Locating the Epicenter of an Earthquake

The Triangulation Method

Earthquake

In an earthquake, stored energy is suddenly released through a movement along a fault.

A fault is a fracture or zone of fractures in rock along which the two sides have been displaced relative to each other parallel to the fracture

Earthquake

Most earthquakes can be explained by plate tectonics and the elastic rebound theory. The theory was proposed by H.F. Reid of Johns Hopkins University in 1906. It says that the constant motion of rocks along one side of a fault boundary causes the rocks on the opposite side to bend.

Earthquake: Seismic Waves

Seismic waves emanating from the focus can travel as body waves or surface waves.

Body waves travel in all directions from the focus through the body of the Earth

Surface waves are different from body waves because they don't travel through the Earth; instead they are constrained to travel along the surface of the Earth from the epicenter.

What is an Epicenter?

- A point on the surface of the Earth directly above the FOCUS of the earthquake.

•The point within the Earth from which earthquake waves originate.

Epicenter

Properties of Seismic Waves

There are two types of **body waves**; the compressional or *P waves* and the shear or *S waves*.

P waves (or primary waves) travel with a velocity that depends on the elastic properties of the rock that they travel through.?

S waves (or secondary waves) are shear waves.

Locating the Epicenter

In order to determine the location of an earthquake, the earthquake needs to be recorded on three different seismographs that are at significantly different locations.

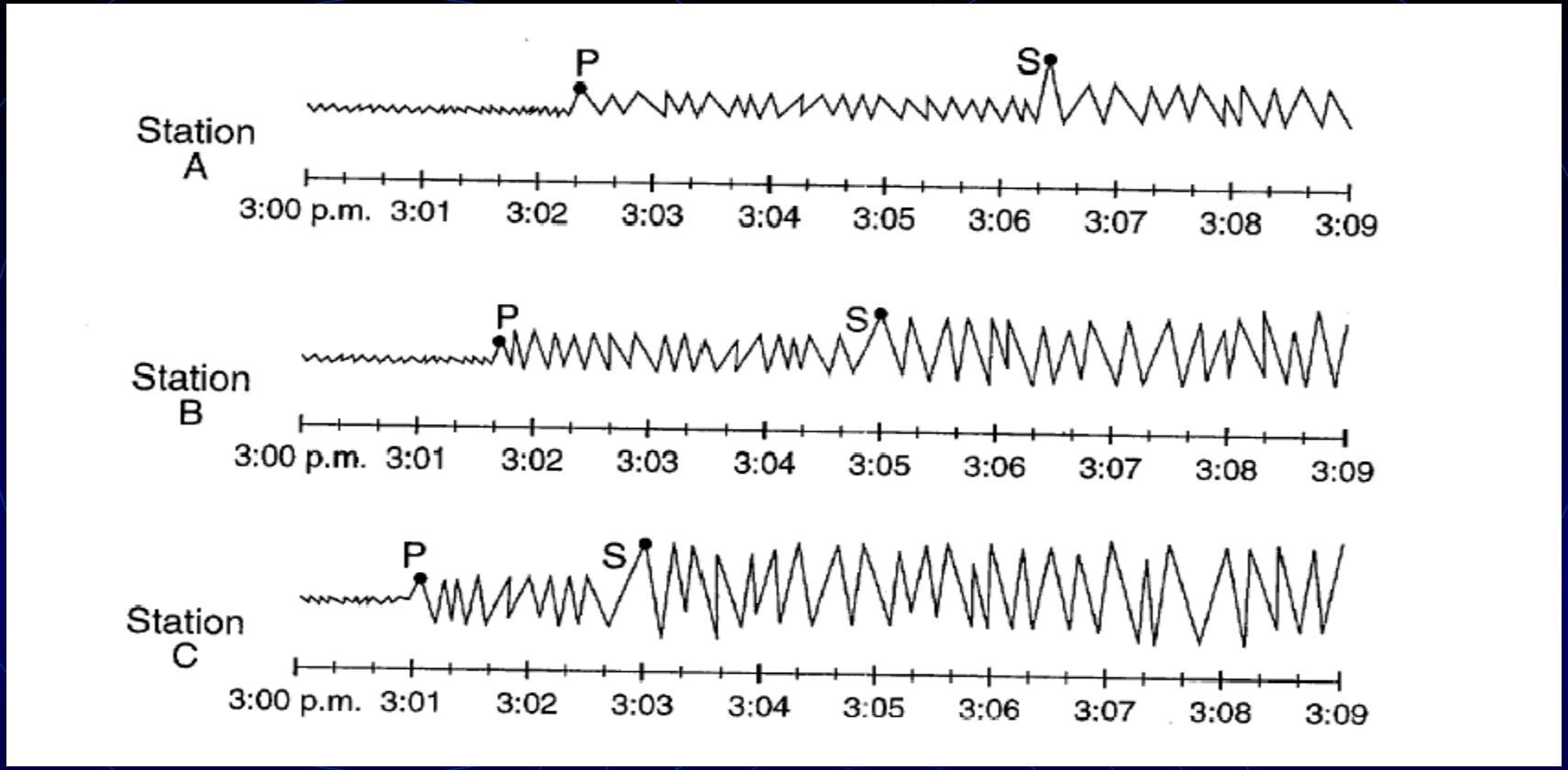
The other piece of information needed is the time it takes for P-waves and S-waves to travel through the Earth and arrive at a seismographic station.

