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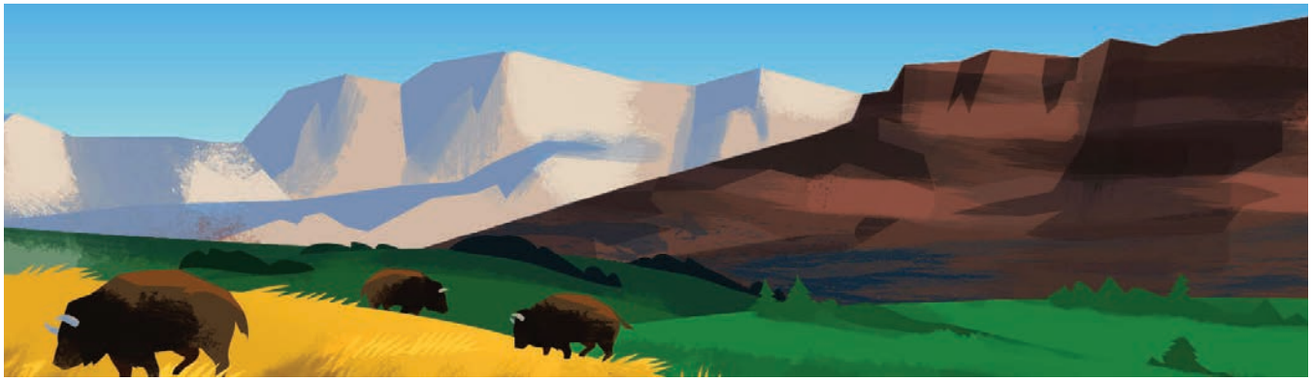

Rock Transformations:

Geologic Puzzle of the Rockies and Great Plains

Investigation Notebook with Article Compilation

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Rock Transformations:

Geologic Puzzle of the Rockies and Great Plains

Investigation Notebook

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Chapter 3: Movement of Rock Formations

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Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.

2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.

3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.

4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.

5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.

6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.

7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.

8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.

9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.

10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.

11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

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Rock Transformations: Geologic Puzzle of the Rockies and Great Plains
Unit Overview

How do rocks form and change? It might seem as if the rock that makes up mountains and cliffs, that covers Earth beneath the soil and the ocean, has always been as it is without changing. However, you will uncover the real story in this unit. In particular, you will investigate a geologic mystery that connects rock formations in the Great Plains with the rock formations in the Rocky Mountains. The Rocky Mountains are some of the highest, steepest mountains in North America while the Great Plains are a landscape of flat plains and rolling hills. The rocks you will investigate from these two locations look very different, but they are linked by their past—a past you will discover. Later in the unit, a second geologic mystery will take you beyond Earth to the surface of Venus. You will use the *Rock Transformations* Simulation and observe rocks, physical models, and photographs; you will read articles and watch videos to solve these mysteries.

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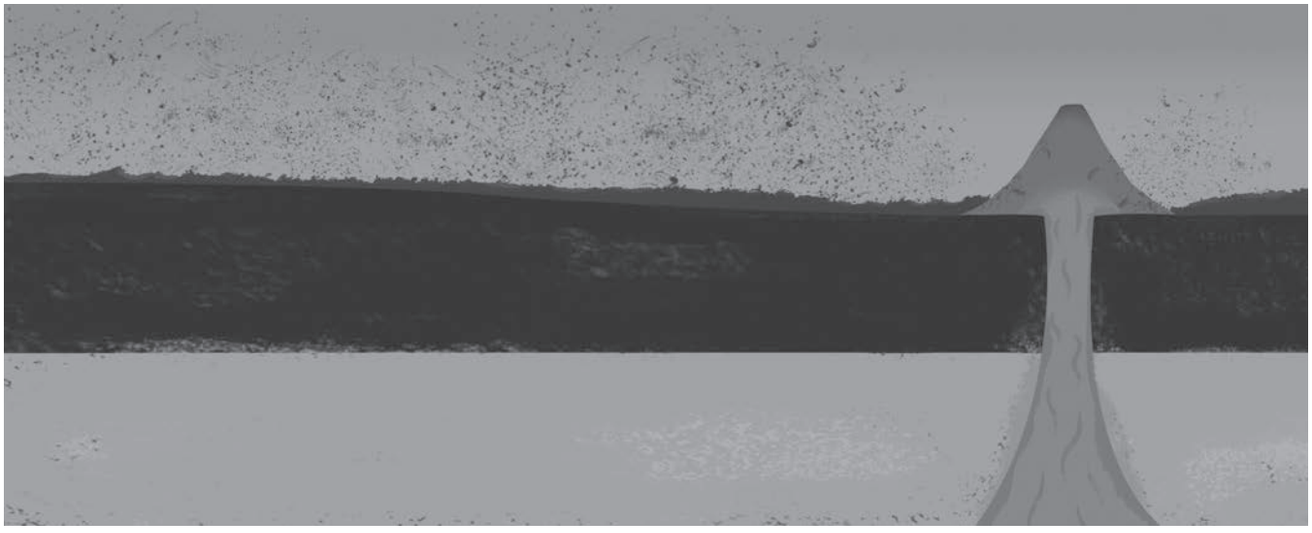
Chapter 1: Rock Formations
Chapter Overview

You'll begin your investigation of how two very different rock formations could have strikingly similar types and amounts of minerals. By examining rock samples and a physical model, exploring a digital simulation, and completing a reading, you will learn about different ways rocks can form.



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Lesson 1.2: Studying Rock Formations and Samples

What do you know about the rocks that make up Earth's solid surface? How do these rocks form? In this unit, you will take on the role of student geologist to discover how rocks form and change. In this lesson, you will make careful observations of rock samples and learn what they can tell us about the large rock formation they came from. You will also begin to think about the rock formations found in the Rocky Mountains and the Great Plains. Throughout the unit, you will investigate how rocks in these two very different-looking places relate to each other.

Unit Question

- How do rocks form and change?

Chapter 1 Question

- How did the rock of the Great Plains and Rocky Mountains form?

Vocabulary

- claim
- matter
- rock formation
- sample

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Warm-Up

How do you think rocks form?

_____

_____

_____

_____

_____

_____

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Thinking Like a Geologist

The Rocky Mountains

The Great Plains

Consider what you learned about the Rocky Mountains and the Great Plains from the video. Discuss these questions with your partner:

- What do you observe about the Rocky Mountains and the Great Plains?
- What do you think could have caused the rock formations in the Rocky Mountains and Great Plains to be so different yet have similar amounts of certain minerals?

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Great Plains and Rocky Mountain Claims

How did the rock of the Great Plains and Rocky Mountains form?

Claim 1: They formed as one rock formation, and then something separated them.

Claim 2: One rock formation formed before the other. Then, the minerals from the older rock became part of the younger rock.

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Observing Hand Samples of Rock

Consider the rock samples with your partner. Then, discuss your observations and record them below.

Record your observations about rock sample 1.	Record your observations about rock sample 2.
Record your observations about rock sample 3.	Record your observations about rock sample 4.

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Lesson 1.3: Investigating How Rocks Are Formed

Rocks can be very different. You saw this firsthand when you examined the hand samples in Lesson 1.2. Those differences can help you determine how the rocks formed. Today, using the *Rock Transformations* Simulation, you will explore the ways in which rocks form. As you explore, consider: *What can you discover about the differences between how rocks form?*

Unit Question

- How do rocks form and change?

Chapter 1 Question

- How did the rock of the Great Plains and Rocky Mountains form?

Vocabulary

- magma
- matter
- rock transformation
- sample
- sediment

Digital Tools

- *Rock Transformations* Simulation

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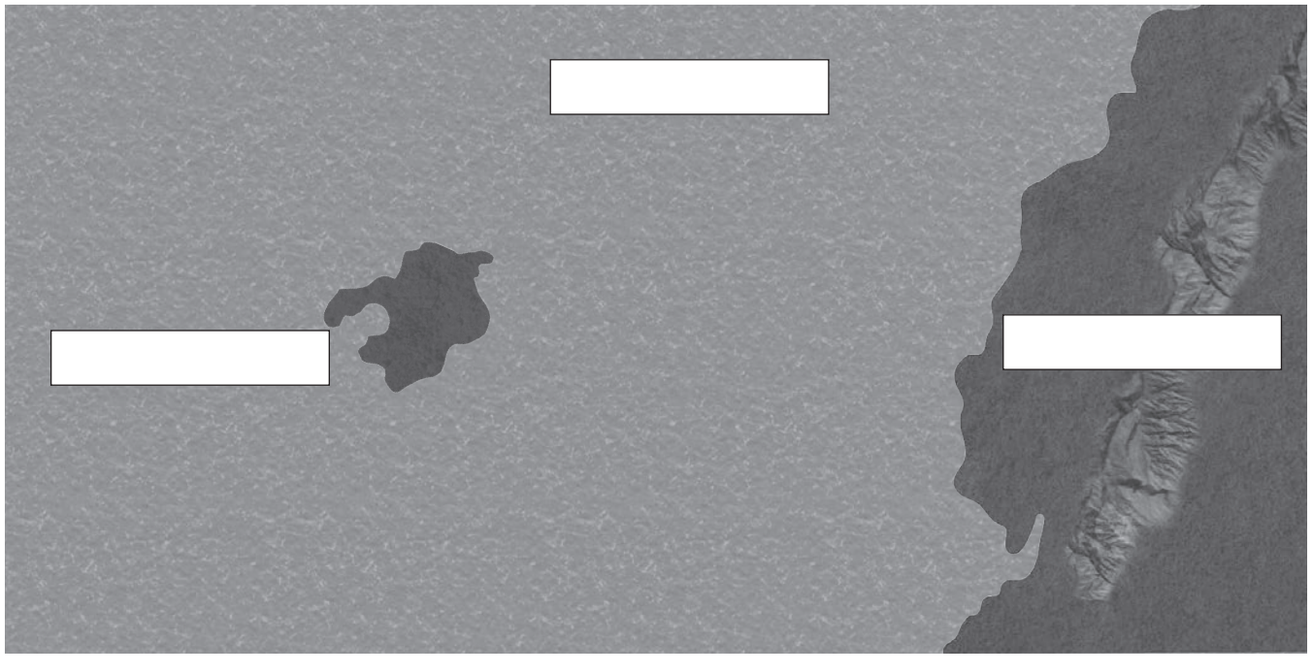
Warm-Up

Map View of Landscape



1. Label the following landforms in the map view of the landscape above.
    - mountain
    - island
    - ocean

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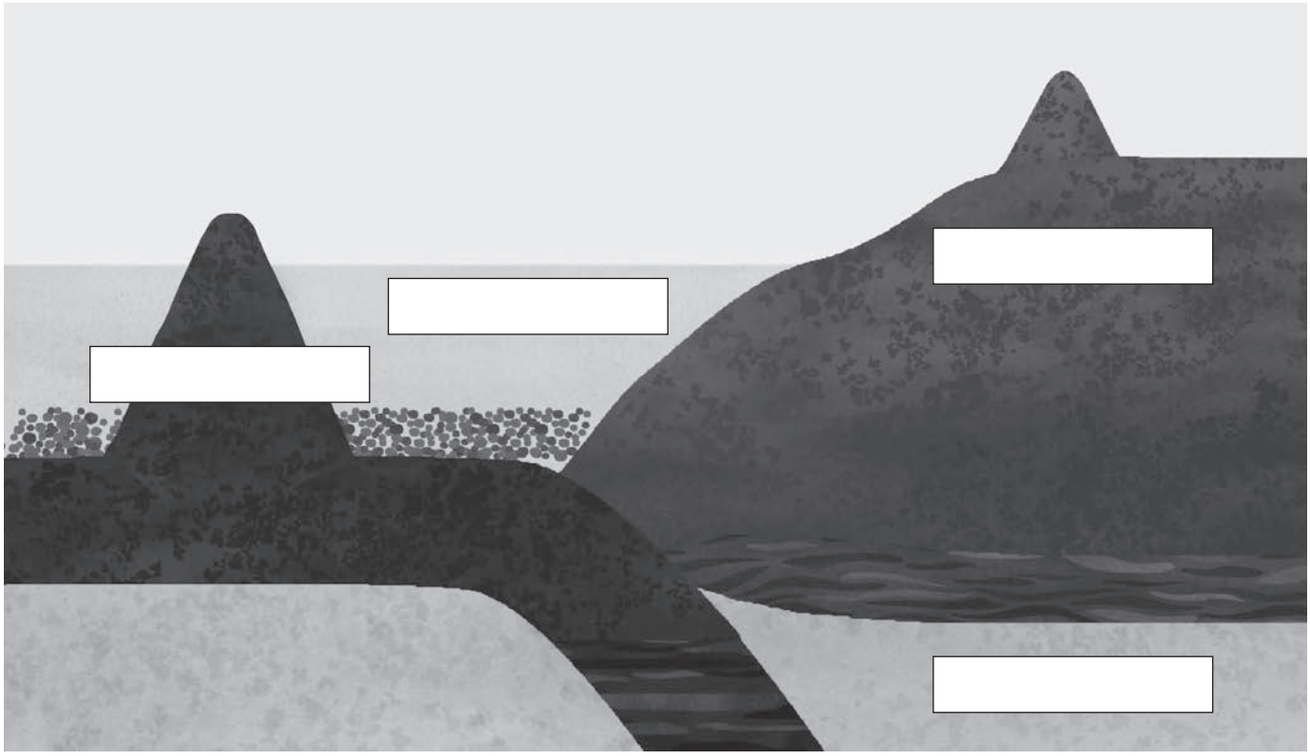
Warm-Up (continued)

Cross-Section View of Landscape



2. The image above shows a cross-section view of the landscape on the previous page. Discuss with your partner how to label the following parts of the landscape.
   - mountain
   - island
   - ocean
   - mantle

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Forming Rocks in the Simulation

Part 1

Open the *Rock Transformations* Simulation and explore the Sim with your partner. Share what you both notice, answering the questions below.

- What can change in the Sim?
- What questions do you have about the Sim?

Part 2

Open the Process Mode of the *Rock Transformations* Simulation.

1. Press ANALYZE ROCKS to learn about the different types of rock in the cross section.
2. Make rocks in as many ways as you can. Changes should occur both above and below Earth's outer layer.
3. After you see rocks form, press ANALYZE ROCKS to learn more about them.
4. As you make and learn about rocks, discuss the following prompts with your partner:
    - What were the different rock materials found in the Sim?
    - What processes did you use to form rocks?
    - How do the rocks you formed differ from each other?

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Reflecting on How Rocks Form

Think about what you saw in the *Rock Transformations* Simulation. Then, answer the questions below.

1. What happened to the sediment? (circle one)

    a. It turned into rock inside another rock.

    b. It turned into a layer of rock.

    c. It turned into a volcano.

    d. Nothing happened. It stayed the same.

2. What happened to the magma? (circle one)

    a. It turned into rock inside another rock.

    b. It turned into a layer of rock.

    c. It turned into a volcano.

    d. Nothing happened. It stayed the same.

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Lesson 1.4: Modeling How Rocks Are Formed

In the last lesson, you saw that rocks can form from different types of rock material. But how does that change occur? What processes form rock? In this lesson, you will use hard candy to model one of the processes that can form rock. You will then watch a video of a second process. You will apply what you learned by revisiting the rock hand samples you observed in Lesson 1.2. For homework, you will further explore how rocks formed in a particular setting—the beach.

Unit Question

- How do rocks form and change?

Chapter 1 Question

- How did the rock of the Great Plains and Rocky Mountains form?

Vocabulary

- cementation
- compaction
- igneous rock
- magma
- matter
- rock formation
- sample
- sediment
- sedimentary rock

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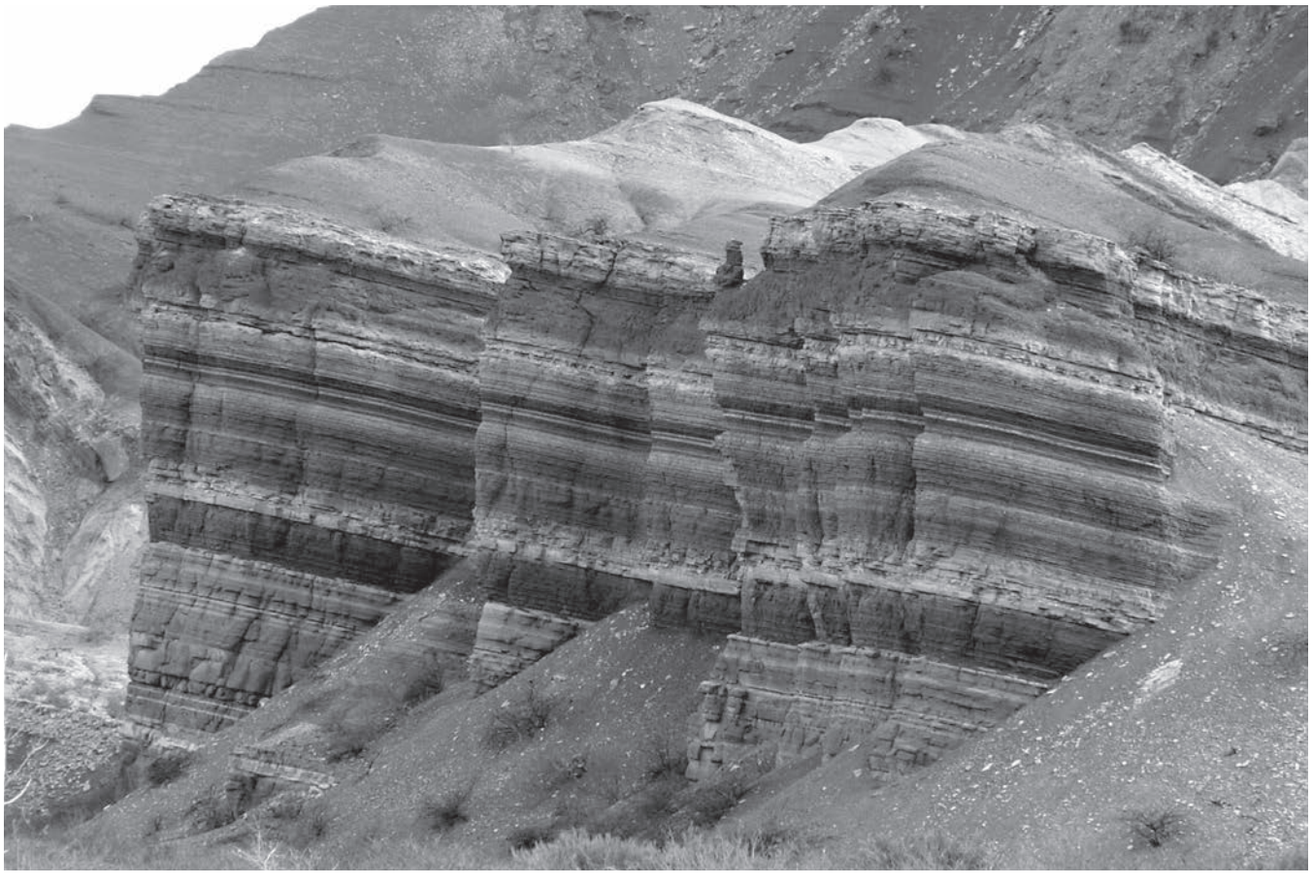
Warm-Up



Rock formations in Quebrada de Humahuaca, Argentina

Each layer of rock in the image is a rock formation. How long do you think it took for each layer to form?

