II

Why and Where Earthquakes Occur

Earthquake Curriculum, K-6 — Scope and Sequence Chart

Unit II: Why and Where Earthquakes Occur

Level	Concept	Laboratory	Mathematics	Language Arts	Social Studies	Art
K-2	The Earth is made up of layers. Earth's outer layer is broken into pieces called plates. The movement of Earth plates is the cause of most earthquakes.	Egg analogy of the earth layers Earth layer simulation game		Vocabulary development of earthquake words	Map puzzle of Earth plates	Color, cut, and paste Earth plates Shape recognition of Earth plate puzzle
3-4	The Earth has a layered structure. Earth's outer layer, the lithosphere, is broken into pieces called plates. Convention currents in the mantle might be the cause of plate motion which results in earthquakes.	Egg analogy of Earth layers Hand movement simulation of Earth layer motion Convection current demonstration	Scale measurements Bar graph of Earth layers	Written description of Earth's interior Vocabulary development of earthquake words	Earth size and distances Map study of epicenter and plate locations	Color in Earth layer diagram Three dimensional model of Earth layers
5-6	The Earth has a layered structure and an outer layer broken into pieces called plates. Three basic movements take place at the edges of the plates. Plate movements create special surface features near the edges of the plates. Convention currents in the mantle may be the cause of plate movements.	Models of Earth plate motions Convection current demonstration	Scale model of Earth layers Metric measurement	Vocabulary development of earthquake words	Map study of epicenter and plate locations Geologic features of the Earth's surface	Model of Earth layers Model of formation and break-up of Pangaea

II

Why and Where Earthquakes Occur

Although our Earth feels solid as we walk along its surface, it is really only partly so. The Earth is divided into three main layers that can be visualized by using a hard-boiled egg as a model. There is a hard outer surface, a softer middle layer, and a central core. The outermost layer of the Earth is broken into irregular pieces, called *plates*, which make the Earth resemble a spherical jigsaw puzzle. These plates are in very slow but constant motion. Plates move in three different ways—colliding with each other, spreading apart, or sliding past one another. Earthquakes can release the energy stored in rocks by any one or a combination of these three kinds of movement. Today many scientists believe that the plates float on currents created in hot plastic-like material beneath the plates.

Why and Where Earthquakes Occur

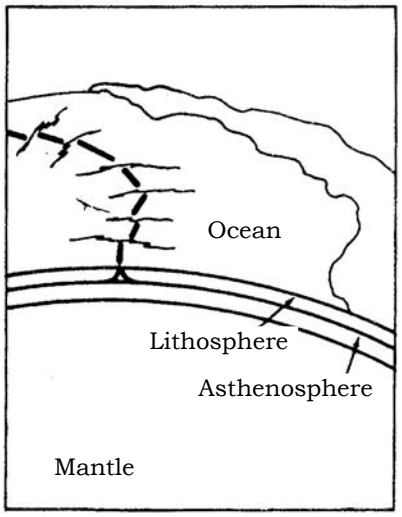
In Unit I we defined earthquakes in a general way, particularly as they affect human beings. To really understand why earthquakes occur, however, we need to know something about the makeup of our Earth. Two concepts are basic to all of the lessons in this unit: that the planet we live on is composed of layers, and that its outermost layer and surface are broken into irregular pieces called *plates*.

The Layers of the Earth

The simplest way of describing the Earth's layers is to compare the globe to a hard-boiled egg. It has a crust something like the shell, a middle layer, or *mantle*, something like the white, and a core that is something like the yolk. The crust and the upper portion of the mantle are often referred to together as the *lithosphere*, or rock sphere. Scientists further divide the core into the *inner core* and the *outer core*.

Crust and Lithosphere

The Earth's crust varies in thickness from about 65 km on the continents to only about 10 km on the ocean floors. Even at its thickest, the crust is not nearly as thick in relation to the whole bulk of the Earth as the shell of an egg is to the egg. This becomes obvious when we compare 65 km to the radius of the Earth, 6,370 km.



The lithosphere is the outer solid portion of Earth that includes the crust and the uppermost part of the mantle. The lithosphere has an average depth of 100 km.

