Earth Science Activities

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(listed in chronological order of publication)

Mining the Learning Cycle by Deb Hemler & Hobart King, *The Science Teacher*, November, 1996

Constructive Contours by Tom Repine & Debra Rockey, *The Science Teacher*, May 1997

Our Earth's Address by James Giles, *The Science Teacher*, September 1998

Changing Seasons by Deborah Ennis, *The Science Teacher*, October, 1998

The Insect Connection by Paula Waggy, *Science Scope*, October, 1998

What's the Connection by Karen Parlett, *Science Scope*, October, 1998

Quake Search by Deb Hemler & Tom Repine, *The Science Teacher*, December 1998

I Hate Field Trips by Robin Stout, *The Science Teacher*, January, 1999

Geodesic Earth by Elizabeth and Robert Strong, *The Science Teacher*, February, 1999

Outcrops in the Classroom by Tom Repine & Deb Hemler, *The Science Teacher*, November, 1999

The Art of Geology by Debra Rockey, *The Science Teacher*, April 2000

Redox Chemistry as a Geologic Tool by Mary Sue Burns, *The Science Teacher*, September 2001

Reconstructing the Geologic Time line by D. Hemler & T. Repine, *The Science Teacher*, April, 2002

Mining the Learning Cycle

Applying constructivist theory to mineral identification

"THIS IS BORING!" HAS BEEN THE consistent opinion of our students over the years when working with mineral identification. Initially we found it hard to believe that anyone could not be excited about minerals because students exhibit curiosity when first given a set to examine.

Rather than resign ourselves to the fact that not everyone shares an enthusiasm for rocks and minerals, we searched for a technique that would meaningfully teach students to understand mineral properties while alleviating the tedious nature of identifying mineral specimens. After seven years of experimentation, the answer finally lay in the learning cycle.

The learning cycle is a constructivist model that promotes the idea that learning takes place in three necessary phases (Barman, 1989):

1. *Exploration Phase:* Data-gathering or an activity on which to build knowledge involving observing, touching, and manipulating materials.
2. *Concept Development:* Students share information in their own words. Concepts are applied to the experiences in the exploration phase to develop student vocabulary.
3. *Application Phase:* Students apply the concepts to a new situation or design ways to answer their questions.

When the application phase is complete, the exploration phase resumes, building on students' acquired knowledge. With this cycle in mind, we redesigned our approach to teaching minerals.

BY DEBRA HEMLER AND HOBART KING

MINERAL PROPERTIES (EXPLORATION PHASE)

Pairs of students are given unknown mineral samples and mineral test kits and are allowed time to simply observe and explore. (Mineral kits and tool kits are constructed specifically for this activity as indicated in Figure 1.) Once students have become familiar with the mineral samples, we ask them to list any properties of the samples that would allow them to distinguish between the specimens.

Without any prior knowledge of minerals, mineral properties, or mineral test kits, students begin to explore the properties of the minerals before using the test kits. As we circulate around the room, we watch students observing the minerals. They immediately recognize that one specimen has magnetic properties (magnetite), one rubs off on their fingers (graphite), and two minerals split into thin sheets (muscovite and biotite). As exploration continues, they try scratching the glass from the test kit with the minerals. When students seem to have exhausted the properties they are able to list, we intervene.

We ask students to volunteer properties they have discovered, and we list them on the board. As we write them, we consciously group them into one of seven properties used to identify minerals (hardness, color, luster, streak, cleavage, fracture, and other). It is important for every group of students to contribute at least one property (even though it may be restating a previously given property). We record the language used by students in each response for future connections to scientifically accepted vocabulary. For example, students will use the terms *sparkly, shiny, metallic,* or *dull,* which we would lump together for the property luster.

When students have depleted their lists, we then reveal the fact that they have identified most of the properties that geologists use to identify minerals. For each of their lists, we identify the term that geologists use to describe that physical property of minerals. The students have generated the list of properties and now have an association for each property in their language, which has more meaning for them. We have not subjected them to a boring 50-minute lecture.

COOPERATIVE LEARNING (CONCEPT DEVELOPMENT PHASE)

The students now have personal constructs and language for each mineral property. They must now learn how to apply these properties to identify unknown minerals. We combine two student pairs to form a cooperative group of four. We explain that each newly formed group will be given a packet of unknown minerals. Before the students can identify these minerals, they must first research the mineral properties they have identified as important in identifying minerals. Each member in the group is responsible for becoming an expert on the two properties assigned to him or her: fracture and cleavage, color and hardness, luster and magnetism, or streak and other.

Students spend the remainder of the period searching their books and classroom resources for explanations of their assigned properties. Group members will depend on each other to know these properties for the identification of their minerals. We also let them know that on the following day they will teach the other members in their group about these physical properties. We make ourselves available to answer any questions or eliminate any confusion as students collect their information.

The following day, students break into their cooperative groups for a peer-teaching session. Each property expert explains his or her two properties to the rest of the group. When all groups have finished their instruction, we assemble as a class to clarify any questions that may have arisen during the peer-teaching sessions or address common misconceptions about mineral properties. We ask pertinent questions of the groups about specific properties to check their understanding of the concepts such as:

- Are all metallic minerals magnetic? (They generally discover during their exploration that the answer to this is "no.")
- Is color a good property for mineral identification? (Students will tend to answer "yes," so it is good to have several color varieties of quartz on hand.)
- Would a pearly luster be considered metallic or nonmetallic? (Often we find that students have not made the distinction between pearly and metallic; instead they lump them together, causing future frustrations with mineral identification.)

FIGURE 1.

Mineral samples and test kit for student groups.

Mineral Samples
graphite, galena, barite, biotite, feldspar, pyrite, muscovite, hornblende, calcite, magnetite, quartz, talc, hematite (specular and red)

Mineral Test Kit
nail, glass, streak, plate, penny, magnet, hand lens

MINERAL IDENTIFICATION (APPLICATION PHASE)

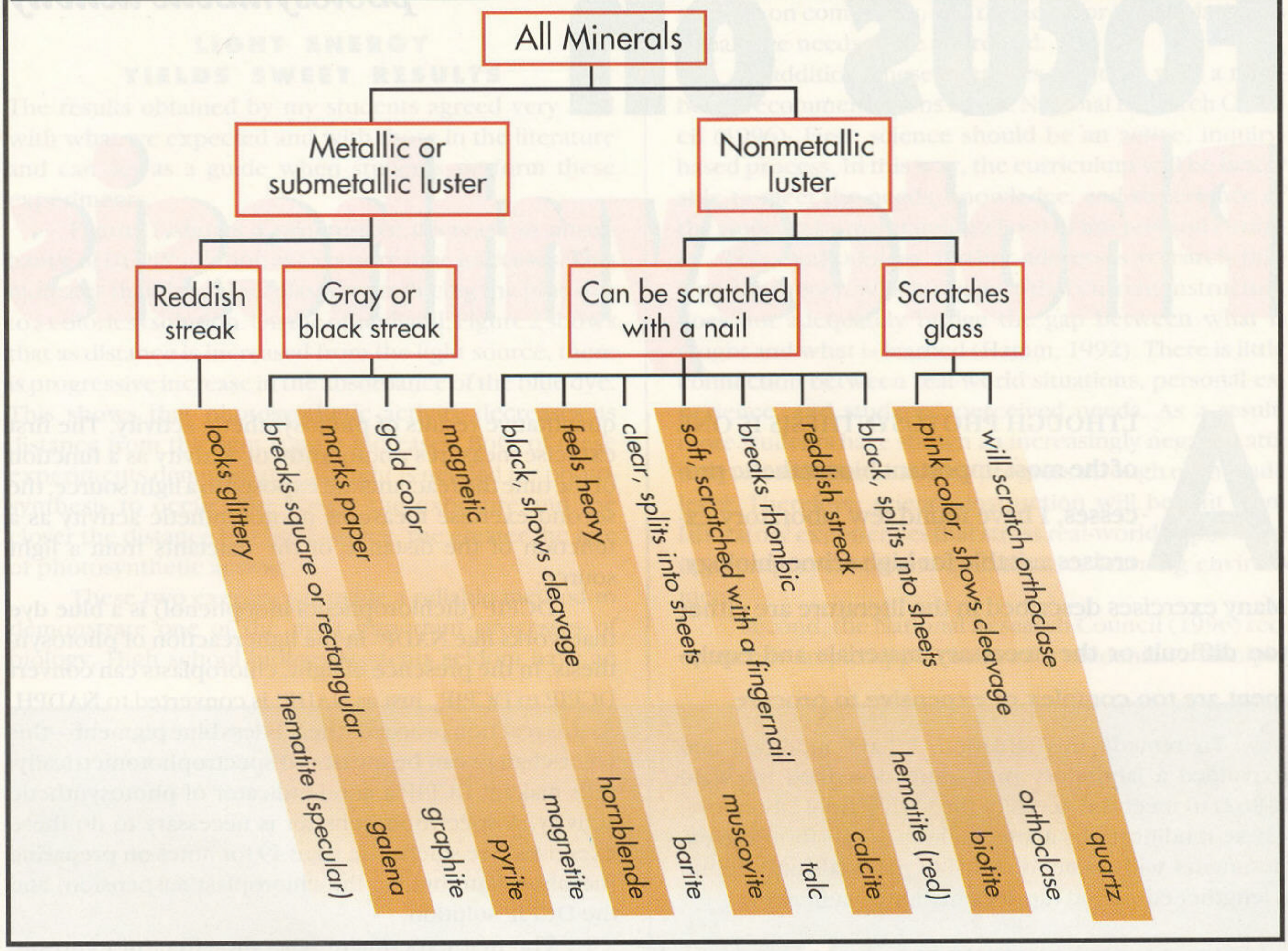
Students now have the tools necessary to experience the process of mineral identification. Rather than using the generalized mineral tables found in the back of textbooks, we opt to use a flowchart (Figure 2) that has been developed for use with these specific minerals employing a variety of mineral properties (King, Hemler, and Williams, 1997). Laminating the enlarged (ledger-size) flowcharts facilitates operation and cleanup because the graphite samples will mark unprotected papers.

Each student cooperative group receives two flowcharts, mineral specimens, and test kits. Within their groups they work in pairs to key out the unknown specimens. Mineral samples are placed in the flowchart area marked "All Minerals," and students begin to move each specimen down to the next appropriate hierarchical level until each mineral is on its respective mineral name. The two groups within the cooperative group then compare their answers to see if they have keyed each specimen to the same mineral name. Here the property experts can troubleshoot and help the group reach a consensus.

At this point we circulate around the room answering questions or settling any conflicts. This is a good time to address additional misconceptions as students begin discussing whether a mineral is metallic or nonmetallic. For example, we might ask why one group of students placed certain minerals in a given category to correct any misunderstanding before it becomes deeply rooted. It is not critical for students to get the right answer initially; it is important for them to understand the properties and process involved in identifying mineral samples. Once the groups have finished, we discuss any problems or misconceptions they discovered they held about mineral properties.

As an extension that can also be used as a means of assessment, we give students five new minerals identified with their mineral names and a large, clean piece of paper. The cooperative groups must now modify the flowcharts they used in the exercise to accommodate the five new minerals. To complete this task student groups must first identify the new mineral samples' properties and incorporate these properties into the flowchart. This

FIGURE 2.
Mineral identification flowchart.



activity is valuable because students demonstrate that they truly understand the systematic approach to mineral identification.

In traditional mineral labs, teachers subject students to structured work without sufficient time for exploration and discovery. This learning cycle approach, however, gives students some control over their learning experience. It allows them the opportunity to explore long and deeply enough so that they are comfortable with the concepts before they are asked to apply them. In other teaching approaches, the teacher gives a protracted sermon on 15 different mineral tests (all at once) and then hands out an identification table and expects students to be systematic.

Our students have become responsible for their learning and view this exercise as a challenge. They come away with pride in the fact that they successfully identified the unknown minerals, and we have the satisfaction of knowing that students understand mineral properties and the *process* of mineral identification. Consequently, students no longer leave our classes with a negative attitude toward mineral identification. Half of the battle in science education is improving science habits of mind. This activity has proven for us to be a step in that direction. ✧

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Constructive Contours

Build a life-size topographic map on school grounds

"THAT'S NOT RIGHT!" PATRICIA SHOUTED. More slowly, but with confidence, she added, "Those lines can't cross each other. I understand why . . . I just can't figure out how to say it." Patricia had intuitively recognized that an important concept of topographic mapping was being violated. Her only problem was finding the words and self-confidence to bring it to the attention of others.

What Patricia was questioning was the placement of two contour lines constructed by classmates on the grassy slope outside our school. Given simple tools and limited instructions, students were constructing a topographic map of the school lawn *on* the lawn. In other words, they were making a full-scale topographic model they could see, walk through, and discuss.

WHY WE DEVELOPED THE ACTIVITY

Before we developed the Constructive Contours activity, our approach to teaching topographic map concepts relied on the traditional use of paper maps, small models, and discussions of important principles such as contour interval, contour spacing, the rules of V's, and so on. Standard assessment practices (multiple-choice questions and short essays) showed that our students could correctly remember or recite definitions. However, when we implemented some new problem-solving exercises that required students to apply map skills, we found that a substantial number of students had not developed a functional understanding of topographic maps. Consequently, the effectiveness of these activities was diminished by time spent on remedial teaching.

We also discovered that the traditional teaching approach did little to dispel students' misconceptions. One such problem was closure of contour lines (contour lines forming circles around hilltops, sinkholes, and so on). Some students firmly believed that every contour line should be a circle. Or, as one student put it, "The circles get larger as the land gets flatter." Because students were finding it hard to construct a useful three-dimensional mental image from a two-dimensional map (as suggested by Kastens, VanEsselstyn, and McClintock, 1996), we needed an activity that helped them see how a paper map can represent a three-dimensional object.

Our activity does this by letting students build a realistic model that clearly shows what a contour line is and why it behaves the way it does. The activity encourages intuitive judgment and gives students a foundation for correcting inappropriate ideas. It also provides students with a chance to improve their cooperative and collaborative communication skills.

THE TOOLS

The primary instrument needed for this activity is a plastic hand level (see photo opposite), which resembles a small telescope. Instead of seeing a magnified image through the eyepiece, the viewer sees a small bubble and a horizontal reference line superimposed in front of an unmagnified image. Alignment of the bubble, reference line, and object indicates the object is the same height above the ground as the viewer's eye. Plastic hand levels generally cost less than 15 dollars and are available from forestry supply companies. One hand level is required for each group of three students.

BY TOM REPINE AND DEBRA ROCKEY

Along with a graduated 2 meter stick (something students can make if time permits), a hand level can be used to measure the height or thickness of distant objects. By following a steplike measuring technique, students can use the measuring stick and hand level to measure changes in elevation. The accuracy of this procedure can be impressive. With practice, our students measure changes of 5 millimeters or less when using commercial folding rulers or surveying scales.

Field geologists use hand levels to measure local and regional changes in the elevation and thickness of rocks, especially along steep hillsides and road cuts. Thus, students have the opportunity to use the same tools and develop the same skills as professional scientists while learning a simple skill that may prove helpful later.

THE ACTIVITY

This two-day activity uses the sloping grassy areas on our school grounds. On the first day, students discover basic skills. Collaborative teams of three are formed. (More than three students per team seems to promote inattentiveness unless each student is assigned a specific role.) Each team is given a hand level and measuring stick. Everyone is shown the location of a previously placed artificial benchmark. (We estimate this elevation from the topographic map for our area.) We next point out the large *X* placed at the top of the slope. Our instructions are confined to a single statement: "What is the elevation of point *X* above sea level?"

Teams are then free to explore how the hand level, measuring stick, and benchmark can be used to accomplish the task. Some individuals quickly figure out how to use the hand level, but it normally takes teams longer to develop the steplike technique needed to actually measure the elevation. Students soon realize that correct calculations and good record keeping are important. Collaboration between teams is encouraged. By the end of the session, everyone is ready for the following day's challenge.

The next day we construct a topographic map of the slope. After clearly defining the work area, we explain that each team is responsible for constructing a contour line. Students are told to use a 0.5 meter contour interval. Smooth wooden or metal stakes are provided for marking points. Colored plastic tape strung on the ground between stakes serves as the actual contour line.

Students must discover how they can use the available equipment (hand level, measuring stick, stakes, tape, and benchmark) to construct their line. Experience gained from the previous day's work quickly bears fruit as teams begin to measure and mark points. Slowly, lines begin to emerge. As students proceed, they see the importance of making correct measurements and that more measurements (stakes) make a smoother line. They also begin to realize that every point on their line is the same elevation.

PHOTO COURTESY OF THE AUTHORS

HELPFUL IDEAS

The trick to this activity is developing the steplike technique required for measuring vertical change. For example, the procedure for using a hand level to determine the total height of a set of stairs is as follows:

1. Starting at the bottom step, hold the hand level along the side of your measuring stick.
2. Sight a level line to the next highest step you can easily see. (This will vary from person to person.)
3. Read and record the height from your stick. Move up to the step you just measured. Repeat this process until you reach the top.
4. Add all your measurements together.

In the field, on uneven terrain, the hand level is used in the same manner. It takes a while, but students eventually discover the process and how to use teammates' feet to mark newly elevated points.

