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Find the Epicenter of an Earthquake

Student Activity Kit

Introduction

On October 17, 1989, as the Oakland Athletics and San Francisco Giants were warming up in Candlestick Park for the third game of the World Series, a major earthquake struck the area. *Seismologists,* individuals who study earthquakes, determined the origin of the quake was located near Loma Prieta Peak in the Santa Cruz Mountains. Discover how the "starting point" of an earthquake is determined.

Concepts

- Earthquakes
- Epicenter
- P-waves versus S-waves
- Seismic waves

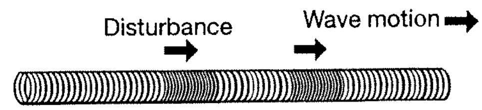

Figure 1.

Background

The rocky plates that make up the Earth's crust are in constant motion. The interactions of these plates create *faults,* or cracks, that offset the Earth's crust. Continuous movement of the plates builds up pressure until the rocks along a fault shift or break, releasing energy that causes an *earthquake.* This is similar to what happens when you snap your fingers. The force between your fingers increases until the fingers suddenly slide past each other. The "snap" is caused by the release of energy in the form of sound waves. Energy from an earthquake is transmitted through the Earth in the form of vibrations known as *seismic waves* (from the Greek word *seismos,* to shake or quake).

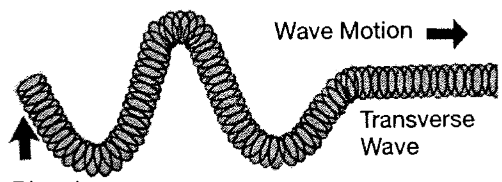

Figure 2.

Two types of seismic waves travel outward from the *focus* (origin within the Earth) of an earthquake. The primary wave, or *P-wave,* is a compression wave that forces rock to compress and expand in the same direction the wave travels (see Figure 1). P-waves travel through the Earth at an average speed of about 5 kilometers per second. Secondary waves travel at a slower rate, averaging about 3 kilometers per second. Secondary or *S-waves* are transverse waves in which the vibrations displace matter perpendicular to the direction the wave is moving (see Figure 2). Primary and secondary waves are called body waves since they travel through the body of the Earth. Once these vibrations reach the Earth's surface, the energy is transmitted as *surface waves.* These waves travel more slowly than body waves and cause the most destruction as the earth moves up and down, like an ocean wave, and also from side to side.

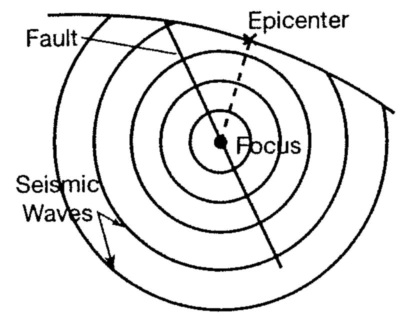

Figure 3.

The *epicenter* of an earthquake is the point on the Earth's surface directly above the focus (see Figure 3). Knowing how seismic waves travel enables seismologists to determine the location of the epicenter of an earthquake. Vibrations from seismic waves are detected by instruments called seismographs and recorded on seismograms all over the world. The faster P-waves are detected first, followed by the S-waves (see Figure 4). The greater the delay between the arrival times of the two waves, the farther the waves have traveled. Think of two runners on a track, where one is running consistently faster than the other. The distance between the two runners will gradually increase as the race continues.

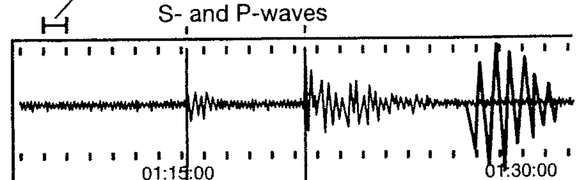

Figure 4. Seismogram

Once the delay time between the P-wave and S-wave is known, the distance the waves have traveled can be determined using a graph. The direction from which the waves traveled, however, is unknown until data is collected from at least three seismograph stations. Circles are drawn around each station on a map, with the radius of the circle representing the distance the waves have traveled from the epicenter. The intersection of the three circles marks the epicenter of the earthquake.

Experiment Overview

The purpose of this activity is to locate the epicenter of an earthquake that occurred somewhere in the United States at 5:48 a.m. The time delay between the arrivals of the P- and S-waves at various seismograph stations around the country will be calculated and the distance from the epicenter will be determined for each station.

Pre-Lab Questions *(Answer on a separate sheet of paper.)*

1. Compare and contrast primary and secondary waves.
2. Why must data be obtained from at least three seismograph stations to locate the epicenter of an earthquake? *Hint:* Draw two intersecting circles (like a Venn diagram) to see how many points of intersection are formed.
3. Vibrations from a primary wave were detected on a seismograph at 2:04:54 p.m. The secondary wave arrived at 2:09:13 p.m. Determine how much time in *seconds* elapsed between the arrivals of the two waves.

Materials

Calculator (optional)
Compass, drawing
Pencil
Ruler, metric
Seismic Waves Graph
Time Delay Scale, 1″ × 5″
United States Map

Safety Precautions

The materials used in this activity are considered safe. Please follow all classroom safety guidelines.

