III

Physical Results of Earthquakes

Earthquake Curriculum, K-6 -- Scope and Sequence Chart

Unit III: Physical Results of Earthquakes

Level	Concept	Laboratory	Mathematics	Language Arts	Social Studies	Art
K-2	Earthquakes cause changes in the Earth's surface	Hand movement simulation of Earth plate motion. Fault movement game Milk carton simulation of earthquake results	Math facts practice	Vocabulary development of earthquake words	Features of a community Map making	Illustration of a community Model construction
3–4	Small-scale topographic changes are associated with plate movements. Earthquake activity causes small-scale topographic changes.	Paper simulations of rock layers and models of faults Sand simulation of liquefaction Landslide simulation Tsunami simulation	Planes and angles recognition Measurement practice	Write-up of landslide activities Vocabulary development of earthquake words	Effects of faults, landslides, and fissures Geographic features locations	Fault model construction Construction of seashore environments for tsunami simulation
5–6	Tectonic movements, including earthquakes, are among the major forces which create Earth's landscape. Mountains, plains, and plateaus are the major features of the continents. Many of the Earth's most significant landscape features are under the oceans.	Paper simulation of rock layer movement Mountain building simulation Ocean turbidity current simulation		Vocabulary development of earthquake words	Map study of plate boundaries	Construction of underwater landscape

III

Physical Results of Earthquakes

Over billions of years, Earth motions and earthquakes have played a major part in shaping the physical features of our Earth, both on land and under water. Over time, small-scale changes make foothills and minor cracks; large-scale changes produce towering mountains and deep valleys. As the plates of the Earth's surface move, warping slowly up, down, and sideways in relation to each other, we may feel these movements as earthquakes. The waves of energy they release not only shake the Earth, but also alter the nature of many soils, giving them an unstable liquid-like consistency. Then structures sink, tip, and topple, and hillsides crumble.

Physical Results of Earthquakes

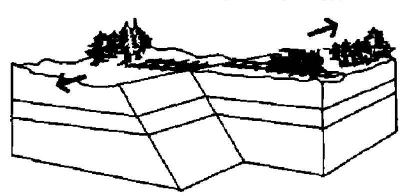
If there were no plate motions, our planet would not look like home. There would be no mountains, no valleys, and no plateaus. Without the uplifting of land caused by tectonic (mountain building) processes, most land above sea level would be uniformly flat, whittled down by the processes of erosion.

Earth-Shaking: Earth-Shaping

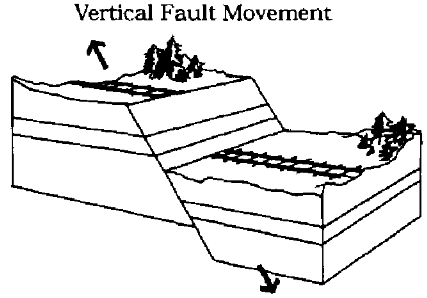
Earthquakes and other tectonic events have been occurring for as long as the Earth has existed. The changes in the landscape associated with these events range from small cracks in the soil to the raising (*uplifting*) or lowering (*downdropping*) of huge chunks (or *blocks*) of the lithosphere.

No large mountain or deep valley has been formed as the result of a single earth-shaking event. The raising and lowering of sections of the Earth generally happens gradually, in small increments. Over thousands and millions of years these increments add up to significant changes, such as fault block mountains and deep graben valleys.

Horizontal Fault Movement



Vertical Fault Movement



Faults and Folds

As a result of plate motions, the accumulated stress and strain within the rocks of the lithosphere may cause great warps or folds in rock layers. Where rock is strained beyond its limit, it will fracture, and the rock mass on either side will move abruptly.

Up, Down, or Sideways
A fault is a fracture within the Earth's crust along which significant movement has occurred. Faults are often classified according to the direction of movement and whether movement is predominantly horizontal or vertical.

Displacement of rock along a fault can occur as a result of vertical or horizontal fault movement. Vertical fault movement changes the elevation of a rock mass on one side of the fault relative to the rock mass on the opposite side. Rock masses on one side of the fault can also shift horizontally in relation to the opposite side. Fault movement is always stated in relative terms.

Vertical fault movement may result in cliffs (scarps) along the fault line. Horizontal or lateral fault movement may cause roads and river banks to change their position. In the lessons that follow, students will use hand movements and paper models to illustrate these fault movements.