_____

_____

_____

_____

_____

_____

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Modeling How Sediment Forms Rock

Making Rocks Using Candy

To compact the hard candy (model of sediment):

1. Observe the crushed candy.
2. Insert an empty plastic cup inside the cup that already contains the candy.
3. Press down on the stacked cups.

How are the pieces of hard candy like pieces of rock (sediment)? How are they different?

_____

_____

_____

How do the pieces of hard candy model the formation of new rock?

_____

_____

_____

How might you use hard candy to model how magma forms new rock?

_____

_____

_____

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Rock Types and How They Form

Rock Characteristics

Sedimentary	Igneous
Observations: • can have many different colors • grains are rounded and can be different sizes (tiny like sand or big like pebbles) • can be crumbly • can appear layered • can have fossils **How the rock was made:** • made when sediment was compacted and cemented	**Observations:** • can have many different colors • grains have sharp edges that fit together like pebble pieces • can be very hard • can have bubbles **How the rock was made:** • made when magma cooled

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Homework: Reading "Rocks on the Beach"

Read and annotate your copy of the article, using the Active Reading strategies you have learned in previous units. Then, answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

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Lesson 1.5: Examining Evidence About Rocks

In this lesson, you will review observations made by student geologists who have visited the Great Plains and Rocky Mountains. You will determine which of their observations are detailed and worth considering as useful evidence. Finally, you will think about what types of rocks make up the Great Plains and Rocky Mountains based on the evidence the student geologists observed about each region.

Unit Question

- How do rocks form and change?

Chapter 1 Question

- How did the rock of the Great Plains and Rocky Mountains form?

Key Concepts

- Rocks can form in different ways. This causes them to be different types.
- When sediment is compacted and cemented together, it forms sedimentary rock.
- When magma cools, it hardens to form igneous rock.

Vocabulary

- cementation
- compaction
- igneous rock
- magma
- matter
- rock formation
- sample
- sediment
- sedimentary rock

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Warm-Up

Match the rock types below to the description of how they formed (in the table).

- igneous rock
- sedimentary rock

Description of how rock type formed	Rock type
1. Some magma cools and hardens while it's still underground. Liquid magma can also be spewed onto the surface through volcanic activity. At Earth's surface, whether it is in open air or underwater, the magma cools and hardens into new rocks.	
2. Loose sediment moves downhill, usually into a low place where there's water, like a lake or the ocean. Layers of sediment begin to build up in the water. Over time, all those layers press on the layers below, compacting the sediment at the bottom. Minerals in the water also create a kind of "glue" that holds the compacted sediment together in a process called cementation. Together, the compaction of many layers and the mineral "glue" transform sediment into new layers of rock.	

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Modeling How Rocks Form

You have been investigating the question: *How do rocks form?* Use the Modeling Tool activity: How Rocks Form on pages 23–24 to show your thinking about this question. Follow the instructions below.

Goal: Show how **sedimentary or igneous rock** is formed by filling in the initial material and process.

Do:

- Fill in the materials box in the Transformation region with the initial rock material.
- Label the arrow with the process that transforms this material into sedimentary or igneous rock.

Tips:

- Options for rock materials and processes are given at the bottom of the page.
- You can also write in other materials and processes.
- You can add drawings as well.

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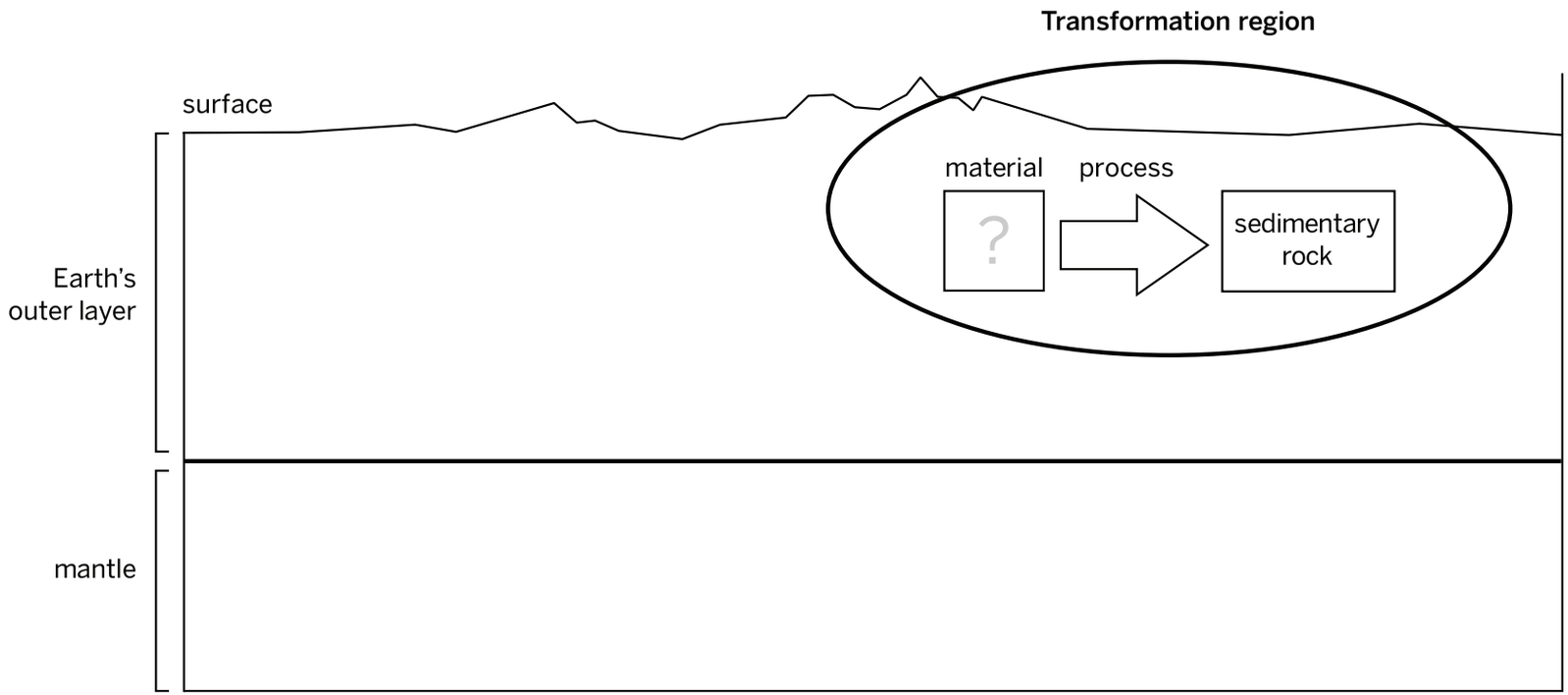
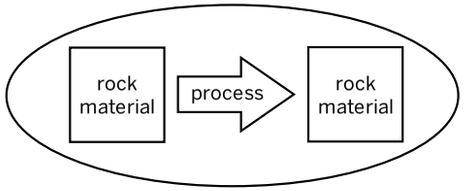
Modeling Tool: How Rocks Form

Goal: Show how **sedimentary rock** is formed by filling in the initial material and process.



Transformation region



Rock materials
- rock
- sediment
- magma

Processes
- cooling
- compaction and cementation
- weathering
- melting

Movement of rock materials

magma rising →

erosion →

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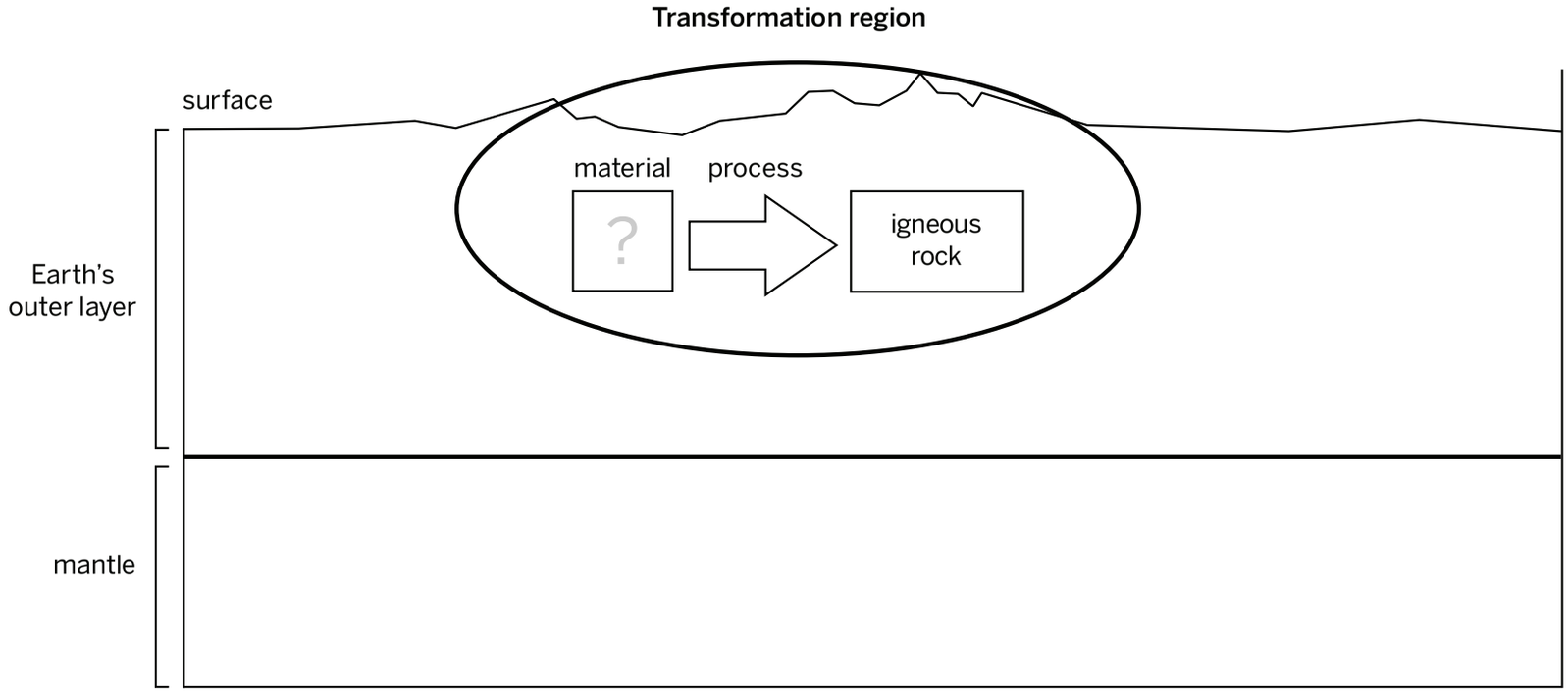
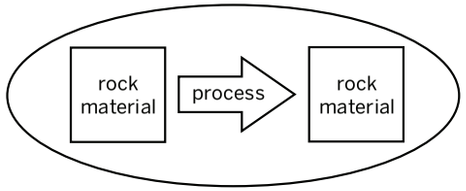
Modeling Tool: How Rocks Form (continued)

Goal: Show how **igneous rock** is formed by filling in the initial material and process.



Transformation region



Rock materials
- rock
- sediment
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Processes
- cooling
- compaction and cementation
- weathering
- melting

Movement of rock materials

magma rising →

erosion →

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Evaluating Rock Observations

Bascom University

To: Student Geologists
From: Dr. Jackie Lewis, Professor of Geology
Subject: Observations of Great Plains and Rocky Mountains

We are continuing our investigation of how the rock formations in the Great Plains and Rocky Mountains formed.

I'm sending you some observations of both regions. These were collected by student geologists in the field. They made observations of both the rock samples and the landscape.

I'd like you to sort through these observations and decide which are worth keeping and which are not detailed enough (and, therefore, do not provide strong enough evidence). We look forward to your response!

Evaluating Observations of the Great Plains and Rocky Mountains

Student geologists in the field made observations about the landscapes and rock samples from the two study regions.

Evidence Criterion: More detailed observations provide stronger evidence.

1. With a partner, look at the image and read the observations written down on the Great Plains and Rocky Mountain Evidence Cards given to you by your teacher. Annotate the cards with any questions or ideas you have.
2. Discuss the cards with your partner and evaluate each observation using the Evidence Criterion included above and the guidelines on the next page.
3. Once you have evaluated each observation, place the cards on the Evidence Gradient sheet with the strongest pieces of evidence near the top and the less strong pieces of evidence near the bottom.
4. When you are finished, prepare to share with other students.

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Evaluating Rock Observations (continued)

Geologist's Detailed Observation Guidelines

1. Observe the number and color of grains in the rock.
2. Observe the sizes and shapes of grains.
3. Observe whether the grains look stuck together or fitted together like puzzle pieces.
4. Observe the rock's texture, including how hard it is.
5. Notice whether there are unusual features in the rock, such as bubbles or fossils.

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Discussing How the Rocks Formed

Answer the questions below with your partner.

- Use the observations you determined were most detailed from the evidence cards and the Rock Characteristics chart on page 18 to help you.

How did the rock of the Great Plains form?

_____

_____

_____

_____

_____

_____

How did the rock of the Rocky Mountains form?

_____

_____

_____

_____

_____

_____

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Homework: Revisiting the Claims

Use the evidence cards to answer the questions below.

Evidence Card A: Great Plains

Observations

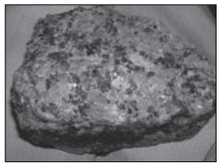
- There are many small, rocky hills made of crumbly rock.
- The hills are covered in brown and green grass.

Evidence Card E: Rocky Mountains

Observations

- The large mountains have jagged tops.
- The chunks of rock vary in size.
- The rock appears to be light and dark gray.
- There is a forest at base of the mountains.

Evidence Card C: Rock from the Rocky Mountains



Observations

- The rock contains visible pink, dark gray, and light brown grains.
- The grains fit together.
- The grains have sharp edges.
- There are no bubbles or fossils in this sample.

Evidence Card G: Rock from the Great Plains

Observations

- The sample contains tan, brown, gray, and white grains.
- The grains are rounded and stuck together.
- The grains are different sizes; some look like tiny sand, and some look like small pebbles.
- This sample crumbles a little in my hand.

1. How did the rock of the Great Plains and Rocky Mountains form? Circle the claim you can eliminate.
   a. Claim 1: They formed as one rock formation, and then something separated them.
   b. Claim 2: One rock formation formed before the other. Then, the minerals from the older rock became part of the younger rock.

2. Why can we eliminate the claim you circled?

_____

_____

_____

3. What do we still need to know in order to determine why the two rock formations have such similar minerals?

_____

_____

_____

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Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why the rock samples from the Great Plains and Rocky Mountains are so similar?

1. I understand what is different about the rock formations in the Rocky Mountains and Great Plains. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

2. I understand how the materials that turned into the rock formations in the Rocky Mountains and Great Plains were formed. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

3. I understand the role of energy in creating the rock formations in the Rocky Mountains and Great Plains. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

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Homework: Check Your Understanding (continued)

4. I understand how the movement of plates is important for the connection between the Rocky Mountains and Great Plains. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

5. I understand how rock from one of the study regions (Great Plains or Rocky Mountains) could have transformed into rock from the other study region. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

6. What do you still wonder about the rock samples from the Great Plains and Rocky Mountains?

_____

_____

_____

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Chapter 2: Sediment and Magma
Chapter Overview

We know sedimentary rocks form when sediment is compacted and cemented, and igneous rocks form when magma cools. But where do sediment and magma come from? In Chapter 2, we will learn about the processes that form sediment and magma and where the energy for these processes comes from. This investigation will move us one step closer to determining how the two rock formations we are studying could have such similar mineral compositions.

