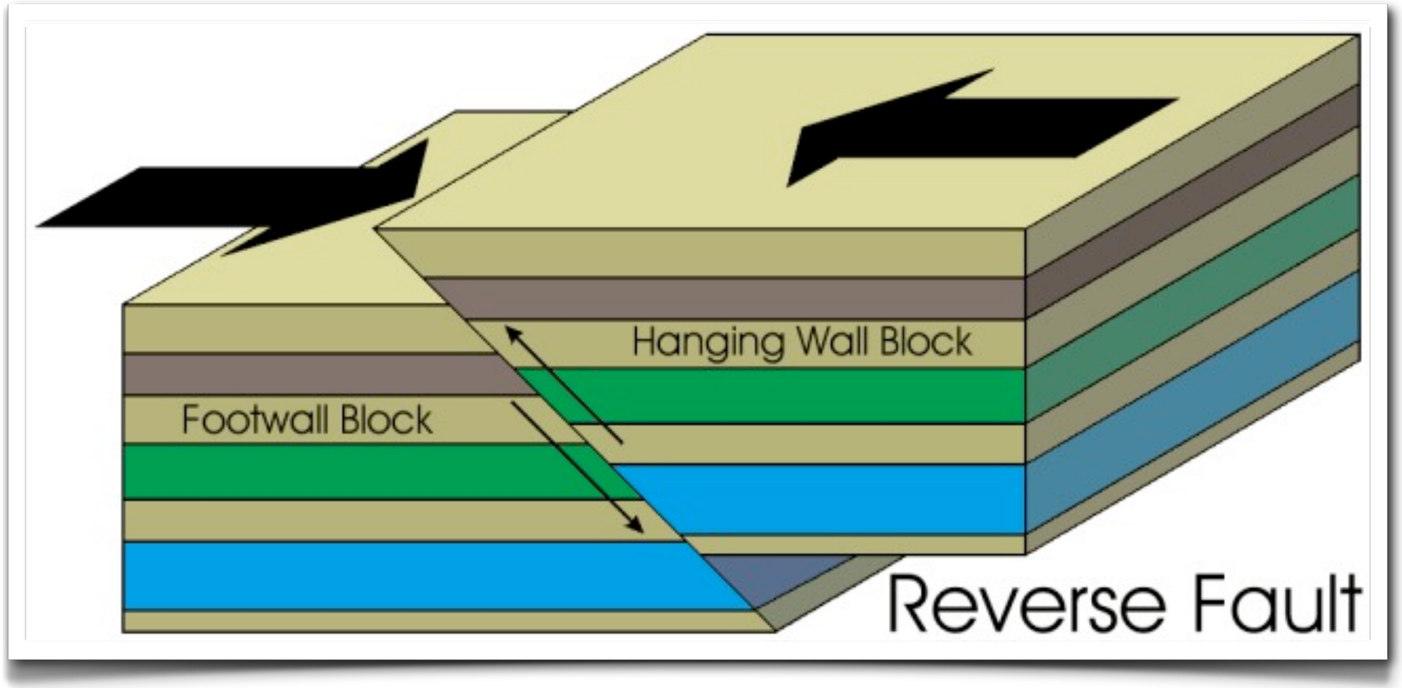
- Vibrating, shaking or rapid motion of the Earth's crust
- The way the Earth "releases her energy!!!"
- Occur along FAULT lines (Massive Cracks in Rock)
- Three types of faults:
  - Normal
  - Reverse
  - Strike-Slip (Transform Plate Boundary)

D. Normal Fault



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

E. REVERSE FAULT



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

F. Strike-Slip Fault
(Transform Plate Boundary)

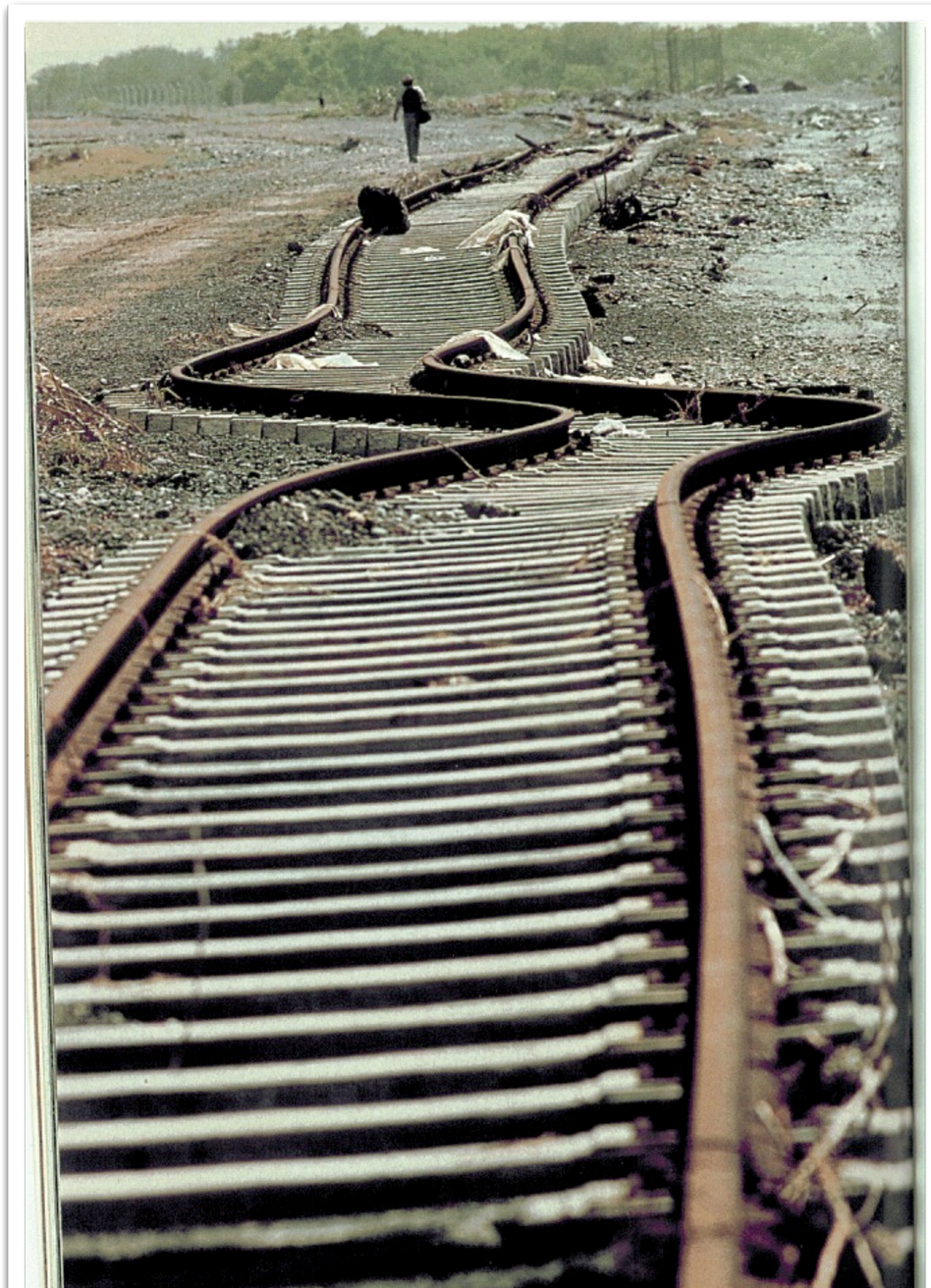
- One side of plate slides past the other of a plate.
- North American and Pacific Plates
- This is also a type of plate boundary.
- San Andreas Fault is an example of this.
- This is called Shear Stress

San Andreas Fault


AMERICAN PLATE
PACIFIC PLATE

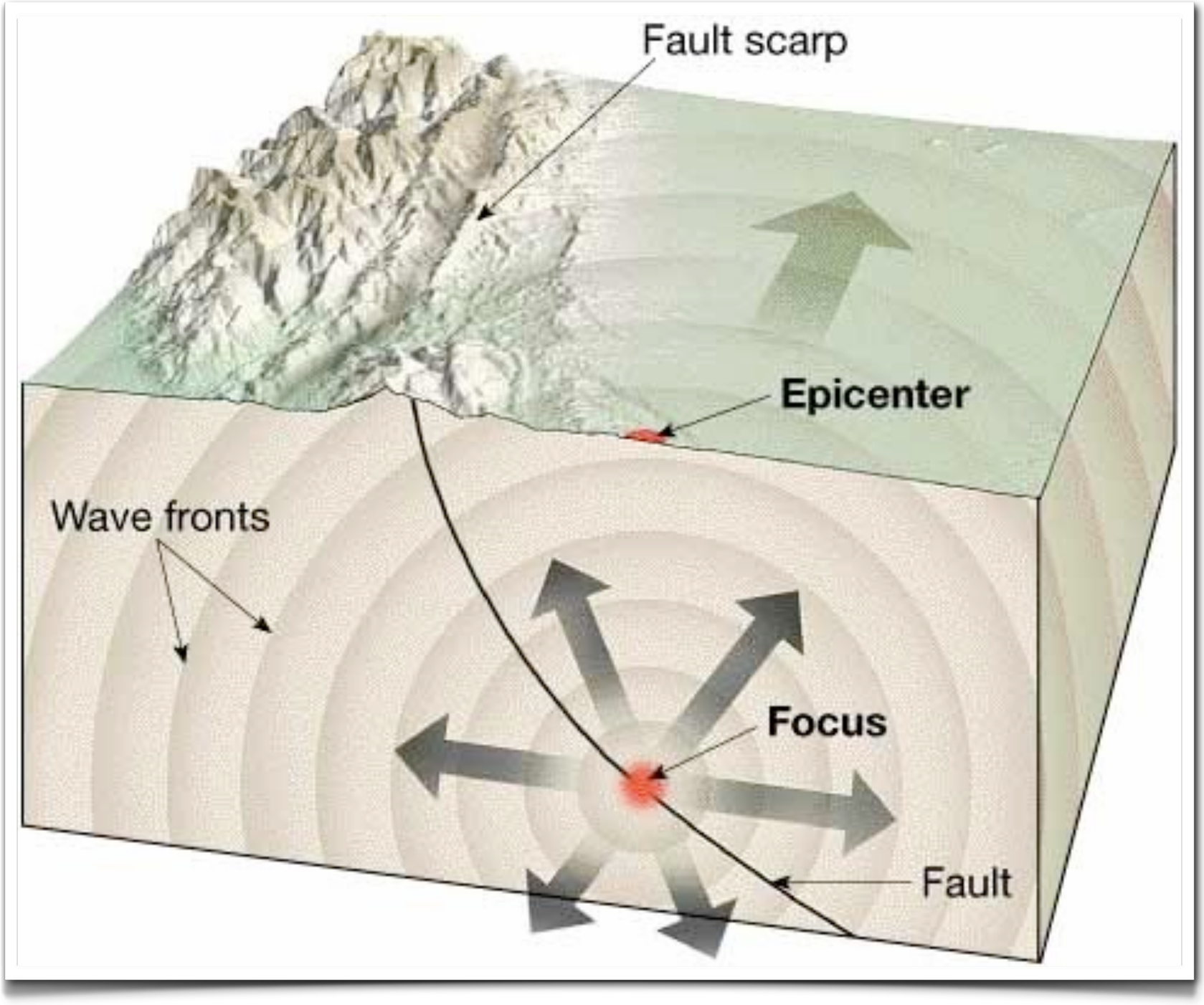
Northridge, CA…1988

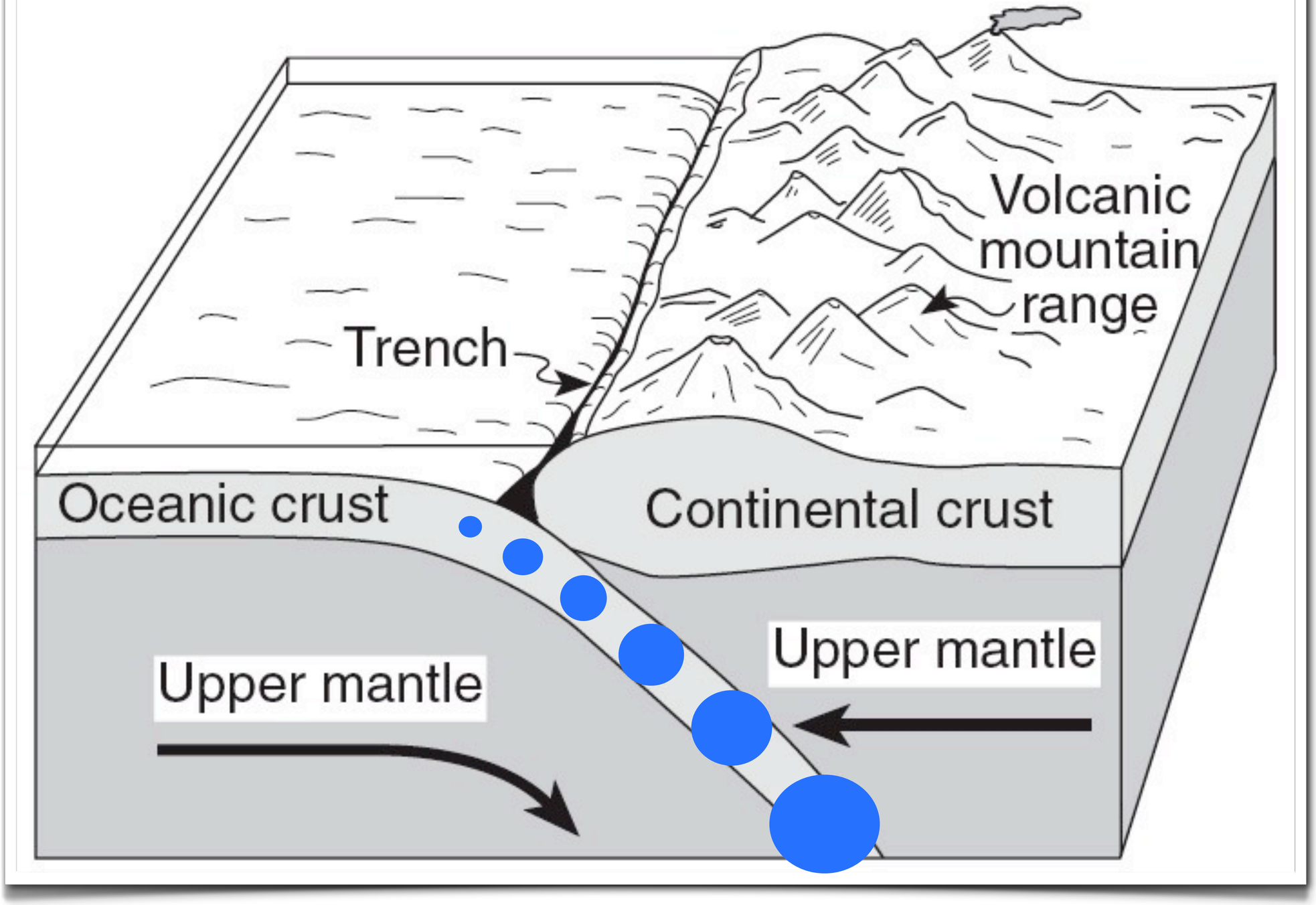

KEEP
TO
RIGHT



G. Parts of an Earthquake

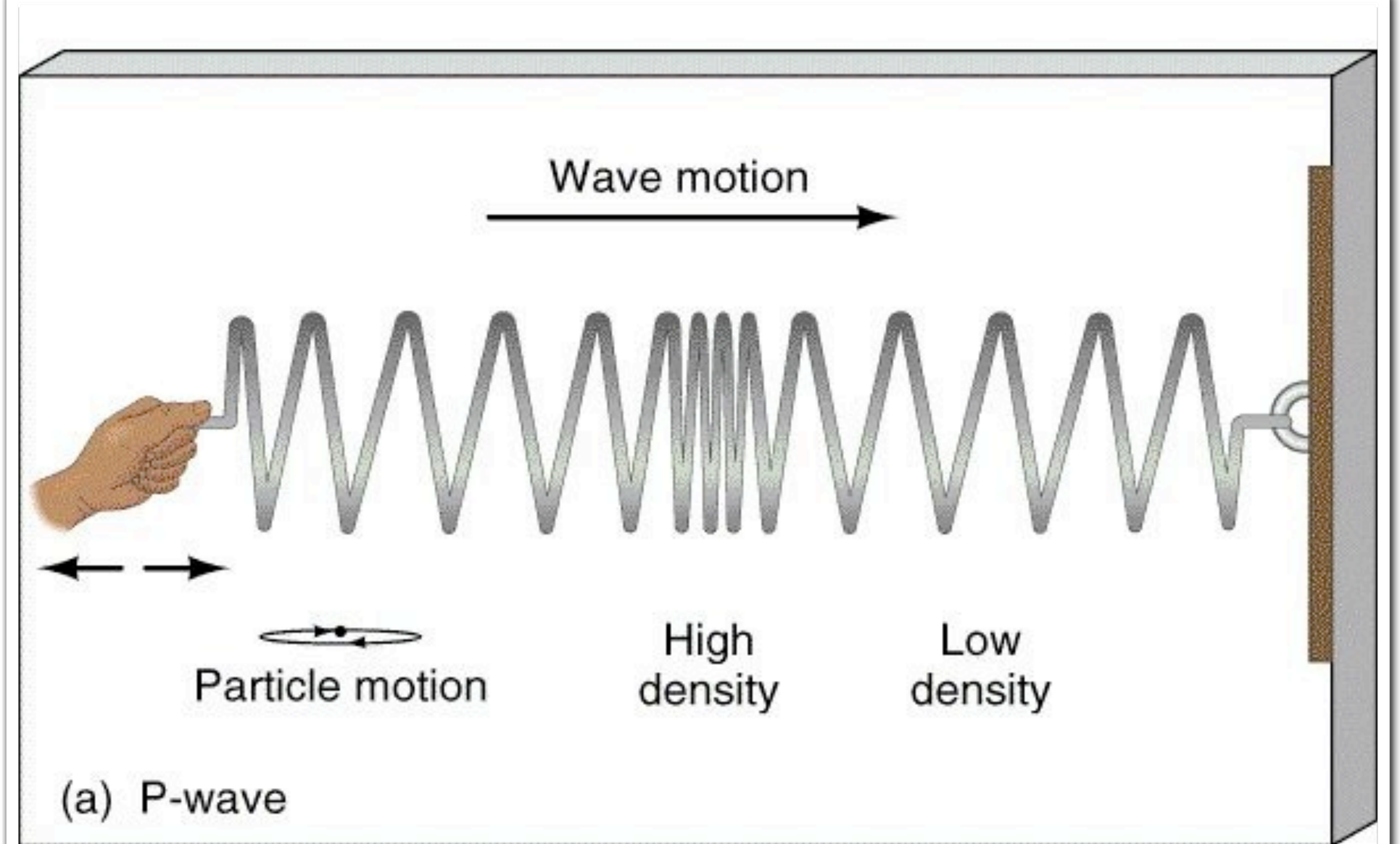
- Focus - Earthquake actually occurs inside the Earth
- Deeper the Focus, the stronger the earthquake. (Focal Depth)
- Epicenter is the location at the surface of crust just above the Focus. Closer to Epicenter, stronger the earthquake
- Seismic Waves are the different waves (vibrations) that are sent throughout the planet from the earthquake
- P- Waves
- S-Waves


Fault scarp
Epicenter
Wave fronts
Focus
Fault


Volcanic
mountain
range
Trench
Oceanic crust
Continental crust
Upper mantle
Upper mantle

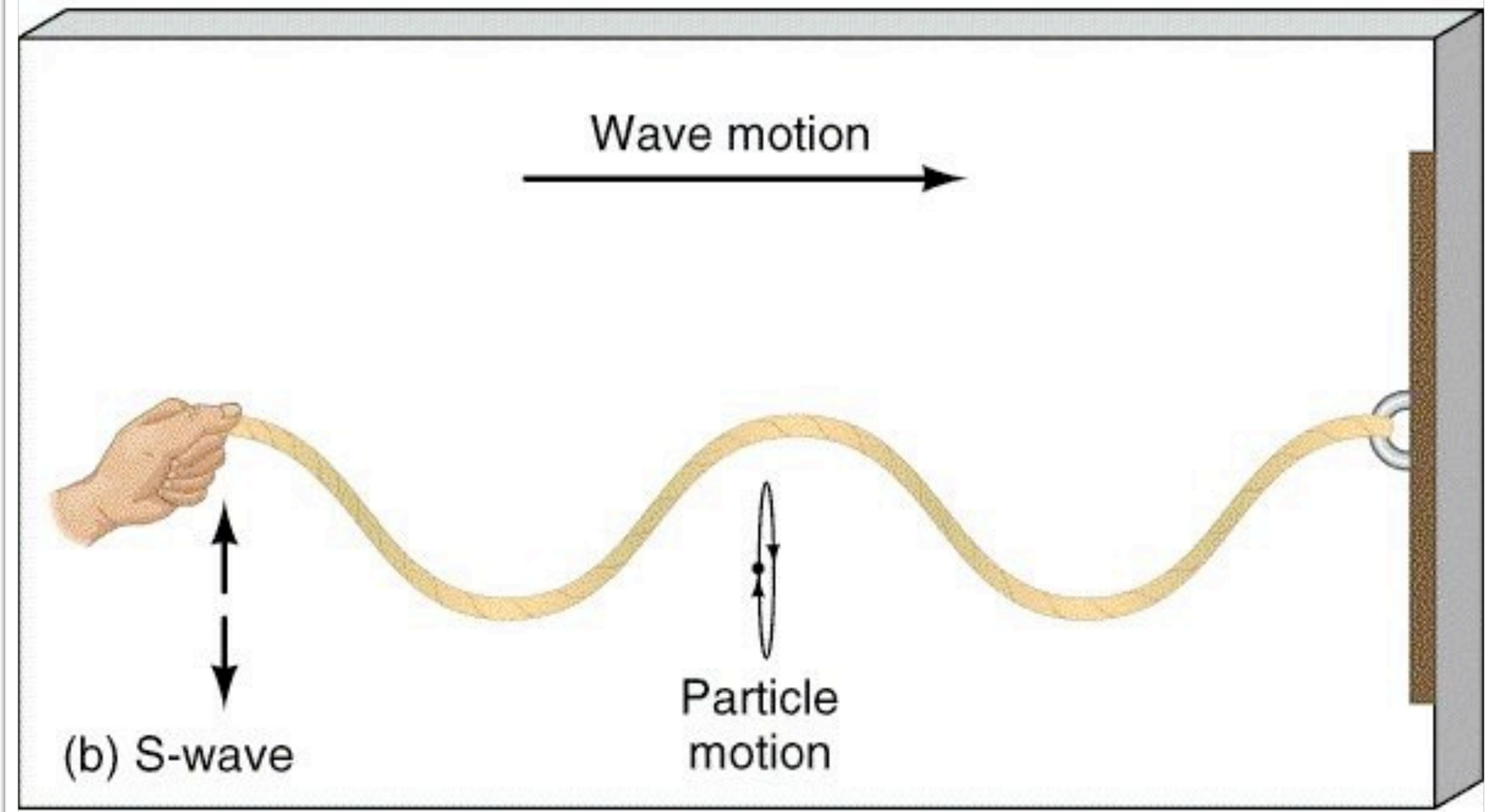
H. TYPES OF WAVES: Primary Waves

- P-wave
- Push-Pull Motion...Think about how a slinky
- Primary or compressional wave
- Travels fastest
- Arrives at seismic station FIRST
- CAN travel through SOLIDS, LIQUIDS, AND GASES


Wave motion
Particle motion
High density
Low density
(a) P-wave

I. TYPES OF WAVES-Secondary Waves

- S-Wave
- Secondary or Shear Waves
- Travel Slower than P Waves
- Arrive at the seismic station second
- Moves in an "S"-Like manner
- P and S waves travel fastest through denser material (further inside the Earth)
- ****CANNOT TRAVEL THROUGH LIQUID SUBSTANCES****
- Inference that the Outer Core is Liquid is based on S-Waves


Wave motion
(b) S-wave
Particle
motion

J. Easy way to remember the waves

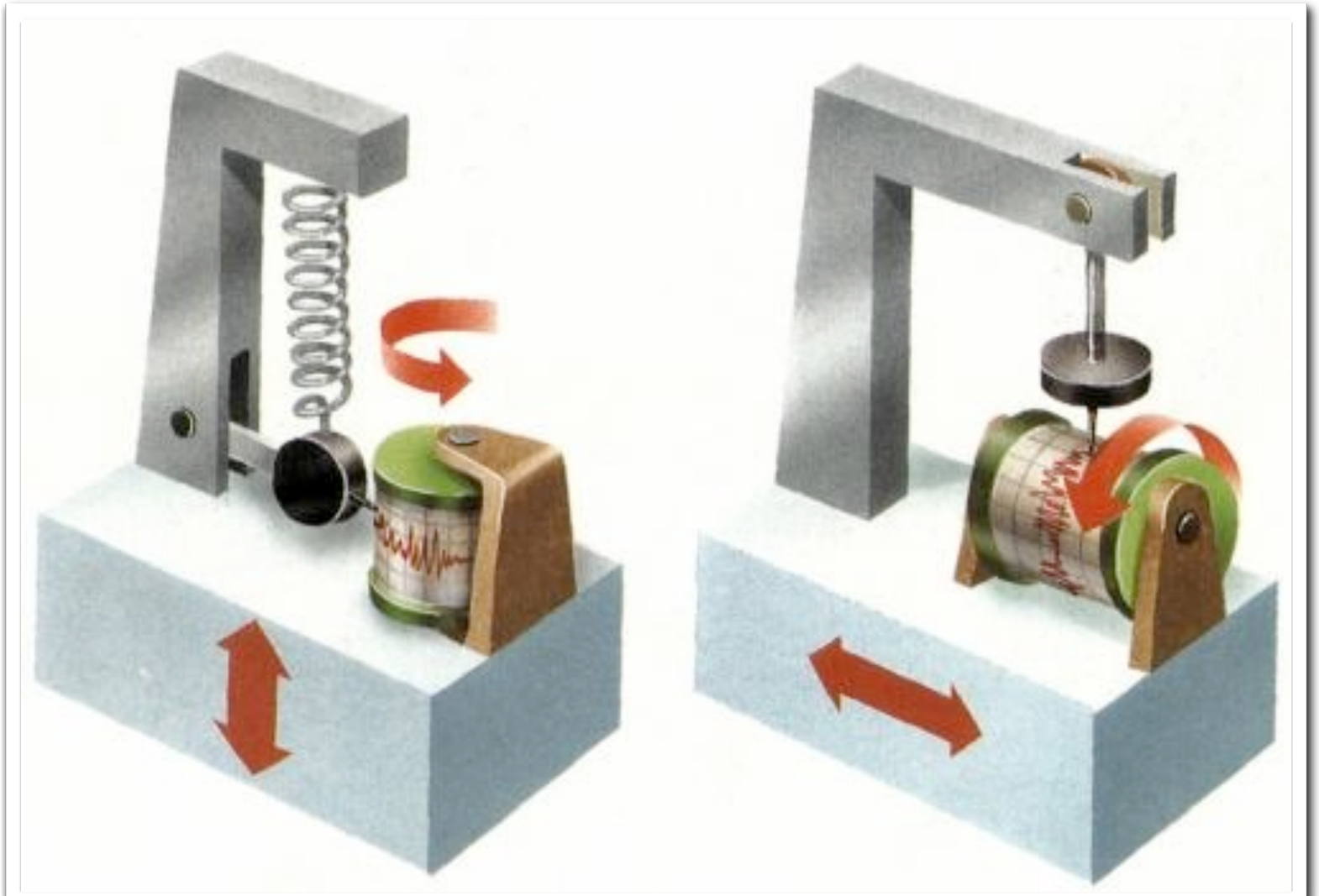
- P- Waves/ Compression
  - **P**rimary Waves
  - **P**hirst to seismic station
  - **P**haster than S wave
  - **P**ush-**P**ull
  - **P**ass through solids,liquids and gases
  - **P**orsche
- S-Waves
  - **S**econdary Waves
  - **S**econd to seismic station
  - **S**lower than P wave (**S**nail)
  - **S**hear
  - **S**olids Only!!
  - Travels in an "**S**"-like pattern
  - **S**nake
  - **S**aturn

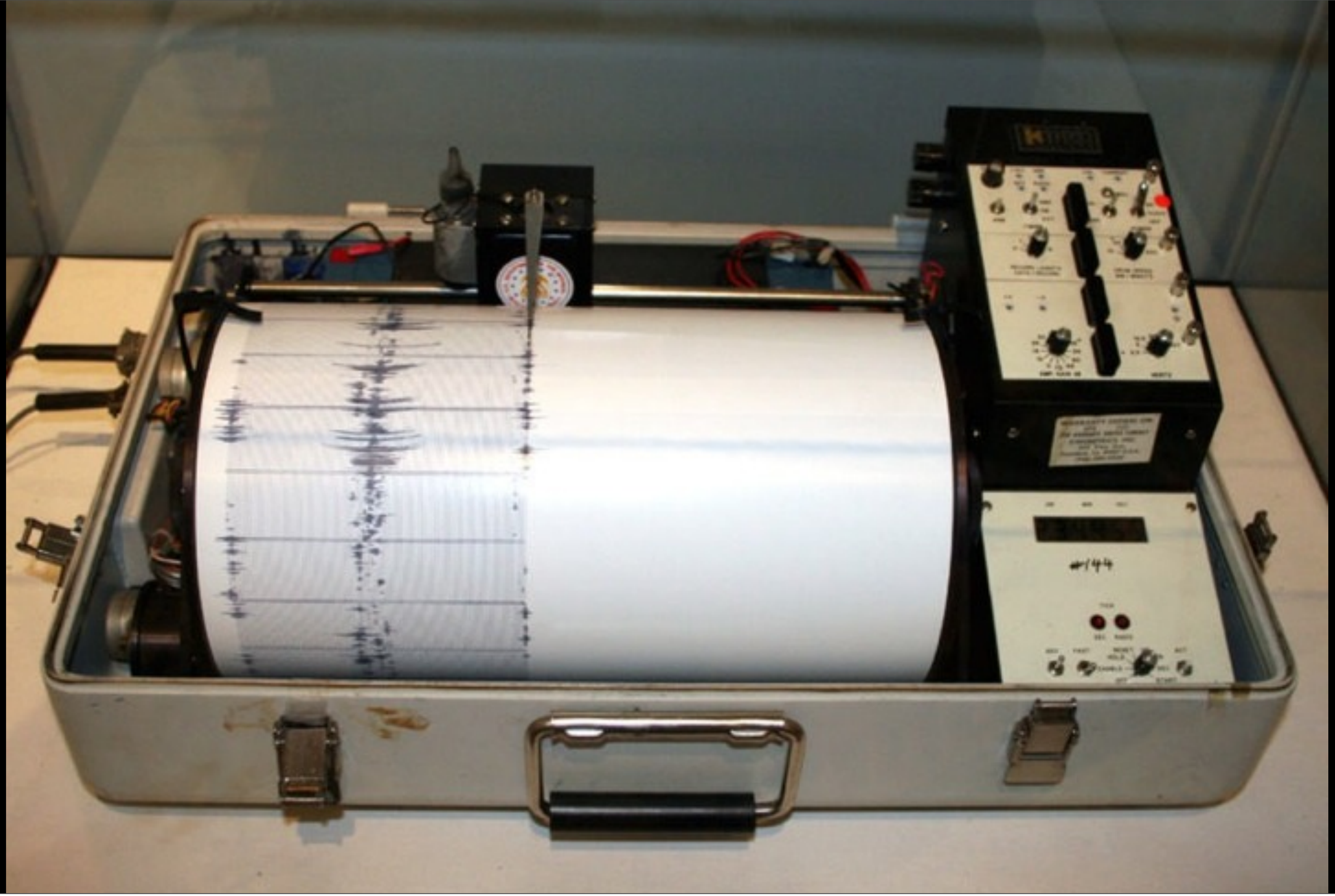
Porsche vs. Saturn

"SEIS"=Earthquake

- Seismologist-Someone who studies earthquakes
- Seismograph-Machine that picks up vibrations
- Seismogram-Printout of the vibrations
- Seismic Waves-P Waves and SWaves
- Seismic Station-Location where waves are recorded
- Vibrations are measured by how big the "zig-zag" pattern is (Amplitude of Waves)
  - Bigger they are....stronger the earthquake
  - Smaller they are....weaker the earthquake

