Earth History

INVESTIGATIONS GUIDE

FOSS
Next Generation

Science & Engineering PRACTICES
Disciplinary CORE IDEAS
CROSSCUTTING Concepts

Full Option Science System
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NGSS Performance Expectations

"The NGSS are standards or goals, that reflect what a student should know and be able to do; they do not dictate the manner or methods by which the standards are taught. . . . Curriculum and assessment must be developed in a way that builds students' knowledge and ability toward the PEs [performance expectations]" (*Next Generation Science Standards*, 2013, page xiv). The chart displayed here shows the bundled performance expectations assessed in this course and where they are extended in other courses.

Middle School NGSS Performance Expectations	FOSS Middle School Course
MS-ESS1-4. Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.	**Earth History** Heredity and Adaptation
MS-ESS2-1. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.	**Earth History**
MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.	**Earth History**
MS-ESS2-3. Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of past plate motions.	**Earth History**
MS-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.	**Earth History**
MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.	**Earth History** Weather and Water
MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	**Earth History** Populations and Ecosystems Weather and Water *
MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per capita consumption of natural resources impact Earth's systems.	**Earth History** Populations and Ecosystems Weather and Water
MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.	**Earth History** Weather and Water
MS-LS4-1. Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.	**Earth History** Heredity and Adaptation

*** This course incorporates this performance expectation, but it is not the course's main focus.**

Middle School NGSS Performance Expectations	FOSS Middle School Course
MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	Electromagnetic Force Variables and Design Chemical Interactions Populations and Ecosystems Weather and Water Gravity and Kinetic Energy
MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.	Electromagnetic Force Variables and Design Chemical Interactions Populations and Ecosystems Weather and Water Gravity and Kinetic Energy
MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	Electromagnetic Force Variables and Design Chemical Interactions Weather and Water Gravity and Kinetic Energy
MS-ETS1-4. Develop a model to generate data for interative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.	Electromagnetic Force Variables and Design Chemical Interactions Weather and Water Gravity and Kinetic Energy

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INTRODUCTION

Human beings have used Earth's resources since prehistoric times. We made tools from stones. We mined raw materials to refine and manufacture into tools, utensils, shelters, ovens, and other useful items. We figured out how to extract precious metals from ores. We captured the energy of flowing streams behind dams and found numerous ways to put this power to use. We diverted water into channels for irrigation. And because it is human nature to try to explain everyday phenomena, we made up stories to explain how Earth was created.

Middle school students are ready to exercise their inferential thinking, and the study of earth history is made to order for this effort. They can begin to grapple with Earth's processes and systems that have operated over geologic time. Students should make observations and do investigations that involve constructing and using conceptual models. They should generate questions for investigation, which may lead to new questions. Through their study of earth history, students should become more confident in their ability to ask good questions and to recognize and use evidence from the rocks to come up with explanations of past environments. This course uses the anchor phenomenon of the Grand Canyon to engage students with history of Earth and introduce them to the geologic history of a place. The driving question for the course is what do we need to know to tell the geologic story of a place?

The NGSS Performance Expectations bundled in this course include:

Earth and Space Sciences
MS-ESS1-4
MS-ESS2-1
MS-ESS2-2
MS-ESS2-3
MS-ESS3-1
MS-ESS3-2
MS-ESS3-3
MS-ESS3-4
MS-ESS3-5

Life Sciences
MS-LS4-1

	Investigation Summary	Time	Guiding and Focus Questions for Phenomena
Inv. 1	**Earth Is Rock** *Earth Is Rock* uses the anchor phenomenon of the Grand Canyon to introduce students to the study of the landforms and rocks that make up Earth's crust. Through observations of aerial images of Earth's surface, sedimentary rock samples, and images from the Grand Canyon, students begin developing awareness about the complexity of Earth's crust and how geologists study it by trying to answer the question "What is the story of this place?"	**Activities** **7 sessions** * **Assessment** **1 session**	***What information can we learn by studying the rocks in the Grand Canyon?*** **Part 1** **What's the Story of This Place?**, 2 sessions **Which landforms occur at different locations on Earth?** **Part 2** **Grand Canyon Rocks**, 3 sessions **Why do there appear to be stripes on the walls of the Grand Canyon?** **Part 3** **Correlating Grand Canyon Rocks**, 2 sessions **Why do there appear to be stripes on the walls of the Grand Canyon?**
Inv. 2	**Weathering and Erosion** In *Weathering and Erosion* students explore the phenomena of earth material movement over the surface of Earth. Students observe a stream table to discover how water can erode sediments from one location and deposit the sorted sediments in a basin downstream. They model how rocks weather and what happens to sediments. Students also consider how soil forms.	**Activities** **7 sessions** **Assessment** **1–2 sessions**	***How are sediments formed, moved, and deposited?*** **Part 1** **Stream Table,** 2 sessions **What happens to earth materials when water flows over landforms?** **Part 2** **Weathering**, 3 sessions **How did weathering and erosion contribute to the formation of the Grand Canyon?** **Part 3** **Soils**, 2 sessions **How is soil related to rocks?**
Inv. 3	**Deposition** In *Deposition*, students investigate the phenomenon of the variety of sedimentary rocks on Earth. They look closely at the processes by which bedrock that is weathered and eroded ends up deposited in basins. There, favorable conditions can turn the sediments into sedimentary rock. Students consider how evidence in sedimentary rocks can lead to inferences about the ancient environments in which they formed.	**Activities** **6 sessions**	***How do sedimentary rocks form?*** **Part 1** **Sandstone and Shale**, 2 sessions **What happens to sediments that get deposited in basins?** **Part 2** **Limestone**, 2 sessions **How does limestone form?** **Part 3** **Interpreting Sedimentary Layers**, 2 sessions **What do sedimentary rock layers reveal about ancient environments?**

* A class session is 45–50 minutes.

Content and Disciplinary Core Ideas	Literacy/Technology	Assessment
• Earth's surface has a variety of different landforms and water features. • Every place on Earth's surface has a unique geologic story. • Rocks hold the clues to the story of a place. • Limestone, sandstone, and shale are rocks found in the Grand Canyon that can be identified by their characteristics.	**Science Resources Book** "Seeing Earth" "Powell's Grand Canyon Expedition, 1869" (optional) **Online Activities** "Landforms Tour" "Scale Model" "Grand Canyon Correlation " **Video and Slide Show** *Grand Canyon Flyover* *Powell's River Trip* slide show (optional)	**Benchmark Assessment** *Entry-Level Survey* **NGSS Performance Expectations** MS-ESS1-4 MS-ESS2-1 MS-ESS2-2
• Most landforms are shaped by slow, persistent processes that proceed over the course of millions of years: weathering, erosion, and deposition. • Rock can be weathered into sediments by a number of processes, including frost wedging, abrasion, chemical dissolution, and root wedging. • Particles of earth material can be categorized and sorted by size. • Most sediments move downhill until they are deposited in a basin. Sediments that do not form rock can become widely distributed over Earth's surface as soil. • Most sediments move downhill until they are deposited in a basin. Sediments that do not form rock can become widely distributed over Earth's surface as soil.	**Science Resources Book** "Grand Canyon Flood!" "Weathering and Erosion" "Soil Stories" (optional) **Videos** *Stream Table: High Flow vs. Low Flow* *Stream Table: High Slope vs. Low Slope* (optional) *Stream Table: Heterogeneous vs. Homogeneous Material* *Glen Canyon Dam High Flow Experiment, USGS* *Debris Flow* *Frost Wedging* *Rock Fall* *Freezing Glass Bottle* (optional)	**Benchmark Assessment** *Investigations 1–2 I-Check* **NGSS Performance Expectations** MS-ESS2-1 MS-ESS2-2
• Sediments deposited by water usually form flat, horizontal layers. • Sediments turn into solid rock through the process of lithification, which involves compaction, cementation, and dissolution. • The relative ages of sedimentary rock can be determined by the sequence of layers. Lower layers are older than higher layers. • The processes we observe today probably acted in the same way millions of years ago, producing sedimentary rocks.	**Science Resources Book** "Where in the World Is Calcium Carbonate?" "Water on Mars?" **Online Activities** "Sandstone Formation" "Shale Formation" "Zion National Park Expedition" (optional) "Limestone Formation" "Rock Column Movie Maker" "Rock Database" (optional) "Sedimentary Rocks Tour" (optional)	**NGSS Performance Expectations** MS-ESS1-4 MS-ESS2-1 MS-ESS2-2

	Investigation Summary	Time	Guiding and Focus Questions for Phenomena
Inv. 4	**Fossils and Past Environments** In *Fossils and Past Environments*, students experience the phenomenon of fossils. Students become familiar with the geologic time scale to understand how old fossils are and begin to comprehend the enormous spans of time that are described by geologic time. They use fossils to put the history of the Grand Canyon into the geologic time scale.	**Activities 8 sessions** * **Assessment 1–2 sessions**	***What can fossils tell us about Earth's past?*** **Part 1** **Fossils**, 3 sessions **How do fossils get in rocks?** **Part 2** **A Long Time Ago**, 2 sessions **How old are fossils?** **Part 3** **Index Fossils**, 3 sessions **When did the Grand Canyon rocks form?**
Inv. 5	**Igneous Rocks** *Igneous Rocks* presents students with new rock samples from a new location. It leads to an investigation of the relationship between crystal size and the formation of igneous rocks. The formation of igneous rocks is the phenomenon investigated by students.	**Activities 6 sessions**	***How do igneous rocks help us understand Earth's interior?*** **Part 1** **Earth's Layers**, 1 session **How do igneous rocks form?** **Part 2** **Salol Crystals**, 3 sessions **Student-generated question, e.g., What affects crystal formation in igneous rocks?** **Part 3** **Types of Igneous Rocks**, 2 sessions **What can crystal size tell us about where an igneous rock formed?**

* A class session is 45–50 minutes.

Course Matrix

Content and Disciplinary Core Ideas	Literacy/Technology	Assessment
• A fossil is any remains, trace, or imprint of a plant or animal that was preserved in Earth's crust during ancient times. • The fossil record represents what we know about ancient life and is constantly refined as new fossil evidence is discovered. • Geologic time extends from Earth's origin to the present. • Earth's history is measured in millions and billions of years. • Index fossils allow rock layers to be correlated by age over vast distances.	**Science Resources Book** "A Fossil Primer" "Rocks, Fossils, and Time" "Floating on a Prehistoric Sea" (optional) **Online Activities** "Rock Column Movie Maker" "Sandstone Formation" "Shale Formation" "Limestone Formation" "Timeliner" "Index-Fossil Correlation" "Dating Rock Layers"	**Benchmark Assessment** *Investigations 3–4 I-Check* **NGSS Performance Expectations** MS-ESS1-4 MS-LS4-1
• Earth is composed of layers of earth materials, from its hard crust of rock all the way down to its hot core. • Heat inside Earth melts rocks; melted rock can cool and form igneous rocks. • Molten rock cools quickly on the surface of Earth and can be identified by small mineral crystals. Molten rock that cools more slowly inside Earth forms larger mineral crystals.	**Science Resources Book** "Minerals, Crystals, and Rocks" **Online Activities** "Pacific Northwest Tour" "Extrusive Rock Formation" "Intrusive Rock Formation" "Yosemite National Park Tour" (optional) "Hawaii Tour" (optional) "Rock Database" (optional) **Video** *Salol Crystal Formation* **Slide Show** *Earth's Interior*	**NGSS Performance Expectations** MS-ESS2-1 MS-ESS2-2

	Investigation Summary	Time	Guiding and Focus Questions for Phenomena
Inv. 6	**Volcanoes and Earthquakes** *Volcanoes and Earthquakes* provides engaging phenomena to investigate and gives students the opportunity to discover a pattern of geologic activity. Subduction, convection, and the theory of crustal plate tectonics are introduced to explain continental drift, plate-boundary interactions, and the patterns of volcanoes and earthquakes.	**Activities 5 sessions *** **Assessment 1–2 sessions**	***How and why are Earth's continents constantly changing?*** **Part 1 Mapping Volcanoes and Earthquakes**, 2 sessions **Where do volcanoes occur on Earth?** **Where do earthquakes occur on Earth?** **Part 2 Moving Continents**, 1 session **Why do volcanoes and earthquakes occur where they do?** **Part 3 Plate Tectonics**, 2 sessions **What causes plates to move?**
Inv. 7	**Mountains and Metamorphic Rocks** *Mountains and Metamorphic Rocks* builds on the phenomena of earthquakes and volcanoes by focusing on new landforms—mountains. Students investigate the interactions at plate boundaries that form mountains and metamorphic rocks, leading students to consider the rock cycle.	**Activities 7 sessions** **Assessment 1–2 sessions**	***How do the interactions between tectonic plates result in different landforms and rocks?*** **Part 1 Plate Models**, 3 sessions **What happens to Earth's crust during plate interactions?** **Part 2 Metamorphic Rocks**, 4 sessions **How do metamorphic rocks form?**

* A class session is 45–50 minutes.