The contour interval should be varied to make sure each team constructs at least one line. However, teams constructing lines far up the slope take much longer to complete their line than do groups working close to the benchmark. For this reason, we now ask some teams to make two lines.

One common problem that we have turned into a learning situation is that some teams suspend the tape from the stakes instead of stringing it along the ground. It is important for the students to figure out what is wrong with suspending the tape. Most students quickly realize that tape suspended in the air does not correlate with the measured ground elevations marked by their stakes—the tape is actually higher. In addition, the sagging of the suspended tape is not representative of the true path of the contour line.

We have also noticed that we must occasionally remind our students to make a contour *line,* not just locate a series of isolated points. Therefore, each team is required to use a minimum of five stakes. Additionally, we have found that having different classes construct maps in different areas stimulates "compare and contrast" discussions.

Some teams will decide to use a line constructed by another team as a reference. They may see this as an easy way to simplify the task. Fear not—frequently this leads to "good" problems, such as crossed lines. Students are then faced with the prospect of questioning peer work. We remind them that scientists constantly review and contest published conclusions. Uneven hillsides, flat playgrounds, and large obstacles (buildings and bushes) test student ingenuity. These situations often lead to "teachable moments" as students explore various possible paths for their line.

FIGURE 1.

Rubric scoring for Constructive Contours activity.

Topic	Scores: 4	3	2	1
Collaborative Effort: Student takes charge of actions during a group activity.	Student willingly participates in team tasks, stays on task, volunteers for active roles within team, encourages sharing of ideas and opinions; cooperates freely with other teams.	Student needs encouragement to participate within team; stays on task, accepts role within the team, shares ideas with others, works well with other teams.	Student requires prompting to work with the group, must be reminded to stay on task, accepts team role, grudgingly shares ideas, unhappy to work with other teams.	Student is uninvolved with the efforts of the team, does not focus on the task, refuses to accept a role on the team, does not share ideas, will not work with other teams.
Skills and Processes: Student uses scientific skills and processes and intuitive reasoning ability to explore, discover, and construct a correct model.	Student explores different ways to use tools, demonstrates proper use of tools, accurate measuring important, makes frequent observations, records changes in model in notebook, demonstrates problem-solving.	Student explores limited ways to use equipment, demonstrates good use of tools, satisfied with good measurements, makes some observations, notes some change in model, tries to solve problems.	Student needs assistance in proper use of equipment, lacks accuracy in measurements, makes few observations, notes few changes in the model, does not demonstrate problem-solving skills.	Student does not try to use tools properly, does not measure consistently, does not make any observations, does not note any changes in the model, does not attempt to solve problems.
Content Analysis: Student responds to discussion questions, reflective assignment, and intuitive learning.	Student relates position of marker flags and tape to changes in slope, compares model to actual land features, compares model and actual land features to a contour map, suggests model variation, communicates clearly and coherently.	Students relates position of marker flags and tape to changes in slope, compares model to actual land features, does not compare model and actual land features to a contour map, communicates in understandable manner.	Student has difficulty relating position of the marker flags and tape to changes in slope, has difficulty comparing model to actual land features and/or a contour map, poor attempt made to communicate.	Student does not relate position of the marker flags and tape to changes in slope, unwilling to compare model with actual land features or a contour map, will not respond to the discussion questions.

TEACHER'S ROLE

Our role in this activity is truly one of exasperated facilitator. Resisting the natural inclination to help struggling teams and individuals is difficult, and waiting for students to recognize blatant mistakes can be frustrating. We wait because when a student points out problems, the discovery has more impact on classmates, provides us additional insights into the student's cognitive processes, and significantly increases the student's self-confidence. However, we will intervene to redirect student discussion toward thoughtful evaluation and constructive resolution.

To ensure meaningful student progress, the teacher must allow sufficient time for experimentation and re-examination. After learning the basic skills the first day, our students can easily make a very good contour map of a 20 by 40 meter area during the next day's 45-minute class. Although the completed map may not be perfect, it does seem to provide the visualization tool many students need to actually understand contour maps.

DID THEY LEARN ANYTHING?

After completing the activity, students seem to have a much better understanding of what a contour line is, why the lines behave the way they do, and what a topographic map represents. Their ability to use topographic maps as a tool in later assignments demonstrates the educational value of this activity. However, to assess student progress in such an experiential learning environment, we needed to develop new evaluation procedures.

Our first assessment tool is a rubric (Figure 1) modeled after ideas presented by Ken Jensen (1995) and Julie Luft (1997). A posted copy of this rubric provides the teacher and students with a clear understanding of expectations. It also satisfies student demand for a clearly defined quantitative scoring procedure.

A more qualitative assessment is obtained through reflective writing. Because many of our students are not adept at this, we use our own directed-response journaling technique. We hand out a worksheet that helps students examine and question their thinking, experiences, interactions, and skill development by asking questions such as the following:

- Reflect on the experience you had—what did it mean to you?
- How did the team work together?
- Describe the model.
- How can a flat piece of paper show the irregular surface of the land?
- Which skills were most difficult for you to use?

Students use their own words to tell us what they have learned. This assessment tool also helps us identify erroneous ideas that need to be revisited and clarified.

Constructive Contours provides our students with the opportunity to build and explore a real, full-scale, three-dimensional model. It improves their understanding of topographic maps. Follow-up activities requiring map skills are more effective. Because it requires simple calculations, the activity engenders an appreciation of mathematics. It also encourages curiosity, stimulates a willingness to entertain new ideas, and makes students question their own and their colleagues' procedures.

The teamwork developed by this activity is one of its most enduring aspects. In a recent use of the activity with an eighth-grade class, students instinctively knew that the contour lines should not cross. They were very aware of this type of error in their model. When this type of problem occurred, the interaction between the groups was lively (to say the least!). First each group wanted to blame the other, and finally each group returned to the benchmark and measured its line again. Accuracy in measurements became important to the group leaders.

The students were very proud of their completed model. They took a few minutes in each class to observe it. They felt that their model closely represented a topographic map. Most felt that they had achieved better understanding of topographic maps.

The students also seemed to exhibit a little more respect for each other because most students took some role in the activity. The teamwork displayed in each class was inspiring—each group had constructed a line, but it took the entire class to have a completed model. ✧

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NOTE

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Idea Bank

OUR EARTH'S ADDRESS

Considering the current expectations of science instruction and knowledge, teachers are faced with a dilemma: Which activity is best or can intensify the learning process and cover the in-depth skills necessary for scientific discovery? Scientific concepts taught through hands-on experimental guidance can challenge students to think for themselves.

The following activity was designed for middle school students and can easily be adapted for higher grade levels. At present, I use the activity as a foundation for 15 other topics I must address under the *National Science Education Standards* and the West Virginia Science Standards. These topics include world wind patterns, climate zones by latitude, climate vegetation zones, world biomes, biodiversity by latitude, topographic maps (reading and constructing), plate tectonics, and constellation and continent locations. As I introduce new ideas and information, my students find it helpful to reflect on the principal concepts covered in this activity.

The goal of the activity is to increase students' knowledge and retention of coordinate systems, specifically latitude and longitude. By the time they complete the activity, I expect students to be able to differentiate between lines of latitude and longitude and to demonstrate why and how coordinate systems are useful.

For the activity, the class needs two skeins of different colored yarn, one roll of masking tape, eight sheets of construction paper, scissors, a globe, and flat maps of the Earth and the United States. The maps are essential for introducing the activity and for future reference. I begin the activity early in the fall.

First we locate the center of the room. Next, students determine where north, south, east, and west are located. At this point, I introduce the compass. After verifying our directions, each wall of the classroom is labeled to represent its correct direction. This process makes the abstract concept more concrete for students.

Next, I arrange the class into heterogeneous groups of four. One group measures and cuts a piece of yarn that will reach across the room. Using masking tape, students attach the yarn to the walls so that it falls across the center of the room, east to west, about 2 meters off the floor. The students label this line as the equator. At this point, we discuss characteristics of the equator, and I ask students to list everything they know about the equator.

Another group has the responsibility of establishing the prime meridian. Using a different color of yarn, they string it across the center of the room, perpendicular to the equator. As with the equator, I ask students to list everything they know about the prime meridian.

Once the equator and the prime meridian are in place, the remaining lines of longitude and latitude can be attached. A math connection is made as students measure the walls of the classroom and divide them into eight equal parts. Some of the students can measure latitude walls while others measure longitude walls. Once the walls are measured and marked, students attach the lines of longitude make the prime meridian. After the lines are in place, we discuss the measurements of degrees, minutes, and seconds. Then students label the lines, starting with 0 degrees and working east and west in 15-degree increments. At this time, the discussion can be expanded to include the concept of world time zones. Next, students construct latitude lines using the same color yarn as the equator.

When the grid system is complete, the students hang cardboard degree signs on each line. After the model is complete, each student must stand under a grid square and, using the grid measurements, describe the location as accurately as possible. Then I initiate a discussion of latitude and world climatic zones. For example, I will ask what climate changes students would see if they moved north or south, which leads to a discussion of climate, weather, habitats, ecosystems, and so forth.

Students learn science by doing science. Whenever possible, I use an experiment as a modality of instruction. What better place to start the study of Earth science than with the Earth?

James Giles, science teacher, Craigsville Elementary School, HC 59, Box 313, Craigsville, WV 26205.

NOTE

This activity was developed as part of the author's participation in Rock-Camp, a teacher-enhancement project now funded by the West Virginia Geological and Economic Survey.

WRITING FOR UNDERSTANDING

As the teacher of a Science, Technology, and Society class, I found myself on the first day of class facing 28 students who were not interested in science. They had all failed some sort

Idea Bank

CHANGING SEASONS

To teach students about seasonal changes, I developed an activity in which students visualize how the Sun's rays diffuse more during winter in the Northern Hemisphere (when the Earth's north axis is pointed away from the Sun) than they do in the summer (when the Earth's axis is pointed toward the Sun).

The activity is inexpensive and easy to set up. Necessary materials include a flashlight, a ringstand, a globe, a paper star, tape, and a pencil. The set-up must be done before students begin the activity. First, I use numbered pieces of paper to mark four places on a table to position the globe—1 is spring, 2 is summer, 3 is autumn, and 4 is winter. I then place the ringstand and flashlight on the table closest to position 4; this way the globe will be closest to the flashlight in "winter" and furthest away during the "summer."

Next, I place the paper star (which represents Polaris) on the wall above position 4. Finally, I lay the flashlight on the ringstand and adjust the height of the ringstand so that the flashlight shines on the Tropic of Capricorn when the globe is placed in position 4 with its northern axis pointing toward Polaris (see photo, right).

Working in groups of three or four, students begin by placing the globe in position 1 and moving it counterclockwise around the table to each "season." I emphasize the importance of keeping the axis pointed toward Polaris at all times. With the globe in each position, the students answer the following questions:

1. Where is the light being received most directly?
2. How is the Sun's energy being distributed?
3. What season is it?

Once students finish the basic lab, I give them a worksheet with other questions to answer. These include questions about the number of daylight hours at various places on the Earth, how seasons in the Northern Hemisphere compare to those in the Southern Hemisphere, and how the distance from the Sun to the Earth relates to the seasons. Usually students will have to repeat the activity to answer all of the questions. Students must also determine where on the Earth the Sun's rays directly hit at noon on the spring equinox (the equator), the summer solstice (Tropic of Cancer, 23.5° N), the fall equinox (the equator), and the winter solstice (Tropic of Capricorn, 23.5° S). Students can then relate this information to the tilt of the Earth being 23.5°.

When students understand that the tilt of the Earth affects the seasons, they can discuss what seasons would be like if the Earth were not tilted and what the seasons are like on Uranus, which is tilted almost completely on its side. The students once again take the globe through all four positions, first with the globe positioned so there is no tilt, and then with the globe tilted 90 degrees.

To visualize changes in day length, students place a straight line of toothpicks on the globe, each toothpick at a 90 degree angle to the surface of the globe. The toothpicks can be adhered to the globe with a small piece of Play-Doh. When the flashlight is on, students can see not only the difference in day length as it relates to season and geographical position but also how the flashlight's


PHOTO COURTESY OF DEBORAH ENNIS

rays spread out more across the surface of the globe when the flashlight is positioned further north or south of the equator. This can be visualized very clearly with the room lights turned off.

Because the flashlight is off-center on the table, students understand that the Earth's distance from the Sun is not the reason for the seasons. The activity can also be set up so the position of the globe more accurately simulates Earth's orbit—the Earth should actually be closest to the Sun shortly after the winter solstice (January 3, perihelion) and furthest away from the Sun shortly after summer solstice (July 4, aphelion).

I assess this activity in two ways. First, I check students' answers to the questions mentioned earlier. Most students answer the three introductory questions correctly. After the activity, students answer these follow-up questions:

1. What causes the seasons?
2. If it is summer in the Northern Hemisphere, what season is it in the Southern Hemisphere?
3. Does the distance from the Sun have any effect on the seasons?

Another way to assess students is to use a rubric (Figure 1). The rubric developed for this activity provides a clear understanding of expected outcomes and gives students a precise quantitative score (Jensen,

FIGURE 1.

Rubric for assessing seasons activity.

TOPIC	SCORES			
	4.	3.	2.	1.
Collaborative effort: Student takes charge of actions during group activity.	Student willingly participates in group activity, volunteers for active roles, encourages sharing of ideas and opinions, cooperates with other groups.	Student needs encouragement to participate, stays on task, accepts role within group, shares ideas with others, works well with other groups.	Student requires prompting to work with the group, must be reminded to stay on task, accepts team role, grudgingly shares ideas, unhappy to work with other groups.	Student is uninvolved with the efforts of the group, does not focus on the task, refuses to accept a role within the group, does not share ideas, will not work with other groups.
Skills and processes: Student uses scientific skills and processes and intuitive reasoning ability to explore, discover, and explain why there are seasonal changes.	Student explores various relationships of the Sun's rays and tilt of the Earth to the position of the globe, makes observations, records proper findings, demonstrates problem solving.	Student explores limited relationships of the Sun's rays and the Earth's tilt to the position of the globe, makes some observations, records some proper findings, tries to solve problems.	Student needs assistance to find relationship of Sun's rays and the Earth's tilt to the position of the globe, makes few observations, records few findings, does not demonstrate problem-solving skills.	Student does not try to relate the Sun's rays and the Earth's tilt to the position of the globe, does not make any observations, does not record any findings, does not attempt to solve problems.
Content analysis: Student responds to discussion questions and intuitive learning.	Student relates the distribution of the Sun's rays, the tilt of the Earth, and the position of the globe to the seasons; compares seasons of Earth to other planets; relates day length to Earth's tilt and position; communicates clearly and coherently.	Student relates the distribution of the Sun's rays, the tilt of the Earth, and the position of the globe to the seasons; does not compare the seasons of the Earth to other planets; does not relate day length to Earth's tilt and position; communicates understandably.	Student has difficulty relating the Sun's rays, the Earth's tilt, and the position of the globe to the seasons; does not compare seasons of the Earth to other planets; does not relate day length to Earth's tilt and position; communicates poorly.	Student does not relate distribution of the Sun's rays, the Earth's tilt, and the position of the globe to the seasons; does not compare the seasons of the Earth to other planets; does not relate day length to Earth's tilt and position; will not respond to discussion questions.

1995; Luft, 1997). This activity is always one of my favorites because students learn a lot and make very positive comments.

Deborah Ennis, science teacher, Wheeling Park High School, 1976 Parkview Rd., Wheeling, WV 26003.

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The Insect Connection

Using insects as a common teaching tool for many science lessons

PAULA WAGGY

I FIND INSECTS TO BE TERRIFIC CLASSROOM subjects. They are cheap, abundant, and easy to find. In the life science arena there is little that cannot be studied using insects. The possibilities are intriguing—insects lend themselves well to studies of diversity, genetics, taxonomy, locomotion, ecology, water quality, anatomy, and physiology.

Each year, students submit insect collections at the end of our diversity and taxonomy unit. The collections are only required to contain 10 insects representing 8 orders, but students become well acquainted with the most common orders of insects as the specimens are collected and classified. Students used to ask what they would do with the collections next, and it was anticlimactic when I said they could take them home. Now I respond that we will save them for the next unit—geology.

GEOLOGY WITH INSECTS

Jurassic Park (Crichton, 1993) was the spark that led me to begin a geology unit with the study of insects. Most students are familiar with the movie or the book, providing a basis for a discussion about the probability of extracting dinosaur DNA from ancient insects. Questions frequently asked are: How long does the blood in the mosquito saliva remain undigested? How would an animal as fragile as a mosquito be preserved as a fossil? What kinds of insects were alive during the Jurassic period? Could scientists really extract DNA from a fossilized insect?

After doing some research I realized that the likelihood of extracting enough DNA from a fossil insect to produce a dinosaur is comparable to randomly pulling letters from alphabet soup and coming up with the Bible. However, I did find reports of scientists being able to extract ancient termite DNA (not dinosaur DNA) from amber (Grimaldi, 1993). This process is now being questioned, and some researchers think that past claims of success may have been the result of stray DNA from living organisms contaminating the laboratories. To date, no one has been able to replicate these results (Gibbons, 1998). I explain these studies to the class, relegating the re-creation of dinosaurs to the realm of fiction. We then progress to easier topics, such as the preservation of insects in amber and the evolution of insects.

