Rock Strata and Earth's History Teacher Guide

Rock Strata and Earth's History At-A-Glance

85 minutes

Guiding Question:

How can scientists use rock layers to determine when environmental changes occurred throughout Earth's history?

Concepts:

Relative dating, rocks, fossils, stratigraphy, faunal succession

Investigation Objective (Inspired by the NGSS Performance Expectations):

Students construct explanations of how scientists determine the relative dates of events in Earth's history by interpreting the proportional and sequential relationships between rock strata and fossils.

Science and Engineering Practices:	Disciplinary Core Idea:	Crosscutting Concepts:
Constructing Explanations Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.	**ESS1-C: The History of Planet Earth** The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.	**Scale, Proportion, and Quantity** Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Student Objective:

Explain how scientists use rock layers to determine when environmental changes occurred throughout Earth's history. Support your explanation with evidence.

Prerequisites:

To successfully complete this investigation, students should have the following prerequisite knowledge:

- Rocks are natural, solid substances made of minerals and sometimes biological materials, such as shells or plant matter.
- Fossils are the remains of once-living organisms that have been preserved by geological processes.
- When all members of a particular species have died, this is called extinction.

- Geology is the study of planet Earth, often through the examination of rocks and Earth's surface features.
- Paleontology is the study of once-living organisms, generally through the examination of fossils.
- The processes that cause major changes on Earth over time include plate tectonics, weathering and erosion, climate change, evolution, and extinction.
- Evolution is the process by which organisms gradually change over time as a result of natural selection.
- When evolution results in enough changes for a new species to develop, it is called speciation.
- Geologic time is organized using the geologic time scale.

Investigation Overview:

In this investigation, students learn how scientists gather clues from the rock and fossil records to reconstruct the sequence of events that have taken place throughout Earth's 4.6-billion-year history. Students observe this type of work by completing a 3D World activity. Students then watch movies and read passages to learn about the principles of relative dating and how they are applied to both the rock and fossil records. By the end of the investigation, students will be able to compose a robust answer to the Guiding Question: How can scientists use rock layers to determine when environmental changes occurred throughout Earth's history?

<table>
<tr><td>Activate
(5 minutes)</td><td>Students view an image of a pile of laundry and answer questions to support engagement and exploration.</td></tr>
<tr><td>Observe and Check
(60 minutes)</td><td>

Fossils: Rock Strata 3D World Students use a 3D World to investigate rock strata and fossils. Students are asked to analyze their own observations of rocks and fossils, as well as the observations of geologists and paleontologists.
Relative Dating Movie Students learn how scientists developed the field of stratigraphy. The movie discusses the age of Earth; the principle of superposition; the work of Nicolaus Steno, James Hutton, and William Smith; and radiometric dating.
Relative Dating "In Practice" Related Reading Students read about the principles of relative dating. The passage discusses the principles of superposition, cross-cutting relationships, horizontal continuity, original horizontality, and uniformitarianism.
Fossils: Relative Dating 3D World Students revisit the 3D World to further investigate rock strata and fossils. Students are challenged to observe what these things indicate about the geographical history of the land surrounding the dig site.

</td></tr>
<tr><td>Checkpoints</td><td>Students complete a quick, formative assessment to check their understanding of the completed resources and ensure they are prepared to answer the Guiding Question with a claim, evidence, and reasoning. Options for the Checkpoints:
<table>
<tr><th>Graded Mode</th><th>Review Mode</th></tr>
<tr><td>On submission, students see their score and the correct answers for review.</td><td>Students proceed to the next question when they select the correct answer.</td></tr>
</table>
</td></tr>
<tr><td>Explain
(15 minutes)</td><td>Students develop a Claim, Evidence, and Reasoning to answer the Guiding Question: How can scientists use rock layers to determine when environmental changes occurred throughout Earth's history?</td></tr>
<tr><td>Reflect</td><td>Students reflect on connections between what they have learned in this investigation</td></tr>
</table>

(5 minutes)	and other aspects of their lives and experiences by answering the question: How can you connect what you learned in this lesson to your life?

