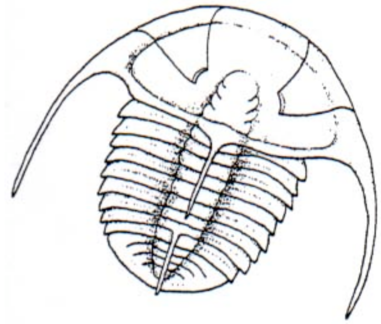

Age Dating of the Fossil Record

Two activities for grades 5 and up.

Teacher's Guide

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Preface

A survey of several teaching supply catalogs has shown that while fossils are readily available for teaching purposes, there are very few ready-made activities to choose from. The primary goal of these activities is to approach the study of fossils the same way a paleontologist would, by studying an outcrop. This way, the student learns about relationships between fossils and their environment, rather than just learning how to classify fossils one-by-one. It also illustrates how geologists use fossils to determine the *relative* age of different rock units.

Absolute ages, however, are required to calibrate the relative ages obtained from the fossils. Although radiometric dating techniques are quite straight-forward, geologists have failed to convince a large portion of the general public that these ages are indeed accurate.

People are generally willing to believe that radioactive decay occurs, but many skeptics will argue that we have no way to test whether or not we have calculated the rates of decay properly. This question is the focus of the absolute dating activity presented here.

Standards-Based Outcomes

In addition to giving students practice using scientific inquiry to study nature, the following activities meet the following Colorado Science Education Standards:

- Explaining how fossils are formed and used as evidence to indicate that life has changed through time.
- Using graphs, equations, or other models to analyze systems involving change and constancy.
- Explaining an exponential model
- Interpreting and evaluating data in order to formulate conclusions.
- Describing and explaining properties and composition of samples of matter using models.

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Fossils
and
Relative Geologic Age Dating

MATERIALS

The materials here should be enough for ~25 students.

Fossil Name	Product#	Price*
Rugosa Coelenterate (10 pack)	3435B	$7.50
Mucrospirifer Brachiopod (10 pack)	3495B	$14.25
Crinoid Echinoderm (10 pack)	3670B	$7.50
Turritella Gastropod (10 pack)	LS3615-02B	$5.75

Order the fossils from American Educational Products.
*(*Prices quoted are for the year 2009)*
401 Hickory Street
P.O. Box 2121
Fort Collins, CO 80522
Phone: 1-800-289-9299
Web: www.amep.com

You will also need 3 Phacopida Trilobites from www.wardsci.com, #53W2885, $9.95 each

10 plastic bins or cardboard boxes
~1 foot square, 4" deep (5 are for the outcrops, the other 5 are to collect the excavated sand)

2-3 bags of sandbox sand from local nursery or hardware store

~10 Spoons (stiff plastic ones will work)

~10 cheap paint brushes (99¢ disposable ones from the hardware store)

Photocopies of activity sheets.

We need 5 mock outcrops for the students to study. Two will be jumbled landslide deposits and three will be intact fossil communities.

SETUP

1. Take a minute to become familiar with the five different types of fossils.

2. Separate them into 5 groups so that each group has one of each.

3. Remove the *Turritella Gastropod* from 3 of the groups and store them in a drawer somewhere.

4. Now you should have 3 groups of 4 and 2 groups of 5.

5. Mix each of the two larger groups into two separate bins. Make sure the fossils are placed randomly in the sand. The goal is to make it look they were caught and tumbled in a landslide

6. Fill the other three bins halfway with sand.

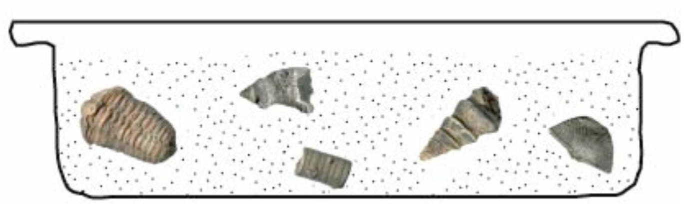
7. Place the four fossils in a community-like group so that they are in the positions shown in the following picture. This is what we call "life position." Then carefully cover them with sand making sure that you do not disturb them.

8. So, now you should have five sand-filled bins that the students can "excavate" with spoons and paint brushes. Two landslide deposits and three life position communities. Leave them unlabeled.