Lower Mantle and Core

Directly below the lithosphere is the *asthenosphere*, a region of the mantle with a plastic, semisolid consistency, which reaches to about 200 km below the surface. The mantle continues to a depth of 2,900 km.

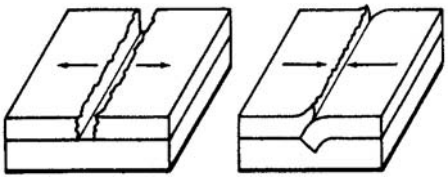
The liquid outer core, which might be compared to the outer two-thirds of an egg's yolk, reaches from 2,900 km to a depth of about 5,100 km. The solid metallic inner core goes the rest of the way to the center of the Earth. Both are composed primarily of iron and nickel.

The oldest rocks of the crust have been dated by radioactive decay at about 4.0 billion years old. We do not know when the lithosphere began to form, but we assume that it broke into plates at this time.

The Earth's Plates

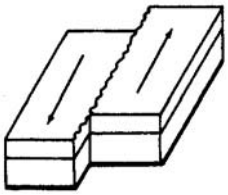
Most earthquakes are caused by large-scale movements of the Earth's lithospheric plates and occur at the boundaries between the plates. Experts recognize seven to twelve major plates and a number of smaller ones. The plates take their names from continents (the North American plate); from oceans (the Pacific plate); and from geographic areas (the Arabian plate).

Types of Plate Movements



Divergent (spreading) plate movement

Convergent (colliding) plate movement



Strike-slip (transform) plate movement

Slow and Steady Motion

The plates are in very slow but constant motion, so that seen from above, the Earth's surface might look like a slowly moving spherical jigsaw puzzle. The plates move at rates of 2 to 15 cm, or several inches, in a year: about as fast as our fingernails grow. On a human scale, this is a rate of movement that only the most sophisticated instruments can detect. But on the scale of geological time, it's a dizzying speed. At this rate, those almost-four-billion-year-old rocks could have traveled all the way around the Earth eleven times.

Three Kinds of Plate Movements

The movement of the plates is generally one of three kinds—spreading, colliding, or sliding. When plates are spreading, or separating from each other, we call their movement divergent. When they are colliding, or pushing each other, we call the movement *convergent*. Movement in which plates slide past each other is called strike-slip (or transform) plate movement. Earthquakes can accompany each of the three types of movement.

Plate Tectonics

Continental Drift: 1910 to 1960

The theory of plate tectonics originated early in the 20th century, although it did not gain general acceptance until the late 1960s. The German meteorologist, geophysicist, and explorer Alfred L. Wegener is now given credit for the first step in understanding the movement of the lithosphere. In the period 1910-1912 he formulated the theory called *continental drift* and collected evidence from the rocks, fossils, and climate of various continents to show that they had once been joined together. Wegener had little data on the oceanic crust, so he thought that the continents merely moved through that crust.

Earth land masses about 200,000,000 years ago.

Earth land masses about 50,000,000 years into the future.

Plate Tectonics: 1960 to the Present

In the early 1960s, Fred Vine and Drummond Matthews showed that the ocean floor was spreading apart at the mid-ocean ridges. They and others soon realized that the continents were also moving. By 1968 a new explanation for the dynamics of the Earth's surface had been born, and christened plate tectonics.

