Earthquake Laboratory* Name_____
Reading Seismograms

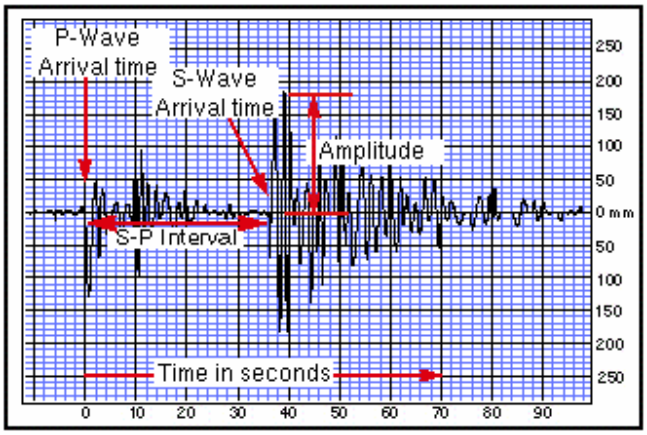
What are earthquake (seismic) waves?
A seismic wave is simply a means of transferring energy from one spot to another within the earth. Although seismologists recognize different types of waves, we are interested in only two types: P (primary) waves, which are similar to sound waves, and S (secondary) waves, which are a kind of shear wave. Within the earth, P waves can travel through solids and liquids, whereas S waves can only travel through solids.

The speed of an earthquake wave is not constant but varies with many factors. Speed changes mostly with depth and rock type. P waves travel between 6 and 13 km/sec. S waves are slower and travel between 3.5 and 7.5 km/sec.

What's a Seismogram?
A highly simplified simulated recording of earthquake waves (a seismogram) can be seen to the left. Study this sample seismogram and be sure you can identify these parts:

- P-waves and the P-wave arrival time
- S-waves and the S-wave arrival time
- S-P interval (expressed in seconds)

S-wave maximum amplitude (measured in mm)



Note: This seismogram is a simulation. The actual records of earthquake waves are far more complicated than what is presented here. As P and S waves travel through the earth, they are reflected by various layers of the earth (such as the core- mantle boundary). This interaction produces additional seismic waves (phases) which will be detected by seismographs.

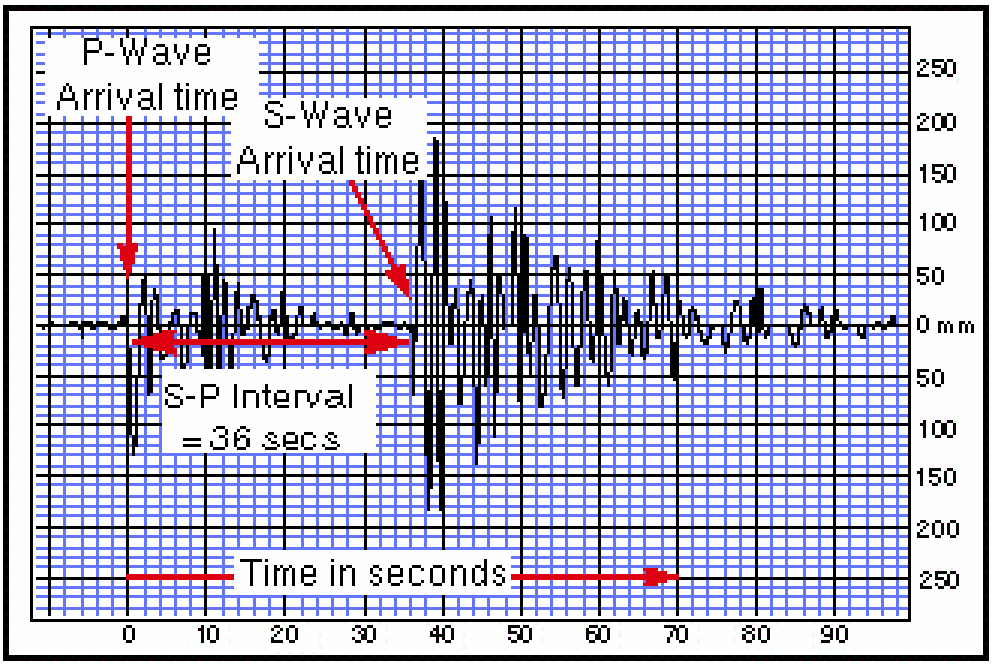
***Adapted from: http://www.sciencecourseware.org**

How is an Earthquake's Epicenter Located?
In order to locate the epicenter of an earthquake you will need to examine its seismograms as recorded by three different seismic stations. On each of these seismograms you will have to measure the S - P time interval (in seconds). (In the figure above, the S - P interval is about 45 seconds. The vertical lines are placed at 2 second intervals.) The S - P time interval will then be used to determine the distance the waves have traveled from the origin to that station.

