Deep Thinking over Geologic Time

Understanding Fossils and Relative Dating by Inquiry

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CONTENT AREA
Earth science

GRADE LEVEL
6

BIG IDEA/UNIT
Fossils and relative dating

ESSENTIAL PRE-EXISTING KNOWLEDGE
None

TIME REQUIRED
Seven 60-minute lessons

COST
$10-20

SAFETY
No concerns

Many students perceive the age of the Earth in tens, hundreds, or thousands of years instead of millions or billions. They also struggle with placing events in chronological order (Hidalgo, San Fernando, and Jose Otero 2004). This article describes a series of activities designed to deepen students' understanding of geologic time. All of the activities align with the *Next Generation Science Standards* (NGSS Lead States 2013; see box, p. 38).

The seven 60-minute lessons in the unit address the overarching questions of "How do fossils provide evidence that life has changed on Earth?" and "How do rocks, fossils, rock layers, and Earth's processes help determine the age and geologic history of the Earth?" More detailed descriptions of each 60-minute lesson (including additional figures, setup, facilitation tips, students' questions, and sample student answers) are available in online teacher and student guides (see Online Supplemental Materials). See the sidebar on page 35 for a list of materials needed for each activity.

Unit structure

Day 1: Relative dating of rock layers

The layering of rock deposits serves as a guide to Earth's history and as a tool in relative dating. To elicit students' prior knowledge and misconceptions of the age of the Earth, have students first examine two different rock samples (fossiliferous limestone and basalt or granite). Next, have students record their thinking about which is older on page 3 of their student guide, then have them first share their ideas with peers through a small-group talk and later as a whole group to formatively assess student understanding. Although photographs may be used, physical samples are ideal. Let students know the actual age of the rocks at the end of the lesson.

The next two activities explore the law of original horizontality (all sedimentary layers are originally deposited horizontally) and the law of superposition (the youngest rocks lie on top of older rocks). On a table, place a stack of cards with a single card set to the side. Ask students which card was laid down first and last and how they know. Students should indicate that the card on the bottom was put down first, but without seeing when the outlier (the card on the side) was laid down, they have no way to place it in chronological order.

To connect this activity with rock layers, students next observe what happens as different types of sand and gravel are added to a graduated cylinder partially filled with water (Figure 1). As the sand and gravel accumulate, students record the action of sediments in water, describing how the shape and placement of rock layers informs us about Earth's history. Specifically, students describe how layers of sediment fall to the bottom and stack up in horizontal layers, one on top of the other.

Day 2: Applying relative ages to layered rocks

First, the teacher guides the class through an analysis of 3-D photographs of the Grand Canyon's layers using questions such as:

- Does anyone recognize this place?
- What do you notice about the formation of rocks?
- Which layer is oldest or youngest?
- How do you know?

Students record their thinking on pages 5–6 of their student guide and make connections to the previous day's activities.

Next, students apply the laws of superposition and horizontality by analyzing a *stratigraphic succession chart*, which is a graphical representation of the rocks in an area. Albeit daunting, most students can make sense of these charts by working with a partner and answering prompts from the teacher, including:

- How does this remind you of the column of sand we observed?
- Can you identify the oldest and youngest layers?

Further probe students' answers to the questions with: "How do you know?" or "What makes you say that?" If students struggle with this, have them compare their observations of the chart with their observations made during the sand activity or when viewing pictures of the Grand Canyon. Eventually, all students should be able to identify the oldest layers as those placed deepest in the Earth and make age-based comparisons between layers and geological events based on the relative position of rock layers.

FIGURE 1: Graduated cylinder with sediment layers

PHOTOS COURTESY OF THE AUTHORS

Day 3: Demonstrating changes over time

Students now make connections between the superposition of rock layers, faunal succession, and relative dating. The "Earth cups" (Figure 2) used in this lesson contain two distinct rock layers, each of which contains a "fossil" of a specific plant or animal. (See Materials for specific directions for creating Earth cups.)