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Lesson 2.1: Exploring How Magma and Sediment Form

In Chapter 1, you discovered that rock can form when magma cools or when sediment cements and compacts. But how is magma formed? How is sediment formed? Uncovering these processes and what drives them will help you make sense of the history of the rock formations in the Rocky Mountains and the Great Plains. In this lesson, you'll gain evidence about the formation of magma and sediment from the Sim and a short video.

Unit Question

- How do rocks form and change?

Chapter 2 Question

- Where did the magma and sediment that formed the rock of the Great Plains and the Rocky Mountains come from?

Vocabulary

- cementation
- compaction
- energy
- erosion
- igneous rock
- magma
- matter
- rock formation
- sample
- sediment
- sedimentary rock
- weathering

Digital Tools

- *Rock Transformations* Simulation
- *Rock Transformations* Sorting Tool activity: Weathering and Melting

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Warm-Up

Investigating Magma and Sediment

Where do you think magma comes from?

Where do you think sediment comes from?

How do you think magma and sediment form?

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Exploring How Magma and Sediment Form

Part 1: Making Magma and Sediment

Open the Process Mode of the *Rock Transformations* Simulation.

1. Use the process menu to form more sediment and magma in the landscape.
2. Do not use the Add Sediment process for this Sim activity.

How did you form sediment? Where on the landscape did the sediment form?

_____

_____

_____

How did you form magma? Where on the landscape did the magma form?

_____

_____

_____

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Name: _____ Date: _____

Exploring How Magma and Sediment Form (continued)

Part 2: Exploring Energy for Processes That Make Rocks

You and your partner will each explore one of the two energy sources in the Sim (energy from the sun and energy from Earth's interior). Open the Energy Mode of the *Rock Transformations* Sim. Then, use your observations in the Sim to support your answers to the questions below.

I saw magma being formed when _____ was turned on. (circle one)

energy from Earth's interior

energy from the sun

I saw sediment being formed when _____ was turned on. (circle one)

energy from Earth's interior

energy from the sun

What new rock formations did you see when the landscape was only exposed to energy from Earth's interior?

_____

_____

_____

What new rock formations did you see when the landscape was only exposed to energy from the sun?

_____

_____

_____

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Name: _____ Date: _____

Sorting Rock Processes

Launch the *Rock Transformations* Sorting Tool activity: Weathering and Melting and follow the instructions below.

Goal: Show where weathering and melting occur and the energy sources that drive these processes.

Do:

- Add the weathering and melting labels to the cross section to show where these processes occur.
- Add energy sources to each label to show which energy source drives each process.

Tip:

- After dragging each label to the cross section, press on the label to see the different energy source options.

How does your model show where weathering and melting occur and the energy sources that drive these processes?

_____

_____

_____

_____

_____

_____

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Homework: Explaining Weathering

Watch the *Understanding Weathering* video again (located in your Digital Resources). Then, answer the question below.

Your friend tells you that sunlight breaks rocks into small pieces. Using what you learned from the video, revise this statement, explaining how the process is more complicated than that.

_____

_____

_____

_____

_____

_____

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Name: _____ Date: _____

Lesson 2.2: "Devils Tower"

For years, people have marveled at the magnificence and beauty of Devils Tower and wondered how it formed. In this lesson, you will read an article to find out how this over 800-foot-tall rock formation in Wyoming was formed. Reading this article will help you understand more about what causes magma and sediment to form. It will also help you think about where the magma and sediment for the Rocky Mountains and Great Plains came from.

Unit Question

- How do rocks form and change?

Chapter 2 Question

- Where did the magma and sediment that formed the rock of the Great Plains and the Rocky Mountains come from?

Vocabulary

- cementation
- compaction
- energy
- erosion
- igneous rock
- magma
- matter
- rock formation
- sample
- sediment
- sedimentary rock
- weathering

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Name: _____ Date: _____

Warm-Up

Transforming Rocks

People claim these rock formations in the Sahara Desert look like a mushroom and a chicken. They were not sculpted by humans. What do you think caused them to be shaped this way?

_____

_____

_____

_____

_____

_____

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Name: _____ Date: _____

Reading "Devils Tower"

1. Read and annotate the article "Devils Tower."
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

What is one thing you discussed with your partner?

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

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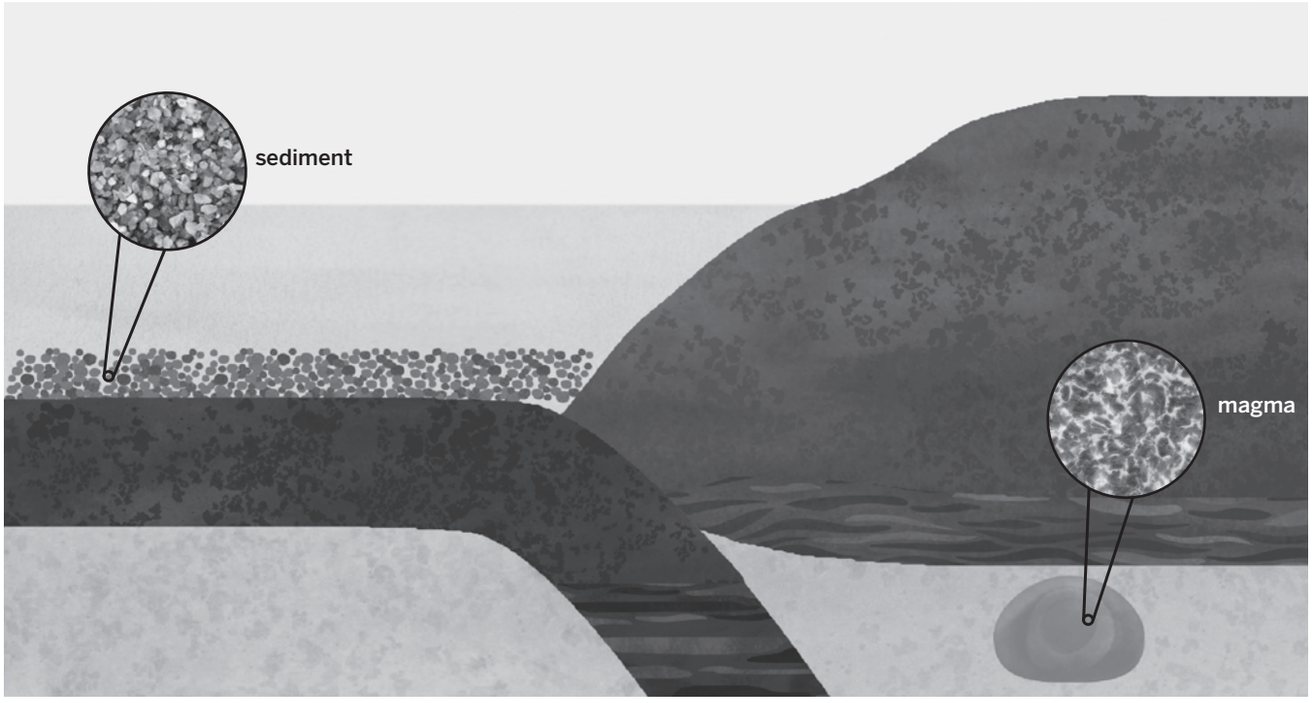
Reflecting on Magma and Sediment



Fill in the blanks using the Word Bank.

Word Bank

melting	energy from the sun	weathering	energy from Earth's interior

Sediment forms through _____ of rocks, which is caused by

_____.

Magma forms through _____ of rocks, which is caused by

_____.

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Name: _____ Date: _____

Lesson 2.3: Energy's Role in Forming Rocks

In this lesson, you will further investigate what causes magma and sediment to form. You will gather evidence from a candy model, watch a video, and return to the "Devils Tower" article. You will consider what type of rocks can transform into magma and sediment. This will later help you determine if the Rocky Mountains or Great Plains formed first. You will consider if only certain types of rock turn into sediment or magma or if all rocks can turn into sediment and magma.

Unit Question

- How do rocks form and change?

Chapter 2 Question

- Where did the magma and sediment that formed the rock of the Great Plains and the Rocky Mountains come from?

Vocabulary

- cementation
- compaction
- energy
- erosion
- igneous rock
- magma
- matter
- rock formation
- sample
- sediment
- sedimentary rock
- weathering

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Name: _____ Date: _____

Warm-Up

Steps to Form Magma and Sediment

Today, we will use hard candy to model how magma and sediment form. Order the steps below (1–3) that are needed to form either magma or sediment.

When **(sediment / magma)** forms . . . ,

_____ rock is exposed to energy from Earth's interior.

_____ part or all of the rock melts.

_____ the rock is heated until it is 700 degrees Celsius to 1300 degrees Celsius.

When **(sediment / magma)** forms . . . ,

_____ weather (storms) move wind and water.

_____ energy from the sun heats Earth's surface and atmosphere.

_____ weathering breaks rock into pieces.

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Name: _____ Date: _____

Making Sediment with Hard Candy

Weathering Rocks

You are about to model how rocks weather. The crushed hard candy pieces you made in Chapter 1 represent **sedimentary rock**. The whole pieces of hard candy represent **igneous rock.**

- Decide which pair will work with the sedimentary rock and which will work with the igneous rock.
- Then, with your partner, weather your rocks by shaking the jar provided.

What happened to the sedimentary and igneous rocks?

_____

_____

_____

_____

Which rock type(s) were you able to transform into sediment? (circle one)

a. the sedimentary rock

b. the igneous rock

c. both rock types

d. neither rock type

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Name: _____ Date: _____

Second Read of "Devils Tower"

Reread the "Devils Tower" article (from the third paragraph to the end). Highlight sentences that describe weathering and melting. Then, add annotations explaining the source of energy for these processes. After that, answer the question below.

Describe at least two ways energy transformed rock matter as Devils Tower formed.

_____

_____

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

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Name: _____ Date: _____

Homework: Reading "Why Can't I Find Gold in My Backyard?"

Read and annotate the article "Why Can't I Find Gold in My Backyard?" Review your annotations and answer the reflection questions below.

Choose two renewable resources described in the article and explain why they are renewable.

_____

_____

_____

_____

_____

Choose two non-renewable resources from the article and explain why these are non-renewable.

_____

_____

_____

_____

_____

Why are some resources more available than others?

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

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Name: _____ Date: _____

Lesson 2.4: Explaining How Energy Affects Rocks

Dr. Jackie Lewis is waiting to hear about your analysis of why the rock in the Great Plains and the rock in the Rocky Mountains have such surprisingly similar mineral compositions. Where did the magma and sediment that formed the rock of the Great Plains and the rock of the Rocky Mountains come from? In this lesson, you will use what you have learned about how rocks transform when they are exposed to different energy sources to discuss different rock scenarios. You will then have a chance to revise your models and add to them in order to provide a more complete explanation of how rocks transform.

Unit Question

- How do rocks form and change?

Chapter 2 Question

- Where did the magma and sediment that formed the rock of the Great Plains and the Rocky Mountains come from?

Key Concepts

- Matter gets transformed by energy, but the same matter is still present.
- Sediment forms when any type of rock is weathered, a process driven by energy from the sun.
- Magma forms when any type of rock is melted, a process driven by energy from Earth's interior.

Vocabulary

- cementation
- compaction
- energy
- erosion
- igneous rock
- magma
- matter
- rock formation
- sample
- sediment
- sedimentary rock
- weathering

Digital Tools

- *Rock Transformations* Sorting Tool activity: Igneous and Sedimentary Rock

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Name: _____ Date: _____

Warm-Up

Launch the *Rock Transformations* Sorting Tool activity: Igneous and Sedimentary Rock, and follow the instructions below.

Goal: Show which words describe processes that form igneous rocks and which describe processes that form sedimentary rocks.

Do: Complete the table by placing each word or phrase from the Word Bank into the category it best describes.

Igneous rock	Sedimentary rock

Word Bank

compaction and cementation	cooling	energy from Earth's interior
energy from the sun	magma	sediment
weathering	melting	

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Name: _____ Date: _____

Write and Share Routine: Student 1: Energy Transforming Rocks

Rock sample: igneous rock

Prompt:

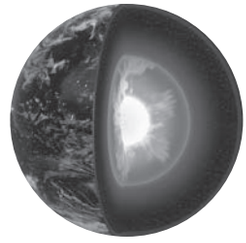
What would happen if the rock sample pictured above was first exposed to energy from the sun and then millions of years later to energy from the Earth's interior?

First

energy from the sun

Millions of years later

energy from Earth's interior



Word Bank

energy	magma	melting	sediment	weathering

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Name: _____ Date: _____

Write and Share Routine: Student 2: Energy Transforming Rocks

Rock sample: sedimentary rock

Prompt:

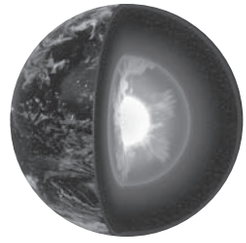
What would happen if the rock sample pictured above was exposed to energy from the sun and then millions of years later to energy from the Earth's interior?

First

energy from the sun

Millions of years later

energy from Earth's interior



Word Bank

energy	magma	melting	sediment	weathering

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Name: _____ Date: _____

Write and Share Routine: Student 3: Energy Transforming Rocks

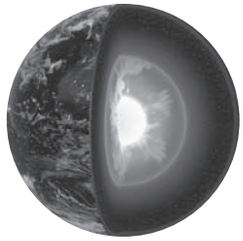
Rock sample: sedimentary rock

Prompt:

What would happen if the rock sample pictured above was first exposed to energy from the Earth's interior and then millions of years later to energy from the sun?

First

energy from Earth's interior



Millions of years later

energy from the sun

Word Bank

energy	magma	melting	sediment	weathering

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Name: _____ Date: _____

Write and Share Routine: Student 4: Energy Transforming Rocks

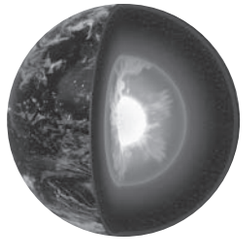
Rock sample: igneous rock

Prompt:

What would happen if the rock sample pictured above was first exposed to energy from the Earth's interior and then millions of years later energy from the sun?

First

energy from Earth's interior



Millions of years later

energy from the sun

Word Bank

energy	magma	melting	sediment	weathering

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Name: _____ Date: _____

Modeling How Rocks Form, Part 2

Goal: Revise and add to your model from Lesson 1.5 on pages 23–24. Show where the sediment and magma that form igneous and sedimentary rock come from and how the sediment and magma formed.

Do:

- Review and revise the transformation region you completed in Lesson 1.5.
- Add another transformation region to show where on Earth the material that became rock was formed.
- Fill in the correct rock materials and process for the transformation region you added.
- Add arrows to show the movement of rock materials through the landscape from one transformation region to the other.
- Label the transformation regions to show if the processes are caused by energy from the sun or energy from Earth's interior.

Tips:

- Be sure to complete the models for both sedimentary and igneous rock.
- Refer to the rock materials and processes section at the bottom of pages 23–24 for help.

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Name: _____ Date: _____

Lesson 2.6: Investigating Hawaiian Rocks

You have done an excellent job investigating the geologic history of the Rocky Mountains and Great Plains so far. To help you deepen your understanding of how rocks form, you will turn your focus to another interesting region on Earth. Today, you will work with a partner to investigate rocks in Hawaii. You will also take on a variety of new challenges, using the Sim and the key concepts from this unit to complete these tasks.

Unit Question

- How do rocks form and change?

Chapter 2 Question

- Where did the magma and sediment that formed the rock of the Great Plains and the Rocky Mountains come from?

Key Concepts

- Rocks can form in different ways. This causes them to be different types.
- When sediment is compacted and cemented together, it forms sedimentary rock.
- When magma cools, it hardens to form igneous rock.
- Matter gets transformed by energy, but the same matter is still present.
- Sediment forms when any type of rock is weathered, a process driven by energy from the sun.
- Magma forms when any type of rock is melted, a process driven by energy from Earth's interior.

Vocabulary

- cementation
- compaction
- energy
- erosion
- igneous rock
- magma
- matter
- rock formation
- sample
- sediment
- sedimentary rock
- weathering

Digital Tools

- *Rock Transformations* Simulation

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Name: _____ Date: _____

Purple Group: Warm-Up

Reading "Rocks on the Hawaiian Islands"

Focus question: *How do igneous rock and sedimentary rock form?*

1. Both igneous and sedimentary rock form on the Hawaiian Islands. You will first read about how these rocks form in Hawaii. Then, you will model these processes in the Sim.
2. Read and annotate the "Rocks on the Hawaiian Islands" article. When you are done, review your annotations, answer the reflection questions below.

How do sedimentary rocks form on the Hawaiian Islands?

_____

_____

_____

How do igneous rocks form on the Hawaiian Islands?

_____

_____

_____

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Name: _____ Date: _____

Purple Group: Making Rock Material in the Sim

Investigating Rocks in Hawaii Using the Sim

Think or look back at the text you read. Plan how you will form igneous and sedimentary rocks in the Sim.

1. Open the Process Mode of the *Rock Transformations* Simulation.
2. Try to form igneous rock in the landscape.
3. Press ANALYZE ROCKS to see if you were successful. If not, try again.
4. After you form igneous rock, answer the first question below.
5. Repeat steps 2–4, forming sedimentary rock this time. Once you are done, answer the second question below.

