Name:

28.1 Understanding Earth

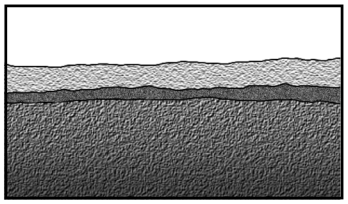
Question: What story is hidden here?

1 Sequencing events after a thunderstorm

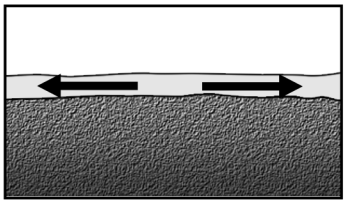
a. From the clues in the illustration, sequence the events listed above in the order in which they happened.

b. Write a brief story that explains the appearance of the dried mud puddle and includes all the events. In your story, justify the order of the events.

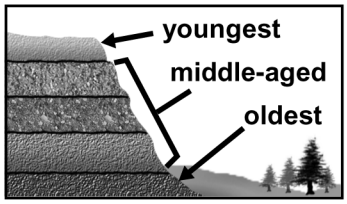
2 Determining the relative ages of rock formations



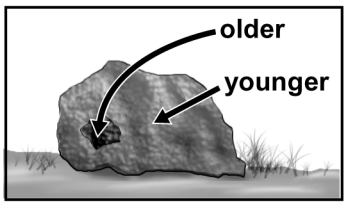
_____ 1. Original Horizontality



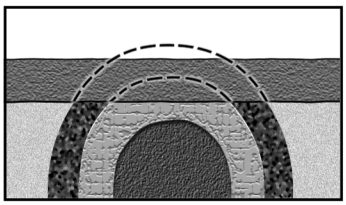
_____ 2. Lateral Continuity



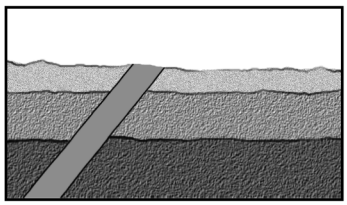
_____ 3. Superposition



_____ 4. Inclusions



_____ 5. Unconformities



_____ 6. Cross-Cutting Relationships

Match each principle to its explanation. Write the letter of the explanation in the space provided under each graphic.

Explanations:

A. In undisturbed rock layers, the oldest layer is at the bottom and the youngest layer is at the top.

B. In some rock formations, layers or parts of layers may be missing. This is often due to **erosion**. Erosion by water or wind removes sediment from exposed surfaces. Erosion often leaves a new flat surface with some of the original material missing.

C. Sediments are originally deposited in horizontal layers.

D. Any feature that cuts across rock layers is younger than the layers.

E. Sedimentary layers or lava flows extend sideways in all directions until they thin out or reach a barrier.

F. Any part of a previous rock layer, like a piece of stone, is older than the layer containing it.

3 Sequencing events in a geologic cross-section

a. Put the rock bodies illustrated below in order based on when they formed.

b. Relative to the other rock bodies, when did the fault occur?

c. Compared with the formation of the rock bodies, when did the stream form? Justify your answer.

4 Creating clues for a story

a. Describe your set of clues in a paragraph. Include enough details in your paragraph so that someone can re-create the set of clues.

b. What relative dating principles are represented with your set of clues? Explain how these principles are represented.

c. Now, have a group of your classmates put your set of clues in order. When they are done, evaluate their work. Write a short paragraph that explains how they did and whether or not they figured out the correct sequence of clues. Describe the clue they missed if they made an error.

5 The significance of stories

a. In the Investigation, you organized your thoughts into stories. How does organizing your thoughts as stories help you understand Earth science?

b. Cross-sections like the illustration in Part 3 have been used to help explain amazing events like the collision of continents or an ancient earthquake. If two continents collided, what features might you see in a cross-section of land?

c. Read about forensic science on the Internet or in your local library. How is forensic science like Earth science? Write a short paragraph that compares and contrasts these two branches of science.

Name:

28.2 Plate Tectonics

Question: What will Earth look like in 50 million years?

1 Reading a bathymetric map

Record your observations in Table 1.

Table 1: Features on a bathymetric map

Features	Examples from the map	Kind of plate boundary (convergent or divergent?)	How do the plates at this boundary move?
mid-ocean ridge			Plate 1 | Plate 2
rise			Plate 1 | Plate 2
deep ocean trench			Plate 1 | Plate 2

2 Starting to find plate boundaries

There are no questions to answer in part 2.