Content and Disciplinary Core Ideas	Literacy/Technology	Assessment
• Volcanoes and earthquakes occur along plate boundaries. • Earth's crust and solid upper mantle make up Earth's plates. Plates can be the size of continents or larger or smaller. • Earth's plates "float" on top of the layer of viscous, semisolid earth material below the asthenosphere. • The asthenosphere is a heated, semisolid, semifluid material that flows due to convection currents. • Plate movements result in plate-boundary interactions that produce volcanoes, earthquakes, and continental drift.	**Science Resources Book** "The History of the Theory of Plate Tectonics" "Historical Debates about a Dynamic Earth" (optional) **Online Activities** "Latitude and Longitude" "Volcano-Plotting Activity" "Volcanoes around the World" "Volcanoes" "Earthquake-Plotting Activity" (optional) "Earthquakes around the World" "Plate-Boundaries Map" (optional) **Videos** *Mount St. Helens: The Eruption Impact* *ShakeAlert* *Wegener* *Convection* *Plate Tectonics*	**Benchmark Assessment** *Investigations 5–6 I-Check* **NGSS Performance Expectations** MS-ESS2-2 MS-ESS2-3 MS-ESS3-1 MS-ESS3-2
• Interactions between tectonic plates at their boundaries deform the plates, producing landforms on Earth's surface. • Mountains form as a result of plate interactions. • When plates interact, high heat and immense pressure can change rock into new forms of rock (metamorphic rock). • The rock cycle describes how rock is constantly being recycled and how each type of rock can be transformed into other rock types.	**Science Resources Book** "Earth's Dynamic Systems" "Rock Transformations" "How One Rock Becomes Another Rock" (optional) **Online Activities** "Convergent Boundary" "Divergent Boundary" "Transform Boundary" "Folding" "Volcanoes around the World" "Appalachian Mountain Tour" "Rock Database" "How Metamorphic Rocks Form" "Slate" **Slide Show** *Mountain Types*	**Benchmark Assessment** *Investigation 7 I-Check* **NGSS Performance Expectations** MS-ESS2-1 MS-ESS2-2 MS-ESS2-3

	Investigation Summary	Time	Guiding and Focus Questions for Phenomena
Inv. 8	**Geoscenarios** In *Geoscenarios*, students apply prior knowledge from the Earth History Course and new, site-specific information to develop a geologic story of a place or process. Students are introduced to four sites across the United States—four phenomena. Each team of students researches the story of one of those places, the processes that shaped it, and the implications of the story for human society.	**Activities** **5 sessions** *	***How do Earth's surface processes and human activities affect each other?*** **Part 1** **Introduction to the Project**, 1 session **What do we need to know to tell the geologic story of a place?** **Part 2** **Research and Writing**, 2 sessions **What do we need to know to tell the geologic story of a place?** **Part 3** **Presentations**, 2 sessions **What do we need to know to tell the geologic story of a place?**
Inv. 9	**What Is Earth's Story?** *What Is Earth's Story?* challenges students to put together what they have learned about Earth's geologic history and to use their knowledge to finish telling the story of the phenomenal Grand Canyon.	**Activities** **3 sessions** **Assessment** **1-2 sessions**	***How does evidence found in rock reveal the geologic story of a place?*** **Part 1** **Revisit the Grand Canyon**, 2 sessions **What is the geologic story of the Grand Canyon?** **Part 2** **Review the Evidence**, 1 session **How do earth materials recycle through constructive and destructive processes?**

* A class session is 45–50 minutes.

Content and Disciplinary Core Ideas	Literacy/Technology	Assessment
• Geologic processes help tell the story of a physical place. • Evidence and observations of a site's geology provide clues to tell the geologic story. • Knowledge of uplift, plate tectonics, volcanism, weathering, erosion, and fossil evidence plus the principles of uniformitarianism, superposition, and original horizontality can help tell the story of a place.	**Science Resources Book** "Geoscenario Introduction: Glaciers" "Geoscenario Introduction: Coal" "Geoscenario Introduction: Yellowstone Hotspot" "Geoscenario Introduction: Oil" **Online Activities** "Geoscenarios" "Timeliner" "Rock Column Movie Maker" (optional)	**NGSS Performance Expectations** MS-ESS3-1 MS-ESS3-2 MS-ESS3-3 MS-ESS3-4 MS-ESS3-5
• Evidence that provides clues about Earth's geologic history comes from observing rocks, landforms, and other earth materials. • Scientists specialize in many different disciplines to collect and analyze evidence to help put together Earth's geologic history. • Scientists use a number of different tools and techniques to analyze and synthesize evidence obtained from Earth to tell its story.	**Science Resources Book** "Research Careers in the Lab and Field" **Online Activities** "Grand Canyon Revisited" "Rock Column Movie Maker" (optional) "Timeliner" (optional) **Video** *Colorado Plateau over Time*	**Benchmark Assessment** *Posttest* **NGSS Performance Expectation** MS-ESS1-4 MS-ESS2-1 MS-ESS2-2 MS-ESS2-3

TEACHING AND LEARNING *about Metamorphic Rocks*

NGSS Foundation Box for DCI

ESS1.C: The history of planet Earth
- Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. (MS-ESS2-3)

ESS2.A: Earth materials and systems
- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the Sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. (MS-ESS2-1)
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (MS-ESS2-2)

ESS2.B: Plate tectonics and large-scale system interactions
- Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart. (MS-ESS2-3)

Developing Disciplinary Core Ideas (DCI)

Students have established an understanding of weathering and erosion that suggests that the surface of Earth is continually being worn away. Now, we ask them to consider formation of new landforms—mountains. Volcanism is a fairly straightforward process for building a mountain. Where molten rock comes to the surface and piles up persistently, a mountain grows, in time.

Volcanic activity is a clue to even more ambitious mountain-building processes at work in Earth's bowels. Students will learn about the largely undetectable disturbances in Earth's crustal plates that result from their ultraslow motion. Some plates crowd others out of their way by brute force, some plates are redirected downward as others ride up and over the conquered plate, and others scrape past and pull on their neighbors. Each violent interaction produces effects that can translate into wrinkles and bulges at the surface. Wrinkles and bulges at the continental scale cause mountains and plateaus. Finally we have an explanation for the landforms on Earth.

In the process of wrinkling and lifting the massive tectonic plates that form Earth's crust, rocks get caught. Surface rocks get dragged down into folds and breaks in the crust, where they get crushed, resulting in spectacular pressures and dramatically elevated temperatures. The heat and pressure alter the minerals and the relationships between them. The result is new kinds of rock, metamorphic rock.

This investigation provides some closure to the big picture of the history of Earth's dynamic surface. To know Earth calls for knowing what Earth is like now, as well as its history. Understanding plate interactions and the rock cycle enables students to piece together geologic evidence and tell the story of a place.

The experiences students have in this investigation contribute to the disciplinary core ideas **ESS1.C: The history of planet Earth**; **ESS2.A: Earth materials and systems**; and **ESS2B: Plate tectonics and large-scale systems interactions**.

Engaging in Science and Engineering Practices (SEP)

In this investigation, students engage in these practices.

- **Developing and using models** to predict the landforms that result form plate-boundary interactions and to explain the recycling of earth materials and changing from one rock type to another.
- **Analyzing and interpreting data** collected from investigations and text and video sources to explain the formation of metamorphic rocks.
- **Constructing explanations** for the formation of volcanoes and other landforms found at plate boundaries and for the uplift of sedimentary rocks of the Grand Canyon that were uplifted more than 2500 meters above sea level.
- **Engaging in argument** to make a claim about the source rock for a selection of metamorphic rocks.
- **Obtaining, evaluating, and communicating information** in videos and text to construct explanations about formation of landforms and metamorphic rocks.

NGSS Foundation Box for SEP

- **Evaluate limitations of a model** for a proposed object or tool.
- **Develop or modify a model—** based on evidence—to match what happens if a variable or component of a system is changed.
- **Develop and/or use a model** to predict and/or describe phenomena.
- **Develop and/or use a model to generate data** to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.
- **Analyze and interpret data** to provide evidence for phenomena.
- **Construct a scientific explanation based on valid and reliable evidence** obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- **Apply scientific ideas, principles, and/or evidence** to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.
- **Apply scientific reasoning** to show why the data or evidence is adequate for the explanation or conclusion.
- **Construct, use, and/or present an oral and written argument** supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
- **Integrate qualitative and/or quantitative scientific and/or technical information** in written text with that contained in media and visual displays to clarify claims and findings.

INVESTIGATION 7 — *Mountains and Metamorphic Rocks*

NGSS Foundation Box for CC

- **Patterns:** Patterns can be used to identify cause-and- effect relationships.
- **Cause and effect:** Cause-and-effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause-and-effect relationships in systems can only be described using probability.
- **Systems and system models:** Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy, matter, and information flows within systems.
- **Energy and matter:** Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.
- **Stability and change:** Stability might be disturbed either by sudden events or gradual changes that accumulate over time.

Exposing Crosscutting Concepts (CC)

In this investigation, the focus is on these crosscutting concepts.

- **Patterns.** Patterns in structures and textures that are found in metamorphic rocks are similar to their source rocks.
- **Cause and effect.** Landforms found at plate boundaries are caused by the interactions of the plates. Each type of interaction results in distinctive landforms. Metamorphic rocks are formed by heat and pressure as the result of plate interactions.
- **Systems and system models.** Models of plate interaction simulate the structures and landforms found at plate boundaries when energy is added to the system. Energy that drives plate tectonics results in the formation of mountains, plateaus, volcanoes, and earthquakes.
- **Energy and matter.** Energy from heat within Earth drives plate tectonics and changes to the crust. The rock cycle traces the recycling of earth materials driven by heat and pressure, weathering and erosion, and melting.
- **Stability and change.** Earth's surface is a dynamic system under constant change. Changes can be sudden (earthquakes and volcanoes), or gradual (uplift and folding).

Connections to the Nature of Science

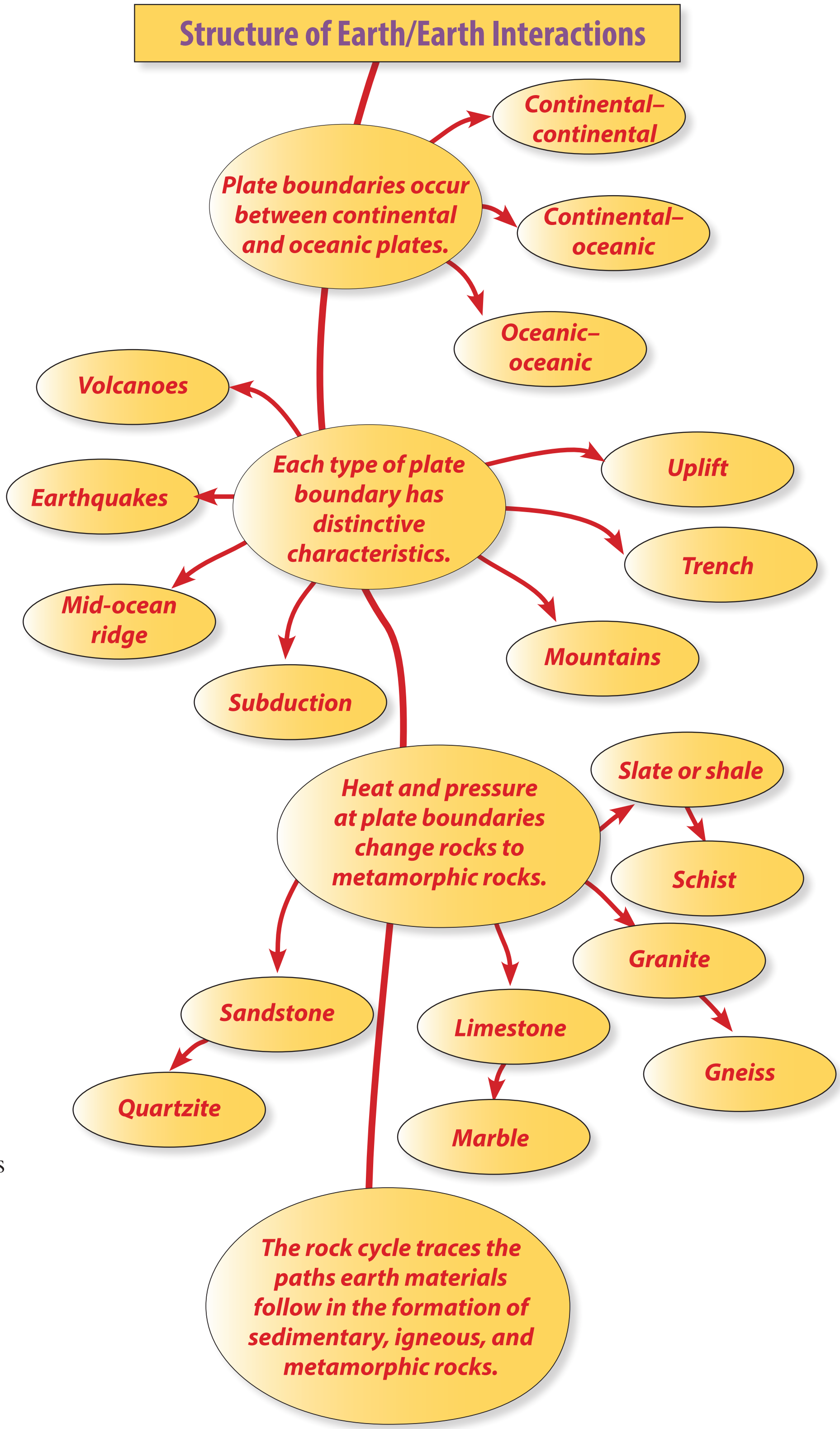
- **Scientific investigations use a variety of methods.** Scientific investigations are guided by a set of values to ensure accuracy of measurements, observations, and objectivity of findings. Science depends on evaluating proposed explanations. Scientific values function as criteria in distinguishing between science and nonscience.
- **Scientific knowledge is based on empirical evidence.** Scientific knowledge is based upon logical and conceptual connections between evidence and explanations. Science disciplines share common rules of obtaining and evaluating empirical evidence.
- **Scientific knowledge assumes an order and consistency in natural systems.** Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. Science carefully considers and evaluates anomalies in data and evidence.

