Fossils and Relative Dating

OBJECTIVES

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

PROBLEM / QUESTION

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?

PRIOR KNOWLEDGE

What you know about the following: Record your thinking

Fossils:____

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The age of rocks: ____

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What were the first forms of life on Earth and when were they here? When did other life forms arrive? What were they and in what order were they first observed?

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If a bunch of sediment is dropped into water, what happens to the sediment? How does the sediment deposit in water? fossils, the age of rocks, and the origin of different organisms on Earth?

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PREDICTIONS

If we dig down and explore the layers of rocks in an area, what patterns might we see? Could we find fossils? If so, what patterns might we observe about the fossils in the rock layers?

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SAFETY

Students should handle all materials with respect. In particular, we will be using gravel and you should take care to make sure all the gravel gets put back in the cups.

MATERIALS

- This student guide packet: charts, tables, data recording sheets, and interim assessment
- 3-D glasses, 3-D images found at: http://3dparks.wr.usgs.gov/index.html
- "Earth" cup, newspaper, spoon

BACKGROUND INFORMATION

Fossils are the remains or evidence of a plant or animal from the remote past.

The term "fossil" comes from the Latin *fossilis* which means "obtained by digging." All fossils, both discovered and undiscovered, and how they are placed in *fossiliferous* (fossil-containing) rock formations and sedimentary layers (strata) is known as the *fossil record*.

The study of fossils across geological time, how they were formed, and the evolutionary relationships between different organisms are some of the most important functions of the science of paleontology. The youngest fossils range in age from ~10,000 years to the oldest fossils: cyanobacteria from Archaean rocks of Western Australia, dated 3.5 billion years old!

The observation that certain fossils were systematically associated with certain rock strata led early geologists to recognize a geological timescale in the 19th century. The development of radiometric dating techniques in the early 20th century allowed geologists to determine the numerical or *"absolute" age* of the various strata and fossils found within each layer. (Fossil, n.d.)

PROCEDURE / DATA AND OBSERVATIONS

Day 1: Relative Dating of Rock Layers

Part 1: Comparing the Age of Two Rocks

Observe the two rock samples as they are passed around the room and answer the following questions:

1. Which of these two rocks is older?

2. How do you know?

3. What additional information might you want to determine their age?

4. Estimate an age in years for each rock.

Part 2: Placing Common Events in Relative Order

On your own, analyze the picture of the playing cards below and answer the questions.

1. Briefly describe the order of the cards, from the first card laid down to the last card laid down.

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

3. Can we do this with layers of rocks?

Part 3: Relative Ages of Rock Layers

Follow along with the class as we observe how sediment moves through water and what happens. Draw and label observations in the long rectangle, and answer the questions on the side as we explore how rocks from layers over time.

DRAW AND LABEL WHAT YOU OBSERVE

ANSWER THE QUESTIONS AS WE GO ALONG

What happened to the sand?

What did it make?

What was the shape of the layer?

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

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

How old is the middle layer?

Write at least two brief statements summarizing your observations:

____

____

Day 2: Relative Ages of Layered Rocks

Part 1: Shoshone Point

Using your 3-D glasses, observe the photo at Shoshone Point (Image from US Geologic Service: http://3dparks.wr.usgs.gov/grca/south_rim/html/gc1789.htm). Follow along with the class to answer the questions that follow.

Shoshone Point

1. Do you recognize this place? If so, what is it called? If not, what's your best guess?

2. What kind of rocks do you think are found here?

3. How do you know?

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

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

6. Are the sand layers deposited as vertical layers, with a gentle slope/diagonally, or as horizontal layers?

Part 2: Relative Ages of Layered Rocks in Michigan

With a partner, analyze the "Stratigraphic Succession in Michigan," (chart on the following page from: Eddy, G.E. Michigan Department of Conservation, Geological Survey Division http://ngmdb.usgs.gov/Prodesc/proddesc_90398.htm). Follow the instructions, and answer the questions below:

- Take a few minutes and discuss with a partner what you observe about the chart.
- Look at the column of rocks near the middle of the chart. These rocks represent the layers of sedimentary rocks in Michigan.

1. How does this picture remind you of the column of sand that we made as a whole class?

2. What is the oldest rock layer?

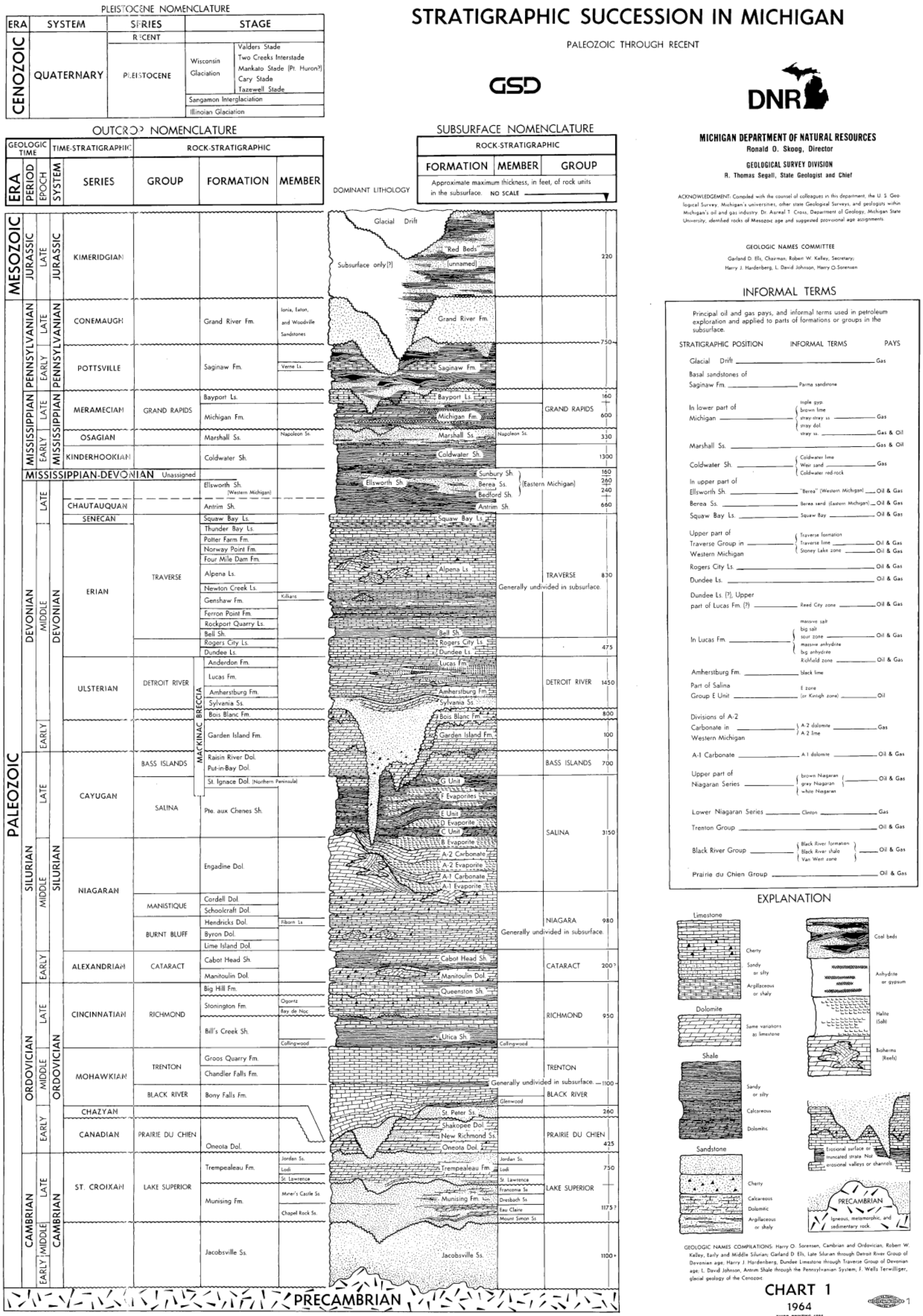
3. How do you know?