Academic Vocabulary:

(Bolded terms are used in the vocabulary support resource)

- Absolute Dating
- Correlation
- **Cross-Cutting Relationships**
- Erosion
- Extinction
- Fault
- Faunal Succession
- Fossil
- Geology
- Geologic TIme
- Geologic Time Scale
- Horizontal Continuity
- Igneous Rock
- **Index Fossil**
- Lava
- Magma
- Metamorphic Rock
- Microfossil
- Mountain
- Original Horizontality
- Paleontology
- Plate Tectonics
- Radiometric Dating
- **Relative Dating**
- Rock
- **Sediment**
- Sedimentary Rock
- **Strata**
- Stratigraphy
- **Superposition**
- Uniformitarianism
- Weathering

Relative Dating In-Depth

The Science!

This investigation focuses primarily on how scientists apply the principles of **relative dating** to evidence from **rock strata** and the **fossil record** to understand Earth's history. The basis for the reconstruction of events from Earth's history is a branch of geology called **stratigraphy**: the study of rock layers and the fossils contained inside them. Using the **fundamental principles of stratigraphy**, scientists can get a good idea of how organisms have evolved and how the rock composition and environmental conditions of an area have changed over time. To get a more complete picture of conditions on Earth, scientists use a process called **correlation** to compare the strata and fossils from one area of the planet to another.

The fundamental geologic principles (sometimes referred to as laws) of relative dating are outlined as follows:

- **Principle of Superposition:** The principle of superposition states that layers of sediment are deposited sequentially: in a series of undisturbed strata, the oldest layer is on the bottom and the youngest layer is on the top. Every layer is older than the layer above it, and every layer is younger than the layer below it.
- **Principle of Original Horizontality:** The principle of horizontality states that rock layers are originally deposited as horizontal layers of sediment. Rock layers that are folded, crumpled, or tilted tell a story of change that occurred after the layers were deposited.
- **Principle of Horizontal Continuity** (also known as the **principle of lateral continuity**): The principle of horizontal continuity states that sediment is deposited in continuous, lateral layers. A stratum that has been split by a **fault** or erosional surface was once a continuous layer.
- **Principle of Cross-Cutting Relationships:** The principle of cross-cutting relationships states that anything that cuts across a rock layer—such as a fault, an **igneous intrusion**, or damage from **weathering** and **erosion**—must be younger than the rock layer through which it cuts. By the same principle, the rock layer must be older than the cross-cutting feature.

These four principles are sometimes referred to as **Steno's Laws**, as they were developed largely by Nicolaus Steno in the mid- to late-1600s. James Hutton (1726–1797) developed the comprehensive theory of **uniformitarian** geology, also known as the **principle of uniformitarianism**. This principle states that the natural processes that occur on Earth today work the same way and to the same degree that they always have throughout **geologic time**. Critical theories and principles of biology also developed out of uniformitarianism.

The fundamental biological and paleontological principles of relative dating are outlined as follows:

- **Principle of Faunal Succession:** Developed by engineer and surveyor William Smith (1769–1839), the principle of faunal succession states that the fossils in Earth's strata are layered in a predictable order, no matter where they're found. Fossils are almost always found in rock that was deposited during the time the fossilized organism existed on Earth, so fossils can be used to reliably determine whether strata in different places are of similar age: a technique known as **correlation**.
- **Principles of Organic Evolution and Extinction:** The principle of organic evolution states that new species develop as a result of evolution from earlier organisms through slow changes over long periods of geologic time. Most of the ancestral species have gone extinct. Therefore, younger strata primarily contain fossils of organisms that are more similar to existing organisms, and older strata primarily contain fossils of organisms that are more distinctly different from existing organisms. Changing faunal sequences can be used to track sequences of geologic time, with each organism in the sequence representing a particular time in Earth's history.

Analyses of rock strata and the fossil record using these principles provide only relative dates, not an absolute scale. For that, scientists employ **radiometric dating**, a form of **absolute dating** that uses **radioactive isotopes** to date objects.

Student Misconceptions and Common Struggles

During this investigation, you may hear some common misconceptions about relative dating. Identifying misconceptions can help determine which resources students should explore more in depth or which additional resources to assign. For example:

Student Misconception or Common Struggle	Relevant Scientific Concept	Response To Misconception or Common Struggle
Except for a few major changes due to large volcanoes that have erupted or meteorites that have struck Earth, environmental conditions have stayed the same throughout Earth's history.	In the past, environmental conditions have undergone both major and minor changes on regional and global scales. They continue to change today.	Reassign Fossils: Relative Dating 3D World *Ask: How do rocks and fossils provide evidence for environmental changes in Earth's history?*
Erosion and weathering can wear away solid rock a little bit, but they are not powerful enough to level mountains, carve valleys, or change Earth's surface in other substantial ways.	Geologic processes like weathering, erosion, and deposition can and do cause substantial changes to Earth's surface. Over millions of years, they have leveled mountains and carved valleys (including the Grand Canyon).	Assign Movie: Types of Rocks *Ask: How are processes like weathering, erosion, and deposition involved in the formation of sedimentary rocks?* Assign Geologic Time "In Practice" Related Reading *Ask: How have weathering and erosion affected the Lewis Thrust?*

