

Activity Overview

Students use a model to investigate how materials bend and then break, drawing parallels with the accumulation of stress in rocks and the sudden release of stored energy in the form of an earthquake. The students use Slinkys to explore how waves transmit energy through solids and draw analogies to the movement of earthquake waves through solid (and for some waves, liquid) rock.

At the conclusion of **Activity 1**, students should be able to explain why earthquakes occur and how they transmit energy. They should be able to describe P waves, S waves, and surface waves and what they tell us about the interior of the Earth. Each student should write a one-page summary of the major concepts to include in their **Chapter Challenge** project. Content reading defines “earthquake” and reviews common terms used to discuss earthquakes, including fault, focus, and epicenter. Also, the different types of seismic waves, including compressional (P), shear (S), and surface waves, are defined.

Preparation and Materials Needed

Cutting the blocks for the rupture investigation can take a couple of hours, depending on the materials and tools you have on hand and your woodworking skills. Ideally, you can show the figures and specifications to your school wood shop and they can cut the blocks. If not, the wood can be purchased inexpensively from a local lumber store (wood trim works well and is the material provided in the *EarthComm* materials kit). Many stores will cut the wood at little or no cost.

SAFETY PRECAUTION: Make sure that the surfaces of the wood blocks are sanded smooth to prevent splinters.

Thin Styrofoam (from containers or packaging) can be used as a rigid solid to bend and break. You can cut up a Styrofoam cup or lunch tray. Have students try different materials, such as strips of balsa wood, wooden coffee stirrers, or strips cut from plastic bottles, to feel variations in the vibrations caused by the rupture of each material. Be sure to have students wear safety goggles during this portion of the activity.

The vibration investigation requires the purchase of Slinkys. An option is to use two Slinkys for the entire class and have groups rotate through the Slinky activity.

Materials

- 2 L-shaped wooden blocks
- Thin Styrofoam strip (about 5 mm in thickness)
- Safety goggles
- 2 Slinkys (the longer Slinkys that stretch 40 or 50 feet work best for this activity)

Think about It

Answer for the Teacher Only

Students in the western states, students that have traveled or lived in states with earthquakes, or Hispanic students that have moved to the United States from Central America can often contribute observations.

Students who have not experienced an earthquake might expect to see everything shaking, stuff falling, lights swaying; emotionally, they might feel excited or scared; physically, they might feel vibrations, like that of a passing train; they might hear rumbling as the waves pass and the crash of stuff falling and shifting.

Investigate

Part A: Rupture and Rebound

Students should note: How quickly they apply force; how quickly the Styrofoam responds; how it responds (bending first, then breaking).

Circulate from group to group asking questions that help the students better understand the process of rupture. Some guiding questions might be:

- How gently or forcefully did you push?
- Can you bend the material without breaking it?
- Do you think rocks can bend without breaking? (Yes. Folded rocks are commonly associated with faults and mountain building.)
- When the material broke, did the blocks slide past each other? (Yes. This is similar to movement of faults during earthquakes.)
- Did you feel any vibrations? (Yes. As the material broke, your hands vibrate.)
- If you had a very thin slice of rock, do you think you could break it by sliding your blocks? (Maybe; it depends on how thin the rock is and how forcefully you can push the blocks. The key point is that the rock has a definite strength, and it will break if the force applied to it exceeds its strength.)

Teaching Tip

Have students try different materials, such as strips of balsa wood, Popsicle sticks, wooden coffee stirrers, or strips cut from plastic bottles, to feel variations in the vibrations caused by the rupture of each material. Be sure to have students wear safety goggles during this portion of the activity.

3. b) The students should have felt a brief vibration when the Styrofoam broke. In a real earthquake, the vibrations would of course have been much stronger and would have lasted many seconds, or even a few minutes, as the large masses of rock broke and then slid past each other.

Teaching Tip

The reason for including **Part B** here is that it is much more realistic than the experiment in **Part A**. After real rocks fracture during an earthquake, they slide past each other for distances as great as several meters, over time periods of tens of seconds, as they rebound elastically to relieve the accumulated internal stresses that caused the deformation. It is that sliding, against the frictional resistance along the fault surface, that generates the earthquake waves. Once the stress has been relieved, the static friction, together with some healing or cementation of the fracture surface over time, allows the stresses to build up again for a long period of time before failure and movement happen again. This buildup of strength

varies greatly from fault to fault; some faults experience frequent small earthquakes, usually undetectable by the local population, rather than becoming locked and waiting a long time to fail again. Obviously, the potential for destructiveness is much greater in the case of locked faults, because when the rock finally fails again, the energy released is much greater. You might challenge the students to try to devise ways of keeping major faults “unlocked” in order to reduce the severity of earthquakes.

Scientists often use thought experiments to help guide their thinking and as a way to develop new actual experiments. Encourage the students to run this experiment carefully in their imaginations. Let them know that this is an experiment that could actually be done, if the right material could be found. The problem with running the real experiment is only that almost all rocks are too strong to be broken in a simple hands-on experiment like this one. You might challenge the students to propose some artificial material they could make or buy that would allow them to do this experiment for real. One material that was tried but then discarded (actually, eaten) by the writers of this chapter was “Rice Krispies® Treats”, chilled in the refrigerator. It was discarded because when it is cold it is too stiff and strong, but when it is warm it acts as a plastic solid rather than as a brittle solid. If your students come up with a suitable material — a brittle solid they can break in shear with their own hands — tell the developers of this module about it!