9. Each bin is a separate station. Distribute the stations around the room. Put landslide bins between the life position bins, so that neighboring groups will have different results.

10. Each station should have a bin, a couple of spoons and paint brushes, and a couple of copies of the fossil chart.

Life Position



Landslide Deposit

Introductory Discussion

1. Start off by asking students what they know about excavating an unknown area in search of fossils.

- **a.** Machine tools vs. hand tools (consider cost)
- **b.** Random vs. systematic coverage of area
- **c.** Careful observation of orientation and placement of fossils.
- **d.** Take careful notes, drawing many diagrams so that the site can be reconstructed on a computer if it turned out to be an import fossil find.

Ask each group to devise a plan for how they intend to excavate their outcrop.

(With luck, one person will dig gently with the spoon until a fossil is struck. Then another person will use the brush to gently uncover it. A third person will draw a map view of the outcrop and the others will draw cross-sections perpendicular to each other.)

Ask each group to tell the class what their plan is before they begin.

Begin Excavation

2. Walk around the room and encourage careful observation.

3. As they remove fossils they uncover, have them use the fossil chart to identify which fossil it is. Once they correctly identify the fossil, they should read the short paragraph that describes what the living organism was like. They should also pay close attention to the age spans of each species.

4. When they are done, have each group interpret what they are looking at. For example:

- **a.** What environment is this?
- **b.** When were these organisms alive?
- **c.** How were they fossilized?
- **d.** Is there anything peculiar that does not make sense?

Discussion of Findings

5. Start by asking each group to describe the distribution of their fossils. (with luck some groups will say spread out and haphazard, and other groups will say grouped together in one layer.)

6. Draw a vertical line down the center of the chalkboard and label one side "Grouped," and the other side "Random."

7. Next, ask each group which fossils they found. List these on the board under the proper heading. (They should notice that the clam only occurs in the random outcrop.)

8. Now have them add the age ranges for each fossil on the board. (They should see that the gastropod is much younger than all of the other fossils. They should also see that the Crinoid lived for a long period of time relative to some of the other fossils.)

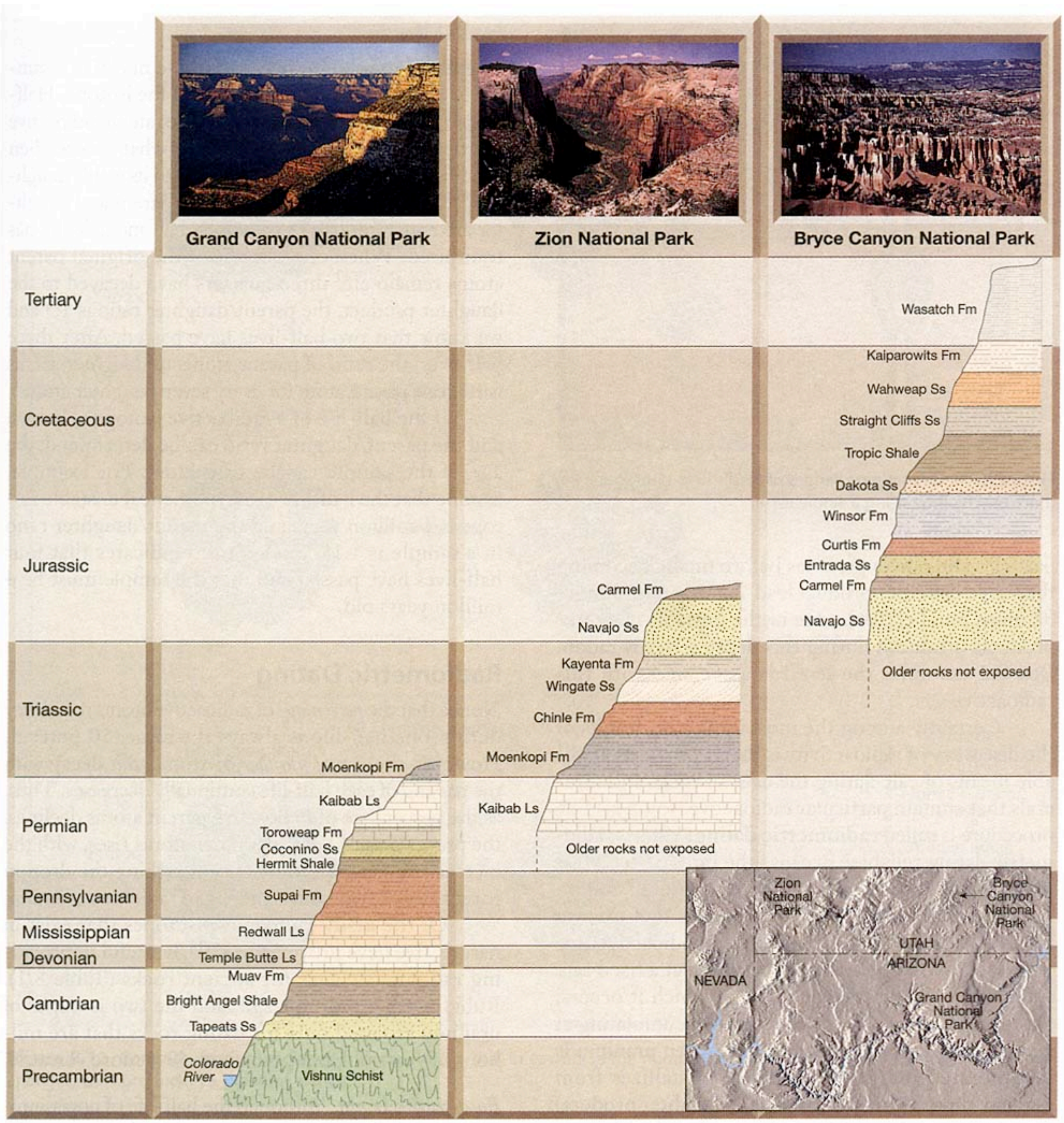
9. Ask them how the gastropod could have been fossilized with older organisms. (Recall that the gastropod is only in the landslide deposit. So it was mixed in with the older fossils during the landslide.) Ask them when the landslide must have occurred. (Cretaceous or after)

