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1/9/03  
Bay Area Science Museum Collaboratory Project

## **Unit: Restless Earth**

### **Lesson: Earth's Interior**

#### **Introduction**

**Standards: 1.b, 7.e**

#### **Objectives**

Students will be able to

- Describe what geologists do
- List the characteristics of Earth's crust, mantle, and core.

#### **Key Terms**

Geologist, rock, geology, constructive force, destructive force, continent, seismic wave, pressure, crust, basalt, granite, mantle, lithosphere, asthenosphere, outer core, inner core

#### **Activating Prior Knowledge**

If you dig down far enough through the dirt, what does your shovel hit?

Other than rock, what else do you think is below the surface of Earth?

Explain that over the rest of the semester we will be focusing on EARTH SCIENCE. This is one of the main 3 branches that science is often broken into. Geologists are scientists who study the forces that make and shape planet Earth. They study the processes that create Earth's features and search for clues about Earth's history. They study the chemical and physical characteristics of rock, the material that forms Earth's hard surface.

#### **Lesson**

##### **Use Visuals/Share Pair**

Use a picture in the book of the island of Surtsey that began to form in the Atlantic Ocean near Iceland in 1963. Also talk about Hawaii and the new island that is forming. Use these examples to reinforce that the earth surface is constantly changing.

Today, geologists divide the forces that change the surface into two groups:

Constructive forces: Shape the surface by building up mountains and landmasses. (i.e. Surtsey)

Destructive forces: slowly wear away mountains and eventually every other feature on the surface. (i.e. Ocean waves)

Have the students **Share/Pair** and come up with lists of constructive and destructive forces. Groups that come up with the most get a candy treat!

##### **Discover Activity**

How do scientists determine what's inside earth? (pg. 6)

Skills Focus: Inferring

Materials: 3 Film Canisters with tops, 3 different materials, masking tape, permanent marker, scale

Time: 10 minutes

- Tips: The different materials that could be used in the canisters include practically anything that will fit in the canisters. Try to include both liquids and solids and vary them in viscosity, density, size, and other physical characteristics.
- Lecture: Have a discussion on how they think scientists gather evidence about Earth's interior.

Scientists can only get so far into the Earth. When scientists want to study Earth's interior, they must rely on indirect methods of observation. When earthquakes occur, they produce seismic waves. Geologists record the seismic waves and study how they travel through Earth. The speed of these seismic waves and the paths they take reveal how the planet is put together. From their studies scientists have found that the Earth is made of layers.

### **Inquiry Challenge**

Help students understand how scientists use seismic waves to map Earth's interior by having them experiment with waves in water. Have the students write-up how the materials changed the waves.

- Materials: bowls, water, pencil, glass jar or bottle and other various objects  
 Time: 15 minutes

The temperature and pressure increase as you travel to the center of the Earth. Give an example of a swimming pool and how as the swimmer goes deeper the pressure increases because more water is pushing on the swimmer.

### **Demonstration**

- Materials water, bucket, 2-L plastic soft-drink bottle, small plastic soft drink bottle.  
 Put the bottle in the bottom of the bucket and have them watch it collapse

### **The Layers of the Earth**

Show overhead of layers

Show how an apple is similar to the Earth

CRUST (5-40 km)

Continental Crust – Granite (light, less dense)

Oceanic Crust – Basalt (dark, dense)

Possibly show examples of each type of rock

MANTLE (2900 km)

Lithosphere – rigid layer

Asthenosphere – weak layer (soft)

CORE (mostly nickel and iron) slightly smaller than the moon

Outer core – thick liquid (2250 km)

Inner Core – dense ball of solid metal (1200 km)

Draw a Venn Diagram showing the overlapping layers of the Asthenosphere and lithosphere

### **Labs you can Eat**

Students create three-dimensional edible models of the interior structure of the Earth, including the inner core, the outer core, the mantle, and the crust.