The Triangulation Method

Triangulation

A mathematical method for locating the epicenter of an earthquake using three or more data sets from seismic stations.

This data is collected using earthquake monitoring instruments called *seismographs* which record the seismic waves of the earthquake.



A seismograph records earthquake activity by plotting vibrations on a sheet of paper to create a ***seismogram***. Above are some sample seismograms:

Triangulation

If three arrival times are available at three different seismic stations then triangulation can be used to find the location of the focus or epicenter and the time of occurrence of the earthquake.

The distance between the beginning of the first P wave and the first S wave tells you how many seconds the waves are apart.

Triangulation

P waves move about 5.5 kilometers per second (k/s) through granite, whereas the slower S waves move only about 3 k/s through granite.

Imagine that at station A a P wave is detected and the S wave follows 42.8 seconds later. Since the S wave is 2.5 k/s slower than the P wave, difference in speed multiplied by the time difference will give the distance to the source. Thus, the earthquake epicenter is 107 km away from station A (42.8 s times 2.5 k/s= 107 km). Although we can determine the distance, we still don't know the direction, which is why we need data from the other stations.

Triangulation

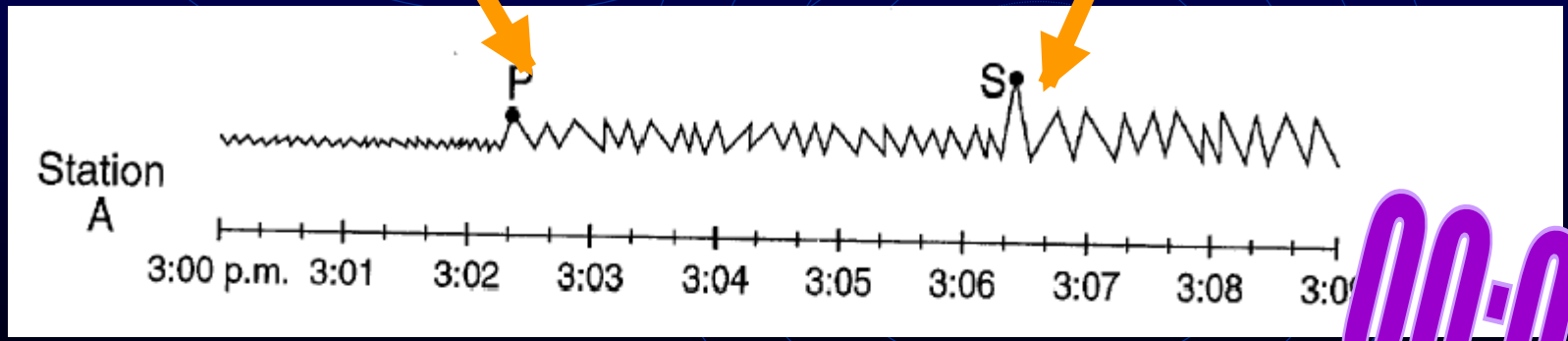
Since the P (or "primary") waves travel faster than the S (or "secondary") waves, P waves will arrive at a given seismograph station sooner than S waves. In other words, the S waves *lag* behind the P waves. In fact, the time difference between when the P waves arrive at a seismograph station and when the S waves arrive at the same station is called ***Lag Time***. Knowing the time lag for a number of seismograph stations is essential in pinpointing the location of the epicenter of an earthquake.