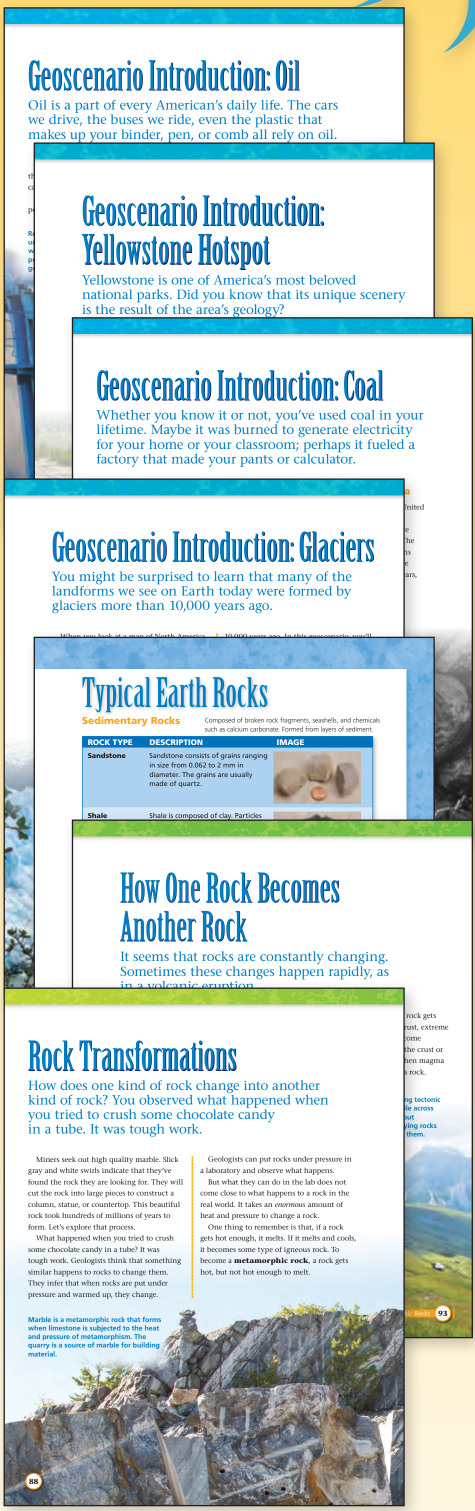
Conceptual Flow

In this investigation, students explore the phenomena of mountain building and metamorphic rock formation. The guiding question for this investigation is how do the interactions between tectonic plates result in different landforms and rocks?

The conceptual flow begins in Part 1 with an investigation of mountain formation. Students investigate **plate boundaries** using models of **continental–continental, continental–oceanic, and oceanic–oceanic boundaries** and mid-continental uplift. They model convergent, divergent, and transform motions at these plate boundaries. Students examine mountain types and describe the types of landforms that might result at plate boundaries.

In Part 2, students take a virtual tour of the Appalachian Mountains and are introduced to **metamorphic rocks**. They use a model to demonstrate the effect of **heat and pressure** on rocks. Students use this model to explain the changes to metamorphic rocks. They examine and make observations about common metamorphic rocks to determine the source rocks. Students then work to develop a model for the **rock cycle**, which includes the processes studied throughout the course.





FOSS Science Resources

MATERIALS *for*

Part 2: *Metamorphic Rocks*

Provided equipment

For each student

1 *FOSS Science Resources: Earth History*
- "Rock Transformations"
- "How One Rock Becomes Another Rock" (optional)
- "Typical Earth Rocks"
- "Geoscenarios Introduction: Glaciers"
- "Geoscenarios Introduction: Coal"
- "Geoscenarios Introduction: Yellowstone Hotspot"
- "Geoscenarios Introduction: Oil"

For each group

1 Set of metamorphic rocks
- Schist, #1
- Gneiss, #14
- Marble, #15
- Quartzite, #18
- Slate, #20

1 Set of sedimentary and igneous rocks
- Redwall limestone, #5
- Hermit shale, #7
- Coconino sandstone, #8
- Granite, #11
- Basalt, #12

2 Containers, 1/2 L
2 Hand lenses
1 Bottle of dilute hydrochloric acid

For the class

2 Candy crushers

Teacher-supplied items

For each student

- 1 Safety goggles
- • Self-stick notes

For the class

- • Chart paper
- • Paper towels
- 1 Plastic-foam cup
- 1 Cup of candy-coated chocolate candy, two or more colors
- • Hot water, about 50°C
- • Ice water (optional)
- 2 Thermometers

FOSSweb resources

For each student

- 1 *Investigation 7 I-Check*

For the class

- • Online activity, "Appalachian Mountain Tour"
- • Online activity, "How Metamorphic Rocks Form"
- • Online activity, "Slate"
- • Online activity, "Rock Database"

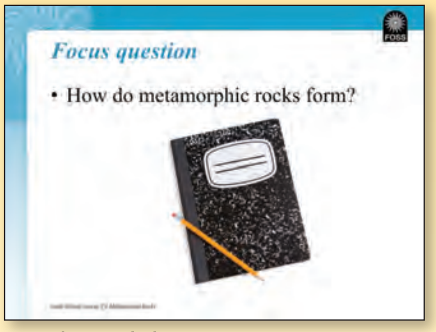
For the teacher

- • *Performance Assessment Checklist*
- • *Assessment Record*
- • Teaching slides, 7.2

GETTING READY *for*
Part 2: *Metamorphic Rocks*

Quick Start

Schedule	3 sessions active investigation 1 session reading 1–2 sessions assessment
Preview	• Preview the FOSSweb Resources by Investigation for this part (such as printable masters, teaching slides, and online activities) • Preview the online activities: "Appalachian Mountain Tour," Step 1 "Rock Database," Step 23 "Slate," Step 24 "How Metamorphic Rocks Form," Steps 25, 28 • Preview the readings: "Rock Transformations," Step 33 "How One Rock Becomes Another Rock" (optional) Step 41 • Preview/plan for homework, Steps 40, 43
Print or Copy	**For each student** • *Investigation 7 I-Check*, or schedule it on FOSSmap **For the teacher** • *Performance Assessment Checklist* • *Assessment Record*
Prepare Material	• Prepare rock sets A • Check acid bottles B • Practice with the candy crushers C • Preview the online activities D
Plan for Assessment	• Review Step 19, "What to Look For" in the performance assessment • Plan for benchmark assessment, Step 41, *Investigation 7 I-Check*



Teaching slides, 7.2

Preparation Details

A Prepare rock sets

Prepare a set of metamorphic rocks and a set of igneous and sedimentary rocks for each group. Put each set in a half-liter container.

B Check acid bottles

Students will need hydrochloric acid to check for calcite in the metamorphic rock samples. Make sure there is enough acid in the bottles to do this. Make safety goggles available for this activity.

C Practice with the candy crushers

Review Steps 9 to 14 of Guiding the Investigation, describing the metamorphic-rock simulation using the pressure tubes. Try it out yourself. The tubes will need to be cleaned in hot soapy water at the end of the day.

D Preview the online activities

Preview "Appalachian Mountain Tour" in Google Earth™. My Places may be cluttered with the media used in previous investigations. Uncheck the unnecessary files, or delete them from the list.

Preview the two animations used in this part, "How Metamorphic Rocks Form" and "Slate." Explore "Rock Database" so you know where to find each rock for display. You might want to plan time for students to use computers on their own so they can further explore the metamorphic-rock animations and "Rock Database."

FOCUS QUESTION

How do metamorphic rocks form?

GUIDING *the Investigation*

Part 2: *Metamorphic Rocks*

Session	Students will . . .
SESSION 1	• View "Appalachian Mountain Tour" (Step 1) • Focus on metamorphic rocks found in mountains (Steps 2, 3) • Examine and describe metamorphic rocks (Steps 4–7)
SESSION 2	• Use a model to explore the effect of heat and pressure in the formation of metamorphic rocks (Steps 8–14) • Discuss metamorphism and melting (Steps 15–17) • Compare metamorphic rocks to sedimentary and igneous rocks and discuss observations (Steps 18–21)
SESSION 3	• Identify the metamorphic rocks (Steps 22, 23) • Examine the source rocks for metamorphic rocks (Steps 24–28) • Investigate and draw a model for the rock cycle (Steps 29–32) • Read "Rock Transformations" (Steps 33, 34)
SESSION 4	• Review vocabulary; answer the focus question (Steps 35, 36) • Review the rock cycle (Step 37) • Review notebook entries for the investigation (Step 38) • Answer the guiding question (Step 39) • Respond to "Rock Transformations" reading questions as homework (Step 40)
SESSIONS 5–6	• Demonstrate understanding by responding to *Investigation 7 I-Check* (Step 41) • Read "How One Rock Becomes Another Rock" (optional, Step 42) • Preview geoscenarios as homework (Step 43) • Review I-Check items through next-step strategies (Step 44)

SESSION 1 *45–50 minutes*

1. View online activity: "Appalachian Mountain Tour"

Show students the first part of the "Appalachian Mountain Tour." Ask them if they recognize what area of the United States they have traveled to. Explain that their new study site will be the Appalachian Mountains, which are a large mountain range stretching across many of the eastern states. Find out what they know about the Appalachians and the states located there (e.g., Georgia, South Carolina, North Carolina, Tennessee, Virginia, West Virginia, Pennsylvania, New York, Vermont, New Hampshire, and Maine).

As they view the tour, ask students to look for landforms and to compare the landforms, terrain, and any visible rock to what they observed in the Colorado Plateau and Pacific Northwest.

2. Focus on *metamorphic rocks*

Tell students that there is a group of rocks that they have not yet studied (other than sedimentary and igneous). Ask students what they know about metamorphic rocks.

Confirm that metamorphic rocks are "changed rocks," and tell students that these rocks were created by heat and pressure. Ask,

➤ *Where might thermal energy and pressure come from to change the rocks?*

➤ *What kind of rocks could be changed to become **metamorphic rocks**?*

Let students take time to think about and respond to these questions. Don't confirm or deny responses at this point. Suggest that students find out more about metamorphic rocks.

3. Focus question: How do metamorphic rocks form?

Tell students that they will answer this focus question.

➤ *How do metamorphic rocks form?*

Have them record the focus question in their notebooks.

4. Introduce metamorphic-rock sets

Show students the set of metamorphic rocks. Explain that these are rocks they might find in the Appalachian Mountains. Explain that their task is to observe the rocks as they did the sedimentary and igneous rocks.

SCIENCE AND ENGINEERING PRACTICES

Obtaining, evaluating, and communicating information

TEACHING NOTE

*If students have not heard of metamorphic rocks, ask them to think about where they have heard the word **metamorphosis** before. Someone may suggest an answer from life sciences, such as caterpillar metamorphosis into a butterfly. This is a very different process, but both processes involve change. They may also recognize the term from science fiction movies or cartoons, where a toy might "morph" from a truck into a robot.*

TEACHING NOTE

Students will work with only the metamorphic rocks in this class session. Save the containers with the igneous and sedimentary rocks for after the breakpoint.

5. Set up a data table

Ask students what types of observations they should make. They should suggest

- texture,
- color,
- fizz,
- hardness (compared to each other), and
- other interesting properties.

