EARTHQUAKES

Teacher Guide

including

Lesson Plans, Student Readers, and More Information

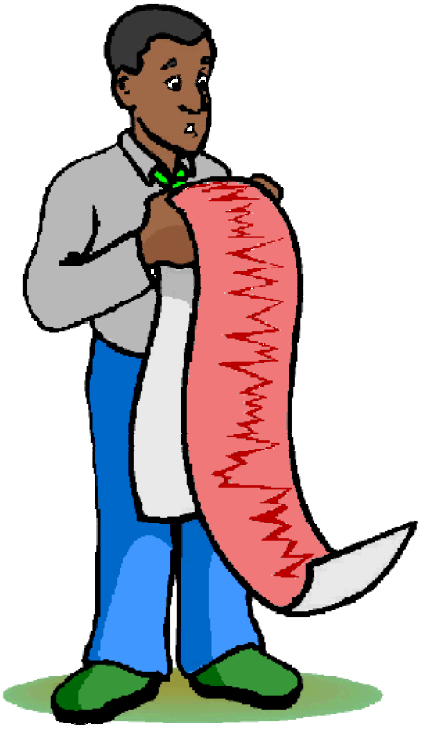
Lesson 1 - General Earthquake Information

Lesson 2 - Earthquake Legends and Science

Lesson 3 - Plotting Earthquake Lab

Lesson 4 - New Madrid, Missouri

Lesson 5 - Earthquake Damage



designed to be used as an Electronic Textbook
in class or at home

materials can be obtained from the Math/Science Nucleus

Creating materials to be used in the classroom requires an understanding of the subject. One person is usually not equipped to create a dynamic learning program for students. The author would like to acknowledge the following persons or organizations who have contributed to this chapter.

U.S. Geological Survey
Joy Lopez, M.A., teacher
Scott Hassler, Ph.D. Geologist

EARTH SCIENCES - EARTHQUAKES

Lesson 1- GENERAL EARTHQUAKE INFORMATION

MATERIALS:

reader
worksheet
glue
crayons
scissors

Objective: Students learn the causes of earthquakes.

Teacher note

This reader gives students a scientific background of earthquakes. The different types of energy that are released through seismic waves are emphasized. The reader also illustrates the different types of faults that can be caused by this energy.

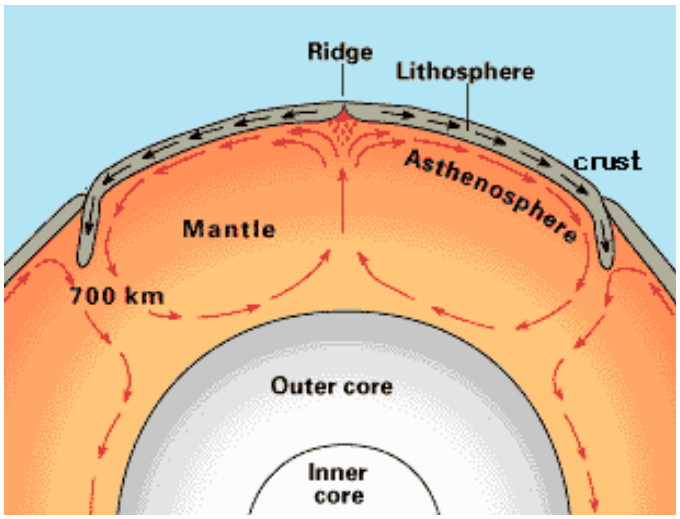
Students are asked to make a fault model and to compare different types of motion.

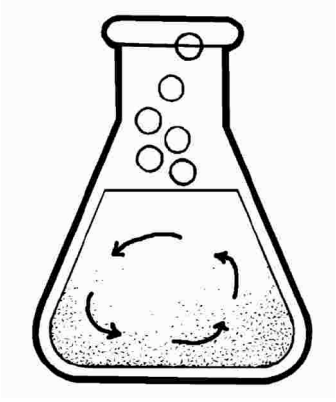
Imagine you are lying on a couch watching television. Suddenly the television set starts to rattle back and forth. At first you think it must be a large truck or a low flying plane. However, instead of fading away, the shaking gets stronger. Books and pictures start falling off the walls. Maybe they fall on you. You try to stand, but the shaking is so strong that you cannot balance yourself. You end up on the floor and you hide under a strong table. A loud roaring noise vibrates in your ears, almost deafening. The power goes out. The television falls over. You hear dishes breaking in the kitchen. The room fills with dust. Gradually the shaking stops, and you can stand up again. You run outside. Trees have fallen over. Power lines litter the street. A nearby building has collapsed.

Experiencing an earthquake of Magnitude 7 is one of the most frightening events you may ever experience. But how can the Earth be so destructive?

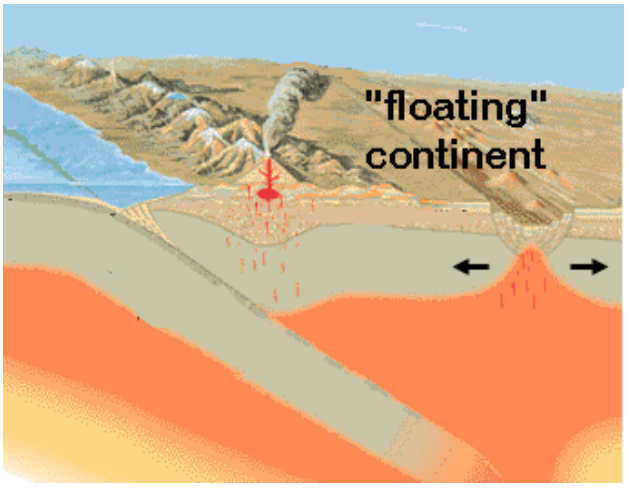
Eight story building in Caracas, Venezuela.

The Earth is not just a solid rock, rotating on its axis. Scientists have determined that the inside of the Earth is composed of different layers. The core, mantle, and crust. The interaction of the crust and the mantle causes many of our deep earthquakes. The upper mantle contains an area called the asthenosphere that is partially molten. The area above the asthenosphere is called the lithosphere. The lithosphere is "floating" of the asthenosphere in large blocks which act together. These "blocks" are what scientists refer to as plates. The plates move slowly due to several reasons including convection, gravity, rotation, and other forces.



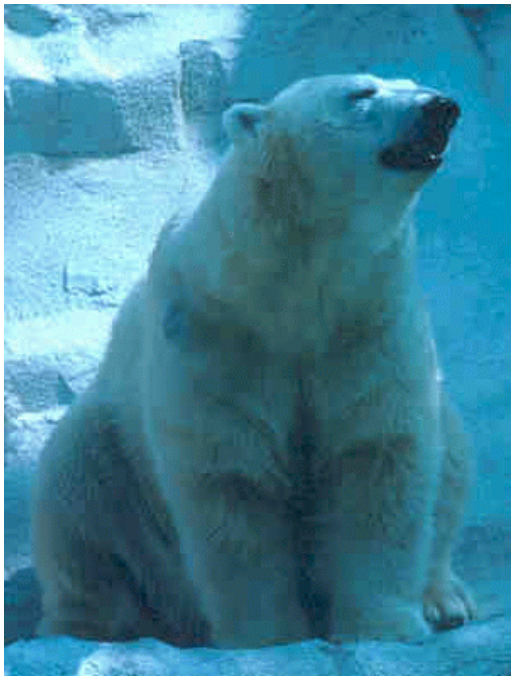


A convection current is when a concentrated area heats up the bottom. Warmer rocks move upwards causing a 3-dimensional circular motion. Heating up a beaker of water causes the same reaction. The water near the flame warms quicker and moves upward, displacing the cooler water on top. The cooler water is heavier and "sinks." The cycle is then repeated and repeated. If you think of convection currents within the mantle this movement causes stress on the crust of the Earth.

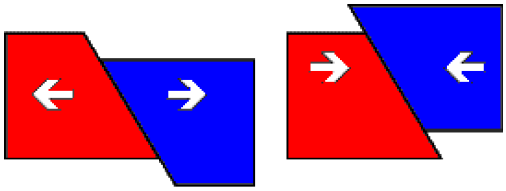


Continents are composed of lighter material and seems to never reenter the convection current. It would be similar to oil floating on top of the boiling water. It always stays on the top.

