

collect 5-3 & 5-4  
discuss: body waves, P, S,  
surface  
difference in arrival times, demonstrate.

## GS 104 Laboratory # 5 EARTHQUAKES: Epicenter Determination and Seismic Waves

### Overview of Earthquakes and Seismic Waves

**Earthquakes** are vibrations of the Earth caused by large releases of energy that accompany volcanic eruptions, explosions, and movements of the Earth's crust along fault lines. The earthquake vibrations are waves of energy that radiate through the Earth away from the **focus**. These waves of energy can be recorded on a seismograph, which produces a recording called a **seismogram**. Seismographs record the two types of **body waves**: **Primary waves (P-waves)** and **Secondary waves (S-waves)**. They also detect **Surface waves** called Love waves (L-waves).

**Travel-time curves** are graphs that indicate how long it takes each type of seismic wave to travel a distance measured on the Earth's surface. The difference between the S-wave arrival time and the P-wave arrival time corresponds to the distance of the seismograph station from the earthquake focus. This time difference can be converted easily into distance using the travel-time curves (Figure 2).

### Part A – Epicenter Determination

The epicenter of an earthquake is the point on the Earth's surface at or above the earthquake's focus. In this exercise, you will determine the location of the epicenter of an earthquake that was recorded on seismograms at three different locations (Figure 1).