When I return students' insect collections, I give each of them a chart of the geologic time periods and the common orders of insects that evolved during each period (Figure 1). I also give each student a Styrofoam strip that is the same length as the chart and is marked with spaces corresponding to the time periods on the chart. Students align the Styrofoam strips with the geologic chart, remove their insects from their collections, and position the insects on the Styrofoam strip in the

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spaces representing the time period during which each insect order evolved.

During the diversity and taxonomy unit students are expected to classify insects in the 14 most common orders. This is a good review of the insect orders and quickly introduces and familiarizes students with the geologic periods. Students are assessed on the number of insects they successfully place in the correct time periods. Rarely does a student miss more than one. The assessment can be done quickly if students leave insects pinned in the Styrofoam strip, lined up with the chart.

Some students do not want to take apart their collections, so I allow them to write the names of their insects and the corresponding geologic periods on pieces of paper and lay them on top of the collection display boxes. Such displays are a little more time consuming to assess but allow the collections to stay intact. The discussion, activity, and assessment can all be accomplished in a 55-minute period.

In the following class, we discuss each geologic time period and the insects that evolved during the period. Special note is made of the Carboniferous period with its oversized cockroaches and giant dragonflies, and I call attention to the fact that all modern orders of insects had arrived on the scene by the end of the Cretaceous period. Students find it quite interesting that, if they could slip back in time to the Jurassic scene, they would see representatives of all the modern insect orders except butterflies, moths, termites, and fleas. From this point, the discussion moves to which plants students would see during the Jurassic period. Would there be flowers? What about rodents? (I explain that the Jurassic world was one of gymnosperms, small mammals, and primitive birds—flowers did not appear until the Cretaceous period.)

GEOLOGIC RESEARCH

Next, pairs of students must choose a geologic time period to research. Students tend to choose the Jurassic period because they are most familiar with that term. So, I supply library books that include pictures as well as text for students to investigate before choosing the time period they will research. I encourage students to make choices that will result in all geologic time periods being covered by the class.

The assignment is to prepare a poster depicting a total ecosystem within a given geologic period. For example, students who choose the Mesozoic era should present a poster in which dinosaurs are surrounded by a representation of large animals, small animals, and plants appropriate to that time period. "Small animals" encompasses the insects, salamanders, lizards, mollusks, crustaceans, birds, rodents, and so forth. If a marine environment is represented, invertebrates as well as vertebrates should be included in the presentation. Students must label the ancient organisms on their poster, exhibit the

FIGURE 1.

Geologic time periods and insects that evolved during each.

CENOZOIC	**Quaternary** 2 million years ago					
CENOZOIC	**Tertiary** 65 million years ago	**bees** bent antennae body quite hairy narrow waist and stinger				
MESOZOIC	**Cretaceous** 144 million years ago	**termites** thick waist	**fleas** small; no wings	**butterflies & moths** antennae often knobbed or feathery and scales on wings	**ants** bent antennae narrow waist	
MESOZOIC	**Jurassic** 208 million years ago	**earwigs** wings do not cover abdomen				
MESOZOIC	**Triassic** 245 million years ago	**wasps** bent antennae narrow waist and stinger	**flies** only two wings			
PALEOZOIC	**Permian** 286 million years ago	**caddisflies** looks like brown moth but no scales on wings	**stoneflies** aquatic insects; two tails	**net-veined insects** lacy wings	**beetles** hard forewings soft hindwings	**hoppers** small triangle between wings; wings do not overlap
PALEOZOIC	**Carboniferous** 360 million years ago	**cockroaches** flattened body long antennae	**grasshoppers** long, tough forewings large hind legs	**dragonflies** clear wings slender abdomen	**mayflies** aquatic insects three tails	**true bugs** triangle between wings; overlapping wings
PALEOZOIC	**Devonian** 408 million years ago	**springtails** no wings small				

poster in class, and present at least a 3-minute lecture about the time period.

There is much discussion in class as the posters are being prepared. Students who choose the Permian period, for instance, might want to know if they should include all animals in the time periods prior to that since those animals would have already evolved. Such questions lead to discussions of extinction and the length of time certain species populated the Earth. The topic of extinction is confusing to students because the insect charts were prepared with only modern insect orders. Students can include any insects on the chart that are below the time period they are surveying because all the insects on the chart are still living today.

Another question that always comes up is: How do we know what color to make the animals? This opens the door for a discussion of uniformitarianism. We explore the concept that the present is the key to the past by considering dinosaurs. Species of modern birds and reptiles (dinosaurs' nearest relatives) include both camouflaged and brightly colored animals. Students need to think about dinosaurs' habitats and behaviors to decide what their coloration would be. This process gives them an idea of what paleontologists must consider as they try to re-create a species from bone fragments.

Preparing the lectures and posters takes about a week of 55-minute class periods. Assessment is based on accuracy of information in both the poster and lecture. Clarity, organization, and familiarity with the subject are also criteria on which the presentations are assessed. This activity is aligned well with the *National Science Education Standards* because it emphasizes the evolution of life at a level that is appropriate for high school students who are capable of understanding such a long-term process.

The main purpose of the exercise is to familiarize students with the terminology used when discussing the geologic past and to provide a basis for the study of stratigraphy in which we discuss local rock strata and the time periods in which they developed. When I turn to a discussion of the Devonian fossils found in the mountains surrounding their homes, students understand. This activity also makes it easier to discuss more advanced geological concepts such as plate tectonics and it puts processes such as mountain building into a more realistic perspective.

The most satisfying aspect of this activity is that it successfully integrates the life sciences with the Earth sciences. Recently, a student interrupted me as I was pointing out the different organisms that had evolved from Devonian to Carboniferous to Jurassic to Quaternary and said, "Hey, it all fits together! It's almost like the classification system!" I could only smile. They were finally getting it. ✧

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NOTE

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FIGURE 2.

Presentation assessment criteria.

Poster	Oral presentation
Includes large animals	When did period occur?
Includes small animals	Important geologic events
Includes plants	Interesting specific details
Organisms labeled	Clarity
Includes name of period	Familiarity with subject

Each item is worth 2 points with the maximum number of points being 20.

Note: The reason that the organisms are listed as large and small animals rather than vertebrates and invertebrates is that the earliest periods had no vertebrates. Also this ensures that students will include both large and small vertebrates during the Mesozoic.

AMBER AND EVOLUTION

Amber is a hard, yellowish-brown substance that comes from resin exuded by conifers. Often, insects were trapped in the sticky sap before it hardened into amber, and the resinous compounds in the sap prevented the trapped insects from decomposing. The transparent qualities of amber allow these fossilized insects to be studied in three dimensions.

The amber with which most people are familiar is Baltic amber, which is from a huge forest of extinct pine trees that stretched from Germany to the Ural River in Russia. More than 150 000 fossil insects have been collected in this region, mainly from the alluvial soils near rivers and beaches. Baltic amber was formed during the Tertiary period after the extinction of dinosaurs. The Dominican Republic amber used in the movie *Jurassic Park* was also of Tertiary origin and therefore is incapable of harboring dinosaur blood.

However, there was some amber formed during the reign of the dinosaurs. Cretaceous amber has been found in western Canada and in New Jersey. Midges have been found in this amber. True modern midges resemble mosquitoes but do not bite, so it is likely that ancient midges were not blood-sucking creatures either. And although insect fossils are also found in shale and in tar pit remnants, these fossils do not contain the actual insect as amber does. They are simply molds, casts, or carbon prints of the insects.

The majority of modern insect orders evolved long before the dinosaurs, and the Paleozoic era is known as the age of insects. The earliest fossil insects are springtails, which evolved in the Paleozoic era more than 400 million years ago. Springtails can be found today living in soil, decaying material, and on pond surfaces.

One of Earth's most successful creatures, cockroaches, evolved in huge coal-producing swamps approximately 360 million years ago. Cockroaches have changed very little since then. It is interesting to consider how these lowly creatures have survived eons of upheaval and change when such magnificent beasts as *Tyrannosaurus* and *Triceratops* succumbed to extinction.

Dragonflies appeared on the scene about the same time as cockroaches. The ancient dragonflies included an extra-large species with a 75-centimeter wingspan and a 38-centimeter-long body. These giant dragonflies, the largest insects ever known to exist, became extinct toward the end of the Paleozoic era, but smaller species have survived to modern times.

By the end of the Permian period, about 245 million years ago, 14 modern orders of insects had evolved. These included beetles, grasshoppers, lacewings, caddisflies, stoneflies, mayflies, and true bugs. The presence of these orders means that the adaptations of complete metamorphosis and incomplete metamorphosis had appeared in the scheme of evolution by that time.

Several other insect groups emerged simultaneously with the evolution of dinosaurs during the Mesozoic era. Wasps and flies appeared at the same time as the early dinosaurs. By the Jurassic period, all but six of the common modern orders of insects had evolved. Butterflies, fleas, ants, and termites evolved in the company of *Tyrannosaurus* during the Cretaceous period, as did flowering plants, which evolved with bees in the Tertiary period.

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What's the Connection?

by Karen Parlett

As a science teacher, I am always looking for ways to encourage my students to make connections between what they learn in science class and the world outside. In order for science to be an important part of my students' lives, they must see its relevance. The following 40-minute activity is a simple way to foster thinking about the real-life connections between science class and the world beyond.

The *National Science Education Standards* call not only for "hands-on," but also "minds-on," experiences in the science classroom.[1] Students need to practice critical thinking skills that enable them to express and communicate their ideas effectively. I base many of my activities on a learning cycle of exploration, concept development, and concept application. This approach encourages students to think for themselves and challenges them to make connections between new material and what they already know.

ANNE BURNS

Many different types of minerals can be found listed in the ingredients of common household products.

As part of an Earth science unit, I introduce students to rocks and minerals and their uses so they can understand the relationships of these materials with their everyday lives. For example, although students readily recognize that rocks and minerals are used as building materials, they consistently fail to consider that rocks and minerals are pervasive in many other areas.

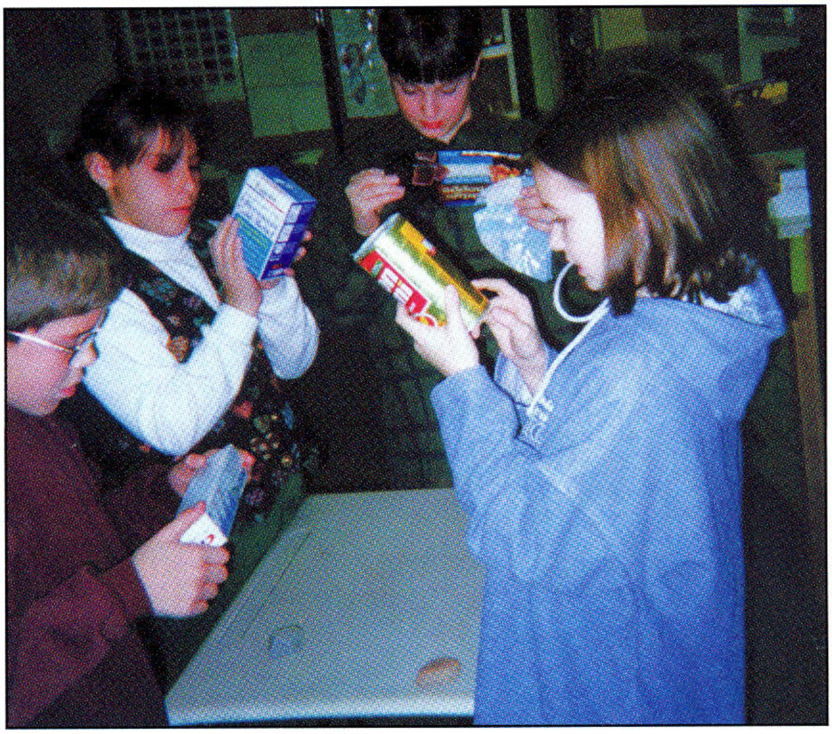
Karen Parlett *is a fifth grade teacher at Pleasants County Middle School in Belmont, West Virginia.*

A rock is a rock?

In the exploration phase of this activity, I set up four identical tables in my classroom with common household items, such as deodorants, dishwasher and laundry detergents, antacids, cleansers, artificial sweeteners, medicines, and empty cookie boxes. Students are cautioned not to open any of the packages or containers. On the same tables are several pieces of sandstone and limestone. Cooperative groups of four or five students visit the tables to study the assortment of items and determine how they are related. After studying the items, the students return to their tables and discuss possible connections.

While they work in groups to determine how the items are related, I hear comments, such as "These are things we clean with," and "This is medicine." I also hear, "These are just rocks, why are they here?" After five minutes of discussion, each group shares its ideas with the class, and as a class, they discuss various methods for grouping the items.

As the students bounce around their ideas, I remind them about the rocks and ask them to describe how they fit in with the other items. The most common answers are that they are used for driveways, sidewalks, buildings, and other outside things: "Sometimes rocks are in flower beds," and "Maybe they can be used as tools." Students are frustrated by the question, "How are they connected to the other items on the table?" The students see little connection between the pieces of sandstone and limestone and the cleaning, medicinal, and food products. It just doesn't make sense to them.



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The typical student doesn't make the connection between minerals listed on a cereal box and minerals that make up rocks. Many have never been required to make this connection until now.

Rocks are useful?

After each group shares its answers, we begin the concept development phase of the activity. I introduce the class to the terms *silica* and *carbonate*. They learn that sandstone is a compound of silicon and oxygen, called a *silicate*, and limestone is a compound of calcium, carbon, and oxygen, called *calcium carbonate*. The students refer to the periodic table to find the chemical symbols for silicon, carbon, oxygen, and calcium. This is a quick introduction to the periodic table, which we will work with in more depth in later lessons. Although it would be great to have students research the composition of sandstone and limestone and report their findings to the class, it saves time to tell them as a group.

I brush my teeth with that?

This is when the "*Ah-has*!" fill the classroom. The light bulbs click on, and the students begin to make the connection. They now recognize that the pieces of rock are composed of specific materials, not just hardened dirt.

The students return to the tables to reexamine the items. Again, they are asked to make connections between the pieces of rocks and minerals and the other items. This time, I encourage them to look

PHOTO COURTESY OF AUTHOR

more closely at the ingredient lists. One student, after seeing silica listed as an ingredient on a toothpaste tube, turned to me and exclaimed, "You mean I brush my teeth with sand!"

Each group now shares new ideas for how the items are connected. This discussion focuses on which items contain silica, which have carbonates, and which have both materials. As part of the concept development phase, I ask each group of students to organize the data in chart form. Now they are ready to classify each item as a silicate, carbonate, or a combination of both.

All of the items contain calcium carbonate, sodium carbonate, sodium bicarbonate, calcium silicate, silica, siliceous Earth, and other examples containing the terms *silica* and *carbonate*. When the students ask if antacids or chalk are ground-up limestone, I explain that although commercial calcium carbonate is formed by chemical reactions, it is still the same compound found in some rocks.

So a rock isn't just a rock?

For the application phase of this activity, I ask the students to extend their charts by adding another column labeled "Use." The students complete their charts with items found at home or in a grocery store. They are instructed to limit their lists to silicates and carbonates since this was the focus of our class discussion.

Although I suggest limiting these lists to five or six items, the students get excited about the assignment, and some extend their charts to a second page. Several students have brought in lists of over 20 household items! The students enjoy getting their parents involved and derive great satisfaction from teaching them. Together, parents and students find silicon dioxide on salt containers and drink mixes and carbonate on mouthwash bottles.

This activity encourages students to look at familiar products in new ways. Initially, they are frustrated by the inclusion of the rocks, which seem to have nothing to do with the other items. However, it isn't long before they realize that silicates and carbonates are common in many items, and the students begin to understand that there's no such thing as just a rock. When faced with the test question, "Name several things made of rocks or rock materials," students are able to list many items that reach beyond the scope of building materials. ❑

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1. National Research Council. 1996. *National science education standards*. Washington, D.C.: National Academy Press.

Note

This activity was developed as a part of the author's participation in RockCamp, a teacher enhancement project (NSF-9155264) now funded by the West Virginia Geological and Economic Survey in Morgantown, West Virginia.

Quake

Students use newspaper reports to map

When the term "earthquake" is mentioned, why do students immediately think of the San Andreas Fault? One reason may be that California tends to receive a large amount of media attention, but most likely many students feel that earthquakes are a far-removed phenomenon that poses no threat to their lives. We decided to design an activity that makes the topic of earthquakes more relevant to all students.

While it is true that episodic earthquakes are generally associated with plate boundaries such as the San Andreas Fault, the midwestern and eastern United States have experienced their share of seismic events. Indeed, *Geotimes* (Snider, 1990) predicted that an earthquake with a magnitude of 6.0 or greater will occur somewhere in the eastern United States by the year 2010. The following activity not only provides a relevant experience for students living in a variety of geographical locations but also introduces them to the type of authentic research that geologists perform while investigating historic earthquakes. This research project was conducted by a junior-senior level environmental Earth science class.

