Magnitude and Intensity: How "Hard" Does an Earthquake Shake?

***Putting Down Roots*, pp. 14-15**

Idaho State Standards:

Earth Science 1.2.1-.3, 1.3.1-.3, 1.6.2-.7, 1.8, 5.2
8th Mathematics 2.1, 3.1.1, 3.5.1, 4.3, 5.1.1-.3, 5.2.1, 5.3.1-5.3.2, 5.4.1-.4, 5.5.1-.3
9th Mathematics 1.2, 2.3, 2.4.1, 3.2, 3.5, 3.6, 4.3, 4.4, 5.1, 5.2, 5.4, 5.5

Objectives:

Students will be able to:

1. Explain how the magnitude of an earthquake, like the dropped water bottle, is tied to the physical properties of a fault and how acceleration is related to the intensity of ground motion.
2. Calculate the amount of energy released when a weight (water bottle) is dropped from different heights.
3. Students will be able to explain the information expressed in a three-component seismogram, particularly direction of motion, peak absolute amplitude and accelerations.
4. Explain several factors that contribute to the intensity of shaking at a particular location.
5. Interpret a Shake Map from the USGS.

RATIONALE

This activity describes the differences between an earthquake's magnitude and intensity. Students calculate the energy released during a weight drop (magnitude) and use an accelerometer (iPhone, QCN sensor, or other) to investigate what happens to this energy as the source is moved further and further from the sensor (intensity). Students examine USGS Shake Maps to explore other factors that, in addition to event size and distance from the source to the receiver, affect the intensity (e.g. structures, land composition, etc.).

FOCUS QUESTION(S):

- How hard does the ground shake during an earthquake?
- What does an accelerometer measure? How can it be used to measure an earthquake?
- What is earthquake intensity?
- How is earthquake intensity measured?

TEACHING CLUES AND CUES

Teachers will need to have access to an accelerometer for one of the activities. There are smartphone apps for accelerometers or a sensor can be ordered from Quake Catchers Network. This lesson can be done as a teacher demonstrated lab using one sensor. If more sensors are available, the activity can be done as a student centered lab. If the lab is student centered, it is important to separate each station from other stations to avoid any station's data interfering with another station. A constant weight is needed. Drop a water bottle weighted with sand from a set height. These are inexpensive, are easily weighted, and provide an easy way to create a consistent source throughout the activity.

Activity 2 does not require an accelerometer but uses the shake map from the USGS site and pages 14-15 from the BHS booklet *Putting Down Roots in Earthquake Country*. The shake map needs to be printed in color. You may want to go to the USGS ShakeMap Atlas and download other maps for comparison. The Atlas starts with 2007 earthquakes. A classroom set can be printed and put in protective covers. Students should be shown the three videos listed in the Materials section with the web addresses where they can be found. Have students look for the different types of motions that are displayed by observing the way objects move. These video clips of the house shaking had a peak acceleration of about 1g.

Note: The footage from the first video listed shows a two story house being tested by a simulated earthquake on a shake table at the University of California at San Diego on July 11, 2000. The test examined the effects of severe ground shaking on a structure with strong construction. The goal was to verify that a new house conforming to all building code regulations and specially engineered can escape with little damage from such an earthquake.

Students also need to understand a three-component seismogram. A three-component seismogram will show motion up and down or vertical, horizontal North – South (front to back), and horizontal East – West (side to side). Examples of these seismograms can be found at http://rev.seis.sc.edu/. On the left side of the webpage, select a "Recent Earthquake." On the next screen, select a station from the list below the seismograms. The following screen will show a three component seismogram--Vertical, North – South and East – West (see p. 45 for a sample).

MATERIALS:
for teacher

- Accelerometer and computer (iPhone, QCN sensor USB, or other) QCN sensor purchased ($49.00) from Quake Catchers Network (QCN): (see QCN Sensor folder on the CD-ROM for activities on use of the sensor) http://qcn.stanford.edu/learning/lessons.php
- Download free software for QCN USB sensor at: http://qcn.stanford.edu/downloads/index.php
- Projection equipment

- Download video clips; Kitchen/Office (5.3MB) and child's Bedroom (4.1MB) from http://abag.ca.gov/bayarea/eqmaps/fixit/videos.html
- Download USGS Shake Map of Borah Peak 1983 earthquake from http://earthquake.usgs.gov/earthquakes/shakemap/
- Download video clip of 1995 Kobe, Japan Earthquake (M7.2) http://www.youtube.com/watch?v=0plbf5w0sbA
- Meter stick
- Tape
- Water bottle (filled with sand for weight)
- Data table and graph paper
- Copies of Student worksheet, pp. 39-43

for the students: (work in pairs)

- Student worksheet, pp. 39-43
- Data table and graph paper
- Accelerometer (per group)
- Meter stick
- Water bottle (weighted with sand)
- Lap top computer with downloaded software for QCN USB sensor

PROCEDURE:

Teacher Preparation

1. Set up the QCN accelerometer, so that it is correctly aligned. Place the sensor on the ground and turn until the red line on the compass is lined up with North (indicated by an arrow on the compass). Use the tape provided to secure the sensor in place. Plug the sensor into the USB port of the computer and start the program QCNLive.

2. Click on the "Sensor 2-Dimensional" button (second from the left) to view output from the sensor. Remember you can use the other buttons to zoom in and out in time and to start and stop recording.

3. Practice starting and stopping the sensor's recording.

4. It is important that the water bottle is dropped from the same height throughout the lesson. The magnitude of the earthquake (dropped bottle from same height) does not change.

5. Measure the amplitude of the largest deviation from zero. Zoom in to the seismogram to get an accurate measurement. The amplitude of the wave is the amount of ground shaking referred to as acceleration and a measure of gravity (g).

A. Introduction

Display the geologic map of Idaho. Make sure students know how to interpret the map. Each student should receive at least three locations to analyze, preferably one each in the northern, southwestern, and southeastern sections of Idaho. Reinforce the connection between earthquakes and geology. Give students time to find their cities/towns on the highway map or Atlas and correlate it to the geologic map. A few, but not all, locations are identified on the geologic map.

B. Lesson Development

1. Measure the mass of each of the weighted water bottles.

2. The student worksheet instructions are designed using the QCN sensor and a lap top computer.

3. Students should be able to read a three component seismogram. The teacher background, pp. 44-45, includes a screen capture of a seismogram. Show the Kobe video so that students can observe the arrival of the P, S, and surface waves.

C. Conclusion

Help students to understand that, while the magnitude of the earthquake (weight of bottle) remains the same throughout the lesson, the intensity, or amount of shaking, does change, based on distance from the earthquake.