4. What is the youngest rock layer?

5. How do you know?

6. Which is older, the Grand River Formation (Fm) or Saginaw Formation?

7. 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.


STRATIGRAPHIC SUCCESSION IN MICHIGAN
PALEOZOIC THROUGH RECENT
GSD
DNR
MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Ronald O. Skoog, Director
GEOLOGICAL SURVEY DIVISION
R. Thomas Segall, State Geologist and Chief
PLEISTOCENE NOMENCLATURE
ERA
SYSTEM
SERIES
STAGE
CENOZOIC
QUATERNARY
RECENT
PLEISTOCENE
Wisconsin Glaciation
Valders Stade
Two Creeks Interstade
Mankato Stade (Pt. Huron?)
Cary Stade
Tazewell Stade
Sangamon Interglaciation
Illinoian Glaciation
OUTCROP NOMENCLATURE
SUBSURFACE NOMENCLATURE
GEOLOGIC TIME
TIME-STRATIGRAPHIC
ROCK-STRATIGRAPHIC
ERA
PERIOD
EPOCH
SYSTEM
SERIES
GROUP
FORMATION
MEMBER
DOMINANT LITHOLOGY
Approximate maximum thickness, in feet, of rock units in the subsurface. NO SCALE
MESOZOIC
JURASSIC
KIMERIDGIAN
PALEOZOIC
PENNSYLVANIAN
CONEMAUGH
POTTSVILLE
MISSISSIPPIAN
MERAMECIAN
OSAGIAN
KINDERHOOKIAN
MISSISSIPPIAN-DEVONIAN Unassigned
DEVONIAN
CHAUTAUQUAN
SENECAN
ERIAN
ULSTERIAN
SILURIAN
CAYUGAN
NIAGARAN
ALEXANDRIAN
ORDOVICIAN
CINCINNATIAN
MOHAWKIAN
CHAZYAN
CANADIAN
CAMBRIAN
ST. CROIXAN
PRECAMBRIAN
INFORMAL TERMS
EXPLANATION
Limestone
Dolomite
Shale
Sandstone
Coal beds
Anhydrite or gypsum
Halite (Salt)
Bioherms (Reefs)
CHART 1
1964

Day 3: Changes in Biological Evolution over Geologic Time

Part 1: "Earth Cup" Excavation

Your group will be given a cup of "Earth" containing sedimentary rock layers and fossils.

Two of you will have the job of "digging" out the layers, and two of you will have the job of reassembling the cup when finished.

List the two excavators: ____

List the two re-assemblers: ____

EACH of you must record your observations on and answer the questions that follow.

Step 1: Excavate the first layer of your "Earth" cup. Use the spoon and place the first layer in a pile on the newspaper. Use the large, blank cup on the next page to record your data (fossil and type of sediment) by making drawings, coloring, and labeling your observations.

Step 2: Repeat the same procedure with the second layer.
NOTE: It is easier to clean up after the activity if you put the sediment in separate piles on newspaper as you remove it from your cup.

Step 3: After ALL group members have drawn and labeled their observations (**use the cup outline on the next page**), reassemble the bottom layer making sure to place the correct fossil on the bottom and then cover it with the correct layer of sedimentary rock.

Step 4: Repeat the same procedure reassembling the top layer.

When all cups have been reassembled and all observations are complete, we will have a whole group discussion, completing the table of vertical cups, and answering the discussion questions.

For your cup: Which organism is older and which is younger? How do you know?

