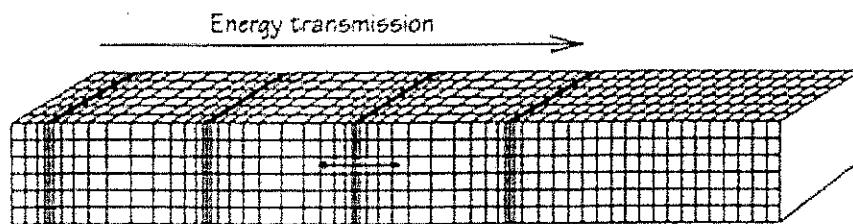


## Earthquake Exercise Information Sheet

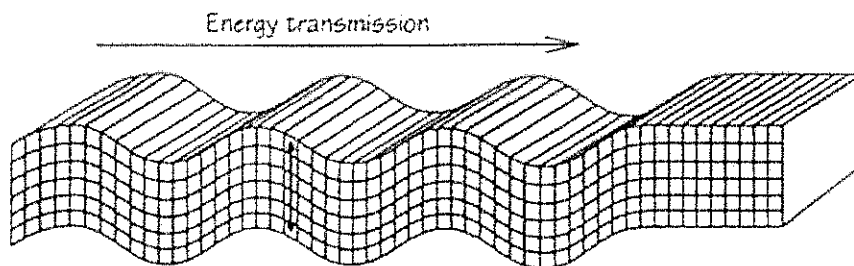
This exercise was adapted from one created by Professor Tom Freeman of the University of Missouri-Columbia (Freeman, 1996).

### Introduction

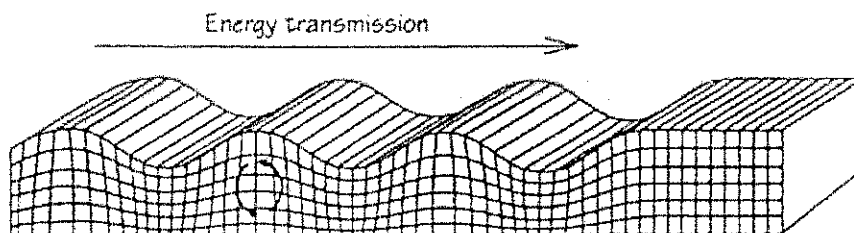
An earthquake occurs when there is abrupt motion along a fault zone. The earthquake generates the three types of **seismic (earthquake) waves** illustrated in Figure 12-2 below:



Primary, or "P," wave. Motion of rock particles (arrow) is parallel to the direction of wave transmission. Compression and relaxation of rock.



Secondary, or "S," wave. Motion of rock particles (arrow) is perpendicular to direction of wave transmission. Standing waves result, like the distortion of a trampoline.



Surface wave. Rolling of rock particles (arrows) in response to passage of moving wave. This is analogous to a wave on a body of water. Motion diminishes downward.

Figure 12-2. Three kinds of earthquake waves. P and S waves are penetrative, or body, waves. The surface wave is, as its name suggests, a land-surface wave. (After an illustration by the Missouri Geological Survey.)

