Fossils and Relative Dating

MI Content Expectations

- **E.ST.06.31**: Explain how rocks and fossils are used to understand the age and geological history of the Earth (timelines and relative dating, rock layers).
- **E.ST.06.42:** Describe how fossils provide important evidence of how life and environmental conditions have changed.
- **S.IP.06.13:** Use tools and equipment (spring scales, stop watches, meter sticks and tapes, models, hand lens, thermometer, models, sieves, microscopes) appropriate to scientific investigations.
- **S.IP.06.14:** Use metric measurement devices in an investigation.
- **S.IP.06.16:** Identify patterns in data.
- **S.IA.06.12:** Evaluate data, claims, and personal knowledge through collaborative science discourse.
- **S.RS.06.15:** Demonstrate scientific concepts through various illustrations, performances, models, exhibits, and activities.

NGSS

- **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.
- **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.

TYPE OF INQUIRY

These lessons have been designed to engage students in guided inquiry.

TIME

This lesson takes place over the course of six 70 minute class periods, and can be modified based upon curriculum/student needs.

This lesson has been designed to enhance Battle Creek Science 6th grade Unit: Earth: Yesterday, Today, and Tomorrow lesson 8-11 which take place over the course of eight 55 minute class periods

EDUCATIONAL OBJECTIVES

The Learner will be able to:

1. Place everyday events in relative order by analyzing a picture of playing cards and after whole group discussion.
2. Define laws related to the deposition of sediment in water by observing different layers of sediment placed in a cylinder containing water and after whole group discussion.
3. Place classes of plants and animals in relative order by creating a timeline after compiling class data from their "Earth cup" dig.
4. Place classes of plants and animals in absolute order by creating an incrementally correct timeline after small and whole group discussion.
5. Correlate stacks of layered rocks between different regions by analyzing stratigraphic charts of Zion, Bryce Canyon, and the Grand Canyon and answering discussion questions.
6. Explain how index fossils provide evidence of geologic time and biological change by analyzing a geologic timescale and answering discussion questions.

Objectives Addressed by Each Lesson

	Lesson Title and Objectives Addressed	1	2	3	4	5	6
Day 1	Which of these two rocks is older?			X	X	X	X
	Placing Common Events in Relative Order	X					
	Relative Ages of Layered Rocks		X				
Day 2	Relative Ages of Layered Rocks in the Grand Canyon		X				
	Relative Ages of Layered Rocks in Michigan		X			X	
Day 3	Demonstrating Changes in Biological Evolution over Geologic Time		X	X			X
Day 4	A Timeline of Earth History			X	X		X
Day 5	Matching Rock Layers over Large Distances		X	X		X	X
Day 6	Geologists Build a Time Scale		X	X	X		X

CONCEPTS ADDRESSED

- Rock layers and fossils provide evidence about the nature of ancient life and the history of the Earth.
- Rocks, fossils, and Earth's processes help to determine the age and geologic history of the Earth. (Battle Creek Area Outreach Staff, 2009)

COMMON STUDENT DIFFICULTIES

*Lessons designed to address misconception

1. Most students cannot identify useful evidence to place samples in relative order for their age. *Days 1,2,3,4,5,6
2. Most students lack skills in providing a useful, basic description of geologic materials. *Days 1,2,3,4,5,6
3. Most of the students perceive ages in tens, hundreds, or thousands of years, not the more realistic spans of millions or billions of years. *Day 1, 4
4. The history of the Earth is only slightly longer than the time that humans have existed. *Days 5, 6, 8

5. The Earth is only a few thousand years old. * Days 5, 6, 8
6. Fossils do not relate to living organisms. * Days 5, 6, 7, 8
7. Fossils are the actual remains of living things. * Days 5, 6, 7, 8
8. People lived during the same time as the dinosaurs. * Days 5, 6, 7, 8
9. People have lived on Earth for a longer period of time than dinosaur. * Days 5, 6, 7, 8
10. Scientists cannot tell how old rocks and fossils are. * Days 1, 2, 3, 4, 5, 6, 7, 8

(Battle Creek, 2009; Hidalgo, 2004)

PREREQUISITE KNOWLEDGE

Students may have had previous 6th grade instruction in which they learned about the three main types of rocks: sedimentary; metamorphic; and igneous, how these rocks are formed and change within the rock cycle, and how scientists observe, classify, and identify rocks and minerals.

TEACHER BACKGROUND

Purpose of Daily Lessons

Each day consists of student-centered activities designed for students to collect evidence to answer scientific questions.

- Lessons are aligned with NGSS, MI Content Expectations, and learning objectives
- Activities are student-focused, hands-on, inquiry-based, and often done in groups
- Students hypothesize, predict, make observations, collect data, discuss learning
- Includes facilitation questions to probe, guide, and redirect students' thinking or work

Earth Science Background

Three scientific laws were needed before early geologists could begin constructing a geologic time scale.

1. **Original horizontality** (1669, Nicholas Steno) states that layers of sediment that accumulate in water form horizontal layers.
2. **Superposition** (1669, Nichols Steno) states that for a stack of undisturbed sediment or rock layers, the oldest layer is on the bottom and the youngest is on the top.
3. **Faunal succession** (1815, W. Smith) states that fossil organisms (faunas and floras) succeed one another in a definite and recognizable order, each geologic formation having a different total aspect of life from that in the formations above and below it. Meaning, the relative ages of rocks can be determined from their fossil content.

- 1760: Geologists in Italy started describing the rock layers and fossils that were designated the Tertiary (as seen in the Geologic Time Scale provided in Day 6)
- 1795: Jurassic was identified by work in the Jura Mountains of Switzerland
- 1822-1841: Most of these detailed studies of rock layers were completed
- 1879: About 10 geologists working at 11 different sites designated the eleven periods we use today

Creating the geologic timescale can be likened to the analogy of building a staircase, but nailing down the steps in a random order until all were in their proper place.

Fossils provided the evidence needed to match rock layers across the globe. Based on rock types alone, it was difficult to match rock layers between these different locales. Once geologists realized fossils are organized in a systematic way (faunal succession) they had a new tool to apply to matching layers. Geologists could confidently match the top of one rock unit to the base of the next time unit using fossils, thus layers could be correlated across broad regions, even continents, and placed in relative order from the oldest (Cambrian) to youngest (Holocene).

The timescale was tested as geologists explored new areas and new continents. Fossils were always encountered in the same systematic order they had recorded in the time scale.

Since the late 1800s, each period has been divided into smaller units called epochs. The eleven periods have been grouped into layer blocks of time called:

- Paleozoic (ancient life)
- Mesozoic (middle life)
- Cenozoic (recent life)

The end of the Paleozoic and Mesozoic were marked by mass extinctions.

Interestingly, the geologic time scale was developed independently of absolute dating methods for geologic time. Absolute dating of geologic materials was developed in the early 1900s and confirmed the relative time scale. In the last century, geologists have dated materials contained in the periods, verifying, for example, the Paleozoic began 542 million years ago and ended at 248 million years ago.

SAFETY

There are no safety concerns with this lab other than being careful with materials in order to preserve their integrity and careful handling of scissors when creating the timeline.

MATERIALS, PREPARATION, AND DISPOSAL

Day 1:

Which of these two rocks is older?

- Two different geologic specimens, one should be fossiliferous limestone (with Paleozoic fossils) and the other igneous, basalt or granite. Both can be collected on field trips, borrowed from your university geology teacher, or purchased online.

Placing Common Events in Relative Order

- Deck of playing cards or handout (attached in teacher guide)

Relative Ages of Layered Rocks

- Clear plastic or glass graduated cylinder per group
- Several different types of sand
- Spoon per group
- Funnel per group
- Water

Day 2:

Relative Ages of Layered Rocks in the Grand Canyon

- Computer or projection of the image of Geology of National Parks: 3-D Tours Featuring Park Geology found at: http://3dparks.wr.usgs.gov/index.html. (attached in teacher guide)
- Go to Thumbnail Gallery and select Shoshone Point or other locale displaying horizontal, sedimentary rock layers
- Students will need 3D glasses

Relative Ages of Layered Rocks in Michigan

- Handout or an overhead of the stratigraphic column (attached in teacher guide)
- Additional charts can be accessed from the Association of American State Geologists at http://www.stategeologists.org/surveys.php.