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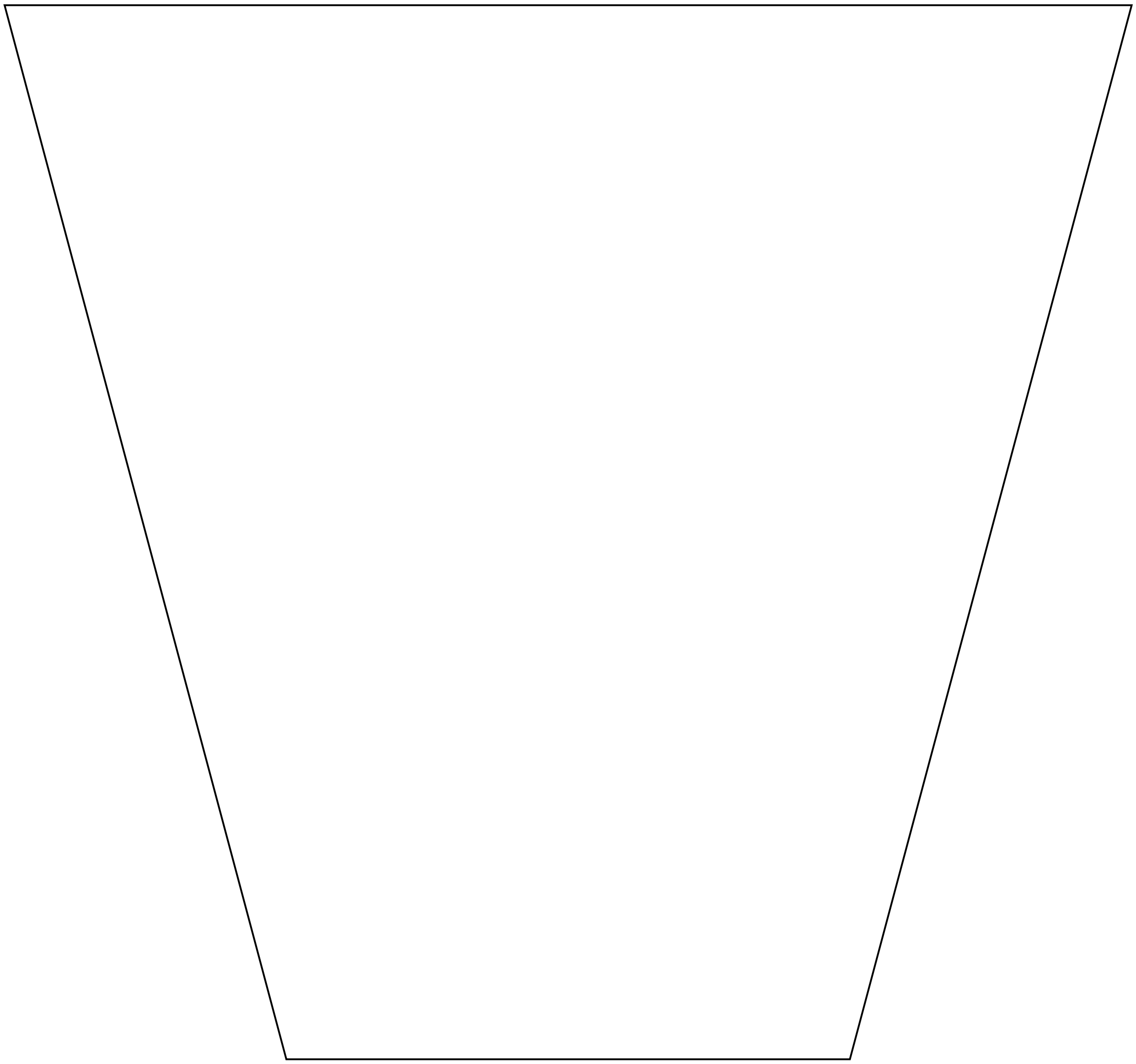
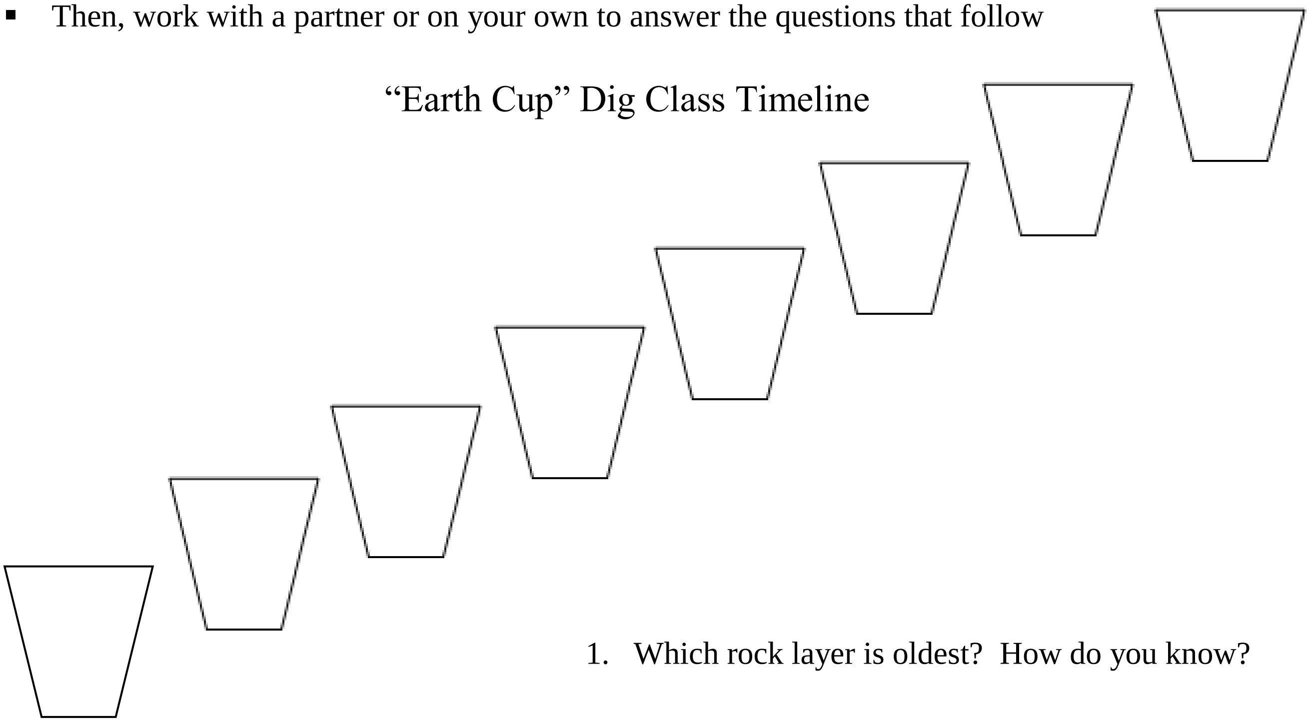
Draw and label the rock layers and fossils that you and your group observe in the cup below.



Part 2: Whole Group Discussion

- As we share our findings, record class data below
- Then, work with a partner or on your own to answer the questions that follow

“Earth Cup” Dig Class Timeline



1. Which rock layer is oldest? How do you know?
2. Which rock layer is the youngest? How do you know?
3. Of all these plants and animals which one is the oldest? How do you know?
4. Of all these plants and animals which one is the youngest? How do you know?
5. Please list the organisms from oldest to youngest.
6. Which of these organisms seem familiar?
7. Which of these organisms are you seeing for the first time?
8. Which of these organisms are extinct?

Day 4: A Timeline of Earth History

Part 1: Designing a Timeline

You will make a scale to represent ALL of geologic time, the time from the formation of the Earth to the present.

- Working with your group, use the guide below to develop a plan for creating your timeline.

Geologists have used the radioactive dating (measuring the decay of unstable elements) to determine an *absolute* age for the Earth. The age of the Earth is 4.6 billion years.

Using a meter stick and a roll of register paper, can you think of a time scale we can use so that we represent all 4.6 billion years on one piece of paper that will fit in this classroom?

Use a pencil, and play with some measurements:

1 meter = ____ years.

How long would our paper need to be? _________________________________

If 1 meter = ________________________ years, we need 1 meter x ________
We will need ________________________meters of paper.

If 1 meter =_________________________years, how many years does 10 cm equal?

Hint: Think in fractions ☺

10 cm = what fraction of a meter? ____________________________________
So, 10 cm = _________________________ years.

If 10 cm = __________________________ years, what does 1 cm. equal?

1 cm = what fraction of a decimeter? __________________________________
So, 1 cm = __________________________years.

If 1 cm = ___________________________ years, what does 1 mm. equal?

1 mm = what fraction of a centimeter? _________________________________
So, 1 mm = __________________________years.

Part 2: Assembling the Timeline

Now you are ready to work with your table group to create your timeline!

- Measure out the adding machine tape
- Apply the scale you created to the paper
  - Mark one end "0" to represent TODAY and measure back to mark every billion years (1 billion, 2 billion, etc…) until you reach 4.6 billion years ago.
- Cut out the fossils with their absolute age (bya: billion years ago, mya: million years ago)
- Place each fossil at the appropriate absolute age along the scale.

When finished, tape your timeline to the board and help other groups if needed.

Part 3: Whole Group Discussion Questions

Looking at the top three timelines that we voted to be the best:

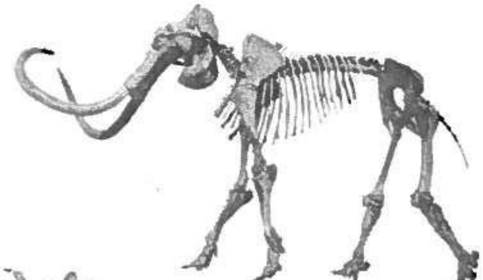
1. What general patterns can you describe?