3 Using earthquakes to find plate boundaries

There are no questions to answer in part 3.

4 What direction do the plates move?

There are no questions to answer in part 4.

5 Coloring and cutting the plates

There are no questions to answer in part 5.

6 Moving the plates

There are no questions to answer in part 6.

7 Reconstructing Earth

There are no questions to answer in part 7.

8 Analyzing your map

a. Your teacher will have a completed map for you to examine. Compare your map to this map. How did you do?

b. Some of the oldest records of mankind come from the Middle East and Northern Africa. What has become of this "Cradle of Civilization" 50 million years into the future?

c. What has become of China, the islands of the western Pacific Ocean, and Australia? Do all of the maps in your class look the same in this region?

d. Where will the longest mountain range be located 50 million years from now?

e. Your map is only an approximation of the future Earth, but it is more reliable than a map that attempts to represent Earth 200 million years from now. What limits the accuracy of maps that try to project four times further into the future?

f. You know that plate movement is related to the nature of Earth's mantle. What conditions would have to be true to have movement of tectonic plates on the moon? What might the surface of the moon look like if plate tectonics **did** occur there? Hint: Review the role of the mantle in plate movement in the student reading.

Name:

28.3 Earthquakes

Question: What mechanical factors affect earthquakes?

1 Setting up an earthquake model

Record your observations in Table 1.

Safety Tip: To avoid injuries, do not shoot or overstretch the rubber bands.

Table 1: What does each item represent?

Material in setup	What does it represent?
The book	
The sandpaper strip	
The boundary between the book and the sandpaper	

2 Working with the model

Wear goggles to protect your eyes if a rubber band snaps during an experiment.

a. Did the book move when the stretch was 1 centimeter?

b. What does the movement of the book on the sandpaper strip represent in this Investigation?

3 Simulating the timing of an earthquake

Follow the procedures and record your data in Table 2.

Table 2: Simulating the timing of an earthquake

Trial number	Length of slip stretch (cm)	Length of stop stretch (cm)
1		
2		
3		
Average		

a. The movement of tectonic plates occurs all the time, but earthquakes do not. Why doesn't plate movement cause continual small earthquakes? Why do earthquakes occur every once in a while? Explain your answer.

b. Did all of the energy stored in the rubber band release when the book slipped? Do you think an earthquake releases all of the stored energy when it occurs?

4 Simulating the duration of an earthquake

Follow the procedures and record your data in Table 3.

Table 3: Simulating the duration of an earthquake

Trial number	Length of stretch while the book is moving (cm)
1	
2	
3	
Average	

a. How does the data from Table 2 compare with the data from Table 3? Why do you think this is?

b. Earthquakes last longer than a few seconds. They do not simply start and quickly stop. Explain the relatively long duration of earthquakes based on the results of this experiment.

5 Simulating the intensity of an earthquake

Follow the procedures and record your data in Table 4.

Safety Tip: Make sure your work table is stable before you start drumming. Use only gentle to medium force in your drumming.

Table 4: Simulating the intensity of an earthquake

Trial number	Length of slip stretch (cm)	Length of stop stretch (cm)	Length of stretch while book is moving (cm)
1			
2			
3			
Average			

a. How does the data from Tables 2 or 3 compare with the data from Table 4? Why do you think this is?

b. How did the drumming affect the intensity of the "earthquake" in the model?

c. Do you think one earthquake can cause another earthquake? Explain your answer.

6 Simulating the damage caused by an earthquake

Follow the procedures and record your data in Table 5.

Table 5: What happens to the sugar cubes when you simulate an earthquake?

Earthquake experiment	One cube	Two cubes	Three cubes	Four cubes
Timing simulation				
Duration simulation				
Intensity simulation				

a. Which sugar-cube building experienced the most damage? Develop a hypothesis to explain this result.

b. Which experiment resulted in the most damage? Develop a hypothesis to explain this result.

c. Given the results, propose one safety tip that would minimize structural damage during an earthquake.

7 Drawing conclusions

a. Based on your observations in this Investigation, what are some conditions that affect the timing of an earthquake? What conditions affect the duration? What conditions affect the intensity?

b. CHALLENGE! Describe what happens to cause an earthquake and what happens during an earthquake. In your answer, address these questions: How is the build up and release of stress involved in earthquakes? How are potential energy and kinetic energy related to earthquakes?

Name:

29.1 Volcanoes

Question: Why do some volcanoes erupt explosively?

