Measuring and Predicting Earthquakes

To access a customizable version of this book, as well as other interactive content, visit www.ck12.org

CK-12 Foundation is a non-profit organization with a mission to reduce the cost of textbook materials for the K-12 market both in the U.S. and worldwide. Using an open-content, web-based collaborative model termed the **FlexBook**®, CK-12 intends to pioneer the generation and distribution of high-quality educational content that will serve both as core text as well as provide an adaptive environment for learning, powered through the **FlexBook Platform**®.

Printed: August 10, 2014

CHAPTER 1 Measuring and Predicting Earthquakes

Lesson Objectives

- Describe how seismologists can use seismic waves to learn about earthquakes and the Earth's interior.
- Describe how to find an earthquake's epicenter.
- Describe the different earthquake magnitude scales and what the numbers for moment magnitude mean.
- Describe how earthquakes are predicted and why the field of earthquake prediction has had little success.

Vocabulary

- Mercalli Intensity Scale
- moment magnitude scale
- Richter magnitude scale
- seismogram
- seismograph
- seismometer

Introduction

Seismograms record earthquake strength. Scientists can use them to determine the distance to an earthquake. Using at least three seismograms, they can locate the earthquake's epicenter. Scientists measure earthquake intensity in several ways. So far no one has found a way to predict earthquakes.

Measuring Seismic Waves

Seismic waves are measured on a seismograph. Seismographs contain a lot of information, and not just about earthquakes.

Seismographs

A **seismograph** is a machine that records seismic waves. In the past, seismographs produced a **seismogram**. A seismogram is a paper record of the seismic waves the seismograph received. Seismographs have a weighted pen suspended from a stationary frame. A drum of paper is attached to the ground. As the ground shakes in an earthquake, the pen remains stationary but the drum moves beneath it. This creates the squiggly lines that make up a seismogram (**Figure** 1.1).

Modern seismographs record ground motions using electronic motion detectors. The data are recorded digitally on a computer.

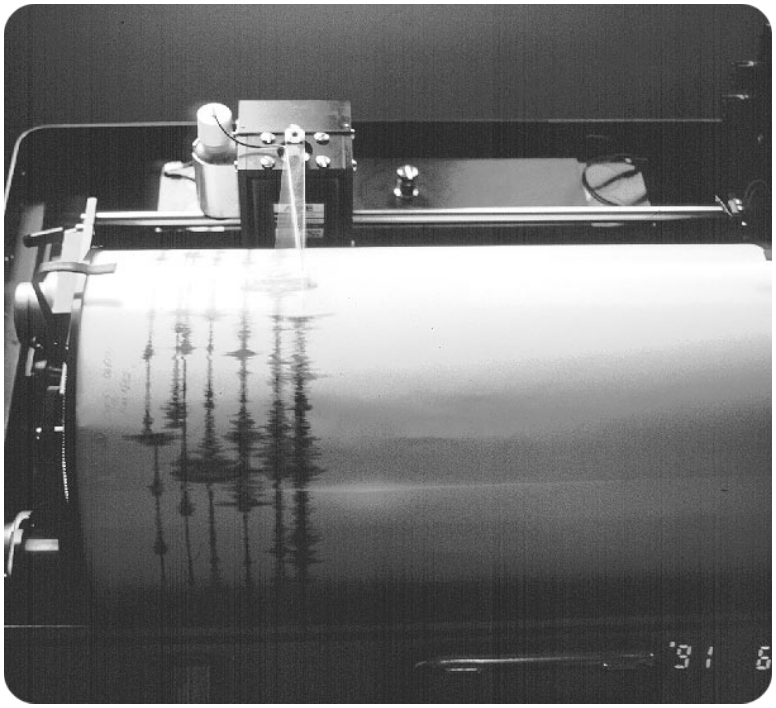

FIGURE 1.1
This seismograph records seismic waves.

What We Learn from Seismograms

Seismograms contain a lot of information about an earthquake: its strength, length and distance. Wave height used to determine the magnitude of the earthquake. The seismogram shows the different arrival times of the seismic waves (**Figure** 1.2). The first waves are P-waves since they are the fastest. S-waves come in next and are usually larger than P-waves. The surface waves arrive just after the S-waves. If the earthquake has a shallow focus, the surface waves are the largest ones recorded.