10. Now ask them to tell you how old the "Grouped" outcrop is. (Devonian) Which fossil is this age largely based on? Not the Crinoid which had a long "range." It's based on the age range of the Mucrospirifer. Fossils that have short age ranges are called "Index Fossils." Index fossils are used by geologists to correlate sequences of rock from one place to another. This is how geologists "piece together" sections of the geologic record. (There is no place on earth where we have a continuous sequence of rocks starting at the age of the earth and ending with the present. Geologists must piece together the rock record by carefully studying the physical relationships between outcrops.) See figure below.

11. What did they learn about the individual organisms? Did they share a common environmental niche? (Shallow ocean). Were they mobile or were they attached to the seafloor? (Phacops and the young landslide fossils were mobile, all of the others were attached to the seafloor) Have them list all of the characteristics they can about this fossil community, based on their observations and the descriptions they read. Is the sand consistent with this environment? Geologists use many clues in the rocks to tell us more about the habitat of the fossils. Paleontologists study each fossil in great detail to learn about how it lived, what it ate, and even it's behavior.

12. Lastly, how do we know how old these fossils really are? By looking at intact communities in different layers of rock, geologists can work out the sequence in which the fossils appeared *relative to the different layers of rock.* This doesn't tell us how old the fossils actually are. Geologists, however, have learned that deposition of thick sequences of rock takes millions of years. Catastrophic events can change the surface geology quickly, but cannot deposit the large volumes of rocks we see today or preserve intact fossil communities such as the ones we just excavated.

13. Geologists have been studying fossils for hundreds of years, but only within the last 50 years have they been able to determine their exact age using simple principles of physics and chemistry. They now use radioactive isotopes as geological clocks. The next activity explains how this is done. But fossils still remain a reliable way to determine the age of a rock if the rock contains an index fossil.



How geologists correlate short sequences of rock from one region to another. The figure does not show it, but index fossils are frequently used to help match up the sequences. (Figure by Dennis Tasa in Tarbuck and Lutgens, 1999)

Radioactive Isotopes and Absolute Geologic Age Dating

MATERIALS & SETUP

Materials

1. Bag of unpopped popcorn.

2. ¾″ pompoms, both white and green.