1 The Volcanic Explosivity Index

Table 1: Examples of volcanoes and VEI ratings

VEI	Plume height	Volume (m^3)	Average time interval between eruptions	Example
0	<100 m	≥ 1000	one day	Kilauea
1	100-1000 m	≥ 10,000	one day	Stromboli
2	1-5 km	≥ 1,000,000	one week	Galeras, 1992
3	3-15 km	≥ 10,000,000	one year	Ruiz, 1985
4	10-25 km	≥ 100,000,000	≥ 10 years	Galunggung, 1982
5	> 25 km	≥ 1,000,000,000	≥ 100 years	Mount St. Helens, 1981
6	> 25 km	≥ 10,000,000,000	≥ 100 years	Krakatoa, 1883
7	> 25 km	≥ 100,000,000,000	≥ 1,000 years	Tambora, 1815
8	> 25 km	≥ 1,000,000,000,000	≥ 10,000 years	Toba, 71,000 years ago

Based on C.G. Newhall and S. Self (*Journal of Geophysical Research*, v. 87, p. 1231-1238, 1982).

a. What characteristics of a volcano might increase the plume height?

b. Would it be possible to have two eruptions with a VEI of 7 in the same year?

2 Finding a pattern of volcanoes

a. How do the locations of the two kinds of volcanoes relate to the locations of plate boundaries?

b. What is the relationship between the nature of a volcanic eruption and plate boundary features?

3 Magma chemistry

a. How does magma chemistry differ between violent and gentle volcanoes? How does the chemistry of magma cause an explosive eruption?

b. Does magma chemistry seem to be related to the location of the volcano? Explain your answer.

c. Imagine you are asked to investigate a newly discovered volcano to find out whether it will produce a gentle or violent eruption. Develop a research plan for studying the volcano. What evidence will you need to be able to identify the nature of the eruption? Assume that you can use any resources you need.

Name:

29.2 The Surface of Earth

Question: How have meteors affected Earth's surface?

1 Why are missions to the moon useful for understanding Earth?

a. You have probably seen footprint marks in a cement sidewalk. How are the craters in Mare Imbrium like footprints that are preserved in cement?

b. Why can we assume that the craters happened after Mare Imbrium formed 3.5 billion years ago? Is this a form of relative dating? Explain your answers to these questions.

c. The area of Mare Imbrium is about 1,226,562 km^2. For the Investigation, you will study a section of Mare Imbrium that is 46,000 km^2. What percentage of Mare Imbrium's surface is this section?

2 Counting the number of craters in a section of Mare Imbrium

Follow the procedures and record your data in Table 1.

Table 1: Number of craters in a section of Mare Imbrium

Strip number	Number of craters
1	
2	
3	
4	
5	
6	
7	
Total number of craters	

3 Estimating the effects of meteor impacts on Earth

Follow the procedures and record your data and calculations in Table 2.

Table 2: Comparing the area of Mare Imbrium with various areas on Earth

Areas on Earth (km^2)	Area of the section of M. I. (km^2)	Earth area ÷ M. I. area	Total number of craters in Mare Imbrium (from Table 1)	Number of crater collisions for each Earth area
Texas = 681,239	**46,000**			
Alaska = 1,484,166				
United States = 5,708,615				
World's oceans = 361,000,000				
Earth = 510,000,000				

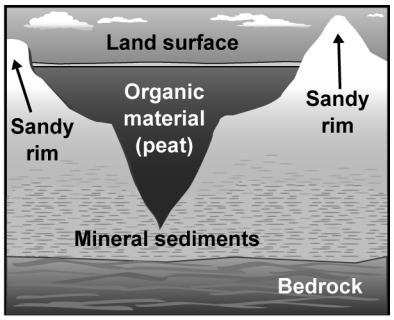
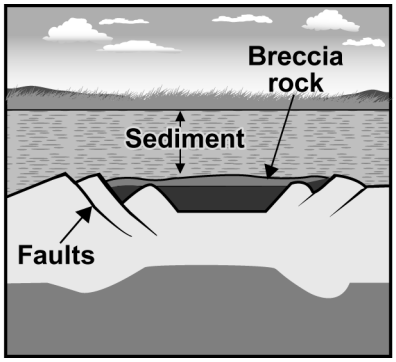
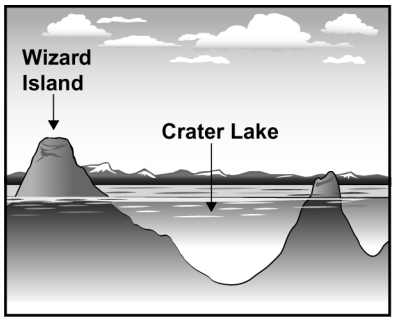
a. Given the number of meteor impacts that likely occurred in the last 3.5 billion years, what would the United States look like if erosion and plate tectonics had not changed Earth's surface during this time?