2. Do you recognize any fossils similar to the ones we saw in the "Earth cup" dig?

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?

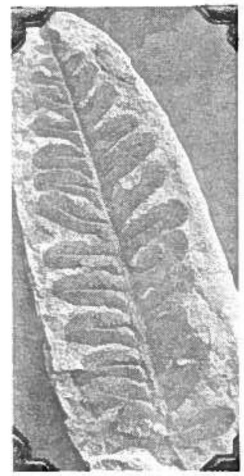
4. Using the timeline you created today and what we learned from yesterday's dig, what can you determine about changes in life over geologic time?

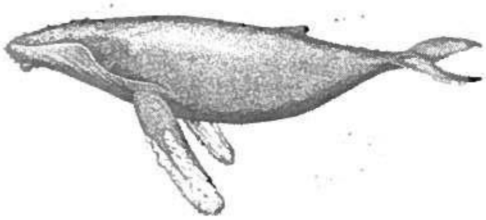
Precambrian Stromatolite – 2.2 bya



Quaternary – 200k yrs ago

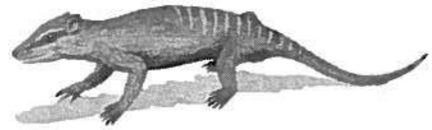
Pennsylvanian Fern – 300 mya



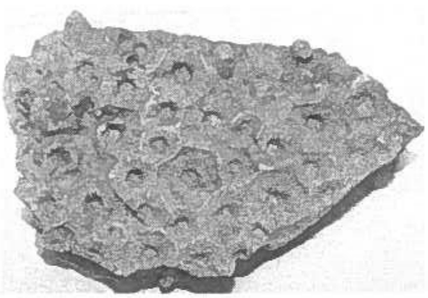


Quaternary – 1 mya

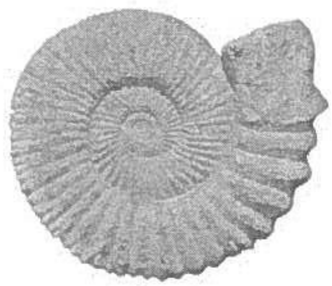
Ordivician-Silurian Crinoid – 440 mya



Jurassic first mammal – 200 mya



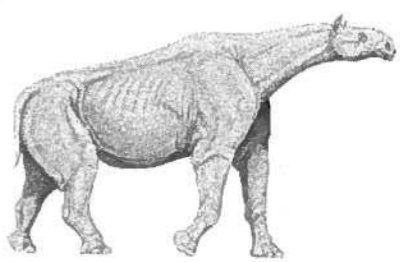
Devonian Hexagonaria – 380 mya



Cretaceous

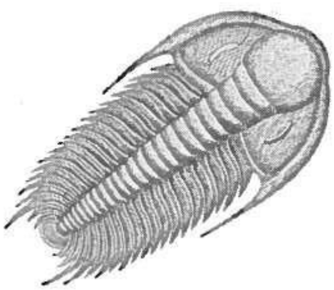
Jurassic Archaeopteryx – 150 mya

Devonian Mucrospirifer – 375 mya

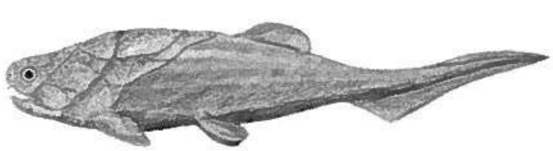


Miocene – 20 mya

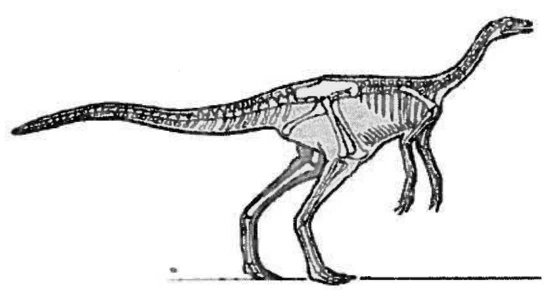
Devonian Heliophyllum – 360 mya



Cambrian Trilobite – 525 mya



Devonian Protitanichthys – 350 mya



Cretaceous Struthiomimus – 100 mya

Day 5: Matching Rock Layers across a Region

Part 1: Comparing Stratigraphic Succession Charts

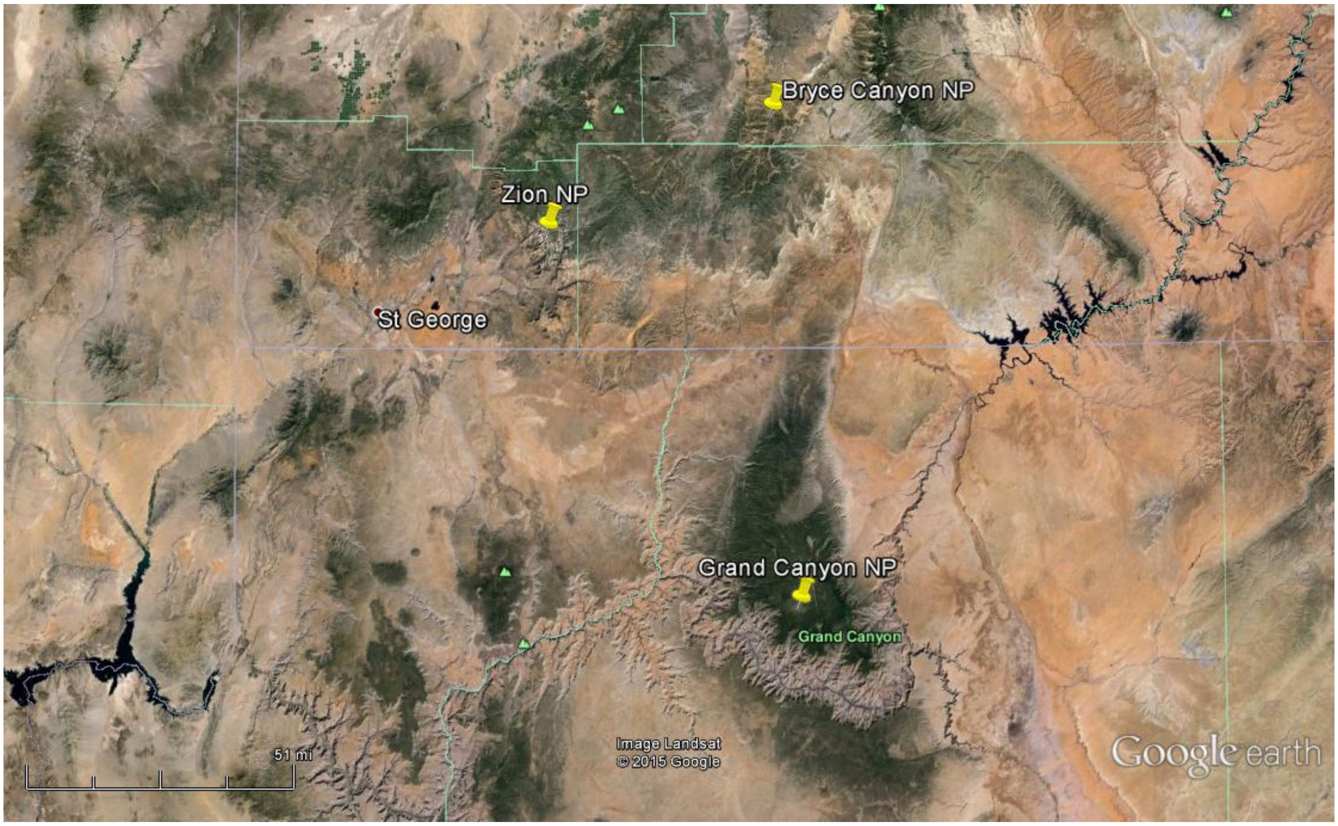
Spend some time thinking about how geologists work to understand how the Earth has changed over long periods of time.