Have students set up a table in their notebooks to record their observations. They will need an extra blank column for the next session ("Source Rock").

6. Observe the metamorphic rocks

Have Getters pick up a set of metamorphic rocks, two hand lenses, an acid bottle, safety goggles, and some paper towels for their group. Remind students that they need only one drop of acid to perform the acid test. Give students time to observe the metamorphic rocks and record observations in their notebooks.

7. Share observations

Stop the observations 5 minutes before the end of class. Have students share their observations of the metamorphic rocks and describe which rocks they found the most interesting. Students should return all the rocks to the half-liter containers and return the containers to the materials station.

SESSION 2 *45–50 minutes*

8. Discuss pressure and heat

Remind students that metamorphic rocks are found in mountains and that metamorphic rocks are created by heat and pressure. Ask,

➤ *How could pressure and heat cause a rock to change?*

Give students a few minutes to discuss this in their groups. Have them offer their ideas to the rest of the class. They may suggest that the rocks could get squeezed together, get smaller, get so hot they start to melt, and more.

SCIENCE AND ENGINEERING PRACTICES

Analyzing and interpreting data

CROSSCUTTING CONCEPTS

Cause and effect

Ask,

- *If a rock got so hot that it totally melted, could it become a metamorphic rock? Why?* [No. If it totally melted and then cooled to become a solid, it would be a new igneous rock.]

Ask students to think about where there might be enough heat and pressure to change a rock into another type of rock. As students respond, focus on suggestions that include the forces of plate tectonics and the heat and pressure deep in Earth's crust. Students should mention the pressure created when plates interact, as seen with the models in Part 1.

9. Introduce metamorphic-rock model

Tell students that no one has ever seen a metamorphic rock form but that geologists make inferences about what they think is happening inside the earth during metamorphism. They come up with models to support their inferences. Geologists have actually designed equipment in their labs that can put rocks under great amounts of heat and pressure so they can observe what happens.

Tell students that you have some materials that they could use to come up with their own laboratory model to show how materials change when undergoing increases in heat and pressure. Show students the tube (crusher) and the chocolate candies. Ask students what the candy might represent in a metamorphic-rock model. They may say that the candy could represent rocks in Earth's crust, or minerals in the rocks. Remind students of Investigation 5, where they learned that rocks are made of minerals, some of which form crystals.

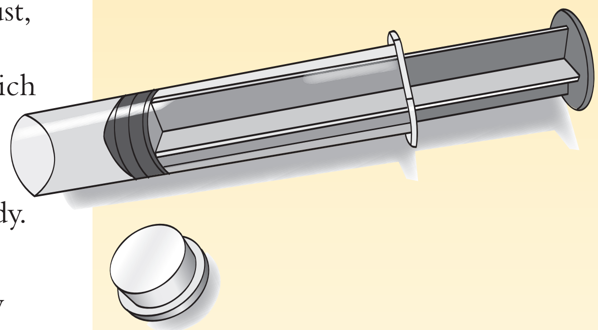
10. Develop a model

Show the class how the candy crusher operates without the candy. Ask,

- *How can the tube be used in the metamorphic-rock model?* [Apply pressure to the candy to see what changes.]
- *What happens when chocolate candy gets warm?* [The chocolate inside melts, but the candy shell outside doesn't.]

Explain that this could be a model for what happens to the minerals in rocks. Some minerals have lower melting temperatures than others. The chocolate models one mineral, and the candy shell models another mineral.

NOTE
Remind students not to put anything in their mouth in science class.



TEACHING NOTE

*Students should remember this if they have completed the **FOSS Weather and Water Course**. Remind them what happened to the temperature in the 2 L soda bottle when they squeezed it. (There is a video of this in the Weather and Water multimedia.)*

SCIENCE AND ENGINEERING PRACTICES

Developing and using models

11. Try out the model

Designate a couple of volunteers to help you with the model. Have these volunteers help you set up the simulation in front of the rest of the class.

a. Remove the cap and add about 30 mL of candy to the tube.

b. Push the cap on securely and push the plunger in to hold the candy in the bottom of the tube. Make sure everyone can view the setup with the candy.

c. Explain that when pressure is applied to a material in a closed system, its temperature increases.

d. Ask students if they think the volunteers are strong enough to melt the candy in the tube with pressure.

e. Model how to position the crusher cap down on a table, holding the tube in one hand and the plunger in another, so the cap won't pop off under pressure.

f. Have one student push on the plunger to crush the candy—no hammering, just pressure. Give him or her about 10 seconds to push.

g. Have another student describe the results. He or she should observe that some of the candy pieces have broken, but none of them appear to have melted.

h. Have another volunteer apply additional pressure to the candy for about 10 seconds. The results should be similar.

12. Record the results

Have the volunteers confirm that it took a lot of effort pushing on the plunger to break the candy into pieces (although results may vary depending on the classroom temperature). Have students write a few sentences in their notebook about what happened when pressure alone was applied to change the candy. They should note that both the chocolate and the candy coating didn't change much.

13. Add energy by heating

Explain that because students can't seem to apply enough pressure to elevate the temperature of the candy significantly, they can help a little by setting the pressure tube in hot water for 30 seconds. Ask students to think about what part of Earth the hot water might represent. They should suggest that the hot water could represent the mantle or high temperatures deep in the crust.

14. Set up the model with hot water

Set up the hot-water model.

a. Pour hot water (about 50°C) into a cup (about a half cup will be plenty). Have a new volunteer use a thermometer to read and report the temperature. Another volunteer can report the air temperature from a second thermometer.

b. Have a volunteer submerge the end of the tube with the candy in the hot water for 30 seconds. Don't apply pressure while heating the tube.

c. Have students remove the tube from the hot water and dry it off.

d. Have the volunteers observe the candy and describe any softening or melting that may have occurred, without added pressure.

e. Now have a student apply pressure to the plunger again. Have other students observe and report to the rest of the class. (You might have them draw their observations on the board and/or take the tube around to the rest of the class for close observation.) They should notice that the chocolate has started to soften and that the shards of candy coating are beginning to organize into layers.

f. Have students record their observations with words and drawings in their notebooks.

g. Allow the pressed candy to cool. (You could put the tube in ice water to hasten this process.) Have a volunteer unscrew the cap and push the simulated metamorphic rock out onto a piece of paper. Show the result to the rest of the class.

15. Discuss the model

Have students discuss the results of the demonstration in relation to metamorphic rocks. Use questions to guide the discussion.

➤ *How did the candy change when pressure was applied to it?* [It cracked and crumbled.]

➤ *If the students kept pushing long enough, would the candy eventually heat up?* [Probably not.]

➤ *How did the candy change when heat was added?* [The chocolate "mineral" started to soften and melt, but the candy coating "mineral" did not.]

➤ *How did the candy change when pressure was added after the tube was heated?* [The chocolate smushed together and filled up the spaces; the candy coating broke into little pieces and organized into lines or layers.]

SCIENCE AND ENGINEERING PRACTICES

Developing and using models

SCIENCE AND ENGINEERING PRACTICES

Constructing explanations

CROSSCUTTING CONCEPTS

Cause and effect

Spend some time discussing what the result suggests about the formation of metamorphic rocks. Also discuss the limitations of the simulation. Heat alone is not sufficient, nor is pressure. Only under the right combination of heat and pressure does metamorphic rock form.

Point out, if students haven't already mentioned it, that the different materials of the candies started to soften at different temperatures. The heat from the water was enough to soften the chocolate but not the candy coating. When rocks undergo metamorphosis, the minerals that make up the rocks often soften at different temperatures, just like the candy. Some of the minerals that soften at lower temperatures may mix, react, and form new minerals.

ELA CONNECTION

This suggested strategy addresses the Common Core State Standards for ELA for literacy.

SL 1: Engage in collaborative discussions.

16. Review melting

Mention that although the chocolate actually melted, this wouldn't happen with a rock being changed into a metamorphic rock. The rock never actually melts; it still is solid but softens just enough to be reshaped and reorganized. Prompt students to name what type of rock forms when another rock completely melts (igneous rock).

17. Think about how metamorphic rocks could form

NOTE

Go to FOSSweb for *Teacher Resources* and look for the Crosscutting Concepts and Integration chapter for details on how to engage students with the concept of energy and matter to integrate content at this grade level.

CROSSCUTTING CONCEPTS

Energy and matter

SCIENCE AND ENGINEERING PRACTICES

Constructing explanations

Tell students,

We used a simulation to demonstrate how rocks and the various minerals in them might be affected by heat and pressure.

➤ *What do you think would have to happen to an actual rock or rock layer in order to change into a metamorphic rock?*

Give students a moment to discuss this question in their groups. Suggest they make a group model to explain their thinking.

Discuss their models and ideas as a class. Ideas should include that the rock material would have to be buried under lots of other layers or rocks and probably would be squeezed in some way by tectonic activity, such as when folding occurs. This might result in sufficient heat and pressure to produce metamorphosis.

Tell students,

Metamorphic rocks are formed from other rocks. Even under intense heat and pressure, matter cannot be created or destroyed, but it can be recombined into new forms during chemical reactions. The metamorphic rocks may have new minerals (compounds) but those minerals are made from the same elements as the source rock.

18. Compare rocks

CROSSCUTTING CONCEPTS

Patterns

Tell students that each of the metamorphic rocks they looked at earlier started out as a sedimentary or igneous rock.

Explain that each group will get a set of igneous and sedimentary rocks to compare to the metamorphic rocks. Their challenge is to find clues to which rock is a possible source for each metamorphic rock. In other words, which sedimentary or igneous rock matches up with a particular metamorphic rock?

Suggest that students record their evidence and notes in the same chart they set up for the metamorphic-rock observations. They should add a column labeled "Source Rock." Point out that acid bottles and safety goggles are available for testing. Ask students to explain why they might want to use some acid on the rocks [to detect calcite]. Allow time for students to make the comparisons and record their rock identification.

19. Assess progress: performance assessment

Students work together to compare igneous and sedimentary rocks to determine the origin of metamorphic rocks. Listen to the group discussions and observe how students work together to assess students' three-dimensional learning. Note student progress on the *Performance Assessment Checklist*.

What to Look For

- *Students analyze properties using techniques for rock observation learned earlier in the course, such as color, apparent particle size, texture (when rubbed between fingers), and acid test. (Analyzing and interpreting data.)*
- *Students compare similarities, differences, and other observations for each rock in an organized manner in their notebooks. (Analyzing and interpreting data.)*
- *Students use evidence to make a claim about the source rock for each metamorphic rock. (Engaging in argument from evidence; ESS2.A: Earth materials and systems; patterns; cause and effect.)*

20. Discuss observations

About 10 minutes before the end of class, have students record their final rock identifications in the "Source Rock" column. Have students report their conclusions and support their arguments with evidence.

➤ *Which sedimentary or igneous rocks do you think changed to become these metamorphic rocks?* [Suggestions should be supported by evidence, and any reasonable evidence should be accepted.]

Encourage students to ask questions of other students if the evidence presented is unclear.

21. Clean up

Have students return the rocks to their containers, taking care to put the metamorphic rocks in one container and the igneous and sedimentary rocks in the other, and return the containers to the materials center.

SCIENCE AND ENGINEERING PRACTICES

Analyzing and interpreting data

Engaging in argument from evidence

DISCIPLINARY CORE IDEAS

ESS2.A: Earth materials and systems

CROSSCUTTING CONCEPTS

Patterns

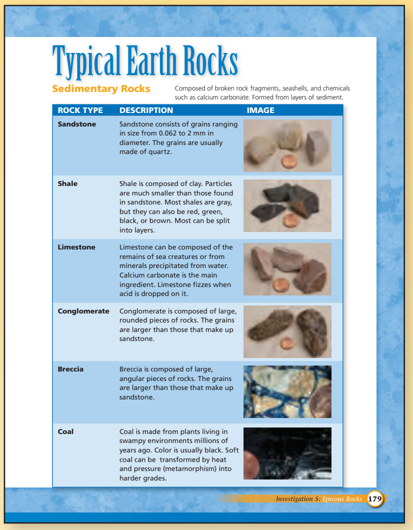
Cause and effect

TEACHING NOTE

Some of these rocks are easier to infer than others. Tell students scientists often don't know if their answers are right, but they are based on the best evidence they have at the time.

SCIENCE AND ENGINEERING PRACTICES

Analyzing and interpreting data



Typical Earth Rocks

Sedimentary Rocks Composed of broken rock fragments, seashells, and chemicals such as calcium carbonate. Formed from layers of sediment.

