Investigation Overview

Students follow a hypothetical rock through the rock cycle on an interactive diagram. Each arrow in the diagram reveals an animation of the rock-forming processes it represents. Students observe that each of the three rock types can be transformed into other rocks. Students then write detailed descriptions of how rocks change to form igneous, sedimentary, and metamorphic rocks.

Instructional Context

You can introduce the rock cycle by comparing it to the familiar concept of the water cycle. Draw a rough outline of the water cycle and ask students to describe the processes that move water from one part of the cycle to another. Present the rock cycle by explaining that rock-forming processes move rocks from one part of the rock cycle to another, continually forming the three types of rocks. You may want to discuss the disruptive effects of human activities on the rock cycle. Ask students to consider how human processes such as road building and melting ore mimic natural rock-cycle processes.

KEY CONCEPTS

- Rock-forming processes move rocks through the rock cycle.
- Rocks are classified as igneous, sedimentary, or metamorphic based on how they formed.

KEY SKILLS

- Interpreting diagrams
- Observing and summarizing igneous, sedimentary, and metamorphic processes

ESTIMATED TIME REQUIRED

- 30 minutes Internet use
How Do Rocks Undergo Change?

1. Sketch the rock cycle diagram (above) on your answer sheet. Go back to step 2, and put the name of each process illustrated in the animation on the appropriate arrow.

2. Use your own words to describe the sequence of processes that result in igneous rocks. Describe a specific example of a sedimentary rock becoming an igneous rock.

   Answers will vary. Solid rock of any kind is subjected to heat and melts. Once the liquid rock cools back down below its melting point, it is an igneous rock. One example of a sedimentary rock becoming an igneous rock would be a layer of sandstone that was subducted beneath a continent, and it melted then cooled.

3. Use your own words to describe the sequence of processes that result in sedimentary rocks. Describe a specific example of a sedimentary rock becoming a new type of sedimentary rock.

   Answers will vary. Rocks are broken into smaller bits by weathering and erosion. When these bits are cemented together, a sedimentary rock is formed. One example of a sedimentary rock becoming a new type of sedimentary rock is if conglomerate is broken into sand-size particles then recemented to form a sandstone.

4. Use your own words to describe the sequence of processes that result in metamorphic rocks. Describe a specific example of a sedimentary rock becoming a metamorphic rock.

   Answers will vary. Any rock that has been changed by heat and pressure is a metamorphic rock. One example of a sedimentary rock becoming a metamorphic rock is a sandstone that is buried and heat and pressure cause the sandgrains to interlock to form quartzite.
Investigation Overview

Students view and describe images showing clear examples of coarse-grained, fine-grained, and porphyritic igneous rock textures. The term igneous rock texture is introduced; students learn that the igneous rock texture can be used to infer cooling rates of magma. Students view animations illustrating formation of the three textures. Students examine photographic images of igneous rocks and use their knowledge to draw conclusions about the cooling rate of the magma that formed the rocks.

Instructional Context

You may want to model the process of igneous rock formation with this simple demonstration: Melt three thumb-sized chunks of sulfur in a test tube over a propane torch or bunsen burner. This molten liquid is your model magma. Cool a portion of the sulfur very slowly (pour it into a warmed crucible). Cool some of the sulfur somewhat more quickly (pour a portion into a depression in a piece of aluminum foil). Cool the last portion of the sample very quickly (pour into a shallow pan of water). Have students use a hand lens to view the model igneous rocks that were formed at different cooling rates.
Describe the four igneous rocks shown in the images.

Answers will vary.

**Sample 1**
- Reddish color
- Large visible, interlocking crystals

**Sample 2**
- Black color
- Looks like glass

**Sample 3**
- Red color with white spots
- Fine-grained background

**Sample 4**
- Dark color
- No visible crystals

Identify the texture of each of these igneous rocks as coarse-grained, fine-grained, or porphyritic. Record your answers in the table.

<table>
<thead>
<tr>
<th>Rock</th>
<th>Texture</th>
<th>Cooling Rate and Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>Coarse</td>
<td>Slow cooling rate; formed in magma chamber</td>
</tr>
<tr>
<td>Sample 2</td>
<td>Fine</td>
<td>Fast cooling; erupted from volcano</td>
</tr>
<tr>
<td>Sample 3</td>
<td>Fine</td>
<td>Fast cooling; erupted from volcano</td>
</tr>
<tr>
<td>Sample 4</td>
<td>Porphyritic</td>
<td>Two-staged—slow, then fast. Deep cooling followed by eruption</td>
</tr>
<tr>
<td>Sample 5</td>
<td>Porphyritic</td>
<td>Two-staged—slow, then fast. Deep cooling followed by eruption</td>
</tr>
<tr>
<td>Sample 6</td>
<td>Coarse</td>
<td>Slow cooling rate; formed in magma chamber</td>
</tr>
</tbody>
</table>

Identify the cooling rate (fast, slow, or two-staged) and cooling environment (magma chamber, eruption from volcano, or deep cooling followed by eruption) of the rock in each image. Record your answers in the table.
Investigation Overview
Students use an interactive animation to visualize water contained within and flowing through different rock materials. Students compare the flow rates of groundwater pumped from sandstone, limestone, and shale and then describe porosity and permeability for each rock type. Finally, students describe characteristics that make each type of rock a desirable or undesirable aquifer for supplying human water needs.