Day 3:

Demonstrating Changes in Biological Evolution over Geologic Time

- Eight clear or frosted plastic cups, 24 ounce
- Two 5 pound bags of sediment: either two different sizes (fine grain and large grain gravel) or two different colors (found in aquarium supplies sections of stores)
- Models: one of each: trilobite, human
- Models: two of each: brachiopod, fish, amphibian, reptile, flower, dinosaur, and mammal. Real fossils are best for the trilobite and brachiopod (can be found online, rock and gem shows, or university geology dept.) Small plastic kid's play toys work well for the other items (found in toy section of stores or online)
- Newspaper

Day 4:

A Timeline of Earth History

Per group:

- One roll of adding machine tape
- Scotch tape/glue stick
- Meter stick
- Handouts (attached in teacher guide)
- Scissors

Day 5:

Matching Rock Layers over Large Distances

- Set of handouts for each group of students (attached in teacher guide)

Day 6:

Geologists Build a Time Scale

- Handout or projection of the geologic time scale (attached in teacher guide)

Results and Analysis and Discussion:

- Handouts for each student (attached in teacher guide)

PRELAB ENGAGEMENT / QUESTIONS

Day 1: Relative Dating of Rock Layers

Part 1: Comparing the Age of Two Rocks

The overarching questions for this lab are:
"How do fossils provide evidence that life has changed on the planet?"

"How do rocks, fossils, rock layers, and Earth's processes help to determine the age and geologic history of the Earth?"

Day 1, Part 1: Which of these two rocks is older?

1. Pass two different rocks among the students (one sample is basalt and the other sample is a fossiliferous limestone). Each student should hold each sample. Encourage the students to look closely.
2. Direct the students to **write their response** to the questions in the Data and Observations section of their student guide under "Day 1: Comparing the Age of Two Rocks."
3. As students record their thinking, circulate the room. Encourage students to address each question. Encourage speculation. Look to see the range of answers for each question.
4. After 5-10 minutes, ask the students to spend a couple minutes comparing their responses with a peer.
5. Compile some responses on the board by calling on students.
6. Accept all responses.

Note: In general, the ages of the rocks are irrelevant. This activity is focused of gaining insights into students' prior knowledge and misconceptions.

Common responses (based on previous classes):
T: 1. Which of these two rocks is older?
Basalt/granite: 50% of students
Fossiliferous limestone: 50% of students

T: 2. How do you know?
Basalt/granite: The fossils in the other rock don't look very old…it takes more time for this rock to form…this rock is volcanic without any fossils…this rock contains pores and grooves…it formed over a longer period of erosion…

Fossiliferous limestone: It contains fossils…it takes longer to make…it's been around long enough to make fossils…

T: 3. What additional information might you want?
Where are they from…what type of rock are they…depth sample was taken...what type of fossil is it…how did the rock form

T: 4. Estimate an age, in years, for each rock.
Basalt: based on previous classes, 25 years to 3 million years but, about 50% of the students will suggest the rock is less than a 1,000 years old.

Fossiliferous limestone: based on previous classes, 25 years to 10 billion years but, about 75% of the students will suggest the rock is less than a 1,000 years old.

Invariably, a student will ask "So, which rock is older?" Smile, you have at least one student hooked, and tell them that at some point this year, they will be able to tell you!

PROCEDURE

Day 1: Relative Dating of Rock Layers

Part 2: Placing Common Events in Relative Order

1. Project an image of the playing cards (below) for the students. Or on the overhead, lay down ten playing cards, one on top of the other yet stacked so that each card is visible, allowing for one outlier (see card 2 to the left in the image below).
2. Direct the students to the Procedure/Data and Observations for "Day 1, Part 2" section of their student guide where they will work individually to write their responses to the following questions**.** (Tarbuck et al., 2000).

3. After students have had time to answer the questions on their own, briefly discuss responses as a whole group.

T: 1. Briefly describe the order, from the first card laid down to the last card laid down, reflected in this stack of playing cards.

Order: 2, 10, 3, 7, A, 8, 2, 4, 3, 8 (As seen in the image above)

T: 2. Do all the cards fit neatly within the order? In not, which card is difficult to place within the sequence? Why? When do you think this card was laid down? Cite your evidence.

T: Do all the cards fit neatly within the order?
S: No. The 2 is difficult to place. It is not part of the sequence.

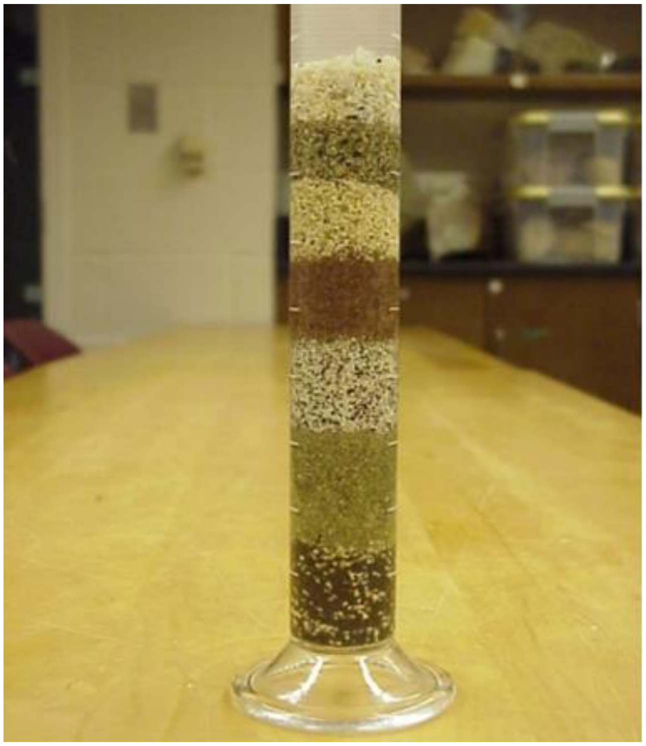
T: When do you think this card laid down?
S: Answers will vary and most will be possible. The 2 could be laid down first, then the sequence or the sequence might be first and then the 2. Perhaps the first few cards of the sequence, then the 2, and the remainder of the sequence.

Key point:
- We commonly infer the relative order of a sequence of events. Some poorly constrained events are difficult to place or compare to know sequences.

T: 3. Can we do this with layers of rocks?
Accept all predictions.

S:Yes, some stacks are straight forward and easy to interpret. However, other single isolated layers without fossils can be hard to interpret for relative age.

Part 3: Relative Ages of Layered Rocks



Teacher Background: Limestone and sandstone are examples of sedimentary rocks. Sedimentary rocks form at the Earth's surface as horizontal layers. Some, but not all, sedimentary rocks form in association with water (sand dunes would be an example of an exception).

This demonstration explores the relative ages of layers that form in water.
Preparation:
a. You will be need a glass graduated cylinder, several types of sand, a funnel, and a spoon.
b. Fill the cylinder about half way with water.

1. Direct the students to the Procedure/Data and Observations for "Day 1, Part 3" section of their student guide where they will write their responses to the following questions, and draw their observations during the progression of the whole group demonstration.
2. Modeling for the whole group, ask a student to come up and add one spoonful of sand to the cylinder. Then ask:

T: What happened to the sand?
S: It fell through the water.
T: What did it make?
S: A layer of sand.
T: What's the shape of the layer?
S: It's flat.
T: Do you mean horizontal?
S: Yes

3. Have a student add a second spoonful of sand to the cylinder, then ask:

T: Which of the sand layers was deposited first (which is the oldest)?
S: The bottom one.
T: Which of the sand layers was deposited last (which is the younger)?
S: The one on top.
T: Are the sand layers deposited as vertical layers, with a gentle, diagonal slope, or as horizontal layers?
S: Horizontal layers.