ROCK TYPE	DESCRIPTION	IMAGE
Sandstone	Sandstone consists of grains ranging in size from 0.062 to 2 mm in diameter. The grains are usually made of quartz.	
Shale	Shale is composed of clay. Particles are much smaller than those found in sandstone. Most shales are gray, but they can also be red, green, black, or brown. Most can be split into layers.	
Limestone	Limestone can be composed of the remains of sea creatures or from minerals precipitated from water. Calcium carbonate is the main ingredient. Limestone fizzes when acid is dropped on it.	
Conglomerate	Conglomerate is composed of large, rounded pieces of rocks. The grains are larger than those that make up sandstone.	
Breccia	Breccia is composed of large, angular pieces of rocks. The grains are larger than those that make up sandstone.	
Coal	Coal is made from plants living in swampy environments millions of years ago. Color is usually black. Soft coal can be transformed by heat and pressure (metamorphism) into harder grades.	

Investigation 5: Igneous Rocks 179

FOSS Science Resources

TEACHING NOTE

You can also use the "Rock Database" to project images of each rock for side-by-side comparison during this discussion.

CROSSCUTTING CONCEPTS

Patterns

Energy and matter

SESSION 3 *45–50 minutes*

22. Review metamorphic rocks

Ask,

- *Are sedimentary and igneous rocks the only rocks that can become metamorphic rocks?* [No.]
- *What type of rock can form when heat and pressure causes the original rock to totally melt?* [Igneous rock.]

23. Identify the metamorphic rocks

Have students open *FOSS Science Resources* to "Typical Earth Rocks" and use it to confirm the identities of the rocks and their source rocks. They could also use the online "Rock Database."

Rock ID	Name	Source rock
1	Schist	Slate (shale)
14	Gneiss	Granite
15	Marble	Limestone
18	Quartzite	Sandstone
20	Slate	Shale

24. Compare shale and slate

With students looking at their data table of observations and *FOSS Science Resources*, ask,

- *The source rock for* ***schist*** *is* ***slate****, and the source rock for slate is shale. How can that be?* [It depends how much metamorphism has occurred, how much heat and pressure, how much the rock changed. If the shale changes a little, it becomes slate. If it changes a lot, it becomes schist.]

Redistribute the rock samples. Ask students to pull the shale, slate, and schist samples out of the rock sets and compare them. Show students the "Slate" animation.

25. Compare granite and gneiss

Ask students to pull the granite and **gneiss** samples out of the rock sets and compare them. Ask,

- *How are these two rocks alike?* [They have about the same colors and contain crystals.]
- *How are they different?* [The gneiss has lines in it.]

Remind students that the crystals they see in the rocks are pieces of minerals. Ask students to look in their notebook to find their definitions of mineral from Investigation 2. [Minerals are the ingredients that make up rocks. Minerals form crystals with characteristic shapes.] Students investigated crystal size in igneous rocks in Investigation 5 as well.

Tell students that the minerals they see in the granite and gneiss are the same. The clear, sparkly crystals are quartz; the pearly white or pink crystals are feldspar; and the dark minerals are hornblende and mica. You may want to mention that gabbro and shale contain similar minerals and can also change into gneiss during metamorphism.

Show students the animation "How Metamorphic Rocks Form." Ask them to look for the changes in crystals that they observed earlier. Point out that it's impossible to see the metamorphism occurring because in real life, this takes place deep within Earth.

26. Compare sandstone and quartzite

Have students pull out the sandstone and **quartzite** samples and compare them. Ask students to report what is alike and different about the rocks. Make sure they get a good view of the rocks with a hand lens. They should be able to see the matrix between the grains of sand in the sandstone and the particles in the quartzite that look melted together.

27. Focus on limestone and marble

Ask students which rock changed into **marble** and why. They will probably suggest limestone because the marble fizzed in the acid. Have them pull out the samples of limestone and marble and compare them. They may have seen that the marble looks more crystalline than the limestone.

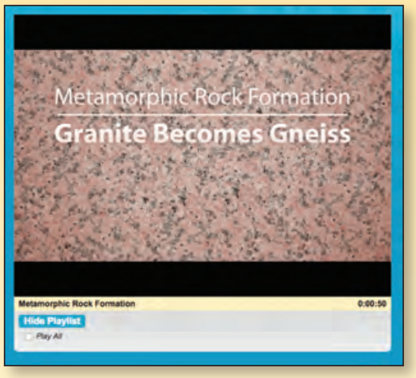
28. Introduce *foliation*

Tell students that one clue that helps identify metamorphic rocks is layering of similar minerals due to heat and pressure. The layers often appear wavy. Geologists call that layering **foliation**. Metamorphic rocks like slate and gneiss have foliation. Other metamorphic rocks like quartzite and marble are nonfoliated, because they are each primarily composed of one mineral that deforms at the same temperature. Sometimes it's tricky to discern between foliation in metamorphic rocks and the layering in sedimentary rocks. Have students look at their metamorphic rock samples to confirm the foliation.

Replay "How Metamorphic Rocks Form" and have students look for foliation (wavy lines) in the gneiss.

EL NOTE

Draw and label a diagram of granite with these mineral names.



TEACHING NOTE

For a more in-depth review, have students answer these questions in their groups first. They can write their answers on mini-whiteboards or pieces of blank paper to hold up during the class discussion.

SCIENCE AND ENGINEERING PRACTICES

Constructing explanations

29. Introduce *rock cycle*

Tell students,

We've learned about three different kinds of rocks, sedimentary, igneous, and now metamorphic. Let's see if we can put it all together.

- *How are sedimentary rocks formed?* [Sediments accumulate in a basin and eventually turn to rock, sometimes held together by a matrix.]
- *Where do the sediments come from?* [Other rock that has weathered and eroded away into little pieces of rock like sand or clay, and calcium carbonate that precipitates in water.]
- *How are igneous rocks formed?* [Molten rock (magma) enters or breaks through the crust and cools.]
- *How are metamorphic rocks formed?* [Rocks are exposed to enough heat and pressure to change them, without melting them.]

Summarize the discussion.

For each type of rock, the source is another rock. Rocks get eroded away and create sediments that become other rocks. Rocks can get buried underground and transformed by heat and pressure to become other rocks. Or rocks can completely melt into magma to become other rocks. This is what geologists call the ***rock cycle****, because rocks keep changing into other kinds of rocks, over and over again, for as long as Earth has existed. It continues today.*

30. Draw the rock-cycle diagram

Have students turn to a blank page in their notebook and write the names of the three categories of rocks as shown below, spread out to fill a notebook page. Model this on a whiteboard or chart paper.

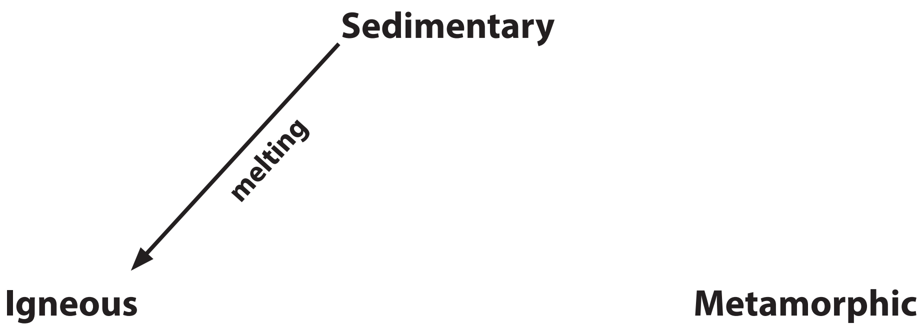
Sedimentary

Igneous **Metamorphic**

Ask,

➤ *How can sedimentary rock turn into igneous rock?* [It could be subducted, melt into magma, and eventually return to Earth's crust to become igneous rock.]

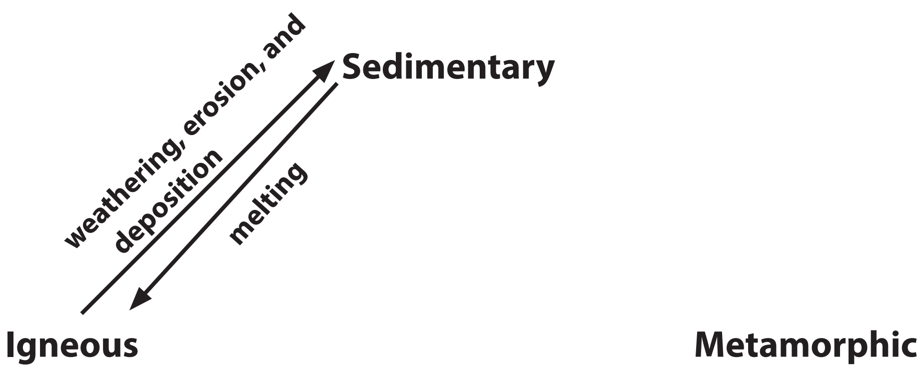
Ask students how they might show this process in a diagram. If necessary, suggest drawing an arrow from sedimentary to igneous and label it "melting" to represent how the transformation could occur.



Ask,

➤ *How can igneous rock turn into sedimentary rock?* [It could weather and erode away as sand, silt, or clay, be deposited in a basin, and eventually become sedimentary rock.]

Ask students to continue asking questions and drawing process labels with arrows indicating the direction of the transformation. Have them work in groups to continue the discussion and add to the diagram.



SCIENCE AND ENGINEERING PRACTICES

Developing and using models

CROSSCUTTING CONCEPTS

Systems and system models

31. Provide scaffolding as needed

Encourage students to work in their groups to come up with the processes that transform rocks from one type to another. If groups need scaffolding, provide these questions as needed.

- *How can a sedimentary rock turn into a metamorphic rock?* [It could be buried deep underground and be exposed to heat and pressure as a result of tectonic activities, but not enough to melt it.]
- *How can metamorphic rock change into sedimentary rock?* [It could erode away into sand, silt, or clay, be deposited in a basin, and eventually become a sedimentary rock.]
- *How can metamorphic rock change into igneous rock?* [It could be subducted, melted into magma, and eventually return to Earth's crust to become igneous rock.]
- *How can igneous rock turn into metamorphic rock?* [It could be buried deep underground and be exposed to heat and pressure as a result of tectonic activities, but not enough to melt it.]

ELA CONNECTION

This suggested strategy addresses the Common Core State Standards for ELA for literacy.

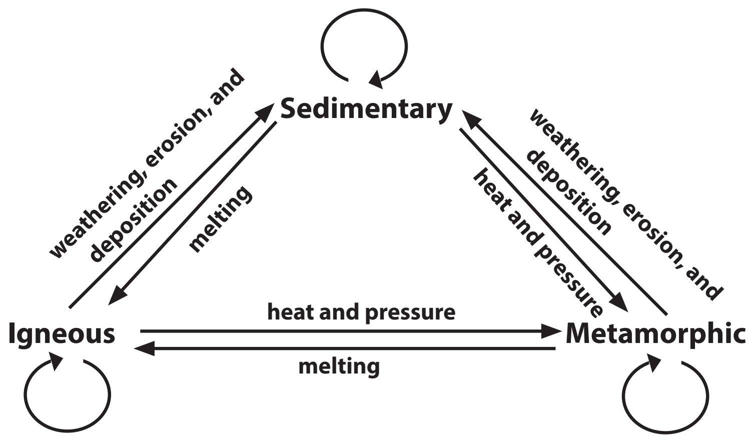
L 6: Acquire and use academic and domain-specific words and phrases.

32. Have a sense-making discussion

Lead a class discussion to help students summarize the rock cycle. Provide a clean sheet of chart paper for students as a class to build the rock cycle diagram and to explain the processes.

As students add to the diagram, encourage others to build on the ideas by adding on, agreeing and disagreeing, and providing evidence to support or refute their claims about about the rock cycle processes.

If it does not come up during the discussion, point out that it is also possible for sedimentary rock to weather and erode, be deposited, and eventually become new sedimentary rock; igneous rock could melt and cool into new igneous rock; metamorphic rock can undergo further metamorphosis. Add three curled arrows to represent these transformations.



TEACHING NOTE

Refer to the Sense-Making Discussions for Three-Dimensional Learning chapter in Teacher Resources *on FOSSweb for more information about how to facilitate this with students.*

CROSSCUTTING CONCEPTS

Systems and system models

SCIENCE AND ENGINEERING PRACTICES

Developing and using models

Constructing explanations

READING *in Science Resources*

33. Read "Rock Transformations"

The article "Rock Transformations" will help students think more about the metamorphism that can occur to rocks. Have them begin by discussing the images with a partner. They should also read the captions, subtitles, and the words in bold.

Have them read the article independently first using the reading comprehension strategy. As they finish, they can begin working on the Think Questions. Lead a whole-class discussion of the article, using the prompts and questions indicated in the breakpoints.

