Integrated Science Program

James Madison Memorial High School

Unit 9; Handout No. 6

Name _____

Period _____ Date _____

Teacher _____

LAB: LOCATING AN EPICENTER

Introduction:

Even though earthquakes occur in many distant places, a seismologist does not have to be near one to determine its location, depth, and magnitude. The tearing and shearing of the earth that we call an earthquake sends out some of its energy in the form of waves radiating in every direction from the focus (the point in the earth where the rocks have moved). Sensitive instruments called seismographs detect and record the time of arrival and the intensity of these wave patterns. With three such records (called seismograms), a seismologist can rather easily locate the epicenter (the point on the earth's surface directly above the focus of the earthquake) and determine the magnitude of the earthquake.

Problem:

How can an epicenter be located?

Procedure:

A. Method of locating an epicenter:

You have already discussed the difference between the various types of waves sent out by an earthquake (P - or primary waves, S - or shear waves, and R - or surface waves). The Travel Time Graph for Earthquake Waves (Located on page 9) shows the travel time of P - and S - waves for various distances. This graph was drawn using data indicating how long it takes waves from a quake to reach various observation points. Use the graph to answer the following questions.

1. How long does it take a P wave to travel 3000 km? _____

2. How long does it take an S wave to travel 3000 km? _____

If you answered 5 minutes 36 seconds for the P- wave and 10 minutes 10 seconds for the S - wave, you know how to use the graph, and you can see that S - waves travel slower than P - waves. If your answers were very different, then check your work again.

Since P - waves travel faster than S - waves, P - waves always arrive first at the seismograph station; the farther the station is from the epicenter, the longer will be the time interval between the arrival of the P - wave and the arrival of the S - wave. For example, for an earthquake 3000 km away, the difference in travel time of P - and S - waves is (S - P), or (10 minutes, 10 seconds) - (5 minutes, 36 seconds) = 4 minutes, 34 seconds

3. What is the difference in travel time between the P- and S - waves for an earthquake 2000 km away from the seismograph recording station?

   _____

4. What is the difference in travel time between the P - and S - waves for an earthquake 8000 km away from the seismograph recording station?

   _____

If you answered 3 minutes and 20 seconds for an earthquake 2000 km away and 9 minutes and 20 seconds for an earthquake 8000 km away from the seismograph recording station - you are right on track. In fact, if you make a simple subtraction, the graph will tell you the difference in travel time of P - and S - waves for any given distance. Conversely, if you know the difference in arrival time of P - and S - waves from a given earthquake, you can use the graph to determine the distance.

Example:

P - waves from an earthquake are detected at 02 hour 33 minutes 15 seconds; the following S - waves are detected at 02 hour 36 minutes 30 second. The interval is
(S - P) = 00 hour 03 minutes 15 second

To find how far the waves have traveled, take a piece of paper and lay the edge next to the travel-time scale (y - axis) on the graph. Mark off a distance on the edge of the paper to represent 3 minutes 15 second.

Now move the edge of the paper with the time marks on it along the P and S lines of the graph until the upper mark is on the S - wave curve, and the lower mark is on the P - wave curve. (Be certain to keep the paper's edge parallel to the vertical distance lines of the graph) When you have found where the time marks on the paper are exactly on the P - and S - wave curves, you have found the epicenter distance where the S - wave would arrive exactly 3 minutes
15 seconds later than the P - wave. This distance is 1900 km.

5. What is the epicenter distance in kilometers when the S - wave arrives exactly 2 minutes and 40 seconds later than the P - wave?

   _____

6. What is the epicenter distance in kilometers when the S - wave arrives exactly 9 minutes and 20 seconds later than the P - wave?

   _____

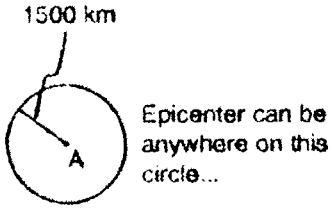
Problem: Find the epicenter distance of an earthquake from three seismic stations; A, B and C, using the data below and the method just described.