- Materials: Graham cracker crumbs, peanut butter mixture, jelly, chocolate chips

Time: 30-45 minutes

### **Earth's Magnetic Field**

Currents in the outer core force the inner core to spin. The inner core spins faster than the rest of earth. This creates a magnetic field

# SURTSEY



Ragnar Larusson/Photo Researchers, Inc.  
**Volcanic Island**

The small Icelandic island of Surtsey was created in November 1963 when a volcano erupted in the North Atlantic Ocean.

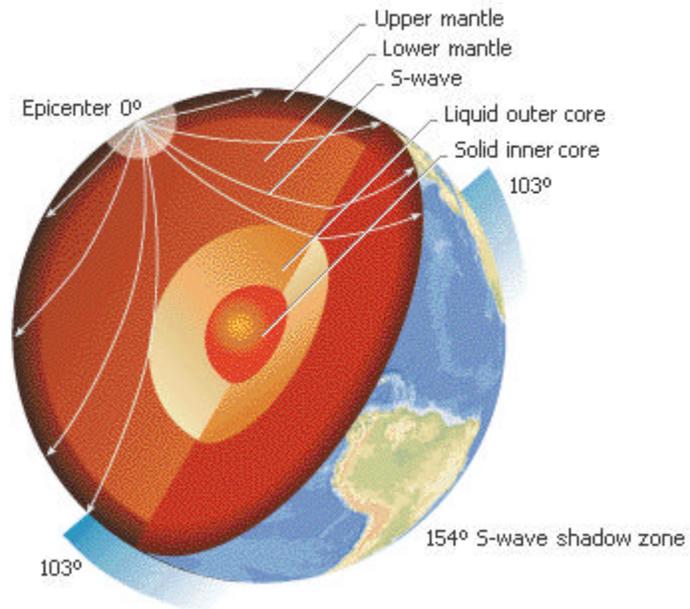
# PLATE TECTONICS



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**Volcanoes and Plate Tectonics**

Scientists have determined that there is a close connection between the formation of volcanoes and the movement of the tectonic plates. Nearly 80% of the earth's volcanoes are found near the tectonic plate boundaries of the Pacific Ocean. The oceanic crust is subducting, or plunging beneath, the continental crust in this region. Volcanoes can also be found at divergent plate boundaries where tectonic plates are splitting apart, or in the middle of tectonic plates, such as the volcanoes of the Hawaiian Islands in the North Pacific Ocean.