A geologist will typically select an area that he or 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. For almost any place on Earth, geologists have made stratigraphic columns and maps.

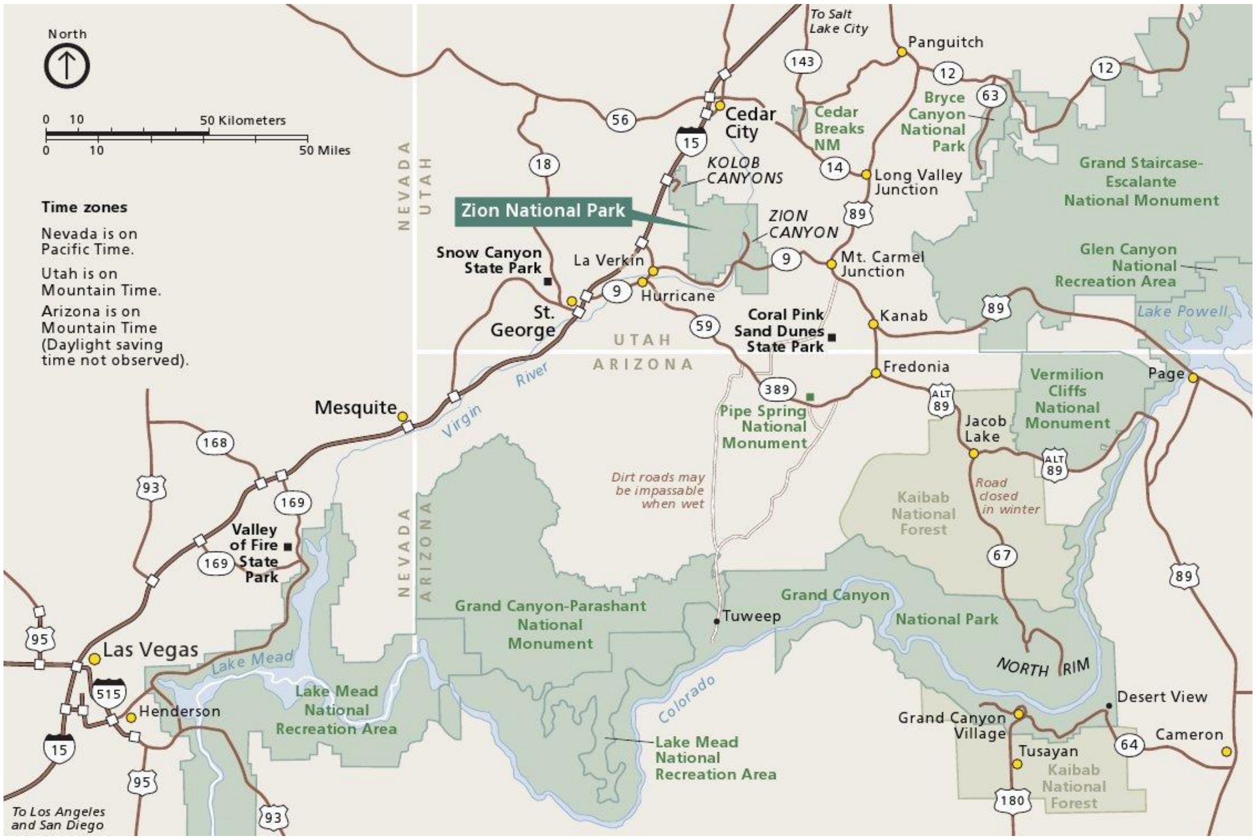
In this activity, you will analyze and compare columns of rock from three different locations in Arizona and Utah. The locations are:

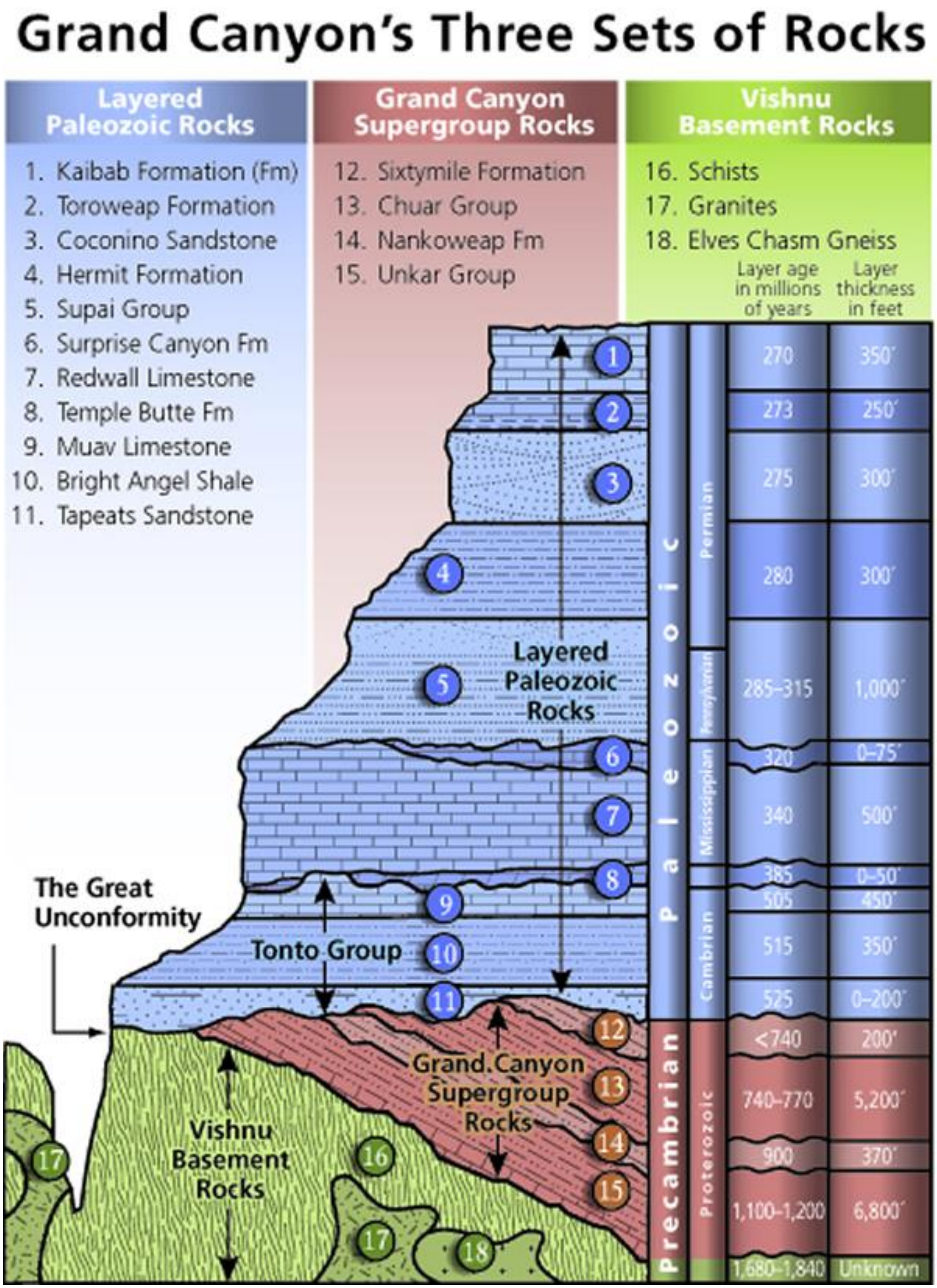
- The Grand Canyon (Arizona),
- Zion National Park (Utah)
- Bryce Canyon National Park (Utah).