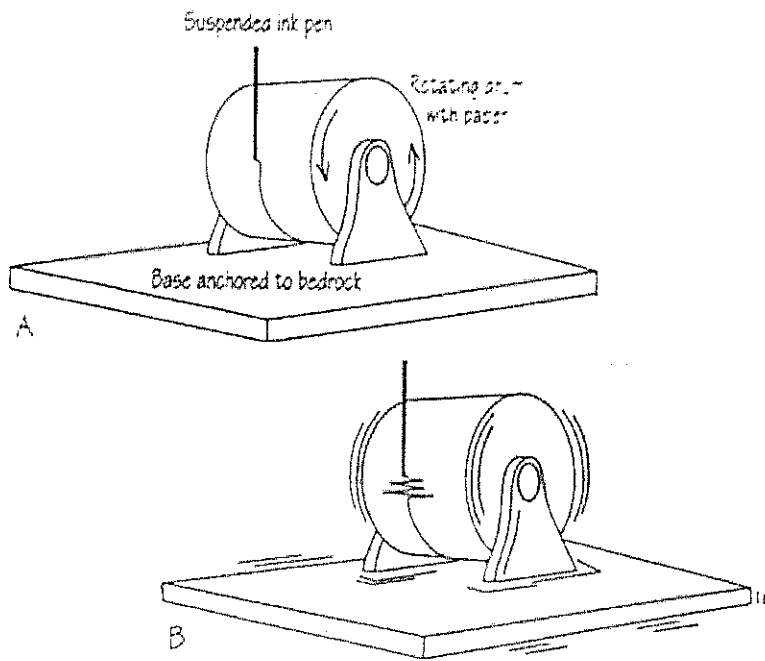


Figure 12-3. A seismograph is designed so that during an earthquake there is motion between rotating paper and an ink pen. (A) A seismograph before an earthquake. (B) A seismograph during an earthquake.

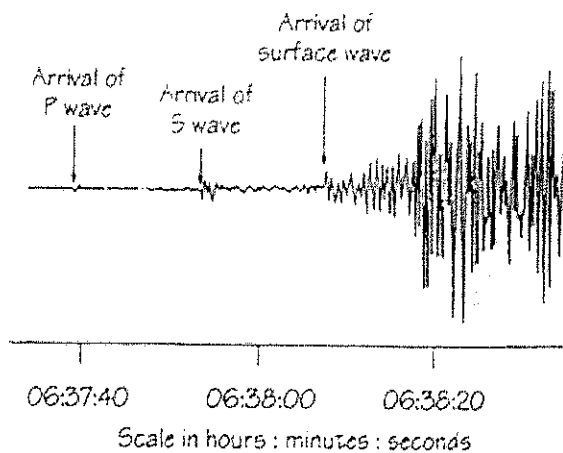


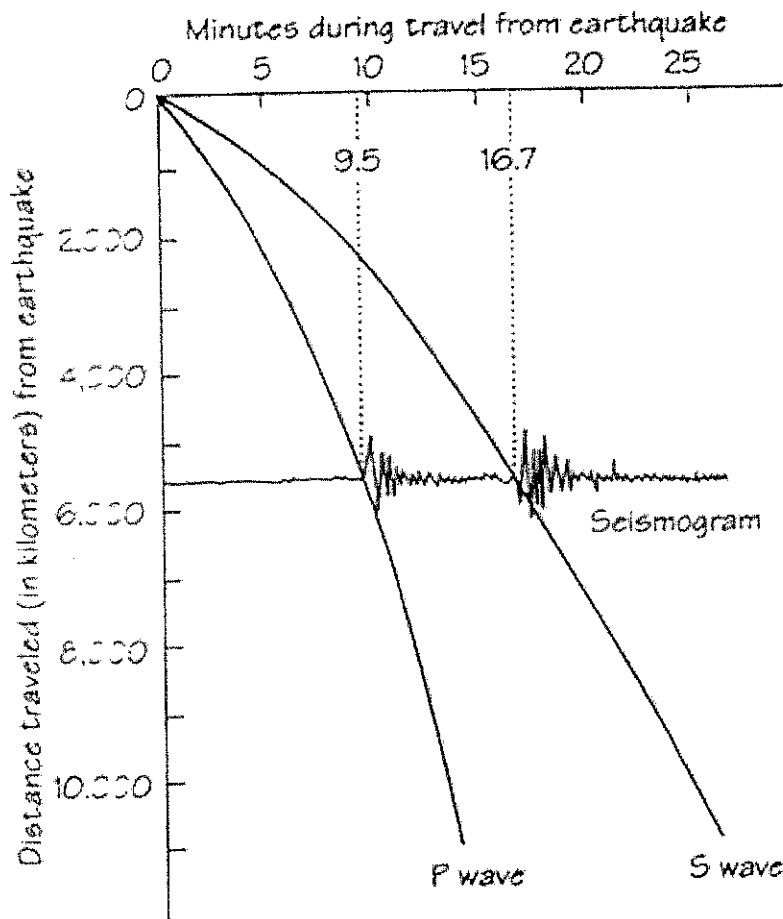
Figure 12-4. Schematic drawing of a seismogram showing arrivals of the three kinds of seismic waves. The paper was moving from your right to your left, so the earliest part of the record is to the left. The record is graduated in 20-second intervals.