4. Have a student add a third spoonful of sand to the cylinder, then ask:

T: Which of the sand layers was deposited first (which is the oldest)?
S: The bottom one.
T: How old is the middle layer?
S: It's younger than the bottom layer but older than the top layer.
T: Which of the sand layers was deposited last (which is the youngest)?
S: The one on top.

5. Ask the students to **write at least two brief statements** describing their observations.

Key points:
- Sediment is deposited in horizontal layers.
- The oldest layer is at the base of a sequence. The youngest is at the top.
- For any two adjacent layers, the older one is on the bottom and the younger one is on top.

Day 2: Relative Ages of Layered Rocks

Part 1: Shoshone Point

Visit Geology of National Parks: 3-D Tours Featuring Park Geology at http://3dparks.wr.usgs.gov/index.html. Students will need 3D glasses. Go to Thumbnail Gallery and select Shoshone Point.

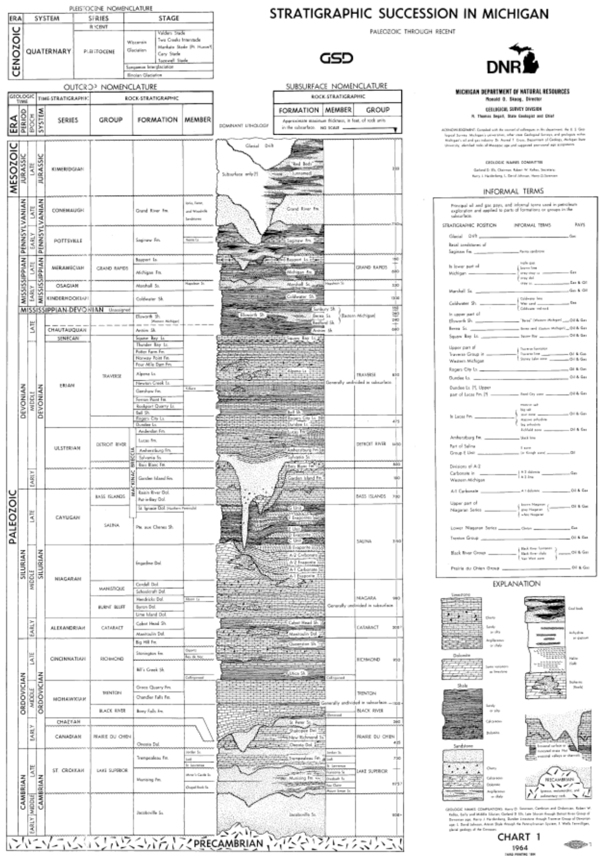
1. Refer students to the Procedure/Data and Observations for "Day 2, Part 1" section of their student guide where they will write their responses to the following questions during a whole group discussion**.**

T: 1. Does anyone recognize this place?
S: It's the Grand Canyon in Arizona.
T: 2. What kind of rocks do you think are in the Canyon?
S: Sedimentary.
T: 3. How do you know?
S: I see layers.
T: I need a volunteer. Can someone show me a layer?
S: Here's a layer.
T: Great can you follow it all the way across the picture? Thank you.
Note: some layers, like the cliff forming units are easier to trace.
T: 4. Which of the layers was deposited first (which is the oldest)?
S: The bottom one.
T: Show me: Note: The youngest layer is just above the deepest gorge. It forms a broad platform at the base of the canyon.
T: 5. Which of the layers was deposited last (which is the younger)?
S: The one on top.
T: Show me. Note: The youngest layer is near the top left and capped by trees. It also caps a small mesa in the top center of the photo.
T: 6. Are the sand layers deposited as vertical layers, with a gentle diagonal slope, or as horizontal layers?
S: Horizontal layers

Part 2: Relative Ages of Layered Rocks in Michigan
Use the chart "Stratigraphic Succession in Michigan" to assess the students' understanding of yesterday's key points:

- Sediment is deposited in horizontal layers.
- The oldest layer is at the base of a sequence. The youngest is at the top.
- For any two adjacent layers, the older one is on the bottom and the younger one is on top.

Remind the students it is much like the column of sand they just made.



Full size, readable version found in student guide.

Image courtesy of Michigan Oil & Gas Producers Education Foundation (MOGPEF) can be found at http://www.mogpef.org/Portals/0/images/stratmap1_full.jpg .
Additional charts can be accessed from the Association of American State Geologists at http://www.stategeologists.org/surveys.php.

1. Direct the students to the Procedure/Data and Observations for "Day 2, Part 2" section of their student guide where they will work with a partner to compose their responses to the following questions**.**

T: This column of rocks represents the layers of sedimentary rocks in Michigan. 1. **What is the oldest rock layer?**
S: Jacobsville Sandstone because it is on the bottom.

T: 3. What is the youngest rock layer?
S: "Red Beds" or Glacial Drift (the drift is a layer but not turned to rock yet) because it is on the top.
T: 5. Which is older, the Grand River Formation (Fm) or Saginaw Formation?
S: The Saginaw Formation.
T: 6. Why do you think this explore is called "Relative Ages of Layered Rocks in Michigan?" Why isn't it called "Absolute Ages of Layered Rocks in Michigan?" Use evidence from the chart to explain your thinking.
S: The chart only shows us how old the rock layers are in "relation" to each other. For example, you can tell that the oldest rock layers must be on the bottom, and the youngest must be on the top. This chart does not tell us absolute age, which would be a specific number, like 1 million years old.

Day 3: Changes in Biological Evolution over Geologic Time

Part 1: "Earth Cup" Excavation

"Earth cup" Models

Prior to class, the teacher must assemble a set of "Earth cups". Each cup contains two rock layers made of sediment/gravel (see photo below). Within each layer there is a fossil that represents the geology of a region. To mimic layers of land sedimentary rocks (shale, sandstone, limestone) we use sand and gravel of different sizes (sand or gravel) or various colors. To represent key flora and fauna, we use real fossils when possible and small plastic figures. The plastic figures can be purchased at toy stores, in the toy section of larger stores, or online. We commonly use the following (in order of appearance): **trilobite, brachiopod, fish, amphibian, reptile, flower, dinosaur, mammal, and a human**. Except for the bottom-most and top-most organisms, two fossils or figures of each organism will be needed.

Preparation:

To assemble the first cup, start with the single specimen of the oldest fossil, the trilobite. Place it in the bottom of the cup and cover it with a layer of sand or gravel, filling the cup only halfway. Place the next oldest organism, one brachiopod, in the cup on top of the bottom layer of sediment. Then, fill the cup with a different type of sediment (either different in size and/or color).

To make the second cup, put the other brachiopod in the bottom of the cup and fill it half-full with the same sediment that formed the top layer in the first cup. Place the next oldest organism, one fish, in the cup on top of the bottom layer of sediment. Then, fill the cup with a different type of sediment (either different in size and/or color).

Fill the remaining cups in a similar way making sure that the fossil and sediment that top off one cup are repeated on the bottom of the next cup (see photo below). The cups will be assembled in a systematic way to reveal the first appearance of an organism on Earth or the common organism of an era.