You and a partner will analyze the map(s) above and the following rock column charts of the Grand Canyon, Bryce Canyon National Park, and Zion National Park to make observations and answer the questions that follow.



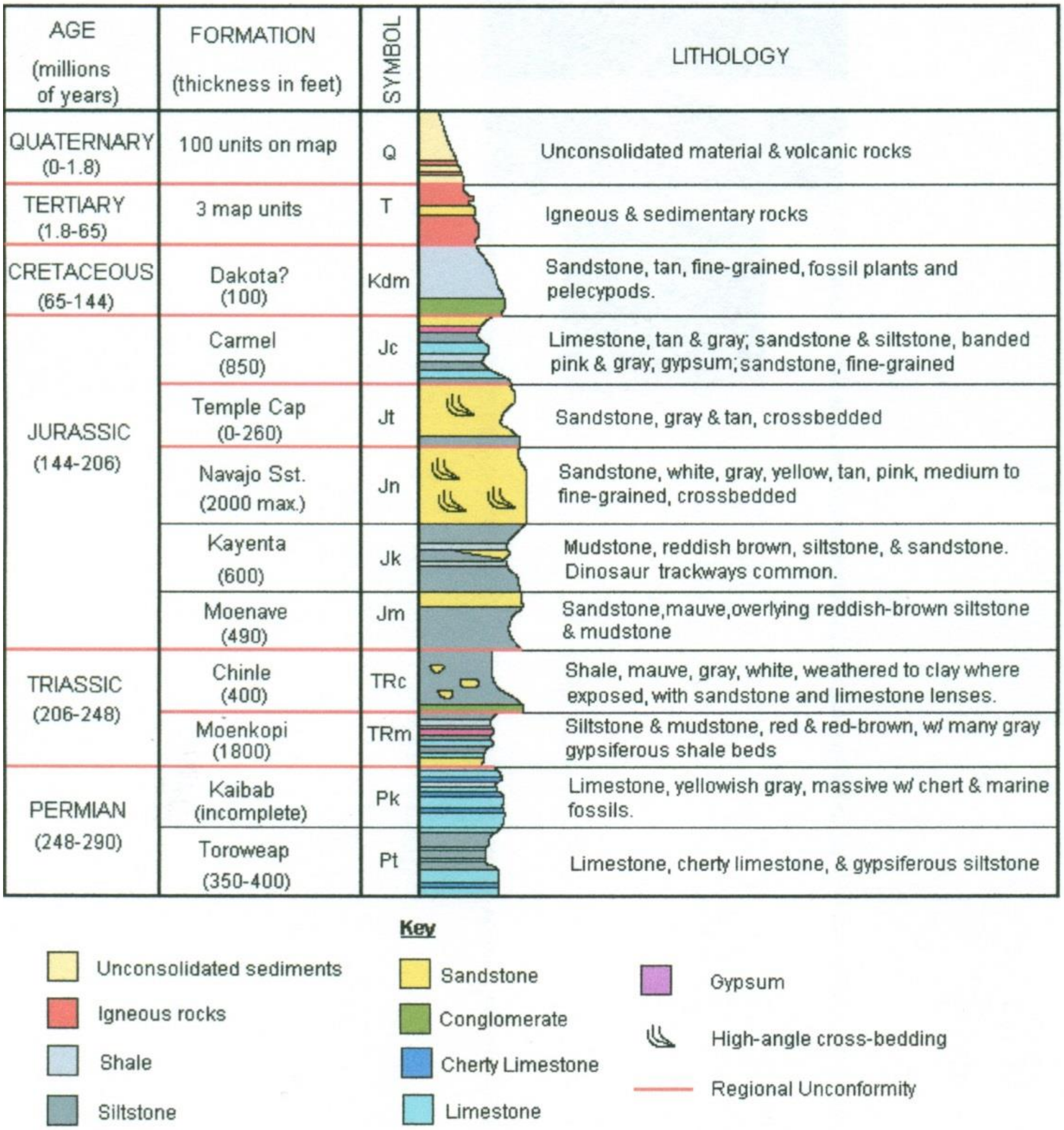
Relative location image of Bryce, Grand Canyon, and Zion National parks from: https://www.backroads.com/trips/MBGQ/bryce-zion-grand-canyon-biking-hiking-tour


North
0 10 50 Kilometers
0 10 50 Miles
Time zones
Nevada is on Pacific Time.
Utah is on Mountain Time.
Arizona is on Mountain Time (Daylight saving time not observed).
NEVADA
UTAH
ARIZONA
Zion National Park
To Salt Lake City
Panguitch
Cedar City
Cedar Breaks NM
Bryce Canyon National Park
KOLOB CANYONS
ZION CANYON
Long Valley Junction
Grand Staircase-Escalante National Monument
Glen Canyon National Recreation Area
Lake Powell
Snow Canyon State Park
La Verkin
Hurricane
St. George
Mt. Carmel Junction
Coral Pink Sand Dunes State Park
Kanab
Fredonia
Page
Mesquite
Virgin River
Pipe Spring National Monument
Vermilion Cliffs National Monument
Jacob Lake
Dirt roads may be impassable when wet
Road closed in winter
Kaibab National Forest
Valley of Fire State Park
Las Vegas
Lake Mead
Henderson
Lake Mead National Recreation Area
Grand Canyon-Parashant National Monument
Tuweep
Grand Canyon National Park
NORTH RIM
Colorado
Desert View
Grand Canyon Village
Tusayan
Cameron
To Los Angeles and San Diego