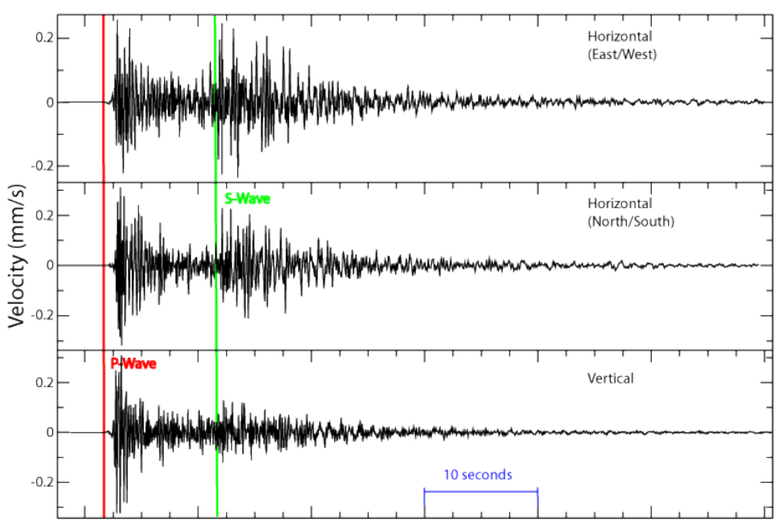

FIGURE 1.2
These seismograms show the arrival of P-waves and S-waves.

A seismogram may record P-waves and surface waves, but not S-waves. This means that it was located more than halfway around the Earth from the earthquake. The reason is that Earth's outer core is liquid. S-waves cannot travel

through liquid. So the liquid outer core creates an S-wave shadow zone on the opposite side of the Earth from the quake.

Finding the Epicenter

One seismogram indicates the distance to the epicenter. This is determined by the P-and S-wave arrival times. If a quake is near the seismograph, the S-waves arrive shortly after the P-waves. If a quake is far from the seismograph, the P-waves arrive long before the S-waves. The longer the time is between the P-and S-wave arrivals, the further away the earthquake was from the seismograph. First, seismologists calculate the arrival time difference. Then they know the distance to the epicenter from that seismograph.

Next, the seismologists try to determine the location of the earthquake epicenter. To do this they need the distances to the epicenter from at least three seismographs. Let's say that they know that an earthquake's epicenter is 50 kilometers from Kansas City. They draw a circle with a 50 km radius around that seismic station. They do this twice more around two different seismic stations. The three circles intersect at a single point. This is the earthquake's epicenter (**Figure** 1.3).

FIGURE 1.3

Seismographs in Portland, Los Angeles, and Salt Lake City are used to find an earthquake epicenter.

Earthquake Intensity

The ways seismologists measure an earthquake have changed over the decades. Initially, they could only measure what people felt and saw, the intensity. Now they can measure the energy released during the quake, the magnitude.

Earthquake Intensity

Early in the 20th century, earthquakes were described in terms of what people felt and the damage that was done to buildings. The **Mercalli Intensity Scale** describes earthquake intensity.

There are many problems with the Mercalli scale. The damage from an earthquake is affected by many things. Different people experience an earthquake differently. Using this scale, comparisons between earthquakes were

difficult to make. A new scale was needed.

The Richter Magnitude Scale

Charles Richter developed the **Richter magnitude scale** in 1935. The Richter scale measures the magnitude of an earthquake's largest jolt of energy. This is determined by using the height of the waves recorded on a seismograph.

Richter scale magnitudes jump from one level to the next. The height of the largest wave increases 10 times with each level. So the height of the largest seismic wave of a magnitude 5 quake is 10 times that of a magnitude 4 quake. A magnitude 5 is 100 times that of a magnitude 3 quake. With each level, thirty times more energy is released. A difference of two levels on the Richter scale equals 900 times more released energy.

The Richter scale has limitations. A single sharp jolt measures higher on the Richter scale than a very long intense earthquake. Yet this is misleading because the longer quake releases more energy. Earthquakes that release more energy are likely to do more damage. As a result, another scale was needed.

The Moment Magnitude Scale

The **moment magnitude scale** is the favored method of measuring earthquake magnitudes. It measures the total energy released by an earthquake. Moment magnitude is calculated by two things. One is the length of the fault break. The other is the distance the ground moves along the fault.

Earthquake Magnitudes

Each year, more than 900,000 earthquakes are recorded. 150,000 of them are strong enough to be felt by people. About 18 each year are major, with a Richter magnitude of 7.0 to 7.9. Usually there is one earthquake with a magnitude of 8 to 8.9 each year.

Earthquakes with a magnitude in the 9 range are rare. The United States Geological Survey lists five such earthquakes on the moment magnitude scale since 1900 (see **Figure** 1.4). All but one, the Great Indian Ocean Earthquake of 2004, occurred somewhere around the Pacific Ring of Fire.

Earthquake Prediction

Scientists are not able to predict earthquakes. Since nearly all earthquakes take place at plate boundaries, scientists can predict where an earthquake will occur (**Figure** 1.5). This information helps communities to prepare for an earthquake. For example, they can require that structures are built to be earthquake safe.

