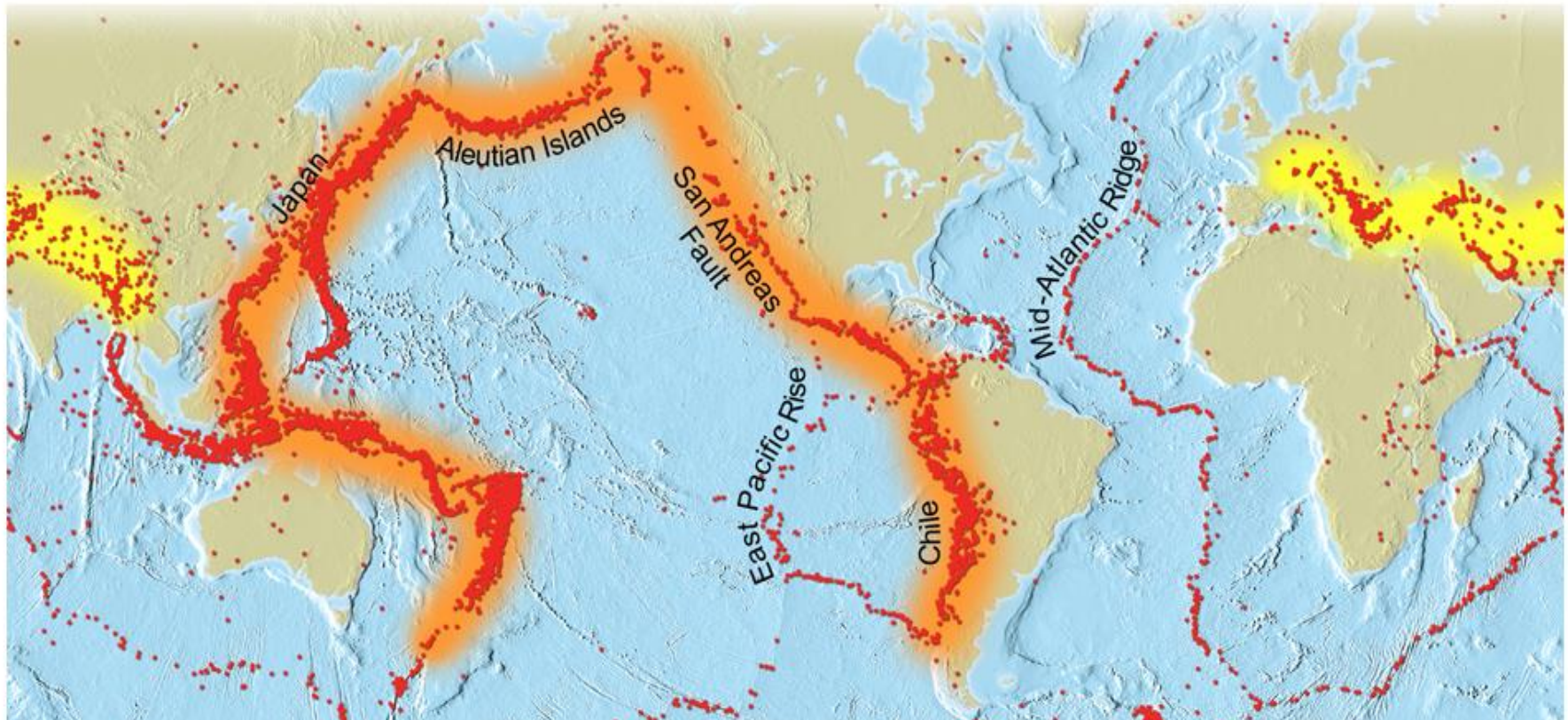


# Review: What is an earthquake?

- Earthquake is the **vibration (shaking) and/or displacement of the ground** produced by the sudden **release of energy**.
- The point inside the Earth where an earthquake begins (*point of initial rupture*) is called **focus**.
- The area on the surface of the Earth directly above the focus where the shaking is usually felt most strongly is called **epicenter**.
- **Energy** released from the earthquake source (its focus) propagates in the form of waves called **seismic waves**.