Procedure/Data and Observations

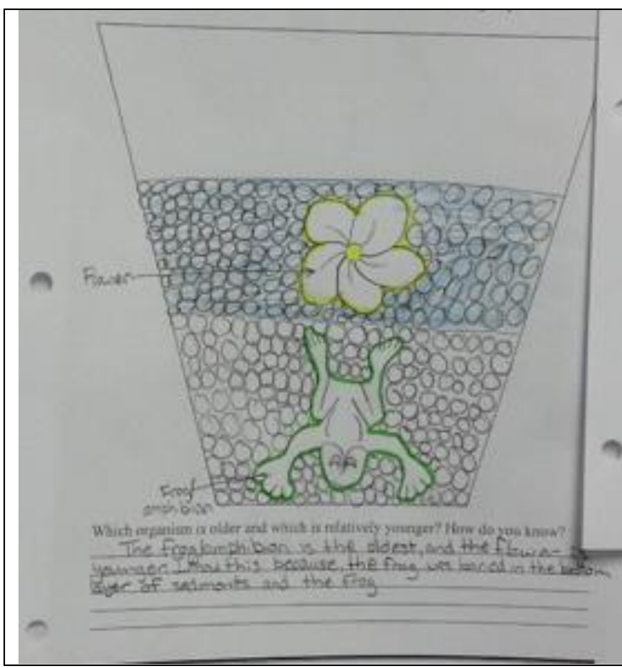
1. Direct the students to the procedure/ Data and Observations for "Day 3, Part 1" section of their student guide, then, to the corresponding "big cup" figure where they will work with their table group to complete the activity**.**
2. Ask a student to read the instructions aloud and assign roles for excavators and re-assemblers.
3. Finish reading the instructions aloud.
4. Distribute the cups randomly to groups of students making sure that each group of four has:
   - One "Earth cup"
   - Two pieces of newspaper (one for each pile of sediment)
   - Two spoons
5. As the first student excavates the top layer of their cup with a spoon, all members of the group record their data (type of sediment and fossil found) by making drawings and observations on the large "cup" in their packet (see example below).

NOTE: It is easier to clean up after the activity if students put the sediment in separate piles on separate sheets of newspaper as they remove it from their cups.

6. The second excavator continues the dig making sure to place the second layer of sediment in a separate pile. Again, all members of the group add to their drawings by making and recording their observations.
7. The re-assemblers each choose a layer and rebuild the cup.

NOTE: Make sure that the cups are re-assembled with the correct layers and fossils on top and bottom. Share with students that it is easiest to bury the fossil if the first is placed on the bottom of the cup and then covered with the first layer. Then the second fossil is placed directly on top of the first layer sediment and buried in the second layer sediment.

8. After recording observations and rebuild are complete, there should be four student drawings, essentially cross-sections, of each of the eight cups.



Part 2: Whole Group Discussion

In Part 2, students will match the layers from different cups (representing different regions) based on the fossils they contain and the characteristics of their sediment (color and/or size).

1. In their groups, ask students to compare their drawings and choose one to be shared with the whole group. Then, ask that student to pull their cup drawing data page out of their packet.
2. Ask one group of students to tape their data (cup observation) near the middle of the board (which cup drawing is used first is not important but **one from the middle** makes the activity go easier).
3. Ask the students to describe their data and state which organism in their cup is older and which is relatively younger.
4. Next, ask which group of students have fossils that match those shown on the board. Two groups should reply (one with a fossil that matches the fossil on the top of the cup on the board and the other that matches the bottom).
5. Again, each student group must describe their data and match it to the appropriate layer to the existing card on the board.
6. Repeat this pattern with the students until they have all presented their data and matched their fossils. When completed the cup observations should form a pattern resembling a flight of stairs with each step defined by a set of matching layers (see example below).

7. Refer students to the Day 3, Part 2: Whole Group Discussion section. Ask students to draw and label our whole group observations and data in the "cups" and to answer the following questions:

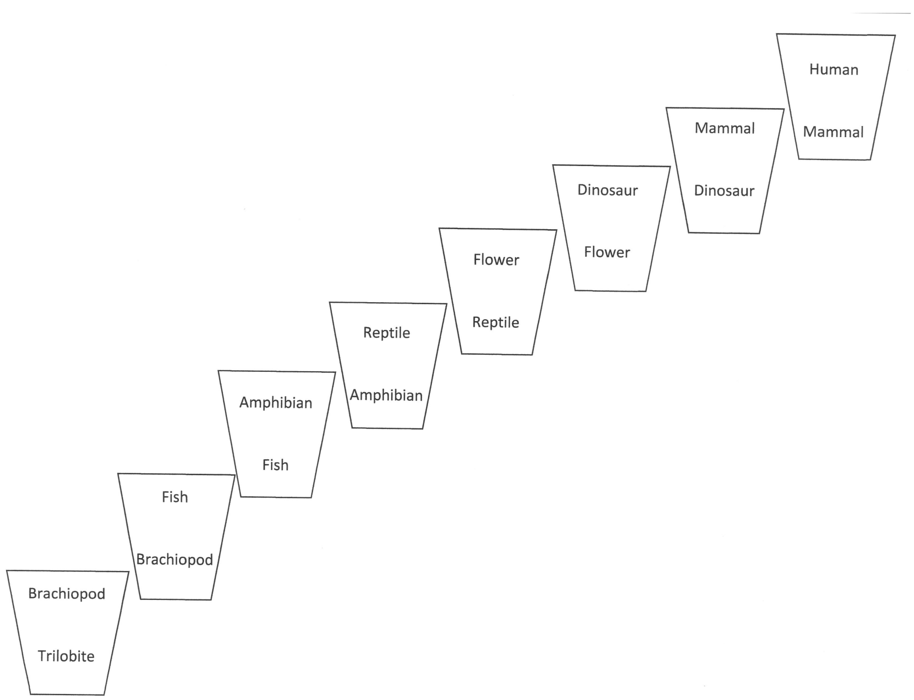
T: 1. Which rock layer is oldest?
S: The one on the bottom.

T: How do you know?
S: In a stack of layered rocks the oldest is on the bottom.
T: 2. Which rock layer is the youngest?
S: The one on the top.
T: How do you know?
S: In a stack of layered rocks the youngest is on the top.
T: 3. Of all these plants and animals which one is the oldest? How do you know?
S: Trilobite. It is on the bottom.

T: 4. Of all these plants and animals which one is the youngest? How do you know?
S: Human. It is on the top.

T: 5. Please list the organisms from oldest to youngest.
S:Trilobite, brachiopod, fish, amphibian, reptile, flower, dinosaur, mammal, and a human.
T: 6. Which of these organisms seem familiar?
S:All should be familiar except the trilobite and the brachiopod.
T: 7. Which of these organisms are you seeing for the first time?
S: For most, the trilobite and the brachiopod.
T: 8. Which of these organisms are extinct?
S: Trilobite, most brachiopods, dinosaurs.

"Earth Cup" Dig Class Timeline Answer Key



Day 4: A Timeline of Earth History

Part 1: Designing a Timeline

(Introduction)

T: In the last activity, we used our simple rules (what we've learned) about the relative ages of layers of rocks to determine the order that major classes of animals became abundant in Earth history. Ask students to explain what these simple rules are. What did they do to place the cups in order to create a relative timescale? A: Students matched cups from many different "regions" by matching corresponding rock layers and fossils. **In this activity we'll revisit the relative order of plants and animals in both relative time (first, second, etc…) and in an absolute time (millions of years) frame.**

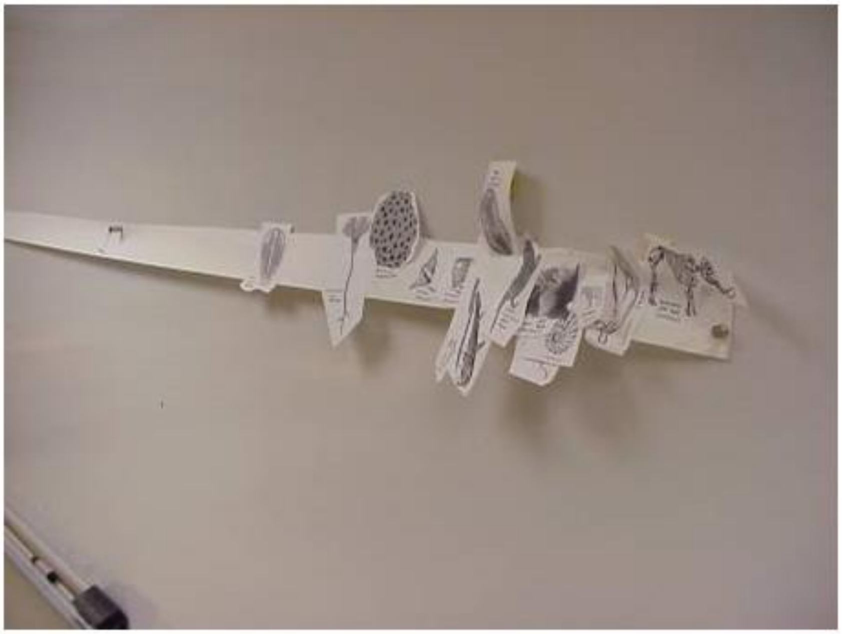
1. Direct the students to the "Day 4" procedure/Data and Observations section of their student guide where they will work with their table group to design their timeline plan, **in pencil.** Then, we will discuss our calculations and make any necessary changes before creating our timelines.