Collecting data from the recording stations:

- Station A: San Francisco, California

P-Wave arrival 0**3:02:20**S-Wave arrival 0**3:06:30**

What is the time difference between P and S wave arrivals?



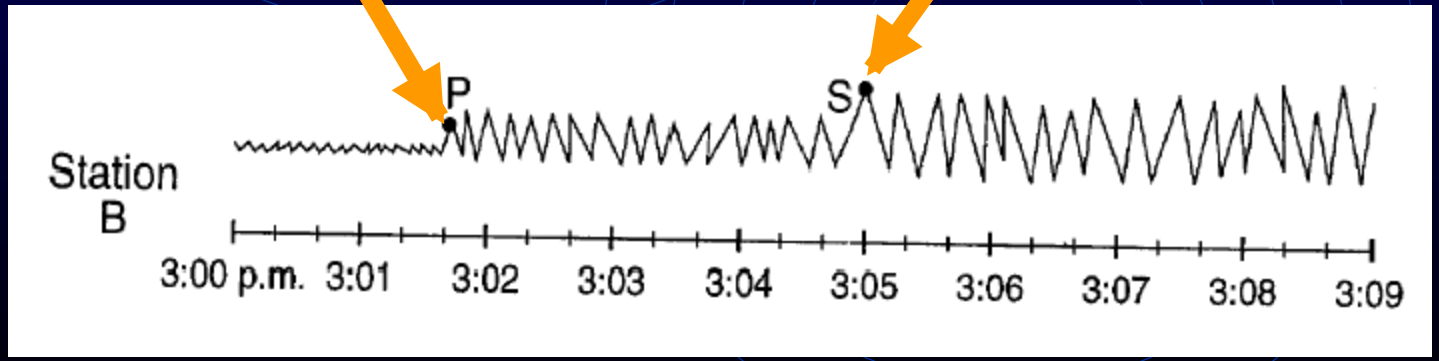
00:04:10

Collecting data from the recording stations:

- Station B: Denver, Colorado

P-Wave arrival 0**3:01:40**S-Wave arrival 0**3:05:00**

What is the time difference between P and S wave arrivals?



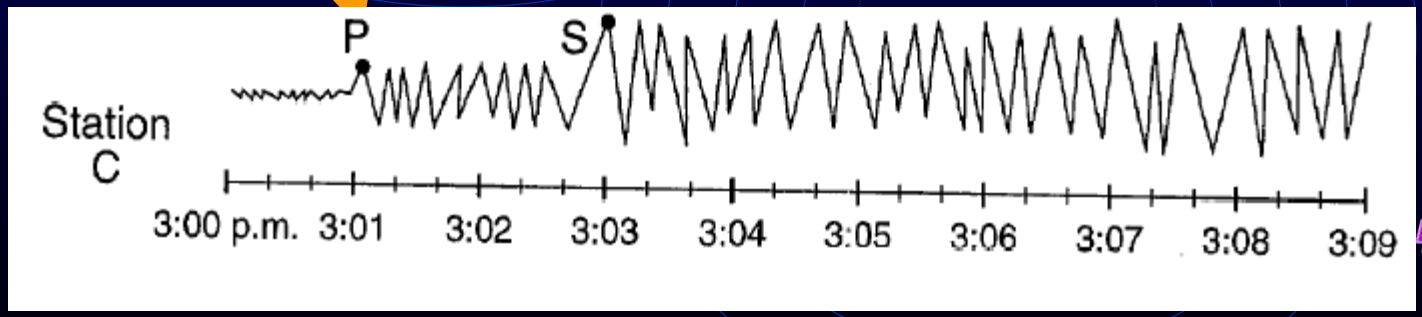
Collecting data from the recording stations:

- Station C: Missoula, Montana

P- Wave arrival 0**3:01:00**

S wave arrival 03:03**:00**

What is the time difference between P and S wave arrivals?