Ask the following questions:

- How much energy was released when you dropped the water bottle?
- Does the energy change depending on where you drop the bottle horizontally?
- How would the graph look different if we increased the mass, height, or both?
- If the energy did not change, why did the amplitude of the wave change? Where did the energy go as the distance from the sensor increased? Answer: Attenuation.

Adaptations and Extensions

Students may want to research probability maps of different areas of the United States, including Alaska and Hawaii Suggest cities located along major rivers, edges of mountain ranges, along coast lines, etc.

Challenge students to see if they can determine the magnitude of the largest probable earthquake in Idaho *(M7.4, due to the types of faults that exist and rock structure in the state).*

Student worksheet

Magnitude and Intensity Lab
(How Hard does the Ground Shake?)

Name____ **Date** __________________________

Introduction

Magnitude: an earthquake's magnitude describes the strength of the earthquake, or how much energy was released during the earthquake. If the earthquake is recorded by several different seismometers at different locations, the seismogram recorded will have different amplitudes. However, the magnitude of the earthquake will not change. Magnitude is measured from seismograms.

Intensity: A measurement of earthquake intensity describes how much ground motion was felt at a specific location. For a single earthquake, the amount of ground motion will be different at different locations. Often, the highest intensity is closest to the earthquake. You do not feel earthquakes that are very far away, but that does not mean they are small! The intensity at your location is just very low. Intensity is measured based on what people felt and what was damaged.

Introductory Questions:

1. How hard does an earthquake shake the ground?

2. Describe what the display of the accelerometer shows. What units does it measure in?

3. What factors might influence the amount of shaking from an earthquake?

Experiment with the accelerometer

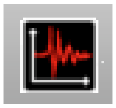
Materials:

- Accelerometer with USB cable and software downloaded onto computer
- Tape
- Meter stick
- Data table and graph paper
- Water bottle (weighted)
- Student worksheet

Set-up:

1. Set up the accelerometer so it is correctly aligned. Place the sensor on the ground and turn until the red line on the compass is lined up with North (indicated by an arrow on the compass). Use the tape provided to secure the sensor in place. Plug the sensor into the USB port of the computer, and start the program QCNLive.

2. Click on the "Sensor 2-Dimensional" button (second from the left) to view output from the sensor. Remember you can use the other buttons to zoom in and out in time and to start and stop recording. Practice starting and stopping the sensor's recording. Determine the units of measurement.



3. Practice zooming in and measuring the amplitude of the recording with the greatest deviation from zero.
4. Use a meter stick to determine the height from which the water bottle will be dropped (not over 1 meter). It is important that this height be consistent throughout the lab.
5. Position the water bottle .2m from the sensor.
6. Begin recording with the accelerometer, then drop the bottle.
7. Look at the resulting seismograms generated (it might help to pause the recording in order to look at the graph).
8. Record the absolute value of the largest wave deviation from zero in your data table.
9. Repeat steps #5 through #8 two more times at this same distance.
10. Next move the distance the water bottle will be dropped from the sensor to the next position indicated in the data table.
11. Collect three trials of data at this position.
12. Repeat steps #10 & #11 until the sensor no longer detects the energy from the dropped water bottle.
13. Average the data collected in the three trials to complete the data table.
14. Graph the average amplitude of ground motion (vertical axis) vs. distance between sensor and water bottle dropped (horizontal axis) on the graph provided. Make sure you follow graphing conventions as required.

Examining the data:

1. How much energy is released when the water bottle was dropped? (KE = M*D**g*) KE= kinetic energy, M= mass of water bottle, D= distance bottle was dropped, *g*=acceleration due to gravity ($10 m/s^2$)

2. Does the amount of energy released change depending on its horizontal position (relative to the sensor)?

3. How does the amplitude recorded by the sensor change as the source moves further and further away?

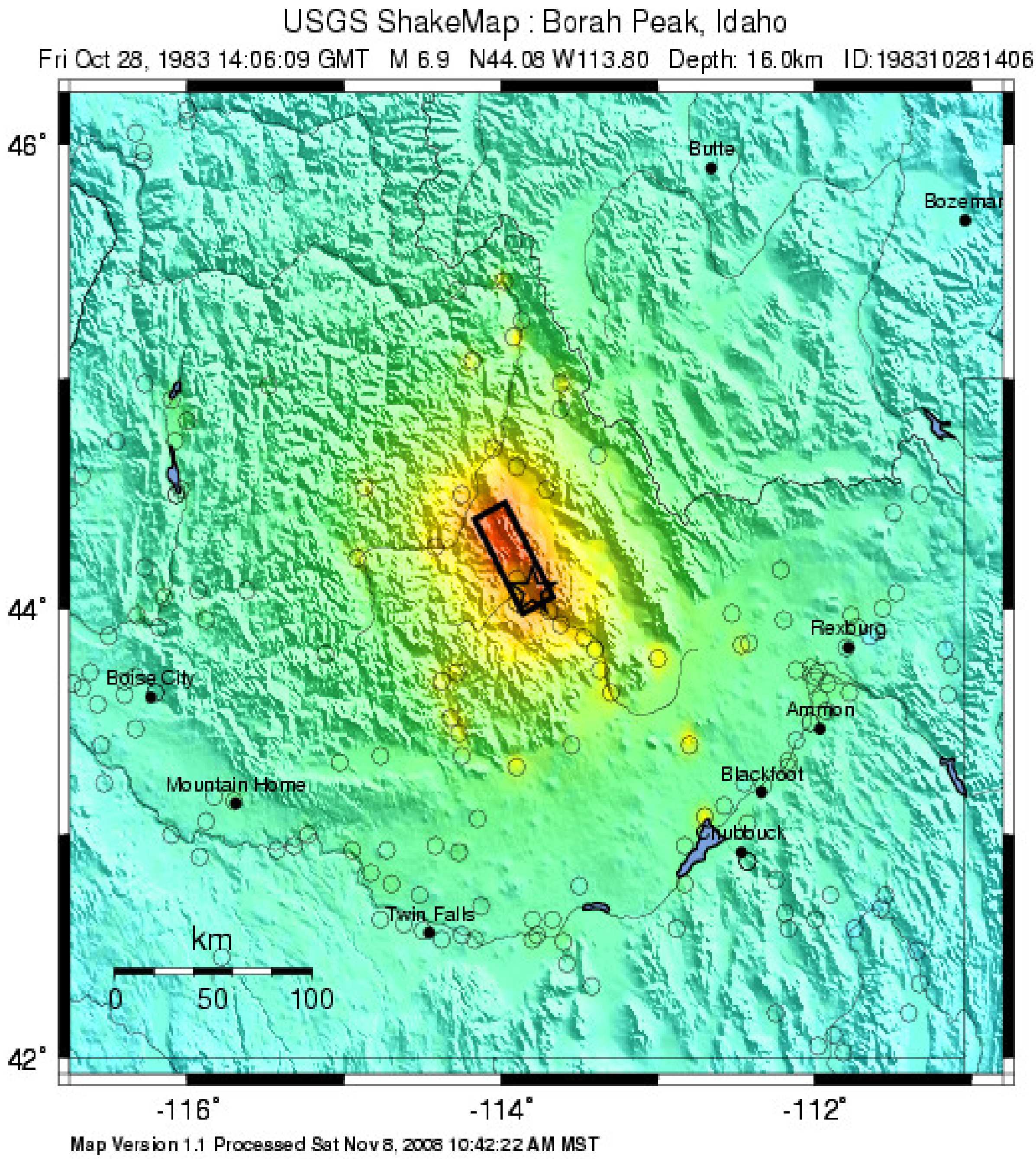
4. How could we modify the experiment to shift the graph upwards or increase the recorded amplitude at each position?