What processes in the Sim form igneous rock? (circle as many as needed)

a. weathering rock

b. adding sediment

c. melting

d. compacting and cementing

e. cooling at the surface

f. cooling below the surface

What processes in the Sim form sedimentary rock? (circle as many as needed)

a. weathering rock

b. adding sediment

c. melting

d. compacting and cementing

e. cooling at the surface

f. cooling below the surface

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Name: _____ Date: _____

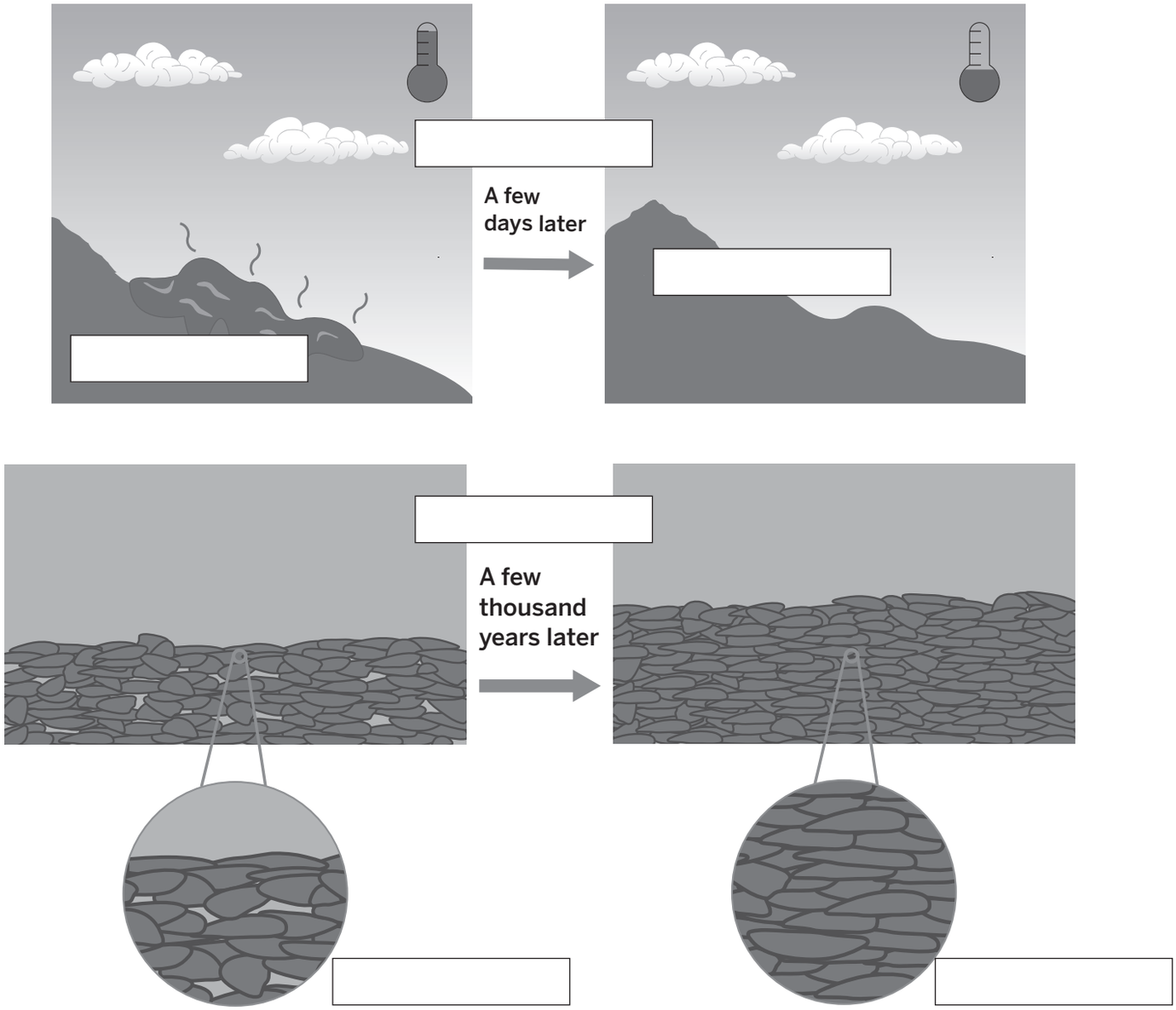
Purple Group: Making Rock Material in the Sim (continued)

Using What You Learned

Using what you learned from your article and the Sim activity, use the Word Bank to label the diagrams below.

Word Bank

sediment	magma	sedimentary rock
igneous rock	cooling	compaction and cementation



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Name: _____ Date: _____

Green Group: Warm-Up

Reading "Hawaiian Volcanoes and Beaches"

Focus question: *How do underwater volcanoes and volcanic sediment form?*

1. You will first read about how volcanoes and sediment in Hawaii form. Then, you will model this process in the Sim.
2. Read and annotate the "Hawaiian Volcanoes and Beaches" article. When you are done, review your annotations and answer the reflection questions below.

How does the magma in underwater volcanoes in Hawaii form?

_____

_____

_____

_____

_____

_____

How does volcanic rock in Hawaii turn into sediment?

_____

_____

_____

_____

_____

_____

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Name: _____ Date: _____

Green Group: Making Rock Material in the Sim

Investigating Rocks in Hawaii Using the Sim

Think or look back at the text you read. Plan how to form an underwater volcano and volcanic sediment in the Sim.

1. Open the Process Mode of the *Rock Transformations* Simulation.
2. Try to form an underwater volcano in the landscape.
3. After you form the underwater volcano, answer the first question below.
4. Next, form a volcano on land. Then, try to form sediment from the new volcano.
5. After you form the sediment, answer the second question below.

How did you form an underwater volcano?

_____

_____

_____

_____

_____

_____

How did you form sediment from a volcano?

_____

_____

_____

_____

_____

_____

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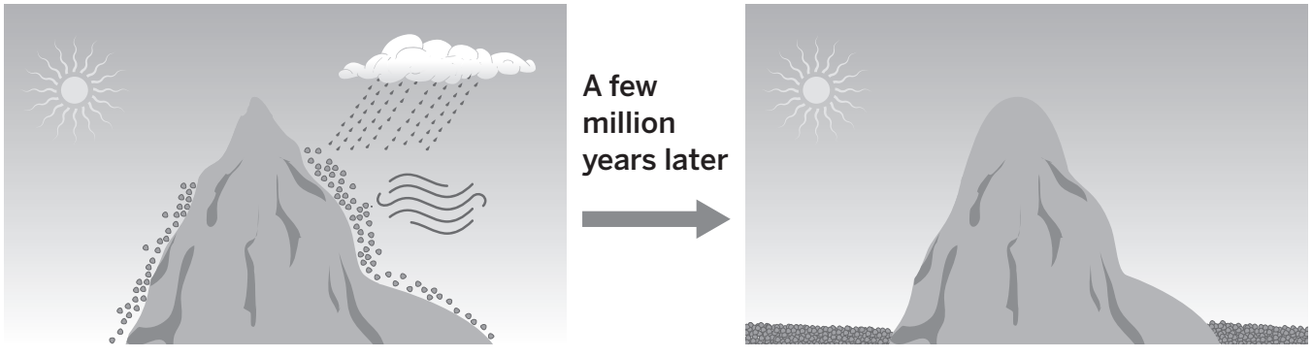
Name: _____ Date: _____

Green Group: Making Rock Material in the Sim (continued)

Using What You Learned

Using what you learned from your article and the Sim, answer the questions about the diagrams below.



Explain what transformation process is happening in the above diagram. Use the following terms to help you with your explanation:

- energy from the sun
- weathering
- sediment

_____

_____

_____

_____

_____

_____

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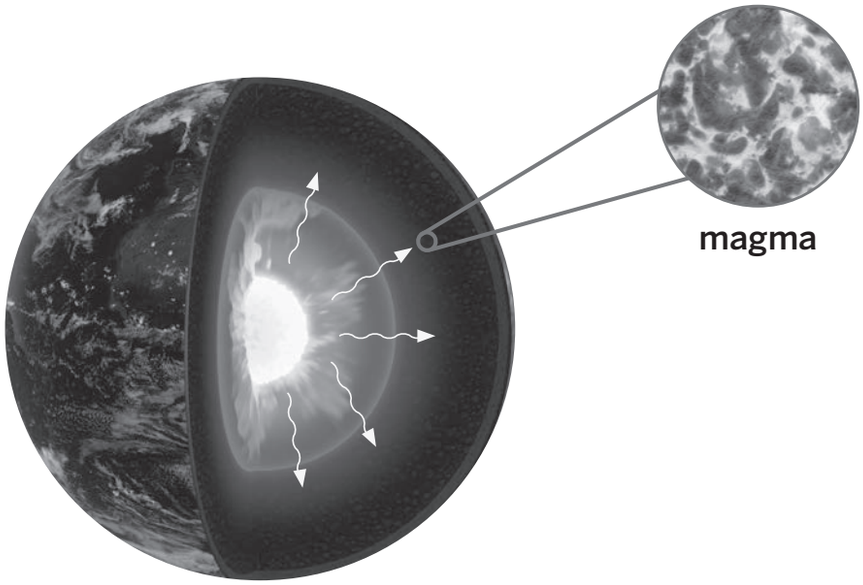
Name: _____ Date: _____

Green Group: Making Rock Material in the Sim (continued)



Explain what transformation process is happening in the above diagram. Use the following terms to help you with your explanation:

- energy from Earth's interior
- melting
- magma

_____

_____

_____

_____

_____

_____

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Name: _____ Date: _____

Blue Group: Warm-Up

Reading "Hawaii's Colorful Sand"

Focus question: *How do different kinds of igneous rock form?*

1. There are many different colors of sand on Hawaiian beaches. You will first read about what causes these different colors of sand. Then, you will model the process in the Sim.
2. Read and annotate the "Hawaii's Colorful Sand" article. When you are done, review your annotations and answer the reflection question below.

Why might sand on beaches in Hawaii be different colors even though the sand all formed from igneous rock?

_____

_____

_____

_____

_____

_____

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Name: _____ Date: _____

Blue Group: Making Rock Material in the Sim

Investigating Rocks in Hawaii Using the Sim

Think or look back at the text you read. Plan how to form different kinds of igneous rock in the Sim.

1. Open the Process Mode of the *Rock Transformations* Simulation.
2. Make as many different kinds of igneous rock as you can.
3. Check your work by pressing ANALYZE ROCKS and selecting rock material to see if the kinds of igneous rock you formed are different from each other.

How many different kinds of igneous rock did you form?

_____

_____

_____

_____

_____

_____

How did you form the different kinds of igneous rocks?

_____

_____

_____

_____

_____

_____

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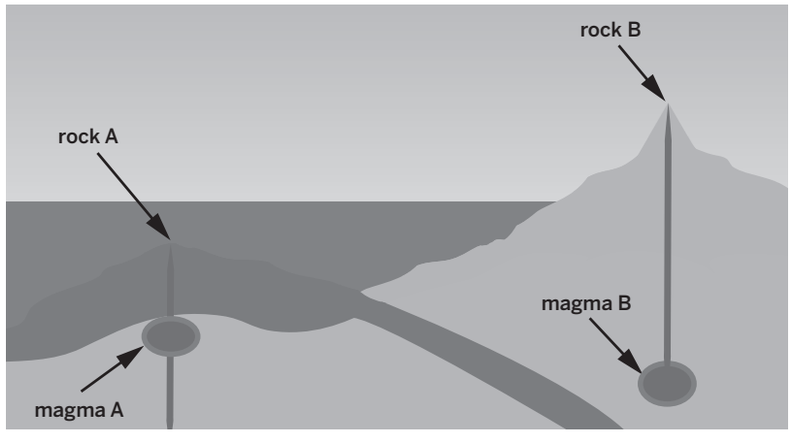
Name: _____ Date: _____

Blue Group: Making Rock Material in the Sim (continued)

Using What You Learned

Using what you learned from your article and the Sim, answer the questions about the diagrams below.

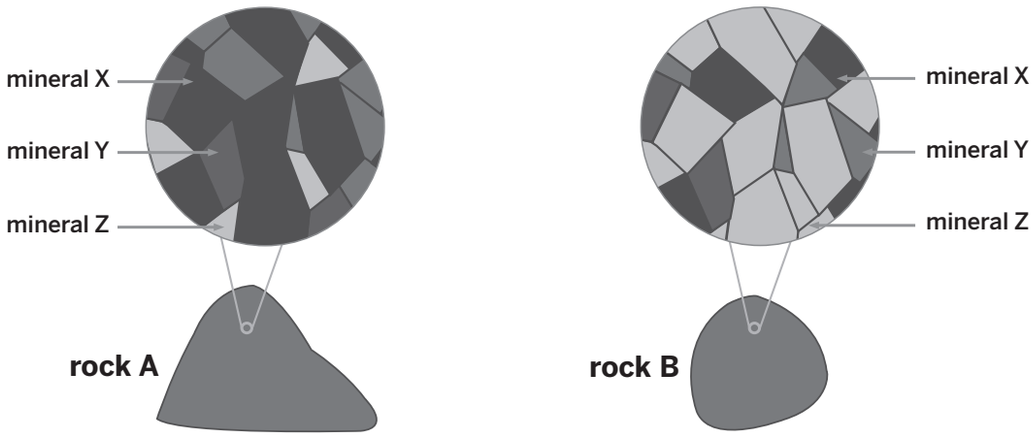


Examine the above diagram. Then, write your own key concept to summarize what is shown.

_____

_____

_____



The rocks shown in the above diagram formed from magma. Examine the rocks and write your own key concept to summarize the diagram.

_____

_____

_____

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Name: _____ Date: _____

Blue Group: Making Rock Material in the Sim (continued)

Optional: Considering Waimea Canyon in Hawaii

Two famous canyons in the United States are pictured below. After reviewing, discuss the questions with your partner and then write responses.

The Grand Canyon in Arizona is made of sedimentary rock.

Waimea Canyon in Hawaii is made of igneous rock, but people still call it "The Grand Canyon of the Pacific."

1. What similarities do you observe about the rock formations of the Grand Canyon and Waimea Canyon?

_____

_____

_____

2. How do you think Waimea Canyon formed?

_____

_____

_____

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Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why the rock samples from the Great Plains and Rocky Mountains are so similar?

1. I understand what is different about the rock formations in the Rocky Mountains and Great Plains. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

2. I understand how the materials that turned into the rock formations in the Rocky Mountains and Great Plains were formed. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

3. I understand the role of energy in creating the rock formations in the Rocky Mountains and Great Plains. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

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Homework: Check Your Understanding (continued)

4. I understand how the movement of plates is important for the connection between the Rocky Mountains and Great Plains. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

5. I understand how rock from one of the study regions (Great Plains or Rocky Mountains) could have transformed into rock from the other study region. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

6. What do you still wonder about the rock samples from the Great Plains and Rocky Mountains?

_____

_____

_____

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Name: _____ Date: _____

Chapter 3: Movement of Rock Formations
Chapter Overview

You have figured out that when rock is weathered, sediment forms and when rock melts, magma forms. These processes are driven by energy from the sun and energy from Earth's interior. You have also figured out that sediment can then be transformed into sedimentary rock and that magma can then be transformed into igneous rock. But how can rocks that have already formed be exposed to a new energy source and transform again into a different rock type? In this chapter, you will learn about the role that plate motion plays in moving rock formations between Earth's surface and interior.

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Lesson 3.1: "The Oldest Rock Formations on Earth"

You have learned how rocks form and how energy can change them. You know that energy from inside Earth can melt rock into magma, and energy on the surface (from the sun) can cause rock to weather and break into sediment. But how could a rock from Earth's surface ever melt into magma? How could a rock in Earth's interior ever get weathered into sediment? In this lesson, you will read an article about one of the oldest rock formations on Earth that will help you answer these questions.

Unit Question

- How do rocks form and change?

Chapter 3 Question

- How could rock from one of the regions have transformed into a different type of rock in the other region?

Vocabulary

- cementation
- compaction
- energy
- erosion
- igneous rock
- magma
- matter
- metamorphic rock
- rock formation
- sample
- sediment
- sedimentary rock
- weathering

Digital Tools

- *Plate Motion* Simulation

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Warm-Up

New Information About the Rocky Mountains

To: Student Geologists
From: Dr. Jackie Lewis, Professor of Geology
Subject: New Information About the Rocky Mountains

Greetings, student geologists! You did an excellent job understanding which processes formed the sediment and magma that ended up making rock formations in the Great Plains and Rocky Mountains.

We now know the magma that formed the Rocky Mountains cooled underground. Use this new information to help you figure out more about the claims: How could the sediment that formed the Great Plains have come from the rock of the Rocky Mountains? How could the magma that formed the Rocky Mountains have come from the rock of Great Plains?

What are your initial thoughts about this new information? What additional information do you think you would need in order to evaluate the claims?

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Reading "The Oldest Rock Formations on Earth"

1. Read and annotate the article "The Oldest Rock Formations on Earth."
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

What is one thing you discussed with your partner?

_____

_____

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

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Homework: Exploring Plate Motion

Open the *Plate Motion* Simulation.

- Select Region 1.
- Press RUN and observe how the Cross-Section View changes as the Sim runs. You may want to press the Reset button in the top right corner to replay the Sim.
- Observe the plates, considering how rock formations move between the surface and Earth's interior.

After observing plate motion in the Sim, record detailed observations of how the plates moved. How can this result in the movement of rock formations?