3. Green spray paint and newspaper

4. Five covered sauce pans.

5. Photocopies of the activity sheets.

6. Photocopies of the Solution (last 2 pages) to be handed out towards the end of the activity.

Setup

1. Place a few hundred popcorn kernels on the newspaper and spray lightly with the green spray paint.

2. Place the following ingredients into covered pans:

Pan #1: 40GK, 60GP, 75RK, 25RP

Pan #2: 5GK, 95GP, 30RK, 70RP

Pan #3: 1GK, 99GP, 16RK, 84RP

Pan #4: 60GK, 40GP, 90RK, 10RP

Pan #5: 10GK, 90GP, 50RK, 50RP

Key: GK = green kernels, GP = green popcorn (pompoms), RK = regular kernels, RP = regular white popcorn (pompoms).

First, let's set the stage with a fictitious story…

A committee at Jiffy Pop decides that popcorn sales can be improved if they can devise a way to genetically produce a faster popping breed of popcorn. They send their best genetic engineer (let's call her Lucille) into the lab to work on the problem. She manages to produce a variety that, in theory, should pop faster. Unfortunately, the new popcorn is green. The theory is based on the chemistry and physics involved in what actually makes popcorn pop. Using the principles of chemistry and physics, Lucille produces the following theoretical curves.

For each type of popcorn, she produced two curves that are mirror images of each other. They are pretty simple to interpret. You start out with all kernels and no popcorn. As you start to pop the kernels, they turn into popcorn until you end up with all popcorn and no kernels.

Unfortunately, Lucille's stopwatch is not working for some reason, and she has to present her results to the board within the hour. She could just show them the theoretical curves, but a multimillion dollar ad campaign is in the works and she doesn't want to lose her job if she is wrong. In the nick of time, she comes up with an ingenious way to test her theoretical curves without the aid of any kind of timing device. They were indeed correct, and now the world is a better place. How did she do it without keeping track of time? (Geologists are faced with this exact same dilemma. They have two types of radioactivy isotopes that are decaying at two different rates. No human was around to time them, so how do we know if we got the rate right?)

Have your class break up into discussion groups to try to work out the problem. You can tell them that the solution does require that she popped some popcorn on one burner of the stove. The answer must be quantitatively accurate, i.e., she did not observe that one popped faster than the other. Have the groups write down their solution.

Once they have spent enough time trying to solve the puzzle, let them open the pan that contains the results of Lucille's experiment.

1. Their first observation should be that she popped both types of popcorn in the same pan at the same time.

2. They should also recall that she popped the corn for an unknown length of time, because she does not have a stopwatch.

3. Because some kernels are still present, she must have stopped popping the mixture before it was all popped. So, essentially, she froze the process of decay in time.

The students should dump out the popcorn and kernels, separate them into four piles (green kernels, green popcorn, regular kernels, and regular popcorn), and then count each pile. They should then put a dot on the appropriate curve for each of the four types.

4. What do they notice about the dots? (They all fall on a vertical line that corresponds to the duration the corn was popped).

5. Each group's dots will plot at different times, because she did the experiment several times without keeping track of when she stopped popping.

6. Remind them that the curves are theoretical. She was testing them with an experiment. The experiment showed that the popcorn popped at the predicted rates.

7. Now, ask them what would happen to the dots if they were plotted on a set of incorrect popping curves. (They would not line up vertically, which is impossible since both varieties of popcorn were popped for the same duration in the same pot.)

Discussion

So how does this all relate to geology? It is a direct analogy. Instead of regular kernels we have ^{238}U and instead of regular popcorn we have ^{206}Pb. The radioactive isotope of uranium changes (decays) into an isotope of lead. Instead of 45 seconds, it takes billions of years. The green kernels are ^{40}K and the green popcorn is ^{40}Ar.

8. Now pass out the last 2 pages that shows the solution.

Geologists can easily measure the quantities of ^{238}U, ^{206}Pb, ^{40}K, and ^{40}Ar in a rock, just like the students were able to count the contents of Lucille's pans. Lucille came up with the theoretical popcorn curves using simple laws of chemistry and physics. Geologists can also produce theoretical curves for the rates of decay of the isotopes. The test is the same. We count the isotopes present and see if they fall on a vertical line. They do.