5. When you modify the procedure, as described above, is this equivalent to changing the magnitude of the earthquake or the intensity of the earthquake? Why? (Review the Background Information if you need to.)

6. Drop the same mass from the same height above two different surfaces (e.g. floor and table) with the sensor placed at the same horizontal distance to the source.
   (a) How does the amplitude of the recorded waves compare to each other?

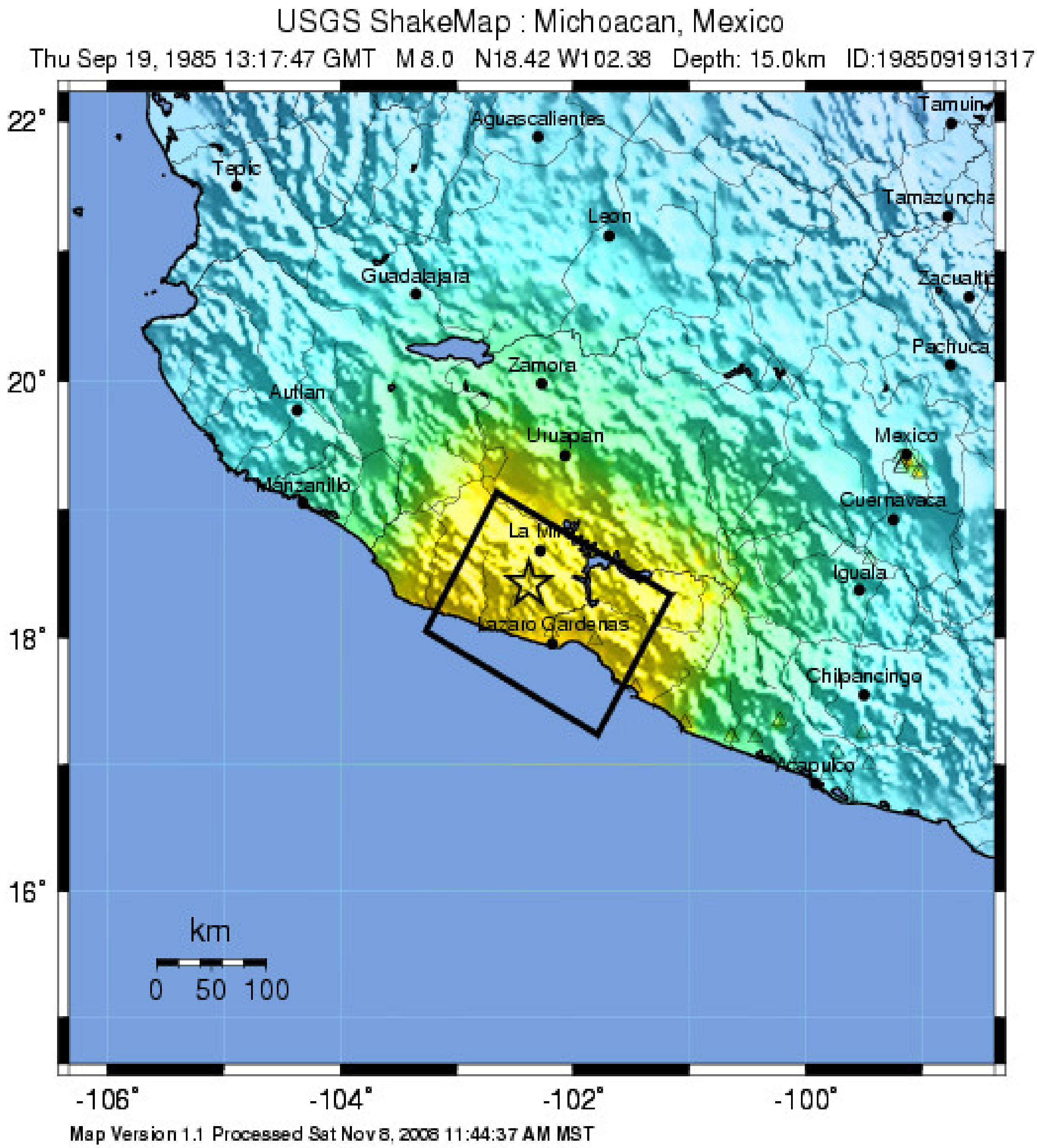
   (b) Examine the Borah Peak ShakeMap below (Figure 1), noting differences in shaking between mountains and valleys near the epicenter. How might your exploration in 6(a) account for this observation?

Figure 1



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 2



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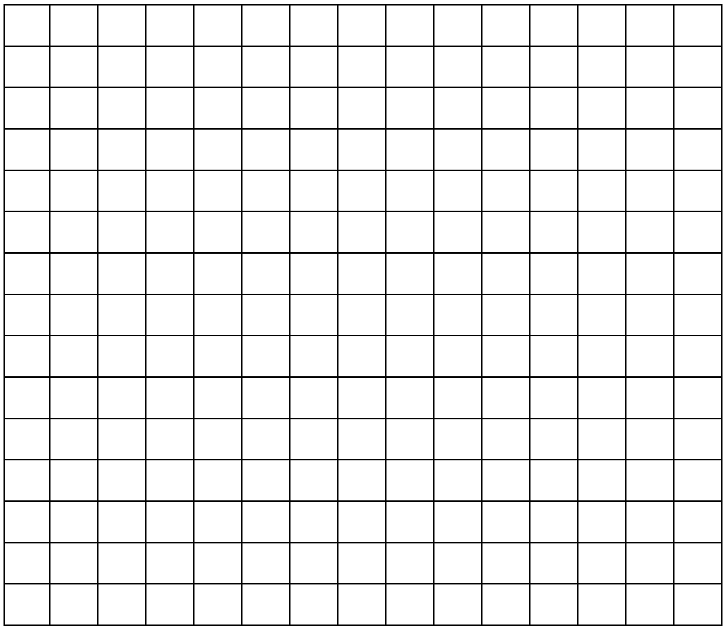
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Data Table