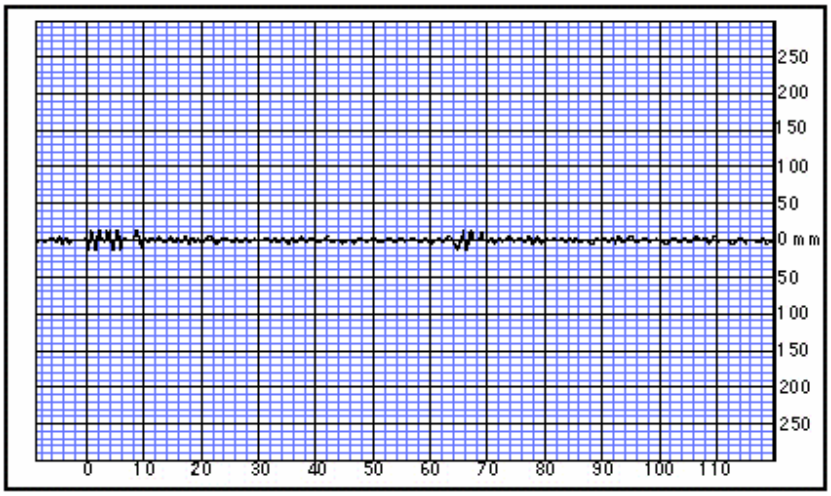
The actual location of the earthquake's epicenter will be on the perimeter of a circle drawn around the recording station. The radius of this circle is the epicentral distance. One S - P measurement will produce one epicentral distance: the direction from which the waves came is unknown. Three stations are needed in order to "triangulate" the location.

Measuring the S-P interval

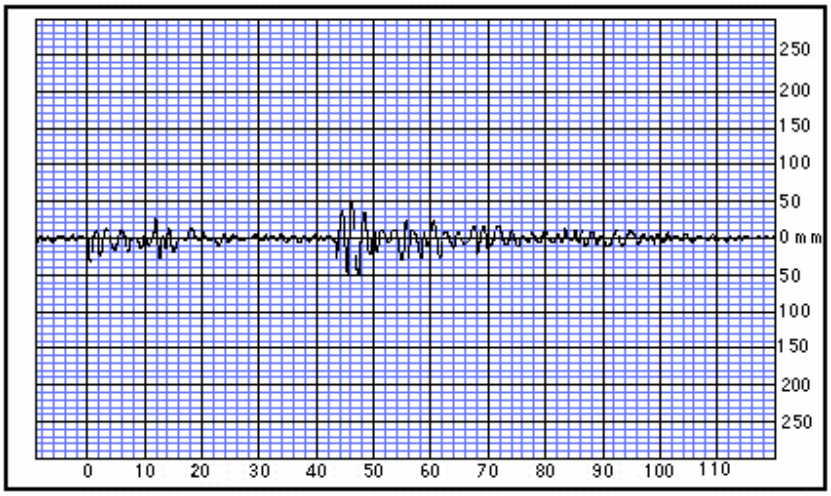
There are hundreds of seismic data recording stations throughout the United States and the rest of the world. In order to locate the epicenter of this earthquake, you need to estimate the time interval between the arrival of the P and S waves (the S-P interval) on the seismograms from three different stations. You have to measure the interval to the closest second and then use a graph to convert the S-P interval to the epicentral distance. On the sample seismogram at the right the vertical lines are spaced at 2 second intervals and the S-P time interval is about 36 seconds.



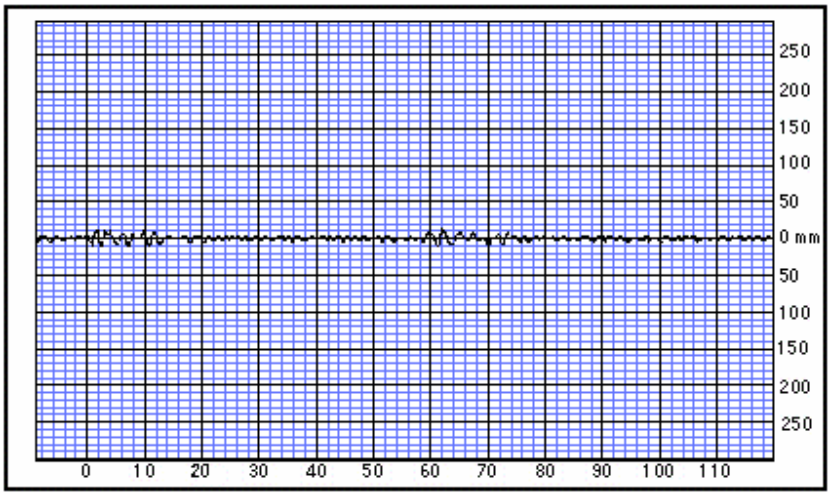
This Earthquake's Seismograms are Below: Use these three seismograms to estimate the S-P time interval for each of the recording stations. Record your measurement for the S-P interval in the box below each seismogram.