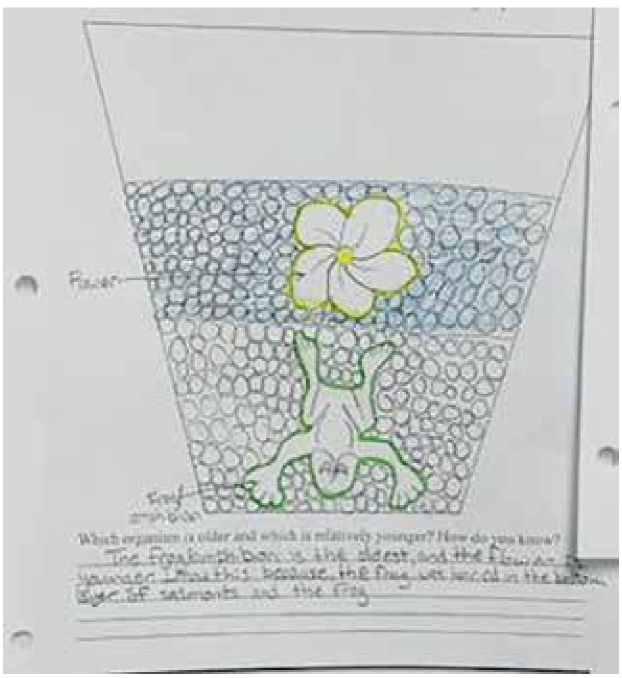
In groups of four, students work as paleontolo-

FIGURE 2: Earth cups

gists to complete a "dig" in their Earth cup, then draw and label their discoveries. As they carefully dig the first layer, they uncover a "fossil" of an organism and another "fossil" in the second layer that will illuminate some of the biological changes of life in Earth's history. They should stop and draw the fossils and the size and color of the surrounding rock on page 9 of their student guide until their cups are empty. Students may want to make separate piles of rock to remember which fossil they found in each layer.

The class then creates a relative geologic timeline based on the organisms' position in the rock layer (Figure 3). Yet, most students are unaware of the meaning behind the organisms' position in the rock layer until they begin to match layers and organisms on the board (Figure 4). To encourage connections to previous activities, ask probing questions such as "Which organism is older/younger? How do you know?"

FIGURE 3: Student drawing of Earth cup



Next, ask students if they notice any patterns on the board, then ask them which organisms must have come first and how they know that other organisms must have preceded humans in Earth's history. Discuss how geologists use faunal succession and relative dating to add detail to the timescale and to extend it to younger and older layers. (*Note:* Students should carefully excavate their cups on newspaper, keeping the different-colored rocks separate, then reassemble their cups exactly the way they found them to help with cleanup and so they can be reused in future classes.)

Day 4: A timeline of Earth history

Next, we connect the relative order of plants and animals to absolute time by placing them on a 4.6-billion-year timeline that extends across the room. To create the timeline, students make a scale on paper to represent geologic time. In small groups, students explore reasonable options to measure 4.6 billion years in equal increments using a piece of cash register roll paper. Students often suggest using 10 cm to represent 1 million years, but this would result in

FIGURE 4: Student Earth cup timeline

an excessively long timeline. To make this point, ask students to determine how many centimeters would be needed to represent 1 billion years using the proposed scale. Ultimately, students will conclude that a good scale tends to be 1 m = 1 billion years.

Subsequently, students glue organisms from a handout (see Online Supplemental Materials) on the timeline. Tape completed timelines along the front of the room so students may compare them to each other and discuss patterns. Students are often surprised by the long spans in time from Earth's formation to the origin of the first oxygen producers to the occurrence of all other life as we know it.

Day 5: Matching rock layers over large distances

On Day 5, students make connections among the stratigraphic succession charts of Bryce Canyon, Grand Canyon, and Zion national parks (see Materials). By comparing layers between different areas, students learn that geologists can use the relative ages of the rocks to compile a complete geologic record and history of Earth.

