

## Lab 08 - Seismology - Locating the Epicenter of an Earthquake

Every year earthquakes take a tremendous toll on human life and property throughout the world. Fires from broken gas lines, flooding by large tsunamis (tidal waves caused by seaquakes), and the collapsing of buildings and other artificial structures are just a few of the devastating results of a major earthquake event. Most of the damage caused by an earthquake occurs at its geographic origin, or epicenter. It is, therefore, imperative that the epicenter of an earthquake be rapidly located, so that emergency relief personnel can be rushed to the area as quickly as possible. In this exercise we will learn more about how earthquakes are formed and how they may be rapidly located through the science of seismology.

An earthquake has its origin below the earth's surface when rocks that have been placed under extreme pressure are suddenly released from the pressure and move rapidly. The position below the earth's surface where this rapid movement takes place is called the focus. Energy released at the focus propagates through the ground as seismic waves. Much of this energy is concentrated at the geographic point that lies directly above the focus. This point is called the epicenter of the earthquake, and is nearly always the point where most of the earthquakes' devastation is concentrated.

There are two major classes of seismic waves. Body waves move through the interior of the earth and are capable of penetrating the entire earth. Surface waves move up to the epicenter of the earthquake and spread out along the surface. It is the surface waves that provide the energy causes earthquake devastation. Each of these two major classes of seismic waves occur in two forms. The two types of body waves are called P-waves and the S-waves. The two types of surface waves are called Love waves and Rayleigh waves. Each of these 4 types of seismic waves are distinct in the wave the move (also known as propagate) through the ground.

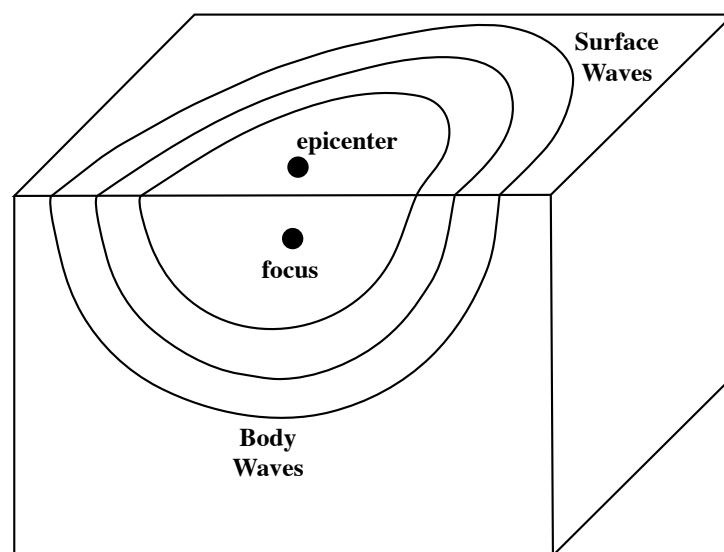
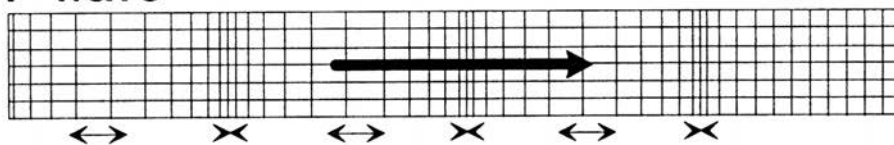
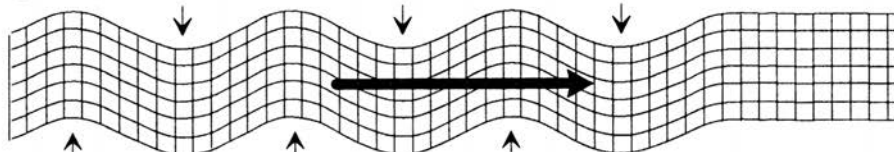


Figure 1.