Height of water bottle					
Distance (m)	Height (m)	Trial #1 – Absolute Z axis value	Trial #2 – Absolute Z axis value	Trial #3 – Absolute Z axis value	Average of three trials
0.2					
0.4					
0.6					
0.8					
1.0					
1.2					
1.4					
1.6					
1.8					
2.0					
2.2					
2.4					
2.6					
2.8					
3.0					

Graph



Modified Mercalli Scale

Measuring Shaking: Intensity is a qualitative measure of the strength of ground shaking at a particular site. Currently in the U.S., the Modified Mercalli Intensity Scale is used (see below). Each earthquake that is large enough to be felt will have a range of intensities. Usually (but not always) the highest intensities are measured near the earthquake epicenter and lower intensities are measured farther away. Roman numerals are used to describe intensities to distinguish them from magnitudes. For example, the magnitude of the Borah Peak earthquake was 6.9. The intensities ranged from IX (violent) close to the epicenter, to V (moderated)at a distance of about 126 miles (203 Km) southwest in Caldwell and a III (weak) at Teton also at a distance of 126 miles, but southeast of the epicenter (USGS).

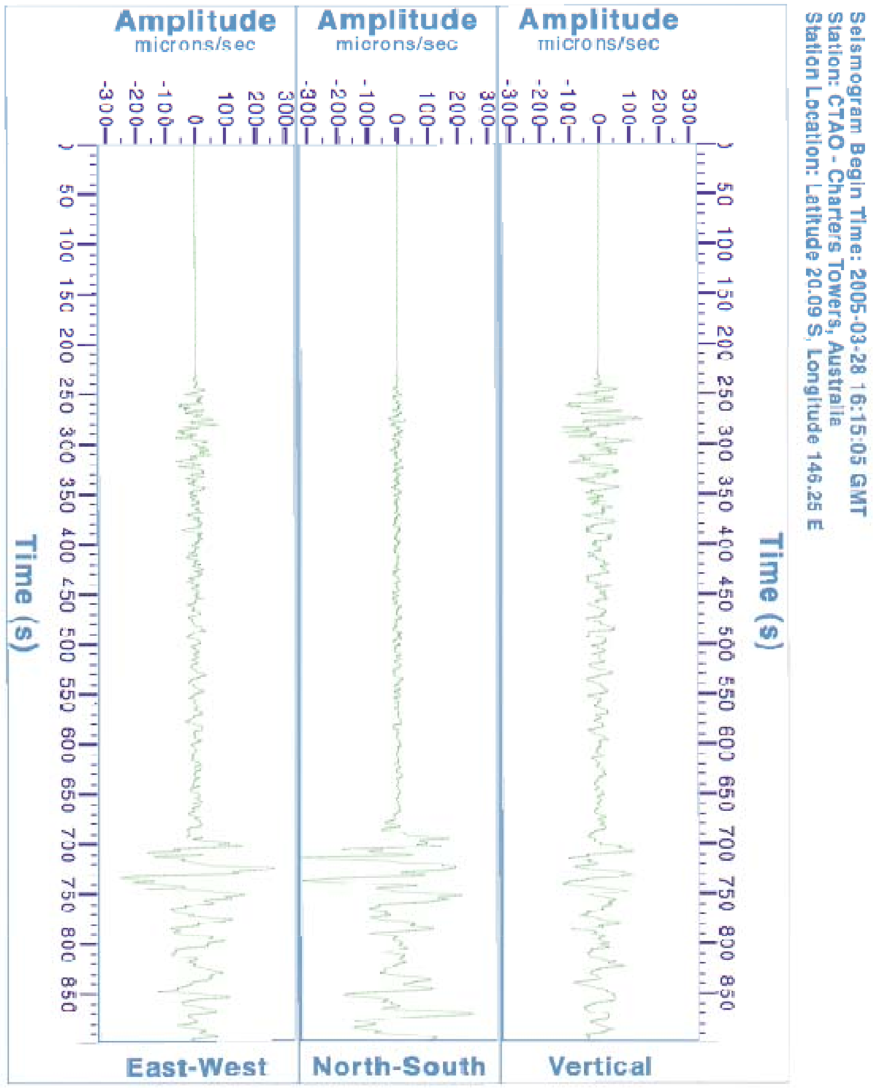
Modified Mercalli Intensity	Acceleration (g)	Description of Intensity Level
I	<0.0017	Not felt except by a very few under especially favorable circumstances.
II	0.0017	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	0.014	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.
IV	0.014 – 0.039	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	0.039 – 0.092	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	0.092 – 0.18	Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	0.18 – 0.34	Damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars.
VIII	0.34 – 0.65	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	0.65 – 1.24	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	> 1.24	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	> 1.24	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII	> 1.24	Damage total. Lines of sight and level distorted. Objects thrown into the air.

Adapted from Richter, C 1958, and Wald et al, 1999

Teacher Resource- Three Component Seismogram

Sample Three-Component Seismogram – 3/28/05 N. Sumatra M 8.7

To connect the seismograms that students have studied to actual earthquake ground motion, re-show the 1995 Kobe earthquake (7.2M) video clip "Earthquake in Kobe, Japan," found at http://www.youtube.com/watch?v=0plbf5w0sbA and challenge students to identify the arrivals of the different seismic waves in the video.



Challenge Answer: At about 1 second into the video clip, "Earthquake in Kobe, Japan," a man who was lying down suddenly sits up, so that his head appears in the bottom center of the screen. He likely was awakened by the P wave. At approximately 4 seconds into the video clip, the first horizontal motion begins. This motion is likely the S wave, either combined with or closely followed by the arrival of surface waves.

Activity #1

What is a Seismometer?
Elementary School Level

Objective
Students will learn that a seismometer detects 3 components of motion and that a seismogram is the record of an earthquake.

Background
Prior to this activity, students should be introduced to the basics of earthquakes. Curriculum for this can be found at http://www.redcross.org/disaster/masters/
This curriculum is designed for k-2, 3-5, and 6-8 grade levels. Other good activities can be found at http://www.dlese.org/ or http://web.ics.purdue.edu/~braile/.