CONTACTING SOURCES

Because earthquakes are usually associated with plate boundaries, the study of plate tectonics provides an opportunity to initiate the study of earthquakes. The initial phase of such a research project takes a considerable amount of time and should begin before the topic of earthquakes is formally discussed. We posed to our students the following scenario (based on fact): In response to the increase in nuclear waste and the necessity of finding safe disposal sites, the Nuclear Regulatory Commission (NRC) has funded studies to investigate the probability of earthquakes in the eastern United States.

DEB HEMLER AND TOM REPINE

Students investigated a particular earthquake that occurred on May 31, 1897, and was felt in our county and throughout West Virginia. Students had to make a summary of the impact of the quake statewide, a determination of the earthquake's epicenter, and a geological explanation for the event.

Research teams, consisting of three students each, began by generating a list of resources to contact. Typically, students generated short lists of sources on the first day—the Internet, the county courthouse, and the state university. As homework, students thought about additional sources and presented them to the class the following day. After some reflection and discussion, students considered using newspapers from other towns and the state geological survey. The names of organizations from their final list were dropped into a hat, and each research team drew their contacts. Some teams were able to visit their contacts directly, while others relied on mail service. If e-mail addresses were unavailable, teams were instructed to draft a letter to their organizations requesting any information pertaining to the earthquake on May 31, 1897, or events in the days that followed. The e-mail and letter drafts were edited, and teams used word processors to generate business letters on high school stationery. These letters, along with self-addressed, stamped envelopes, were mailed to the potential contacts.

Because not all libraries are willing or able to cooperate with students, a backup plan for obtaining newspaper citations is critical for project completion. Checking with the state's geological survey, the U.S. Geological Survey (*www.usgs.gov*), or with seismic repositories such as the Virginia Tech Seismological Observatory may provide general information on earthquake

Search

the intensity of historical earthquakes

OCTOBER 31, 1935, HELENA, MONTANA

Location: almost directly beneath Helena; Affected area: 363 000 km^2; Damage: $4 million

A series of earthquakes beginning on October 3, 1935, shook the area. The strongest of the shocks was on October 18. Several shocks of lesser intensity were followed by a second strong earthquake on October 31, destroying many buildings that had been previously damaged. The shocks continued with additional strong shocks on November 21 and November 28, 1935.

The photo shows the west wing of Helena High School that collapsed in the October 31 earthquake. The collapsed part of the school had reinforced concrete frame, floors, and roof, and the tile floors were faced with brick. The greatest amount of damage to a single structure was incurred by this school. Construction on the building had been completed only two months prior to the earthquake.

dates and locations of epicenters. Newspaper articles, however, are the crux of the research project. Thanks to the efforts of the National Endowment for the Humanities, all states are currently participating in the U.S. Newspaper Program, which has facilitated the archiving of each state's local newspapers in one location such as a university library. To find the location of a particular state archive, teachers can write to the National Endowment for the Humanities (1100 Pennsylvania Ave., NW, Washington, DC 20506) or visit its website (*www.neh.fed.us*). Once teachers have found the articles, arrangements can be made with the geological survey to send the articles as students request them in subsequent years.

NEWSPAPER ACCOUNTS

As responses from sources began to arrive, we made copies for later use and gave the originals to the respective research teams. Team members sent thank you notes to their contacts. The replies continued to come in as we covered plate tectonics and mountain building in preparation for the unit on earthquakes.

Not all information requests were successful. Some groups received replies indicating the information they requested was not available, and others did not receive any reply at all. Students found, to their surprise, that many newspapers claimed not to have the information on hand. Not surprisingly, some libraries did not have the personnel to search for the specific earthquake citations necessary to complete the study. Our fail-safe source for information was the West Virginia Geological and Economic Survey (WVGES). The education specialist for WVGES agreed to send the appropriate newspaper citations for any complete article collections that were available. Regardless of the sources of data, the students were responsible for acquiring the information and writing appropriate business letters.

During the unit on earthquakes we talked about seismographs and the Richter scale. Students were then asked about historical quakes such as the one they were researching. How was the severity of an earthquake determined prior to the invention of the seismograph? After some discussion, students mentioned how much damage was reported to have occurred during the quake. Eureka! Students recognized the need for the scale that geologists used prior to the seismograph.

The Modified Mercalli Intensity Scale, as it is known, is based on what was felt by the residents, the reaction of observers, and the damage reported for historical quakes. Using this constructivist technique, students were able to understand the scales used to rate earthquake intensities and took an active interest in understanding their design. The research teams were armed with enough background to begin interpreting their own earthquake data.

> Because plate tectonics had previously been covered, students could apply their knowledge about the Appalachian Mountains to draw conclusions about why the quake occurred.

MAPPING WITH MERCALLI

Each research team was given copies of all the newspaper accounts received and a copy of an unabridged Modified Mercalli Intensity Scale. Students read the newspaper excerpts and used the Mercalli descriptions to assign an intensity to each location documented in the articles. For example, the earthquake mentioned in the following passage might be designated as an intensity of III: "Monday afternoon at 2:10 o'clock a distinct shock of earthquake was felt in the entire surrounding country, the tremor lasting according to the estimate of various people, from five to ten seconds. Although the shock was very slight here, in many places throughout pictures, dishes, and the like were tumbled to the floor. This was the first shock publicly noticed since 1885, and produced a great deal of excitement in many localities. The vibration passed from north to south" (Preston County Journal, 1897).

Immediately, students realized the difficulty of assigning intensities based on historic accounts. They observed that the intensity is not always obvious since the articles are often sketchy, and two newspapers may report conflicting accounts for the same location. Research team members were required to agree on the assigned intensity for each location based on evidence and reason.

During their research, students discovered that the epicenter of the earthquake was not actually in West Virginia but just over the state line near Pearisburg, Virginia. Once the accounts of the earthquake were assigned appropriate Roman numeral intensities, students used a West Virginia road map to locate each town identified in the articles and record the intensities felt by the people in the towns. Some teams found references to towns that no longer exist and had to do additional research in order to map all of the data.

Once the intensities were plotted, teams connected the intensities to form intensity contours (Figure 1), which can be highlighted using color pencils. For each team, the end result was an isoseismal map of intensities for the Giles County, Virginia, earthquake as it was felt in the state of West Virginia. Once these maps were completed, the task of providing possible explanations for the quake remained. Because the topic of plate tectonics had previously been covered, students could apply existing knowledge about the Appalachian Mountains to draw conclusions.

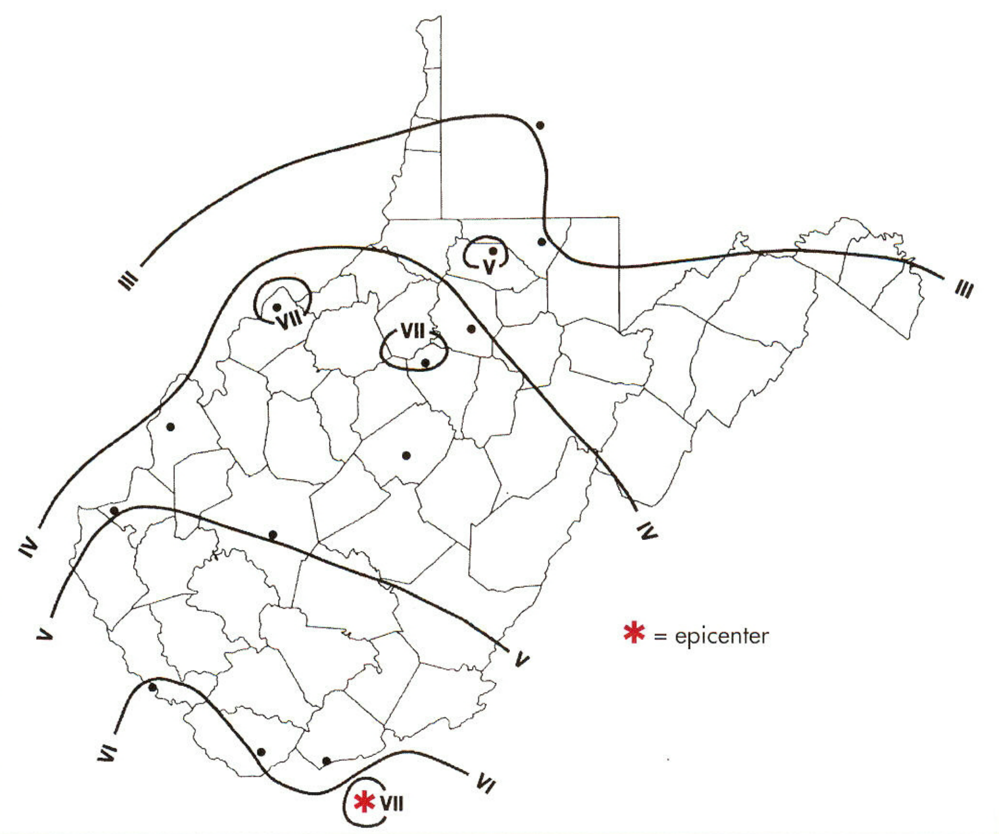
DISCUSSION AND PRESENTATION

The research teams posted their maps in the classroom, and each group briefly discussed their results and conclusions. Students first discussed the difficulty of assigning intensities for each location on the map. They mentioned the subjective nature of assigning objective numbers to each location depending on individual interpretation of the newspaper accounts, many of which lacked detail. Some articles were brief, consisting of a line or two, and others were vague in description.

Students observed that various articles contradicted each other about the events in a specific area, leading to a discussion of possible explanations for these discrepancies. It occurred to students that some newspapers may have exaggerated the damage or not gotten all the facts. Although high school students are prone to believe that anything in print must be true, this activity made students realize that they should be more skeptical about what is printed in a newspaper.

FIGURE 1.

Student isoseismal map of the Giles County, Virginia, earthquake of 1897, generated from newspaper accounts.



Students went on to observe that even if the intensities they labeled for each town were consistent, their interpretation of the location of the contour lines differed. Some students pointed out that the contours could not be closed because there was no data for the surrounding states. This led to a debate on whether isoseismal mapping should follow the same rules as contour mapping. An intensity of VII may be mapped in an area surrounded by a IV intensity interval, a situation never seen on a contour map. The question of who is correct resulted in the resounding answer, "We all are!" We placed the stipulation that students base their interpretations on sound logic and support them with data.

Discussion stemming from these maps can be as geologically in-depth as desired. For example, our students generally assumed that the further from the epicenter of an earthquake residents are, the less intense the quake will feel. But some students noticed in the case of this earthquake that the intensity was felt more severely in some areas to the north, further away from the epicenter, than was felt by people in closer locations to the east. Consulting a geologic map of West Virginia revealed the presence of glacial lake clays in this region, which are more unstable during quakes than bedrock. The students' observations extended their knowledge well beyond what might be covered in a typical lesson on earthquakes, with connections made to their prior geology lessons including mapping, plate tectonics, and historical geology.

To finish our discussion, we showed a map of the Giles County earthquake that geologists had generated and asked students to compare their maps to that of the geologists. The geologists' map was much different than the student maps—most of West Virginia is labeled as an intensity of III by geologists. After their initial panic, students realized that the geologists' map was less detailed than their own. Further, they recognized that they had more data points and information about the state of West Virginia than the geologists who drew the map, making the student maps more accurate! They had become scientists in the true sense of the word.

Once the discussions were exhausted, concept application began. Students synthesized all they had learned from working in their group as well as from other group presentations. Each student was given the individual task of writing a report to the NRC describing the historic Giles County earthquake as it affected our county—the intensity of the quake, the location of its epicenter, the cause of the quake, and the risk of future seismic events in our area. Students based their future

FIGURE 2.

List of some historical earthquakes (Snider, 1990).

The oldest written records of earthquakes in the eastern United States date to the mid–1500s. Since then, hundreds of earthquakes have been recorded. These are among the more significant events.

Cape Ann, Mass., 1755. Magnitude 6.0; felt from Chesapeake Bay to Nova Scotia. In Boston, walls, chimneys, and stone fences were knocked down. Waves like the swelling of the sea were reported on the Earth's surface.

New Madrid, Mo., 1811–12. The three largest earthquakes documented in all of North America with magnitudes 8.6, 8.4, and 8.8. Observers saw the Earth roll in waves a meter high. On the Mississippi River, great waves overwhelmed many boats and washed thousands of trees into the river. Church bells rang in Boston, 1770 kilometers away. The damage to property and loss of life was small, mostly due to the extremely sparse population of that time.

New York, N.Y., 1884. Magnitude 5.0, felt from Vermont to southern New Jersey. Greatest damage in Jamaica and Amityville, N.Y., where large cracks appeared in walls, windows were broken, and chimneys toppled.

Charleston, S.C., 1886. Magnitude 7.7; felt for a radius of 1290 kilometers, strongly shaken to 160 kilometers. Widespread and extensive damage to buildings, railroad lines, and communications.

Charleston, Mo., 1895. Magnitude 6.2; felt in 23 states. Extensive damage to buildings in Charleston and Cairo, Illinois.

Giles County, Va., 1897. Magnitude 5.8; felt from Georgia to Pennsylvania. Old brick houses were cracked, and bricks were thrown from chimney tops.

St. Lawrence River, 1925. Magnitude 7.0; felt in eastern Canada, south to Virginia, and west to the Mississippi River. Damage and loss of life were minimal due to sparse population in epicentral area.

Attica, N.Y., 1929. Magnitude 5.8; felt from Ontario to Ohio, Pennsylvania, Connecticut, Maine, Vermont, and New York. Two hundred and fifty chimneys were knocked down. Walls cracked as far away as Sayre, Pa.

Massena, N.Y., 1944. Magnitude 5.6; felt from Maine to Michigan to Maryland and Pennsylvania. Damage estimated at 2 million dollars (1944 value) in the epicentral area.

Wilkes-Barre, Pa., 1954. Magnitude 5.0. A local shock damaged hundreds of homes. Streets and sidewalks were cracked, and gas and water mains snapped. Damage was assessed in excess of 1 million dollars.

risk assessment on their determination of what caused the fault, how active the fault has been since the Giles County event, and their distance from the epicenter.

We evaluate the groups on their ability to defend their drawing of intensity contours and the plausibility of their maps (contour map mechanics must be employed properly to represent the data). Students are also assessed individually on their reports to the NRC for accuracy (intensity, epicenter, and cause of earthquake) and recommendations as to how a nuclear waste repository would be affected by potential earthquakes in the area. Students are required to make a scientifically sound recommendation based on the evidence for future seismic activity.

This activity can be adapted for use in most areas of the United States. Contacting any state geological survey will provide, at the least, the dates of some local historical earthquakes. The only actual information necessary to get started on this activity is the date of the earthquake. Figure 2 lists some historical quakes that are good starting places.

The benefits of student research include promoting scientific attitudes and habits of mind. Our students knew they were performing authentic scientific research and investigating a historical earthquake just as geologists do. The project also had the benefit of being long-term; students had sustained contact with a topic and data that tied into prior knowledge. They realized that the term "research" does not imply a literature review; rather, it is the collection, manipulation, and interpretation of data.

Students demonstrated scientific habits of mind such as persistence and skepticism as they endeavored to collect their research and were invested in the project because they felt it was student directed. They realized that earthquakes are not necessarily only a concern of West Coast residents but that the faulting that resulted from the formation of the Appalachian Mountains and withdrawal of Africa creates the potential for a sizeable earthquake in the eastern United States. What better way to learn that lesson? ✧

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Idea Bank

I HATE FIELD TRIPS

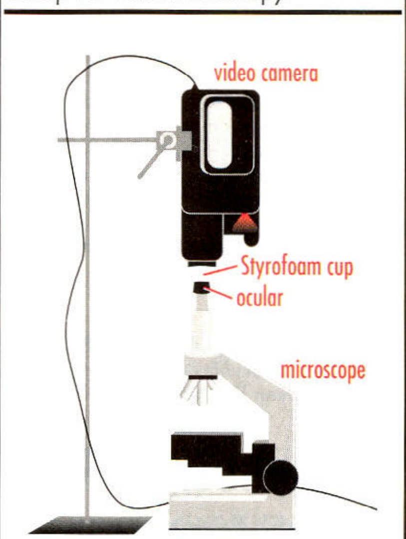
Field trip! These words bring joy into the hearts of students and dread into the hearts of many of my colleagues. Field trips can be valuable teaching tools, yet I have often found planning a field trip to be as frustrating as learning to run a new program on my computer. To help myself overcome field-trip anxiety and go from hating field trips to loving them, I developed a guide and checklist to make planning field trips less stressful and to virtually eliminate "system errors."

Using this guide, I am better able to introduce and reinforce previously learned concepts, explore new ideas, motivate otherwise totally bored students, provide situations in which ordinarily awkward students can shine, provide lessons involving hands-on learning, and demonstrate thematic approaches to science. Most importantly, I have figured out how to make field trips learning oriented—not play days.

The following is the guide and checklist used to plan a field trip to a wildlife refuge. I found this strategy to be instrumental in winning administrative approval for the trip; and when I plan to repeat the trip or share my ideas with a colleague, the guide becomes a useful collection of notes and handouts that make the next visit a breeze.