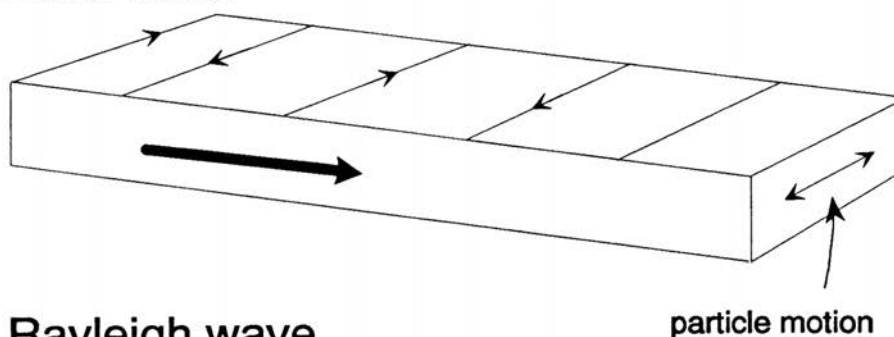
### P-wave



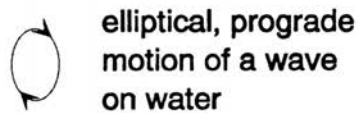
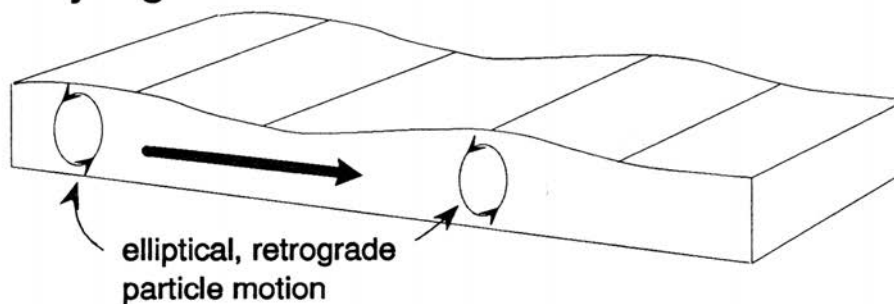
### S-wave




### Love wave



### Rayleigh wave



  
wave propagation direction

  
particle motion directions

Particle motions for different kinds of seismic waves.

Seismologists, scientists who study seismic waves, use devices called seismographs to record earthquake activity. The next figure shows a typical seismogram (recording) taken from a seismograph (the recorder) during an earthquake event.

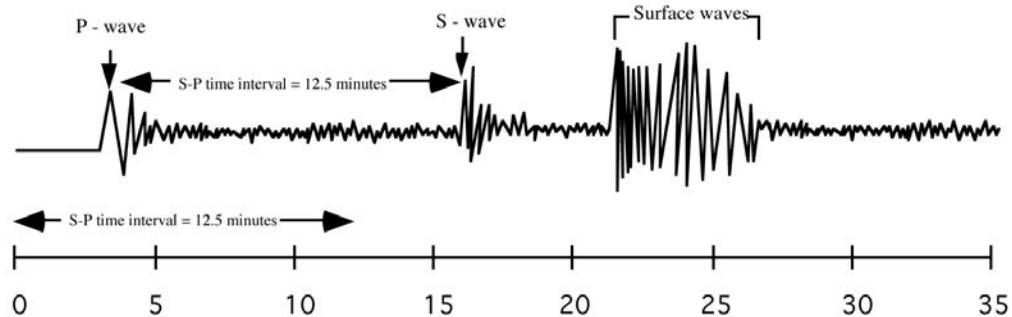


Figure 3.

The first peak on a seismograph always corresponds to the P-wave or primary body wave. It is a fast traveling compressional wave that can move through any type of matter (solid, liquid, or gas). The second major peak is the S-wave or secondary body wave. The S-wave always moves slower than the P-wave, and can only move through solid matter (not liquid or gas). The high amplitude waves that follow behind the S-wave are the Love and Rayleigh surface waves. These are seismic waves that only travel along the surface of the earth, and are responsible for the major ground shaking during an earthquake.

To determine the approximate distance from an earthquake epicenter to a seismograph, seismologists first measure from a seismogram the amount of time that has elapsed between the arrival of the P-wave and the arrival of the S-wave (called the S-P time interval). The closer a seismograph is to the epicenter, the shorter this time interval becomes (because the faster P-wave has less change to move away from the slower S-wave). Figure 3 also illustrates how an S-P time interval is measured from a seismogram using a time scale bar.

Next, the s-p time interval is taken to a set of curves (called an S-P graph) which plot the s-p time interval as a function of the distance from the epicenter and a distance is read directly from these curves. The next figure shows how a distance is derived from an S-P graph using the seismogram in Figure 3.