Instruments that record earthquake waves are called **seismographs**. A basic seismograph consists of a recording pen in contact with a rotating drum covered with paper (Fig. 12-3). The zig-zag line produced by the pen on the paper is called a seismogram (Fig. 12-4).

## Determining the Distance to an Earthquake

Although the actual speed at which earthquake waves travel depends on the nature of the rocks or sediment along their paths, the relative speed of the three types of waves is always the same. P waves travel the fastest, followed by S waves. Surface waves are the slowest of the three types (Fig. 12-4). Because of this, it is the difference in the arrival time of the P and S waves at the seismograph station that indicates the distance to an earthquake.

1. Using Figure 12-5 below, it is possible to determine the distance from the earthquake to a seismograph station that received the P and S waves a certain number of minutes



apart. Mark the number of minutes on a piece of paper or ruler, then slide that distance down the gap between the arrival of the P and S waves until the distance is the same as the gap. Then read the number of kilometers on the scale to the left.

Figure 12-5. Graph of distance vs. travel time of P and S waves. For any degree of difference in arrival times, there is a unique distance to the earthquake. Example: A difference in arrival time of 7.2 minutes (i.e., 16.7 minus 9.5) indicates a distance to the earthquake of 5,600 kilometers.

## Locating Earthquakes

Locating earthquakes is a two-step process (Figure 12-6):

Step 1 - Determine the distance to the earthquake for each of three seismograph stations using the distance versus time diagram of Figure 12.5..

Step 2 - Use a drafting compass to construct a circle around each seismograph station. The radius of each circle is the distance between the earthquake and the seismograph station. For example:

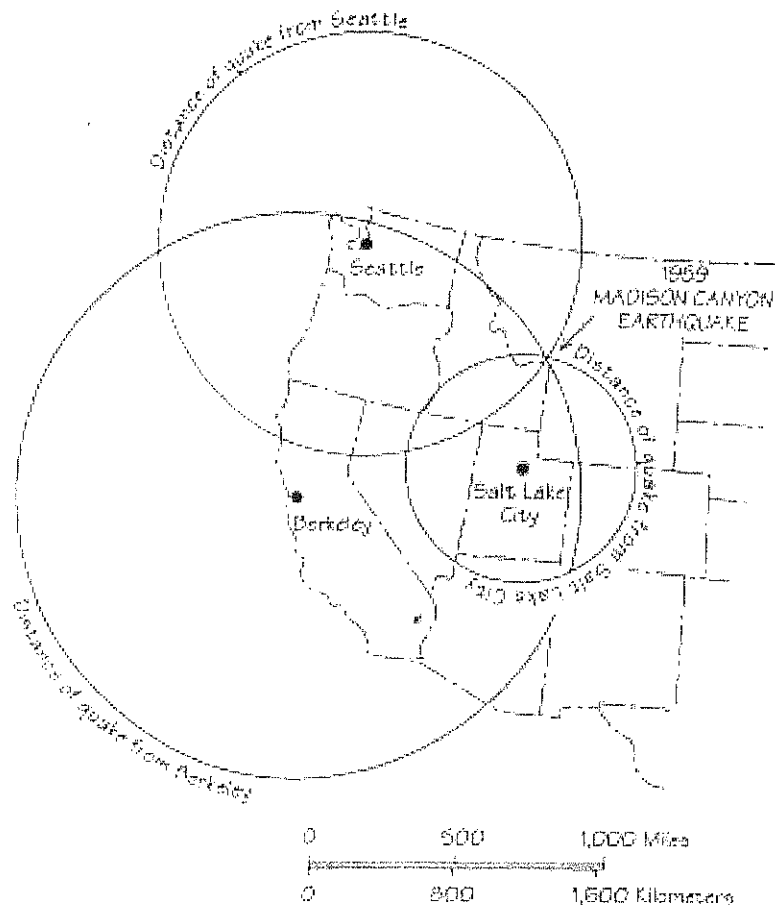


Figure 12-6. Determination of the location of the 1959 earthquake in the Madison Canyon area of southern Montana. Distances from seismograph stations at Seattle, Berkeley, and Salt Lake City were 725, 950, and 375 miles, respectively. Each circle is drawn with a radius equal to the distance between its enclosed station and the earthquake. The intersection of the three circles marks the location of the earthquake.