FIGURE 1.

Setup for videomicroscopy.



Decide on concepts. (Why am I doing this?) One of the first and most important steps in planning a field trip is to decide what concepts can be applied, reinforced, or explored during the trip in a way that that will help students remember them and be able to apply them in other settings. I try to plan a field trip to happen between units or chapters so that the trip will apply or reinforce concepts from previously learned lessons and provide an opportunity for students to explore new areas for the next unit.

This approach is appropriate for thematic science, in which various disciplines of science are studied together. For example, when studying the weather, students may study the chemistry of acid rain, the physics involved in measuring barometric pressure, the effect of geology on weather patterns, and the effects of climate on dominant species. With careful selection and planning, I can meet objectives in several areas at the same time and link them in a logical way.

Using this plan, students were able to apply, reinforce, and explore concepts on the trip to the wildlife refuge. Students applied their knowledge of tree species by correctly identifying trees in the park. They reinforced what they were learning about topographic maps by mapping their path through the park, describing the terrain along the way, and constructing life-sized contour lines; and they explored the concept of dominant species of trees by noting the environmental conditions in which each species thrived. The concepts we had discussed in class were made real to them as they stood on moist soil, noted the dominant tree species, and looked at their topographic maps to confirm that the elevation of the area was lower than the surrounding area, allowing water to collect.

Decide where to go. (Can I really go there?) Keeping my objectives in mind, I explore places that meet my needs. If funds are limited, a great science classroom is readily available outside the doors of almost every school—the local park. There are also plenty of other places: hospitals, museums, dentists' offices, opticians' offices, manufacturing centers, power plants, and so on. I have found that some business owners are willing to help if I explain what students will be learning and involve the owners in the planning.

Make the arrangements. (Try to remember not to forget . . .) I have found the following checklist indispensable. It gives me peace of mind to know that the details are completed and that everything will fall into place on the day of the trip (often planned months ahead). These are the details I check off:

- Obtain trip approval. After deciding where to go, get the trip approved through the principal. Most school districts are fairly specific in regard to the channels to go through for approval.
- Arrange the trip with the facility to be visited. Even when going to an open field or park, I have found it wise to make arrangements ahead of time. Owners of the facilities may have special events planned or may be closed for some unusual reason. There are other benefits to calling

ahead, such as acquiring printed information or scheduling a tour with a guide.

■ Schedule and reconfirm the transportation. Paperwork can be misplaced, and mistakes can be made. I once waited an hour for a bus to arrive only to find that I had made a typo that cost us an hour.

■ Arrange for chaperones, depending on class size and age. Chaperones must know the school rules and be prepared to enforce them. Parents are often willing to help and enjoy the trip most when given a specific task or when stationed at a particular place to lead an activity. If the class is very large, I consider dividing students into small groups and going on different days or times.

■ Distribute permission slips. Most schools require specific forms with legal releases and parent information that includes emergency phone numbers. I never allow students to go on the trip if I think they have forged their parent's signature or have not turned in a permission slip. It is important to take the emergency numbers on the trip.

■ Plan activities and estimate the time needed to complete them. It is best to have too much to do. The brightest group of students in the classroom may take twice as long as expected to complete their activities, or they may finish more quickly than expected. Having a back-up activity prevents students from having too much time with nothing to do.

■ It is important to go to the facility or park ahead of time to scout it out. Things may have changed since the last visit. If it is impossible to get there ahead of time, ask the facility for the name of a group that has been there recently and contact its members for tips.

Prepare students. (No, you cannot bring your Frisbee!) Often students have a different idea of the purpose of a field trip than the teacher has—students may expect a fun day of goofing off. Make sure that students understand that this is an alternative classroom, that learning can take place anywhere, and that learning can be fun. If the trip is intended to reinforce or apply concepts learned in the classroom, make sure students have an adequate knowledge base. I have discovered that if students know ahead of time that certain skills will be required, they can be motivated to study more in the classroom. It is important to give students a clear idea about what they will be doing and how they will be evaluated. I do this both verbally and in writing. Individual work can be assigned in addition to group work to prevent one person from doing everything.

Let students know what to wear. I have found that even high school students and adult chaperones often need to be reminded about proper attire for hiking or other out-of-school activities. Rain gear is a must in many climates for outdoor activities, regardless of the forecast.

Decide what equipment to take. I find it best to assign pieces of equipment to specific (and responsible) individuals. I recommend that students carry backpacks for sweaters, notebooks, pencils, lunches, and so on. Expectations for student behavior should be clear. Review safety guidelines, remembering that a new environment offers different challenges than the classroom.

Go on the trip. (It's a great day for a field trip!) Carry out the plan. At least one thing will go wrong, but roll with the punches and enjoy the fruits of good planning. I have often found it helpful to train the chaperones or older students to help others so I do not have to try to be everywhere. Watch for "teachable moments" that are not on the agenda but are interesting and educational and take some time to discuss them. Also watch for the "ah-ha's." It is rewarding to know that students finally understand a difficult concept.

Student evaluation. (Is this for a grade?) Following up with evaluation is critical. I usually do some sort of informal evaluation immediately after the trip, noting each student's participation level and behavior. I follow up later with a more formal rubric that evaluates group, class, and individual assignments. Because students know ahead of time the goals that are important to accomplish, they are more likely to focus during the trip. This eliminates some of the "goofing off"—not all of which needs to be discouraged. Students need time for discovery and exploration as well as the more focused "on task" time.

Teacher follow-up. (The next time I will . . .) After returning to the classroom, review what has been learned. Students should be bubbling with enthusiasm and ready to discuss all the details of the trip. Students should discuss what they liked, how much they felt they learned, and how to improve the trip for the next time. I always write myself an evaluation of the trip with a description of some of the details to use as a reference for the next time I go.

Extend the learning into the classroom. If the activities during the field trip enabled students to explore the next unit, bring up these concepts. If permitted, bring some sort of memento from the trip. (Never remove anything from a state or national park without permission . . . not even rocks!) I always take photos because students love to see themselves on bulletin boards and in the yearbook, and photos help them remember what they did and saw.

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NOTE

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TELLING STORIES

One way to add depth to science lessons is to consider the stories behind the people and circumstances that built the knowledge base called "science." Why should teachers add these stories to science class?

■ Stories are a hook. We use laboratory activities and demonstrations to capture students' attention and bring theoretical concepts to life; stories can also capture students' imagina-

Geodesic Earth

Models help students understand the size and scale of the Earth

MAKING SCALE MODELS IS AN EXCELLENT way to integrate science and mathematics. To provide a physical framework for science education, we use geodesic spheres as models to convey not only size and scale but also the interior of objects such as the Earth. Students can use models to learn about Earth's structure, composition, size, and geography while also learning mathematical and verbal skills and studying science history.

During discussions in our eighth grade integrated science class, we found that students have many misconceptions about the Earth. To teach them about the planet's three-dimensional nature, we designed an activity that incorporates mathematics skills into the building of an Earth model. The activity required students to work cooperatively to research and create the model. The project takes approximately six weeks to complete.

BUILDING ON KNOWLEDGE

To begin, we asked students to write an essay titled "What I know about the Earth." Students were encouraged to supplement their essays with diagrams, charts, or other forms of graphic information. When completed, the essays were collected by the instructor, read, and filed for comparison with post-project essays.

Next, the class compiled a list of 36 questions about Earth. Students were then assigned to six different groups, each of which was given six questions to research as a team. Their charge was to find reasonable answers from the classroom resources available and to design and prepare mini-presentations including artwork, charts, diagrams, and activities for the class at the completion of the project. Each team kept a running log of which students researched the questions, did artwork, and performed other duties. This work was done concurrently with the building of the scale model of the Earth.

After completing the project, each student wrote an essay titled "What I now know about the Earth." A comparison of the pre- and post-project essays was made using the following scale:

- Student increased knowledge base by less than 25 percent—no points.
- Student increased knowledge base by 25-50 percent—1 point.
- Student increased knowledge base by 50-75 percent—2 points.
- Student increased knowledge base by 75-100 percent—3 points.
- Student increased knowledge base by more than 100 percent—4 points.

A careful reading of both pre- and post-project essays was necessary to compare the number of concepts represented accurately in each. Most students increased their Earth knowledge base by more than 75 percent. The percent of student increase in knowledge was determined by counting the number of correct facts presented in their pre-test essays and comparing the total to the number of correct facts in the post-test essays. Students who already had considerable pre-knowledge were not penalized because their papers were compared to the list of objectives for the unit. If they demonstrated high levels of mastery, they were given a 4. These points were later added to points gained in other sections, such as the rubric in Figure 2, for a possible total of 24 points.

GEOMETRY AND CONSTRUCTION

The icosahedron used as the framework structure in this project has 20 equilateral triangular faces that connect to form a sphere-like shape. As a class, we discussed the triangle as the strongest building structure and the basis for many natural and architectural structures. The triangular faces of an icosahedron are used in the Dymaxion Airocean map of the world by Buckminster Fuller (1938) to depict the landmasses and oceans of the world with very little distortion. As part of their research assignment, students were encouraged to use the Internet to research the fascinating details of Buckminster Fuller's life and work.

The wooden frame for the geodesic sphere struc-

ELIZABETH A. STRONG
AND ROBERT E. STRONG

ture was constructed in one 45-minute class period. Students were not given detailed instructions on constructing the sphere itself, only general guidelines that included safety instructions. (See Figure 1 for detailed instructions for teachers.) The construction was done on the floor in a 2- × 2-meter cleared area of the classroom. (If space is limited, the model can be scaled down.) Students were told to use all of the available materials and to attach the 20 triangles to form the icosahedron.

Each day, each group assigned one member to work on construction while the other members researched and developed the group's presentation. When the structure was completed, it was covered with black garden plastic secured with duct tape. Oceania was left open to allow viewing of the interior of the "Earth."

To accurately depict the landmasses and oceans of the world, we copied the Dymaxion Airocean map as a transparency and used an overhead projection of it for students to trace the various triangles of the geodesic sphere onto paper. Two students numbered the Dymaxion Airocean map's triangles to facilitate placement of each triangle on the large structure. After being traced, the landmasses were colored, cut out, and attached with duct tape to the appropriate triangles of the icosahedron on the black garden plastic. This provided a large reference model of the Earth for students to use as they made their presentations.

In addition to geometry, other aspects of mathematics were encompassed by this project. When the model was completed, students measured its diameter in metric

FIGURE 1.

Geodesic Earth model instructions.

The materials needed for this project are:

- One meterstick per group
- Crayons or markers
- Two sheets of poster board per group
- One pair of scissors per group
- Several rolls of string
- Overhead transparency of Dymaxion Airocean map
- One roll of cellophane tape per group
- One calculator per group
- One roll of butcher paper
- Several rolls of duct tape
- Overhead projector
- Various resources for student research
- Thirty wooden struts of the same length
- Twelve starplates (purchased through an agriculture supply company)
- Sixty nuts, bolts, and 5/16-inch washers
- One 5/16-inch wrench per group
- One large roll black garden plastic
- Wood, cardboard, or poster board for the inner and outer cores
- Clamp light
- Red bulb
- Extension cord
- Rope to suspend inner and outer cores

The wooden model is first constructed and then covered with black plastic and the map. The struts may range from 0.6 to 2 meters in length (size is largely dependent on classroom space). Prior to construction, the wood must be drilled 4 centimeters from the ends through the widest part of the strut and the 5/16-inch carriage bolts placed through the holes. The holes should be drilled in the wood so that a connection with the starplates is accomplished, and the struts remain the same length. (Measure from hole to hole, not from end to end of the wooden strut). Make sure the bolts come out the drilled side so that the connections remain equal distances apart.

Students must wear full-wrap, splash-proof goggles. They begin the construction of the geodesic sphere with one triangle with a starplate at each of the three vertices. Each of the wooden struts should be attached to the starplate connectors with bolts, nuts, and washers, with students finger-tightening the nuts before using wrenches. The goal is to use 30 wooden struts, 12 starplates, 60 bolts, 60 nuts, and 60 washers to complete an icosahedron. Depending on the size of the wooden struts chosen, step stools may be necessary. Students must understand that each side is a triangle; no other shapes will work. As the first several triangles are finger-tightened and then tightened with a wrench, students will see the creation taking shape.

In a very short time, the icosahedron will be finished. Make sure that each of the nuts is tightened with a wrench. Cover the structure in black garden plastic secured with duct tape or with cloth and Velcro. When the structure is complete, students can use an enlarged overhead projection of a Dymaxion Airocean map (available electronically from the Buckminster Fuller Institute at *www.bfi.org*) to make landmass models that may be colored and added to the exterior of the sphere. Our model used simple drawings of the landmasses, but three-dimensional, topographic mapping would also be appropriate.

Leave part of the structure open so the interior may be viewed with the outer core, inner core, and the mantle labeled and constructed to scale. A ball or other spherical object of the proper size may represent the inner core, and the outer core may be represented by a cardboard or wooden construction made to scale. We used two wooden circles of the proper diameter to represent the inner core and connected them together with one circle placed vertically and the other horizontally. The light was placed on the horizontal circle of wood to illuminate the interior.

During construction of the large geodesic sphere, rotating construction crews allow teachers to manage a large class of students. Not all students in a class of 30 can actively build at the same time!

units; the sphere measured approximately 2 meters in diameter. Students used classroom reference materials to determine the actual diameter of the Earth, 12 756 kilometers, and the actual diameter of the inner core, 2400 kilometers (Shipman and Wilson, 1987). To determine the correct diameter of the scale model's inner core, students used the following: The diameter of the model/12 756 kilometers is equal to the diameter of the scale model's inner core/2400 kilometers. Therefore, because the diameter of our model was 2 meters, then the expression would be .002 kilometers/12 756 kilometers is equal to x/2400 kilometers, and x would equal 0.376 meter.

Students built a scale model of the inner core and placed a red light in it to represent its high temperature. The model's outer core and mantle thicknesses were derived similarly to how the model's inner core diameter was found, and the actual thicknesses were found in resource materials. The outer core and mantle were then constructed to scale and placed within the model Earth. The mantle layer was constructed to show subduction zones and hot spots.

Finally, each group presented the answers to their research questions. These presentations were scored according to the rubric shown in Figure 2.

GOALS AND OBJECTIVES

The *National Science Education Standards* emphasizes learning the structure of the Earth system and technological design as objectives for students in grades 5–8 (National Research Council, 1996). Likewise, the instructional goals and objectives for West Virginia schools were followed throughout this project and include the major themes of systems, changes, and models. Depending on the nature of the questions posed by students, forces and energy, change and constancy, and life science concepts may be addressed as well. The history of science, through discussions about Platonic solids and Buckminster Fuller's inventions, is also integral to this series of activities.

In a truly active fashion, students explored Earth science concepts as they participated in a student-driven project that gave them a sense of ownership of their learning. The essence of scale modeling was captured by one student's comment at the project's completion: "Look, we shrunk the Earth!" ✧

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FIGURE 2.

Rubric for group presentations.

Criteria	1	2	3	4
Accuracy	inaccurate or misleading information throughout	some inaccuracies in presentation	few inaccuracies	accurate in most areas
Creativity	mere reading of information; no visuals in presentation	some spontaneity in presentation; includes some visual material	novel approaches; visuals used to describe and/or explain	novel and unique approach; visuals neatly completed
Clarity	mumbled; disorganized information	some disorganization; poor presentation	explanations clear; most of presentation is engaging and interesting	clear, easy-to-understand explanations; engaging and interesting
Shared responsibility	group worked poorly together; one member of the group dominated	team members seldom worked well together; work was not equally distributed	team members worked well together most of the time; most work was equally distributed	team members worked well together; all members contributed to presentation

Outcrops in the Classroom

An active simulation of basic geologic fieldwork

WE WERE AT THE POINT IN OUR geology curriculum when we had described sedimentary rocks and needed to let students apply their newly acquired geologic knowledge. We wanted to take them into the field so they could "do" geology, but it was winter—not the best season for gaining field experience! We tried to simulate fieldwork for students by putting some rocks on a table and having students work with them, but this setup did not take into account the three-dimensional nature of geology. By casually ignoring the vertical stacking of sedimentary rocks, we were violating the very principles (such as superposition) we wanted our students to visualize. We needed a better simulation that would correctly demonstrate the vertical stacking of sedimentary rock. As a result, our "telling about" time is now devoted to exploring students' "whys?" instead of our "becauses!"

"Outcrops in the Classroom," an easily constructed, hands-on, geology simulator, provides students with the observational, record-keeping, and interpretative experiences—without the weather—of field geologists. Outcrops are locations where the bedrock or area is naturally exposed. Using the activity to encourage simple identification of sedimentary rocks in a vertically stacked sequence suffices for elementary students. Middle and high school students can use the same activity to investigate increasingly more difficult concepts such as change through geologic time. Pedagogically, the activity revolves around student resolution of discrepant events. Questions such as "How do you know that?" or "How can you draw that conclusion based on what you see?" act both as an impetus for insightful student observations and interpretations and as a way for us to assess their progress.