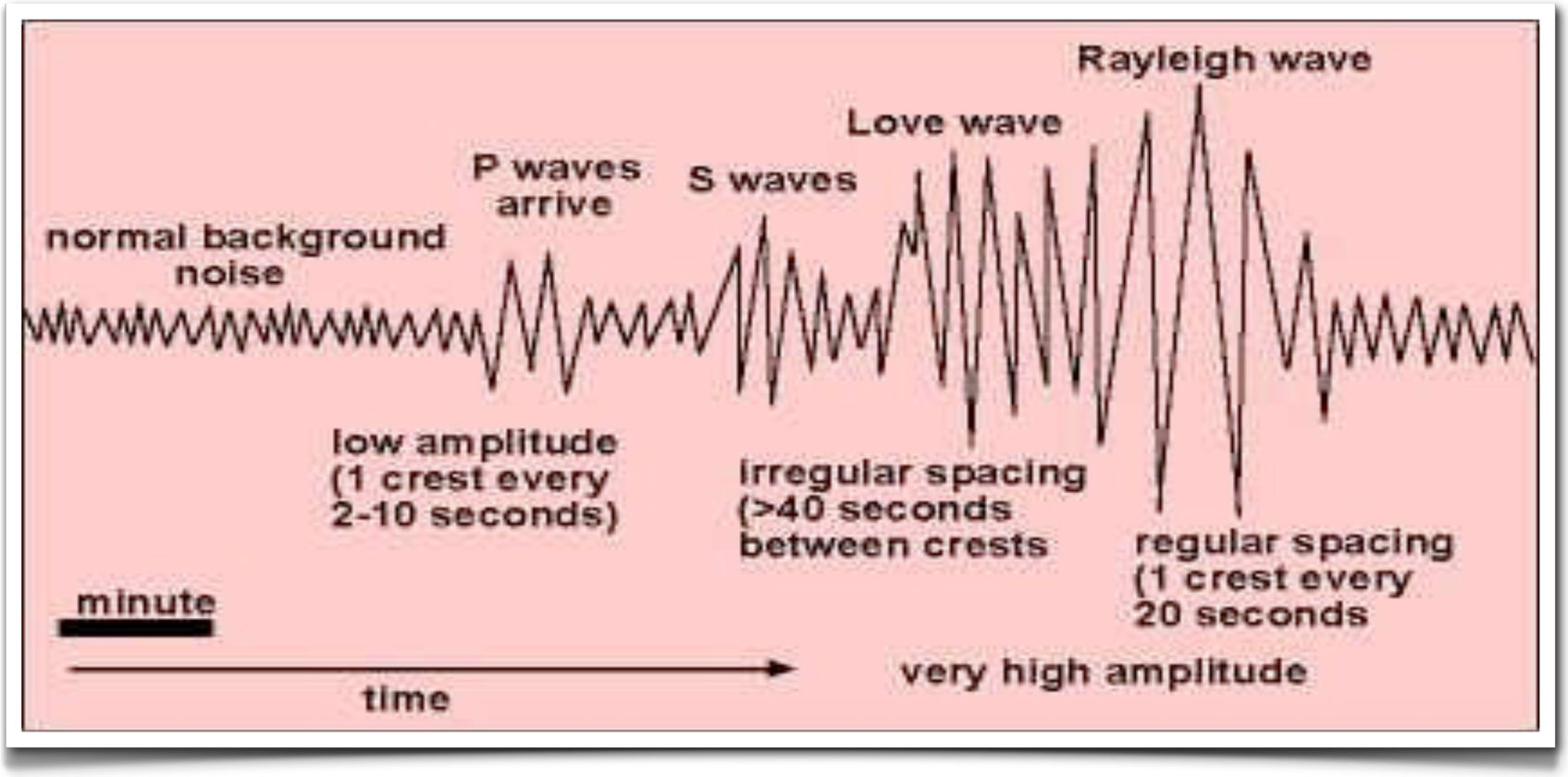
Seismograph



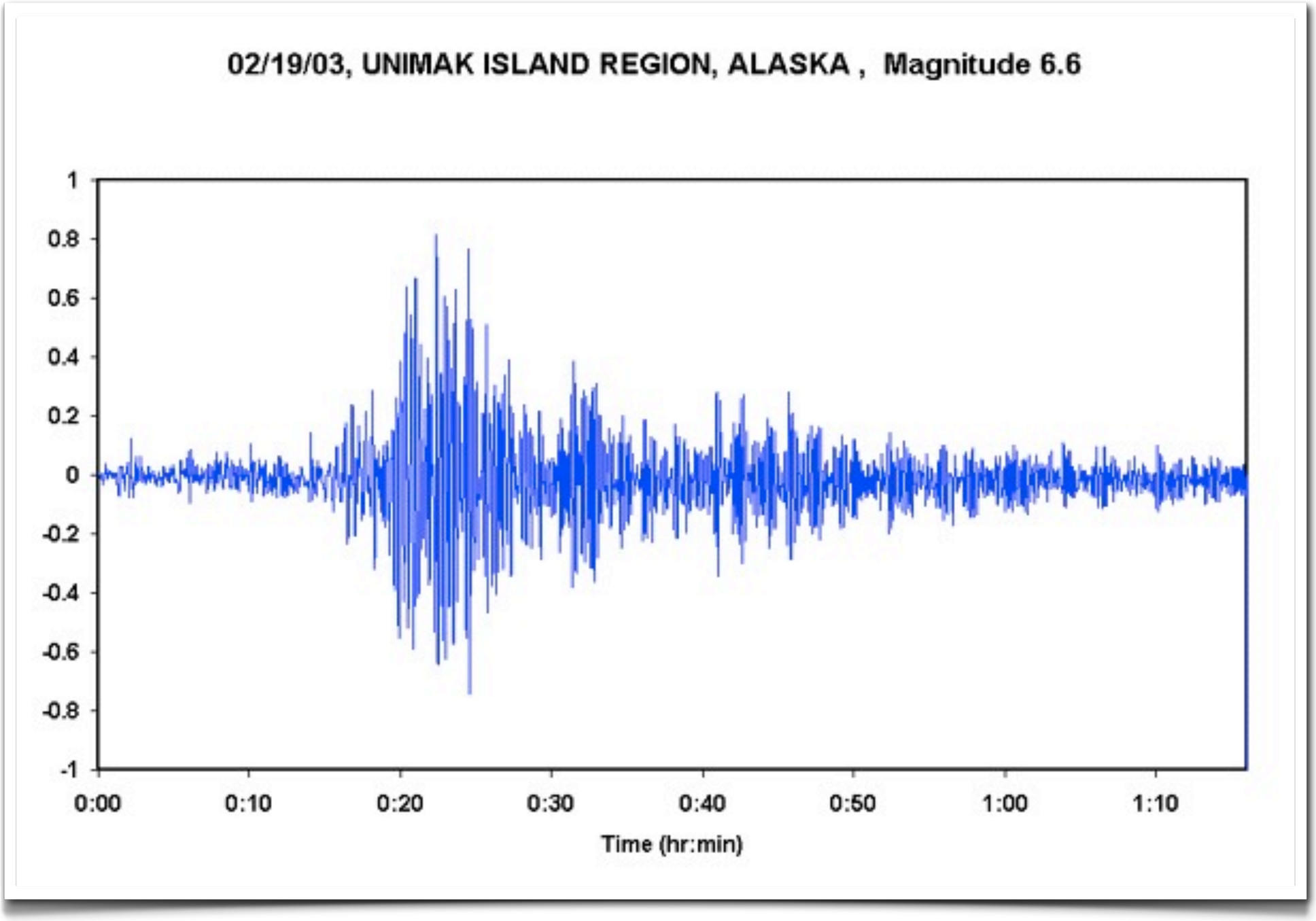


Thursday, December 10, 2009

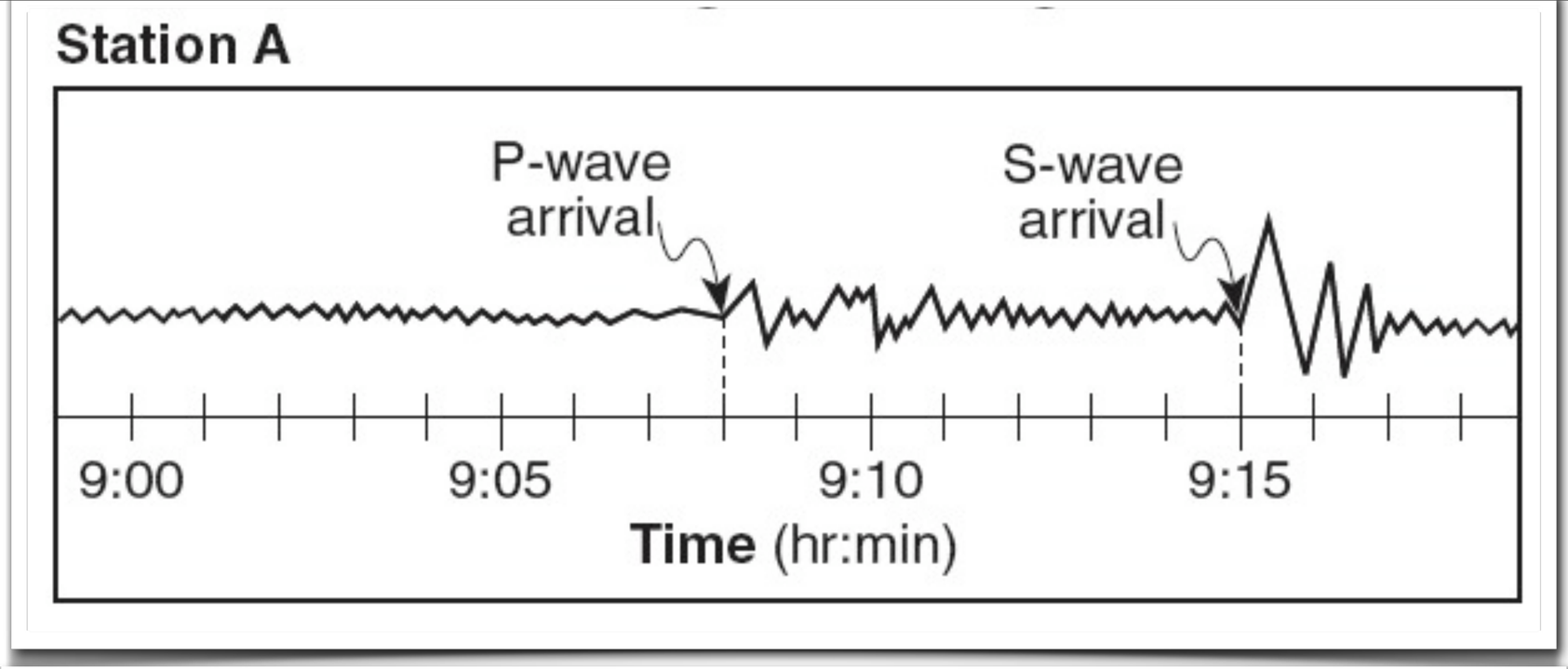
A Seismologist uses a Seismograph to record a Seismogram



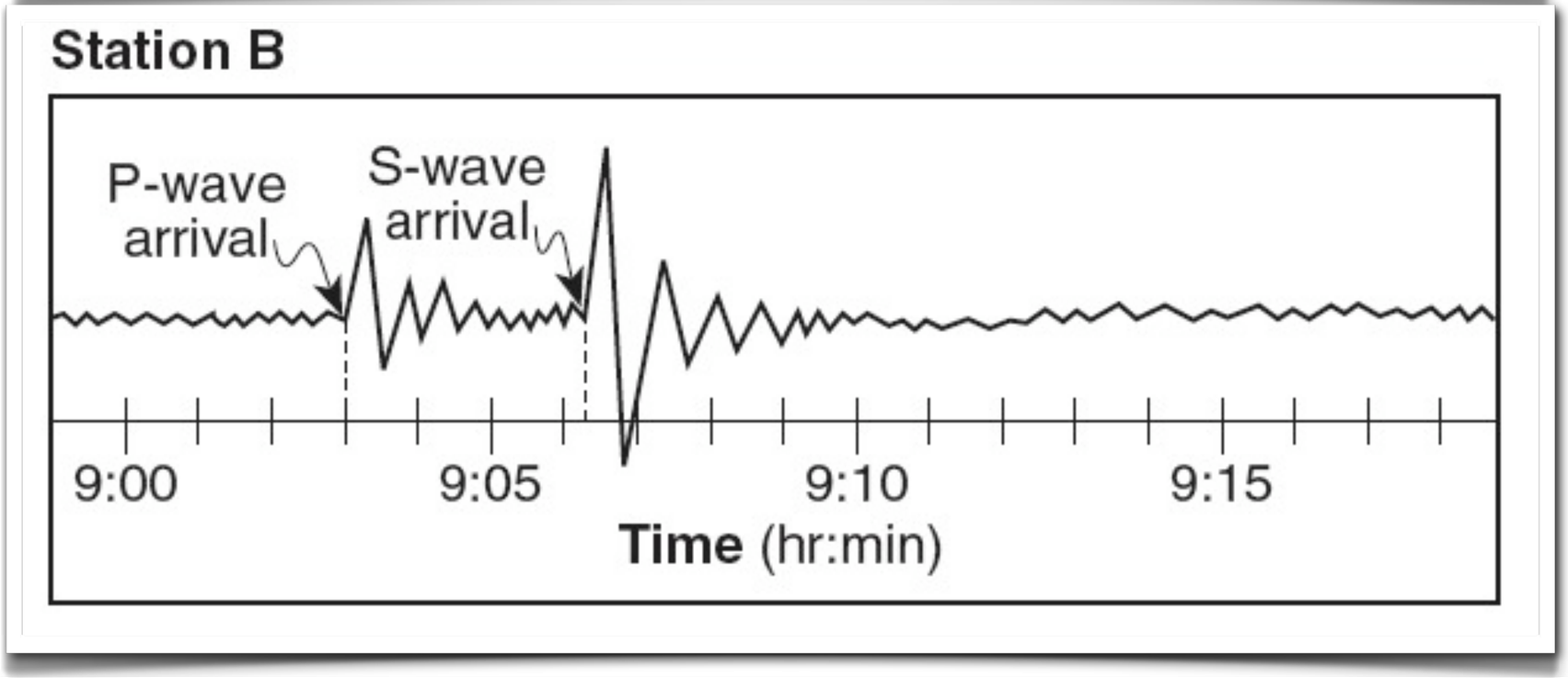
The bigger the zig-zag pattern, the larger the earthquake



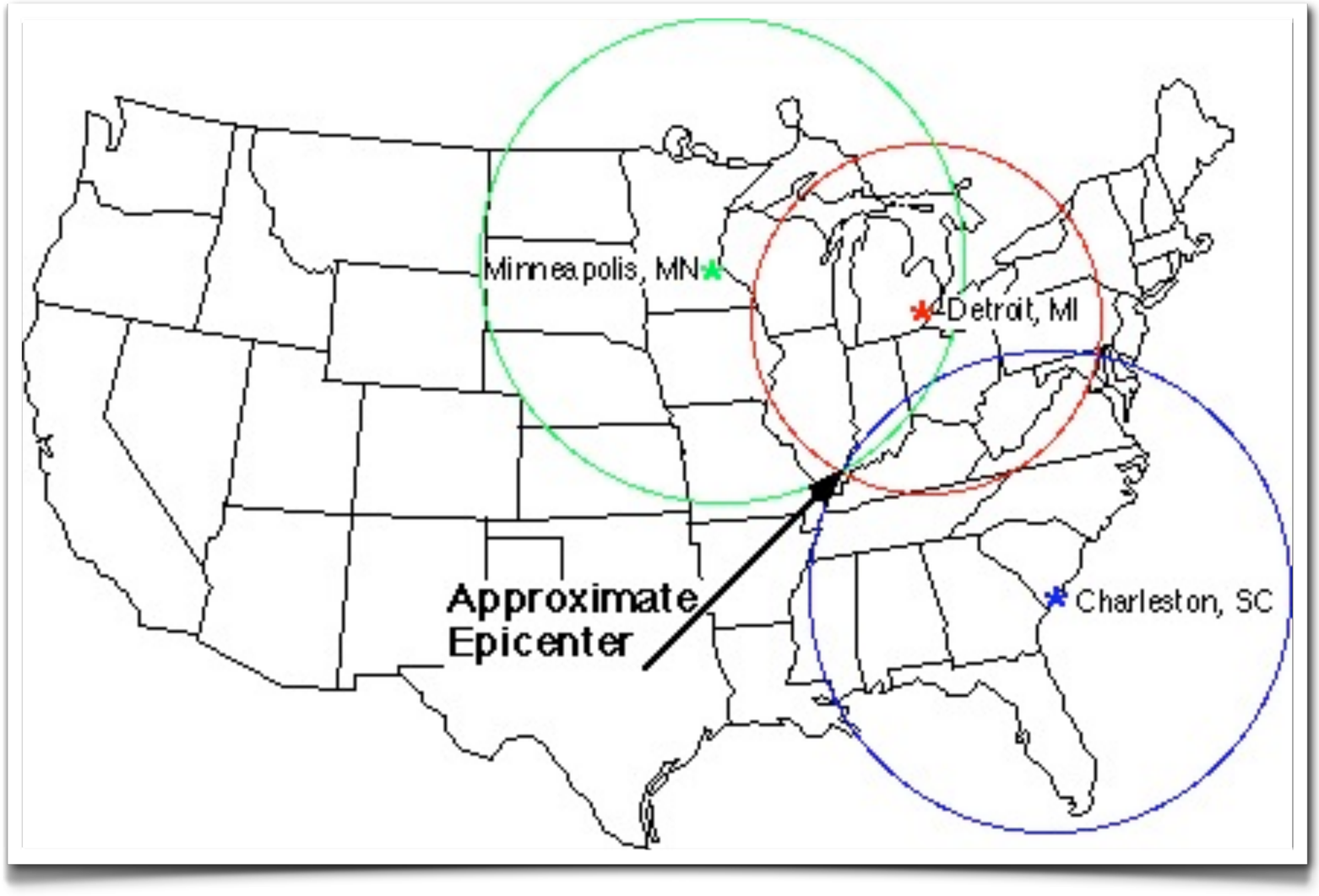
Farther Apart P and S Waves are...Farther the epicenter is... Smaller the wave!



Closer P and S Waves are...closer the epicenter is... Bigger the waves!



Minimum of 3 Seismic Stations needed to determine Epicenter Location



K. How to determine epicenter location

- 1 Seismic Station tells you epicenter distance, not location
- 2 Seismic Stations takes 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

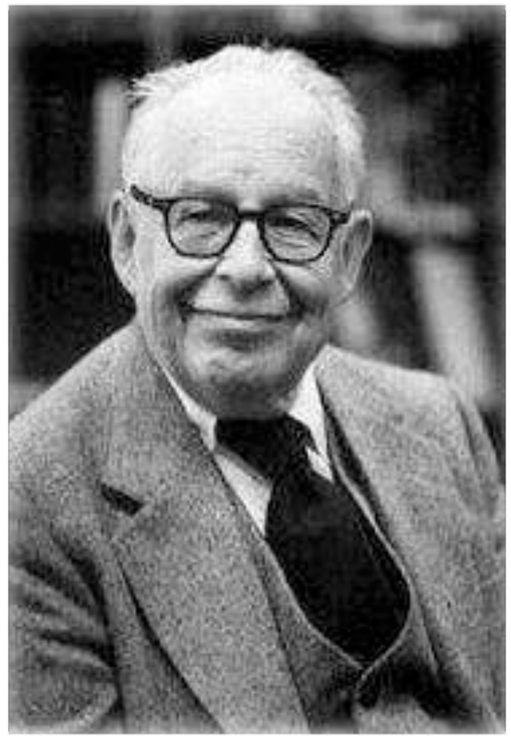
Modified Mercalli Intensity Scale

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

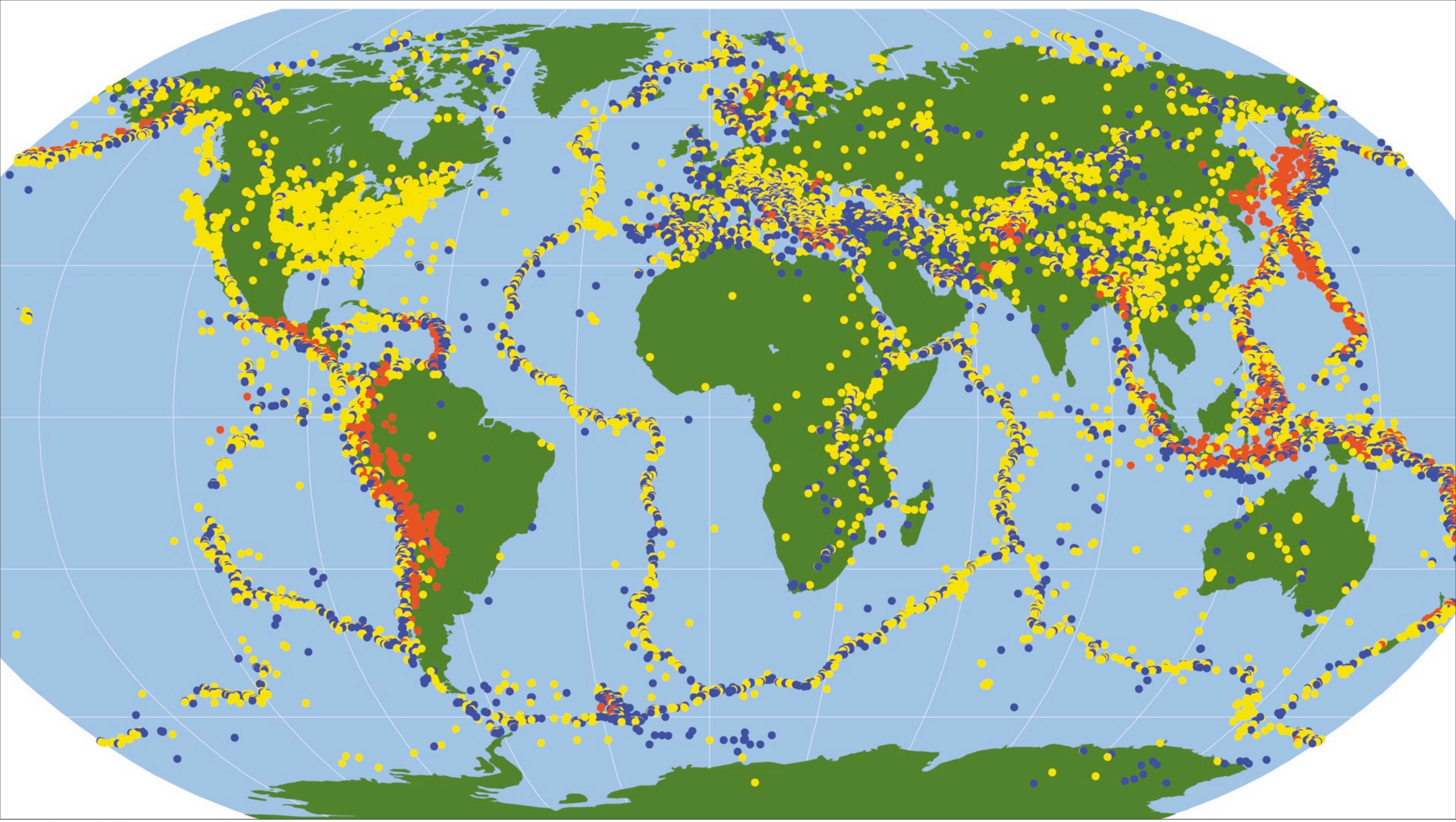
Guiseppe Mercalli

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	

Magnitude
=
Strength



Charles Richter



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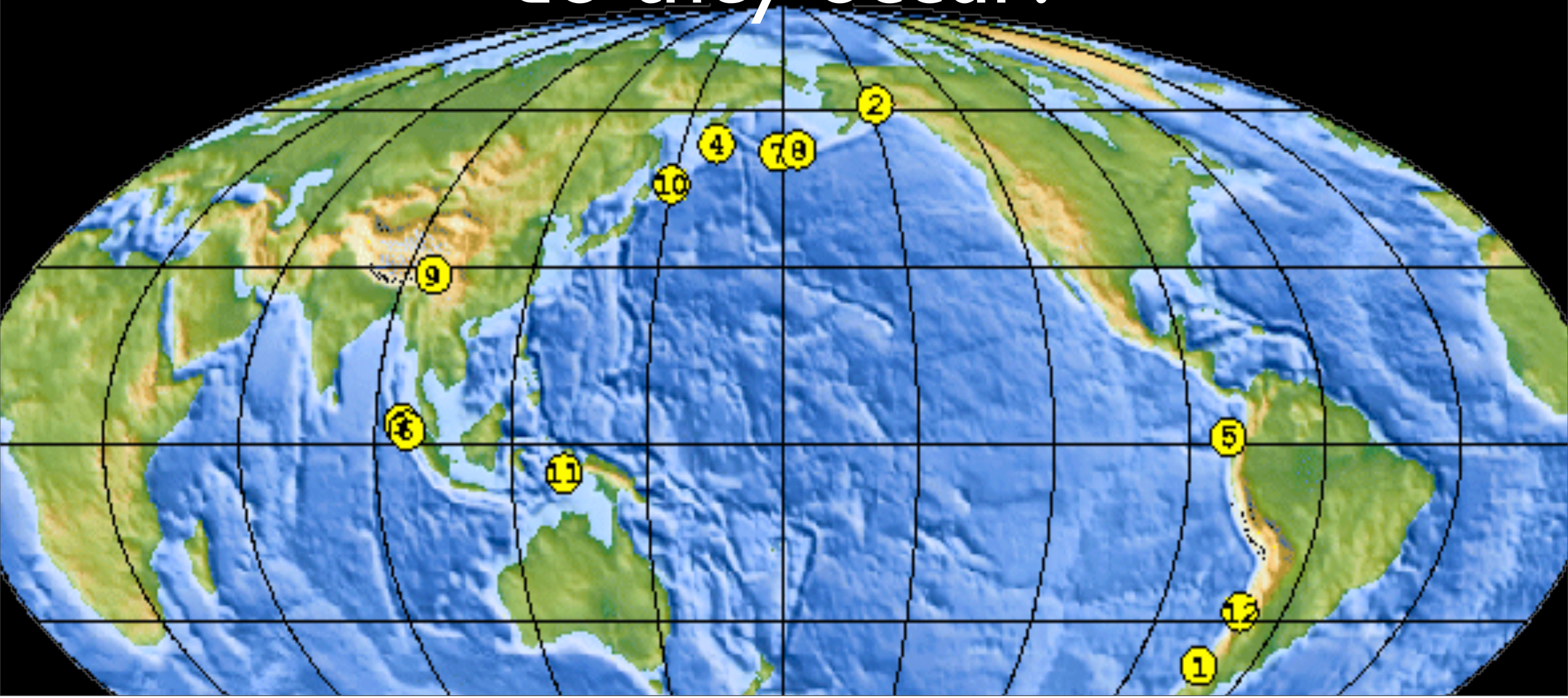
Top 12 Earthquakes since 1900...Where do they occur?