# Earth's Interior

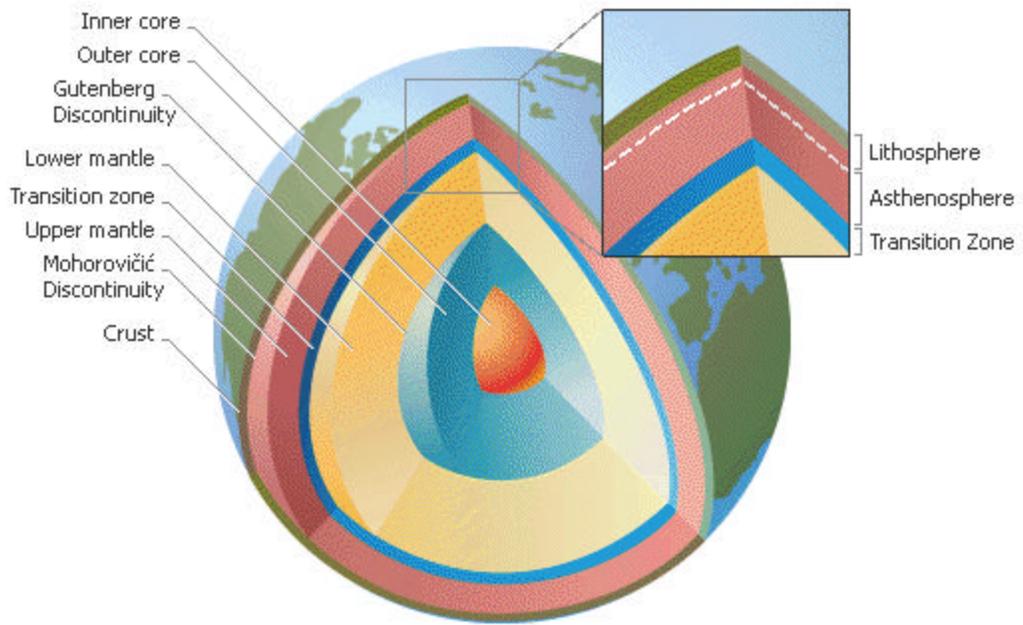


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**Liquid Outer Core of Earth**

Scientists used waves generated by earthquakes to determine that the outer core of the earth is liquid. Earthquakes generate P-waves and S-waves within the earth. Shadows occur on the opposite side of the earth from the earthquake epicenter because the outer core reflects S-waves, and bends P-waves. S-waves are reflected because they cannot travel through liquids, and they cast a larger shadow than the bent P-waves. Geologists and seismologists determined the size of the outer core by using the 154-degree arc of the S-wave shadow and measurements taken on the surface of the earth.

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# Earth's Interior



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**Internal Structure of the Earth**

Seismologists study the way earthquake waves travel through the earth to determine the earth's internal structure. The earth is composed of a series of layers, including the crust, mantle, and inner and outer core. The lithosphere, part of the upper mantle and the crust, is composed of solid rock. Deeper within the earth, the less rigid asthenosphere surrounds the molten lower mantle, the liquid outer core, and the solid inner core.  
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# Lesson 2 Earthquakes: Earth's Crust in Motion

## Introduction

### Anticipation Guide

As an introduction to this lesson on Earthquakes give students an anticipation guide which they will return to at the end of the lessons on Earthquakes.

**Standards: 1.c, 1.d, 1.e, 1.f, 7.e**

### Objectives

Students will be able to

- Describe how stress forces affect rock.
- Describe the types of faults, why faults form, and where they occur.
- Describe how movement along faults changes Earth's surface.

### Key Terms

Earthquake, stress, shearing, tension, compression, deformation, fault, strike-slip fault, normal fault, hanging wall, footwall, reverse fault, fault-block mountain, folds, anticline, syncline, plateau

### Activating Prior Knowledge

Ask students who have experienced an earthquake to describe the event – where they were at the time, how they first became aware that an earthquake was occurring, what happened to buildings and objects around them, how they felt during and after the quake, and so on. If students have not experienced an earthquake, let them relate what they have learned from television reports, movies, newspaper and magazine articles, and other sources.

Have them fill out a **K W L** (What they know, want to know and then at the end of the lesson go back and fill in things that they learned.)

## Lesson

### Design Challenge

**House of Cards - from Tech Museum, if students have visited the Tech they may have tried this design challenge at the Earthquake station downstairs.**

Skills Focus: Design a building (as tall as you can make it) to withstand an Earthquake.

Materials: 3 index cards, scissors, 10cm of tape

Time: 20 minutes

Test buildings on a shake table.

An earthquake is the shaking and trembling that results from the movement of rock beneath Earth's surface. The movement of earth's plates creates powerful forces that squeeze or pull the rock in the crust. These forces are examples of stress, a force that acts on rock to change its shape or volume.

### Types of Stress

Show overhead of stresses (8)

Demonstrate the types of stress with silly putty

**SHEARING**

Stress that pushes a mass of rock in two opposite directions.

**TENSION**

Stress that pulls on the crust, stretching rock so that it becomes thinner in the middle.

### COMPRESSION

Squeezes rock until it folds or breaks.

Any change in the volume or shape of Earth's crust is called deformation. Most changes in the crust occur so slowly that they cannot be observed directly.