Folding Rock Layers
Folding is another way that rock layers respond to stress. They may crumple sideways, without fracturing, like wrinkles in a rug. We can see small folds in hand specimens of sedimentary rock; larger examples of folded rock layers can be seen in mountain sides and road cuts. Some mountain chains, such as the Alps or the Folded Appalachians, show primarily folded
structures.

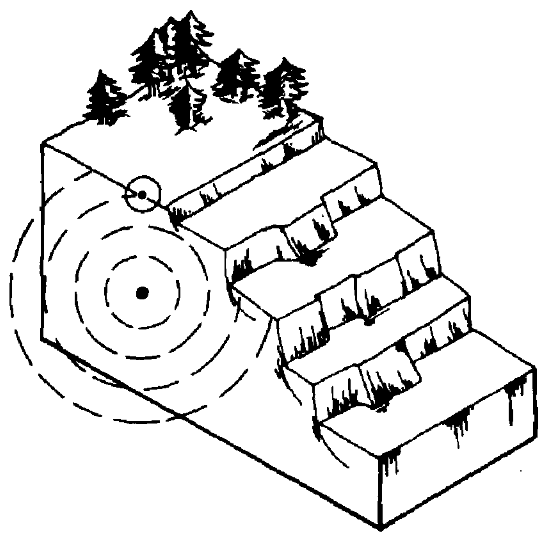
Soil Liquefaction

Although deep-down earthquake action takes place in the rocky lithosphere, much of the dollar damage that occurs in earthquakes results from the *liquefaction* of soil. When earthquake vibrations pass through soil which has a high water content, the soil loses the properties of a solid and takes on those of a semiliquid, like quicksand or pudding. The foundations of heavy buildings suddenly lose the support of the soil, and they may topple, or settle deeper into the Earth.

You have experienced liquefaction on a small scale if you have ever walked along the beach and seen water rise to the top of the sand at your every step. When liquefaction happens on a large scale, however, as it did at Nigata, Japan, in 1964, it spells disaster.

Why Land Slides

Earthquakes may trigger many landslides, particularly during the rainy season. The potential for landsliding is highest in soft sediments on steep slopes; where seasonal rainfall is high; where vegetation is shallow, rotted or sparse; where erosion is high; and where ground shaking is intense.



Underwater Earthquakes

Earthquakes on the ocean bottom may result in the up or down shifting of large blocks of the crust. Such motion can generate a special kind of ocean wave called a tsunami, or seismic sea wave. A series of these waves may travel at speeds up to 800 km/hr in the deep ocean, where they are too small to be seen. But, when they reach land, they mount to heights of tens of meters and break against the shore and its buildings. Low coastal areas can be flooded, and much loss of life can result.

It is difficult to adjust our focus wide enough, in both space and time, to recognize the geological events and structures that surround us on dry land. It is even more difficult to think about those events and structures when they occur underwater, where we cannot see them. Yet water covers about 70 percent of our planet, and the same tectonic forces are at work on the floors of the oceans as on the continents.

Although the same processes are at work, we need a new vocabulary to understand them. Mountain ranges in the ocean are called *mid-ocean ridges*; plains are called *abyssal plains*. Landslides (or submarine slides) occur as well, but we call them *turbidity currents*. The fourth activity for Grades 5 and 6 gives students a chance to model turbidity currents.

A Word to the Wise

If you can communicate the scope and magnitude of tectonic events to your students, and make them aware that earthquakes are something more than disasters on a human scale, you will have done a great deal. Enjoy these activities with them.

Earthquakes Shape Our Earth

Content Concept

Earthquakes cause changes in the Earth's surface.

Vocabulary

fault
rural

Objectives

Students will
—demonstrate three faulting actions.
—describe a rural community.
—draw a model of such a community.
—demonstrate the effects of earthquakes on the model community.

Assessment

Choose one kind of fault and describe its movement. If an earthquake occurred, tell what would happen to a new fence that a farmer built across that fault.