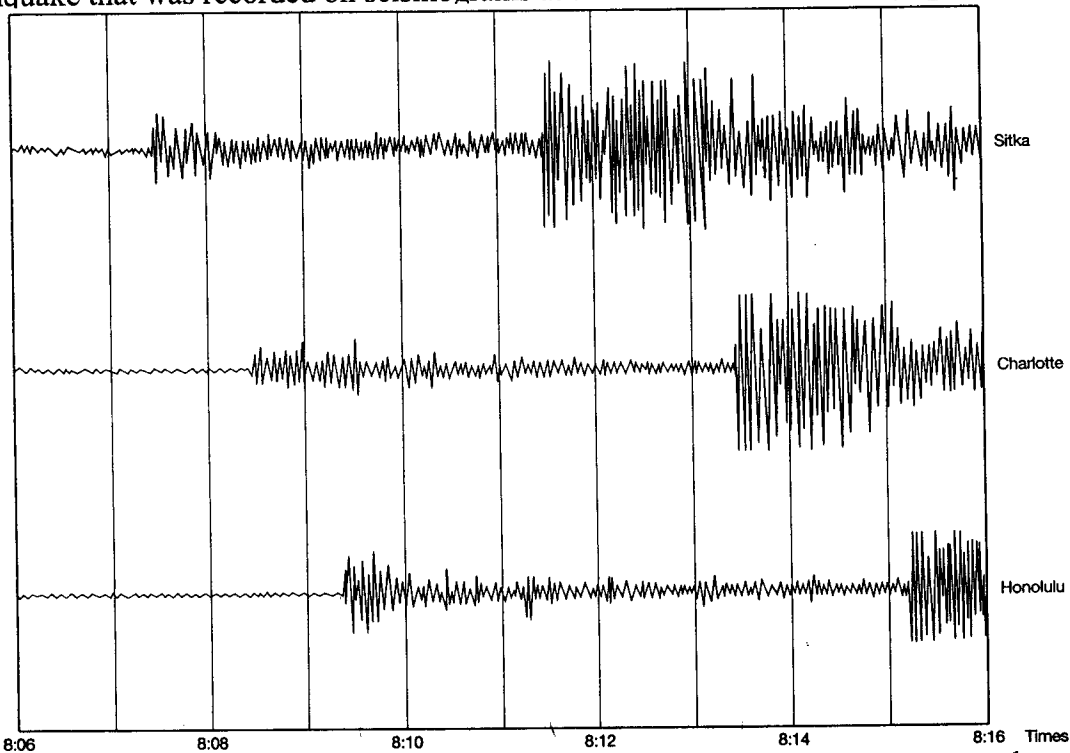
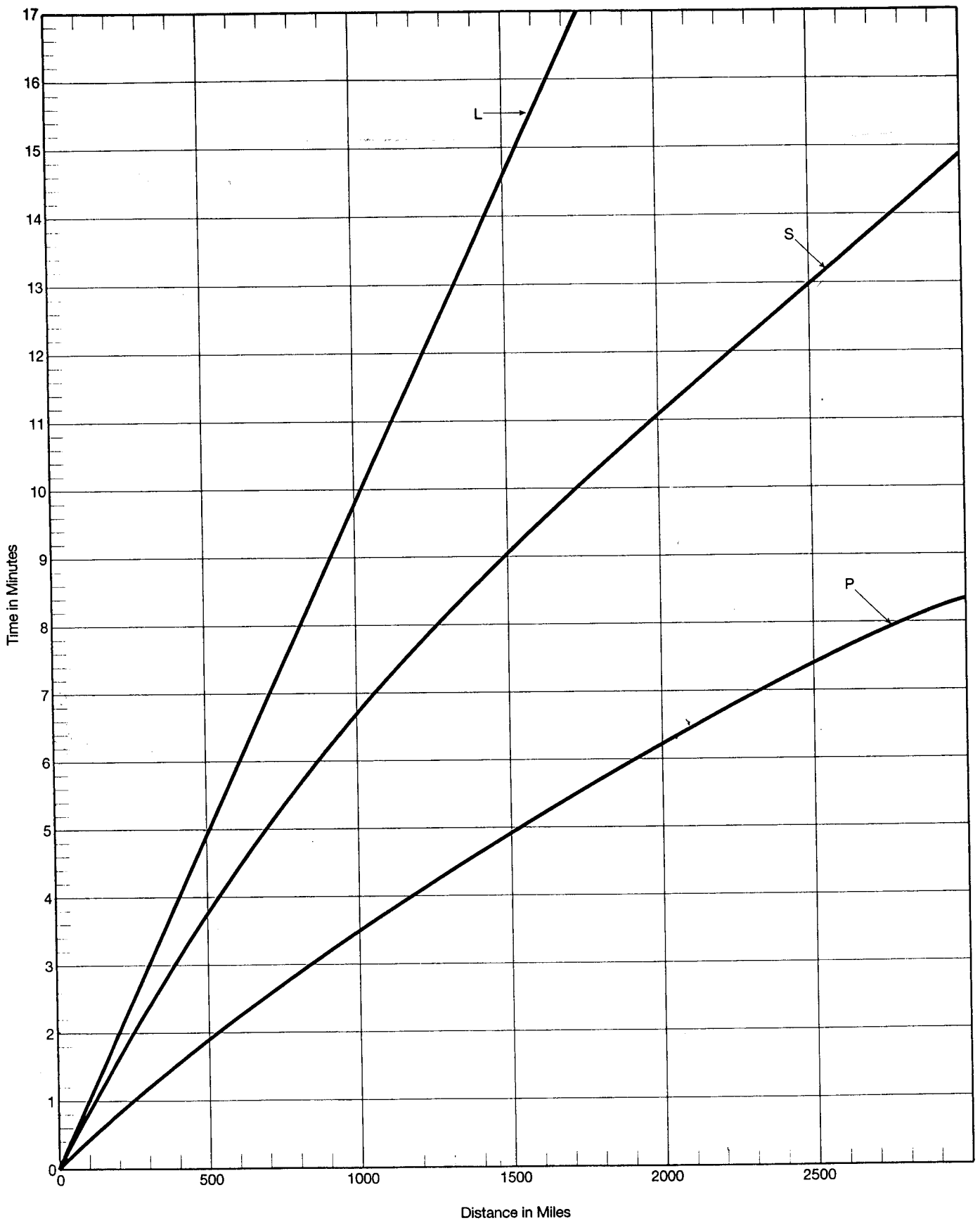


Figure 1: Seismograms recorded at three different locations for the same earthquake.



**Figure 2:** Travel-time curves for P-waves, S-waves, and L-waves.

1. Estimate to the nearest tenth of a minute, the times of the first arrival of the P-waves and S-waves at each station in Figure 1. Then subtract S minus P.