02:00

Difference in arrival times:

San Francisco: 4:10 minutes/sec

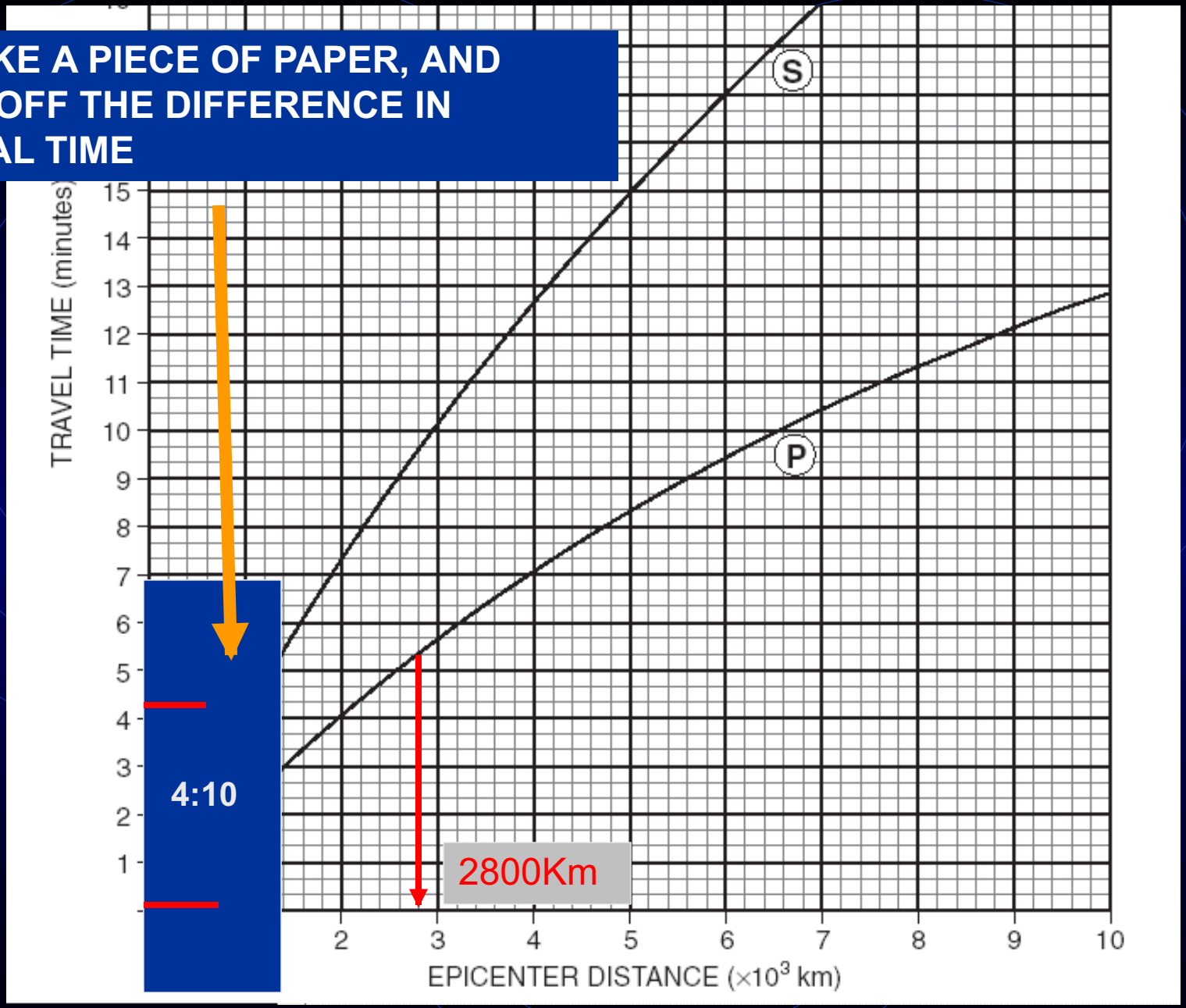
Denver, Colorado: 3:20 minutes/sec

Missoula, Montana: 2:00 minutes/sec

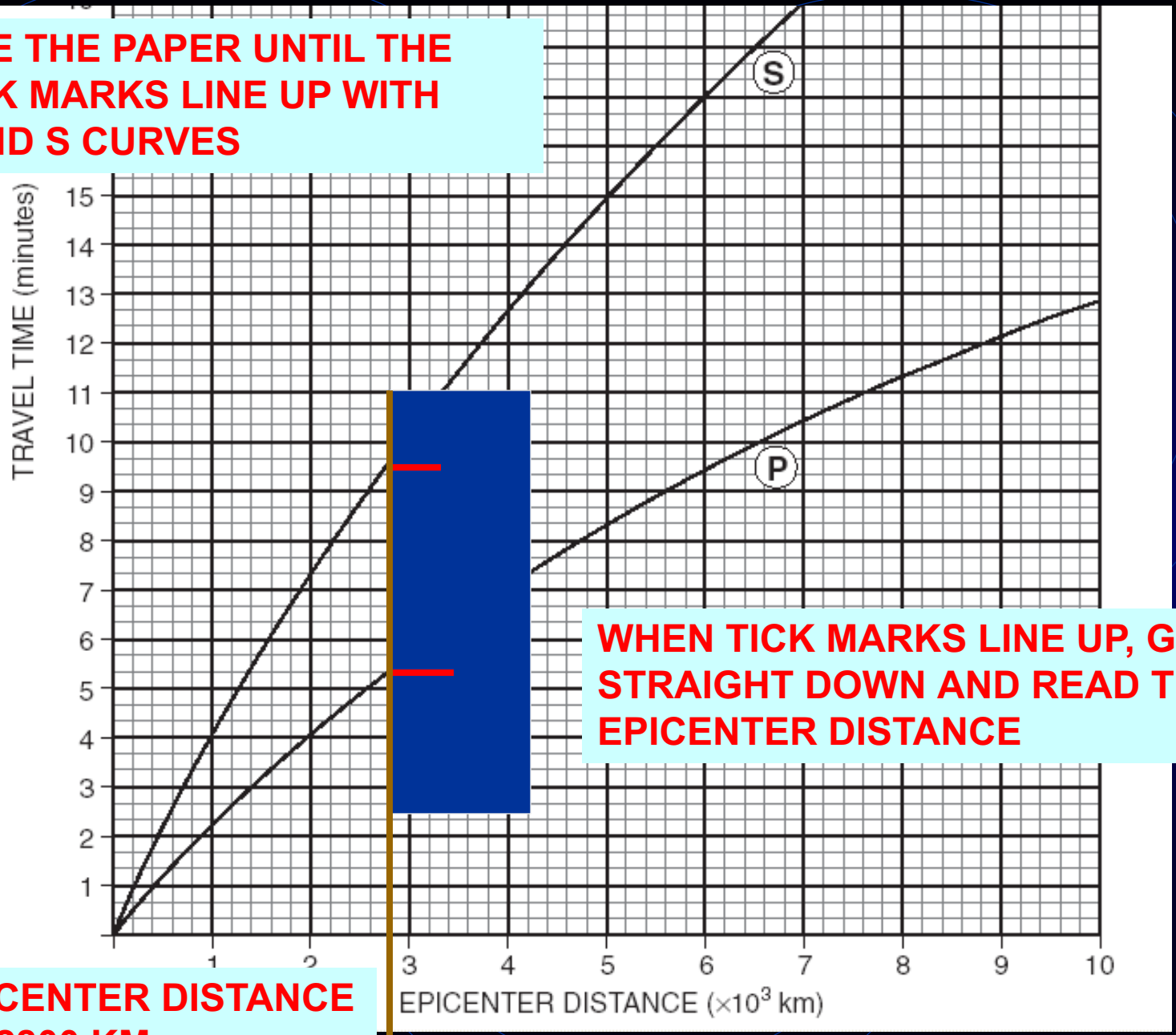
Locating the Epicenter

Finally we plot the P and S wave travel-time curves to find the distance from each station to the earthquake epicenter. We do this by finding the unique epicenter distance where the difference in the P and S wave travel times is exactly equal to the difference you calculated from the seismogram. (we use a time/distance curve plot)

