

LOCATE-A-QUAKE

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Purpose

This is a simplified exercise that will let you and your students work with earthquakes the way a seismologist (a person who studies earthquakes) would. You will be able to measure the distance to an earthquake from three recording stations and locate it on a map. You can also learn something about how their intensity shows on an earthquake recording.

Definitions

Earthquake - a sudden motion or trembling of the earth caused by the abrupt release of strain, which has slowly accumulated in the earth. An earthquake is caused by a breaking of rocks and we feel it as waves coming to us through the earth.

P-wave or primary wave - the earthquake wave that is a push-pull wave, alternating compression and expansion in the direction in which the wave is moving. Its speed is 5.5-7.2 km/sec in the crust of the earth so it is the first, or primary, wave to reach us. Take a Slinky and stretch it between two people, bunch several coils at one end and then let them go. The wave moving along the slinky is a P-wave. Sound is a P-wave.

S-wave or secondary wave - the earthquake wave that is a shake wave, the wave moves up and down as it moves through the earth. Its speed is 3-4 km/sec in the crust of the earth, it is the second wave to reach you. If you take a length of clothesline and stretch it loosely between two people, one person shakes their end up and down. The wave moving along the rope is an S-wave. A vibrating string on a violin is an S-wave.

Surface Wave - an earthquake wave that moves along the surface of the earth. These are much slower than P- or S-waves. A good example of a surface wave would be an ocean wave. The waves on a body of water move only along the surface.

Fault - a crack in the rocks of the earth. These cracks are caused by the rocks being bent until they break. Like a stick, you can bend rocks a lot before they break. The bending, or strain, builds up over time and then the rock cracks. If the rock has broken once, it can break again along the same fault. Because the surface of the fault is rough and the rock is pressed together by a lot of pressure, a long build-up of strain occurs before the rock breaks again and the break can be violent.

Seismograph - an instrument for measuring earthquakes. It makes a graph (seismogram) of the motion of the earth as it is recorded at the seismograph station, figure 1.

Epicenter - the location of the earthquake.



Figure 1. Seismograph

Teacher Information

The oldest known geologic instrument is a form of a seismograph. It consisted of a large bronze pot with frog sculptures around the lip. In the mouth of each frog was a delicately balanced ball. When an earthquake occurred, the jar would shake and the ball would fall out of the mouth of the frog nearest the direction of the epicenter.

A seismograph is a very simple device, see figure 1. The main part is a large mass hung on a rod at the end of a pivot like a pendulum. A large mass is used so that the pendulum has a large inertia, or resistance to movement. When an earthquake occurs, the earth moves, but the pendulum, because of its inertia, stays still. If you put a pen on the bottom of the pendulum just touching a piece of paper, the earth will move the piece of paper as it moves during the earthquake and the pen will make a line. Move the paper and you will have a seismogram, or a tracing of the movement of the earth under the inertia pendulum. The paper is usually mounted on a rotating drum. Modern seismographs are much more sophisticated, but consist of the same basic parts. The movement of the earth under the pendulum is now amplified electronically and electricity makes the pen move that draws a trace of the earthquake on a drum (see figure 1). In the most sophisticated seismographs, all the earth movements are measured electronically, and then stored, analyzed, and printed by computer.

The size of the wiggly trace on the seismograph is directly related to the size of the earthquake and inversely related to the distance to the epicenter. Remember that the P-wave travels faster than the S-wave. The earth is always vibrating, so a seismogram always shows a wiggly line even when there are no earthquakes. When an earthquake occurs the wiggles become noticeably bigger (figure 2). The P-wave is always the first noticeably larger trace on the seismogram. Then the trace relaxes to the normal earth vibrations. The S-wave is always the second noticeably larger trace. The distance between these two traces on the seismogram is the difference in the time of arrival of the P- and the S-wave. Since we know the speed of the two waves, the distance between the P and the S is a measure of the distance to the epicenter of the earthquake:

The P-wave travels at 6 km/sec and the S-wave at 3 km\sec. These would be average speeds for waves in a granite.

The difference between the velocity of the P- and S-waves = 3 km.

Each inch on the seismogram is one minute.

The distance between the P-wave and the S-wave measured on the seismogram is six inches.
6 inches = 360 seconds.

The distance to the epicenter is 3 km X 360 seconds = 1080 km.

