EARTHQUAKE!   John J. Thomas

Purpose

The material in this exercise will let you talk about earthquakes with your students so that both you and they will learn something about their cause, their analysis, and their probability and location.

Definitions

Earthquake - a sudden motion or trembling of the earth caused by the abrupt release of strain slowly accumulated in the earth. An earthquake is caused by a cracking 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 you. If you take a Slinky™ and stretch it between two people, bunch several coils at one end and them 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 in short quick shakes. 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 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 when the rock is 100 miles long. 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, figure 2) of the earthquake as it is recorded at the seismograph station.

Figure 1. Seismograph (U.S. Geological Survey)

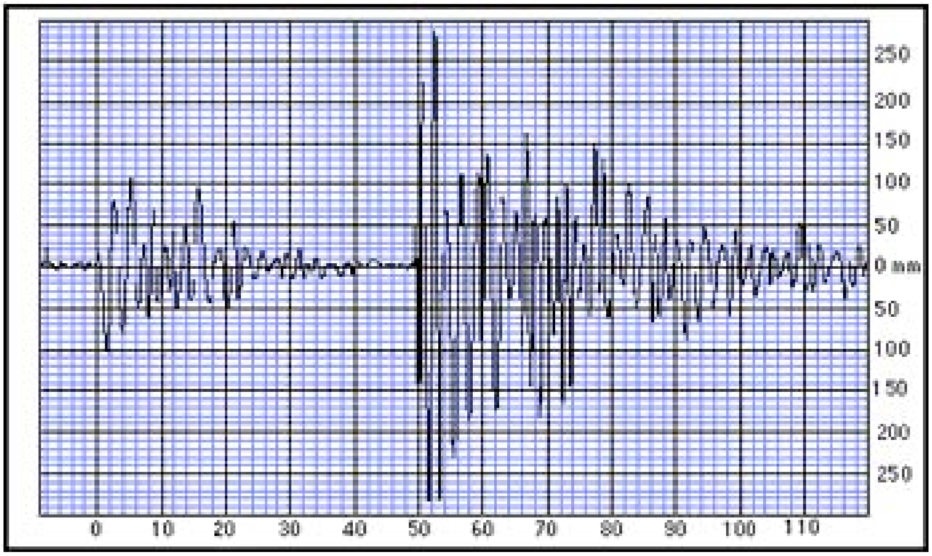

Figure 2. Seismogram (U.S. Geological Survey,)
(http://earthquake.usgs.gov/image_glossary/seismogram.html)

Earthquake Magnitude - the scale for measuring the intensity of an earthquake is the Richter Scale (Table I). The magnitude is measured by the size of the largest wave recorded on a seismogram at the recording station. Since the size of the wave depends on the distance to the earthquake, the first estimate of magnitude can be modified when the location of the earthquake is known. The Richter Scale is logarithmic which means that an earthquake wave from a 5-magnitude earthquake is 10 times higher than a 4-magnitude wave. Each unit of magnitude increase on the Richter Scale, is roughly a 30-fold increase in energy release. The largest magnitudes are near 8.6. This is the equivalent of the detonation of 1,000,000,000 tons of TNT.

Epicenter - the location of the earthquake.

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. It is a large mass hung 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 wiggly 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.

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. However, since you do not know either the size of the earthquake or the distance to the epicenter, the size of the trace tells you nothing about either of these two interesting facts. However, remember that the P-wave travels faster than the S-wave. The earth always vibrates so a seismogram always has a wiggly line on it. The P-wave is always the first noticeably larger wiggle on the seismogram. The S-wave is always the second noticeably larger one. The distance between these two traces on the seismograph is the difference in the time of arrival of the P- and the S-wave. Since we know the speed of the two waves, then the distance between the P and the S is related to the distance to the epicenter:

> The P-wave travels at 6 km/sec and the S-wave at 3 km/sec.
> The difference between the velocity of the P- and S-waves = 3 km/sec.
> 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.
> Distance to the epicenter is 3 km X 360 seconds = 1080 km.

But the earthquake could be in any direction. The distance to the earthquake would have to be drawn as a circle with a diameter of 1080 km around the location of our seismograph. We need three seismographs, hopefully in a triangle, to locate our earthquake.

For a complete description of how to locate an earthquake:

http://www.geo.mtu.edu/UPSeis/locating.html.

For a computer exercise in locating earthquakes go to:

http://www.sciencecourseware.com/eec/Earthquake/.

This is a very sophisticated program, but is great for the more advanced student.

Web Pages

Earthquakes for Kids - http://earthquake.usgs.gov/4kids/
U.S. Geologic Survey National Earthquake Information Center - http://wwwneic.cr.usgs.gov/
U.S. Geologic Survey Earthquake Hazards Program - http://earthquake.usgs.gov/
U.S. Geologic Survey Western Region - http://quake.wr.usgs.gov/
U.S. Geologic Survey Earthquake Education Resources - http://earthquake.usgs.gov/4kids/
I.R.I.S. Earthquake Page - http://www.iris.washington.edu/quakes/quakes.htm
University of Alaska, Fairbanks Earthquake Page - http://www.avo.alaska.edu/Seis/
California Institute of Technology Earthquake Laboratory - http://www.gps.caltech.edu/seismo/seismo.page.html
San Francisco Exploratorium Earthquake Information - http://www.exploratorium.edu/faultline/index.html
Southern California Earthquake Data Center - http://www.scecdc.scec.org/
Jan T. Kozak's Collection of Pictures of Historical Earthquakes - http://nisee.berkeley.edu/kozak/
University of California, Santa Barbara Earthquake Page - http://www.crustal.ucsb.edu/ics/sb_eqs/
Seismosurfing the Internet - http://www.geophys.washington.edu/seismosurfing.html

Demonstration

Where are earthquakes likely to be located in the United States? Figure 3 illustrates earthquake susceptibilities in the United States. Notice that California is not the only place that has to think about earthquakes.