Learning Links

Language Arts: Discussing features of a rural community, describing results of earthquake simulations

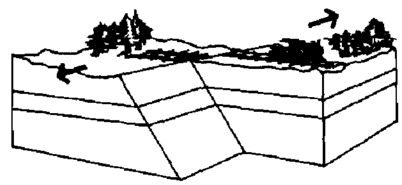
Social Studies: Extending the concept of community, completing a map

Art: Drawing a diagram of a community, constructing a model

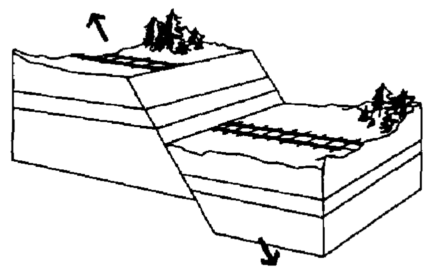
Activity One: Earth Movers

Materials for the teacher
- Overhead projector
- World map or transparency of Master 13, Earth Plates
- Transparency of Master 21, Fault Movements

Horizontal Fault Movement



Vertical Fault Movement



Master 21, Fault Movements

Procedure

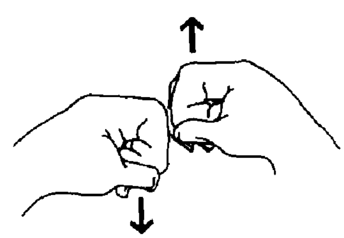
1. Review with the students the concepts that the Earth's surface is made up of plates, and that those plates have been shifting and moving over millions of years. Direct their attention to the map.

2. Explain that earthquake movement does not occur just at the edges of the plates, but also within the continents. Movements may happen at cracks in the Earth called *faults*. These movements are of two main kinds—up and down, and sideways.

3. Display Master 21, Fault Movements and point out the directions of the two movements. Demonstrate the types of faults with hand movements, and ask students to perform the movements along with you.

Up and down movements

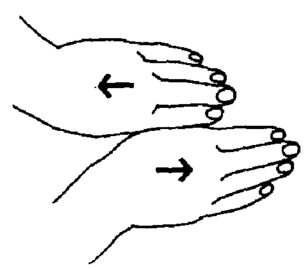
Down movement (Normal faulting). Make your hands into fists and press the flat edges of the fingers together. Release the pressure and let one hand drop about 4 cm. The straight fingers and knuckles of the other hand will resemble a fault cliff.



Illustrate up and down plate movement by raising and lowering fists in relation to each other.

Up movement (Reverse faulting). Press knuckles and fingers tightly together as before. Without releasing the pressure, let one hand slide up about 4 cm. Again, the result will look like a cliff, but students should be able to see the difference in the two processes.

Sideways movement (Lateral, or transform faulting). Press the sides of the hands together. As you release the pressure, slide your two hands past each other in a jerky motion. You will feel the vibrations and see the horizontal displacement of the two sides which occurs in this type of faulting.



Illustrate lateral, sideways, movement by sliding one hand next to the other.

fault

A fault is a crack in rock or soil where movement has taken place.

ru • ral

A rural community is a farming community where people do not live close together as they do in cities.

Activity Two: Model Communities

Materials for the teacher
- Overhead projector
- Transparency made from Master 22, Rural Community after an Earthquake

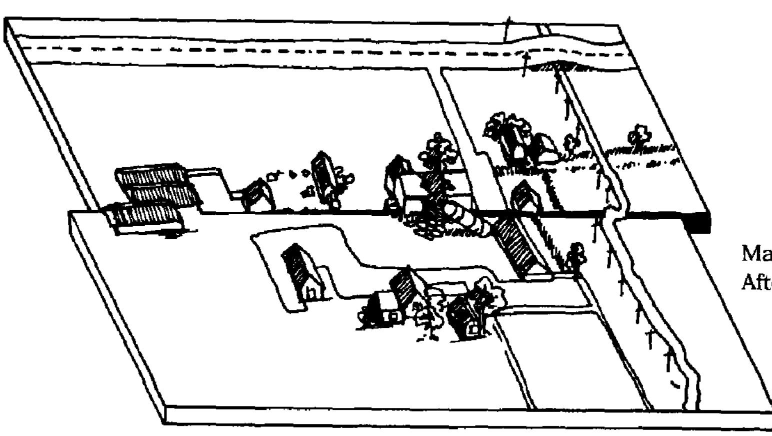
Materials for each pair of students
- Two 1/2-gal. milk or juice cartons
- Rubberbands
- Pencils and felt markers or crayons
- Paper to cover top and sides of each carton
- Colored construction paper (strips)
- Scissors
- Masking tape or glue
- Clay, Play-Doh™
- Odds and ends (e.g., toothpicks, string, paper clips)

Procedure

1. Review faulting actions with students. Project Master 22, Rural Community, and ask students what they see. Discuss the effects of the earthquake on the rural community pictured.