Convection Currents

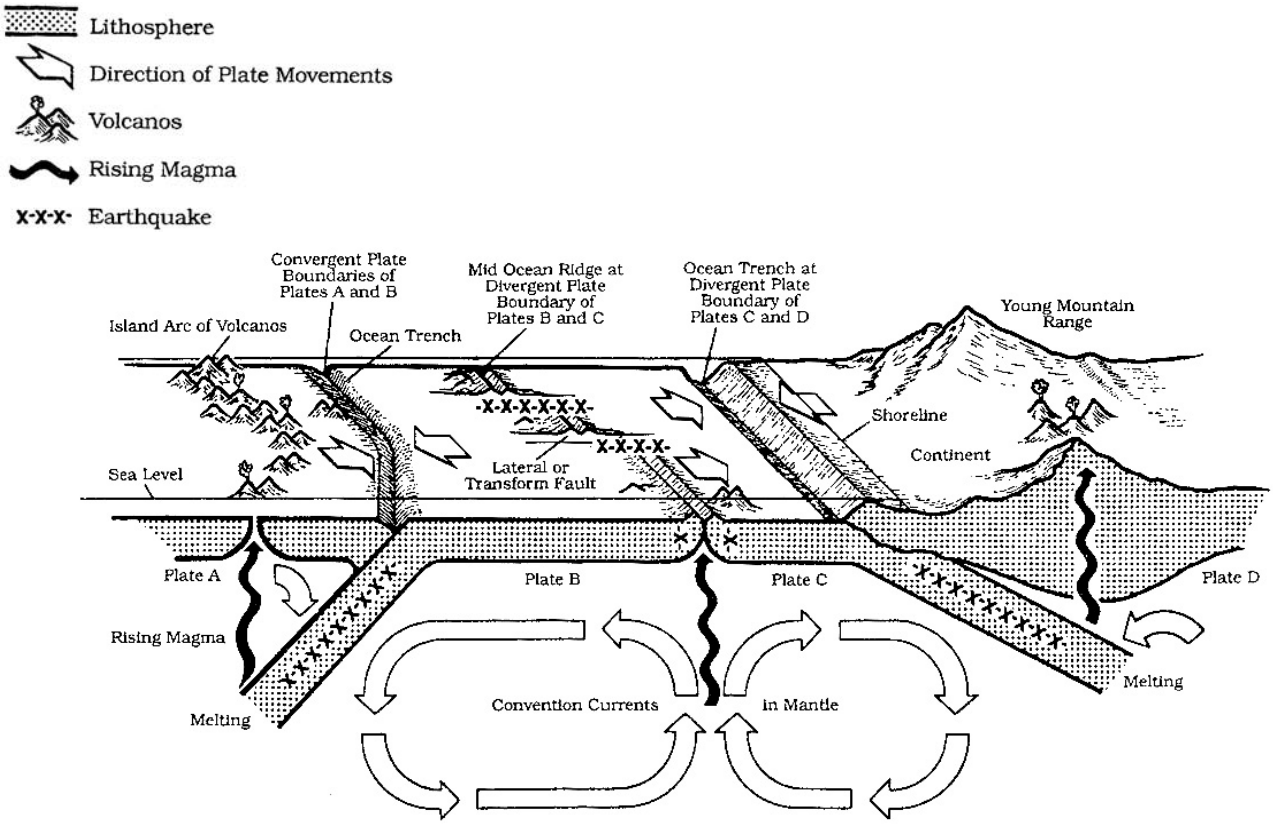
The force that drives the plates, however, is still something of a mystery. Wegener thought that centrifugal force, caused by the rotation of the Earth, was the cause of continental drift. The weight of modern scientific opinion favors convection currents—systems of heat exchange that form in the Earth's mantle.

Beneath the lithosphere the mantle is semi-molten to a depth of about 260 km. Its plastic-like material rises in response to heat and sinks when the temperature drops. You can see this kind of movement if you boil water in a clear glass pot.

This convective movement acts as a drag on the underside of the lithospheric plates, causing them to separate where mantle material is rising and collide where it sinks. As the plates are dragged along over the mantle, like potato chips riding on honey, the leading edges of some plates are destroyed, while others pick up new material. Sometimes the edge of one plate slides under another, in the process we call subduction.

Some scientists explain the motion of plates as a downhill sliding. They are high at the mid-ocean ridges, and extend deep into the mantle at their leading edges. As a subducting plate sinks, it fractures from the stress and causes deep earthquakes. Eventually, because of the high temperature of the mantle, the subducting plate melts. Then this molten plate material rises into the crust, where it feeds volcanoes.

Somehow, these various processes maintain a kind of balance, so that the size of the lithosphere stays about the same. Remember to emphasize, with your students, the great sweep of geological time in which tectonic processes occur. Discovering the dynamic nature of this seemingly solid Earth should be exciting, but not frightening.



Master 18, Convection Currents and Plate Boundaries

Inside Planet Earth

Content Concepts

1. The Earth is made up of layers.

2. Its outer layer is broken into pieces called plates.

3. The movement of the Earth's plates is the cause of most earthquakes.

Vocabulary

core
mantle
crust
plate

Objectives

Students will
— name and identify layers of the Earth.
— observe a model of the Earth's plates.
— create a model of the Earth's layers with their bodies.
— construct a representation of the Earth's plates with jigsaw puzzle pieces.