TOM REPINE AND DEB HEMLER

Our goal is to ensure a collective exclusion of ideas about geological formations until students realize that one or two particular interpretations most plausibly correspond to all the data. At the end of this process, we make it clear that different interpretations, based on well-thought-out ideas that honor the data, can all be valid. Students are sometimes dismayed by the fact that there may be more than one right answer. Needless to say, when we are done, students have a firm grasp of the nature of scientific debate.

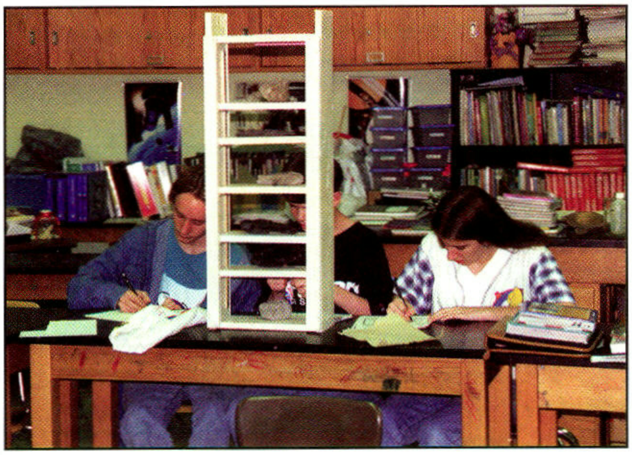
A STORY OF TIME AND DISTANCE

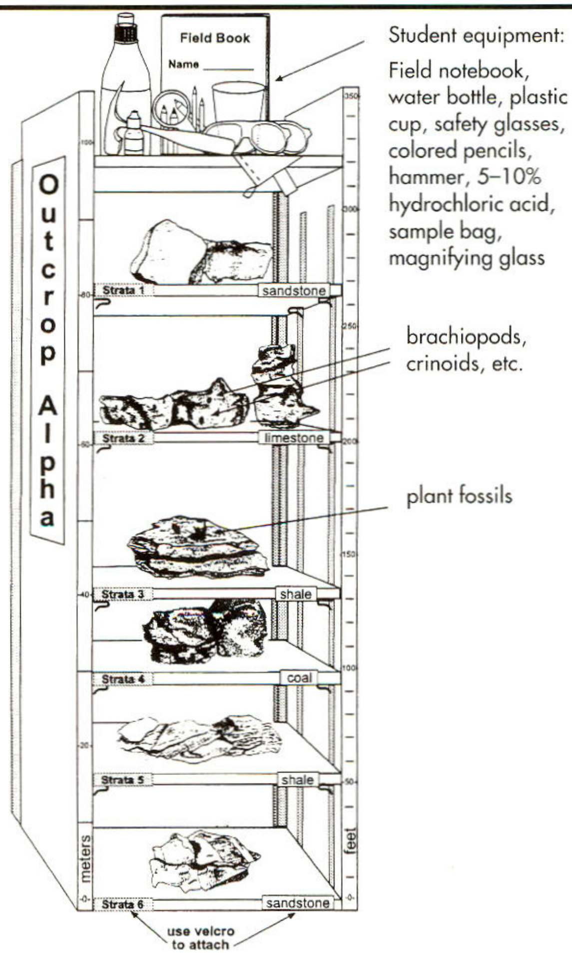
"The best geologist is the one who sees the most rocks!" This unattributed witticism supports our belief that geology is best learned in the field. With this in mind, we designed a simple device that allows us to simulate the vertical and horizontal changes found in the rocks near

IMAGES BY BETTY SCHLEGER

FIGURE 1.

Outcrop simulator.





Each group of students will record data in the field notebook and compose a story of geologic change through time for their own outcrop. After each group has finished an interpretation, data from all of the simulators is cooperatively shared to allow class discussion of variations in stories from outcrop to outcrop. Students must develop a comprehensive story to explain the observed lateral changes in depositional environments. Classroom discussion of these interpretations often reveals flaws in student reasoning. Thus, they quickly realize that while there can be multiple right answers, all of the evidence tends to adequately support only one or two interpretations.

PHOTO AND DIAGRAM COURTESY OF THE AUTHOR

our school. These changes are modeled by placing various rock specimens on the simulator's adjustable shelves. Our first goal is for students to develop descriptions of the vertical succession of the rocks in their simulators. We then explore horizontal relationships. Just like real field geologists, students are required to incorporate all the data about vertical change in each single simulator into an expanded vision explaining any and all changes seen from simulator to simulator. What an eye-opening phenomenon! The observation that a layer of sedimentary rock, if followed from outcrop to outcrop, may change its appearance (form, composition, thickness, and so forth) is really surprising to many. The fact that a layer of rock may actually stop (have an edge) is even more astonishing! How can this happen? What causes it?

Without a prior knowledge base, these questions and concepts seem unanswerable to students, so we tell them to think of a river. Does a river begin and end someplace? Does it have sides? What is beside a river? These geographic relationships, which students take for granted, are the key to understanding many geologic processes and open the door for discussions centering on uniformitarianism—the geologists' credo that the present is the key to the past. Once students begin to think of a sandbar in a river or the beach along an ocean, their imaginations help them define the concept of "depositional environments." Competing theories on what each layer of rock represents or why one layer stopped and another started are explored. The presence of plant and/or animal fossils is used to postulate what sort of ancient land or water environments were present when the organisms lived. The connections between past geologic and present geographic conditions become clear. Students no longer see rocks as just rocks but rather as indicators of dynamic systems in the geologic past. A coal bed is seen as a swamp, and sandstone may be imagined to be an old beach, dune, sandbar, or delta. Shale becomes mud from a flood, and limestone with seashells means an ocean existed. Now our students are thinking like geologists!

GETTING STARTED

When possible we try to have each simulator (Figure 1) depict a real outcrop or road cut in our area. To accurately model the rocks in our area, we used publications and maps obtained from geologists working for the State Geological Survey Office. However, this is not always necessary. For example, some of our simulations use fictitious arrangements of rocks designed to present students with a dilemma to explore. "Field teams" of no more than four students observe and record data such as rock type, rock texture, color (both weathered and fresh surfaces), appearance (grain size, shape, angles, fractures, and laminations), presence and kind of plant or animal fossils, thickness, and so forth. Each group member records data in a field notebook and creates a rudimentary geologic column of the outcrop by sketching the sequence in the notebook. A scale is required, and colored pencils are used to approximate color variations.

As stated earlier, students approach this activity after having been introduced to basic rock types. Thus, we welcome them to their first day of fieldwork, and their assignment is to observe and record as much data as possible from their outcrop. Such open-ended directions are frustrating for many—initially they spend a lot of energy and time discussing what is or is not important. At the conclusion of the activity we touch on this point by noting that real scientists are observant and diligent because they often do not know exactly what is important. To head off tangential conversations and comparisons with friends at adjacent simulators, we remind students that sedimentary rocks vary from outcrop to outcrop. Thus, their results may differ from those of their neighbors. We also remind them that, as rookie geologists, their work is subject to evaluation by the management.

We try not to give too much away at the beginning. Many students intuitively realize that different kinds of rocks and different sequences of rocks imply change; that these changes happen through time; and that, historically, the sequence must progress from the lowermost to the topmost layers of rock. In the past, we would have defined these same ideas in a lecture, but by allowing students to come to their own conclusions based on their own observations, we find that they remember the concepts longer and more clearly. If and when the opportunity for a real field trip presents itself, students who have done this activity gain more from the experience.

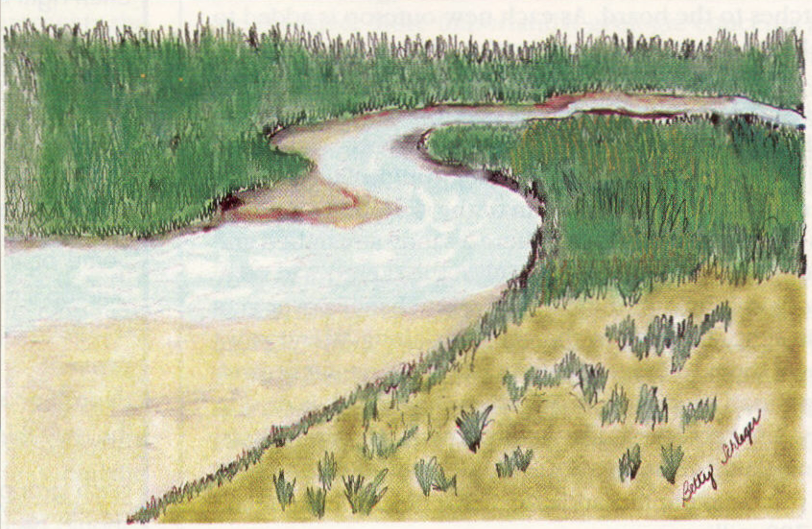
As they work on the simulators, we encourage students to envision the sequence of sedimentary rocks as lithified accumulations of transported sediments. Asking students, "How did the sediments that formed your rocks get there?" helps them focus on the dynamics of sediment transport and deposition. Forming a clear mental picture of what these depositional environments look like is important, and we facilitate this process by providing each group with a sketch such as the one shown in Figure 2. Once the students reach a consensus on the environment responsible for accumulating the particular sediment composing each rock, they attach a sketch to the shelf beside each specimen. The posted sketches serve a dual purpose. They provide the students with visual reinforcement and provide us with a device for spot-checking the accuracy of their decisions. If a student's association of a sketch with a rock is not reasonable, then we ask leading questions to assess and redirect the group's work.

Students no longer see rocks as just rocks but rather as indicators of dynamic systems in the geologic past. A coal bed is seen as a swamp, and sandstone may be imagined to be an old beach, dune, sandbar, or delta.

Using the sketches, each group composes an explanation which, in their own words and based on

FIGURE 2.

Sandbar in a stream.



Sandbars commonly occur in streams. Sand particles are deposited in areas where the current velocity is unable to move the particles. Sandbars are very common on any sized stream or river and are usually composed of similar looking and sized, rounded sand grains. They have fine layers within them that commonly slope into the water. Plant life is very close by, and it may fall onto the sandbar and be covered over by more sand during a flood.

ART BY BETTY SCHLEGER

We try not to give too much away at the beginning. Many students intuitively realize that different kinds of rocks and different sequences of rocks imply change; that these changes happen through time; and that, historically, the sequence must progress from the lowermost to the topmost layers of rock.

their data, provides a realistic story explaining how their vertical assembly of sediments accumulated. This includes plausible explanations for the geology changing from one environment to another. In their own words, we let students introduce themselves to the concepts of uniformitarianism, lithification, superposition, and so forth. We may not have used the terms, but the students do understand the principles. All members of each group assume active roles in presenting their group's interpretation to the entire class. We, and other members of the class, then constructively question the group's explanation.

Once we have discussed each group's interpretation of their outcrop, each group tapes their sequenced sketches to the board. As each new outcrop is added to the board, it becomes apparent that environments change not only vertically but also horizontally. It is here that their appreciation of modern analogs becomes helpful. In the past, asking our students to explain how sandstone and shale could be side by side would elicit a stony silence. Now, we direct them to the sketches. Suddenly it is obvious—it might be where a sandy streambed and muddy floodplain meet. Looking at the sketches in vertical columns allows them to interpret changes over geologic time. Looking at the sketches along lateral rows allows them to begin thinking of how an ancient landscape may have looked. Whether they know it or not, they are recreating the environment of depositions, determining changes over geologic time, and constructing paleogeographic landscapes that have not been seen for 300 million years.

MAKING SIMULATORS

Dimensionally, each simulator is 1 meter tall, about a half-meter wide, and 15 centimeters deep. We built our simulators using scrap lumber, so the only expense was an important modification to our original design—adjustable shelf brackets. We found that students assumed that the equally spaced, fixed shelves in our first simulators meant that all of the rock layers were of the same thickness. This severely limited our ability to introduce horizontal variations in thickness. Our new models have a bottom fixed shelf and five adjustable shelves that can be positioned to provide a clear visual signal that some of the rocks change thickness between adjacent outcrops. Each shelf holds one to three good-sized rock specimens collected from local outcrops.

The top of the simulator is used to hold colored pencils, a written problem statement (Figure 3), several inexpensive, plastic hand lenses, a small plastic bottle of water (wetting the rock surface sometimes reveals additional details), an empty plastic bottle labeled "10 percent hydrochloric acid," a chisel-end geologic hammer, and safety glasses.

FIGURE 3.

Student introduction and problem statement.

These rocks are approximately 300 million years old. They are sedimentary rocks that formed when sediments were transported to a new area by wind, water, or ice. Sediments vary in size. Faster moving water can move bigger grains of sediment than relatively slower moving water. So, cobbles and boulders are often interpreted as evidence of fast moving water. Very small sediments, like clay and mud, fall out only when the water is not moving at all. So, as the water slows down, the different grain sizes fall out in different places—often right beside each other. A geologist refers to this as deposition. The location where it happens is called the environment of deposition. This could be a sandbar, seashore, lake, or swamp. At some point in geologic time, these individual grains become cemented together. This is called lithification. We then have a sedimentary rock.

Some of the common sedimentary rocks are in the outcrop simulator. Each different rock type represents a different depositional environment. Remember—the present is the key to the past. That means the depositional environments we see today are models of the way things happened in the geologic past.

Each group must observe and record data. All data should be recorded in a field notebook. Once this is done, develop a story which, supported by the data, explains the origin of the sequence of rocks in your outcrop. Although each group must collectively develop an interpretation, each student is responsible for recording observations and ideas. Sketches showing important observations that support interpretation are helpful and suggested.

PREPLANNING

The teacher should consider how "Outcrops in the Classroom" might be used before deciding on which rocks to use and the physical placement of the simulators in the classroom. Before beginning, teachers should consider the following points:

- A straight-line arrangement across the classroom may simulate a series of local highway or railroad cuts. A nonlinear placement might be used to realistically simulate how geologic interpretations may be developed from seemingly randomly spaced outcrop data.
- Will the activity be used for elementary and middle school students? If so, will they simply observe and record data to develop a better understanding of introductory geologic concepts? Or, will high school students be using the simulated rock record to develop increasingly complex interpretations of changeable paleo-environments (ocean, river channel, swamp, and so forth)? Or, might environmental Earth science students be asked to relate geologic conditions to environmental situations (such as the placement of a landfill near the simulated outcrops)?
- How will this activity be used pedagogically? Within a learning cycle context, we normally use "Outcrops in the Classroom" as an exploratory activity. Therefore, we normally choose not to assess students' progress but to use the activity as an opportunity for students to learn how to work with data and deal with problems. However, we do occasionally use the activity for concept development, concept application, or performance assessment. Taking into account the grade level involved, scoring is based on a rubric emphasizing rock description, interpretation of environments, and development of vertical and lateral geologic changes.

SAFETY CONCERNS

Geologists routinely use rock hammers and dilute hydrochloric acid. The chemical reaction that occurs when the acid hits limestone or calcite is an important and observable identification determinant. For elementary and middle school students, an empty acid bottle on the top of each simulator is our way of reminding them to use this test. However, we restrict direct access to the hydrochloric acid to ourselves or a responsible assistant—students must request that acid be applied to specific rocks. We have found that limiting the application of acid to three of their six specimens encourages more serious observation of all of the rocks. Specimens subjected to the acid test are thoroughly rinsed in water before the students are permitted to handle them again.

Like the acid test, color differences between fresh and weathered rock surfaces provide quite a bit of information. To reveal a fresh face of the rock, students use the rock hammer to break it into two pieces. This is accomplished by first placing the specimen in a cloth sample bag and then placing the bag on the floor. The hammer is then used to strike the rock while it is inside the bag, eliminating flying debris and dust. We have found that the omission of these tests lessens the realistic nature of the simulation. Therefore, safety is a primary concern. All students must wear full-wrap, splash-proof goggles while doing this activity.

Whether they know it or not, students are recreating the environment of depositions, determining changes over geologic time, and constructing paleogeographic landscapes that have not been seen for 300 million years.