All species began at the same time and still exist today.	There are similarities and differences between organisms living today and those that lived in the past; many evolved over time from common ancestors. However, the majority of species of organisms that lived in the past are now extinct.	Assign Fossils movie *Ask: How do fossils provide evidence for the similarities and differences between organisms living today and those that lived in the past?* *Ask: How do fossils provide evidence that the majority of species of organisms that lived in the past are now extinct?* Assign Geologic Time movie *Ask: How is the story of life on Earth a major part of Earth's history?*
Only a few of the many species of organisms that lived in the past are now extinct. Most of the species of organisms that lived in the past are still alive today.	The majority of species of organisms that lived in the past are now extinct.	Assign Fossils movie *Ask: How do fossils provide evidence that the majority of species of organisms that lived in the past are now extinct?*

INVESTIGATION ROADMAP

Read the Guiding Question aloud: How can scientists use rock layers to determine when environmental changes occurred throughout Earth's history? Explain that students will investigate resources to gather evidence to answer this question.

OBSERVE

Step 1	**Phenomenon**
This resource assesses prior knowledge and captures students' interest using a phenomenon.	
• Have students view the image of the laundry pile and then answer the Activate questions in the resource. Discuss answers to check for understanding. 1. If you wanted to find a shirt that you last wore two weeks ago, where would it be in the laundry basket? Why? *[Possible answer: That shirt would probably be near the bottom of the pile, because I would have piled more laundry on top of it over the past two weeks.]* 2. If someone wanted to figure out what you did over the last few weeks, what clues could they gather from your laundry pile? (Hint: Think about things like the types of clothing in the pile, the position of pieces of clothing within the pile, and items in your pockets.) *[Possible answer: Someone could probably tell the kinds of activities I did, and in what order. For example, if my soccer uniform was at the bottom of the pile, someone could tell that I played soccer, but not in the past few days. If there was a movie ticket in my pocket, they could tell what movie I went to see. If the date was on the ticket, they could tell exactly when I went to the theater. If the*	

pants with the ticket in the pocket were in the middle of the pile, above my soccer uniform, they could tell that I haven't played soccer since I went to the theater, and that it was most likely a few days before.]

3. If the bottom of your laundry pile contained mostly shorts and short-sleeved shirts, but the top of the pile contained mostly pants and sweaters, what would that tell someone about environmental or weather changes over the last few weeks?
   [Possible answer: Someone could conclude that the weather must have been warm when I was wearing shorts and short-sleeves. Since those are on the bottom of the pile, that was probably a week or so ago. Since there are pants and sweaters at the top of the pile, someone could conclude that the weather has cooled off significantly over the past few weeks.]
4. How can geologists use the same kind of reasoning when they study rock layers and the fossils to learn more about when and where rocks formed?
   [Possible answer: Geologists might be able to tell that rock layers at the bottom of a sequence are older than rock layers at the top. Fossils might tell them about the kinds of organisms that lived in the past. Fossils might also tell scientists about how the environment has changed. For example, if they found fossils of fish near the bottom and trees near the top, scientists could conclude that there was water in an area a long time ago, and then it dried up later.]

Expected Outcome: Students see an image of a pile of laundry, then answer questions about how the laundry pile can tell a story about the recent past. Students are asked about how similar logic can be applied to the rock and fossil records to tell a story about Earth's history. Students likely will not use the term *strata* at this early stage of the investigation. This discussion should serve as an entry point into the concepts of relative dating and Earth's history.

OBSERVE AND CHECK

Step 2	**Fossils: Rock Strata 3D World**

This resource is a 3D World in which students visit an immersive fossil dig site and use their observation and listening skills to collect evidence. Students can follow Moby around the dig site, listen to conversations between scientists for contextual information, hear relevant facts from Tim, observe rocks and fossils, and use tools to access more detailed information. This BrainPOP 3D World™ covers subject areas connected to stratigraphy, superposition, faunal succession, and geologic time.