_____

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Lesson 3.2: Moving Rock Formations

How could the igneous rock of the Rocky Mountains have moved up toward the surface to be weathered into sediment that formed the Great Plains? How could the sedimentary rock of the Great Plains have moved down to be melted in the magma that formed the Rocky Mountains? In this lesson, you will gather evidence about how rock material can move between the surface and Earth's interior. You will then use that information to help you plan and complete missions in the Simulation. Each mission is similar to one of the possible claims about the Great Plains and Rocky Mountain rock formations.

Unit Question

- How do rocks form and change?

Chapter 3 Question

- How could rock from one of the regions have transformed into a different type of rock in the other region?

Vocabulary

- cementation
- compaction
- energy
- erosion
- igneous rock
- magma
- matter
- metamorphic rock
- rock formation
- sample
- sediment
- sedimentary rock
- subduction
- uplift
- weathering

Digital Tools

- *Rock Transformations* Simulation

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Warm-Up

Simulating Plate Motion

How do rock formations move between the surface and Earth's interior? You will use the *Rock Transformations* Sim to observe how rock formations move.

Open the Process Mode of the *Rock Transformations* Simulation and complete the following:

1. Form sedimentary rock.
2. Form igneous rock.
3. Press MOVE PLATES. If needed, press UNDO in the top right corner. You can then press MOVE PLATES again and make additional observations.

What happened to the igneous and sedimentary rock formations during plate motion? Record your observations.

_____

_____

_____

_____

_____

_____

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Second Read of "The Oldest Rock Formations on Earth"

Reread the "Plate Movement and Rock Transformations" section of "The Oldest Rock Formations on Earth." As you read, highlight evidence that can help you answer the Investigation Question below.

How do rock formations move between Earth's surface and interior?

_____

_____

_____

_____

_____

_____

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Moving Rock Formations

Transforming Rock

Open the Process Mode of the *Rock Transformations* Simulation. Complete the below missions and share your observations with your partner. Then, circle the word that completes each sentence about the missions.

Mission 1: Form igneous rock below Earth's surface. Then, use uplift and subduction to transform the rock into sedimentary rock.

(Uplift, Subduction) leads to the transformation of igneous rock into sedimentary rock by moving it **(upward, downward)**, exposing it to energy from **(the sun, Earth's interior).**

Mission 2: Form sedimentary rock. Then use uplift and subduction to transform the rock into metamorphic rock.

(Uplift, Subduction) leads to the transformation of sedimentary rock into metamorphic rock by moving it (**upward, downward),** exposing it to energy from **(the sun, Earth's interior)**.

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Homework: Rock Transformation Challenges

Choose one or more of the below missions.

Mission 1: Transform sedimentary rock into sediment.

Mission 2: Make igneous rock that cooled at the surface subduct.

Mission 3: Transform igneous rock that cooled below the surface into metamorphic rock.

Open the Process Mode of the *Rock Transformations* Simulation to complete your mission. Press ANALYZE ROCKS to explore the rock formations both before and after you complete your mission. Once finished, answer the questions for the mission you completed.

Which mission did you complete? (circle one)

a. Mission 1

b. Mission 2

c. Mission 3

What steps did you take to complete your chosen mission in the Sim?

_____

_____

_____

What energy sources were required to complete your chosen mission?

_____

_____

_____

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Lesson 3.3: Plate Motion and Rock Transformations

How do uplift and subduction lead to the transformation of rocks? In the last lesson, you learned that uplift moves rock upward toward Earth's surface, and subduction moves rock down, below Earth's outer layer. In this lesson, you will learn more about how that movement of rocks can lead to new rock transformation processes.

Unit Question

- How do rocks form and change?

Chapter 3 Question

- How could rock from one of the regions have transformed into a different type of rock in the other region?

Key Concepts

- Plate motion moves rock formations.
- Subduction moves rock down, below Earth's outer layer.
- Uplift moves rock upward toward Earth's surface.

Vocabulary

- cementation
- compaction
- energy
- erosion
- igneous rock
- magma
- matter
- metamorphic rock
- rock formation
- sample
- sediment
- sedimentary rock
- subduction
- uplift
- weathering

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Warm-Up

Today, you will participate in a model to see what types of rock transformations can occur. Review the Rock Transformations Tracking Chart sheet on pages 80–81. Be sure to read over both the instructions and the chart. Then answer the question below.

There are seven possible processes. How many processes do you think your rock material will go through? (circle one)

a. All of them. (Any rock material can transform into any other rock material.)

b. Only one. (Each rock material can only be transformed once).

c. Some of them. (Each type of rock material can only go through certain processes.)

d. Some of them. (Rock material can transform in any way, but my rock might not go through all of the processes.)

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Rock Transformations Tracking Chart

1. Circle your starting rock material based on the Starting Rock Material projection.
2. Go to your assigned starting station.
3. Write down the station number and process. Then, determine the rock material you become after the process takes place. Circle this process in the table below.
4. Roll the die.
   - Refer to the table and read what happens to you after you transform.
   - Move on to the station indicated.
5. Repeat steps 3–4 until you run out of time.

Starting rock material before first process (circle one):

magma sediment metamorphic rock igneous rock sedimentary rock

Station	Process	What rock material are you after the process? (circle one)	
		magma sediment metamorphic rock	igneous rock sedimentary rock
		magma sediment metamorphic rock	igneous rock sedimentary rock
		magma sediment metamorphic rock	igneous rock sedimentary rock
		magma sediment metamorphic rock	igneous rock sedimentary rock
		magma sediment metamorphic rock	igneous rock sedimentary rock
		magma sediment metamorphic rock	igneous rock sedimentary rock

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Rock Transformations Tracking Chart (continued)

Station	Process	What rock material are you after the process? (circle one)
		magma sediment metamorphic rock igneous rock sedimentary rock
		magma sediment metamorphic rock igneous rock sedimentary rock
		magma sediment metamorphic rock igneous rock sedimentary rock
		magma sediment metamorphic rock igneous rock sedimentary rock
		magma sediment metamorphic rock igneous rock sedimentary rock
		magma sediment metamorphic rock igneous rock sedimentary rock
		magma sediment metamorphic rock igneous rock sedimentary rock
		magma sediment metamorphic rock igneous rock sedimentary rock
		magma sediment metamorphic rock igneous rock sedimentary rock
		magma sediment metamorphic rock igneous rock sedimentary rock

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Name: _____ Date: _____

You can use this page to record notes or make drawings.

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Mapping Rock Transformation Paths

Refer to your Rock Transformations Tracking Chart on pages 80–81 to map your path through your rock transformations on page 84.

1. Locate your starting process on your map.
2. Draw an arrow between the first process and the second process.
3. Map the rest of your path with arrows.
4. Share your completed map with your partner and discuss the questions below.
    - What do you notice about your maps?
    - How are the two maps similar?
    - How are the two maps different?

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Mapping Your Path Through Rock Transformations

melting

weathering

cooling

compaction and cementation

metamorphic process

uplift

subduction

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Thinking About Your Path Through Rock Transformations

Now that you have modeled rock transformations, consider the below questions with your classmates.

1. What process happens before weathering? What process happens after weathering?
2. What process happens before melting? What process happens after melting?
3. What process happens after uplift?
4. What processes happen after subduction?
5. Look back at your chart. What type of rock can be uplifted? Subducted?

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Reflecting on Rock Transformations

How do uplift and subduction lead to the transformation of rocks?

_____

_____

_____

_____

_____

_____

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Lesson 3.4: Preparing the Final Report

Today, you will wrap up your work for Dr. Lewis. You will receive the final piece of evidence needed to determine why the rock in the Rocky Mountains and the rock in the Great Plains have similar mineral compositions. Using this evidence, you will write your final report to Dr. Lewis and provide an explanation of how rock from one of the regions could have transformed into a different rock type in the other region. Along with your report, you will create a visual representation of the processes causing the rock to transform.

Unit Question

- How do rocks form and change?

Chapter 3 Question

- How could rock from one of the regions have transformed into a different type of rock in the other region?

Key Concepts

- Plate motion moves rock formations.
- Subduction moves rock down, below Earth's outer layer.
- Uplift moves rock upward toward Earth's surface.
- Uplift and subduction can expose rock formations to different energy sources, which can transform them.
- Any type of rock can transform into any type of rock because of plate motion.

Vocabulary

- cementation
- compaction
- energy
- erosion
- igneous rock
- magma
- matter
- metamorphic rock
- rock formation
- sample
- sediment
- sedimentary rock
- subduction
- uplift
- weathering

Digital Tools

- *Rock Transformations* Sorting Tool activity: Moving Rock Formations

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Warm-Up

Launch the *Rock Transformations* Sorting Tool activity: Moving Rock Formations and follow the instructions below.

Goal: Show what happened to the circled rock material as a result of plate motion.

Do:

- Add circles to the After plate motion diagram to show where rock formation A and rock formation B are now located.
- Add labels to show what energy sources rock formation A and rock formation B are now exposed to.

Tip:

- The arrows represent the direction the plates are moving.

How does your model show what happened to the circled rock material as a result of plate motion?

_____

_____

_____

_____

_____

_____

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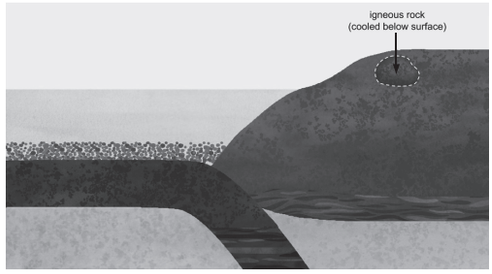
Write and Share Routine: Student 1: Moving Rock Formations

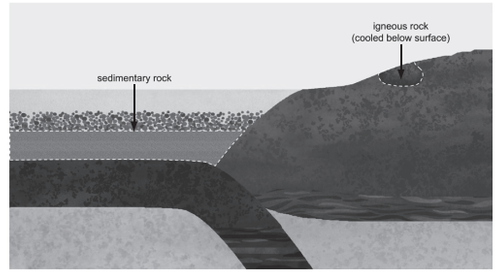
Rock Transformations Simulation

The illustrations below show how igneous rock (such as the Rocky Mountains) could transform into sedimentary rock (such as the Great Plains).

Time 1

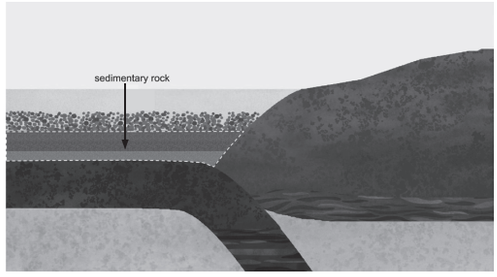


Time 2 (60 million years later)

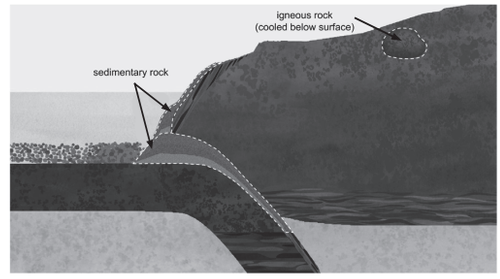


The illustrations below show how sedimentary rock (such as the Great Plains) could transform into igneous rock (such as the Rocky Mountains).

Time 1



Time 2 (60 million years later)



Prompt: Use the evidence above to answer both questions below:

1. How could the Great Plains have transformed into the Rocky Mountains?
2. How could the Rocky Mountains have transformed into the Great Plains?

Word Bank

energy	subduction	uplift

_____

_____

_____

_____

_____

_____

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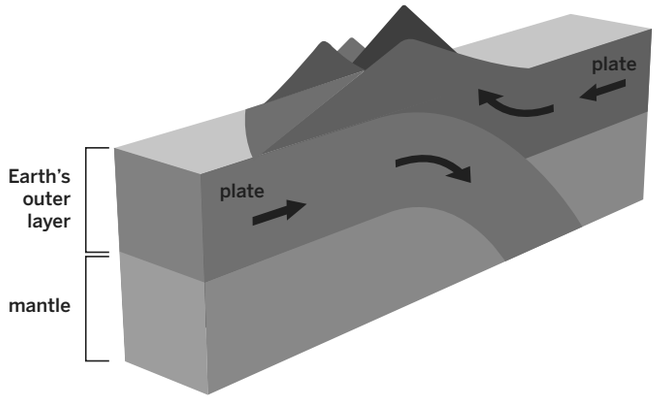
Write and Share Routine: Student 2: Moving Rock Formations

Excerpt from "The Oldest Rock Formations on Earth"

Plate Movement and Rock Transformations

During subduction, one plate, along with all of its rock formations, moves under another plate and farther inside Earth. When one plate moves under another plate, the rock formations move under Earth's outer layer, to where energy inside Earth can transform the rock. In contrast, uplift is the process that pushes rock formations from down below up to Earth's surface. When one plate moves under another, the plate on top is pushed upward, which exposes it to weathering and erosion at the surface.



Subduction takes place when one plate moves under another plate. Subduction causes some rock from the surface to move deep into the Earth. It can also cause mountains to form as they are uplifted.

Prompt: Use the evidence above to answer **both** questions below:

1. How could the Great Plains have transformed into the Rocky Mountains?
2. How could the Rocky Mountains have transformed into the Great Plains?

Word Bank

energy	subduction	uplift

_____

_____

_____

_____

_____

_____

_____

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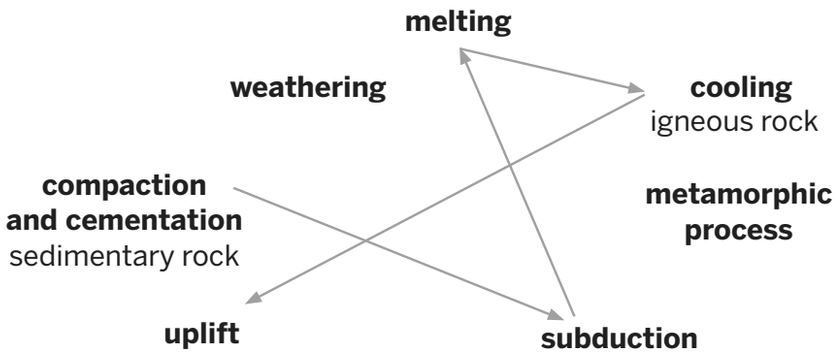
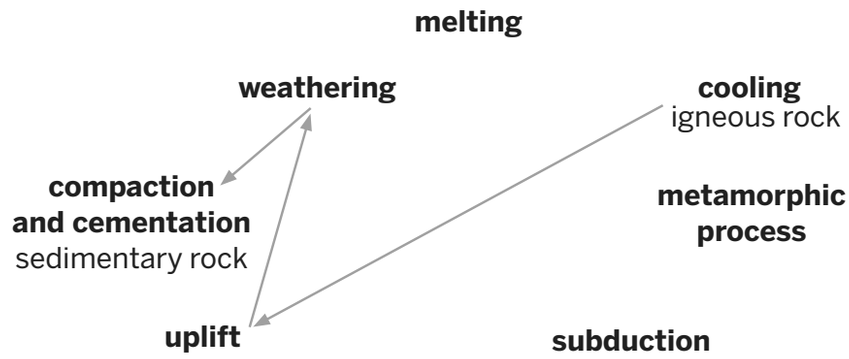
Write and Share Routine: Student 3: Moving Rock Formations

Modeling Rock Paths

This is the path the Great Plains would have to take in order to transform into the Rocky Mountains.



This is the path the Rocky Mountains would have to take in order to transform into the Great Plains.



Prompt: Use the evidence above to answer **both** questions below:

1. How could the Great Plains have transformed into the Rocky Mountains?
2. How could the Rocky Mountains have transformed into the Great Plains?

Word Bank

energy	subduction	uplift

_____

_____

_____

_____

_____

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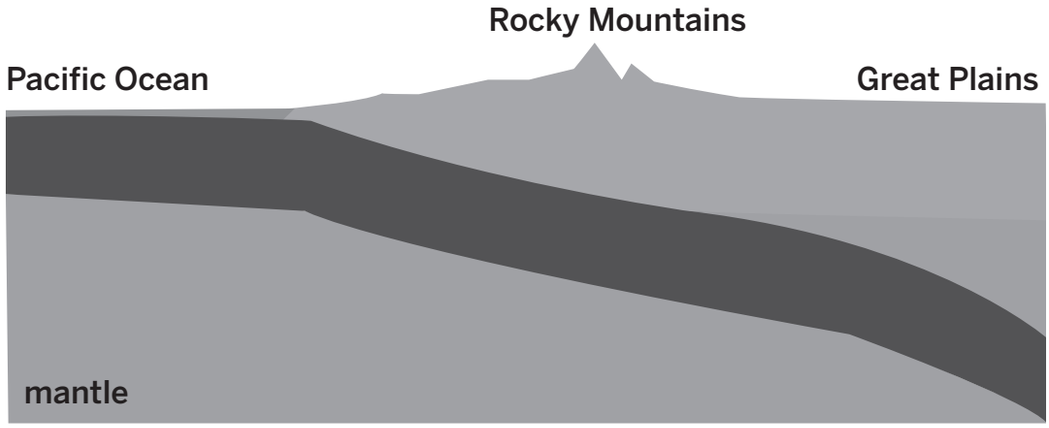
Modeling Rock Transformations

To: Student Geologists
From: Dr. Jackie Lewis, Professor of Geology
Subject: Location of Plate Boundary

Bascom University

The diagram below will help you determine if the sediment that formed the Great Plains came from the Rocky Mountains or if the magma that formed the Rocky Mountains came from the Great Plains. Notice the location of the plate boundary in the image below. If the plates moved, which rock formation would be subducted and which rock formation would be uplifted? I look forward to receiving your final reports!