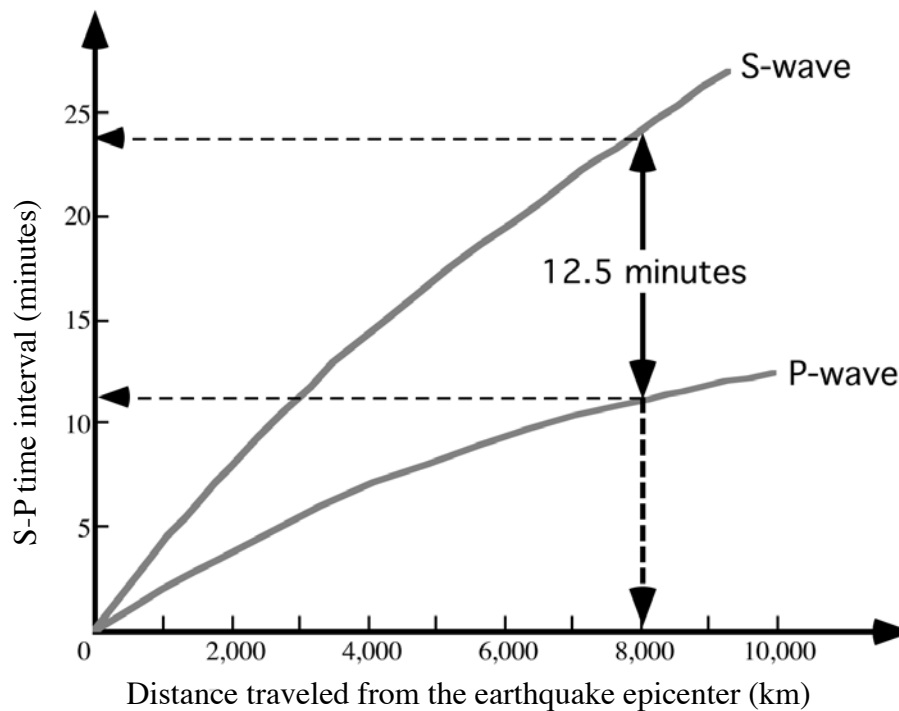


Figure 4.

The S-P time interval will provide a distance to the epicenter (in this case ~ 8,000 km), but will not yield a direction. The epicenter of an earthquake may fall anywhere on a circle whose center is the seismograph and whose radius is the distance as provided by the S-P time interval. That is why it takes readings from at least three different seismic stations in order to approximate the location to the epicenter of an earthquake. The following pages give a brief pictorial outline and a full step by step procedure for locating the epicenter of an earthquake using seismographs from seismographs at 3 different locations.

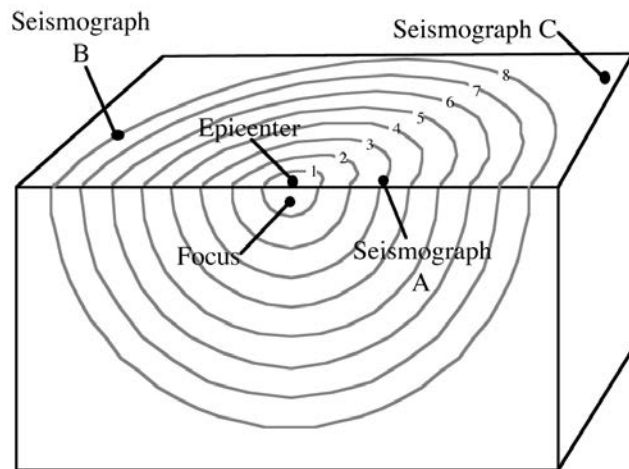


Figure 5. Three seismographs are shown with respect to the epicenter of an earthquake. The numbers on the seismic lines indicate S-P time intervals for 2 of the 3 seismographs (the S-P interval for Seismograph C ~ 11 minutes).