- Direct students to explore the 3D World to learn about how geologists and paleontologists use evidence from rocks and fossils to reconstruct Earth's history. Students should answer the following questions in the resource:
  1. Select the Fossiltron tool and explore the dig site. What's in this world? What can you observe?
     [Possible answer: This world is currently a desert environment. There are exposed rock walls made of different layers. The layers are made of different rock types, and some contain fossils. There is a geologist station where geologists study rocks and a paleontologist station where paleontologists study fossils.]
  2. How can you use the Fossiltron to learn more about the animals and plants that once lived here?
     [Possible answer: Using the Fossiltron, I can collect information about fossilized animals and plants. Fossils can be found near the paleontologist station, lying on the ground, and in the rock walls. I can use the Fossilitron to learn about animal species and the environment in which they lived. For

example, there are fossils of clams that live in water, salamanders that live on land near water, and fossil pollen from land plants.]

3. Restart the 3D World and choose the Rock-O-Matic tool this time. How can you use the Rock-O-Matic to learn more about the types of rocks in this area?
   [Possible answer: The Rock-O-Matic tells me information about the ages and composition of the rock layers in this area. The rock types give clues about what the area was like at the time when the rocks formed, such as whether or not water was present at that time.]

Differentiation

Extend and Deepen Learning:	Provide Extra Support:
Challenge students to answer these questions, which encourage extended learning and connections to related science concepts: ○ What would a dig site look like in real life? How would it compare to the dig site you saw in the world? ○ In 30 million years, what fossils might people find from the 21st century? ○ What kinds of tools do paleontologists and geologists need to do their jobs?	If students feel overwhelmed, work through the movement controls and 3D World Setup with them before they begin exploring on their own. They can also follow Moby in order to familiarize themselves with the different parts of the world. Make sure students are comfortable navigating the 3D World, and give them a few minutes to just play around before bringing their focus back onto collecting evidence and answering questions. Let students know that they will get another chance to go through the 3D World at the end of the investigation.

Discussion Questions

1. What was the difference between the tools used in the 3D World?
   [Possible answer: The Fossilitron gave information about fossils, such as the species of animal or plant and the environment it lived in. The Rock-O-Matic gave information about the rocks, such as the rock type, the composition, and the age.]
2. How does being a paleontologist differ from being a geologist?
   [Possible answer: Paleontologists study fossils to learn about the species that existed in the past and the environments in which they lived. Geologists focus on the ages and compositions of rocks and the environments in which different rock types formed.]
3. Why do you think this 3D World was designed this way? How did it help support the questions you were asked?
   [Possible answer: This 3D World was designed to show what a real dig site might look like. I think the tools were designed to show the kinds of information that geologists and paleontologists can gain from rocks and fossils using their actual tools and expertise. The information about rocks and fossils, plus listening to the conversations between the characters, helped me understand how geologists and paleontologists learn about the past.]

Expected Outcome: Students will

- Learn about the work of geologists and paleontologists.
- Use the Fossilitron to reveal facts about fossils within the 3D World, such as the type of organism and the environment in which it lived.
- Use the Rock-O-Matic to reveal facts about rock layers within the 3D World, such as their age and composition.

Step 3	Relative Dating Movie

This resource describes the development of stratigraphy: the science of using rock layers, or strata, to put together a timeline of Earth's history. Scientist Nicolaus Steno's principle of superposition showed that younger strata always form on top of older ones. This simple idea helps scientists determine which layers are older based on their positions, a method known as relative dating. Geologist James Hutton took the next step by estimating that each layer took thousands of years to form—which meant Earth must be much older than anyone realized at the time. Then came geologist William Smith, who used fossils to match up, or correlate, strata around the world. Finally, the invention of radiometric dating made it possible to determine a rock's absolute age in years.

- Direct students to watch the movie and make observations about geologic time. As they watch the movie, consider asking these questions.
  1. What was Nicolaus Steno's explanation for how rock strata form?
     [Possible answer: He reasoned that they're made of sediments: bits of rock and other debris. They get picked up by water or wind, and dropped off somewhere else. Because of gravity, sediments settle in horizontal layers. Over time, these layers compress and harden into sedimentary rock.]
  2. What was Steno's reasoning about which strata are older or younger than others?
     [Possible answer: Younger strata always form on top of older ones. Steno called this idea the principle of superposition. It let him identify one layer as older than another layer based on their positions.]
  3. What conclusion did James Hutton draw about the age of Earth?
     [Possible answer: Hutton concluded that Earth is much older than 6,000 years, as people believed at the time based on the Bible.]
  4. What was William Smith's conclusion about fossils?
     [Possible answer: Rock layers with the same fossils are connected, so you can correlate strata in separate places. If they have the same fossils, they must have formed around the same time.]