WE TAKE A PIECE OF PAPER, AND MARK OFF THE DIFFERENCE IN ARRIVAL TIME



WE MOVE THE PAPER UNTIL THE TWO TICK MARKS LINE UP WITH THE P AND S CURVES



WHEN TICK MARKS LINE UP, GO STRAIGHT DOWN AND READ THE EPICENTER DISTANCE

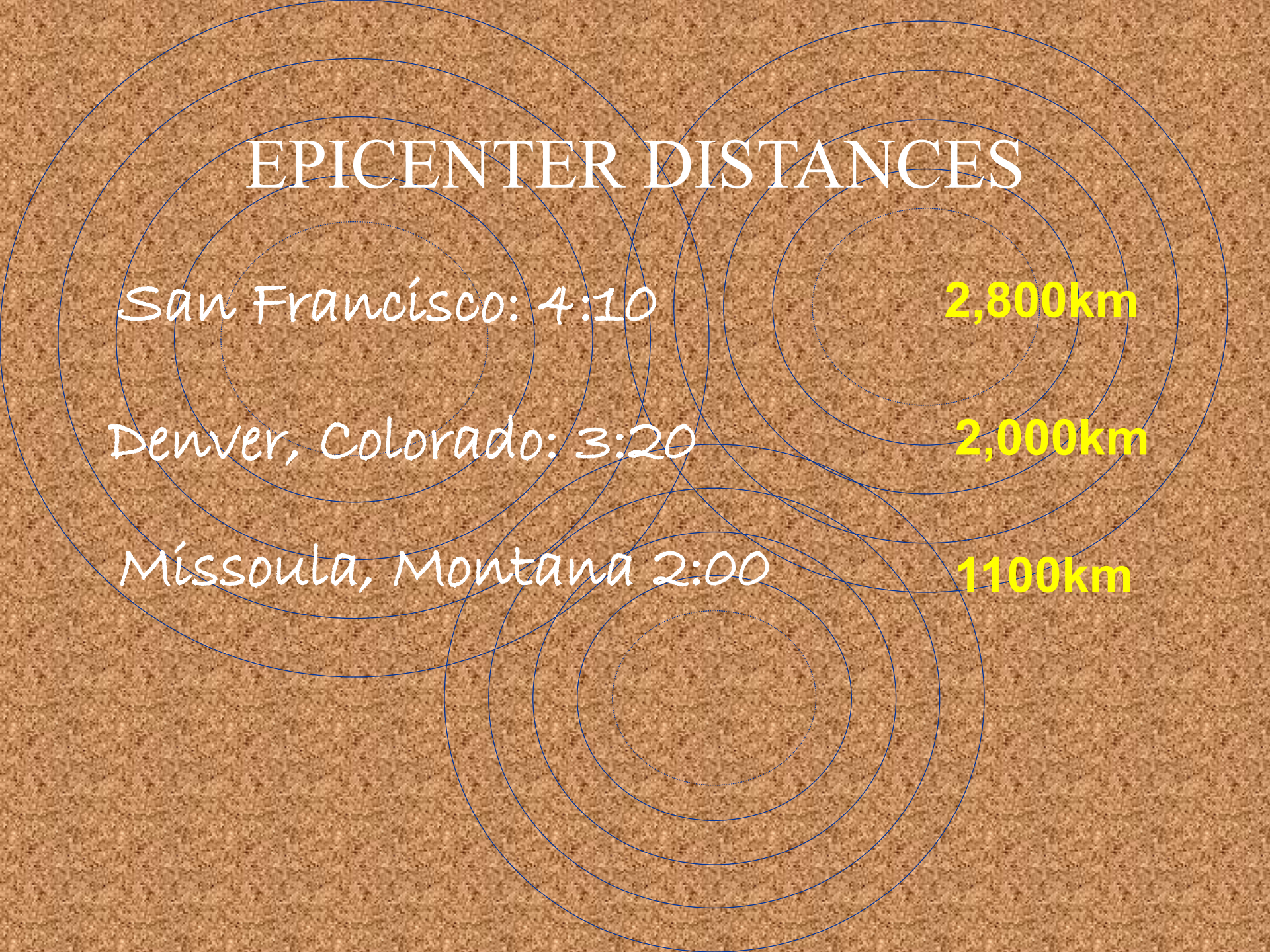
EPICENTER DISTANCE OF 2800 KM

EPICENTER DISTANCES

San Francisco: 4:10 — 2,800km

Denver, Colorado: 3:20 — 2,000km

Missoula, Montana 2:00 — 1100km