Predicting when an earthquake will occur is much more difficult. Scientists can look at how often earthquakes have struck in the past. This does not allow an accurate prediction for the future. Small tremors, called foreshocks, often happen a short time before a major quake. The ground may also tilt as stress builds up in the rocks. Water levels in wells also change as groundwater moves through rock fractures. These do not usually allow accurate predictions.

Folklore tells of animals behaving strangely just before an earthquake. Most people tell stories of these behaviors after the earthquake. Chinese scientists actively study the behavior of animals before earthquakes to see if there is a connection. So far nothing concrete has come of these studies.

Once an earthquake has started, many actions must take place. Seismometers can detect P-waves a few seconds before more damaging S-waves and surface waves arrive. Although a few seconds is not much, computers can shut down gas mains and electrical transmission lines. They can initiate protective measures in chemical plants, nuclear power plants, mass transit systems, airports, and roadways.

FIGURE 1.4
Earthquake and tsunami damage in Japan, 2011. The Tōhoku earthquake had a magnitude of 9.0.

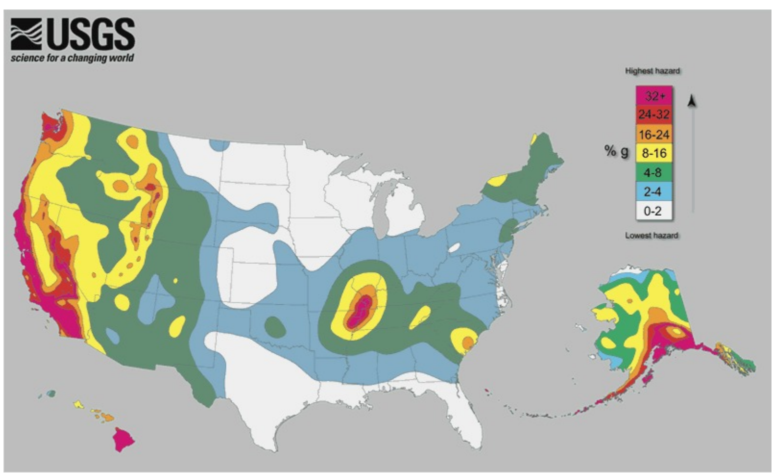

FIGURE 1.5
This map shows earthquake probability regions in the United States.

Lesson Summary

- Seismologists use seismograms to determine how strong an earthquake is, how far away it is, and how long it lasts.
- Epicenters can be calculated using the difference in the arrival times of P-and S-waves from three seismograms.
- The intensity of an earthquake can be determined in many ways. The Mercalli Scale identifies the damage done and what people feel, the Richter Scale measures the height of the largest seismic wave, and the moment

magnitude scale measures the total energy released by an earthquake.
- Despite some successes, seismologists cannot yet accurately predict earthquakes.

Lesson Review Questions

Recall

1. How does a seismograph work?

2. In what order do waves arrive at a seismograph?

3. What information is needed for seismologists to calculate the distance that a seismic station is from an earthquake's epicenter?

4. Describe how to locate an earthquake epicenter.

Apply Concepts

5. Draw a picture to show the S-wave shadow zone. How does this indicate a liquid outer core?

6. While the Mercalli scale is still used for measuring earthquake magnitude, why is it not the only scale used? Where does it fall short relative to the Richter and moment magnitude scales?

Think Critically

7. Like the Richter scale, the moment magnitude scale is logarithmic. The 2011 Tōhoku earthquake in Japan was 9.0 and did tremendous damage. A few months earlier, an 8.8 struck Chile and did much less damage. Why?

8. What are the characteristics of a good earthquake prediction? Why are these features needed?

Points to Consider

- If you live in an earthquake prone area, how do you feel about your home now that you've read this section? Since earthquakes are unlikely to be predicted, what can you do to minimize the risk to you and your family? If you do not live in an earthquake prone area, what would it take to get you to move to one? Also, what risks from natural disasters do you face where you live?
- What do you think is the most promising set of clues that scientists might some day be able to use to predict earthquakes?
- What good does information about possible earthquake locations do for communities in those earthquake-prone regions?

References

1. Courtesy of R. P. Hoblitt, US Geological Survey. http://commons.wikimedia.org/wiki/File:Seismograph_Pinatubo.jpg . Public Domain

2. User:Crickett/Wikimedia Commons. http://commons.wikimedia.org/wiki/File:Seismogram.gif . The copyright holder of this work allows anyone to use it for any purpose including unrestricted redistribution, commercial use, and modification
3. CK-12 Foundation. . CC BY-NC 3.0
4. Courtesy of the US Navy. http://commons.wikimedia.org/wiki/File:Tsunami_damage_north_of_Sendai_1x1_resized.jpg . Public Domain
5. Courtesy of the US Geological Survey. http://earthquake.usgs.gov/hazards/about/basics.php . Public Domain