Chichuahua Seismic Station S-P Interval = _____ seconds



Mazatlan Seismic Station S-P Interval = _____ seconds



Rosarito Seismic Station S-P Interval = _____ seconds

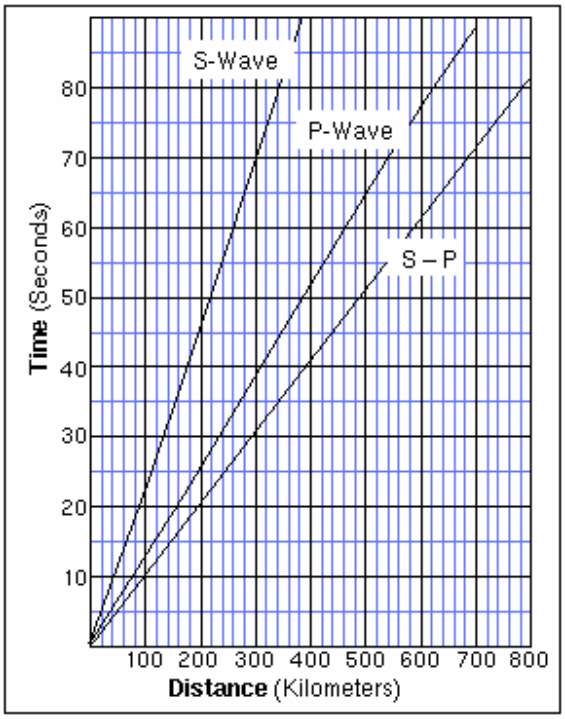
Determining the Earthquake Distance

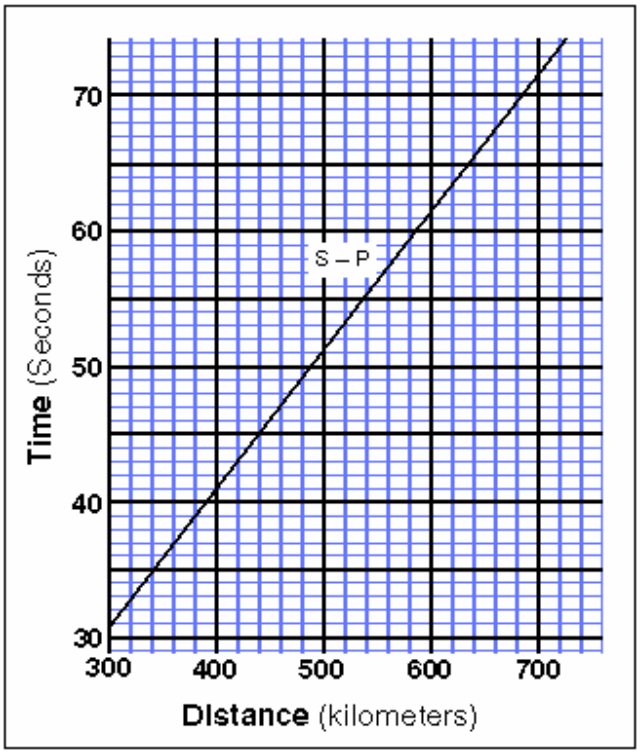
You can now determine the distance from each seismic recording station to the earthquake's epicenter using the known times of travel of the S and P waves.

Examine the graph on the left, a graph of seismic wave travel times. There are three curves on the graph: The upper curve shows S wave travel-time graphed versus distance, the center one shows P wave travel time versus distance, and the lower one shows the variation in distance with the difference of the S and P travel times. It takes an S wave approximately 70 seconds to travel 300 kilometers.

For practice, how long does it take the P wave to travel this same distance?

For the rest of this exercise you won't need the individual S and P curves, only the S-P curve. To determine the epicentral distance, we need greater resolution on graph. We will an expanded part of the S-P curve.