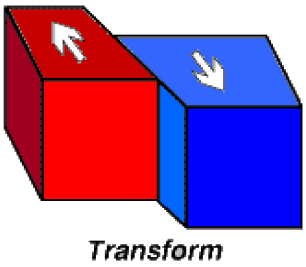
There is also other stresses on the lithosphere caused by the very fact that our Earth rotates on its axis. The equator moves much faster than the poles. It's like when a basketball player can balance a spinning ball on its finger. The player has found the point of the axis that is not moving and balances it. As you go to the equator of Earth from the rotational axis you travel from 0 miles per hour to 1000 miles per hour. On Earth we don't feel it because of other physical constraints, but to an "Alien" looking down at us. Well, a polar bear on the North Pole and penguins on the South Pole would be standing still, while people in New York would be moving about 600 miles per hour, even if they were standing still in traffic. So what does this have to do with earthquakes?

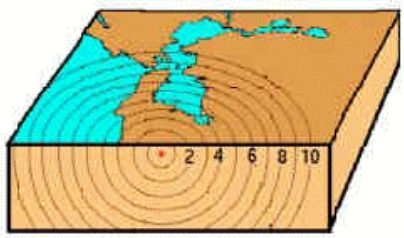


These basic stresses caused by rotation and convection is just too much for the lithosphere. It relieves its stress by "cracking" or better known as faults. However, the movement along the faults cause energy to be released called seismic waves. When the waves reach the surface of the Earth it shakes, causing earthquakes.



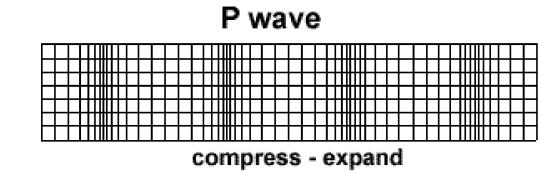
Earthquakes are caused by the sudden movement and fracturing of rock masses along pre-existing faults. A fault is a broken surface within the Earth's crust. The point on the fault at which the displacement begins is called the focus of the earthquake. The point on the surface of the earth directly above the focus is the epicenter. Faults can be caused by pull apart (extensional), compressional, or slip slide (transform) motion.



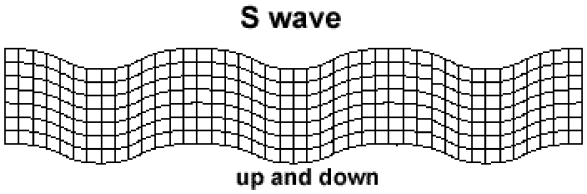


Seismic waves travel throughout the Earth. There are many different types of waves that can be distinguished. There are two major types P and S waves.

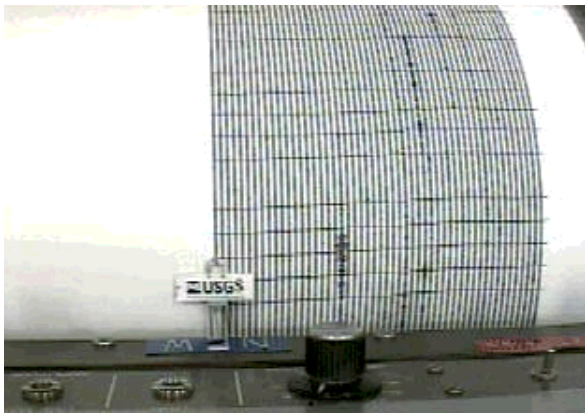
The first type are called P-waves or primary waves, because they are the fastest type of seismic wave and are the first waves that a seismogram records. The P wave can be described as a push-pull wave, because it moves by contracting and expanding material along a horizontal path. A P-wave travels through a material as a compressional force.



The second major type of seismic wave is called an S-wave. S-waves are shear waves. S-waves are slower than P-waves. The particle motion in shear waves is perpendicular to the direction of the wave.



The energy released during an earthquake causes the ground to shake. If you are close to the epicenter of an earthquake, the shaking is usually more severe than if you were farther away. This change occurs for many reasons. Most important, seismic energy dissipates as it travels through rocks, due to friction and other effects. In addition, the different types of seismic waves travel at different speeds. This means that close to the epicenter of an earthquake, all the waves arrive at about the same time, and the ground shakes very hard for a short period of time. Further from the epicenter, the fastest waves arrive ahead of the slower waves. This spreading out of energy makes the shaking is less intense.



The seismic waves generated by an earthquake can be recorded and measured on a seismograph. The record produced by a seismograph is called a seismogram.

ACTIVITY -FAULT MODEL

I. Make model

1. Color the fault model that is included according to the color key provided.
2. Paste or glue the fault model onto a piece of construction paper.
3. Cut out the fault model and fold each side down to form a box with the drawn features on top. Make sure you fold all parts before you glue or tape.
4. Tape or glue the corners together. This box is a three dimensional model of the top layers of the Earth's crust.
5. The dashed lines on your model represent a fault. Carefully cut along the dashed lines. You will end up with two pieces. You may wish to have your students tape or glue a piece of construction paper on the side of the two fault blocks along the fault face. This will help with the demonstration.

II. Illustrate fault motion

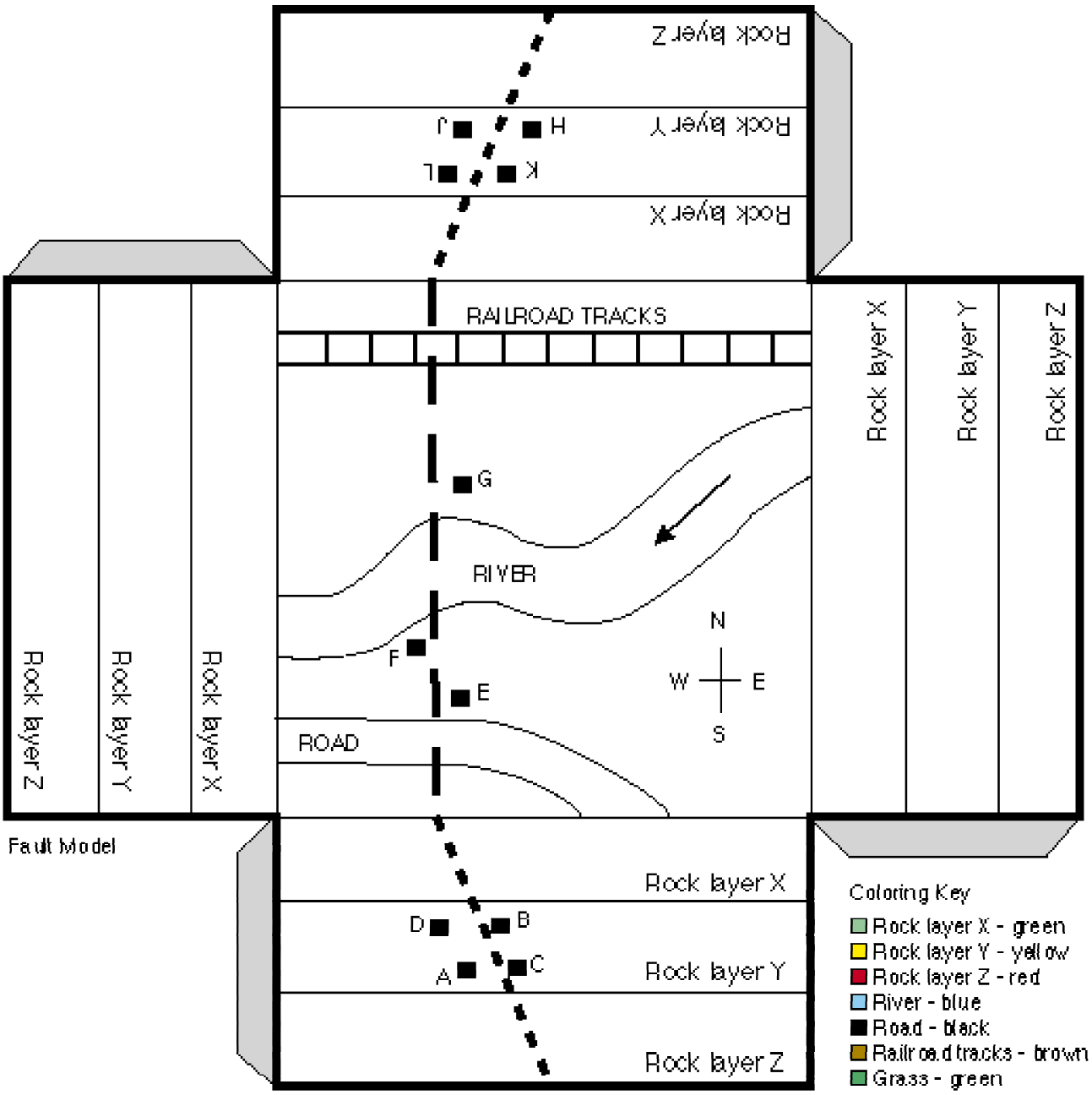
This exercise has students develop a model of a normal fault. After you make the fault model from directions above, illustrate a “normal fault.”