Differentiation

Extend and Deepen Learning:	Provide Extra Support:
Have students make a list of the scientists mentioned in the movie. Challenge them to choose one of these scientists to research further and give a report or presentation on the life and work of the scientist they have selected.	Have students make a list of unfamiliar vocabulary words as they watch the movie. Define select keywords for students (e.g., *strata*, *sediment*, *superposition*, *radiometric dating*), and have students watch the movie again after learning the key words.

Discussion Questions

1. Stratigraphy is the practice of studying rock layers and the fossils within those layers to piece together information about the history of an area. What are some of the principles, practices, and limitations of stratigraphy?
   [Possible answer: One of the principles of stratigraphy is superposition, which states that a rock layer is most likely older than the layers above it in a sequence, and younger than the layers below it in a sequence. However, because other natural forces can change rock layers after they form, superposition doesn't always apply. Processes like weathering and erosion can also erase layers, leaving gaps in the rock record.]

2. How do you think stratigraphers compare the rock formations of one area to those of another in order to get a more global picture of Earth's history?
   [Possible answer: Stratigraphers probably look for multiple areas that contain similar sequences of rock layers: for example, sequences that have the same types of rocks or fossils in the same order. They probably also look for rocks and fossils that have the same age according to radiometric dating.]
3. What is the difference between relative and absolute dating? How do you think they complement each other to form a more complete picture of Earth's history?
   [Possible answer: Relative dating tells you whether something is older or younger than something else. Absolute dating tells you the exact age of something (e.g., This fossil is 10 million years old.). Relative dating puts the events of Earth's history in order, telling a chronological story. Absolute dating gives the context of exactly when those events in the story took place.]

Expected Outcome: Students will

- Be introduced to the concept of relative dating.
- Learn the age of Earth.
- Learn the history of science pertaining to how the age of Earth was determined.
- Discover some of the important scientists involved in developing the principles of relative dating.
- Be introduced to the principle of superposition.
- Be introduced to the concept of radiometric dating.
- Understand that science changes with the discovery of new evidence.

Step 4	**Relative Dating "In Practice" Related Reading**

This resource is a reading about several fundamental principles of relative dating. This passage discusses Steno's laws and uniformitarianism.

- Direct students to read the passage to learn about the fundamental principles of relative dating. Consider asking the following questions to support understanding.
  1. What is the principle of superposition?
     [Possible answer: The principle of superposition states that layers of sediment are deposited sequentially, so that in a series of undisturbed strata, the oldest layer is on the bottom, and the youngest layer is on the top. Every layer is older than the layer above it, and every layer is younger than the layer below it.]
  2. What is the principle of original horizontality?
     [Possible answer: The principle of horizontality states that rock layers are originally deposited as horizontal layers of sediment. Rock layers that are folded, crumpled, or tilted tell a story of change that occurred after the layers were deposited.]
  3. What is the principle of horizontal continuity?
     [Possible answer: The principle of horizontal continuity states that sediment is deposited in continuous, lateral layers. A rock layer that has been split by a fault or erosional surface was once a continuous layer.]
  4. What is the principle of cross-cutting relationships?
     [Possible answer: The principle of cross-cutting relationships states that anything that cuts across a rock layer, such as a fault, an igneous intrusion, or damage from weathering and erosion, must be younger than the rock layer through which it cuts. Vice versa, the rock layer must be older than the cross-cutting feature.]

Differentiation

Extend and Deepen Learning:	Provide Extra Support:
Challenge students to write their own version of this passage, using a different type of real-life example to illustrate the principles of relative dating.	Have students keep a list of unfamiliar vocabulary words from this passage and write definitions in their own words as they read. Encourage students to search for additional resources to expand on their definitions.

Discussion Questions

1. How do all of the other principles of relative dating come out of the principle of uniformitarianism?
   [Possible answer: The principle of uniformitarianism states that the natural processes that occur on Earth today work the same way and to the same degree that they always have throughout geologic time. If Earth's processes worked very differently in the past than they do now, the principles of relative dating would not work.]
2. How can you apply the principles of relative dating in your everyday life?
   [Possible answer: As an example, the principles of superposition and original horizontality can be applied to a brick wall. When looking at a brick wall, it is usually safe to assume that the horizontal rows of bricks are in their original positions, and that the bricks at the bottom were put there first, and the bricks on top put there last.]