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Highest hazard

% g

32+
24-32
16-24
8-16
4-8
2-4
0-2

Lowest hazard

Thursday, December 10, 2009

L. Liquefaction

- Occurs in areas with very little stable bedrock under the soil

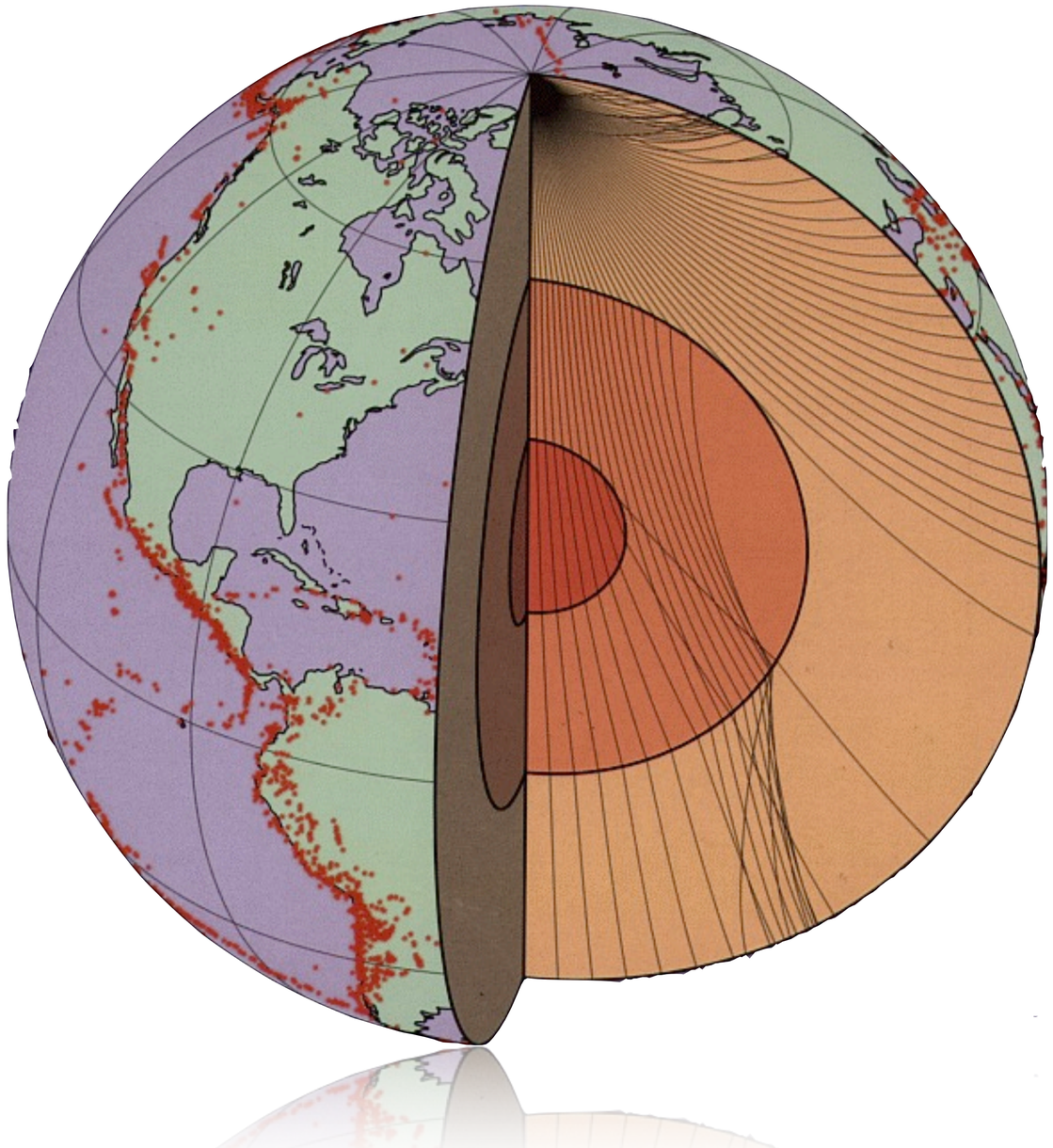
- Earthquake vibrations "lubricate" soil paricles (soft clay and silt) and they act almost in a fluid fashion

- Earthquakes cause the ground to become very unstable and extremely soft

M. Shadow Zone

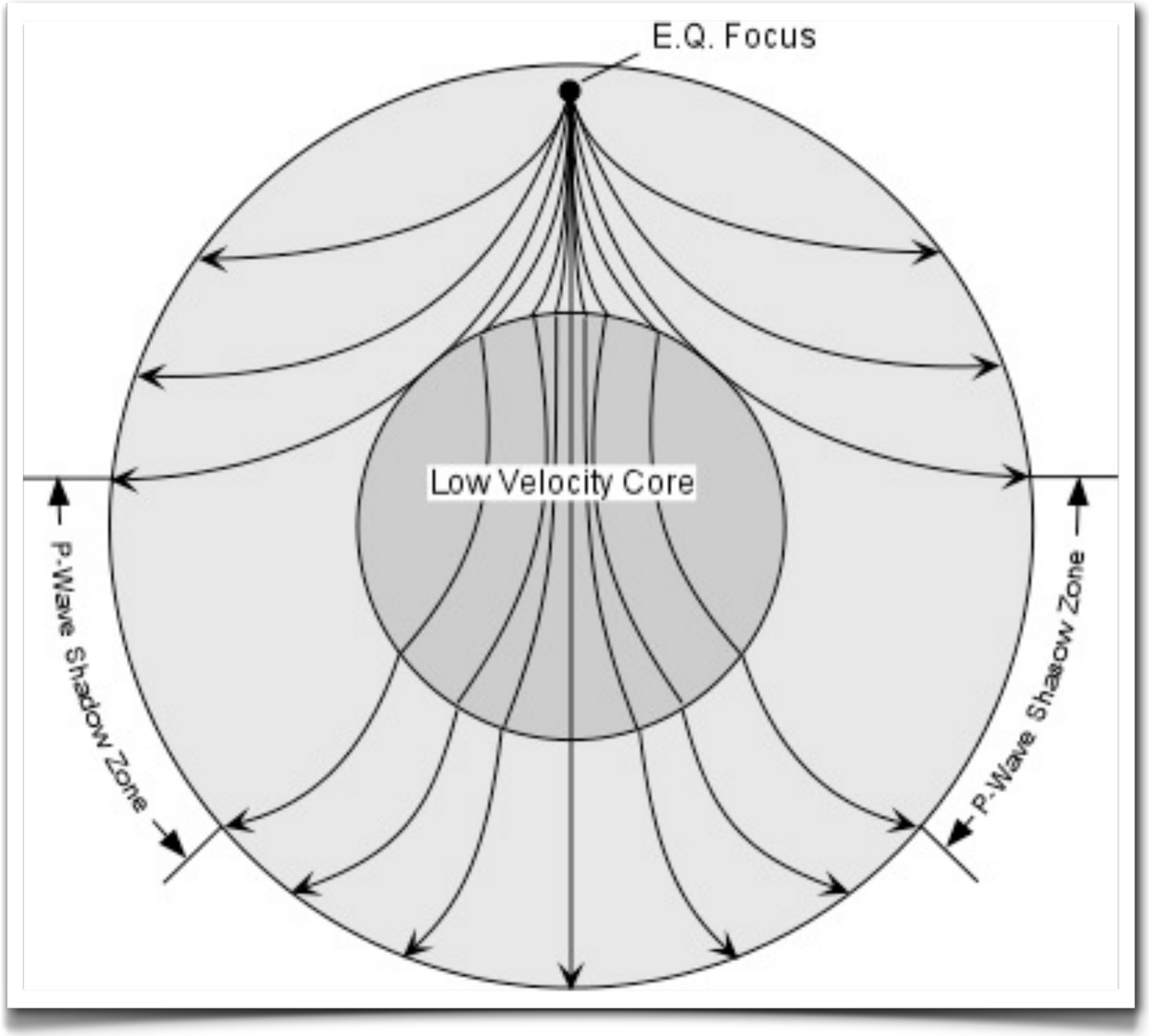
- Area on planet where earthquake waves do not travel
  - P-Wave shadow zone
  - S-Wave shadow zone

M. Shadow Zone



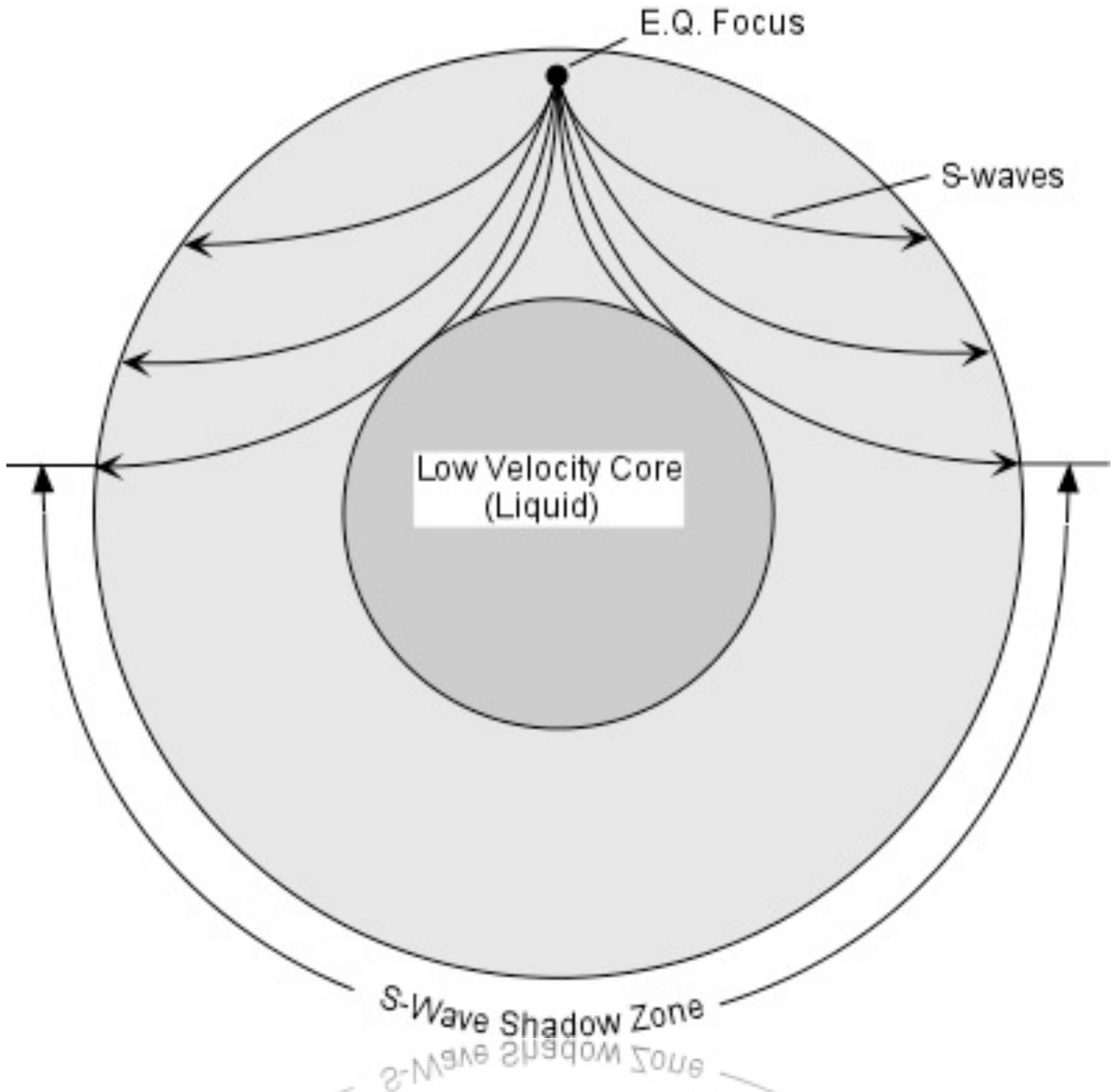
- Area on planet where earthquake waves do not travel
  - P-Wave shadow zone
  - S-Wave shadow zone

N. P -Wave Shadow Zone



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

O. S-Wave Shadow Zone

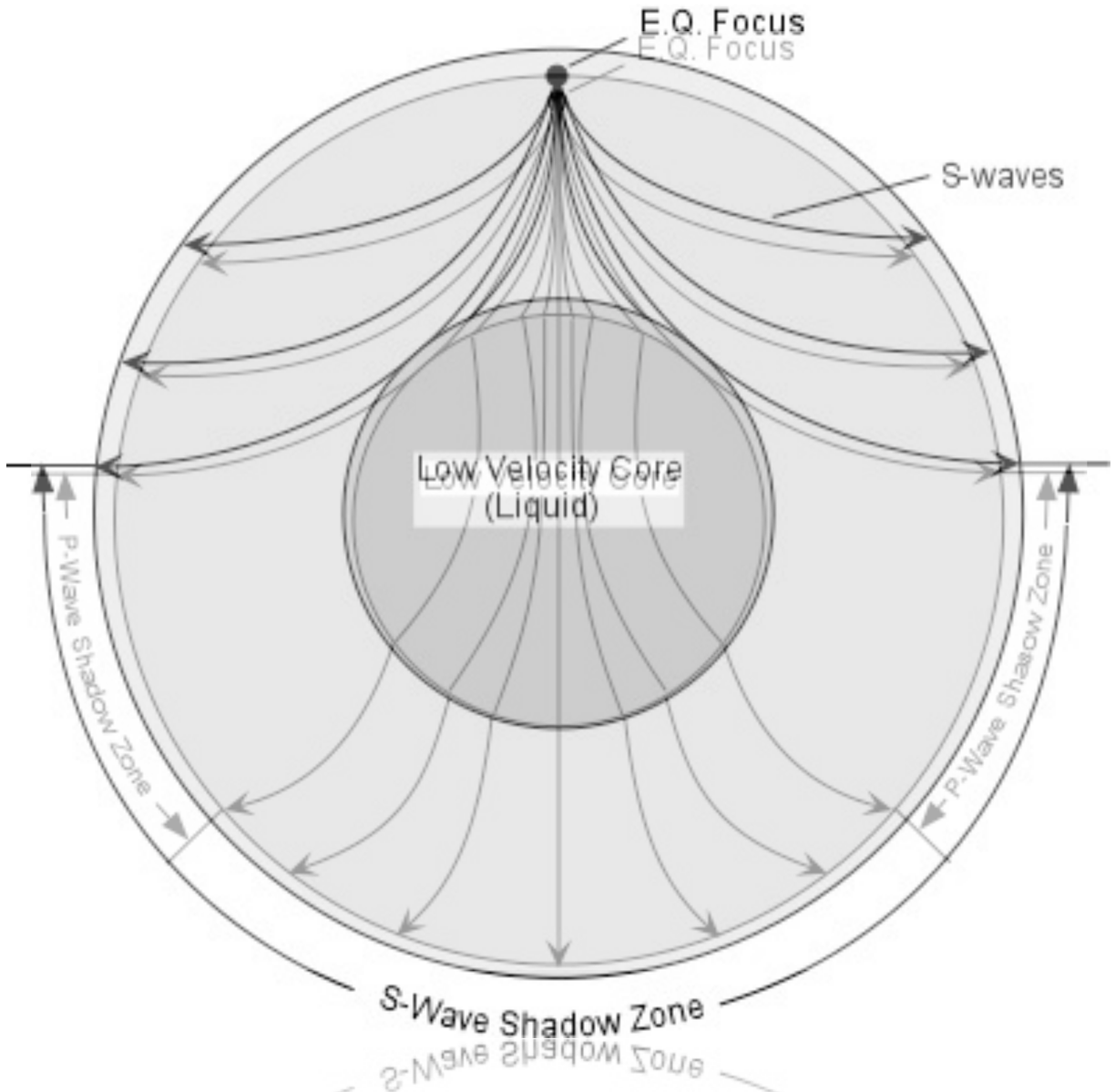


- Caused by S-Waves not being able to pass through the liquid outer core

S-Waves get absorbed by the liquid outer core

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

O. S-Wave Shadow Zone



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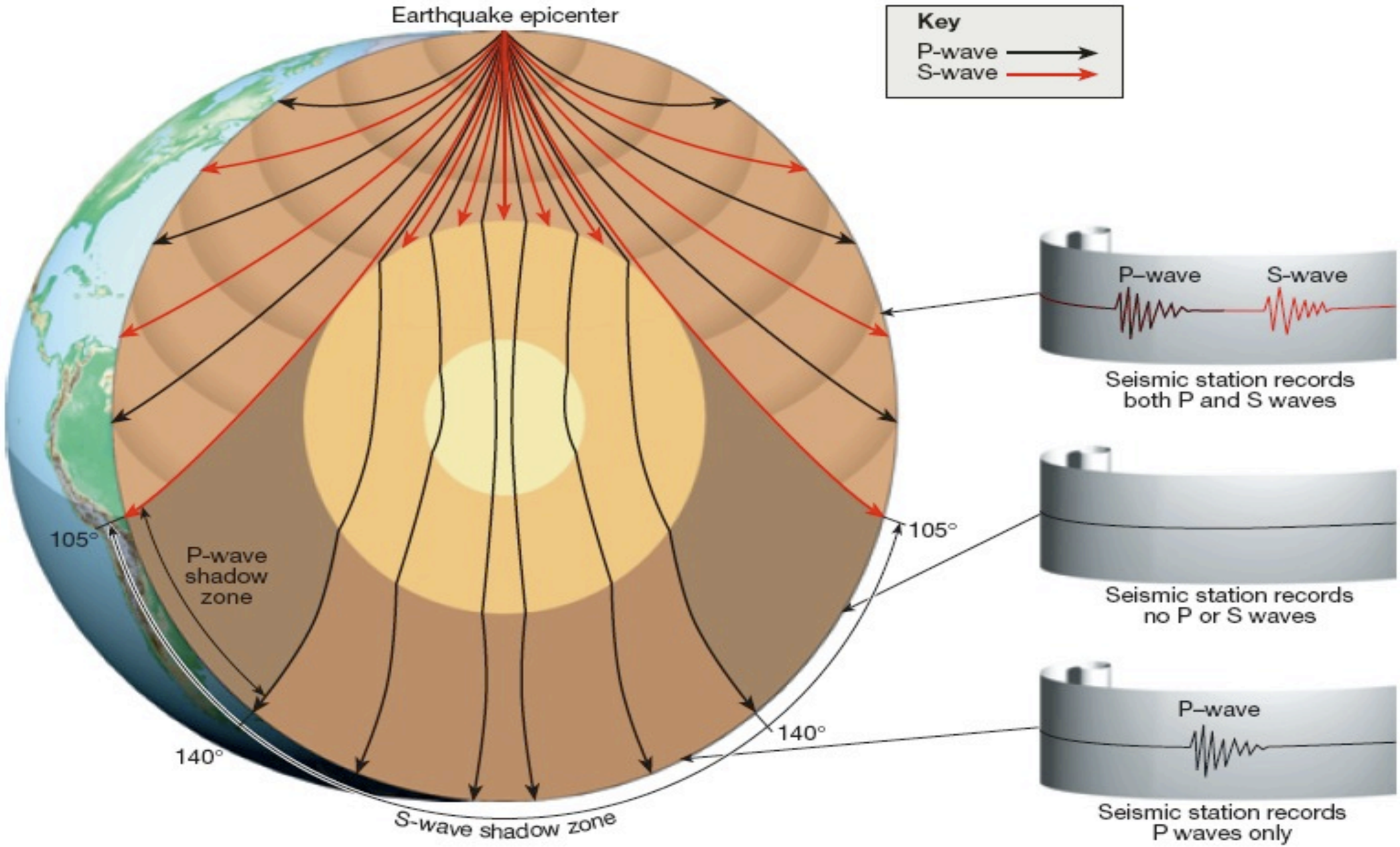

Earthquake epicenter
Key
P-wave
S-wave
105°
P-wave
shadow
zone
140°
S-wave shadow zone
105°
140°
P–wave
S-wave
Seismic station records
both P and S waves
Seismic station records
no P or S waves
P–wave
Seismic station records
P waves only

P. Earthquake Safety

- Inside a building or school:
  - Drop to the floor
  - Take cover under sturdy piece of furniture
  - Stand in door ways
  - Stay clear of windows or objects that will fall
  - Stay calm
  - Stock up with flashlights, batteries, radios, first aid kits, food, water, tools , warm clothes, fire extinguisher

P Wave and S Wave

Earthquake Chart

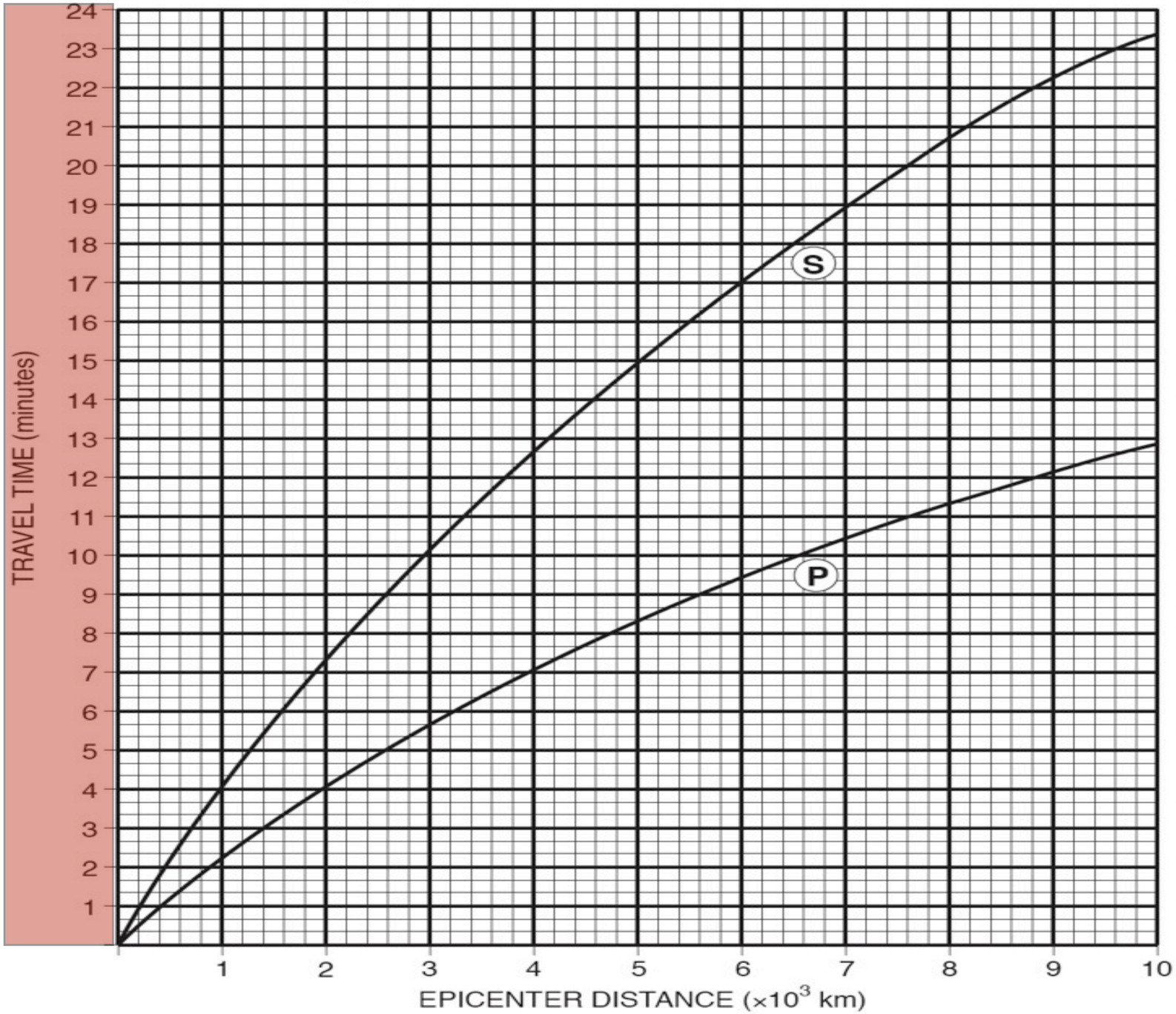
Things to think about.....

- 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

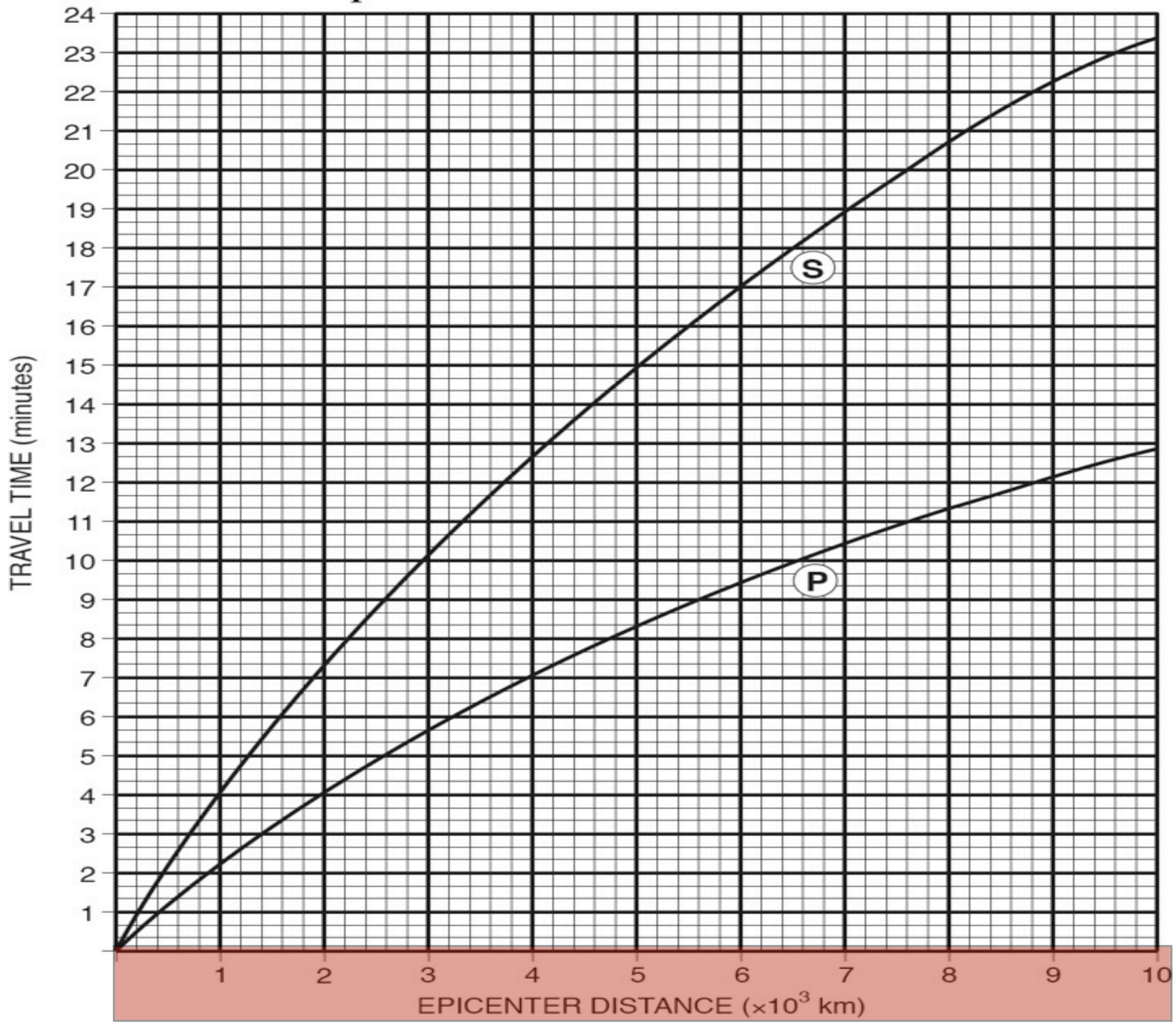
Think about this....

- Travel Time-Think about how long it takes for you to get to your friends house
- Arrival Time-Think about the time you get to your friends house
- Origin Time-Think about when you left your house to get to your friends house

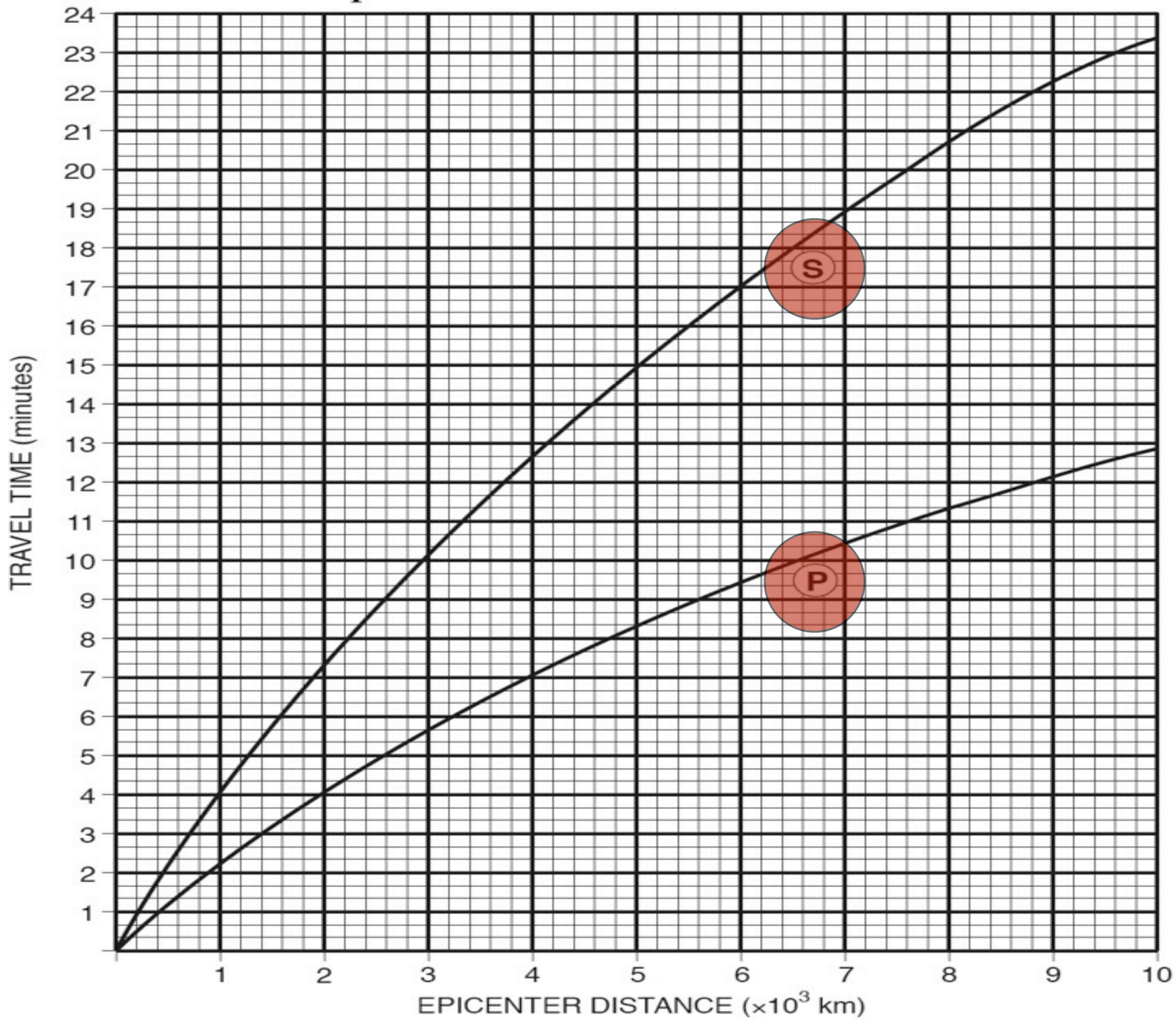
Earthquake P-wave and S-wave Travel Time



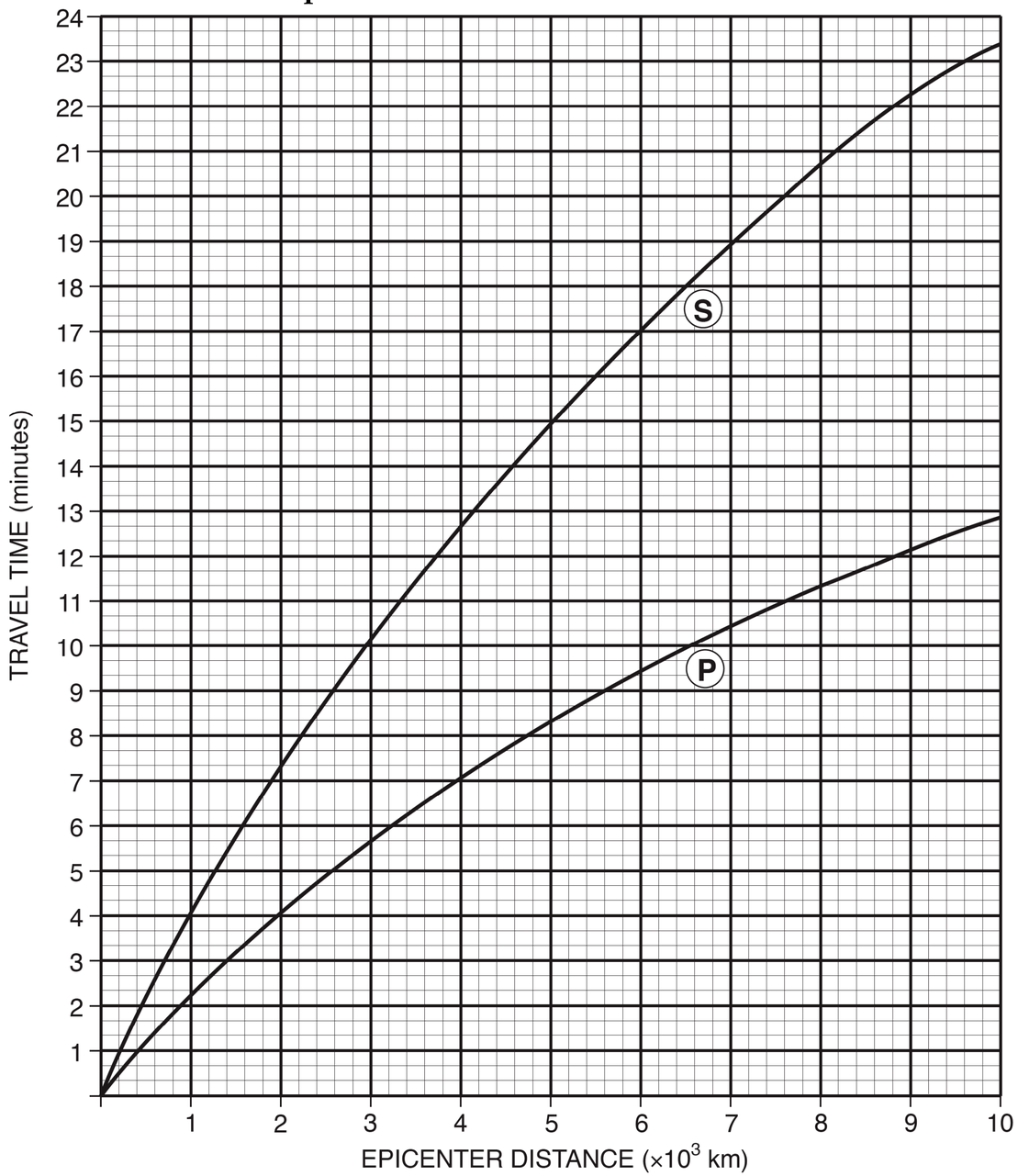
Earthquake P-wave and S-wave Travel Time