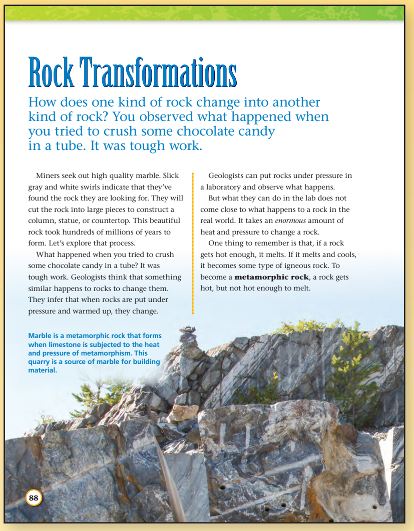
34. Use a reading comprehension strategy

Have students make text connections. Give them self-stick notes to make notes about connections they make as they read.

If they have a personal connection, they should jot it down along with the text-to-self symbol (T-S), meaning that what they read reminds them of firsthand experiences.

Text-to-text (T-T) connections are when students discover a new idea that reminds them of something they've read in another text.

Text-to-world (T-W) connections involve students' recognition of more global connections to the text.



Rock Transformations

How does one kind of rock change into another kind of rock? You observed what happened when you tried to crush some chocolate candy in a tube. It was tough work.

Miners seek out high quality marble. Slick gray and white swirls indicate that they've found the rock they are looking for. They will cut the rock into large pieces to construct a column, statue, or countertop. This beautiful rock took hundreds of millions of years to form. Let's explore that process.

What happened when you tried to crush some chocolate candy in a tube? It was tough work. Geologists think that something similar happens to rocks to change them. They infer that when rocks are put under pressure and warmed up, they change.

Geologists can put rocks under pressure in a laboratory and observe what happens.

But what they can do in the lab does not come close to what happens to a rock in the real world. It takes an *enormous* amount of heat and pressure to change a rock.

One thing to remember is that, if a rock gets hot enough, it melts. If it melts and cools, it becomes some type of igneous rock. To become a **metamorphic rock**, a rock gets hot, but not hot enough to melt.

Marble is a metamorphic rock that forms when limestone is subjected to the heat and pressure of metamorphism. This quarry is a source of marble for building material.

88

FOSS Science Resources

ELA CONNECTION

These suggested strategies address the Common Core State Standards for ELA for literacy.

RST 10: Read and comprehend science texts independently and proficiently.

WHST 9: Draw evidence from informational texts to support analysis, reflection, and research.

SCIENCE AND ENGINEERING PRACTICES

Obtaining, evaluating, and communicating information

A

Share notes: Ask students to share their text connections.

B

Determine central idea: Point out the last paragraph and take a minute for students to discuss how the difference in the amount of heat affects rock formation.

A

Rock Transformations

How does one kind of rock change into another kind of rock? You observed what happened when you tried to crush some chocolate candy in a tube. It was tough work.

Miners seek out high quality marble. Slick gray and white swirls indicate that they've found the rock they are looking for. They will cut the rock into large pieces to construct a column, statue, or countertop. This beautiful rock took hundreds of millions of years to form. Let's explore that process.

What happened when you tried to crush some chocolate candy in a tube? It was tough work. Geologists think that something similar happens to rocks to change them. They infer that when rocks are put under pressure and warmed up, they change.

Geologists can put rocks under pressure in a laboratory and observe what happens.

But what they can do in the lab does not come close to what happens to a rock in the real world. It takes an *enormous* amount of heat and pressure to change a rock.

B One thing to remember is that, if a rock gets hot enough, it melts. If it melts and cools, it becomes some type of igneous rock. To become a **metamorphic rock**, a rock gets hot, but not hot enough to melt.

Marble is a metamorphic rock that forms when limestone is subjected to the heat and pressure of metamorphism. The quarry is a source of marble for building material.

88

ELA CONNECTION

This suggested strategy addresses the Common Core State Standards for ELA for literacy.

RST 2: Determine the central ideas or conclusions of a text; provide an accurate summary.

The Place for Change

Where is there just enough heat and pressure to make a metamorphic rock? That place is deep inside Earth's crust. Imagine you were a layer of sandstone and all your classmates were other layers of rock. If you were deposited first, and then all the rest of them were deposited on top of you, how would you feel? You might feel that you're under a lot of pressure, and a lot warmer, too.

Now think about a layer of rock that has been buried deep inside Earth's crust. It is under a lot of pressure because a lot of rock is piled on top of it. What about the heat? That is an interesting thing about pressure. Heat and pressure usually work together. As you go deeper into Earth, heat and pressure both rise. When you put pressure on something in a closed area, it warms up, too. If you could have measured the temperature of the candy in the tube, you would have found it got a bit higher. Not high enough to melt the candy, but warm enough to make it soft.

There is another source of heat. As the rock gets buried deeper and deeper, it gets nearer the hot mantle. Heat from the mantle can transfer to the buried rock, making it even warmer.

Yet another factor can increase the heat and pressure. Geologists call it strain. Remember how tectonic plates interact with each other? They can push together, pull apart, or slide past each other. Those movements can also put stress on rocks and change them.

C

Integrate information: Ask students to think about their candy experiment. Was pressure alone enough to cause metamorphosis? How do they know?

D

Analyze author's purpose: Ask students how the layered-classmates analogy helps them understand this process. Why does the author use this analogy?

E

Make a diagram: Suggest students make a quick diagram in the their notebooks of their understanding of how metamorphic rocks form.

ELA CONNECTION

These suggested strategies address the Common Core State Standards for ELA for literacy.

RST 6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST 9: Compare and contrast information from experiments, simulations, video, or multimedia sources with that from reading a text on the same topic.

F

Cite evidence: As a review, ask students to describe several ways sedimentary and igneous rocks can form.

G

Cite evidence: Discuss the Take Note question. Encourage students to cite evidence from the text to support their ideas.

Making a Metamorphic Rock

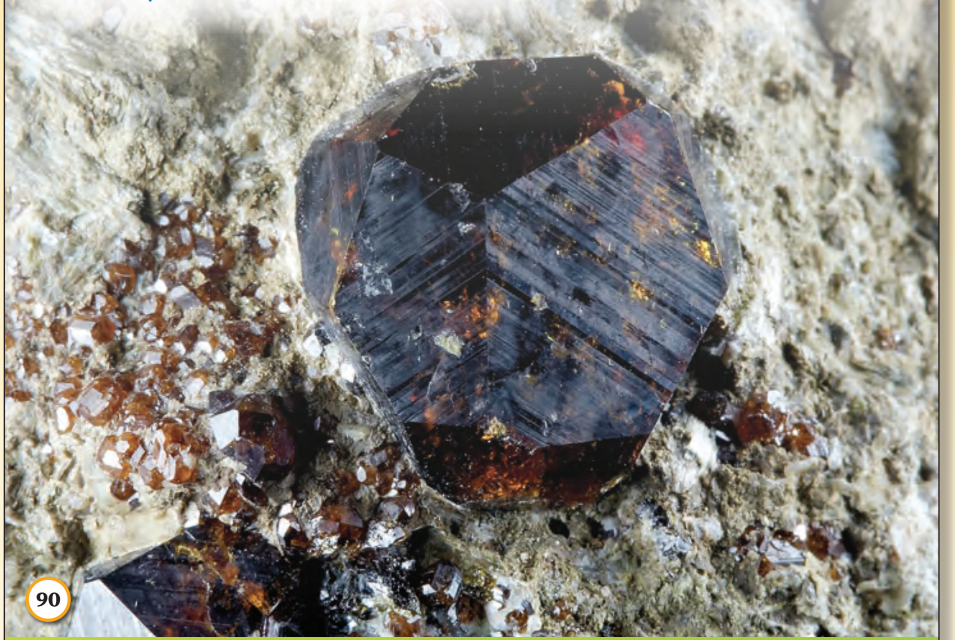
There is more than one recipe for making metamorphic rock, just as there is more than one way to make sedimentary and igneous rocks. Metamorphic rocks start out as some other type of rock, whether it is sedimentary, igneous, or another metamorphic rock. Normally, three things are required to change one type of rock into a metamorphic rock. These are lots of heat (but not enough to melt the rock), lots of pressure, and lots of time. If you had these three conditions and you could wait around for several million years, you might be able to watch a metamorphic rock forming. F

Heat, pressure, and strain cause changes in rocks. Some or all of the atoms in the original rock are rearranged to form new minerals. The minerals in the metamorphic rock might be totally different from the minerals in the **source rock**, the rock you started with. New minerals, like garnets, might appear in the metamorphic rock.

Take Note G

Review your metamorphic rock observations. How can you determine a metamorphic rock's source rock?

Heat and pressure can break chemical bonds and cause atoms to reorganize into new crystalline structures. Most garnets form as new minerals this way when rock metamorphoses.

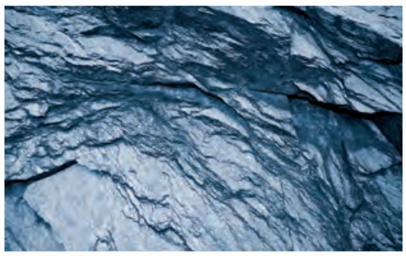


90

ELA CONNECTION

This suggested strategy addresses the Common Core State Standards for ELA for literacy.

RST 1: Cite evidence to support analysis of science texts.



Gneiss (above) and schist (right) show different bands of foliation. **H**

I

Hardening. Sometimes the minerals in the source rock just become harder. For example, particles of the mineral quartz, which is often part of sandstone, can become more strongly cemented together. When you look at a piece of the metamorphic rock called quartzite, you can see that the quartz grains look sort of melted together. You will not see a matrix holding the grains together.

Foliation. Metamorphic rocks may also become foliated. **Foliation** happens when minerals like mica and feldspar in granite start moving around and form wavy layers of similar minerals. What the final metamorphic rock becomes depends on how much pressure is applied and how long it takes. Gneiss has wide bands of foliation. Schist has a finer texture with narrower bands.

Contact. Sometimes metamorphic rocks form when the source rock comes in contact with hot magma or lava. These rocks are baked and changed by the heat. Remember, they are still metamorphic rocks as long as they have not been heated enough to melt. Even underground **coal** fires can bake the surrounding rocks.

H

Integrate information: Have students compare the two images. What is the same? What is different? What can they infer?

I

Understand vocabulary: Point out the three headings. Challenge students to make a graphic organizer in their notebooks that shows the relationship between these concepts and formation of metamorphic rock.

ELA CONNECTION

These suggested strategies address the Common Core State Standards for ELA for literacy.

RST 4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases.

RST 7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.

J

Summarize: Discuss the Think Questions and have students record their responses in their notebook. Encourage them to cite evidence from the text to support their ideas.

- *What is* similar *about a source rock and the metamorphic rock that results from it?* [The metamorphic rock will have the same elements as the source rock.]
- *What is* different *about a source rock and the metamorphic rock that results from it?* [The metamorphic rock might become harder, foliated, or baked.]
- *Where do new rocks come from?* [New metamorphic rocks can come from any rock that has been subjected to heat, pressure, and time. New sedimentary rocks form when sediments are buried and compacted over time. New igneous rocks form when magma or lava cools.]

What evidence can you see that this rock is metamorphic?

Metamorphic Rock Types

Geologists have come up with a way to classify metamorphic rocks. You can see the relationship between rocks by looking at the metamorphic rocks chart in the Images and Data section of this book. Each row represents a different chemical composition. If you look across the row, all the rocks in that row started with similar chemical composition and are different only in how much they have changed. For each row, the source rock is on the left, the corresponding rock with low-grade metamorphism is in the middle, and the corresponding rock with high-grade metamorphism is on the right.

Think Questions J

1. **What is *similar* about a source rock and the metamorphic rock that results from it?**
2. **What is *different* about a source rock and the metamorphic rock that results from it?**
3. **Where do new rocks come from?**

92

ELA CONNECTION

This suggested strategy addresses the Common Core State Standards for ELA for literacy.

RST 1: Cite evidence to support analysis of science texts.

SESSION 4 *45–50 minutes*

35. Review vocabulary

Give students a few moments to review the vocabulary developed in this part. This is a good time to update their vocabulary indexes and tables of contents if they haven't already done so.

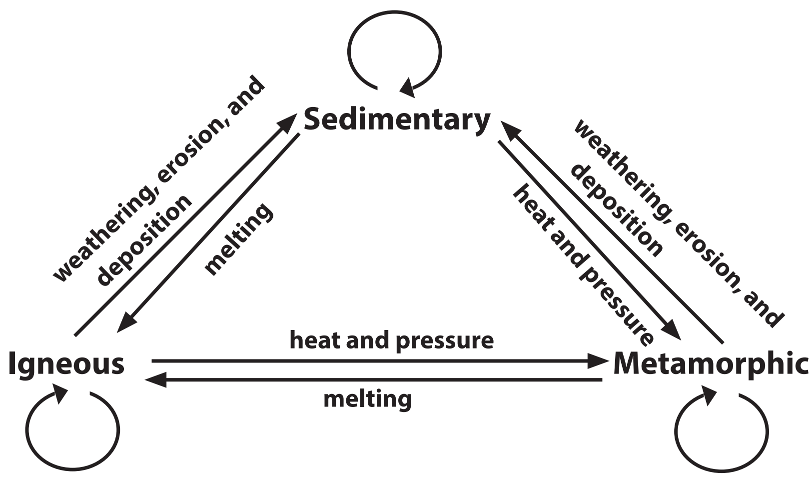
36. Return to the focus question

Have students return to the focus question and record their responses to it.