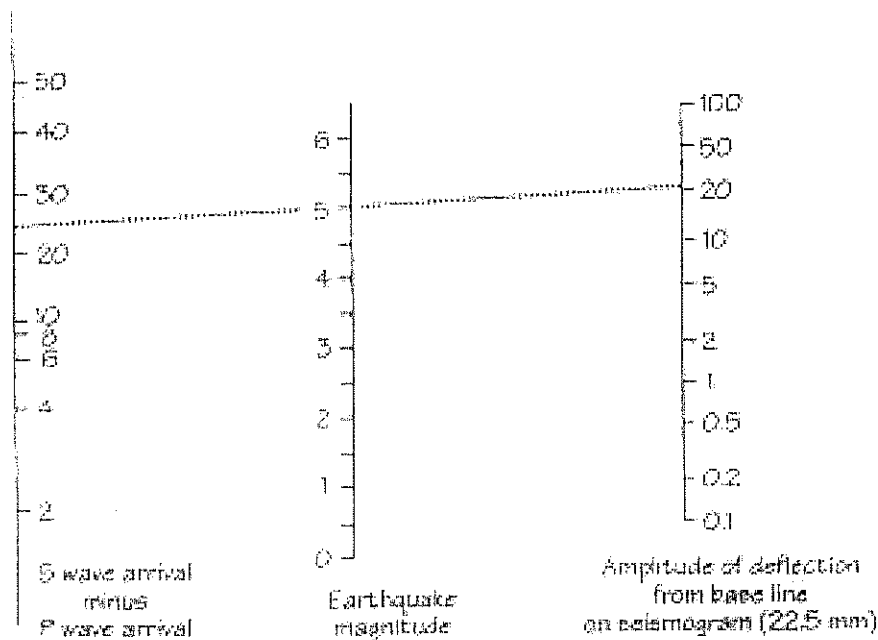
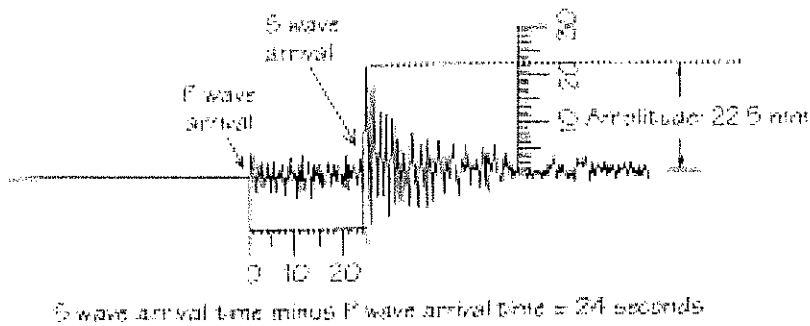


Figure 12-8. Nomogram for solving for earthquake magnitude at a distant seismograph station. The example is of an earthquake producing a difference in arrival times of P and S waves of 24 seconds and a maximum wave amplitude of 22.5 millimeters. Magnitude is 5.0. (Nomogram courtesy of the California Institute of Technology.)

### Determining the Magnitude of an Earthquake

The magnitude of an earthquake can be approximated by the amount of zigzag deflection on a seismogram. This is done using three bar graphs positioned as a nomogram (Fig. 12-8). Follow the four-step procedure described below to answer question #2:

Step 1 - Measure the difference in arrival times of the P and S waves. This difference should be expressed in seconds.

Step 2 - Measure the amplitude (height) of the greatest deflection on the seismogram. This amplitude should be expressed in millimeters.