### Kinds of Faults

A fault is a break in Earth's crust where slabs of crust slip past each other. The rocks on both sides of a fault can move up or down or sideways. Faults usually occur along plate boundaries, where the forces of plate motion compress, pull or shear the crust so much that the crust breaks.

Show overhead or draw on whiteboard

Give Graphic Organizer for students to take notes

Three main types of fault boundaries

#### Strike-Slip Fault

Shearing forces create these

When rocks on either side of the fault slip past one another

**Transform Boundary** – plates slip past one another

#### Normal Fault

One block of rock lies above another block

Hanging Wall

Footwall

When movement occurs along a normal fault, the hanging wall slips downward.

Tension forces create normal faults where plates diverge, or pull apart.

**Divergent Boundary** – plates move apart

#### Reverse Fault

Same structure as a normal fault, but the blocks move in the opposite direction.

**Convergent Boundary** – plates come together

The San Andreas Fault forms a transform boundary between the Pacific Plate and the North American Plate.

### Making Models of Faults

Modeling Movement Along Faults

Guide students through making a model of the various types of faults

Materials: modeling clay, marking pen, butter knife

### Mountain Building

Over millions of years, fault movement can change a flat plain into a towering mountain range.

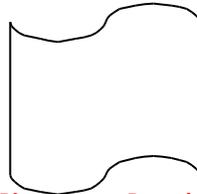
Mountains Formed by Faulting

Mountains Formed by Folding – folds can also cause earthquakes and lead to faults

### Folds

Anticline – bends up to an arch

Syncline – bends down to a bowl



### Homework or Computer Lab

Visit <http://www.thetech.org/exhibits/online/quakes/>

Name: \_\_\_\_\_  
Date: \_\_\_\_\_  
Period: \_\_\_\_\_

*Anticipation Guide*  
*(before to lessons)*  
*Earthquakes!*

**Directions:** In the space provided, place an “X” below in the agree column if you agree with the statement. Place and “X” below in the disagree column if you disagree with the statement.

**Agree**

**Disagree**

\_\_\_\_\_

\_\_\_\_\_

1. In California we don't have to worry about earthquakes.

\_\_\_\_\_

\_\_\_\_\_

2. An earthquake can occur at any time without warning.

\_\_\_\_\_

\_\_\_\_\_

3. Scientists have no idea how earthquakes occur.

\_\_\_\_\_

\_\_\_\_\_

4. Every city on earth has an equal chance of experiencing an earthquake.

\_\_\_\_\_

\_\_\_\_\_

5. There is no way to prepare yourself or your family for an earthquake.

\_\_\_\_\_

\_\_\_\_\_

6. There is no way to tell exactly where an earthquake originated.

Name: \_\_\_\_\_  
Date: \_\_\_\_\_  
Period: \_\_\_\_\_

*Anticipation Guide*  
*(after to lessons)*  
*Earthquakes!*

**Directions:** In the space provided, place an “X” below in the agree column if you agree with the statement. Place and “X” below in the disagree column if you disagree with the statement.

**Agree**

**Disagree**

- |       |       |   |
|-------|-------|---|
| _____ | _____ | 1. In California we don't have to worry about earthquakes.                |
| _____ | _____ | 2. An earthquake can occur at any time without warning.                   |
| _____ | _____ | 3. Scientists have no idea how earthquakes occur.                         |
| _____ | _____ | 4. Every city on earth has an equal chance of experiencing an earthquake. |
| _____ | _____ | 5. There is no way to prepare yourself or your family for an earthquake.  |
| _____ | _____ | 6. There is no way to tell exactly where an earthquake originated.        |