➤ *How do metamorphic rocks form?*

37. Review rock cycle

Have students review their rock cycle one more time. It will help them to consider all the arrows pointing toward each rock type at once. For example, all the arrows pointing toward sedimentary rocks describe weathering, erosion, and deposition.



foliation
gneiss
marble
metamorphic rock
quartzite
rock cycle
schist
slate

EL NOTE

Encourage students to talk through their rock-cycle diagrams with a partner before responding in writing. You can also provide a writing framework such as
The important points to remember are ______.
As you can see from the diagram, ______.
It's still hard for me to imagine ______.

ELA CONNECTION

This suggested strategy addresses the Common Core State Standards for ELA for literacy.

WHST 2: Write informative/ explanatory texts.

WRAP-UP

38. Review notebook entries

Ask students to go through their notebook entries and select one key point that summarizes an important finding from this investigation. They should record this point in their notebooks.

Have students share their key points with their group, selecting one key point within the group to share with the class. Create a class chart of key points by recording each group's idea on a piece of chart paper, whiteboard, or a document projected from the computer. You might need to help groups rephrase their key points for clarity as they share them.

TEACHING NOTE

This is the group key-points strategy introduced in Investigation 1.

Students should record the key points in their notebook and reference the page numbers in their notebook where additional information can be found that supports that key point. Add additional key points if necessary. By using science and engineering practices and exploring core ideas through the lens of crosscutting concepts, students should come forward with these big ideas in the review discussions.

- Plate interactions and movements can form different types of mountains. (Developing and using models; constructing explanations; engaging in argument from evidence; ESS1.C: The history of planet Earth; ESS2.B: Plate tectonics and large-scale system interactions; cause and effect; systems and system models.)
- Plate movements can provide the intense heat and pressure required to change rocks into metamorphic rocks. (Constructing explanations; ESS2.A: Earth materials and systems; ESS2.B: Plate tectonics and large-scale system interactions; cause and effect; energy and matter; stability and change.)
- Metamorphic rocks have changed from the original rock due to heat and pressure. (Analyzing and interpreting data; ESS2.A: Earth materials and systems; patterns; energy and matter; stability and change.)

Ask students to draw a line of learning under their last notebook entry and then to compose a concise statement summarizing what they know about mountains and metamorphic rocks.

39. Answer the guiding question

Ask students to discuss the investigation guiding question.

➤ *How do the interactions between tectonic plates result in different landforms and rocks?*

You might ask students to use the images from *FOSS Science Resources*, such as the one on page 85, to connect mountain building (including the uplift that formed the Grand Canyon), metamorphic rocks, and the rock cycle as all being the result of plate tectonics. Students can also ask additional questions about the phenomena of mountain building and metamorphic rock formation.

SCIENCE AND ENGINEERING PRACTICES

Developing and using models

Analyzing and interpreting data

Constructing explanations

Engaging in argument from evidence

DISCIPLINARY CORE IDEAS

ESS1.C: The history of planet Earth

ESS2.A: Earth materials and systems

ESS2.B: Plate tectonics and large-scale system interactions

CROSSCUTTING CONCEPTS

Patterns

Cause and effect

Systems and system models

Energy and matter

Stability and change

40. Extend the investigation with homework

The questions at the end of the article "Rock Transformations" are suitable for a homework assignment to show how well students understand the process by which rocks undergo metamorphosis.

SESSION 5 *45–50 minutes*

41. Assess progress: I-Check

Administer *Investigation 7 I-Check*, asking students to respond to the items on paper or online on FOSSmap. Students should independently answer the questions. When taking the I-Check, students should not use their notebooks, but the notebooks are a good tool to use when students later reflect on their answers.

READING *in Science Resources*

42. Read "How One Rock Becomes Another Rock" (optional)

The article "How One Rock Becomes Another Rock" is suitable for students who finish the I-Check early. Suggest that students pause after each section of the reading to write or make a quick drawing that summarizes the main idea. They can work on the Think Questions when they finish reading.

43. Extend the investigation with homework

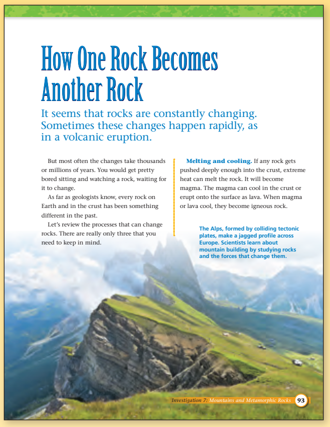
If you want students to pick which geoscenario they'd like to work on in the next investigation, have them read the introductory paragraphs of each "Geoscenario Introduction" in *FOSS Science Resources* after they finish the I-Check or at home. Students can submit their choices and rationale to you in writing.

SESSION 6 *45–50 minutes*

44. Discuss the I-Check results

Code the I-Check items, but do not make any marks on student responses. Note that FOSSmap automatically codes most of the items and provides you with student and class reports. Coding guides can be found on FOSSweb. You can record student results on the *Assessment Record* or download spreadsheets from FOSSmap for recording. Note important points about the items to review with students.

Return the I-Checks to students. Use self-assessment strategies as described in the Assessment chapter for each item to facilitate reflection and clarify student thinking.



FOSS Science Resources

SCIENCE AND ENGINEERING PRACTICES

Obtaining, evaluating, and communicating information

TEACHING NOTE

During or after these next steps with the I-Check, you might ask students to make choices for possible derivative products based on their notebooks for inclusion in a summative portfolio. See the Assessment chapter for more information about creating and evaluating portfolios.

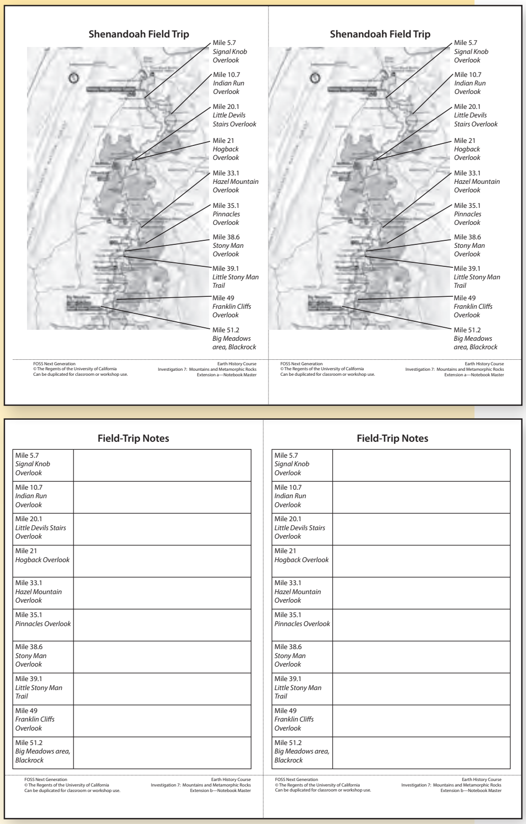
TEACHING NOTE

Encourage students to use the Science and Engineering Careers Database on FOSSweb.

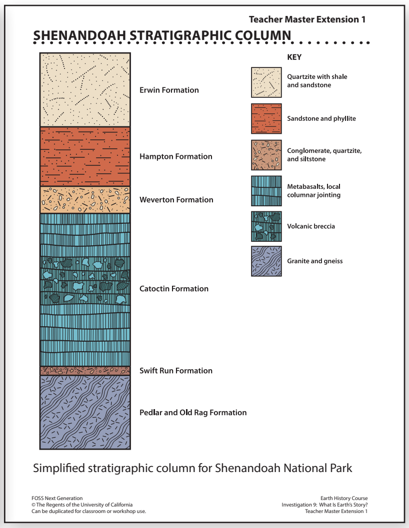
EXTENDING *the Investigation*

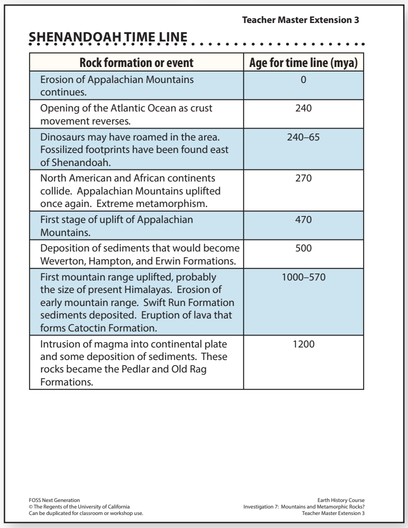
- **Explore Shenandoah National Park**

  Students can explore Shenandoah National Park through an online tour (available on FOSSweb) and samples of rocks (in the kit) similar to those at the park. Students use this information and a stratigraphic column of the park's rocks to interpret the geologic history of the area. Masters are available for students for this extension project.



Nos. 43–44—Notebook Masters





Teacher Master Extension 3

SHENANDOAH TIME LINE

Rock formation or event	Age for time line (mya)
Erosion of Appalachian Mountains continues.	0
Opening of the Atlantic Ocean as crust movement reverses.	240
Dinosaurs may have roamed in the area. Fossilized footprints have been found east of Shenandoah.	240–65
North American and African continents collide. Appalachian Mountains uplifted once again. Extreme metamorphism.	270
First stage of uplift of Appalachian Mountains.	470
Deposition of sediments that would become Weverton, Hampton, and Erwin Formations.	500
First mountain range uplifted, probably the size of present Himalayas. Erosion of early mountain range. Swift Run Formation sediments deposited. Eruption of lava that forms Catoctin Formation.	1000–570
Intrusion of magma into continental plate and some deposition of sediments. These rocks became the Pedlar and Old Rag Formations.	1200

Teacher Masters KK–MM

- **View animated plate tectonics**
  The National Park Service has created a website with links to animations that depict plate-tectonic concepts. If you would like to visually reinforce student learning about plate tectonics, you can access this link through FOSSweb.
- **Find plate boundaries**
  Students can use notebook sheet 41, *Plate-Interaction Map*, to consider what plate boundaries are nearest to them, and to extrapolate what continental movements may take place at those boundaries over time.
- **Research igneous and metamorphic rocks**
  The online Atlas of Igneous and Metamorphic Rocks, Minerals, and Textures includes photomicrographs of many minerals and igneous and metamorphic rocks. It gives students the opportunity to compare thin sections of metamorphic and igneous rocks. Go to FOSSweb to access the link to "Igneous Rocks."
- **Visit other national parks**
  Many of the national parks around the United States have features that are evidence for mountain-building processes. A NPS website includes a list with links to these national parks, including sites in the eastern United States, Rocky Mountains, and others. Go to FOSSweb to access the link.

Performance Assessment Checklist by Student

	Investigation 7, Part 2				
	Science and Engineering Practices		DCI	Crosscutting Concepts	
Student	Analyzing and interpreting data	Engaging in argument from evidence	ESS2.A Earth materials and systems	Patterns	Cause and effect

NOTE: See the Assessment chapter for a discussion about how to use this checklist.

Name________________________

Portfolio Checklist
EARTH HISTORY

My portfolio includes pieces of work that show **what I can do** using these **science and engineering practices**.

- ❏ Asking questions
- ❏ Developing and using models
- ❏ Planning and carrying out investigations
- ❏ Analyzing and interpreting data
- ❏ Using mathematics and computational thinking
- ❏ Constructing explanations
- ❏ Engaging in argument from evidence
- ❏ Obtaining, evaluating, and communicating information

My portfolio includes pieces of work that show **what I know** about these **disciplinary core ideas**.

- ❏ Rocks contain the evidence to make inferences about different environments and events that have occurred on Earth since its origin. (ESS1.C, ESS2.A, LS4.A)
- ❏ Many landforms are shaped by slow, persistent processes that proceed over the course of millions of years: weathering, erosion, and deposition. (ESS1.C, ESS2.A, ESS2.C)
- ❏ The relative ages of sedimentary rock can be determined by the sequence of layers. Index fossils allow rock layers to be correlated by age, although there are vast distances between the layers. (ESS1.C, ESS2.A, LS4.A)
- ❏ Convection currents within the mantle drive plate tectonics and cause plate interactions that result in landforms and processes like earthquakes and volcanism. (ESS2.A, ESS2.B, ESS3.B)
- ❏ Geologic processes cause mineral formation and distribution in various areas. Many of these processes create nonrenewable natural resources. (ESS3.A, ESS3.C, ESS3.D)

My portfolio includes pieces of work that show **how I think** using these **crosscutting concepts**.