Materials
QCN Demo installed on laptop
LCD projector or monitor
internet access to view video
slinky

Activity
1. Begin with the computer on a level surface.

2. Let students observe the seismic sensor for a few minutes. Encourage them to jump up and down or bang on the table with a fist or drop books.

3. Have students explain what they observe on the screen. What does each graph mean? What is the horizontal axis and the vertical axis? (You may want to avoid using x and y since the directions of the sensor are described by x, y, and z). Where on the graph is the time now? Why does the picture move to the left? Any ideas about the Earthquake Significance graph? What about the trigger line? Let students wonder about the Earthquake Significance for now.

4. Begin to lead students to think about what the purpose of the software is. What do you think this program is designed for? Why? The purpose of the Quake Catcher Network is to detect earthquakes and record the seismic activity on many internet-connected computers to rapidly detect earthquake activity.

5. Ask students if they have ever felt an earthquake. Ask for a few descriptions of what they felt. Use their experiences to introduce the Earthquake Simulation. Explain to the students that they are going to pretend that an earthquake occurs. Read the Earthquake Simulation Script three times.
   Round 1. move in any direction
   Round 2. move up and down only
   Round 3. move side to side only

After wrapping up the Earthquake Simulation, show video clips of a real earthquake. Video from the 2001 Earthquake in Seattle, WA was captured by serveral security cameras and can be see at http://www.classzone.com/books/earth_science/terc/content/visualizations/es1005/es1005page01.cfm?chapter_no=visualization or several on Youtube.com.

Earthquake Simulation Script

Imagine that you hear low, rumbling sounds. The noise is getting louder and louder, for just a few seconds. Then you feel a large shake. It's as if you were thrown out of bed, or a truck just hit the side of a building.

The floor or ground is moving beneath you. You move up and down and side to side, shaking and moving every which way. The building is creaking. The trees are swaying. Books fall from the shelves, lights swing, windows may break. Imagine what it feels like as all this chaos is going on. You try to get under your desk to protect yourself from falling and flying objects.

Then it stops. It is quiet. The ground is no longer moving. Everything is a mess.

Ask students how if felt. If they were scared, say that it is ok to feel that way. This is what happens during earthquakes. We build buildings today to withstand earthquakes. Also, we study them to understand how they occur. And with the QCN, we are trying to develop an early warning system for when earthquakes occur for safety reasons.

What direction did they move as the earthquake was occurring? Up and down? Side to side? Was the first jump the biggest and did they get smaller over time?

Repeat with all students going up and down. Then all students going side to side. Make these much shorter than the first.

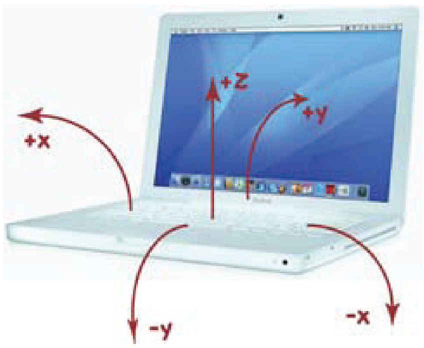
Earthquake Review

Earthquakes happen because of a sudden slip on a fault in the earth's surface where the rock on one side moves up, down, or sideways relative to the other side. An earthquake is felt as a sudden, rapid shaking on the surface of the earth. This shaking can last a few seconds or even a few minutes. The motion causes waves that move through Earth.

Earthquakes are detected with instruments that measure and record the seismic waves. In general, seismologists now use seismometers and digital recorders, rather than the older seismographs (drum of paper spinning with a needle) which are only used for show on TV when there is a big earthquake because the TV channels like to show them. The record or graph is called a seismogram.

6. There are a few kinds of waves generated by earthquakes. A good way to explain P- and S- waves is with a slinky. Have two students sit opposite each other with a slinky pulled taught across the floor between them. When one student pushes their end of the slinky toward the other, it creates a wave like a P wave. When the student pushes the end of the slinky to the right or left, it creates a wave like an S wave.

7. Demonstrate how different motions of the computer are recorded by the sensor. Move the computer in the different directions as shown in the figure. X is the motion from left to right (east to west). Y is the direction from front to back (north to south) and z is the motion up and down (vertical component). Earthquake Significance is a calculated value based on the X, Y, and Z over the last minute. It helps distinguish noise from a real earthquake signal.



Explanation for the Teacher: One way to think about the different directions is to imagine a boat floating at the surface of the ocean. It moves with the ocean waves, up and down, and side to side. The pitch of the boat is the angle from bow to stern (front to back), measured here as the Y component. The roll of the boat is the angle from port to starboard (left to right), measured here as the X component. The sensor measures angular rotation which is a bit more complex than just measuring a linear distance, which is how the vertical component Z is measured.

8. Bring groups of students up to the computer to experience the changing of the measured motion as they move the computer. This gives each student a chance to experience this 3 component system of the motion themselves.

9. While the other students are at their desks, have them write a letter to a friend describing what they felt during the earthquake simulation. Rotate all the students through the experience of moving the computer.

10. Ask students what they learned from their experience with moving the computer. How are the records similar for the computer and the letter that they wrote? What is the EQ Significance? How does that change? What sources of error are there in the classroom? (doors slamming, table shaking, etc)

11. Describe the Quake Catcher Network and how the computer will always be running the program in the background to detect earthquakes. Discuss EQ Significance graph.

Explanation for the Teacher: Earthquake Significance

The Earthquake Significance is a calculated value based on the last 60 seconds to detect significant signals. It helps detect strong new vibrations measured by the laptop's sensor. If EQ Sig is above some level, the laptop informs the QCN server that it has detected a new vibration. It sends the time, amplitudes (x, y, and z) and the EQ Sig. If many laptops tell the server there is a strong shaking all at once, we know it is an earthquake. The QCN server evaluates triggers from 100s to 1000s of laptops. If the QCN server suddenly receives more triggers than expected from a particular area, we know there is an earthquake. If only a few laptops produce triggers in an area, we know that it is probably people bumping their laptops. If successful, it may be possible for anyone participating to learn of a large earthquake before they feel it and take safety precautions.

Activity #1-HS

What is a Seismometer?
High School Level

Objective
Students will learn that a seismometer detects 3 components of motion and that a seismogram is the record of an earthquake.

Background
Prior to this activity, students should be introduced to the basics of earthquakes. Curriculum for this can be found at http://www.redcross.org/disaster/masters/
This curriculum is designed for 9-12 grade levels. Other good activities can be found at http://www.dlese.org/ or http://web.ics.purdue.edu/~braile/.

Materials
QCN Demo installed on laptop
LCD projector or monitor
internet access to view video
slinky

Activity
1. Begin with the computer on a level surface.