T: We need to make a scale to represent all of geologic time, the time from the formation of the Earth to the present. Geologists have used the radioactive decay of unstable elements to determine an absolute age for the Earth. The age of the Earth is 4.6 billion years old. How can we create a scale to represent all that time on one piece of paper that will fit in this classroom?

NOTE: At this point students are usually stumped. I begin by connecting to other absolute timelines they may have made in the past. Many students have created a timeline of their life. I then ask them to draw an example on the board and to show their unit of measure. Most commonly, their unit of measure is counting by single years. I ask if it would make sense to make the timeline of their life and count by seconds. Of course not, that measure would be too small. I ask if it would make sense to measure their life timeline in increments of decades and they see that unit of measure is too big. This is a good stepping stone for students to problem solve how to create the timeline of the Earth. Let them struggle, and ask them lots of guiding questions to think through their units of measure.

S: I think we should use 1 meter equals 1 million years.
T: Let's think it through. How long would our paper need to be?
S: There are 1,000 million in a billion. So, we'd need 1,000 meters times 4.6 = 4,600 m. That won't fit in the classroom.
T: Any other ideas?
S: I think we should use 1 meter equals 1 billion years.
T: Are you sure? How long would our paper need to be?
S: If 1 meter equals 1 billion years, we'd need 1 meter times 4.6 = 4.6 m. That will fit.
T: If 1 meter equals a billion years, what does 10 cm equal?
S: 10 cm is one-tenth of a meter, so one-tenth of a billion = 100 million.
T: If 10 cm equals 100 million years, what does 1 cm equal?
S: 1 cm is one-tenth of a decimeter, so one-tenth of 100 million = 10 million
T: If 1 cm equals 10 million years, what does 1 mm equal?
S: 1 mm is one-tenth of a centimeter, so, one-tenth of 10 million = 1 million.
T: Great! Measure out about five meters of adding machine tape. Then cut out the fossils. Note each one tells you when that organism lived. Work out the scale on the paper (mark

one end "0" to represent today and measure back 4.6 meters to mark of 4.6 billion years ago. Place each fossil at the appropriate absolute age along the scale.



2. When students have finished their timelines, have them tape them up on the board.
3. Refer students to Day 4, Part 2: Timeline of Earth History Discussion, to answer the following questions:

Part 2: Timeline of Earth History Discussion

T: Ok class, what do you notice?
S: They don't all look the same. Some groups must not have used accurate measurements.
T: Let's look at the top three timelines. 1. What general patterns can you describe?
S: Everything is pushed to one side.
T: What do you mean?
S: Well, most of the animals we know have only been around the last 500 million years or so.
T: What about before about 500 million years ago?
S: Not much. Just the Precambrian Stromatolite.
T: Stromatolite is a fossil made by blue-green algae. It represents the most common life on the planet from about 3.8 billion to about 500 million.
T: 2. Do you recognize any fossils similar to the ones we saw in the "Earth cup" dig?
S: Yes: dinosaurs, plants, trilobites, brachiopods, and fish
T: 3. Are the fossils on this timeline in the same order that we saw when we dug them out of the cups of gravel? What's the order?
S: Trilobites, brachiopods, fish, plants, and dinosaurs
T: In conclusion, direct students to complete summary question #4.

Key points:

- Most of Earth's history was dominated by simple life, blue green algae.
- About 560 million years ago, bigger organisms became abundant (trilobites and brachiopods).
- Since then, life has changed from more ancient forms (trilobites and brachiopods) to reptiles (and dinosaurs), to mammals, and then to humans.

Day 5: Matching Rock Layers across a Region

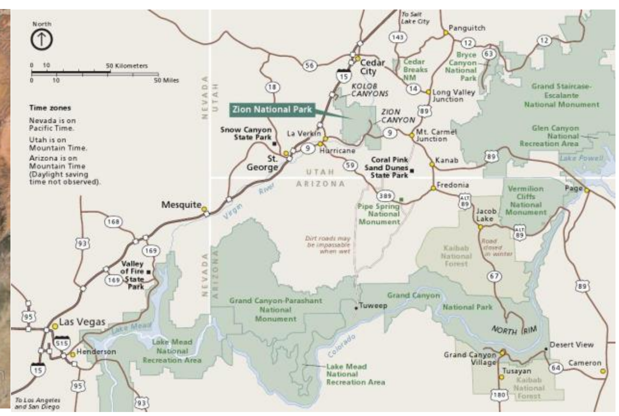
Part 1: Comparing Stratigraphic Succession Charts

1. Refer students to the procedure for Day 5, Part 1: Comparing Stratigraphic Succession Charts where they will work with a partner, spend a couple of minutes looking over the columns, then answer the questions in the data and observations section of their student guide.

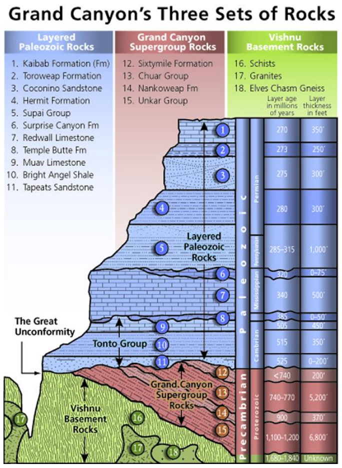
T (Introduction): Class, I want you to spend some time thinking about how geologists work to understand how the Earth has changed over long periods of time. A typical geologist will select an area that she is interested in studying and spend years or decades slowly and methodically making measurements, collecting and analyzing rocks, doing laboratory work, and making maps. If the rocks are layered, there will also be stratigraphic columns like we saw on Day 1 in the glass cylinder, and Day 2 for Michigan. In fact, for almost any place on earth, geologists have made stratigraphic columns and maps.

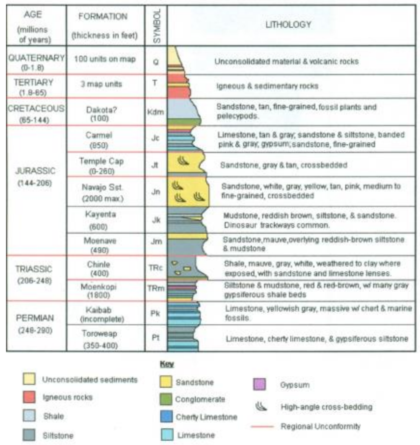
In this activity, we will match columns of rock from three different locations in Arizona and Utah. The locations are the Grand Canyon, Zion National Park (Utah), and near Bryce Canyon National Park (Utah).