b. Why is the surface of Earth so much different from the moon's surface?

c. The smallest craters that you were able to count on Mare Imbrium would be catastrophic events today on Earth. But what of more frequent, smaller collisions? Exposed lunar rocks show many deep pits caused by micrometeorites smaller than the thickness of your hair. On Earth, frictional heating destroys much of what enters our atmosphere; only the largest and smallest objects reach the surface. Because micrometeorites are so tiny, they are slowed and fall to Earth as a gentle rain. About 30,000 tons of micrometeorites land on Earth *each year*. Given the volume of micrometeorites that encounter Earth's surface, chances are that you have been hit by a tiny space object more than once in your lifetime. Calculate how many tons of micrometeorites fall on Earth's surface *each day*.

4 Identifying meteor craters on Earth

Table 3: Which of these geographic formations is an impact crater?

Name and age of the geographic formation	Description	Cross-section
Carolina Bays Southeast coast, U. S. 12,000 years	1. A single Carolina bay may be 60 m to 11 km across and up to 15 m deep. 2. The bays are elliptical depressions often filled with organic material and bordered with a sandy rim. 3. At least 500,000 bays exist in the southeast of North and South Carolina. 3. Aerial view of the coast shows many bays. These appear as large elliptical rings on the ground. 4. Bedrock can occurs below the bays.	
Avak Crater Alaska 95 million years	1. The diameter of this feature is 12 km. 2. Several hundred feet of overlying sediment cover this geological feature. To study it, scientists drill to collect cores of sediment. 3. Rocks in the region appear to be pulverized. 4. Breccia is present. Breccia is a type of sedimentary rock that is composed of many sharp fragments stuck together	
Crater Lake Oregon 7,000 years	1. This feature is about 1.2 km deep in its deepest part and about 9 km across. 2. A small formation called Wizard Island is in the lake. 3. Crater Lake is in the top of Mount Mazama, an ancient mountain that is part of the Cascade mountain range. 4. About 25 miles of ancient lava flows extend beyond the base of Mount Mazama.	

a. Based on the information in the table and on any research you do, describe how each of these geologic features may have formed.

b. Which of these features seems to have changed the most since it was formed? Explain your answer.

c. Of the three scenarios above, which was most likely caused by a meteor? Give three pieces of evidence that justify your answer.

Name:

29.3 Rocks and Minerals

Question: How can we interpret the stories inside rocks?

Section 1: Igneous Rocks

1 Prepare a crystal-growing solution

a. Making a prediction: How do you think the crystals will look in each dish after the water has evaporated? Describe your prediction in a few sentences in the space below. Then, draw a picture to illustrate your prediction.

2 Observing the size of crystals that form

Crystal growth is slow and will take more than one day. Make a table for recording your observations on a separate sheet of paper.

3 Interpreting the size of crystals that form

a. In which dish did the liquid crystal solution remain for a longer time?

b. Which dish had more time to grow crystals?

c. Which dish grew the biggest crystals?

d. Write a conclusion statement about the time available for crystals to form and the size of the crystals that form.

4 Applying your conclusion to igneous rock formation

a. List two events or conditions (other than the methods you used in this Investigation) that might slow the cooling of a rock melt.

b. List two conditions that might speed up cooling of a rock melt.

c. What would the crystals from a rapidly cooled melt look like? Explain your answer in terms of your conclusion statement from 3(d).

d. Find samples of granite, gabbro, rhyolite (felsite), and basalt in your rock kit. Compare the appearance of each sample. Based on your work in this part of the Investigation, which rocks formed slowly and which rocks formed relatively quickly? Explain your answer to this question.

e. Igneous rocks that form on Earth's surface are *extrusive* and those that form underground are called *intrusive*. Based on your observations of the igneous rocks in 4(d), which of them are likely to be extrusive? Which are likely to be intrusive? Explain your answer.

Section 2: Sedimentary Rocks

1 Preparing sedimentary deposits

a. Once you see layers in the sediment bottle, make a sketch of the layers. Add labels to your sketch to help describe what you see. Where is the coarsest sediment? Where is the finest sediment?

b. Is there a change in color from bottom to top? If so, shade your sketch to show the change.