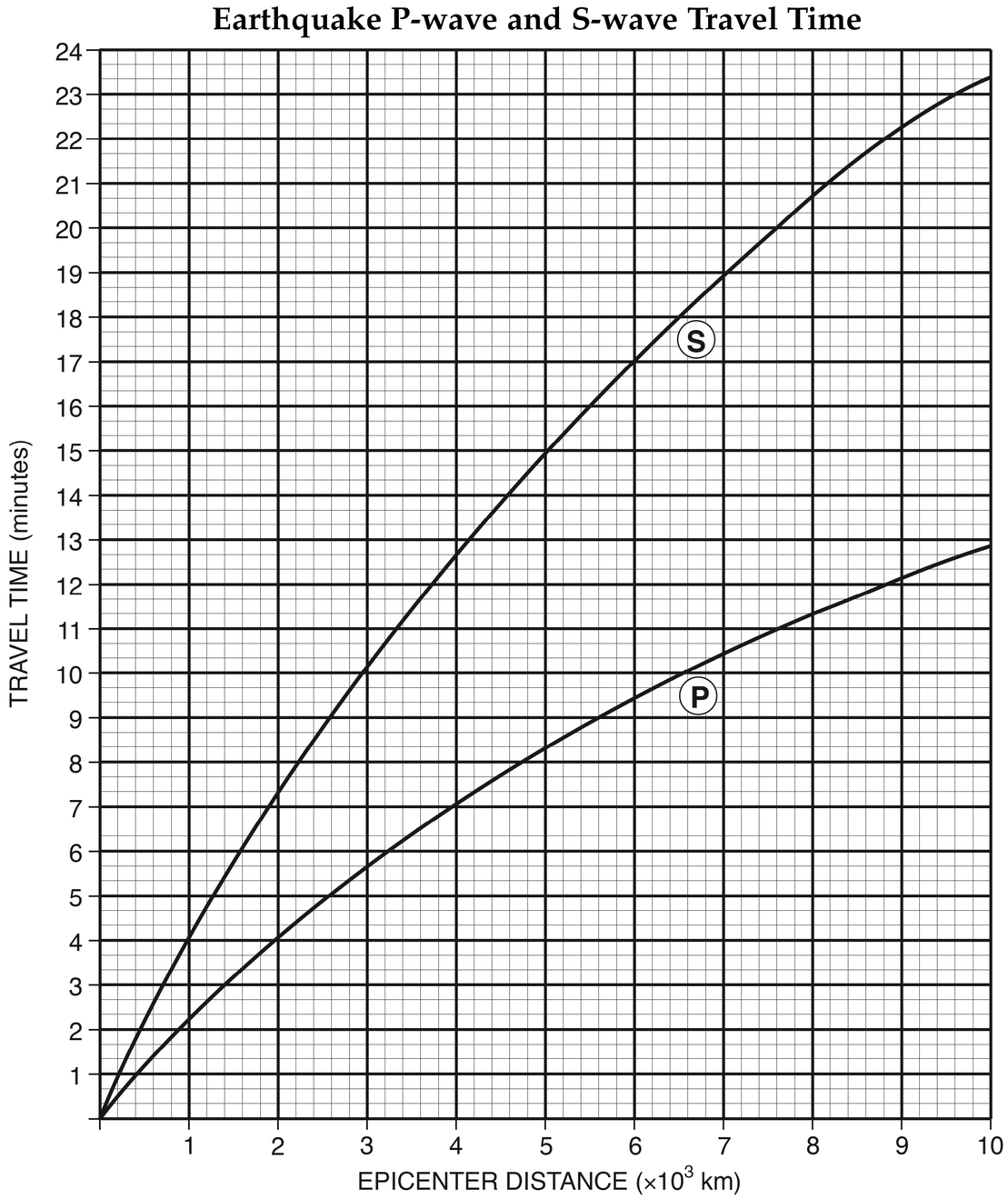


Earthquake P-wave and S-wave Travel Time

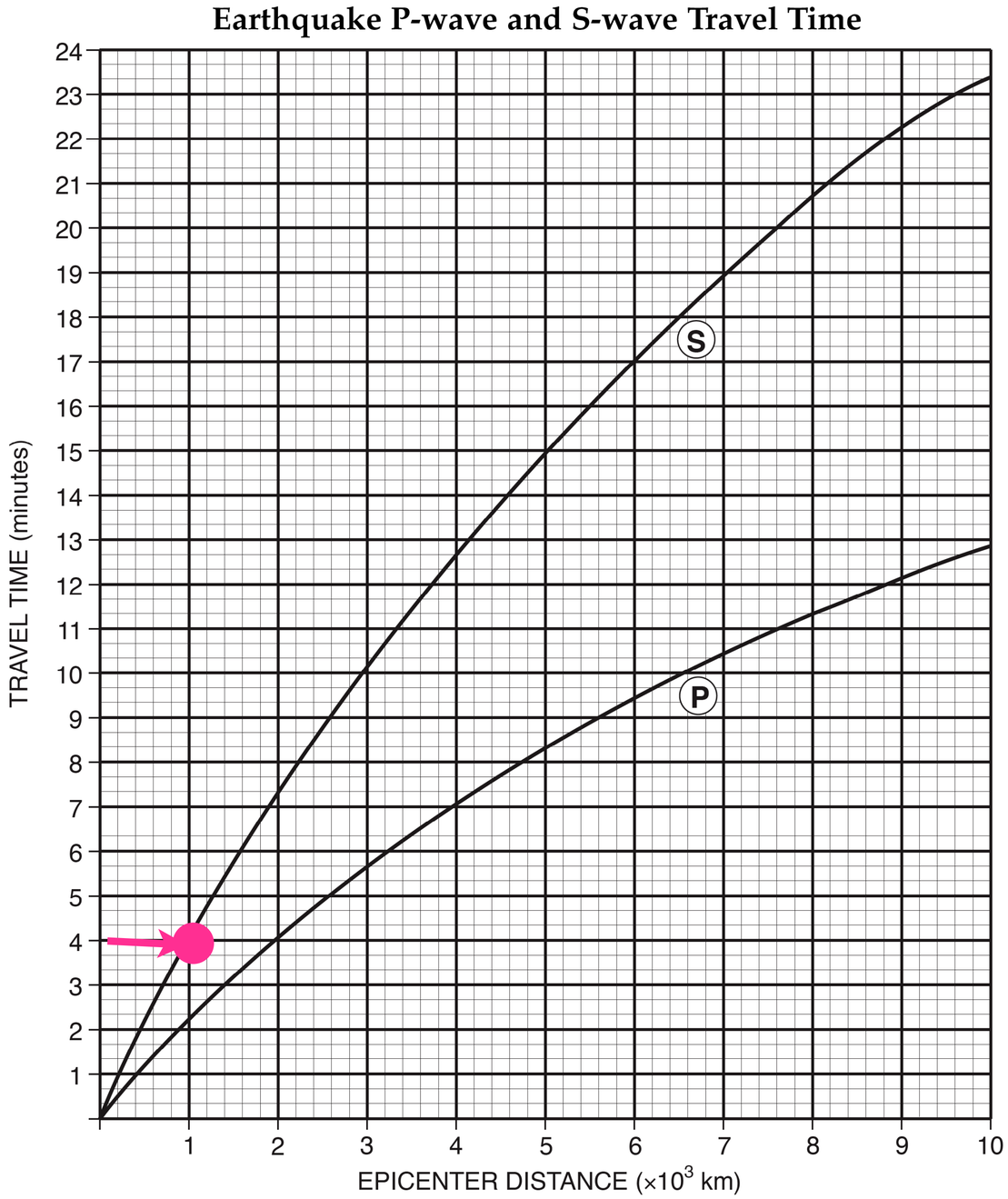


Earthquake P-wave and S-wave Travel Time





S Wave travel time is 4 minutes...how far does it travel in this time?



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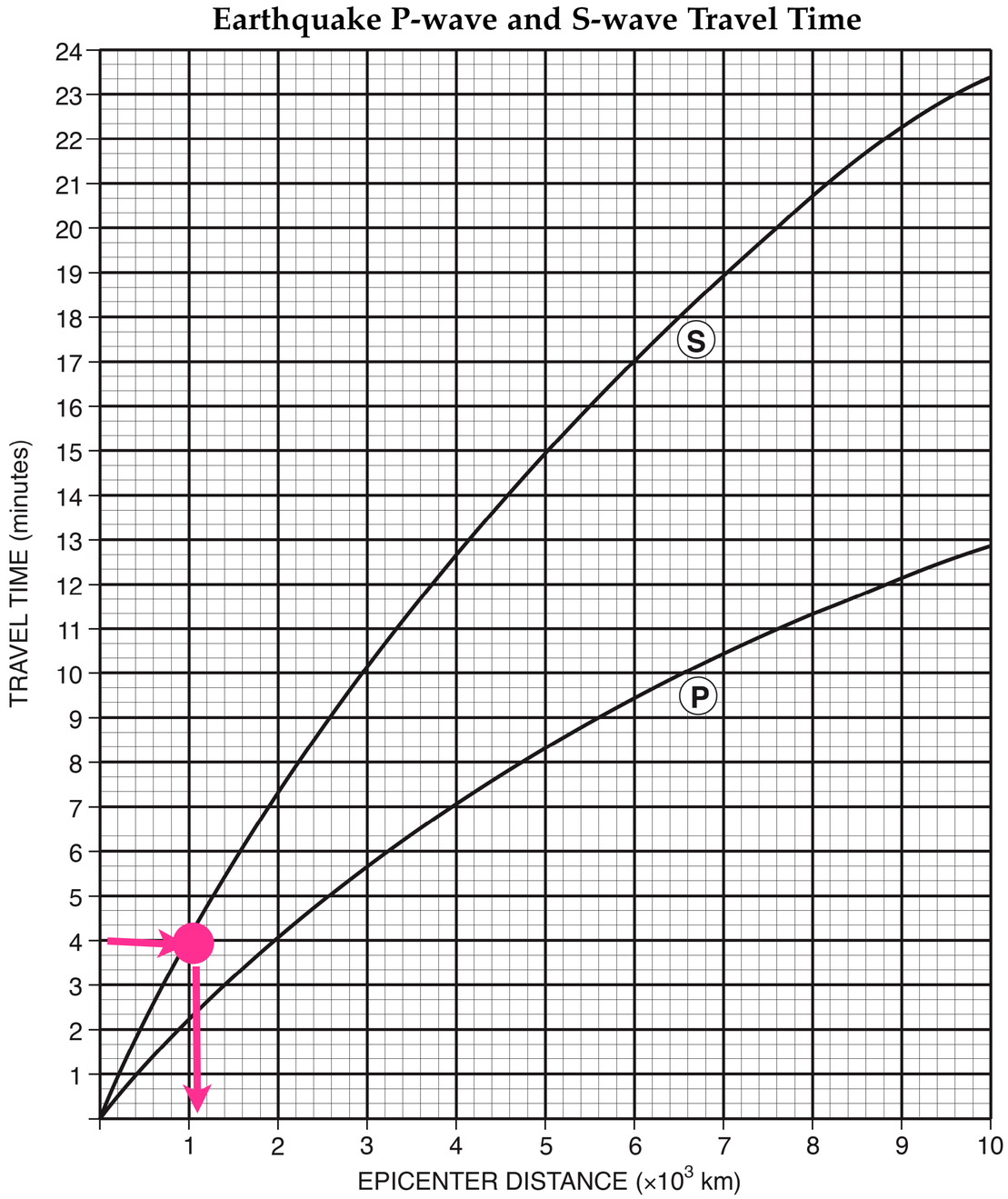

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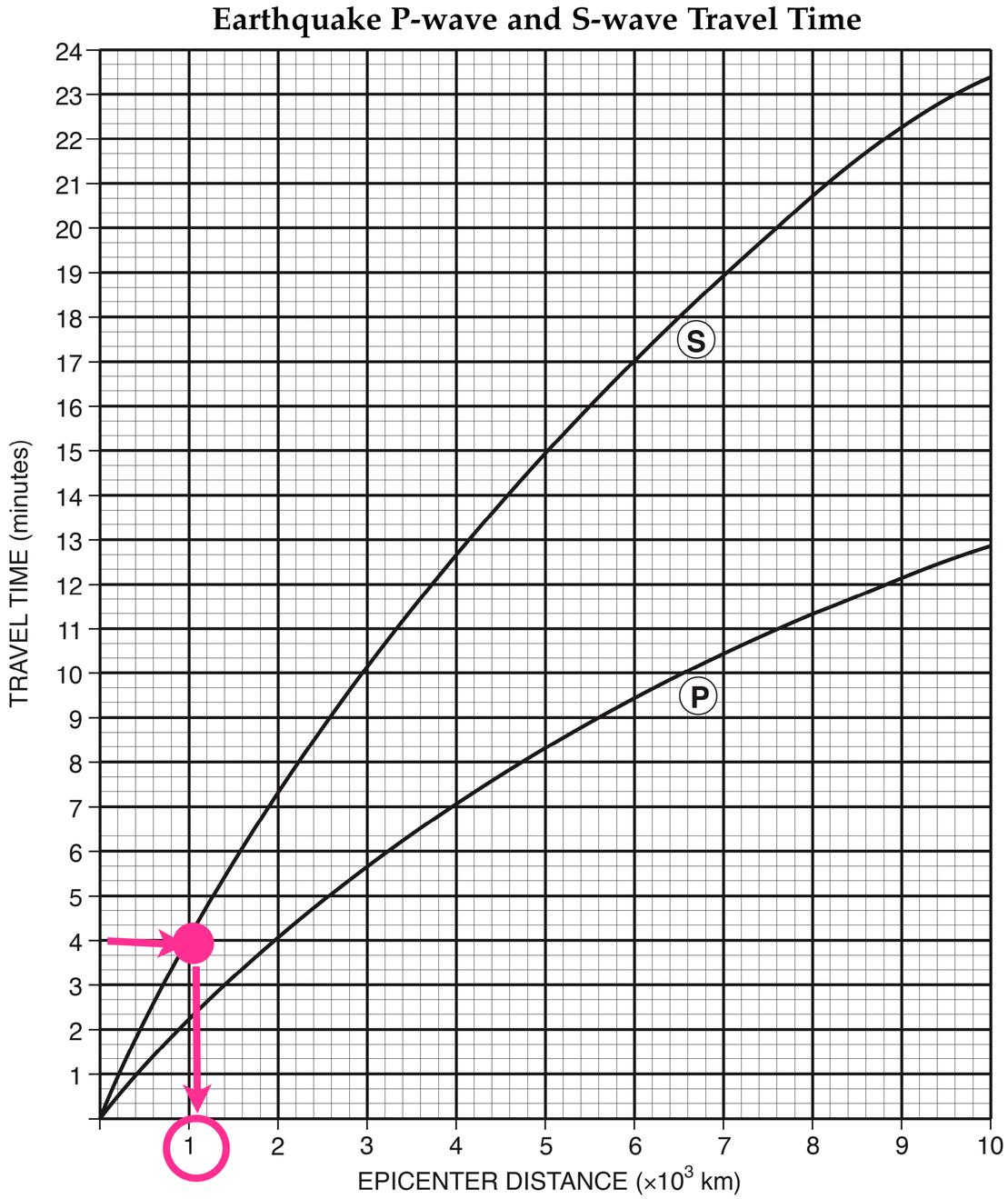
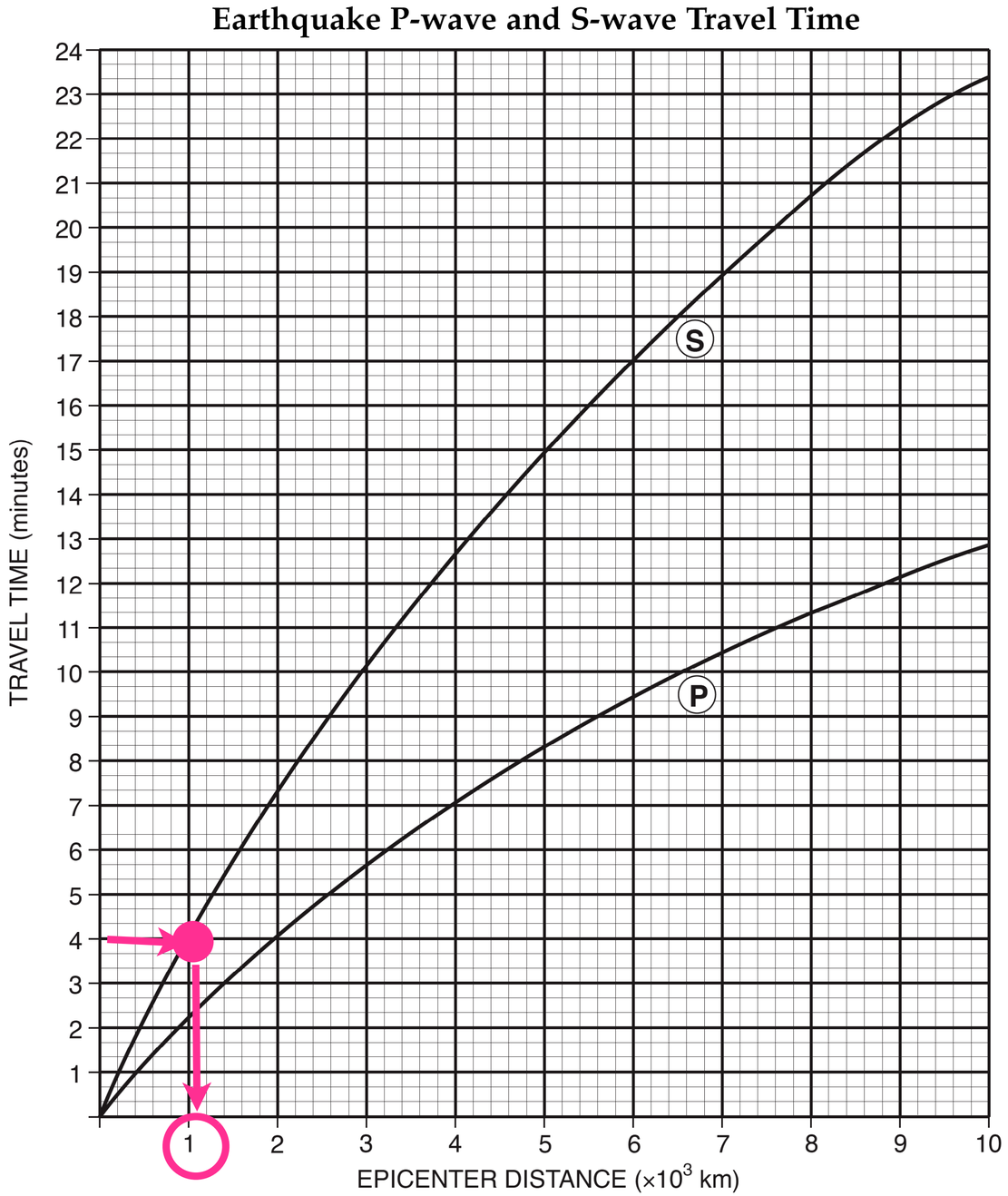


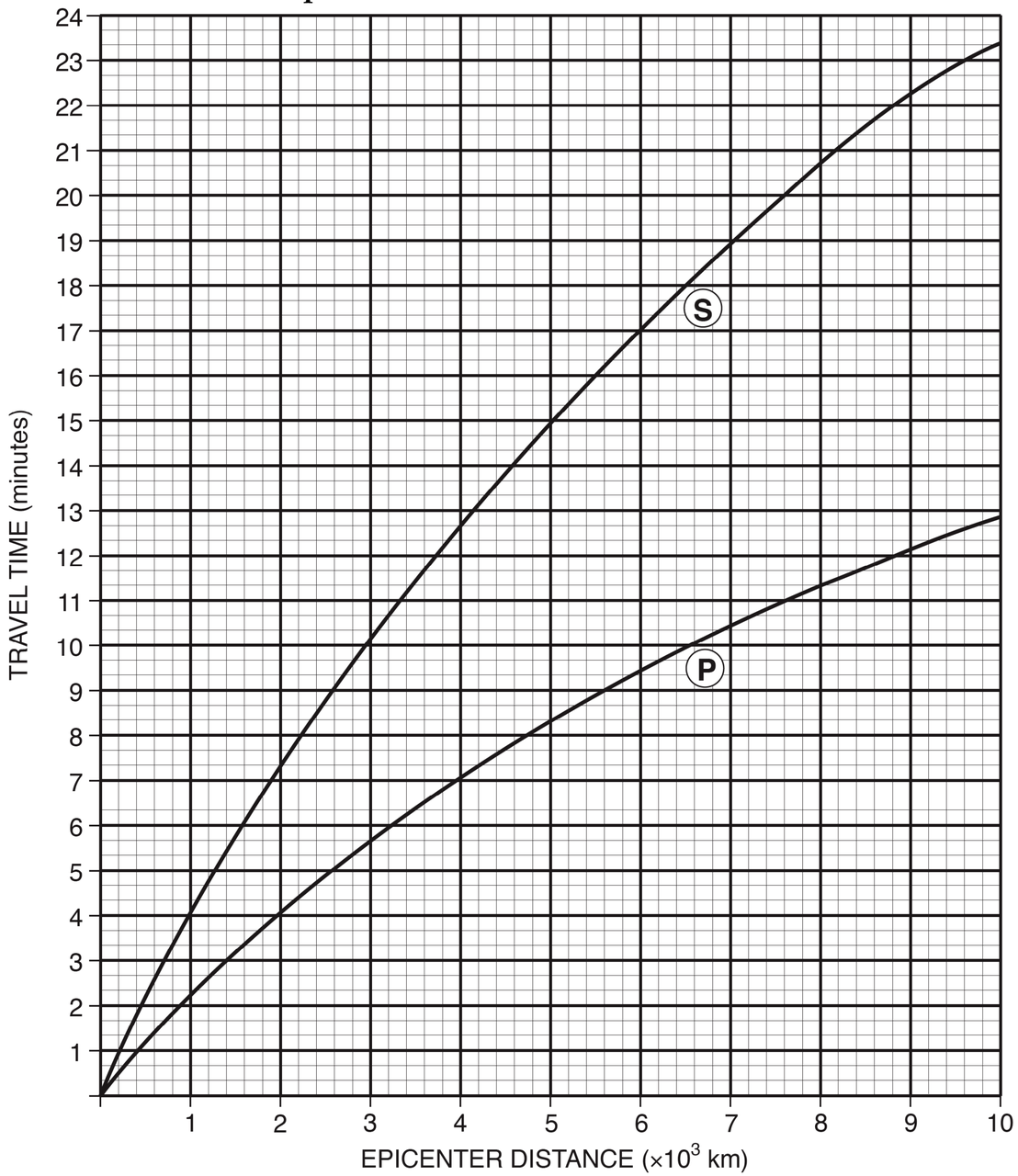
S Wave travel time is 4 minutes...how far does it travel in this time?

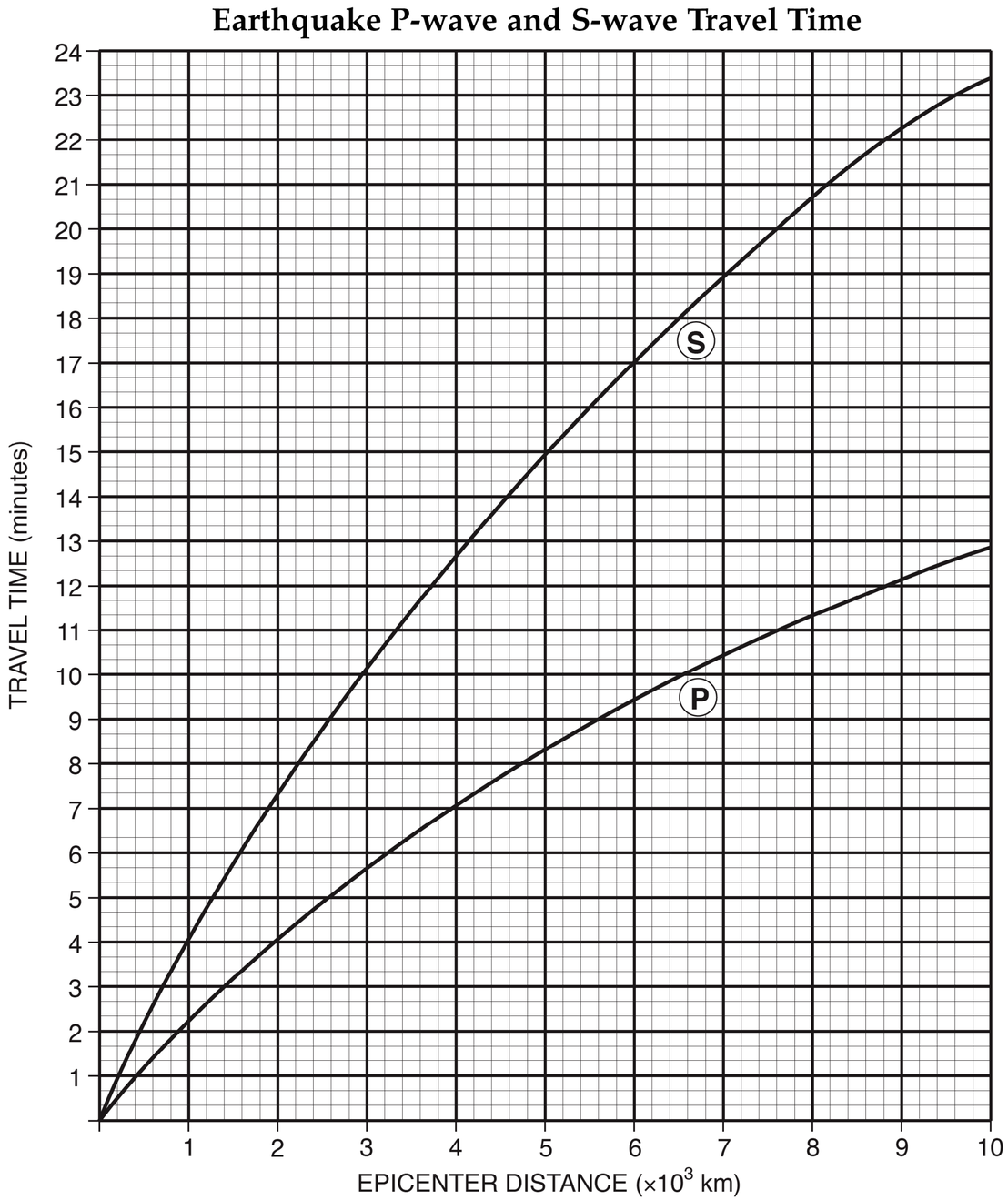


S Wave travel time is 4 minutes...how far does it travel in this time?