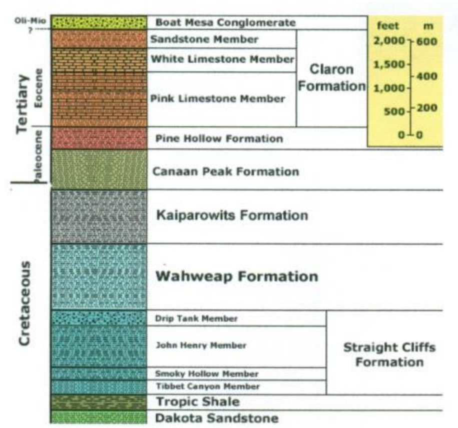
Overview of Park's Relative Locations:



Stratigraphic Succession Charts of Grand Canyon, Zion, and Bryce National Parks:







Full size, readable versions with references found in student guide.

Part 2: Questions for Comparing Stratigraphic Succession Charts

T: What types of data do these charts show?
S: Rock type.
T: Such as…
S: sandstone, lava, gypsum, limestone…
T: What else do you notice?
S: There are some ages.
T: What do you mean?
S: I see Cretaceous.
T: What's the Cretaceous?
S: It's the time when dinosaurs lived.
T: Great. The words to the left side of the columns, like Permian, Triassic, Jurassic, Cretaceous, and Tertiary…refer to time periods that geologists designated for certain layers of rocks.
T: Anything else?
S: The column for Zion mentions fossil plants.
T: Good. There is a bit of fossil data.
T: Anything else?
S: Some of the layers have names.
T: What do you mean?
S: Navajo Sandstone, Carmel Formation.
T: Right. Geologists divide the layers based on the type of rock (sandstone, limestone, etc) and characteristics like color (red-brown, pink, etc) and other features (cross-beds, fossils, oil seeps).

T: Ok, put your columns side-by-side. See if you can find layers that matchup between the different places.
Possible hints:

- **What are the oldest and youngest rocks in each column?**
- **Do you see the youngest rocks in some columns at the base (oldest layers) of other columns?**

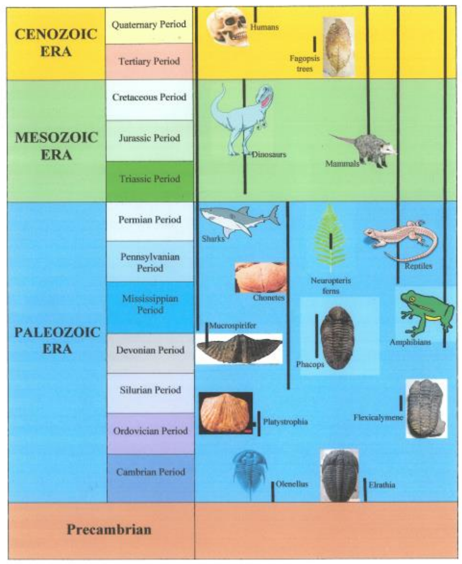
T: What sequence of rocks is oldest?
What sequence of rocks is youngest?
Which set of layers is in the middle? Be ready to support your answers.
T: What sequence of rocks is oldest?
S:The one from Grand Canyon because it has layers older than the Toroweap and Kaibab limestones.
T: What sequence of rocks is youngest?
S: The one from Bryce Canyon because it's lowest layer is the Dakota Sandstone and that is younger than the Carmel Formation layers.
Which set of layers is in the middle?
S: The one at Zion. The Toroweap and Kaibab limestones are at the base and the Dakota Sandstone is towards the top.
T: Great. What time eras are represented by this three stacks of rocks?
S: Precambrian and Paleozoic Era at the Grand Canyon, Permian Period through Quaternary Period at Zion would be mostly Mesozoic Era, and the Cretaceous Period and Tertiary Period at Bryce would be part of the Cenozoic Era.
T: How does this activity compare to some of the previous activities.
S: Well, we matched layers.
T: How?
S: By type of rock and the position of layers.
T: What else?
S: We put layers in order, from oldest to youngest.
T: Do you think the fossils in these rocks follow any patterns?
S: No, because we didn't have many fossils on the handouts, only "fossil plants."
Or Yes, They should occur in the same sequence we determined in the last activity.

PROCEDURE / DATA AND OBSERVATIONS

Day 6: Geologists Build a Time Scale

Part 1: Time Scale Analysis

1. Refer students to the procedure for Day 6, Part 1 where they will work with a partner to analyze a simplified time scale and answer the questions in the data and observations section of their student guide.



Full size, readable version found in student guide. Based on Busch (2000) and others. All fossil figures are public domain from sites such as Wikipedia

T: 1. What types of rocks were used to construct the time scale?
S: Index Fossils

T: 2. What are the three eras (time intervals), in order from oldest to youngest, that contain abundant fossils?
S: Paleozoic, Mesozoic, and Cenozoic

T: 3. What in the name of the era (time intervals) prior to the presence of abundant fossils?
S: Precambrian

T: 4. What are two organisms that were abundant in the Paleozoic that went extinct before the Mesozoic?
S: Trilobites and Brachiopods

T: 5. What are two organisms that first appeared as fossils in the Paleozoic that have survived to the present day?
S: Sharks, reptiles, and amphibians

T: 6. Which appeared first in the fossil record, amphibians or reptiles?
S: Amphibians

T: 7. What is one type organism that was abundant in the Mesozoic that went extinct before the Cenozoic?
S: Dinosaurs

T: 8. What are organisms were abundant in the Cenozoic?
S: Mammals, reptiles, amphibians, and sharks

T: 9. When did Hominid fossils appear first in the fossil record?
S: In the Cenozoic

At the conclusion of the Day 6 discussion, ask students to complete the "Result and Analysis" portion of their study guide for homework and be prepared to share their thinking in class tomorrow.

DATA

When reviewing student lab packets, I am looking for evidence that students are recording observations in relation to the overarching questions of the lab:

1. "How do fossils provide evidence that life has changed on the planet?"
2. "How do rocks, fossils, rock layers, and Earth's processes help to determine the age and geologic history of the Earth?"

Each lesson was designed to target specific learning objectives (listed at the beginning of this teacher guide) in order to develop a scientifically sound explanation for the overarching questions of the lab.

Day 1: Most students are easily able to construct accurate responses, observations, and drawings for all activities.

Day 2: The 3-D engagement activity is well worth the time as it well serves students as a connection to the previous days learning. Many students struggle with reading the stratigraphic succession chart in Part 2 as most have never analyzed charts like these before. After circulating among groups and asking the guiding questions that are listed in the student guide, most are able to correctly answer the questions and have gained analytical and communication skills.

Day 3: Students really enjoy the Earth cup excavation and produce high quality drawings with descriptions when told that only one drawing from each group will be selected for Part 2. Be careful to model the correct disassembling and reassembly of the cups to save yourself time and frustration. The greatest learning takes place during Part 2 when students are able to make a connection between what they have learned about relative layers and index fossil location when collaborating to make the relative timeline.

Day 4: The creation of this timeline is a difficult task, and it is a great time to let students struggle. I once went almost an hour allowing students to problem solve, and the sense of accomplishment when they determined a valid increment of measure was almost better than the creation of the timeline itself. Once the increment of measure has been determined and students begin construction, they often struggle with an end of time to begin with. Allow them to discuss this in their groups and determine what is best for them. Students are most struck by the bunched, outbreak of flora and fauna so close to current time.

Day 5: This activity has posed the greatest challenge to my students. They need a lot of guidance about what they are observing. A whole group discussion of what can be observed on each chart may be of use if your group is giving up. Literally have them match up each map side by side for questions 5-9. For question 10, students may or may not know the difference between an era and a period of time, and this may present a teachable moment for the group.

Day 6: Seeming, this activity is simple. However, I have observed students needing guidance with the starting and stopping points of index fossils on the chart.

RESULTS AND ANALYSIS

1. How would you explain relative dating as compared to absolute dating?

   Look for understanding that relative dating is a comparison of two time periods such as younger or older whereas absolute dating provides a specific date or time period such as an era or period.

2. Think back to the lessons that you've done and describe what it looks like when sediments are deposited. What does this tell Geologists about the history of the Earth?