1.Instructions to students: Locate points A and B on your model. Move point B so that it is next to Point A. Observe your model from the side (its cross-section). You have just observed a “normal fault.” Are there other ways faults can cause movement?

This fault model was develop by Tao Rho Alpha of the U.S. Geological Survey, Menlo Park. More information on how to use the material can be found on the following website.

http://www.usgs.gov/education/learnweb/ESLesson1.html#Background

Fault sheet


Rock layer Z
Rock layer Y
Rock layer X
H
J
K
L
RAILROAD TRACKS
Rock layer X
Rock layer Y
Rock layer Z
G
RIVER
F
E
ROAD
N
W
E
S
Rock layer Z
Rock layer Y
Rock layer X
Fault Model
Rock layer X
D
B
A
C
Rock layer Y
Rock layer Z
Coloring Key
Rock layer X - green
Rock layer Y - yellow
Rock layer Z - red
River - blue
Road - black
Railroad tracks - brown
Grass - green

EARTH SCIENCES - EARTHQUAKES

Lesson 2 - EARTHQUAKE LEGENDS AND SCIENCE

MATERIALS:

reader

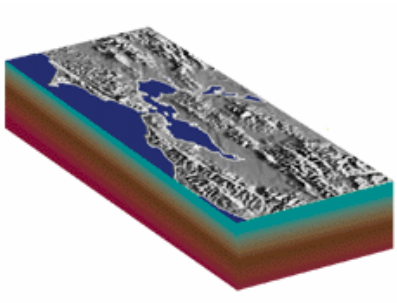
Objective: Students learn about the legends and science begin earthquakes.

Teacher note

Stories that are sometimes bizarre are created when information is lacking. It was not until the last century that scientists started to understand the causes of earthquakes. Students in this reader learn about early legends and also about what geologists understand about earthquakes.

You can extend these lessons easily by having students write their own legend of what they think an earthquake is about. Have them illustrate their legend and have students vote on which story is the most creative.

Throughout the ages, the fear of earthquakes has been justified. Words like "destructive" and "catastrophic" are always used to describe the energy released by an earthquake. However the Earth, with all its beautiful mountains and valleys, depends on these processes to create the landforms that we see. Earthquakes are a natural way for the upper portion of the Earth to release energy due to stress caused by movement internally and externally.



A geologist can look at the features of the Earth and determine how they were formed. For example, in the San Francisco Bay area you have series of parallel mountains and valleys. This is a good sign that these represent faults that have occurred through time. However, when you don't understand what cause these features, your mind can go wild! Myths and legends are born.

Early civilizations had no idea what the shaking was all about. Myths and legends started to develop in order to justify this unknown shaking. In Mexico, El Diablo, the devil, makes giant rips in the Earth from the inside. He and his devilish friends use the cracks when they want to come and stir up trouble on Earth. In West Africa, the Earth is considered a flat disk, held up on one side by an enormous mountain and on the other by a giant. The giant's wife holds up the sky. The Earth trembles when he stops to hug her.

In **India** an earthquake legend has the Earth held up by four elephants that stand on the back of a turtle. The turtle is balanced on top of a cobra. When any of these animals move, the Earth trembles and shakes.

Between **Bangladesh and China** in a land called Assam, there is a race of people living inside the Earth. From time to time, they shake the ground to find out if anyone is still living on the surface. When children feel a quake, they should shout "Alive, Alive!" so the people inside the Earth will know they are there and then they will stop shaking.

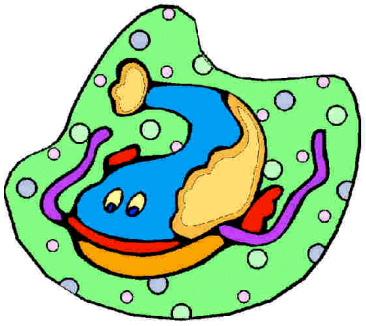
Early people from **Mozambique** claimed the Earth is a living creature. The Earth has the same kinds of problems people have. Sometimes, it gets sick with fever and chills and we can feel its shaking.

Once a Chickasaw chief (**American Indian**) was in love with a Choctaw princess. He was young and handsome, but he had a twisted foot, so his people called him Reelfoot. When the princess' father refused to give Reelfoot his daughter's hand, the chief and his friends kidnapped her and began to celebrate their marriage. The Great Spirit was angry and stomped his foot. The shock caused the Mississippi River to overflow its banks and drown the entire wedding party.

The god Loki from **Scandinavia** is being punished for the murder of his brother, Baldur. He is tied to a rock in an underground cave. Above his face is a serpent dripping poison, which Loki's sister catches in a bowl. From time to time, she has to go away to empty the bowl. Then the poison falls on Loki's face. He twists and wiggles to avoid it, and the ground shakes up above him.

Early people from **New Zealand** saw Mother Earth with a child in her womb, the young god Ru. When he stretches and kicks as babies do, he causes earthquakes.

The **East African** saw a giant fish carrying a stone on his back. A cow stands on a stone, balancing the Earth on one of her horns. From time to time, her neck begins to ache, and she tosses the globe from one horn to the other.



West Africans claimed that a Giant carries the Earth on his head. All the plants that grow on the Earth are his hair, and people and animals are the insects that crawl through his hair. He usually sits and faces the east, but once in a while he turns to the west and then back to the east. This causes the Earth to shake.

ACTIVITY - HOMEWORK ASSIGNMENT

Talk to several adults who may not understand the science behind earthquakes. Record their information. Try to weave a "myth" from their discussions. Remember a myth can be based on some truth, but can also be entirely fictional. Draw a picture in the space provided.

EARTH SCIENCES - EARTHQUAKES

Lesson 3 - PLOTTING EARTHQUAKES LAB

MATERIALS:

reader
ruler
compass (math) optional
worksheet

Objective: Students interpret earthquake magnitude and intensity.

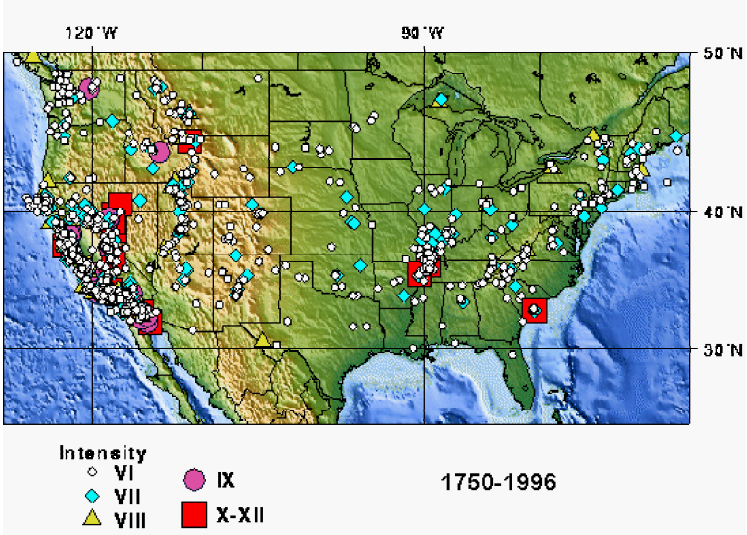
Teacher note

Students learn the difference between intensity and magnitude of an earthquake. The intensity is the severity of ground motion at a specific location. We use the modified Mercalli Scale to measure the intensity using Roman numerals from I-XII. The magnitude of an earthquake is a mathematical measurement of the amount of energy released. A revised form of the Richter scale is used today and uses numbers from 1-10. An earthquake has many intensities depending on where the earthquake is located. However, an earthquake has only one magnitude.

The U.S. Geological Survey (USGS) provides scientific information on earthquakes to teachers, community, and students. The USGS is the agency involved with understanding the science of earthquake (seismology) and collects data throughout the world. In the reader below students are asked to look at the USGS website (http://earthquake.usgs.gov) to look for earthquakes that have occurred recently. You may want them to identify 5 to 10 different earthquakes and list the magnitude found on the website. Make sure they record the date and place.