This is only distance, the earthquake could be in any direction. So the distance to the earthquake would have to be drawn as a circle with a diameter equal to 1080 km around the location of our seismograph. To locate the earthquake, we need three seismographs, preferably in a triangle around the earthquake, to locate the earthquake. The following exercise will show how to locate an earthquake and why we need three seismographs.

Equipment

Figures 2 and 3

A ruler

A circle drawing compass or a pencil with a string tied around it to act as a compass.

Student Activity

You may use the following instructions to do this exercise with your class or let the students use the Worksheet on the following page.

1) Figure 2 shows four seismograms of the same earthquake measured at four different cities. The students should first measure the distance between the P- and S- waves on each of the

seismograms. By using the scale at the bottom of the figure, they can translate this distance into miles. Notice that the further the seismograph is from the epicenter, the later the P-wave arrives and the longer the separation between the P- and S-waves.

2) Using the measurements from #1 and the scale on Figure 3, set the compass for the distance between the P- and S-waves on the seismogram for any of the cities. With the point of the compass at the city, draw a circle around the city. Now take a second city, and repeat the process. Notice that the circles intersect at two points. This is why you need a third city.

3) Choose a third city that will make a triangle with the other two. Repeat the process of measuring and drawing the circle and the three circles will intersect at only one point. You have now located the earthquake! Depending on the accuracy of your measurements, the intersection will probably be a small triangle. This used to be called the triangle of error, but is not known to be related to the depth of the earthquake. If you used both Buffalo and Boston, your accuracy will normally not be as good as if you had substituted Montreal or New York for one of them.

You can get a very sophisticated exercise in locating earthquakes called Virtual Earthquake by going to:

<http://www.sciencecourseware.com>

This is an excellent exercise, but is for the more advanced student.

WORKSHEET

John J. Thomas

1) A seismograph is an instrument for measuring earthquakes. Look at figure 1. The heavy weight does not move during an earthquake, but the earth does. The rotating drum moves with the earth. Draw the kind of line that you think the pen would make when an earthquake shakes the earth under the heavy weight.

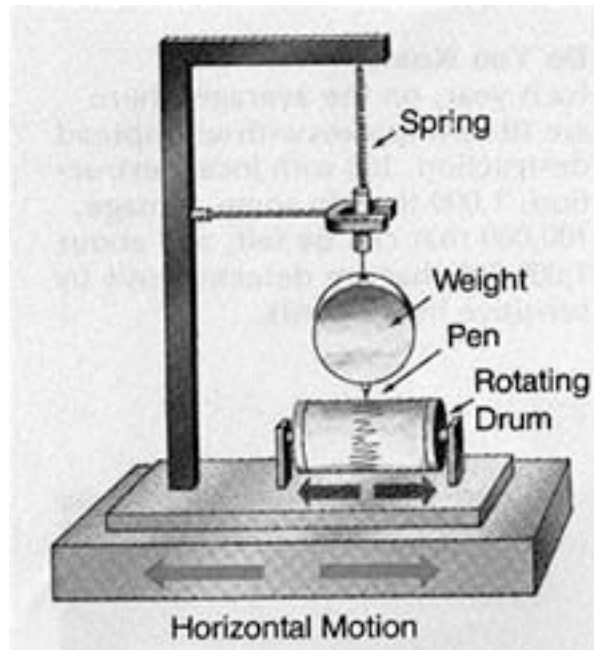


Figure 1. Seismograph

2) Figure 2 shows four seismograms recorded at four different cities. The P-wave (shown as P on the seismograms) is the fastest traveling wave and arrives at the seismograph first. The S-wave (shown as S) is a little bit slower.

The seismograph station nearest the earthquake will receive the P-wave first and will have the shortest distance between the P- and S-waves.

Which city is closest to the earthquake? _____

Which is farthest? _____

3) The distance between the P-wave and the S-wave is the distance of the earthquake from the seismograph. Using a ruler and the distance scale at the bottom of the figure 2, measure the distances from the earthquake to each of the cities.