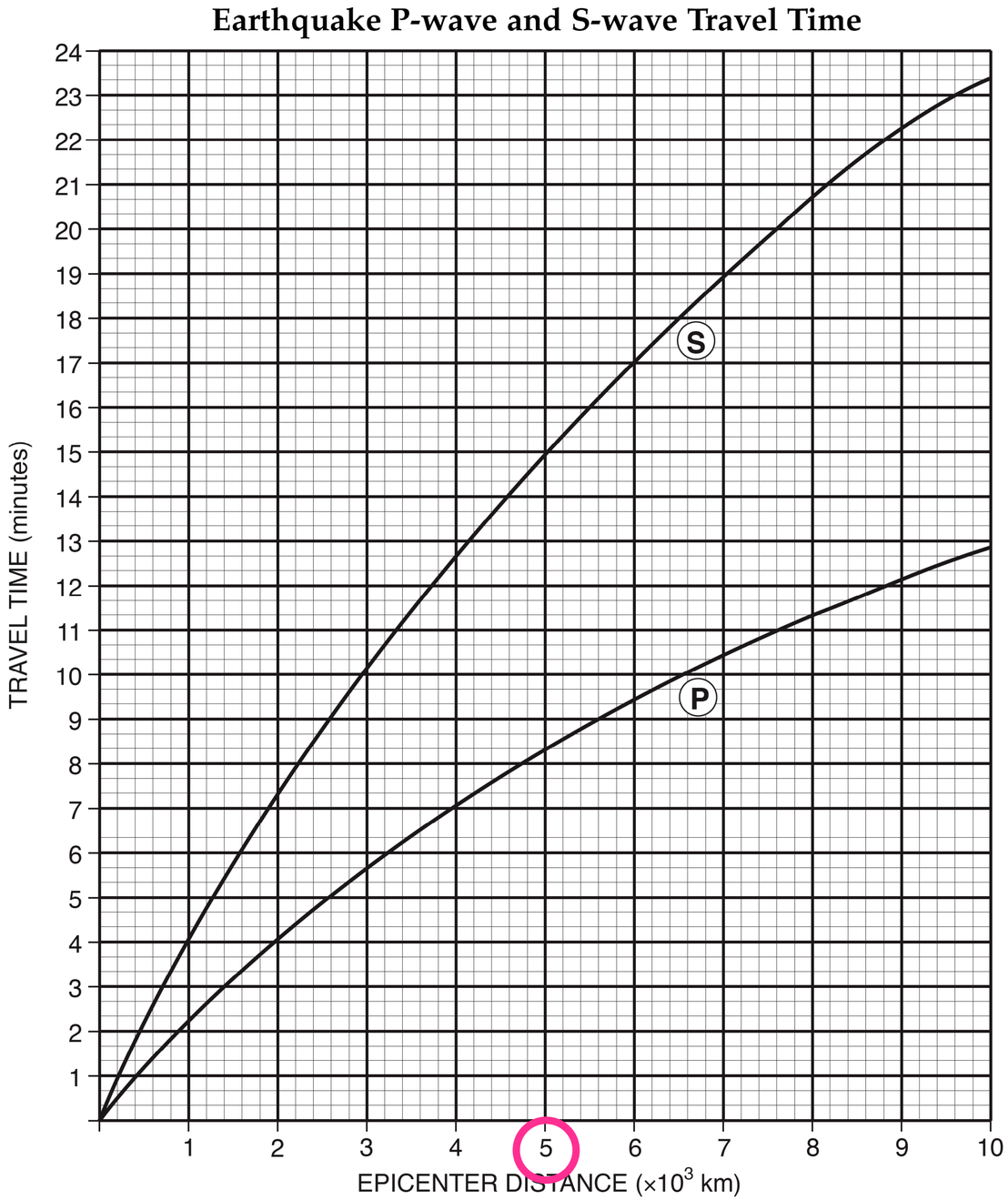
2 km

Earthquake P-wave and S-wave Travel Time

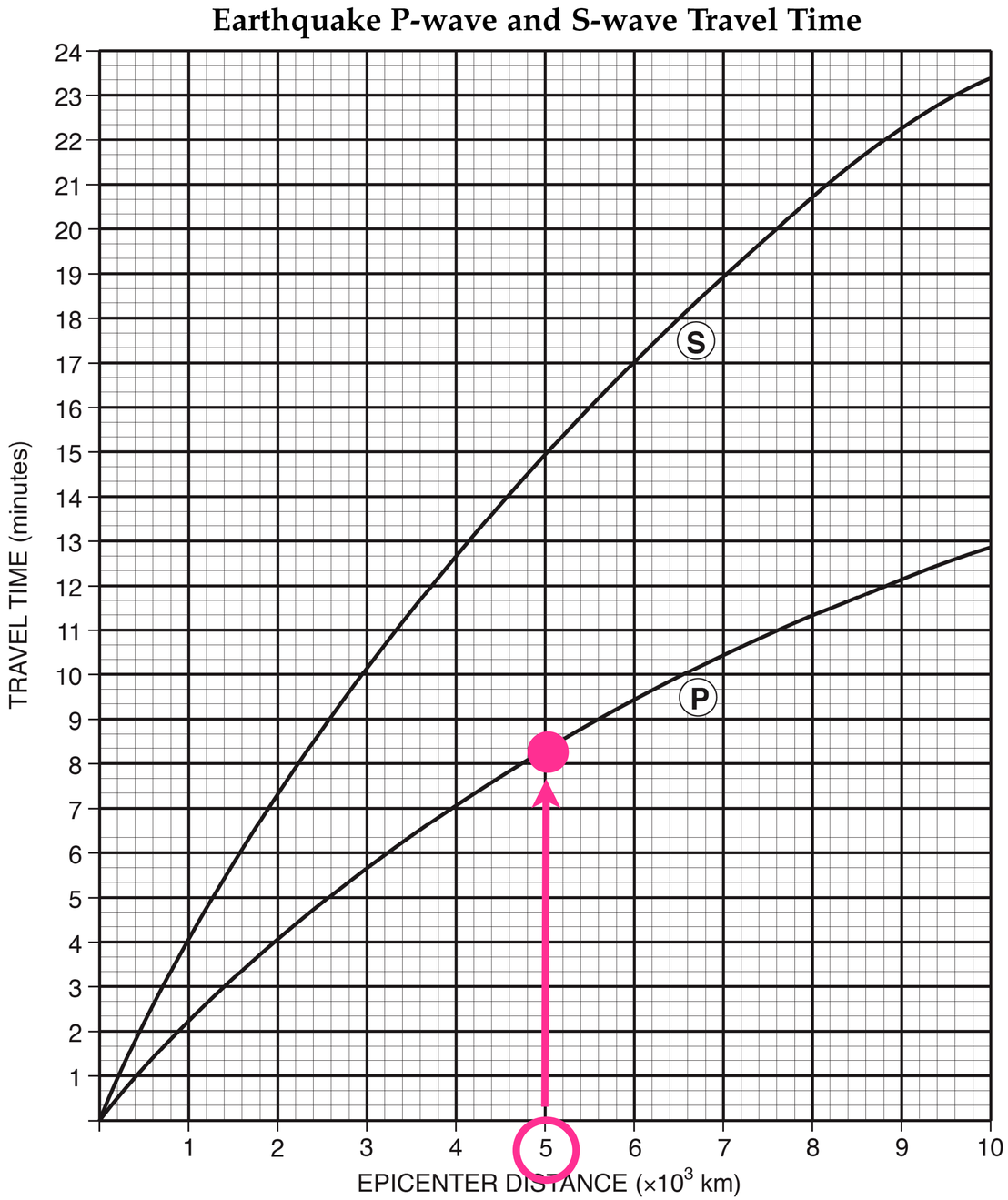




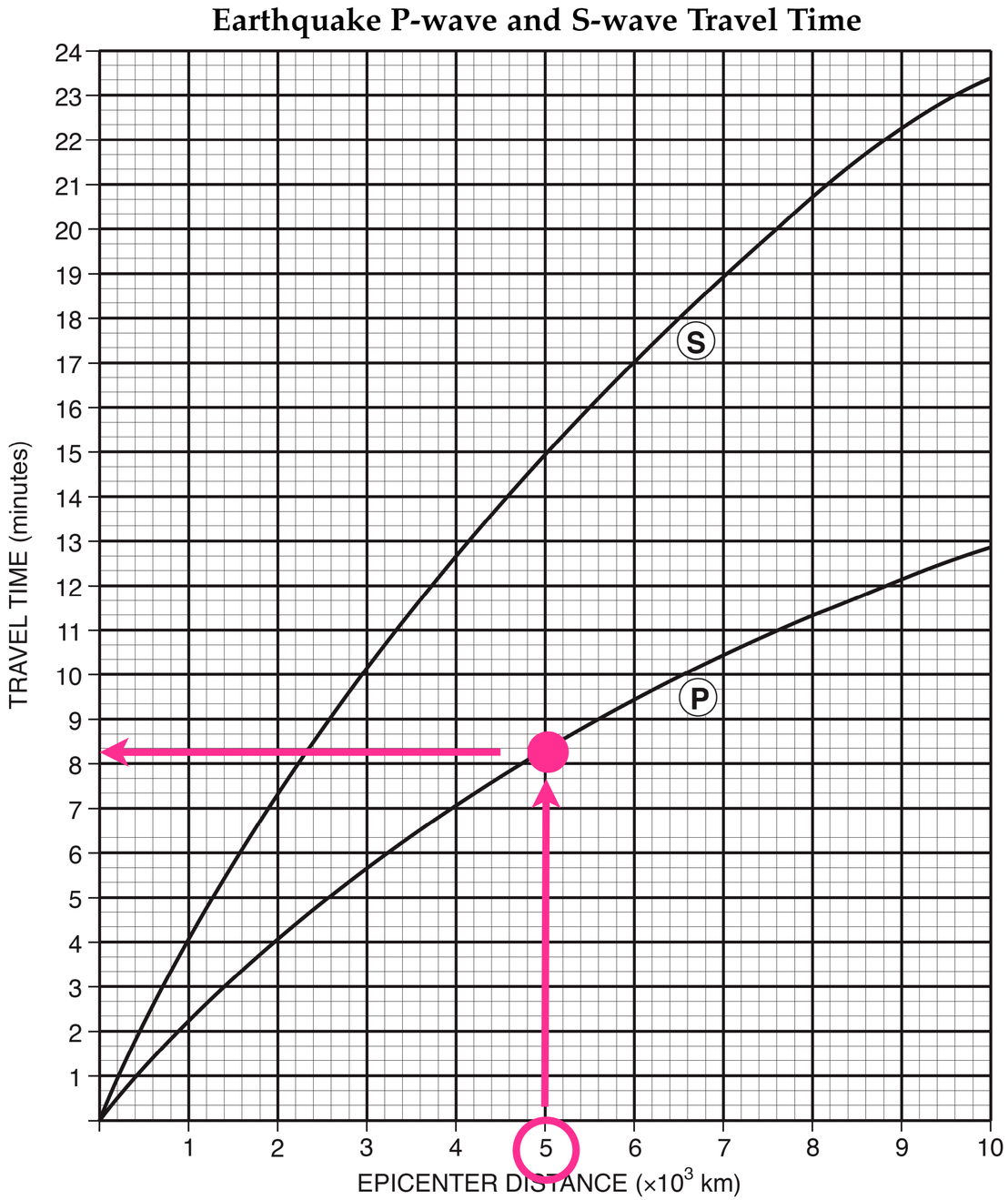
How long does it take a p-wave to travel 5,000 km?



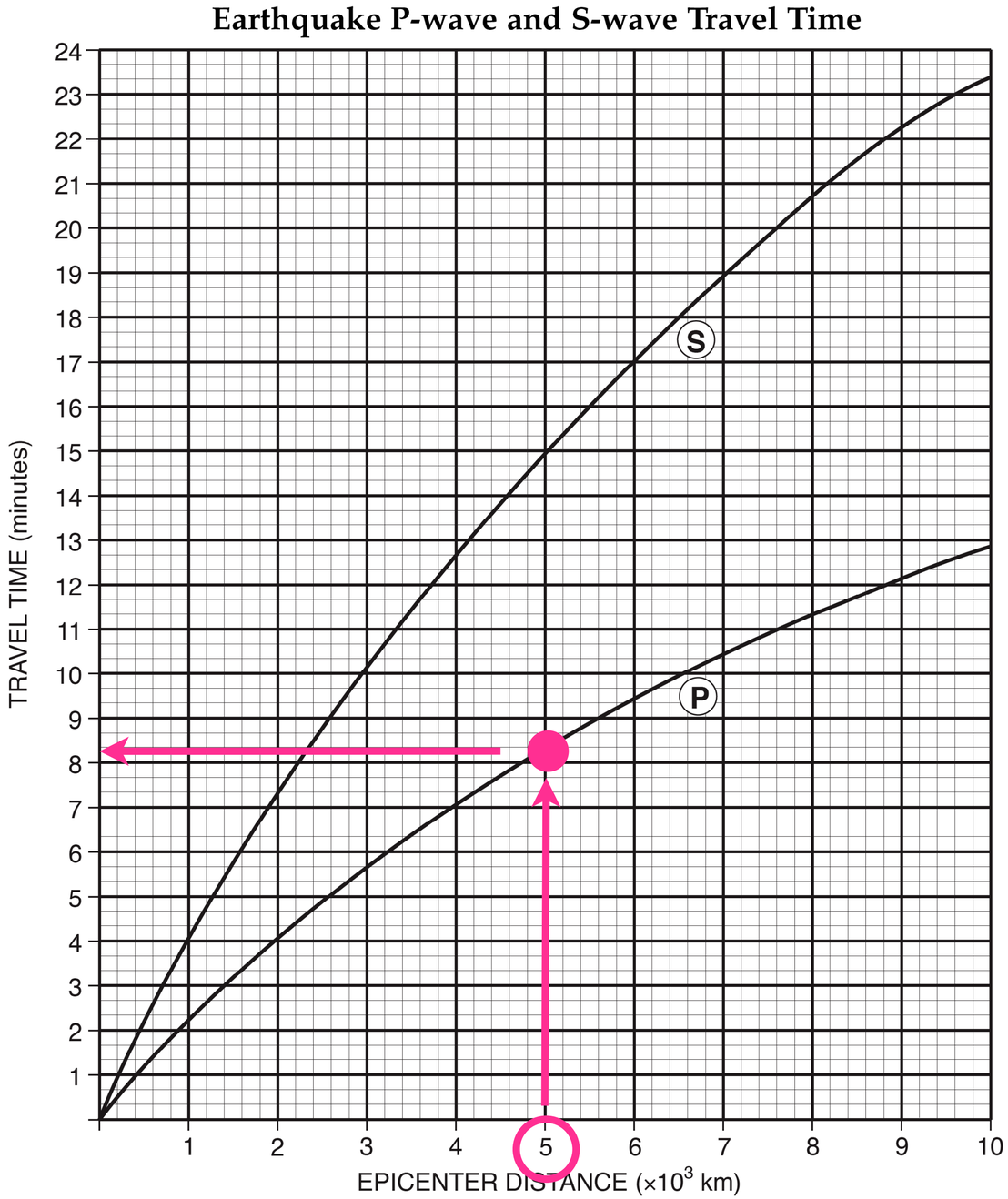
How long does it take a p-wave to travel 5,000 km?



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



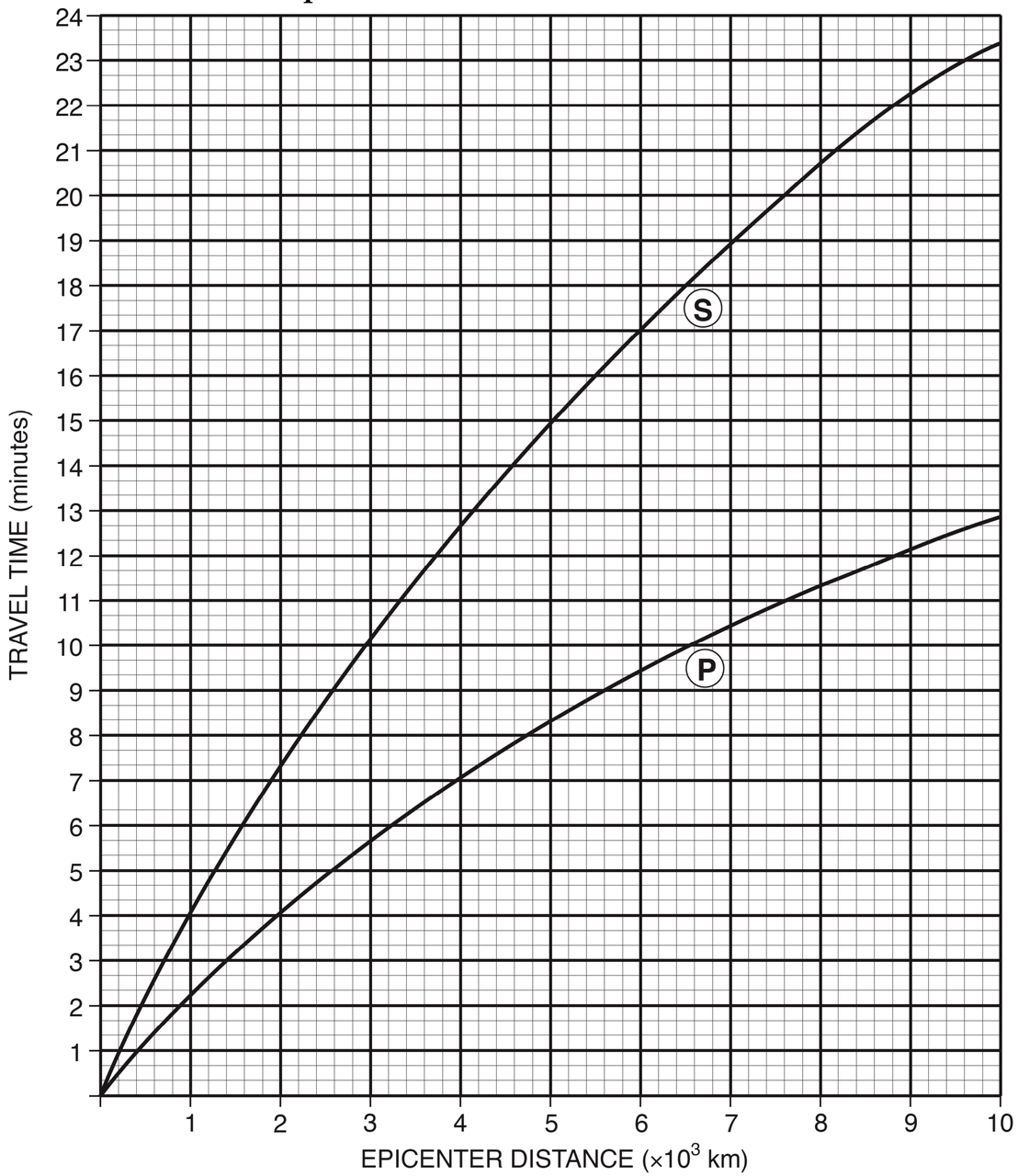
How long does it take a p-wave to travel 5,000 km?

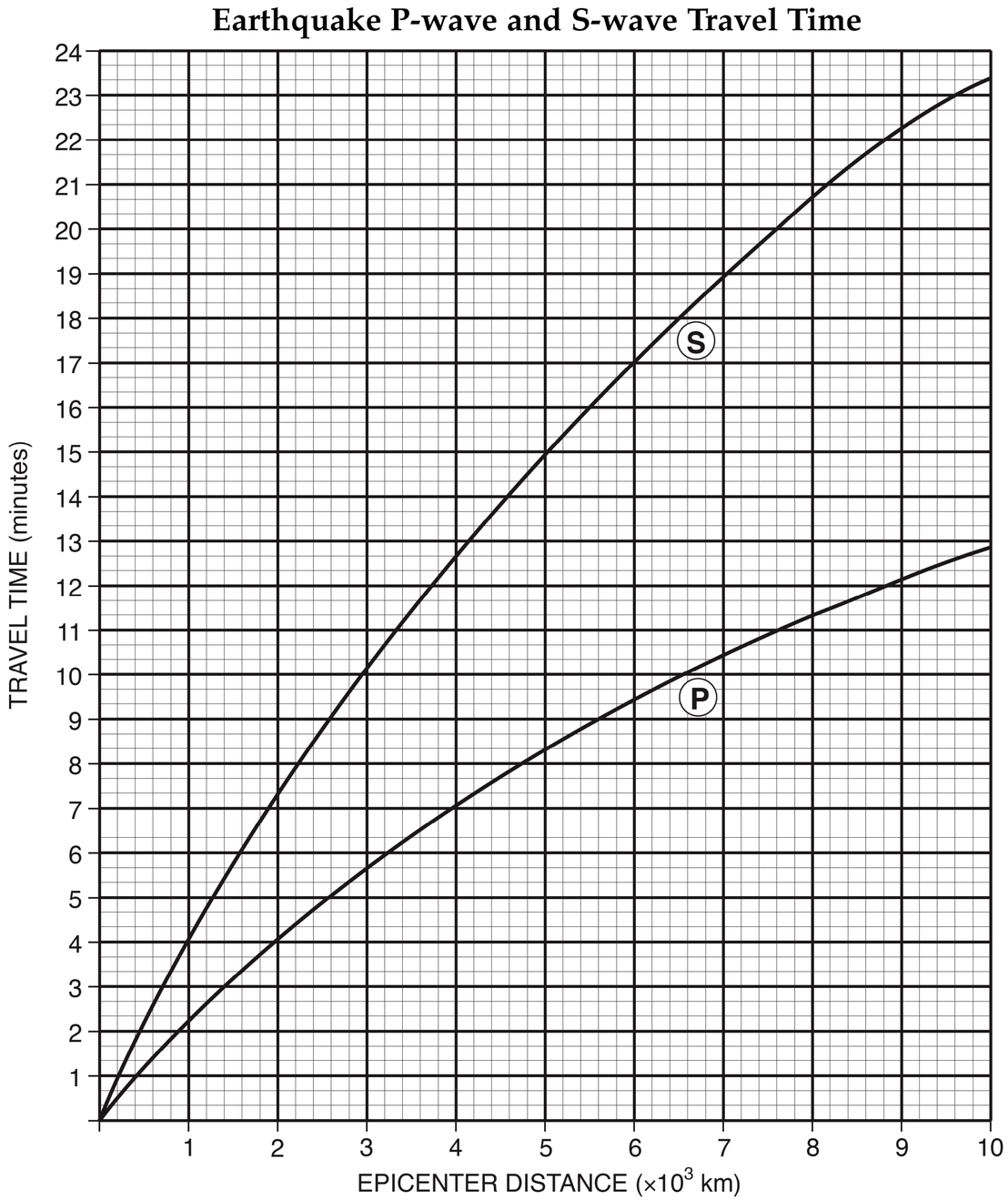


How long does it take a p-wave to travel 5,000 km?

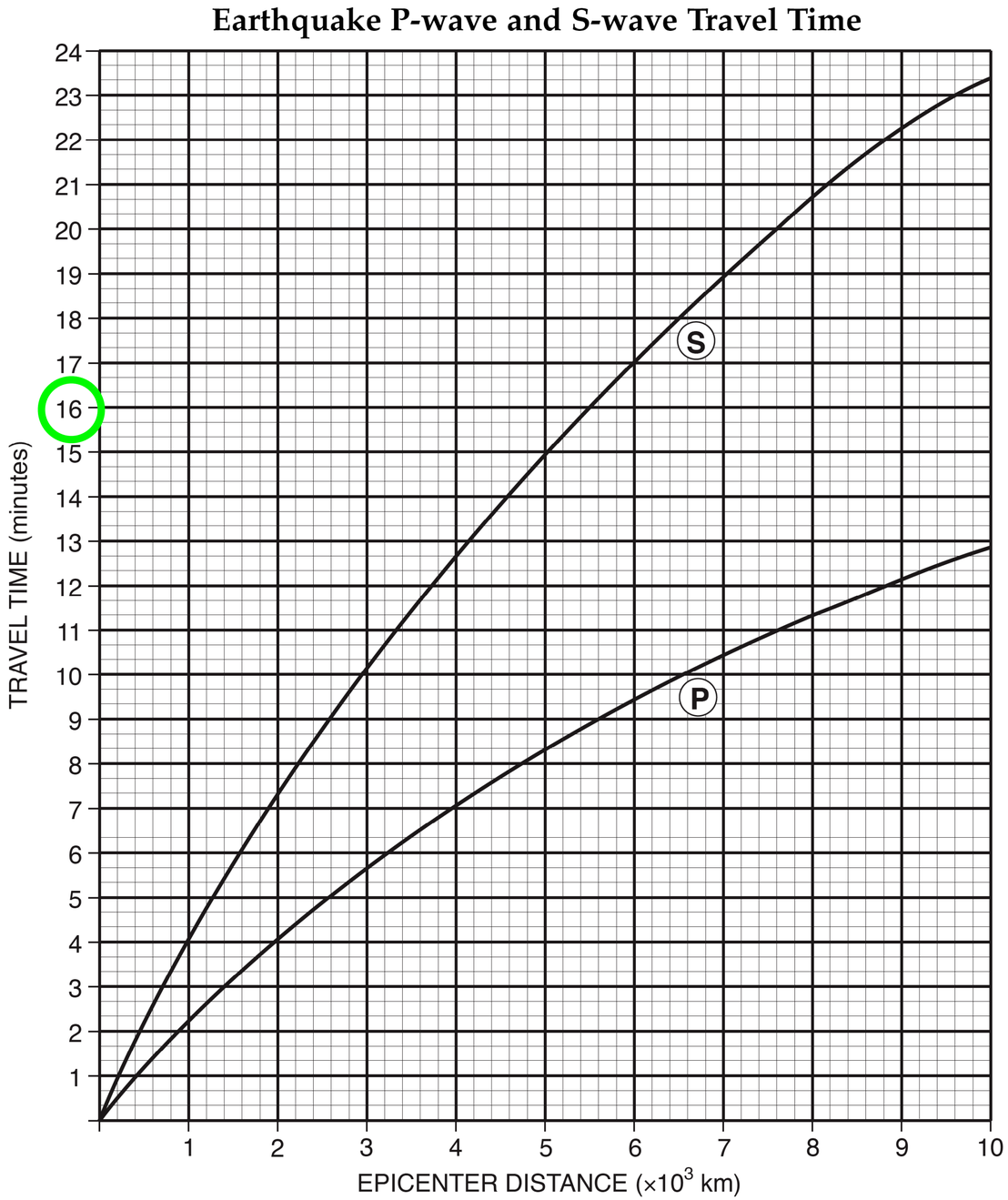
8 minutes
20 seconds

Earthquake P-wave and S-wave Travel Time

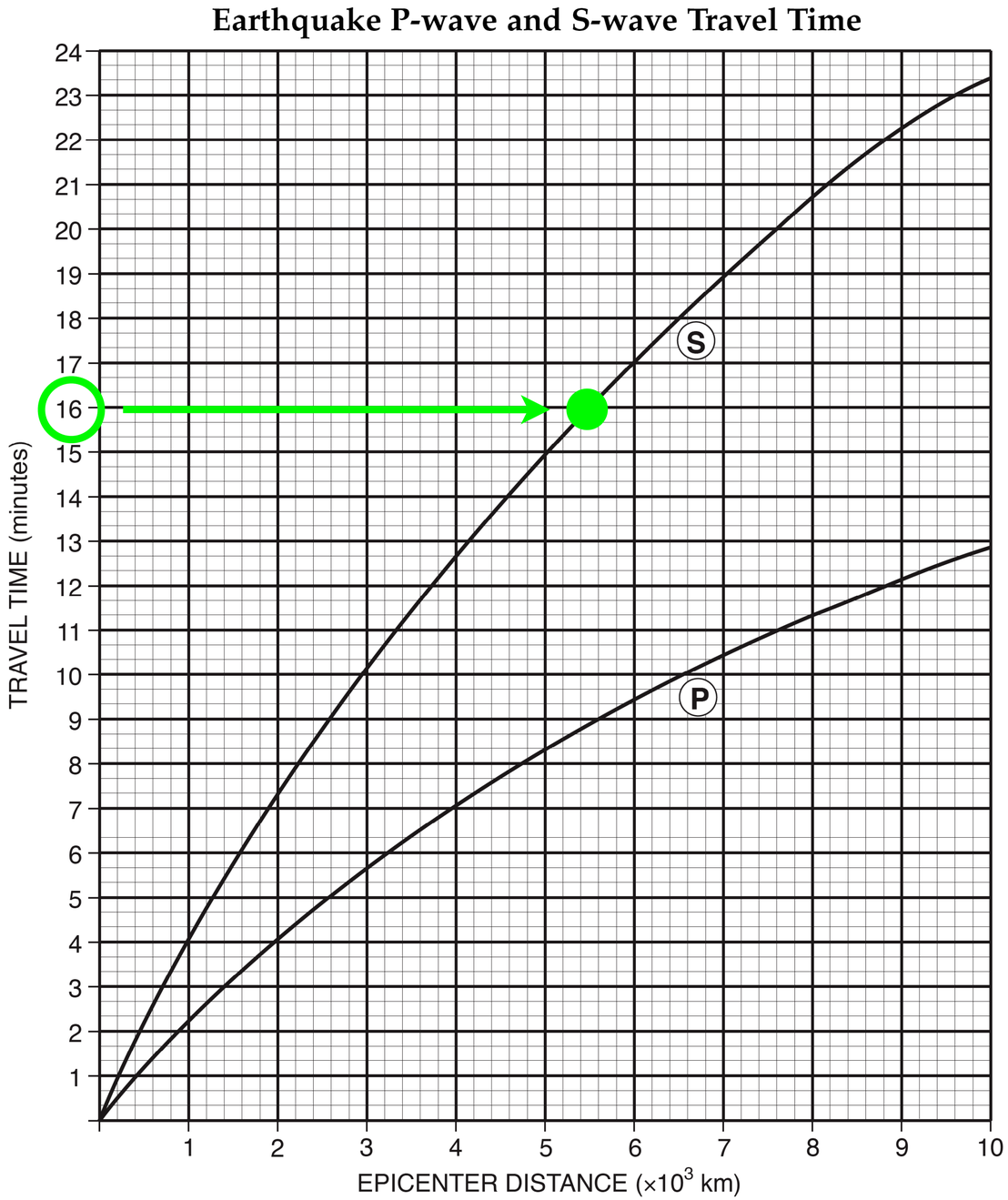




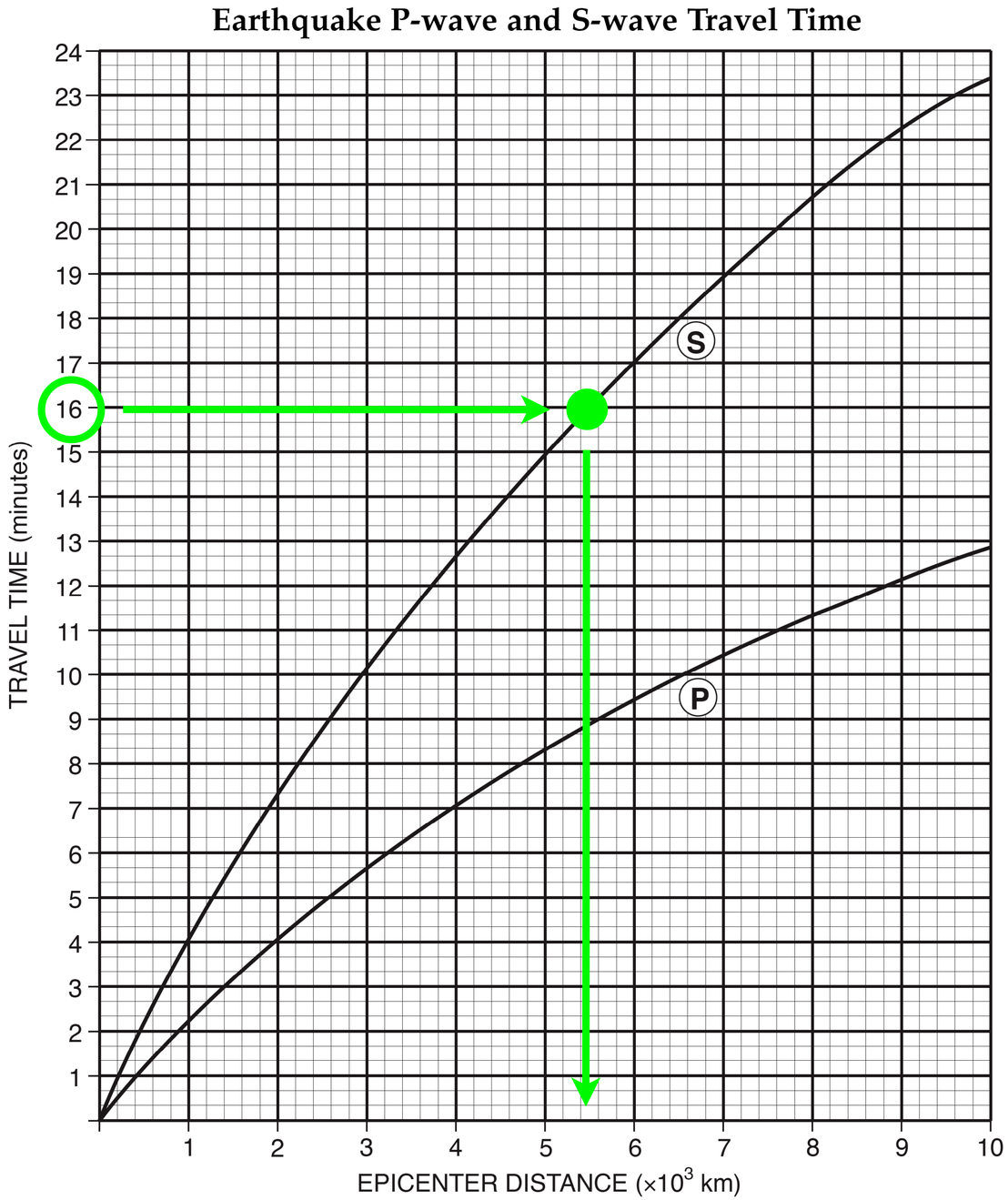
How far does an S-wave travel in 16 minutes?



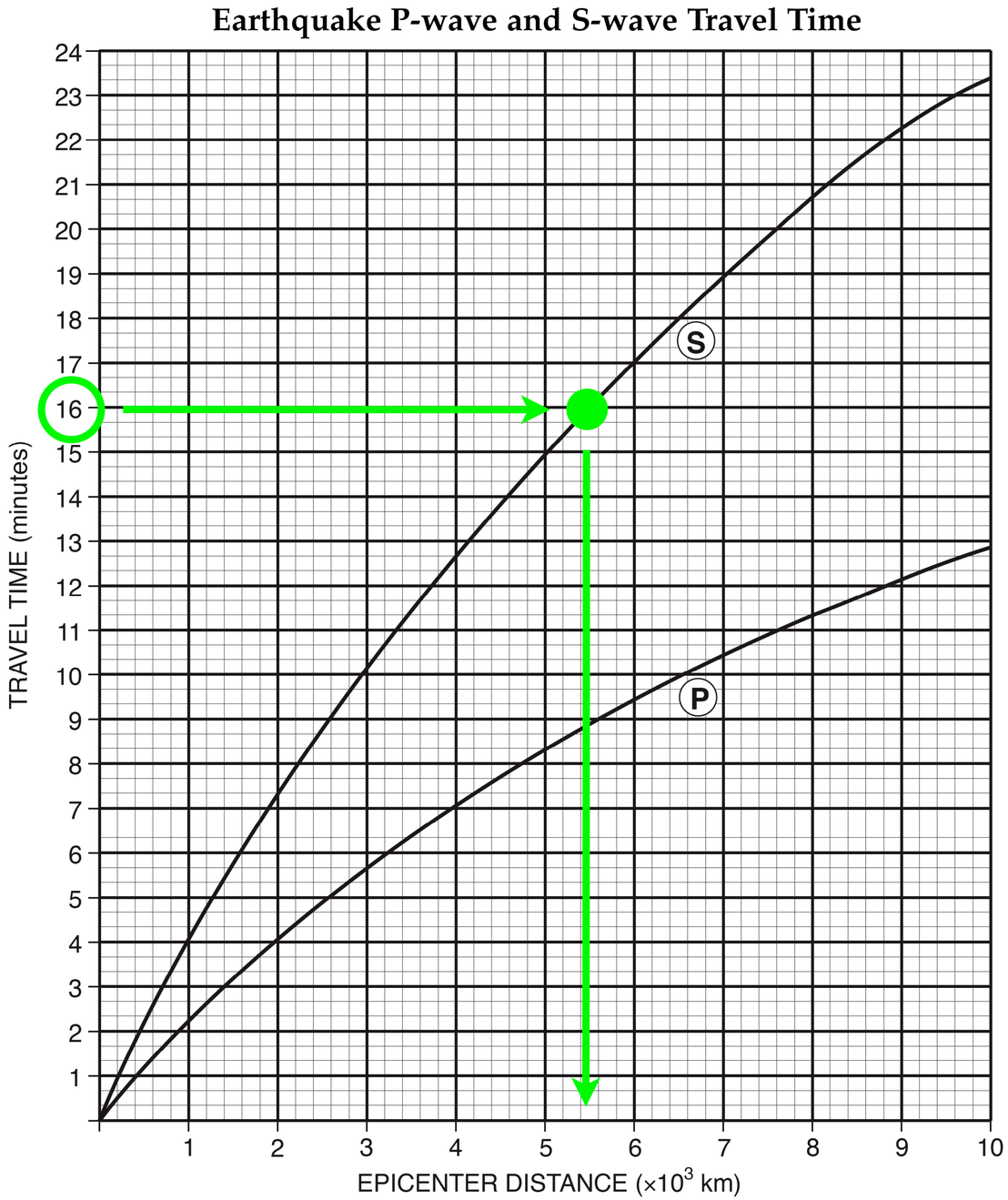
How far does an S-wave travel in 16 minutes?