2. Let students observe the seismic sensor for a few minutes. Encourage them to jump up and down or bang on the table with a fist or drop books.

3. Have students explain what they observe on the screen. What does each graph mean? What is the horizontal axis and the vertical axis? (You may want to avoid using x and y since the directions of the sensor are described by x, y, and z). Where on the graph is the time now? Why does the picture move to the left? Any ideas about the Earthquake Significance graph? What about the trigger line? Let students wonder about the Earthquake Significance for now.

4. Begin to lead students to think about what the purpose of the software is. What do you think this program is designed for? Why? The purpose of the Quake Catcher Network is to detect earthquakes and record the seismic activity on many internet-connected computers to rapidly detect earthquake activity.

5. Review earthquake basics with students. Show video clips of a real earthquake. Video from the 2001 Earthquake in Seattle, WA was captured by serveral security cameras and can be see at http://www.classzone.com/books/earth_science/terc/content/visualizations/es1005/es1005page01.cfm?chapter_no=visualization or several on Youtube.com.

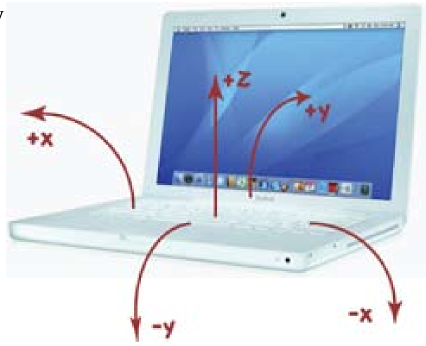
Earthquake Review

Earthquakes happen because of a sudden slip on a fault in the earth's surface where the rock on one side moves up, down, or sideways relative to the other side. An earthquake is felt as a sudden, rapid shaking on the surface of earth. This shaking can last a few seconds or even a few minutes. The motion causes waves that moves through Earth. The first waves are compressional waves, also known as primary or P waves, travel fastest, at speeds between 1.5 and 8 kilometers per second in the Earth's crust. Shear waves, also known as secondary or S waves, travel more slowly, usually at 60% to 70% of the speed of P waves.

Earthquakes are detected with instruments that measure and record the seismic waves. In general, seismologists now use seismometers and digital recorders, rather than the older seismographs (drum of paper spinning with a needle) which are only used for show on TV when there is a big earthquake because the TV channels like to show them. The record or graph is called a seismogram.

6. There are a few kinds of waves generated by earthquakes. A good way to explain P- and S- waves is with a slinky. Have two students sit opposite each other with a slinky pulled taught across the floor between them. When one student pushes their end of the slinky toward the other, it creates a wave like a P wave. When the student pushes the end of the slinky to the right or left, it creates a wave like an S wave.

7. Demonstrate how different motions of the computer are recorded by the sensor. Move the computer in the different directions as shown in the figure. X is the motion from left to right (east to west). Y is the direction from front to back (north to south) and z is the motion up and down (vertical component). Earthquake Significance is a calculated value based on the X, Y, and Z over the last minute. It helps distinguish noise from a real earthquake signal.



Explanation for the Teacher

One way to think about the different directions is to imagine a boat floating at the surface of the ocean. It moves with the ocean waves, up and down, and side to side. The pitch of the boat is the angle from bow to stern (front to back), measured here as the Y component. The roll of the boat is the angle from port to starboard (left to right), measured here as the X component. The sensor measures angular rotation which is a bit more complex than just measuring a linear distance, which is how the vertical component Z is measured.

8. Pass out the Siesmogram Worksheet to all students. Remind students that the first waves are compressional waves, also known as primary or P waves, which travel fastest. Shear waves, also known as secondary or S waves, travel more slowly, usually at 60% to 70% of the speed of P waves.

9. Bring groups of students up to the computer to experience the changing of the measured motion as they move the computer. This gives each student a chance to experience this 3 component system of the motion themselves. Challenge each group to figure out what the EQ Significance and triggers are.

10. Ask students what they learned from their experience with moving the computer. How are the records similar for the computer and the Tonga siesmogram? What is the EQ Significance? How does that change? What sources of error are there in the classroom? (doors slamming, table shaking, etc)

11. Describe the Quake Catcher Network and how the computer will always be running the program in the background to detect earthquakes. Discuss EQ Significance graph.

Explanation for the Teacher: Earthquake Significance

The Earthquake Significance is a calculated value based on the last 60 seconds to detect significant signals. It helps detect strong new vibrations measured by the laptop's sensor. If EQ Sig is above some level, the laptop informs the QCN server that it has detected a new vibration. It sends the time, amplitudes (x, y, and z) and the EQ Sig. If many laptops tell the server there is a strong shaking all at once, we know it is an earthquake. The QCN server evaluates triggers from 100s to 1000s of laptops. If the QCN server suddenly receives more triggers than expected from a particular area, we know there is an earthquake. If only a few laptops produce triggers in an area, we know that it is probably people bumping their laptops. If successful, it may be possible for anyone participating to learn of a large earthquake before they feel it and take safety precautions.