Boston _____ miles

Buffalo _____ miles

Montreal _____ miles

New York _____ miles

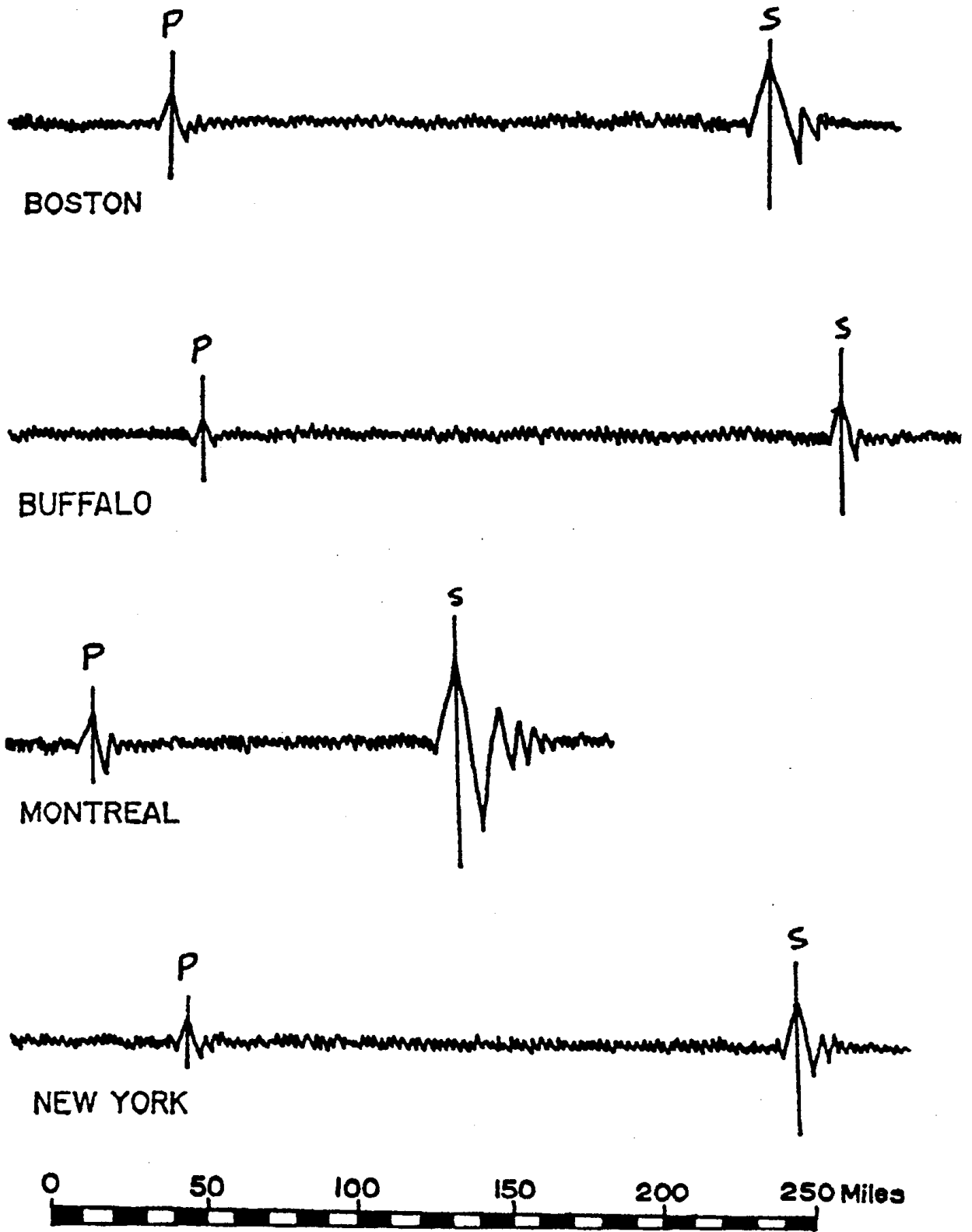


Figure 2. Seismograms for Locate-a-Quake

4) Do the following exercise using figure 3 as your base map and figure 2 as your data.

On the scale on figure 3, set the point of your compass on zero and the point at the correct distance. Without changing this distance, pick up the compass and put the point on the dot

for Boston and draw a circle around Boston. The seismogram only gives us distance, not direction. That is why you draw the distance as a circle.