Instructional Context
Though relatively few students have familiarity with wells, dramatic increases in the populations of arid regions means that increasing numbers of humans depend on groundwater for their survival. Availability of uncontaminated water at accessible depths is an issue that will affect many towns and cities. Find out what types of aquifers are below ground where you live—you may be able to check the flow rates of private or municipal wells in your region.
1. What characteristics of a rock layer allow it to hold water?
   A rock layer would need to have spaces between grains or cracks or hollow spaces to hold water.

2. Record the volume of water pumped and the time it took to pump it. Calculate the flow rates.

<table>
<thead>
<tr>
<th></th>
<th>Volume</th>
<th>Time</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shale</td>
<td>1 L</td>
<td>4350 years</td>
<td>0.00023 L/yr</td>
</tr>
<tr>
<td>Sandstone</td>
<td>1 L</td>
<td>3.76 hours</td>
<td>0.27 L/hr</td>
</tr>
<tr>
<td>Limestone</td>
<td>1 L</td>
<td>43 years</td>
<td>0.023 L/yr</td>
</tr>
</tbody>
</table>

3. What differences do you see in the material of each rock layer? Describe particle size, particle shape, and the general shape and number of pore spaces in each rock.
   Sandstone has sand-sized particles that are relatively round with many pore spaces and good connection between the pore spaces. Shale has smaller, flatter particles than sandstone. The pore spaces are more numerous, but smaller than in sandstone, with less area for water to move between the spaces. Limestone has no particle structure. It provides space for water storage only if cracks and cavities have been dissolved in the rock.

4. Describe how the shape and number of pore spaces affect permeability of these three rock types.
   The more pore space there is, the more water can be held. If the shape of the pore space allows easy movement between pore spaces, the permeability will be higher.

5. Explain why the sandstone had the highest flow rate.
   Water moves easily between the large, interconnected pore spaces.

6. Shale is composed of individual particles with pore spaces between them, similar to the structure of sandstone. Why was the flow rate for shale so much lower than for the sandstone?
   Particles that make up shale are somewhat flat. They pack together more tightly than rounded sand grains. The resulting pore spaces are small and not well interconnected.

7. How could limestone’s ability to hold and transfer water be increased?
   If the voids and cracks in limestone were to become larger and better connected as water dissolves away rock material, it could hold more water.

8. Discuss the suitability of sandstone, limestone, and shale as aquifers for supplying human water needs.
   Shale makes a poor aquifer. Water flows through shale so slowly that it is considered impermeable. Sandstone makes a very good aquifer, because it generally has high porosity and permeability. Limestone can also be a good aquifer if it has high porosity and permeability, though the water would contain more dissolved minerals.
What Does the Ocean Floor Look Like?

Investigation Overview
Students observe a map showing global relief and hypothesize about the shape of the ocean floor and the location of specific features. They view animations of water draining from the Atlantic and Pacific Oceans, revealing the topography of the ocean floor. Using images of the drained oceans, students identify specific seafloor features and infer how they were formed. Students explore differences between active and passive continental margins.

Instructional Context
This investigation can be used as an introduction to ocean floor features. It provides students an opportunity to visualize the unfamiliar rocky surface of the 70% of our planet that is covered by oceans. The investigation also serves as a review of plate tectonic concepts, as most of the ocean floor features encountered are formed by plate tectonic processes.

KEY CONCEPTS
• The geological features of the ocean floor are formed by tectonic activity.
• Passive continental margins are associated with wide continental shelves.
• Active continental margins are associated with steep continental slopes, trenches, and tectonic activity.

KEY SKILLS
• Interpreting bathymetric maps
• Identifying ocean floor features
• Inferring how ocean floor features were formed

ESTIMATED TIME REQUIRED
• 45 minutes Internet use
What evidence did you look for to predict the location of each feature?
Answers will vary. The lowest sea depths indicate the deepest parts of the ocean where the ocean floor and trenches could exist. Shallower sea depths are closer to the surface and could indicate the presence of features such as ridges or seamounts. The shallowest waters would be over areas very close to the surface, such as the continental shelves.

Describe at least three observations from the animation.
Answers will vary. Water immediately drains off islands and the shelves that extend from the continent. The area of the continents increases and the area covered by the ocean decreases. As the water drains, it exposes a long ridge down the middle of the ocean. Water drains from the continents toward the middle of the ocean and from the ridge toward the continents. Water drains last from deepest part of the ocean on either side of the ridge.