Location	First P Arrival	First S Arrival	S minus P
Sitka, AK	8:07:30	8:11:30	4:00
Charlotte, NC	8:08:30	8:13:25	4:55
Honolulu, HI	8:09:20	8:15:15	5:55

2. Using the S-minus-P times and the travel-time curve (Figure 2), estimate the distances from the focus that correspond to these values.

Location	Distance (miles)
Sitka, AK	1450
Charlotte, NC	2050
Honolulu, HI	2720

3. Find the earthquake's epicenter using the distances you just obtained.
- a. First locate and mark the three seismic stations on the world map provided below (Figure 3):

Sitka, AK:            57° N latitude, 135° W longitude  
 Charlotte, NC:        35° N latitude, 81° W longitude  
 Honolulu, HI:        21° N latitude, 158° W longitude

- b. Use a drafting compass to draw a circle around each seismic station. Make the radius equal to the distance between the station and the epicenter that you determined above. Use the scale for the world map to set this radius on the drafting compass. The circles you draw should intersect at one point, which is the epicenter. (If the three circles do not intersect at a unique point, choose a point equidistant between the three circles.) The location of the epicenter is:

latitude 39 N

longitude 119 W

4. What is the **origin time** of the earthquake (at what time did it occur)?

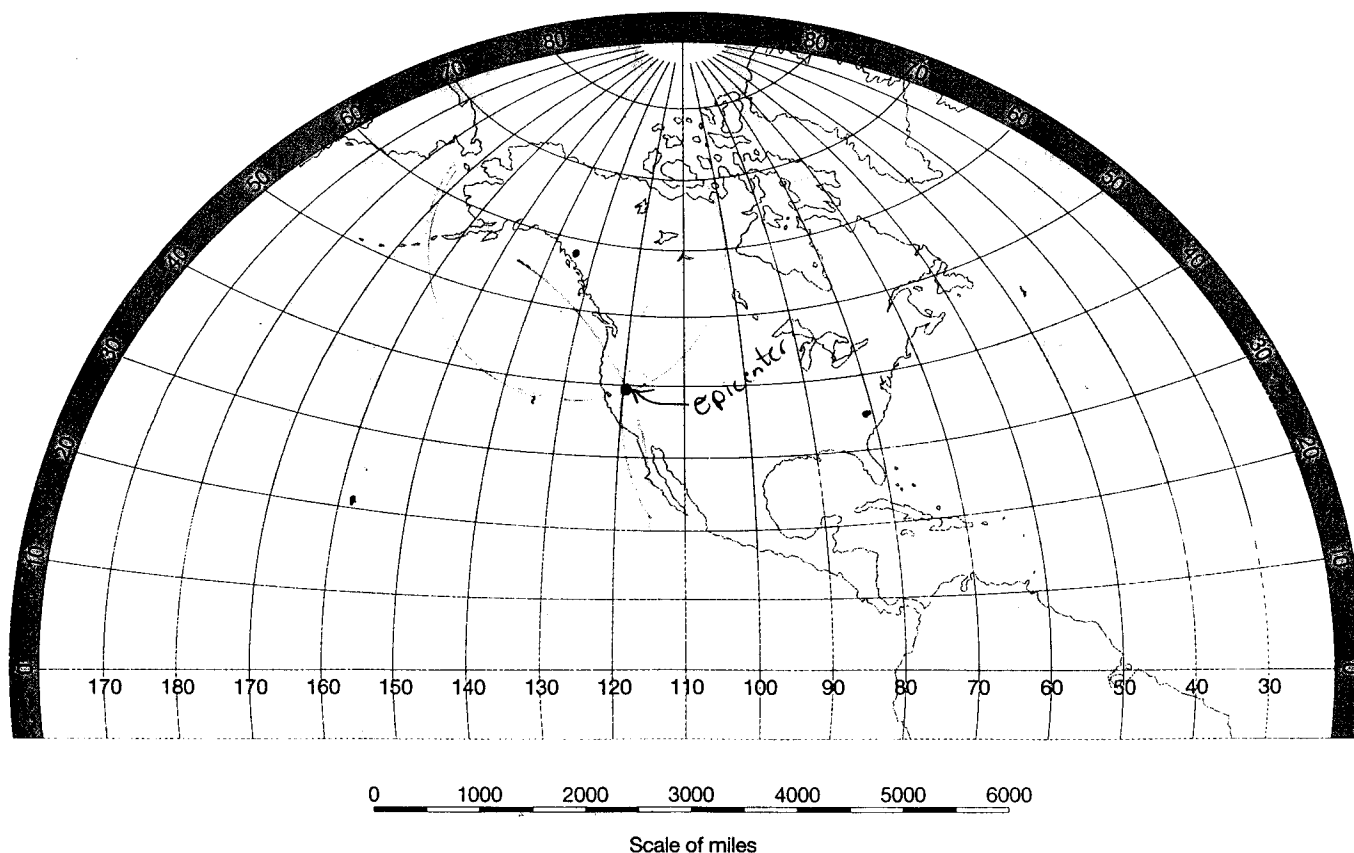
P-wave travel time to Charlotte = 6:20

$$8:08:30 - 6:20 = 8:02:10$$

5. What time would you estimate did the L-waves from this earthquake begin to arrive at the Sitka station?

L-wave travel time = 14:25

$$\text{arrival time} = 8:02:10 + 00:14:25 = 8:16:35$$



**Figure 3:** Map of Earth, for use in plotting data and locating the earthquake's epicenter.

## Part B – Earthquakes Hazards

Examine the *Geologic Map of the West Salem Area* and the Earthquake Hazard Maps for this area. Answer the following questions:

1. Locate Minto Island (central) and McNary Field (southeast) on the *Geologic Map of the West Salem Area*. These areas are underlain by sediments labeled Qal, Qtlw, and Qlg. Briefly describe these sediments, then

- a. **Qal** unconsolidated, cobbles, coarse gravel, sand, silt & clay
- b. **Qtlw** low terrace deposits of unconsolidated to semi-consolidated gravel, sand, silt, clay, muck, & organic matter
- c. **Qlg** coarse to fine fluvial gravels