Also included is a classic worksheet on determining position of earthquakes by reading a seismogram. All seismograms are labeled in units that represent Greenwich time. It avoids the confusion of local dates and times. Each dot and long dash represent one minute. This will be used to determine the arrival of P and S waves. Provide students with a compass to help make it easy to measure the radius to construct a circle from the given locations.

ANSWERS: Prince Rupert, British Columbia; C (A) time lab: 3 min, 50 sec; km: 230 sec x 8= 1840 km; New Orleans, Louisiana (B) time lab: 3 min 40 sec; km: 300 sec x 8 km = 2400 km; Honolulu, Hawaii (C) time lab: 5 min, 40 sec; km 340 sec x 8 km = 2720 km. The epicenter is somewhere in central California.

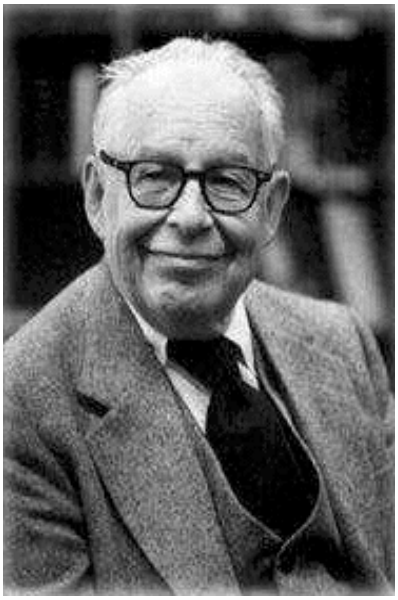


All earthquakes don't shake the Earth the same. People can feel different shaking intensities at different locations. Some earthquakes shake everything (high intensity), and others are not felt at all (low intensity). It is important to compare these earthquakes so we can determine how to prevent damage.

Before seismographs were invented different methods of recording an earthquake were used. In Italy, Giuseppe Mercalli created a 12 point scale in 1902 which was based on stories of damage from people.

Today, the Modified Mercalli Scale represents the local effect or damage caused by an earthquake. The "intensity" reported at different points generally decreases away from the earthquake epicenter. The intensity ranges, from I - XII, is always expressed in Roman numerals. For example, an earthquake of intensity "II" would be barely felt by people, while heavy damage would be assigned a "X."

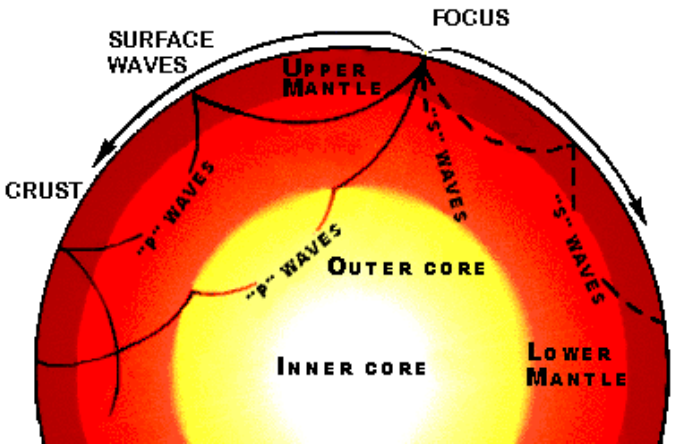
Another type of scale called the Richter scale is a mathematical measurement of the energy released as measured by a seismograph. It is actually a measurement of the size of the waves produced by an earthquake. The Richter Scale, was developed by Charles F. Richter of the California Institute of Technology in 1935. This scale is the best known scale for the measuring of magnitude (M) of earthquakes. The scale is logarithmic. A magnitude 7, for example, records a disturbance with ground motion 10 times as large as a recording of 6 magnitude earthquake. The energy released by an earthquake of M 7,however, is approximately 30 times that released by an earthquake of M 6. An earthquake of M 8 releases 900 times (30x30) the energy of an earthquake of M 6. There is only one "magnitude" for an earthquake using the Richter scale.



Charles F. Richter

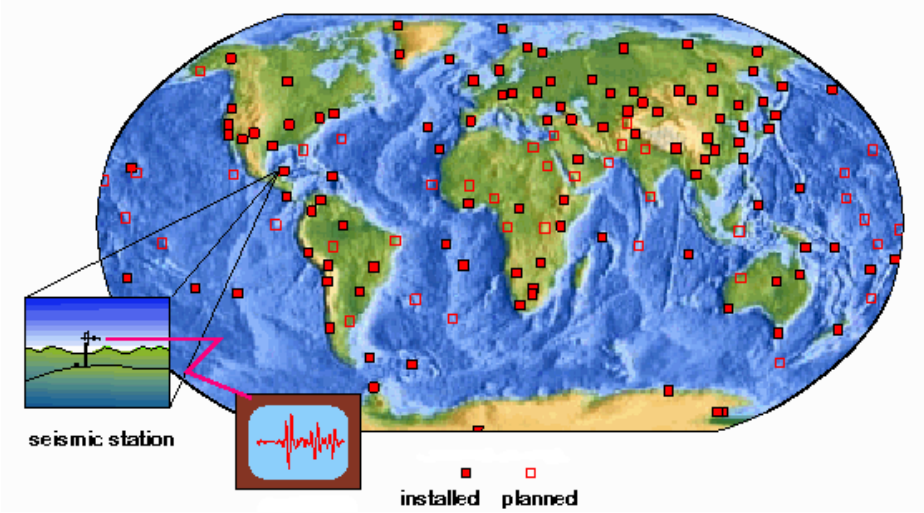
As the Richter scale does not adequately differentiate between the largest earthquakes, a new "moment magnitude" scale is being used by seismologists today to provide a better measure. On the moment magnitude scale, the San Francisco earthquake is estimated at magnitude 7.7 compared to an estimated Richter magnitude of 8.3.

Seismograms record the energy emitted by seismic or earthquake waves that radiate from the focus (point at which earthquake begins). Seismograms are created by machines called seismographs. Seismograms are used by seismologists (scientists who study earthquakes) to mathematically describe the magnitude of an earthquake.



Earthquakes generate many different types of seismic waves. Two major types are P (push/pull, compressional, or primary) and S (shear or secondary). Seismograms will record P-wave arrivals before S-wave arrivals. Surface waves are also generated that travel on surface of the crust.

Scientists of the U.S. Geological Survey (USGS) have operated seismographic stations throughout the world for more than 35 years. They work with other scientists in over 80 countries in the Global Seismographic Network. The principal use of seismograph networks is to locate earthquakes. Although it is possible to infer a general location for an event from the records of a single station, it is most accurate to use three or more stations.



When an earthquake occurs, data from the seismographs feeds into a major research center, where the seismograms are analyzed. This analysis determines where the earthquake occurred, and determines its magnitude. Major earthquake data centers in the United States include Menlo Park and Los Angeles, both in California, and Boulder, Colorado.

Given a single seismic station, the seismogram record will yield a measurement of the S-P time arrival (seconds from when P arrived to when S arrived). The distance between the station and the event can be calculated. Let's look at an example of an earthquake that occurred somewhere in the United States and determine an approximate location.