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

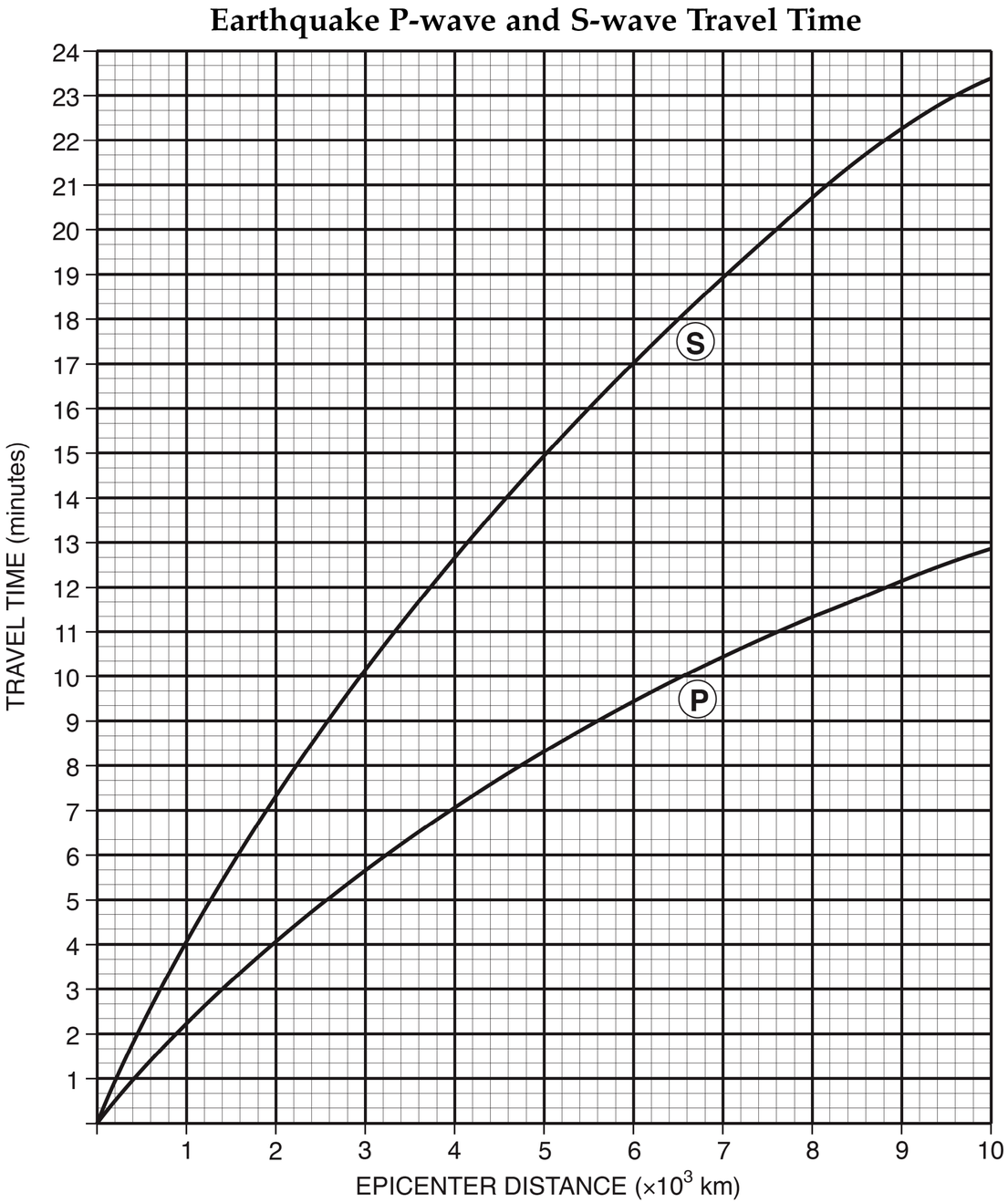


How far does an S-wave travel in 16 minutes?



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

5,400 km


Earthquake P-wave and S-wave Travel Time
TRAVEL TIME (minutes)
EPICENTER DISTANCE (×10³ km)
S
P
1
2
3
4
5
6
7
8
9
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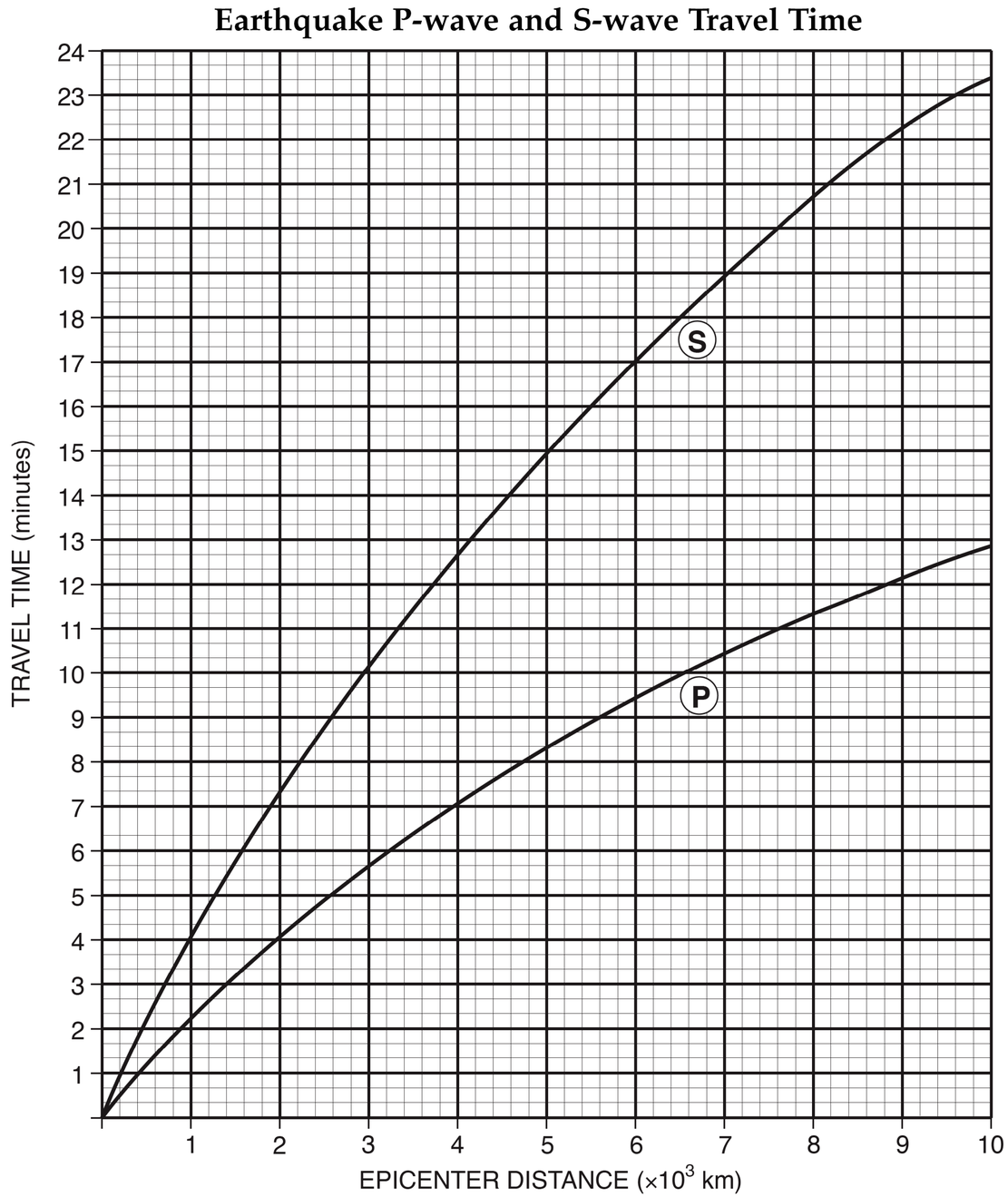
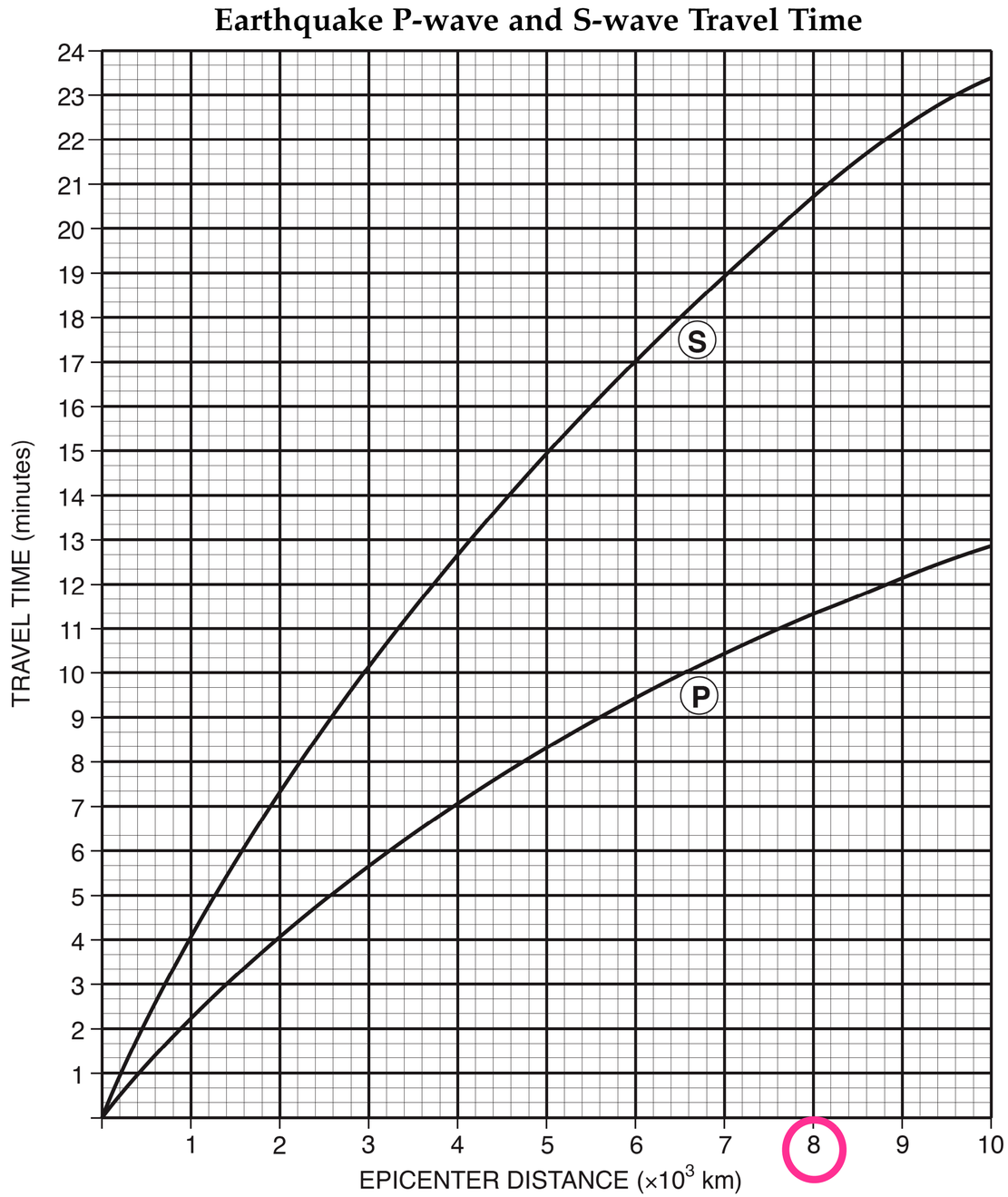
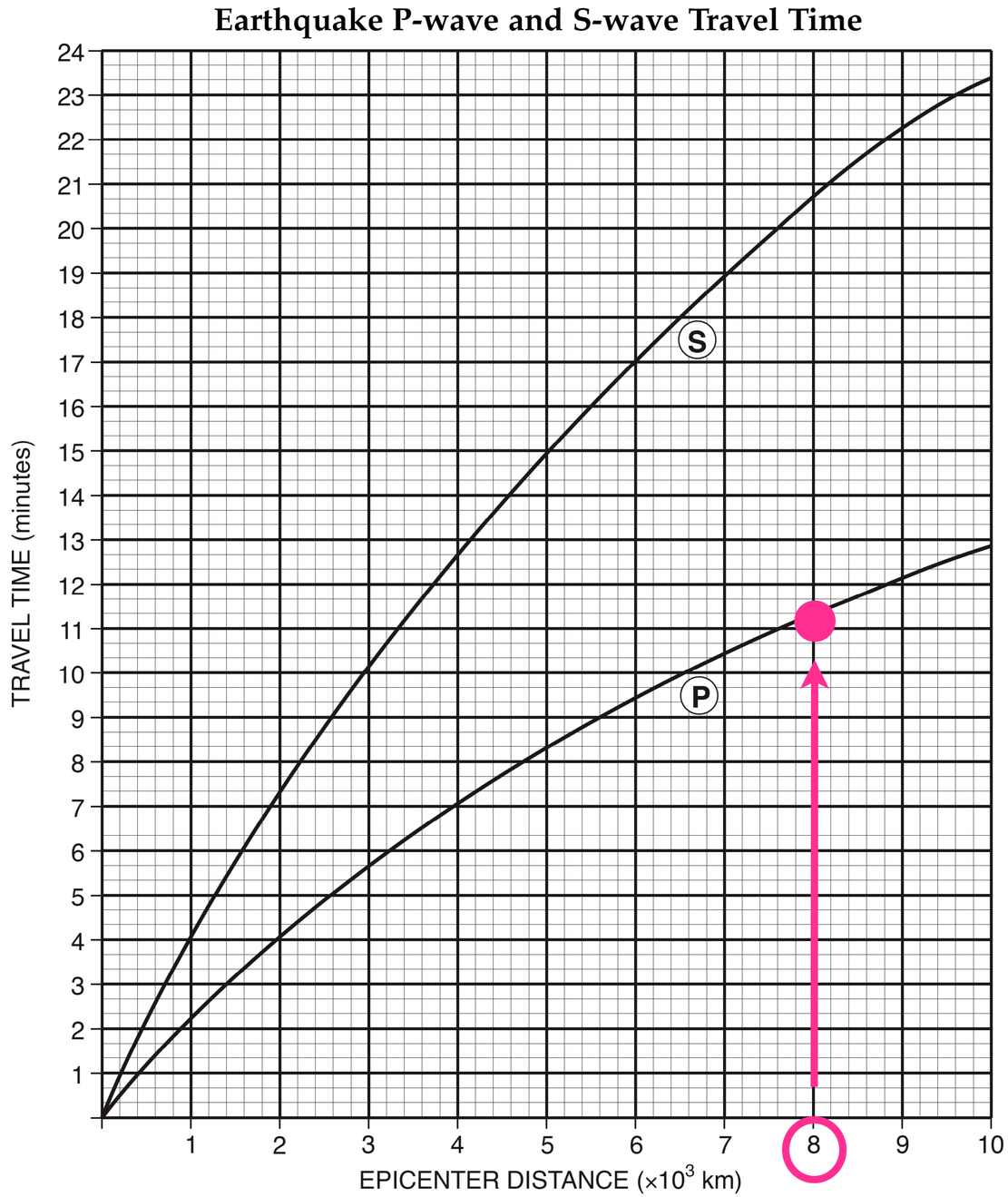
11
12
13
14
15
16
17
18
19
20
21
22
23
24



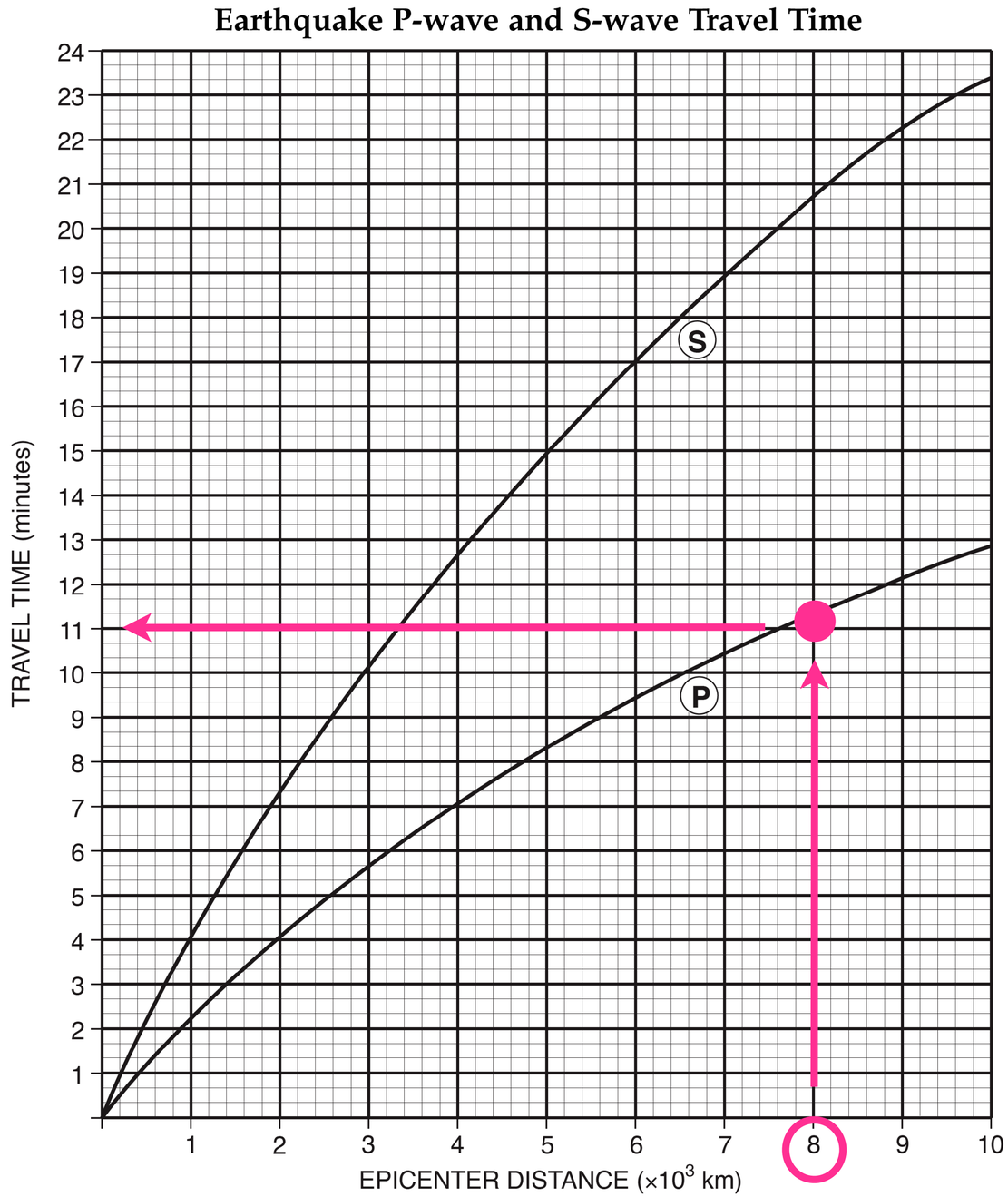
If an Earthquakes P-Wave travels 8000km and arrives at a seismic station at 11:40am, What is the origin time of the Earthquake?



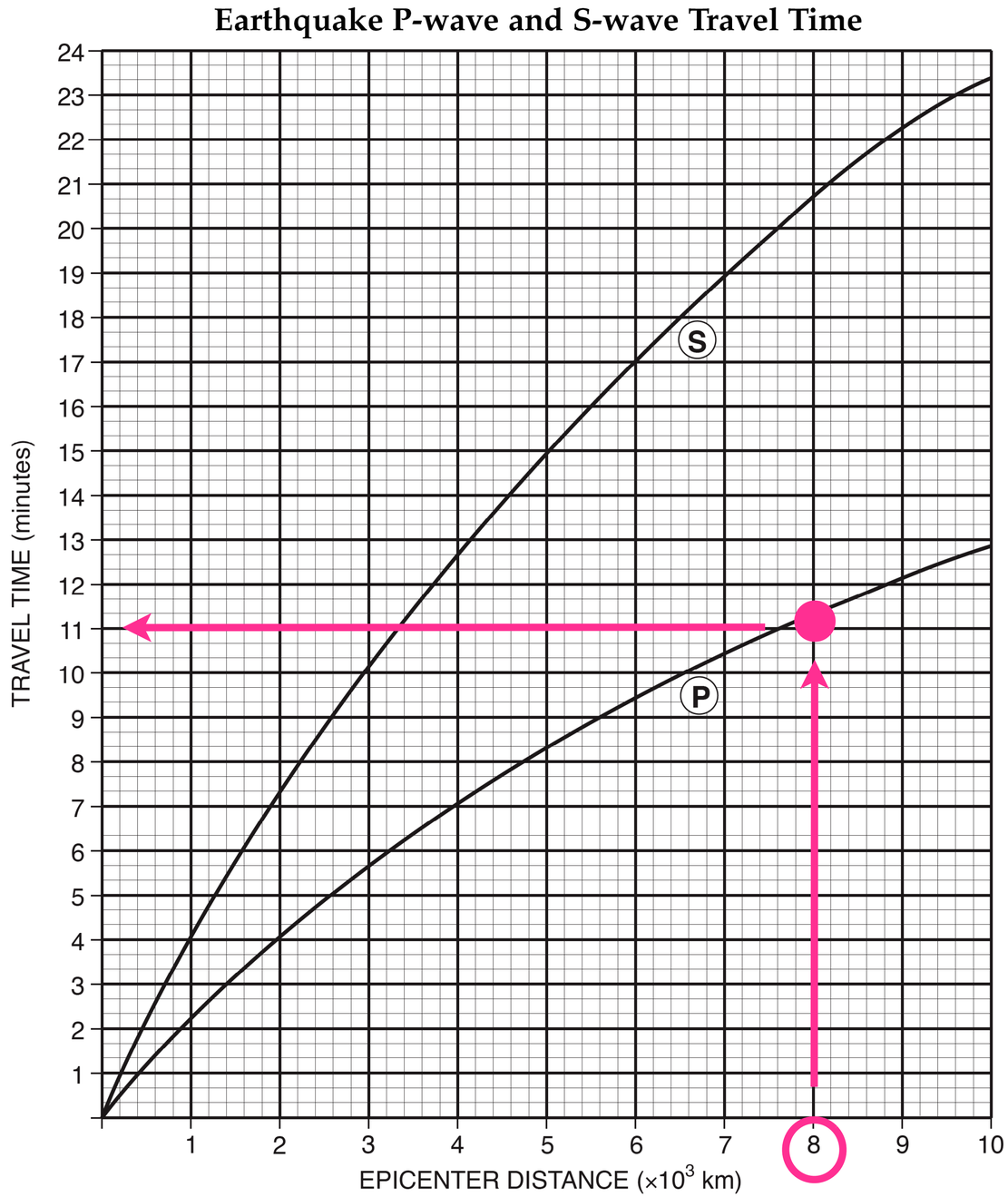
If an Earthquakes P-Wave travels 8000km and arrives at a seismic station at 11:40am, What is the origin time of the Earthquake?



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



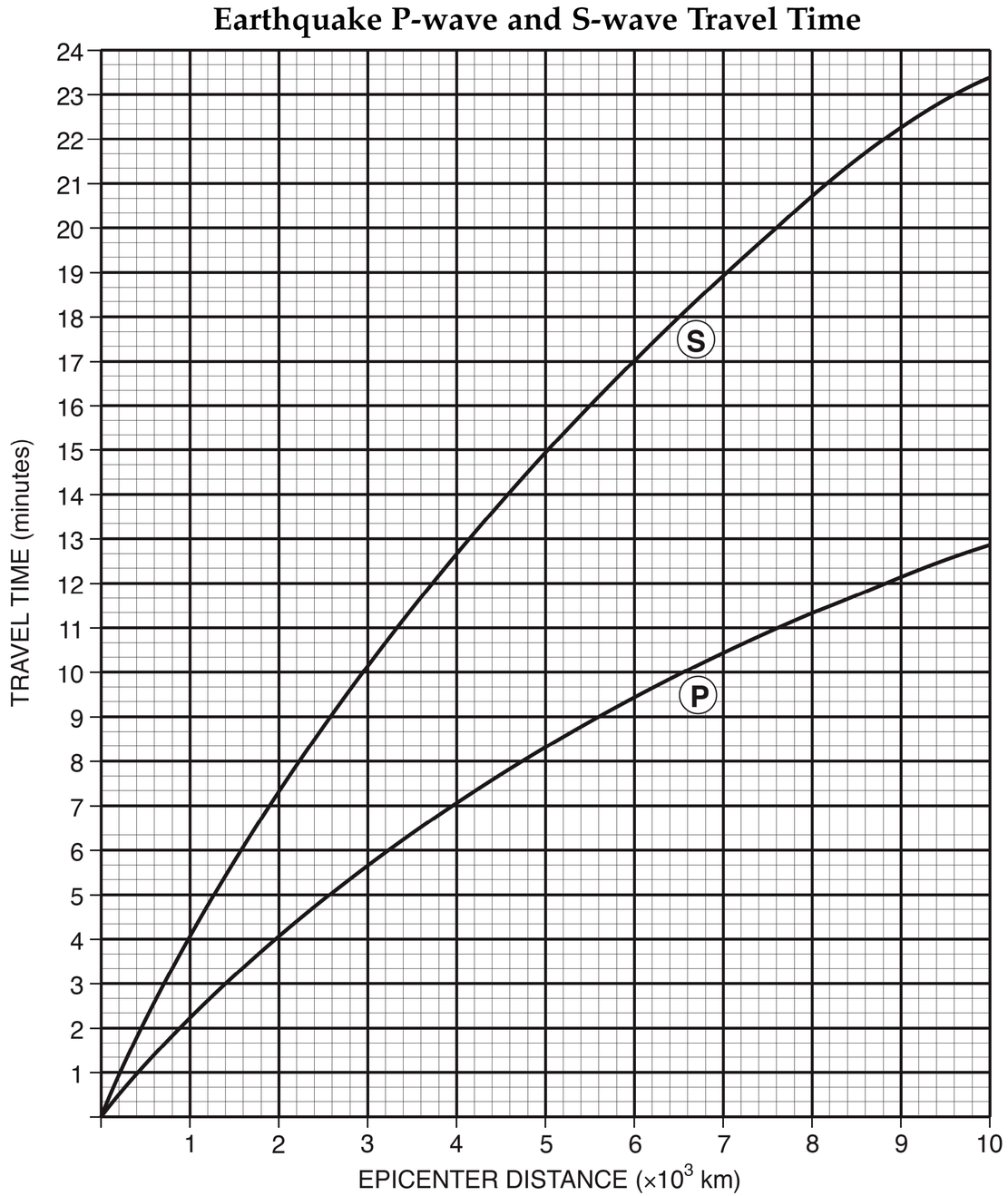
If an Earthquakes P-Wave travels 8000km and arrives at a seismic station at 11:40am, What is the origin time of the Earthquake?



