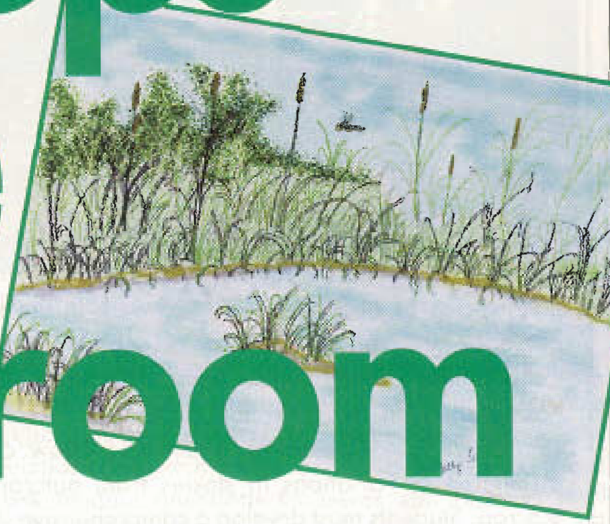
Outcrops in the Classroom



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

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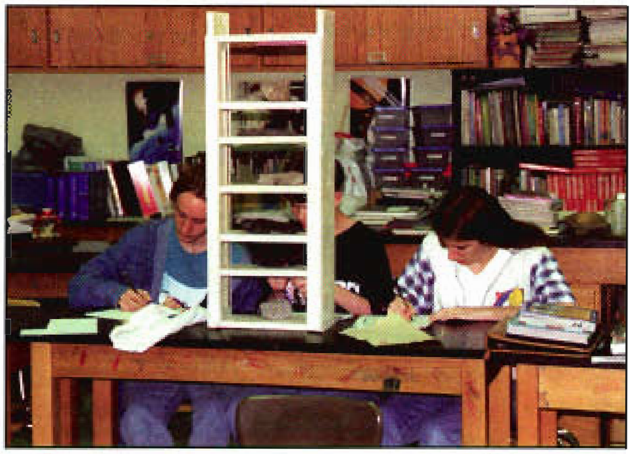
Our goal is to ensure a collective exclusion of ideas about geological formations until students realize that one or two particular interpretations most plausibly correspond to all the data. At the end of this process, we make it clear that different interpretations, based on well-thought-out ideas that 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

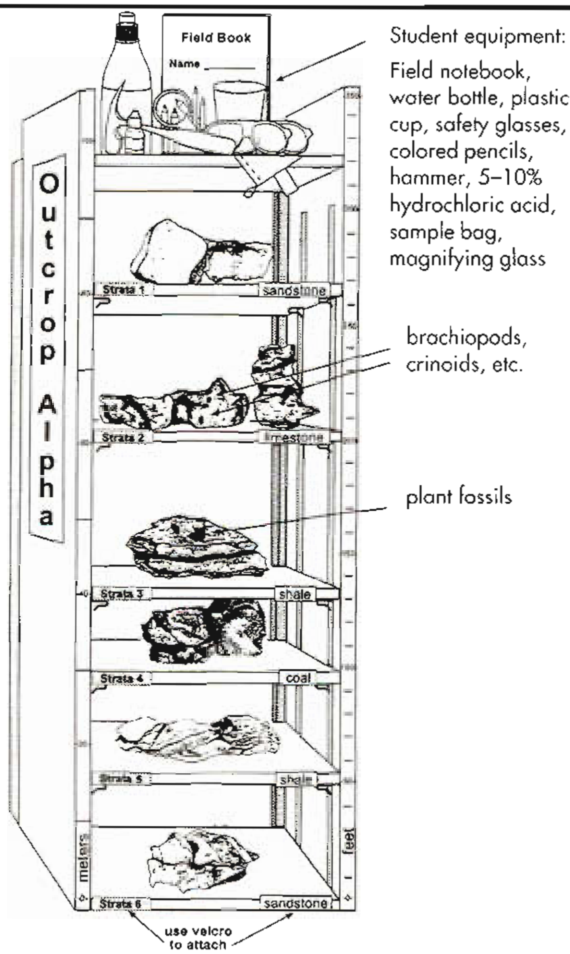
"The best geologist is the one who sees the most rocks!" This unattributed witticism supports our belief that geology is best learned in the field. With this in mind, we designed a simple device that allows us to simulate the vertical and horizontal changes found in the rocks near

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.



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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.

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

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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.

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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. ✧

Tom Repine (e-mail: repine@geosrv.wvnet.edu) is an education specialist at the West Virginia Geological and Economic Survey, P.O. Box 879, Morgantown, WV 26507; and Deb Hemler (e-mail: dhemler@wvu.edu) is a visiting assistant professor in the Department of Educational Theory and Practice at West Virginia University, P.O. Box 6122, Morgantown, WV 26506.

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