3.4 Explore

**How Do Scientists Find the Epicenter of an Earthquake?**

Seismograph data says that the earthquake is 100 km (62 mi) away, but at which point on the circle is the earthquake located?
When an earthquake occurs, the seismic waves move out from its focus in all directions. Finding the exact location of the epicenter is very important, both to study the earthquake and to know what might happen next. To find the epicenter, scientists must have data from several seismograph locations. Seismologists have made it easy to identify the epicenters of earthquakes by placing seismographs all over the world and recording their data in files that scientists around the world can examine. After an earthquake occurs, seismologists look at the data files to determine which seismic data they need for their calculations.

**Conference**

The map shows the Chilean coast where the largest earthquake ever recorded hit in 1960. A seismic station near the coast has received the P and S waves, and the data has been recorded on the seismogram. Using the map, determine where the epicenter of the earthquake might be.

Discuss in your group where you each think the epicenter of the earthquake is. Make sure that each member of your group describes in detail why they have located the epicenter in that place.

**Reflect**

1. What disagreements did you have in your group about where the epicenter is?

2. Did you have enough data to make a good judgment about the epicenter?

3. How might you get more data to make a more accurate judgment?

There may have been disagreements in your group about where the epicenter of the earthquake was. It is impossible to know where an earthquake’s epicenter is by looking at the P waves and S waves at only one station. One set of data tells you only how far away an earthquake is from the station, but it cannot tell you the direction from which the waves came. The epicenter could be located at any point in any direction that is the right distance from the seismograph. You need more information to pinpoint the location of the epicenter.
Procedure

Your task is to determine the epicenter of an earthquake in the United States. P and S waves travel differently and move at different speeds. The difference between the arrival times of these two wave types is the most important data scientists use to determine the epicenter of an earthquake.

You will be given data from seismograph stations in the United States. From the data, you will calculate the distance from each city to an earthquake’s epicenter, and then you will be able to determine the epicenter itself.

Part One: Salt Lake City, Utah

Seismograph Station

One station that reported seismic activity from this earthquake is in Salt Lake City, Utah. The difference in arrival times between P and S waves is 3 min and 10 s.

Using the graph on the following page, follow these steps to determine the distance from the seismograph in Salt Lake City to the earthquake’s epicenter. The y-axis of the graph represents differences in arrival times. The x-axis represents distance to an earthquake’s epicenter. Every horizontal marking on the y-axis of the graph represents one minute. Every vertical marking on the x-axis represents 1000 km (about 620 mi).

1. The difference in arrival time between the waves in Salt Lake City is 3 min, 10 s. Find this time on the y-axis. You will have to estimate.

2. Follow this time to the right until you intersect the curve on the graph. Use a straight edge to make sure you have found this point accurately.

3. Identify the value of the point on the curve on the x-axis. You can do this by using the straight edge to follow the point down to the x-axis. The number you get to on the x-axis represents the distance from the seismograph station to the epicenter.

You should find that the distance is 2000 km (about 1240 mi). This means the epicenter of the earthquake is 2000 km (about 1240 mi) from the seismograph in Salt Lake City.
4. Use the instructions below to draw a circle on the map to indicate 2000 km (about 1240 mi) from Salt Lake City.

a. Set your compass at a radius equal to 2000 km (about 1240 mi) using the scale on the map. Do this by placing the point of your compass on the mark at 0. Open the compass until the tip of your pencil is at 2000 km (about 1240 mi). Make sure you are reading the scale in km. Lock your compass at this distance.

This graph shows the difference in arrival times between P and S waves at different distances from the epicenter of an earthquake.
b. Draw a circle on your map by placing the point of your compass on Salt Lake City and rotating the compass to draw a complete circle. Draw your circle on the map very carefully.

Stop and Think

1. Where is the epicenter of the earthquake? The distance to the epicenter from Salt Lake City is 2000 km (about 1240 mi). How many different places are within 2000 km (about 1240 mi) of Salt Lake City?

2. What do you think should be the next step to determine the epicenter of this earthquake?

Part Two: Houston, Texas
Seismograph Station

1. Another seismograph station is in Houston, Texas. The difference in arrival time between the P and S waves in Houston was 2 min, 0 s.
Repeat the steps from Part One, but use the differences in arrival times for the seismograph station in Houston.

**Stop and Think**

1. Now that you have drawn the circle to show the distance between the epicenter and Houston, what do you now know about where the epicenter was?

2. Do you think you are closer to knowing the location of the epicenter? Why?

3. What do you still need to do?

**Part Three: Savannah, Georgia Seismograph Station**

1. Savannah, Georgia, also reported seismic activity. They reported a difference in arrival times of 1 min, 50 s. Using the same procedure, determine how far the epicenter is from Savannah. Remember to draw the circle carefully so the data are represented accurately on the map.

**Reflect**

1. Where did you determine the epicenter of the earthquake to be?

2. Why were three seismic stations required for you to accurately locate the earthquake’s epicenter?

3. Describe why the epicenter might not always appear as a single point.

4. If someone suggested that you needed to plot the information for one more station, what would be your response?

5. When would seismographs in two different cities record the same difference in arrival times of P waves and S waves?

6. When would a seismograph show no difference in the arrival times of P waves and S waves?

7. How can seismograph information help you determine where plate boundaries are?
Learning Set 3 • What Happens at Plate Boundaries?

Be a Scientist

**Triangulation**
Knowing the distance from one seismograph to the epicenter of an earthquake does not give you the exact location of the epicenter. A seismogram records only the shaking of the seismograph, not the direction from which the seismic waves arrived at the instrument. As you saw, if you draw a circle around a seismograph with a radius equal to the distance to the epicenter, any point on the circle could be the epicenter. This is because all those points are the correct distance from the seismograph. The data from one seismograph provides evidence about where the epicenter might be, but that evidence is not complete enough to know exactly where the epicenter is.

You saw that you needed data from three seismographs to locate the epicenter of the earthquake. After collecting data from one seismograph, you know that the earthquake’s epicenter was somewhere on a given circle. After adding to those data from the second seismograph, you narrowed down the epicenter to two points. Only after you had data from a third seismograph could you identify exactly where the earthquake occurred. When you combined evidence from three seismographs, the data you needed to determine the earthquake’s epicenter was complete. Scientists call this process **triangulation**. Triangulation is the process of finding an unknown location using its relationship to known locations, such as the distance of the unknown location from known locations. Scientists use triangulation to determine the exact location of an earthquake’s epicenter.

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**What’s the Point?**
Using data from P and S waves, scientists can determine the distance from any seismograph to the epicenter of an earthquake. Using this data and their knowledge of wave speed, seismologists can graph the information. Data from any one seismograph can be used to identify how far away the epicenter of an earthquake is from that seismograph, but it cannot identify the direction of the earthquake. Seismologists need data from three different seismic stations to determine the exact location of the epicenter. This process is called triangulation.