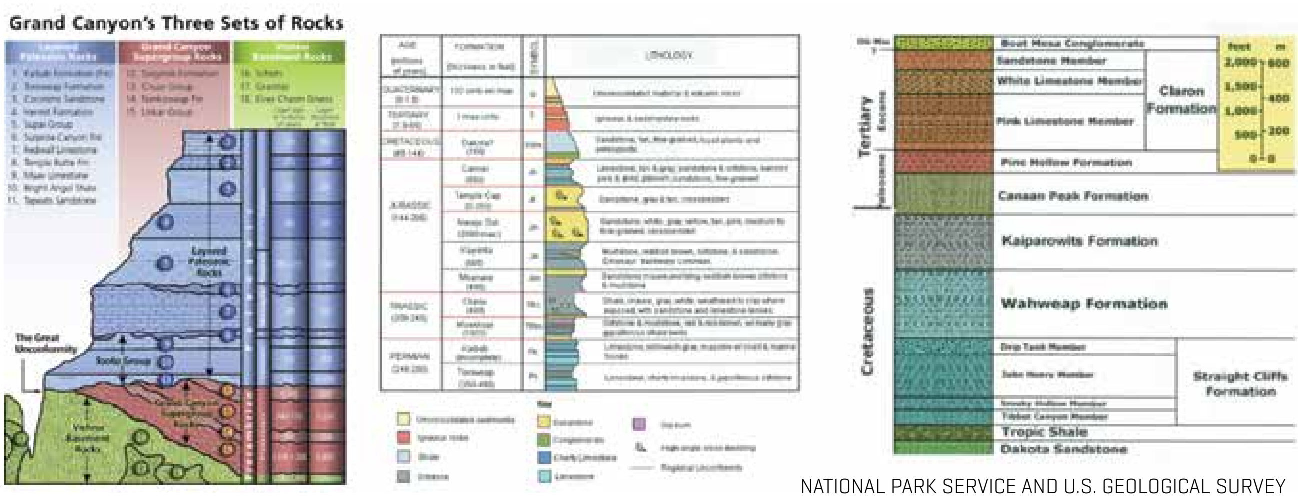
We first lead a class discussion about the data these charts represent. Then, students work together to identify the differences in the rock columns, the variety of rock types, the ranges of geologic time periods, and similarity and differences in fossils. Afterward, students compare and contrast the charts to determine which area has the oldest sequence of rocks and which has the youngest sequence. Here, it is helpful for students to compare the charts by removing them from their student guides and laying them side by side in order to determine the relative ages of the rocks (Figure 5). They should note that the youngest layer in one national park might be the oldest layer in another national park. The result of the correlation creates a stair-stepped pattern in the charts. This process is known as *correlation*.

If students struggle, ask them to recall previous activities, such as the playing card and graduated cylinder activities, where they learned how to determine the oldest and youngest rock layers. After students have determined the oldest and youngest rock layers on the succession charts, they record and explain their thinking using evidence from the charts and knowledge they gained from previous activities. By identifying relationships among rock layers from different locations, students learn how geologists use these layers to create a relative time scale of our past.

Day 6: Building a time scale

Finally, students learn how fossils provide evidence of geologic time and biological change by analyzing

FIGURE 5: Grand Canyon, Zion, and Bryce succession charts



NATIONAL PARK SERVICE AND U.S. GEOLOGICAL SURVEY

Materials

Day and activity	Materials
Day 1: Relative dating of rock layers	• Two different rock samples: fossiliferous limestone and an igneous sample (basalt or granite). Both can be collected on field trips, borrowed from your university geology teacher, or purchased online. • Deck of playing cards. • One hundred mL graduated cylinder filled with 30 mL of water and four or more different types of sand and gravel such as varieties of aquarium gravel, landscaping sand, or local river or beach sand. The graduated cylinder can be purchased online or borrowed from a local science department. Sand and gravel are located in animal specialty and hardware stores and departments.
Day 2: Applying relative ages to layered rocks	• 3D photograph of Grand Canyon's layers (3D glasses are required) (*http://3dparks.wr.usgs.gov/grca/index.html*) • Stratigraphic succession chart (*http://www.stategeologists.org/surveys.php*)
Day 3: Demonstrating changes over geologic time	Earth cups (see Figure 2) contain two different rock layers, each with a fossil buried in it. Cups are made as follows: • Cup 1: bottom layer contains brown gravel with trilobite; top layer contains blue gravel with brachiopod. • Cup 2: bottom layer contains blue layer with brachiopod; top layer contains brown gravel with fish. Continue the pattern of colors and fossils for the remaining cups. Earth cup materials: • Eight clear or frosted 24-ounce plastic cups. • Two 5 lb. bags of sediment: either two different sizes (fine grain and large grain gravel) or two different colors (found in the aquarium supply section of stores) • Models of a trilobite and human • Models of two of each: brachiopod, fish, reptile, amphibian, flower, dinosaur, and mammal. Real fossils are best for the trilobite and brachiopod. (They can be found online, at rock and gem shows, or at university geology departments.) Small plastic kids' toys work well for the other items. (They can be found in the toy section of stores or online). Photos of organisms may also be used. • Newspaper
Day 4: A timeline of Earth history	• Rolls of register tape (one per group) can be purchased online or at office supply stores. • Page of fossils with dates for students to cut out and place on timeline (see Online Supplemental Materials)
Day 5: Matching rock layers over large distances	Stratigraphic succession charts for: • Grand Canyon (*https://3dparks.wr.usgs.gov/coloradoplateau/grandcanyon_strat.htm*) • Bryce Canyon (*https://3dparks.wr.usgs.gov/coloradoplateau/bryce_strat.htm*) • Zion (*https://www.nps.gov/zion/learn/nature/rock-layers.htm*)
Day 6: Building a time scale	• Geologic time scale using index fossils, flora, and fauna • Results and analysis questions