Expected Outcome: Students will

- Learn the principles of superposition, original horizontality, horizontal continuity, cross-cutting relationships, and uniformitarianism.
- Learn to apply the principles of relative dating to scenarios from everyday life.

Step 5	**Fossils: Relative Dating 3D World**

This resource is a 3D World in which students visit an immersive fossil dig site and use their observation and listening skills to collect evidence. They can listen to conversations between scientists for contextual information, hear relevant facts from Tim, observe rocks and fossils, and use tools to access more detailed information. This BrainPOP 3D World™ covers subject areas connected to stratigraphy, superposition, faunal succession, and geologic time.

- Direct students to revisit the 3D World to learn about how geologists and paleontologists use evidence from rocks and fossils to reconstruct Earth's history. Students should now have a better understanding of how to examine rocks and fossils for clues about how environments have changed over time. Direct students to answer the questions in the resource:
  1. Examine the rock layers and fossils and listen to the paleontologists and geologists. What do the rock layers tell you about how this environment changed over time?
     [Possible answer: Leah observes that a layer of gray volcanic ash is present in Rock Wall A. The layer is missing from the layers near the geologist station. Theodore hypothesizes that there may have been a river in the area sometime after the ash layer was formed. Erosion from the river wore the ash layer away. This would mean there was once water in this environment.]
  2. How do fossils help to determine when these changes happened?
     [Possible answer: I saw dinosaur fossils in the bottom rock layers, which are the oldest rocks here. Younger rock layers on top do not have dinosaur fossils, so the dinosaurs went extinct before those

rocks formed. The older rock layers have evidence of a forest with some slow moving water. I found rocks, such as shale, that form beneath the water. And with the Fossiltron, I saw animals such as the T. Rex that lives near water, as well as the plesiosaur, clam, and ammonite that live in water. This place changed a lot after the dinosaurs became extinct. In the upper, younger rock layers, I found fossils of birds who lived in forests containing ferns 60 million years ago and camels that lived in forests and open plains 25 million years ago.]

Differentiation

Extend and Deepen Learning:	Provide Extra Support:
Challenge students to answer these questions, which encourage extended learning and connections to related science concepts: ○ What causes rock layers to shift from horizontal positions? If layers shift, how can you tell when they formed? ○ What kinds of information are you unable to get from rocks and fossils? How else might you get that information?	Guide students through the 3D World with questions such as: ○ What's in this world? What can you observe? ○ How can you use the Fossiltron to learn more about the animals and plants that once lived here? How do different animals and plants provide clues about the environments that existed at the time they lived? ○ How can you use the Rock-O-Matic to learn more about the types of rocks in this area? What information does the Rock-O-Matic tell you about the environment in which some of the rocks formed?

Discussion Questions

1. In which part of the dig site did you find the most helpful clues? Why were they helpful?
   [Possible answer: I found the most helpful clues near the geologist station because the Rock-O-Matic revealed a lot of information in that area. Understanding how the rocks formed gave a lot of clues about the past environments, and knowing the rocks' ages let me track when different environments existed and changed.]
2. Certain parts of the 3D World are fictional or exaggerated to make it easier to teach the lesson concepts and gather information. Which aspects of the 3D World do you think are not fully accurate?
   [Possible answers: Fossils are not usually this well preserved. Often, paleontologists will find incomplete fossils or ones that are less well preserved. Additionally, fossils are not usually vertical or perfectly aligned with the edge of the wall. The tools are fictional. While tools can be used to date rocks and fossils, there is no tool that gives you that kind of information by simply pointing. The layers in the rock wall would likely be more shifted. While it is possible to see perfect layers, it doesn't always happen; things might shift from human or natural means. Dig sites are rarely open to the public.]

Expected Outcome: Students will

- Apply lesson concepts related to stratigraphy, superposition, faunal succession, and geologic time.
- Synthesize information from rock and fossil evidence to draw conclusions about past environmental conditions.
- Gather evidence about how the rock and fossil records are used to reconstruct events, environmental conditions, and changes in Earth's geological and biological history.