# Earthquakes around the world mostly happen near tectonic plate boundaries



**80% - Circum-Pacific Belt**, border of the Pacific Ocean.

**15% - Alpine-Himalayan Belt**, from southern Asia to the Mediterranean region.

**5%** - parts of the Arctic, Atlantic, and Indian Oceans.

**Antarctica** and **Australia** experience the least amount of earthquake activity then any other areas of the world.

Legend:  
Circum-Pacific belt (orange)  
Alpine-Himalayan belt (yellow)

Graph shows 15,000 larger magnitude (>5) earthquakes over 10-year period.

# How strong?

Two measurements that describe the “power” or “strength” of an earthquake are:

Mercalli  
scale

- **Intensity** – a measure of the **degree of shaking** at a given locale based on the amount of damage.

Richter  
scale

- **Magnitude** – estimates the **amount of energy** released at the source of the earthquake:
  - Magnitude is a *logarithmic* scale (not linear!)
  - Magnitude 2 or lower earthquakes cannot be felt by humans.
  - Magnitude 7 and over potentially cause serious damage over larger areas, depending on their depth.
  - The **largest earthquakes in historic times** have been of magnitude **slightly over 9**, although there is no limit to the possible magnitude.

# Modified Mercalli Scale vs. Richter Scale



Intensity category	Effects	Magnitude scale
I. Instrumental	Not felt	1-2
II. Just perceptible	Felt by only a few people, especially on upper floors of tall buildings	3
III. Slight	Felt by people lying down, seated on a hard surface, or in the upper stories of tall buildings	3.5
IV. Perceptible	Felt indoors by many, by few outside; dishes and windows rattle	4
V. Rather strong	Generally felt by everyone; sleeping people may be awakened	4.5
VI. Strong	Trees sway, chandeliers swing, bells ring, some damage from falling objects	5
VII. Very strong	General alarm; walls and plaster crack	5.5
VIII. Destructive	Felt in moving vehicles; chimneys collapse; poorly constructed buildings seriously damaged	6
IX. Ruinous	Some houses collapse; pipes break	6.5
X. Disastrous	Obvious ground cracks; railroad tracks bent; some landslides on steep hillsides	7
XI. Very disastrous	Few buildings survive; bridges damaged or destroyed; all services interrupted (electrical, water, sewage, railroad); severe landslides	7.5
XII. Catastrophic	Total destruction; objects thrown into the air; river courses and topography altered	8 +

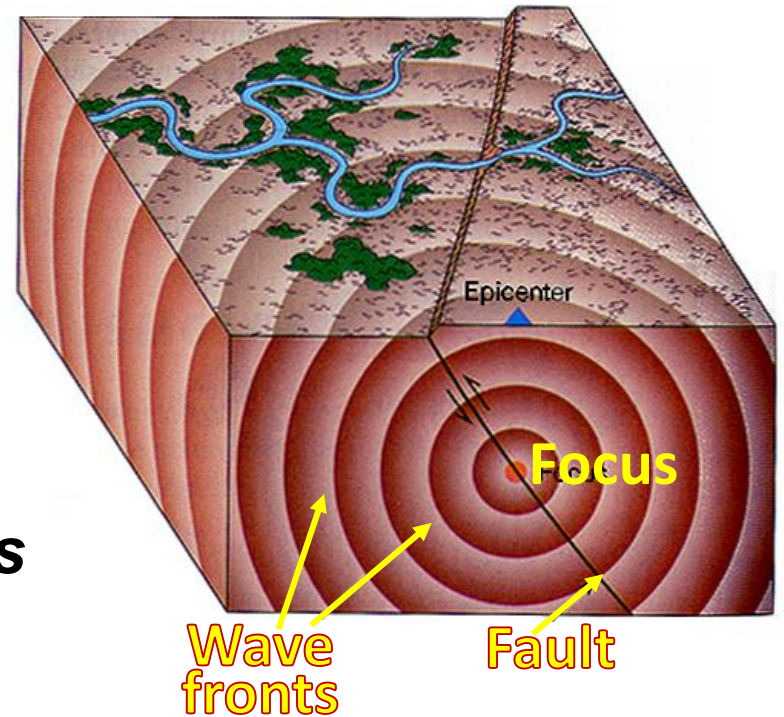
# How common are earthquakes?