Station Name	P – Wave Arrival Time	S – Wave Arrival Time	(S – P) Difference in Arrival Time (min, sec)	Distance (km)
A	14:05:25	14:08:00		
B	14:13:15	14:22:20		
C	14:08:15	14:13:05		

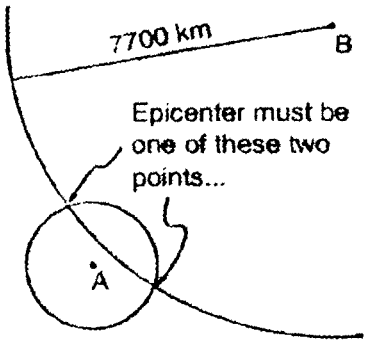
**Times are Greenwich Mean Time in hours, minutes, and seconds.*

You now know how to find the distance from an seismograph recording station to the epicenter of an earthquake. How can this information enable you to locate the epicenter?

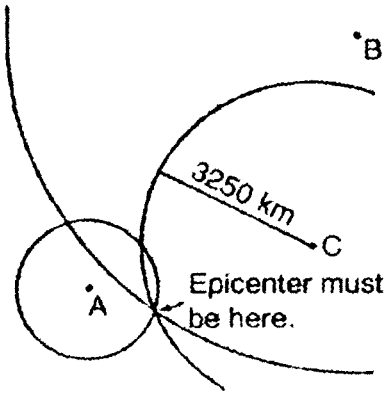
Suppose you are at Station A, and you have just determined that the epicenter of an earthquake is 1500 km away. Since you do not know the direction to the epicenter from the recording station, it could be anywhere that is 1500 km from Station A. That is, it could be anywhere on a circle of radius 1500 km with a center at Station A, as shown on the next page.



But you also have data from Station B. The same epicenter is 7700 km from Station B. So you can draw a circle with a radius of 7700 km from Station B, as shown on the diagram below. Since the epicenter must be on both circles, you have narrowed the possibilities of the epicenter location down to two points.



Now using the data from Station C, you draw a third circle, which fixes the location of the epicenter at one point, as shown in Figure 3. Thus you see that data from three stations is needed to locate an earthquake epicenter. (Data from more than three would confirm the location but would not give any more information.)



B. Locating an epicenter from seismograms

Using the method outlined above, attempt to find the epicenter of an actual earthquake from the three seismograms (next page) of the earthquake as recorded at three distant cities. Use the P - and S - wave travel-time graph, the outline map of the North American continent and a drawing compass capable of making large circles.

1. Study the seismograms on which arrivals of the P - and S - waves are marked. You must establish to the nearest second the time of arrival of the P - and S – waves for all three stations. Write these arrival times in the data table on the next page.

2. Find the difference between the arrival time of the P - wave and the arrival time of the S - wave by subtracting (S - P) to find the time interval.

3. Convert the difference in arrival time to the distance from the earthquake epicenter using the travel-time graph.

4. Use the scale on the map to set your compass to a radius equivalent to the distance from one of the seismograph recording stations. Then draw a circle of that radius around that station on the map.

5. Repeat this operation for the other two stations. If you have worked carefully, the three circles should intersect at one point, which marks the epicenter of the earthquake.

6. If, as in some cases, the circles pass very close to one another, leaving a small triangle of arcs, then assume the epicenter to be the center of this triangle. By careful work, try to keep this triangular area of uncertainty as small as possible.