2. Tell students that they are going to construct a similar community. Ask them to name some physical features of a rural community, and list them on the overhead or on the blackboard. (Do not include people or animals.) Your list may look something like this:

long fences	barns
crops planted in rows	bridges
roads	trees
houses	utility poles and wires



Master 22, Rural Community After an Earthquake

3. Distribute 1/2-gal. milk cartons to each pair of students. Ask them to plan a model community and include some of the features they listed above.

a. Open completely one end of each carton.

b. Place the cartons side by side, with the open ends facing opposite direction.

c. Place one or two rubberbands around the middle of both cartons, locking them together.

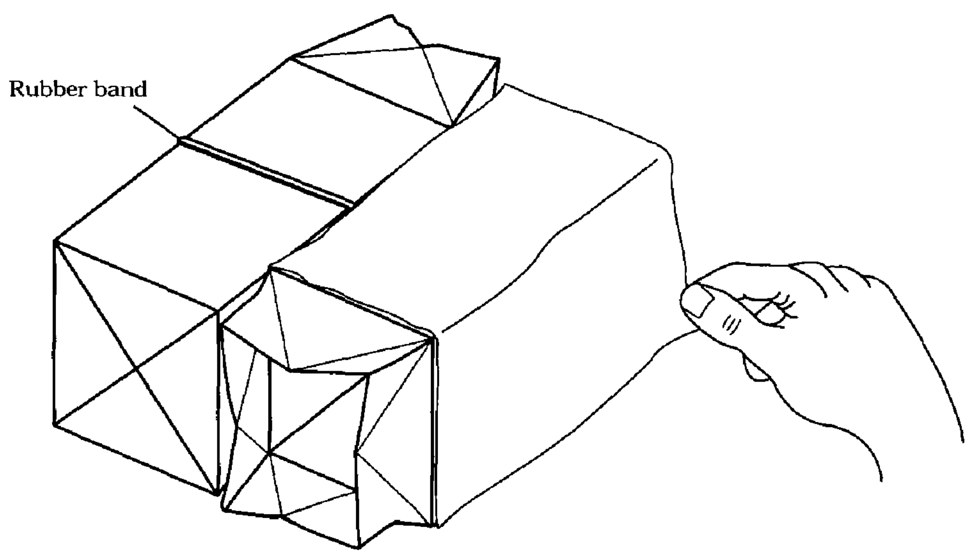
d. Cover the top and side of each carton with construction paper. Wrap each carton from the long edge where the cartons meet and cover top and one side. Do not cover the ends.

e. Use the materials provided to construct a 3-dimensional community on the top surface of the cartons.

4. Tell students that the place where the two cartons meet represents a fault.

Direct students to use the cartons to simulate the two faulting actions from Activity One that they have demonstrated with their hands: up and down faulting, and sideways faulting. (Note: Students can place their hands in the cartons while carrying out this step.) Remind them that earthquakes result from a release of energy, and ask them to place pressure on the fault and release it rapidly each time they want to bring the cartons into a new position.

5. Ask students to observe and describe the changes to their community after each simulation.



Landscape on the Loose

Vocabulary

normal fault
reverse fault
lateral (strike-slip) fault
Appalachian mountains
fault plane
fold
groundwater
landscape
landslide
liquefaction
tsunami

Learning Links

Language Arts: Labeling types of faults, following oral instructions, writing paragraphs

Social Studies: Locating geographic features, discussing how faults, landslides, and tsunamis affect people's lives and property

Math: Measuring materials for liquefaction demonstration

Art: Making fault models, constructing seashore environments for tsunami simulation

Content Concepts

1. Small-scale topographic changes are associated with plate movements.

2. Earthquake activity causes small-scale topographic changes.

3. Earthquakes on the ocean floor sometimes cause giant seismic sea waves, or *tsunamis.*

Objectives

Students will
—understand that many landscape features are a result of earthquake activity.
—construct models of three types of faults and be able to name and identify them.
—demonstrate the formation of folded rock.
—demonstrate liquefaction, and describe how it happens.
—demonstrate a landslide and describe some factors that influence the results of landslides triggered by earthquakes.
—identify tsunamis as an earthquake event, and demonstrate their mechanism and effects on shore faults.