- It is estimated that **around 500,000 earthquakes occur each year**, detectable with current instrumentation.
- About **100,000** of these **can be felt** (ground shaking during a moderate to large earthquake typically lasts about 10 to 30 seconds).
- **Minor earthquakes occur nearly constantly** around the world; **larger earthquakes occur less frequently**.
- While most earthquakes are caused by movement of the Earth's tectonic plates, the following human activities can also produce earthquakes:
  - storing large amounts of water behind a dam
  - drilling and injecting liquid into wells
  - coal mining and oil drilling/fracking



# Seismic Waves

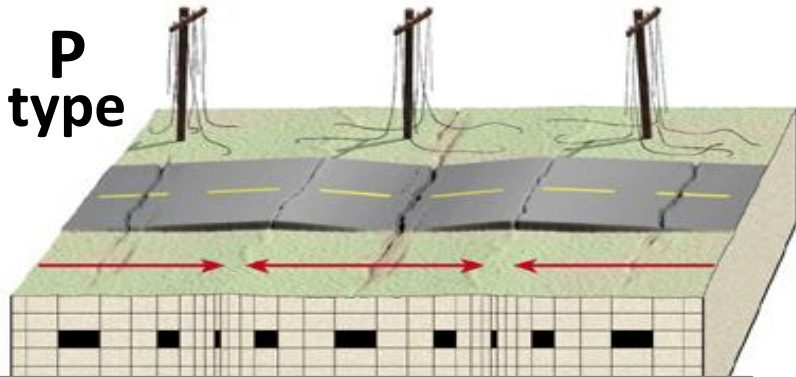
- Energy released from the earthquake source (its focus) radiates in all directions.
- Energy is in the form of waves called **seismic waves**:
  1. Body waves (*Primary waves and Secondary waves*) - travel fast through the Earth interior.
  2. Surface waves (*Love waves and Rayleigh waves*) - travel on the Earth surface; have lower frequency and travel more slowly than body waves - **more destructive**.