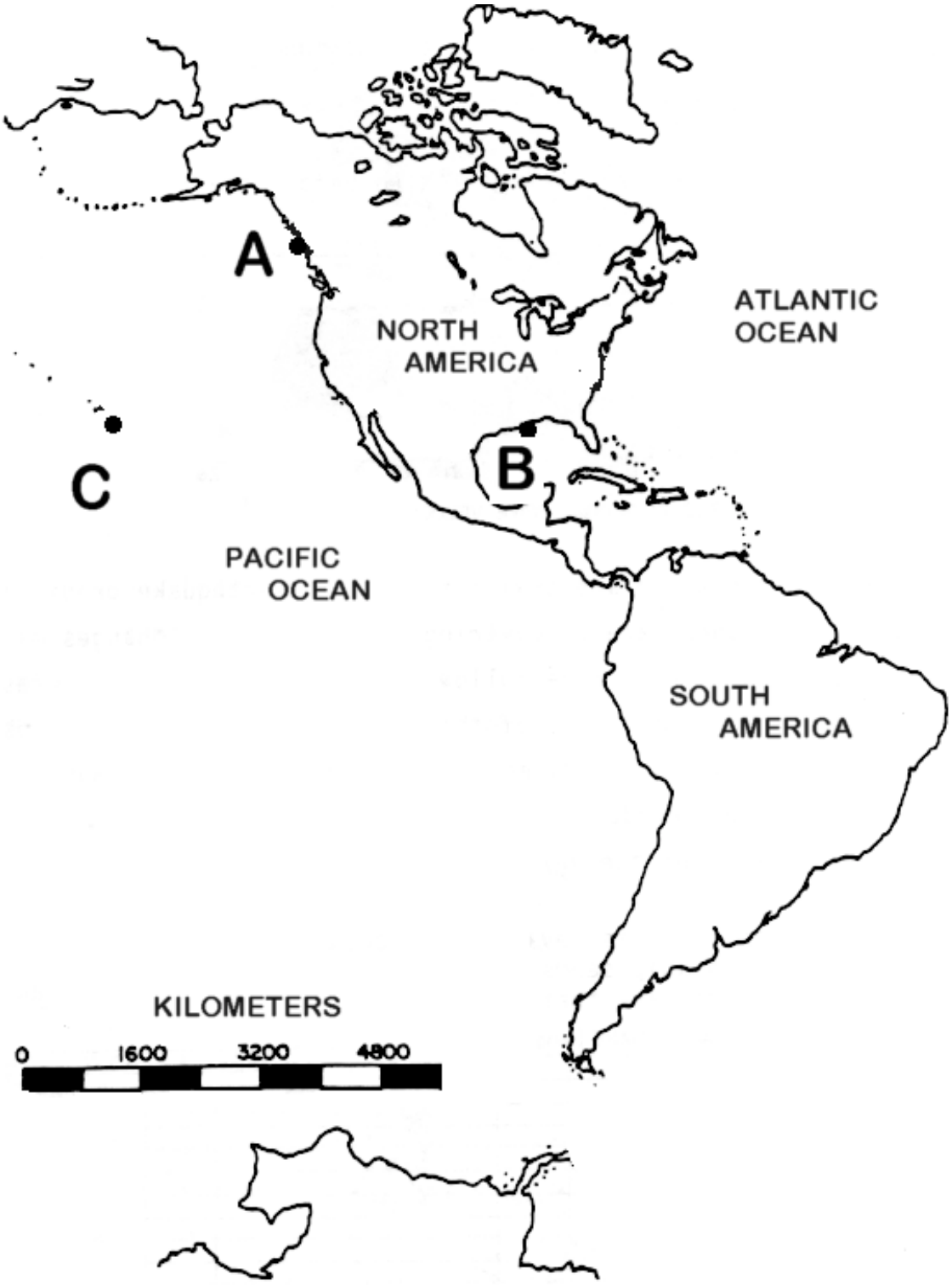
We will use 3 stations including Prince Rupert, British Columbia (A), New Orleans, Louisiana (B) and Honolulu, Hawaii (C). The arrival of the P and S waves have already been determined in the graph provided. Subtract the S arrival from the P arrive and determine the "Time Lag" and record the information.

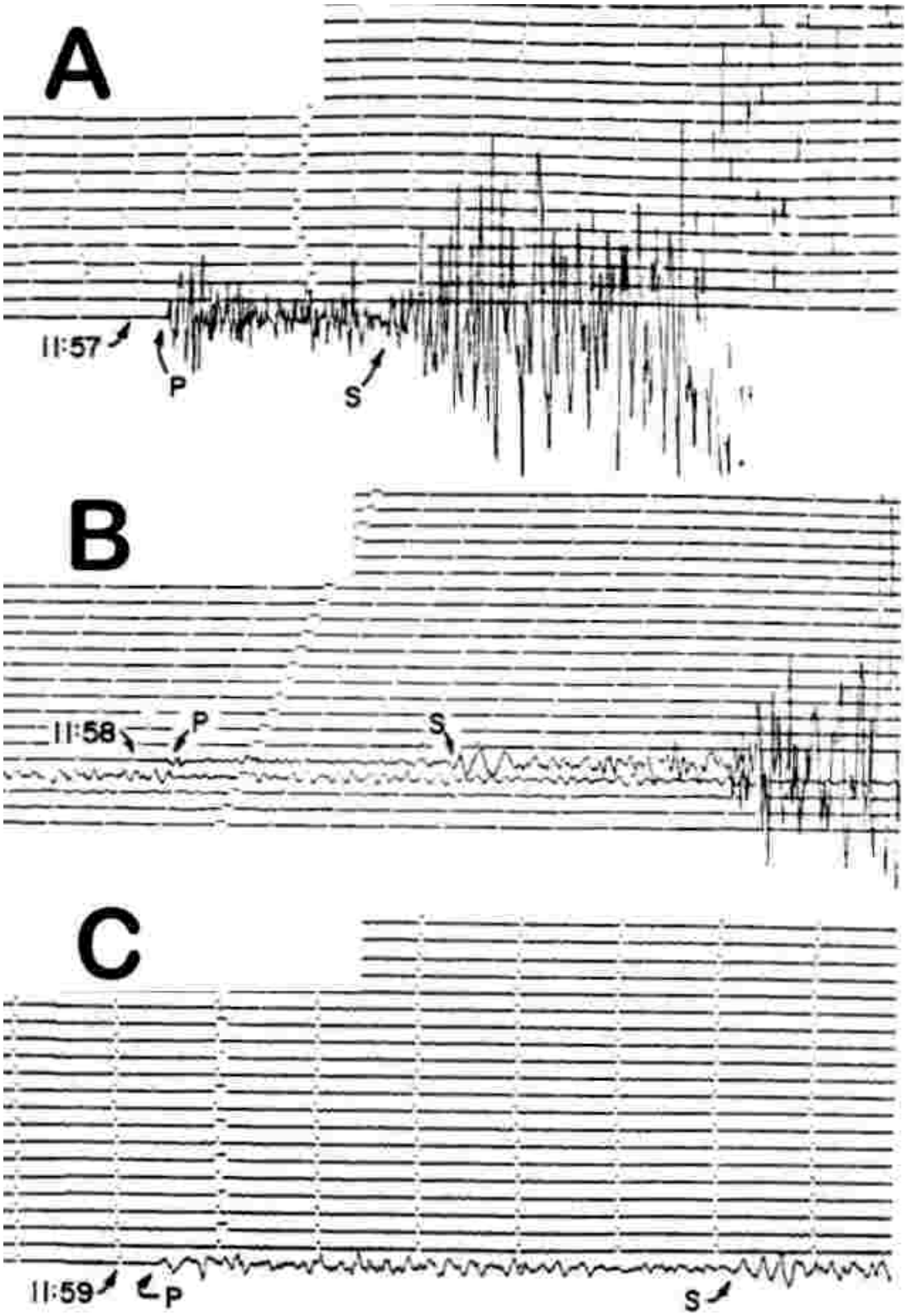
Multiply the seconds of S-P time by 8 km/s for the kilometers of distance and record them on the graph. Use the scale and draw a circle on a map around the station's location using a compass, with a radius equal to the distance. With the S-P time from a second station, the circle around that station will narrow the possible locations down to two points. It is only with a third station's S-P time that you can draw a third circle that should identify which of the two previous possible points is the real one.

Can you determine where the earthquake's epicenter is located?