By estimates based on historical data California is fourth in the earthquake hierarchy. It is likely to have large earthquakes, but few of them. By contrast New York is rated as second. New York has fairly frequent small to moderate earthquakes. South Carolina and Ohio are rated first and third. Their rankings are based on two spectacular earthquakes, the Charleston quake in 1886 and the New Madrid quake in 1811. Does New York's ranking mean that we are in danger of having our homes crumble around our ears? The answer is no. The earthquakes in the New York region usually range from 3-5 on the Richter scale, figure 3, and as you can see from Table I this means that we can feel them, but very little damage is done.

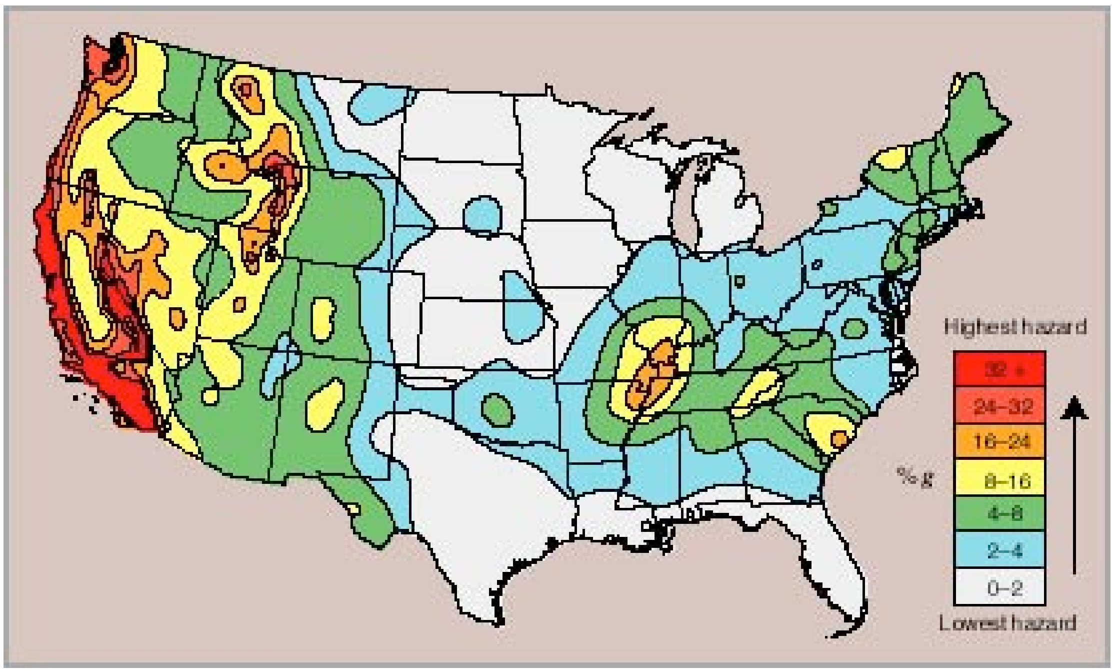

Figure 3. Earthquake Hazard Map in the Coterminous United States.
(Wesson and others, USGS, 1999, http://geohazards.cr.usgs.gov/eq/html/graphics.html)

In Saratoga Springs, New York, there is a prominent valley running through the center of the town. In this valley are several springs. A stream will always erode where the rocks can be washed away easily. The easiest place is one where the rocks are already crushed up. Springs occur where water can easily rise to the surface. The easiest place is where the rocks are crushed and therefore the water can get through. The best way to crush rock is with a fault and a fault means earthquakes. Add to this that the springs flow mineral water and the water source has to be fairly deep. Therefore, Saratoga Springs can expect to have earthquakes, and we do. Approximately every three years we feel an earthquake and often they are along our fault system or a related one.

The most famous fault in the United States is the San Andreas Fault in California, figure 3. The San Andreas stretches from San Diego in the south to north of San Francisco. It is the fault that caused the 7.9 San Francisco earthquake of 1906, the 6.5 San Fernando quake of 1971, the 7.1 San Francisco quake of 1989, and many more tremors ranging from 2-6. The San Andreas Fault area is one waiting for another quake to occur. Figure 3 shows the earthquake susceptibility of California. The big earthquake has not yet happened. Geologists estimate that San Francisco should have a major earthquake every 50 years. The major one is now 30 years overdue. That means that the amount of strain on the rocks is 60% greater than is needed to crack them. If this strain is released all at once, we could see a new record setting earthquake. Notice from figure 3 that San Francisco is only one of three areas along the fault that can expect a major fault.

TABLE I

Richter Scale:

2 - Not usually felt, but measured by seismograph.
3 - Felt quite noticeably, but not recognized as an earthquake, vibration like a passing truck.
4 - Felt by nearly everyone, many awaken, some dishes broken, unstable objects overturned, tall objects may sway.
5 - Felt by all, many run outdoors, heavy furniture moved, fallen plaster or damaged chimneys, poorly designed buildings damaged.
6 - Damage is slight in specially designed buildings, considerable damage in substantial buildings with partial collapse, great damage in poorly built buildings; fall of chimneys, columns, monuments, walls; heavy furniture overturned; persons driving cars disturbed.
7 - Damage considerable in specially designed buildings, houses shifted on their foundations, ground cracked, railroad tracks bent, landslides, water splashed over the banks of streams and lakes.
8 - few structures remain undamaged, destruction can be total, waves can be seen on the ground surface, objects can be thrown into the air.