http://www.nature.nps.gov/geology/parks/grca/age/image_popup/yardstick.htm

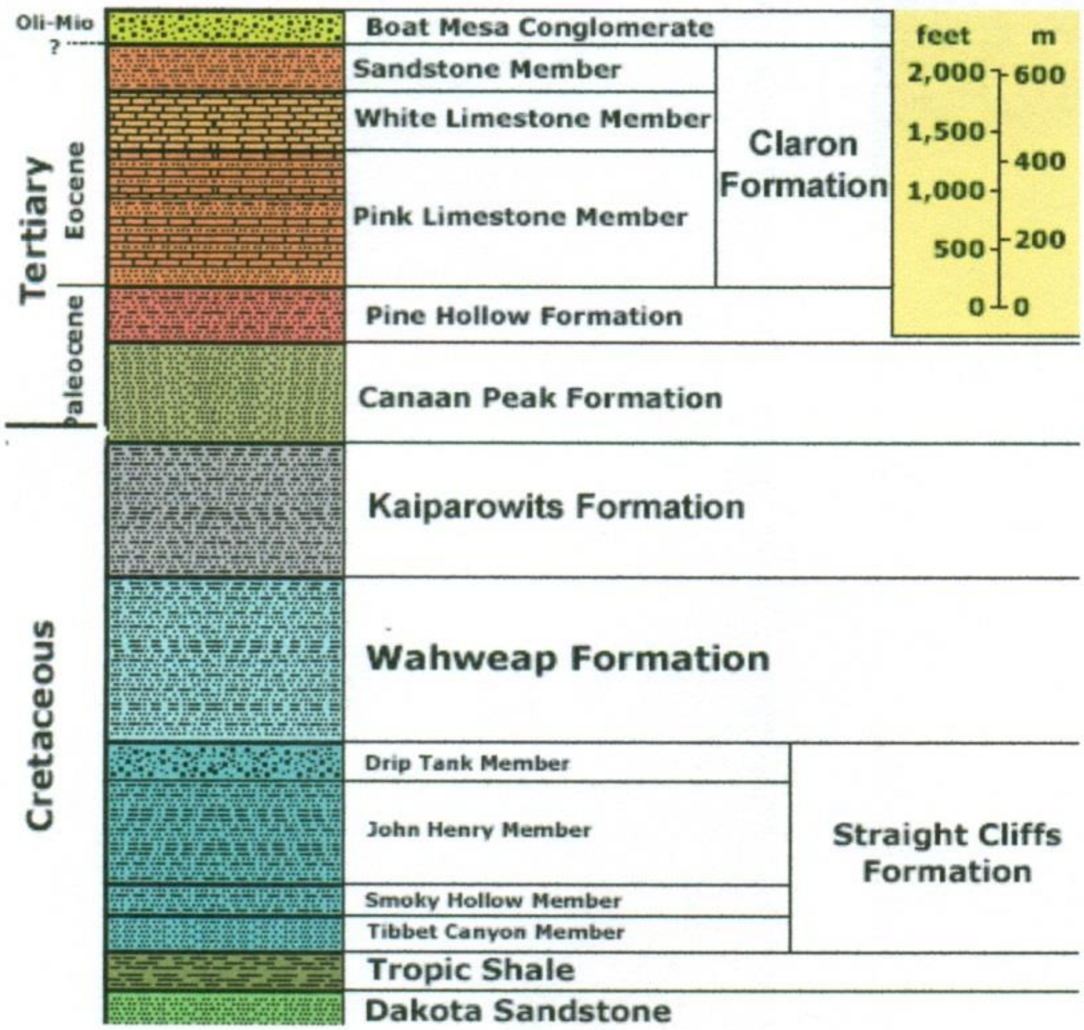
Zion National Park



AGE (millions of years)	FORMATION (thickness in feet)	SYMBOL	LITHOLOGY
QUATERNARY (0-1.8)	100 units on map	Q	Unconsolidated material & volcanic rocks
TERTIARY (1.8-65)	3 map units	T	Igneous & sedimentary rocks
CRETACEOUS (65-144)	Dakota? (100)	Kdm	Sandstone, tan, fine-grained, fossil plants and pelecypods.
JURASSIC (144-206)	Carmel (850)	Jc	Limestone, tan & gray; sandstone & siltstone, banded pink & gray; gypsum; sandstone, fine-grained
	Temple Cap (0-260)	Jt	Sandstone, gray & tan, crossbedded
	Navajo Sst. (2000 max.)	Jn	Sandstone, white, gray, yellow, tan, pink, medium to fine-grained, crossbedded
	Kayenta (600)	Jk	Mudstone, reddish brown, siltstone, & sandstone. Dinosaur trackways common.
	Moenave (490)	Jm	Sandstone, mauve, overlying reddish-brown siltstone & mudstone
TRIASSIC (206-248)	Chinle (400)	TRc	Shale, mauve, gray, white, weathered to clay where exposed, with sandstone and limestone lenses.
	Moenkopi (1800)	TRm	Siltstone & mudstone, red & red-brown, w/ many gray gypsiferous shale beds
PERMIAN (248-290)	Kaibab (incomplete)	Pk	Limestone, yellowish gray, massive w/ chert & marine fossils.
	Toroweap (350-400)	Pt	Limestone, cherty limestone, & gypsiferous siltstone

http://nature.nps.gov/geology/parks/zion/figures/figure_5.pdf

Bryce Canyon National Park



http://3dparks.wr.usgs.gov/coloradoplateau/bryce_strat.htm

Part 2: Questions for Comparing Stratigraphic Succession Charts

With your partner, look at the columns on the charts and discuss what you notice.

1. What types of data do these charts show?

2. Look at the words to the left side of the columns, like Permian, Triassic, Jurassic, Cretaceous, and Tertiary. What do these names refer to?

3. List some fossil data that you notice and where you located it:

4. Some of the layers have names. How does it appear that scientists have named some of these layers?

Place your charts side-by-side and see if you can find layers that matchup between the three different locations.

Things to look for:

- 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?

5. Which layers did you find in common? List the name of the layer and the location it was found:

6. What are three similar features that helped you to identify that these layers were a match?

7. What does this tell you about the relative age of the rocks in these locations? Meaning, which of these locations is home to the oldest sequence of rocks: Zion, Bryce Canyon, or Grand Canyon? How do you know?

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____
____

8. Which of these locations is home to the youngest sequence of rocks: Zion, Bryce Canyon, or Grand Canyon? How do you know?

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____
____

9. Which of these locations is home to the middle sequence of rocks: Zion, Bryce Canyon, or Grand Canyon? How do you know?

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____
____

10. What time eras are represented by these three stacks of rocks?
Grand Canyon: ____
Zion: ____
Bryce Canyon: ____

11. How does this activity remind you of some of the previous activities we have done?

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Day 6: Geologists Build a Time Scale

Part 1: Time Scale Analysis

The diagram on the following page shows a simplified time scale that geologists developed about 100-150 years ago. Independently, or with a partner, analyze the diagram and answer the questions:

1. What types of rocks were used to construct the time scale?

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2. What are the three eras (time intervals), in order from oldest to youngest, that contain abundant fossils?

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

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4. What are two organisms that were abundant in the Paleozoic that went extinct before the Mesozoic?

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5. What are two organisms that first appeared as fossils in the Paleozoic that have survived to the present day?

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6. Which appeared first in the fossil record, amphibians or reptiles?

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

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8. What are organisms were abundant in the Cenozoic?

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9. When did Hominid fossils appear first in the fossil record?

