VARVES: DATING SEDIMENTARY STRATA

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INTRODUCTION: Most of our knowledge about earlier life forms on Earth comes from fossils left in sedimentary rock. In order to place those fossils in a meaningful time frame, we need to determine when they lived. Sedimentary rocks are formed in layers, with the more recent sediments lying on top of older sediments. If fossil "A" is found in a lower layer than fossil "B", we can usually say that fossil "A" lived before fossil "B"; A is older than B. This is RELATIVE DATING. Scientists can also obtain fairly accurate measurements of a sample's real age (how long ago it formed) by "radioactive analysis" of igneous (volcanic) rocks, and various other methods (ABSOLUTE DATING). In this investigation, we will be doing a form of absolute dating *within a particular time frame*. We will be looking at small samples of varved shale from the Green River Formation in southwest Wyoming. The fossils of fish and other organisms found in these sediments have been dated by radiometric methods, and indicate that the lake in which these sediments formed existed during the Eocene epoch, about 40-50 million years ago.

The layers in the lake bottom sediments are called "varves"; they generally occur in alternating light and dark pairs. These were generated by the changing amount of organic matter in the water between dry summer/fall months and wet winter/spring months. Each dark/light pair (one varve) thus represents a year's worth of deposits. The rock sample (shale "billet") that you have been asked to study is actually a tiny piece of the compressed sediments taken from a portion of the bottom deposits of this dried up lake.

NOW: Answer the eight Check Questions on your **worksheet** before proceeding with the lab work.

PURPOSE: To determine the total time it took to form these lake sediments of the Green River Formation.

MATERIALS:

- binoc. dissecting scope, 10x hand lens, or low power (40x) of compound scope
- piece of polished shale billet
- tiny 10 mm piece of millimeter scale fine line graph paper;
- forceps
- small metric ruler
- calculator (optional)

PROCEDURE: (answer all questions and record all data on special worksheet provided. If you are working in pairs, be sure that both of you observe, measure, and count varves on the specimen, compare your individual observations; they should be the same or very close.)

1. Examine a shale billet. How thick is your sample (in mm)? (Be sure to measure from the bottom layer to the top layer. Remember that you are measuring the distance from where the bottom layer was laid down to where the top layer of your sample was laid down). Which layer is "top" and which layer is "bottom" is not important for this measurement. Be sure to measure a typical portion of your sample; ignore any "extended" portion caused by a slanting cut or broken corner. Record the sample's thickness.

2. Just by looking at your sample (without magnification and without counting), guess the number of thin dark layers that run horizontally through your shale billet (seen as thin dark lines along one side). Each line is the edge of the dark layer of a dark/light varve-pair. Record your estimate before proceeding.

3. Place your sample on a plain microscope slide so that the varve edges are on top, and place this on your microscope stage. Put the piece of mm graph paper on the sample so that its mm lines are parallel with the varves. If using your compound scope, use only the 4x objective, w/ the light off, so the sample is illuminated only from the room lights. Move the sample and the graph paper so that you can count the number of varves (dark lines) in a typical 1 mm portion. You may want to repeat this for 3 or 4 different regions, and report the average How many varves did you count per millimeter? Record this.

4. Calculate the TOTAL number of varves in the main part of your specimen (ignoring the few additional layers left by a slanting or broken cut). This, or course, would be your count of varves per mm (step #3) times the total thickness measured (step #1). Record this on your worksheet.

5. A class tally will be taken of the number of students who count each particular number of varves per mm in their sample. Record those numbers in the histogram on your worksheet.

(Continue with DISCUSSION QUESTIONS overpage)

DISCUSSION QUESTIONS (answer on back of your WORKSHEET)

6. a) Do the layers occur in distinct bands, like pages in a book, or do they run into and cross over each other? b) Why do you think they formed this way?

7. How thick is one average year's deposit in this ancient dried up lake bottom? (show how you calculated)

8. Using this shale billet as a model of deposition rates, how long would it take for "mother nature" to deposit a set of layered sediments 1 meter thick? (show how you calculated)

9. Some areas of the deposit are 80 meters thick, other areas are over 200 meters thick. How can you account for this drastic difference in thickness for the same lake? (several reasonable answers are possible here; think!)

10. The Green River deposits have a maximum thickness of 260 meters. Calculate how long this lake had to be in existence before it permanently dried up. Show how you calculated.