FIGURE 6: Discussion questions

1. What was the point of starting off with the playing cards?
2. What was the point of dropping spoonfuls of sand into the cylinder?
3. Where would you find the layer of sediment that was deposited first in the cylinder (which is the oldest)?
4. Where would you find the layer of sediment that was deposited last in the cylinder (which is the youngest)?
5. Were the layers of sediment deposited as vertical layers, with a gentle diagonal slope, or as horizontal layers?
6. Have you ever seen anything like this out in the real world? If so, what?
7. Think of rivers, beaches, lakes … Do you think their sand layers are deposited as vertical layers, with a gentle diagonal slope, or as horizontal layers?
8. What was the point of looking at a 3-D picture of the Grand Canyon?
9. What was the point of digging the fossils out of the cups?
10. What kind of order did you put the cup drawings in on the board?
11. Can you remember the order that the fossils arrived in? List them youngest to oldest:
12. What was the point of creating the "Earth cup" fossil timeline? How did this timeline compare to the one you made on the paper roll?
13. What was the most surprising realization when you created the paper roll timeline?
14. Why was matching layers across the Arizona-Utah region important?
15. How does matching rock layers demonstrate biological changes over geologic time?
16. What's the big takeaway from the Geologic Time Scale the geologists constructed?

a simple geologic time scale on page 23 of their student guide. The time scale helps students see the progression of the origin and extinction of specific flora and fauna over geologic time; apply their knowledge of the laws of superposition and original horizontality; and solidify the relationship among rock layers, relative dating, index fossils, and biological change. Use reflection questions to cultivate understanding of the appearance and abundance of classes of animals and plants (faunal succession).

In this activity, students also learn about *index fossils*, which are organisms that existed for only a certain period of time and can identify and date the layer in which they are found. To check for student understanding of the meaning and usefulness of index fossils, have them come up with a working definition of the term *index fossil* based on the time scale's information. Then, have students observe these fossils on the absolute timeline to see what sets these fossils apart.

Ideally, students will discover that index fossils have existed for a defined period of time and can be used to identify or date the rock layer in which it is found. Challenge students by asking how index fossils can be used to create a time scale. For example, *mucrospirifers*, a brachiopod, lived from late Devonian (419–359 million years ago) to earliest Mississippian (359–323 million years ago). Ask students when the rocks would have been deposited if they were to find a mucrospirifer embedded in them. To encourage students to make connections between this time scale and preceding activities, ask such questions as:

- What are some of the earliest fossils? (trilobites)
- Most recent? (humans)
- If a geologist found a mucrospirifer and phacops together, in what time period did the rocks form? (late Devonian to earliest Mississippian)
- If a geologist found a mucrospirifer and fossils of a very early shark together, in what time period did the rocks form? (earliest Mississippian)
- What organisms help define the Paleozoic Era? (trilobites)
- What organisms help define the Mesozoic Era? (dinosaurs)
- What organisms help define the Cenozoic Era? (abundant and diverse mammals)

To make sure students understand the concepts they've learned so far, provide an assessment to check for their understanding (see sidebar at right).

Day 7: Discussion

Students conclude the lessons by processing their learning through small-group discussion, and then sharing their thinking with the whole class. See Figure 6 for questions to use during the discussion. The discussion solidifies student understanding of how fossils, rock layers, and Earth's processes help determine the age and geologic history of the Earth and provide evidence that life has changed on the planet. By now, students should be able to:

- place everyday events in relative order.
- informally define laws related to the deposition of sediment in water.
- correlate stacks of layered rocks between different regions.
- place classes of plants and animals in relative order and in the correct geologic era or period.
- create an absolute timeline that places classes of plants and animals in order.

Extended lessons

Although these lessons were designed to cover seven, 60-minute class periods, they can be extended beyond the intended timeframe—on Days 3, 4, and 5 in particular.