   Look for understanding that sediments deposit in horizontal layers and that this can inform geologists about the relative age of those layers and the area that they are found in. For example, older layers would be found on the bottom and younger layers would be found on top and you can compare these layers/columns of rock to other layers/columns of rock around the world to determine which is older or younger.

3. Can scientists correlate stacks of layered rocks between different regions? What does these layers tell them?

   Look for understanding that geologists CAN correlate rocks between different regions because they did that using the National Parks stratigraphic succession charts. By comparing these layers/columns of rock to other layers/columns of rock around the world, we can determine which is older or younger.

4. Have all classes of plants and animals always existed? How do you know?

   Look for understanding that all classes of plants and animals have not always existed because if they had, then all of the plants and animals in the cups, or on the timelines would have arrived together much earlier and this is not what we observed. 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?

   Look for understanding that scientists can place geological events in relative order using rock layers/stratigraphic succession, and index fossils.

DISCUSSION

Refer students to the Discussion section of their student guide. Have them work together to answer the questions and review the answers as a whole group.

Explain:

T: Ok, class, let's review what we've learned about geologic time. Have we discussed how geologists date rocks in specific absolute numbers, such as millions of years?
S: No, not really. We did see some numbers on the timeline but we didn't talk about how they were determined.

T: We have been focused on relative time, just putting simple events in order. We'll learn more about absolute time soon.

T: 1. What was the point in starting off with the playing cards?
S: That simple events could be put in relative order.
T: 2. What was the point in dropping spoonfuls of sand into the cylinder?
S: That simple events could be put in relative order.

T: Can you be more specific?
S: Sure. We could assign a relative order to the time the layers formed.

T: 3. Which of the sand layers was deposited first (which is the oldest)?
S: The bottom one.

T: 4. Which of the sand layers was deposited last (which is the younger)?
S: The one on top.

T: 5. Were the sand layers deposited as vertical layers, with a gentle diagonal slope, or as horizontal layers?
S: Horizontal layers.

T: 6. Have you ever seen anything like this?
S: What do you mean?

T: 7. Rivers, beaches, lakes…do you think their sand layers are deposited as vertical layers, with a gentle slope, or as horizontal layers?
S: They seem parallel to the earth's surface so I guess I'd say horizontal.

T: Congratulations! You have just worked out two simple laws!

1. **The first law is called the Law of Original Horizontality. It states that for undisturbed layers of sediment (sand, mud, etc…) and sedimentary rocks, the layers are deposited (laid down) as horizontal layers. "Undisturbed" means the rocks haven't been tilted or overturned by a fold.**

2. **The second law is called the Law of Superposition. It states that for two adjacent rock layers, the oldest is on the bottom and the youngest in on top.**

These laws were figured out by Nicholas Steno in the 1660s.

T: 8. I had you look at a 3D picture of the Grand Canyon. Why?
S: So we could see layers.
S: So we could see the old layers at the bottom and the young layers at the top.
T: Right. So you could apply the laws to a real geologic setting.

T: Layers of sedimentary rock are pretty common. So, now you can interpret the geology of many of the parks and places you might visit when you get older.

T: We also applied these two simple rules to the Earth cups.
T: What did you dig out of cups?
S: Fossils.
T: 9. What was the point?
S: We could put fossils in order.

T: 10. What kind of order did we use to put the cups on the board?
S: Relative order, from old to young.
T: Right. So we used a simple model to show how geologists help us look at biological evolution over long spans of geologic time.

T: 11. Do you think you could remember the order that the fossils arrive inform youngest to oldest?
S: Old stuff first like trilobite and brachiopod, dinosaurs in the middle, and mammals last because they are the most recent.

T: 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?
S: We learned that you can use rock layers and fossils to create a relative timeline.
S: And, that life has been around for a long time but it was pretty simple, algae, for most of Earth history.

T: 13. What was the most surprising realization when you created the paper roll timeline?
S: That lots of kinds of life showed up at the end of the timeline.
T: Such as?
S: Like trilobites, Petoskey Stones, and brachiopods.
T: What else?
S: Then fish, dinosaur, and mammals…
T: Great. Did you see this somewhere else?
S: Sure, when we dug out the pots.

T: 14. Why was matching layers across the Arizona-Utah region important?
S: Well it showed that only one place didn't tell us the whole story.
T: What do you mean?
S: Well, one place only has so many layers.
T: And how much time does one place represent?
S: Only a certain amount.
T: So why match layers between different places?
S: Because you can add to the top and bottom of your local time scale.
T: Exactly! It is a way to look for patterns in rocks over longer spans of time.
In the mid- to late 1800's geologists in Europe, England and Russia began describing the layered rocks in their areas and correlating the layers between regions.
The data the geologists gathered consisted of the first and last appearance of specific fossils and the physical characteristics of the sedimentary rock.

T: 15. How does matching rock layers demonstrate biological changes over geologic time?
S: You can tell how old a rock layer is by comparing it to other layers. So, if you find a fossil in a rock layer, you can know how old the fossilized organism must have been. Fossils are in the rocks, and if you compare/match rock layers, you can tell how old the rocks and fossils are, and can see how organisms must have changed over time.

T: You got it! Once the early geologists had their rock correlation of Europe, England, and Russia complete, the changes in flora and fauna clearly demonstrated biological changes over geologic time, a basic premise for the emerging hypothesis of evolution, and provided geologists with a time scale.

T: 16. What's the big take away from the Geologic Time Scale the geologists constructed?
S: Well, if I have a certain type of fossil I can place it in the correct relative order or know what time period it is from.

T: Such as?
S: Trilobites are only from the Paleozoic and dinosaurs are from only the Mesozoic.

T: The timescale that we looked at in class was a very simple version of what geologists have really discovered. The amount of detail of what we know is far beyond what we observed. For example, we could show one specific chart that details just the dinosaurs of the Mesozoic era.

GOING FURTHER

Extension Activities:

- Research famous fossil localities
- Research their favorite ancient organism(s) and place it on the timeline
- Research rules for collecting fossils on federal lands
- PhET interactive simulations: radioactive dating game; natural selection

ASSESSMENT

Provided is a list of possible assessments:

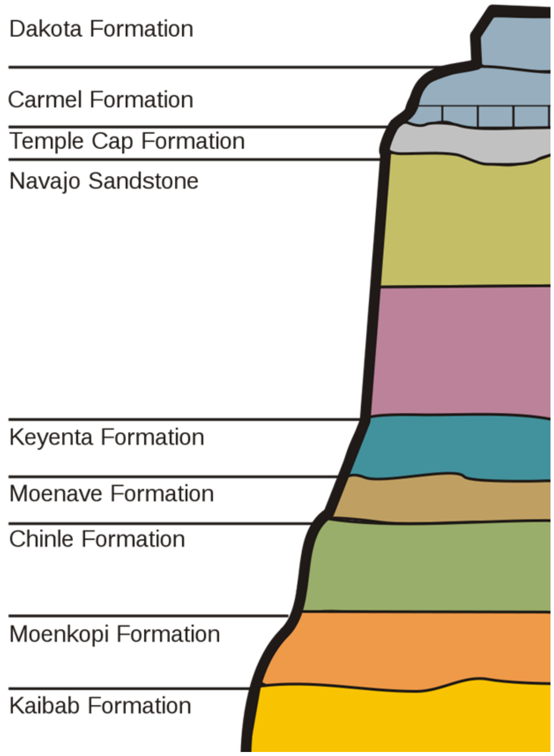
Assessment 1. **Exit Slip:**
Did humans live at the same time as the dinosaurs? How do you know? Provide specific examples/evidence from one of our daily activities to support your thinking.

Assessment 2. **Scientific Explanation:**
Choose and answer one of the following overarching questions:

1. "How do fossils provide evidence that life has changed on the planet?"
2. "How do rocks, fossils, rock layers, and Earth's processes help to determine the age and geologic history of the Earth?"