# Plate Boundaries

**Transform Boundary** –  
Plates move past one another

**Divergent Boundary** –  
Plates move away from one another

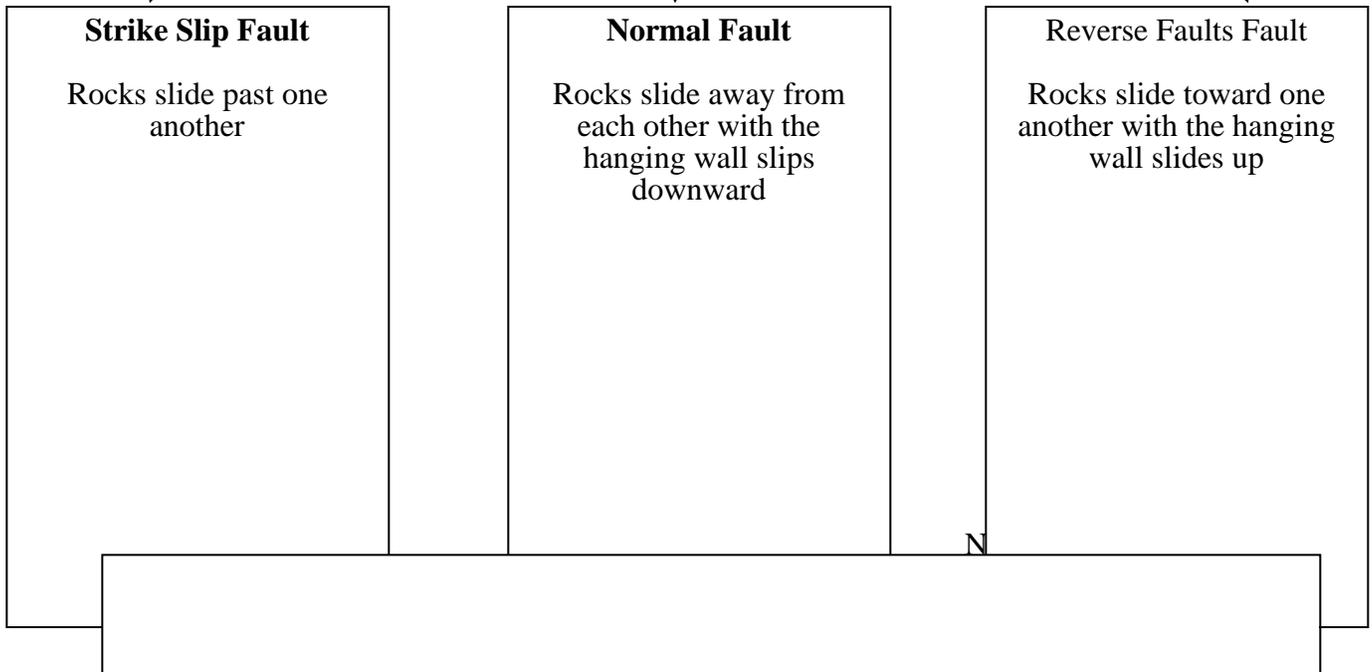
**Convergent Boundary** –  
Plates move towards each other