2 Additional sedimentary deposits

There are no questions to answer in part 2.

3 Final observations

a. Gently wipe off the side of the sediment bottle. Turn the bottle, and look for where a layer of settled slurry has been cut, or added to, by a new layer. Use your first observations to detect where an earlier slurry ends and a newer one begins. You will probably find several places where the bottom of a newer layer has broken the top of an earlier layer. Is each slurry represented by a distinct layer?

b. Observe, sketch, and label the appearance of these layers. Try to sketch clearly the appearance of an earlier slurry *top* cut by a new slurry *bottom*. Use shading to show color changes. You may want to make multiple views (front view, side views, and back views) of the sediment in the bottle.

4 Applying your experience

a. In Part 2, you saw that when a turbulent mixture of different soil particles is added to water, the largest particles settled first and the smallest particles settled last. Can you explain why this happens based on the effect of flowing water described above?

b. Imagine that 2 million years ago there was a valley surrounded by foothills. In the middle of the valley lay a large, shallow lake. Rainstorms would cause small streams to run hard into the lake for a few days, but usually the streams ran gently. A million years later, volcanic ash covered the valley, including the streams and the lake. Later, glaciers scraped away the ash, exposing the sedimentary rock that was once the lake and the streams. Your geology team has collected samples of sedimentary rocks from three sites in the valley. Describe and sketch what each rock would look like in the table below. Then, explain why these samples look the way they do.

Site where samples were collected	What do these rock samples look like?	Why do these rock samples look the way they do?
Stream bed		
Stream mouth		
Lake center		

c. Examine a sample of conglomerate and shale (preferably oil shale) from your rock kit. Come up with an explanation for how each of the rocks was formed based on their appearance. How do you know they are sedimentary rocks?

Section 3: Metamorphic Rocks

1 Preparing a metamorphic rock

There are no questions to answer in part 1.

2 Simulating metamorphism

1. On a piece of newspaper, stand the package so that the layers are vertical.
2. Wrap newspaper around a small, hardcover book. Hold the book level over the play dough package.
3. Create *compression* on the package by pressing the book down on the package. You do not need to press down hard. Press the package until it is about 3 centimeters high.
4. Take your metamorphic package to your teacher to slice so that you can see the folding.
5. Sketch the folded layers. This is a simple fold representing **low metamorphism**. Show the compression by drawing arrows pointing inward in the direction of compression.

3 Making and interpreting complex folds

1. **High metamorphism:** You have shown a single fold in the play dough. Sometimes folds in rock go back and forth and look more like an accordion. To see this for yourself, cut file cards into six pieces that are 4-by-8 centimeters. Make a layered package using five pieces of card and six pieces of dough. Stand the layered package tall-end-up before applying pressure to create folds. It may take more than one run before you get good results. Make a sketch of this fold.

2. **Angled metamorphism:** Usually, layers of rock are not perpendicular to the direction of metamorphic pressure. When this happens, the folds are uneven. To see this, build your package slightly off-center by placing each layer a little to one side. You can do this with the original size (4x4) file card pieces or the longer (4x8) pieces. After you have made your package, set it up as shown in the diagram at right. The package should lean to one side. Press a piece of triangular piece of play dough on one side to support the leaning package. Apply compression as shown in the graphic at right. Make a sketch of this fold.

3. **Extension:** Repeat the process using different techniques. For example, change the number of layers or the amount of pressure used. In each case, carefully record your techniques for building each package and compressing it. Finally, sketch the appearance of the folded package.

4 Applying your experience

a. How can the shape of metamorphic folds allow geologists to reconstruct the direction of metamorphic compression?

b. It is common to find folds of folds. Some of these refolded folds seem to have been formed by two different directions of compression. How might a refolded fold occur? Write a short description of events that might cause a refolded fold in rocks.

c. In small metamorphic rocks, it is difficult to see folding. However, it is possible to see some effects of metamorphism. Compare a sample of shale from your rock kit to a sample of slate, a metamorphic rock made from shale (a sedimentary rock). Do you see evidence of metamorphism?

Section 4: Interpretation of Rock Formations

a. Evaluate your ability to interpret the photographs of the land formations. How did you do? Write your evaluation of your efforts in one to two paragraphs.

b. Describe a land or rock formation near your home or at a place you have visited. Using what you have learned, write an interpretation of how it formed and provide its history.