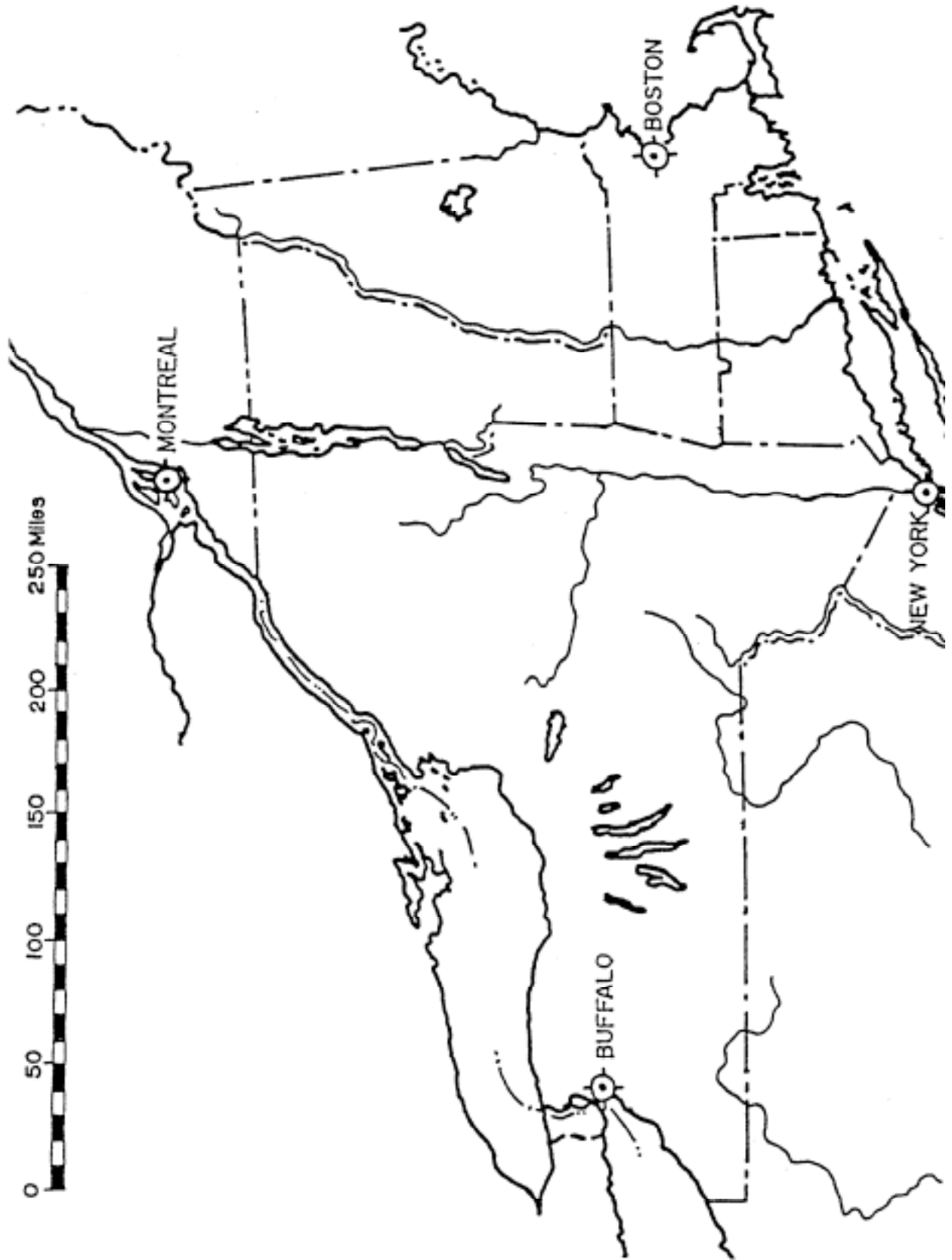


Figure 3. Base map for Locate-a-Quake

Do the same thing for Montreal. Notice that the two circles cross at two points. You are still not sure which of these two points is the location of the earthquake. You need a third seismogram.