11. What are two kinds of evidence that would lead scientists to conclude that these layers were formed at the bottom of an ancient lake (and not a shallow sea, or in some other way)?

12. What conditions caused the formation of varves in this ancient lake bottom? (a) Where did these very fine sediments come from? b) How did they get to this spot in the lake? Think!

13. Why does this lab illustrate an example of *absolute* dating and not relative dating?

14. a) In your best estimate, the dark sediment bands represent what type of seasonal sediments? b) How about the light sediment bands? c) Briefly explain how you might go about collecting evidence to check your answers to a) and b).

15. What do the occasional very thick dark bands suggest?

16. a) If all students are looking at samples from the same lake bottom, why didn't they all get the same number of varves per mm? b) Which count is most likely "correct"?

Name:_____ S.N.____ Date_____ Per.___

Partner:_____ S.N.____

WORKSHEET: VARVES: DATING SEDIMENTARY STRATA

A. CHECK-QUESTIONS (answer before doing "procedure")

1. How old is the sample you will be studying?_____

2. What is a "varve"?

3. Why is a varve light and dark?

4. a) Which do you think is the organic layer of a varve: the light band, or the dark band; b) why?

5. Where did these billets come from, precisely?

6. What is relative dating?

7. What is absolute dating?

8. Which of these two dating types are we using here?_____

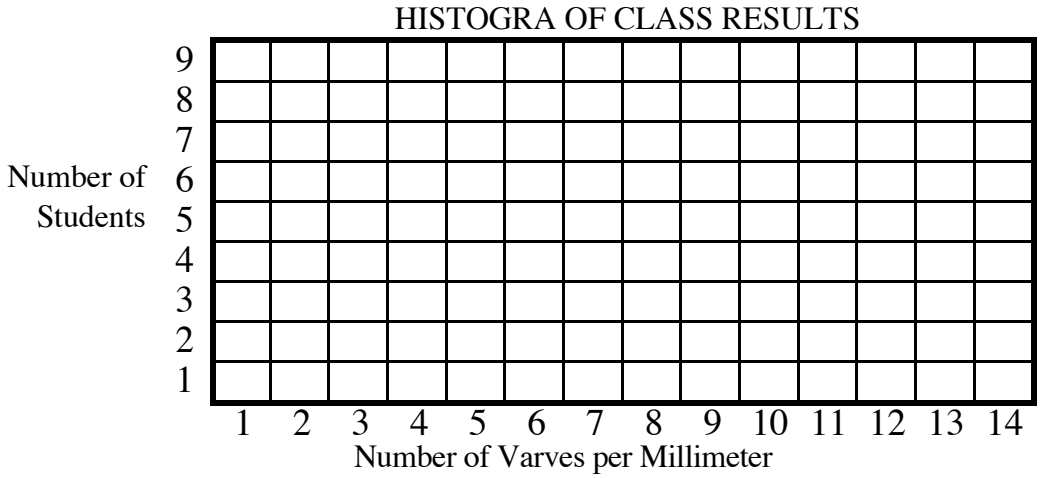
B. RESULTS: from "procedure questions"

1. Sample thickness:_____mm 2. Number of varves in sample (estimated):_____ varves.

3. Number of varves per millimeter in sample:_____varves/mm (actually counted)

4. Total number of varves in sample (calculated):_____varves

5. Histogram of class results: From class tallies, mark the box for the number of students reporting each particular number of varves per millimeter, then shade box and all others below it.



ANSWERS TO DISCUSSION QUESTIONS:

6. a) like pages of book, or run into and cross over each other? (circle your choice) b) Why?

7. Thickness of one average year's deposit: _____ mm. (Show how calculated):

8. Time for 1 meter of sediments to form: _____ years. (Show how calculated):

9. Why differences in thickness of deposits?

10. Total time for all 260 meters of sediments to form: _____years; show calculations:

11. 1)_____

2)_____

12. a) Source of sediments:_____

b) How did they get to this spot?_____

13. Why lab is an example of absolute dating?_____

14. a) Dark sediments probably formed in the (season:) _____

b) Light sediments probably formed in the (season:) _____ c) How would you check this?

15. Why an occasional very thick dark band?_____

16. a) Why different varve counts? _____

b) Which count most likely correct? _____ Why?