	Time of P Arrival			Time of S Arrival			Time Lag		Distance Epicenter
	hr	min	sec	hr	min	sec	min	sec	(sec x 8km)
Prince Rupert, BC	**11**	**57**	**40**	**12**	**01**	**30**			
New Orleans, LA	**11**	**58**	**40**	**12**	**03**	**40**			
Honolulu, HA	**11**	**59**	**30**	**12**	**05**	**10**			

ACTIVITY - LOCATE THE EPICENTER OF THIS MAGNITUDE 7.7 EARTHQUAKE

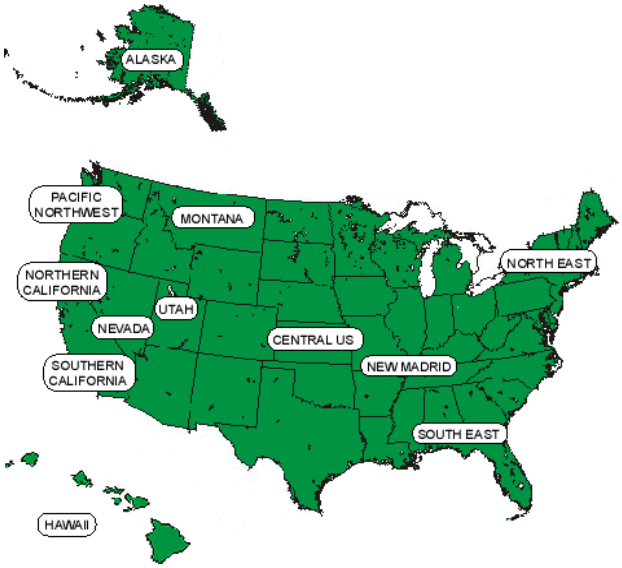



A
11:57
P
S
B
11:58
P
S
C
11:59
P
S

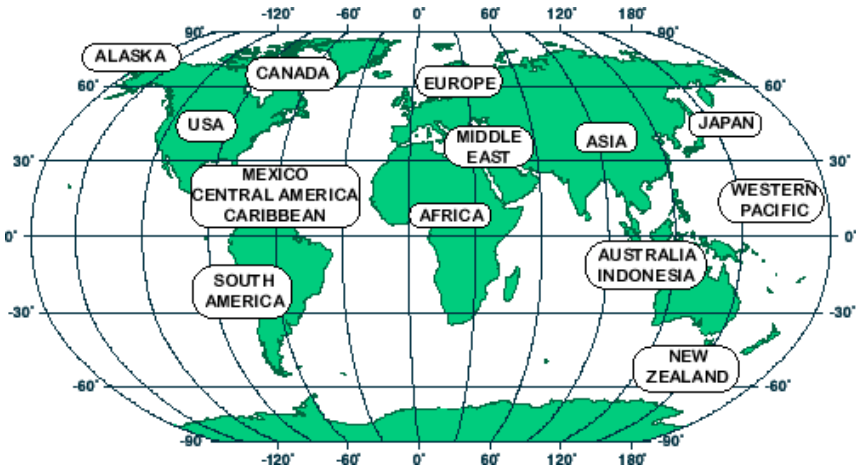
ACTIVITY - LOCATING EARTHQUAKES USING THE INTERNET

Earthquakes occur everyday throughout the world. On the following websites locate 10 earthquakes in the United States and 10 earthquakes from around the world. Record their information on the worksheet.

http://earthquake.usgs.gov/activity/present.shtml



http://earthquake.usgs.gov/activity/worlds.html



ACTIVITY - RECENT EARTHQUAKES

Using the websites provided by your instructor locate 10 earthquakes in the United States and 10 throughout the world. List the magnitude and other comments of interest.

place	magnitude	comments
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		
16.		
17.		
18.		
19.		
20.		

EARTH SCIENCES - EARTHQUAKES

Lesson 4 - NEW MADRID FAULT ZONE

MATERIALS:

reader

Objective: Students explore an historical earthquake.

Teacher note

The New Madrid Fault Zone is not considered to be in "earthquake country." However, the earthquakes of 1811-12 caused many geologists to think about the causes of earthquake. This area in the midwestern part of the United States is not on a plate boundary nor near volcanic activity. It lies on a suture of an ancient plate. Ancient faults that have been buried through the ages are still zones of weakness and are still capable of producing dangerous earthquakes.

Instruct students to read the information and then have a discussion about what it would be like to experience a shaking that you have no idea what caused it. Students should transport their "thoughts" to early pioneers living in the area.

For more information on the New Madrid Fault Zone we recommend the following sites:

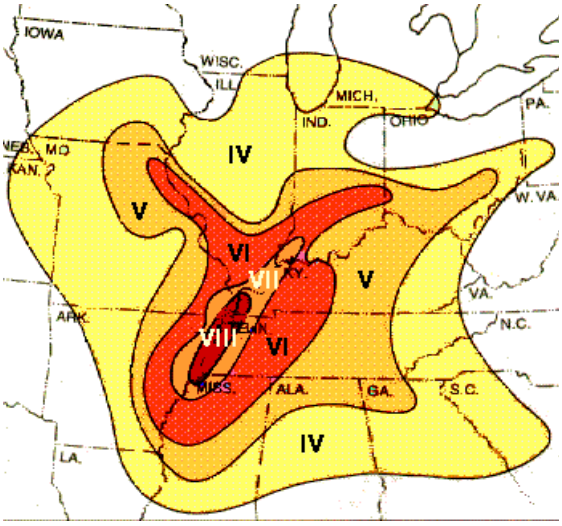
http://www.uky.edu/ArtsSciences/Geology/webdogs/virtky/index.html/ - an excellent description of the New Madrid Fault Zone -its history, current activity, and future hazards.

http://hsv.com/genlintr/newmadrd/ - another good New Madrid Link

http://www.rootsweb.com/~armissi2/earthquk.htm - the full text of the letter written by Eliza Bryan.

The New Madrid Earthquakes of 1811 to 1812

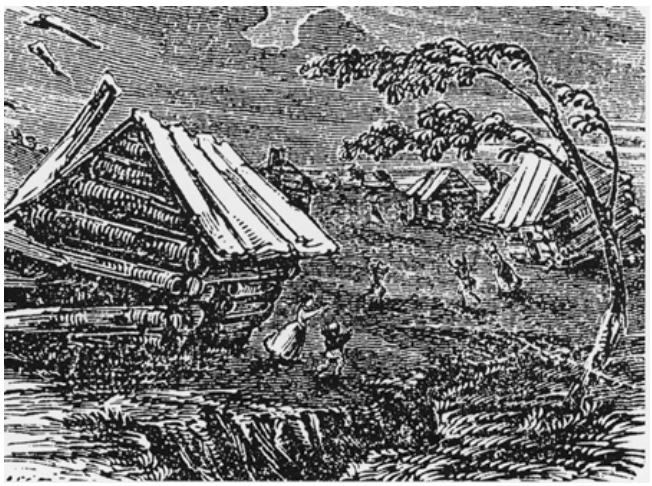
In the United States, most earthquakes occur along the active plate boundaries in California, Oregon, Washington, and Alaska. If you live in one of these states, you may have felt an earthquake. However, several of the largest earthquakes ever recorded in the United States occurred in the Midwest, far from any plate boundary. These earthquakes took place in an area called the New Madrid Fault Zone, named after the town of New Madrid, Missouri. Over a three-month period in the winter of 1811 to 1812, the New Madrid Fault Zone was struck by three huge earthquakes estimated to be greater than magnitude 8.0. Aftershocks were felt in the region for more than a year. These included seven aftershocks between magnitude 7 and 8, ten between magnitude 6 and 7, and eighty-nine between magnitude 4 and 5. Many aftershocks were strong enough to ring church bells on the east coast of the United States.



Modified Mercalli Scale, based on maps in W. Atkinson, 1989, The Next New Madrid Earthquake, Southern Illinois, University Press

The 1811 to 1812 New Madrid earthquakes released the most seismic energy of any known event in the continental United States. More energy was released than in any one earthquake in California. The only larger event in North America was the Great Alaska earthquake of 1964.

The New Madrid earthquakes caused great destruction in the Central United States. The earthquakes devastated large areas of the Central United States. Fault movement caused the course of the Mississippi River to change. In other areas the ground was broken and uplifted more than 30 feet. Cracks in the ground opened up that were "too wide for a horse to jump". Homes and other buildings up to hundreds of miles away, were totally destroyed. An eyewitness account of the earthquakes by Eliza Bryan, a settler who lived in the area, tells a story of destruction.


A woodcut showing damage during the 1812 New Madrid earthquake.

On the 16th of December, 1811, about two o'clock, am, we were visited by a violent shock of an earthquake, accompanied by a very awful noise resembling loud but distant thunder, but more hoarse and vibrating, which was followed in a few minutes by the complete saturation of the atmosphere, with sulphurious vapor, causing total darkness. The screams of the affrighted inhabitants running to and fro, not knowing where to go, or what to do - the cries of the fowls and beasts of every species - the cracking of trees falling, and the roaring of the Mississippi - the current of which was retrograde for a few minutes, owing as is supposed, to an irruption in its bed -- formed a scene truly horrible. From that time until about sunrise, a number of lighter shocks occurred; at which time one still more violent than the first took place, with the same accompaniments as the first, and the terror which had been excited in everyone, and indeed in all animal nature, was now, if possible doubled. The inhabitants fled in every direction to the country, supposing (if it can be admitted that their minds can be exercised at all) that there was less danger at a distance from, than near to the river. In one person, a female, the alarm was so great that she fainted, and could not be recovered.