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


Earthquake P-wave and S-wave Travel Time
TRAVEL TIME (minutes)
EPICENTER DISTANCE (×10^3 km)
S
P
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
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7
6
5
4
3
2
1
1
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3
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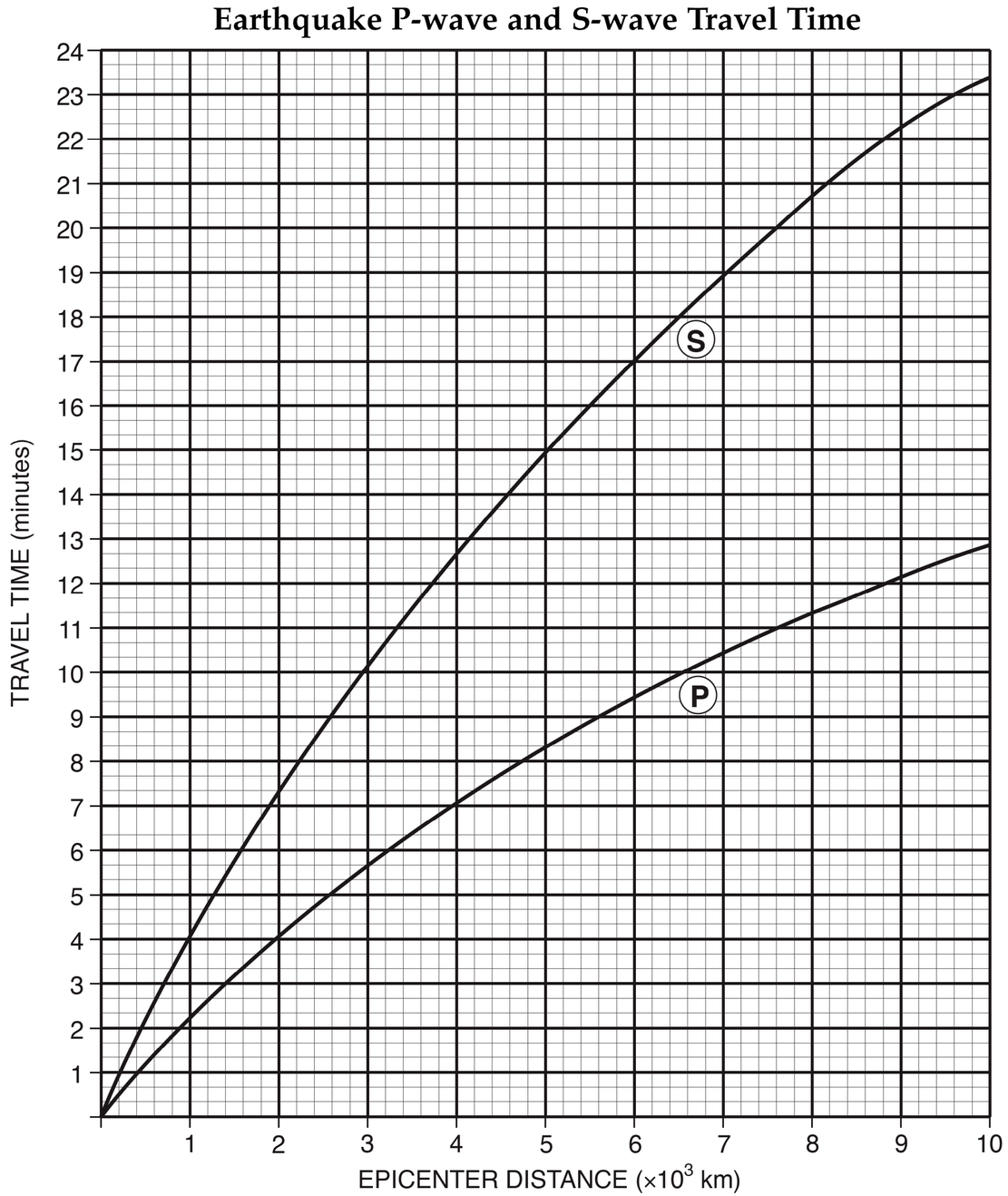
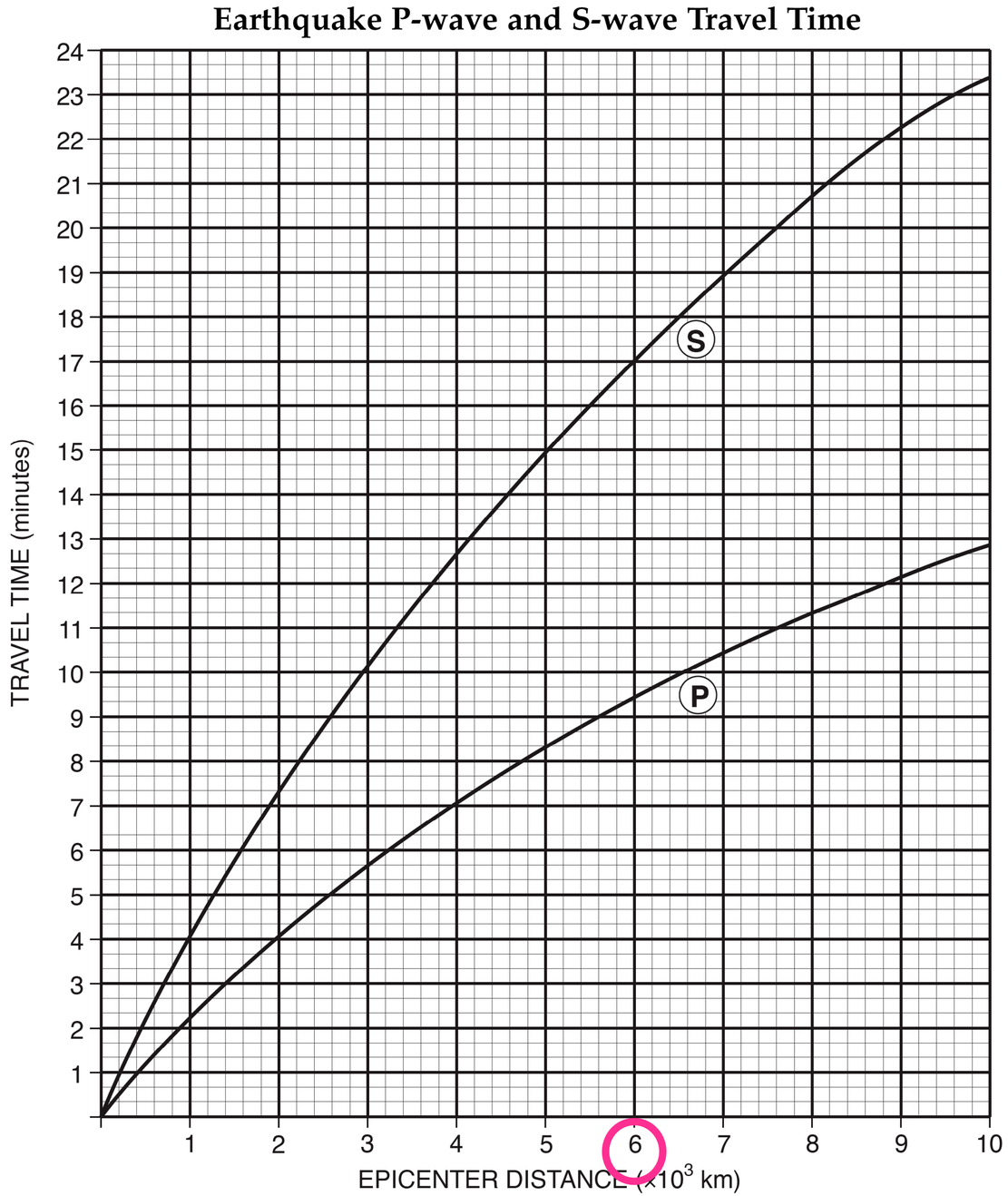
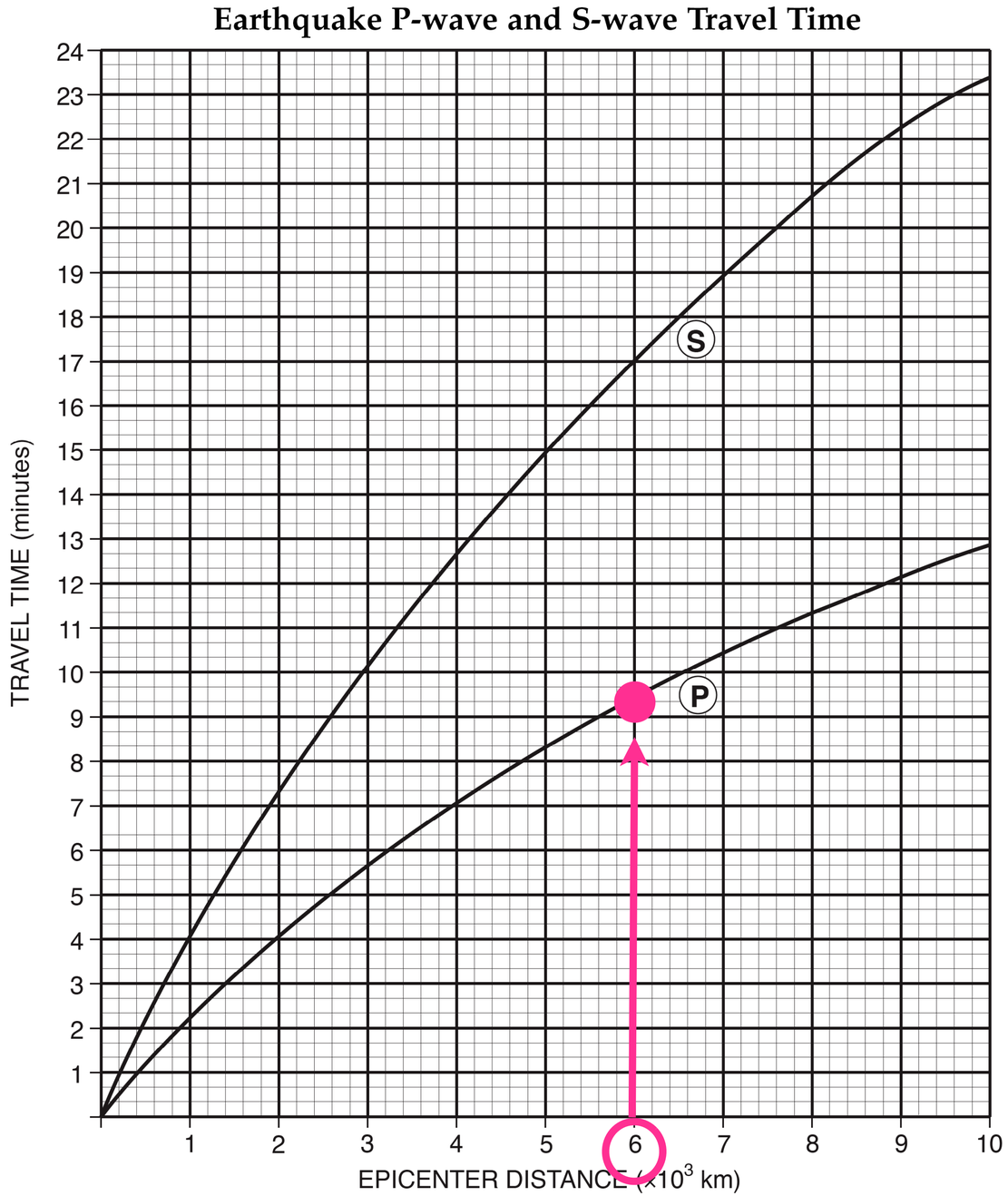
6
7
8
9
10



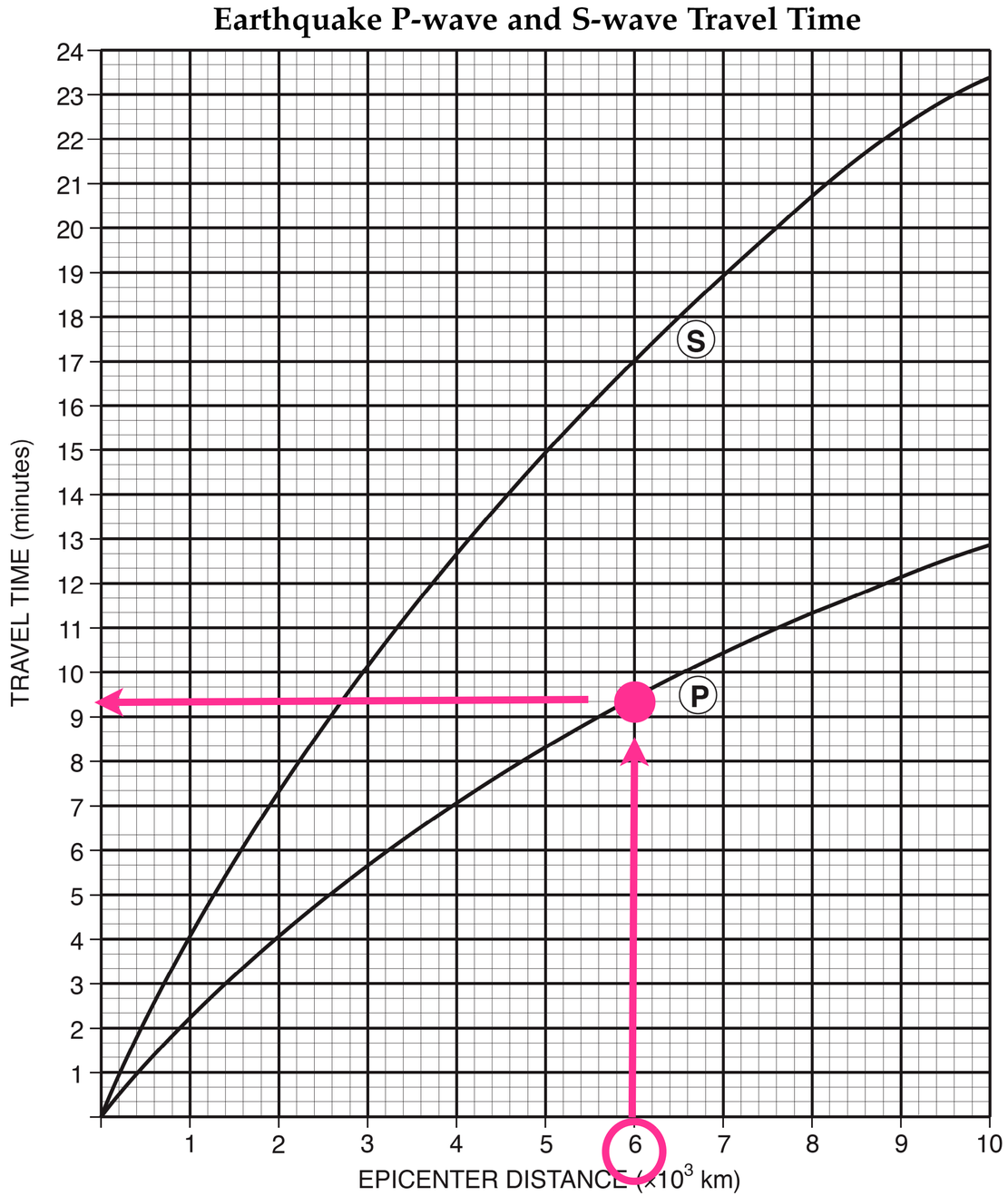
If an Earthquakes P-Wave arrives at 12:00pm and travels 6000km, what time will the S-Wave arrive?



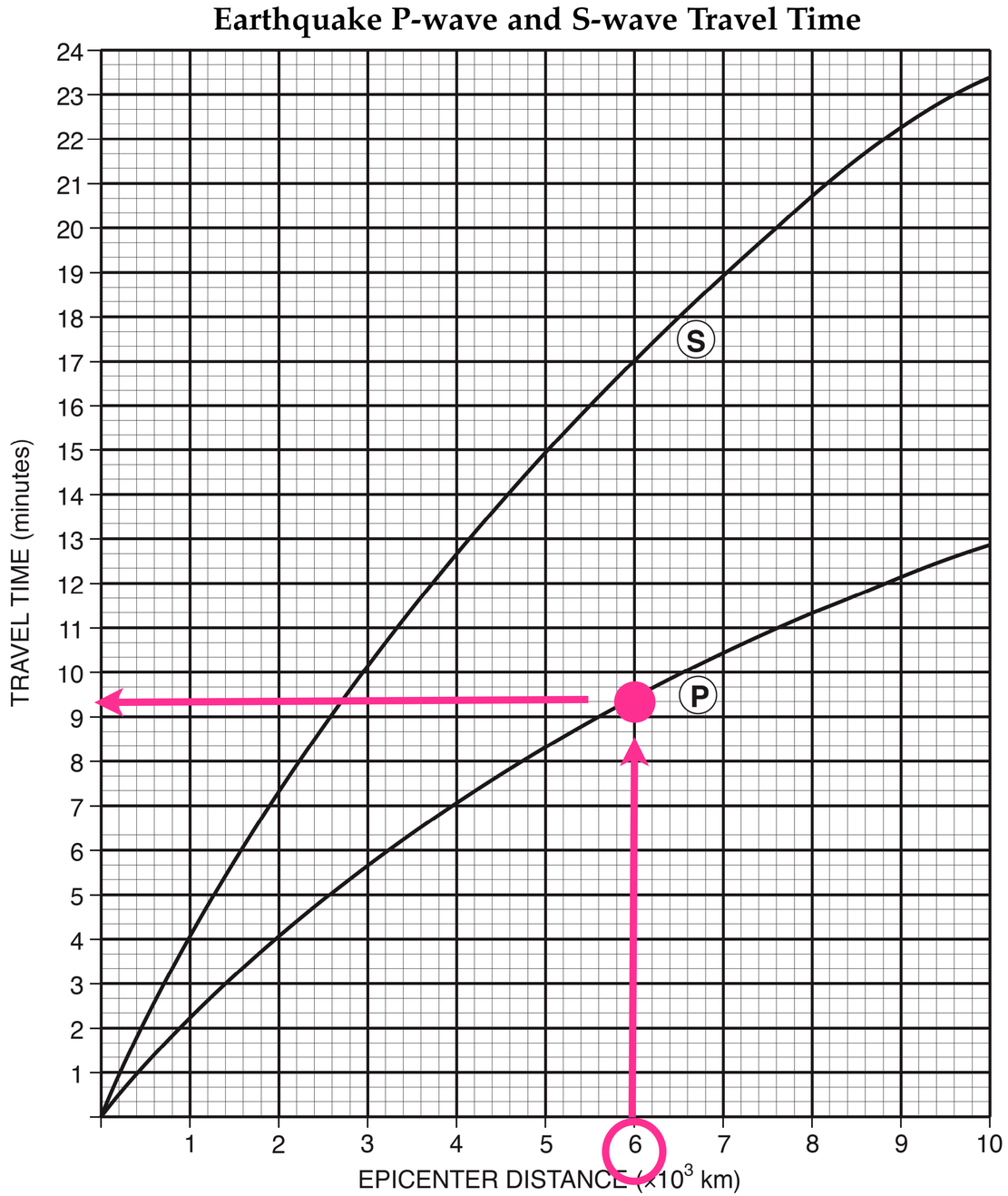
If an Earthquakes P-Wave arrives at 12:00pm and travels 6000km, what time will the S-Wave arrive?



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



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



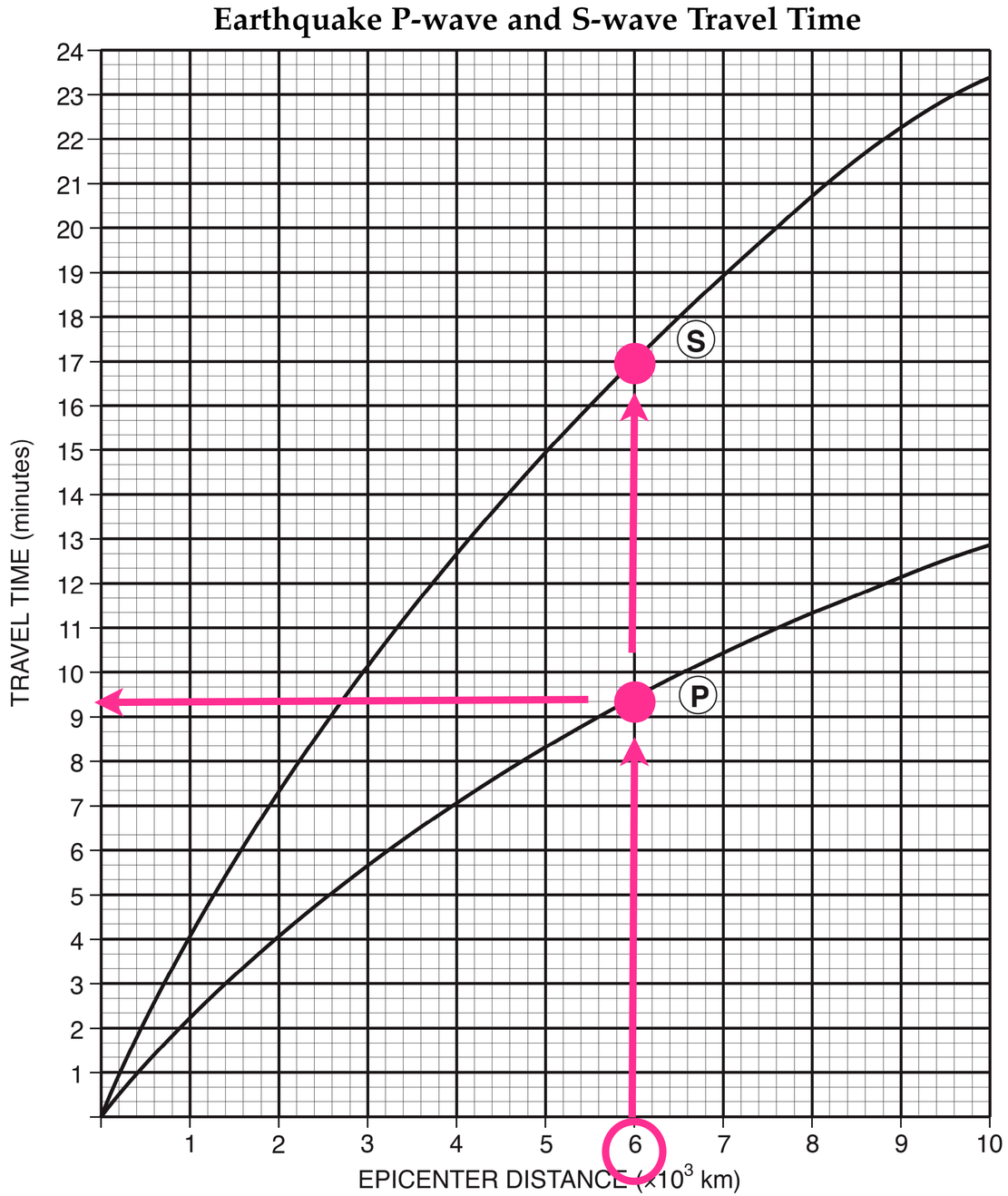
If an Earthquakes P-Wave arrives at 12:00pm and travels 6000km, what time will the S-Wave arrive?

P-Wave Travel Time: 00:09:20

S-Wave Travel Time: 00:17:00

Difference: 00:07:40

Time of Arrival: 12:07:40



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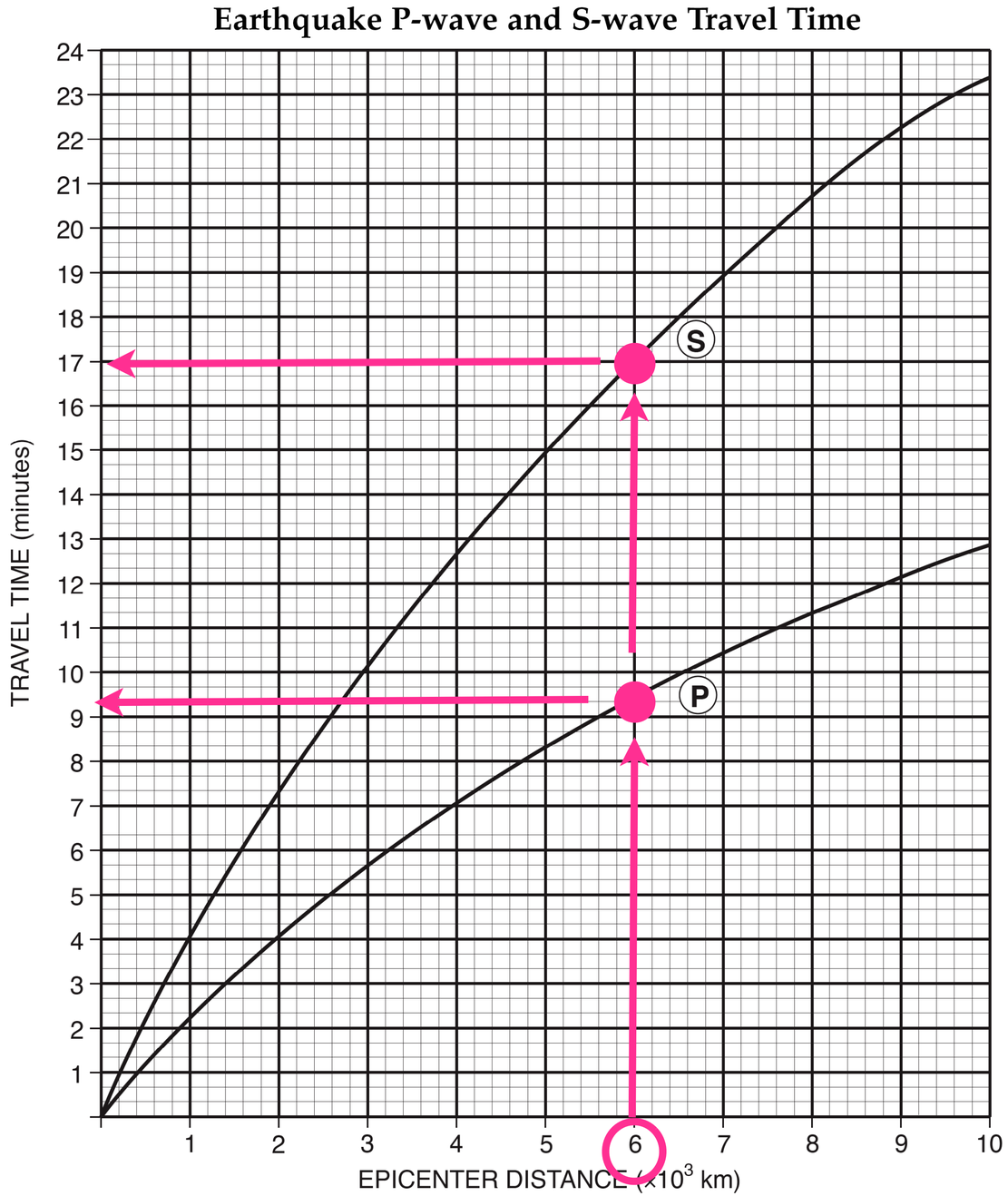
P-Wave Travel Time: 00:09:20

S-Wave Travel Time: 00:17:00

Difference: 00:07:40

Time of Arrival: 12:07:40



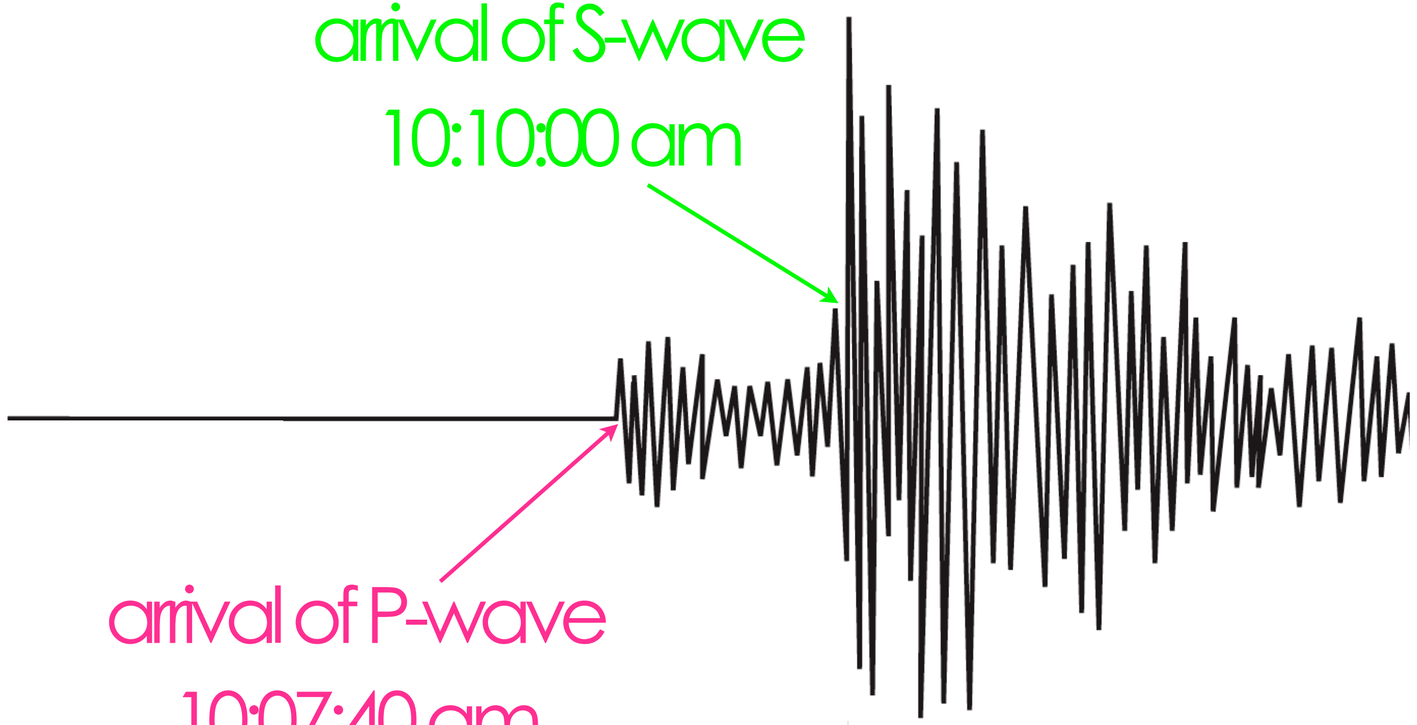
If an Earthquakes P-Wave arrives at 12:00pm and travels 6000km, what time will the S-Wave arrive?