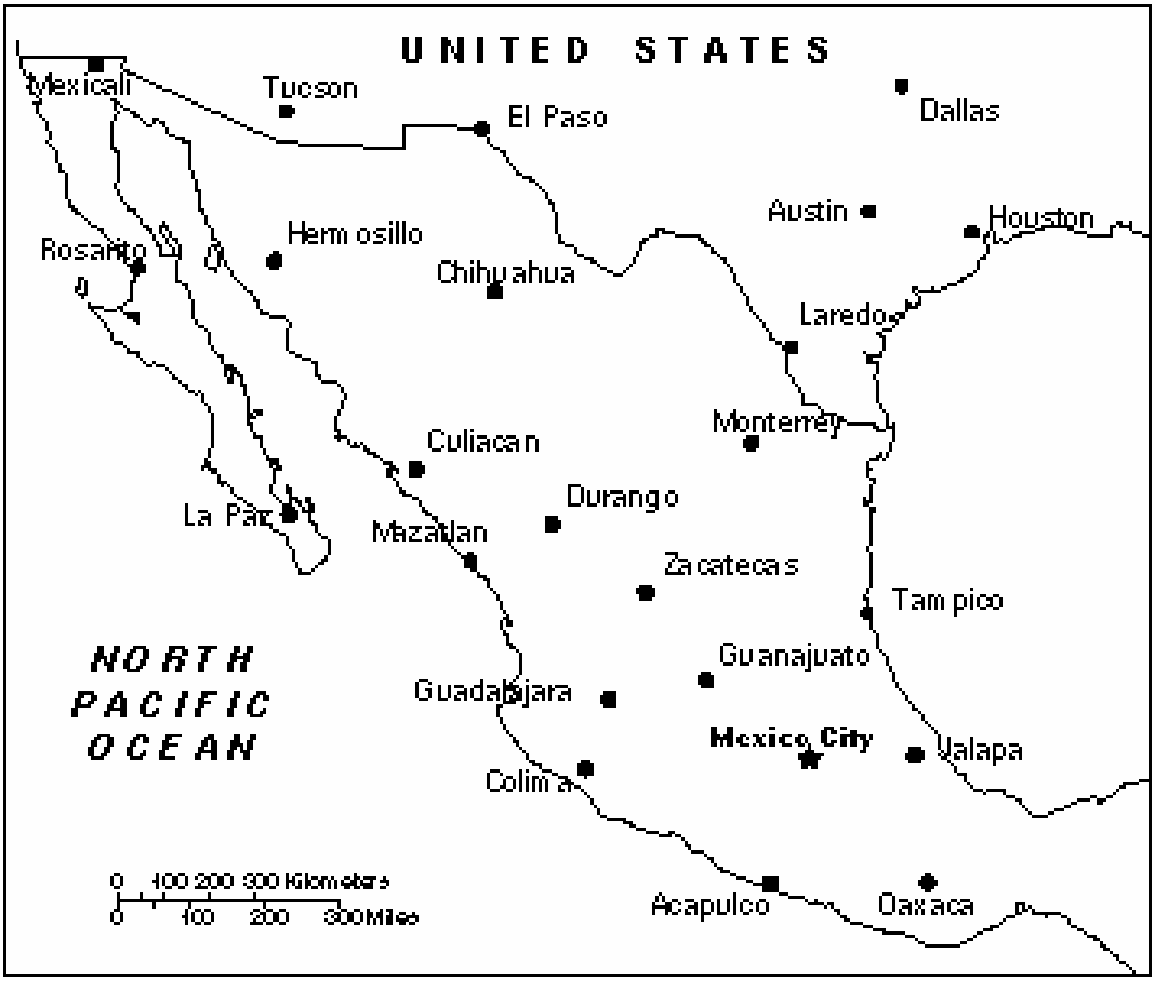


Determining Distance from S-P

Use the S-P graph and the estimates you made for the S-P time intervals for the three seismograms to complete the table below.

Station	S-P Interval (seconds)	Epicentral Distance (km)
Chichuahua		
Mazatlan		
Rosarito		

Draw three circles on the map with the radius equal to the epicentral distance.



Richter Magnitude

Magnitude Explained

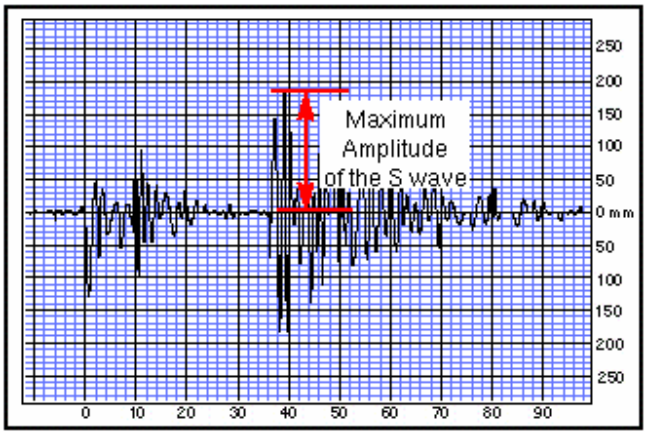
So far you have worked on locating the epicenter of an earthquake. The next questions to ask are "How strong was this particular earthquake and how does it compare to other earthquakes?"