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Modeling Rock Transformations (continued)

On the next page, make a model that shows your thinking about how the Great Plains and Rocky Mountains formed.

Goal: Show how rock from one of the study regions transformed into rock in the other one.

Do:

- Circle the name of the region you think formed first.
- Add a transformation region between the two existing ones to show how the first rock formation transformed into the other rock formation.
- Add arrows to show the movement of rock materials from one region to the other.
- Label any transformation regions that include processes caused by energy from the sun or energy from Earth's interior.
- Make sure all transformation regions are complete.

Tips:

- The rock types for the two regions are already labeled on the landscape.
- Refer to the rock materials and processes section at the bottom of the page for help

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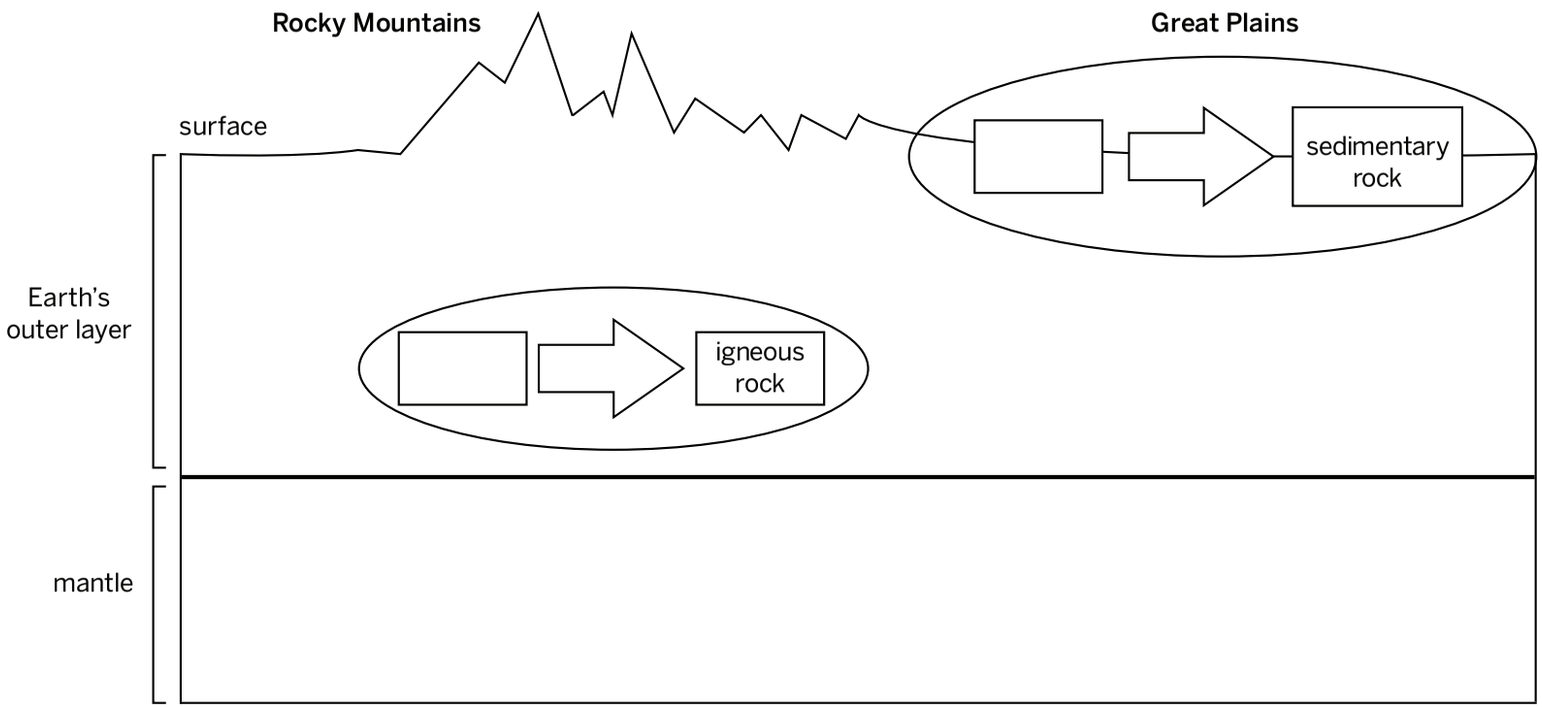
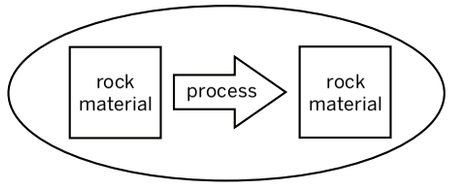
Modeling Tool: How the Great Plains and Rocky Mountains Formed

Goal: Show how rock from one of the study regions transformed into rock in the other one.



Transformation region



Rock materials
- rock
- sediment
- magma

Processes
- cooling
- compaction and cementation
- weathering
- melting

Movement of rock materials
- magma rising →
- erosion →
- uplift →
- subduction →

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Homework: Writing About How the Great Plains and Rocky Mountains Formed

Circle a claim and then write a report to Dr. Lewis explaining why you support that claim.

Claim 1: The sediment that formed the Great Plains came from the rock of the Rocky Mountains.

Claim 2: The magma that formed the Rocky Mountains came from the rock of the Great Plains.

Choose the claim that is best supported by evidence, explaining why the rock of the Rocky Mountains and Great Plains have surprisingly similar mineral compositions.

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Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why the rock samples from the Great Plains and Rocky Mountains are so similar?

1. I understand what is different about the rock formations in the Rocky Mountains and Great Plains. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

2. I understand how the materials that turned into the rock formations in the Rocky Mountains and Great Plains were formed. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

3. I understand the role of energy in creating the rock formations in the Rocky Mountains and Great Plains. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

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Homework: Check Your Understanding (continued)

4. I understand how the movement of plates is important for the connection between the Rocky Mountains and Great Plains. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

5. I understand how rock from one of the study regions (Great Plains or Rocky Mountains) could have transformed into rock from the other study region. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

6. What do you still wonder about the rock samples from the Great Plains and Rocky Mountains?

_____

_____

_____

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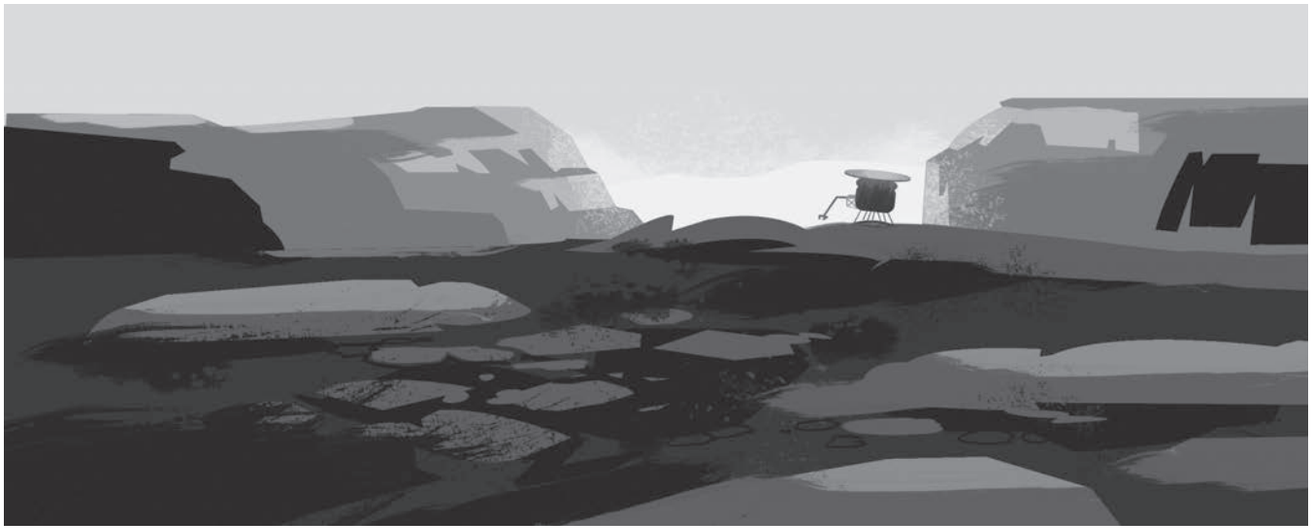
Chapter 4: Rock Transformations on Venus
Chapter Overview

Now that you understand the rock processes that formed the rock of the Rocky Mountains and Great Plains, it's time to take your expertise to another planet. Dr. Lewis would now like you to investigate the rock transformation processes occurring on Venus. This is an area of research her colleagues are currently studying. You will analyze evidence from Venus and use what you know about the rock transformation processes that occur on Earth, drawing inferences about the rock transformation processes that are happening on Venus.



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Lesson 4.1: Examining Evidence From Venus

You have learned a lot about rocks and how they form and change on Earth. But how might those transformations be different on another planet? Are rocks on other planets formed in the same way as those on Earth? You will explore images from Venus in order to determine how rocks on this planet can form and change.

Unit Question

- How do rocks form and change?

Chapter 4 Question

- What rock transformation processes are happening on Venus?

Key Concepts

- Rocks can form in different ways. This causes them to be different types.
- When sediment is compacted and cemented together, it forms sedimentary rock.
- When magma cools, it hardens to form igneous rock.
- Matter gets transformed by energy, but the same matter is still present.
- Sediment forms when any type of rock is weathered, a process driven by energy from the sun.
- Magma forms when any type of rock is melted, a process driven by energy from Earth's interior.
- Plate motion moves rock formations.
- Subduction moves rock down, below Earth's outer layer.
- Uplift moves rock upward toward Earth's surface.
- Uplift and subduction can expose rock formations to different energy sources, which can transform them.
- Any type of rock can transform into any type of rock because of plate motion.

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Name: _____ Date: _____

Lesson 4.1: Examining Evidence From Venus (continued)

Vocabulary

- cementation
- claim
- compaction
- energy
- erosion
- evidence
- igneous rock
- magma
- matter
- metamorphic rock
- rock formation
- sample
- sediment
- sedimentary rock
- subduction
- uplift
- weathering

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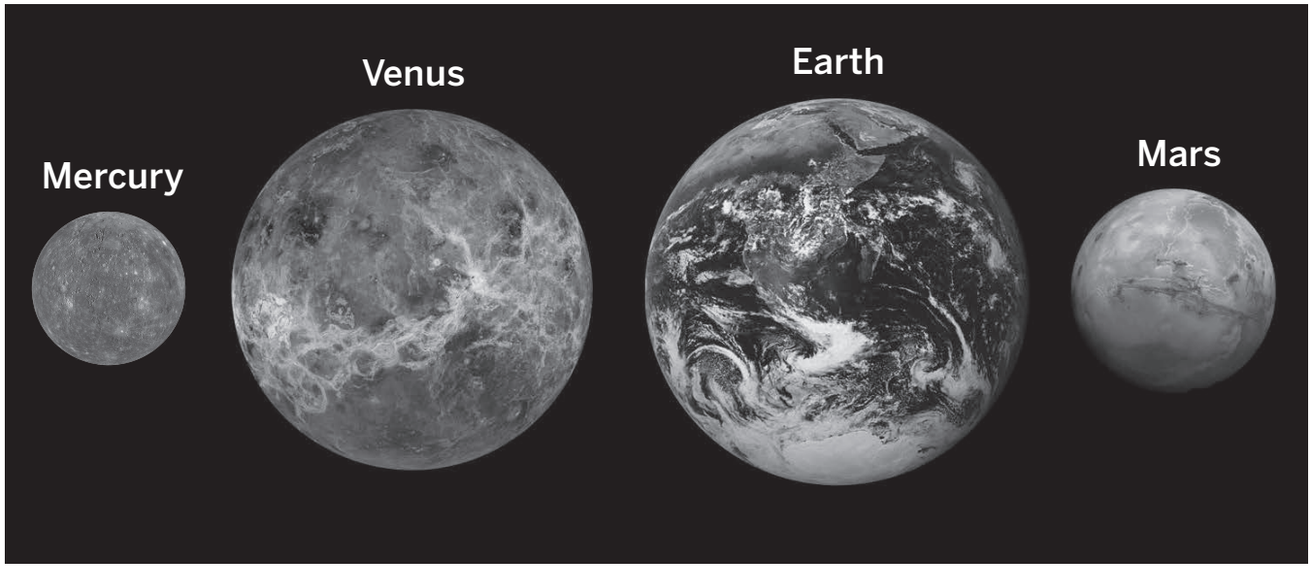
Name: _____ Date: _____

Warm-Up

The Four Rocky Planets



Just like Earth, some of the planets in our solar system are also made of rock. Do you think the rocks on these planets transform? Why or why not?

_____

_____

_____

_____

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_____

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Rock Transformations on Venus

To: Student Geologists
From: Dr. Jackie Lewis, Professor of Geology
Subject: Rocks on Venus

You did a great job determining the history of the rock formations in the Rocky Mountains and the Great Plains!

Several of my colleagues are planetary geologists at the Universal Space Agency. They are studying the rock processes that occur on Venus. I would like you to investigate these processes further. You will be given some evidence from Venus. You can use this evidence to determine which rock transformations are occurring there.

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Evaluating Rock Observations

Venus Evidence Cards: Set 1

1. Carefully review each evidence card and discuss them with your partner.
2. With your partner, annotate the cards with any questions or ideas you have.
3. Sort the cards using the Evidence Gradient. Which cards include detailed observations that might be useful in answering the Chapter 4 Question: *What rock transformation processes are happening on Venus?*

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Comparing Rock on Earth and Venus

What rock transformation processes are happening on Venus?

Claim 1: Venus's rock transformation processes form mostly sedimentary rock.

Claim 2: Venus's rock transformation processes form mostly igneous rock.

1. Compare the images of rocks on the Venus Evidence Cards to images of rocks on Earth on Reference Card 1.
2. Discuss what you notice with your partner. What does the evidence reveal about the types of rocks found on Venus?

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Lesson 4.2: More Evidence About Venus

Your mission in understanding geology on Venus continues! You've examined photographs of Venus's surface, but these photographs did not provide enough evidence to determine what types of rocks form there. Today, you'll analyze more evidence and prepare your argument.

Unit Question

- How do rocks form and change?

Chapter 4 Question

- What rock transformation processes are happening on Venus?

Key Concepts

- Rocks can form in different ways. This causes them to be different types.
- When sediment is compacted and cemented together, it forms sedimentary rock.
- When magma cools, it hardens to form igneous rock.
- Matter gets transformed by energy, but the same matter is still present.
- Sediment forms when any type of rock is weathered, a process driven by energy from the sun.
- Magma forms when any type of rock is melted, a process driven by energy from Earth's interior.
- Plate motion moves rock formations.
- Subduction moves rock down, below Earth's outer layer.
- Uplift moves rock upward toward Earth's surface.
- Uplift and subduction can expose rock formations to different energy sources, which can transform them.
- Any type of rock can transform into any type of rock because of plate motion.

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Lesson 4.2: More Evidence About Venus (continued)

Vocabulary

- cementation
- claim
- compaction
- energy
- erosion
- evidence
- igneous rock
- magma
- matter
- metamorphic rock
- rock formation
- sample
- sediment
- sedimentary rock
- subduction
- uplift
- weathering

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Warm-Up

Follow the instructions below. Then, answer the question below.

Goal: Show what evidence is needed in order to determine whether igneous or sedimentary rocks form on Venus.

Do: Complete the table by placing each word or phrase from the Word Bank into one of the categories.

Igneous rock formation processes	
Melting	Cooling

Sedimentary rock formation processes	
Weathering	Compaction and cementation

Word Bank

body of water	high temperatures	low areas	low temperature
moving water	pressure	wind	

What evidence would you need to look for to know which rock transformation processes happen on Venus?

_____

_____

_____

_____

_____

_____

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Examining Evidence About Venus

Today, you will use the Venus Evidence Cards you evaluated in the previous lesson. You will also receive some new evidence cards.

- Carefully read and annotate each evidence card.
- Add connections and questions as you read. These connections might help you determine which types of rocks can form on Venus: igneous or sedimentary.
- As you read, circle any words you are unfamiliar with.

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Sorting Evidence About Venus

Part 1: Discussing and Organizing Data

What rock transformation processes are happening on Venus?

Claim 1: Venus's rock transformation processes form mostly sedimentary rock.

Claim 2: Venus's rock transformation processes form mostly igneous rock.

Sort the Venus Evidence Cards using your Argument Organizer.

- Examine each evidence card with your partner, deciding if it contains information that will support Claim 1 or Claim 2.
- Place evidence cards on either the Claim 1 or Claim 2 sheet, depending on which claim the evidence best supports.

Part 2: Evaluating the Claims

Which claim about rocks on Venus do you think is best supported by the evidence? (circle one)

Claim 1: Venus's rock transformation processes form mostly sedimentary rock.

Claim 2: Venus's rock transformation processes form mostly igneous rock.

Which evidence cards support your answer?

_____

_____

_____

_____

_____

_____

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Lesson 4.3: Engaging in a Science Seminar

What transformation processes are happening on Venus? Is there evidence that these processes on Venus are forming either sedimentary or igneous rocks? In this lesson, you will participate in a Science Seminar, discussing the evidence that will help you answer this question. Listening to each other and sharing your thoughts during the Seminar will help you to determine which claim is the strongest and best supported.

Unit Question

- How do rocks form and change?

Chapter 4 Question

- What rock transformation processes are happening on Venus?