Assessment

Construct a scientific drawing showing layers of the Earth.

Learning Links

Language Arts: Vocabulary building, following directions

Art: Coloring, cutting, pasting, shape recognition

Social Studies: Locating plates on a world map and identifying major global features (continents and oceans)

Activity One: Earth from the Inside Out

Materials for the teacher

- Transparency made from Master 12a, Layers of the Earth
- Overhead projector
- Hard-boiled egg with the Earth's plates outlined in permanent marker (Crude markings will do.)
- Kitchen knife or dental floss

Materials for each student

- Batches of Play-Doh™, modeling medium (see recipe), or plasticine modeling clay
- Master 12b, Earth Layers Worksheet
- Small strips of yellow, blue, and red construction paper
- 3 toothpicks
- Scissors
- Paste or glue
- Dental floss or butter knife

Procedure

1. Show the transparency on the overhead projector, pointing out the three basic layers of the Earth—core, mantle, and crust—and describing each.

2. Show students the egg and point out the marks that indicate the plates.

Explain: The Earth's top layer is broken into pieces called plates. The plates are always moving, but usually very slowly—about as fast as your fingernails grow. Sometimes, when the plates move away from each other, bump into each other, or grind past each other, we experience earthquakes. Then we feel shaking, and sometimes we hear rumbling.

3. With a sharp knife, slice the egg, shell and all, and show students the layers inside. Explain that the crust is something like the shell, the white is something like the mantle, and the yolk is something like the core.

4. Prior to this activity make batches of modeling medium if Play-Doh™ or modeling clay is not available.

core

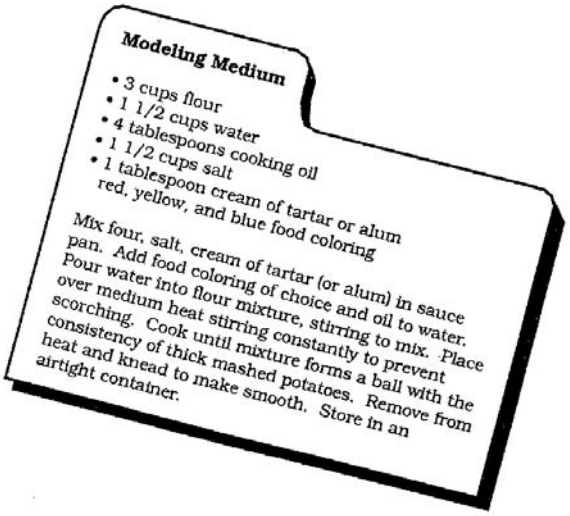
The core is the deepest layer of the Earth. It helps to heat the Earth from inside like a furnace.

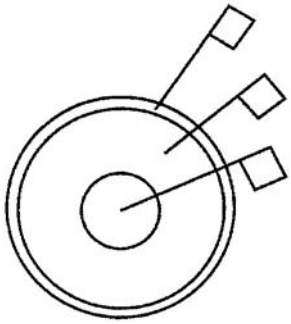
man • tle

The mantle is the layer between the core and the crust. It is mostly solid. Just below its top is a semi-solid layer with a consistency something like modeling clay or gelatin dessert.

crust

The crust is the top layer of the Earth, solid and very thin compared to the other layers.





Model of inside of the Earth with labeling flags.

Toothpick flags: toothpicks with a piece of paper wrapped and glued around one end.

5. Encourage students to create their own model of the inside of the Earth beginning with the core and working out to the crust.

Have students choose a small portion of red clay to represent the core of the Earth. They will need a greater portion of yellow (mantle), and then blue (crust) to create their model.