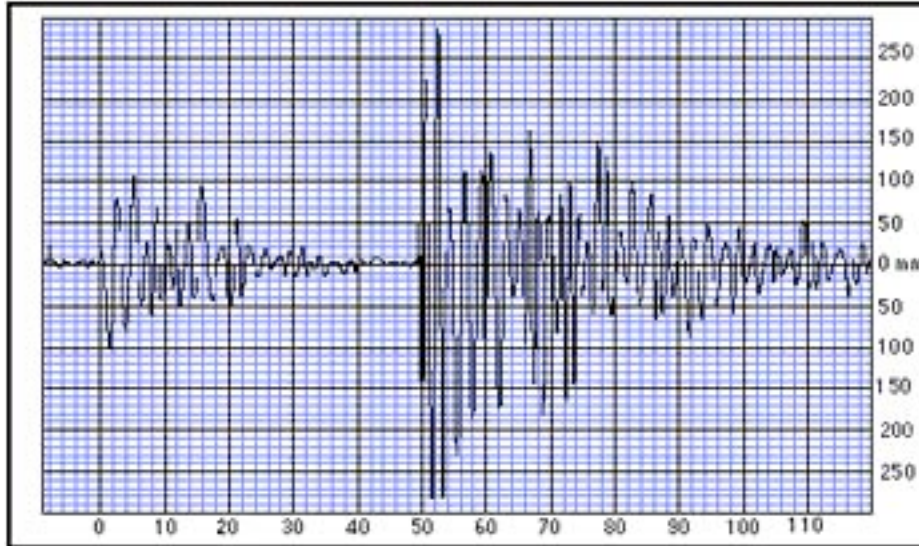
The best arrangement for the seismograms is in a triangle around the earthquake. The worst is a straight, or nearly straight, line through the earthquake. The best city for the third seismogram would be:

Choose your third city, set your compass at the right distance, and draw your third circle on figure 3. There is only one place that all three circles meet. This is the location of the earthquake! Depending on the accuracy of your measurements, the intersection will probably be a small triangle. This used to be called the triangle of error, but is not known to be related to the depth of the earthquake. The earthquake was at Blue Mountain Lake NY and had an intensity of 3.5. It occurred at night. We felt the earthquake in Saratoga Springs as a shaking and rattling of our bed and the entire house. One of my students was in bed in a cabin 50 feet from the epicenter and she was tossed right out of bed onto the floor.

ANSWER SHEET – WORKSHEET

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1) A seismograph is an instrument for measuring earthquakes. Look at figure 1. The heavy weight does not move during an earthquake, but the earth does. The rotating drum moves with the earth. Draw the kind of line that you think the pen would make when an earthquake shakes the earth under the heavy weight.



The correct answer can be any wiggly line it does not have to be as complex as this.

2) Figure 2 shows four seismograms recorded at four different cities. The P-wave (shown as P on the seismograms) is the fastest traveling wave and arrives at the seismograph first. The S-wave (shown as S) is a little bit slower.

The seismograph station nearest the earthquake will receive the P-wave first and will have the shortest distance between the P- and S-waves.

Which city is closest to the earthquake? Montreal

Which is farthest? Buffalo

3) The distance between the P-wave and the S-wave is the distance of the earthquake from the seismograph. Using a ruler and the distance scale at the bottom of the figure 2, measure the distances from the earthquake to each of the cities.

Boston 192 miles.

Buffalo 207 miles.

Montreal 120 miles.

New York 200 miles.

4) Do the following exercise using figure 3 as your base map and figure 2 as your data.

On the scale on figure 3, set the point of your compass on zero and the point at the correct distance. Without changing this distance, pick up the compass and put the point on the dot for Boston and draw a circle around Boston. The seismogram only gives us distance, not direction. That is why you draw the distance as a circle.

Do the same thing for Montreal. Notice that the two circles cross at two points. You are still not sure which of these two points is the location of the earthquake. You need a third seismogram.

The best arrangement for the seismograms is in a triangle around the earthquake. The worst is a straight, or nearly straight, line through the earthquake. The best city for the third seismogram would be:

New York

Choose your third city, set your compass at the right distance, and draw your third circle on figure 3. There is only one place that all three circles meet. This is the location of the earthquake! Depending on the accuracy of your measurements, the intersection will probably be a small triangle. This used to be called the triangle of error, but is not known to be related to the depth of the earthquake. The earthquake was at Blue Mountain Lake NY and had an intensity of 3.5. It occurred at night. We felt the earthquake in Saratoga Springs as a shaking and rattling of our bed and the entire house. One of my students was in bed in a cabin 50 feet from the epicenter and she was tossed right out of bed onto the floor.