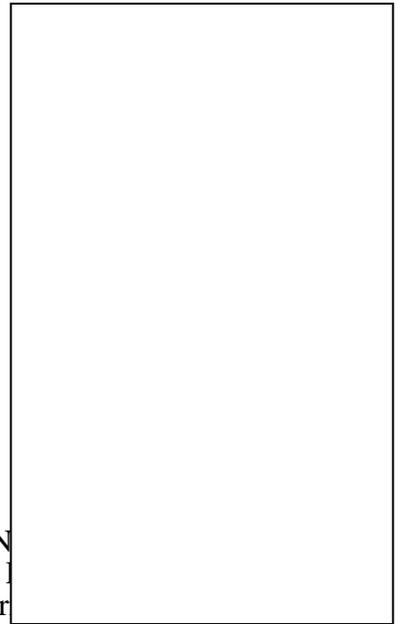
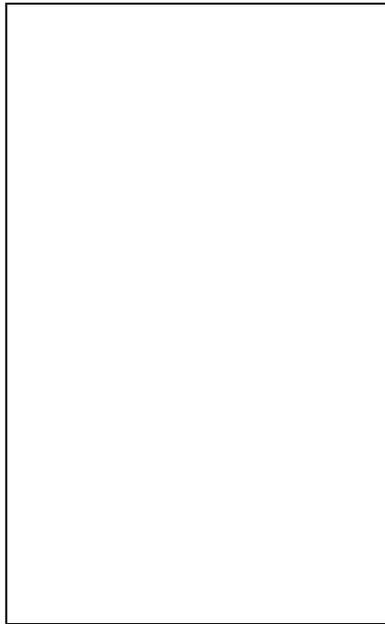
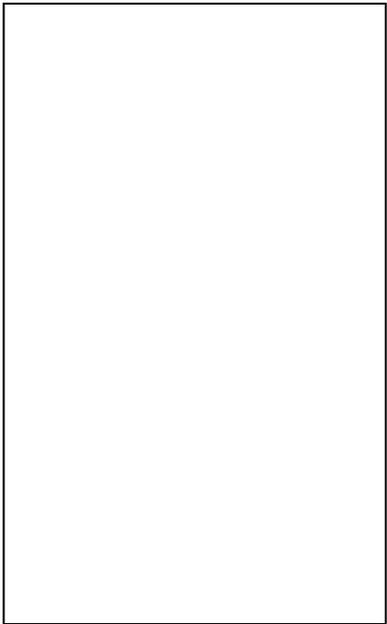
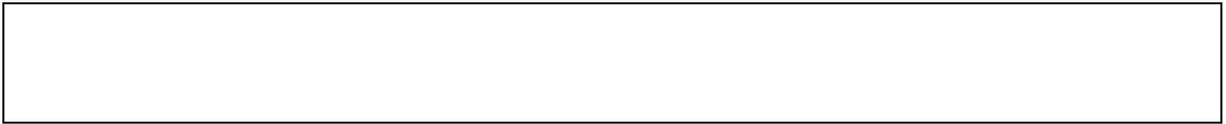
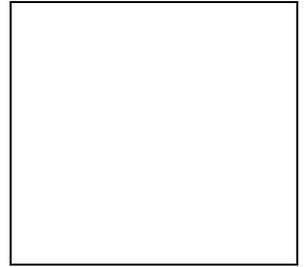
# Earthquakes

**Strike Slip Fault**  
Rocks slide past one another

**Normal Fault**  
Rocks slide away from each other with the hanging wall slips downward

**Reverse Faults Fault**  
Rocks slide toward one another with the hanging wall slides up





N  
Per

# **SAN ANDREAS FAULT**

## **Strike-slip fault**



Francois Gohier/Photo Researchers, Inc.

### **San Andreas Fault, California**

The San Andreas Fault, unlike most faults that stay below the ocean, emerges from the Pacific Ocean and traverses hundreds of miles of land. It runs through California for about 1000 km (about 600 mi) from Point Arena to the Imperial Valley. The fault marks the boundary between the North American and Pacific tectonic plates; earthquakes are caused by these plates sliding together.

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# Earthquakes!

**Know**

**Want to know**

**Learned**

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# Lesson 3 Earthquakes: Measuring Earthquakes

## Introduction

**Standards:** 1.g, 3.a, 7.c

### **Objectives**

Students will be able to

- Describe how the energy of an earthquake travels through Earth.
- Identify the different kinds of seismic waves.
- Name the scales used to measure the strength of an earthquake.

### **Key Terms**

Focus, epicenter, seismic waves, P waves, S waves, surface waves, seismograph, magnitude, Mercalli scale, Richter scale, moment magnitude scale

### **Activating Prior Knowledge**

Overhead of focus and epicenter

You guys now know how earthquakes occur – by the movement of the faults. Did you know that earth is never still. Every day, worldwide, there are about 8,000 earthquakes. Most of them are too small to notice. Earthquakes always begin in the rock below the surface. The **focus** is the point beneath Earth's surface where rock that is under stress breaks, triggering an earthquake. The point on the surface directly above the focus is called the **epicenter**.