Assessment

You visited a town that had a leaning building. Use what you know about sandy soils and water beneath the surface to explain what may have caused the building to lean.

Activity One: Up, Down, and Sideways

Materials for the teacher
- Map of U.S.

Materials for each student
- Worksheet made from Master 23, Fault Model
- Scissors
- Colored pencils or crayons
- Tape
- Paper strip 5/8 inch wide from standard size paper.

Procedure

1. Distribute worksheet with fault diagrams. Tell students that they are going to make a model to illustrate the three basic types of faults.

2. Explain that horizontal lines on sides of the diagram represent different rock layers below the surface, as we might see them exposed on the side of a cliff. Instruct students to color each layer a different color. (All layers with the same letter should be the same color.)

3. Instruct students to cut out the fault model. Fold the rock layer extensions down to form a box with the features (trees, train track, river) on the top. Taping sides together, the box will make a 3-dimensional model of the top layers of the Earth's crust.

4. The dashed line on your model represents a fault. Carefully cut along the dashed line. You will end up with two pieces.

5. Place the two pieces of your model together so that point A is next to point C. Move the two pieces so that point A is next to point B. This represents a normal fault.

Ask students to describe how the Earth's surface has changed after the normal fault occurred. (The surface is not level. The left side of the Earth's surface along the fault line is higher than the right side.)

Ask students to predict what might happen to the river now that the rock layers have moved. (There may be the formation of rapids or a waterfall.)

fault plane

A fault plane is a surface along which faulting movement has occurred.

lat • er • al fault

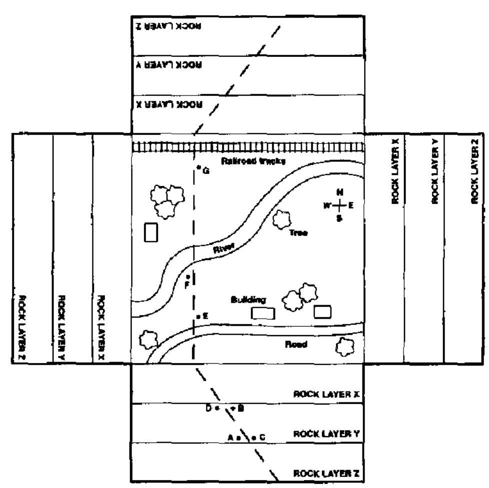
A lateral fault is a fault with edges that slip past each other.

nor • mal fault

A normal fault is a fault in which the upper block moves downward.

thrust fault

A thrust fault is a fault in which the upper block slides over a lower block.



Master 23, Fault Model

6. Place the two pieces of your model together so that point A is again next to point C. Move the pieces so that point C is next to point D. This represents a thrust fault.

Ask the students to describe how the Earth's surface has changed after the thrust fault had occurred. (The right side is overhanging the left side.)

Ask students to predict how the landscape will change after the movement along the thrust fault. (The Earth's surface will erode along the overhang and fall down to the ground below. Eventually a gentler slope will result.)

7. Place the two pieces of your model back to its original position (point A and C together). Viewing the model from above, move it so that point E is next to point F. This represents a lateral fault.

Ask the students to describe how the Earth's surface has changed. (Surface features will not be aligned.)

What will happen to the flow of the river as a result of this lateral fault? (The river will change its course to follow the fault line.)

Ask students to describe how rock layers X, Y, and Z have changed as a result of the lateral fault. (The rock layers have slid horizontally past each other.)

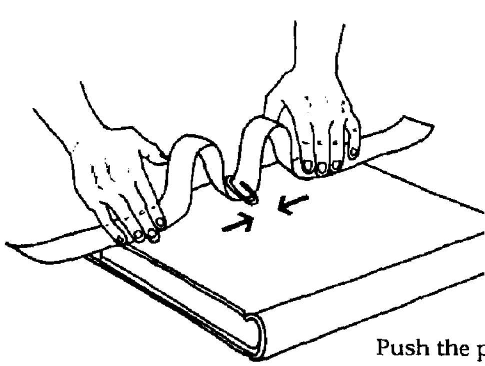
8. Explain that sometimes, when rock layers are exposed to pressure, they do not break or fault, but fold instead. Give these directions for a simple model of folding activity.

Have students cut a narrow strip 5/8" (about 7 cm) wide from a standard sheet of paper.

