VARVE DATING
Dating Sedimentary Strata

Created by John Banister-Marx
Adapted By Larry Flammer

NOTICE: If a student ever challenges you with criticisms of the reliability or validity of geological age-dating methods, CLICK HERE

SYNOPSIS:
Students count the number of varves (annual layers of sediment) in shale billets, taken from the Green River Formation in Wyoming, formed during the Eocene. The count is then extended to reflect the entire 260 meters of sediments where the billets originated, a period of nearly 2 million years during which the annual lake sediments (varves) were laid down. This provides a vivid tangible experience to see real data first hand showing the passage of at least nearly 2 million years for the existence of a large lake, in contrast to a traditional view that the entire Earth is only about 6-10 thousand years!

PRINCIPAL CONCEPT:
There is clear evidence of geological events over many millions of years.

ASSOCIATED CONCEPTS:
1. Varve counts in natural samples will vary in a predictable way, fitting a normal curve.
2. There are reasons why varve count variations occur.
3. Varve counting is one of many methods of geological dating.
4. Several geological processes, combined with seasonal changes, can be inferred from patterns seen.
5. Distinction between relative and absolute dating
6. Uniformitarian processes in geology
7. How one can do scientific extrapolation.

ASSESSABLE OBJECTIVES:
1. complete their worksheets accurately (individually, in pairs, or in groups).
2. calculate the time taken to form a known thickness of lake bed deposits by extrapolating from a small sample of those sediments.
3. recognize that the geological history of Earth covers at least many millions of years (rather than only a few thousands of years.
4. describe and explain the evidence for this time frame.

MATERIALS:
See RESOURCES below for details in obtaining real varves (items #5-6), or using the pictures provided (item #7).
1. piece of polished shale billet, about 1 cm cube (or picture of same)
2. 10x-40x lens (magnifier, dissecting scope, or compound scope)
3. small metric ruler (or picture of same)
4. 10 mm piece of millimeter graph paper
5. forceps to maneuver the graph paper
6. calculator (optional)

ALTERNATIVE VARVE SAMPLES: Set of photographs of microscopic views of varve billets (see Resources, item #7 below)

TIME: One 40-55 min. period
STUDENT HANDOUTS:
1. Two-sided handout of the lesson, giving background information, purpose, materials, procedure and discussion questions.
2. Two-sided Worksheet (for answering questions and recording data).
3. Key to Worksheet (for teacher use)

TEACHING STRATEGY:
1. Have materials in trays available for convenient student access, with one set for every two students, including hand lenses or access to microscopes.
2. Have copies of the lesson and worksheet pages for all students.

PROCEDURES:
1. Distribute copies of the lesson and worksheet pages to all students.
2. Students are to read Introduction and answer the Check Questions.
3. Students continue with the lesson, working in pairs, getting the materials and following the procedure provided. All observations are to be recorded on the worksheet.
4. When all teams (pairs) have recorded the number of varves per millimeter, ask for this information from each team, and display these numbers on the board or overhead. Students are to complete their histogram using these class data.
5. Students answer discussion questions (they can discuss them within each team). If necessary, this part can be completed as homework, to be collected the next class day.
6. You might bring out in discussion that the entire Green River Formation was laid down in a huge lake bed during the Eocene (55-34 mya), leaving a 15-20 million year continuous record - and we're just looking at a small part of it. It averages about 5.6 varves per mm, but this can vary quite a bit. The formation covers a large area from SW Wyoming down through much of Utah. Be sure to show the photo of the GRF taken in Utah, showing cows near the river at the base of the formation for scale (see end of this lesson).

ASSESSMENT:
1. Observe and record active participation by all students
2. Prepare quiz to assess the objectives listed above.

EXTENSIONS & VARIATIONS:
1. Interested students could (for extra credit?) look for more information about the Green River Formation in Wyoming or Utah (using internet). What kinds of fossils have been found there? Can they find a picture of a huge erosional cut through the formation, showing hundreds of meters of thin-bedded sediments? Can they find someone who has been there? (interview). Prepare a report on this topic.
2. Explore other methods of dating (both absolute and relative methods). List and explain those methods, and the time ranges for which each can be used.
3. Seriously consider spending a session with the interactive tutorial on radiometric dating: Deep Time. This lesson on the ENSI site emphasizes the basis for the high level of reliability in geological age dating, and also exposes the fallacy of a young, 6-10,000 year age for Earth, based on one interpretation of traditional accounts of creation. This lesson also provides an introduction to the excellent online interactive tutorial on Virtual Age Dating.
4. To help students to grasp the vastness of Deep Time - to get a sense that relates to something familiar, take a look at our Patterns in Time, where students can take a scale where 1 mm = 10 years of their life, and discover that a million years on that scale would be about 1 football field long, and 500 million years would be about 30 miles away! Also shows patterns of stepwise emergence of vertebrate classes over about 400 million years, based on the earliest fossils of each group.
RESOURCES:
1. If possible, read about varves in Strahler, Arthur N. Science and Earth History, 1987, Prometheus Books, page 232. Other dating methods are also presented in this very useful resource, available at a discount from NCSE.

2. Geologist Jere Lipps (UC Berkeley Museum of Paleontology) offers the following perspective on the generally accepted view of these varves. If anyone in your class claims that the Green River varves are not annual, share this statement with them, and encourage them to bring in their source. "The Green River Formation laminae are considered varves, although not formed under glacial conditions. They consist of a thin, dark winter layer and a thicker lighter summer layer. These formed by seasonal events-increased spring and summer productivity of algae, and accumulation of finer material in the winter. Some geologists have had a few other ideas about the Green River Fm, but the seasonal changes accounting for the laminations seems secure. Thus, they are generally considered as annual varves," like tree rings.