What kinds of waves have you observed?

How do waves move in water?

Earthquakes travel like the waves you guys were talking about. They are called **seismic waves** and are vibrations that travel through Earth carrying the energy released during an earthquakes. Seismic waves carry the energy of an earthquake away from the focus, through Earth's interior, and across the surface.

Seismic waves carry the energy of an earthquake away from the focus, through Earth's interior, and across the surface.

## Lesson

### **Categories of Seismic Waves**

Bring a slinky to show the different kinds of waves

Primary Waves (P waves)

- These are waves that compress and expand the ground like an accordion.
- Travel through liquids and solids.

Secondary Waves (S waves)

- Waves that vibrate from side to side as well as up and down. They shake the ground up and down and side to side.
- Travel through solids but can't travel through liquids.

Surface Waves

- When P waves and S waves reach the surface, some of them are transformed into surface waves.
- They move more slowly than P and S waves.
- Produce the most severe ground movements.

Why do you think surface waves produce more severe ground movements than P waves and S waves do?

Students should infer that because the surface consists of loose soil, sand, gravel, mud, small rocks, and the like rather than solid rock, it is susceptible to greater movement as the particles shift and slide.

### **Detecting Seismic Waves**

Scientists record and measure the vibrations of seismic waves, geologists use instruments called seismographs. A seismograph records the ground movements caused by seismic waves as they move through the Earth

Skills Focus: Inferring

Materials: large book, pencil, paper strip 1 meter long, pen

Time: 10 minutes

Group: 3 students at minimum

Tips: make sure students hold the pencil and rolled strip parallel to the book and tabletop.

Lecture: Encourage students to try different types of earthquakes.

### **Measuring Earthquakes**

Geologists want to know the size of an earthquake – there are 20 different ways to rate earthquakes.

Ask students if they can tell you any of the scales that earthquakes are measured?

Three of the most common scales will be discussed.

The Mercalli Scale – rates earthquakes according to intensity. An earthquake's intensity is the strength of ground motion in a given place. Show overhead of The Mercalli Scale. It is not precise. It describes how earthquakes affect people, buildings, and the land surface.

The Richter Scale – rating of the size of seismic waves as measured by a particular type of seismograph. Provides accurate measurements for small, nearby earthquakes.

The Moment Magnitude Scale – estimates the total energy released by an earthquake. Can be used to rate all size earthquakes near and far. At each rating it is 32 times stronger. Thus a 5 is 32x stronger than 4 and 6 is 32x32 (1000ish times) larger than 4. Under 5 is little damage, over 5 can produce great destruction.

### **Video**

Bill Nye the Science Guy: Earthquakes

### **Locating the Center of an Earthquake**

Real-World Lab: Careers in Science

Give students an opportunity to use a graph of P and S wave arrival times to identify the location of the epicenter by doing the lab Locating an Epicenter.

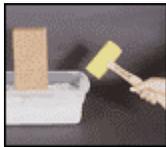
## Computer Lab

Here are some activities to do that are from the Exploratorium Museum.

<http://www.exploratorium.edu/faultline/activities/index.html>

Try the following activities to learn more about earthquakes.

### LIQUEFACTION



Under some conditions, the earth can behave like a liquid when an earthquake hits. With a baking pan full of sand, some water, and a brick, you can see this for yourself.

### HIGHWAY SEISMOGRAPH



Take a ride down a bumpy road and become a human seismometer.

### SEISMIC SLINKY



What goes on under the ground during an earthquake? Make a Slinky wiggle and warp, and you can model the invisible forces that make the earth tremble.