Key Concepts

- Rocks can form in different ways. This causes them to be different types.
- When sediment is compacted and cemented together, it forms sedimentary rock.
- When magma cools, it hardens to form igneous rock.
- Matter gets transformed by energy, but the same matter is still present.
- Sediment forms when any type of rock is weathered, a process driven by energy from the sun.
- Magma forms when any type of rock is melted, a process driven by energy from Earth's interior.
- Plate motion moves rock formations.
- Subduction moves rock down, below Earth's outer layer.
- Uplift moves rock upward toward Earth's surface.
- Uplift and subduction can expose rock formations to different energy sources, which can transform them.
- Any type of rock can transform into any type of rock because of plate motion.

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Lesson 4.3: Engaging in a Science Seminar (continued)

Vocabulary

- cementation
- claim
- compaction
- energy
- erosion
- evidence
- igneous rock
- magma
- matter
- metamorphic rock
- reasoning
- rock formation
- sample
- sediment
- sedimentary rock
- subduction
- uplift
- weathering

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Warm-Up

Preparing for the Science Seminar

To prepare for the Science Seminar, you will organize your evidence and practice forming your argument with your partner.

1. Take out your Argument Organizer sheets and evidence cards from Lesson 4.2.
2. With your partner, take turns sharing which claim you think is the most convincing and why.
3. Use the Scientific Argument Sentence Starters below to help you with your explanation.

Scientific Argument Sentence Starters	
Describing evidence:	**Describing how the evidence supports the claim:**
The evidence that supports my claim is . . .	If _____, then . . .
My first piece of evidence is . . .	This is important because . . .
Another piece of evidence is . . .	Since _____, . . .
This evidence shows that . . .	Based on the evidence, I conclude that . . .
	This claim is stronger because . . .

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Science Seminar Observations

Write a check mark in the right-hand column every time you hear one of your peers say or do something listed in the left-hand column. If you hear an interesting idea, write it in the last row of the table.

Observations during the seminar	**Check marks**
I heard a student use evidence to support a claim.	
I heard a student respectfully disagree with someone else's thinking.	
I heard a student explain how her evidence is connected to her claim.	
I heard a student evaluate the quality of evidence.	
I heard an idea that makes me better understand one of the claims. That idea is: _____ _____ _____ _____	

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Homework: Writing a Scientific Argument

Write a scientific argument to Dr. Jackie Lewis below. As you write, remember to:

- include your strongest, most convincing evidence.
- use the Scientific Argument Sentence Starters and the word bank below to explain your thinking.

What rock transformation processes are happening on Venus?

- **Claim 1:** Venus's rock transformation processes form mostly sedimentary rock.
- **Claim 2:** Venus's rock transformation processes form mostly igneous rock.

Scientific Argument Sentence Starters	
Describing evidence:	**Describing how the evidence supports the claim:**
The evidence that supports my claim is . . .	If _____, then . . .
My first piece of evidence is . . .	This is important because . . .
Another piece of evidence is . . .	Since _____, . . .
This evidence shows that . . .	Based on the evidence, I conclude that . . .
	This claim is stronger because . . .

Word Bank

cementation	compaction	energy	erosion	igneous rock
magma	matter	rock formation	sediment	sedimentary rock
subduction	uplift	weathering		

Write a scientific argument that addresses the question: *What rock transformation processes are happening on Venus?* First, state your claim. (You may choose to use one of the two claims given above, or you can create your own.) Then, use data from the Venus Evidence Cards to support your claim. Make sure to explain how energy makes these processes possible.

_____

_____

_____

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_____

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Homework: Writing a Scientific Argument (continued)

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Homework: Reading "Earth and Venus: Sister Planets"

You have learned a lot about rock transformations on Earth. To learn more about another planet, read and annotate the article "Earth and Venus: Sister Planets," then answer the questions below.

How are Earth and Venus the same?

_____

_____

_____

_____

_____

_____

How are Earth and Venus different?

_____

_____

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

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Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

1. I understand that more detailed observations provide stronger evidence. (check one)

   ☐ yes ☐ not yet

Explain your answer choice.

_____

_____

_____

_____

2. What are the most important things you have learned in this unit about how rocks form and change?

_____

_____

_____

_____

_____

_____

3. What questions do you still have?

_____

_____

_____

_____

_____

_____

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Rock Transformations Glossary

cementation: the process of sediment being glued together

cementación: el proceso en el que el sedimento se va pegando

compaction: the process of sediment being buried and pressed together

compactación: el proceso en el que el sedimento se va enterrando y comprimiendo

cross section: a diagram that shows what the inside of something looks like

corte transversal: un diagrama que muestra cómo es el interior de algo

energy: the ability to make things move or change

energía: la capacidad de hacer que las cosas se muevan o cambien

erosion: the movement of sediment from one place to another, often caused by wind or flowing water

erosión: el movimiento del sedimento de un lugar a otro, a menudo causado por el viento o por agua que corre

igneous rock: the rock type formed when magma cools and becomes solid

roca ígnea: el tipo de roca que se forma cuando el magma se enfría y se hace sólido

magma: hot liquid rock below the surface of Earth

magma: roca líquida y caliente bajo la superficie de la Tierra

matter: anything that has mass and takes up space

materia: cualquier cosa que tenga masa y ocupe espacio

metamorphic rock: the rock type formed when heat or pressure deep underground changes existing rock

roca metamórfica: el tipo de roca que se forma cuando el calor o la presión de la profundidad subterránea cambia la roca ya existente

mineral: one of the many different types of matter that make up rocks

mineral: uno de los diferentes tipos de materia que forman las rocas

plate: one of the very large sections of hard, solid rock that make up Earth's outer layer

placa: una de las muy grandes secciones de roca dura y sólida que forman la capa externa de la Tierra

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plate boundary: the place where two plates meet

límite de placas: el lugar donde se juntan dos placas

rock formation: a region of rock that formed together as a single rock type

formación de roca: una región de roca que se formó junta como un solo tipo de roca

rock materials: everything made of rock: magma, sediment, and all rock types

materiales rocosos: todo lo que está hecho de roca: magma, sedimento y todos los tipos de rocas

sample: a small part that is meant to show what the whole is like

muestra: una pequeña parte que sirve para mostrar cómo es el todo

sediment: small pieces of rock

sedimento: pedacitos de roca

sedimentary rock: the rock type formed when sediment is pressed and glued together

roca sedimentaria: el tipo de roca que se forma cuando el sedimento se comprime y se pega

subduction: the process by which rock material moves under Earth's outer layer and into the mantle due to plate motion

subducción: el proceso por medio del cual el material rocoso se mueve bajo la capa externa de la Tierra y hacia dentro del manto debido al movimiento de las placas

uplift: the process by which all the rock formations of a region are pushed up due to plate motion

levantamiento: el proceso por medio del cual todas las formaciones de roca de una región son empujadas hacia arriba debido al movimiento de las placas

weathering: the process of rock breaking down into smaller pieces due to wind or moving water

desgaste: el proceso en el que la roca se descompone en pedacitos debido al viento o el agua en movimiento

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Rock Transformations:

Geologic Puzzle of the Rockies and Great Plains

Article Compilation

Table of Contents: Articles

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All beaches are covered in pieces of rock. Some beaches are covered in tiny pieces of rock called sand, while others, like this one, are covered with larger rocks.

Rocks on the Beach

Imagine you're standing on a beach in Washington state. It's a sunny day, the ocean waves are crashing against the beach, and a bald eagle sits in a nearby tree. You might expect the beach to be covered in fine, white sand—but this beach is covered with rocks of all shapes and sizes. Some of the rocks are smooth and round. Others are rough or jagged. Where did all those rocks come from, and how did they form? That depends on the type of rock. It turns out that whether a rock is smooth, jagged, pink, or brown doesn't tell us what type of rock it is. Geologists study rocks to find clues about how the rocks were formed. Once they know how a rock was formed, they can tell what type of rock it is.

This sedimentary rock is made of sediment that has been pressed together over a long period of time.

Some rocks form from sediment, which is made up of small bits of rock such as sand and pebbles. How does sediment turn into new rocks? Loose sediment moves downhill, usually into a low place where there's water, like a lake or the ocean. Layers of sediment begin to build up in the water. Over time, all those

layers press on the layers below, compacting the sediment at the bottom. Minerals in the water also create a kind of "glue" that holds the compacted sediment together in a process called cementation. Together, the compaction of many layers and the mineral "glue" transform sediment into new layers of rock. Since it's formed from sediment, this type of rock is called sedimentary rock.

Other rocks form from cooled magma—liquid rock. Some magma cools and hardens while it's still underground. Liquid magma can also be spewed onto the surface through volcanic activity. At Earth's surface, whether it is in open air or underwater, the magma cools and hardens into new rocks. Rocks that are made from magma are called igneous rocks. The rocks you find on the beach may be made from sediment or cooled magma, and there may be some of each type.

This igneous rock is made from cooled magma.

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Devils Tower is a tall rock formation surrounded by flat land.

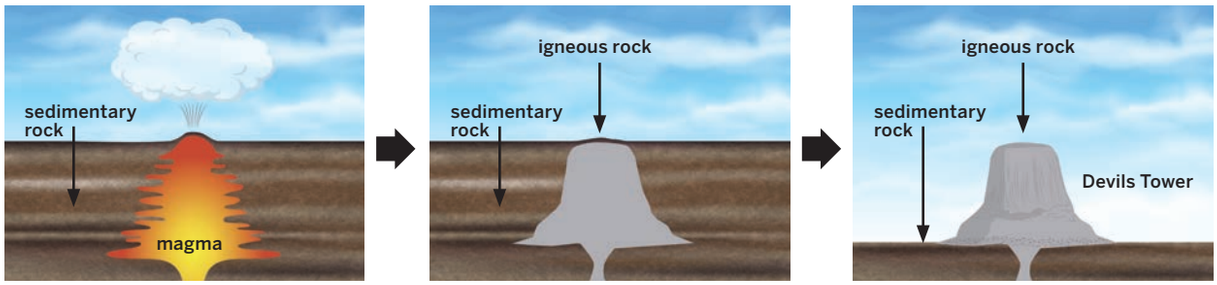
Devils Tower

Far out in the wilderness of Wyoming, a giant rock formation towers above the landscape. Devils Tower is a natural wonder visited by thousands of tourists, hikers, and climbers each year. The Lakota and other American Indian tribes in the area consider the rock formation a sacred site. Legends describe the columns of the tower being formed by the claws of a bear, and the Lakota name for the formation is *Mato Tipila*, which means "Bear's Lodge." In 1875, *Mato Tipila* was incorrectly translated into Bad God's Tower, which later became Devils Tower. The formation has been a national monument since 1906, but people have been visiting this huge tower of rock for thousands of years. How did Devils Tower form, and why is it so much taller than the surrounding landscape?

Devils Tower is made of igneous rock, but is surrounded by sedimentary rock. These types of rock are formed by different processes. Exploring the different geological processes that formed Devils Tower can help explain its history.

This climber looks tiny compared to Devils Tower!

Devils Tower © 2018 The Regents of the University of California. All rights reserved. Permission granted to purchaser to photocopy for classroom use. Image Credit: Shutterstock.



Devils Tower formed when magma pushed up through Earth's surface and cooled into hard rock. Over time, the land around it eroded away, leaving a tower looming over a flat landscape.

When you first see Devils Tower rising up above the dry landscape, it's hard to imagine that the whole region was once underwater. However, two hundred million years ago, this area of Wyoming was covered by a shallow sea. Blowing wind and falling rain weathered nearby rock formations over and over, causing small pieces to break off and become sediment. As bits of sediment ran into each other, they became smaller and smaller. They were driven downward by moving water and gravity. This erosion carried the sediment to the bottom of the sea. Over millions of years, compaction and cementation turned the sediment into solid sedimentary rock. Gradually, the sea drained away, leaving dry land in its place. That's how the land around Devils Tower formed.

However, Devils Tower itself is not sedimentary rock. About 50 million years ago, rock underneath Earth's outer layer in this region melted into magma. This only happens when rock gets up to very high temperatures—in the hundreds of degrees Celsius. Magma can cool to form different igneous rocks, depending on the way it melts. A column of the hot magma forced its way up into the layer of sedimentary rock, then cooled and became hard igneous rock called phonolite (FO-no-lite). After the magma solidified, it cracked into columns of rock. Over time, the sedimentary rock that covered the igneous rock was weathered and eroded away by wind and water, leaving a tower of hard igneous rock standing like a skyscraper above the surrounding land.

The weathering of rocks into sediment isn't uncommon—it happens to rocks all over the place. However, the revealing of the columns in Devils Tower as the sedimentary rock around it weathered and eroded away has made it a dramatic sight and attracted visitors from all over the world.

Even though the igneous columns of Devils Tower are very hard, they are slowly being weathered and eroded—that is, they are being worn away as wind and water remove bits of sediment from them. The tower that now stands is much smaller than the original mass of magma that pushed up from below. Millions of years from now, Devils Tower will be completely weathered and eroded away.

After the hot magma that formed Devils Tower cooled, it cracked into flat-sided columns.

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Why Can't I Find Gold in My Backyard? © 2018 The Regents of the University of California. All rights reserved. Permission granted to purchaser to photocopy for classroom use. Image Credits: Shutterstock

People dig for gold underground. Why can't I find gold wherever I dig?

Why Can't I Find Gold in My Backyard?

Wouldn't it be great if we could just dig a hole and find gold? Gold is one kind of natural resource—that means anything from nature that humans rely on to meet our needs. Some important natural resources include sunlight, water, wind, soil, forests, wildlife, fossil fuels, and rocks and minerals (such as gold). People dig underground for many natural resources, like fossil fuels, rocks, and minerals. Why can't we dig up these resources just anywhere at all? Why can't I find gold if I go digging in my backyard?

One important reason has to do with the way natural resources are formed. These resources build up through natural processes that may happen over millions of years. Different processes form different types of resources. For example, gold and other metals tend to build up in places where there has been volcanic activity. Fossil fuels tend to build up in places where biotic matter settled long ago at the bottoms of ancient oceans. Soil tends to build up in places where rocks are being weathered and deposited as sediment.

Because the processes that form these resources happen in different places, resources are found in different places. Some areas are rich in certain resources and not others. Some resources are very rare and hard to find anywhere at all. In order to figure out where resources can be found, geologists work hard to understand the natural processes that form different resources.

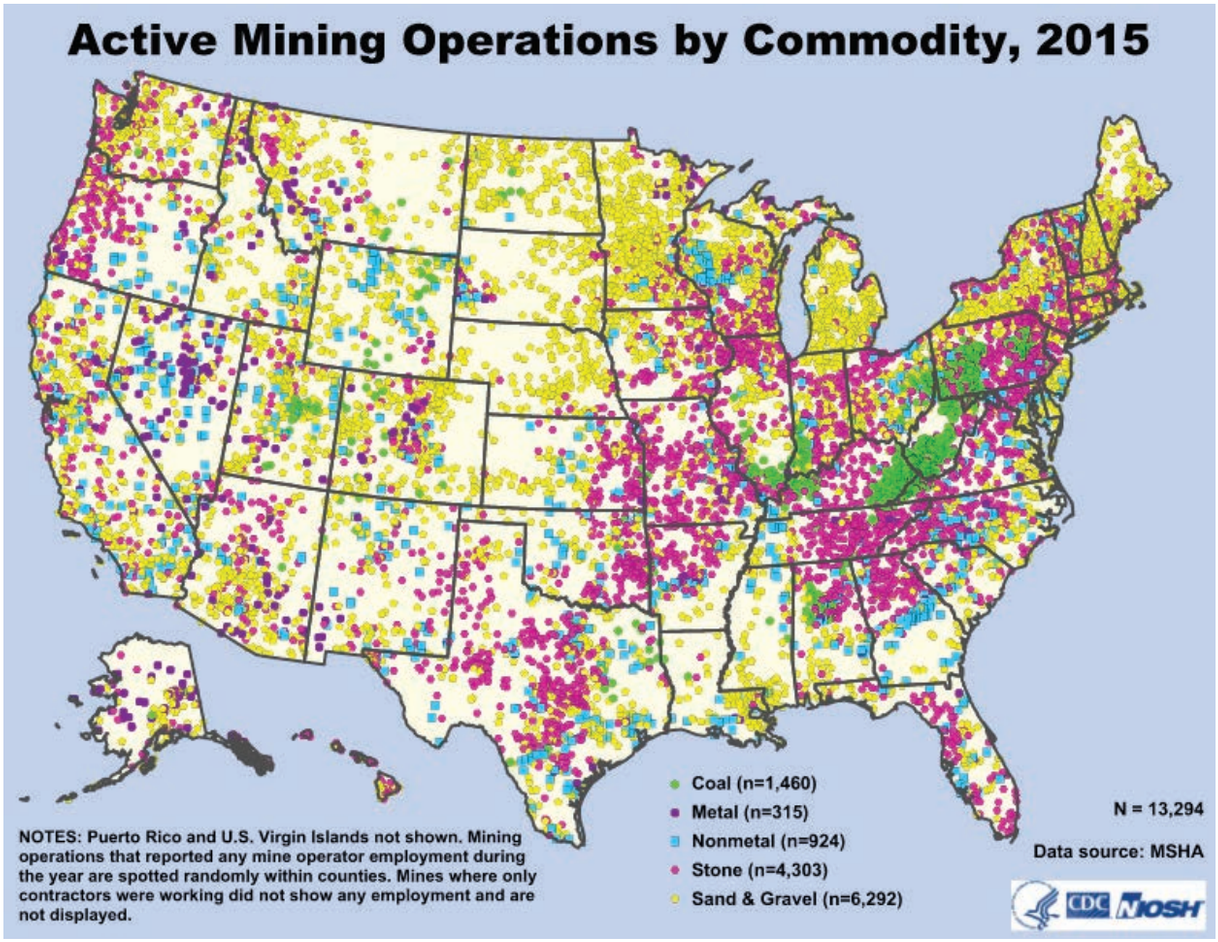
Another important reason why resources can be found in some places and not in others is that people have been using these resources and moving them around. Even if there were gold in my backyard, once I dug it all up I wouldn't be able to dig up any more. That's because gold is a non-renewable resource. Many natural resources are non-renewable—that means people are using them up much faster than they can be replaced by natural processes. Gold and other metals are non-renewable resources. So are coal, oil, and natural gas. The processes that form these resources happen over millions of years. When we use non-renewable resources like fossil fuels, they can't be replaced.