Part B: A Thought Experiment on Rupture and Friction

1. a) Because of friction along the rough surface of fracture.
- b) It would probably break again along the original fracture surface. The needed force would be less than originally, provided that the strength afforded by the bit of glue is less than the original strength of the unfractured rock.

Assessment Tool

Investigate Notebook Entry-Evaluation Sheet

The **Investigate Notebook Entry-Evaluation Sheet** is designed to help students get a sense of the expectations for *EarthComm* notebook entries. You might wish to review the criteria as this is the first time that students use the sheet.

EarthComm Notebook Entry-Checklist

The ***EarthComm* Notebook Entry-Checklist** provides a quick summary of important processes, concepts, and skills that you might wish to assess during and after an investigation. You can add further criteria specific to your classroom needs or a particular investigation. The checklist provides a quick guide for student self-assessment and also provides you with an opportunity to quickly score student work.

Part C: Vibration

Teaching Tip

Students should note that how, and how hard, they strike the Slinky influences the kind of wave that is generated and how far the wave travels.

Circulate from group to group asking questions that help the students better understand the process of vibration. Some guiding questions might be:

- Did you push-pull or shake the Slinky?
- What determines whether the wave travels the length of the Slinky?
(If the Slinky is not hit hard enough, friction causes the wave to die out before it reaches the other end.)
- How do the coils change as the wave passes?
(They are compressed together as the push-pull wave passes. They slide past each other sideways (that is, they are sheared) as the shake wave passes.)
- What happens when the wave reaches the other end?
(It bounces back (it is reflected) off the other person's fist.)
- How does the material move as the wave passes, compared to the orientation of the Slinky?
(Push-pull waves make the material move parallel to the direction of the Slinky. Shake waves make the material move perpendicular to the orientation of the Slinky.)
- Do you think waves travel through rocks?
(Yes. Think about a passing truck, or about striking the ground with a sledgehammer. A person standing nearby would feel vibrations.)

4. a) The push-pull wave is faster.

Reflecting on the Activity and the Challenge

This is an opportunity to note the observations the students should have made. It also serves as a transition from the simple models (blocks and Slinkys) to the real geologic world. Point out that geologists often use models because natural systems are large (the size of mountains), complex (stress applied to different kinds of materials in different orientations), and often move at very slow speeds (centimeters per year). Remind the students that they have seen these forces and responses frequently in their lives (as various materials break).

Note: Waves behave the same way whether they move in air, water, or rocks. The simple, low-cost models in this activity are simplified versions of what happens to earthquake waves as they travel deeper in the Earth. This explains why earthquakes generated on one side of the Earth can be recorded by instruments on the other side of the Earth.

Digging Deeper

Assign the reading for homework. The questions in **Check Your Understanding** on page 130 can be provided as a homework assignment.

Teaching Tip

Use the **Blackline Masters of Figures 1 and 2 (Blackline Master Earthquakes 1.1 and 1.2)** in this Teacher's Edition) to produce overheads of the illustrations. These overheads can be incorporated into a lecture/discussion of what an earthquake is, the types of waves earthquakes generate, and how these waves are measured. This is also an opportunity to review with students the S wave shadow zone produced by the fact that S waves will not travel through liquid medium. The existence of this shadow zone helped scientists to discover the liquid outer core. For information about this topic, visit the *EarthComm* web site dedicated to the Plate Tectonics chapter.

Check Your Understanding

1. The sudden movement of shaking or vibration of the Earth's surface caused by the arrival of seismic waves from a distant movement on a fault or from an explosion.
2. As the rock is fractured along an extensive fracture surface and the rock masses slide past each other to relieve accumulated stress, vibrations are produced, which travel away from the place of fracture as seismic waves.
3. The focus is the place in the Earth where the fracture takes place; the epicenter is the point on the Earth's surface directly above the focus.
4. See *Figure 3*, page 130.
5. P waves are fastest, S waves are slightly slower, and surface waves are even slower.

Assessment Opportunity

Use (or rephrase) the questions in **Check Your Understanding** for a brief quiz to check comprehension of key ideas and skills. Use the quiz (or a class discussion about the questions in the textbook) to assess your students' understanding of the main ideas in the reading and the activity.

A sample quiz is shown below:

Indicate whether the following statements are True or False. For those statements which are False, correct the statement to make it True.

1. An earthquake is caused by the abrupt release of slowly accumulated strain.
2. S waves are the fastest-moving waves, followed by surface waves, and then P waves.
3. The epicenter of an earthquake is the point of an earthquake within the Earth where rupture first occurs.
4. A secondary, or S, wave is produced by a shearing motion that involves vibration perpendicular to the direction in which the wave is traveling.
5. A primary, or P, wave will not travel through liquids.