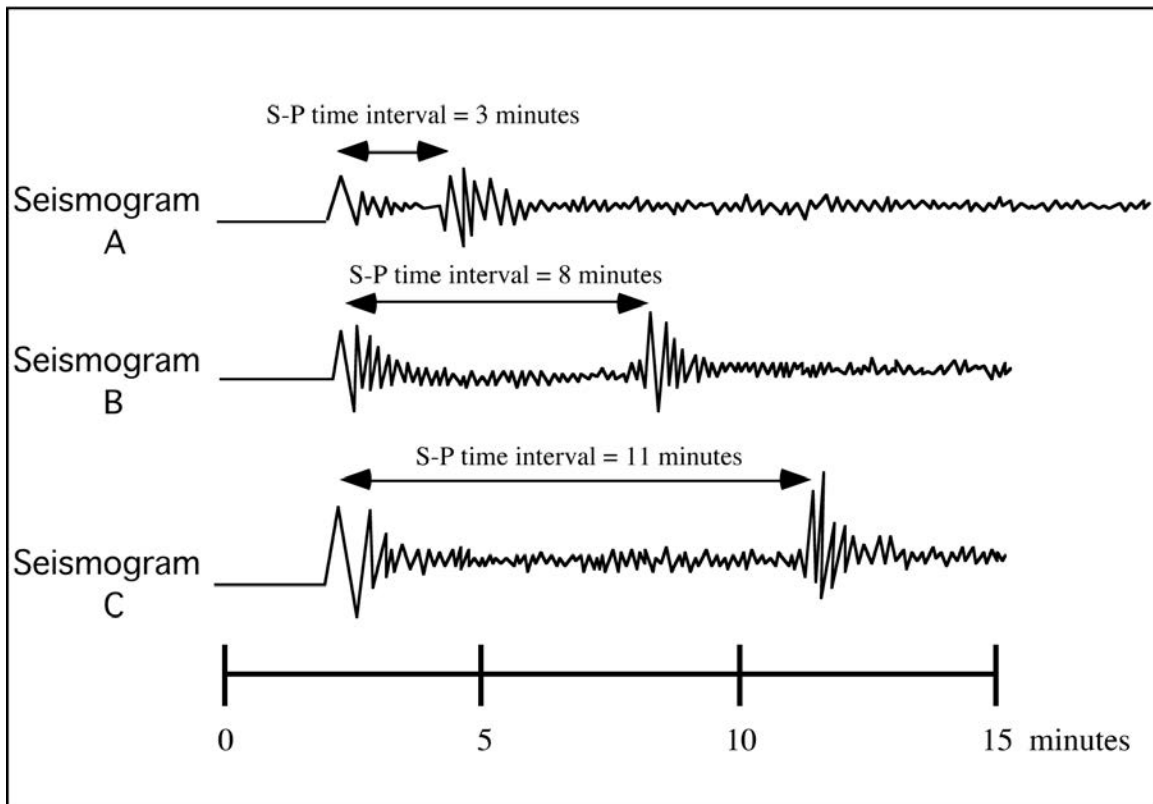


Figure 6. S-P time intervals for seismograms are read off of a time scale and their values are recorded.

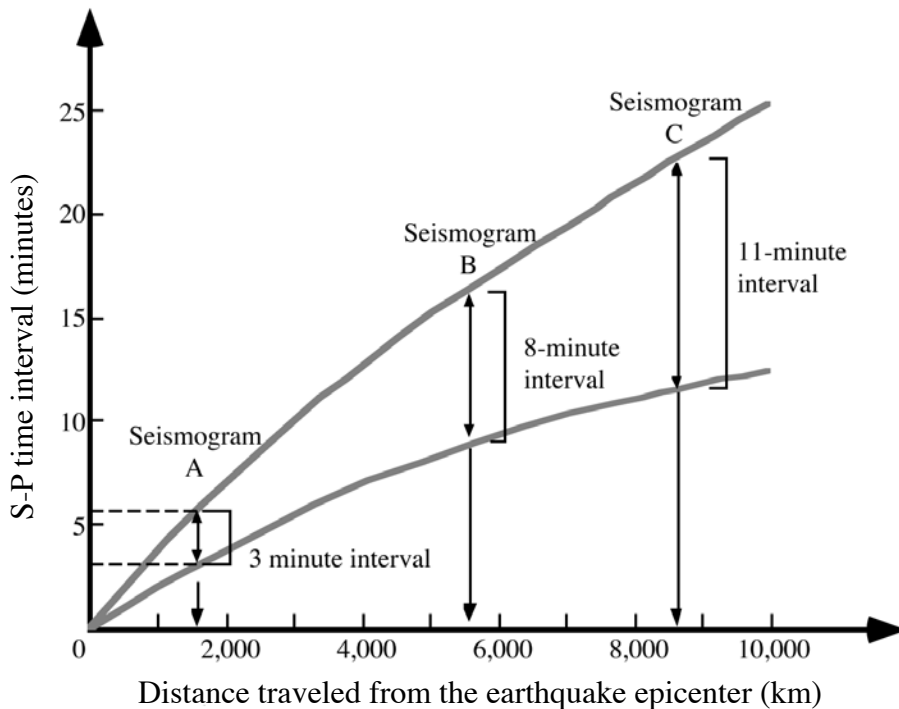


Figure 7. Distances to the epicenter are taken from the S-P graph for all 3 seismographs. Pay attention to the method that the s-p time interval is used to obtain the distances! The S-P time interval is scaled vertically between the S- and P- curves and the distance is read by extending this line down to the x-axis.