2. Explain how the abundance/concentration of groundwater contained in these sediments may change in relation to the proximity of the Willamette River.

closer to the river, the abundance of ground water increases

3. How does the type of sediment (Qal, Qtlw, or Qlg) relate to the liquefaction potential and relative earthquake hazard potential of these areas? (Refer to the *Liquefaction Susceptibility Map* and *Relative Earthquake Hazard Map* of the Salem area to support your answer.)

Qal - high hazard

Qtlw - lower hazard

Qlg - low hazard

Coarser sediments are harder to liquify.

4. Locate portions of the *Geologic Map of the West Salem Area* which are underlain by Eocene-Oligocene sedimentary rocks (Toe). Would you build a beautiful new home overlooking the river in these areas? Why or why not? (Hint: Examine the susceptibility to earthquake damage in these areas and how this relates to the topography and geology from the *Liquefaction Susceptibility Map*, *Landslide Susceptibility Map*, and *Relative Earthquake Hazard Map* of the Salem area.)

This is a bad area to build upon due to high landslide hazard. The high hazard results from steep topography and weak rock.

5. Examine the *Geologic Map of the West Salem Area*. Locate Fairview Hospital (southeast), West Salem and Marion Square Park (central), and the Salem Heights and Morningside Schools (south central) on the map. Describe the geology and topography of each location.

Location	Geology (i.e., rock units)	Topography (steep or flat)	Earthquake Susceptibility
Fairview Hospital	Q <sup>th</sup> sand, silt, clay	flat to moderately steep	high
West Salem	Q <sup>th</sup> sand, silt, clay	flat	moderate
Salem Heights	T <sup>cr</sup> basalt	moderately flat	low

6. Using the Relative Earthquake Hazard Map of the Salem area, rank each of the above locations in order of decreasing susceptibility to damage from earthquakes. Then describe why each is or is not susceptible to damage. (Refer to *Liquefaction Susceptibility Map* and *Landslide Susceptibility Map* of the Salem area and your answer to Q. 3 to support your answer.)

Fairview hospital is at the highest hazard due to the high risk of landslides.

West Salem faces moderate hazard due to liquefaction.

Salem Heights is at the lowest hazard for landslides of liquefaction.