Write your response providing a claim, evidence, and reasoning. You may use your lab packet help guide your thinking. Use specific evidence from the daily activities. Use the scientific vocabulary and principles we covered in the discussion section.

Assessment 3. **Relative Ages of Rocks:**
The diagram below shows some rock formations in Utah. Examine the column and use it to answer the questions below.



What kind of rocks do you think are shown?

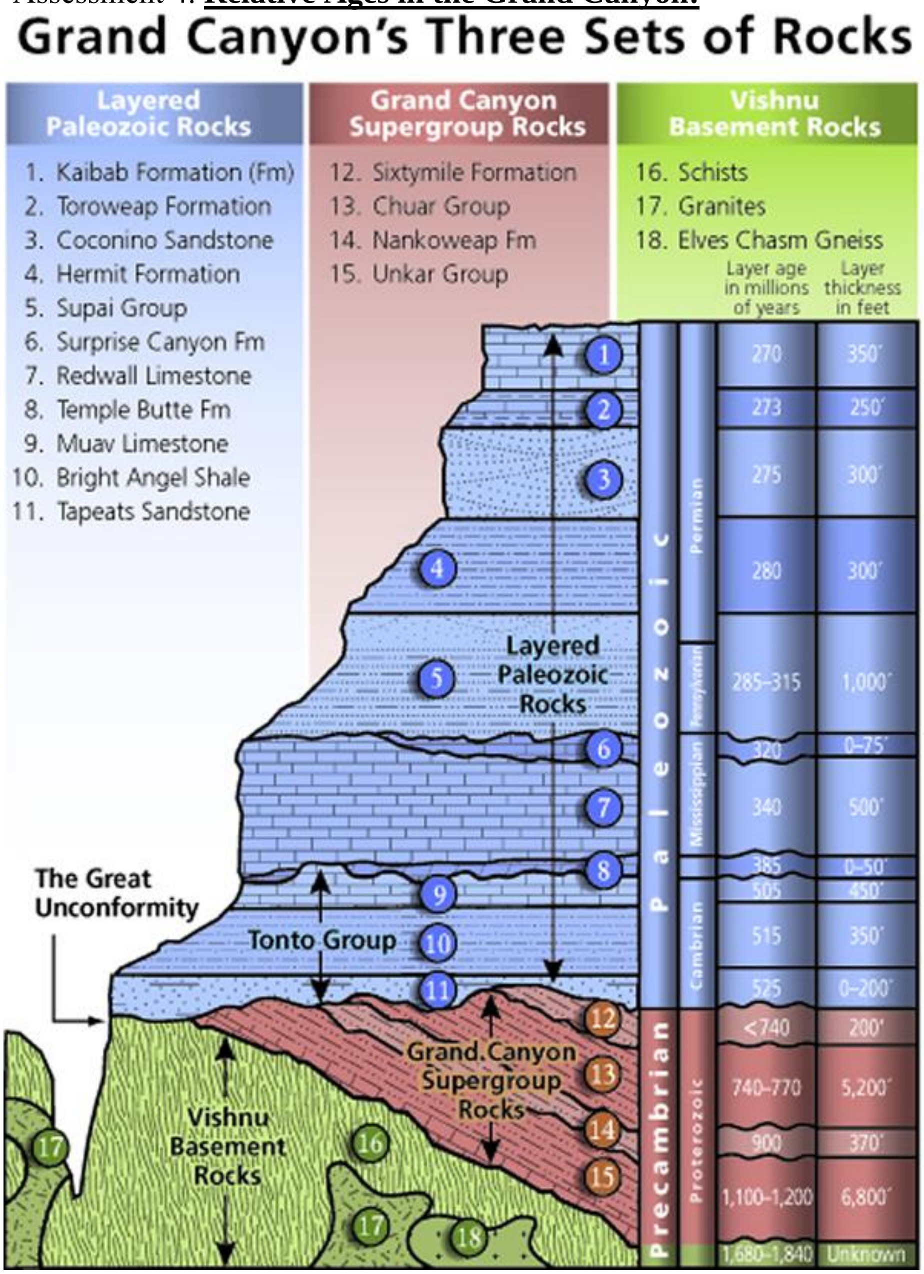
How do you know?

Which of the layers was deposited first (which is the oldest)?

Which of the layers was deposited last (which is the younger)?

Are the sand layers deposited as vertical layers, with a gentle slope, or as horizontal layers?

Assessment 4. **Relative Ages in the Grand Canyon:**



- What is the name of the oldest GROUP of rocks? How do you know?
- What is the name of the youngest GROUP of rocks? How do you know?
- What is the name of the oldest SEDIMENTARY rock layer?
- What is the name of the youngest SEDIMENTARY rock layer?
- Are the SEDIMENTARY layers positioned vertically, with a gentle slope, or as horizontal layers?
- Describe, in your own words, the geologic laws that allow you to put these layers in order?

ANSWER KEY FOR ASSESSMENT ACTIVITIES

Assessment 1. **Exit Slip:**
Did humans live at the same time as the dinosaurs? How do you know? Provide specific examples/evidence from one of our daily activities to support your thinking.

Humans did not live at the same time as dinosaurs. I know this because we created an absolute timeline where dinosaurs appeared much before even the first mammals and humans did not even appear on the timeline at all. This makes me think that the dinosaurs had to have been extinct when humans arrived. Which is also what we saw on the index fossil chart and when we did the Earth cup dig.

Assessment 2. **Scientific Explanation.**
Choose and answer one of the following overarching questions:

1. "How do fossils provide evidence that life has changed on the planet?"
2. "How do rocks, fossils, rock layers, and Earth's processes help to determine the age and geologic history of the Earth?"

Use your preferred rubric for grading explanations.
Claim must answer the question correctly.
Evidence must be cited directly from the lab using specific examples to support the claim.
Look for reasoning including Law of Superposition, Original Horizontality, and Faunal Succession.

Assessment 3. **Relative Ages of Rocks**

What kind of rocks do you think are shown?
Sedimentary

How do you know?
Layers are present. Plus, it names the sedimentary rock "sandstone."

Which of the layers was deposited first (which is the oldest)?
The bottom one, Kaibab Formation.

Which of the layers was deposited last (which is the younger)?
The one on top, Dakota Formation.

Are the sand layers deposited as vertical layers, with a gentle slope, or as horizontal layers?
Horizontal layers

Assessment 5. **Relative Ages in the Grand Canyon**

What are the oldest sedimentary rock layers?
The Proterozoic layers: conglomerate and Bass Dolomite up to the Dox Sandstone

What is the name of the oldest sedimentary rock layer?
The conglomerate below the Bass Dolomite

Are the layers vertical layers, with a gentle slope, or as horizontal layers?
A gentle slope

Are the sand layers deposited as vertical layers, with a gentle slope, or as horizontal layers?
Horizontal

What are the youngest sedimentary rock layers?
The Tapeats to Kaibab

What is the name of the youngest sedimentary rock layer?
The Kaibab

Are the layers vertical layers, with a gentle slope, or as horizontal layers?
Horizontal

Are the sand layers deposited as vertical layers, with a gentle slope, or as horizontal layers?
Horizontal

Describe, in your own words, the geologic laws that allow you to put these layers in order?
The first law is called the law of original horizontality. It states that for undisturbed layers of sediment (sand, mud, etc…) and sedimentary rocks the layers are deposited (laid down) as horizontal layers.

The second law is called the law of superposition. It states that for two adjacent rock layers the oldest is on the bottom and the youngest in on top.

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Image: Zion Formation: "Zion-Nationalpark-Gesteinsschichten" by Stefan-Xp - Own work. Licensed under CC BY-SA 3.0 via Commons - https://commons.wikimedia.org/wiki/File:Zion-Nationalpark-Gesteinsschichten.svg#/media/File:Zion-Nationalpark-Gesteinsschichten.svg

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