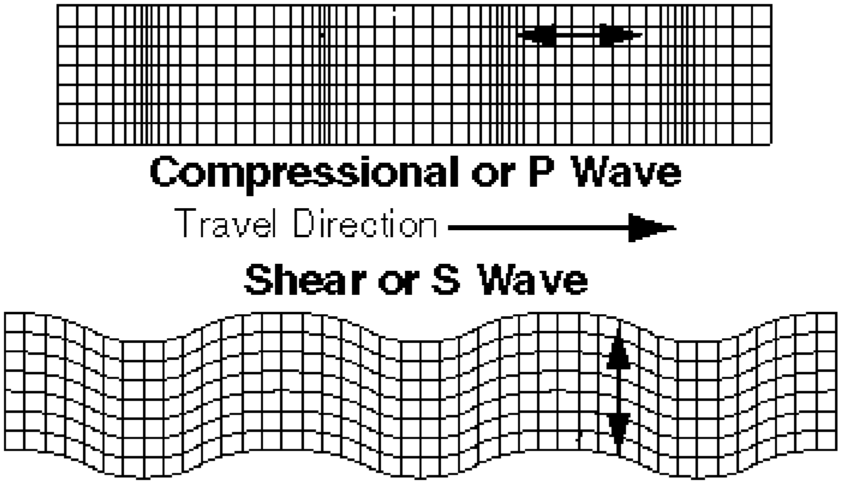
Seismogram Worksheet

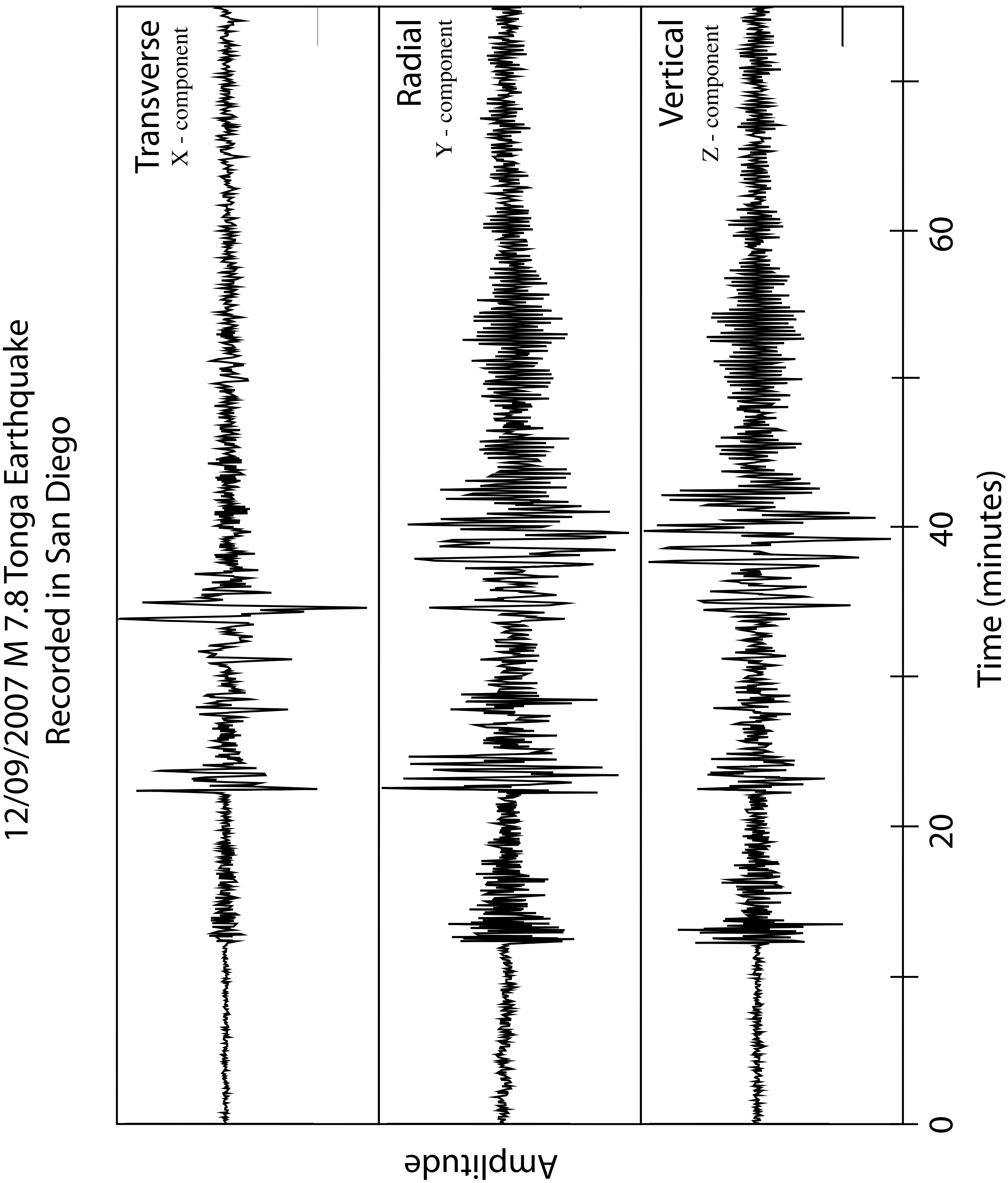
1. Examine the seismogram. When and where did this earthquake occur?

2. Find the beginning of the record where the time is zero. When did the first wave of the earthquake reach this station?
   Label this with a P on each of the 3 components of motion.

3. The first wave is called the P wave, P for primary.
   a. Which direction of motion has the largest disturbance by the P wave?
   b. P waves are compressional waves. Using the diagram of the slinky below, which direction does the slinky move when the P wave goes by?

4. The second wave is called the S wave.
   a. Label the S wave on the seismogram.
   b. Which direction of motion has the largest disturbance by the S wave?
   c. S waves are shear waves. Using the diagram of the slinky, which direction does the slinky move when the S wave goes by?




12/09/2007 M 7.8 Tonga Earthquake
Recorded in San Diego
Transverse
X - component
Radial
Y - component
Vertical
Z - component
0
20
40
60
Time (minutes)
Amplitude

Seismogram Worksheet Teacher Answers

Answers in bolded italics.

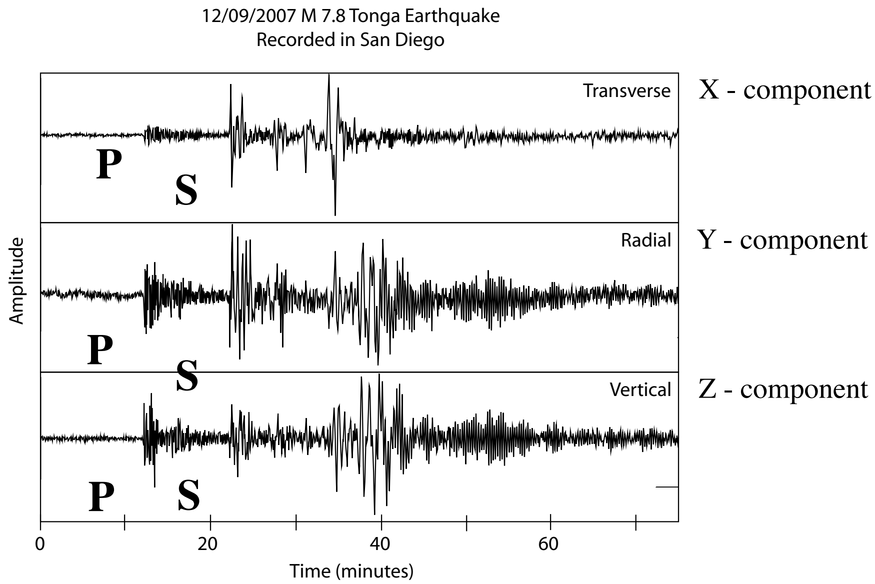
1. Examine the seismogram. When and where did this earthquake occur?
in Tonga on December 9, 2007. This was recorded in San Diego.