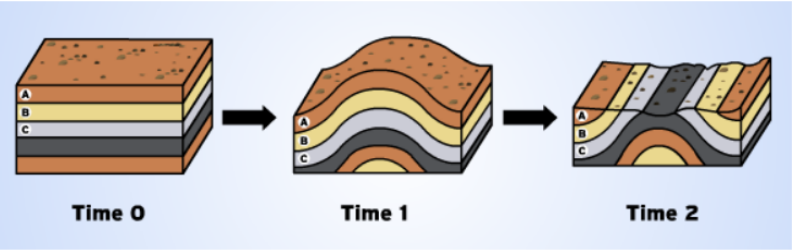
CHECKPOINTS

Step 6	Checkpoints

These resources assess student understanding of relative dating and stratigraphy.

Checkpoint One (after required resource 2, “Relative Dating Movie”)

1



Use relative dating principles to order the sequence of events depicted in the illustration above from first to last.

1. Layer C was deposited ✓
2. Layer B was deposited ✓
3. Layer A was deposited ✓
4. Tectonic forces caused the layers to fold ✓
5. Erosion removed the upper portion of the rock formation ✓

2

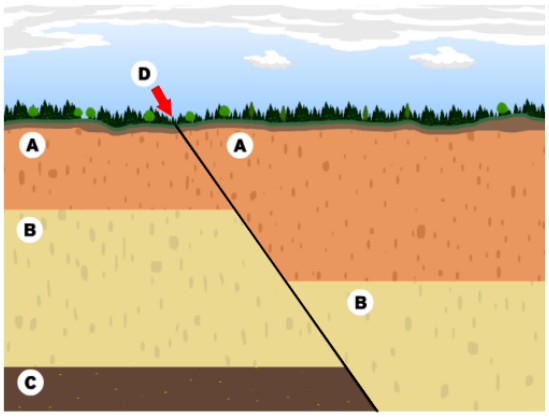
Rock strata help scientists piece together parts of Earth's history. For example, a thin layer of the element iridium was discovered in the strata deposited a little over 66 million years ago. Scientists believe that this layer may reflect the impact of a large asteroid colliding with Earth.

Which additional piece of information supports the asteroid collision hypothesis?

- ○ Asteroids do not typically contain fossils
- ◉ Asteroids that have recently collided with Earth contain iridium ✓
- ○ Large asteroids can create huge craters on impact
- ○ Asteroids used to collide with Earth more frequently than they do now

Checkpoint Two (after required resource 3, "Rock Strata and Earth's History 'In Practice' Related Reading")

1



Using rock strata, scientists are able to identify which geologic features are older than others. In the sample shown, scientists claim that the most recent change is the shift illustrated by feature D.

Which relative dating principle supports this claim?

- ○ Principle of superposition
- ○ Principle of original horizontality
- ◉ Principle of cross-cutting relationships ✓

EXPLAIN

Step 7	Claim, Evidence, Reasoning
Students construct a Claim, Evidence and Reasoning answer to the Guiding Question: How can scientists use rock layers to determine when environmental changes occurred throughout Earth's history?	
Expected Outcome: Students write a scientific claim using collected evidence and scientific reasoning. See rubric below.	

REFLECT

Step 8	Student Reflection
Students answer a reflection question to consider their experience with the investigation.	
Reflection Question: How can you connect what you learned in this lesson to your life?	
Expected Outcome: Students will reflect on the concepts from this lesson and relate them to things they experience in their everyday lives, circling back to the connections they made during the Activate step.	

Claim, Evidence, and Reasoning (CER) Framework Rubric

Please use the rubric as a guide and adjust accordingly for your specific needs and use.

	0	1	2	3
Claim Statement that answers the Guiding Question	Not attempted	Claim is attempted but it: ☐ Does not answer the Guiding Question ☐ Is not accurate or relevant	Claim attempts to answer the Guiding Question but it: ☐ Is incomplete ☐ Is not completely accurate	Claim is present and it: ☐ Completely answers the Guiding Question ☐ Is scientifically accurate
Evidence Scientific data and observations that support the claim	Not attempted	☐ Evidence is attempted ☐ Evidence is inaccurate, inappropriate, or irrelevant	☐ Has at least one piece of evidence that supports the claim ☐ Some evidence is missing, inaccurate, or irrelevant	☐ Has two or more pieces of evidence that sufficiently support the claim ☐ Does not include any inaccurate or irrelevant evidence
Reasoning Scientific principle(s), concepts, and definitions that connect evidence to the claim	Not attempted	Reasoning is attempted but it: ☐ Does not link the claim to the evidence ☐ Includes unrelated scientific principles ☐ Is not scientifically accurate	Reasoning is present but it: ☐ Only connects some evidence to the claim ☐ Only cites some of the relevant scientific principles ☐ Includes some inaccuracies	Reasoning is present and it: ☐ Sufficiently and clearly links all evidence to the claim ☐ Includes only relevant scientific principle(s) ☐ Is scientifically accurate

Example Claim, Evidence, and Reasoning (CER) Responses

Example CER Responses

The following are three sample student responses (*Meets Expectations, Approaches Expectations,* and *Needs Improvement*). Please note that student claims, evidence, and reasoning will vary and should be assessed individually using the rubric above.