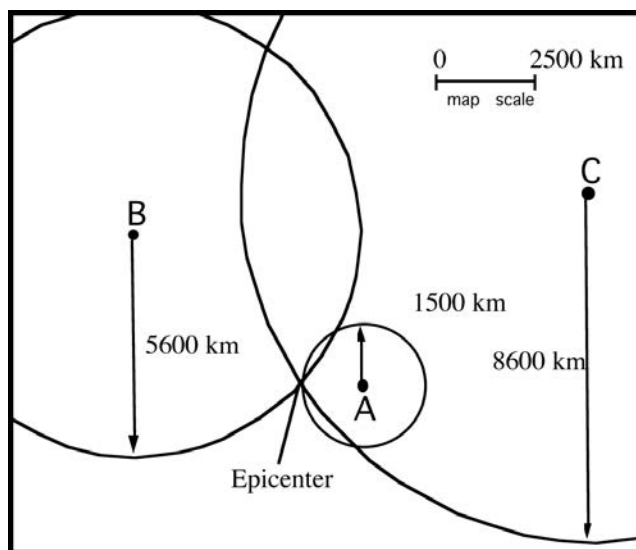


Figure 8. Finally, the location of the 3 seismographs are placed on a map and the distance to the epicenter is used to draw a circle with an origin at each seismograph and a radius equal to the distance to the epicenter as taken from each seismograph. Where the 3 circles intersect is the approximate location to the epicenter of the earthquake.

## Earthquake Size: Richter Magnitude Scale

In 1935, Professor Charles F. Richter of the California Institute of Technology devised a magnitude scale to describe the sizes of earthquakes in southern California. The scale depended on the amplitude of the largest surface wave on a seismogram and the distance from the seismograph to the earthquake epicenter. The Richter magnitude ( $M$ ) is logarithmic, so that increasing the amplitude of the ground motion by a factor of 10 increases the magnitude by 1. The “Richter magnitude” is commonly reported by the news media when a damaging earthquake occurs anywhere in the world.

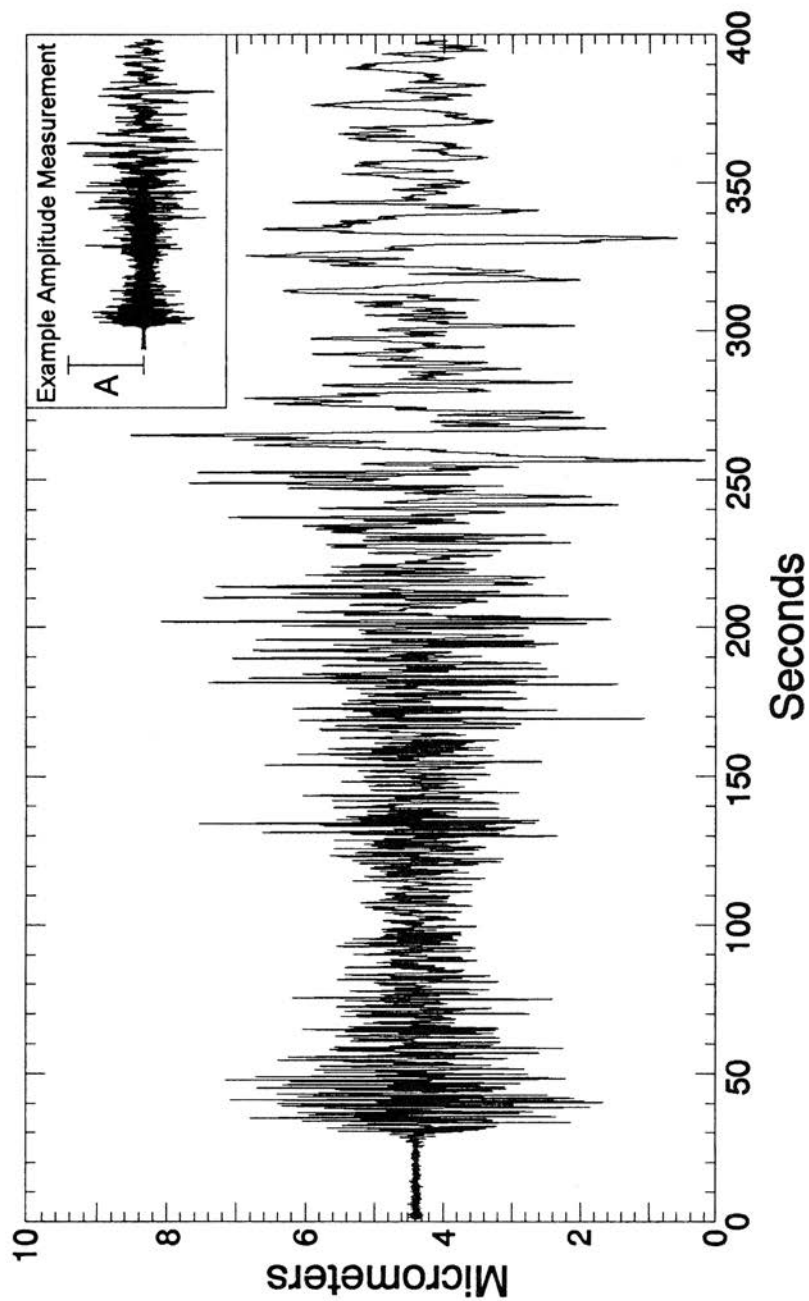
The equation Richter used for earthquake magnitude was:

$$M = \log_{10}A + 2.56\log_{10}D - 1.67$$

where  $A$  is the peak amplitude in micrometers of the earthquake and  $D$  is the distance in kilometers from the seismograph to the earthquake epicenter. Note that the above equation only applies to earthquakes in California. Professor Otto Nuttli of Saint Louis University devised the following, similar equation to describe the sizes of earthquakes observed in the central United States:

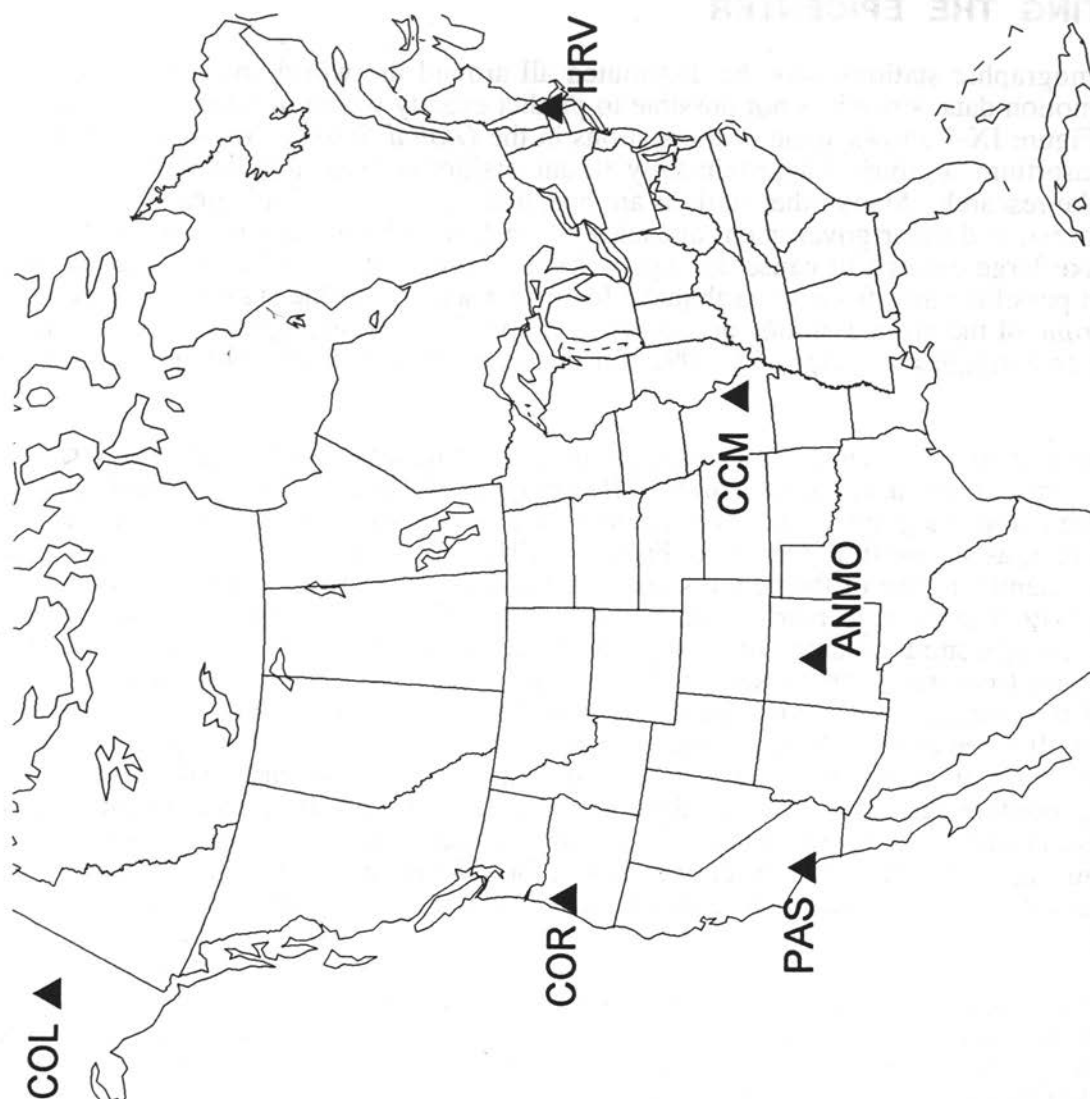
$$M = \log_{10}A + 0.83\log_{10}D + 0.00027D + 1.76$$

As in Richter’s equation for California, a factor of 10 increase in the ground motion amplitude ( $A$ ) results in an increase of 1 magnitude. However, the distance ( $D$ ) enters into the equation very differently, due to differences between the geology of California and the central United States. One obvious difference in the geology is that earthquakes in California are associated with the collision zone between North American and Pacific tectonic plates, while earthquakes in the central United States occur in the interior region of the North American Plate, most of which is not tectonically active.