The goal of "Outcrops in the Classroom" is to provide students with an interpretive classroom environment when actual fieldwork is either impractical or impossible. From the experience, they develop an appreciation of the type of information found in rocks, conduct good geologic investigations, and use personally collected data to construct plausible geologic interpretations. They gain a better appreciation of the realistic world of open-ended, team-oriented science and, in doing so, the real functions of scientific skepticism, reasoning, deduction, habits of mind, and criticism are revealed. More importantly, geologic concepts and principles are no longer just illustrations and words in a text. Where they used to read how field work, geologic columns, and cross-sections could be used to explain geologic principles, students now collect the data and construct their own interpretation and understanding of geologic concepts. ✧

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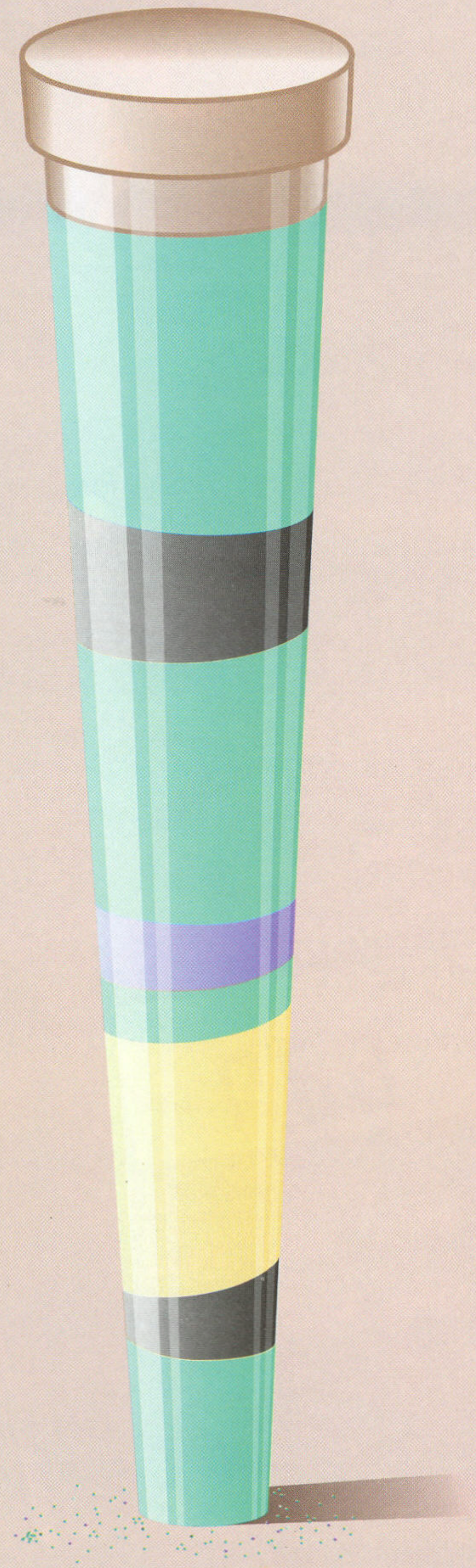

The Art

DURING A TEACHER WORKSHOP CONducted by our state geologic survey, I learned that geologists often use specific colors and patterns to enhance their graphical depictions of sedimentary rock sequences. For example, blue is used to represent limestone, green for shale, yellow for sandstone, orange for siltstone, and purple for the clay sometimes found under coal beds. I also learned that sections of an outcrop are often covered over by vegetation or talus slopes. In this case, geologists use white to indicate concealed, and therefore undescribed, rocks.

Several months later, the art teacher at my school and I took a class called "Energy and the Environment," sponsored by the American Electric Power Company. In the class, we studied coal as an energy source and its effect on the environment. Our final assignment was to develop a classroom activity related to the workshop. While I felt it would be relatively easy to develop an activity for my science classroom, the art teacher wondered how to develop an activity on coal for the art class. For several days we sought ways to combine art and geology until a colored sand art souvenir provided us with inspiration.

We received permission from the course instructors to conduct a cooperative project using both art and science to construct model geologic columns. The art teacher emphasized the construction of scale models and the use of color to enhance visual design and understanding. I concentrated on the accurate representation of the rock layers and the application of the model in my Earth science lesson on local mineral resources.

SCILINKS.
Keyphrase: geologic columns
Go to: www.scilinks.org
Code: tst0420

COLUMN CONSTRUCTION

I have incorporated the construction of sand art geologic column models into my Earth science class. Students work in groups of three to construct sand art geologic columns, and these groupings are maintained in the art

DEBRA ROCKEY

ART BY SERGEY IVANOV

# of Geology

Creating sand art geologic columns

class. To ensure that the scales of the columns are calculated with accuracy, each group has one student with a strong math background.

Students understand concepts best when they develop and apply them in realistic situations. To relate this activity to the work of geologists, students use real data from rock descriptions and drilling records found in geologic publications to construct their models. Because some of these records are quite old, many of the measurements are in the English units still preferred by the coal mining industry, but we convert them to metric.

A class of 21 students takes three 50-minute class periods to complete the project, but it can be modified to fit any schedule. To build the columns, we use plastic tubes cut to 37.5 centimeters in length and end caps purchased from a commercial company. We use glue to permanently seal one end of each tube. Tempera paint-dyed sand provides brilliant colors that do not fade when exposed to light. The white sand and nontoxic powdered tempera paints are premixed with water to enhance their color and eliminate the problem of dust. To color 2 kilograms of sand, we mix 50 grams of paint with 50 to 75 milliliters of water. Used sand can be placed in cheesecloth and rinsed with water to remove the coloration. After drying, this sand can be redyed for future use.

During the first class period, each group is given a plastic tube with end caps, a dowel rod, masking tape, and small paper cups for handling sand. Large containers of dyed sand are placed in a central area of the classroom, and the students obtain the sand as needed for their model. They examine the clear plastic tubes that will hold their column models, making sure that the bottom end cap is properly sealed. On a piece of masking tape attached to the outside of the tube, students note special features of each rock layer, such as the presence of fossils.

Each group is given a published diagram of a local outcrop or roadcut. Before constructing their model, students use colored pencils to shade this illustration in the specific colors used to represent the different rock types present. This work familiarizes students with rock sequences, and the shaded illustrations are guides for the construction of their dyed sand models (Figure 1).

During the second and third class periods, students complete their models. First, they determine the appropriate scale for their model by dividing the total thickness of the rock measurement taken from the diagrams of the sites by the length of the tube. These calculations are transferred to the tape strip.

Each group member has an assigned role. One gets the colored sands as needed; another steadies the tube and fills it with sand. The third student makes sure the sand is filled to the appropriate thickness for each layer. As each layer is poured, it has to be compacted

PHOTO COURTESY OF THE AUTHOR

with a dowel rod. If the layers of colored sand do not completely fill the tube, the remainder is filled with undyed sand.

Each completed tube is capped and labeled with the site location and the scale used for the model. Students then use a series of handouts and rock unit labels to identify and name three rock layers, including one coal bed, on their completed model.

Accurate replication of the paper diagram into a useful colored-sand model is emphasized. If students make an error they are allowed to acknowledge it on the tape strip and continue the model with the proper rock sequence. However, most groups prefer to start over rather than have an error.

PHOTO COURTESY OF THE AUTHOR

MODELING REALITY

As students use the models, they realize that changes in rock type are related to changes in early geographic environments. They are amazed to find that several limestones containing crinoids and brachiopods can be found throughout the northern panhandle of West Virginia, and they examine their models for evidence of sea level changes. Sedimentary rock samples from many sites are put in the classroom to help distinguish the rocks.

Students complete a written summary of their model and its rock types. The lab groups give verbal presentations on their models to share their information with the class. They relate present rock types to their ancient environment of deposition, and this emphasizes the truth in the phrase, "The present is the key to the past." Using their knowledge of modern depositional environments, such as beaches and stream channels, students list various environments in which sedimentary rocks, and specifically coal deposits, form.

After completing the analysis of their own models,

FIGURE 1.

Sample shaded illustrations.

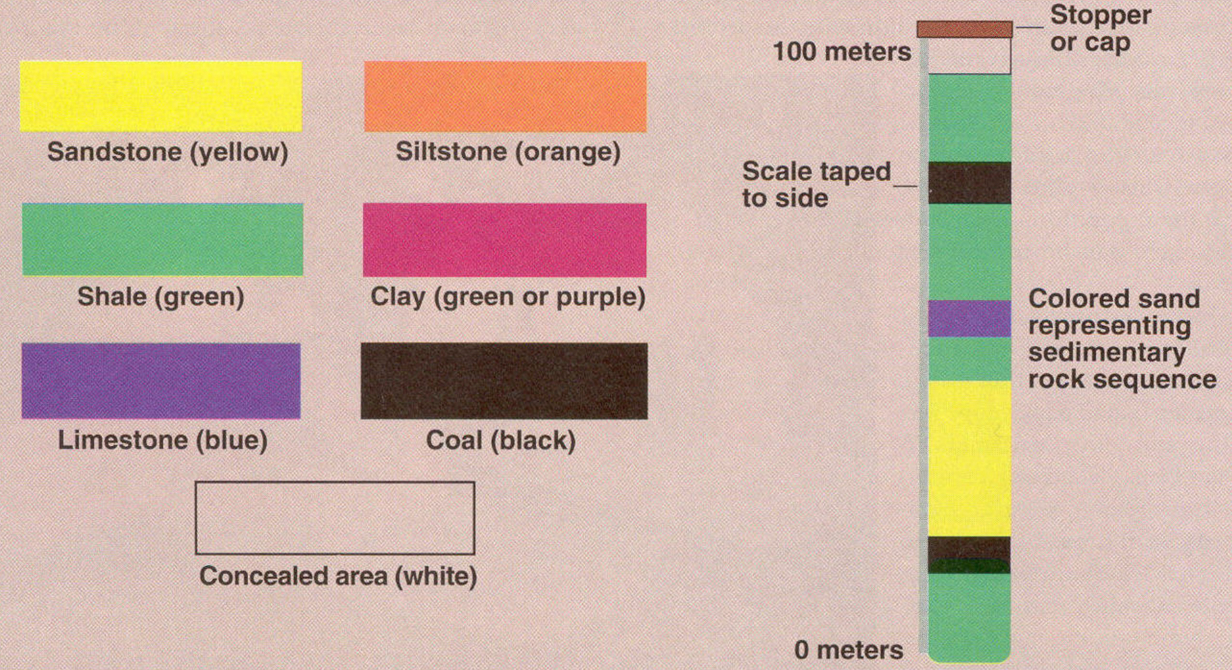

FIGURE 2.

Geologic columns rubric: This will be used to assess your group's model of a stratigraphic sequence of sedimentary rock.

Topics	Scores			
	4	3	2	1
Stratigraphic model	Model site and scale labeled properly Accuracy in measurements Rock layers are in proper sequence	Model site and scale identified properly Few errors in measurements Rock layers in proper sequence	Model site and scale identity incomplete Measurements inaccurate Error in rock sequence	Does not identify site and scale Measurements are inconsistent Inaccurate rock sequence
Cooperative effort	Student actively participates in task Assumes an active role within group	Student needs encouragement to participate Accepts role within group	Student requires prompting to work with the group Accepts role within group	Student is uninvolved in group effort Refuses to accept role within group
Collaborative effort	Stays on task	Briefly distracted from task	Reminded to remain on task	Does not remain on task
Conceptual ideas	Identifies rock strata Relates rocks to ancient environments Responses are given in clear, coherent manner	Identifies rock strata Difficulty relating rocks to ancient environments Communicates responses in an understandable manner	Difficulty identifying rock strata Unable to relate rocks to ancient environments Poor attempt to communicate discussion questions	Does not identify rock strata Does not relate rocks to ancient environments Does not respond to discussion questions

the groups exchange models and compare and contrast them by considering rock types and ages of the rocks in each. In an extension of this analysis, students use the models as a data platform to enhance classroom discussion of geologic and environmental issues relevant to our locality. This includes topics such as slope failures and acid mine drainage.

IT'S NOT ALL BLACK AND WHITE

The sedimentary rocks of our northern Ohio River Valley are mostly brown and gray. This makes distinguishing one layer from another difficult for the novice. Having students construct geologic columns using dyed sand provides them with a more visual, and therefore more useful, interpretational tool.

Formal assessment of the students' efforts is done with a rubric (Figure 2) to assess model construction in the art class and application work in the science class. The rubric provides students with known expectations for their roles within the group and for the completed models (Jensen, 1995).

The activity generates interest in geology, and students become more observant of local outcrops and roadcuts. When asking questions about these rocks, their verbal responses include descriptive terminology such as thin-bedded or massive sandstones. Students also begin to notice and refer to prominent rock units by their official geologic names: "It's not just a limestone, but the Ames marine limestone." What began as a colorful model using colored sand to replicate rocks has evolved into a learning tool that brings a new respect for the geology of our area. ✧

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Chemistry ROCKS

Redox chemistry as a geologic tool

Mary Sue Burns

Rocks may seem like strange adornments for a chemistry lab, but I conspicuously display a collection of sedimentary rocks across the front counter of my classroom. Students like to place the dark, solid-red sample of local sandstone beside the powdery yellow sample of limonite because they resemble our school colors of maroon and gold. One of my favorite rocks is a green and red layered one from the banded iron formations in Minnesota. Another favorite is a green rock with orange swirls that I found in a damp drainage ditch. Students can see additional rock samples of various colors in photographs I have displayed.

So, my students ask, what do all of these colored rocks have to do with chemistry class? I tell them that the influence of many elements and chemical processes can be seen in rock formations. For instance, iron compounds are a common component of many rocks. Iron oxides and iron carbonates can serve as the cement for sandstones, and many rocks contain iron or iron compounds that are oxidized by weathering. So, matching a rock's color to a form of iron allows us to hypothesize what environment was present when the rock was formed. This deductive process allows students to observe firsthand the abstract topics of transition metal chemistry, oxidation states, and oxidation–reduction reactions.

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Explore redox reactions at *www.scilinks.org.* Enter code TST0930.

PHOTO BY MICHAEL OLLIVER

Teachers can use students' interest in the colors in rocks as a starting point for a redox chemistry lesson.

Integrating Earth science and chemistry allows teachers to address several points of the *National Science Education Standards* for grades 9–12 (National Research Council, 1996). Specifically, I address the physical science content standards of structure and properties of matter and that of chemical reactions, as well as the Earth and space science content standards involving geochemical cycles and the evolution of the Earth system.

Applying chemistry to geology

When compounds of transition elements are present in rocks, particular colors indicate the availability of oxygen and the level of the water table at the time the rock formed. Due to its abundance and striking color variations, iron can be a good indicator of sedimentary environments. Iron-containing shale can be red or green. Iron-containing minerals that were deposited as tidal plain sediments exposed to the air would have quickly been oxidized to a red or rust color. Iron containing minerals that were not exposed to the air, such as deep water sediments or those trapped beneath decaying plant material in a swamp or marsh, like the coal swamps that covered West Virginia 300 million years ago, would have been in a reducing environment. Under these conditions, iron-containing material would appear black or dark green.

Near our school, we have some sedimentary rocks that are mottled or even striped with red and green. These markings can be interpreted as the result of alternating zones of oxidation and reduction produced by variations in groundwater penetration of the original sediment. Many rocks became red due to later oxidation from weathering and staining from iron leaching and oxidizing of nearby materials. The famous Red Wall limestone of the Grand Canyon is actually a gray rock that has been stained red by oxidized iron compounds from overlying rock layers. These facts form the perfect basis for the integration of historical geology and the chemistry of iron compounds. Through a series of short activities, students can explore the relationship between color and oxidation state for iron and then use rock color to describe possible ancient sedimentary environments.

Ironclad chemistry

Safety is an important factor in any chemistry activity. Students must wear full-wrap, splash-proof, safety goggles and aprons throughout these activities. Students should never handle chemicals directly, and caution should be emphasized in all steps.

In this activity, each group of students examines one or more of the rocks and describes the sedimentary environ-

Ubiquitous iron

Of all the elements, iron is arguably the most unique because young students can actually experiment with iron in a sequence of coordinated unit plans throughout their post-primary education. Iron and its many compounds thread not only through the fabric of human existence but also through geologic time, reflecting a myriad of environments of mineral and rock formation.

Geologists have much to contribute to the study of human technological advancement, which is often couched in terms of ages of stone, bronze, and iron. Similarly, for well over a century, the men and women who study the Earth have engaged in vigorous debate, in which iron is central, about the composition of the core of the Earth; the origin of such iron-rich deposits as the Precambrian banded iron formations (BIF); the origin of red beds; the origin of iron ore through igneous, metamorphic, or sedimentary processes; and the origin of color in soils and rocks in response to the redox potential of the environment and the presence or absence of organic matter.

Through activities, students find out that iron is everywhere on Earth—in meteorites, plants, ourselves, and the water we drink. Igneous, sedimentary, and metamorphic rocks and the minerals that form them are studied through an examination of the following:

- Banded iron formation from the Mesabi Range, Minnesota;
- Bog iron ore from the Carboniferous rocks in Appalachia;
- Magnetite from Cornwall, Pennsylvania;
- Red beds of the Ordovician, Devonian, Mississippian, Pennsylvanian, Permian, and Triassic ages;
- Oolitic iron ore of the Silurian age;
- Taconite pellets;
- B-horizon materials from selected soils; and
- Basalt.

Unit plans enhance the ability to compare and contrast goethite, hematite, and magnetite. Additionally, students experience the problems associated with:

- The rusting of metals;
- Acid mine drainage (AMD);
- The staining of items in streams and lakes containing AMD; and
- The amelioration of AMD by chemical treatment and/or wetlands.

Chemical treatments, when handled with appropriate safety precautions, will lead students to discover the nature of Fe(II) and Fe(III) and what lies beneath the coat of iron minerals. Activities could include the use of 3 percent hydrogen peroxide, iron reagent powder pillows packaged with a commercial iron test kit, a dithionite-citrate system buffered with sodium bicarbonate (D-C-B), or Tamm's oxalate solution. A simple color disc method of determining iron concentrations will suffice in these experiments.

The holistic study of iron can expose students to geology, chemistry, physics, and biology, as well as history, geography, social studies, and English. Students can read and write about iron. They can examine various forms of iron and perform laboratory tests to explore the properties of iron and its many, many compounds. Iron exists in and around us every day. It could be said iron has a "magnetic" personality of its own.