P-Wave Travel Time: 00:09:20

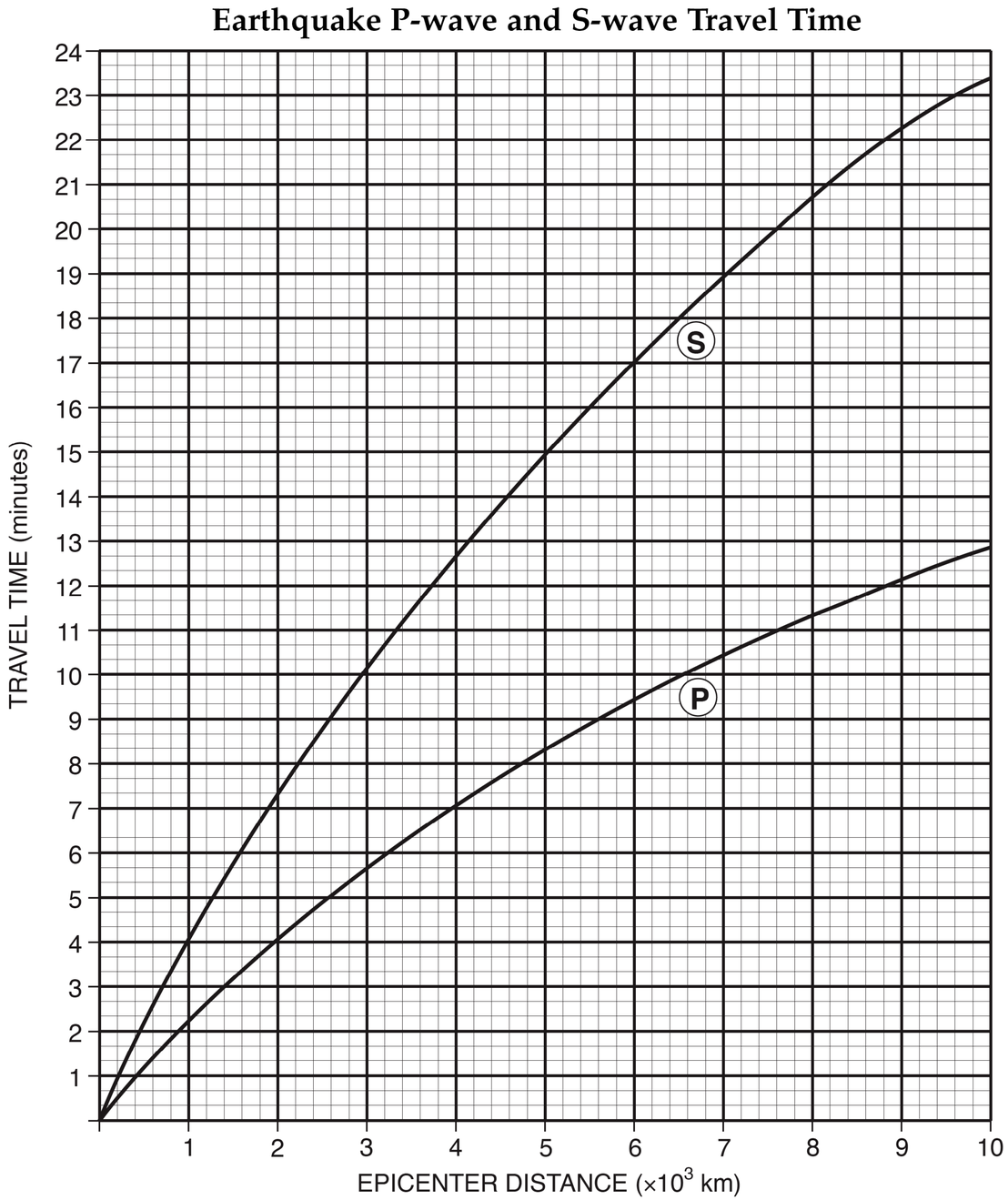
S-Wave Travel Time: 00:17:00

Difference: 00:07:40

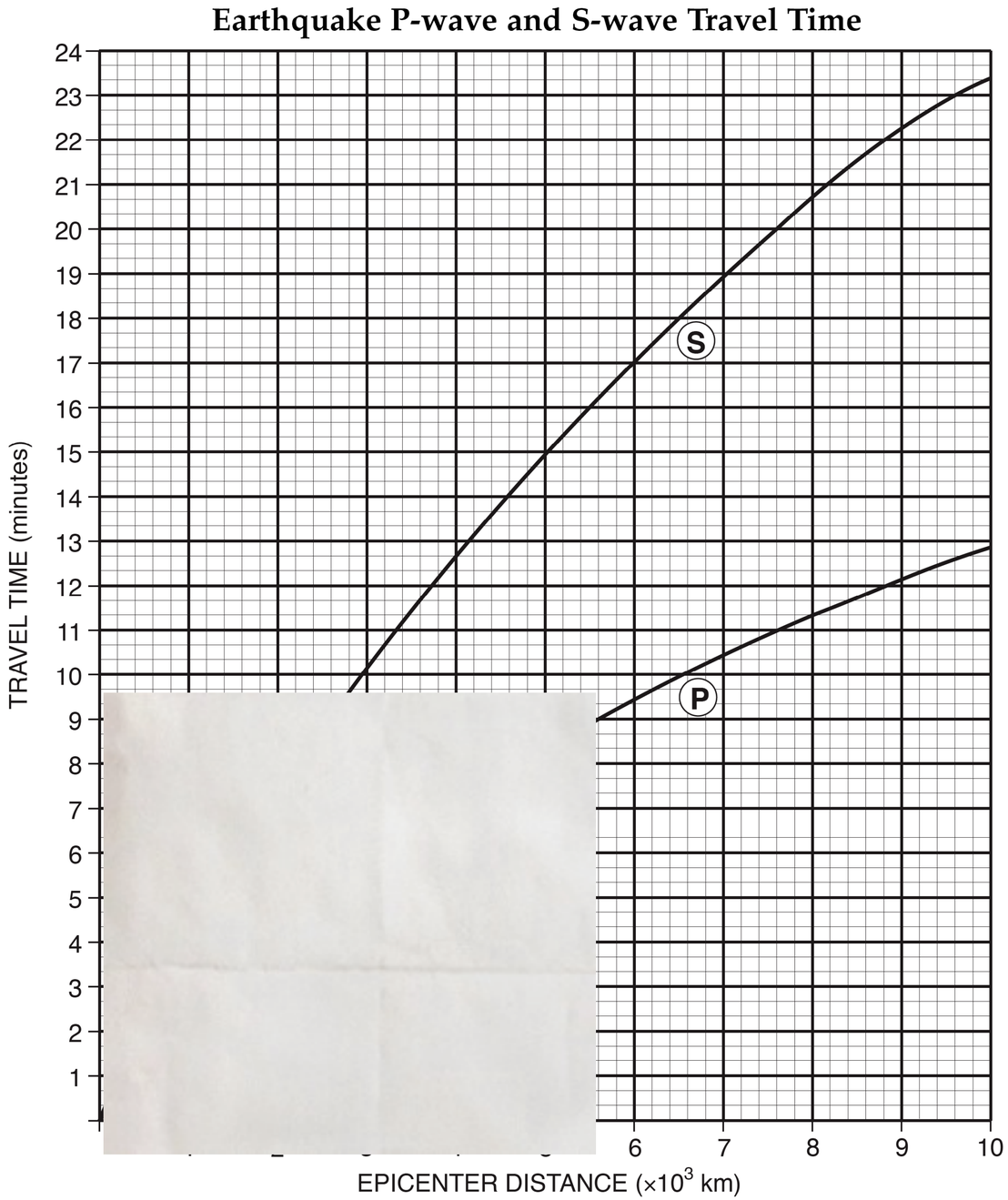
Time of Arrival: 12:07:40



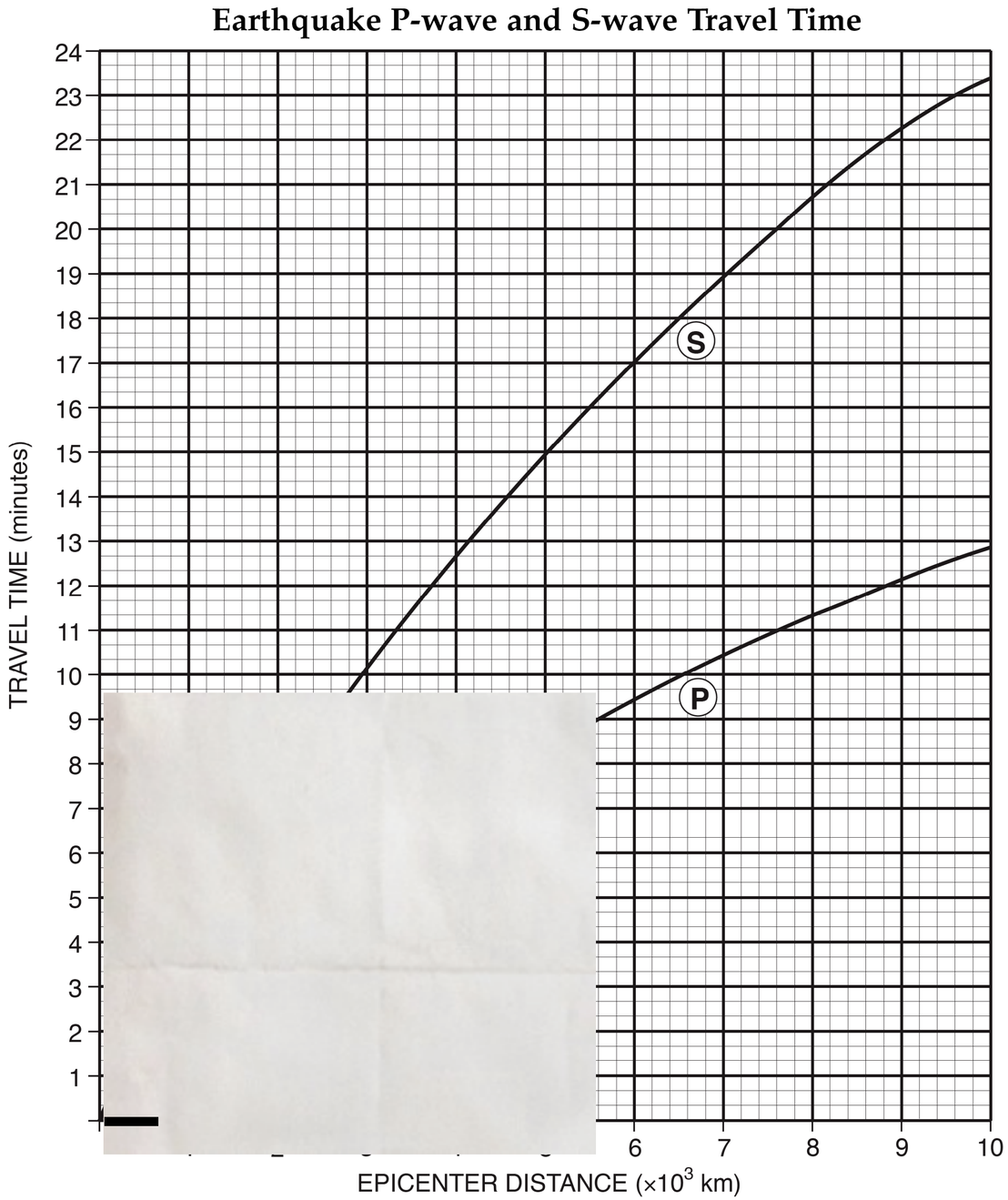
- ✓ P_{arr} = 10:07:40
- ✓ S_{arr} = 10:10:00
- ✓ Lag time = 00:02:20
- ✓ Epicenter distance?



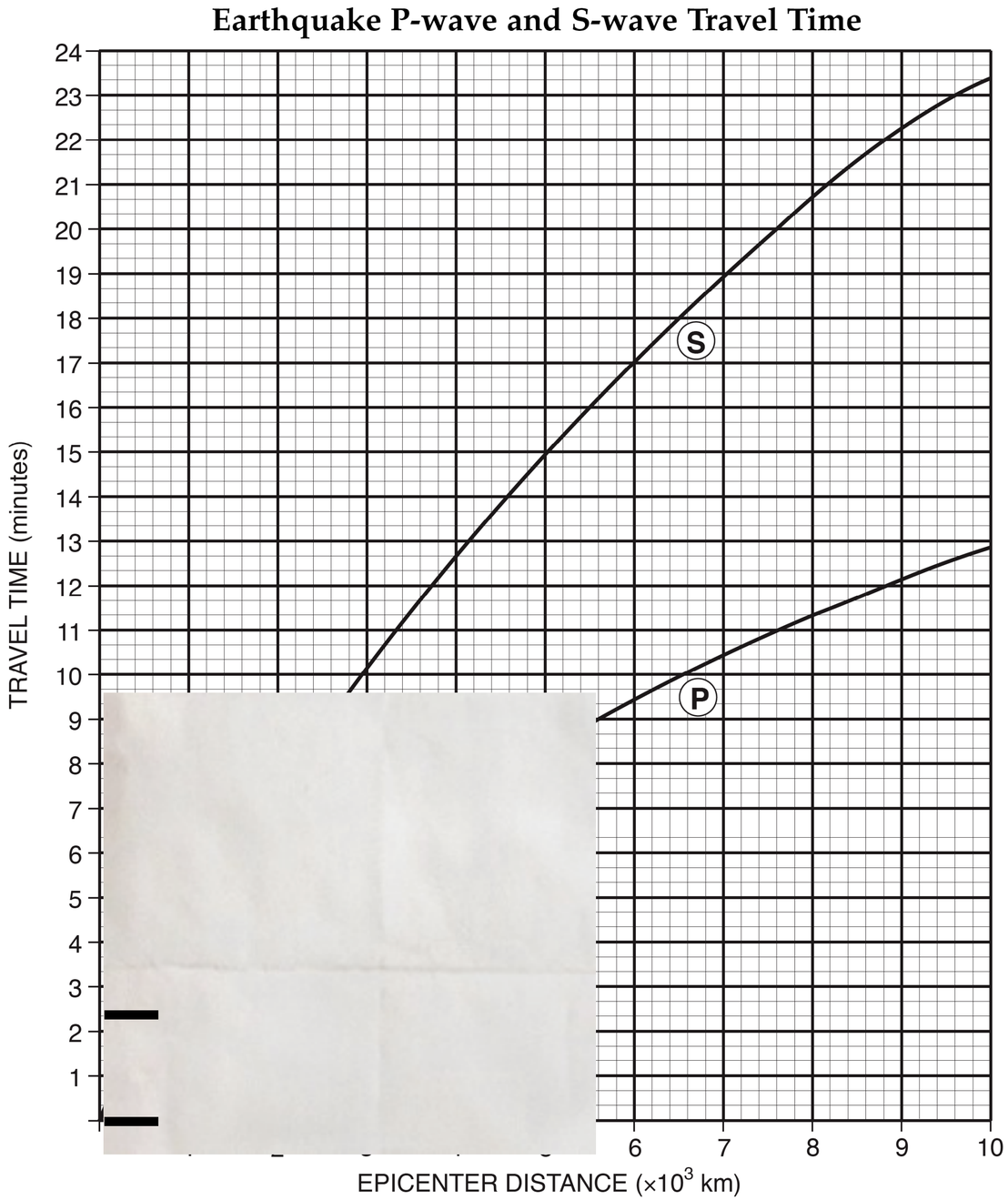
- ✓ S_{arr} = 10:10:00
- ✓ P_{arr} = 10:07:40
- ✓ Lag time = 00:02:20
- ✓ Epicenter distance?



- ✓ S_{arr} = 10:10:00
- ✓ P_{arr} = 10:07:40
- ✓ Lag time = 00:02:20
- ✓ Epicenter distance?



- ✓ S_{arr} = 10:10:00
- ✓ P_{arr} = 10:07:40
- ✓ Lag time = 00:02:20
- ✓ Epicenter distance?



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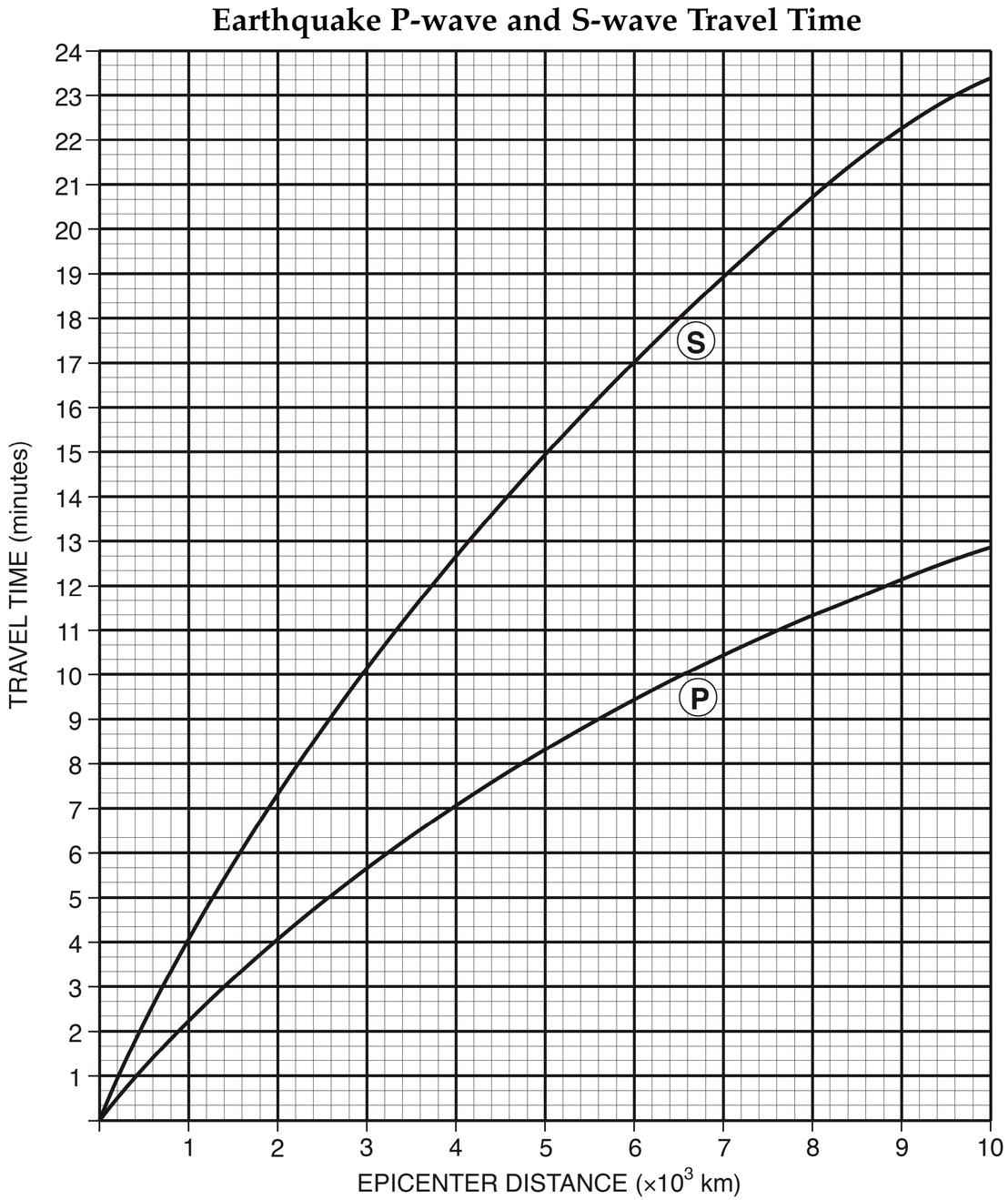
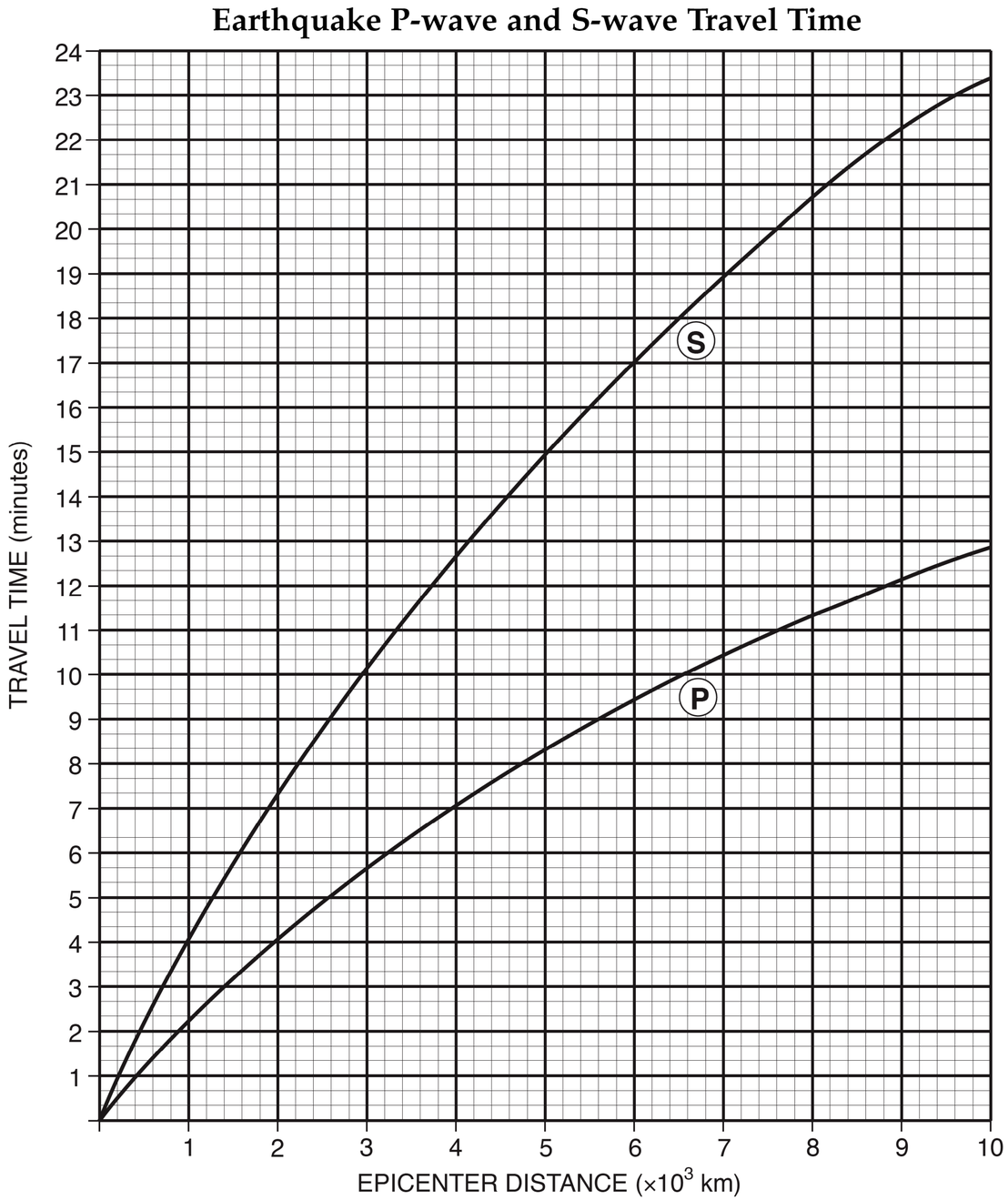
- ✓ P_{arr} = 10:07:40
- ✓ Lag time = 00:02:20
- ✓ Epicenter distance?



- ✓ S_{arr} = 10:10:00
- ✓ P_{arr} = 10:07:40
- ✓ Lag time = 00:02:20
- ✓ Epicenter distance?

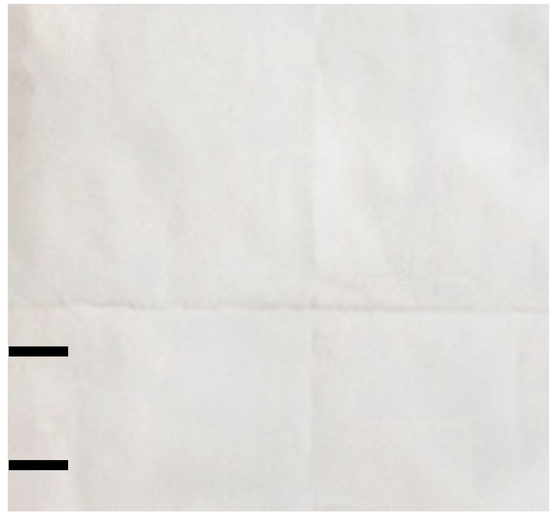


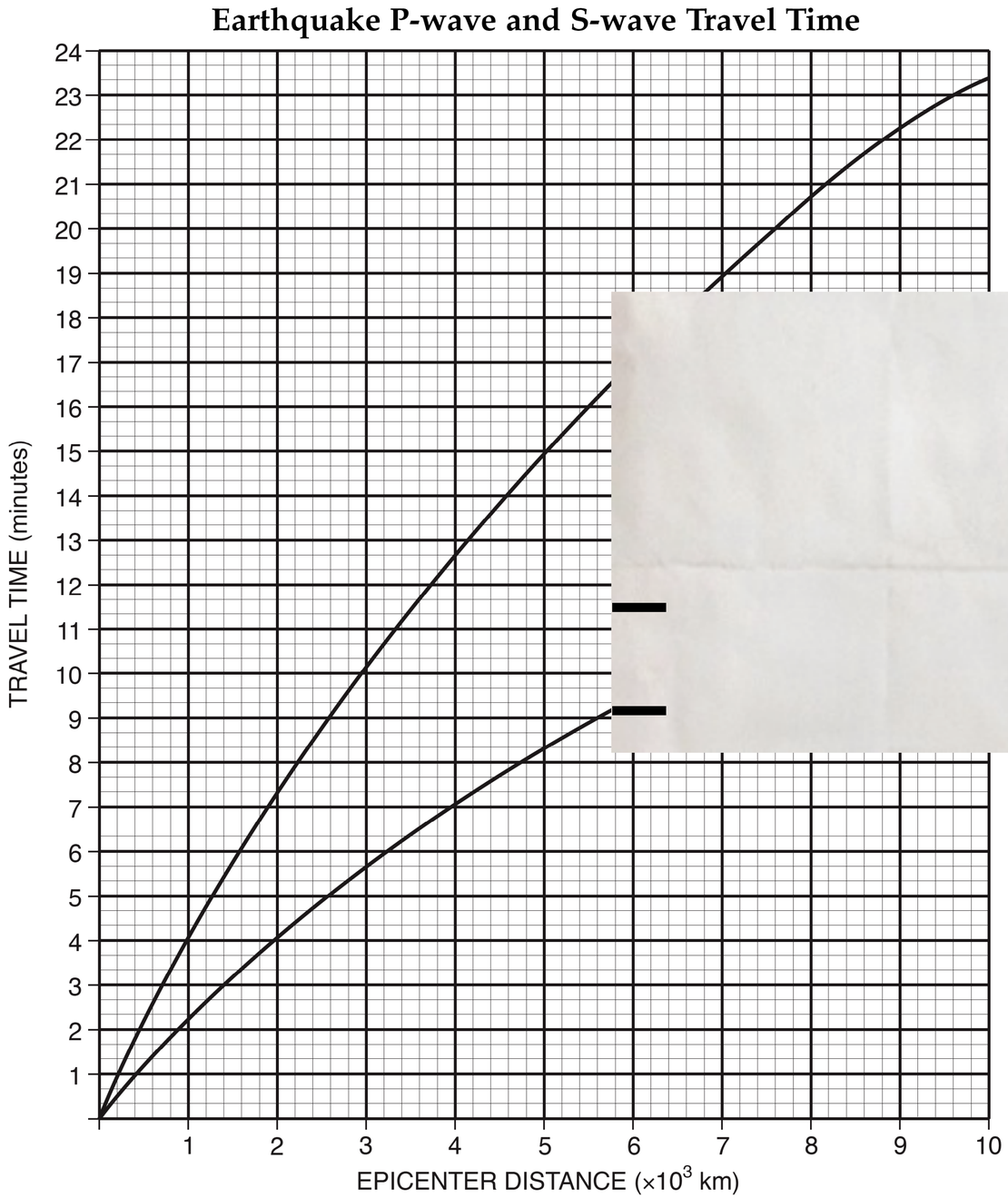
✓ S_{arr} = 10:10:00

✓ P_{arr} = 10:07:40

✓ Lag time = 00:02:20

✓ Epicenter distance?



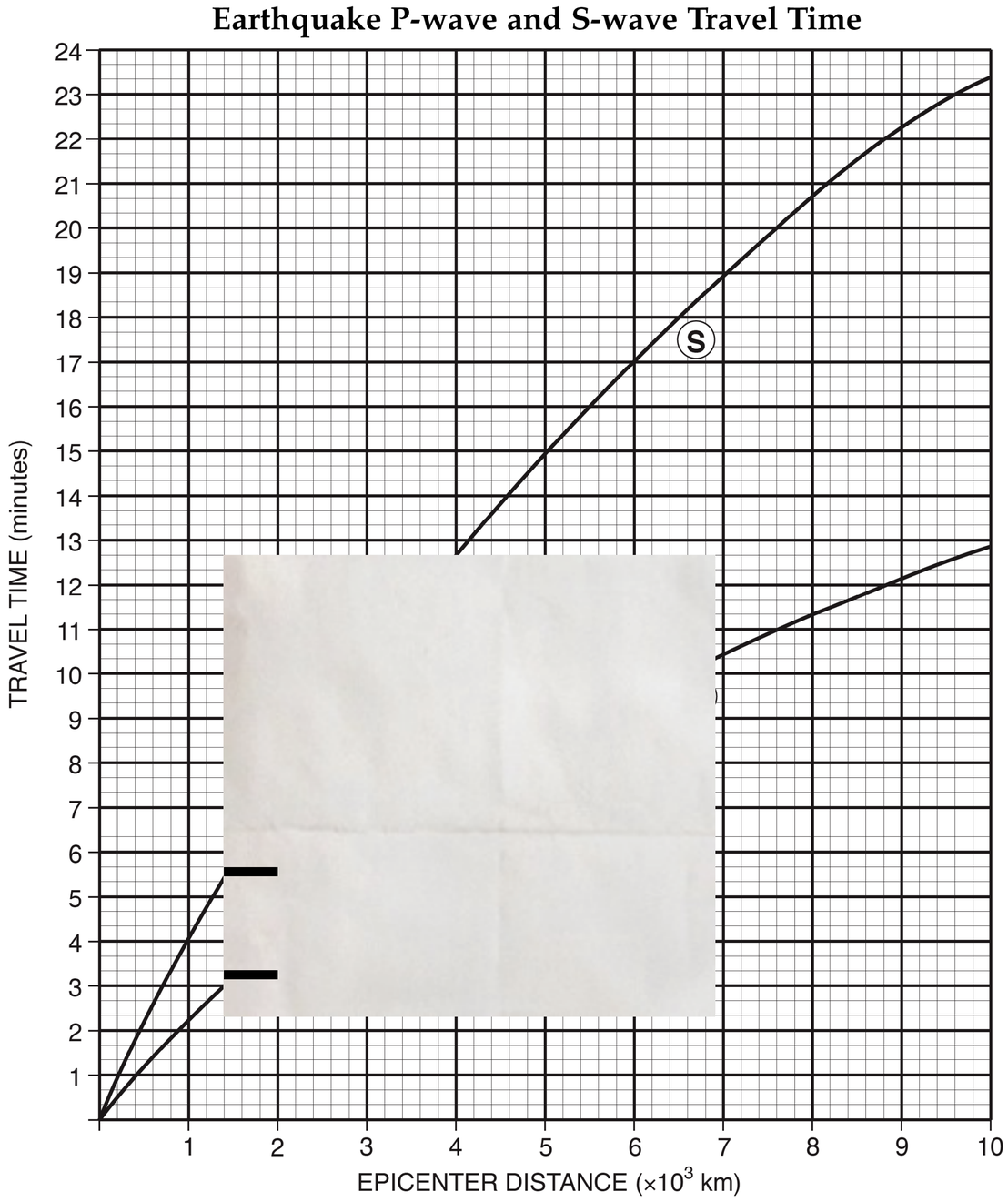


✓ S_{arr} = 10:10:00

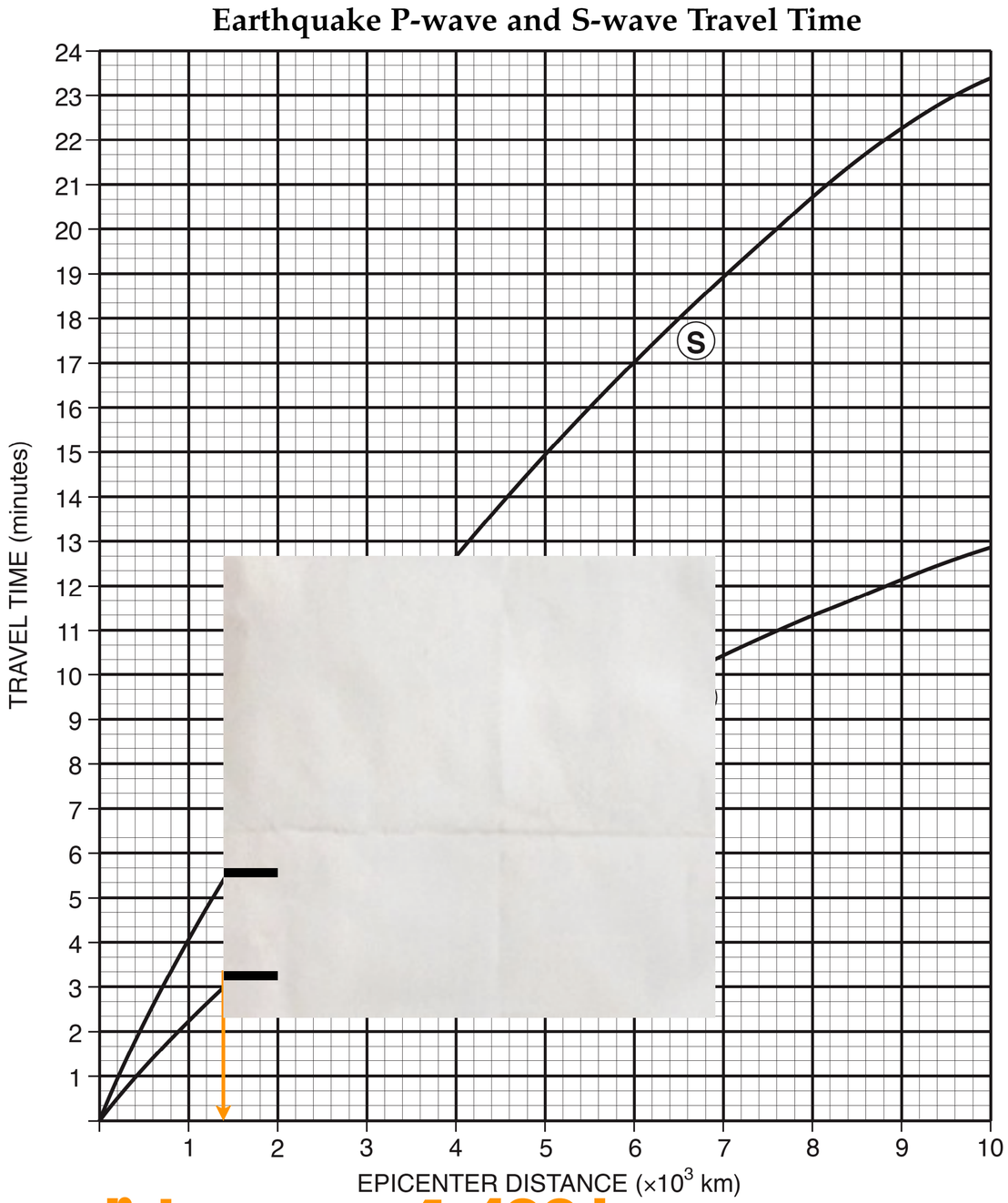
✓ P_{arr} = 10:07:40

✓ Lag time = 00:02:20

Epicenter distance?



✓ S_{arr} = 10:10:00
✓ P_{arr} = 10:07:40
✓ Lag time = 00:02:20
✓ Epicenter distance?



✓ S_{arr} = 10:10:00

✓ P_{arr} = 10:07:40

✓ Lag time = 00:02:20

✓ Epicenter distance?

Epicenter distance = 1,400 km