Procedure

Part A. Calculating the Time Delay and Distance

1. Using the data from the Find the Epicenter Worksheet, calculate the difference in time (T_{S-P}) between the arrival of the P-wave and the S-wave for each city. Record the time delay in seconds in the data table.
2. Obtain a card with the time delay scale. Carefully fold the card back on the dotted line. Crease the fold.
3. Note the delay time for the first seismograph station, New York.
4. Using a pencil, make a small mark on the time delay scale corresponding to the delay time for New York. See Figure 5.
5. Obtain a Seismic Waves Graph. Place the time delay scale along the *y*-axis (Time) of the graph, matching the zero point on the time delay scale with the zero on the graph.
6. Slowly move the time delay scale along the curved line representing the P-wave data, keeping the scale vertical and the zero point of the scale on the P-wave line.

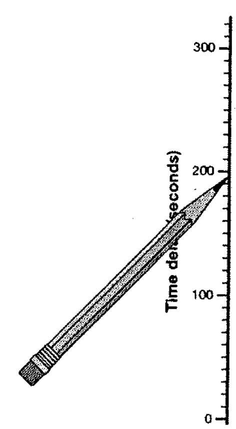

Figure 5.

7. Stop when the pencil mark on the time delay scale reaches the curved line representing the S-wave data. Make sure the time delay scale is straight vertically, the pencil mark is on the S-wave line, and the zero point is on the P-wave line (see Figure 6).
8. Follow the vertical edge of the time delay scale down to the *x*-axis (Distance) on the graph. This point represents the distance from the epicenter to the seismograph station for that particular time delay. In Figure 6, the distance is approximately 780 km.

9. Record the distance to the nearest hundred kilometers in the data table on the worksheet.
10. Repeat steps 3–9 using the data for each seismograph station.

Part B. Locating the Epicenter

11. Obtain a map of the United States. Note the map scale (1 cm = 200 km). Convert each distance recorded on the data table in kilometers to centimeters by dividing the distance in kilometers by 200. Record each value as "map distance" in the data table.
12. Choose one seismograph city on the map and obtain a drawing compass.
13. Using the scale on the map or a metric ruler, set the compass to the proper radius in centimeters. *Note:* The radius is the distance from the epicenter to the seismograph station.
14. Placing the point of the compass on the selected city, lightly draw a circle in pencil around the city, being careful to keep the compass set at the proper distance. *Hint:* Depending on the type of compass, it may be easier to hold the compass still and rotate the map.
15. As a check, measure the radius of the drawn circle to see if it is the same as the distance recorded in the table. If not, erase the circle, adjust the compass, and draw the circle again.

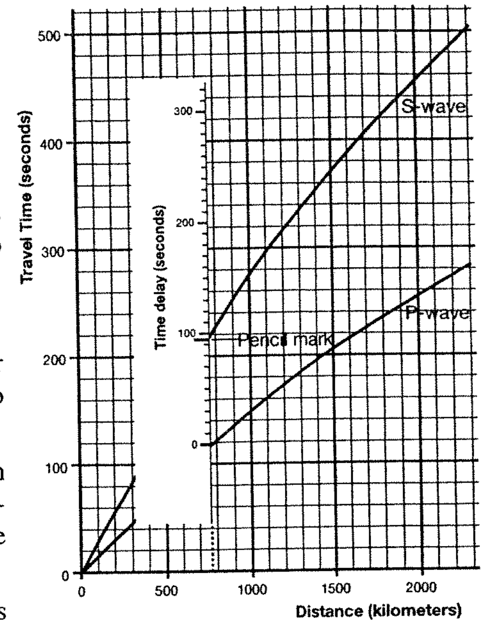

Figure 6.

16. Repeat steps 12–15 for at least two more stations.
17. Circle the area on the map where the circles from the three cities intersect. Label this area "Epicenter." *Note:* Three or more circles may not intersect at precisely one point; however, they should cluster together in a small area.
18. Answer the *Post-Lab Questions*.

Name: ______________________________

Find the Epicenter Worksheet

Data Table

Seismograph Station	P-wave Arrival Time (hr:min:s)	S-wave Arrival Time (hr:min:s)	Time Delay T_{S-P} (s)	Distance to Epicenter (km)	Map Distance (cm)
New York, NY	5:52:40 a.m.	5:55:18 a.m.			
Louisville, KY	5:49:20 a.m.	5:50:11 a.m.			
Green Bay, WI	5:50:20 a.m.	5:51:52 a.m.			
Pueblo, CO	5:52:00 a.m.	5:54:21 a.m.			
Phoenix, AZ	5:54:40 a.m.	5:58:00 a.m.			

Post-Lab Questions

1. Near what major city is the epicenter located? (Look at a more detailed map of the United States, if necessary.)

Use the Seismic Waves Graph to answer Questions 2 and 3.

2. A seismograph station is 3000 kilometers away from the epicenter of an earthquake. How many seconds after the arrival of the P-wave would the S-wave arrive?

3. What happens to the distance between the P-wave line and the S-wave line as the distance from the epicenter increases? Why is this so?

4. Describe the difference between the focus and the epicenter of an earthquake.

5. Why is useful to know the location of the epicenter once an earthquake has occurred?

Find the Epicenter
Seismic Waves Graph