Describe the sequence of how the water drains. Which features are exposed first? Last? Why does the water drain in this way?
Draining exposes the continental shelves and islands first, then the ridges. The water drains in toward the middle of the ocean along the basins and finally out of the fracture zones and trenches. It drains this way because shallowest areas empty first and deepest areas last.

Imagine that you could travel across the ocean floor from Casablanca, Morocco, to Norfolk, Virginia, to Caracas, Venezuela. Narrate a brief "tour" of this path, describing the ocean floor features you would encounter. Use a map of this area to help you locate islands and distinguish them from seamounts.
After moving down the continental shelf, we pass several islands. We cross a deep abyssal plain until we come to the middle of the Atlantic where we encounter many seamounts. We cross many fracture zones and ascend up the side of the Mid-Atlantic Ridge. After we come down the other side of the ridge, we cross an abyssal plain and pass another group of seamounts. We climb a relatively steep shelf just before we arrive at Norfolk, Virginia. Leaving Norfolk, we descend the shelf and go across a plain. We cross a very deep trench near Puerto Rico. We then cross a ridge between Puerto Rico and the Dominican Republic. We descend to a deep plain then climb over another ridge before ascending the shelf to Caracas.
How Do Tides Work?

Investigation Overview
Students predict tide patterns for two specific days, one week apart, based on images of the moon’s phases. They observe a sequence of still images showing tide levels at Cape Porpoise, Maine, for these two days and make inferences about the relationships between tides and moon phases. Students observe time-lapse animations of changing tide levels correlated with corresponding data on graphical tide charts. Students interpret the visualizations to compare tide patterns and predict when the next high or low tide will occur. Students also predict tide patterns for another day of the month, when the moon is full.

Instructional Context
This investigation gives students the opportunity to analyze changes in tidal levels from time sequence photographs. The visual changes are linked with a diagram that shows how tidal changes are depicted graphically. Students should already be familiar with material in Chapter 24 about the alignment of the sun, moon, and Earth during various phases of the moon.

KEY CONCEPTS
• The relative positions of the moon, sun, and Earth control tide levels.
• Two high tides and two low tides occur every 24 hours and 50 minutes.

KEY SKILLS
• Determining relationships between tides and lunar phases
• Interpreting tide charts
• Predicting tide patterns

ESTIMATED TIME REQUIRED
• 35 minutes Internet use

Carl Baldwin, NOAA
1. What is the phase of the moon on October 17, 2001? On October 24?
   New moon; First Quarter moon.

2. Predict the effect the moon's phase had on the level of the high tide and the low tide on October 17. Explain your reasoning.
   Answers will vary. Very high high tides and very low low tides occurred because the sun's and moon's "pulling power" on Earth's water is combined in the same direction.

3. Predict the effect the moon's phase had on the level of the high tide and the low tide on October 24. Explain your reasoning.
   Answers will vary. High and low tides would be at more moderate levels, because the sun and moon are at right angles to each other, which reduces the effect of the sun's gravitational pull on Earth's waters.

4. Describe the changes in tidal levels that occurred on October 17. At what times did the highest and lowest tides occur?
   The tide is very low just after 7:00. The tide is coming in, because by 8:33, more of the shore is covered. By 10:35, the little channel is filled. By 12:20, almost all the land in the foreground is covered. This is the highest tide in the sequence. The tide goes out in such a way that 14:12 looks just like 9:35, 15:13 looks like 8:33, etc. By 18:10 all the land in the view is exposed again. This is the lowest tide.

5. There are roughly two high tides and two low tides every 24 hours. At what time do you think the next high tide occurred?
   Answers will vary. The next high tide should be about 12 hours after the last high tide (or 6 hours after the last low tide), at about 12 a.m. (0:00) on October 18.

6. Describe the changes in tidal levels that occurred on October 24. At what times did the highest and lowest tides occur?
   The morning images show the tide is going out. Highest tide in the morning sequence is in the first image at 8:44. The tide seems to be all the way out at 12:15, though not quite as far as the low tide on Oct 17. This is the lowest tide. From then, the tide comes in, and at 18:10 the water is at the highest point in the sequence.

7. Predict when the next low tide occurred.
   The next low tide should occur about 12 hours after the last low tide (or 6 hours after the last high tide), at about 12 AM (0:00) on October 25.

8. Did the high tides occur at the same time on October 17 and October 24? Why or why not?
   No, the high and low tides occurred around 6 hours (about 350 minutes) apart from Oct. 17 to Oct. 24. Because the tides correspond to the moon's cycle, which changes about 50 minutes each day, after seven days the high tide was 6 hours later.

9. Predict the changes in tide levels you would see at Cape Porpoise on October 31.
   October 31, 2001 was a full moon, so tides would have been similar to those observed on October 17. High tide would have occurred around 12:00 (noon) and low tides at about 6:00 and 18:00.