3. Further verification that Green River varves are annual layers is provided in a detailed letter from USGS geologist John Dyni. This is a pdf file, includes the paragraph above (by Dr. Lipps), and could be printed out for students to read.

4. For any students who maintain that the varves are not annual, and/or the sediments were deposited during the great worldwide Noah's flood, ask them to check this site: geological analysis of evidence of Noah's flood. This is a very interesting and useful discussion of detailed evidence that effectively and clearly refutes claims that the sediments were deposited during Noah's worldwide flood. It is fairly detailed, in about 15 pages.

NOTICE: If a student ever challenges you with criticisms of the reliability or validity of geological age-dating methods, in addition to the "geological analysis" just mentioned, CLICK HERE

5. GETTING REAL VARVE BILLETS:
   Bulk shale can be ordered as pieces of "scrap shale" from Ulrich's Fossil Gallery, Fossil Station, Kemmerer, WY 83101, or call them at (307) 877-6466 to order. Ask for a piece of "scrap shale" that has good, well-defined laminations and is very firm. Flaky shale will crumble when it is cut. A piece about 4" x 6" x 3/8" thick (10x15 cmx1.5cm) will run about 3.00 plus s&h, or $6.85 total (as of Dec. 2003). 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.

6. You can usually have your bulk piece of shale cut into tiny billets at a local rock shop. If this is unavailable, you can send your piece to Burnham Petrographics, 5029 West Lodestar Ave., Rathdrum, ID 83858. You can call them at (626) 359-3797, or email to burpet@linkline.com. Request to have the slab cut into a set of approximately 8mm x 20mm x 15mm thick billets. Cost is about .90 each plus s&h. The slab described above (and pictured on the left) would make about 60 billets, making it about $60 total cost for more billets than you will need (a class set would be about 16 or 32 billets), so you can share or sell to other teachers (how about doing a workshop?). You should check on current prices via phone or email before ordering.

7. NEW! PICTURES OF VARVES AND RULERS:
   If you lack the time or resources for getting actual varve billets from the Green River formation, you could try using our pictures of these. We have a page of 16 varve-billets (edge views) that could be cut apart and distributed so students can see what they look like. However, in order for students to be able to count all the very thin varves, we needed to enlarge them 17 times, along with a 10mm ruler enlarged the same amount. The enlarged varve sections are arranged in fours on 4 pages for 16 varve sections. There are also 4 10mm enlarged rulers on one page:
   Page with 4 10 millimeter-rulers (x17)
   Page with 4 varve sections #1-4 (x17)
Download each PDF page. For one class set, print 4 copies of the 10mm rulers and 1 page each of the 4 pages of varve sections. Cut the rulers and varve sections apart. Each varve section has a number (1-16). You could put each varve section and an enlarged ruler into a plastic ziplock bag or envelope - for easy handout to each pair - and for easy storage.

Students can work in pairs, lay the enlarged 10mm ruler across the layers on their enlarged varve section so they can count the number of varves in say a 5mm segment, and record that number as x out of 5. Divide x by 5 to get the number of varves per mm, then multiply that number by 1000 to get the number of varves per meter. Perhaps have one student count the varves, then the partner counts the varves to check. They could average their counts - or recount.

The counting can be tricky, as sediments are laid down unevenly, so students should glance along each varve line (easier to count the dark lines) to see if there are two or more merged at that level, or not. If they are careful and pay attention to detail, they should get about 35 varves in 5mm (= average of about 7 varves per mm). Not to worry if this varies, but should generally get about 6-8 varves per mm. If not, have them try again.

There is also a large 3D view of the slab of varve material (like the one on the left) from which the billets were cut. This could be used for an overhead or PowerPoint presentation for instructions and discussion. Note especially the inclusion cross-sections showing. Have students speculate on what the inclusion was (especially when they see the shape of the surface bulge in the top layer). They could also try to figure out whether the slab is right side up, or upside down (in terms of its original position in the formation), and explain their reasoning.

REMEMBER - The real billets are best, (real stuff!), but the photos can be just as impressive if done well. Consider having the pictures (varve billets and rulers) laminated for durability and convenient re-use.

8. NEW! For an excellent 9' video clip showing paleontologist Michael Bell hunting and exposing stickleback fish fossils in the varves from a fossil-rich former lake site in Nevada, get the HHMI - Evolution DVD set. On disk 1, select the DVD Features: "Fossil Documentary." There is another 3' clip (from the third lecture) showing stickleback changes over about 25,000 years, graphically, in great detail, year by year, including the intermediate fossils formed along the way. This is in the Video Clips: "Fossil Record of Stickleback Evolution" on the disk. Very compelling clips.


BTW, correspondence with one of the authors (Stearley) revealed a significant error on page 310: The thickest part of the Uinta Basin of the Green River formation in NE Utah is around 10,000 ft. (not 22,000 as printed). Also, earlier, on page 259, the 2500 ft. measure for the thickest part of the Green River formation refers only to the Green River Basin proper in SW Wyoming.
Photo of Green River Formation by Kevin Delaney of Salt Lake City, Utah

Sample of the southern portion of the Green River shale formation, as seen in Desolation Canyon.

This was photographed during a river raft trip down the Green River, in eastern Utah. For scale, note the feral cows grazing along the river shoreline. If possible, show this photo to your class, so they can actually see about 300 meters (~1,000 feet) of ancient lake sediments in the nearest cliffs, deposited over about 2 million years. Note the many more layers rising higher in the distance. You may want to point out that 7,000 years would create only about 1 meter (3 feet) of sediments, about the height of the cows!