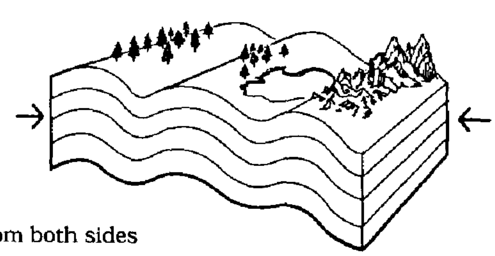
Place it on top of a hardcover book, along the front edge. Hold it in place at the center with a paper clip.

Slowly push the paper from both sides toward the center. Notice the hills and valleys that form as it folds.

Point out the Appalachian Mountains on a United States map, and explain that parts of the Appalachians and other U.S. mountains were formed by the folding of rock layers.



Push the paper slowly from both sides toward the middle



Activity Two: Liquefaction Lab

Materials for each small group
- Newspapers to cover work surfaces
- About 300 mL (1-1/4 cup) of medium- to fine-grain sand in a container (e.g., plastic margarine tub)
- About 100 mL (1/3 to 1/2 cup) of water
- Measuring cup or breaker marked in metric units

Procedure

Introduce the activity by telling students that liquefaction accounts for considerable damage to property. Define the term. Tell students they have experienced it if they have ever felt a foot sink into a patch of extremely muddy ground or in the sand along a shoreline. Give these instructions for the simulation:

1. Place about three fourths of the sand in the bottom of your container. Spread it out to form a flat, even surface. Place the container on a table or desk. This represents soil in an earthquake zone.

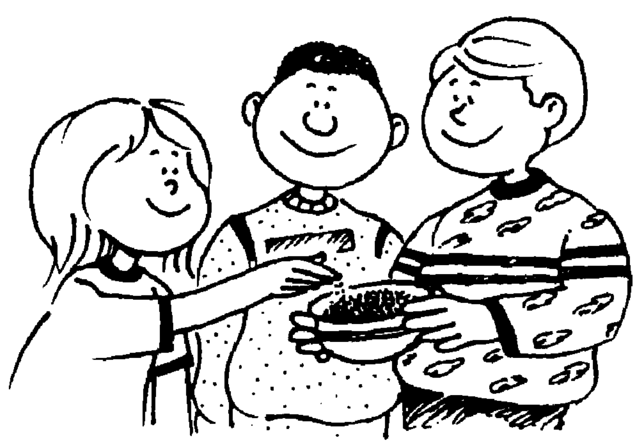
2. DO NOT handle your container of sand until instructed to do so. (This is very important. Containers must not be disturbed throughout Steps 3 and 4.)

3. SLOWLY add water to the sand until water just appears at the surface. Let students know that the sand needs time to absorb the water. Discuss with the students that the water they are adding represents precipitation.

liq • ue • fac • tion

Liquefaction is the process in which soil or sand suddenly loses the properties of solid material and instead behaves like a liquid.

Teacher Take Note: For this activity to work, it is very important for students not to handle their containers until instructed to do so.



4. Carefully sprinkle dry sand over the wet surface so that the entire top of the sand is barely dry to the touch. Press gently with your index fingertip to test for firmness, and add more sand if necessary. (Sand should be firm to the touch.)

5. Place a hand over the top of the container and rapidly slide the container back and forth on the table (the container should not come off the table top). Continue sliding until you observe standing water at the surface. (Explain that the shaking simulates earthquake waves traveling through the ground.)

6. Now press your finger into the sand. What happened? (It should sink easily because the waves of energy you produced by sliding the container have caused water to move up and liquefy the sand.) What would happen to buildings on top of the soil that was liquefied? (They would topple over or sink into the soil.)

Extension

A possible extension is to use weights, such as fishing weights, to model buildings sinking because of liquefaction. Plastic buildings do not have enough weight to sink.

Liquefaction of soil can cause buildings to slump and sometimes to collapse entirely.

Activity Three: A Slippery Slope

Materials for the teacher

- Newspapers to cover work surface
- Large tray (Ask your grocer for a supply of large plastic foam meat trays.)
- Local soils of various textures, or potting soil
- Builders sand
- Fine gravel
- Aluminum foil
- Water

Teacher Take Note: Do some hill building of your own before class, to get the feel of the activity. Although this activity has been designed as a teacher demonstration, it could be done by students in small groups.