There were several shocks of a day, but lighter than those already mentioned until the 23d of January, 1812, when one occurred as violent as the severest of the former ones, accompanied by the same phenomena as the former. From this time until the 4th of February the earth was in continual agitation, visibly waving as a gentle sea. On that day there was another shock, nearly as hard as the proceeding ones. Next day four such, and on the 7th about 4 o'clock am, a concussion took place so much more violent than those that had proceeded it, that it was dominated the hard shock. The awful darkness of the atmosphere, which was formerly saturated with sulphurious vapor, and the violence of the tempestuous thundering noise that accompanied it, together with all of the other phenomena mentioned as attending the former ones, formed a scene, the description of which would require the most sublimely fanciful imagination.

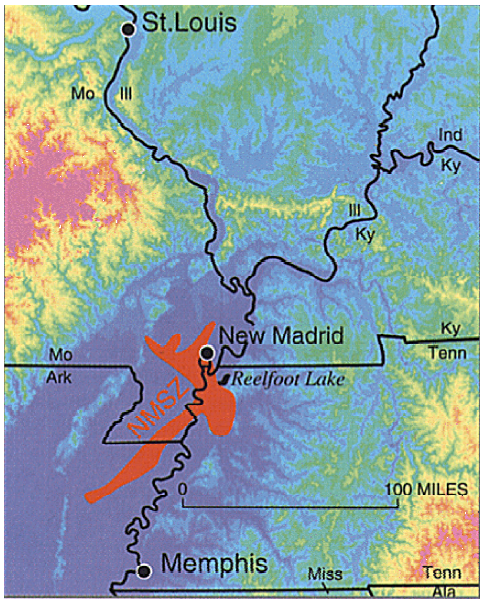
At first the Mississippi seemed to recede from its banks, and its waters gathering up like a mountain, leaving for the moment many boats, which were here on their way to New Orleans, on bare sand, in which time the poor sailors made their escape from them. It then rising fifteen to twenty feet perpendicularly, and expanding, as it were, at the same moment, the banks were overflowed with the retrograde current, rapid as a torrent - the boats which before had been left on the sand were now torn from their moorings, and suddenly driven up a little creek, at the mouth of which they laid, to the distance in some instances, of nearly a quarter of a mile. The river falling immediately, as rapid as it had risen, receded in its banks again with such violence, that it took with it whole groves of young cotton-wood trees, which ledged its borders. They were broken off which such regularity, in some instances, that persons who had not witnessed the fact, would be difficultly persuaded, that is has not been the work of art. A great many fish were left on the banks, being unable to keep pace with the water. The river was literally covered with the wrecks of boats, and 'tis said that one was wrecked in which there was a lady and six children, all of whom were lost.

In all the hard shocks mentioned, the earth was horribly torn to pieces - the surface of hundreds of acres, was, from time to time, covered over, in various depths, by the sand which issued from the fissures, which were made in great numbers all over this country, some of which closed up immediately after they had vomited forth their sand and water, which it must be remarked, was the matter generally thrown up. In some places, however, there was a substance somewhat resembling coal, or impure stone coal, thrown up with the sand. It is impossible to say what the depths of the fissures or irregular breaks were; we have reason to believe that some of them are very deep.

Eliza Bryan

If there is no plate boundary in the middle of the United States, why did these earthquakes take place? Geologists are beginning to understand the answer. The New Madrid Fault Zone is part of an *ancient* plate boundary. In this area, the North American Plate tried to form a divergent plate boundary about 500 million years ago. The splitting stopped before new plates could form. The faults in the New Madrid Zone are remnants of this old event. Earthquakes occur because the North American Plate is still "settling down".

The faults in the New Madrid Zone do not reach the Earth's surface. They are buried beneath thousands of feet of rock and sediment deposited by the Mississippi River. Geologists have located them by looking at the patterns of earthquakes in the zone.

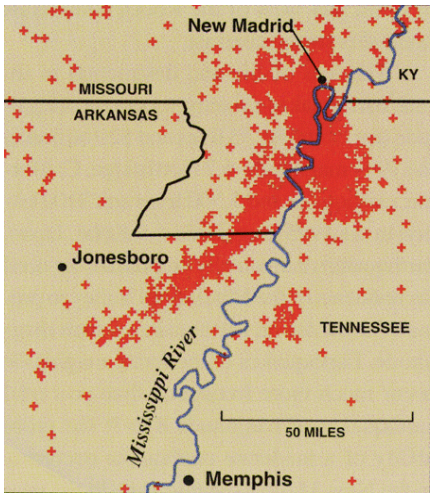


This satellite photograph shows major cities near the New Madrid Fault Zone.

When these catastrophic earthquakes took place, the central United States was sparsely inhabited by settlers. Since then, this area has been developed extensively. Several major cities, including Memphis and Nashville, Tennessee, Little Rock, Arkansas, St. Louis, Missouri, and Louisville, Kentucky are within 250 miles of the fault zone. This is well within the area devastated in 1811 to 1812.

Geologists have thus studied, and continue to study, the New Madrid Fault Zone. It is clear from their work that a devastating earthquake could happen again. As the map to the right shows, little earthquakes happen all the time. In addition, the 1811 to 1812 earthquakes have not been the only significant events in the New Madrid Fault Zone. An earthquake in January, 1843 registered a 6.0 magnitude, while on October 31, 1895 a magnitude 6.2 quake struck.

Current estimates suggest a magnitude 6.0 earthquake should occur before the year 2040. This is within your lifetime! Luckily, it seems that larger, destructive events like those in the 19th century will not happen again for several hundred years.



Earthquakes from 1969-1994.

EARTH SCIENCES - EARTHQUAKES

Lesson 5 - EARTHQUAKES DAMAGE

MATERIALS:

reader
worksheet

Objective: Students learn historic magnitude damage of earthquakes.

Teacher note

Earthquake education is important in both school and society. All 50 states can experience small earthquakes, and 39 states are subject to a moderate to major seismic risk. The mobility of our society makes the number of individuals who may one day experience a damaging earthquake is even greater.

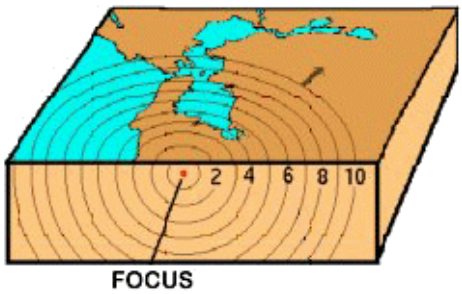
Disasters caused by earthquakes are an excellent way to introduce earthquakes preparedness. As students read the material, they will see that not all major earthquakes are catastrophic. Some cities that build homes of inappropriate materials will have more deaths than cities that with strict building code. Also remote areas with large earthquakes may cause little human damage.

Preparedness at a school site is a good place to start. Discuss with your school administration if there is a plan in case of a disaster. In many states, the schools become the logical place for meeting and to handle people who may have lost their home. In your own classroom you should consider an escape route. Science labs are usually more vulnerable especially if they have flammable liquids and poisons. Glassware should be secured.

Some of the geographic areas mentioned in this section may not be familiar to students. Go over with students on a map where these areas are located. For more information look at http://neic.usgs.gov which is the website of the National Earthquake Information Center of the U.S. Geological Survey.

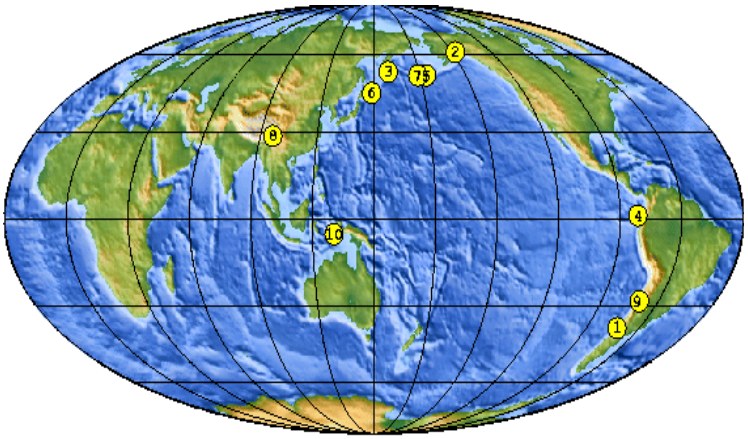
Seismic waves radiate outward from the focus of an earthquake throughout the Earth. These waves can cause damage in some areas, but not in others. Many factors can affect the amount of damage. Distance from an earthquake focus is important. Seismic energy is lost as waves travel through the Earth, so the further you are from the epicenter of an earthquake, the less shaking you will feel. The type of ground through which the waves travel is another factor. For instance, if the waves shake sand particles, the energy will tend to make the particles "settle." This may cause the Earth's surface to sink with large movements, damaging human-made structures. In contrast, if the waves pass through hard, solid rock, no settling occurs, and the movement is less.