KEY

A. CHECK QUESTIONS:

1. 40-50 million years old
2. Layers of lake bottom sediments; one varve consists of one dark layer and one light layer
3. Dark layer has more organic matter in it, light layer has less organic matter
4. a) dark band; b) organic material typically decays to black carbon and carbon compounds (like coal or oil)
   You might suggest to your students to scrape the side of the shale piece with edge of glass slide, then smell it ("sniff and smell"). Ask what it smells like; most will recognize a distinct oil odor!
5. Compressed, dried up lake bottom sediments in southwest Wyoming's Green River Formation.
6. Going out with someone in your family (just kidding!)....actually determining whether a layer of sediment (or fossil IN that sediment) is younger or older than another layer (or fossil) in that sediment.
7. Determining how long ago a particular rock sample (and/or fossils in, above, or below it) formed.
8. Relative.

B. RESULTS:

1. about 10 mm; 2. (most estimates will be in the neighborhood of about 50 varves)
3. should range from about 4 varves/mm to 12 varves/mm; average may about 7 varves/mm
4. about 70 varves (if 7 varves/mm); 7 v/mm X 10 mm = 70; (40-120 range)
5. (should get a "bar graph", with the tallest bars in the 6-8 v/mm columns, forming a rough normal curve)

C. DISCUSSION:

6. a) cross over; b) currents, disturbances by fish or other creatures, as sediments formed.
7. about 1/7 mm (0.14 mm), if based on 7 varves/mm. 1 varve / 7 varves per mm = 1/7th mm
8. about 7,000 years (4,000 to 10,000 range); x is to 1000 mm as 7 is to 1 mm, so $x = 100 \times 7 / 1$
9. nearness to stream outflows or inflows; lake dried up at times, exposing portions to erosion;....
10. about 1.82 million years (~1 mill. to ~2.6 mill. range); 260 meters X 7000 years per meter = 1.82 million
11. - fossils of freshwater fish, algae, plankton, other freshwater organisms;
    - nature of sedimentary particles or grains typical of lake bottoms (different from those of shallow seas)
12. a) from stream-carried silt, and eroded silt from shoreline; dust blown off land onto lake surface
    b) stream currents, wind-created currents of lake moved particles out to deeper parts, where they settled.
13. Because we are counting the years, actually measuring time (in a particular time period). [This is a special case, since we are NOT measuring the actual age of the rock layers from the present, which absolute dating usually does.] Relative dating merely indicates that a layer or fossil is older or younger, not how much older or younger, than another layer or fossil.
14. a) winter/spring; b) summer/fall; c) gather samples of existing lake bottom surfaces in winter and summer to compare relative amounts of organic matter; (winter/spring floods would carry more dead leaves, etc.)
15. Probably periods of unusually heavy rainfall and flooding
16. a) samples may come from different parts of lake bottom, so could be real variations; even in same sample, some layers may be thicker at one point than at another; also, students may differ in their judgments about where mm marks and layers line up. b) those near the middle of the range (most commonly reported) are probably most typical, and therefore most "correct" for purposes of our calculations.

NOTES By John Banister-Marx (ENSI grad):

Description: The Green River Formation is an 80-260 m thick deposit found in SW Wyoming near Kemmerer, Wyo. In this ancient formation are the remains of many types of organisms that once thrived in this shallow lake. In addition to fossils, the bottom of its approx. 100 foot water depth collected a series of carbonate sediments alternating with rich organic deposits. They form a series of varves that indicate annual deposition. Students count number of layers (either light or dark bands, not both...like tree rings).

Key concepts taught: 1 relative dating vs absolute dating; 2. uniformitarian geologic processes; 3. great age of earth, at least in this small formation; 4. scientific extrapolation; 5. microscope skills; 6. histogram: making and interpretation

Other Information: Pieces of shale from the Green River Formation can be cut into tiny billets by sending your piece to Burnham Petrographics 846-1 South Myrtle Ave., Monrovia, CA 91016. Request to have it cut into a set of 6mm x 10mm x 16mm billets, d. Cost is about .75 each plus s&h. Should you want more of the bulk shales, you can order pieces of "scrap shale" from Ulrich's Fossil Gallery, Fossil Station, Kemmerer, WY 83101, or call them at (307) 877-6466 to order. A cut piece 3" x 5" will run about 1.00 plus s&h. Special Note: They also sell grade 1 and 2 Eocene fish fossils that are intact, and unexcavated and provide a little "excavation/preparation " kit for students to prepare a fossil --- just like a museum paleontologist would do (at $7.50 I prefer the cheaper grade 2 fossils). The fish is typically one of three different species.