# Types of Seismic Waves

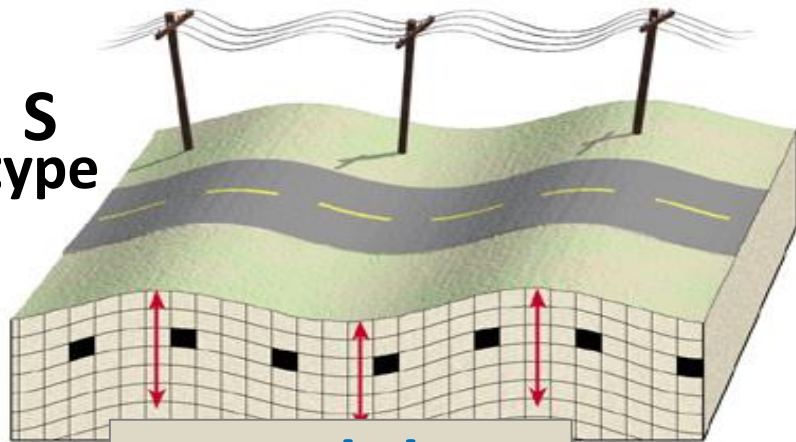
## BODY WAVES

**P**  
type



**Compression-expansion**

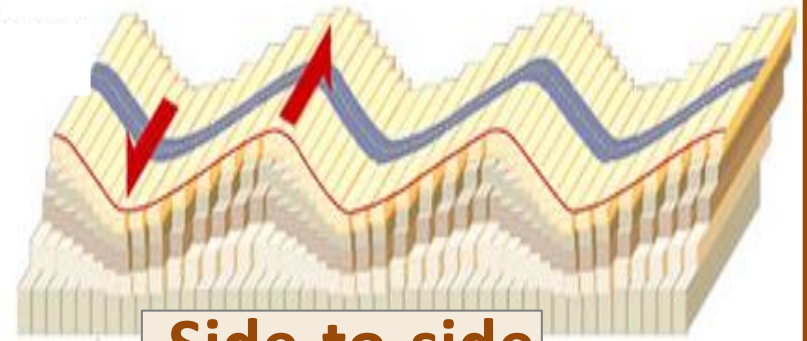
**S**  
type



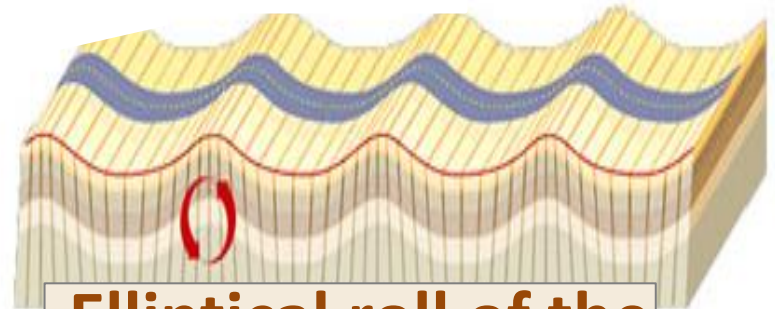
**Up-and-down**

## SURFACE WAVES

**L**  
type



**Side-to-side  
horizontal  
movement**



**Elliptical roll of the  
ground oriented  
vertically**

**R**  
type

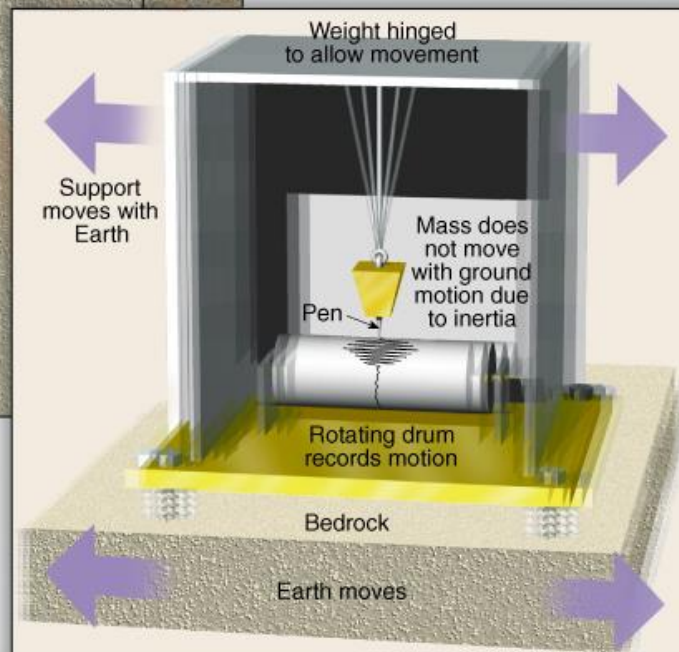
# Measuring an Earthquake

Earthquakes are measured using observations from **seismographs**, instruments that record seismic waves.

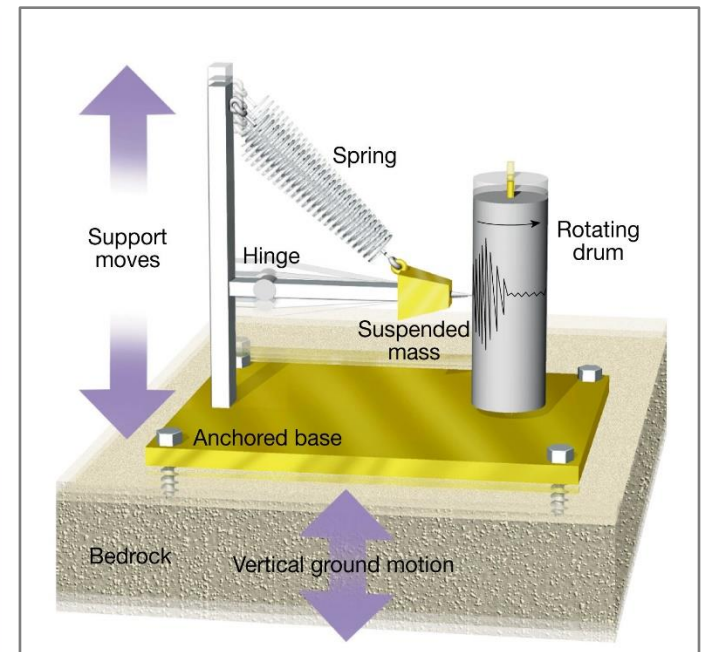


Different *seismograph* types are needed to record both vertical and horizontal ground motion:

## Horizontal



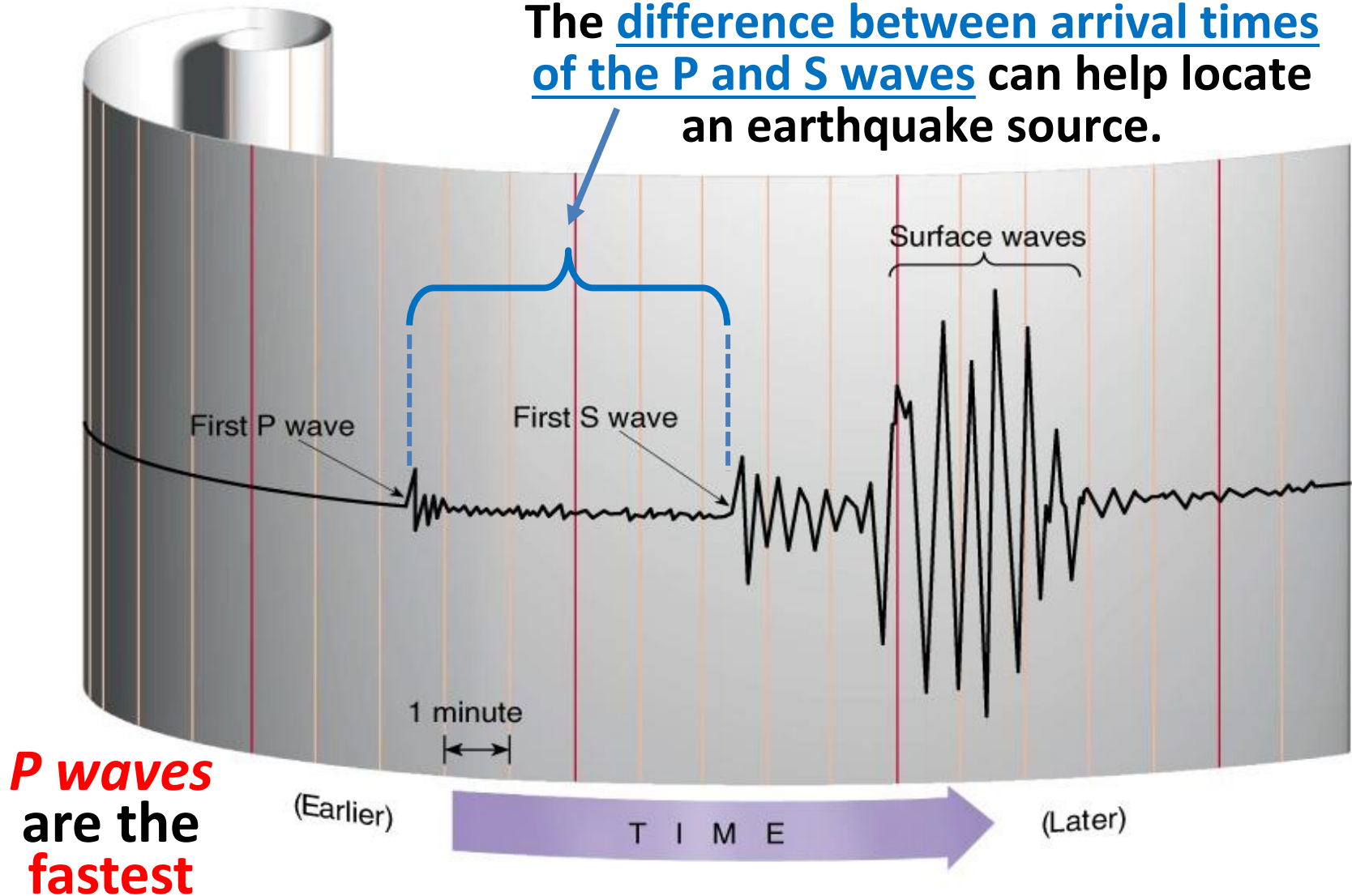
## Vertical





# Simplified Seismogram

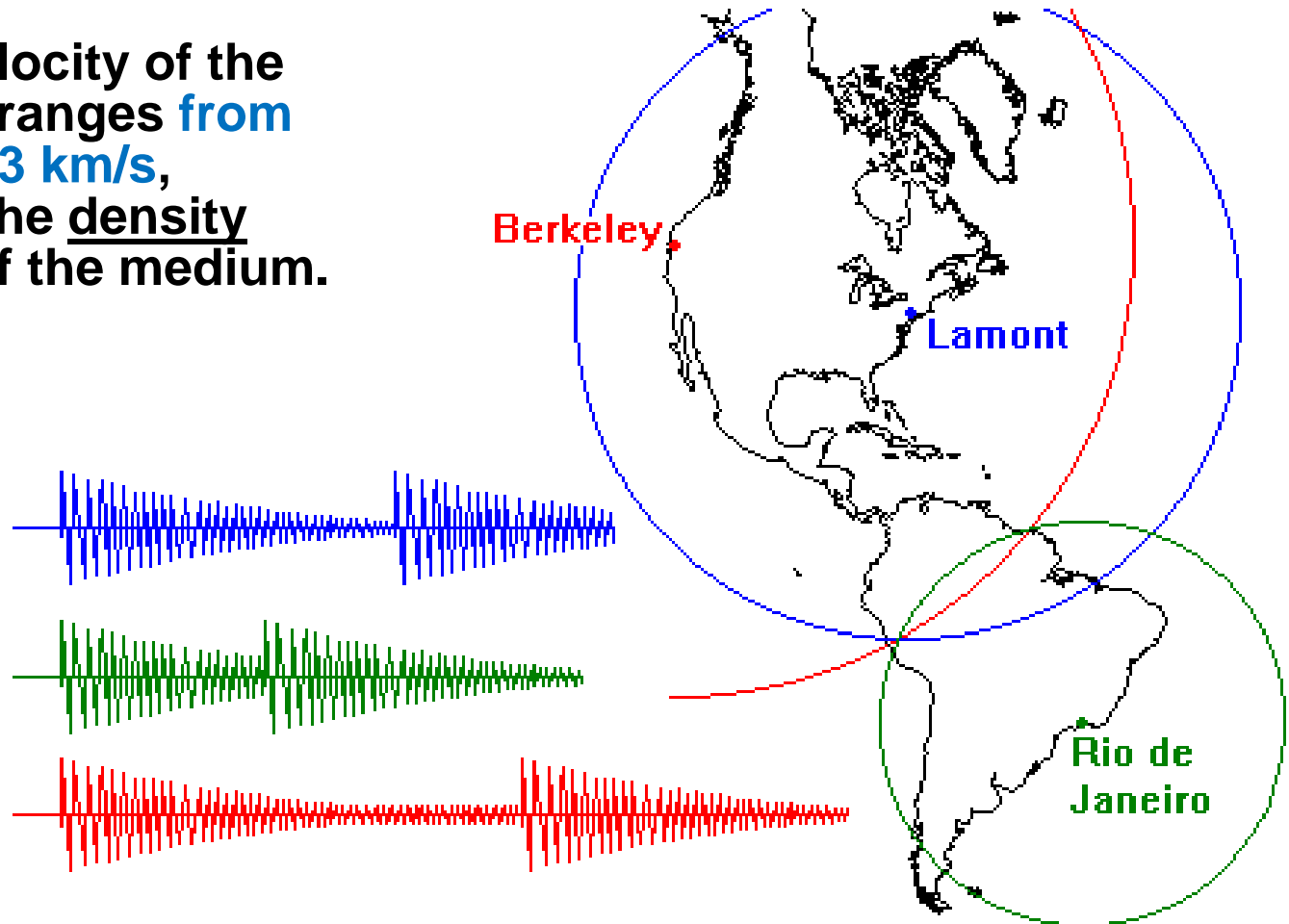
The difference between arrival times of the P and S waves can help locate an earthquake source.



# Locating Earthquakes

The further away an earthquake is from the point of detection, the greater the time between the arrival of the P waves and the S waves.

- Propagation velocity of the seismic waves ranges from **~3 km/s up to 13 km/s**, depending on the density and elasticity of the medium.
- Data from several different (*at least three*) seismic stations is combined to determine the earthquake epicenter location.



# Detecting an Earthquake

Chinese created the first earthquake detector  
over 2000 years ago!

It was designed to indicate  
the *direction* of the tremor.