Collapse of two layered freeway in a 1989 earthquake in the San Francisco Bay area.



The largest earthquakes are not always the most disastrous. For example you can have a large earthquake of a magnitude 9.0 with little damage because it is located in a remote area. But a 6.0 can cause death to thousands of lives if it occurs in an area with poor construction and high concentration of people. Imagine being a survivor. Think about how long it would take to heal a family that lost family members, houses, jobs, and friends. The overwhelming helplessness of a disaster is something you hope you never feel!

The 10 largest earthquakes from 1900 to 2000 are located on the world map. Notice that they are located in an area referred to as the Ring of Fire around the edges of the Pacific Ocean. Let's learn about several historic disasters.



1. Chile, 9.5; 2. Alaska, 9.2; 3. Russia, 9.0; 4. Ecuador, 8.8; 5. Alaska, 8.8; 6. Kuril Islands, 8.7; 7. Alaska, 8.7; 8. India, 8.6; 9.; Chile, 8.5 10. Indonesia, 8.5 (from U.S. Geological Survey)

The largest recorded earthquake was located in southern Chile on May 22, 1960. A 9.5 magnitude earthquake is a very violent movement, with more energy released than an atomic bomb. A person could not stand up and would be tossed around. Amazingly, only 2,000 people were killed and 3,000 injured with 2,000,000 homeless as most homes collapsed. The influence of this earthquake caused a large tsunami in Hawaii (61 deaths), Japan (138 deaths) and the Phillippines (32 deaths). This earthquakes caused elevation changes as far as the west coast of the United States.


Government Hill Grade School cracked into pieces.

The largest earthquake recorded in the United States, a 9.2 in March 27, 1964 was centered in Prince William Sound. The Government Hill Grade School, sitting astride a huge landslide, was almost a total loss. This great earthquake and tsunami took 125 lives and caused about $311 million in property loss.

A 9.0 earthquake in 1952 located in Kamchatka, Russia caused severe shaking and a tsunami caused damage on Hawaiian Islands. Only 6 cows were reported killed with no human lives lost.

A catastrophic magnitude 8.8 earthquake off the coast of Ecuador and Colombia in 1906 generated a strong tsunami that killed about 1000 people. It was observed all along the coast of Central America and as far north as San Francisco and west to Japan. This was not associated with the 1906 earthquake in San Francisco, which was only a 8.1 but caused more lost of lives and damage.


A town in Peru destroyed in a 5.5 earthquake.

In 1957 an 8.8 magnitude earthquake occurred in the Andreanof Islands, Alaska.This great earthquake destroyed two bridges on Adak Island, damaged houses, and left a 4.5 meter crack in a road. A tsunami caused by this earthquake, hit the islands of Hawaii, where is destroyed two villages and inflicted about $5 million in property damage on Oahu and Kauai Islands.

Kobe, Japan (1995)

A 8.7 magnitude earthquake hit the Kuril Islands in November, 1958. The Japanese government evacuated some of its coastal towns, but their fears of a giant tsunami never happened! In 1965 another 8.7 magnitude earthquake on Rat Islands, Alaska caused only $10,000 damage in this remote area.

A 8.6 earthquake struck an area near Tibet in 1950 which destroyed 70 villages with 156 casualties due to landslides. The Brahmaputra River was blocked causing several villages to be submerged with a lost of 532 lives 8 days after the earthquake.

1906 San Francisco Earthquake is well known throughout the world, but is neither the largest nor most destructive.

A magnitude 8.5 earthquake in 1922 occurred in the southern part of Atacama Province, central Chile. Locally, a tsunami caused extensive damage in several coastal Chilean cities that killed more then 100 people. Another 8.5 earthquake was felt in Indonesia in 1938, with few deaths.

ACTIVITY - COMPARING EARTHQUAKE DAMAGE

Part I. After you read the information on the 10 largest magnitude earthquakes, determine the damage caused by each and record the information in the space provided.

Part II. Look at the chart of the 10 most largest human disasters. All of these earthquakes where less than 8.0 M earthquake. Answer the following questions based on both lists.

1. Which area has the largest earthquakes?

2. Which country has had the most deaths?

3. Explain why the countries with the most deaths are not the largest earthquakes? (Hint: Construction of buildings.)

10 LARGEST MAGNITUDE IN THE MODERN WORLD

	place	**year**	**magnitude**	**damage**
1	Chile	1960	9.5	
2	Alaska	1964	9.2	
3	Russia	1952	9.0	
4	Ecuador	1906	8.8	
5	Alaska	1957	8.8	
6	Kuril Islands	1958	8.7	
7	Alaska	1965	8.7	
8	India	1950	8.6	
9	Chile	1922	8.5	
10	Indonesia	1938	8.5	

10 LARGEST LOSS OF HUMAN LIFE THROUGHOUT HISTORY

(all earthquakes lower than an 8.0 magnitude earthquake)

	place	year	killed
1	Syria, Upper Egypt	Jul 5, 1201	1,100,000
2	Huaxian, China	Jan 23, 1556	830,000
3	Tangshan, China	July 27, 1976	655,237
4	Calcutta, Inda	Oct 11, 1737	300,000
5	Anhwei, China	1662	300,000
6	Sichuan, China	Sept 8, 1850	300,000
7	Allepo, Syria	Sept 8, 1138	230,000
8	Qumis, Iran	Dec 22, 856	200,000 ?
9	Jeddo, Japan	1703	200,000
10	Gansu, China	Dec 16, 1920	200,000

Earth Science - EARTHQUAKES - Unit Test

Part 1. Definitions Match the number of the term or concept in Column 1 with the letter of the correct definition in Column 2.

Column 1	Column 2
1. focus	a. Push pull or primary wave
2. Fault	b. magnitude
3. Chile	c. part of upper mantle
4. Prince William Sound, Alaska	d. thickness of plates
5. S wave	e. location of largest U.S. earthquake
6. Richter Scale	f. Surface break of an earthquake
7. Mercalli scale	g. Compression or secondary wave
8. P wave	h. location of largest earthquake measured (9.5)
9. Asthenosphere	i. The point where seismic waves begin
10. Lthosphere	j. intensity

Part 2. Multiple Choice Choose the best answer to complete each statement.

1. Which is not a layer of the Earth?
    a. mantle
    b. inner core
    c. trench
    d. crust

2. Plates are part of the
    a. crust and upper mantle
    b. lower mantle
    c. mantle and upper core
    d. crust and entire mantle

3. Continents are not pulled into the mantle because
    a. they are fixed
    b. they are hard
    c. they “float”
    d. they don’t fit

4. Which is not a stress caused by movement in the lithosphere?
   a. extension
   b. compressional
   c. transform motion
   d. water

5. The first seismic waves to be recorded is
   a. B wave
   b. P wave
   c. C wave
   d. S wave

6. A record produced by a seismograph is called
   a. a gram
   b. a seismogram
   c an earthquake
   d. a record

7. Myths about the reasons for earthquakes are due to
   a. not knowing the scientific reason
   b. fear
   c. looking for an explanation
   d. all of the above

8. Guiseppe Mercalli (Mercalli Scale) created a 12 point earthquake scale that measures
   a. magnitude
   b. force of the earthquake
   c. intensity of local damage
   d. none of these

9. The Richter scale measures
   a. mathematical measurement of energy released
   b. force
   c. intensity
   d. modified Mercalli

10. The New Madrid Earthquake in the southern part of the United States is significant because it
   a. is the only place where earthquakes occur in U.S.
   b. is on a plate boundary
   c. is not on a plate boundary
   d. none of these

ANSWERS:

PART I.

1. I
2. F
3. H
4. E
5. G
6. B
7. J
8. A
9. C
10. D

PART II.

1. C
2. A
3. C
4. D
5. B
6. B
7. D
8. C
9. A
10. C