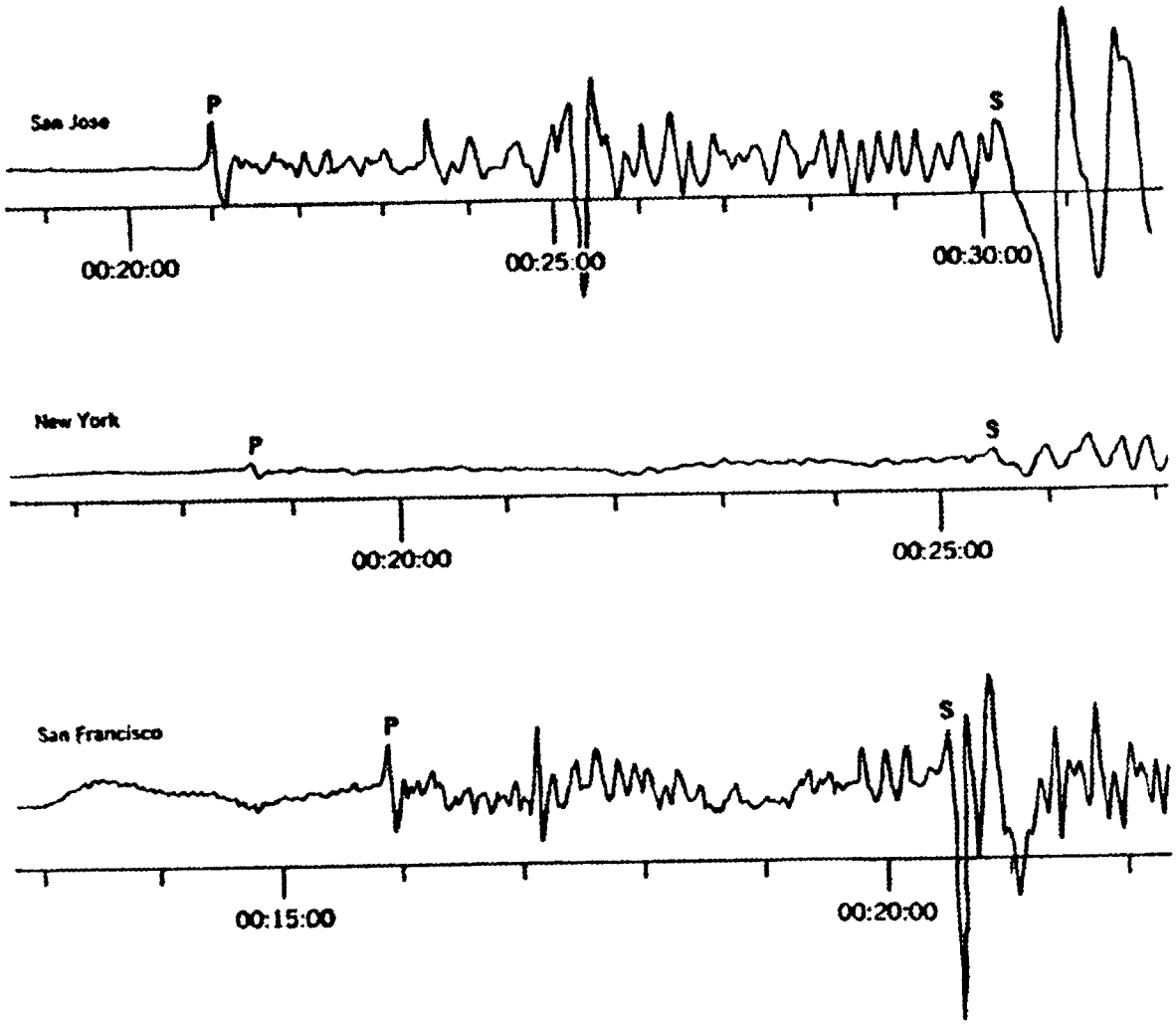
Station Name	Arrival or Clock Time		Difference ($St_a - Pt_a$)	Distance (km)	P travel time (Pt_t)	Time of Rock Rupture ($Pt_a - Pt_t$)
	P-Wave (Pt_a)	S-Wave (St_a)				
San Jose						
New York						
San Francisco						

Locating an Epicenter

REPORT SHEET

PARTIAL SEISMOGRAM RECORDS SHOWING THE SAME EARTHQUAKE AS RECORDED AT THREE DISTANT CITIES

**NOTE: Times are Greenwich Mean Time in the 24-hour system. Time scales for the three cities are not the same.



C. Calculating the origin time

In addition to finding the location of the epicenter, a seismologist also needs to know when the earthquake occurred (origin time). Calculating the origin time also serves as a useful check on the epicenter determination. You have all the information you need to do this. All you need in addition is the travel-time graph. In the table on the Report Sheet, write the distance and P - wave arrival times for the three cities; then, using the graph, determine the travel time of the waves (P_1) and subtract the travel time from the arrival time (P) to find the origin time. As a check on your calculations, note how closely the three computed origin times agree.