Other resources are renewable—that means they can be replaced naturally. Some examples of renewable resources are sunlight, water, trees and other plants, oxygen, and wind. Renewable resources are constantly being recycled by natural processes that happen relatively quickly. When we use freshwater for drinking, more freshwater will fall from the sky as rain or snow. When we cut down a few trees in a forest, more trees can grow to take their place.

As long as we use renewable resources responsibly, we don't have to worry about them ever running out. However, we have to be careful even with renewable resources. A forest is a

renewable resource, as long as people don't cut too many trees down at once. If people cut down the whole forest at once, it will take many years to grow back—and it may never grow back with all the different plants and animals it once had. A resource is only renewable as long as it can be replaced faster than people are using it up.

Sunlight is one resource that is always renewable. You can use sunlight to generate electricity or grow plants. You can do that every day, all day, for the rest of your life, and you'll never change the amount of sunlight that is coming to Earth from the sun. Golden sunlight is one kind of "gold" that I *can* find in my backyard, and it's a renewable resource that can never run out!



This map shows the places where people are mining for different natural resources. You can see that the mining for certain resources is concentrated in certain areas.

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Igneous rock in Hawaii forms when lava cools on Earth's surface.

Rocks on the Hawaiian Islands

When people think of Hawaii, they often imagine beautiful tropical beaches and palm trees. They may not realize that the islands were formed and are still being formed by volcanic activity. Over millions of years, volcanic eruptions have formed the Hawaiian islands. Each island has had at least one big, active volcano on it. Most of them are extinct and haven't erupted for hundreds, thousands, or millions of years. However, there are still active volcanoes on the big island of Hawaii. Despite Hawaii's fascinating formation history, the rocks on Hawaii are the same basic types we see everywhere on Earth. Because they are the same types, we know that they formed in similar ways.

Like many other places on Earth, Hawaii has both igneous rock and sedimentary rock. Igneous rock forms when melted rock known as magma comes from below Earth's outer layer to the surface and cools. (When magma comes to the surface, it is called lava.) Igneous rock continues to form as volcanoes on the island of Hawaii erupt and magma is released onto the surface. Sometimes this happens on land, and sometimes under water. Most rock in the Hawaiian islands is igneous rock. However, there is also sedimentary rock there.

Sedimentary rock forms through different processes: Small pieces of rock known as sediment collect in layers over time. As the layers build up, the pressure on the bottom layer increases. This squeezes the buried layers more and more, forcing the water out. This part of the process is called compaction. During compaction, the sediment starts to stick together–this is called cementation. Through compaction and cementation, layers of sedimentary rock build up on the Hawaiian Islands, just as they do in other places on Earth.

These cliffs in Hawaii are sedimentary rock. They formed from small pieces of rock called sediment.

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Hawaiian Volcanoes and Beaches © 2018 The Regents of the University of California. All rights reserved. Permission granted to purchaser to photocopy for classroom use. Image Credit: Shutterstock.

The black sand on this Hawaiian beach is made of pieces of rock from volcanoes.

Hawaiian Volcanoes and Beaches

Picture yourself on a sandy Hawaiian beach, with waves crashing in front of you and the rocky slope of a volcano rising behind you. Volcanoes and beaches are two of the most noticeable landforms on the islands of Hawaii–and although they look very different, they actually have a lot in common.

Volcanoes form when energy from Earth's interior causes rock under Earth's outer layer to melt into magma and then rise to the surface. Over millions of years, volcanic eruptions have formed the land that we call the islands of Hawaii. Each island has, or once had, at least one big active volcano on it. Most are extinct and haven't erupted for hundreds, thousands, or millions of years, but volcanoes are still active on the big island of Hawaii. When the volcanoes that make up Hawaii first formed, they were underwater. Over time, rock built up from eruptions until the volcanoes reached the surface.

Since volcanoes formed Hawaii, much of the sand on Hawaiian beaches comes from volcanoes too. This sand is tiny bits of igneous rock. Sand forms when rock (or another material, such as shell) is broken down into sediment by wind and moving water in a process called weathering. Weathering is driven by energy from the sun. On the Hawaiian islands, weathering breaks off pieces of igneous rock, forming sediment. Erosion moves that sediment down the slopes of volcanoes. The sediment builds up on the coast to form beaches. So if you dig your feet into the sand on a Hawaiian beach, you may get little pieces of volcanoes between your toes!

Hawaii's Colorful Sand © 2018 The Regents of the University of California. All rights reserved. Permission granted to purchaser to photocopy for classroom use. Image Credit: Shutterstock.

This green sand beach is made of pieces of sand that were weathered off a green igneous rock. It is mostly made of a green mineral called olivine.

Hawaii's Colorful Sand

You probably know that Hawaii has beaches, but did you know that the sand on the beaches can be many different colors? Some beaches in Hawaii are made of black, red, or green sand. The sediment that formed those beaches came from igneous rocks that were black, red, or green. The igneous rock that formed most of Hawaii originally came from below Earth's outer layer: rock there melted and formed magma when it was exposed to energy from Earth's interior. When the magma came up to the surface and cooled into igneous rock, it was exposed to energy

The sand on this Hawaiian beach is made of pieces of rock from volcanic rock. These rocks are made mostly of black minerals called pyroxene and plagioclase.

from the sun. The sun's energy caused the rock to be weathered and eroded into sediment that formed colorful, sandy beaches.

Rock below Earth's outer layer is mostly made of a mineral called olivine—so how could it become different kinds of igneous rock, which produce different kinds of sand, just by melting and cooling again? The type of igneous rock that forms from magma depends on how and where the magma forms. Rock that melts in different ways, or in different parts of Earth's interior, can have different compositions of minerals. When the different minerals cool into igneous rock, they are different colors. (Some sand is not made from rock at all, but rather from pieces of shell or coral. This sand is usually white or another light color.)

This red sand beach is made of sediment that formed through the weathering of igneous rock from a volcano with a lot of iron, which makes it red.

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The Oldest Rock Formations on Earth

The Nuvvuagittuq (NOO-voo-AG-it-tuck) Greenstone Belt is a large group of rock formations located in Quebec, Canada. The Greenstone Belt is special—it's one of the oldest groups of rock formations on Earth. In fact, measurements show that the Nuvvuagittuq Greenstone Belt is between 3.8 billion and 4.3 billion years old. That's almost as old as Earth itself!

When the Nuvvuagittuq Greenstone Belt formed at Earth's surface, it was made of sedimentary and igneous rock. Now it is made of metamorphic rock. However, all the rock formations that make up the belt have stayed together ever since they formed billions of years ago. To understand how the rock in the Greenstone Belt could have transformed—and how it could have stayed together as one group of rock formations—it's important to understand how rock material transforms and moves on Earth.

How Rock Can Change

It may seem like rocks never change, but the opposite is actually true. Over millions or billions of years, rocks are always in the process of being changed from one type of rock to another. Geologists classify rocks into three main types, based on how they are formed. Rock that has formed from the cooling and hardening of liquid magma is called igneous rock. Rock that has formed through the compaction and cementation of sediment is called sedimentary rock. When a rock formation is exposed to heat or pressure deep underground, it becomes a third type of rock: metamorphic rock. Metamorphic processes transform rock without melting it.

The Nuvvuagittuq (NOO-voo-AG-it-tuck) Greenstone Belt is one of the oldest groups of rock formations on Earth.

The Nuvvuagittuq Greenstone Belt is located in northern Quebec, Canada.

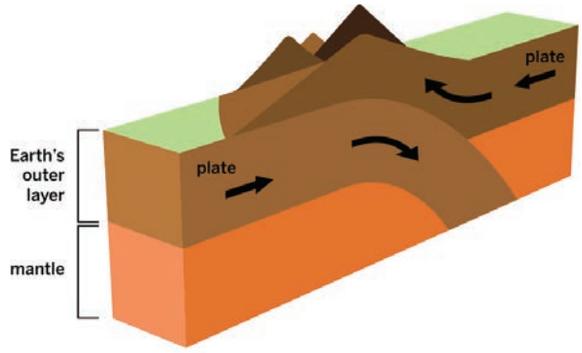
Plate Movement and Rock Transformations

The Nuvvuagittuq Greenstone Belt is made up of metamorphic rock, so it must have been buried deep underground in the past. How can a giant rock formation like the Nuvvuagittuq Greenstone Belt move deep underground… and then move back up to the surface? It's possible thanks to the processes of subduction and uplift. Earth's rocky outer layer is divided into plates. During subduction, one plate, along with all of its rock formations, moves under another plate and farther inside Earth. When one plate moves under another plate, the rock formations move under Earth's outer layer, to where energy inside Earth can transform the rock. In contrast, uplift is the process that pushes rock formations from down below up to Earth's surface. When one plate moves under another, the plate on top is pushed upward, which exposes it to weathering and erosion at the surface.

The plate motion that causes both uplift and subduction is driven by energy inside Earth. Because these processes are caused by enormous moving plates, entire regions of Earth's surface slowly subduct or are uplifted to form mountains. When this happens, the high pressure and heat caused by plate motion can change rock formations into metamorphic rock. These processes are usually very, very slow, but they never stop.

Explaining the Nuvvuagittuq Greenstone Belt

Billions of years ago, the Nuvvuagittuq Greenstone Belt was made of sedimentary and igneous rock formations that were probably located near a plate boundary. The Greenstone Belt experienced its last rock transformation 2.7 billion years ago, when it was subducted and changed into metamorphic rock. Those metamorphic rock formations were buried so deep inside Earth that they



Subduction takes place when one plate moves under another plate. Subduction causes some rock from the surface to move deep into the Earth. It can also cause mountains to form as they are uplifted.

were covered by many more layers of other rock. It took billions of years for the rock layers above the Greenstone Belt to be slowly weathered and eroded away by wind, ice, and water. Once the rocks on top were gone, the rocks of the Greenstone Belt were finally exposed. They had been transformed into metamorphic rock. Today, the Nuvvuagittuq Greenstone Belt has been weathered nearly flat, but is still made of the same rock formations that were formed so long ago.

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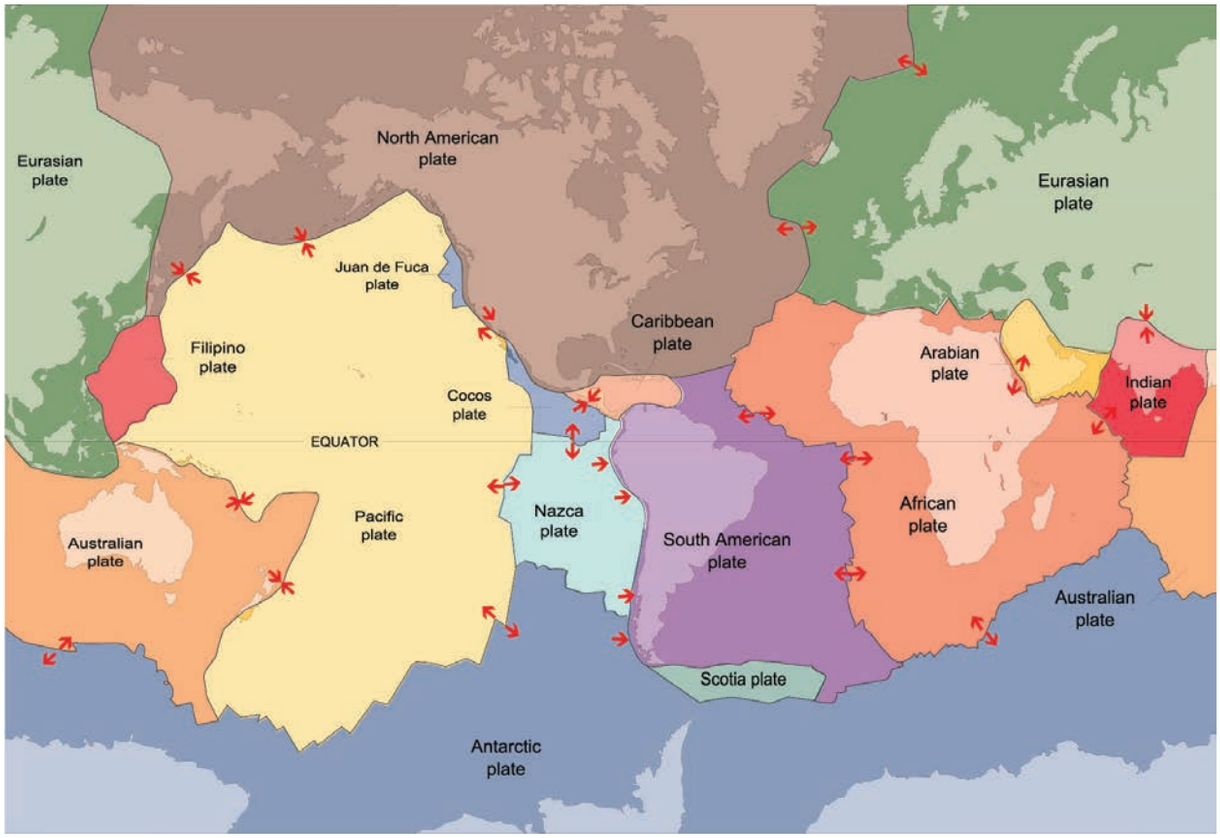


Earth is covered by large plates that move, releasing energy. This map shows Earth's major plates. Since Venus doesn't have moving plates, the energy inside it must be released in another way.

Earth and Venus: Sister Planets

The inside of Earth is a hot place. The processes that formed Earth 4.6 billion years ago produced so much heat that our planet still hasn't cooled off completely, even though it is always releasing heat into space! In addition, radioactive decay inside Earth constantly generates heat. Heat from Earth's interior escapes through volcanic activity, mostly at plate boundaries. All that heat is able to escape because Earth has plates that move around and release the energy.

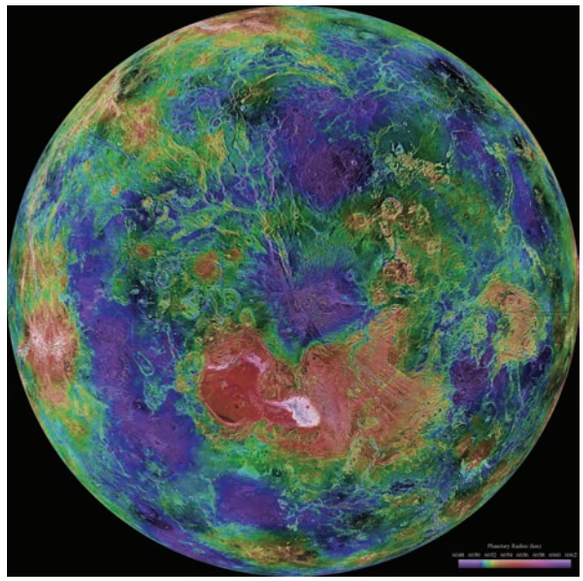
The inside of Venus is hot, just like the inside of Earth. In fact, Earth and Venus have a lot of things in common: they're about the same size, Earth is just a little farther from the sun than Venus, and the two planets were formed at the same time. Those similarities tell scientists that Earth and Venus were made of the same materials in about the same amounts. However, Venus does not have plate motion like Earth does. Since Earth and Venus are so similar in all those other ways, Venus must have some other way to release heat from inside the planet.

Since it doesn't have plate tectonics, Venus can't continually release small amounts of heat the way Earth does. Instead, scientists have evidence that Venus has released its heat in just a few big bursts that re-formed the surface

of the whole planet! According to mathematical models made by scientists, the heat inside Venus builds up, heating up the mantle until it begins to melt the surface above it. Hot magma spills out onto the surface as lava, releasing large amounts of heat into space all at once. New igneous rock forms all over the surface of Venus as the lava cools. According to the models, this process may have happened several times in the planet's history.

There's another reason that plate tectonics makes Earth different from Venus: plate motion on Earth causes subduction and uplift of rock formations. Without plate motion, subduction does not occur on Venus. Any uplift on Venus would have to be caused by some other mechanism.

Humans have never set foot on Venus, so what evidence do scientists have that their models are accurate? One type of evidence has to do with craters that are formed when objects flying through space collide with a planet or moon. The surface of Venus has very few craters compared to the planet's nearest neighbors–Mercury and Earth's moon–even though they have both existed for about the same length of time as Venus. Venus has probably experienced about the same number of collisions as the Moon or Mercury throughout its history, so the fact that its surface doesn't have many craters means the surface may have been replaced with a new surface fairly recently. Evidence from craters tells us that, while Venus formed about 4.5 billion years ago, the surface of Venus is only about 500 million years old! That's strong evidence that the planet's whole surface was re-formed at that time.



This image of Venus has been color-coded to show elevation. Venus has geologic features like Earth does, but it doesn't have plate motion.

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