There are many ways that one could evaluate the relative strength of an earthquake: from the cost of repairs resulting from damage, from the length of rupture of the earthquake fault, from the amount of ground shaking, etc. But determining the strength of an earthquake using these kinds of "estimators" is full of potential problems and subjectivity. For example, the cost of repairs resulting from a strong earthquake in a remote region would be much less than that of a moderate earthquake in a populated area. Furthermore, the degree of damage would depend greatly on the quality of construction. Also, only a few earthquakes produce actual ground ruptures at the surface.

A well-known scale used to compare the strengths of earthquakes involves using the records (the seismograms) of an earthquake's shock waves. The scale, known as the **Richter Magnitude Scale**, was introduced into the science of seismology in 1935 by Dr. C. F. Richter of the California Institute of Technology in Pasadena. The **magnitude** of an earthquake is an estimate of the total amount of energy released during fault rupture. The Richter magnitude of an earthquake is a number: about 3 for earthquakes that are strong enough for people to feel and about 8 for the Earth's strongest earthquakes. Although the Richter scale has no upper nor lower limits, earthquakes greater than 9 in Richter magnitude are unlikely. The most sensitive seismographs can record nearby earthquakes with magnitude of about -2 which is the equivalent of stamping your foot on the floor.

The Richter magnitude determination is based on measurements made on seisograms. Two measurements are needed: the **S-P time interval and the Maximum Amplitude of the Seismic waves**. You already know how to measure the S-P interval.

The following illustration shows how to make the measurement of the S wave's maximum amplitude. The blue horizontal grid lines are spaced at 10 millimeter intervals. In this example the maximum amplitude is about 185 mm.

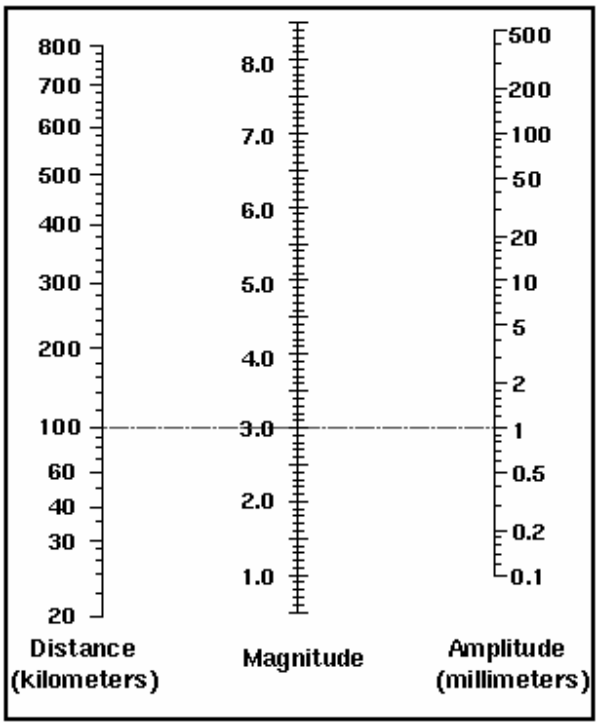


The Richter Nomogram

Although the relationship between Richter magnitude and the measured amplitude and S-P interval is complex, a graphical device (a nomogram) can be used to simplify the process and to estimate magnitude from distance and amplitude.

In the diagram below the dotted line represents the "standard" Richter earthquake. This standard earthquake is 100 km away and produces 1 mm of amplitude on the seismogram. It is assigned a magnitude of 3. Other earthquakes can then be referenced to this standard.

Note that a 100 km-away earthquake of magnitude 4 would produce 10 mm of amplitude and a magnitude 5 would produce 100 mm of amplitude: 1, 10 and 100 are all powers of 10 and this is why the Richter Scale is said to be "exponential." A change of one unit in magnitude (say from 4 to 5) increases the maximum amplitude by a factor of 10.



Return to the seismograms of the earthquake and determine the maximum S Wave Amplitude for each seismogram. Then draw three lines on the nomogram from the distance in kilometers to the amplitude. Estimate the magnitude of this earthquake: _____