Questions:

1. What is the difference between an epicenter and a focus?

2. Give at least 2 ways that P - waves differ from S - waves.

3. What is a seismogram - a seismograph - a seismologist?

4. What is meant by the S - P interval?

5. Why is it necessary to know the distance to the epicenter of an earthquake from three different recording stations?

6. How long does it take for a P-wave to travel from the focus of an earthquake to a seismograph station 2000 km away?

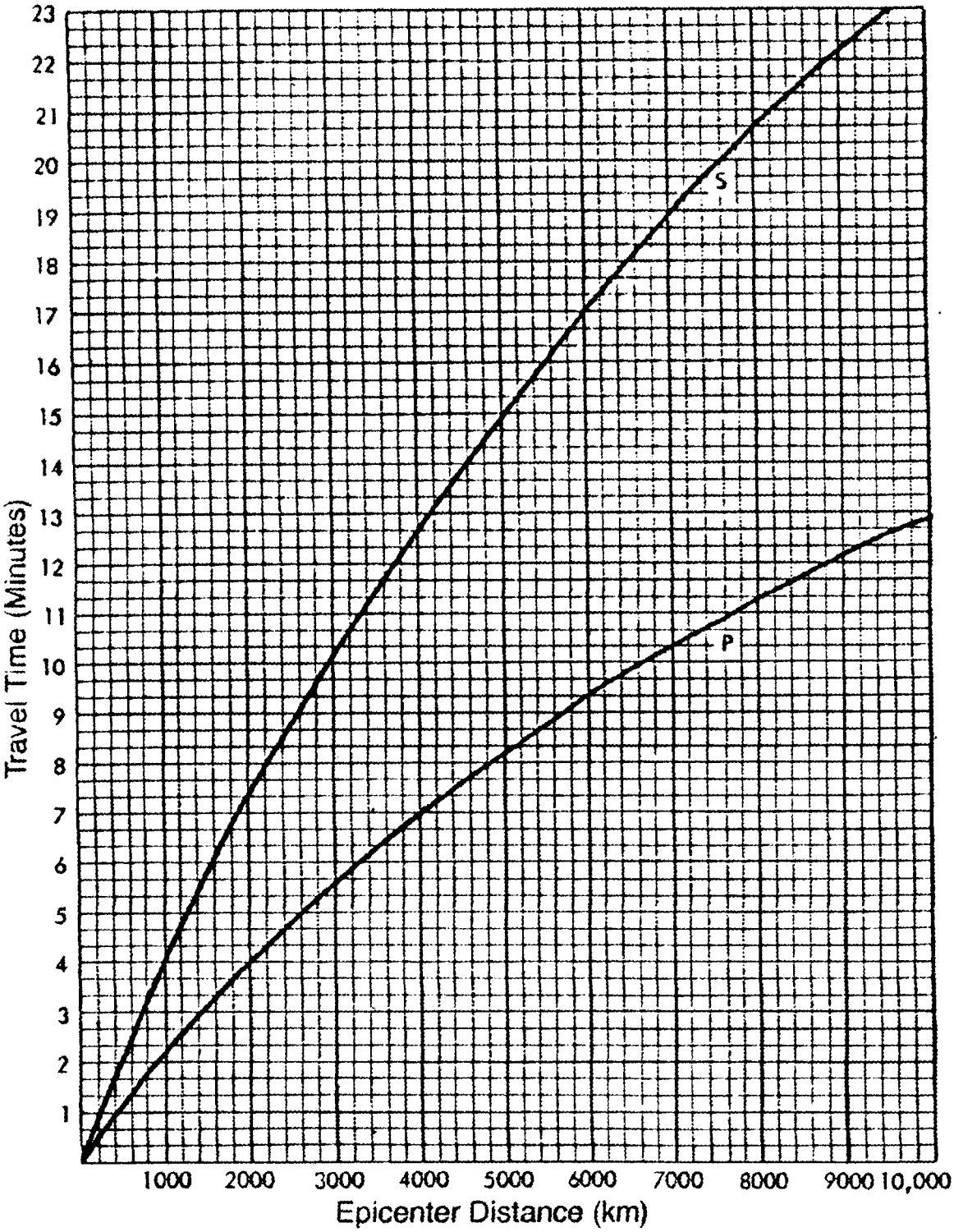
7. How long does it take for an S-wave to travel the same distance?