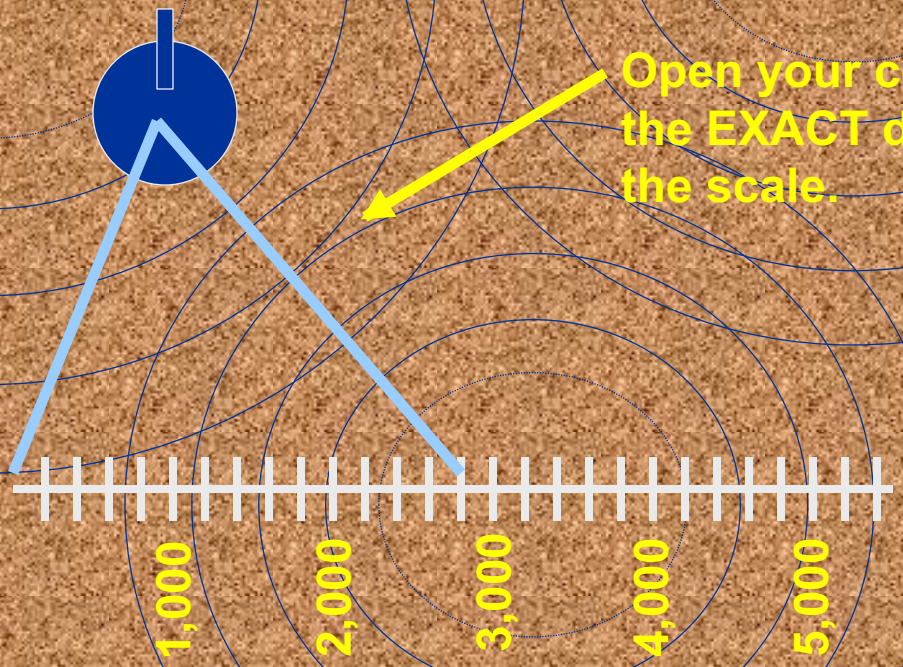
Epicenter Distances

Using the map scale, and a drafting compass we set it to the appropriate length for the distance from the first location to the epicenter. Place the compass point at this location and draw an arc using the distance as the radius. Repeat for the other two locations. The intersection of the three arcs identifies the epicenter of the earthquake.