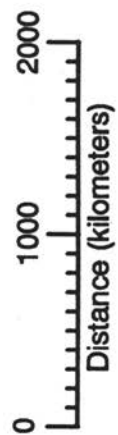
Seismogram for the April 25, 1992, earthquake recorded by a Wood-Anderson seismograph at Pasadena, California. Inset in the upper right corner illustrates the measurement of amplitude (A) used to calculate the Richter magnitude.

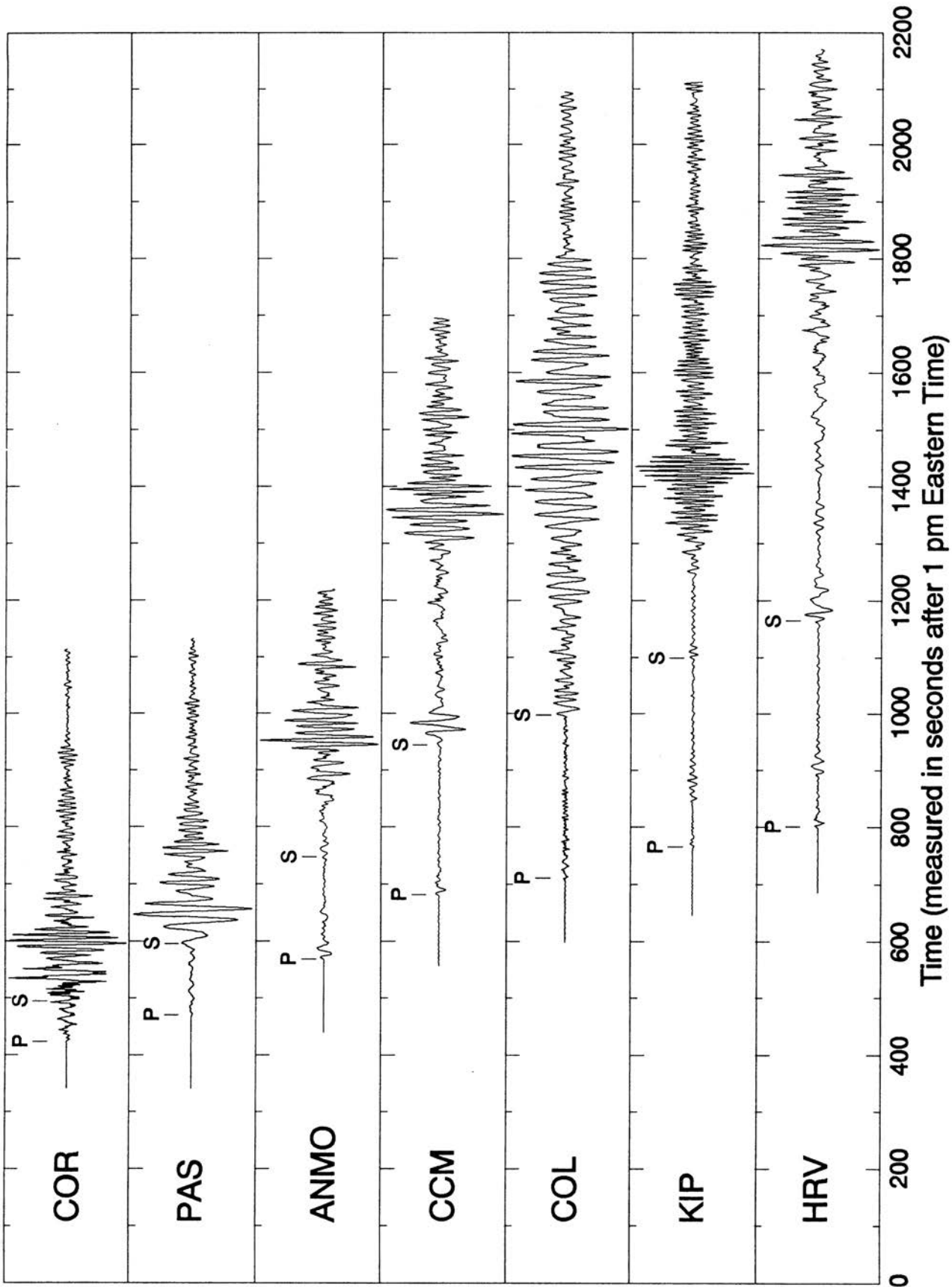


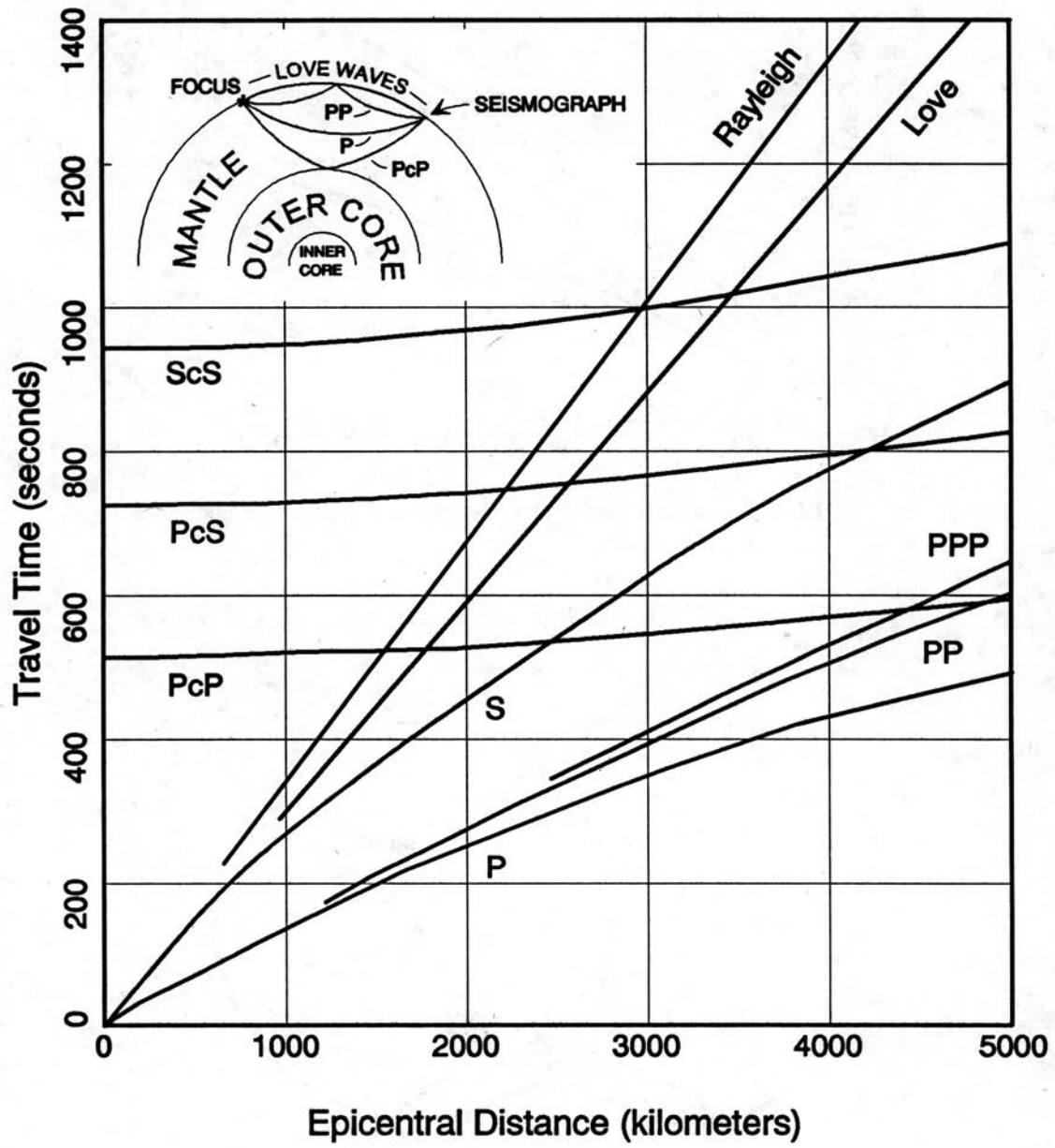


**IRIS Global Seismographic Network Stations**

- ANMO Albuquerque, New Mexico
- CCM Cathedral Caves, Missouri
- COL College, Alaska
- COR Corvallis, Oregon
- HRV Harvard, Massachusetts
- KIP Kipapa, Hawaii
- PAS Pasadena, California







Lab 8 - Seismology

Name \_\_\_\_\_

Date \_\_\_\_\_

1. Contrast the wave propagation and internal movement associated with P-waves and S-waves.
2. Indicate the relative velocities of P-waves, S-waves, and surface waves.
3. How do P-waves and S-waves differ in terms of the type materials these waves can transverse and how can this property be used to image the different layers inside of the earth?
4. Contrast the terms epicenter and focus.
5. In your own words describe how the S-P interval can be used to determine distance from an earthquake's epicenter.