As an alternative, make up a story (fraught with errors) about an earthquake that uses concepts explored in the investigation and the reading and ask students to identify and correct the errors. The beginning of such a story is shown below: *"The epicenter of an earthquake that rocked (our community) last night was pinpointed as being 5 km below the Earth's surface downtown. Earthquake recording devices in a nearby city recorded shear waves from the earthquake at 9 PM, with compressional waves arriving shortly thereafter...."*

Assessment Tool

Check Your Understanding Notebook Entry-Evaluation Sheet

This evaluation sheet is used to help you evaluate the extent to which students understand the key concepts explored in the activity and explained in the **Digging Deeper** reading section.

Understanding and Applying What You Have Learned

Teaching Tip

Stress that answers to the questions and related explanations are to be based on evidence.

1. Some combination of up-and-down motion and side-to-side motion.
2. Damage to buildings, ranging from minor to total destruction; cracking or even offsetting of roads; sliding about or toppling over of household furnishings.
3. Surface waves, because P and S waves move through the interior of the Earth, whereas surface waves have large amplitudes right at the Earth's surface.
4. a) Answers will vary. Because controlled experiments are not possible, answers would have to involve some kind of statistical analysis of earthquake data by climatic belt. The “statistics of small numbers” might be a problem in this.
b) Most students will need to use a database on earthquakes to answer the question. See **Activity 4**.
5. Answers will vary. If you need additional information to help evaluate their ideas, see the reading sections in the following activities or use a general reference book like *Earthquakes*, by Bruce Bolt.
6. See the commentary on **Part B** of the investigation section, above.
7. In **Part A** of the investigation, and also in **Part B**, large-scale Earth movements are needed to build up internal stresses in rocks great enough for failure by rupture.

Preparing for the Chapter Challenge

The purpose of this section is to have students pull something from the activity that can be used for their end-of-chapter report (the Chapter Assessment). Rather than waiting for the end of the last activity to solve the **Chapter Challenge**, students will be producing work all along the way that helps them to meet the challenge. Remind students of the criteria for judging their work that were discussed at the start of the chapter, where the **Chapter Challenge** was presented. Students can work on this as a homework assignment, or within groups. Remind students that the assignment provides an opportunity to revise and correct their work to reflect what they have learned during the investigation, and to communicate what they have learned to others.

Inquiring Further

Teaching Tip

Students may tend to place less importance on this section unless they know that the suggested activities are keyed to the objectives, assessment, and **Chapter Challenge**. Take time to discuss additional questions posed by students and stress how they present an opportunity to extend the depth of understanding of the objectives and provide important information that can improve the quality of their **Chapter Challenge**.

1. Forming questions to investigate

Students are encouraged to write down other questions they have about the causes of earthquakes and their effects, and they are asked how they would go about gathering information to answer these questions. Suggest that to find answers to most questions the students use a general reference book like *Earthquakes*, by Bruce Bolt, or use a web search. Check the *EarthComm* web site for helpful links.

2. Using seismic waves to study the Earth's interior

This is a major topic, and one that has been far more significant than any other in helping geoscientists learn about the Earth's interior. Students are not likely to be able to gain anything more than a superficial understanding of this topic without much more physical and mathematical background. What seismologists measure is the travel time of seismic waves from a source somewhere in the Earth to a receiver somewhere else on the Earth's surface. The first problem is to locate the (unknown) position of the source by analysis of travel times to many stations. Basically, this is done by triangulation. Then the travel times have to be converted to how seismic wave velocity varies with depth in the Earth, which is what geoscientists want to know because that is closely related to the kinds of rocks through which the waves are traveling. This involves a complicated mathematical technique called inversion. This is how the Earth's layered structure (inner core, outer core, mantle, and crust) was discovered. More and more sophisticated techniques, following from the same basic idea, continue to be developed and applied by geoscientists to study the structural details of the Earth's interior.

3. Using seismic waves to explore for oil and gas

Exploration for oil is an important application of seismology. Geologists use a vibrating or explosive device to send elastic waves below the ground surface. When the waves encounter a boundary between two materials, some are reflected, and others continue on through to the next material. By collecting the patterns with which the waves bounce back, geologists are able to “map” the rock layers below the Earth's surface. Geologists trained in petroleum explorations are able to recognize structural features that trap oil, like faults, folds, and domes. This helps them to decide where they should drill for oil. Direct students to the *EarthComm* web site www.agiweb.org/earthcomm to allow them to learn more about oil and gas exploration.

4. Earth science careers

A seismologist is someone who applies the principles reviewed thus far in this activity to interpret and predict earthquakes. Students can read profiles of famous seismologists and obtain more information about Earth science careers by visiting the *EarthComm* web site www.agiweb.org/earthcomm.

Teaching Tip

Inquiring Further Parts 3 and 4 provide opportunities for students to explore careers in Earth science. Refer students to the AGI Member Society web site www.agiweb.org/members/index.html where students can investigate the following professional societies that focus on oil and gas exploration:

- American Association of Petroleum Geologists (AAPG)
- Seismological Society of America (SSA)
- Society of Exploration Geophysicists (SEG)
- Society of Professional Well Log Analysts (SPWLA)