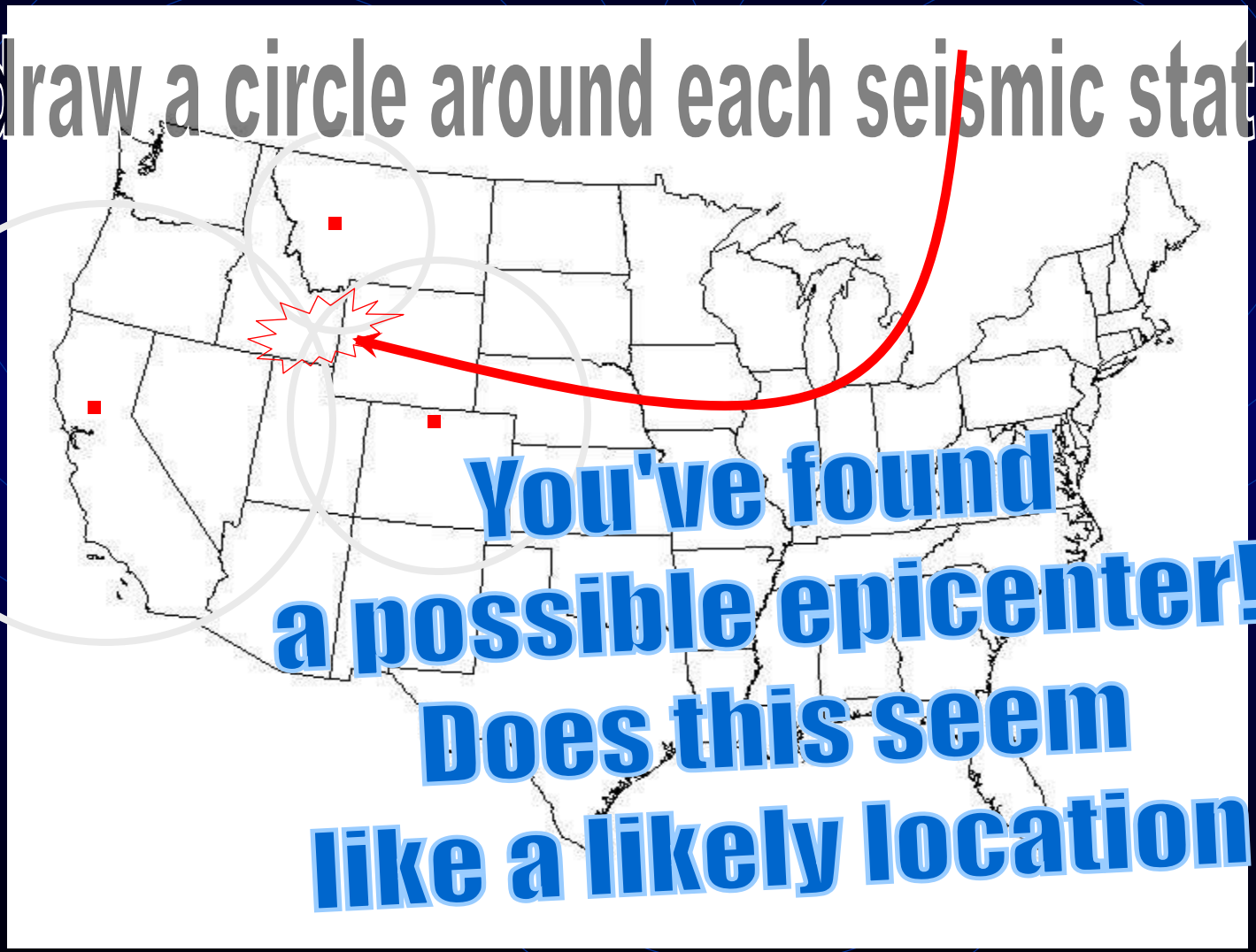
Recording Board
Difference in arrival times:

San Francisco: 41:0

2,800km



Use your carefully set compass to draw a circle around each seismic station.



5 steps to triangulation

- 1. Calculate the P and S arrival time.
- 2. Calculate lag time(difference between P and S arrival time)
- 3. Using the lag time ;mark on a scratch sheet the zero and lag time, then apply the wedge method to find epicenter distance in kilometers.
- 4. While wedge is still in place , trace over to find the P travel time, and S travel time.
- 5. Calculate the origin time of the earthquake by substracting the P travel time from P arrival time.
- ** Now you are ready to use the epicenter distance, compass, and map scale to locate the epicenter .