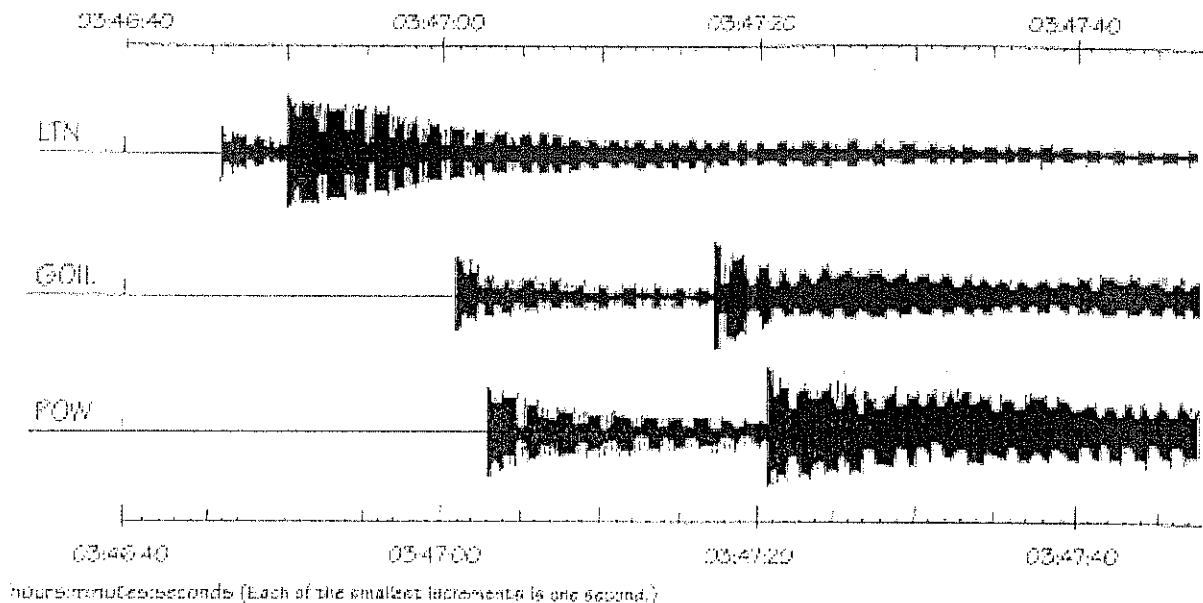
Step 3 - Lay a ruler or other straightedge on the nomogram at the values determined for arrival time difference (S wave arrival minus P wave arrival) and the amplitude (of the deflection from baseline).