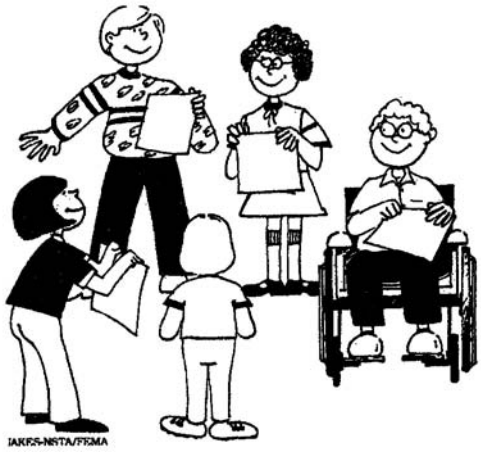
Using dental floss or a butter knife, have students cut their model in half, then label each section with a toothpick flag.

6. Distribute copies of Master 12b, Earth Layers Worksheet. Direct students to color the Earth's layers in paper wrapped and glued around one end different colors: red for the core, yellow for the mantle, and blue for the crust. Readers can cut out the labels and paste them in the correct boxes.

Activity Two: Energy Transfer

Materials for each student

- A color-coded sign saying Core (red), Mantle (yellow), or Crust (blue), perhaps on a string to hang around the neck.



Procedure

1. Invite students to use their bodies to represent the layers of the Earth.

2. Select a small group of children (2 or 3) to represent the core, and give them red signs which say **Core**. Ask them to stand in the center of the room. Students should show that they are very hot, perhaps by mopping their brows and fanning themselves.

3. Select a larger group (8 to 10 students) to represent the mantle. Give them yellow **Mantle** signs and ask them to form a circle around the core group. Students should move very slowly around the core group.

4. Give blue **Crust** signs to about 15 more students and ask them to hold hands and surround the mantle group.

5. Tell the mantle students that when you call out "Earthquake," they are to bump into the crust students, causing them to move and break their circle. This transfer of energy from mantle students to crust students simulates roughly what happens during an earthquake.

Teacher Take Note: In later grades students will also learn about the *lithosphere*, the layer to which the plates belong. For now the three basic layers are enough.

Activity Three: Giant Jigsaw Puzzle

Materials for the teacher

- Egg model from Activity One
- World Map
- Transparency made from Master 13, Earth Plates
- Overhead projector

Materials for each student

- Handouts made from Masters 13, Earth Plates, 14a, Puzzle Pieces, and 14b, Puzzle Pieces
- Crayons
- Scissors
- Paste

Procedure

1. Repeat the egg demonstration to establish the relationship of the crust to the shell and the existing plates. Draw continents onto the egg shell, crack the egg, and gently manipulate both parts of the egg back and forth, demonstrating the movement of the Earth's plates.

2. Recall the turtle story in Unit I, and explain that the theory of plate movement gained general acceptance among scientists only in the late 1960s. Also remind students of the activity in which they represented the layers of the Earth. Ask:

> What causes most earthquakes? (The Earth plates move.) When one part of the crust moves, what happens to the other parts of the crust? (They move too.)

3. Display Master 13, Earth Plates, on the overhead, and compare it to the world map. Explain that the Earth's crust can be divided into major plates which fit together like the pieces of a gigantic jigsaw puzzle. Help students observe that some of the plate boundaries are under the ocean.

4. Hand out Masters 13, 14a, and 14b, and direct students in cooperative groups to color all the shaded areas on the Master 14 pages brown. These represent the Earth's major land masses. Have them leave the remaining areas blue. These represent oceans and seas.

5. Ask students to count the puzzle pieces so that they perceive the boundaries and can point to each piece. (This is important to be sure that they are interpreting positive and negative space correctly.) Point out that one plate has no land on it, and another has very little land.

6. Direct students to cut out the Master 14 puzzle pieces, and paste them on the worksheet made from Master 13, the Earth plate outlines. Be sure they understand that their diagram represents a flattened view of the Earth and its plates.

Extensions

1. Tell the turtle story from Unit One. How would you explain an earthquake if you were a modern Gabrielino who had studied about the layers of the Earth and its plates?

2. On a paper plate, draw a diagram of the layers of the Earth. Label each layer.

Some of the smaller plate regions are not cut apart into puzzle pieces on Masters 14a and 14b as they would be too small for the children to handle comfortably.

Teacher Take Note: To make a larger floor or learning center version of the puzzle, enlarge Masters 14a and 14b. Paste the enlargements onto tagboard, laminate (if possible), and cut out the pieces. Put Velcro™ on the back of each piece so you can use it on a flannel board.