Meets Expectations:

Claim	Scientists can use clues from different types of rocks and fossils to understand the type of environment that existed in an area, the principles of relative dating to determine the order in which different environments existed, and correlation to gain a bigger picture of these changes throughout Earth's global history.

Source	Evidence
Relative Dating movie	Strata are made of sediments which settle in horizontal layers. That means younger strata always form on top of older ones. This is called the principle of superposition, and this kind of ordering is called relative dating.
Relative Dating movie	Some kinds of fossils always show up in layers above other kinds. Even in faraway places, these fossils appear in the same order. Scientists correlate strata in separate places. If strata contain the same fossils, it means they formed around the same time.
Relative Dating "In Practice" Related Reading	Principle of Superposition: Layers of sediment are deposited one on top of another. The oldest layer is on the bottom and the youngest layer is on the top. Every layer is older than the layer above it, and every layer is younger than the layer below it. Principle of Uniformitarianism: The present is the key to understanding the past. The natural processes that occur on Earth today work the same way that they always have.

Reasoning	The order of **rock strata** allows for **relative dating** since the oldest layers are found the farthest down (**Principle of Superposition**). The **fossils** found in each layer of rock can provide clues about the environment they lived in. For example, if the rock layers in a particular place contain fossils with shells or evidence of fins, scientists know that the area was once aquatic. Changes in the fossils as you move through the layers can provide information about changes to the environment also. Scientists can also combine information from multiple different areas to form a bigger picture. This helps to explain how scientists go from understanding the history of **environmental changes** in a particular area to understanding Earth's history of environmental changes as a whole.

Scoring Rationale:

- Claim (3 points) - The student's claim is scientifically accurate and fully answers the Guiding Question.
- Evidence (3 points) - The response includes at least two pieces of evidence that are scientifically accurate and clearly relate to the claim. The claim is sufficiently supported by the evidence provided.
- Reasoning (3 points) - The student's reasoning thoroughly explains how the evidence supports the claim. The reasoning is scientifically accurate and explicitly mentions relevant scientific principles (shown above in bold).

Approaches Expectations:

Claim	Scientists can use the principles of relative dating to determine the order in which the different rock layers formed.

Source	Evidence
Relative Time movie	Some kinds of fossils always show up in layers above other kinds. Even in faraway places, these fossils appear in the same order. If strata contain the same fossils, it means they formed around the same time.
Relative Dating "In Practice" Related Reading	Principle of Superposition says layers of sediment are deposited one on top of another. The oldest layer is on the bottom and the youngest layer is on the top. Every layer is older than the layer above it, and every layer is younger than the layer below it.

Reasoning	Superposition is an important principle for understanding relative dating. However, superposition doesn't work if other forces have tilted or broken the rock layers. If the processes that happen on Earth today were very different from the processes that happened in the past, we could not use clues from rock strata to learn about Earth's history because we would have no way of knowing how those strata formed.

Scoring Rationale:

- Claim (2 points) - The claim attempts to answer the Guiding Question but it is incomplete.
- Evidence (2 points) - There is at least one piece of evidence that is scientifically accurate and clearly relates to the claim. However, there is some evidence missing.
- Reasoning (2 points) - The student's reasoning connects some of the evidence to the claim and is generally accurate. However, it does not mention all relevant scientific principles.

Needs Improvement:

Claim	The Principle of Superposition says layers of sediment are deposited one on top of another.

Source	Evidence
Relative Dating movie	Some kinds of fossils always show up in the same layer of rock.

Reasoning	Fossils from different areas are connected.

Scoring Rationale:

- Claim (1 point) - A claim is present but it does not answer the Guiding Question.
- Evidence (1 point) - One piece of evidence is included but it is not relevant to the claim.
- Reasoning (1 point) - Reasoning is attempted but it does not explain how the evidence supports the claim, nor does it mention the relevant scientific principles.