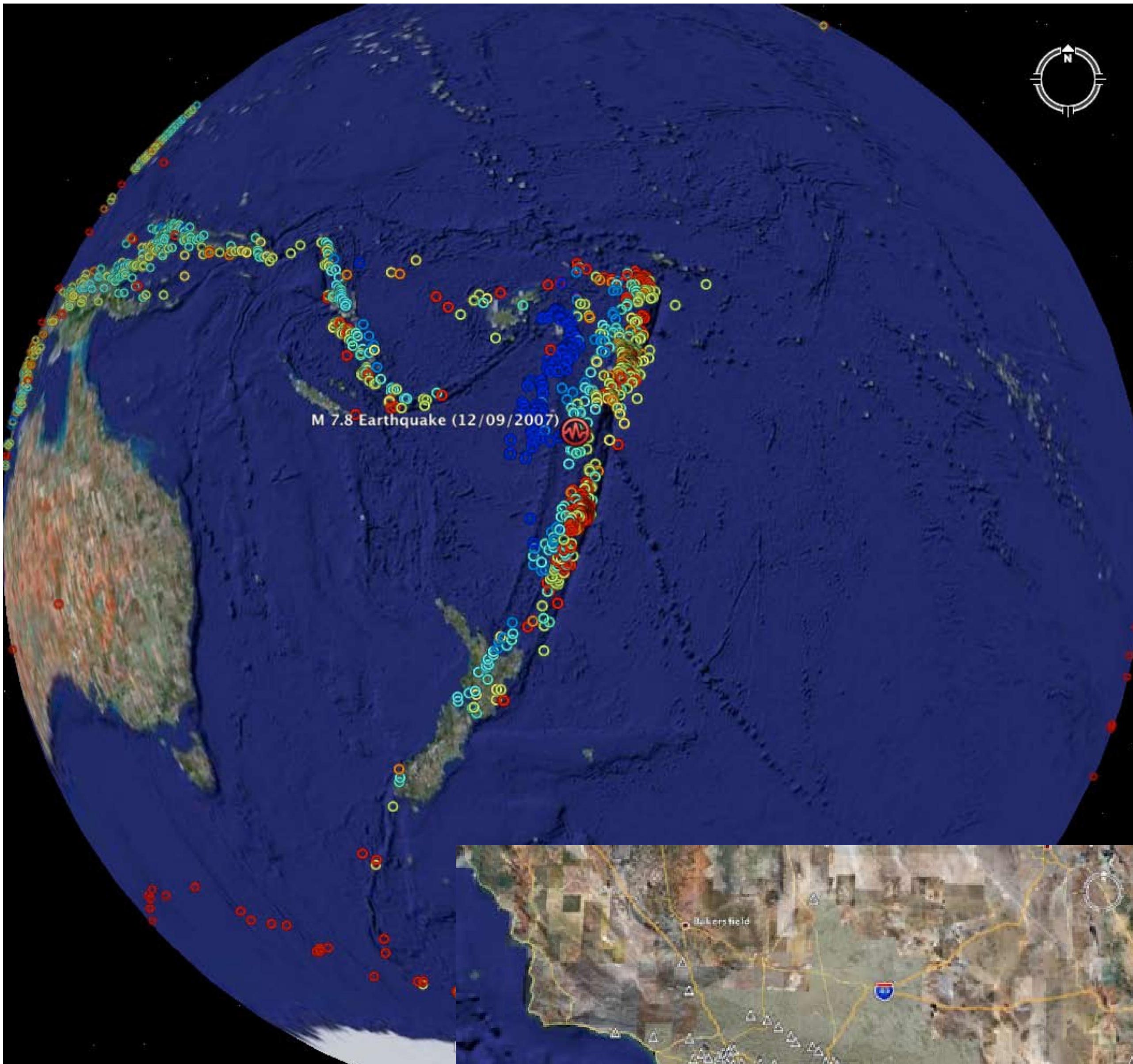
2. Find the beginning of the record where the time is zero. When did the first wave of the earthquake reach this station? ***9 minutes from the start***
Label this with a P on each of the 3 components of motion.

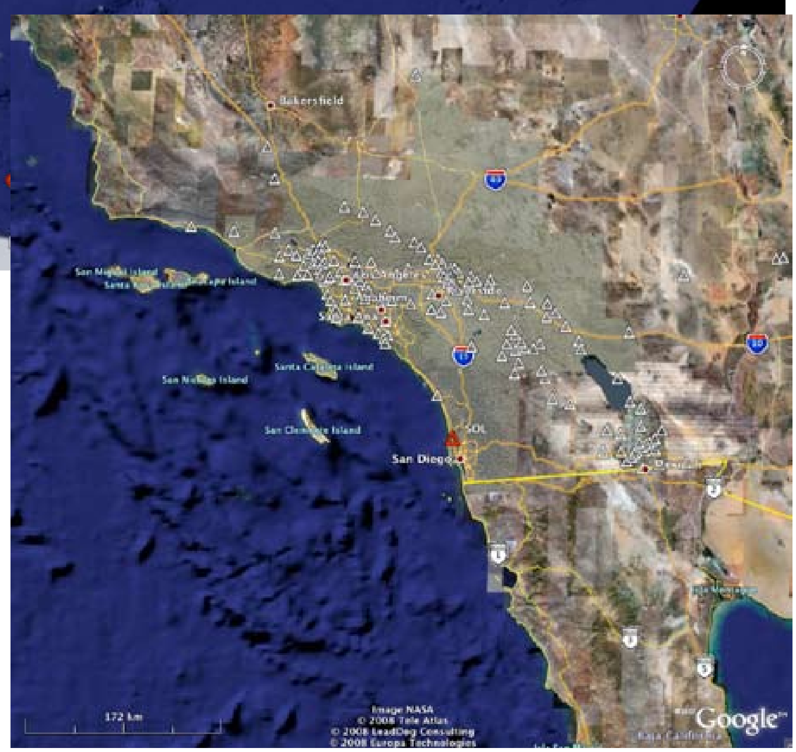
3. The first wave is called the P wave, P for primary.
   a. Which direction of motion has the largest disturbance by the P wave? ***Z, although Y is pretty close***
   b. P waves are compressional waves. Using the diagram of the slinky below, which direction does the slinky move when the P wave goes by? ***left to right***

4. The second wave is called the S wave.
   a. Label the S wave on the seismogram.
   b. Which direction of motion has the largest disturbance by the S wave? ***X and Y***
   c. S waves are shear waves. Using the diagram of the slinky, which direction does the slinky move when the S wave goes by? ***up and down***

Slinky image from http://www.seismo.unr.edu/ftp/pub/louie/class/100/seismic-waves.html







The earthquake was located on Tonga, a south Pacific Island. The record is from a seismic station in San Deigo, California.