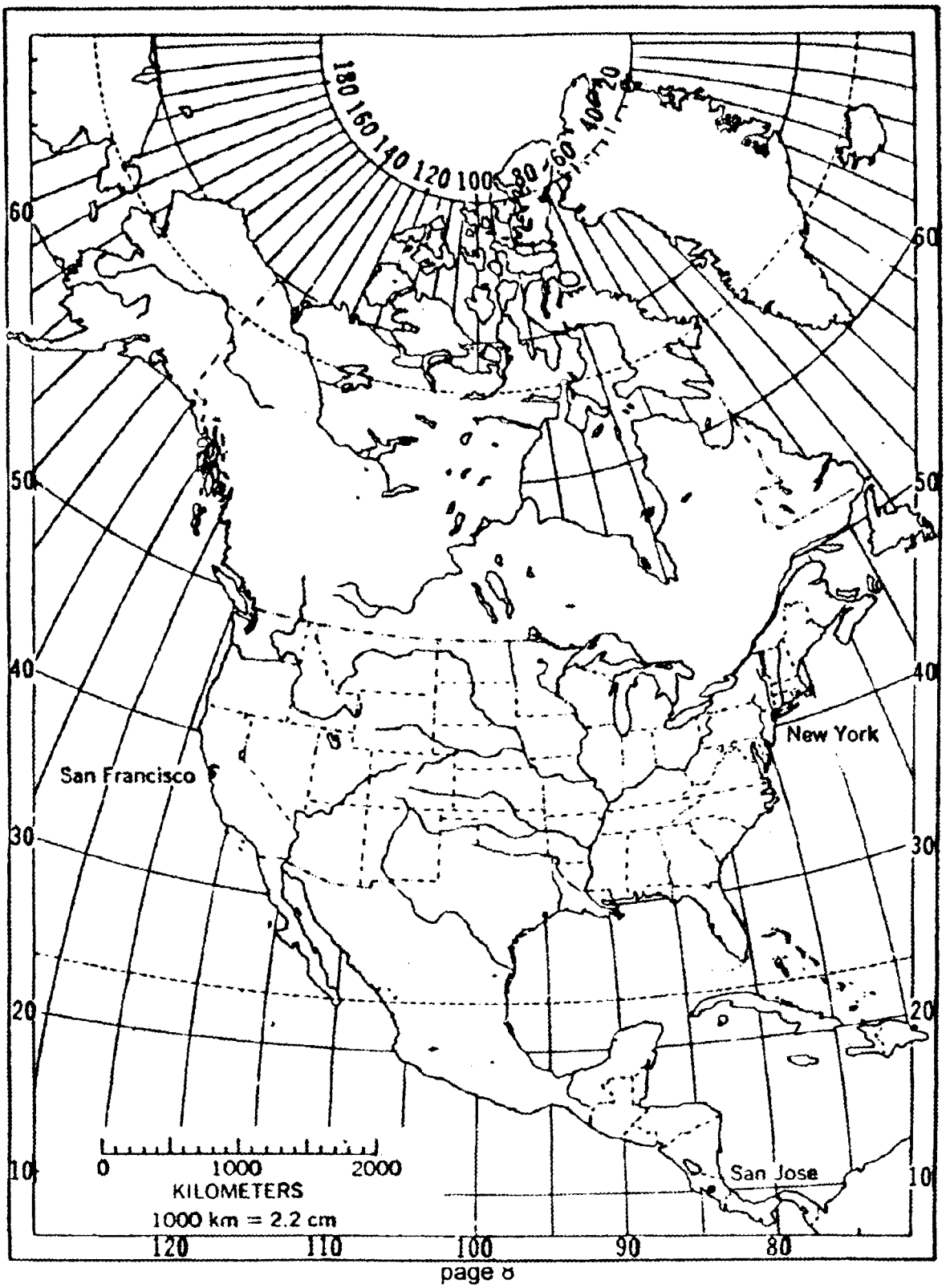
8. What is the difference in arrival time between P and S-waves for an earthquake that is 3000 km away from the recording station? 5000 km from the recording station?

   3000 km _____ 5000 km _____

9. How is the distance of a seismograph station from the earthquake related to the arrival time of the P - and S - waves?

TRAVEL TIME OF P AND S EARTHQUAKE WAVES




180 160 140 120 100 80 60 40 20
60
50
40
30
20
10
San Francisco
New York
San Jose
0 1000 2000
KILOMETERS
1000 km = 2.2 cm
120 110 100 90 80