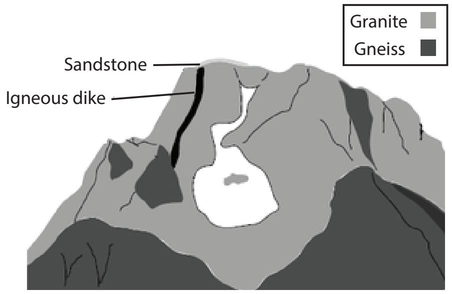
- ❏ Patterns
- ❏ Cause and effect
- ❏ Scale, proportion, and quantity
- ❏ Systems and system models
- ❏ Energy and matter
- ❏ Structure and function
- ❏ Stability and change

INVESTIGATION 7 I-CHECK

ANSWERS

INVESTIGATION 7 I-CHECK
EARTH HISTORY

1. Mount Moran is a tall mountain in Wyoming. The mountain formed when the North American Plate was uplifted far from the plate boundary. Mount Moran is composed mostly of granite and gneiss. It also has a small patch of sandstone on the top of the mountain and an igneous dike running up through the mountain to the peak.



a. Which is older, the granite or the igneous dike? Why do you think so?

The granite is older. The granite had to be there for the igneous dike to cut through it.

b. The sandstone found at the peak of the mountain is approximately 3,840 meters above sea level. How can you explain the sandstone on the top of the mountain?

Sandstone forms in basins, which are low points, so it must have formed before the mountain was uplifted. Most of the sandstone has since eroded away.

Focus on Science and Engineering Practices
Focus on Disciplinary Core Ideas
Focus on Crosscutting Concepts

Item 1

This item provides evidence that students can construct explanations about how different kinds of rock formed as part of a mountain (patterns, cause and effect). (Contributes to MS-ESS2-1, MS-ESS2-2, MS-ESS2-3)

Item 1a

Code	If the student . . .
3	explains that the granite is older than the igneous dike because the granite had to be there for the dike to cut through it.
2	writes that the granite is older than the igneous dike; doesn't explain why.
1	writes anything else.
0	makes no attempt.

Item 1b

Code	If the student . . .
3	explains that the sandstone layer formed in a low basin and was later thrust upward by other geological processes such as faulting or folding.
2	writes something about sandstone forming in a basin or that the sandstone was uplifted, but not both.
1	writes anything else.
0	makes no attempt.

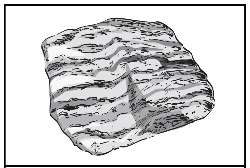
ITEM 1ab Next Steps

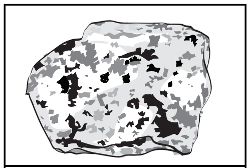
Use a class-debate strategy to review this question with students. Students then draw a line of learning and build upon their responses. See "Next-Step Strategies" in this chapter for more information.

ANSWERS

INVESTIGATION 7 I-CHECK
EARTH HISTORY

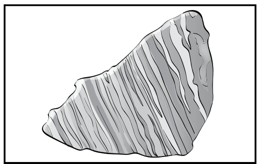
2. Consider the following rock samples. Both samples are made of the same minerals.


Sample A


Sample B

a. One sample is an igneous rock, and the other is a metamorphic rock. Which one is which? What feature from the samples provides evidence to support your argument?

Sample A is the metamorphic rock because the crystals in the sample are foliated by intense heat and pressure. Sample B has crystals like we've seen in other igneous rocks.


Sample C: Sedimentary

b. What processes formed the layers in sample A compared to the processes that formed the layers in sample C?

The foliation in sample A was formed by intense heat and pressure. The layers in sample C formed as sediments were deposited horizontally on top of each other.

Focus on Science and Engineering Practices
Focus on Disciplinary Core Ideas
Focus on Crosscutting Concepts

Item 2

This item provides evidence that students can use evidence to identify rock samples based on interpretation through observation (patterns, cause and effect, energy and matter). (Foundational to MS-ESS2-1)

Item 2a

Code	If the student . . .
3	uses the process of foliation to support the argument that sample A is metamorphic and sample B is igneous.
2	writes something about a change in the crystals; answer is incomplete or vague.
1	writes anything else.
0	makes no attempt.

Item 2b

Code	If the student . . .
3	describes the wavy layers in sample A as caused by heat and pressure (foliation) while the layers in sample C were caused by deposition of sediments.
2	accurately describes the process in which sample A formed, or the way sample C formed, but not both.
1	writes anything else.
0	makes no attempt.

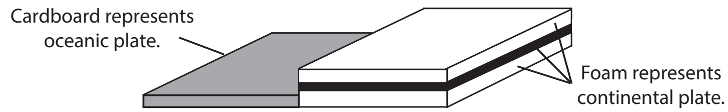
ITEM 2ab Next Steps

Have students review notes on rock observations in their notebooks. Use the group-consensus/whiteboard strategy to share group ideas as a class. See "Next-Step Strategies" in this chapter for more information.

ANSWERS

INVESTIGATION 7 I-CHECK
EARTH HISTORY

3. The diagram represents a model of two plates of Earth's lithosphere.



a. What are the possible interactions between these two plates?
Write **Y** next to each statement that could happen when these plates interact; write **N** next to each statement that could not happen.

N The plates converge, and both rise high above sea level as they compress.

N The continental plate subducts below the oceanic plate.

Y A rift forms between the two plates as they diverge.

Y No movement occurs between the two plates.

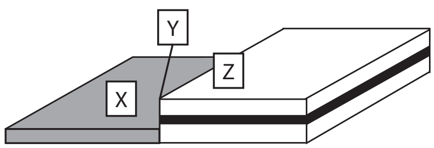
b. What are the limitations of this model for explaining what happens at plate boundaries?

It does not show what causes the plates to move; it does not include heat from Earth's interior; and it cannot show how oceanic crust bends as it subducts.

c. Assuming the two plates converge, at which locations would volcanoes likely emerge?

(Mark the one best answer.)

- ○ **A** Locations X and Y
- ○ **B** Location Y only
- ○ **C** Locations X and Z
- ● **D** Location Z only



Focus on Science and Engineering Practices
Focus on Disciplinary Core Ideas
Focus on Crosscutting Concepts

Item 3

This item provides evidence that students can interpret a model to explain how plates interact and cause landforms at plate boundaries (systems and system models, energy and matter).
(Foundational to MS-ESS2-1, MS-ESS2-3)

Item 3a

Code	If the student . . .
3	writes from top to bottom: N, N, Y, Y.
2	marks one statement incorrectly.
1	writes anything else.
0	makes no attempt.

Item 3b

Code	If the student . . .
3	identifies limitations such as it does not show how plates move, it does not include heat from Earth's interior, or it does not show how oceanic crust bends as it subducts.
2	attempts to describe a limitation as in code 3, but includes minor errors.
1	writes anything else.
0	makes no attempt.

Item 3c

Code	If the student . . .
2	marks D.
1	marks any other way.
0	makes no attempt.

ITEM 3a–c Next Steps
Review the animations of plate-boundary interactions on FOSSweb. Discuss the item in small groups after watching the videos, and have students revise their answers as needed.

ANSWERS

INVESTIGATION 7 I-CHECK

EARTH HISTORY

4. Scientists recently discovered a patch of oceanic crust deep beneath the Mediterranean Sea that is estimated to be 340 million years old. It is the oldest oceanic crust ever found.

   a. If scientists believe Earth is actually 4.6 billion years old, why haven't scientists found older oceanic crust?
   (Mark the one best answer.)

   ❍ **A** Rocks did not cool on Earth until about 340 million years ago.

   ❍ **B** It is too hard to collect samples of oceanic crust.

   ● **C** Oceanic crust subducts under continental crust as new oceanic crust forms.

   ❍ **D** Oceanic crust is younger than continental crust.

   b. The oldest surface Earth rocks that scientists have found are continental crust and estimated to be 3.8 billion years old.

   Why have scientists been able to find rocks in continental crust so much older than the oldest rocks found in oceanic crust?

   (Mark the one best answer.)

   ❍ **F** It is much harder to collect samples of oceanic crust.

   ● **G** Less-dense continental crust is not subducted.

   ❍ **H** Continental crust cooled and formed long before oceanic crust.

   ❍ **J** Oceanic crust is harder to date than continental crust.

5. For a sedimentary rock to change into another kind of sedimentary rock, it would first need to _____.

   (Mark the one best answer.)

   ❍ **A** melt

   ❍ **B** compress under pressure

   ● **C** be weathered

   ❍ **D** be deposited somewhere

Focus on Disciplinary Core Ideas
Focus on Crosscutting Concepts

Item 4

This item provides evidence that students know some of the differences between oceanic and continental crust (cause and effect, energy and matter). (Foundational to MS-ESS2-3)

Item 4a

Code	If the student . . .
2	marks C.
1	marks any other way.
0	makes no attempt.

Item 4b

Code	If the student . . .
2	marks G.
1	marks any other way.
0	makes no attempt.

ITEM 4ab Next Steps
If the class cannot reach a consensus, use the multiple-choice-discussion strategy. See "Next-Step Strategies" in this chapter for more information.

Focus on Disciplinary Core Ideas
Focus on Crosscutting Concepts

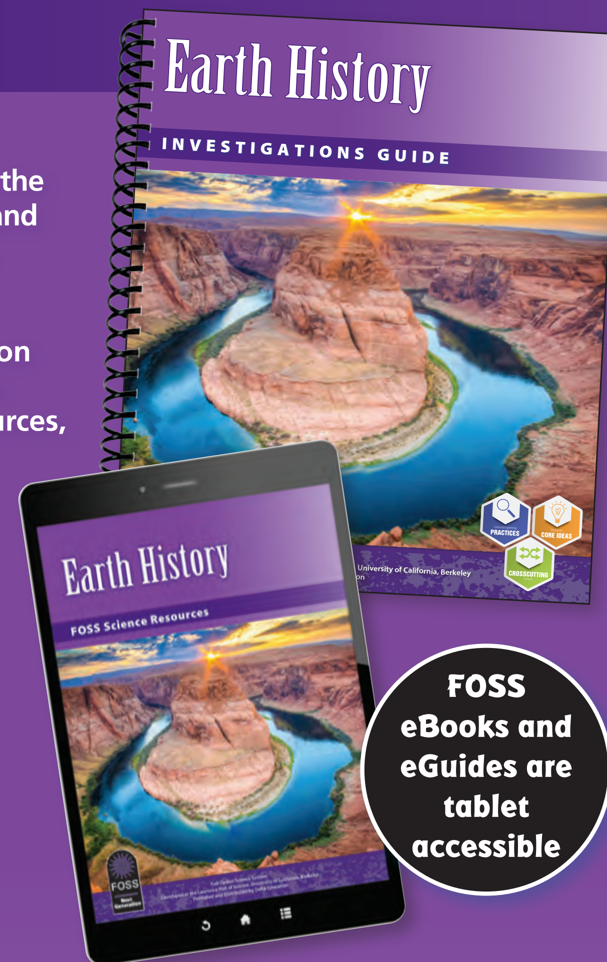
Item 5

This item provides evidence that students know the processes that form sedimentary rocks (energy and matter, cause and effect). (Foundational to MS-ESS2-1)

Code	If the student . . .
2	marks C.
1	marks any other way.
0	makes no attempt.

ITEM 5 Next Steps
Have students review "Rock Transformations" in *FOSS Science Resources*. Discuss the item in small groups after reviewing the article, and have students revise their answers as needed.

FOSS NEXT GENERATION INCLUDES:



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A spiral-bound guide containing the active investigations, which are the core of the program. Other chapters include: Overview, Framework and NGSS, Materials, Technology, and Assessment. Also available online.

Teacher Resources

A grade-level planning guide and other teacher-support chapters on three-dimensional teaching and learning, connections to Common Core, access and equity, and environmental literacy. Teacher Resources, including duplication masters, are available online.

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Recommended FOSS Next Generation Scope and Sequence

Grade	Integrated Middle Grades				
6–8	Heredity and Adaptation*	Electromagnetic Force*	Gravity and Kinetic Energy*	Waves*	Planetary Science
	Chemical Interactions		Earth History		Populations and Ecosystems
	Weather and Water		Diversity of Life		Human Systems Interactions*

*Half-length courses — Physical Science content — Earth Science content — Life Science content — Engineering content

Grade	Physical Science	Earth Science	Life Science
5	Mixtures and Solutions	Earth and Sun	Living Systems
4	Energy	Soils, Rocks, and Landforms	Environments
3	Motion and Matter	Water and Climate	Structures of Life
2	Solids and Liquids	Pebbles, Sand, and Silt	Insects and Plants
1	Sound and Light	Air and Weather	Plants and Animals
K	Materials and Motion	Trees and Weather	Animals Two by Two

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