# Earthquake Scales

Mercalli Scale	Richter Scale
<b>I.</b> Felt by almost no one.	<b>2.5</b> Generally not felt, but recorded on seismometers.
<b>II.</b> Felt by very few people.	<b>3.5</b> Felt by many people.
<b>III.</b> Tremor noticed by many, but they often do not realize it is an earthquake.	
<b>IV.</b> Felt indoors by many. Feels like a truck has struck the building.	
<b>V.</b> Felt by nearly everyone; many people awakened. Swaying trees and poles may be observed.	
<b>VI.</b> Felt by all; many people run outdoors. Furniture moved, slight damage occurs.	<b>4.5</b> Some local damage may occur.
<b>VII.</b> Everyone runs outdoors. Poorly built structures considerably damaged; slight damage elsewhere.	
<b>VIII.</b> Specially designed structures damaged slightly, others collapse.	<b>6.0</b> A destructive earthquake.
<b>IX.</b> All buildings considerably damaged, many shift off foundations. Noticeable cracks in ground.	
<b>X.</b> Many structures destroyed. Ground is badly cracked.	<b>7.0</b> A major earthquake.
<b>XI.</b> Almost all structures fall. Bridges wrecked. Very wide cracks in ground.	<b>8.0 and up</b> Great earthquakes.
<b>XII.</b> Total destruction. Waves seen on ground surfaces, objects are tumbled and tossed.	

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 Earthquake Scales: Mercalli and Richter

The Mercalli and Richter scales are used to rate and compare the intensity of earthquakes. The Modified Mercalli scale is somewhat subjective, because the apparent intensity of an earthquake depends on how far away from its center the observer is located. Rating intensities from I to XII, it describes and rates earthquakes in terms of human reactions and observations. The Richter scale measures the motion of the ground 100 km (60 mi) from the earthquake's epicenter, or the location on the earth's surface directly above where the earthquake occurred. The rating scale is logarithmic; each increase of 1 on the scale represents a tenfold increase in the motion of the ground.

# Lesson 4 Earthquakes: Earthquake Hazards and Safety

## Introduction

Standards: 1.g, 2.d, 3.a

### Objectives

Students will be able to

- Describe how earthquakes cause damage and the kinds of damage they cause.
- Explain what can be done to reduce earthquake hazards.

### Key Terms

Liquefaction, aftershock, tsunamis, base-isolated building

### Design Challenge

*Shake, Rattle and Roll: Building for the Big One*

<http://www.thetech.org/learning/challenge/design/BuildingForTheBigOne.pdf>

***Building for the Big One - from Tech Museum, if students have visited the Tech they may have done this as a lab. You can also take a field trip to the Tech and take a class with this design challenge.***

Challenge: You are a structural engineering student at Stanford. Your dog ate your homework project, which was to make a scale model of your favorite building. You've used up all of your original building materials. There is nothing in the house but craft sticks and hot glue & 30 are left.

Materials: film canister with rocks to serve as a person to save, 30 craft sticks with a rubber band around it, 1 hot glue stick, 1 hot glue gun

Soil Types: 1 pan play-dough (bedrock), 1 pan grape-nuts (gravel fill), 1 pan wet grape-nuts (alluvium), 1 pan cornstarch/H<sub>2</sub>O (sand)

## Lesson

### How Earthquakes Cause Damage

This will be discussed when doing the design challenge. See above. Make sure to bring up liquefaction which occurs in sand. Also discuss how the soil on top of rock can shake more violently.

### Overhead of Exploring an Earthquake Safe House

Most earthquake-related deaths and injuries result from damage to buildings or other structures. New buildings must be made stronger and more flexible. Older buildings must be modified to withstand stronger quakes.

### Protecting Yourself During an Earthquake

Discuss Drop, Cover, and Hold

Crouch under a desk or table

Crouch against an interior wall and cover your head and neck with your hands

### Homework

Have students devise an earthquake safe house plan for where they live.