Procedure

1. Tell your students that you are going to make a model of a hillside. Follow the directions below:

a. Cover your work surface with several layers of newspapers. In the meat tray, build a hill from moistened sand or soil. It may be any height or shape you choose. You may want to make one side steeper than the other.

b. Wrap a sheet of foil around your hill to simulate the slippery layer of rock or soil that allows outer layers to slide off during an earthquake.

c. Completely cover the foil with another layer of sand, soil, or gravel.

d. Ask students to predict the effect of an earthquake on the model. Which parts will be most affected by the earthquake?

e. Hold the tray on which your hill rests with both hand, and slide it back and forth sharply on your work surface to simulate an earthquake.

Extension

Show pictures of famous landslides caused by earthquakes, such as those that happened at Hebgen Lake in Montana, and in Alaska during the 1964 earthquake. Invite students to research and present reports on these or other landslide events.

2. After producing a landslide, conduct a class discussion including these questions:

   How did the shape of the hill affect the landslide? (The steeper the slope, the more easily the material will slide down.)

   How did the type of material on top of the foil affect the landslide? (Various answers are possible.)

   What would have happened if less water had been used in the soil mixture? What if more had been used? (Landslides are more likely when the surface is water-logged.)

   How should the potential of a site for landslides caused by earthquakes affect decisions on locating homes and other structures on or under it? (Such a site would make a poor choice unless it can be reinforced in some way.)

   What are some events other than earthquakes that can cause landslides? (Heavy rains, freezing and thawing of the ground, erosion).

3. Have students in groups write a report describing how the hill was built, what they observed during the land-slide, and what considerations and precautions should be taken into account when building on or near a slope.

Activity Four: Tsunami!

Materials for the teacher
- Transparency made from Master 24a, Tsunami Facts and Master 24b, Notable Tsunamis
- Overhead projector

Materials for each pair or group of students
- Glass or metal baking pan or plastic shoe box
- About 1 liter of water
- Plastic lid of the type used to reclose coffee or margarine containers
- Punching tool or drawing compass
- Scissors
- String
- Sand
- Erasers, toothpicks, popsicle sticks, and other small objects to represent shore features
- Book or block of wood to serve as wedge
- Metric ruler

Procedure

1. Ask students the following questions:

Do earthquakes occur under the ocean? (Yes)

Do earthquakes under the ocean ever affect people: (Some students may think of tsunamis. If not, introduce the topic.)

2. Project the transparency of Master 24a, Tsunami Facts. Begin with what students already know about tsunamis, and share the information on the master. Then tell class that they are going to build a model of a tsunami.

tsu • na • mi

A tsunami is a giant ocean wave caused by movements of the ocean floor, such as earthquakes and volcanic eruptions.

3. Divide students into pairs or small groups, distribute materials, and give these directions:

a. Use the wedge to tilt the pan at an angle of about 20 degrees.

b. Pour water into the pan to cover the lower end, leaving about a third of the pan at the upper end dry.

c. Pack a layer of sand 1 in. (2-3 cm) thick on the dry end of the pan to simulate a beach or coastline. Use your hands to mold dunes or drifts. Draw roads parallel to the shore with a stick or your fingers. Build docks and other small, lightweight structures to complete the shore environment. Be creative.

d. Punch the plastic lid on one end near the rim to make a hole, and thread it with a piece of string 8 in. (20 cm) long. Tie knots to hold the string in place.

e. Gently (in order not to make waves) place the plastic onto the bottom at the deep end of the pan. Trim it to fit if necessary. The string should be next to the low side of the pan.

f. Have one student use several fingers to hold the plastic down tightly on the shallow end, while another student pulls the string up at the deep end with a rapid movement. Tsunami!

4. When all groups have completed the simulation, ask them to describe what happened and discuss their observations.

5. Project the transparency of Master 24b, Notable Tsunamis. Discuss data found on overhead. Ask students where do damaging tsunamis occur? (Along any shoreline) What kind of damage is caused by tsunamis? (Property damage, crop loses, etc.) Where do the earthquakes originate that cause tsunamis? (Ocean floor. They also can be generated when large coastal landslides occur on oceanic islands.)

Extensions

1. Read to your students:

The *Magic Fan*, written and illustrated by Keith Baker; *The Big Wave* by Pearl Buck; or *The Wave*, a Japanese folk tale by Margaret Hodges.

2. Use the art print of *The Wave* to initiate a critical review of the print. Discuss medium, colors, and feelings when looking at the print.