—Courtesy of Robert E. Behling, geology professor, West Virginia University

PHOTO BY MICHAEL OLLIVER

ment in which each rock formed. I also ask them to assess the oxygen availability and water table level at the time the rock was being formed. But first, they have detective work to do.

Students begin by exploring samples of various iron compounds. The samples are sealed in transparent vials and labeled with the chemical name of the compound. I include several samples that contain iron(II), such as iron(II) chloride and iron(II) oxide, and several that contain iron(III), such as iron(III) chloride and iron(III) oxide.

We discuss the similarities and differences among the compounds. Students may notice that all are crystalline solids, but the grain size may vary. However, the main focus of this activity is color. Many students will notice a

FIGURE 1

Data table of iron oxides and chlorides. (Other iron compounds may be used.)

Compound	Formula	Oxidation state of iron	Color
Iron(II) oxide	FeO	+2	Green
Iron(III) oxide	Fe_2O_3	+3	Orange
Iron(II) chloride	$FeCl_2$	+2	Green
Iron(III) chloride	$FeCl_3$	+3	Orange

pattern; all of the iron(III) compounds are orange, while the iron(II) compounds are not. Most of the iron(II) compounds will be green, but iron(II) sulfide is black. Compounds containing complex ions exhibit an even greater variety of colors.

This is a good time for students to further develop their skills in formula writing and identification of oxidation states. I usually provide chemical formulas for the compounds used in the exploration and assist students in determining the oxidation state of the iron in each. A table of common oxidation states or a periodic table is useful at this point, and teachers may need to point out that transition metals, like iron, can commonly have more than one charge, or oxidation state, in compounds. Other elements, like oxygen and chlorine, are more predictable, and their charges can be determined using a periodic table. The sum of the charges within a compound's formula is always zero. If students construct a table showing both their observations of color and the oxidation states of iron for each compound, the pattern of orange for iron(III) and green for iron(II) should be clear to all (Figure 1).

In further discussion, I point out that FeO and Fe_2O_3 are both common oxides of iron. I ask students to determine which one has the higher ratio of oxygen atoms to iron atoms (Fe_2O_3). Students can identify that this compound contains Fe^{+3}, which is the source of the orange color. We discuss which of these compounds would be more likely to form under a limited oxygen supply or an abundant oxygen supply.

Application activities

Once students have some experience relating oxidation state to iron compound color, they can apply their knowledge. We do this with two simple activities. The first activity shows the role of water in iron oxidation. I sprinkle iron filings in the bottom of two cups and add a little water to one. After sitting open in the air for at least a day, the wet filings become very rusted while the dry filings appear unchanged. From their previous work, students can now identify the familiar orange-red color as the result of oxidation to iron(III). Therefore, they realize that "rusting," as they normally use the term, is an oxidation process of iron. Although the reaction they observe is readily anticipated, it brings the complex concept of oxidation into a meaningful context for them.

In the second activity, students observe a change from iron(II) to iron(III). This change is brought about by adding a small amount of 3 percent hydrogen peroxide to a small amount of a green iron(II) compound such as iron(II) sulfate. The familiar orange color appears immediately, and the material also "fizzes." This is an important visual clue, which students must try to explain. (It is a release of oxygen gas.)

At this point, students are ready to return to the original challenge of speculating on the presence of oxygen and water in the ancient geologic environments just by looking at a rock specimen. I direct their attention back to the iron-containing rocks on the front desk. Working in small cooperative groups they brainstorm possible scenarios, which they then present to the entire class. The very nature of the investigation means that any plausible explanations for the colors of the rocks are potentially acceptable.

I assess students' understanding of these concepts in the field. Near our school we have a large outcrop of red sandstone, and during a visit and discussion there, the various ideas mentioned in class resurface. Usually one or two prevail as the most popular. At the end of the field trip, I review students' field notes. Their notes, observations, and conclusions provide me with a quick way to assess each student's application and depth of understanding of the connection between geology and chemistry. After this lesson and activities, students can appreciate why rocks are an attractive and relevant adornment for a chemistry lab.

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Reconstructing the

Deb Hemler and Tom Repine

"I've seen that one before" secondary teachers often mutter when we demonstrate this geologic timeline activity during NSTA workshops or short courses. The audience, however, is soon engaged when they realize that the innovation, in this case, is not our activity but how it is used in a constructivist classroom. This project provides evidence that time-honored activities still have a place in today's science classes. Often the way an activity is presented can make the difference between a simple laboratory activity and an involved, learning experience.

When modeling geologic time in the past, our students were given the classic list of events with times they calculated and scaled on five meters of adding machine tape. They always managed to do the conversions necessary to determine that one millimeter equals one billion years. We felt, however, that students were just going through the motions. With nothing vested in the activity, there was often little thrill or discovery. We knew there had to be a better way to make this classic model for geologic time minds-on, and we wondered how we could develop an activity that allowed students to manipulate the data, explore their understanding, and confront misconceptions. The answer lay simply in resurrecting the old clothesline model with a constructivist slant.

Engaging the students: Ordering events

To prepare for the activity, we copy the 28 events in Figure 1 onto a card stock and cut a separate card for each event. Laminating the cards increases their longevity and reduces future preparation. We divide students into groups of four and give each student a card. Depending on the class size, cards can be left out or added, or additional cards may be given to some groups. We ask students to discuss the events, and based on their prior knowledge, decide as a group which came first and last. Energetic scientific debate typically ensues at this time as students attempt to determine the correct order.

At this point, vocabulary questions may arise. For example, some cards refer to the various tectonic events that formed the Appalachian Mountains—students are surprised to discover that an orogeny is a mountain building incident. This gives students a reason to learn the vocabulary and immediately use it in context; therefore, they do not easily forget the words and their definitions.

Exploring: Time on a line

We used to string the traditional 4.6 m clothesline somewhere in the classroom to give students enough space to construct a model of geologic time. This proved cumbersome and was difficult to display during the unit. Using a timeline composed of hook and loop fasteners is a more manageable approach. The model can be left permanently on the wall and used alternatively throughout the semester for hanging posters or student work. Rolls of hook-and-loop fasteners, approximately 5 m long, can be purchased in office supply stores. A small hook is adhered to the back of each card, and students are instructed to place their events on the line in the order they occurred, relative to other groups' events. The spacing is irrelevant at this point since students have not yet associated this exercise with a timeline. Each group is given a few minutes to discuss their card placement before approaching the line, and groups are permitted to shift cards to make room for new ones.

As the groups place their cards, we ask questions about the terms on the timeline. The students that have cards with specialized vocabulary define their events to the class. Archaeopteryx (first bird), Lucy (ancestral human), Ediacaran (primitive yet multicellular life forms in Precambrian), and orogeny are examples of vocabulary that should be clarified. A discussion often results involving what students in other groups know about each of the events. Adjustments to the timeline are made as new information surfaces. At least one student usually knows that birds evolved after the first dinosaurs, and we use this deduction to focus on students' prior knowledge. For instance, students generally recognize that the simpler organisms evolved first and readily associate the Mesozoic era and Jurassic period with dinosaurs. Also, many recognize humankind's presence as a fairly recent development in the scheme of things. Oftentimes, however, exploring their prior knowledge reveals misconceptions, such as the belief that dinosaurs predated mammals or that life is evolving into more complex organisms.

Elaboration: Constructing scales

Once the discussion is exhausted and students have made last-minute changes in the event positions, it is time to verify the order. Figure 1 (page 34) is replicated as an overhead for this stage of the activity. Using an overhead projector, the students are only shown the left column of the table (the "years ago" column remains hidden). By revealing the correct sequence, we open the door for further discussion about errors, rationales, and misconceptions. Some students are surprised to find that mammals actually coexisted with dinosaurs. Previously certain that all dinosaur species were contemporaries, they are amazed to discover that the Tyrannosaurus Rex did not regularly fight with the Stegosaurus. A more subtle revelation is the relatively late evolution of grass compared to other events. The discussion of grass as a highly specialized, flowering plant clarifies any confusion. Grass adapted to be cropped from its apex to withstand constant "mowing" by grazers. This discussion also presents the opportunity to address the classic misconception that early humans coexisted with dinosaurs. After establishing the proper order of events and their alternate conceptions, we ask "How can we make our model more representative of geologic time?" The students determine that it needs to be "like a timeline in history."

At this point, we integrate mathematics and scaling into the activity by asking: "You have 4.6 m of hook-and-loop fasteners to represent geologic time. Using the metric system, what unit could you use to represent a billion years?" Students identify 1 m as the appropriate unit to represent one billion years. To make sure everyone understands this concept, we ask students to develop a scale that can be used to arrange event cards. Working collaboratively in their groups they determine that 1 cm equals 10 million years, and 1 mm equals one million years.

Attention now turns back to the hook-and-loop fasteners line, and Figure 1 is distributed as a handout.

Expansion: Students construct a time scale

Using their new scale, students convert the events on their handout (Figure 1) into a timeline with calculated distance. We move between groups and observe peer instruction as students explain the conversion process to one another. The groups work cooperatively to calculate the distances between each event.

Once the event times have been converted, they are ready to be moved onto the timeline. Using metersticks and metric rulers, groups return to the line and replace their original events. The product is a scaled model of geologic time that can be left up during the semester. The traditional observations from the adding machine tape activity are addressed as students comment on the lack of events present on the early portions of the timeline. Many students become frustrated trying to place events of recent time using the correct spacing since these are usually only millimeters apart.

Geologic Timeline

Adding a constructivist slant to a classic activity

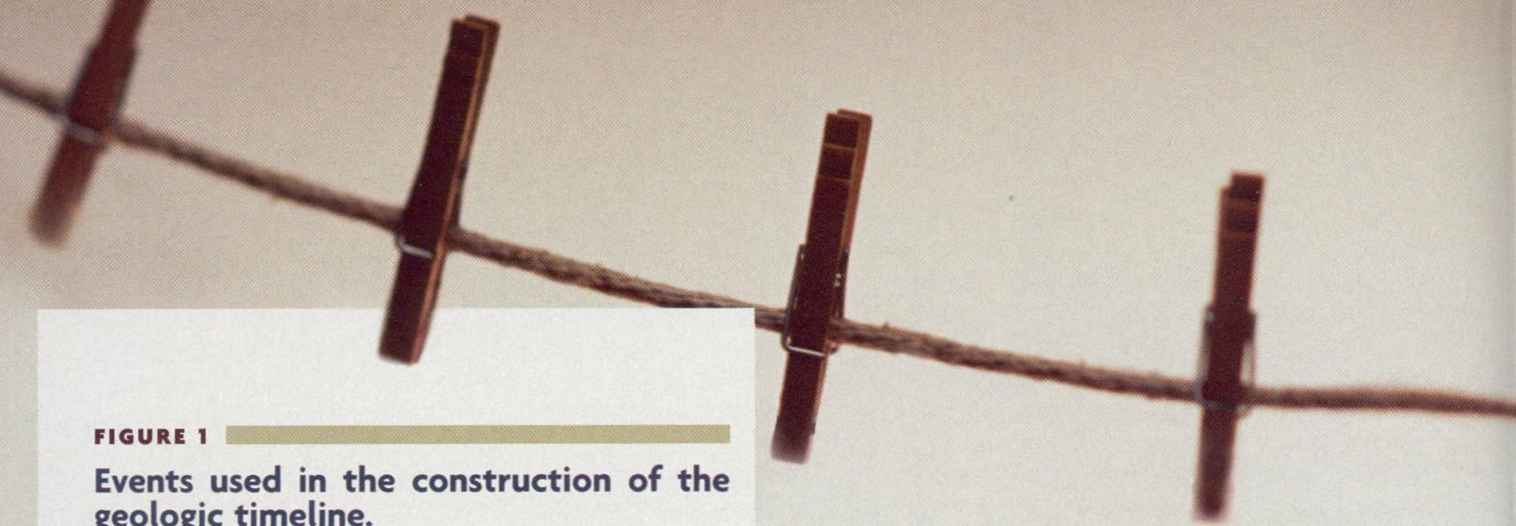

FIGURE 1

Events used in the construction of the geologic timeline.

Event	Years Ago	Scale Distance
"Lucy"	4 mya	
Camel	35 mya	
Grass	55 mya	
Cenozoic era (begins)	65 mya	
Tyrannosaurus	65 mya	
Ants	100 mya	
First flowering plants	125 mya	
Archaeopteryx	140 mya	
Stegosaurus	160 mya	
First mammal	240 mya	
Mesozoic era (begins)	250 mya	
Pangaea forms	260 mya	
Earthworms	300 mya	
Allegheny orogeny (begins)	320 mya	
Cockroaches	330 mya	
Ferns	370 mya	
Sharks	400 mya	
Acadian orogeny (begins)	410 mya	
Spiders	450 mya	
Taconic orogeny (begins)	460 mya	
First vertebrate	515 mya	
Trilobites	520 mya	
Jellyfish	545 mya	
Paleozoic era (begins)	545 mya	
Ediacaran	600 mya	
Green algae	1 bya	
Bacteria	3 bya	
Precambrian era (begins)	4.6 bya	

Note: (mya = million years ago, bya = billion years ago) These dates are approximations and will vary depending on the source consulted. The event list was modified from Scotchmoor (1996). Dates used in this figure were obtained from Pan Terra, Inc. (2000).

Evaluation: Creating a new time scale

To evaluate students, we assign groups a period or epoch to investigate. We encourage each group to identify at least 10 significant events in their period. They demonstrate their understanding of the material by selecting a scale for these events, using ratios to calculate distances, constructing their timelines, and presenting their results to the class as poster models of geologic time (Figure 2). A rubric for assessment can be developed based on proper scaling, geologic historical accuracy, clarity, and group cooperation.

The products of this group activity can be placed around the room as reference for future class discussions. The student-created timelines can be used to illustrate points during a lecture, generate more questions for discussion, or be employed for individual investigations. The students have come full circle; their questions are used to guide future instruction. This is an example of student-directed learning.

This activity can be tailored to the needs of any classroom. For example, if hook-and-loop fasteners are not feasible, teachers can use adhesive magnetic tape on the event cards, which is compatible with many modern blackboards. The traditional clothesline can be hung between a VCR cart and an overhead projector arm. In addition, the activity event can be modified to more closely relate to specific geographic areas. In the Eastern states we tend to focus on the Appalachians. Western states might focus on the Laramide and Sevier orogenies. We highly recommend that any significant geologic event in the area, such as an earthquake, be added to the timeline. This enhancement, rather than sticking solely to a generic textbook list, makes the project more relevant to the local area.

Also, some teachers in past workshops have expressed an interest in modifying the activity by using multiple timelines. We tried this at the recent NSTA meeting in Columbus with great success. Four hook-and-loop fastener lines were placed in the room (one

Activity Outline

1. Give each student an event card and divide students into groups (distribute any extra cards to assembled groups).
2. Have groups arrange the events from oldest to youngest.
3. The hook-and-loop fastener line is identified as a timeline of Earth's history. Student groups place their events in order of occurrence on the line.
4. Discussion with the class involves and expands on prior knowledge that students use for placement of events and clarification of unfamiliar vocabulary.
5. The correct order of events is provided on an overhead and students discuss misconceptions and revelations.
6. Because the hook-and-loop fastener line is 4.6 m long, a scale for the 4.6 billion year history of Earth is then devised by the students and verified by the instructor.
7. Students are provided with a handout of Figure 1. The groups convert the event times to distances for timeline placement.
8. Student groups use meter sticks and metric rulers to place their events to scale on the hook-and-loop fastener line.
9. Discussion of event development, spacing, and relative length of eras is facilitated by the instructor.
10. Student groups are assigned a period or epoch to research. Events are identified, a scale is selected, a poster of timeline is created, and events are added to the timeline. Groups present their timelines to the class.

on each wall), and the class was divided into four groups. Fewer students work directly with more geological events, which increases student engagement. The only consideration is added time investment. The exploration phase lasted longer because more groups had to resolve conflicts over event placement. If time is not an issue, then we advocate the use of several timelines.

In true constructivist fashion, students become engaged in a topic, demonstrate their prior knowledge, assimilate new concepts into their existing frameworks, apply their knowledge, and are evaluated using performance assessment. Students work in collaborative groups that are engaged in peer teaching and evaluation. Robert Yager, a noted educator and former NSTA president, wrote that teachers could move toward constructivist approaches with very little shift in their current practices. All that is truly necessary, he said, is "reorganization with a new emphasis" (2000, 45). Many teachers have valuable activities that only need to be complemented with more focus on the student. With a little tweaking, a time-honored activity can become "constructive."

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FIGURE 2

Cambrian period timeline

An example of authentic assessment that could be used for this lesson is a student generated timeline. The following is a student sample of a timeline for the Cambrian period timeline (scale: 1 cm = 2 million years).

495 mya	Mass extinction/in WV beginning of Ordovician similar
	Trilobites speciation reaching peak (more than 90 kinds)
	Mass extinction
	Conodonts evolve
	Mass extinction
	Sea conditions continue in WV
	Carbonate muds accumulating in WV
	Tommotian life present
	Life in the Burgess Shale develops
545 mya	West Virginia is underwater

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