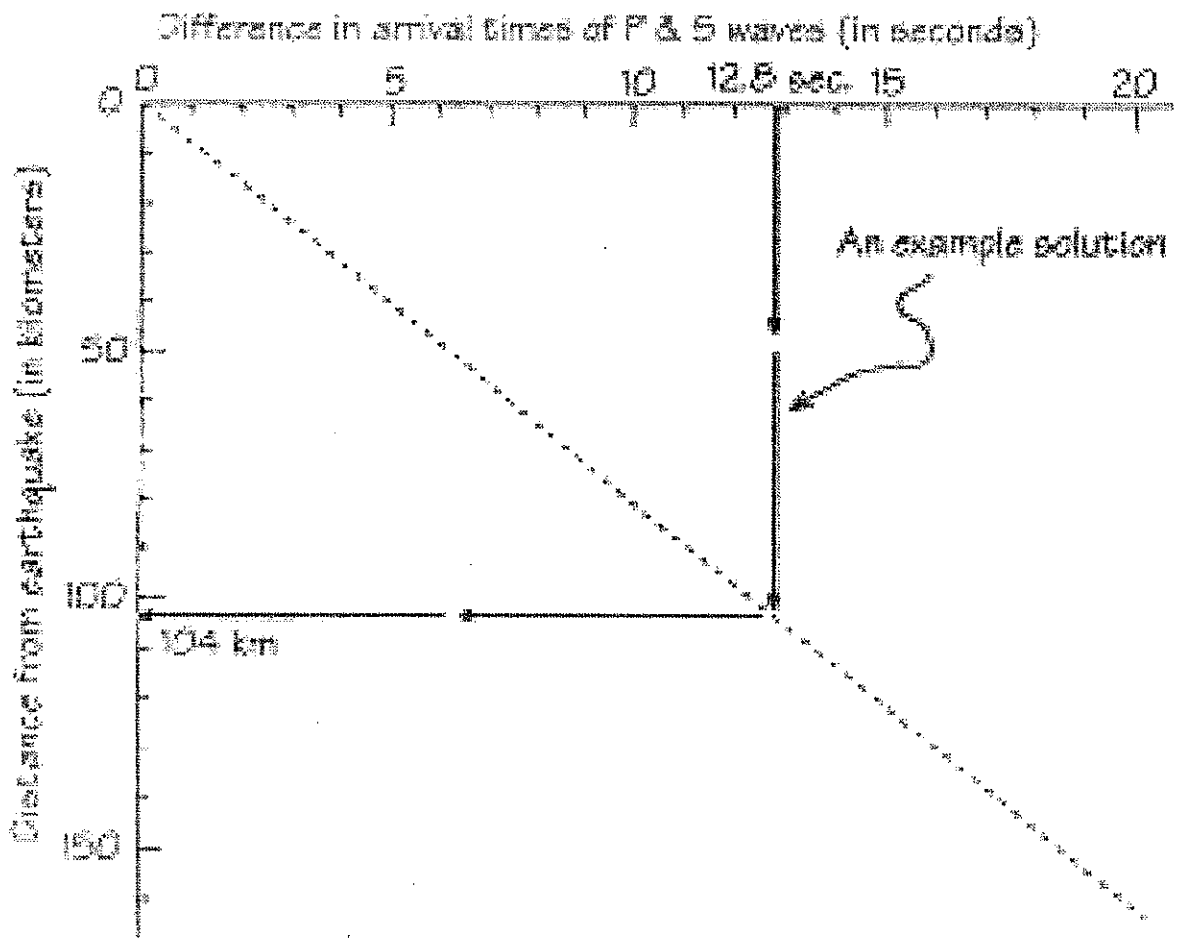
Step 4 - Read the magnitude directly from the Earthquake Magnitude bar graph (center scale).

### Determining the Location of an Actual Earthquake

The middle Mississippi Valley is one of the areas of the U.S. that frequently experience earthquakes. Three earthquakes took place near New Madrid, Missouri in 1811-1812 which are thought by seismologists to have been the strongest in recorded history for North America. These earthquakes rang church bells in Boston, Massachusetts and briefly reversed the course of the Mississippi River! Statistical studies indicate that there is a 50:50 chance that a magnitude 6.5 earthquake will occur in this region by the year 2000.

The three seismograms, below record a magnitude 3.0 earthquake that occurred in the Missouri region around 3:46 AM on June 19, 1987. Use these seismograms and the arrival time graph below it to complete the table on the hand in exercise. This information was provided by Professor Brian J. Mitchell of Saint Louis University.





Note: This is a graph of distance from earthquake vs. difference in arrival times of P and S waves. This graph differs from Figure 12-5 on page 3, which is a graph of distance vs. separate travel times of P and S waves.

**Earthquakes**

This exercise was adapted from one created by Professor Tom Freeman of the University of Missouri-Columbia (Freeman, 1996).

1. From Figure 12-5 on the information sheet, determine the distance from the earthquake to a seismograph station that received the P and S waves 5.0 minutes apart:

\_\_\_\_\_ km

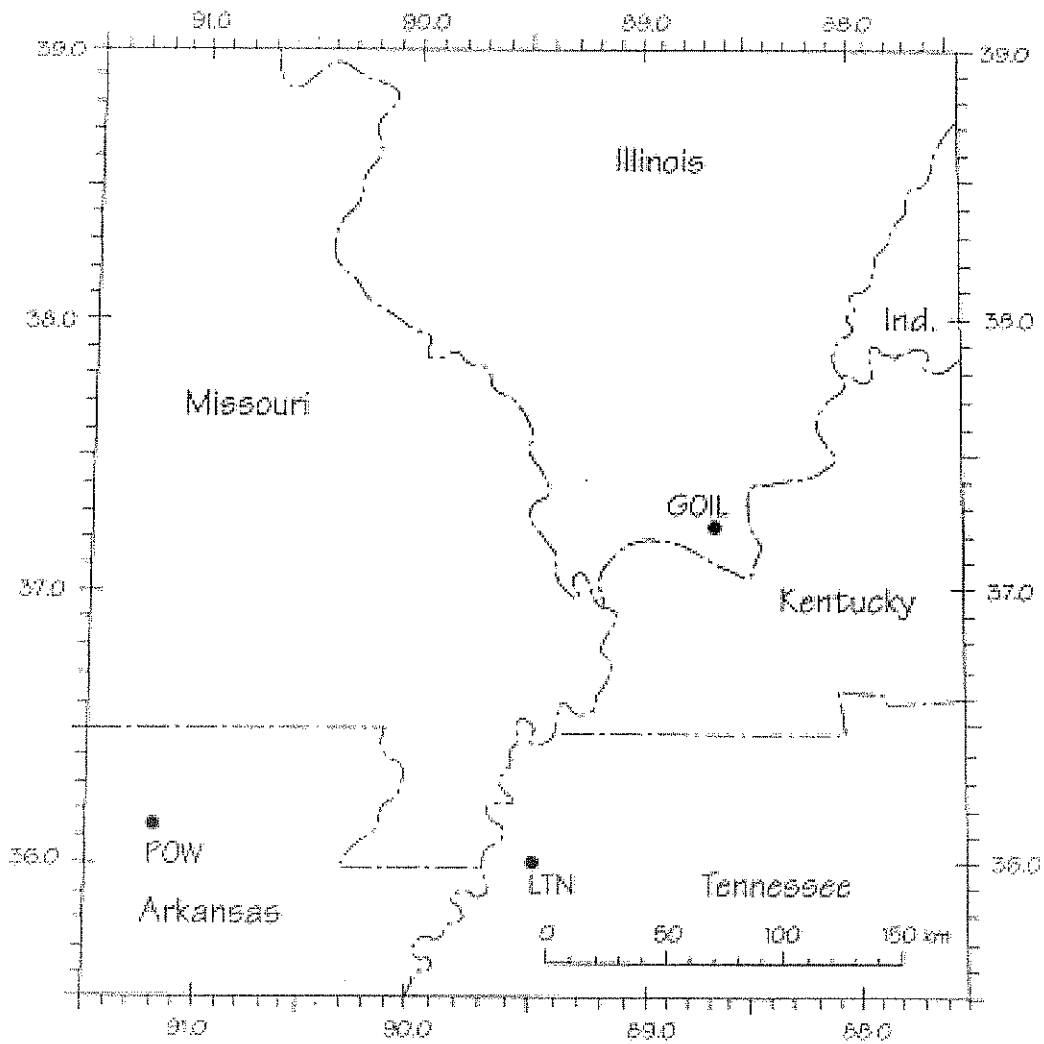
2. Using the nomogram in Figure 12-8, determine the earthquake magnitude for the three earthquakes listed below (A, B, and Q).

Earthquake	S-P Difference in Arrival Times	Amplitude of Deflection	Earthquake Magnitude
A	8 seconds	20 mm	
B	8 seconds	0.2 mm	
C	6 seconds	10 mm	

3. Use the three seismograms from the earthquake information sheet for a magnitude 3.0 earthquake that occurred in the Missouri region around 3:46 AM on June 19, 1987. Use these seismograms and the arrival time graph below it to complete the following table. This information was provided by Professor Brian J. Mitchell of Saint Louis University.

location	P arrival time (hours:minutes:seconds.tenths of seconds)	S arrival time (hr:min:sec.1/10 sec)	Difference in P & S arrivals (seconds.tenths of seconds)	Distance in kilometers
LTN				
GOIL				
POW				

4. Use the distances from the table above with Figure 12-9 below to determine the location of the 1987 earthquake. Refer back to the earthquake information sheet of this exercise if you need



to review the method for determining earthquake locations.

Figure 12-9 is a map of the New Madrid seismic zone, showing three of the seismograph stations in the region: Powhatan, Arkansas (POW); Lennox, Tennessee (LTN); and Rosebud, Illinois (GOIL). Degrees north latitude and degrees west longitude are shown along the margins. Subdivisions of degrees are in tenths of a degree rather than in minutes.