On Day 3, students may need more time to synthesize connections between relative dating, the law of original horizontality, and biological evolution. Also on Day 3, you may extend learning by adding additional plants and animals to the activity, investigating a phylogenetic tree for all your favorite organisms (e.g., dinosaurs or cats), or making a connection to local rock layers and their fossils by visiting the website of your state geological survey. On Day 4, students may need guided questions to help them design a workable timeline. On Day 5, you can extend students' thinking through an analysis of stratigraph-

Checking for understanding

Students are asked to reflect on their learning as they answer the following questions. Ideal student answers are in *italics*.

1. How would you explain relative dating as compared to absolute dating? [Relative dating *is a comparison of two rock layers or time periods, such as younger or older, whereas* absolute dating *provides a number of years for the material.*]
2. Based on your observations, describe what it looks like when sediments are deposited. What does this tell geologists about the history of the Earth? [*Sediment is deposited in horizontal layers. This can inform geologists about the relative age of those layers and the history of the location where they are found.*]
3. How do scientists correlate stacks of layered rocks between different regions? What do these layers tell them? [*Geologists correlate rocks between different regions by comparing these layers of rock and the fossils they contain to other layers of rock and their fossils around the world, which can determine which is older or younger.*]
4. Have all classes of plants and animals always existed? How do you know? [*All classes of plants and animals have not always existed. We observed that various plants and animals emerge and become extinct at varying times.*]
5. If scientists were not alive to observe it, how do they know how to place geologic events in relative order? [*Scientists can place geological events in relative order using rock layers/stratigraphic succession, and index fossils.*]

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

- The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectations listed below.

Standard

MS-LS4: Natural Selection and Adaptations
https://www.nextgenscience.org/topic-arrangement/msnatural-selection-and-adaptations

Performance Expectation

MS-LSS4-1. 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.

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practice	
Analyzing and Interpreting Data	Students collect observations during a "fossil dig," analyzing and comparing their data to discover the processes of biological change over geologic time and the technique of relative dating. Students analyze stratigraphic succession charts to deepen their understanding of geologic time and processes.
Disciplinary Core Ideas	
LS4.A: Evidence of Common Ancestry and Diversity • The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossils record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.	Students unearth and observe the presence of various life forms during the "fossil dig." Students create a relative timeline of Earth's history based upon the presence of the "fossil" and the "sedimentary rock layer" the fossil was discovered in.
ESS1.C: The History of the 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. (MS-ESS1-4)	Students analyze and compare a variety of stratigraphic succession charts to interpret geologic time scale from superposition of rock strata.
Crosscutting Concept	
Patterns	Students create visual images of their "fossil dig" observations and use this information as a whole group to create a visual timeline by following the patterns of observed sedimentary rock layers and excavated "fossils." Students model a fossil dig, which allows them to construct a relative timeline based on their findings by correlating rock strata patterns they have previously observed and the occurrence of various organisms through geologic history.

ic succession charts through which they cultivate a deeper understanding of the relationship between Pangea and Earth's geologic and biological history.

Classroom management tips

When formatively assessing students throughout the lessons, use cooperative learning strategies. In the Write Around learning strategy, each group member adds to the learning. The first student in a group creates a written response to a prompt and passes it to the next member in the group to add to the thinking or to clarify or summarize the response. This process continues around the table until all group members have contributed. With the Numbered Heads strategy, individual students in groups receive a number and put their heads together to determine one response; then, one number is called upon to share his or her response.

Strategies such as Team Jigsaw and Tea Party interactive discussions provide opportunities for students to explore and evaluate their thinking. In Team Jigsaw, each student in a group investigates a piece of information. Subsequently, they research the information with members of other groups who were assigned the same topic, then report back to their original group to "piece together" the topic of discussion. Using the Tea Party strategy, students form two circles or two lines facing each other. Ask a question of interest and have students discuss the answer with the student facing them. After one minute, the outside circle or one line moves to the right so that students have new partners. Pose a second question for them to discuss.

Conclusion

After these lessons, students will be able to identify relationships among rock layers of differing locations and explain how geologists use rock layers and fossils to understand the age and geologic history of the Earth. These guided inquiry lessons allow students to make deeper connections, generate new understanding, apply scientific reasoning skills, think and act like scientists, and lay the foundation for their understanding of deep time. ●

ONLINE SUPPLEMENTAL MATERIALS

Handout, teacher guide, and student guide—*www.nsta.org/scope1217*

REFERENCES

Hidalgo, A.J., I.E.S. San Fernando, and I.C.E. Jose Otero. 2004. An analysis of the understanding of geological time by students at secondary and post-secondary level. *International Journal of Science Education* 26 (7): 845–857.

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