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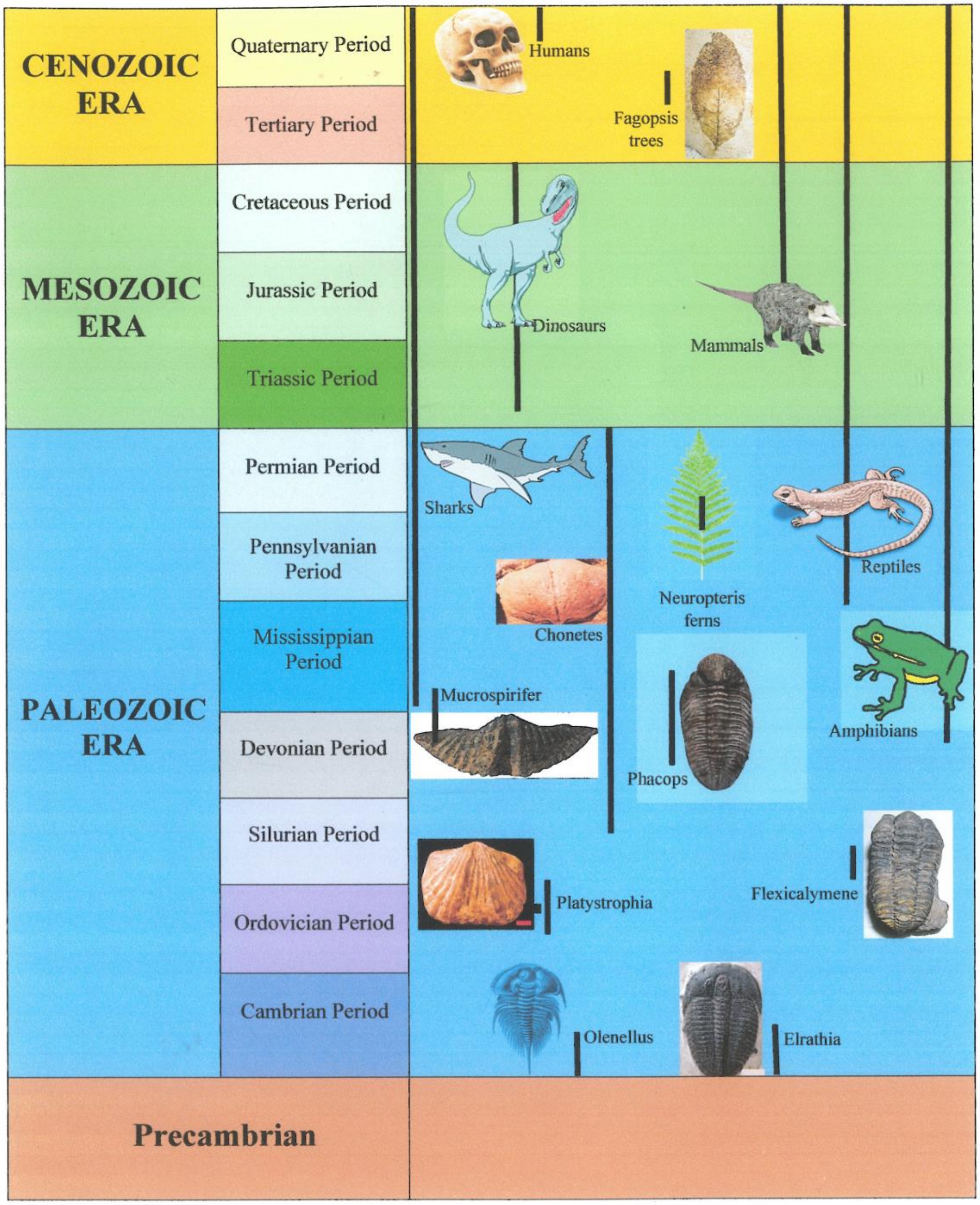

Based on Busch (2000) and others. All fossil figures are public domain from sites such as Wikipedia.

RESULTS AND ANALYSIS

Complete individually, then we will discuss as a group.

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

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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?

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

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

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5. If scientists were not alive to observe it, how do they know how to place geologic events in relative order?

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DISCUSSION

Let's discuss what we've learned as a group and answer the following questions:

1. What was the point of starting off with the playing cards?

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____

2. What was the point of dropping spoonfuls of sand into the cylinder?

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____
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3. Where would you find the layer of sediment that was deposited first in the cylinder (which is the oldest)?

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4. Where would you find the layer of sediment that was deposited last in the cylinder (which is the youngest)?

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____

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?

____
____
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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?

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____
____

Congratulations! You have just worked out two simple laws!

- 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.
- 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.

When applied skillfully, YOU can explain the geologic history of many places on the Earth’s surface. This is the same knowledge that has allowed paleontologists to use fossils to understand biological evolution over geologic spans of time.

8. What was the point of looking at a 3D picture of the Grand Canyon?

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Do you see how you applied the laws to a real geologic setting?
Layers of sedimentary rock are pretty common. Now you can interpret the geology of many of the parks and places you might visit! ☺

9. What was the point of digging the fossils out of the cups?

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10. What kind of order did you put the cup drawings in on the board?

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11. Can you remember the order that the fossils arrived in? List them youngest to oldest:

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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?

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13. What was the most surprising realization when you created the paper roll timeline?

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14. Why was matching layers across the Arizona-Utah region important?

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15. How does matching rock layers demonstrate biological changes over geologic time?

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16. What’s the big take away from the Geologic Time Scale the geologists constructed?

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GOING FURTHER

How have these lessons peaked your curiosity? What questions came up for you that would you like to investigate next?

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Interested in learning more about the Geologic Timescale?

Take a journey back through the history of the Earth! Jump to a specific time period and examine ancient life, climates, and geography. You can start in our era of present time, the Cenozoic Era (65.5 mya to today) and work back to the beginnings of life. Or start with Hadean time (4.6 to 4 bya) and journey forward to the present day!

Check it out at through the University Of California Museum Of Paleontology at the following web address: http://www.ucmp.berkeley.edu/help/timeform.php (Collins, 2011)

REFERENCES

Albritton, C.C., Jr. (1984). Geologic Time: *Journal of Geological Education*, 32, p. 29-37.

Busch, R.M., ed. (2000). Laboratory Manual in Physical Geology, 5th ed.: American Geophysical Institute, National Association of Geology Teachers, 276 p.

Collins, A., Guralnick, R., Speer, B., Rieboldt, S., & Smith, D. (2011, May 26). Geologic Time Scale. Retrieved July 16, 2014, from http://www.ucmp.berkeley.edu/help/timeform.php

Eicher, D.L. (1976). Geologic time: Prentice Hall, 150 p.

Fossil. (n.d.). In *Wikipedia*. Retrieved July 19, 2014, from http://en.wikipedia.org/wiki/Fossil

Tarbuck, E.J., Lutgens, F.K., and Pinzke, K.G. (2000). Applications & Investigations in Earth Science: Prentice Hall, 353 p.

Relative location image of Bryce, Grand Canyon, and Zion National parks from: https://www.backroads.com/trips/MBGQ/bryce-zion-grand-canyon-biking-hiking-tour

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